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Chronicle and Comment

Summer Meeting at White Sulphur Springs

THE 1925 Summer Meeting will convene at White Sulphur Springs on June 15 and extend through June 19. Read what is said of this in the account in this issue of the Business Session of the Annual Meeting held at Detroit last month.

A Riding-Qualities Bibliography

INTEREST has been expressed in the bibliography, prepared by the Research Department, concerning which an announcement was made at the Research Session of the Annual Meeting. The material, consisting of 534 references, relates principally to items associated with the problems of riding-qualities. Members wishing further information as to the nature and the scope of the work will find a more detailed account on p. 162 of this issue of THE JOURNAL. A copy of the bibliography or any portion thereof will be furnished by the Research Department upon request.

Society Meetings for the Year

DURING the Annual Meeting a general session of the 1925 Meetings Committee was held. A majority of the Committee were present and also President Horning. Eight Society meetings will be held during this administration, in addition to the 1926 Annual Dinner and participation in the Automotive Maintenance Equipment Show and the National Service Convention this spring. Except in the case of the Summer Meeting, which will be of a general nature as heretofore, the meetings will be devoted to specific subjects including Tractors, Buses, Rail-Cars, Taxicabs, Fleet Operation, Production, Aeronautics, Service, Motorboats and Engines.

Warner in Charge of Meetings and Sections Work

JOHN A. C. WARNER, who latterly was manager of the Research Department of the Society, has been placed in charge of its Meetings and Sections Department, in succession to Mr. Hill. By virtue of the nature of the research work he was following, and by special assignment, he has been a regular attendant at Society meetings in recent years, as well as at many Sections meetings. Many articles prepared by him have appeared in THE JOURNAL.

Mr. Warner is graduate mechanical engineer of Worcester Polytechnic Institute. He was formerly engaged in sales and engineering work on lubrication problems, and also associate physicist at the Bureau of Standards, where he was chief of the aeronautic instruments section.

Hill Leaves the Society Staff

L. CLAYTON HILL, who for several years has been assistant general manager of the Society, left its service this month to go into sales engineering work for Valentine & Co., with headquarters in Detroit. Equipped by sound training, good professional experience and enthusiastic temperament, Mr. Hill has naturally done much work of a constructive nature of value to the Society and its members, with reference markedly to National and Sections meetings and THE JOURNAL. He has been thanked, dined and feted by the officers, staff and members of the Society and the Sections, with many expressions of regret at his change of position, but with hearty good wishes for his future happiness and prosperity.

Mr. Hill is a University of Michigan man. He was formerly a draftsman and designer with the Studebaker Corporation of America; designer, body engineer and airplane designer with the Packard Company, and chief engineer and manager of the Franco-American Engine Co.

Research Graduate Assistantships

THE University of Illinois maintains 14 graduate research assistantships in its engineering experiment station. These, as well as other such assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American or foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry. An appointment is made and must be accepted for 2 consecutive collegiate years of 10 months each, at the expiration of which, if requirements have been met, the degree of master of science will be conferred. The graduate assistant is required to devote half of his time to the work of the department to which he is assigned.

Applications for appointment should be made not later than April 1 to the Director, Engineering Experiment Station, University of Illinois, Urbana, Ill. Appointments become effective in September.

Society to Help Develop Motorcoach Standards

AT a meeting of the Equipment Committee of the American Electric Railway Association in New York City on Jan. 16, that was attended by Charles Froesch, representing A. F. Masury, vice-chairman of the Motorcoach Division of the Standards Committee, and Standards Manager R. S. Burnett, the progress of the American Electric Railway Association's Motorcoach Subcommittee and the Society's Motorcoach Committee last year was reviewed. It was believed that the program promulgated last year to establish a recommended nomenclature for types of motorcoach, and standard dimensions for general construction, such as body widths and lengths, door widths, seating arrangements and dimensions, should be taken up this year before detail standards are considered. The Motorcoach Regulations adopted last December by the Board of Public Utility Commissioners of New Jersey looking toward ensuring safety to the traveling public embody many of the recommendations of the committees, which cooperated with the New Jersey municipal traffic supervisors in drafting the regulations. These were set forth on p. 45 of the January, 1925, issue of THE JOURNAL.

These New Jersey regulations embody several major motorcoach-body dimensions and general equipment specifications to which the Motorcoach Division will probably give careful consideration this year in drafting a model code for motorcoach construction that will be definitely recommended as the basis for motorcoach regulations similar to those of New Jersey that may be adopted by other States. If this can be accomplished, it will be a strong factor in establishing uniform general constructional specifications for motorcoaches in all the States. Action of this kind should save motorcoach manufacturers and operators many grievances such as have been encountered in operating motor trucks in different States.

At the meeting held in New York last month, A. T. Clark, chairman of the American Electric Railway Association's Subcommittee, was designated by Chairman A. B. C. See to act on the Motorcoach Division of the Society's Standards Committee until a definite appointment shall have been made by the Board of Governors of the Association.

It is planned to have the Motorcoach Division review the work already accomplished and meet with the American Electric Railway Association's Committee in Cleveland on March 16, to make definite recommendations regarding nomenclature, general constructional dimensions, and a code of engineering regulations.

The Head-Lamp Problem

COMMISSIONER STOECKEL, of the Department of Motor Vehicles of the State of Connecticut, issued recently a statement on the educational phase of the subject of motor-vehicle lights. He called attention to the fact that the Connecticut law provides broadly that head-lamps shall furnish sufficient light to make an object or person 200 ft. ahead of the car plainly discernible and sufficient "side-light" to show objects to the right and the left in front of the car and also that the light produced must not glare. In the States that participate in the Eastern Conference of Motor Vehicle Administrators, which include all of the New England States, New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia and the District of Columbia, as well as the Canadian Provinces of Ontario and Quebec, no device alleged to meet the requirements stated above is approved until it has been recommended by the Conference Lighting-Committee and approved by the Conference as a whole.

As to the need for periodical inspection and adjustment of head-lamps, Commissioner Stoeckel states that variations in the head-lamp illumination of cars are frequently found, which, if not corrected, produce poor lighting conditions. The following is prescribed as a simple and feasible method of adjustment.

> Place the car on a level space, preferably a floor, facing a wall or screen, the car lamps being 25 ft. distant from the wall. Mark a horizontal line on the wall, which line shall be the same height from the ground as the centers of the lamps on the car. Call this line the "Lamp-Level Line." With lights on and both lenses installed, cover one lamp to shut off the light and move the screw or device in the other lamp, which regulates the position of the bulb, until the narrowest horizontal, left to right, beam of light is secured on the wall. Then perform the same operation with the other lamp. Having thus focused the lamps, tilt or bend each lamp until the top of the beam is no higher than the "Lamp-Level Line" on the wall, being sure that the car is fully loaded at the time. The wall will then be illuminated below and up to the "Lamp-Level Line," which is the result desired. If the light spreads on the wall above the "Lamp-Level Line," the lamps are not properly aimed and focused.

Commissioner Stoeckel emphasizes the need for the car operator or owner always paying attention to the lamp adjustment. Recently, on a highway in Connecticut, 600 cars were checked up as to the performance of their lights. About 40 showed insufficient driving-light. In 34 cases the head-lamps appeared to glare, due probably to the fact that the bulbs were out of focus. There were 17 "one-light" cars.

Parking-lights are not required on any car parked upon a Connecticut public highway where the light is sufficient for the car to to be seen from any direction at a distance of 200 ft. The authorities have announced that the operating of a car with only one head-lamp working will be tolerated no longer. Lack of a working tail-light may be a serious offense. It is stated that many accidents have been caused by cars not having the tail-lamp lighted.

With regard to glare, attention is called to the fact that a long line of glaring headlights is apt to restrict traffic going in the opposite direction to an unreasonably low rate of speed, this resulting in drivers becoming impatient and in the engendering of conditions in which accidents become imminent. The statement of the Department of Motor Vehicles is concluded with the observation that the enforcement authorities have been extremely patient with car-owners but that, to protect the citizens of the State, the rigid enforcement of the legal requirements as to the head-lamps must be begun in the very near future.

This statement is typical of the conditions of the present head-lamp problem. It cannot be said that night-driving has been made more agreeable or safe in recent years so far as head-lamp illumination is concerned. The Research Committee of the Society held a session recently for the purpose of outlining in a preliminary way a program for a restudy of the elements involved in safe, rational, effective, reliable and economical automobile head-lamp illumination.

ROOM FOR 10,000,000 MORE CARS

Number of Families Is Limiting Factor, Members Are Told at Annual Dinner

Twenty-seven million automobiles is the new saturation-point set by Col. Leonard P. Ayres, vice-president of the Cleveland Trust Co. and well-known bank statistician, in his address at the Annual Dinner of the Society, held at the Hotel Astor, New York City, on the night of Jan. 8. The family is the unit of use of a car, he said, just as the average family uses one bathtub or one telephone, and there are about 27,000,000 families in the Country. There are 17,000,000 motor vehicles now in use, so there are still plenty of opportunities for salesmanship. He pointed out, however, that increasing length of service due to the improvement of automobiles is cutting down the replacement demand, which he put at about 2,250,000 cars per year at the present time, and said that this is the most important hazard of the industry. But so long as engineers are able to make worth-while improvements, the demand for new cars will continue, because of the inherently competitive nature of the motor car. The speaker forecast a particularly good sales year in 1925, due to fundamentally sound economic conditions, and estimated that production and sales this year would reach 3,600,000. Colonel Ayres's address is printed in full in another part of this issue of THE JOURNAL.

There were more than 900 attendants at the Dinner. The reunion of old friends and renewal of acquaintances was, as always, a delight in itself and the spirit of mirth and good-fellowship was stimulated by a full repertory of organ music and singing of airs that were popular a quarter of a century ago and in which the diners joined with a gusto that made the walls of the great ballroom reverberate with a tremendous volume of sound. The food was excellent, too, and appealed to even the jaded taste of those who had attended the succession of preceding Automobile Show week functions of a similar nature.

When the demi-tasses had been pushed back, cigars lighted and the chairs turned to face the guest-of-honor dais, the flow of oratory for the stimulation of the mind began. This followed the opening of the business meeting of the Society by President Crane and the election of officers for the ensuing year. The results of the election are given elsewhere in this issue.

Dr. Arthur E. Morgan, president of Antioch College, and Leonard P. Ayres delivered the principal addresses, which were of a serious nature, and the program was concluded with a humorous-philosophical talk by Strickland Gillilan directed to, and at, the engineers and statisticians, the thrusts of which brought many a laugh while leaving behind some disturbing thoughts to ponder upon.

Following adjournment of the business meeting, President Crane reviewed briefly the progress of the Society during the last year and its present status, saying that membership was again assuming a satisfactory rate of growth which he believed was due to the fact that each member gets more from the Society in service of some kind than he gives to it. He was more than convinced, he said, that the value of the Society to the engineer must come through personal contact among the engineers. For a number of years the Society has been operated on a budget system, and during the last fiscal year the income exceeded the expenditures, he said, by more than $22,000, which evoked applause. The spending of the income wisely for the greatest good of the members is a matter of continual discussion in the Council. We are now nearly ready, he said, to reap great benefit from the beginnings made in the Research Department, started about 2 years ago, and the results have more than justified it. It was a source of optimism, he observed, that the incoming President was chairman of the Research Committee.

Toastmaster Kettering then introduced Dr. Morgan with a few brief, characteristically humorous remarks.

MAKING WHOLE MEN BY EDUCATION

Obligation of every school of higher education to develop every resource in a student and turn out "whole men" was the theme of Dr. Morgan's address, in which he explained the methods followed at Antioch College, Yellow Springs, Ohio. The students, who are drawn from all parts of the Country, spend 5-week periods alternately at the college and working in some practical jobs, some as remote as New York City, Chicago and in the Gulf States. The college is cooperating with about 200 different employers in many lines of practical endeavor, he said. In America we have found that we cannot run life entirely out of the classics and so decided to or-

The full story of the Annual Meeting begins on p. 119

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COL. L. P. AYRES

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A. E. MORGAN

ganize some institutions where people actually learn to do things, but America is beginning to be impatient with one kind of development alone and wants to make a normal, symmetrical life, which is the aim at Antioch, where they are trying to compare and budget the requirements of such a life by deciding their relative importance. A distinction is drawn, Dr. Morgan said, between the universals of education and the specific needs, those elements that should be a part of everyone's education and the particular ones that relate to the individual to fit him for his specific field of endeavor.

The college gives a good deal of attention to development of a good physical basis for the intellectual life of the student and to education in personal finance so that the student will know how to adjust himself to his economic condition. Efforts are made to develop a sense of beauty, also, and a good deal of emphasis is given to contact with realities, the first-hand experience of physical phenomena and contact with human relations. Behind all these, the college is trying to develop a purpose in life and the underlying feeling that life is good and worth all the effort one can put into it, said Dr. Morgan in conclusion.

NEW ERA FORECAST

President-Elect H. L. Horning was next introduced. After acknowledging the honor conferred on him by his election, he traced briefly the experience of mankind to illustrate the rapidity with which we are now moving, saying that, if all of human experience were compressed into 50 years, the Christian era would represent only the last 2 months and the quarter century of development of the automobile industry would cover only the last day. Economic circumstances set the limits to the rapidity with which we can utilize the great discoveries of our day, he said, and he offered the idea that it would be a good thing to have more business in engineering and more engineering in business. The most important thing is to know what men want; therefore, he had no greater hope for the coming year's work than to impress upon the members the value of studying psychology as applied to their work.

Referring to the fuel question, he said he had reversed his conviction and now believed that not within 100 years will we suffer for lack of fuel and that the quality is assured provided the petroleum industry can meet the economic side of the question. The fact of most tremendous significance is that the energy from the sun that falls on every acre of the earth's surface yearly is equivalent to almost 4000 tons of coal. The great era about to start will come when some man shows us how to get more than 1/200 of 1 per cent of this energy in the form of vegetable life. Then the fuel question will be solved.

Mr. Horning said he deemed it his duty to carry forward this year every effort to solve the great problem of highway accidents and referred to a single driving-rule which would take the place of the present hundreds of regulations but which had to be refined before being announced.

HORNING ELECTED PRESIDENT

Number of Ballots Cast for 1925 Officers Exceeds Any Previous Election

The result of the election of officers to serve during this administrative year which began with the close of the Annual Meeting of the Society held in Detroit last month, was announced at the 1925 Dinner which was held in Hotel Astor, New York City, on Jan. 8.

The tellers of election were F. H. Dutcher, W. E. Kemp and R. E. Plimpton.

It was reported that 1044 ballots had been cast, 23 of these being void. This is the largest number of ballots ever cast in an election of officers of the Society, last year's record of 969 being exceeded by 75. The result of the election with a few scattering votes was as follows:

President

H. L. Horning 1016

First Vice-President

T. J. Litle, Jr. 1017

Second Vice-President
Representing Motor-Car Engineering

H. D. Church 1017

Second Vice-President
Representing Tractor Engineering

O. B. Zimmerman 1018

Second Vice-President
Representing Aeronautic Engineering

P. G. Zimmerman 1016

Second Vice-President
Representing Marine Engineering

C. A. Carlson 1020

Second Vice-President
Representing Stationary Internal-Combustion Engineering

C. F. Scott 1021

For Members of the Council

O. M. Burkhardt 1020
C. H. Foster 1018
E. P. Warner 1019

For Treasurer

C. B. Whittelsey 1021

In addition to those named above, the following members of the 1924 Council will serve as members of the Council for this administrative year: Past-President Crane and Councilors Brumbaugh, Hunt and Rumney. The Council is constituted of 15 voting members. Photographs of the members of the 1925 Council and sketches of their lives will be found on p. 197.

ENGINE-CYLINDER LUBRICATION

Washington Section Told About Lubricating Upper Portions of Cylinder-Walls

NEIL MACCOULL

"Shotgun lubrication," or methods of lubrication that employ oil in too great abundance in the hopes of covering all possible emergencies and that plenty of oil will be delivered at all times, was a characterization specified by Neil MacCoull, of the Texas Co., while presenting his paper on Engine-Cylinder Lubrication to the Washington Section at the meeting held on Jan. 2. He remarked that such methods usually were practised by those who had no knowledge of how small the quantity of oil need be to give satisfaction.

The principal advantage of knowing how great a reduction can be made in oil consumption under varied conditions lies not so much in the saving of a quantity of the oil, and thus diminishing its cost, as it does in reducing the amount of carbon deposit and lessening the likelihood of causing fouled spark-plugs. For special laboratory-work that attempts to determine the relative amounts of carbon deposit due to the use of different oils, it is essential that definite control be had of oil consumption that can be repeated from one run to another.

In his discussion of the subject on a theoretical basis, Mr. MacCoull called attention to that part of the cylinder-wall which is exposed to the flame of combustion. At every explosion, some of the oil on this wall is lost because of evaporation, and the portion lost is some function of the temperature of the cylinder-wall and of the turbulence of the gas. Under ideal conditions, each stroke of the piston will carry to this wall a quantity of oil equal to the quantity lost by evaporation. If it brings up less oil, the wall soon becomes dry and the piston will seize. If it brings up more oil, the excess oil will be scraped off the wall, ahead of the top piston-ring, and will spread gradually over the surface of the piston-head. Referring to the phase of lubrication in which the oil is restored at the same rate at which it is lost by evaporation, Mr. MacCoull calls this the "first phase" and says that, at present, it is not known how much oil is lost during this phase.

Since no better data are available and to afford a working hypothesis, Mr. MacCoull assumed tentatively that the rate at which oil is burned from the cylinder-wall can be expressed in terms of the quantity of gasoline burned for all automobiles. From average practice, 30 to 50 gal. of gasoline is burned to 1 gal. of oil. Statistics available show as high as 100 gal. of gasoline to 1 gal. of oil and, in Diesel-engine practice, even 200 gal. to 1 gal. is reached. For ordinary service, this would be too near the danger point, but there is reason to believe that even better oil-economy can be secured when all the details of lubricating systems become worked out. He said also that it is still to be determined, experimentally, just how far we can go with different oils, and that this subject is now being investigated in the laboratory of the company he represents.

In the so-called "second phase" of lubrication, the excess oil not needed for the cylinder wall is scraped off to the piston-head. It is evaporated very readily by the piston-head, because that is so much hotter than the cylinder-wall. Mr. MacCoull believes that a large proportion of the oil now consumed in automobile engines is consumed by this evaporation from the piston-head, which can be included in the second phase of lubrication and is in no way of value in lubricating the cylinder-wall itself.

A "third phase" of cylinder lubrication is that in which the oil reaching the cylinder wall is in such great quantity that it cannot be evaporated and burned without forming heavy smoke in the exhaust. This seems to result when the gasoline-oil ratio approximates 10 or 15 to 1 values.

Referring to a "fourth phase," Mr. MacCoull defines it as that in which the oil supply is so copious that it cannot be evaporated, or that in which the oil will condense on the cooler metal parts and wet the spark-plug. While still in a liquid state, it may even go out through the exhaust-valve.

How Oil Passes Piston-Rings

After discussing how much oil should be supplied to the upper part of the cylinder-wall and what happens to an excess of oil when it reaches that locality, Mr. MacCoull directed attention to the lower portion of the cylinder-wall, from which the oil passes the piston-rings to reach the upper part. Apparently, when in operation, the piston-rings scrape off a certain percentage of the oil that is thrown on the lower cylinder-wall. He said that the rings almost never seal the oil completely and that this is a fortunate circumstance; because, if the oil-seal were complete, there would be no lubrication of the upper portion of the cylinder. The better the piston-rings fit in their grooves, the smaller becomes the percentage of oil that they will pass; but the proportion of oil that does reach the upper cylinder-wall is some meas-

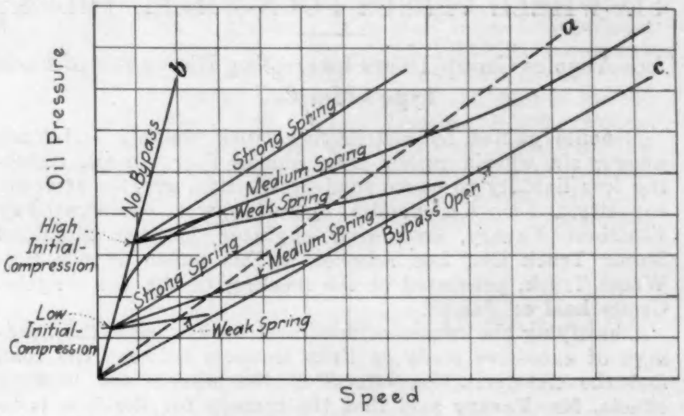


Fig. 1—Spring-Loaded Bypass-Valve Characteristics
When Used on a Full-Pressure Lubricating-System, Line *a* Represents the Relationship Between the Oil Pressure and the Speed of the Car in Miles Per Hour If a Uniform Quantity of Oil Is To Be Thrown on the Cylinder-Wall at Each Revolution of the Engine; Curve *b*, the Variation If There Were No Bypass Valve; and Curve *c*, the Relationship Provided the Bypass Valve Is Open Continuously and That the Passage to This Bypass Might Be of Rather Small Diameter and of Considerable Length

ure of the quantity of oil thrown on the lower cylinder-wall.

Oil viscosity at the piston-rings also affects the percentage that passes to the upper cylinder-wall. Hence, the hotter the piston is, the greater is the amount of oil that will pass up, even when a uniform quantity of oil is thrown on the lower cylinder-wall. Therefore, the temperature of the piston itself regulates automatically the flow of oil that passes it as the load on the engine increases; that is, as the volume of gasoline burned is increased.

Laboratory experiments by Mr. MacCoull's company have shown that, under any one set of conditions, the quantity of oil actually burned in an engine is directly proportional to the quantity of oil thrown on the lower cylinder-wall per revolution of the engine.

Following a discussion of advantages and faults of different lubricating systems, Mr. MacCoull directed attention to the curves shown in Fig. 1 of the characteristic operation of a spring-loaded bypass valve when used on a full-pressure lubricating-system. The line *a* represents the relationship between oil pressure and the speed of the car in miles per hour if a uniform quantity of oil is to be thrown on the cylinder-wall at each revolution of the engine. Line *b* shows the variation if there were no bypass valve; and line *c*, the relationship provided the bypass valve is open continuously and that the passage to this bypass might be of rather small diameter and of considerable length. Other lines in Fig. 1 show the effect of varied spring-stiffness and of high or of low initial compression. Apparently, if a spring-loaded valve is to be used, the best conditions will be met with a very stiff spring having practically no initial compression.

A characteristic of the spring-loaded valve is to supply an excess of oil at low speed and, if the speed is increased in great enough degree, a deficiency of oil at high speed. A high initial-compression of the spring aggravates this feature which, probably, is the cause of the use of throttle or vacuum-controlled bypass-valves.

Mr. MacCoull believes that, if all the ideals of lubrication could be realized in engine design, (*a*) engines can use low-viscosity, low pour-test and low carbon-depositing oils; (*b*) low consumption of lubricating oil will, in itself, result in the minimum carbon deposit; and (*c*) that always a uniformly high factor of safety under all engine speeds and loads will be attained. The only resource service-men have for controlling oil consumption lies in the choice of the viscosity of the oil used; for a high factor of safety for winter operation, an oil of low viscosity should be used.

Attendance at this meeting was reduced because of the heavy snow-fall of the previous evening; but practically all of those present joined in an extensive discussion, following the presentation of the paper.

SIX-WHEEL VERSUS FOUR-WHEEL TRUCKS

Los Angeles Group Hears Interesting Discussion of Each Type's Merits

Benefits gained by distributing truck weights and loads among six wheels rather than among four wheels, including less liability to cause road destruction, greater carrying capacity and more economical operation, were enumerated by Ethelbert Favary, consulting engineer for the Moreland Motor Truck Co., Los Angeles, in his paper on the Six-Wheel Truck, presented at the meeting of the Los Angeles Group held on Jan. 9.

Classifying the causes of road destruction under the headings of excessive loads on tires, impacts between the road and the tires, traction effects of the wheels and braking effects, Mr. Favary said that the remedy for the first is to reduce the load or to correct improper weight distribution. Impacts probably contribute the most destructive effects. Describing in detail what happens when a truck traveling at a given speed strikes a road obstruction, how the impact forces are exerted, he cited tests made by the Bureau of Public Roads to the effect that when a truck equipped with solid rubber tires was traveling at a speed of 16 m.p.h. and hit a road obstruction 1 in. high, the impact on the road surface was seven times the load on the tire; that is, for an 8500-lb. load on the rear wheel, the intensity of the blow imparted to the road surface was almost 60,000 lb. at times. The average impact was about 4 times the static load; with pneumatic tires it was about 25 per cent more than the static load.

Intensity of impact depends primarily upon the mass and upon the acceleration during the upward and the downward flight of the wheel and the axle; upward, when the wheel hits the obstruction and flies up; downward, when the wheel comes down after reaching its maximum upward travel, acquires velocity under the force of gravity and spring pressure and hits the road surface another blow before coming to rest.

Regarding the unsprung weight, Mr. Favary stated that the greater the weight of the wheels, axles and tires is, and the stiffer the springs are, the greater the impact will be. Less unsprung weight and more flexible springs reduce impact. Why this is true was illustrated and explained.

When propelled by engine power, tractive effort causes the driving wheels to tend to slip. The greater the speed of travel is and the smaller the ratio is of the load on the driving wheels, the greater the tendency for the wheels to spin and grind away the road surface will be; but the tendency is lessened when four wheels of a truck are driving wheels or if the load on the driving wheels is proportionately large.

Types of Six-Wheel-Truck Construction

Recent California laws limit the weight of a four-wheel truck to 22,000 lb. and that of a six-wheel truck to 34,000 lb. The maximum load per inch width of tire is 700 lb. Mr. Favary explained that the first advantage gained by distributing a given load over a greater number of wheels is the reduction of load on each wheel. With the type of six-wheel construction shown in Fig. 1, the two rear wheels on each side are tied together by a wheel-connector that is swiveled at the center where it is attached to the spring above. When one wheel is raised, the tendency is to raise the chassis only one-half the distance that the chassis raises in an ordinary four-wheel construction. Hence, when passing over an obstruction that raises one wheel to a certain height, since the center of the connector tying the two axles together is raised only one-half this height, the wheels can go over larger obstructions than possible with a four-wheel construction without raising the chassis to more than one-half the distance, provided both wheels on the same side are not raised at the same time. The springs between the axles and the chassis are flexed only one-half the amount, even though the wheel should rise the same distance as for a four-wheel truck; therefore, this six-wheel construction lessens the impacts between the wheels and the road considerably.

In addition, Mr. Favary remarked that, while the load on each rear wheel of the ordinary four-wheel truck of 22,000-lb. total load is 8500 lb., the load on each rear wheel of the six-wheel truck shown in Fig. 1, with a total loading of 34,000 lb., is less than 7000 lb.; on this account, the weights of wheel and of axle can be reduced correspondingly, thus gaining also a reduced unsprung weight.

Economy of Operation

Comparing percentages of pay load to dead weight of truck, Mr. Favary quoted for the six-wheel truck a total load of 34,000 lb., a pay load of 20,000 lb., a dead weight of 14,000 lb. and a pay-load to dead-weight ratio of 142 per cent; for a modern 5-ton four-wheel truck with a dump body and a hoist, a dead weight of 11,000 lb. and a pay load of 10,000 lb., or a similar ratio of only 91 per cent. In a recent run from Los Angeles to San Francisco made by a 10-ton six-wheel truck of the type shown in Fig. 1, the average running speed was 13.5 m.p.h. with a full load and the fuel consumption was 4 miles per gal. of gasoline.

Supposing a demand for the transportation of 1000 tons of merchandise per day over a stated route, Mr. Favary estimated the needed number of six-wheel trucks weighing 7 tons each and having a pay load of 10 tons each to be 100, or a total dead weight on the road of 700 tons; and the number of four-wheel trucks weighing 5.5 tons each and having a pay load of 5 tons each to be about 200, or a total dead weight on the road of 1100 tons. In such case, an extra 400 tons per day must pass over the road with four-wheel units and, even if but 180 of these were needed to equal the performance of the six-wheel units described, this would call for 80 more trucks and 80 more drivers. For a 100-mile route, allowing 4 gal. of gasoline per mile, the 100 six-wheel trucks would use 2500 gal. of fuel; allowing 5 gal. per mile, the 180 four-wheel trucks would use 3600 gal. of gasoline. The saving of 1100 gal. of gasoline per day by using six-wheel trucks then represents a decrease of 44 per cent in transporting the 1000 tons of merchandise, and a corresponding decrease in oil consumption.

Impact Tests

Mr. Favary quoted other results of tests made by the Bureau of Public Roads. It was shown that the impact forces of a six-wheel truck loaded with 6 tons were lower than those arising from an ordinary 2-ton truck, both being equipped with pneumatic tires. Further, that the ordinary 3 to 5-ton solid-tire Army truck exerts a maximum subsoil pressure of 6½ lb. per sq. in.; but the 5 to 7½-ton six-wheel truck exerted a subsoil pressure of but 2 lb. per sq. in., each truck having been loaded by 10,000 lb. All four rear wheels of the six-wheel and of the Army truck are used for driving and braking.

Steering Ability

After making an illustrated mathematical analysis of impact forces due to four-wheel 5-ton and six-wheel 10-ton trucks, Mr. Favary discussed the steering qualities of six-wheel trucks, some of which being steered by the two front wheels only and others using four wheels for steering. When the distance between the two rear axles is more than a given amount, steering through four wheels is a necessity to avoid a sliding action between the tires and the road surface when rounding a curve. When the two rear axles are close together, as in Fig. 1, in which the distance between the centers of the rear wheels is 40 in., no such sliding action takes place, this having been proved by tests; consequently, no steering linkages are required for the middle wheels, driving as well as braking being through the four rear wheels and steering by the front wheels only.

Summary of Advantages

In conclusion, Mr. Favary compared the capabilities of the four-wheel and the six-wheel truck. Among the advantages of the six-wheel truck, he mentioned the reduced load

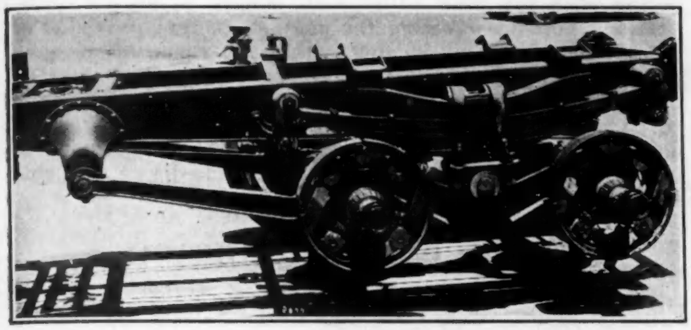


Fig. 1—Rear Construction of a 10-Ton Six-Wheel Truck
The Two Rear Wheels Are Tied Together by a Wheel-Connector That Is Swiveled at the Center Where It Is Attached to the Spring Above. When One Wheel Is Raised, the Tendency Is To Raise the Chassis Only One-Half the Distance That the Chassis Rises in an Ordinary Four-Wheel Construction

on each wheel, which results in lessened static and subsoil pressure; reduced impact forces; improved traction; and reduced tendencies toward wheel spinning and skidding. Also, increased economy in freight transportation, and a smaller number of trucks on the road to carry the same amount of tonnage. Further, that fewer trucks represent an important part in decreasing road destruction, increase the traffic capacity of existing roads and minimize traffic congestion.

As proof of the keen interest in the activities of the Society on the Pacific coast, 130 representative members of the automotive and allied industries attended the Los Angeles meeting. During the progress of the animated discussion that followed the presentation of his paper, Mr. Favary enlarged upon the information he already had presented, and illustrated his replies to queries by blackboard sketches.

LOS ANGELES FEBRUARY MEETING

At the meeting scheduled for Feb. 27 at the Elite Restaurant in Los Angeles, the subject for discussion will be the Cost of Operation and the Economic Life of a Motor Truck. Three representative speakers have been invited to prepare papers and prominent members of the automotive industry have been requested to submit written discussions. The papers are to be presented by Joseph Scott, of the Bureau of Power and Light, City of Los Angeles; Eugene Power, superintendent of automotive equipment of the Union Oil Co., which uses more than 1800 units; and W. F. Fairbanks, superintendent of shops and vehicles for the Southern California Telephone Co. An interesting meeting is promised, and a large attendance is expected.

PRINCIPLES THAT GOVERN LUBRICATION

Buffalo Section Informed Regarding What Constitutes "Quality" of an Oil

Problems that confront the engineer in selecting the proper grade and character of lubricating oil to give the best average performance in particular types of automotive units operating in widely diversified service were enumerated by E. W. Kimball, service engineer of the Vacuum Oil Co., at the meeting of the Buffalo Section held on Jan. 6. He also made suggestions for solving these problems, based upon his own experience and that of the company he represents.

Speaking first of the importance that the producers of automotive equipment attach to lubrication, Mr. Kimball stated that more than 50 per cent of the complaints handled by service-stations are traceable directly or indirectly to lack of care in the lubrication of the vehicle. Further, that the cost of lubricating the vehicle with oil of the best quality obtainable represents less than 3 per cent of the total cost of its operation. By using a lubricant of something less than best quality, it may be possible to effect a saving of one-half the lubrication costs, or 1½ per cent of the total operating cost; but this saving cannot be made without risking a considerable increase in the cost of repairs.

An oil is called upon to perform three major functions: Prevent metal-to-metal contact and consequent wear; seal

SCHEDULE OF SECTIONS MEETINGS

FEBRUARY

3—Dayton Section—Engineers' Club—Charles F. Kettering
4—Milwaukee Section—The Advantages of Different Voltage Electrical Systems for Motorbuses—L. P. Michaud; Advantages of Voltage-Regulated Generators over Third-Brush Regulation for Current Generators—D. S. Cole
4—New England Section (Boston)—Possible Improvements in Passenger Car Design—Herbert Chase
5—Detroit Section—Chassis Lubrication—Joseph Bijur
10—Pennsylvania Section—Digest of Winter Meetings Papers—John Younger
12—Indiana Section—Automobile Finishes—H. C. Mougey; Nitro-Cellulose Finishes from the Service Angle—L. Valentine Pulsifer
13—Washington Section—An Analysis of Steering Mechanisms—F. F. Chandler
16—Cleveland Section—Modern Electrical Instruments—J. H. Hunt
17—Buffalo Section—Modern High-Speed Marine Engines—L. M. Woolson
19—Metropolitan Section—Personal Equations in Driving—H. H. Allen
20—Chicago Section—The Air Mail—Paul Henderson, Second Assistant Postmaster-General
26—San Francisco Group—Efficiency of Air-Cleaning Devices—Prof. A. H. Hoffman
27—Los Angeles Group—Cost of Operation and the Economic Life of a Motor Truck—Joseph Scott, Eugene Power and W. F. Fairbanks
Minneapolis Section—No meeting

MARCH

9—Pennsylvania Section—Service Paper—A. E. Hutt
17—Buffalo Section—Automotive Airbrake Equipment—H. D. Hukill

the pistons and piston-rings, prevent "blow-by" and conserve power; and transmit heat, thereby assisting in maintaining the working temperatures at a practical maximum. To obtain best results from the standpoint of lubrication, an oil possessing real quality must be employed, it must be of the proper body and character to meet the requirements of the engine design and the operating conditions, and care must be exercised to maintain the condition of the oil within a safe working range during the operation of the engine.

Essentials of lubricating quality for an oil are: Careful selection of the grade of crude with reference to its possibilities from the standpoint of lubrication; carefulness throughout the refining process to avoid destroying any of the inherent properties that make for real lubricating value; and careful packing, shipping and handling to prevent contamination. The degree to which a lubricating oil becomes thinned by engine heat depends upon the original character and body of the oil and the temperature to which it is heated. Operating temperatures of engines are extremely variable. For high operating-temperatures, oils heavy in body and rich in character are best adapted to protect the mechanism against wear under the stresses imposed by high temperature; when such stresses are absent, lighter-bodied cleaner-burning oils become suitable.

Discussing details of the foregoing factors of lubricating effectiveness, Mr. Kimball went on to describe differences in lubricating systems and commented also upon sludge and carbon formations. An oil must have sufficient body to provide an adequate seal, and burn clean enough to prevent carbon formation. Engineering experience with lubricants and a knowledge of their properties are required in determining their serviceabilty. The major complaints regarding the performance of a lubricant are: Rapid dilution, emulsification or sludging due to the presence of water, and carbon formation which is an aftermath of oil pumping. In conclusion Mr. Kimball presented specific instructions on how to avoid crankcase dilution, oil sludging, oil pumping and carbon deposits.

In the discussion that followed the presentation of the paper, Mr. Kimball replied to many queries. A point brought out by L. H. Pomeroy in the written discussion he submitted had reference to the internal temperature of the engine, which is, of course, a function of cylinder-wall and piston temperature and, as such, not necessarily dependent upon the size of the engine. Mr. Pomeroy said the determinant is heat-flux per unit time in its relation to the conductivity of the various parts concerned. For example, an aluminum piston having a thick head will run at a lower temperature, at the same engine speed, than if the piston-head were thin. The heat-flux depends upon the total amount of heat rejected, according to Mr. Pomeroy's statement, and is therefore dependent upon the product of cylinder capacity and engine speed. He said also that crankcase-oil dilution is desirable, with the proviso that the thickness of the oil-film with the diluted lubricant shall be greater than the average size of the dirt particles carried by the lubricant. To this last, Mr. Kimball agreed and mentioned recent research work by his company in which particles of dirt were added to the lubricant and microphotographs made that contribute valuable data regarding dilution effects. He said also that the greatest reliance is placed on service tests, following extensive laboratory tests for determining the lubricating value of an oil.

GOVERNOR CHARACTERISTICS

New England Section Discusses Devices for Speed Regulation of Internal-Combustion Engines

Characteristics desirable for a governor intended for motor-vehicle usage were summarized by E. F. Lowe, general manager of the K. P. Products Co., New York City, in the paper he presented at the meeting of the New England Section held at Boston on Jan. 14. These are compactness and sturdiness of construction; dependability; ease of installation and adjustment; capability for being sealed to prevent tampering with the fixed adjustment; ability to prevent overspeeding without affecting the engine's power; provision of quick acceleration by opening within 100 r.p.m. of the governed speed; refusal to increase speed at partial throttle-opening; and failure to over-run, but actually having a sharp cut-off at the governed speed. Such a governor should not cause the engine to "surge," should be impervious to injury due to backfiring, be reasonably priced and available for all types of gas engine.

STUDIO PARTY IN CHICAGO

Entertainment and Dancing Party Given by Local Section During Show Week

The activities of the Chicago Section during the Automobile show of last month took the form of an entertainment and dance at Chez Pierre, of which the presiding genius is Pierre Nuyttens, an artist renowned for his etchings. At the time of this event Mr. Nuyttens was working on a portrait of President Coolidge.

This party, which was held on Jan. 29, was perhaps the happiest and most gratifying ever held by or participated in by the Chicago Section from the good fellowship and entertainment point of view. Over 100 members dined at Chez Pierre and danced until the wee small hours were well under way. A special feature of the occasion was the presentation to President Horning and General Manager Clarkson of three-quarter size crayon portraits of themselves. These works of art had just been finished in Mr. Nuyttens' studio.

LUBRICATION AND DILUTION

Popularized Version of Bureau of Standards Research at Indiana Section Meeting

Lubrication and dilution problems were treated in a most unusual vein at the January meeting of the Indiana Section. S. W. Sparrow, member of the automotive research staff of the Bureau of Standards in the City of Washington, took occasion to present the results of lubrication studies by that organization in a popularized style and greatly pleased the members present with his unusual presentation. It is assumed that Mr. Sparrow's comments will prove as interesting to the reader as they did to the Indianapolis audience and they are published here as an example of deft handling of a highly technical subject with what one might term a human interest appeal.

> That peace-destroying invention, the cross-word puzzle, has acquainted us with the dictionary which appears to know something about everything. Let us see what it knows of that puzzle called lubrication. Webster's Unabridged defines "to lubricate" as "to supply, as moving parts and their bearings, with grease, oil, or other lubricant for the purpose of lessening friction." The chief flaw of this definition is that it suggests the force required to move one surface relative to another rather than the wear occasioned by the rubbing of one surface against another. As far as the internal-combustion engine is concerned, the primary object of lubrication is to prevent or reduce such wear. It is accomplished by maintaining between the two working surfaces some substance which will prevent them from being in contact while they are in motion. In the language of the divorce court lubrication is a "separation arranged on the grounds of mutual incompatibility."
>
> The maintaining of this desired separation between the two working surfaces depends upon the unwillingness or reluctance of the lubricant to depart from between them. That property upon which the reluctance depends is known as viscosity, and the unit of absolute viscosity is defined as the force that will move a unit area of plane surface at a unit speed relative to another parallel plane surface from which it is sepa-

Sections Secretaries

BUFFALO SECTION—L. H. Pomeroy, 155 Cleveland Avenue, Buffalo
CHICAGO SECTION—J. W. Tierney, 140 South Dearborn Street, Chicago
CLEVELAND SECTION—L. L. Williams, 3173 Kensington Road, Cleveland Heights, Ohio
DAYTON SECTION—F. H. Walkley, 262 Fountain Avenue, Dayton, Ohio
DETROIT SECTION—Fred A. Cornell; Assistant Secretary, Mrs. B. Brede, 5-110 General Motors Building, Detroit
INDIANA SECTION—George T. Briggs, Wheeler-Schebler Carbureter Co., Indianapolis
METROPOLITAN SECTION—F. H. Dutcher, Columbia University, 117th Street and Broadway, New York City
MILWAUKEE SECTION—Walter S. Nathan, Ajax Motors Co., Racine, Wis.
MINNEAPOLIS SECTION—A. W. Scarratt, 1663 Laurel Avenue, St. Paul, Minn.
NEW ENGLAND SECTION—G. S. Whitham, Charles Street Garage Co., 144 Charles Street, Boston
PENNSYLVANIA SECTION—Charles O. Guernsey, J. G. Brill Co., Philadelphia
WASHINGTON SECTION—Conrad H. Young, 724 Ninth Street, Northwest, City of Washington
LOS ANGELES GROUP—Ethelbert Favary, Moreland Motor Truck Co., Burbank, Cal.
SAN FRANCISCO GROUP—A. A. MacCallum, S K F Industries of California, Inc., 115 New Montgomery Street, San Francisco

rated by a layer of the liquid of unit thickness. If an increase in viscosity is added insurance against contact, why then should not the highest possible viscosity be sought? The answer has a familiar ring—"It costs more." Cost as here used does not refer to the money that much be paid to obtain a gallon of oil but to the force that must be exerted to shear the oil-film.

POUR-TEST MAY NOT INDICATE COLD PROPERTIES

A recent advertisement for an oil states, "The lunging thrust of plunging pistons is smoothed to silence and smoothed to power by this lubricant which leaps to its work in defiance of cold." This "leaping to work in defiance of cold" is an extremely desirable but somewhat rare characteristic. The ability of an oil to flow at low temperatures is of the utmost importance in aviation-engine practice because of the extremely low temperatures encountered. For this reason experiments have been made at the Bureau of Standards in which oils at a temperature of —10 deg. cent. (14 deg. fahr.) were caused to flow through a tube about ⅛-in. in diam. and 3-in. long. It was found that the rate of flow of a paraffin-base oil increased more than in proportion to the pressure causing flow. This did not occur with oils of other bases. The investigation has shown that the present pour-test fails as a measure of the tendency of an oil to flow at the low temperatures sometimes encountered in the operation of an airplane engine, as under these conditions a paraffin-base oil shows a more rapid rate of flow than a naphthenic oil of much lower pour-test.

Too high a viscosity is bad, too low a viscosity is worse for if the viscosity is too low there will be excessive friction and excessive wear under full-load conditions. With every engine there is some speed, some load, some part of the cycle where unit pressures are a maximum and if the viscosity of the lubricant is adequate for this condition it will, of course, be more than adequate for all other conditions.

Dilution reduces the viscosity of the crankcase oil. Someone has said that it does no harm provided the oil originally is more viscous than necessary. That is granted provided the dilution is considerate enough to stop just when it reaches the critical viscosity. It seldom does. The seriousness of dilution is not primarily the reduction in viscosity but the instability, the continuous changing of viscosity. We sometimes hear the idea advanced that dilution is somewhat of a blessing in that being greater in winter than in summer it automatically provides the less viscous oil which is generally recommended for winter use. It is even pointed out that when the oil is badly diluted operation at full load will eliminate this dilution and thus automatically supply the more viscous oil which such operation demands. Unfortunately the kindness shown by the diluted oil in these instances does not appear to be premeditated but is what in legal jargon is known as an "accessory after the fact." The high viscosity desired for full-load operation comes *after* a period of operation at full load and the low viscosity which makes the engine easy to turn over in starting comes *after* the engine has been turned over and supplied with the rich mixture necessary for starting.

CAUSES OF DILUTION

What causes dilution? Under normal operating conditions, that is to say, after the engine has reached its normal operating-temperature, it appears that it

(1) Depends primarily on the average temperature of the cylinder-walls
(2) Depends directly on fuel volatility
(3) Depends directly on the average fuel-air ratio
(4) Does not depend much upon the charge temperature or the degree of vaporization

It appears that the four influences stated above can be explained by a knowledge of the dew-point temperature, the temperature at which the first drop of fuel will condense on cooling or the last drop will evaporate on heating. If the temperature of the oil-film on the cylinder-wall is below this value liquid spray striking this wall will not be evaporated and vapor striking the wall will be condensed. Hence the influence of jacket-water temperature upon the rate of dilution.

Obviously the dew-point temperature does not depend upon the intake temperature; hence the temperature of the cylinder-walls at which dilution stops should not depend primarily on intake-charge temperature nor should dilution depend upon it directly. If the fuel were entirely evaporated before entering the cylinder, condensation on the cylinder-walls and consequent dilution would occur if the walls were below the dew-point temperature. Upon fuel volatility, however, the rate of dilution is directly dependent and the lower the volatility the more dilution one would normally expect. The reason for the dependence of crankcase-oil dilution upon fuel-air ratio is evident since the dew-point temperature depends upon fuel-content as well as upon volatility.

It is interesting to know that the influence of wall temperatures has been investigated using a temperature of the cooling medium as high as 100 deg. cent.

(212 deg. fahr.). Oil was the medium employed, its choice being dictated solely by convenience. No attempt was made to study its efficiency as a cooling medium, attention being directed only at the problem of dilution. The dilution under such conditions was extremely small, the viscosity actually increasing as is its normal change when dilution is absent. This experiment is of practical interest in that temperatures of this order can be obtained with steam-cooling systems.

Effect of Starting on Dilution

The dilution which has been discussed thus far, that which takes place under normal operating-conditions, is likely to proceed at a rather steady rate and eventually to reach an equilibrium value. The situation is somewhat different with respect to the dilution that occurs during the starting period. An enormous increase in fuel must be provided at low temperatures to get sufficient fuel vapor to form an explosive mixture. It is not an increase of 10 or 20 per cent but of more than 1000 per cent. The portion of the fuel that under such conditions vaporizes in time to enter effectively into combustion bears about the same relation to the total as the frosting does to the rest of the cake. This unvaporized fuel comes in contact with the cold oil-film, dilutes it and eventually reaches the crankcase. Where starts are frequent and periods of continuous operation are rather short, the rate of dilution is likely to be extremely high and the diluent must be eliminated from the oil at a comparatively rapid rate to maintain the viscosity of the oil at a safe value. How the diluent gets out of the oil is an important question and should receive attention as well as how the diluent gets in.

MacCoull, in a paper[1] presented at the 1924 Semi-Annual Meeting of the Society showed that the temperature of the crankcase oil had a marked influence on the rate of dilution. This influence is probably the result of increasing the rate at which the diluent gets out rather than of decreasing the rate at which it gets in. Some investigators have found that the extent to which the crankcase is ventilated is important. The theory may not be known to every washerwoman but the facts are, namely, that heat and a breeze are necessary for evaporation. Devices for eliminating dilution are usually designed to heat all or a part of the oil and their action in principle is somewhat as just described.

There are certain penalties attached to avoiding or eliminating dilution by increasing the average temperature of the jacket-water or by increasing the average operating temperature of the crankcase oil. Increasing the jacket temperature is likely to increase detonation troubles. Increasing the average operating-temperature of the crankcase oil means that its initial viscosity must be higher. This, of course, means increased effort to crank the engine when starting.

Lubricant's Function as a Piston Seal

Thus far, we have dealt with the subject on the assumption that oil serves only as a lubricant. To some extent at least it must act as a seal between the piston and the cylinder-walls and at times this function of the lubricant is decidedly important. Recently some tests were made at the Bureau in which the friction horsepower of an engine was measured with the cylinder-head on and then with it removed. The difference is or at least bears some relation to the pumping loss.

An increase in pumping loss resulted from removing the rings due, of course, to leakage. This increase, however, was only about ½ hp. when the jacket-water temperature was 20 deg. cent. (68 deg. fahr.), but it was more than 2 hp. when the jacket-water was at 90 deg. cent. (194 deg. fahr.). The effect of a change in viscosity upon the oil's effectiveness as a seal is apparent. At a speed of 1200 r.p.m. with a jacket-water temperature of 20 deg. cent. (68 deg. fahr.), this pumping loss was the same with and without the rings which appears to indicate that the oil itself forms an adequate seal under such conditions.

While this matter of leakage is under consideration it may be of interest to know that recent tests have shown no increase in dilution to result from an increase in clearness of $\frac{1}{32}$ in. in diameter or from reducing the number of rings from 3 to 1, but that removal of the last ring caused a very marked increase in the dilution.

The target to be aimed at in lubrication is to provide a lubricant which will keep the metal surfaces apart, produce the minimum amount of friction, effectively seal the combustion-chamber, and not go where it is not wanted. To prepare the target is not difficult; to hit it is no small achievement.

[1] See The Journal, July, 1924, p. 97.

MEETINGS ON INSPECTION

Two round-table meetings of inspectors were held in Detroit during January under the auspices of the Detroit Section for the purpose of organizing a series of meetings devoted to matters directly concerning automotive inspection. It will be remembered that the Detroit Section devoted one of its meetings last spring to papers on inspection methods and the interest aroused at the time indicated that more such meetings would be popular. The committee that has the inspection meeting programs in charge is made up of engineers in the Detroit district who are directing the inspection work of some of the principal car and parts factories.

CLEVELAND SHOW EXHIBIT

Enterprising officers and committee workers of the Cleveland Section staged an interesting Society exhibit in one of the booths at the Cleveland Automobile Show during the third week of January. The exhibit included motion pictures and slides depicting automotive industrial activities in the city of Cleveland and vicinity, posters setting forth the objects of the Society and describing its work and displays of Society literature and other material which gave the motorist some conception of what the Society is and what helpful things it has done for him. The Clevelanders are commended for their interest and justifiable pride in the parent Society and their Section as demonstrated by the unselfish effort needed to stage this exhibit successfully.

PAINT A POPULAR SUBJECT

Methods of finishing automobile bodies continue to attract wide interest among members of the Society. This is evidenced by the fact that both the Milwaukee and Minneapolis Sections devoted their January meetings to papers on nitro-cellulose enamels, their properties and methods of applying them. Both meetings were addressed by R. P. Thayer of Valentine & Co. and R. C. Williams of E. I. du Pont de Nemours & Co. They presented the advantages of the nitro-cellulose materials introduced by their respective companies.

Incidentally, the Indiana Section is to devote its February meeting to this same topic. The meeting will be addressed by H. C. Mougey of the General Motors Research Corporation and L. Valentine Pulsifer of Valentine & Co. It will be held on Feb. 12 at the Hotel Severin, Indianapolis.

SAN FRANCISCO ACTIVITIES

Air cleaners were the topic treated at the meeting held by San Francisco members of the Society in that city on Jan. 29. F. J. Annis, California distributor of the Protectomotor Co., read a paper on Tests of Air-Cleaners in the

Volcanic Ash Districts of California. The meeting was well attended and the paper was productive of considerable interesting discussion.

Members interested in the San Francisco activities of the Society should get in touch with A. A. MacCallum, S. K. F. Industries of California, Inc., 115 New Montgomery Street, San Francisco.

The San Francisco members will meet on Feb. 26 when Prof. A. H. Hoffman, of the University of California, will speak on the Efficiency of Air-Cleaning Devices.

THE ANNUAL MEETING

A Complete News Account of This Important Gathering

ANNUAL MEETING IS GREAT SUCCESS

Papers, Exhibits and Demonstrations Received Enthusiastically by Large Attendance

Judged from all angles, the Annual Meeting in Detroit, Jan. 19 to 22, may be regarded as one of the most successful national gatherings ever held by the Society. Attendance numbered close to the 900 mark, but the number was not the significant thing. Of far greater importance was the predominance of men whose interests are primarily those of a purely engineering nature, the technicians who bear the major responsibilities of current automotive engineering development. Assuredly this was an engineering meeting. There were new things to hear, see and learn in every session. Exhibits and demonstrations that featured nearly every paper aroused an unusual amount of favorable comment. Never before has such keen interest been taken in models, samples and demonstrating apparatus as was evidenced in the displays at this year's Annual Meeting. It was not an uncommon sight to find large numbers of men grouped about the exhibit tables a half-hour after the close of a session.

It is not an easy task to select the topic that aroused the greatest interest at the Detroit meeting. Usually one or two sessions of a national meeting stand out as the ones most largely attended and on that basis the topics discussed in them are judged as those which appeal most to engineers at the time. This was not the case with the 1925 Annual Meeting. Little difference was noticed in the number present at the Wheel-Shimmy, Balloon-Tire, Engine Vibration, Lubrication, Aeronautic or Research Sessions. All sessions were well attended, even when two were being held simultaneously. So no attempt will be made to judge which of the several topics discussed is uppermost in the minds of engineers today. It may be said advisedly that the Meetings Committee struck a respondent chord in laying out a program that seemed to have such a general appeal to the engineering fraternity.

Exceptionally able delivery of papers featured the Annual Meeting program. Perhaps the large number of demonstrations and the quantity of exhibition material was responsible in part for the commendable presentations. At any rate, many members spoke particularly of the unusual amount of interest taken in the actual presentations of the several papers. Formality seemed to have been erased, audiences evidenced an uncommon concentration on the matters in hand, all were alert and the attentiveness was that of an engineering conference of associates keenly interested in a problem, rather than that of a conglomerate assembly of men from many ranks and companies listening to the formal delivery of technical theses. The same keen interest was taken in the discussions.

A complete and illustrated news account of the Annual Meeting will be found on the following pages. This includes abstracts of the discussion of all papers, descriptions of the many exhibits, an account of the Carnival, and the reports of the Administrative Committees and the Treasurer. Also, a majority of the papers read at the meeting are published in full in this issue of THE JOURNAL. The remainder of the papers will, it is expected, appear in full in the March issue.

RESEARCH SESSION DRAWS CROWD

Instruments and Committee Work Discussed; Interesting Exhibits Featured


J. A. C. WARNER

A real indication of the effectiveness of any activity of the Society is the degree to which the members take advantage of the opportunities that are offered. In the work of the Research Department the information service may be taken as illustrative. One thousand requests for information handled through correspondence and a great number of questions answered by direct conference is the record for the past year as presented at the Research Session of the Annual Meeting by President-Elect H. L. Horning in his report of the activities of the Research and Highways Committees, in which the Research Department cooperated.

Among the major research projects with which the Society is directly connected, those on highways, automotive fuels and riding-qualities are perhaps the most important. The highway research, an investigation of motor-truck impact, is being carried on by the Bureau of Public Roads with the Rubber Association and the Society through its Highways Committee cooperating. In the fuel research, satisfactory progress has been brought about through the joint activities of the Bureau of Standards, the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society. Work on the riding-qualities project has thus far been confined to the Research Committee. A Riding-Qualities Group of the Committee includes in its membership H. C. Dickinson, E. C. Newcomb and E. P. Warner.

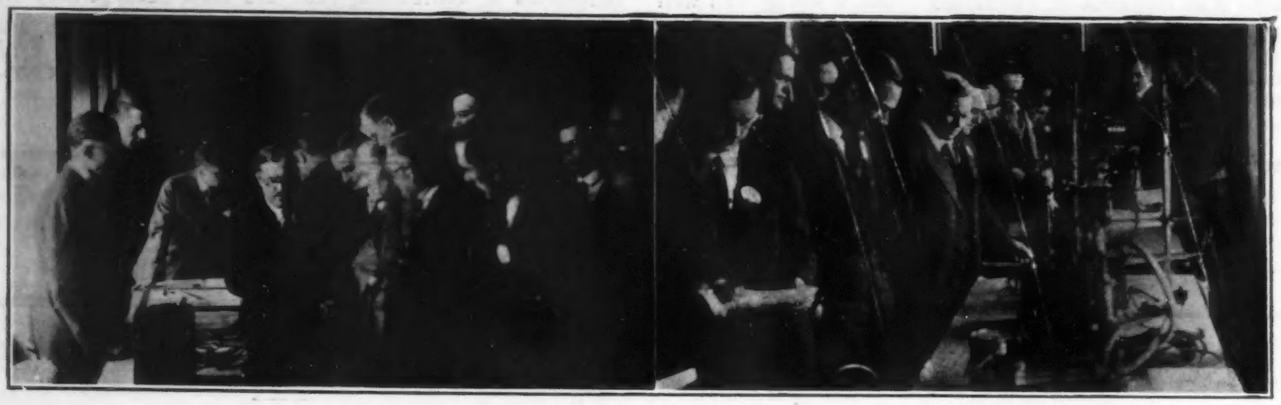
The Automotive Research columns of this issue of THE JOURNAL, p. 161, contain a detailed summary of the Society's research activities as they were discussed by President Horning at the Annual Meeting.

INSTRUMENTS FOR AUTOMOTIVE RESEARCH

Exhibits of some 20 instruments, adapted to automotive research, presented an interesting accompaniment to the paper given by J. A. C. Warner, the Society's research manager.

The following were among the exhibits and exhibitors that so largely contributed to the success of the meeting:

Bureau of Standards
- Apparatus for measuring fuel flow by volume
- Clearance volume indicator
- Carbon pile telemeter
- Engine indicator made by the American Instrument Co.
- Vibrometer
- Pedal pressure indicator
- Decelerometer made by the American Instrument Co.



DEMONSTRATIONS OF INSTRUMENTS AND TESTING APPARATUS AT THE RESEARCH SESSION

The Cambridge & Paul Instrument Co. of America, Inc.
- Electrical apparatus for exhaust gas analysis

Engineering Division of the Air Service
- Farnsboro electric engine indicator
- Elverson oscilloscope

International Motor Co.
- Riding-qualities accelerometer

Lubricating Appliance Mfg. Co.
- Apparatus for determining viscosity and dilution

Rotostat Instrument Co.
- Stroboscopic apparatus

University of Michigan
- Modified engine indicator
- Gas analysis apparatus
- Apparatus for measuring fuel flow by weight
- Loudness evaluator developed for the Timken Roller Bearing Co.

Waukesha Motor Co.
- Phoneloscope for the study of sound, made by H. G. Dorsey

Mr. Warner first discussed the general considerations that apply to all instruments adapted to automotive research and then described a number of special instruments.

GENERAL CONSIDERATIONS

Characterizing the automotive industry as outstanding in its effort to obtain with utmost speed the answer to engineering and research problems, the speaker called attention to the hazards sometimes involved in the type of procedure demanded by tremendous production schedules and rapid advancement. Costly errors have resulted from experimental work improperly planned and executed, from conclusions too quickly drawn and from unjustified interpretation of observed indications. The widespread use of cut-and-try procedure was said to be due largely to the failure of hastily applied research methods in many cases in which mature consideration would have shown the apparently longer course to be promising of more prompt and satisfactory results at a lower net cost.

DESIGN REQUIREMENTS

Clerk Maxwell, in his General Principles of the Construction of Apparatus wrote in part:

> There are certain primary requisites which are common to all instruments and which therefore are to be carefully considered in designing or selecting them. The fundamental principle is that the construction of the instrument should be adapted to the use that is made of it, and, in particular, that the parts intended to be fixed should not be liable to become displaced; that those which ought to be movable should not stick fast; that parts which have to be observed should not be covered up or kept in the dark; and that pieces intended to have a definite form should not be disfigured by warping, straining or wearing.

The concise statement of requirements above quoted was amplified by the speaker under the headings of adequate accuracy and sensitivity, sturdiness and durability, adaptability or convenience in use, good workmanship and reasonable cost.

ROUGH-AND-READY DEVICES

Mr. Warner called attention to the fact that many of our most serviceable and valuable instruments and laboratory set-ups are constructed from miscellaneous material picked up around the plant and assembled by the use of a pair of pilers and a screw driver, with a generous admixture of ingenuity. It is often undesirable, he said, to expend relatively large sums of money on instruments that are to be used for a short series of observations only and that can be constructed in a very homely fashion with the minimum expenditure of time and funds. Good workmanship and flawless finish are impressive but are often unjustified.

Attention was called to the items that should be considered in determining the type of design and construction with respect to the cost.

MOTION STUDY

Automotive engineers are often required to analyze the motion of moving parts or systems. This may be done by (*a*) direct observation, (*b*) graphical recording, (*c*) stroboscopic means and (*d*) photographic processes. The speaker discussed the advantages of the above methods and emphasized the value of stroboscopic and photographic apparatus for this work.

In connection with motion-picture methods, it was stated that camera speeds of from 32 to 5000 exposures per sec. have been satisfactorily used. A 5000-per-sec. camera produced in England was said to weigh approximately 4 tons, and the cost of negative film alone for this camera was said to be approximately $1,500 per min.

Motion-picture methods for studying moving parts have many advantages for certain types of work. The records may be projected in large size upon a screen or the film may be examined carefully through a magnifier. Reasonably accurate measurements may be made by the use of a fixed scale and when desirable a time scale may be produced upon the film by a regulated high-tension spark maintained by a tuning fork. One obstacle to the more extensive use of motion-picture methods is the high relative cost. Continuing his discussion of methods of motion study, the speaker described several types of stroboscopic apparatus and called particular attention to the Elverson oscilloscope which was included in the exhibit.

HOW LOUD IS LOUD?

Direct analysis of sounds or noises by the unaided human ear has the limitations characteristic of other human records. The development of apparatus for the study of noise was reviewed from the application of the listening rod to the modern devices which utilize electrical methods. Among the latter, one of the most interesting is the apparatus developed at the University of Michigan under the direction of Floyd A. Firestone for the Timken Roller Bearing Co.

Firestone Describes Noise Evaluator

In his description and demonstration of the electrical apparatus for determining the loudness of noise from bearings or other sources, Floyd A. Firestone called attention to the wide field of usefulness of this arrangement. The instrument was said to consist essentially of an ordinary microphone combined with a sensitive alternating current voltmeter.

In the demonstration the voltmeter scale was projected upon the stereopticon screen and the pointer moved across its scale in accordance with the loudness of noises that were produced. The extreme sensitivity of the arrangement was of great interest. Mr. Firestone stated that the indications of the instrument are practically independent of pitch and that the quantity indicated is loudness.

In the factory the indicating dial is observed by the inspector who compares indications from the bearings under inspection at the rate of one every 3 sec. with a dial-reading obtained from a bearing known to be satisfactorily quiet.

The apparatus was said to be susceptible of accurate calibration against a given standard. For comparative purposes this may be a 110-volt 60-cycle current properly regulated to cause a certain deflection of this voltmeter.

The loudness of sounds varies greatly from the faintest to the loudest that one would be interested in studying; the factor involved in this variation may be a million or more. It is thus necessary to equip the loudness evaluator with a control device that enables the operator to arrange for a sensitivity adapted to the requirements.

Firestone with His Loudness Evaluator

This Apparatus Has Been Used by the Timken Roller Bearing Co. To Study the Loudness of Noise Issuing from Bearings and Other Parts. The Apparatus Developed at the University of Michigan Includes a Microphone Element Connected in a Suitable Electric Circuit Which Utilizes a Voltmeter To Show the Loudness of Sounds or Noises. A Special Microphone Is Used for Studying Vibrations of Solid Parts

Device for Measuring Fuel Flow by Weight Developed by Prof. W. E. Lay at the University of Michigan

The Apparatus Includes Devices for Operating through Electric Circuits, the Stop-Watch and the Counter-Mechanism That Is Attached to the Dynamometer Shaft

Mr. Firestone called attention to the fact that the type of apparatus described is not selective and that it measures the total loudness without being capable of differentiating between the various component parts of a given noise. He stated further that work is now in progress on an apparatus which will confine the attention of the instrument to any given pitch or frequency that is to be studied. With this arrangement it should be possible to assign the proper noise values to the various parts included in a given mechanism. A number of possible applications of this device in the automotive industry were enumerated.

For measuring the vibration of a given surface from which noise issues a different kind of microphone, resembling the stethoscope is used. This microphone may be likened to a small brass cylindrical container, with a projecting point that is held against the vibrating surface. It was demonstrated that this type responds very little to air vibrations but that it does show a marked effect when subjected to the vibrations from solid objects.

Further Discussion

Prof. W. E. Lay, of the University of Michigan, described certain modifications that he had made upon a well-known type of maximum-pressure engine-indicator of the balanced-piston type. The modification consisted of a cooling arrangement which permits the indicator to be screwed directly into the cylinder instead of at the end of a long constricted passage.

Professor Lay also described and demonstrated an ingenious automatic arrangement for measuring fuel flow by weight in connection with engine tests. The apparatus is rendered automatic by the use of suitable electrical circuits to operate a stop-watch and the counter at the proper point. It was said to require little attention during a run, thus leaving the observer free to make necessary observations and adjustments. The recording may be done at any time after the run at the convenience of the observer. The possibility of error is reduced to the minimum and the apparatus is accurate enough to show consistent results in a run of less than 2-min. duration.

Prof. George Granger Brown, of the University of Michigan, discussed his methods of exhaust-gas analysis and described and demonstrated the apparatus which he uses. The application of this apparatus to the study of distribution, combustion and other factors not only in a laboratory but on the road was explained.

S. H. Woods, of the International Motor Co., described a recently developed apparatus for studying riding-qualities by measuring vertical accelerations. Two records are made simultaneously upon the chart, one being the shock and the other the rebound.

AVIATION PROGRESS

Woolson Describes New Aircraft Engines; Stout, the All-Metal Plane

Recent Advances in Aircraft Engine Design, as exemplified by the Packard Models 1500 and 2500, and the Design of All-Metal Airplanes were the topics discussed respectively by L. M. Woolson and W. B. Stout before a crowded session over which Charles L. Lawrance presided.

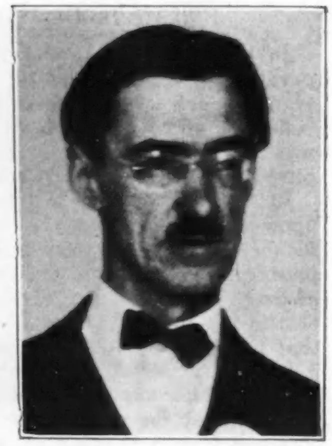
Improvement in airplane performance during the last 6 or 7 years, said Mr. Woolson in part, has been due to two factors: (*a*) advances in aerodynamics, which have improved the structure and decreased the parasite resistance of airplanes so that less power is required to fly at a given speed with a given load and (*b*) improvements in powerplants, which have served to produce more power for the same weight of engine and require smaller overall dimensions for the same power. In addition to being more compact than the Liberty engine in both length and height and weighing 140 lb. less, the Model 1500 500-hp. engine develops about 100 hp. more, when each engine is run at its rated speed. Similarly, comparing the Model 2500 800-hp. engine with its predecessor, the Model 2025, a gain of 250 hp. is made with a decrease of 75 lb. in weight.

When these superiorities are translated into terms of airplane performance as applied to commercial aviation, a comparison of the Model 1500 with the Liberty engine, when used in the Stout "air pullman," shows that it is possible to transport double the pay-load over the same distance at a higher speed, or to transport the same pay-load over 2¼ times the distance at a higher speed. This means a 100-per cent increase in revenue; and lightweight engines properly designed are not more expensive to manufacture, less reliable, or shorter lived than is the Liberty.

Study of Details

In designing the new engines precedent was disregarded when unsupported by well recognized and proved engineering limitations. Nothing was taken for granted and every detail was given the closest possible scrutiny. Believing that the foundation of engine design is represented by the bearing layout, exact knowledge was sought as to the loads to which the bearings were to be subjected, and the design proceeded accordingly. The connecting-rod and main bearings

L. M. Woolson



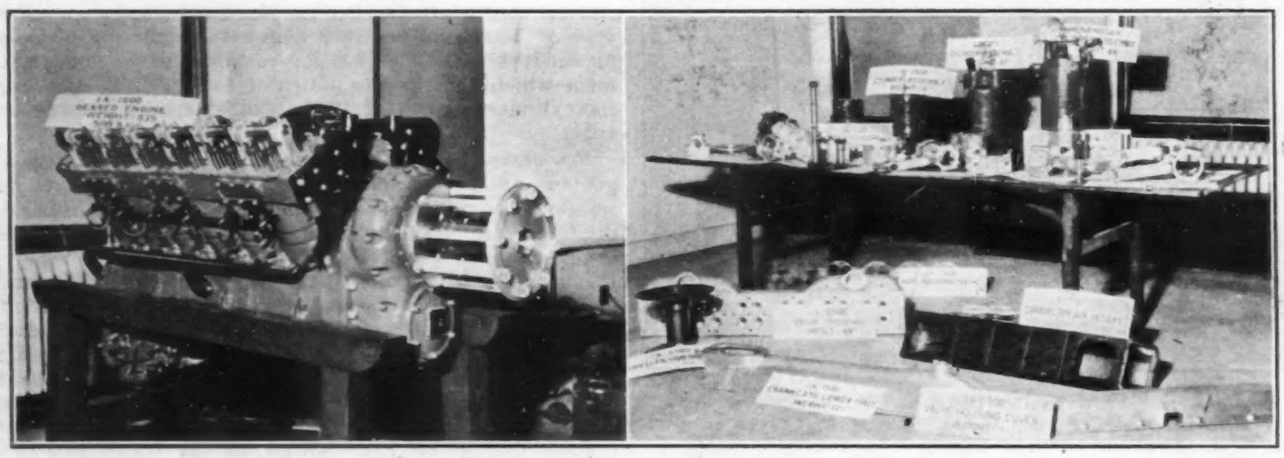
William B. Stout

received first consideration. Providing generous bearings means increasing the length of the engine, hence, increasing its weight, although in many cases the length is dictated by cylinder design.

But, as a new type of cylinder construction and assembly was adopted, the necessity arose for thorough investigation into the possibility of shorter crankshaft and connecting-rod bearings than have hitherto been customary. It was found that failures of bearings were rarely due to lack of lubrication and that the wear often was not measurable, but that the failures were caused by fatigue of the babbitt lining that had been produced by minute flexing of the bearing backing. The importance of more-rigid bearing-backing was thus brought out; and it was evident that if the babbit were prevented from flexing under load far greater loads could be carried without distress. Tests, accordingly, were made to determine the limitations of various types of bearing metal, under no appreciable flexing of the bearing and with ample force-feed lubrication.

The results showed that the greatest *PV* value without seizure was obtained from babbitt-lined steel-backed bearings and that this value ranged from 44,500 to 48,500 lb. per sq. in., depending on the size of the bearing. The *PV* value of the bearing loads, as compared with those of the Liberty engine, were found to be: for the crankpin, 18,520 lb. per sq. in., as against 13,200; center, 35,000, as against 22,650; and intermediate, 27,000, as against 14,000. In general, the tests showed that the new bearings will have at least double the life of the corresponding Liberty bearings.

Experience with the Liberty engine having shown that rigidity of the crankshaft is highly desirable, because torsional vibrations of the crankshaft induce troubles in the timing-gear train, the new crankshafts were designed so



Part of the Packard Exhibit
At the Left Is a Completely Assembled Model 1500 Engine Developing 500 B. Hp. and Weighing 835 Lb.; at the Right the Various Component Parts Are Shown

that the primary critical speed would occur far beyond the critical range of the engine. On the Model 1500 engine the critical speed of vibration is 64 per cent higher than on the Liberty engine and the crankshaft is about twice as stiff as that of the Liberty, although the weight is approximately 30 per cent less, the result being a marked smoothness of operation accompanied by freedom from wear in the timing-gear train.

Cylinder Design

Two major considerations dictated the type of cylinder design that was adopted, namely, (*a*) that adjacent cylinders should be placed as close together as possible, to diminish the bulk and weight of the engine as a whole, and (*b*) that the cylinder assembly should be as light as possible. A completed Model 1500 cylinder weighs 9.5 lb., and it develops nearly 50 hp.; a Model 2500 cylinder weighs 15.2 lb., and it develops nearly 70 hp.

The advantages of the construction selected are that water circulation is provided in close contact with all heated surfaces, the steel cylinder-barrel is used as a wearing surface and also carries the explosion loads down to the crankcase, the hold-down flange is located some distance from the end of the cylinder barrel, which allows a very compact construction and adds depth and rigidity to the crankcase, and the engine can be run successfully in an inverted position.

Other advantages of individual cylinder construction include ease of manufacture, ability to install the largest possible valves while maintaining adequate water-circulation around the valve-seats, and a more closely spaced cylinder arrangement than is possible with any other form of construction.

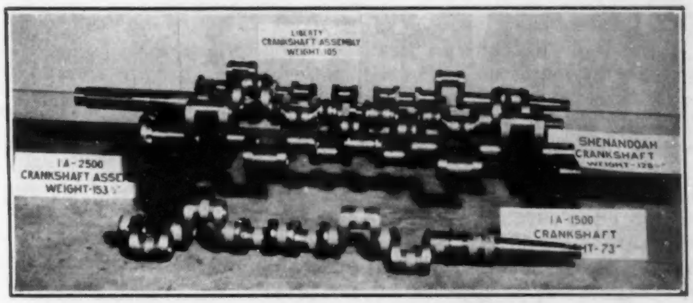
The aluminum valve-housing is bolted to the six cylinders to form a cylinder-block, which remains assembled throughout all the usual operations of assembling and disassembling, but any individual cylinder can be replaced, if necessary, with the minimum of delay. This housing performs the functions of distributing the mixture to the six cylinders from the two carbureter cross-header manifold connections, of forming the exhaust passages into each of which are siamesed the two pairs of exhaust-ports from two adjacent cylinders, of collecting the water circulated through each cylinder-jacket and delivering it through a single outlet at the front of the engine, and of supporting the pedestals and the valve-stem guides.

A single camshaft is used interchangeably for each block of cylinders, each camshaft having 12 cams for operating the six pairs of inlet and six pairs of exhaust-valves in each block. A positive means of cooling the exhaust-valve is provided by pumping a fixed quantity of oil through the valve each time it is opened. The exhaust-valves, consequently, operate at a very low temperature and the valve-seat is preserved in excellent condition for long periods of time.

Valve-Springs

The valve-springs are of the multiple-cluster type and consist of a group of small-diameter piano-wire springs arranged in planetary fashion around the valve-stem, 7 of these springs being used for each valve of the Model 1500 engine and 10 for each valve of the Model 2500 engine. An important point in this construction, and one of the least obvious, relates to the natural period of vibration of the small springs. Other advantages result from the increased factor of safety in numbers, since any valve will continue to function even if several of the springs should be broken, the reciprocating weight of the springs is reduced, and the properties of the small-gage piano wire are superior to those of springs heat-treated after forming.

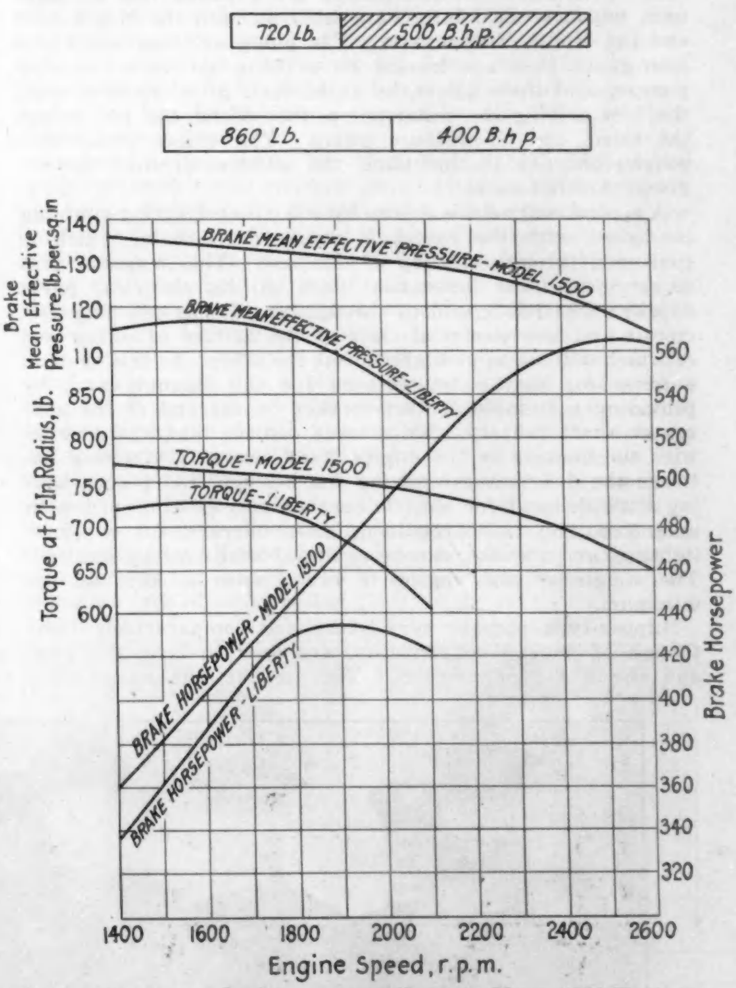
It has been clearly proved that the cause of failure of the valve-springs, previously attributed to fatigue and to minute imperfections in the material, is due to a resonance effect between the natural vibrations of the springs and the forced vibrations of the engine produced by the firing impulses. In the multiple type of spring, the natural frequency of vibration is 250 per sec., as compared with 72 per sec. in the single type; in other words, the frequency is 3½ time as high.



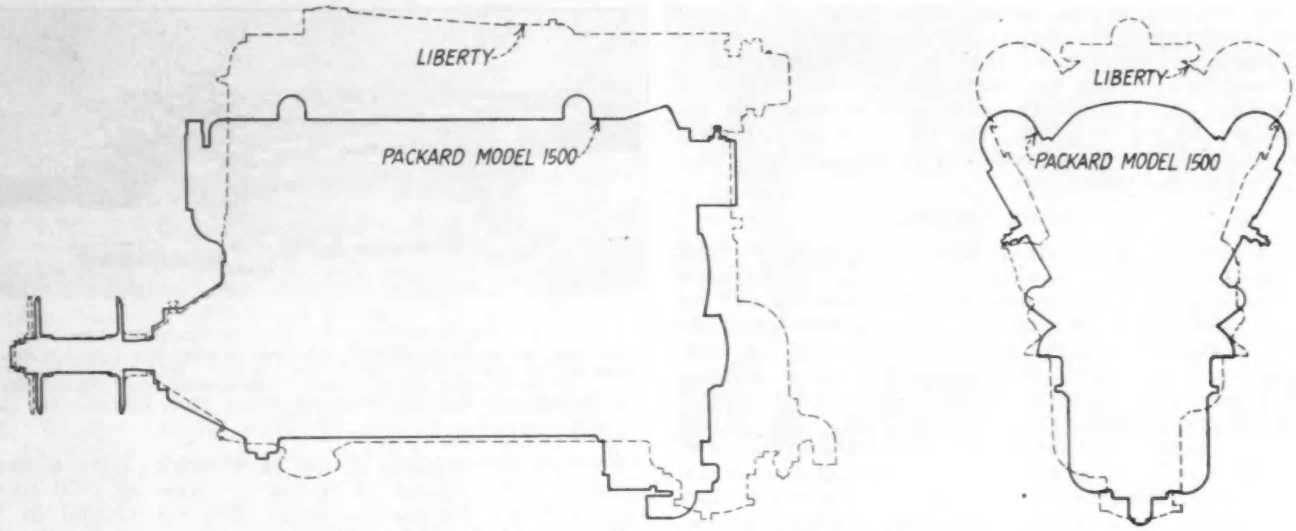
A Very Interesting Exhibit of Crankshafts
The Progress Made in Weight Reduction from the Liberty Engine Assembly Weighing 105 Lb. to the Packard Model 1500 Weighing 73 Lb. Is Strikingly Brought Out. The Crankshaft Assemblies of the Shenandoah and the Packard Model 2500 Engines Are Also Shown

Previously, breakages of the valve-springs have occurred in six-cylinder engines at speeds in excess of 4000 r.p.m., in 12-cylinder engines, at about 2000 r.p.m., and in 18-cylinder engines at speeds not exceeding 1600 r.p.m. Although used in many prolonged tests with high-speed engines, the small springs have been immune from failure. Copious lubrication is furnished by full pressure-feed to the individual camshaft-bearings and is aided by the oil discharge from the exhaust-valve stems at each opening.

As the minimum number of gears is employed, the timing-gear and accessory-drive layout combines simplicity with the integral construction of the shaft and gear, wherever permis-



Comparison of the Liberty and the Packard Model 1500 Engines from Different Standpoints
The Two Blocks at the Top Illustrate the Reduction in Weight and the Increase in Power of the Model 1500 Engine (Above) as Compared with the Liberty Engine (Below). The Liberty Engine Weighed 2.15 Lb. per Rated B. Hp.; the Packard Engine Weighs Only 1.44 Lb. Comparative Performance Curves Are Also Shown



PROFILES OF THE LIBERTY AND THE PACKARD MODEL 1500 ENGINES
The Compact Design of the Latter Engine as Compared with the Earlier Design Should Be Noted

sible, and with the use of pressure-lubricated chilled-aluminum plain bearings throughout. These features combine to save weight while preserving dependability to the utmost extent.

PUMPS

All fuel, oil and water-pumps are grouped into a single unit, which is used interchangeably on both the Model 1500 and the Model 2500 engines. The pump unit contains three spur-gears that are housed in to form the oil-scavenging pumps; and these gears, in turn, each drive another unit, the first driving the water-pump, the second, the fuel-pump, the third, the oil-pressure pump. The entire pump unit weighs only 16 lb. including the oil-strainer and the oil-pressure relief-valve.

A special magneto is driven by a laminated spring-coupling connected with the camshaft center drive-shaft, which is continued through the top of the case. This magneto is a single mechanical instrument with all its electrical parts duplicated and independent throughout. It has one magnetic circuit and two electrical circuits, the failure of either one of which will not appreciably affect the other. In this system, a generator may be substituted for the magneto and, by providing a suitable contact-breaker on the end of the generator shaft, battery ignition may replace magneto ignition with no changes in the engine itself nor in the wiring between the distributors and the spark-plugs. Airplanes having little demand for electric current may be equipped with magnetos, and those requiring more current, for wireless, lighting, and the like, can be equipped with battery ignition. The weight of the engine in either case is kept at the minimum.

Slipper-type pistons, very short and comparatively light though of rugged construction, are used in both the 1500 and the 2500-type engines. The smaller piston, notwithstanding the fact that it has 15 per cent greater area, weighs only 90 per cent as much as the Liberty piston, whereas the larger piston weighs only 63 per cent as much as that used on the Shenandoah, while having only 9 per cent less area. The lengths of the pistons, 3½ and 3$\frac{15}{16}$ in., respectively, were finally determined upon after the skirt had been gradually diminished.

Although both engines were originally designed for direct drive, both have been built in geared form for use with a special gear-reduction of the spur-gear single-reduction type, which is entirely self-contained. A shock-absorbing drive between the crankshaft and the pinion has proved very successful in preventing the gear trouble resulting from impact loading.

ADVANTAGES OF THE INVERTED-TYPE ENGINE

The Model 1500 engine has also been built in the inverted type, the four major advantages of which are: (*a*) improved vision, (*b*) a high center of thrust, which ensures better flying-quality in that it offsets the tendency of the airplane to climb when under full power, (*c*) accessibility for inspection and overhauling while on the ground, and (*d*) favorable location of the carbureters, which allows gravity feed and renders complicated piping and pumping arrangements unnecessary.

As the weight of the Model 1500 airplane engine is about 1.4 lb. per hp., the weight of the airplane complete is but little more than that of the engine alone a few years ago; consequently, maneuvers can now be performed that previously were impossible.

Contemporaneous progress in aviation-engine development consists largely of detailed improvements intended to yield lighter and more reliable engines that will have lower first-cost and be more economical in operation and maintenance.

OFFICERS FROM SELFRIDGE FIELD WHO ATTENDED THE AERONAUTIC SESSION

Although experimental work in engine design is continually directed along unconventional lines, the most important advances during the next few years, in the opinion of the author, will be made with 12-cylinder water-cooled and nine-cylinder fixed radial air-cooled engines, for these types offer the best opportunities for immediate engineering advance.

In the near future, an engine weighing about 1 lb. per hp. is a strong probability. Such an engine would consume its weight in fuel every 2 hr. and the carrying capacity would be reduced correspondingly by the amount of fuel that must be carried.

The Discussion

In the discussion that followed the reading of the paper, the numerous questions that were asked elicited further information from Mr. Woolson, and his replies are summarized as follows:

The valve ports, he said, are not bored but are formed after assembling. The cylinders are interchangeable to a very large degree and are frequently interchanged after the valve-seats have been formed. Rotary engines are practically obsolete for they have been superseded by the fixed radial type, which is superior in every way. A radial-type engine can produce as much power as a rotary engine and does not consume power in rotating itself. Rotation is not necessary for cooling and the centrifugal forces produced in the rotary engine require that it be made of much better material. Inverting the Model 1500 engine requires no change in the method of feeding oil to the bearings, but the drainage of oil from the crankcase is somewhat different. The various compartments formed by the cylinder barrels' projecting through the crankcase must each be drained. Acceleration is greater than gravity and no difficulty is experienced in getting oil into the cylinders, provided the cylinder barrels project inside the crankcase.

The break mean effective pressure, he continued, is about 140 lb. per sq. in., but the operating pressure will depend on the degree of throttling. The fuel consumption is about the same as that of other aviation engines and varies from 0.53 lb. for the maximum output to 0.47 lb. for the maximum economy.

Lack of the necessary flexibility in two-cycle engines was given as the reason for their infrequent use. Aircraft engines must have flexibility. If two-cycle engines could throttle, accelerate and operate wide-open as well as do four-cycle engines, they would be used very largely. The fuel consumption of two-cycle is higher than that of four-cycle engines.

If impedance were present in the circuit, he added, it would make no difference whether one circuit of the primary of the magneto were short-circuited or merely open. If no impedance were present, the engine would miss and possibly stop. The temperatures at which the exhaust-valves operate would make the use of either silchrome or tungsten valves satisfactory, but high-tungsten valves have been preferred. The valve-seats are chrome-nickel forgings, containing 0.40 per cent carbon.

Bearings

No trouble has been experienced with the babbitted bearings on the steel shells, continued Mr. Woolson. The babbitt will loosen when backed with bronze but the elasticity of steel is about double that of bronze.

The disadvantages of flying with an inverted engine, Mr. Woolson continued, have not been fully determined, but the question will undoubtedly be settled by flight tests during the coming year. The lubrication problem is not difficult to solve.

Driving the auxiliaries from the front end of the crankshaft is merely a matter of convenience. Driving them from the rear end would be satisfactory, provided the crankshaft were stiff enough to avoid the effects of torsional vibration.

The size of the engines is largely one of demand. The recent tendency in airplanes has been toward the use of small high-speed engines geared down to slow-speed propellers, but in lighter-than-air craft, the demand has been for heavier engines. Designs have been produced for engines of 3500 hp., which would weigh about 1 lb. per hp.

In arranging the valves so that the four inlet-valves are in one compartment and the four exhaust-valves in another, he continued, no appreciable difference has been noticed because one pair of stems is nearer to the port than is the other.

Babbitt is molded to the steel back by a centrifugal process and is held against the steel by grooves cut into the steel circumferentially. So far, the steel-backed bearings have given perfect satisfaction. Carbonization of the oil in the exhaust-valves does not occur because of the rapidity of the flow of oil through them. The temperature of the oil does not exceed 220 deg. fahr. and carbonization will not take place below 400 deg. fahr.

The very entertaining paper on the Design of All-Metal Airplanes presented by Mr. Stout is printed in full on p. 209 of this issue of The Journal. Before proceeding with the reading of the paper a series of slides, showing the development of the thick-wing type of airplane and various details of its construction, was thrown on the screen. On account of the lateness of the hour at which the meeting came to a close, no discussion of Mr. Stout's paper took place.

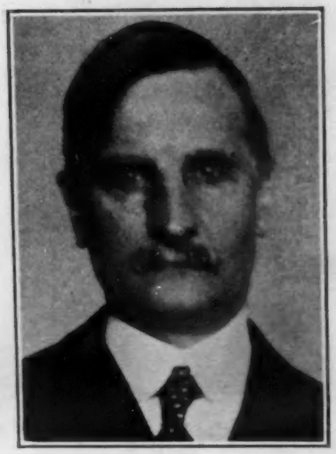
ALL-METAL PASSENGER CAR BODIES

Comparisons Made Between All-Metal and Composite Design Features

STEEL bodies and their advantages when compared with the usual wood-and-metal construction formed the subject for discussion at one of the sessions devoted to passenger-car bodies. The paper on All-Metal Body Design and Construction, by E. G. Budd and Joseph Ledwinka, was presented by Mr. Budd and is printed in this issue of The Journal on p. 219.

Replying to questions, Mr. Budd first explained how the "ring" or tinny sound credited generally to an all-metal body has been exaggerated. He acknowledged a difference in the quality of the sound, compared with that produced by a wood-and-steel body, but claims that an all-metal body is less noisy than one built of wood and steel. He said there is no more thin sheet-metal in a steel body than in a wood-frame body. Although the outer shell is somewhat heavier, it is formed in a manner that stiffens it and eliminates the noise that people like to designate as "tinny." Also, that the shell of the body referred to in his paper is of a more solid construction than is the outer shell of a composite body. As to servicing an all-metal body in case of collision and wreckage, Mr. Budd was not prepared to say that repair is easier than for a composite body but is certain that it is no more difficult. With suitable equipment, he mentioned that repairs on all-steel railroad-coaches have been found to be accomplished more easily than was true for the wood-and-steel type of construction.

J. Ledwinka



E. G. Budd


A. L. Knapp
Packard Motor Car Co.


K. Forbes
Buick Motor Co.


L. A. McDowell
H. M. Body Corporation


W. N. Davis
Cadillac Motor Car Co.

FOUR ENGINEERS WHO ATTENDED THE MEETING

Comparing the weights of all-steel and of composite bodies, Mr. Budd stated that any structure for which a definite requirement of strength is demanded will be lighter if made of steel than if made of wood, and instanced bridge structure and modern steel-frame building-construction as examples. To the query regarding what conditions determine the selection of gas or of electric spot-welding, he replied that gas welding is almost exclusively for seams while spot-welding is used as a substitute for rivets; but by making the spots of welding very close to each other, the effect of seam-welding is attained electrically. He said that both forms of welding have respective merits and that both are needed. For an equal strength of body and an equal weight, he claims that an all-steel body will withstand a crash better than would the composite construction.

"Blind spots" due to the obstructions to the driver's vision interposed by the two front supporting columns of a closed body can be minimized better in all-metal than in composite construction because, for a given strength, the columns can be made smaller.

Production problems were touched upon by Mr. Budd, who said that analysis determined details regarding whether handwork or expensive tools and dies were to be used. For great quantities of product, expensive tools and dies are justified, but for costly bodies, few in number, they are not. As an instance he cited a supposed order for 5000 cars, calling for say 5000 doors. The question then is presented whether to expend say $20,000, or $4 per door, for door dies or to use say half the number of dies and do half of the work by hand at a less costly rate. He explained the problem as being a mechanical one.


Charles L. Lawrance
Aviation


T. J. Litle, Jr.
Air-Cleaner

CHAIRMEN AT TWO OF THE SESSIONS

Mr. Budd believes that the all-steel construction for automobile bodies will become as universal as for railroad coaches. Regarding roof construction, he said that, as yet, his company has not determined how to make a roof of steel that will be as light in weight as is the composite roof ordinarily used. He compared methods of trimming all-steel and composite bodies, and said that trimming for the all-metal construction is entirely made up on the bench. Operators who are skillful at handwork replace the former skilled upholsterers. No tacks are used on the trim below the roof line. The material is mounted on three-ply wood veneer 3/32 in. thick, after being made into pads, folded over the edges of the form and glued to its back, in the case of door and other panels. The panels are clamped in place and then are fastened almost entirely by the hardware fittings that are screwed on afterward. At locations where no such hardware is used, clips on the back of the veneer project under the in-turned flange of the door or the upper back panel. The roof is covered on the bench, inside and out, including head-lining. It is installed after the body is completed and painted, and after the inside fittings of upholstery are put in. It is fastened by screws that come up through the roof rail, through the upper rail of the body in door openings, window openings and the real windows, as well as along the windshield in front. Holes are drilled in the metal work and the wood screws engage in the wood rail of the roof.

In conclusion, Mr. Budd discussed strains that are introduced when a metal sheet is put over a wood frame, due to the different physical characteristics of these materials. Such a metal shell does not strengthen the frame, and distortions of the wood tend to break the shell.

THE BUSINESS SESSION

Remarkable Sections Growth and Good Financial and Membership Conditions Shown

The adjourned session of the 1925 Business Meeting of the Society, which had been convened at the Hotel Astor, New York City, on Jan. 8, was held in Detroit on Jan. 20, with President Crane in the chair. Reports were made by various Administrative Committees and by the Treasurer.

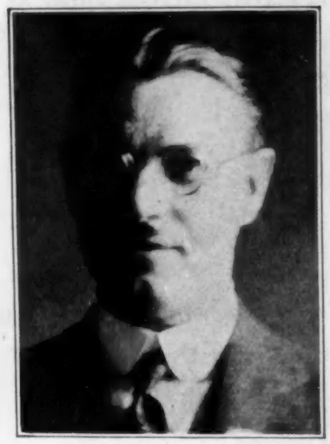
MEMBERSHIP COMMITTEE REPORT

Chairman W. R. Strickland, of the Membership Committee, reported that the Society had on its rolls 5174 members and affiliate member representatives, this constituting an increase of 121 during the last year. This increase represents the difference between 569, the total number of new members who were elected and qualified during the year, and 448, the total number who ceased to be members through resignation, being dropped for non-payment of dues or other cause.

The Committee felt that the practice of dropping members

Ernest Wooler
Cleveland

W. D. Appel
Oakland



A. Boor
Willys-Overland

D. E. Anderson
Cadillac

ANOTHER GROUP OF ENGINEERS WHO WERE PRESENT

who are not sufficiently interested in the Society to pay their dues, within the time provided by the rules, is resulting in a strengthening of the membership. This is indicated by the fact that 83 per cent of the members paid their dues for 1925 before Jan. 1. It is interesting to note that most of the members who resign or drop their membership do so because they have severed their connections with the industry; in parting, they usually have a good word for the Society and its work.

The status of the Society's membership at the end of last year, as compared with that of 1923, was as follows:

	Dec. 31, 1923	Dec. 31, 1924
Members, including Service and Foreign Members	2,871	2,885
Associates	1,422	1,492
Juniors	556	512
Affiliates	103	105
Affiliate Representatives	101	180
	5,053	5,174
Enrolled Students	258	246
	5,311	5,420

The Membership Committee expressed its appreciation to the members who assisted it by sending in the names of prospective members on post cards mailed to them from time to time. The Sections Membership Committees also were complimented on their work. The splendid cooperation of the members with the Society's headquarters staff in carrying out the mail campaign outlined by the Committee at the beginning of last year resulted in the receipt of 760 applications, or an increase of 157 applications over the number received in 1923. The mail campaign was begun about April 1.

REPORT OF THE MEETINGS COMMITTEE

On behalf of the Meetings Committee, Chairman T. J. Litle, Jr., stated that the meetings of the Society during the administrative year were generally successful.

Efforts had been made to secure papers of specific interest to each of the various groups of the membership and to select the papers on the basis of their scientific and practical merit. Care was exercised to confine the meetings to topics of current interest. Most of the papers dealt with problems awaiting solution rather than with problems already solved.

The Meetings Committee has appreciated the increasing importance of industrial research and the year's programs reflect the leadership of the automotive industry in scientific and production activity. A large percentage of the papers have revealed results of what may be termed research investigations. Data of this nature have been invaluable to the members in their development work. Many specialists have been called upon to address the meetings.

The Society intends not only to continue its production activities but to strengthen and extend them. Those members whose interests are primarily of a production nature are urged to assist the Meetings Committee and Council in making the 1925 Production Meeting the best yet held by the Society.

It is the intention of the Meetings Committee to arouse greater interest in aeronautics during the present year. More papers and meetings on commercial aviation are desired. The active interest of those engaged in the aeronautical industry is solicited.

Greater enthusiasm must be aroused in the motorboat field. The number of optimists who look upon this branch of the automotive industry as possessing great possibilities in the immediate future is increasing. The Society has made repeated efforts to be of service to the motorboat industry and intends to continue its work in that field, despite the recent postponement of the New York Motorboat Meeting for lack of industrial interest.

Members of the Society who do not make a practice of attending its meetings are denying themselves a great privilege. Automotive progress is rapid and there is no

THREE FRANKLIN EXECUTIVES WHO ATTENDED THE MEETING
From Left to Right They Are E. S. Moore, Chief Engineer; R. Murphy, Manager of Works; and S. R. Castor, Assistant Chief Engineer

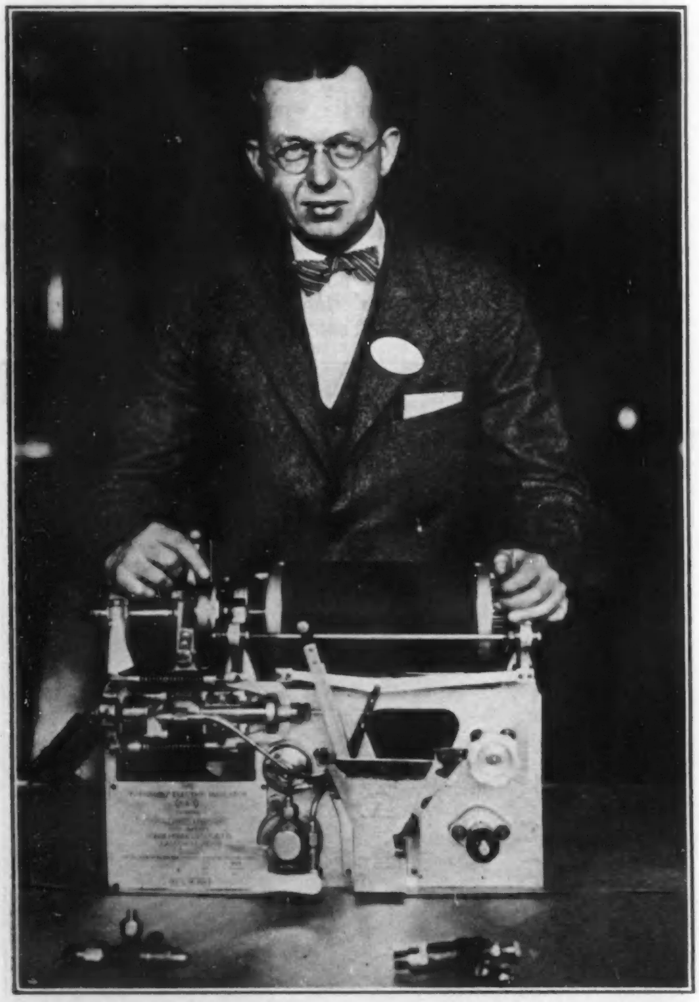
COMPARATIVE BALANCE SHEET AS OF DEC. 31, 1923, AND DEC. 31, 1924

Assets	1924	1923	Increase	Decrease
Cash	$41,737.26	$31,635.70	$10,101.56	....
Accounts Receivable	33,112.29	42,765.48	....	$9,653.19
Securities—Cost Value	133,639.69	112,814.69	20,825.00	....
Accrued Interest on Securities	1,634.51	1,654.58	....	20.07
Inventories	7,606.15	8,216.79	....	610.64
Furniture and Fixtures	6,880.15	7,947.45	....	1,067.31
Items Paid in Advance, Charges Deferred	14,585.16	13,648.16	937.00	....
TOTAL ASSETS	$239,195.20	$218,682.85	$20,512.35	....
Liabilities and Reserves				
Accounts Payable	$6,822.31	$3,812.30	$3,010.01	....
Dues and Miscellaneous Items Received in Advance to Be Credited Monthly	57,505.75	56,614.66	891.09	....
Reserves Set Aside for Anticipated Expense	17,673.95	11,323.20	6,350.75	....
General Reserve	146,721.42	121,444.65	25,276.77	....
Unexpended Income	10,471.77	25,488.04	....	$15,016.27
TOTAL LIABILITIES AND RESERVES	$239,195.20	$218,682.85	$20,512.35	....

better means of keeping pace with new developments than attending Society meetings and studying the accounts of them in THE JOURNAL.

SECTIONS COMMITTEE REPORT

The substance of the report of the Sections Committee, which was submitted by Chairman J. H. Hunt, was that the billing of Section dues by the central office at the same time the bill for Society annual dues is sent out has had most gratifying results. There has been an increase of about 1000 in the total number paying Section dues. This very desirable situation carries with it increased responsibility for the Section officers, who must organize the work of the Sections so that the new members will feel that Section membership is a paying proposition.



FARNBORO ELECTRIC ENGINE INDICATOR
This Instrument Developed at the Royal Aircraft Establishment in England Is of the Balanced-Disc Type and Is Being Demonstrated by R. Insley of the Powerplant Section, Engineering Division, Army Air Service

The Council has taken steps to put through the following changes in the Constitutions of the Society and of the Sections, these changes having been recommended by the Sections Committee:

(1) Make enrolled students and affiliate member representatives eligible to Section membership upon election by the Section Governing Board
(2) Members of the Society automatically become members of Sections upon paying Section dues
(3) Reorganize the Sections Committee personnel to make it directly representative of all of the Sections

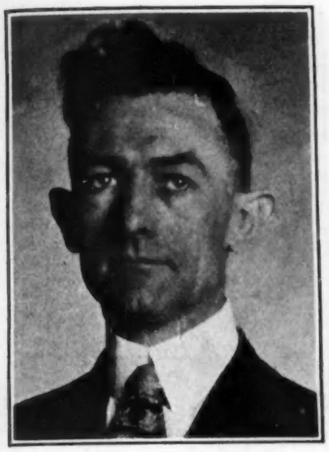
The Sections are carrying on their work in a very satisfactory manner and there is every promise of a successful year.

There is considerable interest in the possibility of establishing Sections on the Pacific coast. Members in California have already held several meetings.

REPORT OF THE TREASURER

Treasurer C. B. Whittelsey, in presenting copies of detail figures, made the following remarks:

> The last fiscal year of the Society ended Sept. 30, 1924. The figures for the year show that our gross income was $325,509.60, or an increase of $23,955.63 over the gross income for the previous fiscal year.
>
> After the cost of sales was deducted, a net revenue of $238,448.94 was available for use in connection with membership benefits.
>
> The total expenses were $216,467.41, an increase of $8,826.47 over the previous year; and the net unexpended income was $21,981.53, or an increase of $3,193.34 over 1923.
>
> The Society owns securities representing a cost value of $133,639.69, which is an increase of $35,839.06 over the previous year. These securities are held in custody by the Chemical National Bank of New York as funds to be drawn upon as emergencies or necessities arise.
>
> The Society's finances are budgeted. First the income is estimated, and, secondly, the expenditures are planned not to exceed such estimate. The actual income of the Society for the year ended Sept. 30, 1924, exceeded the estimated income by $32,100.95; and the



Hiram Walker
Chandler

L. L. Williams
Cleveland

A. A. Cripps
Dodge Bros.

Ferdinand Jehle
White

Still Other Engineers Who Attended the Meeting

actual expenses exceeded the budget figures by $10,-119.42. But, as above stated, we finished the year with an unexpected income of $21,981.53.

Increases in expenditure were made only when they would increase the income; for instance, by improving the work of the Sections, by increasing the membership, and by increasing the miscellaneous and advertising sales, which constitute two-thirds of the total income of the Society. The general expense of conducting the business of the Society was lower than the budget figures by over $2,000, which adds one more accomplishment to the praiseworthy record of our General Manager and genial friend, Coker F. Clarkson, and his efficient and painstaking organization.

President Crane's Remarks

I think that you have seen from the reports of the committees that materially in any case the year has been a successful one. If it has been so, it is because of the work of the committees of the Society. I cannot think of any organization of the size of ours of a voluntary nature in which so large a proportion of the members willingly work for the benefit of all the members and the society as they do in ours. In most organizations a committee is appointed and it is apparently understood and expected that the chairman will do all the work. From attending the meetings of many of our committees this year, I know that that is not the case with us. Committee meetings are enthusiastically attended by a truly surprising percentage of their total members, who take an animated part in all of the discussions.

Besides my connection with the Society, I have been connected with the General Motors Corporation for a couple of years and have therefore been brought much closer to the duties of the engineers actually engaged in production, and in the merchandising of this Country's cars. Seeing, as I do, the conditions under which they work, the stress, the long hours, it becomes increasingly surprising to me that they are able to find the time to do the Society's work in the way they do.

It will be absolutely impossible to prevent the advance of this Society continuously and with increasing strength so long as the members remain in their present frame of mind toward it. Its present position is not the work of any one man or any small group of men. It is the work of all the members.

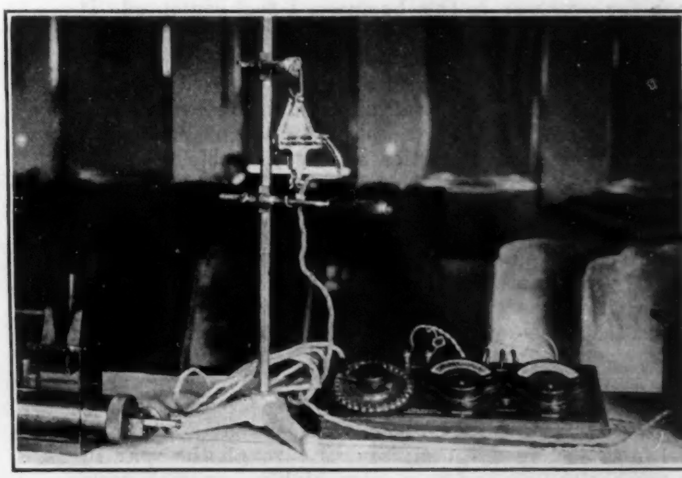
My own feeling is that the advance in professional standing has fully equalled the advance in material matters; that the meetings of the Society, and of the Sections, have added materially to our total sum of knowledge and that the publication of the papers and discussions in The Journal has been of great benefit to all the members and to the industry.

I cannot tell you with what interest the Council and the officers watch the reaction of the members to the Society activities. The Society is for the members. It is not for anybody else. Whether the members approve of the activities or not can be determined largely by the attendance at meetings, by the papers that are prepared, by the increase in membership, and by a hundred smaller details that show real interest.

I can see no place for the Society in the automotive industry just as a social club. It has its good points, as we all know, in that direction but, unless it advances our professional standing and the strength of the industry as a whole, it cannot succeed.

When we see an increase in the number of members taken into the Society we feel that this is probably due to the fact that the members already in have been spreading the good word that it is a good thing to be a member; and that is the only strength that we require. An occasional campaign in which by good selling methods men are interested in something they know little about and join, and then become discouraged and disgusted would never get us anywhere at all.

The officers have always been and still are glad to receive any suggestions, comments or questions regarding the operations of the Society. The fullest possible publicity from the officers about the operations of the Society, the reasons for certain courses of action, are not only the right of the members but they are the



Bureau of Standards Carbon Pile Electric Telemeter

Apparatus Shown Is for Demonstration Purposes. A Force Exerted Upon the Lever Shown at the Center of the Illustration Causes a Variation in Pressure on the Carbon Discs of the Telemeter. These Discs Are in Series in an Electric Circuit with a Voltmeter. As the Resistance Changes the Flow of Current in the Circuit Varies and by Suitable Calibration It Is Possible To Determine the Force Applied

H. W. Alden
Steering and Wheel-Shimmy

G. J. Mercer
Passenger-Car Body

R. E. Wilson
Lubrication

J. G. Vincent
Balloon Tire

FOUR OTHER SESSION CHAIRMEN

strength of the Society if the news is broadcast as to what we are doing and why we are doing it.

We have had various questions brought to the office in the last year. Almost invariably the questions were based on misunderstanding. When the actual facts were brought out, the members were entirely satisfied. For that reason we encourage questions. I hope we shall always anticipate questions by giving as full publicity to all of the detailed business of the Society as we can.

I am glad to tell you that in many instances this year I have taken advantage of contact with executives of high position in the business by telling them what the Society is and what it does. They may not understand some of the papers that we have at the sessions but, when I shake this balance sheet in their faces and point to the fact that we have in cash in the bank and in securities about $140,000, that we are operating on a budget in the most highly businesslike way, that the Society is a paying proposition and that it is run by the members in that way, I find they have an entirely new respect for us. I suggest that the more the members acquaint themselves with the real strength of the Society, and the more they tell about it among their superiors who are not of the engineering lines, the greater will be the respect of those superiors for what the engineers have done in their own private job.

We are entering upon a year that will be a trying one for everyone in this business, I feel convinced. It will be a year of intense competition that is apt to become rather ruthless at times.

The engineers in the past have been accused of many deficiencies and, if car sales fall off or prices have to be cut, the engineers are apt to be again singled out by other interested parties as the probable cause of the lack of interest in the product.

I believe that by a closer adherence to the Society, a greater interest in the Society's affairs, a closer attendance at meetings, a closer coöperation, we can greatly safeguard our position. If we really know our work; if we carry out our engineering on principle on basic facts, not on temporary expedients; if we stand with our feet firmly on the ground and do not attempt to recover ground that has been lost for one reason or another, possibly not of an engineering nature, by some wild and extravagant motion that appears as a life-saver; we will certainly go through the year in a much stronger and in a more highly respected position.

From our very work we should have a cooler grasp of what is going on than those who are in the hectic business of selling, or financing, or possibly production. We, in our business, are dealing with facts which do not change from day to day, the force of gravity, the tensile strength of steel the qualities of fuel, and that very dealing with every-day facts should make our judgment on the whole situation sounder, provided we come together as much as we have in the past, or even more, and concentrate our knowledge in all our hands for the benefit of all of us.

PRESIDENT-ELECT HORNING'S COMMENTS

I wish to extend my thanks and to express the hope that I can come through this year with the wonderful cooperation which has been given President Crane on account of his character and because we all love him and the great results which came about from that cooperation.

I am more impressed every day by the fact that the Society has a growing position in the industry and that it has particularly the duty of getting before the members information concerning great movements in the industry before they happen. I think in this connection that four-wheel brakes are a wonderful thing because they allow a man to stop at a place long after he has passed there.

I am going to put all the force I can behind the Society to see that we get information on new things at least within 2 years after they have been put into cars. I notice that the most interest in such things occurs after the fellows have put them in cars and they are commencing to give trouble. If you want a real active and interesting session, right after a bunch of engineers have adopted some new kind of top or a new kind of a crankshaft is the time to do it.

I think it is the duty of the Society, and we have usually succeeded in this respect, to get the information before the second year of use.

I am very pleased to announce that one of the major sessions of the Summer Meeting this year will relate to the elements of design of motor cars in which highway safety is involved. Mr. Crane produced a report that I was mighty proud of. I wrote him to that effect. It was one of the best written reports that has ever been put out on any subject. Mr. Crane, representing the motor-car industry, had to soft-pedal a lot, and I had to tell him so, too. But he did a fine job. At the Summer Meeting I want to see the report extended honestly, frankly, sincerely, into all the things that go to make for safety. I want to retire from the presidency next year with the feeling that I have done my duty in regard to highway safety.

Some very interesting sessions will be held during the year. I never attended a more satisfactory conference than that of the Meetings Committee today. There will be meetings during the year on special subjects. They are practically planned for, the type of papers has been outlined, and the meetings will all be conducted like this one. We have a wonderful exhibition here tonight. We had a great showing this afternoon in both sessions.

With those things in view and soliciting your hearty cooperation, I will ask you to do just one more thing. We will have a wonderful session this summer. I do not believe we ever approached a Summer Meeting with such forward planning as we have right now for this meeting.

The subjects that are coming up are ripping subjects. We are going to White Sulphur Springs, which every one admits is a real place to go. The Sports Committee is lining up for a real program, and the management of the meeting will be unusually good. I want to ask your utmost cooperation to the end of having as large a meeting there as possible. We will be able to take care of over 1000 and I want every room filled.

I want to thank you again for the great honor that you have conferred upon me. I want to say that, after going through about 16 pp. of lists of Divisions of the Standards Committee alone, and about 18 or 20 more of lists of other committees, I realize that I have been given a job that I did not deserve.

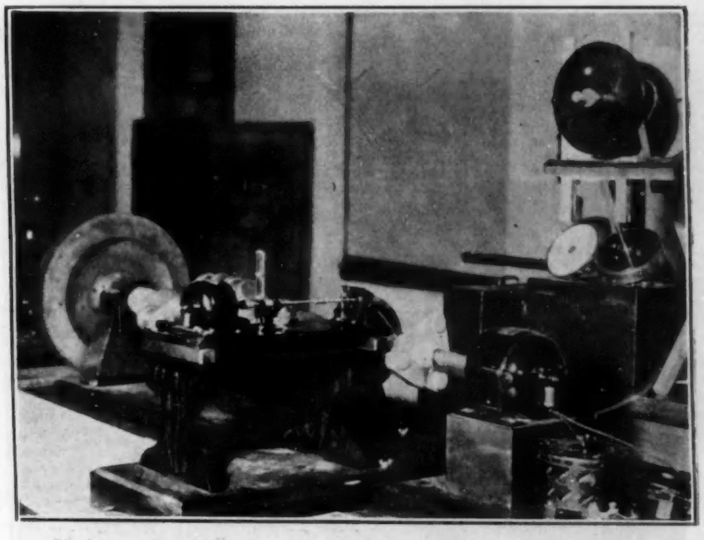
Standards Committee Report

In the absence of Chairman E. A. Johnston, Manager R. S. Burnett of the Standards Department presented the annual report of the Standards Committee, as approved and modified by the Council. This is summarized elsewhere in this issue of The Journal. Upon motion, duly seconded, it was voted unanimously that the report be approved for submission to letter ballot of the voting members of the Society.

Constitutional Amendments

The amendments of paragraphs 2, 8 and 45 of the Constitution of the Society, proposed at the meeting held in Spring Lake, N. J., last June, were brought up for consideration. Copies of these, together with comments of the Council and the Constitution Committee, had been mailed the Members last November. Upon motion, duly seconded, it was voted that the proposed amendments of C2 and C8 should be submitted to letter ballot.

Upon the motion of T. J. Litle, Jr., which motion was duly seconded, it was voted to amend the proposed amendment of C45 so as to provide for the appointment annually by the President of 12 instead of 5 members to serve on the Meetings Committee. Upon motion, duly seconded, it was voted that this proposed amendment of C45, as amended, should be submitted to letter ballot.



C. E. Summers' Apparatus To Show Crankshaft Vibration
A Small Gearbox Driven by an Electric Motor Imparts Vibrations of Known Frequency to the Crankshaft under Investigation. This Apparatus Was Developed by General Motors Research Corporation

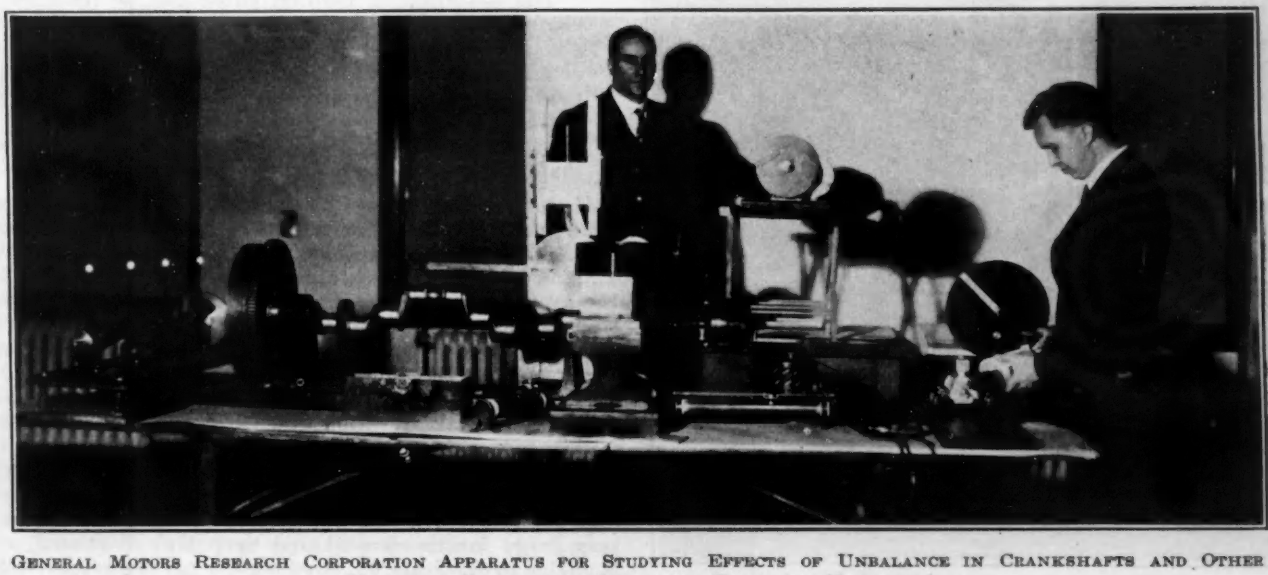
ENGINE VIBRATION

Summers Makes Remarkably Interesting Demonstration of Factors Involved

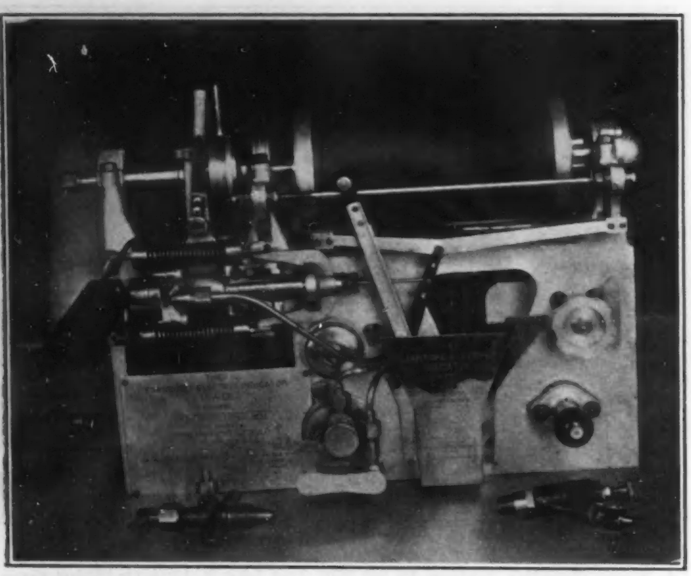
In presenting his paper entitled Measurement of Engine Vibration Phenomena, which is printed in full in this issue, C. E. Summers spoke extemporaneously in a very vivid and forceful manner. Undoubtedly, this paper and demonstration constituted one of the hits of the whole meeting which made it of unparalleled value. Probably the most striking thing about Mr. Summers' address were the demonstrations of running apparatus.

The theme was that a number of things have combined to accentuate engine vibration as an undesirable thing, principal among these being higher average driving-speed on good roads, the more extensive use of closed cars, greater engine-speeds and gear-reductions, and higher compression-ratios with consequent increased tendency to detonation.

The causes of vibration reside in unbalance, bending of shafts, centrifugal force and torsional vibration of shafts. Mr. Summers has made an extended study of just what happens in a crankshaft under the various conditions of operation; both mathematically and through various forms



General Motors Research Corporation Apparatus for Studying Effects of Unbalance in Crankshafts and Other Vibration Phenomena, Including Torsional Vibration

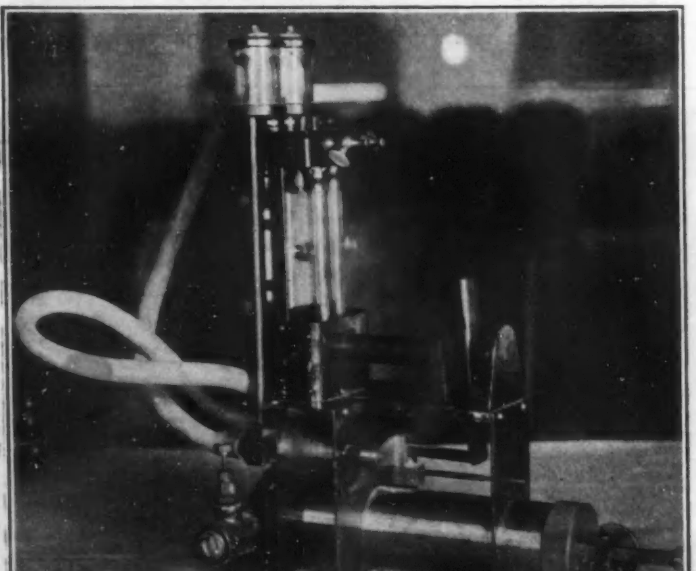


FARNBORO ELECTRIC ENGINE INDICATOR

of apparatus. The crankshaft in recent years has become heavier and stiffer in all its parts. Still all the difficulties are not eliminated. This is due to the fact, President Crane pointed out, that balance involves the whole length of the shaft and localized additional mass does not necessarily suffice.

Illustrating torsional vibration in a shaft, Mr. Summers showed a simple disc so mounted on a rod that it could oscillate torsionally. Not much happens when the disc oscillates at other than its natural frequency, but at its natural frequency great amplitude is built up. Just so, at some speed impulses reach the crankshaft through the connecting-rods at the natural frequency of the shaft. Mr. Summers showed this clearly by clamping a shaft to reduce its effective length. This sort of effect is of course latent in various parts of the chassis.

Mr. Summers' demonstration of the effect of a three-lobe cam, set forth in his paper, was particularly illuminating. Three-sided, six-sided and nine-sided images indicated the torsional vibration at the different speeds. With ordinary engines, Mr. Summers said, the condition of the nine-sided figure occurs at about 30 to 35 m.p.h., other rough spots



BUREAU OF STANDARDS CLEARANCE-VOLUME INDICATOR

coming at one and one-half times the speed of a former one. A more rigid shaft tends to vibrate more rapidly, coming into phase at a higher speed of piston impulse. In no practical engine that he knows of does the triangular effect exist within the driving range.

Mr. Summers demonstrated an instrument that has been designed by his assistant, C. L. Lee, for recording the frequency and amplitude of vibrations. It operates under governor control at uniform speed. He also showed how small gears slightly out of balance can produce marked shaft vibration, emitting a sound very like that of shaft torsional vibration.

The effect was indicated, with running diagrams, of the explosion pressure bending the shaft, a real vertical period being shown by the greater vibration at one speed than at another. The centrifugal force acting on a six-cylinder crankshaft was also illustrated. The manner of measuring crankcase deflection was described. As compared with the deflection under the same force applied statically, the deflection of a crankcase force is about twice as great.

Typical indicator-cards were submitted of the effect of weight at the front end of a shaft. As the front end is lightened, the periods occur at higher speeds. With most engines the audible periods can be placed above the ordinary driving-speeds. In cooperation with J. H. Hunt, an electrical torsional vibration indicator was developed to show the relation of each vibration to the firing of the engine. The characteristic vibrations of different types of engine were set forth by Mr. Summers.

Many of the graphs exhibited by Mr. Summers were reminiscent of nightmares of our worst disturber of sleep. As President Crane, who presided at the session, said, they made plain the great power that resides in small increments of force.

W. R. Griswold, of the Packard Motor Car Co., said that at the plant of that Company about the same conclusions that Mr. Summers stated has been arrived at mathematically, the calculation of torsional speeds having been reduced to a very simple graphical method.

Mr. Summers replied to questions that:

> The judicious use of front-end flywheels is a good thing.
>
> The Lanchester slipping-flywheel type of dampener pulls down the period and also reduces the amplitude.
>
> That it is questionable whether the conventional position of flywheel can be improved upon for all-round utility.
>
> A good six-cylinder crankshaft can be made with anywhere from two to seven bearings.
>
> The principal objection to torsional vibration is unpleasant noise.
>
> The variation in turning effort can be lessened by changing the firing order of certain engines, in which gas pressure rather than piston invention is the predominating cause of vibration, but ordinarily unevenness of torque is the problem to be wrestled with. Securing the ideal is a very long story.
>
> In its vibrations, the camshaft follows the crankshaft, in lesser degree.

H. L. Horning stressed the importance, for smooth engine running, of horizontal as well as vertical stiffness of crankcase. He said that, if timing-gears are maintained in good alignment, they will last almost indefinitely. He pleaded for the avoiding in parts of the chassis, such as foot pedals and radiator rods, of natural frequencies synchronous with those of the engine. The laws of chassis vibration and counter-vibration must be grappled with.

Prof. H. N. Jacklin, of Ohio State University, said that, to reduce torsional vibration, the flywheel weight should be distributed along the whole length of the shaft.

D. G. Roos, of the Locomobile company, reported that he had found that such construction involves a torsional vibration point so persistent that a Lanchester dampener with a very large inertia-element and very high frictional setting is unable to eradicate it. Also that by far the greater amount of deflection is due to torsional twisting of crankshaft cheeks.

Prof. E. P. Warner, of Massachusetts Institute of Technology, took exception to what Professor Jacklin said, on the ground of practical experience and also of theory.

Chairman Crane advanced as the probable solution of the crankshaft problem the picking of a shaft for a given job. He cited the practice of the aeronautic-engine designer in operating the engine at a speed outside a period of vibration. The motor-car problem, involving various speeds, is of course much harder.

O. M. Burkhardt, of the Pierce-Arrow Company, acquitted the flywheel of being source of vibrations. It acts as a resonator of impulses. The front-end flywheel under certain conditions will do some good. The secondary cause of vibrations is a yielding. In a seven-bearing crankshaft torsional vibration originates only in the main bearings, and this can be balanced with frictional elements.

FRONT-WHEEL SHIMMYING

Its Causes, Effects and Remedies as Seen from Different Viewpoints

The causes of and the remedies for front-wheel shimmying had their innings at the Steering and Wheel-Shimmy Session and the viewpoints taken and the opinions expressed were as numerous as the speakers. Agreement was notable for its absence. No two persons seemingly had had like experiences under like conditions and what was suggested as an infallible remedy by one was considered inadequate by another. Among those who presented formal papers or submitted written discussions were W. R. Strickland, O. M. Burkhardt, F. F. Chandler, H. A. Huebotter, R. S. Begg, and J. W. White. H. W. Alden presided.

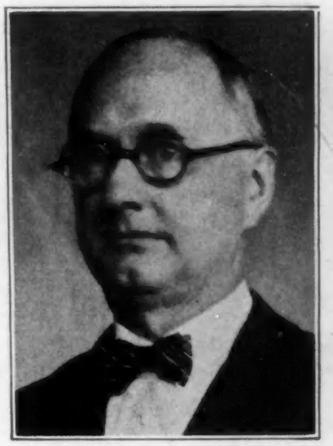
Mr. Strickland was the first to present his views and he did so in an elaborate outline in which each of more than 20 possible causes of shimmying was considered in turn. In his opinion, the predominating reason that shimmying has reached its position as a leading present-day problem is that, of the known expedients used to effect a cure, the most important one, namely, raising the air-pressure, has been denied. Low air-pressure in the tires had been known to produce wheel wabble years before the balloon tire was introduced, and caster-angle, toe-in, stiff and tight parts were recognized specifics for the ailment, with an occasional raising of the air-pressure when it dropped too far below the then high standard.

In the last 3 or 4 years the pressure cure has become more important because tire-builders began to furnish all tires oversize, the public drove with lower pressures than those specified, and cord tires with more flexible side-walls were used. These practices reduced the leeway between the permissible pressure and the shimmying pressure to a point below that to which it was desirable to go.

Shimmying, he said, is used in a general sense. Wabble is a sidewise vibration of the front wheels about the knuckle-pin, and tramping is a bouncing of the wheels vertically, alternately on the two sides.

Causes of Shimmying

The more important conclusions reached by Mr. Strickland are that balancing the tires and the wheels will give a smooth-running car in any case; modifications of the geometry of the steering-gear failed to give beneficial results; reversing the shackles and making the drag-link arc and the steering-knuckle arc coincide solves neither the shimmying nor the kick-back on the wheel when encountering severe or choppy bumps; the flexibility of one system having deep-camber springs seemed to reduce the shimmying as much as did any other tests; a semi-reversible steering-gear seemed to give the greatest satisfaction over 99 per cent of the driving range regardless of the type of gear; an hydraulic check, although effective, is not allowable, because control of the car for quick maneuvering is lost; no shock-absorbers or checks of any kind that would be allowable will cure tramping; tightening the joints in the steering and axle connections will stop mild forms of shimmying caused by loose joints; other mild forms of shimmying can be cured by using plain bearings in the steering-knuckle or by providing loose joints transversely in the spring-eyes and long spring-shackles; the results obtained from the use of reversed or multi-leaf springs are inconclusive; straightening the front wheels or toeing them out would probably not be allowable on account of the wear of the tires; the general use of four-wheel brakes may be responsible for the preponderance of evidence that shimmying is increased by their use; the inertia of balloon-tire wheel-equipment is less than that of high-pressure-tire equipment, but adding weight to compensate for the difference, although reducing the shimmy effect, is undesirable; tests indicate that, in any axle, the greater the distance from the center of gravity of the wheel to the center-line of the pivot, the less


W. R. Strickland


J. W. White


F. F. Chandler Demonstrating the Instruments for Recording Wheel and Drag-Link Movement Described in His Paper

H. A. Huebotter

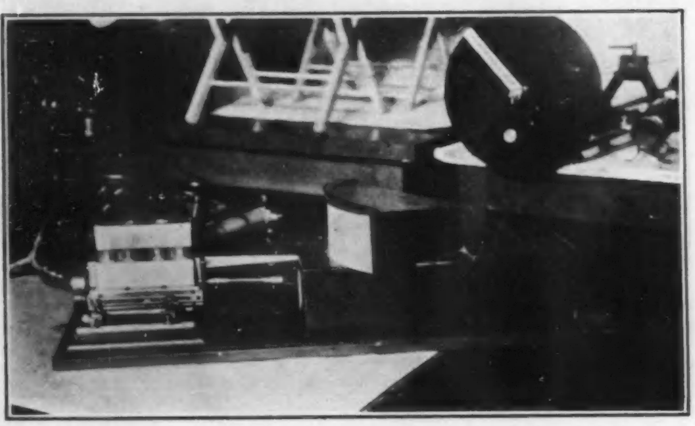
Otto M. Burkhardt

will be the intensity of the shimmying; the use of a vertical pivot-pin, with near center-point steering has produced improvement; the turning effect before and behind the pivot-pin can be equalized by reducing the caster-angle or by giving it sufficient reverse-caster action; a stiffer or better supported tread will better resist the forces that produce shimmying, and closed cars, because of their extra weight and greater stiffness of the frame, increase shimmying.

Lateral Instability

The lateral instability of balloon tires, in the opinion of O. M. Burkhardt, has a profound effect on steering and is the cause of shimmying; their property of absorbing more kinetic energy than do high-pressure tires causes them to assume a periodic rebound on slightly bumpy roads and is responsible not only for shimmying and tramping, but for pitching and bobbing as well. This effect may be alleviated by the use of some device for absorbing the kinetic energy, such as a dash-pot. The three remedies suggested are (*a*) designing so that no slackness can develop. (*b*) designing for rigidity, and (*c*) using devices to absorb the kinetic energy wherever it is likely to accumulate.

H. M. Crane attributed the shimmying effect to the very insecure connection between the steering-rod and the rim of the wheel, even in a normal tire, and this connection becomes still more indefinite with balloon tires. Center-point steering is uncertain because of the continual shifting of the center of pressure of the tire on the road. The caster-angle cannot be accurately determined. A surprising thing, he said, was that one car shimmied the worst while running at 45 m.p.h. on the smoothest possible road, the concrete road at the proving ground. It is customary in marine and in airplane work to balance the rudder effect, and in aviation work not only the rudder but the elevators. A practically perfect balance is obtained by having approximately one-third the area in front of the pivot and two-thirds behind it. If more than one-third is in front, a violent action is produced that is almost identical with the shimmying of a car.



Engine Vibrator Instrument

The effect, said Mr. Crane, may be likened to the violent zigzag motion of an oar held edgewise in the water. Shimmying, he thought, was caused by the tire's taking a zigzag course on the rim, for it does not noticeably increase tire wear. A balloon tire produces the same effect on the rear wheels as on the front, the result being a very violent chatter. A car with stiff rear-springs and stiff shock-absorbers that let the tires do all the work on a rough road could make only 10 m.p.h. over a road that could easily be traversed at 25 m.p.h. with high-pressure tires. The effect of balloon tires is like that of trying to skate with case-hardened rubber blades. Shimmying, he believes, starts in the natural instability of the tire itself and is augmented by any instability in the mechanism of the car that can synchronize with it.

Tramping

In a written communication read by L. C. Hill, R. S. Begg stated that in his experimental work he had not been confronted with low-speed shimmying but with a combination of so-called tramping and shimmying that began at about 52 m.p.h. and continued at higher speeds, according to conditions. The tramping action, so far as could be determined, preceded the wheel wabble, was very severe, and resulted in a swinging motion of the whole front of the car with a very considerable deflection of first one tire, then the other. It was found that, by making minor changes to increase the accuracy of the steering and the wheel balance and by using different rims and tires, the shimmying period could be raised to between 58 and 62 m.p.h., but could not be entirely prevented.

Tests of wheel balance showed that wheels were satisfactory as they were received from the makers, and ran as well as did those that had been accurately balanced. If, however, a severe out-of-balance condition were produced, such as that caused by hanging weights on the wheel rim, the shimmying would be increased and would begin at a lower speed. Four-and-one-half-inch rims ran as well as 5 or 5½ in.

Inasmuch as the speed at which shimmying occurs can be lowered by using weak steering-knuckle arms and a large bow in the axle tie-rod, the conclusion was reached that rigid steering-arms and tie-rods are desirable.

It was found that the caster-angle could be held within close limits, and that, when the tire pressure exceeded 20 lb. per sq. in., tramping and wheel wabble could be eliminated up to the limit of car speed by blocking up the front spring. This led to experiments with stiff front-springs and various shock-absorbing devices, which reduced the wheel wabble but produced hard riding. It was also found that tramping and wheel wabble could be prevented on that car by increasing the tire pressure from 25 to 32 lb.

Synchronized Vibration

Returning to the original spring specification and continuing the tests, it was discovered that the periodicities of the front tire and of the spring were the same. Drawing conclusions from the experiments in blocking the front springs and increasing the tire pressure, it was considered possible that the trouble might lie in a combination of the vibration of the tires with those of the springs. By trying weaker front-springs, one was found that gave the right combination with the periodicity of the tire. Since then, repeated tests with it over all types of road have failed to produce either a tramping or a shimmying action.

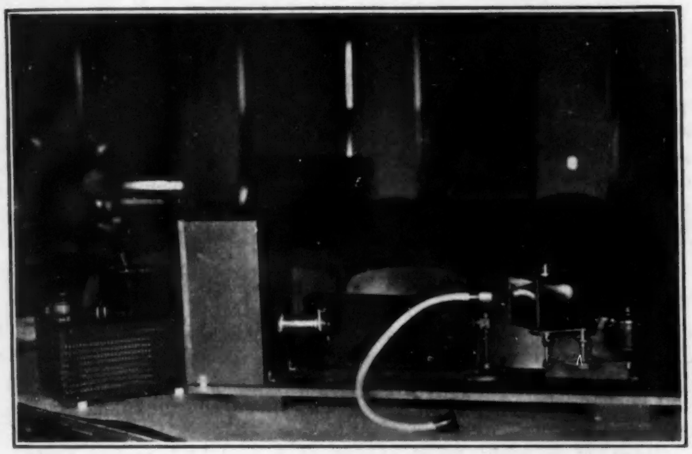
The rates in the first case were from 187 to 190 per min.; the weaker spring has a rate of 140. This difference in periodicity tends to damp out the tendency for road inequalities to set-up a rate of vibration in the spring and the tire that would build up to the maximum and create tramping action and shimmying.

When requested to give his experiences, P. H. Geyser said that all shimmying in his taxicabs had been overcome by merely inclining the steering-knuckle pin. For his purposes, a strictly balloon tire is not satisfactory, but a semi-balloon tire has been found superior to anything that has been tried. Rubber shock-insulators have assisted in reducing shimmy effects.

Low-speed shimmying, remarked Mr. Strickland, is apt to occur with rubber shackles and can be cured by increasing the caster-angle, but curing low-speed shimmying makes high-speed shimmying worse.

Blocking the Front Springs

R. W. Brown remarked that his experiences had differed from those of Mr. Strickland, and that he had yet to find a car that would shimmy at any speed, with any inflation-pressure or with any size of tire, if the front springs were blocked. They should be clamped rigidly to the axle by a stirrup or other means. Merely placing a block between the springs and the frame is not sufficient. He had, likewise, yet to find a car in which shimmying cannot be prevented by using an hydraulic steering-gear. He agreed with Mr. Burkhardt that shimmying, that is, the transverse motion of the front wheels, is produced by various harmonizing vibrations that produce resonance. Tramping, or vertical rotation about the center of gravity of the car, he considered to be a product of the spring-suspension alone.



Dorsey Phonelescope Apparatus for Studying Sounds
By the Use of a Sensitive Diaphragm and Mirror Sounds or Noises That Are Introduced through the Transmitter Tube Cause Variations in the Position of a Beam of Light Which Traces a Curve Characteristic of the Sound upon a Suitable Screen

F. F. Chandler's paper, entitled How Hard Does a Car Steer? which is printed in full on p. 183 of this issue of The Journal, described a method of determining, mechanically, the relative ease of steering by a graphical record that eliminates the personal factor and indicates simultaneously (*a*) the amount of steering effort and the reactions at the steering-wheel and (*b*) the stress imposed upon the drag-link. In designing the instruments, he was assisted by H. A. Huebotter, who presented a supplementary written discussion.

Mr. Huebotter asserted that the entire so-called unsprung weight of a car is suspended between highly elastic supports: the tires below and the springs above. In this position, the front axle is free to vibrate vertically with a wide range of amplitude, damped only by frictional resistance. If the axle receives enough impetus in phase with its oscillations to overcome friction, the vibrations will continue indefinitely. The problem, then, is, (*a*) to determine the conditions of axle vibration, (*b*) to analyze the effect of the vibration upon the car, and (*c*) to show that a force may exist which will amplify the vibration.

Bounces

A study was made of the free vibration periods of the tire and the spring. The tires, mounted on a wheel and spindle, were bounced under varying loads and air pressures, the number of bounces being registered by a counter actuated by a lever and the time being taken with a stop-watch. The ratio of the two readings gave the vibration frequency. In tests of tires, the frequency seems to be a function chiefly of the load on the tire and of the air pressure.

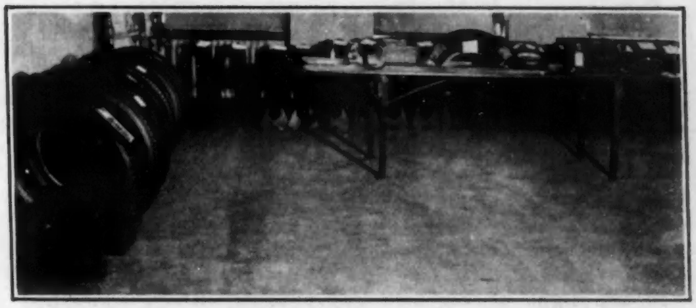


Exhibit of Balloon Tires
This Shows the Various Sizes and Forms of Tread Described in Dr. Lemon's Paper

Analyzing the forces induced by the bouncing wheels, it was found, among other things, that, if the axle is castered, another force is built up that tends to amplify the tire vibration. The amplitude of tire deflection induced by the original cause is aggravated by the castered pivot and a system of self-generating forces tends to bounce the axle and to turn the car.

The elements necessary to the inception and perpetuation of front-wheel shimmying are: (*a*) low free-vibration periods in the front springs and tires under a load equal to the unsprung weight per front wheel, (*b*) a road shock that causes equal deflection in the two front-tires, (*c*) sufficient deflection of the tires to affect appreciably their instantaneous angular velocity, (*d*) high enough road speed for large kinetic forces to be set-up by the angular acceleration of the wheels, (*e*) fore-and-aft rake in the steering pivots, and (*f*) a small amount of friction in the steering mechanism and the front springs.

Mr. White then presented his paper entitled Some Possible Causes of Wheel Shimmying, which is printed in full on p. 205 of this issue of The Journal.

BALLOON TIRES

Their Development, Durability and Effect on Shimmying and Riding Comfort

Balloon tires being closely related to the subject of shimmying, the discussion for the most part continued that begun at the other session, and the opinions expressed were equally diversified and contradictory. Papers were presented by R. B. Day on the Relation of Balloon Tires to the Shimmy Problem; by B. J. Lemon on Advances in the Design of Balloon Tires; and by E. A. De Waters on a Car Manufacturer's Experience with Balloon Tires. Written discussion was also submitted by W. R. Griswold and J. E. Hale. Under the chairmanship of J. G. Vincent, many valuable data were contributed to those already available on the subject.

E. A. DeWaters

B. J. Lemon

Shimmying, said Mr. Day, consists of two kinds: the low-speed variety, which is chiefly a persistent front-wheel wabble without bouncing, and the high-speed type, which is largely a persistent bouncing accompanied by wabbling. As the solution of the problem seemed to lie in making the car control the tire rather than allowing the tire to control the design of the car, recourse was had to stabilizers for checking the bouncing of the axle and to hydraulic dampers for preventing the wabble. He believes that shimmying is a resonance effect between the tire and the body springs that can be worked out mathematically. His paper is printed in full on p. 192 of this issue of THE JOURNAL.

In the light of his own experiments, which concerned principally a study of vibration frequencies, said H. A. Huebotter, he had found in one particular problem that, at a car speed of 40 m.p.h. and a vibration frequency of 7.5 cycles per sec., the force between each wheel and the road is 64 lb. The turning effort required to steer the car would be the product of this force multiplied by the distance between the steering-pivot and the point of contact with the road and, since the two efforts are built-up, will be double that amount for each wheel. Vibration will always occur regardless of the individual characteristics of the spring and the tire. The stiffer the spring and the higher the air-pressure in the tire, the more rapid will be the vibrations, which may reach a point that is out of the range of the car speed.

DEVELOPMENT

Giving satisfactory appearance, practicability and transportation comfort as the reasons for the acceptance of balloon tires, B. J. Lemon outlined the various factors that have been considered in the development of balloon tires. His paper is printed in full on p. 172 of this issue of THE JOURNAL.

The problem of standardization, said J. E. Hale in a written communication read by C. F. Clarkson, is very important. This is essentially something for the automobile manufacturers to handle, for the public has not given approval to the full balloon tire and the industry has had sufficient experience to judge wisely between the various sizes, dimensions and types of construction. The tires themselves have been properly perfected and any claims to the contrary are not justified, as is evidenced by the superior durability and lower tire-mile cost that they are rendering in comparison with those of preceding types. Any standard line-up that does not provide four-ply tires in a full range of sizes for passenger cars is defective and cannot serve as a real standard. The six-ply tire in certain sizes is apparently logical as a transition move toward the final standard, but proof is forthcoming that the four-ply large-section tire offers most in the aggregate of comfort, appearance, traction and durability.

Too few sizes, in Mr. Hale's opinion, would be a mistake. Although such a program might have an appeal from a purely engineering point of view, the original cost to the car manufacturers justifies rather small step-ups in cross-sectional sizes, so that the assemblies can be worked out satisfactorily.

While agreeing with most of the points regarding tire technique set forth in Dr. Lemon's paper, designing tires is more or less a compromise as regards details and his experience has taught that the wide flat or shoulder profile has shortcomings that offset the benefits outlined in the paper. This refers particularly to the tendency of a shoulder to cause tread separation and premature failure of the cord plies inside the carcass. The shoulder localizes the flexing to such a degree that the so-called flexing breaks are very frequent, particularly when the tires are neglected or abused. Round-tread tires are proving their own case by rendering an unsurpassed degree of all-around satisfaction.

DROP-CENTER RIMS

H. Willshaw called attention to the fact that reference had previously been made to the use of drop-center rims as a remedy for shimmying and that they also have considerable merit in connection with the difficulties concerning wide rims and flaps, as referred to by Dr. Lemon. The use of 19-in. wheels in England is prompted by economy and is possible because of freedom from ruts and snowdrifts in that country. English manufacturers have adopted as standard the American type straight-side tire fitted to drop-center rims.

Commenting on the reference made in Dr. Lemon's paper to the uneven wear of balloon tires, because of excessive toe-in and pitch of the wheel planes, W. R. Griswold stated that excessive wear of front tires, in the eyes of the car-owner, is about as inexcusable as is failure of the steering-gear. Many believe that the greater inclination of the king-pin required in center-point steering is the cause of excessive tire wear, but whatever the relation to tread design may be, the same laws of wear apply if the slippage of the tread is increased.

To obtain satisfactory steering, a definite relation must exist between the toe-in of the front wheels and the inclination of the wheel planes. A thorough investigation and tests have shown that the pitch of the wheel rather than the inclination of the king-pin is largely responsible for the tire wear produced by the mechanics of steering. In one test, in which the wheel pitch was decreased but center-point steering was maintained by further increasing the inclination of the king-pin, tire wear was greatly reduced and unevenness was almost eliminated.

Too much emphasis cannot be placed on the need of uniformity of the rolling circumferences of all makes of tire denominated by a particular standard size. Increasing tire sections to gain sales advantage has been the cause of many complaints to the car manufacturers. When a large tire and a smaller one are run together on the rear axle, steering is not only affected but the control is exceedingly trying.

MAINTENANCE OF SIZES OF TIRE

The outside diameter of the tire selected for a car of new design, continued Mr. Griswold, is governed chiefly by road clearance. Once this diameter has been selected and the design of fenders, axle and speedometer ratios giving a desired performance of the car has been established, it is essential that the rolling circumference should be maintained.

Noise is a very troublesome factor. Audiometer tests are based on the relative energy in the sound wave rather than on the psychological value of the sound. Tires are selected in accordance with their effect in inducing noises in other parts of the car. One of the most distressing noises is that of the rear-axle gears. This noise has a very small volume but a very penetrating and irritating pitch. An audiometer would hardly show it to be of importance, consequently, audiometer tests are of little value in proving contentions regarding the noise produced by balloon tires, and tires will be chosen for their effect in exciting other noises.

The springiness of the tires is just as much a fundamental factor in producing shimmying as is the steering layout or the elasticity of the front axle and the steering-system. In any mechanism, when periodic changes take place in the magnitude or the direction of the forces that act on elastically connected bodies, so that these forces are timed with any external forces, a state of synchronized vibratory motion is set up, the amplitude of which will grow until equilibrium is established with the damping forces.

In producing shimmying, the elements entering into the motion are (*a*) the external forces, (*b*) the rotation of the front wheels, (*c*) the mass and the mass distribution of the bodies and (*d*) the elastic properties. When all the forces are in equilibrium, no shimmying will take place.

EFFECT OF UNBALANCE

By means of a flywheel-balancing machine, the centrifugal forces in a tire due to unbalance were found to range from 3.1 to 107.6 lb. for a speed of 60 m.p.h. If only one tire is unbalanced, a complete oscillation of stress and deflection of the steering-system is produced with each revolution of the wheel. If the revolutions of the wheel correspond to the frequency of the steering-system, the deflection will grow

W. R. Griswold

R. B. Day

until the spindle is wabbling back and forth over a considerable angle. The first wabbling brings in other forces, such as those acting through the center of gravity of the car and tending to list it from one side to the other. This listing can occur only because the elasticity of the tires and the springs allow it, hence, periodic elastic forces are excited and, when the condition of synchronism occurs, wheel wabble or shimmying results.

If the wheel at the same time is also rotated about the king-pin axis, because of the wheel's striking an obstruction, a gyroscopic couple is produced that tends to lift one wheel and to depress the other. The influence of king-pin inclination, wheel camber and toe-in are of relatively small importance.

Remedies for Shimmying

To overcome shimmying with balloon tires, the most practical method of procedure is

(1) Obtain the best balance possible in the tires
(2) Reduce the exciting forces due to road shocks to the minimum by the proper geometry of the steering layout
(3) Provide sufficient stiffness in the mechanical layout of the steering-system
(4) Take advantage of all the damping forces possible without sacrificing riding comfort or ease of steering. This includes utilizing the interleaf friction of the front springs to dissipate vibratory energy

Slippage of tires, said H. D. Ayres, has seemed to him to be caused by predominance of the toe-in, that is, by the constrained motion of the tire from the free path in which it would tend to move. He likened the motions of high-pressure and of balloon tires to those of two blocks of wood to one of which a thin piece of rubber and to the other a thick piece had been cemented. If these pieces were moved over a surface the distortion produced in the thin piece of rubber would be so small that the motion would be relatively smooth, whereas friction would cause the thick piece of rubber to move by jumps. The balloon tire not being stiff moves in the path taken by the wheel until distortion causes it to spring back to the path of the car.

Replying to a question, Dr. Lemon stated that the comparative areas of the flat and round treads are as 36.3 to 21.5. The pressure of the round tread is 10 lb. per sq. in. more than that of the flat tread. Both the forward traction and the resistance to side slipping are better in the flat tread.

Difference in Area of Contact

In the opinion of R. K. Jack, the balloon-tire problem on a light car is entirely different from that on a heavy car. Inasmuch as a balloon tire flattens more than does a high-pressure tire, the area of contact with the road is greater and this tends to throw the point of contact of the tire with the road forward relatively to the center line of the king-pin. This gives a greater arm through which to start a pendulum action and is, he believes, the cause of shimmying.

Unbalance in the tires, he thinks, is the cause of galloping. The fact that manufacturers are advertising steering-gears suited to balloon tires is an admission that the steering-gears were not entirely good enough before. Tire sections and air-pressures should be selected with a view to withstanding certain car weights and should not exceed the size of section and the air-pressure at which the easiest riding occurs.

In reply to further questions, regarding the comparative noises produced inside the car by flat and round-tread tires, Dr. Lemon said that, although any configuration will produce noise, the noise made by a flat-tread tire was the lesser.

Discussion on this subject showed a difference of opinion. Mr. Smith of the Firestone Company averred that experiments made by that company over brick pavements showed that the type of profile had very little to do with the volume of noise produced. Mr. Jack remarked that a ribbed-tread tire causes less noise inside the car than does a tire with a non-skid surface. Dr. Lemon took the opposite viewpoint. Mr. Smith added that on pavements in which the spaces between the bricks were deep, no design of tread seems to eliminate all noise but that a combination of the ribbed and the non-skid treads produce the best tire for all-around use.

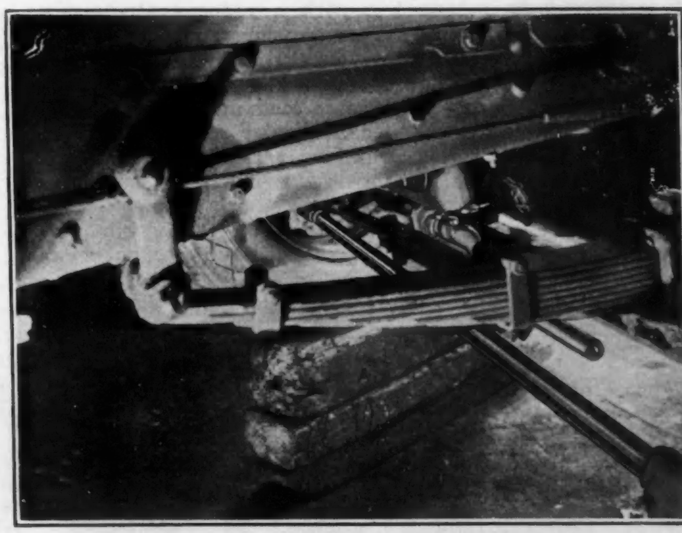
Mr. Wells' observation indicated that on a brick pavement the plain tread tire is more noisy, but that on a smooth concrete road the smooth tread does not make the hum produced by a rough tread.

Improving Operation

Deprecating the fact that the tendency seemed to be toward minimizing the importance of noisy treads, Chairman Vincent related an incident regarding a complaint received from one of the directors of his company, who said that he could not understand why the company turned out so poor a car. When a trial trip with the car had been made in company with one of the assistants in the experimental department, it was found that the car was equipped with a special kind of tire unknown to Mr. Vincent or the assistant. The tires were quietly changed and the car returned to the owner. The report received was that they changed it into a wonderful car.

R. E. Wilson's query, whether the fact that the round-tread tire has a longer tread than the flat-tread tire would not increase the difficulty of turning, brought an affirmative response from Dr. Lemon.

Two distinct contributions toward the advance in balloon-tire construction cited by Dr. Lemon were stressed by Sid-



A Device for Controlling Shimmy
An Hydraulic Cylinder Is Mounted on the Rear Face of the Front Axle. A Piston Moves within This Cylinder and the Piston-Rod Is Attached through a Link to the Left Steering-Knuckle Lever. This Device Tends To Dampen-Out Rapid Oscillation of the Steering Cross-Tube But It Permits Movement of the Front Wheels for Steering Purposes

ney Schott, of the United States Rubber Co., namely, the overcoming of premature wear of the tread and the prevention of noise. As a statement had been made that a difference in pressure of 5 lb. per sq. in. is the margin between success and failure, Mr. Schott believed that the so-called semi-flat tread, which makes this difference unimportant, was an advance in the industry. Regarding Mr. Hale's statement concerning the separation of the rubber and the consequent failure of tires at the edges of the tread, Mr. Schott said that he had examined 300 tires under test at the factory and in no case had a semi-flat tread tire shown failure at the point mentioned. Nor has the flat-tread tire the tendency to throw stones and to produce clouds of dust that is apparent in a round-tread tire. The noise produced inside a car and characterized as rumble may be reduced, he said, by substituting three plain ribs along the center portion of the tire for the true anti-skid design.

Racing Cars

A written communication received from Ray Harroun called attention to the use of small tires on the front wheels of racing cars. Cars so equipped handle more easily and are free from shimmying. He questioned the right to assume that the same tires would answer the requirements of both ends of a car any more than that the same springs would serve both ends.

Chairman Vincent agreed that smaller tires on the front wheels improved the driving quality but said that the practical answer was that the public did not wish to be bothered with carrying two spare tires and two spare wheels.

Mr. Jack's experience, on the other hand, with standard tires in front and balloon tires in the rear had been unsatisfactory, probably, he said, because the spring-suspension had not been altered to suit the conditions.

In presenting his paper on a Car Manufacturer's Experience with Balloon Tires, E. A. De Waters outlined the course of development through which balloon tires had gone in the Buick Company. When the first balloon tires, 32 x 6.20 in. in size, with four-ply casings, were used, the most noticeably objectionable feature was a so-called galloping action. To this was added the familiar steering difficulties, the development of shimmying to a serious degree, the lack of proper clearance for the external brakes because of the small size of the wheels, excessively rapid wear of the tire tread, greater susceptibility to punctures and leaks resulting from pinched inner tubes.

After trying a small size of tire on a smaller car, then the original size with a six-ply instead of a four-ply casing, it was decided to use tires that approximated in size to those previously in use but with a reduced air-pressure. Seven test-cars driven 24 hr. per day covered 1,500,000 miles. An analysis of blowouts and punctures in this test led to the conclusion that although four-ply construction was good for the front wheels, the greater load and driving strains on the rear wheels demanded a heavier construction. The number of plies was accordingly increased. The records clearly show that the front tires are much less susceptible to punctures than are the rear tires. Having settled the matter of tire construction satisfactorily as regards punctures, blow-outs and the like, the remaining trouble was excessive tread wear on the outer edges of the tread of the front tires. This was overcome by raising the pressure 10 per cent.

Conclusions

The results of the tests and experiences were summarized as follows:

(1) Large-section thin-walled balloon tires increase the resistance to steering, particularly at the curb; they increase the tendency to shimmy at the higher speeds; when inflated to relatively low pressures, they tend to set up a galloping action of the car which is distinctly disagreeable; and when driving in or over deep hard ruts, blowouts are likely to be caused by the inner tubes being pinched

(2) Reducing the section of the tire and raising the air-pressure, so that the resulting casing represents a compromise between the very large thin-walled balloon type and the conventional high-pressure type, will eliminate the galloping tendency

(3) Four plies are sufficient to ensure ample protection against punctures and blowouts when low-pressure tires are used on the front wheels

(4) More than four plies are needed on the rear wheels as a protection against the greater wheel-loads and the absorption of driving strains

(5) From the standpoint of durability it is important that tire pressures should be maintained at the recommended figures

WEYMANN BODIES EXTREMELY LIGHT

Weight Is 30 Per Cent Less Than Conventional Body and Cost 20 Per Cent Less

At the Passenger-Car Body Session on Wednesday afternoon George W. Kerr submitted an interesting paper covering the Weymann method of body construction based on information which he obtained on a recent trip to Europe. This paper is printed in full on p. 215 of this issue of The Journal. The paper as presented was illustrated by a large number of slides showing various details of construction. In the discussion that followed, Paul H. Geyser reviewed the experience of the Yellow Cab Mfg. Co. with the Weymann method of body construction. His company, which is the only licensee under the Weymann patents in this Country, has built 35 taxicabs with bodies of this type during the last 6 months.

With reference to the weight of these bodies, Mr. Geyser stated that they weighed about one-third less than the taxicab bodies as usually constructed. Compared to a high-grade passenger-car body, Mr. Kerr thought that such bodies as built in England would weigh about 25 per cent less. According to Mr. Geyser the absence of noise in taxicabs having bodies of the Weymann type is what appeals to them most, as, with the four-cylinder engine used in taxicabs, the noise is considered objectionable. This difference is very noticeable, according to Mr. Geyser, when changing from a taxicab as usually constructed to one having a Weymann body.

Although only 35 bodies of the Weymann type have been produced by the Yellow Cab Mfg. Co., Mr. Geyser predicted that in regular production the cost would be approximately 20 per cent less than that for the conventional construction. He emphasized the fact that in the construction used the posts and pillars are not cut in half by half lapping at the joints, but are bolted together, so that the strength of the framework is much greater, in proportion to the amount of material used, than the framework of a conventional body.

With reference to the durability of the paint on fabric-covered bodies, George J. Mercer cited a car built in 1922 which had been exhibited at the automobile shows and which had been driven 37,000 miles under average conditions. This car had been subjected to extremes of heat and cold and had been allowed to accumulate road tar and mud. Although it had been washed and polished several times, he said, the finish was still in very good condition. He also stated that part of the rear fender fabric had been replaced, yet the difference in appearance between the old and the new fabric was not noticeable. Mr. Geyser thought that this was largely due to the fact that a dark color had been used and that more difference would be noted with light colors. His experience had been that the paint of taxicabs of this type in service for 6 months would be in as good condition as the day they were placed in service. The fact that the usual type of taxicab body has to be revarnished after about 4 months of service clearly shows that the paint on the Weymann body stands up better than that on the usual body. The reason given for the ability of the paint to stand up better on the fabric than on metal was the lack of electrolytic action usually present when metal is used.

J. B. JUDKINS

GEORGE W. KERR

With reference to the matter of assembling the bodies made by his company, Mr. Geyser stated that, although Weymann assembled all bodies on chassis, his company assembled them on sleepers. He extended an invitation to all those present who were interested in the Weymann body construction to visit their plant during the Chicago Show. He stated that a representative of the Weymann Company had worked with them for the last 6 months in connection with the construction of the bodies made during that time.

J. B. Judkins presented an interesting paper on the relation of the custom body-builder to the car producer. Although not of an engineering nature, Mr. Judkins's paper was of particular interest in view of the coming importance of the custom body-builder in connection with large automobile producers. For the purpose of his paper Mr. Judkins considered the custom body-builder as making from 25 to 50 bodies of the same design, these being made for individual or groups of dealers or distributors or for automobile manufacturers.

While the automobile manufacturer has devoted his time and thought to perfection of the chassis, perfection in body design has been left to the custom body-builders according to Mr. Judkins. His ideas of today are found in the standard bodies of tomorrow. The general acceptance of the chassis as being commercially perfect results in the fact that a buyer of a passenger car is influenced largely by body design, comfort, construction and detail. The custom body-builder is consequently playing an even more important part than before.

Although even a successful custom-built model might result in a total production of 300 or 400 bodies of identical design, their exclusiveness is still retained, not only through the great variety of colors and upholstery materials specified, but also through their nation-wide distribution. The appeal of a custom-built job is neither surprising or unusual. It is that same desire to which we yield when we purchase tailor-made clothes or bench-made shoes.

A line of custom bodies insures the availability of distinctive models for show exhibition and it increases the morale of the dealer and his sales personnel. It also supplements his standard line by the addition of such bodies as broughams and cabriolets, for which there is a limited demand and which can be sold at prices that will return a normal profit. Association with a custom builder also makes available to the chassis manufacturer all of the former's talents, ideas and experience. The ownership of cars with custom-built bodies by prominent people carries an advertising or publicity value which reacts to the benefit of the car makers.

Mr. Judkins summed up the rôle of the custom builder as to create new designs and originate new refinements, to meet the demand for the exclusive and distinctive, and to furnish the production builder with accepted improvements and fashions.

Although many production practices in a custom-body-shop may seem antiquated and uneconomical, it must be borne in mind that his equipment cannot equal that of a large producer. The small production, however, permits a careful supervision which reacts beneficially on the character and the quality of the work.

Fifteen or 20 standard bodies of one design are, according to Mr. Judkins, the minimum number which it is economical to produce. Drying kilns are standard equipment in most plants. Milling machinery is not used extensively. The gluing and sub-assembly work is carried on in much the same fashion as practised by larger producers, but the setting-up or erection of the body frame differs. The small quantities ordered as a rule do not permit of a great investment in jigs. It must be admitted that through the lack of such equipment, interchangeability of parts is not assured, but this is not as serious as it may appear to be because the only parts thus affected are the metal panels which are not pressed from dies, but are either hand or power-beaten, depending upon the shape of the panel. Flanging may take place prior to or at the time of installation and the final fitting is always made on the body for which the panel is intended.

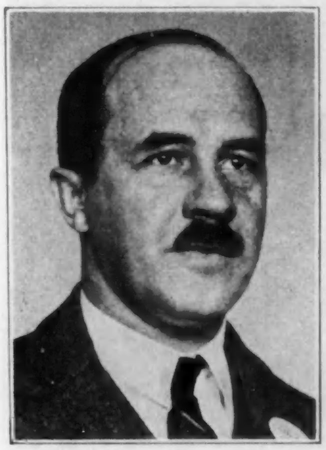
Since frame reinforcements on individual jobs are generally hand forgings, forges are found in all custom plants. The usual run justifies the making of patterns for all reinforcements excepting possibly a few simple angles or straight stock pieces, which are generally hand-forged. The castings will be found to be manganese bronze fully as often as malleable iron.

The methods employed in wiring, blocking, regulator and glass installation and final assembly differ from those of large producers only in that these operations will be manual to a greater extent and each workman, instead of being a specialist, will have several duties. The custom body-builder is rapidly installing paint spraying systems and, like the car manufacturers, some have already adopted a nitrocellulose painting schedule. In the trimming department a considerable difference will be noted. Few, if any, panels will be made up prior to installation. Upholstery costs will obviously be relatively higher, but by this method every body is assured of an accurate and correct fitting of lining, regardless of variations or irregularities, and in a custom job the trimming details must be beyond reproach.

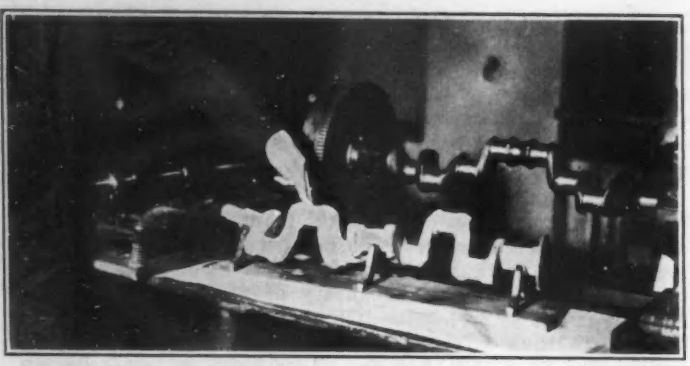
CARNIVAL PLEASES GAY MULTITUDE

Social Event of the Annual Meeting Is Attended by Over 900 Revelers

Painting a word picture of an S. A. E. Carnival is a tough job. Though cross-word puzzles have done much to extend the vocabulary of the average engineer, an insufficient supply of adjectives and superlatives seems available for such a task as the description of the annual Oriole Terrace gaieties. We might start by saying that the 1925 Carnival hit the



DETROIT'S HOSTS TO THE SOCIETY
George L. McCain (at the Left) Was Chairman of the Reception Committee and H. T. Ewald (at the Right) Directed the Activities of the Carnival Committee



CRANKSHAFTS USED BY C. E. SUMMERS, GENERAL MOTORS RESEARCH CORPORATION, TO DEMONSTRATE CRANKSHAFT VIBRATION PHENOMENA

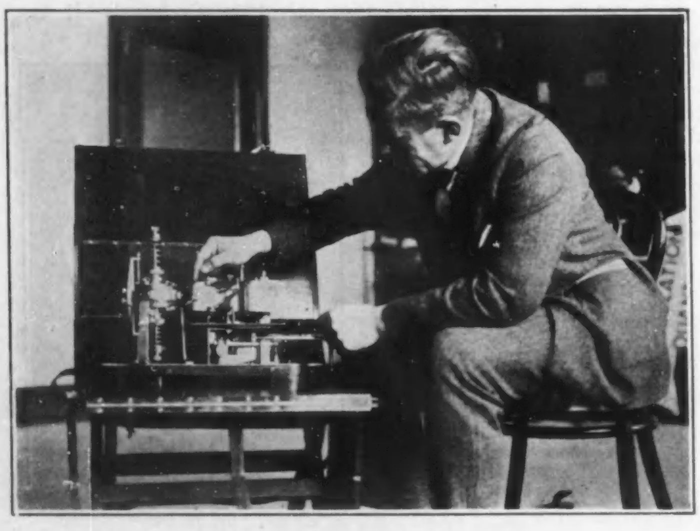
bullseye. That is to say, it satisfied. It was everything that a well-ordered Carnival should be, plus!

As one entered the scene of the carryings-on, gayly colored decorations pleased the eye. Large papier-mache replicas of clownish faces grinned amusingly from the walls. A sea of wriggling dolls and grotesque animals, patterned after the more famous personages of the Sunday funny sheet, dangled over the dance floor. Femininity drifted about in beauteous raiment much the same as the colored crystals that tumble about at the end of a kaleidoscope. Male escorts belied the formality of their dignified evening clothes, prancing about in childish glee like so many youngsters at a May-Pole festival.

Carnivals soon swallow one up in their atmosphere of familiarity. Mr. and Mrs. are dropped for plain Bill and Mary. Everyone knows everyone; the formal handclasp gives way to the more expressive slap on the back. The main topic of conversation is nothing at all. You just talk, laugh and aerate your otherwise serious soul. Bits of nothingness supplant business worries and elderly scions of the commercial world become youths rinsed in merriment.

This year's Carnival was made more resplendent by the presence of an attractive group of young ladies who kicked, wriggled and danced about in impressive chorus numbers produced especially for the occasion with an abundance of automotive flavor. Presumably they sang also; at least their pretty mouths went through the accustomed contortions that are a part of vocal exertion. But the Carnival hub-bub drowned them out. Carnival hub-bub is just that discourteous and unappreciative. However, the antics of the chorus pleased the eye. This is particularly pertinent to their efforts as emulators of the red-hued bathing ladies who grace the windshields and rear windows of America's motor cars.

The much heralded monkey dance exploded prematurely.



INTERNATIONAL MOTOR CO. ACCELEROMETER FOR RECORDING SHOCK AND REBOUND OF AUTOMOTIVE VEHICLES BEING DEMONSTRATED BY S. H. WOODS

So tantalizing did the dangling souvenirs appear to the wriggling mass of humanity on the dance floor, that desire got the better of decorum and sponteous jumption spread through the revelers like the flame-front of a combustion wave. In a few minutes of energetic activity, dolls, animals, Boob McNutts and the rest of the jungle were pulled down into the waiting arms of their future guardians.

When the happy throng was not dancing, they gazed on the beauties of the Oriole Terrace performers. When the performers retired, the dancers monopolized the floor until the wee hours of the morning. Then Henry Theis called his strumping troubadours home to their well-earned rest and Phil Overman took up their labors. Seated serenely in the center of the dance floor he crooned sweet melodies from the strings of his soulful banjo-ukulele while the sun rose over the horizon to begin another day. More and more weary grew the dancing feet. Slowly the enthusiasm began to wane. Finally Phil and his banjo succumbed. The Carnival had not ended; it just wore out!

Congratulations to Henry Ewald! He and his hard-working committee can now rest on their well-earned laurels. In every detail the 1925 Carnival was well done and the praise that is theirs is deserved. Here are the enthusiastic committeemen who made Carnival history in Detroit in January, 1925:

CARNIVAL COMMITTEE

H. T. Ewald, *Chairman*

Gould Allen	R. O. Gill
F. E. Booth	John R. Ide
W. A. Brush	Ralph S. Lane
M. Howard Cox	T. J. Lítle, Jr.
George E. Edmunds	Loren Robinson
Walter R. Flannery	DuBois Young

DUST AND AIR-CLEANERS

Silica Forms Major Part of Dust and Causes Wear—Cleaners Have High Efficiency

Dust from widely separated parts of the Country is much alike in character, contains more than 50 per cent of silica having hard sharp edges, and all is injurious to an automobile engine, causing wear of the cylinder-walls and piston-rings. The amount of dust breathed in by the engine varies with the character of the road, whether paved or not, how closely one car follows another, and other conditions affecting the amount of dust in suspension in the air and the time that has elapsed since the dust of road and field was stirred up. The larger the dust particles are, the more injury they are likely to do to the engine. Air-cleaners, if properly designed and located, remove a high percentage of the dust from the air, as much as from 90 to 99 per cent. Position of the intake to the carbureter or the air-cleaner is of great importance. It should be as high as possible, well back and turned away from the direction of movement of the car. The designers of one American car which has a high reputation for long engine life have accidentally achieved an air-cleaner without knowing it, in that the intake is up high, is placed well back and is turned so that the air has to whip around the edge of the intake to get in.

These were some of the high-light points of the addresses of C. E. Summers of the General Motors Research Corporation, and Prof. A. H. Hoffman of the University of California, at the Air-Cleaner Session. Their papers are printed in full in this issue of THE JOURNAL, together with illustrations. Exhibits, demonstrations and lantern slides added greatly to the interest of the expositions of their subjects.

CHARACTERISTICS OF DUST DEMONSTRATED

Mr. Summers displayed samples of dust collected by traps on cars operated in Iowa, Alabama, Texas and California and a chart of the chemical analyses of the samples showing that in every case more than 50 per cent by weight was silica and that iron oxide was present in a considerable percentage, especially in California. Slides of photomicrographs of dust particles were thrown on the screen to show the relative sizes and the character of the particles as compared with a commercial abrasive. The particles looked like crushed stone, some having sharp edges like broken glass. He demonstrated the specific gravity of dust by pouring 50 grams of dust into 150 grams of colored kerosene and got a reading of 220 cc., showing that the dust has a specific gravity of about 2.5, which is about the same as quartz.

To illustrate the rate of fall of particles of different sizes, the speaker made a demonstration with an apparatus that dropped two very light balls, one about 1 in. in diameter and the other about 3 in. in diameter, from a pair of magnets at the top of a pole reaching to the ceiling, both balls being of the same specific gravity. The larger reached its basket at the floor first. He also showed a chart of the rate of fall of dust particles, indicating a rate of fall for the finer ones of 60 ft. per hr.

Results of tests of wear of cylinder bore and piston-rings were shown by charts and indicated that most wear occurs at the top of the cylinder and is caused by grinding of the dust between the rings and the cylinder-wall.

Model of Centrifugal Cleaner Operated

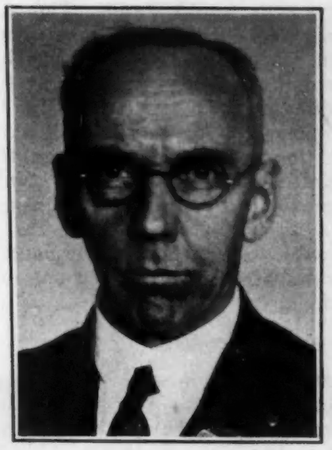
A centrifugal air-cleaner patterned after development by Professor Hoffman was demonstrated by a celluloid model into which 50 grams of dust was fed and driven through by a spirally rotating current of air, the dust being separated out by its greater specific gravity. Relative vacuums in different parts of the cleaner, created by the whirling motion of the air, were demonstrated by inserting two nozzles connected by flexible tubes with a manometer. Loss of energy due to the whirling motion, Mr. Summers said, was recovered by two spiral vanes at the intake from the cleaner to the carbureter, which straightened out the air current and reduced the restriction. The centrifugal cleaner, he said, was most efficient in taking out the larger dust particles that do most harm in engines. Its efficiency depends on the rate of air whirl or centrifugal force generated.

More than half a hundred slides were used by Professor Hoffman to illustrate his address on the 6-months' test of tractors and trucks in California to determine engine wear due to dust. He also showed a cast-iron ring-gage for measuring piston-rings before and after the test and said that the readings were checked up by weighing the rings on a chemical balance. A taper-gage slipped in between gave the readings in hundredths of an inch, whereas with a micrometer it was difficult to get accurate readings with two curved surfaces, and feeler-gages slipped in in a bunch could not be depended on at all. Samples of eiderdown cloth used as air filters were displayed, both unused and after they had collected some dust in tests. A number of the slides showed different types and makes of air-cleaners, in external and sectional views, such as the dry-filter, dry-inertia and oil types. One cleaner had a heater attached and Professor Hoffman observed that, in his opinion, manufacturers were making a mistake in not providing means for heating the air to facilitate starting in cold weather.

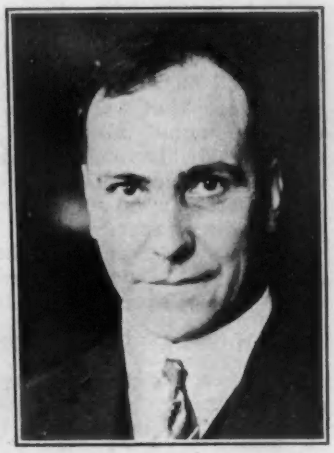
Oil-Type and Dry-Type Cleaners Show High Efficiency

Charts of the tests showed high efficiency for the oil and the dry types, all about equally good and close to 100 per cent effective. Another chart showed that with many of the cleaners the restriction to air passage did not increase greatly after they began to collect dust. Most of them were under 7 in. of water in vacuum reading. It was very difficult to determine efficiency above 99 per cent, the speaker said, but by incinerating the cloth and recovering the dust, it was possible to differentiate among cleaners above this efficiency.

All cleaners should be made so that they can be taken apart for inspection and cleaning and be easily refitted, Professor Hoffman said, as he believed that the only air-cleaner that could be used year in and year out and that is service proof, is simply a periscope that will take the air from high up, about 10 ft. in the air, when the engine



A. H. Hoffman



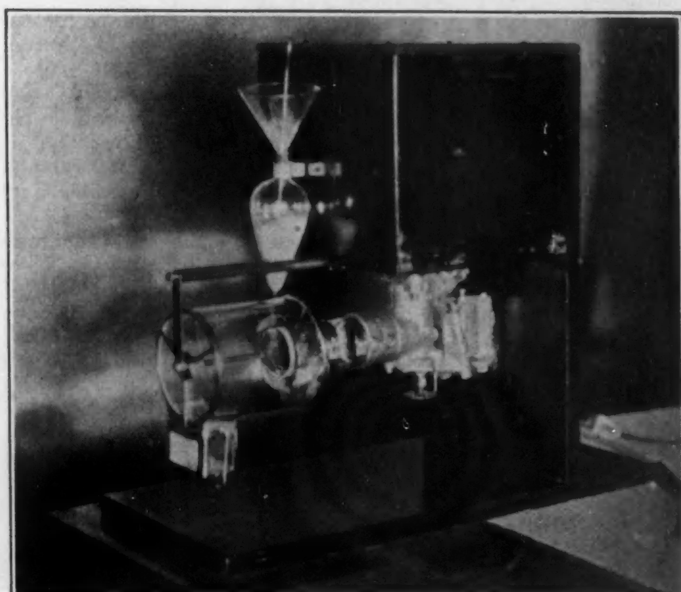
C. E. Summers

will run about the same and wear about the same as it would if it were run on water.

Removal of Coarse Particles Prevents Wear

Discussion on both papers followed, that on Mr. Summers' paper coming first. In reply to questions, C. L. Lee, in the absence of Mr. Summers, who was called away, said that whether coarse particles caused more wear than fine ones depended on the quantities and that it often happens that large particles do not get down between the piston-rings and the cylinder-walls but go out through the exhaust. As to whether the wear in an engine is proportional to air-cleaner efficiency, it was found that the larger dust came in smaller quantities and if the cleaner took out the larger particles up to approximately 90 per cent, the wear was very slight.

Asked if it would be advantageous to take the air from inside of a closed car, he said that had been done several times but that in case of a back-fire from the carbureter, the gas was blown back into the car although the expedient was effective as an air-cleaner. On a new engine the fine dust would cause most wear because the clearances would not permit the coarser dust to get between the piston-rings and the cylinder-walls. Asked what efficiency Mr. Summers' cleaner gave on a car, with average dust of 2.5 specific gravity, at 20 and 40 m.p.h., Mr. Lee replied that results varied with the type of carbureter the cleaner was used



The Glass Air-Cleaner
This Was One of the Features of the Demonstration at the Air-Cleaner Session

on and the restriction the carbureter would stand. The efficiency may be changed to suit the car. If the maximum restriction were put at 5 in., the efficiency at 20 m.p.h. would be around 60 per cent. In reply to another question as to the extent that turbulence due to pulsation of a four-cylinder engine affects the operation of centrifugal air-cleaners, Mr. Lee said that at the higher speeds the length of the manifold would take care of the pulsations and that when there is a vacuum there would not be very much pulsation in the cleaner.

No tests had been made, he said, to determine the amount of dust expelled through the exhaust in an ordinary engine under normal operating conditions.

Hoffman Questioned on California Tests

Professor Hoffman then answered a number of questions relating to the California air-cleaner tests. Asked whether any check was made on fuel consumption to determine the effect of increased vacuum due to the cleaners, he said that records of gasoline and oil consumption were all included in the report given in his paper. Chairman Lítle asked if dust samples should not be measured by volume instead of by weight, but Professor Hoffman said it was difficult to get any determination by volume because the volume depends on how much the dust is shaken down, so it is more accurate to take the weight.

The material used in his so-called absolute cleaners was white eiderdown blanketing but he considered a heavier eiderdown, a sample of which was displayed, better. Sometimes, when making a chemical analysis of the dust cloths to determine the residues of dust collected, there is as much as 10 or 12 times as much moisture in the cloth as there is dust, he said, and therefore he relies on burning of the cloth to get the residues.

Asked if oil vapor from the crankcase breather tended to clog the filter of the dry-filter type air-cleaner when the filter was installed under the engine hood, Professor Hoffman said that he had not observed that himself, but it had been called to his attention that a tractor-type cleaner used for a number of years on the Fageol tractor is located so that oil vapor from the crankcase is breathed on the filter cloth and that, while this produces rather high restriction after dust collects on the cloth, the oil-saturated filter cloth was said to be responsible for the long engine life that the tractors have been getting.

Demonstrations Made Session Vivid

President Horning proposed a resolution of thanks to the contributors to the session and to the General Motors Corporation for the use of the General Motors Building for the Annual Meeting. He wondered, he said, if those present realized that the reason the session had been such a good one was because of the illustrations, the apparatus and samples displayed and the demonstrations made which enabled the audience to visualize as well as to hear. That is the type of exhibition, he said, that made this a vivid and vital session, and it will be followed as far as possible during the present year.

Chairman Lítle said he would see that the resolution was presented and said that in future the Society will have plenty of demonstration apparatus at meetings, which will be staged very carefully. An attempt will be made to have a Motorboat Session next year.

LUBRICATION PROBLEMS DISCUSSED

Dilution Evaluation and Contamination Among Lubrication Session Topics

One subject seems to be perennial with the Society of Automotive Engineers, and that is lubrication. Three or 4 years ago we were particularly interested in the exact properties of the oil when put into the crankcase, and most of the discussion at that time related to whether we should have 250 or 300 viscosity and what the cold test should be. Today we have forgotten what we put into the crankcase and the much more important problem relates to what is there after we run awhile, the foreign material that gets into the crankcase and the lubricating system in general.

With these apt remarks R. E. Wilson, of the Standard Oil Co. of Indiana, who acted as chairman, opened the Lubrication Session of the Annual Meeting.

A paper by G. A. Round, of the Vacuum Oil Co., on Foreign Material in Used Oil; Its Character and Effect on Engine Design, is printed on p. 232 of this issue of The Journal.

A paper by S. W. Sparrow and J. O. Eisinger, of the Bureau of Standards, on Recent Cooperative Fuel Research Progress, will be found on p. 237 of this issue of The Journal.

In the January issue of The Journal, p. 17, an article appeared, entitled A New Way to Evaluate Dilution, which was included by T. S. Sligh, Jr., as an appendix to his Annual Meeting paper on The Measurement of Crankcase-Oil Dilution. Mr. Sligh presented additional material which will be summarized below.

H. C. Mougey, of the General Motors Research Corporation, called attention to the recommendations of the oil and the automobile companies that oil be changed at more or less definite intervals, about every 500 miles. He asked if there is any rational criterion based on the percentage of contamination that can be used to determine the frequency of crankcase-oil replacement. Mr. Round replied that this depends largely upon the unit under consideration. To quote,

> The average car in summer will run perhaps 1500 or 2000 miles before trouble is experienced, particularly with the splash lubricating system. When a high percentage of insoluble material is in the oil and when a force-feed system is used, much of this material is thrown out into the crankshaft drillings. This forms the chief objection to not removing the insoluble material; it continues to build up in the oil until clogging occurs at some important point. I think the average is 1000 miles in summer and 500 miles in winter. I know of a doctor's car that ought to be drained every 250 miles as he drives with the choker pulled up all the time.

W. G. Wall, consulting engineer, emphasized the fact brought out by Mr. Round that if the mesh of the strainers is too fine, they are certain to catch water that will freeze in cold weather, and in cases where a quantity of steam accumulates, the oil-pump will not function properly. In reply to Mr. Wall's question as to the most suitable mesh for a strainer, Mr. Round replied that a mesh of from 25 to 40 will do everything that a screen can be expected to do in an engine. He went on to say that the only way to remove certain insoluble materials is either by filtering or by a centrifugal process. The finely divided particles will not settle out in any reasonable length of time. Mr. Round felt that the screen should be made as nearly self-cleaning as possible. It should be placed so that clogging can be minimized, and a pocket should be provided for the settling of heavy material, like flakes of carbon, and for the collection of water.

Prof. P. H. Schweitzer, of Pennsylvania State College, called attention to the Hele-Shaw filter that is composed of layers of paper between which the oil is led and the dirt deposited. Mr. Round stated that this type of filter has been made up of metal discs held apart about 0.001 in. The device was said to be very effective, but of comparatively small capacity when reasonable size and weight are considered.

John Younger, editor of *Automotive Abstracts*, asked if settling tanks in the sump would not assist in separating some of the insoluble materials. Mr. Round believed that on account of the slowness of settling, this arrangement would not be successful. He felt that some form of filter using either a fabric or centrifugal means is the most satisfactory solution.

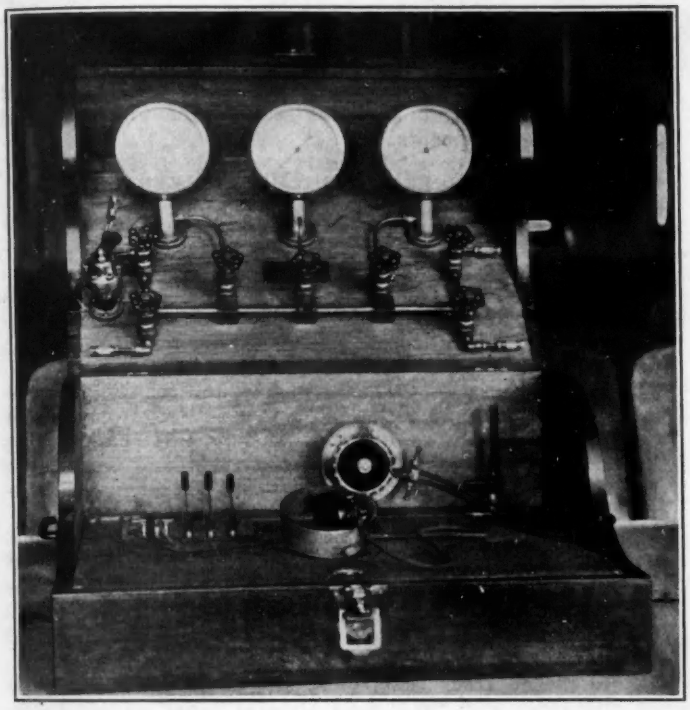
R. R. Matthews, of the Roxana Petroleum Co., inquired if draining the crankcase removes most of the foreign matter or if much of it has a tendency to stick in the crankcase.

Mr. Round stated that any material that is likely to circulate with the oil will be drained off in case the draining is done when the oil is hot. Material that is not thus removed can best be left undisturbed.

Discussion of Sparrow and Eisinger Paper

In reply to Chairman Wilson's question as to why the tests reported by Mr. Sparrow showed percentages of dilution considerably lower than those experienced under ordinary operating conditions, the latter stated that the lack of frequent starting periods would probably account for this fact. Certain other tests with an engine in poor mechanical condition showed much higher dilution.

Prof. H. M. Jacklin, of the Ohio State University, referred briefly to a study of the influence on oil dilution of



Bureau of Standards Balanced-Diaphragm Type of Engine Indicator

crankcase temperature. Mr. Sparrow stated that the crankcase temperature undoubtedly has a marked effect upon dilution. This was accounted for by the more rapid elimination of the diluent from the oil under high-temperature conditions.

Chairman Wilson raised the following question:

> Evidence has been presented at previous meetings to show that the fuel once vaporized will not condense under any condition existing in the manifold or cylinder. Your work seems to indicate the contrary. Am I correct in believing this?

Mr. Sparrow replied that this question can probably not be definitely answered. He believed the whole matter to be associated with the factor of time and the way the gas is swept against the cylinder. It was his belief that if the charge is vaporized and if the cylinder with which it comes in contact is cold enough, the gas will condense. To quote from Mr. Sparrow's remarks:

> Another phase of this must be considered. The change in economy that would be likely to result from the amount of fuel that goes to form crankcase dilution is extremely small. Therefore, a general statement which might be entirely correct as covering the matter of carburetion and the conditions which influence economy might not cover the general conditions that are of importance in considering crankcase dilution.

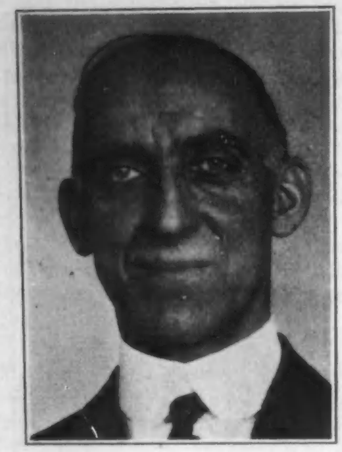
Stanwood W. Sparrow

G. A. Round

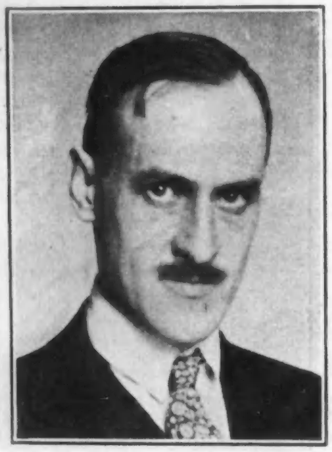
Professor Schweitzer asked if no dilution would occur with cylinder-wall temperature considerably higher than the dew-point temperature of the fuel or higher even than the high-end point constituents of the fuel. To quote from Professor Schweitzer's remarks:

> Another factor enters this question. I have sprayed gasoline and other fuels against frosted glass and have found that gasoline wets the glass even when the temperature of the glass is considerably higher than the dew-point temperature of the mixture. The explanation to my mind is that the fuel does not evaporate as fast as it hits the wall. So, if the wall receives a spray that is so finely atomized that it absorbs sufficient heat from the wall, the fuel vaporizes. If the fuel spray is too coarse or the temperature of the oil is too low, then the surface will become wet. So, in fact, it would not be exactly an evaporation but a film formation that would cause the crankcase dilution. We, at the Pennsylvania State College, have taken an electric

T. S. Sligh, Jr., Bureau of Standards, Demonstrating Apparatus Developed at the Bureau in Connection with the Cooperative Fuel Research for Evaluating the Percentage of Dilution in Crankcase Oil by the Transition Method of Vacuum Distillation



Dr. H. C. Dickinson



H. H. Allen

globe and frosted it. The temperature of this globe, as regulated by a rheostat and measured by thermocouples, was as high as 500 deg. fahr. If we kept the temperature of the globe above a certain point and sprayed gasoline against it, the surface remained dry. When the temperature was lowered, the frosted glass became wet. This temperature did not correspond to the dew-point temperature. It was invariably considerably higher. So I believe that there is another critical temperature besides the dew-point temperature that would detemine to a great extent the crankcase dilution. If the wet particles in the fuel-air mixture are sucked into the cylinder and impinged upon the cylinder-wall, the temperature of the latter must be higher than this critical temperature for these particles to evaporate as fast as they impinge upon the wall. Otherwise, even if the temperature were higher than the dew-point temperature of the fuel, it would not be able to evaporate all the fuel and some would drain down.

Mr. Sparrow stated:

> It seems to me that the question raised is that if the cylinder-wall is at the dew-point temperature and fuel is sprayed upon it, the evaporation of that fuel would necessarily lower the temperature and would wet the surface. Of course, if the temperature of the wall is as high as the dew-point temperature, this does not mean that gasoline can strike it very rapidly and evaporate entirely. In this connection, both the time element and the amount of heat must be considered. It is, of course, highly essential that the rate of heat-flow through the wall must be sufficient to maintain the temperature of the latter high enough to evaporate the fuel. If the wall is below that particular value, evaporation will not take place.

Chairman Wilson called attention to the apparent conflict between the results of different investigations, some of which tend to show that crankcase-oil temperature is important in determining dilution, whereas others show that it is not. It is believed that this fact can be accounted for by considering that crankcase-oil temperature is undoubtedly important if the case is well ventilated. In this event there is an opportunity for the gasoline vapors to be swept out when the temperature is high. To quote Chairman Wilson's remarks:

> The amount of ventilation will depend upon two things: (*a*) the amount of blow-by and (*b*) the inequalities in crankcase volume with different positions of the pistons which in four-cylinder engines is very high and causes rather rapid fluctuations, whereas this is not the case with six-cylinder engines. I believe that six-cylinder engines as a class generally tend to accumulate more diluent than do the four-cylinder types and that crankcase-oil temperature in them is not nearly as important unless by chance there is considerable blow-by. It is interesting in this connection to note that when one difficulty is remedied, another becomes aggravated. The flapper valve on a breather pipe to prevent dust from entering the crankcase is an excellent device for its intended function. It was mentioned as being important on four-cylinder engines. Attention should be called to the fact that the flapper valve would reduce the ventilation effect and would in my opinion make four-cylinder engines about as bad as six-cylinder engines from the dilution standpoint.

John Younger mentioned the development of an internal heater that was designed during the war to maintain truck engines at the proper temperature while not in use. He believed that the application of some such device to engines in general would remedy many of the difficulties that now prevail.

Additional discussion of the Sparrow and Eisinger paper related to the advantages of having a certain amount of dilution for starting in cold weather, suitable viscosities and ventilation requirements.

Sligh on Dilution Measurement

T. S. Sligh, Jr., of the Bureau of Standards, presented a discussion of certain work on the measurement of crankcase-oil dilution that has been included in the cooperative fuel research program. The paper summarized various methods of measuring the percentage of diluent in used crankcase-oils, but did not treat the broader questions of differentiation of the oil due to other factors.

The characteristics of viscosimetric and of steam-atmospheric and vacuum-distillation methods were discussed. It was pointed out that as dilution is not the only change which the oil undergoes in service, methods that are based upon the assumption that the oil is unchanged except by the presence of diluent may yield misleading results.

Distillation methods seem best suited for this determination and those which are rational, in that the evaluation of the diluent is based on the change in the properties of the distillate as the distillation proceeds from diluent to oil, seem to promise the greatest accuracy over a wide range of diluents and oils.

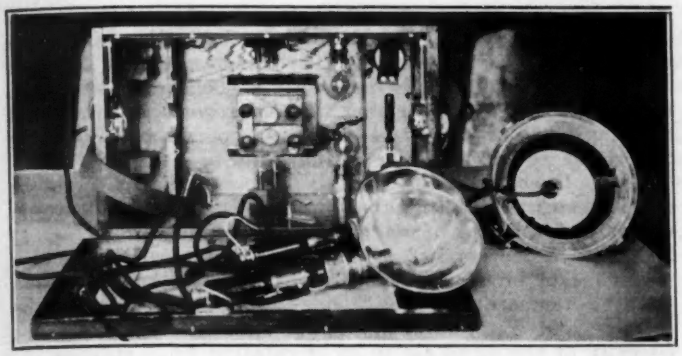
Since the accuracy that is necessary for research work is not attainable with the simple apparatus and procedure desirable for general routine work, two rational methods were suggested for determination of the percentage of crankcase dilution. The first was a vacuum-distillation method carried on at a pressure low enough, about 4 cm. (1.57 in.) of mercury, to avoid cracking of the oil. In this method, distillation date, volume of distillate and vapor temperature are taken, and the percentage of diluent is deduced from these data or from a curve plotted therefrom. Results are accurate to within about ½ per cent.

The second method described is a rapid atmospheric distillation in which no thermometer is used. The distillate is fed from the condenser through a funnel having a capillary section in the stem. The transition from diluent to oil is accompanied by an abrupt increase in the viscosity of the distillate and also by a rapid increase in the rate of distillation with constant heat-input. These two effects combine to produce a rapid rise in the head of distillate in the capillary section. The volume of distillate corresponding to this rapid increase is taken as the diluent. Results may be expected to fall within 2 per cent of the true value.

Demonstration

Mr. Sligh demonstrated the Bureau of Standards apparatus for measuring crankcase-oil dilution. As mentioned above, the details concerning the transition method of dilution determination by vacuum distillation were printed in the January issue of The Journal, p. 17. Additional material will be printed in a forthcoming issue.

In the discussion of Mr. Sligh's paper attention was called to the fact that the methods described are satisfactory



Elverson Oscilloscope, a Device for Studying the Motion of Moving Parts
By the Use of the Stroboscopic Principle the Parts May Be Made To Appear at Rest. By the Use of a Creeper Gear Attached to the Engine or Other Apparatus Under Investigation the Parts May Be Shown in Motion at Any Desired Speed of Rotation. The Mechanism Is Viewed under Light Produced by Neon-Filled Tubes, the Light from Which Is Interrupted at Suitable Frequency by an Appropriate Mechanism

for determinations with blended oils or compounded oils. Mr. Sligh stated that the transition method using atmospheric distillation is not satisfactory, owing to the fact that results are meaningless in cases where cracking of the oil takes place.

Chairman Wilson stated with regard to the constant-temperature method which so many are using at the present time that the objectionable cracking of the oil can be very greatly lessened by making the distillation toward the end very rapid, for example, by limiting the time between the thermometer readings of 400 and 460 deg. fahr. to 2 min. It was stated that in this event practically no cracking will occur, but in case the temperature is allowed to increase slowly in this range, a marked increase due to cracking will be noticed.

AN APPRECIATION

L. C. Hill, Retiring Assistant General Manager, Receives Regrets and Best Wishes

During the Lubrication Session, President Crane made the following announcement:

> The saddest job at the end of my term is to have to tell you that Clayton Hill is leaving the Society's central office organization for work in a private field. The Council and officers have already told him a little how they felt about it and I wanted to tell you all that it is to take place so that you can take advantage of the opportunity of saying what you think about it personally or in a concerted manner.

General Manager Clarkson took the floor and made the following remarks:

> I have had intimate and long contact with Hill and I want to have the pleasure of adding briefly and subscribing the best certificate of merit we can make as to his faithfulness, extraordinary enthusiasm and effectiveness in constructive work of the Society. He is an artist by nature, an engineer by training, and a prince of good fellows by avocation.
>
> I propose three cheers for L. Clayton Hill.

After the demonstration had subsided, Mr. Hill responded with what he termed his "first propaganda talk for the S. A. E." He expressed his great regret at leaving the Society and predicted for it a future that cannot at present be fully appreciated.

Mr. Hill said in part:

> When I look down the list and find the outstanding successes of the industry, I invariably find that these companies are affiliated actively in the work of the Society. * * * I am for interesting meetings. They are what Mr. Litle calls high post-graduate courses in automotive engineering. Everyone of them is given for the good of the industry. I have been given a large share of credit for these programs, but the real credit should go to the men who have taken the trouble, the pains and the care to give unselfishly of their own work and of their time to the general benefit of the industry. It should go to the companies in the industry who have done worlds of good in releasing information of a type which in other industries is considered highly confidential and mysterious.
>
> I only hope that in leaving the Society I can continue to be of service to it. I hope that you will convince others that the activities of the Society have as their real purpose the promotion of scientific advancement.

VAPOR-COOLING ADVANTAGES DISCUSSED

This Session of Annual Meeting Produces Lively Debate and Lack of Agreement

N. S. Diamant

Advocates or defenders of the vapor-cooling system for internal-combustion engines, who took part in the discussion following the delivery of a paper on the subject by N. S. Diamant were very confident that the system offers advantages over the water-cooled system but some skeptics cited cases that they believed proved the contrary and raised questions of the practicability of applying the vapor-cooling system to present engines. Mr. Diamant's paper appears elsewhere in full in this issue. The advantages claimed for this system of cooling are that it is apparently a simple way of attaining quick warming-up of the engine, constant operating-temperature irrespective of the load on the engine or of weather conditions and a slow rate of cooling down after the engine has been stopped.

As an example of a satisfactory steam or vapor-cooling system, John Erskine mentioned the Fairbanks-Morse farm-lighting plants developed some years ago having a small radiator above a small hopper, the radiator acting as a condenser from which the water ran back into the hopper. This maintained a constant operating-temperature of 212 deg. fahr. He said that it seemed to him entirely feasible to build an engine, with suitable design of the water passages and cooling space, that would operate without any circulation or pump and in which the radiator would be used simply as a condenser for the steam formed.

On the other hand, Charles P. Grimes inquired what it was hoped to gain with the steam system over the water system, and referred to work he had done during the last 2 or 3 years with an engine which had a combustion-chamber temperature of 520 deg. fahr. when running normally under full load but which appeared to give a better performance when the temperature was reduced to 360 deg. fahr. with the engine working at full load in a room having a temperature of 160 deg. fahr. The combustion-chamber temperature was taken $\frac{3}{32}$ in. from the inner wall of the cylinder and about $\frac{3}{4}$ in. above the piston. Chairman Alexander Taub, replying, said that the temperature mentioned was an extreme and that anything done to lower it would be of some benefit whereas ordinary operating-temperatures might be too low.

No Boiling Away of Water

Absolutely no boiling away or loss of water occurs in the vapor-cooling system, said Chairman Taub, when C. B. Dicksee suggested that deliberate boiling away of the water would cause a more rapid accumulation of lime on the cylinder-jacket walls. A car fitted with a vapor-cooling system had been driven from Los Angeles to Detroit and arrived with the same water with which it started. Further discussion developed that whereas, with the water-cooling system, it is necessary to have from 30 to 40 lb. of water, the vapor-cooling system requires only 5 or 6 lb. With a constant temperature of 212 deg. the top of the combustion-chamber immediately over the exhaust-valve was at 242 deg. but by using a 50 per cent alcohol solution the constant temperature would be 184 deg. and that of the combustion-chamber, 226 deg. The ideal steam-cooling system, said Mr. Taub, is one that maintains the maximum safe operating-temperature. A temperature of 245 deg. is not one of which we need be afraid. As the operating temperature goes down the friction goes up. In going to a higher operating-temperature with an existing water-cooled system, in which the exhaust-manifold is heated to rather an excess, some means must be used to lower the heat of the manifold or a loss of volumetric efficiency and consequently of engine power will be noticed.

Hot-Spots Do Not Develop

Arthur Pull expressed doubt if some of the vapor-cooling systems described could be applied practically and successfully to present engine constructions, because the increase in temperatures would bring about conditions of unequal expansion and improper valve operation as a result of distortions, which conditions arise when the boiling-point of water is exceeded, although it is entirely practical to operate at a considerably higher temperature than those to which we are accustomed. Mr. Taub replied that no trouble had been experienced in fitting the system to present cars.

Probable development of hot-spots at the exhaust-valves and spark-plugs, particularly if fins are accidentally formed in the jackets when casting the engine block so that pockets are formed, was cited as an objection to vapor-cooling, but it was pointed out that there was a misunderstanding regarding the system and that the cylinder-heads were always covered by water and not by steam alone. Greater turbulence occurred at the hottest places and the heat was carried away more rapidly, so that there was greater uniformity of heat than when operating at lower cooling temperatures. Fins that restricted the flow of the water in water-cooling systems caused little trouble in the vapor-cooling systems. Uniformity of heat in the cylinder-block was one of the beautiful points about vapor-cooling, said Mr. Taub. As the temperature reaches 205 or 212 deg. fahr., hot-spots do not occur but all parts become of the same temperature.

A laugh was raised when Mr. Diamant, replying to a question by Mr. Erskine as to whether it would not be entirely possible to build an engine with a suitable design of water passages and cooling space that would operate without any circulation or pump and in which the radiator would be used simply as a steam condenser, said that, while the problem was more complicated than that, the whole thing was very simple; all that was necessary was to analyze the engine and determine the effect of engine temperature and of water-jacket temperature on volumetric efficiency, on mechanical efficiency and on the thermodynamic efficiency. Determine these, he said, and the problem is solved.

No Technical Difficulties In the Way

Difficulties that stand in the way of adoption of vapor-cooling are commercial rather than technical, according to Mr. Taub, but Mr. Young remarked that the chief trouble was in getting the steam into the radiator, the radiator in present automobiles being set low so that it is necessary to bring the steam down low to introduce it into the radiator or condenser. He said he had conducted the tests for the Fairbanks-Morse lighting outfits, 12,000 of which had been built and were working successfully. The manifold was taken off the top of the engine and the core of the cooler outfit was set on. The steam, of course, rose. The top was not sealed and no vent was provided, he said.

In rebuttal, Mr. Taub remarked that he knew personally of 300 cars with conventional radiators in the usual location which were steam cooled and that no trouble whatever was experienced in getting the steam into the radiators. There were several ways, he said. The steam could be brought downward or could be run in direct. He believed the simplest form was best, merely letting the water come to a boil and allowing the steam to pass directly from the head into the top of the radiator and from there down.

H. A. Huebotter suggested that an experiment might be made in steam jacketing the lower half of the crankcase in winter and, instead of having all the condenser surface at the front of the car, run the hot water or steam down to a steam jacket in the crankcase so as to keep the lubricating oil at a temperature of 212 deg. fahr. and evaporate the gasoline and water diluents, at the same time reducing the viscosity of the oil to aid in its circulation when starting.

Regarding the simpler applicability of the vapor-cooling system to aircraft engines, because of the possibility of placing the radiator high, a point raised by E. W. Weaver, Mr. Diamant said that one system he had shown in the slides had a condenser and radiator that had been used for aircraft work and that, so far as cooling was concerned, there did not seem to be much difference between the automobile and aircraft engines. However, some work done by the Bureau of Standards seemed to indicate that the factor of safety in high-compression engines is reduced when the water-jacket temperature is increased. If the temperature is raised from 180 to 212 deg. fahr., detonation may occur and in any case there is no certainty that the factor of safety is not reduced.

NEW SECTIONS COMMITTEE ACTIVE

Plans for Student Branches and Other Matters Discussed at Informal Dinner

J. H. Hunt

A generally successful year among the Sections of the Society has provided an added impetus for the current year's activities. The meetings have been successful, the membership has increased, financial problems have been solved. The new committee, the personnel of which is listed elsewhere in this issue, has already taken the reins and at an informal dinner in Detroit on Jan. 22, the members expressed a determination to make the present year the best ever.

Student Branches

Installation of student branches of the Society was favorably discussed and attention was called to the fact that a number of engineering institutions are even insistent in their demands that the Society's work be extended to include this activity. By this means it should be possible to establish a contact with prospective automotive engineers that will at once be beneficial to the student, to the Society and to the industry at large. Work now in progress should soon result in the formulation of definite plans concerning this proposed extension of the Society's services.

Pacific Coast Activities

Considerable interest was expressed in the activities of Society members resident in the Pacific Coast States. Some assistance has already been rendered these members in connection with meetings and other activities. It was generally agreed that this important phase of Society work should be fostered.

President to Visit Sections

President Horning showed great enthusiasm in Sections work and told of plans to visit as many of the Sections as possible during the year. He bespoke for the central office organization the continued fine cooperation of the Section units. President Horning mentioned the increasing effectiveness of the Society's research work and promised to discuss this among the Sections.

Assistant General Manager Hill expressed regret in retiring from the central organization and stated that his interest in Society activities will not cease. He called upon the Sections to continue their efforts toward more successful meetings. The advisability of devoting considerable thought to details and to the formulation of plans well in advance of meetings was emphasized.

The following attended the meeting above reported. Chairman J. H. Hunt presided.

H. W. Asire	H. L. Horning
O. C. Berry	J. H. Hunt
G. T. Briggs	G. L. McCain
F. F. Chandler	H. O. K. Meister
C. F. Clarkson	R. E. Plimpton
G. W. Gilmer, Jr.	F. T. Robinson
A. W. S. Herrington	J. A. C. Warner
C. E. Heywood	R. E. Wilson
L. C. Hill	F. M. Young

John Younger

LIFE INSURANCE IN 1950

LIFE insurance fact and fancy are in daily contest. Had the earliest life-insurance pioneers prophesied the present-day accomplishments of life insurance, the soundness of their mentality would have been questioned. During the last 25 years the development of the submarine, the airplane, the radio and many other remarkable inventions have occurred coupled with a marked development in all of our many and varied industries. During the same period the United States has acquired and completed the Panama Canal, which has revolutionized the trade routes of nations and today extends its wonderful benefits to the whole world. Developments in trade, commerce and state have been little short of miraculous. These facts, indeed, warrant the assumption that the creations and achievements of the future will rival and possibly surpass those of the past. Our economists are unwilling to attempt prognostications for a period much beyond the immediate future. This attitude is sane, as economic forces are continually changing not only as to themselves but in their relation to each other. Were these forces to remain the same in all respects, and were it possible adequately to record and measure them over a sufficiently long historical period, we could obtain a sight accurately disclosing the future. It will readily be seen that this cannot be done with certainty, but at the same time we can foresee within reasonable limits of probability. Such a forecast serves our purpose in broadening our views, that we may the better be able to lay our plans and conduct our activities for future prosperity.

At the close of the last century, the continental United States had scarcely 77,000,000 inhabitants, but now we approximate 114,000,000 individuals. Giving various factors consideration and consulting the best authorities, we may estimate for our purpose a population by 1950 of 150,000,000 people. It is estimated that not more than 50,000,000 of our 114,000,000 persons are now insured. It also may be safely assumed that less than 1 per cent of these 50,000,000 policyholders made voluntary application for their insurance. It is true that one of the best-sold ideas in our country today is that "I should insure my life." It is also true, however, that a surprisingly small percentage of men make any effort toward accomplishing this result until influenced to do so by a life insurance underwriter. Aside from any increase in the volume of business in 1950, I believe that life insurance will show a marked increase in value to each individual, because it will be more accurately adapted to his needs. Then fewer men who carry insurance for ridiculously inadequate amounts will be found. Then their policies will correspond more nearly with their needs and will be valued and retained, and the waste now due to heavy lapsing of insurance will, I am confident, be reduced to the minimum.—From address by F. H. Davis before the Association of Life-Insurance Presidents.

GEORGE LOUIS LAVERY

IT is with sincere regret that we announce the death on Jan. 11, 1925, of George Louis Lavery, formerly of Chicago and recently a resident of Cleveland, who died suddenly of heart disease at the home of his daughter, Mrs. Henry A. Bogardus of Elkins Park, Pa., in the 68th year of his age. He was born Feb. 18, 1856, at Boston, and received his technical education in mechanical engineering at the Massachusetts Institute of Technology, being a member of the class of 1876. Following his apprenticeship as a draftsman for the Boston Machine Co., he was successively designer, foreman and superintendent for the Miles Iron Works, Boston, from 1877 to 1884.

Becoming connected with the Yale & Towne Mfg. Co., Stamford, Conn., in 1884, he went to Chicago later as manager of its branch office there and continued this connection until 1900, when he organized and became president of the American Post Office Equipment Co., Chicago. He invented, designed and sold keyless lock-boxes and standardized post-office equipment until 1905, when he disposed of his interests and became president of the American Bank Equipment Co., Chicago. Subsequent to 1908, he became mechanical engineer and Western manager for the West Steel Casting Co., Cleveland, Ohio, and was actively associated with the Metal Wheel Manufacturers Association, being influential in interesting it in metal-wheel standardization.

Appointed a member of the Truck Division of the Society's Standards Committee in 1920, Mr. Lavery was active in standardization work on tires, wheels and rims, and their equipment. He was appointed a member of the Axle and Wheels Division in 1921 and had been reappointed for the year 1925. In January, 1923, he was appointed secretary and general manager of the Tire and Rim Association of America, in Cleveland, which position he held at the time of his death. An important development resulting from his connection with this Association was the Handbook of the Tire and Rim and Felloe Standards of the Association.

Mr. Lavery was elected to Member grade in the Society, March 16, 1916, and exerted a strong influence in building up the cooperative work of the Tire and Rim Association, as well as that of the Society's tire and rim standardization. He is survived by his wife, Marion J. Lavery; his daughter, Mrs. Henry A. Bogardus; and his son, George Louis, Jr.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

USE OF PREFERRED NUMBERS

Purpose and Derivation of Preferred-Number Series Explained by F. J. Schlink

In view of the large amount of discussion occasioned by the development and use of preferred numbers in Germany and France, a special committee was recently appointed by the American Engineering Standards Committee to ascertain what has been accomplished, what series would be most applicable for use in this Country and in what manner the use of such series as are found applicable could be furthered. Cornelius T. Myers was appointed to represent the Society on this Committee, the Chairman of which is C. E. Skinner, assistant director of engineering, of the Westinghouse Electric & Mfg. Co.

In order that the Society members may have a clear understanding of the purpose and derivation of preferred numbers, F. J. Schlink, assistant secretary of the American Engineering Standards Committee, who has made a study of the subject, prepared the following article. In commenting upon this article, Mr. Myers stated that

> The selection of a series of sizes is often a primary consideration in our standardization work, and at times the selection has been more or less haphazard. Some may argue that, within the ordinary limits of error in estimation and calculation, the selection of a particular size does not matter greatly. If this is the case it is certainly advisable to make the selection on a definite and well-known basis, if for no other reason than that it is well-known.

Mr. Myers desires to have the views of the members of the Society on this important and interesting subject as well as suggestions for the application of preferred-number series to automotive parts and materials so that the sentiment of the industry can be placed before the special committee of which he is a member.

Preferred Numbers

A good deal has been written of late on the subject of preferred numbers. In France and Germany particularly, these numbers, or "numbers for standardization," as they are now often called, have been discussed extensively in the technical press. The Germans regard it as one of the two most important projects before their very active national Standards Committee. Several of the more important European papers on the subject have been translated by the American Engineering Standards Committee. C. F. Hirshfeld and C. H. Berry of the Detroit Edison Co. prepared an interesting treatment of preferred numbers which was reprinted by the American Society of Mechanical Engineers with an extended discussion including the views of specialists on ball bearings, bolts and nuts, steam engines, machine tools, engineering physics, engineerig education, electrical machine design, rolled shapes, ordnance, small tools, telephone manufacture and others. An extensive discussion on the subject by C. C. Stutz, C. F. Hirshfeld, C. H. Berry and A. S. McAllister also appeared in *Mechanical Engineering* recently. At the World Power Conference an important paper entitled Considerations as to the Most Economical Ratio of Increase in Series of Standardized Principal Dimensions was read by Dr. Goudriaan, until recently director of the Dutch National Standardizing Body.

It is evident from the amount of discussion that the subject must have considerable importance in the minds of those who are familiar with it.

A good many of the foreign standardizing bodies have recognized for years the need for a system of standard numbers, especially applicable to diameters. These were known as standard diameters and had for their purpose the reduction of the number of gages, tools, patterns, and cores to the minimum. It is obvious that a multiplicity of diameters selected in the drafting room and designing office necessarily implies a multiplicity of apparatus, tools, fittings and supplies to carry out the casting, machining and finishing processes. In the general case every additional diameter means a new pattern and core; a different drilling, boring, grinding, milling, broaching, or threading tool or tools if the article is manufactured in mass production; a different polishing fixture if the surface is to be polished; several different gages to measure it in the process of inspection or test; and finally, even a different plug, protecting sleeve, or container in which to pack it. Obviously any reduction in the number of diameters, occasioned by a selection of a few diameters that will equally serve the purpose, out of a large number of diameters that have grown up more or less at random and to suit individual judgment or fancy, can affect the cost of production at various points by the elimination of unnecessary patterns, tools, jigs, fixtures, gages, handling devices, shipping containers and many other items.

The basic plan of the preferred numbers is to set up series of dimensions which increase, not by uniform increments, as 2, 4, 6, 8, 10............, but by a uniform percentage or proportion, as 2, 4, 8, 16, 32............

In order to get an idea in the briefest possible form of what preferred numbers seek to accomplish, it may be well to examine one of the simplest ways for setting up a series of preferred numbers. Fig. 1 shows a 10-in. slide rule with a scale of equal parts, the *L* scale, adjacent to the lower or *D* scale. If we project every even graduation of the equal-part scale onto the *D* scale, as shown in the lower portion of Fig. 1, we obtain the numbers 10, 16, 25, 40, 64, 100, falling 2 in. apart along the lower scale. This is the first and simplest series of preferred numbers, providing five intervals equally spaced on a scale of proportionate increase between 10 to 100, each number being about 60 per cent larger than its predecessor in the series. Such numbers have the property, which is accounted for by the principle of construction of the slide rule, that the difference of their logarithms is constant and numbers whose logarithms lie in arithmetical series themselves lie in a geometrical or proportionate series. By successive subdivision of the *D* scale, projecting from the equal-parts scale, we may set up series with increasing numbers of terms, such as 10, 20, 40, and 80, between 10 and 100, 100 and 1000, 1000 and 10,000 and so on, each series covering one "order of magnitude." Series founded on other bases than roots of 10 would possess the disadvantage of not repeating in successive orders as is the case with the German and French proposal. The 80-term series corresponds to a difference in size from one standardized article to the next, of only 2 per cent, a much finer division than there is ordinarily any practical need for.

A most important property of these numbers is related to a characteristic of a slide rule which makes it so useful in calculations. If we are calculating the strength of a beam having a cross-section of 2 x 4 in., we can compute our results no more and no less accurately, relatively, than in the case of a beam 20 x 40 in. In each case the errors in our knowledge of the properties of the material and the true cross-section of the beam as manufactured, enter in a proportionate sense, so that our calculated result is likely to be in error by about the samé percentage in each case or, conversely, reliable to about the same number of significant figures. If it were not for this fact, the slide rule would be useful only for calculations involving small numbers, since in the case of large numbers, the errors would be too great to be tolerable. In fact the error in reading the slide rule is about the same on a percentage basis throughout the whole length of the scale. With care we can read to four significant figures at the lower end of the scale, which corresponds to an error of about 1 in 1000, or 1/10 of 1 per cent, and to three significant figures at the upper end of the scale, as 1 in 990, which is about the same percentage.

Now in setting up a series of standardized elements or parts, we have much the same problem. Take the simple case of paint brushes: there could be no occasion for spacing the sizes of brushes closer together than could be readily discerned as giving a distinct difference in the use of the brush; yet in a narrow brush of ½-in. width, a ¼-in. difference would be quite important, while in a brush 5 or 6 in. wide, the user would never detect such a small difference without actual measurement. As a matter of fact psychological experiments dating back to 1850 show that diffenences in sizes of objects which are directly related to our sense impressions—in the example given, the muscular and visual sense—should lie in a geometrical or proportionate series if they are to give the impression of equal spacing in the light of our senses.

As another example, we are able to distinguish two weights as different when lifted by the hand if they are about 10 per cent apart in value. Certainly there would be no sense, therefore, in spacing the sizes of paper weights any closer than this and more likely they should be spaced much farther apart. Thus there would be no reasonable ground for a set of paper weights of 1, 1½, 2, 2½, 3 and 3½ lb. and so on, while a series starting out about the same way, but giving a 60-per cent increase from one size to the next, might be quite useful. Thus: 1, 1½, 2½, 4, 6½ and 10 would be such a series, and would cover the range of from 1 to 10 lb. with only six sizes, while an evenly spaced or arithmetic series like that first mentioned, would require 19 sizes to cover the same range. It is easy to see what this difference would mean in excess manufacturing costs for the closely-spaced series.

Now as a matter of fact no one would think of setting up a series including every ½ lb. from 1 to 10 lb. The manufacturer in the past would have approximated such a series, without explicitly realizing his object, by running along with a constant increase of ½ lb. for one or two terms, then jumping to a 1-lb. increase for the next and so on. Thus the commercial nominal diameters of hexagon-head bolts run as follows: ¼, 5/16, ⅜, 7/16, ½, 9/16, ⅝, ¾, ⅞, 1, 1⅛, 1¼, 1½, 1¾, 2, 2¼, 2½, 3 in.; and of wrought-iron pipe: ¾, 1, 1¼, 1½, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8, 9, 10 in. and so on.

We thus see that in practical work, a series which is in sufficiently common use, tends to develop into an approximation to geometric series, probably due oftentimes to the gradual elimination of some of the arithmetically spaced sizes as they are less and less called for by the consumer. This very slow and rather wasteful process seems to be sufficient evidence for the desirability of a rational scheme of geometric series for size standardization.

As has been stated, in practice we usually arrive at some

TABLE 1—PREFERRED-NUMBER SERIES

5-Series	10-Series	20-Series
10	10	10
..	..	11
..	12.5	12.5
..	..	14
16	16	16
..	..	18
..	20	20
..	..	22
25	25	25
..	..	28
..	32	32
..	..	36
40	40	40
..	..	45
..	50	50
..	..	56
64	64	64
..	..	72
..	80	80
..	..	90
100	100	100
..	..	112
..	125	125
..	..	140
160	160	160
..	..	180
..	..	..
..	..	..

sort of approximation to the geometric series without being aware of it. In some fields we are aware of it and find the whole scheme very useful and practical. For example, copper wire sizes have been for many years on a proportionate-increase basis to the very great satisfaction of all concerned. Similarly the aperture, or shutter openings, of photographic lenses are in a geometric series, having a rate of increase of 2 to 1 or 100 per cent. The great "latitude" of photograph plates and films makes this coarse series possible. Thus the usual shutter openings are equal to the focal length divided by 4.0, 5.6, 8.0, 11.0, 16.0, 22.0, 32.0, 45.0, a series giving a 50-per cent increase in diameter per term which is proportional to the smallness of the area of the openings and hence required times of exposure of 16, 32, 64, 120, 250, 500 and 1000. These numbers appear in the French and German series.

Similarly with incandescent lamps, the watt ratings and hence candlepower of the common Mazda "B" lamps are 10, 15, 25, 40, (50), 60 and 100.

Again in radio sets, each successive stage of amplification increases the audibility of the output in a fixed ratio, thus in the three stages of audio frequency amplification, the sound energy outputs may be in the series:

Detector	First Stage	Second Stage
1	30	900

Machine-tool speeds are already largely on a proportionate-series basis, and those that are not are rapidly being put upon such a basis. Thus at Watertown Arsenal, motor speeds of machine tools are carefully set up by changing rheostats and other control features to produce an accurate speed series in a geometric ratio, each speed being 1.2 times as fast as the preceding, this being determined by a proper combination of the characteristic of the motor and the re-

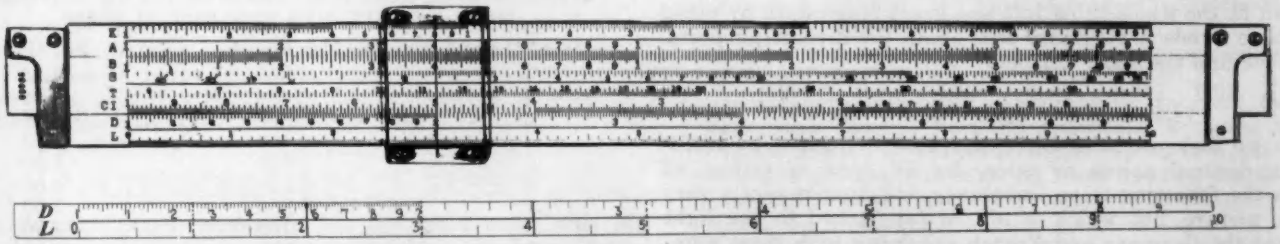


FIG. 1—10-IN. SLIDE RULE SHOWING DERIVATION OF NUMBERS IN GEOMETRIC SERIES

The Lower Illustration Shows the *D* and *L* Scales, with Graduations Simplified for Clearness, Giving over Each Number on the Equally Divided *L* Scale, a Preferred Number of the 10-Series (See Table 1). On the Old Mannheim Slide Rule, the Same Result Can Be Obtained in Conjunction with the *D* Scale, by the Use of the Log Scale Found on the Back of the Slide sistance in the controller units. It is pointed out in a memorandum by F. Bauer of the Watertown Arsenal that in the selling of motor-driven machine tools a statement that a machine has a given number of speeds is an ambiguous expression to one who wants uniform production. Mr. Bauer shows that when there are 48 speeds, for example, the grouping of speeds toward the lower end of the range may give a very uneconomical and inconvenient distribution with the higher speeds too far apart and too irregular. According to Mr. Bauer,

> If the motor speeds were correctly apportioned . . . a statement that a lathe has 16 speeds correctly arranged to give the maximum production would have some weight.

As an example of the waste of material, patterns, stock, and storage space that may be involved in the selection of a uniform spacing of sizes, reference may be made to the 1914 American Standard for Pipe Flanges and Fittings which specifies flanges and fittings increasing by 2-in. steps all the way from the 16-in. size to the 100-in. size. In the smaller sizes the increase in diameter is 12 per cent, 25 per cent on area, and in the larger sizes only 2 per cent, 4 per cent on area. When we come to analyze the basis which must rationally determine the spacing of such sizes, we come to the conclusion that the errors of estimating the size of pipe required for any given purpose on a basis of capacity of connecting pipe-lines, run-off over a drainage area, the extent of the drainage area itself and the probable demand are pretty large at best, and probably just as large on a percentage basis on the 100-in. pipe as on the 16-in. pipe, so that it seems from general engineering considerations, that the larger sized pipes in such a series are spaced far more closely together than the accuracy of the basic data used in a pipe-line calculation can possibly warrant. On the other hand, those near the 16-in. size, corresponding to the 25-per cent increase of area from one pipe to the next, may be too far apart.

On superficial study of the subject of size standardization it appears that there are a good many size series that probably ought to be on a geometric basis, for instance, shoes. Obviously the thing that determines how much larger one size ought to be than the next is how much "pinch" is tolerable, and equally obviously the pinch is a question of proportion. If ⅓ in. is the right increase for a No. 5 shoe, then it is wrong for a No. 12, which is a foot so large that the same ⅓ in. would hardly be noticed. What happens in practice is that half sizes are stocked in the smaller shoes and not in the larger ones, which gives a crude and unsystematic approximation to what is needed. In collar sizes the question is probably not so vital, as the total range of sizes is not very large. In clothing of all sorts the unsystematic spacing of sizes, with transition from boys' to men's sizes, and the like, involves a good deal of wasted energy and error which could be avoided if there were one smoothly progressing size series from the very smallest up to 46-in. chest measure or wherever they stop.

Geometric systems of sizes can be constructed without reference to particular numbers, which is the way the English tend to regard the application of the method, for example, building up geometric series of telephone switchboards, wire, motors, magnetos, push-buttons, and transformers each on an independent basis just as our collar, glove, hat and shoe sizes have no evident relation to each other; or we can fit the whole thing into one great framework by using the same numbers over and over again for diverse purposes. Thus we find the same numbers

10.0 16.0 25.0 40.0 64.0 100.0
12.5 20.0 32.0 50.0 80.0

which we may use with their derivatives obtained by introducing decimal points or zeros, for all sorts of things, of which the following is an imaginary, and numerically a very crude, picture, but which is not so far-fetched in the light of what the Germans and French are doing with these numbers in the mechanical, and more particularly the electrical,

TABLE 2—POSSIBLE USES OF PREFERRED NUMBER SIZES, SHOWING DIVERSITY OF POSSIBLE APPLICATIONS

Picture-Frame Dimensions, in.	5x8, 8x10, 8x12, 8x16, 10x12, 10x16, 10x20
Weight of Sash Weights, lb.	12, 20, 32, 50
Length of Scissor Blades, in.	1.0, 1.6, 2.5, 4.0, 6.0, 10.0
Diameter of Slip Rings, in.	8.0, 10.0, 12.5, 16.0, 20.0, 25.0, 32.0, 40.0
Length of Carbon Brushes, in.	1.6, 2.0, 2.5, 3.2, 4.0, 5.0, 6.4
Length of Slide Rules, in.	5, 8, 10, 20
Capacity of Freight Cars, lb.	32,000, 40,000, 50,000, 64,000
Magnification of Telescopes	5, 8, 12.5, 20, 32
Number of Bolts in a Carton	32, 50, 80, 125, 200
Weight of Tobacco in a Tin, oz.	1.6, 2.5, 4.0, 8.0
Packing-Case Dimensions, in.	10.0x12.5x16.0, 12.5x16.0x20.0, 16.0x20.0x25.0
Length of Flags, ft.	1.6, 2.0, 3.2, 4.0, 5.0, 6.4, 8.0, 10.0
Height of Lettering for Signs, in.	1.0, 1.6, 2.5, 4.0, 6.4, 10.0

industries. A fundamental advantage of the scheme, if it could ultimately reach an almost universal application, would be that one would know what the next size would be in planning for a box, a sheet of bristol board, or a desk without forever needing to refer to a catalog or call up a dealer, and then finding that different dealers and catalogs show little or no agreement, and that because of the enormous total diversity of sizes made, the one wanted is out of stock or has been discontinued, or what not. The happy alternative might be a few well-chosen sizes that every merchant could afford to carry.

The English system of weights and measures, particularly the inch and its customary subdivisions such as quarters, eighths and sixteenths, and the pound and its subdivision into ounces, form in practice what amounts often to a preferred numbers system. For example, the lengths, 4, 2, 1, ½ (0.500) ¼ (0.250), ⅛ (0.125), 1/16 (0.064), 1/32 (0.032), and 1/64 (0.016), with their rounded decimal equivalents given in parentheses, fall into the regular 10 series of preferred numbers, taking every third term. This series, with the third terms italicized, is *4.000*, 3.200, 2.500, *2.000*, 1.600, 1.250, *1.000*, 0.800, 0.640, *0.500*, 0.400, 0.320, *0.250*, 0.200, 0.160, *0.125*, 0.100, 0.080, *0.064*, 0.050, 0.040, *0.032*, 0.025, 0.020, *0.016*. Fortunately, due to the fact that the conversion factor from metric to English units is itself very approximately a preferred number, and since the product of preferred numbers is also a preferred number, the metric equivalents of these are, approximately speaking, preferred numbers as well.

In electrical standardization one runs up against applications of geometric series everywhere, particularly in European practice. A recent paper entitled the Transmission Unit and Telephone Transmission Reference Systems, by W. H. Martin of the engineering staff of the Bell Telephone System, sets up a system of units for the determination and expression of transmission efficiencies of telephone circuits and apparatus. Table 3 shows the equivalents of the transmission units, which we note are the familiar preferred numbers in the 10 series.

TABLE 3—TELEPHONE TRANSMISSION UNITS, SHOWING THEIR IDENTITY WITH PREFERRED NUMBERS

No. of Units	For Losses	For Gains
1	0.800	1.25
2	0.630	1.60
3	0.500	2.00
4	0.400	2.50
5	0.320	3.20
6	0.250	4.00
7	0.200	5.00
8	0.160	6.00
9	0.125	8.00
10	0.100	10.00
20	0.010	100.00
30	0.001	1,000.00

[1] See the *Journal of the American Institute of Electrical Engineers*, June, 1924, p. 504.

In addition to some items already mentioned, the following is given as a partial list of some of the articles that have been dimensioned by preferred number methods, for the greater part in German or French standardization work.

Colors of solutions
Motor, generator and transformer ratings in kilowatts
Carbon-brush dimensions
Motor and generator slip-ring dimensions
Pulley diameters and rotational speeds
Switch and fuse ratings in amperes
Motor-frame dimensions
Dimensions of handles for tools, controllers, etc.
Sizes of aluminum and copper strips for switchboard wiring
Dimensions of handles for tools, controllers, etc.
Sizes of aluminum and copper strips for switchboard wiring
Dimensions of spools for insulated wire
Volumetric capacity of oil cups
Dimensions of knife-edges for weighing scales
Dimensions of washers
Dimensions of thumb screws and knurled nuts
Dimensions of non-circular openings
Dimensions of motor shaft-ends
Dimensions and tolerances for aluminum shapes, tubes, bars, strips, plates and sheets
Dimensions of tool posts
Dimensions of bollards, chocks and manholes
Diameters of steel and iron piping and pipe flanges
Diameters of steel, copper and brass piping
Working and test-pressure ratings of piping, fittings and valves of all sorts
Mesh and diameters of wire for sieves
Dimensions of hoisting machinery drums
Dimensions of handwheels of various types
Diameters of core plugs for patterns
Dimensions of foundation castings
Heights of lettering for signs and drawings

A comment of A. W. Whitney, chairman of the American Engineering Standards Committee, on this subject is very illuminating. Mr. Whitney says of the system of preferred numbers that it has

> An ear-mark that is found in every fundamental solution, namely, that it clears up a larger field than we had hoped initially to affect. As illustrating this I will instance the facts: first, that the number series that obtains where increased refinement is called for can easily be made to include the numbers in all lower series; second, that if linear dimensions are expressible by a geometric series, then areas and volumes are also expressible by number series which are contained in the original series; and third, by the apparent adaptability, due to fundamental consideration, of such number series to the simplification of machine design.
>
> All these facts taken together indicate that we have before us a singularly fundamental and powerful instrument that can scarcely fail to exert a profound effect upon standardization.
>
> One other obvious fact should be noted. The fundamental character of this method adapts it for use as a basis for international standardization. It has been suggested by two foreign national standardizing bodies that no time should be lost in getting the countries of the world together not only in an agreement upon the particular number series to be used, but upon a standardization of roundings. With such a common number series as a basis, we may go far in securing international standardization along other lines.

STANDARDIZATION IN RUSSIA

A standardization movement has now been under way in Russia for about a year. An organization has been developed and is actively at work under the leadership of a commission appointed by the Supreme Council of National Economy of the Soviet Republic, according to information obtained by the American Engineering Standards Committee from D. N. Borodin, of the Russian Agricultural Agency in America. Mr. Borodin states that the Russians are anxious that their standardization work shall be correlated with that going on in the other industrial countries of the world which are active in industrial and engineering standardization, and to that end are giving careful study to the whole subject.

A problem of great importance to Russia, and to countries that export farm machinery to Russia, is that of the standardization of agricultural machinery and implements. A project is being carried on in this connection by the Commissariat of Agriculture, jointly with the commission mentioned above and with the cooperative and state stores dealing in agricultural machinery and implements.

PATCHING OF LEATHER PERFECTED

Certain Tanners Can Now Supply Second-Grade Hides Patched Acceptably

At the 1924 Annual Meeting the patching of grub-holes and other defects in upholstery leather was recommended by K. L. Herrmann of the Studebaker Corporation of America in a paper on Automobile Upholstery-Leather. It was stated that patching methods had been developed which resulted in patches as strong and as flexible as the hide, and which could not be detected from the finished side.

The use of patched hides was not permitted in the S. A. E. Recommended Practice for Upholstery Leather Specifications approved at that meeting, however, as there were no manufacturers equipped to patch leather in production, the patches being used at that time being of a temporary nature intended to prevent the coatings from penetrating the hide. Information recently obtained from the tanners of upholstery leather indicates a rather divergent practice. In general the tanners do not wish to give out any information as to what they have or have not accomplished or are developing. Of the more interesting comments received, the following, submitted by American Oak Leather Co., Blanchard Bros. & Lane, Conneaut Leather Co., General Leather Co., Radel Leather Mfg. Co., John Reilly Co. and Stengel & Rothschild, Inc., are of interest. The comments from these companies are not given in the same order as the company names.

> We have not, up to the present time, experienced any difficulty or complaints with patched leather. We have confined the permanent patching of leather to the lower grades, such as the splits and deep-buffs. Hides were sent in large and small quantities practically all over the world.
>
> We have not had one complaint in the period of 1 year on any of the patchings coming loose or showing the defects on the finished side of the leather. The flexibility of the patch is equal to the flexibility of any other part of the hide. Several trimmers, purchasing agents and engineers have been unable to detect the patches in the leather, some hides examined having contained as many as 16 of these invisible patches.
>
> It is our desire to keep both the type of machine and the kind of cement a secret.

> After a series of experiments involving much time, labor and expense, we have developed a method of patching with which we were satisfied to go into production and are now patching in this manner all our upholstery hides which require patching.
>
> In strength, durability and flexibility frequent tests show these patched portions practically equal to the original hides. In appearance the patches are practically 100 per cent invisible on most finishes, while on some there is still room for improvement, which we believe we are making.
>
> We are using a machine of our own development. A pyroxylin cement is used.
>
> As no product we know of has ever been or probably

ever will be 100 per cent efficient, we cannot claim perfection in this. But we are confident we have a proposition which is practical. The results so far have borne this out and we do not hesitate to recommend that a hide patched in this manner be cut up as if it were free from patches.

There is one point we would like to emphasize, which is that, while we and no doubt all makers of upholstery leathers have been aware of the fact that some improved system of patching would very naturally increase the cutting value of leather, it was not until Mr. Herrmann of the Studebaker Corporation of America got behind the proposition that any real constructive work was done along this line.

It is possible to put on patches with a special adhesive "pyroxylin" mixture, which makes an excellent job and if properly done, we do not think the patch would give any trouble in service. Of course no patches can be put in a job without showing when the leather is finished with linseed oil. The only finish this could be done successfully with is what is commonly called "dope" finish; that is, a cold process requiring no baking. It is used by very few in the trade requiring the best service in the wear and feel of leather.

When we find trade requiring dope-finished leather and they want to use the patched hides, we will give them this leather patched in that way. We believe that, if the patch is properly put on, properly beveled, and applied with the pyroxylin adhesive, they can be assured of proper wearing conditions, and in this way save money by buying No. 2 hides. Such patches will not show in the dope finish.

We feel we have always patched leather successfully. In the majority of instances, the patch cannot be detected from the finished portion of the hide. So far as strength and durability are concerned, we feel that this is practically equal to that of the other portions of the hide.

We have never seen a machine that would skive successfully the various sizes of patches. The cement that we are using is a combination of the best fish glue, with a nitro-cellulose product.

We have experimentally developed a method of patching leather which we believe will produce a patch equal in strength to that of the body of the hide, and will be practically invisible from the finished side of the leather. The machine which we have used is not yet perfected to our satisfaction and we prefer at this time not to go into details as to the design.

So far as we know, the apparatus used by different tanners varies according to their individual ideas and they are not inclined to divulge their methods.

In our opinion, the problem of patching leather in such a manner as to permit automobile manufacturers to cut a patch into a cushion, seat or back with full confidence that it will not develop trouble for them, is so close to a solution by most of the large tanners, that the Society of Automotive Engineers would be justified in revising its specifications on leather accordingly.

We have experimented with various cements with the idea of patching leather so that such leather could be used successfully. Thus far we have been unable to find a cement which would hold the patches so that we could recommend the use of such leather.

We have a cement which will give a waterproof patch that is sufficiently flexible. However, we are not using it, as we do not find any call for it among our customers. We have not found a machine for skiving, although we have found a machine which will skive the patches. It does not work on the hide. However, the patching can be done with a plain knife, provided a little more care is taken than in the ordinary patching.

We notice that one manufacturer states that patches cannot be put on without showing if linseed-oil finish is used. On hand-buffed hides we believe that this is not the case, and we feel that this idea should not be given to the body engineers. If the pyroxylin finish is used, it should be in combination with the linseed-oil finish, as a better grade of leather is made thereby.

Our experience of a great many years has taught us to patch hides in such a manner that the most critical upholstery examiner in most cases is unable to detect the patches. We have as yet to receive the first complaint from any of our customers regarding the patching method now employed.

It is regrettable that the tanners are not cooperatively working out a universal method of patching that could be generally adopted for automobile upholstery-leather. If the automobile manufacturers were faced with a similar problem, it would, without doubt, be solved in open discussion at technical sessions and meetings rather than by each manufacturer developing a method without regard to the work done and the results obtained by other manufacturers equally interested in furthering the interests of the industry.

STANDARDIZATION IN GERMANY

Paper by Dr. Neuhaus Outlines Procedure Followed by German Industry

The following article is abstracted from a paper contributed by Dr. F. Neuhaus at the World Power Conference in July, 1924, and printed in the July 25 issue of *Engineering*, (London). It will be found of special interest in indicating the businesslike way in which German industry has undertaken standardization.

Systematic standardization in Germany dates back to the spring of 1917, when the leading engineering firms formed, in cooperation with scientists, an Engineering Standards Committee. The work of this Committee very soon overstepped the limits of engineering and invaded nearly all branches of industry. The consequence was that in December, 1917, the Standards Committee of the German industry, the Normenausschusses der Deutschen Industrie, was established.

The constitution of this body is based on the principle that German standards should be developed by the cooperation of manufacturers, consumers and scientists. It is understood that the Normenausschusses der Deutschen Industrie should establish fundamental standards for all branches, and should be responsible for the conformity of the standards established for the several branches by special committees with the general standards and with each other. All suggested standards for the German industry are examined at the Inspection Department of the Normenausschusses der Deutschen Industrie, and are published in the official journal of the Normenausschusses der Deutschen Industrie, the *N.D.I.-Mitteilungen*, for criticism. Suggested special standards are published in the technical journals of the branch to which they pertain. Objections are carefully investigated and the suggestions that have been corrected in accordance with such objections, unless the objections are such as to require the complete remodeling of the suggested standards, are laid before the Board of the Normenausschusses der Deutschen Industrie, which causes the standards to be incorporated in the schedule of standards. Only after a standard has been so incorporated is the standard schedule passed for publication and general use.

The entire German industry cooperates with the Normenausschusses der Deutschen Industrie. Funds for its work are obtained by selling the standard schedules and from contributions of comparatively small amounts on the part of the industry. No government subsidy is given. Schedules of the standards that are final, and of those that are being prepared, are issued every quarter, so as to indicate the progress of standardization.

German industrial standards comprise three groups: fundamental standards, dimensional standards, and standards concerning material. Fundamental standards are those which are found in all branches of engineering and must, therefore, be considered when establishing all other standards. Among the most important fundamental standards are screw-threads. Another fundamental standard for the mass production of interchangeable standardized parts and for interchangeable production manufacture generally are fits or the establishing of tolerances and allowances. These standards are of extreme importance.

A number of special standards have been prepared in cooperation with interested industries. An international agreement has already been arrived at for ball bearings by the countries that are most concerned with the manufacture of such bearings: America, Sweden and Germany. Special committees have been appointed for the various industries. These committees work independently, but put their standards before the Normenausschusses der Deutschen Industrie for uniform and final consideration and publication.

The third group of standards, materials, comprises three divisions: (*a*) testing of materials, (*b*) iron and steel and (*c*) non-ferrous metals. In testing materials, symbols and definitions and general rules for testing materials by tensile, Brinell and technological tests are being standardized. Standardization of iron and steel, recently any wrought iron manufactured in liquid condition and without further treatment has been called "steel," comprises the standardization of properties, strength and analyses and of dimensions of rolled and drawn products, such as plates, tubes and sections, and the exactitude of manufacture thereof. Similarly, with non-ferrous metals, the properties of the several metals, such as copper, zinc, tin, aluminum, nickel and their alloys, on the one hand, and dimensions and tolerances for stock made from such metals, such as plates, tubes, bars and wire, on the other hand, are standardized.

Contrary to practice in other countries, the standardization of materials has not been developed in Germany to the same extent as has the standardization of dimensions. The reason for this is that in Germany this matter has been regulated to a great extent by the authorities, the standardization of materials, on account of the opposing interests of producer and consumer, being much more difficult than the standardization of dimensions. Work on the standardization of materials, however, has made considerable progress, and it is to be expected that more than 70 standards will be ready for publication in a short time.

MARKET FOR STANDARD PARTS IN EUROPE

German Manufacturers Consider the Use of S.A.E. Standards in Assembled Cars

Information received from a German automobile builder indicates the possibility of the importation of American automobile parts by the German automobile industry. The German companies will follow S.A.E. Standard practice as far as possible in carrying out this program. The comments given hereinafter, extracted from a letter from a German manufacturer, indicate the possibilities in this connection:

> As the German automobile industry is at the present time still handicapped by unfavorable working conditions, a certain amount of tariff protection is necessary. On the other hand, the manufacturing of parts, such as engines, propeller-shafts and axles, is so highly specialized in the United States that it would be desirable to import such parts under a low tariff. The German automobile industry might then be able to save a part of her business.
>
> To make this possible, it is necessary that the German automobile industry adopt the principal standards of the American automobile industry so that parts so purchased can be used in German designs.

BOLT AND NUT REPORTS TO BE VOTED ON

Sectional Committee to Take Final Action as Result of Meeting Held on Jan. 8

At the meeting of the Sectional Committee on Bolt, Nut and Rivet Proportions held in the rooms of the American Society of Mechanical Engineers in New York City on Jan. 8, the reports of Sub-Committees Nos. 1, 2, 3 and 6 covering rivets, wrench-head bolts and nuts and wrench openings, slotted-head screws, and plow bolts were ordered to a final letter ballot of the Sectional Committee members.

While the reports were not in final form as presented at the meeting by the Sub-Committees, the changes it was thought desirable to make were of such a minor nature that it was not considered necessary for the reports to be held for resubmission at the next meeting. It was therefore understood that the Sub-Committees would revise the reports in some details before they were submitted to the letter ballot.

As the Society is a joint sponsor with the American Society of Mechanical Engineers for the Sectional Committee on Bolt, Nut and Rivet Proportions, the reports will be eventually submitted to the Society for approval. The usual standards procedure will be followed in approving these reports as is now followed for all subjects referred to the Divisions of the Standards Committee.

METRIC-TYPE THRUST BALL-BEARINGS

Revisions of Present Standards Proposed To Obtain International Agreement

At the Ball and Roller Bearings Division meeting held on May 2, 1924, it was voted that the Subdivision on Thrust Ball-Bearings, of which D. F. Chambers, of the Bearings Co. of America, is chairman, should consider the possibility of correlating the present S.A.E. Standards for Metric-Type Thrust Ball-Bearings with the German Standard Thrust Ball-Bearings.

D. F. CHAMBERS

A preliminary study of these standards showed that the Light, medium and Heavy Service Series adopted by Germany do not correspond to the S.A.E. Light, Medium and Heavy Series; but that the German Light and Medium Series correspond to the S.A.E. Medium and Heavy Series respectively, there being no corresponding series for the S.A.E. Light Series or the German Heavy Series.

To make an intelligent study of the matter, Mr. Chambers plotted the outside diameters and heights of the German Light and Medium Series and the S.A.E. Medium and Heavy Series against the inside diameters. He found that many of the German bearings were badly proportioned and that certain of the S.A.E. bearings could be improved. It was, therefore, found desirable to revise the present S.A.E. Medium and Heavy Series to conform to the best engineering practice, such revisions meeting the German dimensions where warranted. Full-size drawings of the revised S.A.E. Series were superimposed upon the German Series to check the bearing proportions. As information covering the ball diameters used in the German Standards was not submitted to the Subdivision upon its urgent request, the German F. & S. sizes were used in the bearing layouts.

Mr. Chamber's report was considered and approved without change by the Subdivision on Thrust Ball-Bearings at its meeting in New York City on Oct. 7, which was attended by D. F. Chambers, chairman, and A. J. Rudy, of the Bearings Co. of America; E. R. Carter, Jr., of the Fafnir Bearing Co.; H. Wickland, of the Strom Ball Bearing Mfg. Co.; O. R. Wikander, R. A. Cornforth, of the Nice Ball Bearing Co., and C. E. Heywood, of the Society's Standards Department.

As there is no present need in this country for the German Heavy Series, which would correspond to an S.A.E. Extra-Heavy Series, it was not considered by the Subdivision, but should such a need arise the Subdivision would, of course, consider the adoption of this series. The S.A.E. Light Series, as printed in the S.A.E. HANDBOOK, is satisfactory and it is suggested that its adoption as an International Extra-Light Series be considered, if a need for such a series should arise in other countries.

QUALITY NOT DETERMINED BY STANDARD

Society's Present Oil Specifications Indicative of Suitability, Not Quality

As a result of matters now being discussed by the members of the Lubricants Division, it seems probable that definite action will be taken in the near future to further the use of the S. A. E. Recommended Practice for Crankcase Lubricating Oils, as printed on p. D151 of the S.A.E. HANDBOOK, not as definite specifications determining the quality of an oil, but as minimum requirements indicating its suitability.

Anyone who is faced with the problem of recommending to dealers what oils should be used in a given model will appreciate the advantages of being able to state definitely in terms generally understood by oil producers, automotive engineers, dealers, service-men and car owners what body of oil should be used, providing it were also generally understood that oils of the same body were not necessarily of the same quality and that consequently the brand of oil used would have to depend on the knowledge of the purchaser and the reputation of the oil producer.

As this entire subject is of general interest, the following has been abstracted from correspondence recently referred to the members of the Lubricants Division.

> Our Service Division has received numerous requests from our dealers for a recommendation for oils to be used in our cars. This is against our policy as we cannot conscientiously recommend a few companies, whom we consider satisfactory, without working a hardship on others, and especially the smaller companies, which are to be found in every locality. For this reason we welcome the S. A. E. Lubricating Oil Specifications. However, they have proved of little value, in that the oil manufacturers have failed to make use of them to the extent of placing the S. A. E. Specification Numbers on labels and in the hands of the oil distributors so that the man actually selling the oil to the car user knows it by S. A. E. Number.
>
> The reason for this is logical. The oil manufacturer realizes that an oil may meet an S. A. E. Specification and still not be of high quality. Therefore, if he puts the S. A. E. Number on his product, he takes the stand that he is putting his oil on a par with that of a company not using the best refining methods. I believe that, perhaps, too much has been expected of the lubricating oil specifications. In my opinion physical specifications of oil aid us in purchasing oils of a certain body or viscosity, but we still have to depend upon the trade name for quality. In other words, due to the field from which the oil is removed, and to the different methods of refining, there is a difference in lubricating value of oils of close physical properties.
>
> With this as a premise, what I would like to do with regard to service requests for specifications, is to give them the S. A. E. Number of both summer and winter oils, but tell them that in addition to this, they would have to depend upon trade names or letting the dealer use his own judgment based on his own experience and knowledge of the companies with whom he is in contact.
>
> May I have your opinion as to the wisdom of such a policy. At the present time, would an S. A. E. Specification help the dealers? Are there any oil companies using the S. A. E. Specifications to the extent that their distributing stations are kept informed of which oils meet certain S. A. E. Numbers? Furthermore, do you know of any automobile company which is making use of the S. A. E. Specifications, in a similar way to that I have outlined?

> It would seem highly desirable for the Society to take some definite action in furthering the use of these specifications, both by the oil companies and by the car manufacturers.
>
> We know that a few oil companies are using the S. A. E. designations, both in their advertising and on their labels. A general letter to the oil producers emphasizing the importance of using the S. A. E. Numbers in addition to their brand names should be sent out and a similar letter should go to the car manufacturers indicating the reasons why they should use S. A. E. designations in indicating what grade or grades of oil should be used on their product.

> I believe the present S. A. E. Oil Specifications are about as satisfactory as is possible under present conditions. We feel that there is a great deal of misunderstanding about the so-called "quality" of lubricating oil. When the specifications were being drawn up, I bought oils ranging in price from $0.20 to $1.35 per gal. and these oils were submitted to the members of the Lubricants Committee for test. All of these oils passed the present S. A. E. Specifications and our actual service tests on these oils showed that they were all satisfactory for use in automobiles.
>
> There was no agreement among the men testing these oils as to the "quality" of the oils, some of the men giving the $0.20 oils first place in "quality," and the $1.35 oils last place in "quality," and no relation could be shown between the price and "quality" or any real indication that any of these oils were really lacking "quality for use as an automobile lubricant."
>
> I believe the S. A. E. Oil Specifications can be used for the purchase and inspection of oils with as high a degree of safety as the S. A. E. Steel Specifications for the purpose of purchasing and inspecting steels. It is true that the larger oil companies prefer to market their oils under their trade names, rather than S. A. E. Specifications, since their entire advertising policy is based on trying to make the public believe that their particular oils have more "quality" than oils made by other companies.
>
> The automobile companies prefer to use their own oil specifications rather than the S. A. E. Specifications since they feel that they can make slight changes in their own specifications to make them more nearly in accord with the changing commercial conditions than would be the case if they were held to one set of specifications in which it was difficult to make small changes.
>
> As you know, the same thing is true with the steel specifications. The large automobile companies have their own steel specifications which differ slightly from the S. A. E. Specifications and the automobile steel

specifications are constantly subject to slight changes depending upon commercial conditions. I believe that the real merit of the S. A. E. Steel Specifications is that they have established a system of nomenclature so that when anyone refers to S. A. E. No. 2315 steel, for example, everyone knows the kind of steel that is required, although each one of the companies may have slight differences in the requirements of the specifications for No. 2315 steel. For example, S. A. E. No. 2315 steel permits 0.045 per cent as the maximum amount of sulphur. General Motors Corporation Specification No. 2315 permits 0.05 per cent sulphur as the maximum. The specifications agree in other chemical properties. Neither the Society of Automotive Engineers nor the General Motors Corporation specification for No. 2315 steel is absolutely complete, since other impurities are always present in small amounts and these impurities are not even mentioned in the specifications. The specifications do not indicate the maximum amounts of oxygen, nitrogen, silicon, chromium, tungsten, molybdenum, and the like, all of which might be present and many of which are present in No. 2315 steel.

Physical properties of the S. A. E. Steels, determined by the nature and amount of hot and cold-working, could differ greatly in steels meeting the requirements of the S. A. E. No. 2315 Steel.

I would suggest that in order to get the S. A. E. Oil Specifications more in use, attempts be made to see if the oil companies and the automobile companies can get together with the Society of Automotive Engineers and use a similar system of nomenclature so that when anyone refers to No. 020 lubricating oil, he will know that an oil approximately in accord with S. A. E. Oil Specification No. 020 is required, although different automobile and oil companies may have slight differences in some of the requirements, just as the steel specifications are subject to slight differences in the requirements in specifications of different companies.

It is very true that the S. A. E. Oil Specifications can be used for the purchase and inspection of oils with as high a degree of safety as the S. A. E. Steel Specifications for the purchasing and inspection of steels. We have our own oil specifications, but as far as physical properties are concerned, they cover the same points as the S. A. E. Standards. Considering the S. A. E. Steel Specifications, when we are buying steel we add more to our specifications than what is specified in the S. A. E. Steel Specification. When we buy special forging grade we include a specification stating the amount of dirt allowed or state that it shall meet the McQuaid-Ehn test. All of these specifications demand better control at the steel mill. Again, for some car parts, we specify that they shall be made from electric furnace steel.

Now, I believe that we have the same situation with our oil specifications with this difference, and that is—as yet we have no positive means of testing for this extra quality, and must depend upon personal judgment based upon road-testing and dynamometer work.

As I stated in my previous letter, due to the field from which the oil is taken and to the methods of refining, there is a difference in lubricating value of oils that will meet the same S. A. E. Oil Specifications. Indications of these differences sometimes can be noticed from a comparison of the flash-points, viscosities of 210 deg. fahr. when compared with viscosities at 100 deg. fahr., color, and the like.

The oil specifications are excellent for grading as to physical properties. However, they will not fulfill their purpose until it can be admitted that oils meeting these specifications are not necessarily equivalent in quality. It is unfortunate that personal opinion enters to such a large extent in determining quality, but I believe it is something we still have to accept and allow for.

In my opinion, one of the big possibilities for application of S. A. E Oil Specifications is to provide a common language for the automobile manufacturers, the automobile dealer and the man at the oil-filling station. We would welcome the opportunity of being able to recommend to our dealers that they use a certain S. A. E. Oil and who in turn would recommend to their customers that they ask for a certain S. A. E. Oil at the oil-filling station. As yet, this is not a practical thing to do.

Since oil becomes contaminated so rapidly after being put into an engine and since the properties of the oils change so greatly as soon as it is put into use in the engine, it seems to me that until we can give reasonable answers to the questions as to how much water, dilution, iron oxide, silica and silicates, and the like, we can have in the oil before the oil is no longer fit for use, we are wasting time in trying to draw up the S. A. E. Oil Specifications with closer limits.

No clear idea of the matter can be obtained unless "lubricating value" is defined, and unless a distinction is made between quality and suitability. Viscosity is a typical test for suitability, but throws no light on quality. When refiners sell oil by brand, they sell engineering experience as well as oil, and it is quite possible that this is the cheapest way that the small consumer, who cannot afford to employ a chemist, can get his engineering advice. Large consumers prefer to employ their own engineers and chemists and buy by specification and not pay extra for branded oils and the advice which goes with them.

It is true that there may be a difference in quality of oils of close physical properties and that the S. A. E. Oil Specifications throw little light on quality. The question which I will take up later is, therefore, how can oils be tested for quality?

At the present time it seems to me that automobile dealers could furnish the public the most valuable information by stating what S. A. E. Oil should be used in their cars in summer and in winter. This at least will insure that the driver of the car uses oil of the right viscosity. Oil refiners claim to assure the same thing by publishing the brand of oil which should be used with a given make of car, but I shall not attempt to decide whether oil refiners or manufacturers of cars are in the best position to know what viscosity is best suited for a given car. Oil refiners, however, attempt to make certain also that oil of high enough quality is used, and here again it is a question whether their testing methods are better suited to test quality than the methods used by the chemists employed by the automobile manufacturers. If the oil refiners can be induced to put the S. A. E. Number on their cans of oil, it would be a great advantage.

There is no force to the argument that in putting an S. A. E. Number on a product, the refiner "is putting his oil on a par with that of a company not using the best refining methods." The S. A. E. Number only guarantees that the oil is of suitable viscosity; the brand name, which would also be on the can, would have to be relied upon as regards the quality of the oil.

At the time the specifications were decided upon the feeling was that they should not exclude any oil on the market and they were so written. I believe, however, when it is stated that "no relation could be shown between price and quality," that this was due simply to the fact that neither service nor laboratory tests were used which were capable of detecting differences in quality. There is considerable justification for writing specifications which will not exclude any oil on the market, so long as the length of time which an oil can be used in service depends upon crankcase dilution, and the crankcase dilution depends upon other factors and not at all upon the quality of the oil. But I believe crankcase dilution is a temporary condition which will be overcome, and then the length of time an oil can be kept in service will depend on the quality of the oil. If we are to plan for the future, or even to have a regard for the fact that cars are made today which reclaim crankcase oil in the car, continuously, then we need tests for quality not now included in the specifications.

If it is assumed that "we have no positive means of testing for this extra quality," as mentioned in the preceding discussion, then the question arises as to why we assume the oil refiners have such a means? If the means is "road-testing and dynamometer work," then we should remember that such tests can only apply to a given sample of oil, and when we want to specify and buy some more oil like a sample which has proved acceptable in service tests we must either assume that two oils of the same brand are equally serviceable, which there is abundant evidence is an untenable assumption, or we must assume that if two samples of oil are alike in laboratory tests they must be alike in regard to all properties which influence their value in service. Without meaning to imply that the second assumption is any more justified than the first, I feel certain that the second assumption is more nearly correct if a suitable oxidation test is included, than when only those tests are included which are now in the S. A. E. Oil Specifications.

It should be admitted that "oils meeting the S. A. E. Oil Specifications are not necessarily equivalent in quality." The choice is therefore whether to change the S. A. E. Oil Specifications by the addition of other tests which more accurately determine quality, or to regard the S. A. E. Oil Specifications as minimum requirements to which further requirements may be added by individuals as far as their necessities demand and their knowledge and courage in regard to valuable new tests permit, realizing that we have much to learn.

It would seem, however, that there could be agreement on the desirability of taking some means for extending the use of the S. A. E. Oil Specifications and making it possible for manufacturers to recommend to dealers. and dealers to recommend to customers "that they ask for a certain S. A. E. Oil at the oil-filling station." I believe it highly probable that the great majority of troubles with crankcase oil is not due to quality at all, but to the use of the wrong grade or viscosity for a certain purpose. If so, much of the trouble could be eliminated if customers could be informed what S. A. E. Number to ask for, and could get it.

We consider the S. A. E. Oil Specifications a very serviceable aid in specifying the proper grade of oil for our engines, and refer to the S. A. E. Numbers in our instruction books. It clears up the mixups that arise from using the terms heavy, medium, light, extra heavy, and the like, and gives the user an idea of what the lubricating properties of an oil are at crankcase temperatures, the temperature at which he uses the oil, not the temperature at which he buys it.

It is true that these specifications do not tie up the quality of the oil to the extent that all oils of a given S. A. E. Number would be of equal quality, but until better and more uniform methods are devised for checking the various characteristics of lubricating oils we see no better way of helping the operator to select oils of the proper grade.

We send out reprints of the S. A. E. Oil Specifications to parties asking information on oils, and if other companies will help disseminate this information we believe the oil companies will soon make use of the numbers.

The opinion that using these numbers places a manufacturer of high-grade oil on the same footing as a competitor making cheap oil is holding back the wider use of this standard. The use of these numbers does not necessarily put all oils on an equal footing, as the wide use of S. A. E. Standards in other fields does not have a similar effect.

NON-STANDARD TERMINALS COSTLY

Die Expense Not Included in Cost of S.A.E. Standard Cable Terminals

The importance of buying cable terminals as specified in the S.A.E. Standard on p. 21 of the S.A.E. HANDBOOK, instead of terminals slightly different, which would require special dies, has been brought to the attention of the Society by a large manufacturer of terminals. Comments submitted in this connection, which are given below, indicate that it is desirable for engineers or purchasing agents to check their terminal requirements to the S.A.E. Standard. Even large automobile producers will find that, if differences exist, considerable saving can be effected by buying S.A.E. Standard terminals on order or from stock.

The cost of cable terminals is such a small item, compared to the cost of larger component parts in the car, that the possibilities of saving on the former are usually overlooked by the average engineer.

However, a checking of the details will show that, while the costs are small as compared with those of other car parts, they amount to much more than necessary, if it is necessary to include die costs.

A small change in any terminal, which may not seem to affect the cost of the part itself, would perhaps require entirely new tools, and in most cases these tools would be idle a great part of the time. This would correspondingly increase the number of parts carried in stock and the replacement difficulties.

For instance, on a terminal that could be purchased from the manufacturer without change at $4 per 1000 in quantities of 5000, should a change be required in the hole, it would mean a $10 total increase on the lot of 5000 or a 50-per cent increase in the cost of the terminal. This charge for repunching would simply cover the manufacturer's cost in changing tools and rehandling the parts. With terminals, when the shape of the part itself is changed, the quantity would have to run well up in the thousands, and then, unless it were a trade standard, the chances are that the cost of the dies would have to be charged over a very long period of time in order that the terminal cost per thousand should not be excessive as compared with that of the standard parts.

With this in mind, the value of standard terminals, whether made by the manufacturers or purchased, will be appreciated. An odd shape or a different hole for screw clearance means a special screw, new tool costs and a considerable increase in the terminal cost, especially if the parts are to be purchased, and corresponding delay in obtaining these parts. With standard parts, the purchase can be made from the reserve stock of the manufacturer to suit any delivery specifications.

It is only in meeting the keenest competition that the small details receive the attention they merit. The value of standardization is realized by the engineer who takes advantage of the standards for such details.

CHROMIUM-SILICO-MANGANESE STEEL

To determine the extent to which chromium-silico-manganese steel is used in the industry and the chemical analyses used, a survey of the practice of passenger-car, spring and valve manufacturers was recently made by the Standards Department. The accompanying table gives the various compositions that this survey indicates are used at the

CHROMIUM-SILICO-MANGANESE STEEL COMPOSITIONS USED

Carbon Range	Chromium Range	Silicon Range	Manganese Range	Phosphorus Maximum	Sulphur Maximum
0.15-0.25	0.60-0.90	0.20-0.40	0.25-0.55	0.030	0.030
0.35-0.45	0.60-0.90	0.40-0.60	0.60-0.90	0.030	0.030
0.35-0.45	0.70-0.90	0.40-0.60	0.70-0.90	0.045	0.045
0.35-0.45	0.65-0.85	0.40-0.60	0.65-0.85	0.030	0.030
0.40-0.50	0.70-0.80	0.45-0.55	0.70-0.80	0.025	0.025
0.40-0.50	0.60-0.90	0.40-0.60	0.60-0.90	0.030	0.030
0.40-0.50	0.70-0.85	0.40-0.60	0.70-0.85	0.040	0.040
0.40-0.50	0.20-0.40	0.30-0.35	0.20-0.50	0.035	0.035
0.40-0.50	0.70-0.90	0.30-0.35	0.20-0.50	0.035	0.035
0.45-0.52	0.70-0.90	0.25-0.40	0.70-0.90	0.030	0.025
0.45-0.55	0.60-0.90	0.40-0.60	0.60-0.90	0.030	0.030
0.45-0.55	0.70-0.90	0.40-0.60	0.70-0.90	0.045	0.045
0.45-0.55	0.70-0.85	0.45-0.55	0.70-0.85	0.025	0.025
0.45-0.55	0.65-0.85	0.40-0.60	0.65-0.85	0.030	0.030
0.50-0.60	0.65-0.90	0.40-0.50	0.70-0.90	0.045	0.045
0.50-0.60	0.65-0.90	0.40-0.55	0.70-0.90	0.045	0.045
0.55-0.65	0.70-0.90	0.40-0.60	0.70-0.90	0.045	0.045
0.42-0.52	1.00-1.20	0.20 Max	0.75-1.00	0.040	0.040
0.45-0.55	1.00-1.25	0.12-0.20	0.70-0.90	0.030	0.030
0.50-0.55	0.80-1.00	0.50-0.75	0.70-0.80	0.020	0.020

present time. The total yearly production of this steel reported was approximately 5000 tons.

L. A. Danse, of the Cadillac Motor Car Co., is chairman of the Subdivision to which is assigned the work of recommending a limited number of specifications that will meet general requirements.

RATING AT 5 AMP. INCORRECT

Storage-Battery Division Favors 20-Hr. or an Intermittent Battery-Rating

That the 5-amp. rating for storage-batteries is technically incorrect, and for this reason should not be approved by a technical society, even though it is widely used by passenger-car engineers, was the consensus of opinion at the Storage-Battery Division meeting held at New York City in September. The present S.A.E. Standard specifies both a 20-min. rating and a 5-hr. rating. The Division members favored withdrawing the 5-hr. rating in favor of either a 20-hr. or an intermittent rating. It was thought, however, that, if the situation could be made clear to the car manufacturers, who at the present time are not familiar enough with storage-battery design to appreciate the objections to the 5-amp. rating, it would be possible to obtain general adoption in practice of either the 20-hr. or an intermittent rating.

To bring about a better understanding of the matter, the following statement was prepared by the Storage-Battery Division. Copies of it will be sent to every car manufacturer. The comments of Society members as to what rating should be adopted will be appreciated.

Storage-Battery Ratings

The S.A.E. Standard given on p. B23 of the S.A.E. Handbook provides for rating passenger-car batteries on the bases of 20-min. and 5-hr. discharge. Two ratings are given because of the dual character of the service that such batteries render. The 5-hr. rate is designed to indicate the ability of the battery to provide lights when the car is standing, and also for ignition when for any reason the generator fails to operate. The 20-min. rate is designed to indicate the ability of the battery to crank the car. Two ratings for batteries of this type are necessary. The performance of the various batteries at high, as compared with low, rates of discharge is influenced by the plate thickness, the separator resistance, the concentration of electrolyte and other factors, so that adequate information cannot be obtained from the performance at a single rate.

The 20-min. rating for these batteries has met with general acceptance. The 5-hr. rating, however, has been used by comparatively few manufacturers, the tendency being to retain the 5-amp. rating previously used.

The following is a brief resume of the advantages and disadvantages of the various methods for rating these batteries, and it is presented for discussion by those interested because the Storage-Battery Division believes that it is desirable that ratings for these batteries should be established which will be satisfactory to the manufacturers of both cars and batteries, and at the same time be technically sound and logical.

5-*Amp. Rating*.—The 5-amp. rating has long been used in the industry. By definition, it is the ampere-hour capacity of a battery when discharged continuously at 5 amp. The 5-amp. rate was originally supposed to indicate the approximate load on the battery for lighting service. The rating possesses the advantage that engineers have acquired the habit of speaking of batteries as of 80 or 100-amp-hr. capacity on the basis of the discharge at the 5-amp. rate.

There are certain serious disadvantages, however, to this method of rating automobile batteries.

(1) It is not logical to rate batteries of different voltages and cell sizes at the same discharge rate. The 5-amp. rate is a more severe tax upon small cells than upon large ones. The capacities of the different sizes of battery, therefore, are not proportional to the number of positive plates that they contain. For example, when a seven-plate battery is compared with one of 13 plates, which contains double the number of positive plates, at the 5-amp. rate, its capacity is materially less than half. Anomalous results may be expected in some cases, when tests are made at the 5-amp. rate, irrespective of the size of the battery

(2) The 5-amp. rating necessitates testing all sizes of battery to determine their ratings. This greatly increases the amount of testing work, especially when it is considered that discharges at the 5-amp. rate will terminate at various times during the day and night. It is very convenient to represent the performance of any type of battery on the basis of given discharge rates per positive plate, irrespective of the size of the battery, by one set of performance curves; but this is impossible with the 5-amp. rating. A separate and a characteristic curve is required for each battery

(3) The 5-amp. rating does not represent a fixed lighting-load as it was originally supposed to do. The load in amperes for a 12-volt battery is in general about one-half that required for lamps of the same candlepower with a 6-volt battery, and the parking requirements for different types of car using the same 6-volt battery vary all the way from 1 to 8 amp., depending upon the lamps and whether the resistance dimmers or parking-lights are used

(4) It is inconsistent to rate this type of battery at 5-amp. in the one case and 20-min. in the other. The ratings should be on the same basis

(5) Rating these batteries on the basis of current discharge is inconsistent with the method used for other types of battery, such as those for isolated electric-lighting plants, stand-by service, electric vehicles, electric locomotives and others, for all of which time ratings are used

5-*Hr. Rating*.—The 5-hr. rating that was adopted by the Society of Automotive Engineers and by the

Motor Transport Division of the War Department in 1920, avoids the disadvantages mentioned above. On the 5-hr. basis, as for any other time-rate, the capacities for the different sizes are comparable and proportional to the number of positive plates contained. The performance curves for any series of batteries, irrespective of the number of plates, may be represented by a single diagram. Tests of batteries at the 5-hr. rate can conveniently be made within the limits of the working-day with an ample allowance for the time necessary in adjusting the specific gravity and the temperature to the proper values before beginning the test. The 5-hr. rating has proved satisfactory to the military service and it is specified in the specifications for starting and lighting batteries for military automobile and truck service, Quartermaster Corps Specification No. 70-1, adopted Nov. 5, 1920. At the 5-hr. rating the performance is consistent irrespective of the thickness of the plates that the batteries may contain. Certain disadvantages of the 5-hr. rating are well recognized.

(1) The period is generally considered too short to approximate the requirements of service. An effort on the part of automobile manufacturers has been made to diminish the load on the battery during the time the car is parked, and it is, of course, expected that the battery should give service under light-load conditions for a much longer period than 5 hr.

(2) The capacities of the batteries are materially less than when they are tested at 5 amp. This means cutting the catalog figures for capacity, which inevitably meets with opposition from the sales point of view

(3) Because of the similarity between 5 hr. and 5 amp., some possibility exists of confusion on the part of those who are not familiar with the subject. In such a case the lower capacity at the 5-hr. rate appears at a disadvantage as compared with the capacity measured at 5 amp.

20-Hr. Rating.—A 20-hr. rating has been proposed to overcome the objections raised to the 5-hr. rate. This more nearly approximates the period of service required from the battery and has the added advantage that, for batteries having a capacity of 100 amp-hr., the result would correspond exactly with its capacity on the old 5-amp. basis. The capacity figures for the other sizes would also be of the same order of magnitude as under the old 5-amp. rating. The 20-hr. rate has all the advantages of the time method of rating which were mentioned above for the 5-hr. rate. The chief disadvantage of the 20-hr. rating is the difficulty of making accurate tests over so long a period of time. Tests may be made without the presence of an observer during the night, by adjusting the discharge rate slightly above the desired average current at the end of the working-day. Such a procedure, however, is not satisfactory in cases where accurate tests are to be made. It inevitably happens that some batteries are on the border-line between passing and failure. In such cases it would be necessary that the tests be given constant attention.

Intermittent Rating.—An intermittent 72-hr. discharge is another method of rating proposed. This would probably approximate most closely the average conditions of service required at the battery and is advantageous for this reason. The importance of knowing the capacity of the battery at low rates of discharge arises primarily in such cases when the generator on the car may be inoperative. It is evident that, with the intermittent use which the battery receives, a test covering a period of several days would most closely approximate the conditions of service. A discharge covering 72 hr. may be described as measuring the ultimate capacity of the battery. The most serious disadvantage of this method of rating arises from the prolonged test and the difficulty of making clear what is meant by an intermittent 72-hr. test. This same difficulty arose with the rating of isolated electric-lighting-plant batteries for which the Society has established a dual method of rating based on 8-hr. continuous discharge or an intermittent discharge covering the period of 72 hr. In the latter case recommendations are made covering the method of test so that no uncertainty can exist as to the proper method of measuring the capacity at this rate.

The Storage-Battery Division feels that now is the proper time to take a definite stand in this matter. A rating should be adopted which will be satisfactory to and be used by all concerned. If the 5-amp. rating is to be perpetuated by car and battery manufacturers and the 5-hr. rating by the Society and by the military authorities and these methods perhaps increased by the adoption by other organizations of ratings at 20 hr. or some other period of discharge, confusion will inevitably result. It is the opinion of the Division that, whatever basis for rating these batteries is selected, it should be technically sound. The Division does not think that the 5-amp. rating is technically sound and recommends that a rating on a time basis be established.

Cases have arisen in which batteries have evidently been mis-rated. This may have been done through ignorance or by wilful attempt to deceive. The battery manufacturers should do all in their power to inspire the confidence of the public in the matter of rating batteries. The ratings should be such as the public as well as the manufacturer can understand, and they should be technically beyond criticism and on a basis that may logically be extended to future changes and extensions in battery usage.

NUMBER AND LIFE OF CARS

DURING the last year the number of people in the Country for each car has been cut from seven to six. California has the most cars per capita, with one for less than every three people. If California's average were nation-wide, approximately 40,000,000 cars would be in use in the Country, or more than double the present registration. If the industry continues to grow at its present rate, within the next 2 years the figure will be one car for every average American family of five people. The fewest cars per capita are found in Alabama, where the average is 1 car for every 15 inhabitants.

About 3,551,000 new cars and trucks were produced in 1924. Deducting the increase in registrations last year, 2,676,426, the remainder, 874,472, gives the approximate number of cars that were discarded in the last year. It is stated that the average life of a car is over 8 years. This relatively great increase in the life of cars reflects the high standard of quality that is being maintained by motor-vehicle manufacturers at the present time.

In the value of finished products, the automotive industry ranks first among all business enterprises. In one branch or another it provides the living for 1 out of every 10 American people. Over 500,000 miles of improved roads now carry the Nation's automotive traffic. This stupendous growth has practically all taken place within the past 25 years.—B. F. Goodrich Co.

Personnel of 1925 Technical Committees

THE accompanying personnel of technical Committees of the Society and of representatives on the Committees of Governmental Bureaus and Departments and other organizations, appointed under the Standards Department activities, practically completes the personnel for 1925. The personnel of Special and Cooperating Committees of the Society and the representatives on other committees is published in this issue to give the members a more definite idea of the fields of work in which the Society is taking an active part and the men who are participating directly. It has been found that many members of the Society do not have a very broad conception of the work that is being done and as a result they do not get as much benefit from their membership in the Society as they might, and the Committees in many cases find it more difficult to obtain the cooperation of the membership in general in much of their work. The personnel of certain committees, especially the Standards Committee and some of the Sectional Committees, changes more or less during the year but in general will remain as published herein.

The Standards Committee is divided into 29 main Divisions classified according to types of vehicle, major automotive component units, parts and materials. Divisions are appointed annually and handle groups of subjects. They are further divided into Subdivisions, each of which handles a specific subject. The Motorcoach Division is a new one succeeding the Special Motorcoach Committee appointed last year. It is anticipated that this Division will be active in this comparatively new branch of the automotive industry from now on.

Special and Cooperating Committees are appointed either temporarily or pemanently to handle specific subjects or such subjects as may not come within the classification of the Divisions. Their reports as a rule are eventually passed upon by the Standards Committee.

Sectional Committees are classified into two groups, one for which the Society is a sponsor and the other on which the Society only appoints representatives. Under the rules of procedure of the American Engineering Standards Committee, of which the Society is a member body, reports issued by Sectional Committees for which the Society is sponsor, must be approved by the Society by regular Standards Committee procedure before they are finally approved by the American Engineering Standards Committee. Reports from Sectional Committees on which the Society is only represented need not necessarily be approved by the Society.

The work of the Committees and Governmental Departments and Bureaus and of other organizations does not as a rule proceed through the Standards Committee but may be acted upon by the Council of the Society in special cases.

STANDARDS COMMITTEE

E. A. Johnston, *Chairman*	International Harvester Co.
C. M. Manly, *First Vice-Chairman*	Manly & Veal
C. C. Carlton, *Second Vice-Chairman*	Motor Wheel Corporation

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H. M. Crane, *Chairman*	New York City
P. G. Zimmerman, *Vice-Chairman*	Paul G. Zimmerman Metal Aircraft
P. H. Adams	Brookline, Mass.
Archibald Black	Garden City, N. Y.
R. S. Barnaby	Bureau of Aeronautics
J. A. Christen	Naval Aircraft Factory
V. E. Clark	Consolidated Aircraft Corporation
W. L. Gilmore	Curtiss Aeroplane & Motor Co., Inc.
L. M. Griffith	National Advisory Committee for Aeronautics
G. C. Loening	Loening Aeronautical Engineering Corporation
G. J. Mead	Wright Aeronautical Corporation
E. C. Richard	Air Mail Service
I. M. Uppercu	Aeromarine Plane & Motor Co.
W. B. Stout	Stout Metal Airplane Co.
R. H. Upson	Aircraft Development Corporation
Edward Wallace	Glenn L. Martin Co.

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C. E. Frudden	Hart-Parr Co.
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works Co.
P. E. Holt	Holt Mfg. Co.
F. N. G. Kranich	Timken Roller Bearing Co.
John Mainland	Advance-Rumely Co.
A. W. Scarratt	Minneapolis Steel & Machinery Co.
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O. B. Zimmerman	International Harvester Co.

AXLE AND WHEELS DIVISION

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R. J. Burrows	Clark Equipment Co.
G. W. Carlson	Eaton Axle & Spring Co.
R. E. Clingan	Bock Bearing Co.
G. W. Harper	Columbia Axle Co.
E. R. Jacobi	Hayes Wheel Co.
H. V. Ludwick	Budd Wheel Co.
O. A. Parker	Parker Wheel Co.
W. F. Rockwell	Wisconsin Parts Co.

BALL AND ROLLER BEARINGS DIVISION

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T. V. Buckwalter, *Vice-Chairman*	Timken Roller Bearing Co.
J. H. Baninger	Marlin-Rockwell Corporation
J. T. R. Bell	Rollway Bearing Co., Inc.
G. R. Bott	Norma-Hoffmann Bearings Corporation
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
R. E. Clingan	Bock Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
H. N. Parsons	Strom Ball Bearing Mfg. Co.
R. G. Schaffner	Bower Roller Bearing Co.
W. R. Strickland	Cadillac Motor Car Co.
R. E. Wells	Hyatt Bearing Division of the General Motors Corporation

CHAIN DIVISION

H. S. Pierce, *Chairman*	Link-Belt Co.
W. J. Belcher, *Vice-Chairman*	Whitney Mfg. Co.
G. M. Bartlett	Diamond Chain & Mfg. Co.
W. F. Cole	Baldwin Chain & Mfg. Co.

K. L. Herrmann	Studebaker Corporation of America
M. C. Horine	International Motor Co.
L. B. Sperry	International Harvester Co.

ELECTRIC VEHICLE DIVISION

J. G. Carroll, *Chairman*	Walker Vehicle Co.
H. M. Pierce, *Vice-Chairman*	Ward Motor Vehicle Co.
G. L. Bixby	Detroit Electric Car Co.
A. K. Brumbaugh	Autocar Co.
E. L. Clark	Commercial Truck Co.
C. H. Meeker	Lansden Co., Inc.
C. R. Skinner, Jr.	New York Edison Co.

ELECTRICAL EQUIPMENT DIVISION

T. L. Lee, *Chairman*	North East Electric Co.
B. M. Leece, *Vice-Chairman*	Leece-Neville Co.
F. W. Andrew	Glen Head, N. Y.
C. R. Alling	Underwriters Laboratories, Inc.
Azel Ames	Kerite Insulated Wire & Cable Co., Inc.
S. F. Briggs	Briggs & Stratton Co.
F. A. Bonham	Durant Motors, Inc.
D. W. Burke	Auto Electric & Service Corporation
W. B. Churcher	White Motor Co.
S. W. Colvard	Dayton Engineering Laboratories Co.
P. J. Durham	P. J. Durham Co., Inc.
C. F. Gilchrist	Electric Auto-Lite Co.
W. S. Haggott	Packard Electric Co.
L. P. Kalb	Continental Motors Corporation
F. C. Kroeger	Remy Electric Co.
A. D. T. Libby	Splitdorf Electrical Co. (also representing Automotive Electric Association)
B. M. Smarr	General Motors Corporation
C. H. Williams	Studebaker Corporation of America
Ernest Wooler	Cleveland Automobile Co.

ENGINE DIVISION

W. C. Ware, *Chairman*	Fay & Bowen Engine Co.
L. P. Kalb, *Vice-Chairman*	Continental Motors Corporation
R. J. Broege	Buda Co.
A. A. Bull	Northway Motor & Mfg. Co.
F. S. Duesenberg	Duesenberg Auto & Motors Co., Inc.
J. B. Fisher	Waukesha Motor Co.
P. E. Holt	Holt Mfg. Co.
R. R. Keith	International Harvester Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
L. B. Sperry	International Harvester Co.
M. J. Steele	Packard Motor Car Co.

FRAMES DIVISION

C. C. Bowman, *Chairman*	Standard Motor Truck Co.
O. B. Harmon, *Vice-Chairman*	Parish & Bingham Division of the Midland Steel Products Co.
D. H. Geiger	Parish Mfg. Co.
W. A. McKinley	Midland Steel Products Co.
Ray Smith	O. E. Smith Corporation

IRON AND STEEL DIVISION

J. M. Watson, *Chairman*	Hupp Motor Car Corporation
F. E. McCleary, *Vice-Chairman*	Dodge Bros.
J. R. Adams	Midvale Co.
H. T. Chandler	Vanadium Corporation of America
B. F. Courtright	Wisconsin Steel Works of the International Harvester Co.
J. D. Cutter	Climax Molybdenum Co.
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
F. P. Gilligan	Henry Souther Engineering Corporation
H. L. Greene	Willys-Overland Co.
G. F. Harper	Allis-Chalmers Mfg. Co.
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Ordnance Department
J. A. Mathews	Crucible Steel Co. of America
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. C. Peterson	Standard Automotive Parts Co.; Fredericksen Co.
W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	American Gear Manufacturers Association
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
W. R. Shimer	Bethlehem Steel Co.
C. W. Simpson	White Motor Co.
T. H. Wickenden	International Nickel Co.
H. M. Williams	General Motors Research Corporation

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

F. L. Tubbs, *Chairman*	Alamo Farm Light Co.
F. C. Barton, *Vice-Chairman*	General Electric Co.
C. R. Alling	Underwriters Laboratories, Inc.
L. F. Burger	International Harvester Co.
C. B. Dicksee	Westinghouse Electric & Mfg. Co.
G. M. Gardner	Globe Electric Co.
C. F. Gilchrist	Electric Auto-Lite Co.
L. S. Keilholtz	Delco-Light Co.
C. E. Reddig	Western Electric Co.
H. L. Zabriskie	Diehl Mfg. Co. (also representing Electric Power Club)

LIGHTING DIVISION

C. A. Michel, *Chairman*	Guide Motor Lamp Mfg. Co.
J. H. Hunt, *Vice-Chairman*	General Motors Research Corporation
R. E. Carlson	Bureau of Standards
G. P. Doll	Thomas J. Corcoran Lamp Co.
R. N. Falge	National Lamp Works of the General Electric Co.
C. E. Godley	Edmunds & Jones Corporation
D. A. Harper	Tung-Sol Lamp Works
A. R. Lewellen	Chevrolet Motor Co.
W. A. McKay	Westinghouse Lamp Co.
L. C. Porter	Edison Lamp Works of the General Electric Co.
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Cincinnati Victor Co.
A. J. Scaife	White Motor Co.
B. M. Smarr	General Motors Corporation
J. C. Stearns	Culver-Stearns Mfg. Co.
T. I. Walker	Providence Base Works of the General Electric Co.
C. H. Williams	Studebaker Corporation of America
Ernest Wooler	Cleveland Automobile Co.
Edward Wotton	Chicago Motor Coach Co.

LUBRICANTS DIVISION

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. S. Cochrane, *Vice-Chairman*	Buick Motor Co.
Sydney Bevin	Tide Water Oil Co.
A. B. Dawson	General Motors Corporation
J. B. Fisher	Waukesha Motor Co.
R. K. Floyd	Frank H. Floyd Co.
W. H. Herschel	Bureau of Standards
K. G. Mackenzie	Texas Co. (also representing the American Society for Testing Materials)
Walter Miller	Marland Refining Co. (also representing Western Petroleum Refiners Association)
C. H. Osmond	Atlantic Refining Co.
W. E. Perdew	Derby Oil Co.
H. J. Saladin	Standard Oil Co. of Indiana
C. W. Simpson	White Motor Co.
H. G. Smith	Gulf Refining Co.
C. W. Stratford	Associated Oil Co.

MOTORBOAT DIVISION

C. A. Carlson, *Chairman*	New Jersey Motors, Inc.
Irwin Chase	Elco Works of the Electric Boat Co.
Carleton Bradley	New England Boat Works
J. W. Hussey	Greenport Basin & Construction Co.
Q. B. Newman	United States Coast Guard
Leonard Ochtman, Jr.	Elco Works of the Electric Boat Co.
P. A. Proal	Red Bank Yacht Works
W. A. Roos, Jr.	Consolidated Shipbuilding Corporation
W. H. Young	Belle Isle Boat & Engine Co.

MOTORCYCLE DIVISION

A. W. S. Herrington, *Chairman*	Quartermaster Corps
C. B. Franklin	Indian Motorcycle Co.
W. S. Harley	Harley-Davidson Motor Co.

MOTORCOACH DIVISION

G. A. Green, *Chairman*	Yellow Coach Mfg. Co.
A. F. Masury, *Vice-Chairman*	International Motor Co.
A. T. Clark	United Railways & Electric Co. (also representing American Electric Railway Association)
F. R. Fageol	Fageol Motors Co.
David Fenner	National Automobile Chamber of Commerce
R. E. Fielder	Fifth Avenue Coach Co.
G. E. A. Hallett	General Motors Research Corporation
E. A. Johnston	International Harvester Co.
William T. Lutey	Lang Body Co.
A. J. Scaife	White Motor Co.
E. W. Templin	Six Wheel Co.

NOMENCLATURE DIVISION

H. L. Pope, *Chairman*	Montclair, N. J.
H. R. Cobleigh, *Vice-Chairman*	National Automobile Chamber of Commerce
W. P. Culver	American Auto Parts Co. (also representing Motor & Accessory Manufacturers Association)
Leonard Ochtman, Jr.	Elco Works of the Electric Boat Co.
B. M. Smarr	General Motors Corporation
O. B. Zimmerman	International Harvester Co.

NON-FERROUS METALS DIVISION

W. R. Webster, *Chairman*	Bridgeport Brass Co.
W. H. Bassett, *Vice-Chairman*	American Brass Co.
A. H. Ackerman	Metallurgical Research Engineering Co.
H. R. Corse	Lumen Bearing Co.
G. K. Elliott	Lunkenheimer Co.
A. P. Eves	International Harvester Co.
E. S. Fretz	Light Mfg. & Foundry Co.
A. J. Hall	General Motors Corporation
Zay Jeffries	Aluminum Co. of America
H. G. Lamker	Wright Aeronautical Corporation
H. C. Mougey	General Motors Research Corporation
W. B. Price	Scovill Mfg. Co.
C. W. Simpson	White Motor Co.
T. H. Wickenden	International Nickel Co.

PARTS AND FITTINGS DIVISION

W. C. Keys, *Chairman*	Gabriel Snubber Sales & Service Co.
H. S. Jandus, *Vice-Chairman*	C. G. Spring & Bumper Co.
C. R. Alling	Underwriters Laboratories, Inc.
F. A. Bonham	Durant Motors, Inc.
Joseph Berge	Montclair, N. J.
A. Boor	Willys-Overland Co.
S. V. Norton	General Motors Truck Co.
W. J. Outcalt	General Motors Corporation
C. W. Spicer	Spicer Mfg. Corporation
E. W. Weaver	George T. Trundle, Jr., Engineering Co.
F. G. Whittington	Stewart Warner Speedometer Corporation

PASSENGER CAR DIVISION

R. S. Begg, *Chairman*	Jordan Motor Car Co.
L. A. Chaminade, *Vice-Chairman*	Studebaker Corporation of America
F. A. Bonham	Durant Motors, Inc.
H. N. Davock	Packard Motor Car Co.
E. A. DeWaters	Buick Motor Co.
Benjamin Jerome	Oakland Motor Car Co.
J. A. King	Checker Cab Mfg. Corporation
Ralph Murphy	H. H. Franklin Mfg. Co.
G. W. Smith	Nash Motor Co.

PASSENGER-CAR BODY DIVISION

G. J. Mercer, *Chairman*	Model Body Corporation
Kingston Forbes, *Vice-Chairman*	Buick Motor Co.
E. J. Bartlett	Baker R & L Co.
P. E. Breneman	Studebaker Corporation of America.
E. J. Connolly	C. R. Wilson Body Co.
E. W. Goodwin	Unison Seat Co. of America
R. A. LaBarre	Murray Body Corporation
A. J. Neerken	Hupp Motor Car Corporation

RADIATOR DIVISION

J. D. Harris, *Chairman*	McCord Radiator & Mfg. Co.
H. A. Higgins, *Vice-Chairman*	Long Mfg. Co.
R. A. Armstrong	Oakland Motor Car Co.
Charles Oppe	G & O Mfg. Co.
C. T. Perkins	Modine Mfg. Co.
L. P. Saunders	Harrison Radiator Corporation
F. M. Young	Racine Radiator Co.

SCREW THREADS DIVISION

E. H. Ehrman, *Chairman*	Standard Screw Co.
O. B. Zimmerman, *Vice-Chairman*	International Harvester Co.

E. J. Bryant	Greenfield Tap & Die Corporation
Earle Buckingham	Pratt & Whitney Co.
Ellwood Burdsall	Russell, Burdsall & Ward Bolt & Nut Co.
Luther D. Burlingame	Brown & Sharpe Mfg. Co.
G. S. Case	Lamson & Sessions Co.
H. H. Edge	Kelly Press Division of the American Type Founders Co.
Einar A. Hanson	Hanson-Whitney Machine Co.
K. L. Herrmann	Studebaker Corporation of America
Wm. R. Mitchell	National Acme Co.
A. W. Reader	General Motors Corporation

SPRINGS DIVISION

F. A. Whitten, *Chairman*	General Motors Truck Co.
W. E. Dunston, *Vice-Chairman*	C. G. Spring & Bumper Co.
R. S. Begg	Jordan Motor Car Co.
B. R. Benjamin	International Harvester Co.
S. P. Hess	Detroit Steel Products Co.
A. M. Laycock	Waukesha Motor Co.
H. R. McMahon	Standard Steel Spring Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
J. E. Reid	International Motor Co.
A. H. Remsen	Rickenbacker Motor Co.
E. W. Stewart	William D. Gilson Co.

STATIONARY ENGINE DIVISION

L. F. Burger, *Chairman*	International Harvester Co.
V. E. McMullen, *Vice-Chairman*	Hercules Corporation
D. B. Jahnke	Fairbanks-Morse Co.
T. C. Menges	Associated Manufacturers Co.
William E. Morgan	Novo Engine Co.
W. R. Olmsted	Nelson Bros. Co.

STORAGE-BATTERY DIVISION

W. E. Holland, *Chairman*	Philadelphia Storage Battery Co.
W. E. Gossling, *Vice-Chairman*	Prest-O-Lite Co., Inc.
E. W. Allen	Edison Storage Battery Co.
A. K. Brumbaugh	Autocar Co.
R. N. Chamberlain	Gould Storage Battery Co.
E. L. Clark	Commercial Truck Co.
Bruce Ford	Electric Storage Battery Co.
C. T. Klug	Willard Storage Battery Co.
A. R. Lewellen	Chevrolet Motor Co.
I. M. Noble	Consolidated Battery Co.
J. L. Rupp	Westinghouse Union Battery Co.
G. W. Vinal	Bureau of Standards
C. H. Williams	Studebaker Corporation of America

TIRE AND RIM DIVISION

To Be Appointed Later

TRANSMISSION DIVISION

L. C. Fuller, *Chairman*	Fuller & Sons Mfg. Co.
P. L. Tenney, *Vice-Chairman*	Muncie Products Division of the General Motors Corporation
A. C. Bryan	Durston Gear Corporation
D. E. Gamble	The Borg & Beck Co.
A. A. Gloetzner	Covert Gear Co., Inc.
G. S. Hendrie	Detroit Gear & Machine Co.
R. K. Jack	Olds Motor Works
D. F. Myers	Service Motors, Inc.
H. W. Sweet	Brown-Lipe Gear Co.
C. E. Swenson	Mechanics Machine Co.
S. O. White	Warner Gear Co.

TRUCK DIVISION

A. J. Scaife, *Chairman*	White Motor Co.
B. B. Bachman, *Vice-Chairman*	Autocar Co.
Nels G. Anderson	International Harvester Co.
F. W. Davis	Waltham, Mass.
J. C. Haggart, Jr.	Republic Motor Truck Co., Inc.
A. W. S. Herrington	Quartermaster Corps
M. C. Horine	International Motor Co.
G. R. Ingersoll	Federal Motor Truck Co.
R. R. Keith	International Harvester Co.
J. A. Kraus	Lima, Ohio
D. F. Myers	Service Motors, Inc.
E. M. Sternberg	Sterling Motor Truck Co.
C. B. Veal	Manly & Veal
F. A. Whitten	General Motors Truck Co.

SPECIAL COMMITTEES

COMMITTEE ON STANDARDIZATION POLICY

H. M. Crane, *Chairman*	New York City
B. B. Bachman	Autocar Co.
H. L. Horning	Waukesha Motor Co.
E. A. Johnston	International Harvester Co.
C. M. Manly	Manly & Veal

METHODS OF EXPRESSING LIMITS AND TOLERANCES

Earle Buckingham, *Chairman*	Pratt & Whitney Co.
E. H. Ehrman	Standard Screw Co.
G. S. Case	Lamson & Sessions Co.

PATENTS COMMITTEE

B. B. Bachman, *Chairman*	Autocar Co.
Lloyd Blackmore	General Motors Corporation
R. A. Brannigan	National Automobile Chamber of Commerce
C. M. Manly	Manly & Veal

COOPERATING COMMITTEES

HARDWOOD LUMBER STANDARDIZATION COMMITTEE

G. J. Mercer, *Chairman*	Model Body Corporation
R. A. LaBarre	Murray Body Corporation
T. J. Lítle, Jr.	Ford Motor Co.
F. F. Murray	Hardwood Manufacturers' Institute
Representative	Forest Products Laboratories

SECTIONAL COMMITTEES SPONSORED BY THE SOCIETY

AERONAUTICAL SAFETY CODE

H. M. Crane, *Chairman*	New York City
Archibald Black	Garden City, N. Y.
V. E. Clark	Consolidated Aircraft Corporation
G. C. Loening	Loening Aeronautical Engineering Corporation
G. J. Mead	Wright Aeronautical Corporation
I. M. Uppercu	Aeromarine Plane & Motor Co.
R. H. Upson	Aircraft Development Corporation

AUTOMOBILE HEADLIGHTING SPECIFICATIONS

H. M. Crane	New York City
R. N. Falge	National Lamp Works of the General Electric Co.
T. J. Lítle, Jr.	Ford Motor Co.
C. A. Michel	Guide Motor Lamp Mfg. Co.
A. J. Scaife	White Motor Co.

BALL BEARINGS

W. R. Strickland, *Chairman*	Cadillac Motor Car Co.
C. M. Manly, *Vice-Chairman*	Manly & Veal
R. S. Burnett, *Secretary*	Society of Automotive Engineers, Inc.
H. E. Brunner	S. K. F. Industries
L. A. Cummings	Standard Steel & Bearings, Inc.
C. H. Day	Elektron Metals Corporation of America
F. W. Gurney	Marlin-Rockwell Corporation
F. G. Hughes	New Departure Mfg. Co.

BOLT, NUT AND RIVET PROPORTIONS

J. A. Anglada	New York City
M. C. Horine	International Motor Co.
W. A. McKinley	Midland Steel Products Co.
C. B. Segner	Domestic Engine & Pump Co.

NUMBERING OF STEELS

F. P. Gilligan	Henry Souther Engineering Corporation
C. N. Dawe	Studebaker Corporation of America
G. L. Norris	Vanadium Corporation of America

SCREW THREADS

P. W. Abbott	Studebaker Corporation of America
D. G. Baker	American Thread Co.
Earle Buckingham	Pratt & Whitney Co.
E. H. Ehrman	Standard Screw Co.
H. E. Fromme	Consolidated Shipbuilding Corporation
W. F. Graham	Curtis Bay Copper & Iron Works
C. M. Manly	Manly & Veal
E. O. Spillman	Herschell-Spillman Motor Co.
O. B. Zimmerman	International Harvester Co.

TRANSMISSION ROLLER CHAINS AND SPROCKETS

Committe now being organized

SECTIONAL COMMITTEES ON WHICH THE SOCIETY IS REPRESENTED BUT NOT A SPONSOR

BRAKES AND BRAKE TESTING

Clarence Carson	Dodge Bros.
R. E. Fielder	Fifth Avenue Coach Co.
C. L. Sheppy	Pierce-Arrow Motor Car Co.
John R. Cautley	Perrot Brake Corporation

CODE ON COLORS FOR TRAFFIC SIGNALS

W. A. McKay	Westinghouse Lamp Co.

GEARS

H. E. Blood	Detroit Gear & Machine Co.
Earle Buckingham	Pratt & Whitney Co.

INSULATED WIRE AND CABLE

F. W. Andrew	Glen Head, N. Y.
W. S. Haggott	Packard Electric Co.

MACHINE-TOOL SAFETY CODE

A. J. Gifford	Leland-Gifford Co.

PIPE FLANGES AND FITTINGS

T. C. Menges	Associated Manufacturers Co.

PLAIN LIMIT GAGES

P. W. Abbott	Studebaker Corporation of America
W. J. Outcalt	General Motors Corporation

USE, CARE AND PROTECTION OF ABRASIVE WHEELS

A. J. Gifford	Leland-Gifford Co.

STANDARDIZING ASSOCIATIONS AND COMMITTEES ON WHICH THE SOCIETY IS REPRESENTED

ADVISORY BOARD FOR UNITED STATES DICTIONARY OF SPECIFICATIONS

C. F. Clarkson	Society of Automotive Engineers, Inc.
R. S. Burnett, *Alternate*	Society of Automotive Engineers, Inc.

AMERICAN ENGINEERING STANDARDS COMMITTEE

B. B. Bachman	Autocar Co.
C. F. Clarkson	Society of Automotive Engineers, Inc.
C. M. Manly	Manly & Veal
Alternates	
R. S. Burnett	Society of Automotive Engineers, Inc.
C. C. Carlton	Motor Wheel Corporation
E. A. Johnston	International Harvester Co.

AMERICAN ENGINEERING STANDARDS COMMITTEE'S SPECIAL COMMITTEE ON PREFERRED NUMBERS

Cornelius T. Myers	Rahway, N. J.

AMERICAN MARINE STANDARDS COMMITTEE

R. S. Burnett	Society of Automotive Engineers, Inc.
H. R. Sutphen	Submarine Boat Corporation

AMERICAN SOCIETY FOR TESTING MATERIALS COMMITTEE A1 ON STEEL

F. P. Gilligan	Henry Souther Engineering Corporation

AMERICAN SOCIETY FOR TESTING MATERIALS COMMITTEE A7 ON MALLEABLE IRON

H. T. Chandler	Vanadium Corporation of America
W. F. Graham	Curtis Bay Copper & Iron Works

COMMITTEE ON FERROUS METALS OF THE BUREAU OF STANDARDS

F. P. Gilligan	Henry Souther Engineering Corporation
W. C. Peterson	Standard Automotive Parts Co.; Fredericksen Co.

COMMITTEE ON STRUCTURES AND FABRICATED METALS OF THE BUREAU OF STANDARDS

C. L. Burns	Wright Aeronautical Corporation
J. H. Nelson	Wyman-Gordon Co.

CONFERENCE ON AERONAUTICAL NOMENCLATURE OF NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

G. C. Loening	Loening Aeronautical Engineering Corporation
W. B. Stout	Stout Metal Airplane Co.
R. H. Upson	Aircraft Development Corporation

CONSULTING COMMITTEE OF THE CENTRAL COMMITTEE ON LUMBER STANDARDS

W. B. Swift	International Harvester Co.

GAGE STEEL COMMITTEE OF BUREAU OF STANDARDS

C. N. Dawe	Studebaker Corporation of America
J. M. Watson	Hupp Motor Car Corporation

HARDWOOD CONSULTING COMMITTEE OF CENTRAL COMMITTEE ON LUMBER STANDARDS

F. J. Bickelhaupt	Studebaker Corporation of America
W. C. Fischer	Baker R & L Co.

JOINT ARMY AND NAVY AERONAUTIC CONFERENCE

E. W. Rounds	Wright Aeronautical Corporation
P. G. Zimmerman	Paul G. Zimmerman Metal Aircraft

JOINT COMMITTEE ON INVESTIGATION OF PHOSPHOR AND SULPHUR IN STEEL

F. P. Gilligan	Henry Souther Engineering Corporation

NATIONAL SCREW THREAD COMMISSION

Earle Buckingham	Pratt & Whitney Co.
G. S. Case	Lamson & Sessions Co.

JANUARY COUNCIL MEETINGS

THE session of the Council held in New York City on Jan. 8 was attended by President Crane, Vice-Presidents Strickland, Pope and Ware, Councilors Hunt, Scaife and Rumney and Treasurer Whittelsey, and by O. M. Burkhardt, H. D. Church, C. H. Foster, H. L. Horning, T. J. Lítle, Jr., C. F. Scott and P. G Zimmerman, nominees for service on the 1925 Council.

One hundred and forty-one applications for individual membership were approved. The following transfers in grade of membership were made: From Member to Service Member, Rico Botta; Junior to Service Member, J. Mackenzie Miller; Junior to Member, Victor R. Ellison, James W. Galloway, Oscar P. Liebreich, A. Rolstan Stalb and Maurice Walter; Junior to Associate, Livingston Disbrow, John A. Heckman, David H. Hirsh, George Ralph Metcalf, Jr., Edwin K. Purchase, Wesley B. Pusey, Henry Schlachter, Harold B. Sweet and John M. Walter.

The resignations of 17 members were accepted and the names of six members were stricken from the rolls for default in payment of dues. The reinstatement of two members who had previously resigned or been dropped for non-payment of dues was approved.

It was voted that the Society accept, jointly with the American Society of Mechanical Engineers, sponsorship for the Sectional Committee on Standardization of Transmission Chains and Sprockets. The following members were named as representatives of the Society on the Sectional Committee on Automobile Lighting: H. M. Crane, R. N. Falge, T. J. Lítle, Jr., C. A. Michel and A. J. Scaife.

T. L. Lee, B. M. Smarr and W. B. Stout were appointed as representatives of the Society on the Sectional Committee on Specifications for Zinc Coating of Iron and Steel. Paul G. Zimmerman was named to attend the conference of the National Aeronautic Association in the City of Washington, Jan. 29, in connection with program for 1925 aviation contests.

The 1924 Council held the last session of its administration on Jan. 19 in Detroit. The following were present: President Crane, First Vice-President Johnston, Second Vice-Presidents Strickland and Ware, Councilors Hunt, Rumney and Scaife, and Treasurer Whittelsey, and O. M. Burkhardt, H. D. Church, H. L. Horning and T. J. Lítle, Jr., nominees for service on the 1925 Council.

Thirteen applications for individual membership and one application for reinstatement were approved. The following transfers in grade of membership were made: from Junior to Service Member, M. A. Thorne; from Junior to Associate, R. L. Smith and W. W. Wing; from Associate to Member, Harvey M. Cronk and W. Ledyard Mitchell.

ORGANIZATION SESSION OF 1925 COUNCIL

The organization Session of the 1925 Council was held in Detroit on Jan. 19 and was attended by President Horning, First Vice-President Lítle, Second Vice-President Church, Councilors Burkhardt, Hunt and Rumney, Treasurer Whittelsey and Past-President Crane.

President Horning announced the personnel of the 1925 Administrative Committees as follows:

CONSTITUTION COMMITTEE

A. L. Riker, *Chairman*

H. M. Crane	A. J. Scaife

FINANCE COMMITTEE

A. R. Erskine, *Chairman*

W. L. Batt	Christian Girl
A. J. Brosseau	C. B. Whittelsey

HOUSE COMMITTEE

David Beecroft, *Chairman*

Vincent G. Apple	G. P. Dorris
A. W. Copland	E. H. Ehrman

MEETINGS COMMITTEE

T. J. Lítle, Jr., *Chairman*

H. W. Asire	G. W. Kerr
O. M. Burkhardt	L. L. Roberts
Charles O. Guernsey	S. W. Sparrow
A. W. S. Herrington	O. B. Zimmerman
K. L. Herrmann	P. G. Zimmerman
L. Clayton Hill	

MEMBERSHIP COMMITTEE

A. F. Masury, *Chairman*

F. A. Cornell	W. S. Nathan
W. L. Moreland	C. H. Warrington

PUBLICATION COMMITTEE

E. P. Warner, *Chairman*

O. C. Berry	W. E. Lay
Herbert Chase	F. C. Mock

SECTIONS COMMITTEE

J. H. Hunt, *Chairman*

F. F. Chandler, *Vice-Chairman*

George T. Briggs	R. E. Northway
William E. England	R. E. Plimpton
G. Walker Gilmer	J. W. White
A. W. S. Herrington	R. E. Wilson
George L. McCain	John Younger

The names of the members who will serve this year as chairmen and vice-chairmen of the Standards Committee and its Divisions were reported. These are listed elsewhere in this issue of THE JOURNAL, as well as those named by the Council for service on the various Divisions.

Those designated to serve during the year on the Research Committee, the Highways Committee, the Fuels Group and the Riding-Qualities Group are listed in this issue of THE JOURNAL in the section devoted to research matters.

Standards Committee Meeting

THE regular annual meeting of the Standards Committee was held at the General Motors Building at Detroit during the afternoon of Jan. 19 with Chairman E. A. Johnston presiding. Fifteen reports by nine Divisions, which were printed in the January issue of THE JOURNAL, commencing on p. 33, were approved as presented or amended in the meeting. The action of the Standards Committee Meeting was approved by the Council and at the deferred business session on Tuesday evening, except in the case of the recommendation for head-lamp doors, which was referred by the Council to the Society's Standardization Policy Committee for a recommendation to the Lighting Division based on the principle of the policy involved.

In accordance with the Standards Committee regulations, a letter ballot of the Society members on final approval of the reports will be returnable and counted 21 days following publication in THE JOURNAL of the action taken on them at the Standards Committee Meeting. A ballot on the following reports is, therefore, returnable on Feb. 25, 1925. The usual ballot-form will be sent to each Member of the Society and will provide for affirmative and negative votes and waivers. Each subject to be voted upon will be given in the ballots by title accompanied by the page reference of the report as published in the January issue of THE JOURNAL, which should be consulted by the members together with this issue in which is recorded the principal discussion on reports and the action taken on them.

Often letter-ballots on Standards Committee reports are returned unsigned by members. These, of course, cannot be counted. Also a considerable number of ballots are usually received after the date on which ballots are counted. Many of these ballots undoubtedly represent the opinion of members who are particularly qualified to vote on the subjects, and to avoid having these ballots thrown out it is urged that all members be particularly careful to sign their ballots and return them within the specified time.

The following includes only such changes as were made in the Division reports printed in the January issue of THE JOURNAL referred to above that were approved for submission to letter ballot by the members and the principal discussion of subjects at the Standards Committee Meeting. This report, together with the original reports published in the January issue, should be considered when filling in the letter ballots.

(1) DIFFERENTIALS
(Axle and Wheels Division)

THE DISCUSSION

S. O. WHITE:—I have no particular comment to make on this proposal for differentials except that the principal purpose the Division has in mind is to establish a recommended practice as a guide chiefly in designing new axles.

In our experience as differential manufacturers we find that nearly every job that comes to us to figure on is frequently different in non-essentials. Sometimes, of course, certain items such as flange offsets on differential cases have to vary but a number of the other dimensions could be maintained in many designs where the proposal could not be adopted in its entirety. Adoption of the proposal will make it possible to reduce the immense variety of designs that are now used, reduce tooling, forgings, patterns and many other items. The inside gears are of a type that has been almost automatically standardized through their use for probably 9 or 10 years.

I move that the report be approved for adoption as S. A. E. Recommended Practice.

[The motion was seconded and carried.]

(2) STORAGE-BATTERY TRAY TERMINALS
(Electric Vehicle Division)

THE DISCUSSION

R. S. BURNETT:—As no members of the Division are here I will present the report. This work was started some time ago and is a considerable refinement of the original report which was in complete detail. The proposal includes the dimensions required for interchangeability for the three sizes of terminal and lug which it is believed will be sufficient for all general requirements.

There are two corrections to be made in the report as printed. Dimension E should be from the cable end of the lug to the center-line of the slot in the lug instead of to the end; and in the table, dimension E for the 0000 size should be 2⅝ instead of 2-5/16 in.

I move that this report be approved for adoption as S. A. E. Recommended Practice.

[The motion was seconded and carried.]

(3) FLYWHEELS AND FLYWHEEL HOUSINGS
(Engine Division)

THE DISCUSSION

MR. BURNETT:—This report should include limit dimensions 2.0472 to 2.0480 in. for the pilot-bearing bore in the flywheel which have been approved by the Division. The present standard gives only the dimension 2.0472 in.

R. J. BROEGE:—I move that this be approved for adoption as an extension of the present S. A. E. Standard.

[The motion was seconded and carried.]

(4) ENGINE REAR-SUPPORT ARMS
(Engine Division)

THE DISCUSSION

MR. BROEGE:—I move that the report be approved for adoption as a revision of the present S. A. E. Standard.

[The motion was seconded and carried.]

(5) HEAD-LAMP DOORS
(Lighting Division)

THE DISCUSSION

C. A. MICHEL:—I move that the report be approved for adoption as S. A. E. Recommended Practice.

[The motion was seconded and carried.]

[This report was discussed again following its approval by the Standards Committee's vote, but remained as approved.]

B. M. SMARR:—The majority of the Sub-Division appointed to report on this subject was in favor of abandoning the bayonet type of head-lamp doors but could not make a report. In the Lighting Division we were able to make a definite decision against the bayonet type of door. The report as printed says that the bayonet type of door is permitted. We tried to make a distinction between the bayonet and the rotating types of door, ruling against the former and permitting the latter.

C. E. HEYWOOD:—The meaning of the report might be more definite if the word "conventional" in the second line of the last paragraph was omitted. As the report reads it might be considered as meaning that the rotating type is really a bayonet type of door.

PRESIDENT H. M. CRANE:—I think it will be very regrettable if we attempt to use the Standards Committee to approve or disapprove any particular form of design or construction. There is no limit to what we can try to do if we standardize from that point of view. I am not advocating the bayonet or any other type of door. I do think, however, that the present head-lamp equipment on the cheaper cars is bad beyond belief, but I do not think it is entirely a matter of design. One car that I have operated had a bayonet type of door that was pretty handy to operate.

G. S. CASE:—Does this report include any real standardizing?

MR. BURNETT:—This is one of the more difficult problems that we have been asked to consider, being largely an outgrowth of a request by the motor-vehicle administrators of several States to do something definite toward improving head-lamp construction.

PRESIDENT CRANE:—I do not believe the Society should attempt to solve this kind of problem for the motor-vehicle administrators. It reminds me of the request we had to standardize the motor truck and define what is a 2-ton and what is a 3-ton truck. I am thoroughly convinced that we cannot accomplish it.

If this report included dimensional standards for interchangeability, I would favor it; but as it is simply an attempt to censor the design and construction of lamps on automobiles, I think it is wrong.

CHAIRMAN E. A. JOHNSTON:—It seems to me that much of this discussion would have been to better advantage before we voted on this report.

MR. BURNETT:—Unless we can get frank and full discussions on the reports at this meeting, reports regarding which questions are raised are bound to be held up later by the letter ballot of the Society's members.

I would like to have the members who are familiar with this subject discuss it thoroughly here and hold up this report if necessary because it will save considerable time and trouble if we can clear up these questionable reports at the meetings of the Standards Committee.

L. C. PORTER:—I believe the general public has difficulty in operating the present types of lamp door on their cars. I have known of many cases where car-owners have tried to get the lamp doors off to replace the bulbs or focus the lamps and have been unable to do so. This indicates that something is radically wrong with many present lamp-door designs. Whether the matter involves a question of policy, or whether the motor-vehicle administrators want us to standardize designs, I think they are right in trying to in some way bring about the use of better equipment and greater ease of operation. I think that the Division has made a good start in this matter and that the recommendation should stand as approved.

(6) HEAD-LAMPS
(Lighting Division)

THE DISCUSSION

MR. MICHEL:—The present standard maximum mounting height for head-lamps on all vehicles is 42 in. Some of the motor-truck manufacturers have had trouble in mounting their head-lamps as low as 42 in. because they wish to mount them back from the front end of the truck. Motorcoach manufacturers also have experienced considerable trouble in mounting their head-lamps and it is therefore recommended that the 42-in. mounting height be restricted as applying to passenger cars only. There is a Sub-Division now working on the problem to determine upon a recommendation for motortrucks and motorcoaches.

I move that the report be approved for adoption as a revision of the present S. A. E. Recommended Practice.

[The motion was seconded and carried.]

(7) WROUGHT ALUMINUM BRONZE
(Non-Ferrous Metals Division)

THE DISCUSSION

MR. BURNETT:—I move that this report be approved for adoption as a revision of the present S. A. E. Standard.

[The motion was seconded and carried.]

(8) DOOR HINGES
(Passenger-Car Body Division)

THE DISCUSSION

MR. CASE:—The Sectional Committee on Bolt, Nut and Rivet Proportions, which is sponsored by the American Society of Mechanical Engineers and this Society, has a tentative standard on the included angle of the countersink, the limits being, as I recall, 80 and 82 deg. I know that is present practice. Seventy-eight degrees, which has been suggested, is the old rivet standard, but I think the minimum of 80 deg. should be adopted in this report.

E. H. EHRMAN:—I think the nominal included angle of the countersink should be 80 deg., which is the minimum angle for flat-head screws or bolts, and will make the bolt or screw heads set on the bearing edge and not at the hole.

W. J. OUTCALT:—I think the angle should be from 80 to 82 deg.; also that the diameter of the hole that is now 0.438 in. should be 7/16 in.

MR. CASE:—I move that this report be approved for adoption subject to correction of the countersink both as to minimum angle and diameter, to agree with the tentative Sectional Committee report on wood-screw heads.

[The motion was seconded and carried.]

(9) STORAGE-BATTERIES
(Storage-Battery Division)

THE DISCUSSION

W. E. GOSSLING:—I move that the report be approved for adoption as an addition to the present S. A. E. Standard.

[The motion was seconded and carried.]

(10) GAGING OF CASTLE-NUT SLOTS
(Screw Threads Division)

THE DISCUSSION

MR. EHRMAN:—A slight revision should be made in the text beginning in the sixth line of the descriptive paragraph so that it will read: "owing to differences of bore due to drilling and to tapping of the nut."

This report specifies a simple means for gaging the useability of cotter-pin holes in bolts and cotter-pin slots in nuts that has been tried out in practice and has served its purpose very well.

I move that the report be approved for adoption as S. A. E. Recommended Practice.

[The motion was seconded and carried.]

(11) Tap-Drill Reference Tables
(Screw Threads Division)

THE DISCUSSION

Mr. Ehrman:—Table 1 is a proposed list of standard tap-drills for general commercial purposes.

Tables 2 and 3 might be more precisely named if the captions were changed to read, "Reference Table—Minor Diameters—Basic, maximum and minimum, with nearest drill sizes available." These two tables are for reference purposes only with relation to tap drills for the standard series of coarse and fine threads. The Division is ready to offer a third series covering the S. A. E. Extra Fine Threads.

A few typographical errors and some slight revisions should be noted and these will be made before the report is printed in the S. A. E. Handbook.

With reference to Table 1, the whole series has been worked out within the limits specified in the report of the Sectional Committee on Screw Threads.

All important points bearing on the selection of the drill sizes have been taken into account in the formulation of these tables, which will, I believe, meet general requirements in practice.

A. W. Reader:—The 5/8-18 size should be included. Since the S. A. E. Standard for bolts and nuts includes 1½ in. I would suggest that this size be added to have the tables and standards consistent.

The larger holes might be reamed instead of drilled and I therefore suggest that such sizes be indicated by a footnote.

Mr. Ehrman:—When these tables are made more complete in accordance with the suggestions just made, is it the wish of the Standards Committee to include the S. A. E. Extra Fine Thread tables and to extend the reference tables to include the 3-in. diameters to conform to the American Standard tables?

I move that the report, including the changes and extensions recommended here today, be approved for adoption as General Information.

[The motion was seconded and carried.]

(12) Application of Screw-Thread Fits
(Screw Threads Division)

THE DISCUSSION

Mr. Ehrman:—The Screw Threads Division has made a survey of all of the various screw threads specified in S. A. E. Standards and Recommended Practices. Some threads in the standards are of special pitch with reference to diameter, but these are to be reported later on.

Mr. Case:—Is it intended to give all the tolerance dimensions for each thread in all the standards listed or to refer only to the class of fit?

Mr. Burnett:—Only to give a reference to the class of fit. Where such a reference is made to a series of screw threads in the several standards, the complete dimensions will be found in the S. A. E. Standard for Screw Threads in the S. A. E. Handbook, which is complete.

Mr. Outcalt:—It seems to me that the report is inconsistent with regard to the code letter *N* being used to denote American Standard. The standard taper pipe thread is referred to as American Standard while the letter *N*, meaning National, is used in this report.

I think it should be changed to American, using the code letter *A*.

Mr. Burnett:—This question of nomenclature has, I understand, been thoroughly considered by the Sectional Committee and the National Screw Thread Commission, which have not included pipe threads in their reports.

Mr. Outcalt:—The point I want to bring out is that the Society was one of the sponsors for the Sectional Committee and yet we are proposing something that is different from a previously adopted report.

Mr. Case:—This matter has been discussed by the Sectional Committee to the extent of very many more hours than it seemed to me was worthwhile.

The tentative standards for screw threads were issued by the National Screw Thread Commission before the Sectional Committee was active in this work. The report was published and widely distributed by the Commission as the proposed national standard, the Commission having been authorized by Congress for that purpose.

The Sectional Committee then took over the report of the Commission and after modifying it somewhat adopted it as standard. The Commission's report was later revised to agree with the Sectional Committee's report. It has been customary for the standards of Sectional Committees to be known as American standards although there may be some exceptions.

In this case, as the data have been widely distributed as the National Standard it was thought that it would only confuse the matter to introduce the word American and after numerous discussions it was left as National and is so published here. Although I am a member of the Commission and the Sectional Committee, it never seemed to me a matter of much importance.

Mr. Burnett:—As a matter of information, two representatives each that were appointed by the Society and the American Society of Mechanical Engineers comprised the civilian representation on the National Screw Threads Commission.

Mr. Ehrman:—I move the approval of this report for adoption in revision of the standards listed in the report.

[The motion was seconded and carried.]

(13) License-Plate Bracket Slots
(Parts and Fittings Division)

THE DISCUSSION

H. S. Jandus:—I move that the report be approved for adoption as S. A. E. Standard.

[The motion was seconded and carried.]

(14) Flexible Discs
(Parts and Fittings Division)

THE DISCUSSION

Mr. Jandus:—I move that the report be approved for adoption as an addition to the present S. A. E. Recommended Practice.

[The motion was seconded and carried.]

(15) Compression-Type Tube Fittings
(Parts and Fittings Division)

THE DISCUSSION

Mr. Outcalt:—Two things in particular in this report I think should be changed. The 17/32-24 thread for the 3/8-in. size and the 19/32-24 thread for the 7/16-in. size are odd, and should be changed to 9/16-24 and 5/8-24 respectively to conform with the Screw Thread Standards.

I also think the dimensions *O* and *Q* for the 7/16-in. size, which read 27/32 and 29/32 in. respectively, could be changed to even sixteenths.

B. B. Bachman:—I question also the 11/16-20 thread which it seems to me is outside of any public standard that I know of. I also question the amount of stock from the bottom of the threads to the counterbore of the fittings which is shown as dimension *I*.

The report also seems to specify a relatively large number of hexagon sizes differing within this list as well as differing from those already established in the flared tube sizes that we now have. This brings up the point of whether proper consideration has been given to the wrench situation as ordinarily found in a tool kit, and whether the dimensions that are included in the report are not an incentive for the use of pliers.

Mr. Jandus:—I believe the sizes listed in the report are somewhat of a compromise between those of the various manufacturers. While they do not represent a perfect service, probably they are the best that could be arrived at in view of existing circumstances.

President Crane:—Are we adopting a unified set of sizes of article in common use today or are we trying to design new ones? If we are going to design new ones, we would do it from an entirely different point of view than if we were attempting to bring a little order out of a more or less chaotic condition at the present time. If we are standardizing what is already in use, it might be better to leave out any sizes that are not in extensive use at the present time.

These fittings are evidently made of the smallest amount of material to produce the result, which is a very commendable thing, but if we are bringing out any new sizes or types, their utility also ought to be considered. It might be desirable to have a second series of fittings in which utility is given a greater consideration, and eventually allowing the manufacturers and public to decide between the two types. In other words, we would approve the best compromise on the existing type and ask the Division to lay out another set of a heavier, stronger, and more easily serviced design.

I feel hopelessly at sea when it comes to redesigning a table like this in a Standards Committee meeting. I do not see how any one can do it and know what they are doing. If any figures are to be changed in this report, that mean more than clerical corrections, the report had better be referred back to the Division.

Mr. Ehrman:—Are some of the larger sizes that have apparently been more recently added to the list new enough to stand a little further revision along the lines suggested by Mr. Outcalt and others? If such is the case, we could pass upon the smaller sizes that are merely a unification of present practice and leave two or three of the larger sizes for further consideration. This would avoid holding up the entire report and allow of some progress by accepting those that are clearly unifications of present practice.

Mr. Outcalt stated that the 17/32-24 thread is used by some and 9/16-24 by others, showing that a division of practice exists which might warrant not adopting that size of fitting at this time.

President Crane:—I did not propose to return the whole report to the Division but only such parts of the report as are subject to design changes. If the Standards Committee thinks the designs are not satisfactory let us withdraw the sizes that need changes in design and pass the rest of the report.

Mr. Outcalt:—When this report was first presented, the thread diameter was 9/16-24 but was changed later.

I move that this table be approved for the 1/8 through and including the 3/8-in. sizes, changing the thread size from 17/32-24 to 9/16-24 and referring the 7/16 and 1/2-in. sizes back to the Division.

Mr. Case:—It seems to me it is unwise to change that figure. A note under the table reads "A short flat will appear on the sleeves for the 1/4, 5/16 and 3/8-in. sizes as a result of the stock diameters selected." Apparently, if we change the 17/32-in. diameter it will be necessary to change some other dimensions.

We should either pass them as they are or else refer the entire report back.

Mr. Outcalt:—The only reason for specifying the 17/32-in. diameter is to take care of stock that is distributed among the jobbers and dealers.

Mr. Case:—I move as an amendment to Mr. Outcalt's motion to approve the report up to and including the 5/16-in. size and refer back to the Division the 3/8-in. and larger sizes.

Mr. Outcalt:—I accept the amendment.

[The amended motion was seconded and carried.]

Attendance at Meeting

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

A. H. Ackerman	J. H. Hunt
Azel Ames	H. S. Jandus
B. B. Bachman	E. J. Janitzky
A. Boor	E. A. Johnston
C. C. Bowman	B. M. Leece
R. J. Broege	G. C. Mather
E. J. Bryant	C. A. Michel
O. M. Burkhardt	A. J. Neerken
R. S. Burnett	W. M. Newkirk
R. J. Burrows	S. V. Norton
G. S. Case	W. J. Outcalt
L. A. Chaminade	L. C. Porter
C. F. Clarkson	A. W. Reader
H. M. Crane	J. E. Reid
W. V. DeGalan	L. P. Saunders
W. E. Dunston	A. J. Scaife
H. H. Edge	M. H. Schmid
E. H. Ehrman	B. M. Smarr
R. N. Falge	W. R. Strickland
L. C. Fuller	P. L. Tenney
D. E. Gamble	R. H. Upson
G. Walker Gilmer, Jr.	W. C. Ware
E. W. Goodwin	E. E. Wemp
W. E. Gossling	S. O. White
C. E. Heywood	F. A. Whitten
F. C. Hubley	G. A. Young

Society Members and Guests

L. L. Baker	R. W. Gibson
C. E. Banta	H. L. Horning
Donald Blanchard	W. L. Kaiser
S. H. Caldwell	R. R. Keith
C. S. Collinson	O. A. Parker
R. W. Daniels	J. A. C. Warner
W. H. Fenley	C. B. Whittelsey

W. E. Williams

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RESEARCH ACTIVITIES IN 1924

The Department's Cooperative Work with the Research and Highways Committees

The 1924 activities of the Research and Highways Committees with whom the Research Department cooperates may be said to comprise the following divisions: major projects, miscellaneous activities and routine work. An enumeration and a brief discussion of the items that compose these three divisions should be of interest at this time in a survey of the work of the past year.

The major projects deal with investigations relating to highways, fuels and riding-qualities.

HIGHWAYS

The highway research, an investigation of motor-truck impact, under the direction of the Highways Committee, B. B. Bachman, chairman, is pursued in cooperation with the Bureau of Public Roads and the Rubber Association of America. The work during the early part of the year was devoted principally to studying instrumentation, determining what ought to be measured and how and selecting suitable instruments. Considerable progress has been made on the motor-truck impact tests, and the results obtained therefrom were outlined in a report presented by C. A. Hogentogler in December, 1924, at the annual meeting of the Highway Research Board of the National Research Council. This report appeared in the January, 1925, issue of THE JOURNAL, p. 21.

FUELS

The cooperative fuel research program has been continued throughout the year. The research work has been carried on at the Bureau of Standards. The other bodies cooperating in the investigation are the American Petroleum Institute and the National Automobile Chamber of Commerce. An important phase has been the stimulating contact of the participating organizations, one with another.

The work of the past year has resulted in the development of a satisfactory method for *measuring dilution*, the statement of a reasonable explanation of the *mechanism of dilution* and the establishment of much additional information relating to the factors that influence the *rate of dilution*.

The investigation has substantiated the conclusions that under average operating conditions crankcase-oil dilution (*a*) depends primarily on the average temperature of the cylinder-walls, (*b*) is likely to reach an equilibrium value if starting periods are not too frequent, (*c*) depends directly on fuel volatility, (*d*) depends directly on the average fuel-air ratio, (*e*) does not depend much upon the piston temperature and (*f*) does not depend much upon the charge temperature or the degree of vaporization.

A progress report covering these points was prepared by Dr. H. C. Dickinson and S. W. Sparrow and presented in December, 1924, at the annual meeting of the American Petroleum Institute by H. K. Griffin, who also read a paper by T. S. Sligh, Jr., of the Bureau of Standards, on the measurement of crankcase-oil dilution by the vacuum distillation transition method. Mr. Sligh's paper was printed in the January, 1925, issue of THE JOURNAL, p. 17.

In accordance with the wishes of the Research Committee, the attention of Committee D-2 of the American Society for Testing Materials has been called to the need for a practical and precise method for crankcase-oil dilution evaluation, and details concerning the transition method have been transmitted to that committee for its careful consideration in determining the method most suitable for adoption.

Another paper read at the annual meeting of the American Petroleum Institute was one entitled Automotive Fuel Observations that was prepared in the Research Department.

Progress reports of the fuel research have been published during the year in THE JOURNAL in the following papers: Winter Tests Show Greater Dilution with a Heavy Fuel, by John A. C. Warner, February, 1924; Economic Motor-Fuel Volatility, by Roger Birdsell, March, 1924; and Factors Affecting the Rate of Crankcase-Oil Dilution, by J. O. Eisinger, July, 1924.

RIDING-QUALITIES

An investigation of the many factors influencing the riding qualities of automotive vehicles was initiated in January, 1924, and a symposium to discuss the subject was held in Detroit during the Annual Meeting of the Society. Accounts of this meeting appeared in THE JOURNAL, February, 1924, p. 254, and March, 1924, p. 335. The year's work on this problem embraces the accomplishment of the necessary preliminary work and the appointment of a Riding Qualities Group of the Research Committee to formulate plans for future research. The preliminary work included: the holding of interviews with psychologists and physiologists as well as with engineers interested in the project, by whom many interesting ideas have been suggested; a survey of technical literature from which has been obtained a view of what has hitherto been attempted or accomplished in this connection; the presentation of a paper, at the Summer Meeting, summarizing work thus far done by other organizations, describing instruments and methods, and suggesting lines of suitable attack; and the compilation of a bibliography covering 18 factors that enter into the riding qualities problem. This bibliography contains over 500 references, more than 100 of which have been abstracted briefly.

In addition to the three major projects just discussed, several miscellaneous activities have engaged the attention of the Committee.

SULPHUR IN FUELS

Early in 1924 a Fuels Group was appointed as a division of the Research Committee to cooperate with the Research Department on matters relating to fuels. The most important question thus far studied by the Fuels Group has been an investigation of the effects of sulphur in fuels, with a view to obtaining recommendations on the proper maximum allowable content for satisfactory gasoline. The attitude of the industry as regards the allowable sulphur-content included in Government fuel specifications has been sought through a questionnaire and through personal conferences and interviews. A number of companies reported that they possessed no information upon which they could base their conclusions intelligently. The Group does not feel justified at this time in recommending the reduction of the amount that is allowed by the Government specifications, but additional study is being devoted to this matter.

VARIOUS PHASES OF THE DILUTION PROBLEM

Another matter that has been under consideration is a proposal that the Research Committee sponsor a project calculated to determine the importance of various factors that enter the general problem of crankcase-oil contamination. The criterion which should determine the frequency of changing crankcase oil is involved, and it is believed that the topic is of wide-spread interest and that it should be investigated in a practical and thorough manner. The Committee now has under consideration plans for this work.

Interest has been expressed by the Committee in a proposal that was submitted relative to the simpler methods for crankcase-oil dilution evaluation that may be used by service-men and others for rough determinations. Helpful suggestions in this regard have been obtained.

As the result of an effort to ascertain the views of the industry regarding the danger-point of dilution, the frequency of changing crankcase oil and other phases of the dilution problem, answers were obtained from 26 engineers, representing as many prominent firms of the industry, who very kindly presented conclusions based upon their experience. A summary of their statements was published in THE JOURNAL, August, 1924.

GEARS

The possibility of doing some research with reference to gears has been brought to the attention of the Committee; and, with a view to obtaining opinions on the subject from both automobile men and gear men, a gear dinner meeting was arranged which took place in Detroit at the time of the Society's Production Meeting. The interesting ideas brought out at the dinner were presented in a brief account of this meeting which was published in the November, 1924, issue of THE JOURNAL, and in a more detailed report of it in the January, 1925, issue.

SAFETY CODE FOR BRAKES

A Sectional Committee on a Safety Code for Automobile Brakes and Brake Testing has been organized under the procedure of the American Engineering Standards Committee. The Research Department, representing the Society, has participated in all preliminary work required for the formulation of a tentative code, and has arranged for Society representation on the Sectional Committee besides actively participating in meetings and reporting them to the Society through the medium of THE JOURNAL. An account of the meeting of the Sectional Committee appeared in the January, 1925, issue.

TRAVEL

Approximately one-fourth of the time of the Research Manager has been devoted to travel, for the purpose of attending committee and other meetings, discussing research projects with the members of the Society, obtaining information on various engineering problems and imparting information requested by members.

AUTOMOTIVE COURSES OF STUDY

With a view to having available correct and up-to-date information concerning the educational facilities in automotive work in universities and colleges throughout the Country as well as in vocational schools, catalogs and other descriptive literature have been obtained from as many educational institutions as possible. This material has been analyzed to show the maximum of information about automotive courses that are being offered, and it is planned to present the results of this analysis in THE JOURNAL at an early date.

CONTRIBUTIONS TO THE JOURNAL

Copy contributed by the Department to THE JOURNAL during 1924 has amounted to *more than* 250 *columns*, comprising two papers, 46 columns of Automotive Research, 55 columns of reports of meetings and 111 columns of Notes and Reviews. Eleven items for Chronicle and Comment are not included in this figure. Besides material published in THE JOURNAL, a leaflet telling about the services of the Department to Society members was written and distributed last summer.

INFORMATION SERVICE

The Information Service is a very interesting activity of the Department. In this connection, 100 technical and trade journals are perused each month, and a card-index file is kept that makes more readily available the outstanding articles in current technical literature. A Technical Information file contains much material of value in the form of reports and clipped material. More than 3000 letters were written in the Department during the year; of these, approximately 1000 were in connection with the Information Service. Other information was given by the Department in personal interviews and in telephone conversations.

PERSONNEL OF COMMITTEES AND GROUPS FOR 1925

The following constitute the membership of the Research Committee and the Highways Committee for the coming year, as well as the Fuels Group and the Riding-Qualities Group of the Research Committee for the same period:

RESEARCH COMMITTEE

H. C. Dickinson, *Chairman*

H. W. Alden	T. J. Lítle, Jr.
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A RIDING-QUALITIES BIBLIOGRAPHY

Loose-Leaf Book, Containing More Than 500 References, Available to Members

A bibliography, prepared by the Research Department as part of the preliminary work on the riding-qualities investigation, has been printed and is available for members who desire a copy. Although the references center around the problems connected with riding-qualities, a great many topics are necessarily included because of the number of elements involved in the study of riding qualities.

The 534 references that compose the bibliography are divided into 18 sections as follows: balance, body, brakes, chassis, engine and transmission, instruments, methods of test, psychological and physiological, riding comfort, roads, seating, shock-absorbers, springs, steering-gear, tires, torque, vibration and wheels.

The articles listed in the section on Instruments have been briefly abstracted and are grouped in the following subdivisions: accelerometers, decelerometers, impact, integrator, miscellaneous, oscillation, photographic, profilometer, roll, torsion and vibration.

The loose-leaf form was adopted in the preparation of the bibliography to facilitate the insertion of additional material. It will, therefore, be possible, with the minimum of effort, both to keep the present topics up to date and to add new topics when desired. The size and the form of the sheets were chosen with a view to their suitability for insertion in a regulation binder.

In accordance with the announcement made at the Research Session of the Annual Meeting, the whole bibliography or any portion thereof will be sent to members who will express their desires by writing to the Research Department.

Measurement of Engine Vibration Phenomena

By C. E. Summers[1]

Annual Meeting Paper — *Illustrated with* Photographs and Drawings

ABSTRACT

SMOOTH operation of motor cars becomes increasingly important as average driving-speeds become higher and as the public demands greater luxury and freedom from vibration. An analysis of vibration shows that it is caused by forces which can be calculated with considerable accuracy. Vibration itself is very complex, due to the inter-relation of forces, deflection and periodicity in the parts of the engine. In this paper a number of indicating and recording instruments devised for recording the actual resultant vibration and determining its exact character, are described and their operation explained. Vibration due to unbalance of rotating parts, piston unbalance inherent in four-cylinder engines, bending of the crankshaft, centrifugal force and torsional periods are discussed. Indicator-diagrams of the various kinds of vibration are shown.

Unbalanced force and elastic reaction are the two general causes of vibration. The former includes static and dynamic unbalance of reciprocating and rotating parts, while elastic reaction includes bending and twisting of the crankshaft and crankcase caused by centrifugal forces of unopposed masses and uneven turning-effort. The amplitude and frequency of torsional vibrations can be calculated from indicator-diagrams made by the new instruments. Half of all vibration in motor cars is due to simple unbalance of rotating and reciprocating parts and as much care should be given to balancing pistons, connecting-rods, flywheel and clutch as to balancing the crankshaft. Four-cylinder engines are inherently unbalanced and when the vibration impulses come into step with the natural period of the chassis on its springs, a period

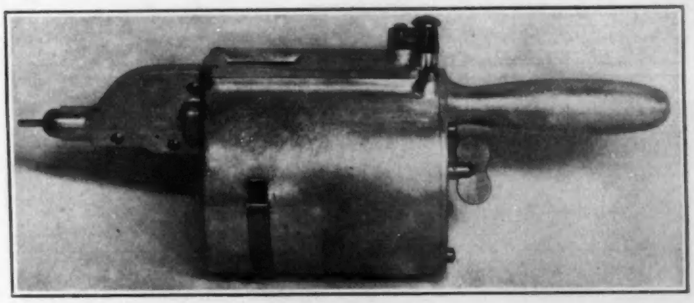


Fig. 1—Vibration Recording Instrument

This Instrument, Which Is Capable of Following with Accuracy Vibrations up to 300 per Sec., Has Been of Value in Measuring the Vibration of Various Parts of a Motor Car

[1] Special problems section, General Motors Research Corporation, Dayton, Ohio.

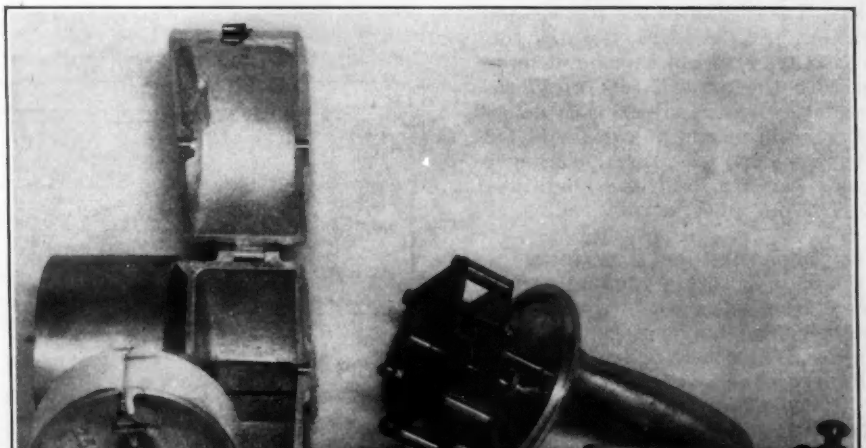


Fig. 2—The Component Parts of the Instrument Illustrated in Fig. 1

In Measuring the Vibration of Any Object the Plunger Is Held against the Object, the Motion Imparted to the Plunger Being Multiplied Seven Times in Its Transmission to a Brass Needle That Makes Contact with a Strip of Chemically Treated Indicator Paper and Traces Thereon a Record of the Vibration under Consideration. The Paper Is Carried by a Governor-Controlled Spring-Driven Drum That Rotates One Revolution at a Uniform Speed when Tripped by the Operator. The Indicator-Card Therefore Shows a Space-Time Chart of the Vibration Together with Its Amplitude, Frequency and Wave Character

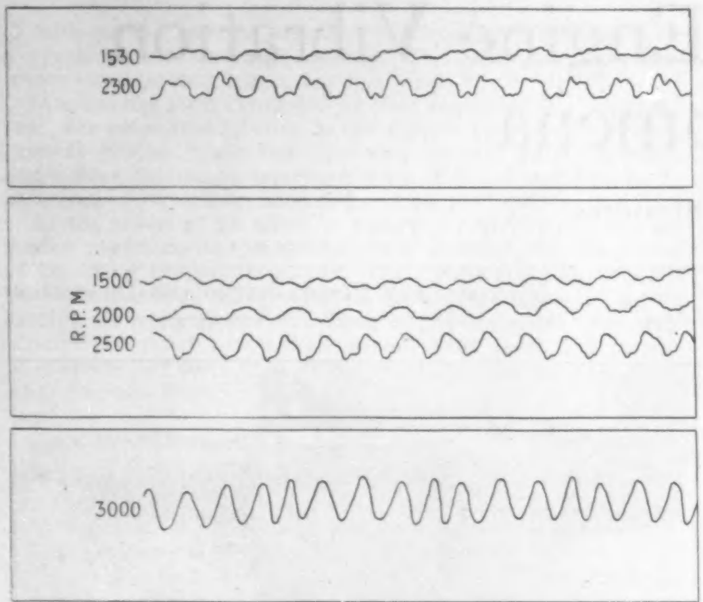


FIG. 3—GROUP OF RECORDS MADE BY THE INSTRUMENT
These Indicator-Cards Show the Lateral Vibratory Deflection at the Middle of a Crankcase for Different Speeds

of large amplitude results. In an engine operated at full load and slow speed, explosion pressure causes downward deflection of the crankshaft, and this effect is practically doubled when detonation occurs. Centrifugal forces, although balancing one another, are in different planes and introduce bending stresses in the shaft which are transmitted to the crankcase. Deflection caused by the dynamic centrifugal force is twice that caused by equal static force. The crankcase has its own period of vibration and bending increases as the square of the speed, so that it becomes significant only at the higher speeds.

The crankshaft tends to wind and unwind under intermittent turning-efforts, the degree varying with the stiffness of the shaft, the inertia of the pistons and the mass of the flywheel. It therefore vibrates torsionally at a definite frequency which, at some definite speed, falls into step with the natural rate of vibration of the shaft assembly. When the period is determined for one rate of rotation, it can be calculated for all other speeds. The frequency of vibration ranges from 180 to 250 cycles per sec. and the amplitude ranges from 0.01 to 0.03 in. at crankpin radius at normal speeds.

It is not desired to emphasize the importance of vibration unduly, as the most smoothly running engine may not be entirely free from vibration in some of its forms and even a rough engine may not be seriously objectionable to its owner. However, undue vibration must be overcome and progress is being made by a better understanding of its causes, so that eventually an engine that is free from vibration may be more cheaply built than one in which vibration occurs.

DEMAND for smoothness in motor-car operation is one phase of the broader requirement on the part of the automobile buying public for greater all-round refinement of the product. The higher average driving speed which has come as a result of good roads has served to accentuate engine vibration as an undesirable quality. Vibration is objectionable principally because it is annoying to driver and passengers. The noise produced by vibration, aside from being disagreeable, gives the driver a feeling that his engine is undergoing strain and damage, which it is to some degree. An automobile owner seldom complains of vibration to his dealer, because he realizes that it was present when the car was purchased and believes it cannot be remedied. For this reason, the sales resistance caused by a rough engine is sometimes underestimated.

Vibration of automobile engines results from two general causes. For convenience, in this paper we shall call the first *unbalanced force* and the second *elastic reaction*.

Unbalanced force includes static and dynamic unbalance of rotating parts, piston unbalance inherent in conventional four-cylinder engines and piston inertia torque. The forces involved are all capable of accurate calculation and have been presented many times. The nature of this vibration is a displacement of the engine block, which transmits the motion to the entire car.

Elastic reaction includes bending of the crankshaft and crankcase, due to the centrifugal forces of rotating masses equal but not oppositely disposed, vertical deflection of the crankshaft under piston forces, and torsional displacement of the crankshaft caused by uneven turning-effort impressed upon it by the connecting-rods. This class of vibration is developed characteristically between parts of the engine itself and affects the chassis only to a small degree. It is heard rather than felt. The quantities involved in this elastic reaction cannot be calculated with accuracy.

The complexity of the problem becomes apparent when

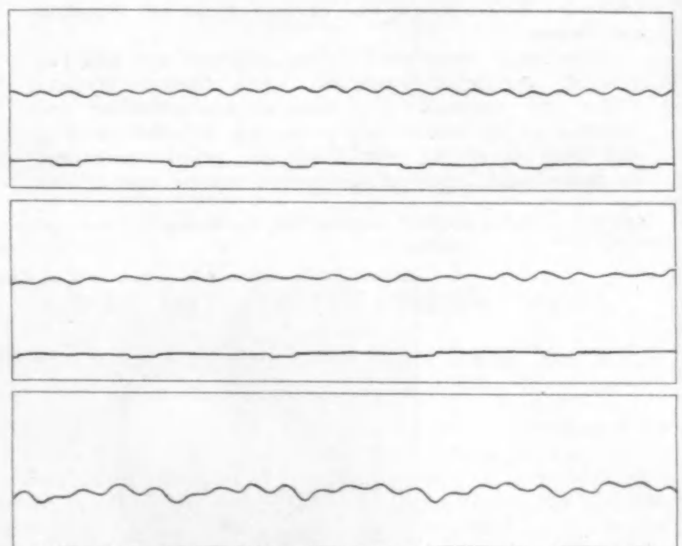


FIG. 4—ANOTHER SET OF INDICATOR-CARDS
The Vibration of Different Parts of a Car Caused by the Inherent Piston Unbalance in a Four-Cylinder Engine Is Illustrated. From Top to Bottom These Are the Vertical Movement of the Cylinder-Head, the Side of the Engine, a Point on the Fender, Another Point on the Fender and the Head-Lamp

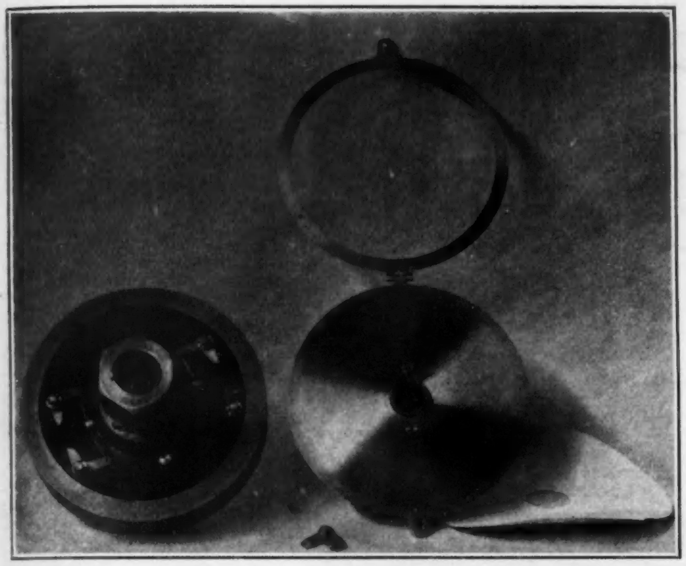


FIG. 5—TORSIONAL VIBRATION INDICATOR AND RECORDER
The Instrument Consists Essentially of a Shaft Capable of Being Coupled Rigidly to a Crankshaft, a Disc Keyed Tightly to the Shaft and a Spring-Driven Flywheel Floating upon the Shaft. With the Instrument in Position and Torsional Vibration in the Crankshaft, the Disc Vibrates with the Crankshaft and the Flywheel Rotates at a Constant Speed. The Relative Motion of These Two Members Transmits and Multiplies Itself through a System of Links to a Stylus Carrying a White Disc, the Displacement of Which Is Radial and Representative of the Torsional Vibration Multiplied by a Known Coefficient

we attempt to determine by calculation the amplitude and frequency of the torsional vibration of a given crankshaft. The solution requires an accurate pressure-volume and pressure-time indicator-diagram, the piston and connecting-rod weights, the crankshaft rigidity in bending and torsion for each section, the effective moment of inertia of the crankshaft at every pin, the relative phase of the vibration wave with respect to piston position, the piston friction, the bearing conditions and, perhaps, other data. The variables introduced in the gas-pressure characteristics caused by distribution, spark-advance and detonation may result in 100-per cent difference in the amplitude of vibration and, owing to the irregular shape of a crankshaft, its simultaneous distortion by bending and to centrifugal and torsional forces having assembled with it the rods and pistons, which vary throughout the revolution in effective moment of inertia—it is not possible to calculate the natural rate of vibration of the shaft assembly with even approximate accuracy.

NEW INSTRUMENT MAKES RECORDS OF VIBRATIONS

In beginning research work on engine vibration, it seemed necessary to design instruments which would indicate and record the character of vibration which is actually taking place in an automobile engine under the various conditions of load and speed to which it is subjected in practice. Actual measurement of the fre-

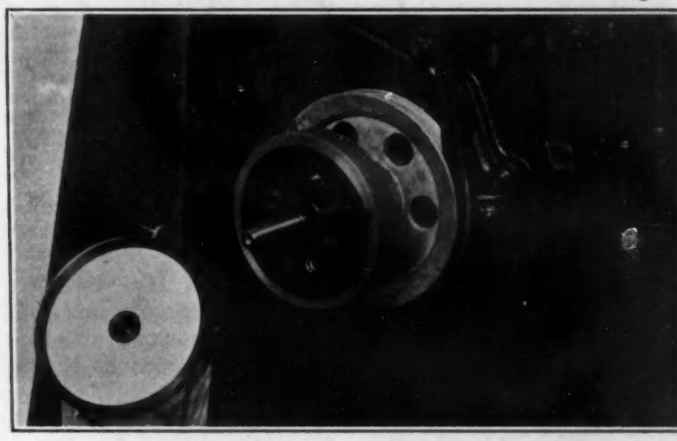


FIG. 6—THE INDICATOR IN PLACE ON THE CRANKSHAFT
This Instrument Indicates and Records the Torsional Vibration Occurring in a Crankshaft Operating Normally throughout Its Range of Speed and Load. If the Speed Is Normal and Torsional Vibration Is Absent, the Trace of the White Disc, Which Has Been Removed and Can Be Seen at the Left, Appears as a Circle. Any Torsional Vibration of the Crankshaft and Angular Displacement between the Disc and the Flywheel Cause the End of the Lever Carrying the White Disc To Move In and Out while Rotating. This Makes the Trace of the White Disc Stand Out as a Wave Curve Departing from a True Circle in Proportion to the Intensity and the Frequency of Vibration

FIG. 7—TORSIONAL VIBRATION RECORDS OF A TYPICAL FOUR-CYLINDER CRANKSHAFT
These Records Were Obtained at the Various Speeds Marked. The Middle Card in the Lower Row Shows That the Natural Frequency of Vibration Is 180 Cycles per Sec. The Loop at "1 O'clock" Brings Out the Relative Deflection Caused by the Firing in the No. 1 and No. 4 Cylinders

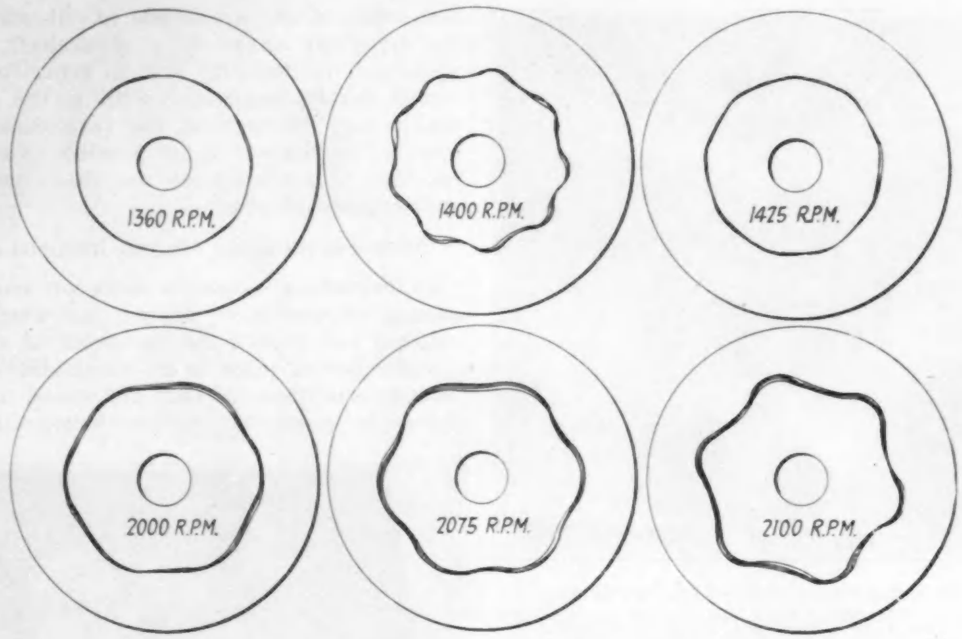


FIG. 8—ANOTHER SET OF TORSIONAL VIBRATION INDICATOR-CARDS
These Show the Second and Third Harmonic of a Fairly Rough Crankshaft at Different Speeds

quency, amplitude and wave character of the vibration not only saves doubtful calculations of these quantities but forms a convenient and accurate means for comparing different engines and various combinations in the same engine.

Fig. 1 shows an instrument which has been of value in measuring the vibration of various parts of a motor car. The instrument, shown disassembled in Fig. 2, carries a plunger which may be held against any object the vibration of which it is desired to determine. The motion imparted to the plunger is multiplied seven times in its transmission to a brass needle, which contacts with chemically treated indicator paper and leaves thereon a record of the vibration. The paper is carried by a governor-controlled, spring-driven drum, which, when tripped by the operator, rotates one revolution at uniform speed. The indicator-card, therefore, shows a space-time chart of the vibration, together with its amplitude, frequency and wave character. The instrument is capable of following vibrations up to 300 per sec. with accuracy. Sometimes it is desirable to know the relation which a certain vibration wave bears to some definite part of the cycle. In order to secure this information, the instrument is provided with a quick-acting electromagnet which operates a second brass needle bearing on the indicator-card. The winding of the magnet is connected to a battery through a contact which establishes current at some known point in the cycle, thereby shifting the brass point suddenly to make a jog in the line. From this reference line, all of the vibrations re-

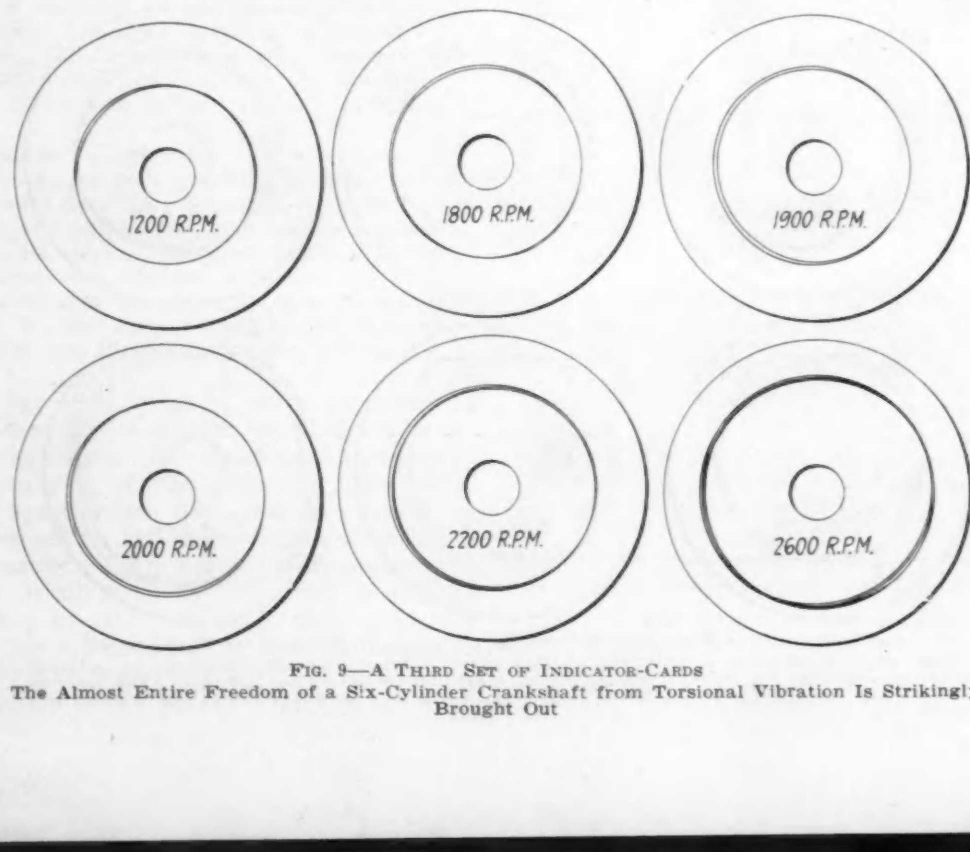


FIG. 9—A THIRD SET OF INDICATOR-CARDS
The Almost Entire Freedom of a Six-Cylinder Crankshaft from Torsional Vibration Is Strikingly Brought Out

corded can be studied in their relation to the movements of the parts of the engine. Indicator-cards made by this instrument are shown in Figs. 3 and 4.

How Torsional Vibration Is Recorded

In the study of torsional vibration, it is necessary that the instrument record the vibratory motion which is

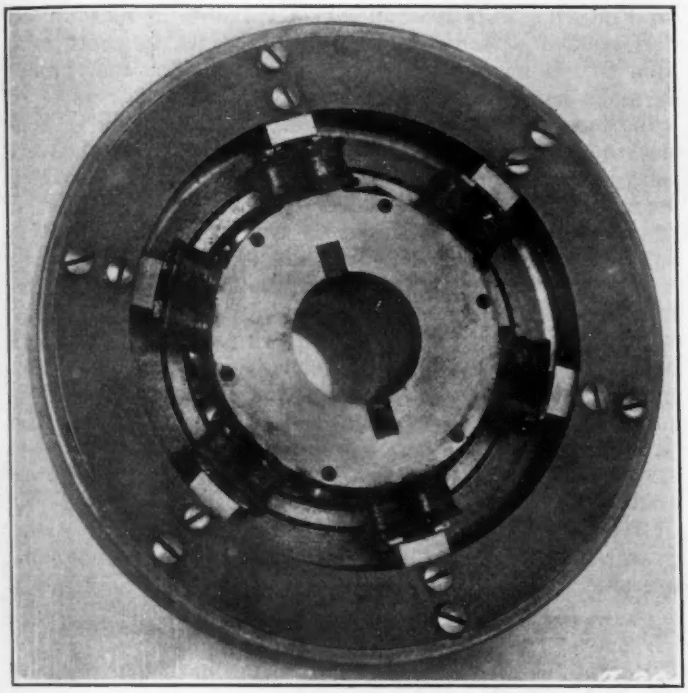


Fig. 10—An Electrical Instrument for Measuring Torsional Vibration
This Instrument Is Valuable in Making Detail Studies of Individual Vibration Waves in Their Relation to the Movements of the Pistons. Any Torsional Vibration in the Crankshaft Produces a Displacement between the Six Pairs of Windings on the Armature and the Six Poles of the Permanent Magnet, Which Induces an Electromotive Force in the Windings

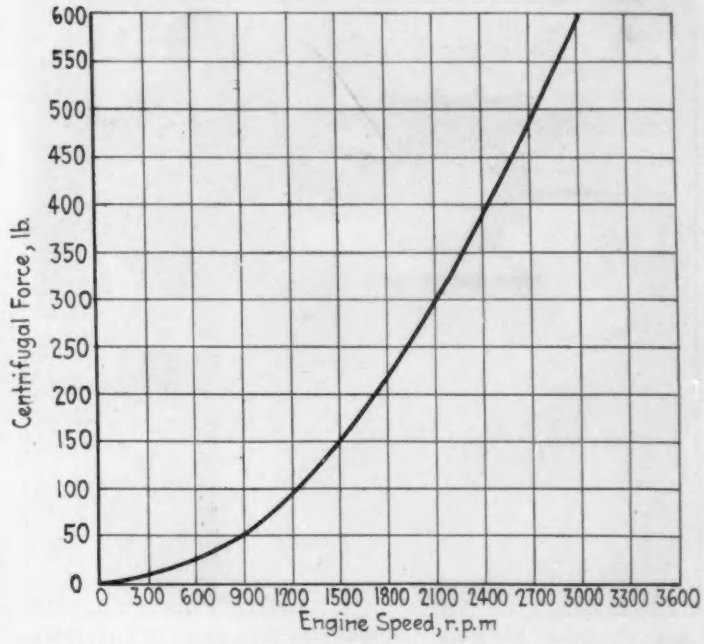


Fig. 12—Variation of the Centrifugal Force with the Speed
This Chart Shows the Centrifugal Force of 1 Lb. at a Radius of 2⅜ In. for Various Speeds of Rotation

superimposed upon the rotary motion of the shaft. Fig. 5 shows a torsional vibration indicator and Fig. 6 its installation on a test engine. This instrument indicates and records the torsional vibration occurring in a crankshaft operating normally throughout its range of speed and load. The instrument consists essentially of a shaft capable of being coupled rigidly to a crankshaft, a disc keyed tightly to the shaft, and a spring-driven flywheel floating on the shaft. With the instrument in position and torsional vibration in the crankshaft, the action of the indicator will be as follows:

The rigidly mounted disc vibrates with the crank-

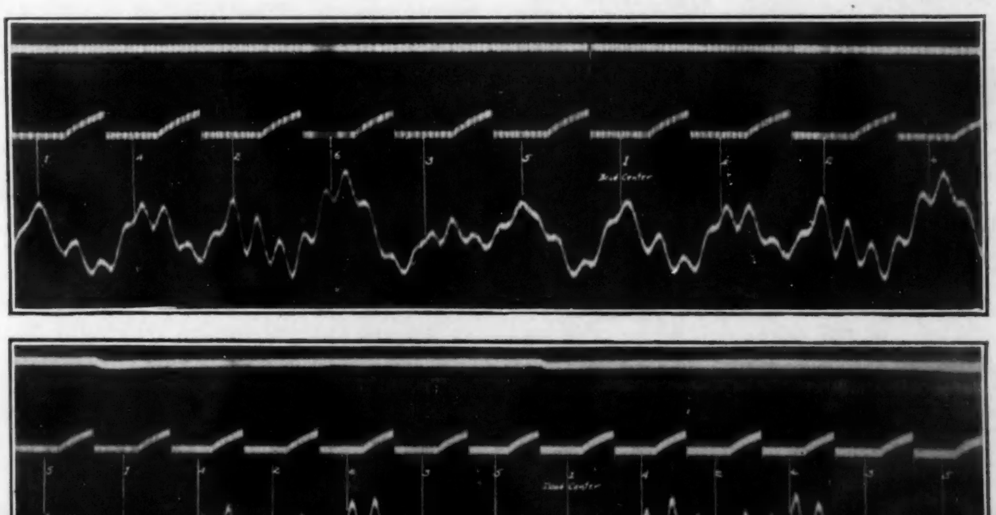


Fig. 11—Oscillogram of Crankshaft Torsional Vibration
The Armature Windings of the Indicator Illustrated in Fig. 10 Are Connected to Slip Rings and through Brushes Establish a Circuit through an Oscillograph Causing a Deflection of the Instrument, Which Is Proportional to the Current and This, in Turn, Is Proportional to the Rate of Angular Displacement between the Poles and the Windings. By Suitable Calibration Curves the Operator Can Translate the Diagram That Is Photographically Produced by This Instrument into Terms of the Frequency and the Amplitude of the Torsional Vibration

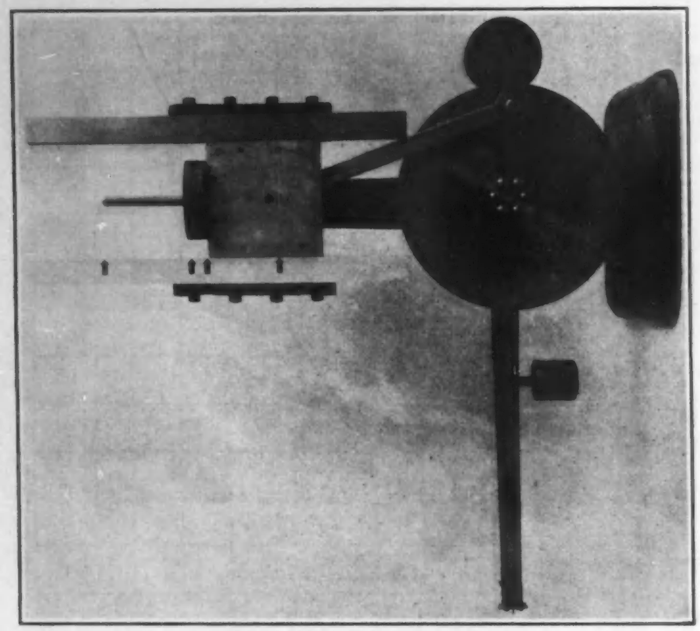


FIG. 13—MODEL SHOWING THE RELATIVE MOVEMENT OF THE PISTON AND THE CRANKSHAFT
This Shows That Approximately 58 Per Cent of the Stroke Is Accomplished in 90 Deg. of Crankshaft Revolution

shaft; the floating flywheel rotates at substantially constant speed, and the relative motion of these two members transmits and multiplies itself through a system of links to a stylus carrying a visual white disc, the displacement of which is approximately radial and representative of the torsional vibration multiplied by a known coefficient. The trace of the white disc can be seen as a circle when the engine is run at normal speed and if there is not torsional vibration. When, however, there is torsional vibration of the crankshaft and angular displacement between the disc and the flywheel, the end of the lever carrying the white disc moves in and out while rotating. Since torsional vibration is of harmonic nature, it repeats itself, making the trace of the white disc stand out as a wave curve departing from a true circle in proportion to the intensity and frequency of vibration. Frequency of vibration is the product of the number of waves and the engine speed. Amplitude of vibration is proportional to the distance between the peaks of the waves and a true base-circle. When it is desired to make permanent records of the vibration of a crankshaft in operation, an indicator-card of the specially prepared paper referred to in connection with the former instrument is brought into contact with the stylus which registers a trace. These records may be preserved for study and comparison. Typical indicator-cards made by this instrument are shown in Figs. 7, 8 and 9.

An electrical instrument for measuring torsional vibration, developed by the Electrical Section, is shown in Fig. 10. This instrument is valuable in making detail studies of individual vibration waves in their relation to the movements of the pistons. The instrument is made as follows: An armature, having six pairs of windings, is mounted rigidly on a shaft which is connected as an extension of the crankshaft. A relatively heavy brass ring, carrying permanent magnets which terminate in six poles, floats on ball bearings and is driven through weak springs. Any torsional vibration in the crankshaft results in a displacement between the windings of the armature and the poles, which movement induces electromotive force in the windings. These windings are connected to slip rings, which, through suitable brushes, establish a circuit through an oscillograph, causing a deflection of the instrument that is proportional to the current, the current in turn being proportional to the rate of angular displacement between the poles and the windings. Suitable calibration curves enable the operator to translate the diagram into terms of frequency and amplitude of torsional vibration. Diagrams, photographically produced by this instrument, are shown in Fig. 11.

PARTS OPERATING IN ENGINE NEED BALANCE

Perhaps half of all the vibration in motor cars is caused by simple unbalance, either static or dynamic, of rotating and reciprocating parts. The importance of balancing the crankshaft is generally recognized but equal care should be given to the pistons, connecting-rods, flywheel and clutch. The force due to unbalance increases as the square of the speed, causing vibration from this source to manifest itself particularly at the higher speeds. The force of a 1-lb. weight at a radius of 2⅜ in. at various speeds of rotation is shown in Fig. 12. Frequency of the vibration caused by unbalance is relatively slow, being only one cycle per revolution of the engine. If we assume any engine running at 1500 r.p.m., the rates of vibration in cycles per second due to various causes are as follows: simple unbalance, 25; piston unbalance inherent in four-cylinder engines, 50;

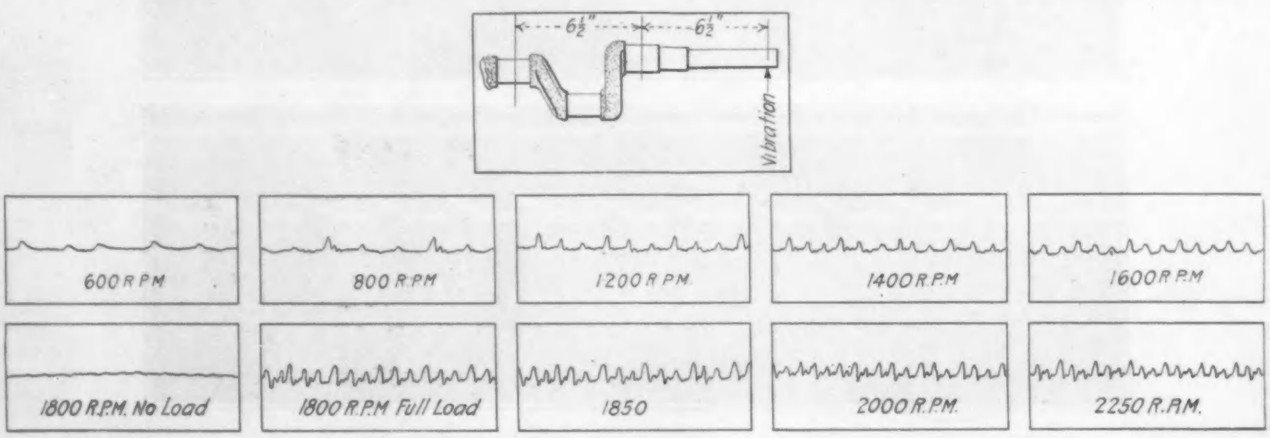


FIG. 14—INDICATOR-CARDS SHOWING THE VERTICAL DEFLECTION OF THE CRANKSHAFT CAUSED BY THE EXPLOSION PRESSURES
When an Engine Is Operated at Full Load and More Especially at Slow Speed the Explosion Pressure Causes a Downward Deflection of the Crankshaft, This Condition Varying with the Relative Sizes of the Piston and the Crankshaft, the Arrangement of the Bearings, the Compression-Pressure, the Spark-Advance and the Character of the Combustion. Measurements of This Vibration Were Taken on the Extension of the Crankshaft as Shown

piston inertia torque of a six-cylinder engine, 75; torsional vibration of the crankshaft of a six-cylinder engine, about 200. The vibration due to lack of balance, therefore, manifests itself as a quiver of the chassis, being of too low a frequency to produce an audible sound, except as it may cause loose parts to rattle or come into resonance with other vibrating parts of the car. The remedy for this class of vibration is more careful balancing.

The four-cylinder engine and, to a lesser degree, the conventional eight, are subject to a vibration caused by unbalanced piston inertia. This subject has been discussed and analyzed many times and need not be reviewed, since it is generally well understood. In the indicator-diagram shown in Fig. 4, it is noted that the vibration frequency is double the engine speed. The force due to this unbalance increases as the square of the engine speed and is the result of the inharmonic motion imparted to the piston, as illustrated by Fig. 13,

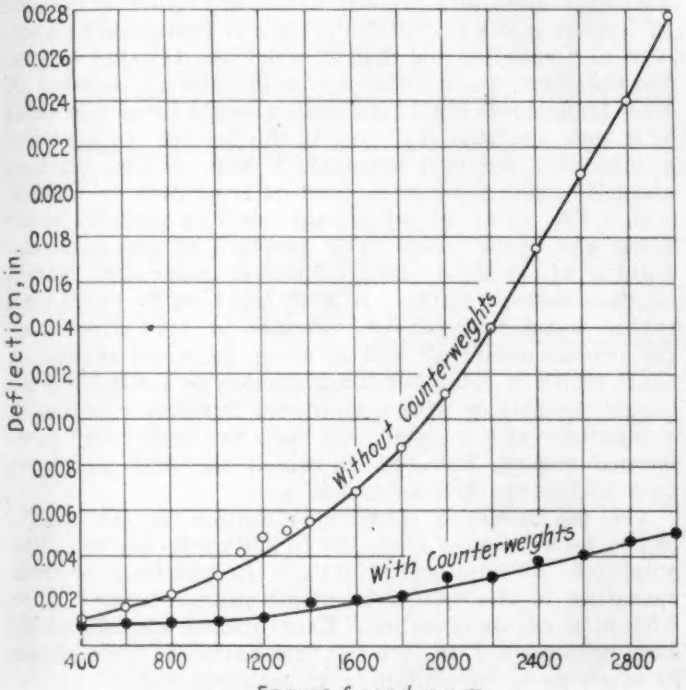


FIG. 15—MEASURED CRANKCASE DEFLECTION WITH AND WITHOUT COUNTERWEIGHTS

This Chart Shows How the Bending Strain Introduced into the Crankshaft by Unbalanced Forces Is Transferred by the Bearings to the Crankcase and the Effect of the Elimination of These Forces

which shows approximately 58 per cent of the stroke accomplished in 90 deg. of crankshaft revolution. The amplitude of forced vibration set-up in the chassis is practically constant. When, however, the vibration impulses come into step with the natural period of the chassis on its springs, a period of large amplitude results. At higher or lower speeds the force comes into interference with the natural rate of vibration, limiting movement to the relatively small forced vibration. Means commonly used to reduce or eliminate this vibration are light pistons, long connecting-rods, the generation of equal and opposite forces to cancel the vibratory forces generated in the engine, and means to prevent the vibration of the engine from being transmitted to the chassis.

Bending Stresses in Shaft and Crankcase

When an engine is operated at full load, and more especially at slow speed, the explosion pressure causes a downward deflection of the crankshaft. This condition

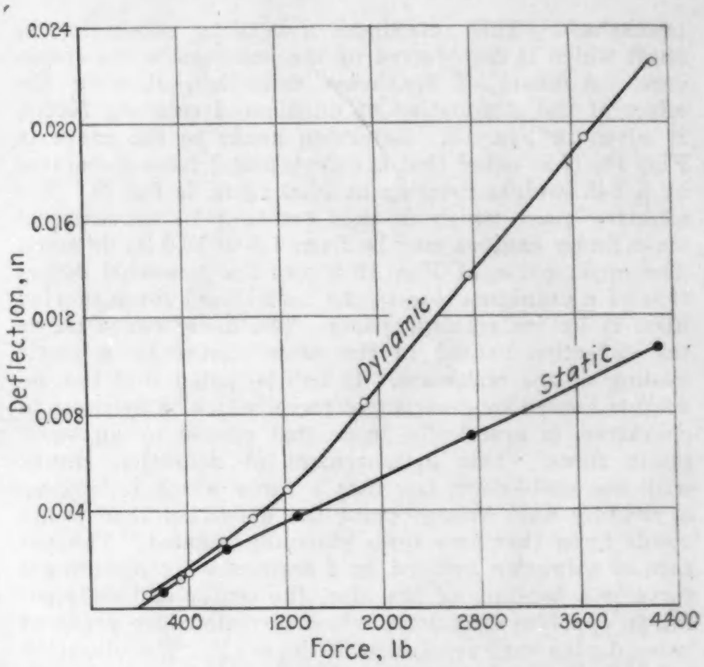


FIG. 16—RELATIVE DEFLECTIONS OF THE CRANKCASE CAUSED BY DYNAMIC AND STATIC FORCES

The Upper Curve Shows the Measured Deflection of a Crankcase Caused by the Centrifugal Force Exerted upon It by the Rotating Parts and the Lower Curve the Deflection in the Same Engine Produced by a Static Loading of the Crankcase. It Should Be Noticed That the Deflection Caused by Centrifugal Force Which Is Dynamic in Character Is Practically Twice That Caused by an Equal Static Force

varies with the relative sizes of piston and crankshaft, arrangement of bearings, compression pressure, spark-advance and the character of combustion. Where there is detonation, with other conditions the same, the crankshaft deflection is practically twice as great as for normal combustion. The deflection of the crankpins downward causes the forward end of the shaft to move upward. The nature of this vibration is shown by the diagram in Fig. 14.

The centrifugal forces in any crankshaft balance one another, making their resultant zero; however, the forces which cancel one another are in different planes, being applied at different points along the axis of the

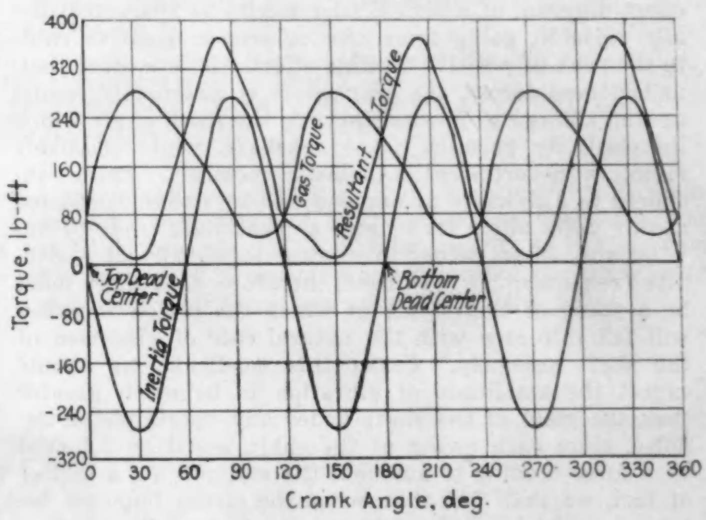


FIG. 17—DIAGRAM OF THE FORCES TENDING TO EXCITE TORSIONAL VIBRATION IN CRANKSHAFT

This Applies to a Six-Cylinder Engine at a Speed of 2500 R.P.M. The Character of This Curve Changes with the Speed Owing to the Relative Effect of Piston Inertia, but at All Speeds the Turning-Effort Diagram of a Six-Cylinder Engine Is Characteristically Variable, Going from Zero or Even a Negative Value to the Peak of Positive Turning-Effort crankshaft. This introduces a bending strain in the shaft which is transferred by the bearings to the crankcase. A chart of crankcase deflection, showing the effect of the elimination of unbalanced rotating forces, is given in Fig. 15. Referring again to the curve in Fig. 13, it is noted that the centrifugal force generated by a 1-lb. weight rotating at 3000 r.p.m. is 605 lb. The effective mass which is thus rotating in conventional six-cylinder engines may be from 7.5 to 12.0 lb. or more. The upper curve of Fig. 16 shows the measured deflection of a crankcase due to the centrifugal force exerted upon it by the rotating parts. The lower curve shows the deflection caused in the same engine by a static loading of the crankcase. It will be noted that the deflection caused by centrifugal force, which is dynamic in character, is practically twice that caused by an equal static force. This measurement of deflection checks with the well-known law that a force which follows up a yielding body causes twice the deflection that would result from the same force statically applied. The nature of vibration induced in a crankcase by centrifugal force is a bending of the case, the center and ends going in opposite directions, which directions are reversed twice during each revolution of the shaft. The vibration is confined largely to the engine but is transmitted in some degree to the chassis. The diagrams in Fig. 3 show the nature of vibration of the middle of the crankcase and how it varies with the engine speed. A crankcase, being elastic, has its own natural period of vibration, at which point the amplitude is built up higher than at immediately preceding or following speeds. Bending of the crankcase, so far as it is controlled by force alone, increases as the square of the speed. It is, therefore, significant only at the higher speeds.

Crankshaft Winds and Unwinds

Torsional vibration is characterized by periods which occur along the speed range with intervals of relatively smooth operation between. Torsional vibration is induced by the uneven turning-effect impressed upon the crankshaft by the connecting-rods. A typical turning-effort diagram is shown in Fig. 17. The character of this curve changes with the speed, owing to the relative effect of piston inertia, but at all speeds the turning-effort diagram of a six-cylinder engine is characteristically variable, going from zero or even a negative value to the peak of positive turning-effort. It is evident that, under these forces, the crankshaft is alternately wound up and allowed to unwind through the small angle which its elasticity permits. A crankshaft, while relatively rigid, is nevertheless an elastic member. Being anchored to a flywheel at one end and torsionally deflected at any point along its length, a crankshaft tends to unwind and, in so doing, to vibrate torsionally at a definite frequency. It is evident, therefore, that there must be a speed of the engine at which the piston impulses will fall into step with the natural rate of vibration of the shaft assembly. Under this condition, we should expect the amplitude of vibration to be much greater than the yield of the shaft under any single piston-impulse, since each swing of the shaft would be followed by a force tending to augment the motion. As a matter of fact, we shall find that, when the piston impulses become a multiple of the rate of vibration of the shaft, a period is built up; that is, the shaft may vibrate one, two, three or four times for each piston-impulse and yet build up a definite audible period.

The torsional indicator shown in Figs. 5 and 6 has been found very useful in determining the various quantities involved in the torsional vibration of crankshaft and camshaft. The indicator-cards shown in Fig. 8 were taken from a typical six-cylinder engine. It will be noted that at 2100 r.p.m. the indicator-card has six sides. This shows that the rate of vibration was $6 \times 2100 \div 60$ or 210 cycles per second. On another card we note the diagram has nine sides, the speed in this case being two-thirds the speed at which the six-sided figure was taken, or 1400 r.p.m. The frequency of vibration computed from this card is $9 \times 1400 \div 60$ or 210, which is exactly the same as the frequency computed in the former case.

Rigidity and Weight Determine Vibration Period

The rate of vibration of the crankshaft assembly—namely, the crankshaft, connecting-rods, pistons and other parts—is as definite as that of a tuning-fork. As soon as one period is located, all the others can be determined readily. If a hexagon shows on the indicator at a certain speed S, we know that a nine-sided figure will appear at a speed of $2/3S$, and a 12-sided figure at a speed of $\frac{1}{2}S$. It is also known that, if the engine could be operated at a speed double that at which the hexagon occurs, the indicator would show a triangle and a vibration of such tremendous amplitude that it would break the shaft if it were operated very long in the period. In practical crankshafts, the first harmonic is very seldom reached, since it would occur at a speed of from 3600 to 5000 r.p.m. The point at which the various periods occur along the speed range is a function of the torsional rigidity of the shaft and the effective moment of inertia of the shaft assembly. A stiff, light shaft having all excess metal trimmed off, vibrates at high frequency, the periods occurring well up along the speed range. A shaft which is relatively long, slender, or equipped with counterweights or with a front-end flywheel, vibrates at a relatively slower rate. We have not tested any commercial engine, however, in which the first harmonic falls within the driving range.

The frequency of torsional vibration in the crankshafts tested ranges from 180 to 250 cycles per sec. The amplitude of torsional vibration in practical engines operating in the second harmonic ranges from 0.01 to 0.03 in. at crankpin radius. Experimental engines which have been pushed up into the first harmonic have shown as much as $\frac{1}{4}$ in. deflection at crankpin radius.

Fig. 18 shows a set of cards taken from a crankshaft in which the natural frequency of vibration is sufficiently low to permit the occurrence of four periods. The relative amplitudes of these periods, as taken from the cards, with the car and engine speeds, is shown by the insert below the indicator-cards.

By the display of measurements shown in the paper, we do not wish to emphasize vibration unduly nor to place it out of its proper perspective. As stated at the outset, smoothness is one of the many improvements included in the demand for better motor-cars. Perhaps the smoothest engine is not entirely free from vibration in some of its forms and the roughest engine may not be seriously objectionable to its owner. The fight against vibration is more or less a common cause. Vibration must be overcome, not alone by correct design, but also by eternal vigilance in balancing. Progress is being made throughout the industry. The concentrated effort of many minds is beginning to overcome the difficulties which were not solved at all, or were solved in an inefficient way, when the problem was less perfectly understood. When we finally understand this thing, we may be able to leave the vibration out of an engine more cheaply than we can put it in. Then smooth operation

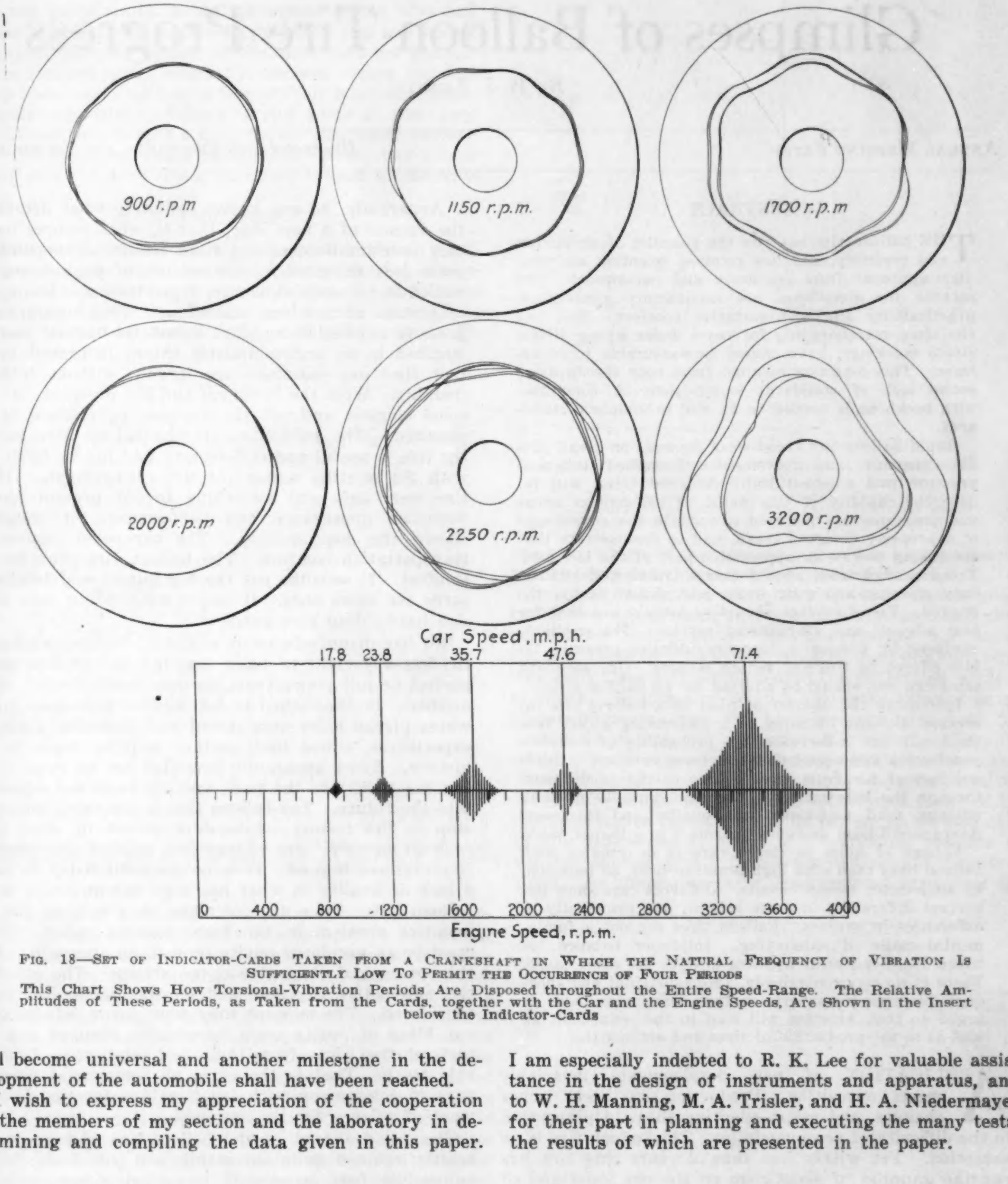


FIG. 18—SET OF INDICATOR-CARDS TAKEN FROM A CRANKSHAFT IN WHICH THE NATURAL FREQUENCY OF VIBRATION IS SUFFICIENTLY LOW TO PERMIT THE OCCURRENCE OF FOUR PERIODS

This Chart Shows How Torsional-Vibration Periods Are Disposed throughout the Entire Speed-Range. The Relative Amplitudes of These Periods, as Taken from the Cards, together with the Car and the Engine Speeds, Are Shown in the Insert below the Indicator-Cards

will become universal and another milestone in the development of the automobile shall have been reached.

I wish to express my appreciation of the cooperation of the members of my section and the laboratory in determining and compiling the data given in this paper. I am especially indebted to R. K. Lee for valuable assistance in the design of instruments and apparatus, and to W. H. Manning, M. A. Trisler, and H. A. Niedermayer for their part in planning and executing the many tests, the results of which are presented in the paper.

Glimpses of Balloon-Tire Progress

By B. J. Lemon[1]

Annual Meeting Paper *Illustrated with* Drawings and Photographs

ABSTRACT

THE balloon tire has run the gauntlet of skepticism and credulity, and has received scientific and popular approval from engineers and car-owners. The reasons for acceptance are satisfactory appearance, practicability and transportation comfort. Tire and rim sizes, masquerading for years under wrong dimensional markings, have caused immeasurable inconvenience. This condition resulted from poor standards or entire lack of standards supervision. A committee with backbone is needed to fix and to maintain standards.

Rapid balloon-tire tread-wear depends on tread profile, pressure and movement. Increased inflation-pressure and a scientifically designed tread will reduce the rapidity of this wear. Tread-contact areas and pressures are pictured to explain the advantages of a properly designed tread, and to demonstrate that the casing carries an appreciable part of the tire load. Tread configuration should assure traction, flexibility, easy steering and good wear, and should be not too rugged. Tread surface should be largely non-skid for best all-year and all-highway service. The public is confused by diverse balloon-tire inflation-pressure tables offered by tire and vehicle makers. One standard table can and should be adopted for all balloon tires.

Increasing the number of plies in a balloon tire increases the ease of entry of a puncturing object into the tread, but it decreases the probability of complete penetration and actual deflation from puncture. Gradual loss of air from tires is due chiefly to diffusion through the tube rubber. The rate depends on daily mileage, road conditions, tube quality and thickness. Average diffusion amounts to from 1 to 5 lb. per week.

Volume of noise in closed cars is no greater with balloon tires than with high-pressure tires, as indicated by audiometer measurements. Different cars show important differences in noise volume, due principally to differences in engines. Balloon tires are not a fundamental cause of shimmying. Improper balance between front-end units appears to offer the chief cause. There is no common remedy. More original and thorough research by experts in their particular fields is urged so that America will lead in the refinement as well as in the production of tires and automobiles.

APPLICATION of new developments invariably meets opposition. Production engineers abhor changes, and resist adopting them in proportion to the difficulty of accommodation. The balloon tire is no exception. Yet within less than 2 years this tire has run the gauntlet of skepticism on the one hand and of unwarranted credulity on the other, has passed from the realm of uncertainty and received scientific credentials from the majority of forward-looking automotive engineers. Moreover, the public has approved the idea of the large-section tire. Its currency and significance are established through acceptance by a multitude of first users, as well as by the willingness of non-users to test it. Such tolerance by the engineer and by the user is of far-reaching commercial-significance.

[1] M.S.A.E.—Research department, tire division, United States Rubber Co., Detroit.

Apparently, no one knows definitely what determines the success of a new idea; that is, what secures its victory over indifference and rival beliefs. The public appears less attracted by the science of engineering embodied in an automobile tire, regrettable as this is, than by certain unconscious reasonings. That technical progress in automobile and tire industries has not been humanized to an understandable extent is proved by the fact that our salesmen are largely without technical training. With the salesman and his prospect, the personal element and not the engineering element is emphasized. The public accepts the balloon tire because the tire is useful and satisfactory and fits in fairly well with the existing notions of tire requirements. If the tire were ugly and disturbing to our present idea of vehicular appearance and performance, it would be shown the door quickly. The car-owner appreciates transportation comfort. The balloon tire provides this comfort. It smooths out the big bumps and totally absorbs the small ones. It makes good-riding cars better and hard-riding cars good.

No tire manufacturer or engineer, however enthusiastic, has any right to claim that the balloon tire sprang perfect or full grown from his own fertile brain. It did neither. It came when it did because numerous minds, whose pigeon holes were stored with historical facts and experiences, willed that another step be taken in tire history. Every apparently new idea has its roots reaching far back into the past, and its branches extending into the future. The balloon tire is the third important step in tire history. Like development in other lines, each progressive tire change has pointed the way for improvement beyond. It is no discredit today to admit a lack of finality in what has been accomplished in the balloon tire. Time did not allow an attack on the balloon-tire problem in the true research spirit. There must be an uncolored purity in such an approach. Also, the commercial element was too strong. The effect on the automotive engineer and on the public had to be considered. The moment they were taken into account, our ideas of purity were necessarily changed and our facts shifted away from their real relation to discoverable truth. That is the price all commercial research pays in comparison with investigation for the development of science for its own sake.

The rapid spread of the balloon-tire idea created a healthy commotion in automobile and tire fields; in the automobile field because it compelled closer study of front-end layout including wheels, brakes, springs, steering mechanism, vibrations and noises; in the tire field because it featured the demand for closer cooperation among tire manufacturers. That this cooperation was sadly lacking is evidenced by the number of tire sizes first adopted. We manufacturers ventured at length to look each other shyly in the face and the encounter was more comforting than we anticipated.

How the balloon-tire commotion was met by the automotive engineer is not for me to tell; but I can draw an analogy from the tire makers' predicament. They were like the suburbanite in the Christmas crowd who had spilled a basket of miscellaneous presents and was trying to gather them all up and at the same time not get left in the onward rush. Some tire makers caught the first train home carrying only a few of their bundles of high-pressure-tire tricks. Others carried along all their past experience, but caught a later train. The most successful took what he could comfortably carry, but not so many as to impede steady progress toward an ultimate goal.

Tire Sizes

Since the advent of the high-pressure cord-tire, nominal section tire sizes have been very much of a camouflage and a misnomer, for several reasons. Cord tires were more flexible than fabric tires and, due to resulting greater deflection, tire sections were made larger with-

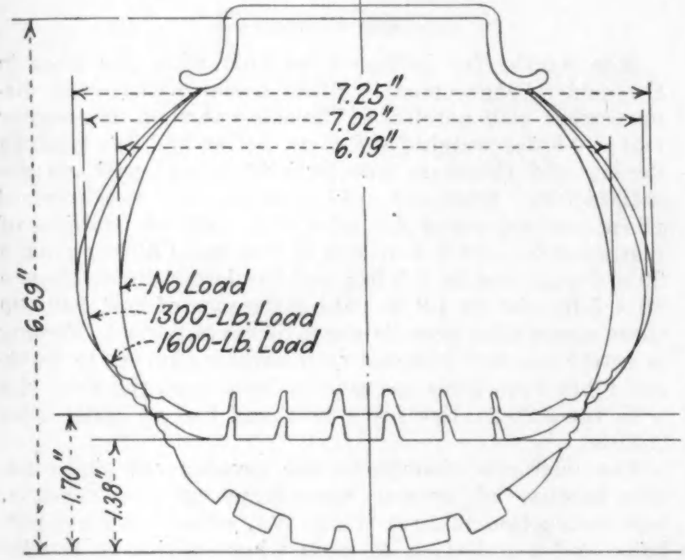


Fig. 1—Actual Profiles of a Round-Tread Tire under Different Static Loads
Note Distortion of the Blocks as Compared with the Absence of Such Distortion in Fig. 3. Note Also the Small Amount of Support Afforded by the Outside Rows of Blocks

out change of size markings. Tire production was increasing by leaps and bounds to keep up with automobile manufacture. Competition had not yet reached the present stage in which a small increase in production cost means little or no profits. As there were no fixed limits for sectional sizes, it was comparatively easy for a tire maker to increase a tire size, quietly let the fact be known and extend the sales of his product. The sales aspect was beginning to become paramount instead of being secondary. Also, there were always a few cars fitted with undersized tires. If a tire maker protested this practice and stood by his principles, a competitor filled the order, perhaps by boosting his tire sectional size a small percentage. The tire maker who protested not only lost original-equipment business, but dealer trade as well; because his smaller tire could not compete with a larger one in the field. So, the practice of oversizing sectional rather than nominal sizes became customary. As a result, energy and profits were spent buying competing products and feverishly recutting mold equipment to a size equal to the largest. Only an occasional outcry was heard from a user who unwittingly tried to run a 5-per cent oversize tire on one wheel, against a 15-per cent oversize casing on the opposite wheel. Finally, the industry agreed on a 10-per cent

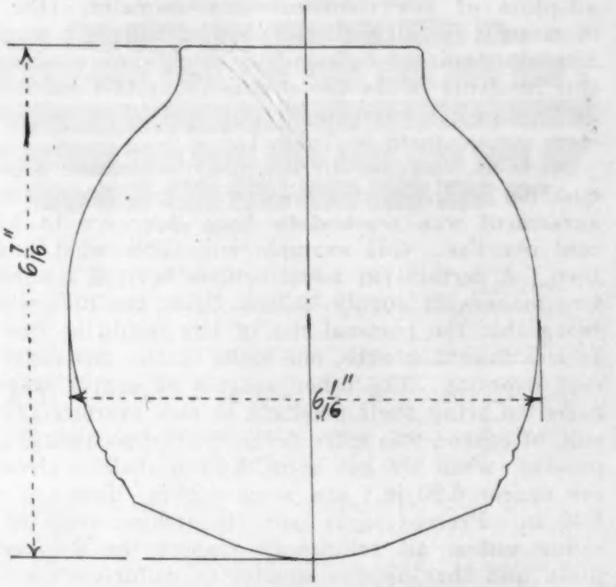


Fig. 2—The Profile to Which a Round-Tread Balloon-Tire Wears in Road Service
A Tread Designed to Such a Profile, Which Is Called a Natural-Wear Profile or Flat Tread, Will Give Even Wear If Run at from 16 to 22-Per Cent Deflection

oversize, which is the present status for high-pressure-tire sections and this is not too closely followed.

Original balloon-tire sectional sizes were chosen so as to allow a considerable increase in air volume and corresponding reduction of inflation-pressure for loads equal to those carried by the replaced high-pressure tire. The early tires actually measured the advertised sectional width. Balloon-tire heights also were selected so as to permit interchange with high-pressure tires, both for immediate use on cars in service and for original equipment, without appreciably affecting vehicle performance. These sectional sizes and overall tire-heights required for a 20 to 22-per cent sectional deflection a range of inflation-pressure from 20 to 40 lb. per sq. in. to take care of the differences in front and rear-wheel weights of vehicles falling within rather distinct weight classifications. As there was early disagreement regarding the

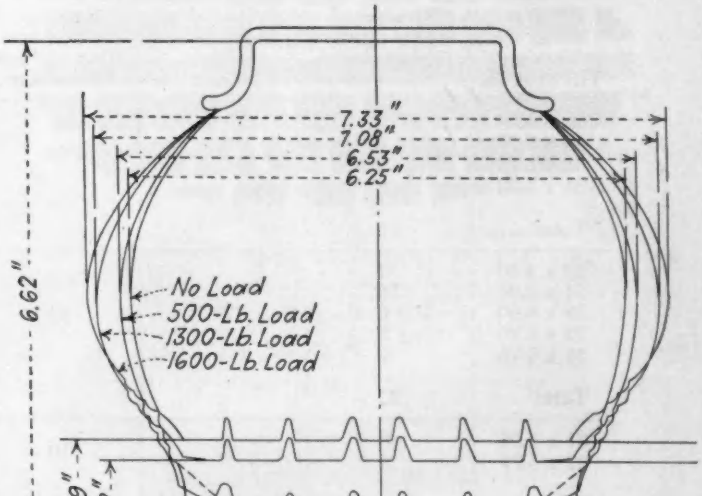


Fig. 3—Actual Profiles of a Natural-Wear Profile or Flat-Tread Tire Under Different Static Loads
Note the Evenness with Which the Blocks Carry the Weights as Compared with Evidences of Strain in Fig. 1. Also Note the Better Support Afforded by the Outside Rows of Blocks

adoption of one common wheel-diameter, (the 20-in. diameter), for all sectional sizes of balloon tire, no definite standards of balloon-tire heights were adhered to, this resulting in the use at present of 11 tires for original equipment covering 20, 21 and 22-in. wheel-diameters, as set forth in Table 1.

With an increase in demand for balloon tires, the question of sectional tolerance was discussed. An agreement was reached to limit tolerance to 2½ per cent oversize. One example will show what happened then. A certain car manufacturer invited a number of tire makers to supply balloon tires, the understanding being that the nominal size of tire would be furnished. In less than 2 months, one make of tire measured 3 per cent oversize. The other sources of supply were then asked to bring their products to this oversize. The result, of course, was more feverish mold-recutting. So, at present, when we get some 6.00-in. balloon-tires, they are nearer 6.20 in.; and some 6.20-in. tires are nearer 6.40 in. Present signs point to another orgy of oversizing unless all religiously respect the 2½-per cent limit, and that applies equally to motor-vehicle and to tire engineers.

A glance at the sectional sizes of tires, Table 1, used on 20, 21 and 22-in. wheels, indicates that it appears possible from the standpoint of vehicle construction, to confine overall tire-heights to either a 20 or a 21-in. wheel-diameter; that is, both light and heavy cars have been designed successfully to use 20 and 21-in. wheels.

From the tire maker's standpoint, one main objection exists at this time to standardizing on an ideal program of 21-in. wheels; it is the amount of investment in tire-building equipment for tires already used on 20 and 22-in. wheels. So, the tire maker cannot exactly be blamed for not voicing at once strong approval of a list of 21-in. ideal-sizes, at least until such time as the change can be brought about without too sudden and great an equipment loss. This, too, is the position of many car, wheel and rim manufacturers. However, in spite of failure to advocate immediately and enthusiastically a simplified program by tire and vehicle makers, there is a decided undercurrent running through both industries for simplification, and a rather general belief that such procedure will be a satisfactory solution from both practical and economical standpoints.

For years, the tire industry has reported progress in the standardization of tire sizes. On this problem of supreme moment to the tire maker, and of major importance to the vehicle manufacturer, confusion rather than order has ruled. The reason is the lack of definite orderly development supervision. The existence of a permanent supreme council representing those vitally interested, with power and initiative to control, could have kept order. Such control as has been exercised was called into being to guide rather than standardize a new development. We shall continue to report only progress until a representative committee with power, and backbone to use it, is placed in permanent control.

Rim Widths

Rim widths for balloon tires vied with tire sizes in the early disagreement. Table 1 shows that this disagreement still persists. The advocates of the narrow rim cite lower weights and costs, better and less localized flexing and therefore greater cushioning, with no unsatisfactory front-end performance, if synchronized vibrations are cared for otherwise. On the subject of rim weights, a 28 x 4-in. rim of one make differs from a 29 x 4½-in. rim by 1.5 lb.; and the latter differs from a 30 x 5-in. rim by 1.2 lb. The difference of cost between these consecutive sizes is about 50 cents per set. Flexing is better and less localized on a narrow rim. As to front-end vibrations, some car-makers have used the 4-in. rim with the 6.20-in. tire for 1 year and had no appreciable trouble.

The wide-rim champions cite greater carrying-capacity because of greater air-volume, greater stability, less destruction to tires if run flat, easier steering, perhaps, and a reduction of costs where a tire of smaller sectional-size can be adapted. Wider rims give some-

TABLE 1—BALLOON-TIRE SIZES, PLIES, WHEELS AND RIMS USED BY AUTOMOBILE MANUFACTURERS

Nominal Tire Size, In.	Number of Manufacturers Using Each Size Tire	Overall Diameters, Wheels and Rims, In.	Percentage of Wheels and Rims in Each Diameter	Plies of Fabric		Number of Manufacturers Using Each Size of Rim				
				Four-Ply	Six-Ply	3½ In.	4 In.	4½ In.	5 In.	6 In.
29 x 4.95	1	20	49	1	..	..	1	..	..	..
30 x 5.77	4			3	1	..	4	..	..	..
32 x 6.20	22			22	1[a]	..	5	16	1	..
34 x 7.30	9			9	..	..	..	6	3	..
Total.....	36									
29 x 4.40	2	21	41	2	..	2	..	..	..	..
31 x 5.25	16			16	..	..	14	2	..	..
33 x 6.00	5			4	1	..	1	2	2	..
33 x 6.20	3			3	..	..	..	3	..	..
33 x 6.75	6			3	3	..	..	3	2	1
Total.....	32									
31 x 4.95	3	22	10	3	..	..	3	..	..	..
32 x 5.77	5			3[b]	3[b]	..	..	5	..	..
Total.....	8									
Totals....	76		100	69	9	2	28	37	8	1
				78		76				

[a] One car manufacturer uses four and six plies, 6.20-in. tires.
[b] One car manufacturer uses four and six plies, 5.77-in. tires.

what greater air-capacity, thereby permitting in some cases the use of the tire next smaller in size. For example, a 33 x 6.00-in. tire on a 5-in. rim has the same deflection as a 32 x 6.20-in. tire on a 4½-in. rim; that is, their load-carrying capacities for the same deflection are equal. However, the possibilities of such substitutions occur only where different nominal-size tires vary but little in actual size. In such instances as the 6.00-in. and the 6.20-in. tires, one tire should be made standard and the other should be eliminated. The wide rim unquestionably permits less side-swaying on turns, and perhaps less bead and rim strain. As yet, however, there are no large number of failures of narrow rims in ordinary passenger-car service. Instances have occurred where 4½-in. rims have failed when used on 11 passenger touring-car buses fitted with 7.30-in. tires. This, however, is an exceptional condition of service.

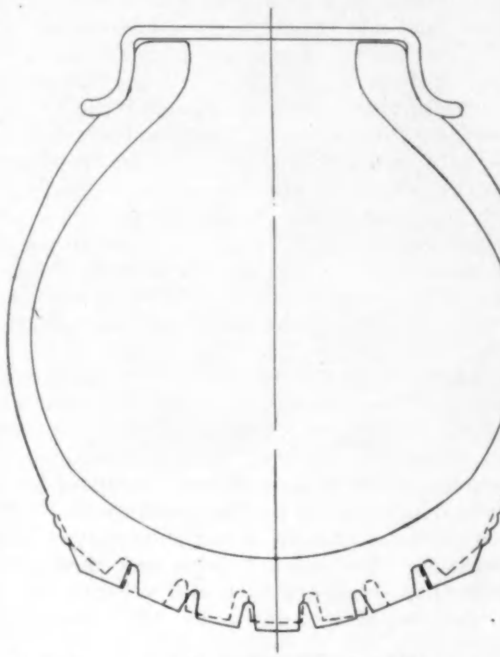


Fig. 4—Comparison of the Profiles of Two Tires
The Solid Lines Show the Profile of a 32 x 6.20-In. Natural-Wear Profile or Flat-Tread Balloon-Tire, while the Dotted Lines Are the Profile of the Same Size of Tire of the Round-Tread Type

Due to varied practice of using one size of tire on rims of varied size, and vice versa, tire makers and dealers are faced with a complicated flap-problem, since, to function properly, each flap should fit the rim seat and the tire beads accurately without wrinkling. Even with the exercise of the utmost care in factory assembly, and branch and dealer education regarding this problem, cases are bound to occur in which flaps will be used wrongly and trouble will result. The flap situation would be simplified greatly by the adoption of a standard rim line-up, using one size of rim for each tire size. Our opinion is that a satisfactory rim-width is one that measures, between the flanges, from 62 to 65 per cent of the width of the inflated-tire cross-section. This does not mean that tires will not function well on narrower or on wider rims, for tires are doing so today; but the industries should simplify, adopt a standard and live up to it, as the most satisfactory solution of the rim problem.

Plies of Cord Fabric

The number of plies of fabric in balloon tires depends on the size, the strength and the spacing of the cords and the load to be carried. Tire-manufacturing practice

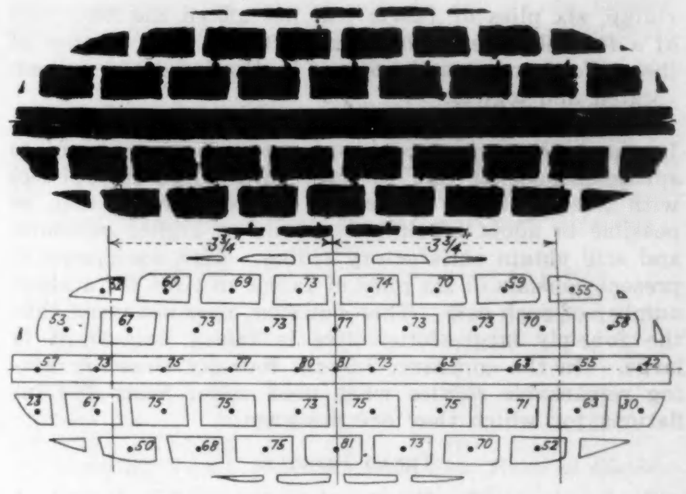


Fig. 5—Tread-Contact Area and Pressure for a 32 x 6.20-In. Round-Profile Balloon-Tire
These Measurements Show the Smaller Area and the Higher Pressures of a Round-Profile Tread as Compared with the Larger Area and the Lower Pressures for the Natural-Wear Profile or Flat-Tread Tire Shown in Fig. 6; also the Small Amount of Weight Carried by the Outside Rows of Blocks. The Load in This Case Was 1300 Lb.; the Inflation-Pressure, 30 Lb.; the Gross Contact-Area, 35.45 Sq. In.; and the Net Contact-Area, 21.48 Sq. In.

discloses differences mainly in the size and the spacing of the cords, but shows practically no difference in the number of plies, due to economic reasons. Regardless of the number of plies, the size and the spacing of the cords, sufficient fabric must be used in all tires to maintain a safe bursting-strength factor as determined by road, hydraulic and bruising tests, under conditions comparable with maximum tire-load and vehicle-speed. On the other hand, because of constant flexing and the heat generated therefrom, and to secure a riding-quality demanded of balloon tires, the number of plies and the amount of cotton must be kept at the lowest point consistent with the strength requirement. Reference to Table 1 indicates that 90 per cent of the car manufacturers use four-ply balloon-tires. In regard to ease of

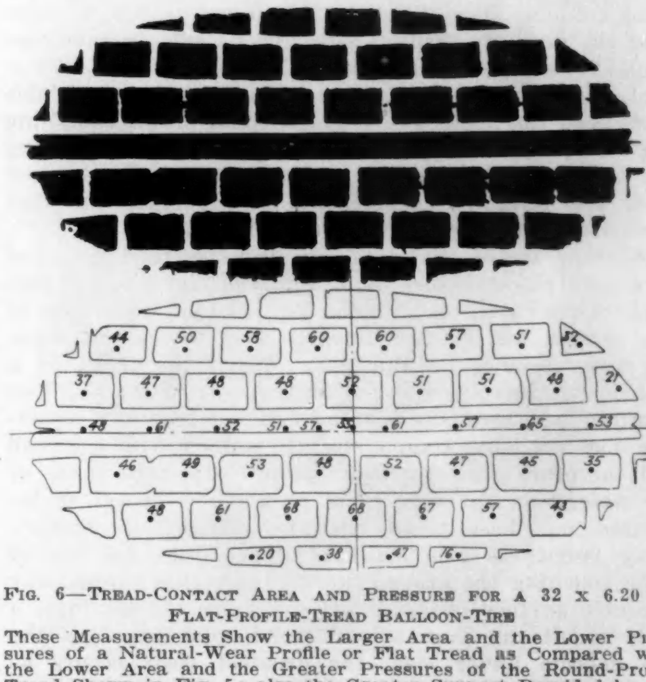


Fig. 6—Tread-Contact Area and Pressure for a 32 x 6.20 In. Flat-Profile-Tread Balloon-Tire
These Measurements Show the Larger Area and the Lower Pressures of a Natural-Wear Profile or Flat Tread as Compared with the Lower Area and the Greater Pressures of the Round-Profile Tread Shown in Fig. 5; also the Greater Support Provided by the Outside Rows of Blocks. The Load and the Inflation-Pressure Were the Same in This Case as in Fig. 5, 1300 and 30 Lb. Respectively. The Gross Contact-Area Was 41.47 Sq. In. and the Net Contact-Area 26.30 Sq. In.

riding, six plies of fabric will not afford the flexibility of a four-ply tire of the same sectional size, because of the stiffer carcass and because higher inflations are advocated and logical.

But riding-comfort is not determined solely by tires. In the higher-priced cars, more care can be given to spring-suspension and to the coordination of springs with tire inflations; therefore, in such cars, it may be possible to adopt a stiffer tire, run at higher pressure, and still obtain satisfactory riding. Tire equipment at present consists of six plies of fabric in tires for a small number of such cars. This, however, does not mean that the four-ply large-section tire is faulty because it is large. On the contrary, 7.30-in. four-ply tires are giving remarkable service when used under loads and inflations for which they are designed.

Tread Profile

Surface wear of a tire tread on the road is dependent mainly on tread profile, pressure, movement and materials. Pressure and movement are closely related to profile. Tread materials must be able to resist cutting, wear better than steel and flex over 6,000,000 times in 10,000 miles of service. Tread compound will not be considered, since we are interested in the mechanics of the tread and not in its composition.

Physics teaches that confined gases exert equal pressures in all directions, so that any perfectly elastic casing inflated to 30 lb. per sq. in. and carrying a 1300-lb. load will flatten to a theoretical area of 43 sq. in. of road surface. A 6.20-in. natural-wear-profile tread four-ply Royal Cord balloon tire covers a gross area of 42 and a net area of 26.3 sq. in. under the above-named load and inflation. The average road-pressure is therefore 50 lb. per sq. in. These differences between the theoretical area and the air pressure, 43 sq. in. at 30 lb. per sq. in., and the actual net area and the road pressure 26.3 sq. in. at 50 lb. per sq. in., amount in part to the load carried by the carcass and not by the air, and indicate the extent of strain concentrated on a certain undefined area of tire tread and carcass mainly adjacent to the region of road contact. The differences also refute assumptions that the pressure inside a tire, and outside on the tread contact-area, are approximately the same. The fact is that, with all tires, the carcass walls carry an appreciable portion of the load. For a given tread profile stiffening the tire carcass by additional plies of fabric or boosting the inflation-pressure reduce the area of tire contact with the road and correspondingly increase the load pressure on each square inch of contact area.

Another factor that tends to decrease road-area and increase tread-pressure is a round-profile tread. Tire casings are cured on a rubber bag so that the inside of the carcass will be curvilinear. This too is the shape the tire assumes on inflation. When the tread of a balloon tire has a round profile, the area of road contact is minimized, because the tread farthest from the center-line does not come completely into contact with the road and therefore does not bear its proportionate share of the weight on the tire. The pressure is therefore increased on those tread portions actually in contact. Since rubber is practically incompressible, the loaded tread touching the ground flows or stretches toward any available surface openings. If there are no openings, a wave results as in a smooth-tread solid-tire. As the tire deflects under load, the greatest wear occurs at points of greatest pressure and movement, and that is the cause of irregular wear on balloon-tire treads. On front wheels, this uneven wear is accentuated on one side of the balloon-tire tread when excessive toe-in and pitch are permitted. On rear wheels, irregular wear is reduced somewhat because the tire squats appreciably, due to transmittal of the driving force, and thus brings more surface into contact and grips with less movement than in the case of front tires, due to this same power transference.

One remedy for irregular wear on round-profile treads is to use a greater inflation-pressure. While this reduces the width of the contact area and increases the tread-pressures per square inch, it confines tread movement to an area closer to the tread center-line and results in a smaller movement and more even wear. This is analogous to tread wear on high-pressure tires which, from the irregularity standpoint, was never a factor of proportions sufficient to cause worry. Another method of reducing irregular tread-wear is to design the tread so that it conforms to a profile to which the tire wears at its normal load and inflation. We have adopted such a design; it is illustrated and compared with a round-profile tread in Figs. 1, 2, 3 and 4. The natural-wear-profile tread contrasted with the round tread in Figs. 5 and 6 offers several advantages; a greater road-contact area, 26.3 sq. in. against 21.5 sq. in., a lower tread-pressure, 50 lb. as compared with 60 and a reduced tread-movement. Tests extending over a period of 6 months indicate that the natural-wear-profile tread produces longer and more even wear over a larger range of inflations, helps stabilize front-end unbalance and reduces sidesway and strain on bead and rim, as indicated in Fig. 7.

Tire designers were put to the test to overcome uneven balloon-tire tread-wear. The solution demanded a thorough study of the mechanics of tread movement, and of the wear of a moving resilient material under load distortion. Wear of a uniformly compounded moving surface is dependent on profile, pressure and velocity. Slow-motion pictures showed a complex uneven balloon-tire-tread velocity. We feel it to have been demonstrated satisfactorily that tread-pressure and velocity and wear therefrom can be slowed-down by the natural-wear-profile tire.

Tread Configuration

Anyone who has worn hob-nail mountain-boots appreciates their non-skid features when negotiating sand, ice, rocks and rough going in general. Athletes wear cleats, spikes and corrugations or depressions on their shoes for the one purpose of getting a firm hold on the ground, especially when making a supreme effort. The same practice obtains in shoeing an automobile, except that rubber has displaced metal. If all our roads were hard-surfaced, always clean, dry and free from snow and ice, automobiles might run on smooth or rib-tread tires. But we still have 7 miles of dirt road to every 1 mile of hard-surface highway, sand, mud, snow, ice and oil, which require a sure grip under ordinary conditions and the maximum grip under adverse conditions. This accounts for the popularity of the non-skid tread to provide traction and prevent skidding. On the other hand, tread configuration can be too rugged. The time is past when a design with large obtruding, widely separated nobs or bars will be tolerated on the tires of a high-class passenger-car. Better roads, the popularity of closed cars, demand better riding-qualities and more attention to riding refinements by car engineers. The public have eliminated many bumpy treads and should cause others of that type, which served their purpose on dirt roads, to become obsolete.

In the larger-section balloon-tire sizes, the companies

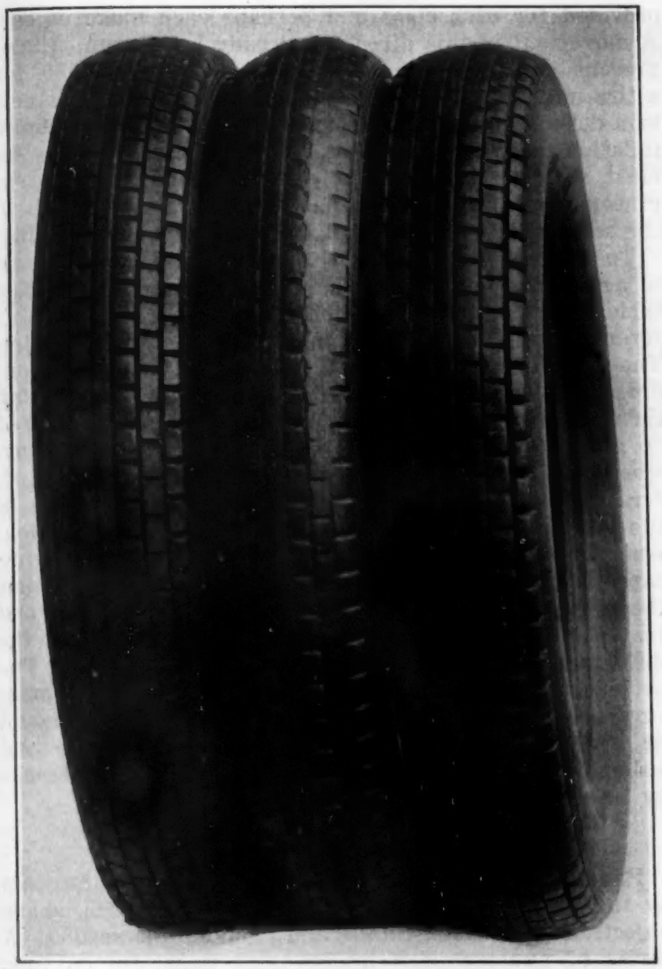


FIG. 7—COMPARISON OF THE WEAR ON ROUND AND NATURAL-PROFILE OR FLAT-TREAD TIRES
Note the Irregular Wear on a Round-Profile Tread After 8032 Miles (Middle Tire) as Compared With Two Natural-Wear Profile or Flat-Tread Tires after 10,134 Miles (Left) and 9679 Miles (Right)

started with an all non-skid design, only to compromise later on a combination rib non-skid design in about equal proportions. The change was brought about by irregular tread-wear and vibration that affected riding-quality. Our own opinion is that the car owner still needs a non-skid design in larger doses than 50 per cent of the tread-contact area. We designed and tested our quota of treads in the search for one to give maximum traction and flexibility in all directions, stability, ease of steering and uniform wear over a reasonable range of inflation-pressures. The result was the present Royal-Cord balloon-tread built to the natural-wear profile, having one central rib flanked on each side by three rows of sharp-edged blocks, as shown in Fig. 8. This tread can be modified to become a composite Royal-Rib design as indicated in Fig. 9. This compromise however does not produce as good traction on wet asphalt, in snow, sand or mud as does the Royal tread.

Results of a preliminary series of traction tests, Table 2, made with the Royal tread and the Royal-Rib tread on dry asphalt and dry concrete indicate no appreciable differences in traction between the two treads, or between the two road surfaces at a temperature below 40 deg. fahr. However, on wet asphalt the Royal tread showed 15 per cent better traction and on asphalt covered with 2 in. of snow, 12 per cent better traction than does the combination tread. All inflation-pressures were at 30 lb. per sq. in. Tape measurements for distances were supplemented by readings on the James decelerometer. All results are averages of a number of tests.

INFLATION-PRESSURE

The car-owner is less influenced by fact than by precedent, and is indifferent to tire pressures. With his unlimited capacity for taking things for granted, he already is applying to the balloon tire the past practice of running high-pressure tires underinflated. Only one way

TABLE 2—TRACTION-TEST, ROYAL TREAD AND ROYAL-RIB TREAD[2]

Speed, M.P.H.	Dry Asphalt, Ft.	Dry Concrete, Ft.	Wet Asphalt, Ft.	Light Snow Covered Asphalt, Ft.
Royal Tread, One Rib and Six Rows of Blocks				
20	35	37	29	...
25	51	60	42	...
30	77	87	74	140
35	109	117	109	
Royal-Rib Tread, Three Ribs and Four Rows of Blocks				
20	33	40	35	...
25	50	57	51	...
30	80	80	81	160
35	109	114	115	...

[2] These preliminary results of traction tests indicate that an all-non-skid tread affords from 12 to 15 per cent more traction than does a rib-non-skid tread under wet conditions. The figures given are foot-brake stopping-distances for a car equipped with two-wheel brakes.

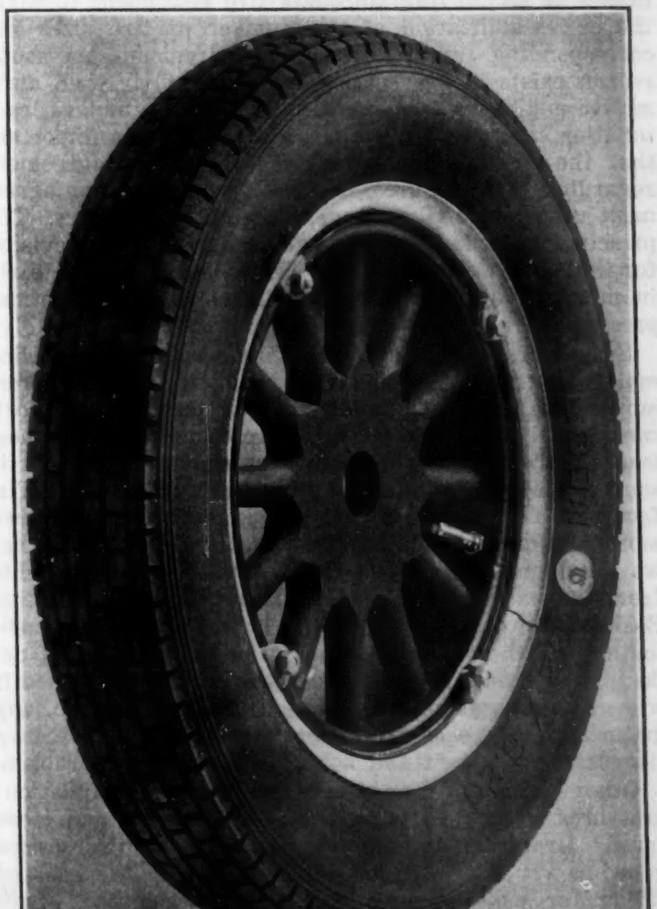


FIG. 8—A COMMERCIAL FLAT OR NATURAL-PROFILE TIRE
This Tire, It Is Claimed, Affords Even Tread-Wear, Easy Steering and Excellent Traction under Practically All Road Conditions

exists in which to impress the owner with the importance of proper balloon-tire inflation; it is to have factory, sales and dealer representatives administer copious doses of education. Continually living with tires and testing them on the road and in the laboratory leads to the unmistakable conclusion that a tire will give its best service when run at a specific deflection that results from a definite fixed load and inflation. With high-pressure cord-tires that deflection varies with sizes from 9 to 13 per cent; with four-ply balloon tires from 18 to 22 per cent. For high-pressure tires, there is a standard load and inflation table that is generally approved and recommended by all tire companies. There is no such table for balloon tires. Three companies follow one table, based on very nearly a 20-per cent deflection. Other companies have tables differing from each other and from the three previously cited. Some car manufacturers, with the assent of companies supplying tires, adopted a still different table. Other car-manufacturers altered a previously adopted table without consulting the tire manufacturer. Small wonder that the car-owner is confused and negligent of his inflation-pressure when manufacturers themselves do not agree within limits which are called abuses if adopted by the car-owner.

The causes for such a babel of tables are not hard to find. Earlier steering difficulties, shimmying, undersize-tire equipment, variation in number of plies of fabric and premature tread-wear offer the explanation. With easier-steering methods, better diagnosis of the causes of shimmying, adequate tire equipment to carry the car, stabilization of the number of tire sizes and corresponding carcass-strength requirements, no sound reason exists to prevent the majority of tire and automotive engineers from agreement upon a standard load-inflation table for balloon tires. It is just as important that the related industries get into prompt agreement regarding inflation-pressures as it is concerning agreement upon sectional and overall-height dimensions. The principal advantage of the balloon tire is its provision for improved riding-comfort. That should be kept clearly in mind. We lose this improvement if high inflation-pressures are used.

Some persons claim that riding-comfort is supplied mainly by rear tires and that front-tire inflation-pressures can be raised, without appreciable discomfort, considerably above the deflection required on front-wheel loads. This has been done in a number of cases, but it sounds illogical because the tire fights the road. The fact that front-seat riding usually has been considered more comfortable than rear-seat riding is no reason that we should not accept the full front-seat riding-benefits from the balloon tire instead of part of those benefits. Besides, the engine will benefit by the additional cushioning. If the tire will stand up under 20-per cent deflection on the driving wheels, when properly designed it will give corresponding service on front wheels; so, any material increase of front-wheel inflation-pressure is a temporary expedient and not a solution of the problem.

Other authorities claim the need of high inflation-pressures all around to permit quick pick-up and more speed. Granting that they get this, which, so far as we know, is yet unproved, they are sacrificing the ease of riding for which the balloon tire was adopted. Still others justify the use of higher inflation-pressures by the fact that their system of superior springing does not require low air-pressure to secure adequate riding-qualities. Probably, there is merit in this contention; however, if put into practice, our load-inflation tables must be based on car classifications, and a different table provided for each class and perhaps each make of car. A movement in this direction already has begun. Under present go-as-you-please practice, it is impossible for a tire manufacturer to uphold his contention that a certain deflection resulting from a definite load and definite inflation-pressure gives best all-around tire results. He must sacrifice fundamental principles and facts to engineering caprice and the haste of the moment and, in the scramble for orders, that is exactly what he is doing.

To indicate how closely tire manufacturers can come to agreement and yet not agree on a load and inflation table, Fig. 10 shows load-deflection curves of four different well-known makes of 6.20-in. four-ply balloon-tire. The curves represent 26 and 34 lb. per sq. in. inflation-pressure. The makers of three of these tires, including those showing greatest and least deflections, have agreed on one table for the public, while the fourth company, whose tire falls between the extreme deflection limits, offers a different table. The greatest average variance in the two tables for any load is 2 lb. per sq. in. inflation, which is less than the small differences in carrying capacity of some makes of tire. It is not contended that the three companies are entirely right, necessarily, and that the fourth company is partly wrong, but that the differences are too small to warrant disagreement. The problems of standardizing balloon-tire inflation-pressures, as well as urging their better maintenance, should be given immediate attention by leaders in tire and automobile lines. The need is acute; the obstacles are by no means insurmountable.

Punctures and Bruises

Punctures are distinguished from bruises and cuts by the fact that punctures are produced by slim, sharp objects, such as tacks, nails and phonograph needles. A series of puncture and bruise tests were run on four and on six-ply balloon-tires with the following results:

(1) A nail or other sharp object penetrates or enters the tread rubber of a six-ply tire more easily than it does a four-ply tire, due to the greater rigidity of the six-ply carcass

(2) The higher the air pressure is, the more easily the puncturing object first penetrates the treads of the two types of tire

(3) The complete penetration of the carcass as well as the tube, after the object has entered the tread, is less difficult with a four-ply than with a six-ply tire. The difference in degree is about proportional to the carcass thickness

(4) When a tire is dealt a heavy blow by a stone or rut and the obstruction does not drive the carcass to the rim, generally, a four-ply tire suffers less than one with six plies of fabric. The reason is that the thinner carcass deflects to a greater degree and over a longer period, and thus slows-up the acceleration or rate of change of velocity of the blow. This ability to stretch out the time period of an impact blow is one of the great virtues of the balloon tire, and is more conspicuous in a thin than in a thick carcass

(5) The rupture of a balloon tire by bruising does not occur usually in stages of one ply at a time, except where the tire is first cut. The blow breaks either all plies or none. In this respect cord tires differ from those made of square woven fabric. Therefore, a balloon tire may endure thousands of reasonably heavy road-blows without damage, but he put completely out of service by one crushing impact

Reason and judgment should be exercised in all things; but both are badly strained by the motorist who rides curbs and railroad crossings at high speed, and completely ruptured by the advertiser who tempts him to such practice.

Loss of Air from Tubes

The balloon tire has been accused of losing air faster than does the high-pressure tire, either by diffusion through the rubber tube or by escape from the valve-stem. It appears that this accusation has not been followed up with the necessary evidence to accomplish a clean-cut indictment. To get some preliminary facts, tests were made with a view to locating the sources and measuring the amounts of such reported losses in different types and sizes of tubes of varied thickness. These preliminary tests definitely indicate that loss of pressure in tubes is due chiefly to diffusion through the rubber and not through the valve-stem or about the valve base, since similar losses are obtained when the valve is sealed. Conclusions reached are that:

(1) Tubes in balloon tires, at both high and low inflation-pressures, do not lose air more rapidly than do tubes in high-pressure tires; generally they lose air less rapidly. However, the effect of such air-loss is more detrimental to the balloon than to the high-pressure tire, due to a lower initial inflation

(2) In balloon-tire tubes as made at present, the inflation-pressure loss runs from 1 to 5 lb. per week, depending on the quality of tube, the length of time in service and the mileage of such service

(3) Tubes operated at both high and low pressures continue to lose pressure steadily in proportion to the nature of the gas used and to the thickness of the tube

(4) Inflation-pressure loss is greater for tubes running than for tubes static. The greater the daily mileage is, the greater the loss will be when measured at uniform temperature

(5) A tube inflated with carbon dioxide loses pressure much faster than one inflated with nitrogen, the ratio being approximately the same as the rate of diffusion of these gases through a rubber diaphragm

(6) The loss during the first day is higher in all tubes than for the second day. Thereafter, pressure diminution follows a slowly decreasing constant. Evidence is not yet available to permit drawing conclusions regarding the limit of pressure loss with an increase in tube service

(7) There may be a period in tube service, before the tube structure begins to weaken, at which pressure loss is negligible. A series of pressure-loss curves for tubes run to destruction in service would be interesting

(8) Balloon-tire experience clearly points to the need of more frequent inspection of inflation-pressure than has been customary with high-pressure tires. Once a week is not too often even when tubes are in first-class condition. To the three prerequisites of automobile operation, water, oil and gasoline, the motorist should add a fourth, *air*, and be sure that what is free is neither forgotten nor short-measured.

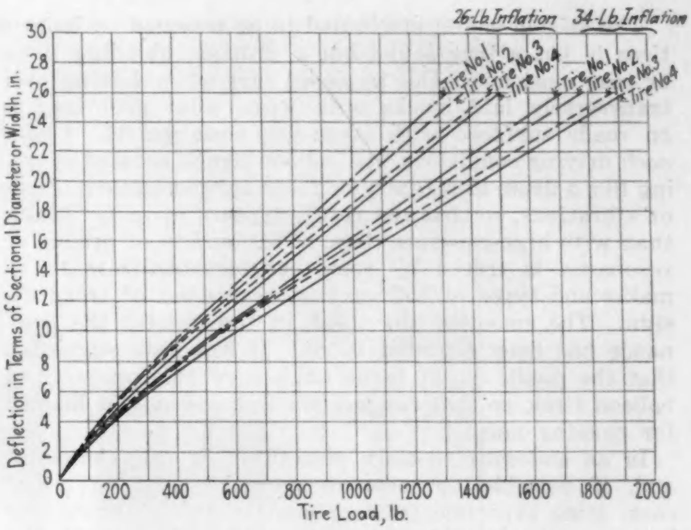


Fig. 10—Load-Deflection Curves for Four Different Makes of Balloon Tire

Four Different Makes of 6.20-In. Four-Ply Balloon-Tire Were Measured for Deflection under Identical Conditions. Curves 1, 3 and 4 Represent Tires of Makers Who Use the Same Inflation Table; Curve 2, a Maker Who Uses a Different Table. The Greatest Average Variance in the Two Tables Is 2-Lb. Inflation, Which Is Too Small To Warrant Disagreement. The Tests Were Made at Inflation-Pressures of 26 and 34 Lb. as Indicated

Fig. 9—A Commercial Natural or Flat-Profile Tire with a Ribbed Tread

The Rib Tread Is Said To Afford Even Tread-Wear, Easy Steering, but Not as Good Traction under Wet Conditions as Does the Tire Shown in Fig. 8

Sounds and Noises

In general, there art two sorts of sound produced by or attributed to balloon tires. The first is a true sound resulting mainly from air waves set in motion by the tread configuration. This sound varies in pitch with the size and shape of the non-skid design and with the speed of the car. Except in an exaggerated form, and when in harmony with gear sounds which it then magnifies, tread sound is not disagreeable and is rarely objected to by car-owners.

The second sound attributed to or revealed by balloon tires is not a true sound but a grating, grinding noise or roar most noticeable in closed cars when driving over transversely laid bricks with worn joint grouting, or on roads surfaced with large-size loose gravel. Under such driving conditions, the balloon tire is accused of acting like a drum to magnify or focus car-mechanism noises or vibrations, so that the result appears more noticeable than with high-pressure tires. This quality of producing resonance is traced by some car-manufacturers to all makes and types of balloon tire, regardless of tread design. The smoother the tread is, the greater the resonance has been reported to be. It has been suggested that the public ought to be advised of this property of balloon tires, so that car mechanisms will not be blamed for causing noise.

In an endeavor to learn something of this complaint and, if possible, to measure vibration roar in closed cars, some experiments were made with an instrument known as the No. 3A audiometer, shown in Fig. 11, developed by the Western Electric Co. and described in detail in a bulletin issued by that company. This audiometer produces a sustained complex tone, the intensity of which is adjustable on a control dial. The faintest tone from the vibrator or buzzer that can be heard by the ear under given conditions is taken as the threshold of hearing. The sound to be measured, for example, that in a closed car at 20 m.p.h., is then produced and the buzzer tone is increased to a point at which it just masks the noise outside the audiometer. The difference between the dial readings of the arbitrary scale, at the threshold of hearing and when the buzzer tone masks the outside noise, is the measure of the outside noise. Table 3 shows the results that were obtained.

Since only small variations were shown between audiometer readings for balloon and high-pressure tires on the same car, results with high-pressure tires are not given in Table 3. It is therefore evident that the use of balloon tires does not generally increase noises in closed cars, as determined by audiometer measurements. This does not mean that the two types of tire have the same effect on passengers, for vibrations not measured by the audiometer may produce more discomfort than noises. Also, only minor differences were noted when windows were open and when they were closed. Readings were slightly higher with closed windows. Engine noises, especially in the four-cylinder car, far exceeded those from other sources. Traveling upgrade or in second speed materially increased engine noises.

It should be understood that such measurement of noises in automobiles by the audiometer as has been accomplished is merely preliminary and incidental to a more technical research that should be undertaken to locate the sources and causes of these noises. It is not our intention to pursue the project to such a termination. Problems of greater importance to the tire in-

TABLE 3—NOISE MEASUREMENT BY THE NO. 3A AUDIOMETER[3]

Vehicle	Speed, M. P. H.	Kind of Tire	Inflation-Pressure, Lb. per Sq. In.	Gear	Audiometer Reading			
					Smooth Asphalt		Cross Laid Brick	
					Car 1	Car 2	Car 1	Car 2
Two Eight-Cylinder Sedans	Standing	Balloon	25 to 30	High	31	32	..	..
Two Eight-Cylinder Sedans	Standing, Engine Running 30	Balloon	25 to 30	High	40	47	..	..
Two Eight-Cylinder Sedans	Standing, Engine Running 20	Balloon	25 to 30	High	38	45	45	47
Two Eight-Cylinder Sedans	Standing, Engine Running 35	Balloon	25 to 30	High	45	48	49	51
					Car 3		Car 3	
Six-Cylinder Sedan	Standing	Balloon	25 to 30	High	33	..	..	..
Six-Cylinder Sedan	Standing, Engine Running 30	Balloon	25 to 30	High	42	..	..	..
Six-Cylinder Sedan	Standing, Engine Running 20	Balloon	25 to 30	High	42	..	44	..
Six-Cylinder Sedan	Standing, Engine Running 35	Balloon	25 to 30	High	52	..	49	..
					Car 4		Cobbles Car 4	
Four-Cylinder Sedan	Standing	High Pressure	......	High	25	..	..	..
Four-Cylinder Sedan	Standing, Engine Running 30	High Pressure	......	High	55	..	..	..
Four-Cylinder Sedan	Standing, Engine Running 20	High Pressure	......	High	40	..	45	..
Four-Cylinder Sedan	Standing, Engine Running 25	High Pressure	......	High	50	..	50	..
Single-Deck Motorbuses, Detroit	20	Solid	......	High Speed	56	Third Speed	Accelerating	61
Double-Deck Motorbuses, Detroit	25	Solid	......	High Speed	50	Third Speed	Accelerating	60
Double-Deck, Six-Wheel, Motorbus, Detroit	20	Pneumatic	......	High Speed	35	Third Speed	Accelerating	41

[3] Audiometer measurements failed to prove that balloon tires magnify noises in closed cars. Table 3 gives representative readings of this instrument used in four different makes of car and in motorbuses operated in Detroit.

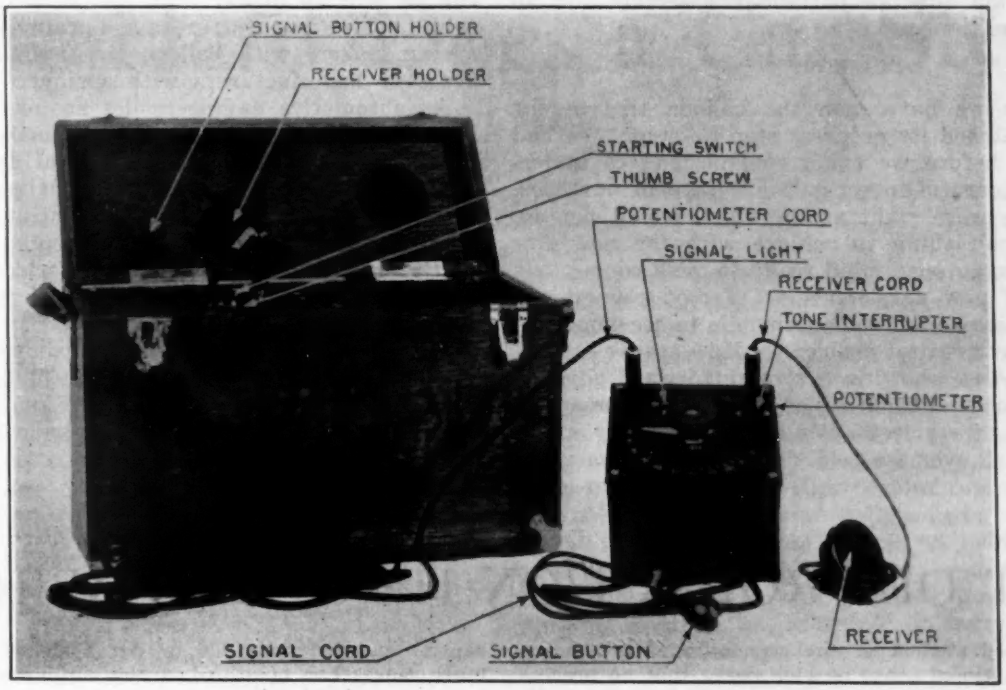


Fig. 11—Instrument Used To Measure Vibration Roar in Closed Cars
The Audiometer Produces a Sustained Complex Tone Transmitted by a Double Telephone-Receiver to the Ear. The Volume of the Tone Can Be Varied Until It Is Masked by Sounds, for Example, Inside an Automobile. Sound Volume Is Read on an Arbitrary Scale

dustry take precedence. The audiometer as a sound-measuring device is brought to your attention for whatsoever future use you believe it merits. We believe it has possibilities of application that are both practical and worthy of further utilization.

It seems feasible to develop the idea of the audiometer or a similar device further, so as to measure separately the source, quality and volume of each important group of sounds or noises produced in an automobile. A possible refinement is some modification of the two-direction detector used during and since the war to magnify underwater sounds, such as the approach of submarines and icebergs. This detector was invented by the French and was improved in this Country. It consists of a lens for bringing to a focal point incoming sound impulses. Submarines could be heard at a distance of from 1 to 10 miles, and the direction was determinable within 1 or 2 deg. Thus, the device was five times as accurate from the directional standpoint as the human binaural sense, which can determine sound directions within from 5 to 10 deg. Utilizing the recent advances made in electricity and telephony, we ought to be able to refine the audiometer, or instruments devised for similar purposes, in order to locate accurately, segregate, and measure noises in automobiles as easily, quickly and accurately as a physician stethoscopes our pulmonary regions.

Shimmy

The word "shimmy" and the motion it describes have provoked more discussion than any other factor uncovered by the balloon tire. The reason lies as much in the word itself as in the motion. Give the salesman and the consumer a familiar, non-technical word that suggests but does not explain, and this word travels faster than rumor. Such nomenclature is good advertising and good sales psychology—witness the "balloon" tire—but it is poor engineering practice. The problem of shimmying would have been solved quietly, by vehicle and allied engineers rather than by salesmen, car-owners and editors, had the motion been described as magnified synchronization of front-end vibrations, for such terminology would have been as little understood and discussed by the layman as torque or turbulence. This does not mean that final solutions of such problems should not be a matter of general public concern. A radical change like the balloon tire, in any part of a rather delicately balanced automobile, is bound to upset several things. But, in such cases, the thing to do is to talk our own language until a solution is well under way. Then let democratization take its course.

The first impulse was to attribute shimmying to the tire, because the tire was the recipient and focus of the motion. This diagnosis is like treating our shoulder for the first tinge of rheumatism. It is only local treatment and generally does not reach and correct underlying constitutional causes. Wheels, rims, axles, brakes, speed, steering mechanism and toe-in, each in turn, have been diagnosed as the producer of the trouble and in some instances, special remedies have been employed. Sometimes such treatment sufficed, but the fact that each particular make of car requires a specific and generally different remedy is reasonable evidence that the cause of shimmying motions lies in improper balance. The correction is to take-up lost motion, to change fundamentally the unbalance to balance whenever and wherever it occurs and not to increase inflation-pressure unduly or add otherwise unnecessary devices which, even at best, are, generally speaking, nothing better than temporary expedients.

Therefore, shimmying is not exclusively a tire problem, although a tire greatly out-of-balance may be a contributing factor. That it was first blamed on the tire has been beneficial to the tire industry, for attention was thereby directed to possible refinements and resulted in producing tires of better average balance. There is no common panacea for shimmying as revealed in different makes of car. Each designer must study his own problem and make such corrections as will eliminate the motion for his particular assembly for all serviceable conditions.

SUMMARY

For 2 years we have seen the balloon tire in the making and watched its progress step by step. We had to understand before we could control, and to understand required careful investigation. To shut our eyes, secure that we were right at the start, would not do. The most difficult thing to achieve with the new tire was, and still is, an open mind ready to mold convictions in the light of new developments. Today, refinements of the balloon tire and of the automobile to accommodate it appears as our greatest problems. How are we attacking them? Are we showing a straightforward advance against the major difficulties of engineering and the minor troubles of service? We are not! Many of us are zigzagging all over the field, dissipating our energies in minor flank encounters while more important difficulties directly in our own line of advance remain unsolved. Tire manufacturers are grappling with shimmy; spring makers with balloon tires; snubber and shock-absorber manufacturers with springs.

As automotive engineers, let us get ourselves examined! Are we doing our share to make automotive-engineering research a growing vital force of genuine experiment, leavened with personality? Are we to initiate our own refinements or continue contentedly to take an annual pilgrimage to foreign shores for next year's ideas? We must lead the world in refinement as well as in production and still find time to make our work a matter of public concern.

The surest solution of the balloon-tire problem is a closer exchange of real facts, an understanding that amounts to an informal conspiracy among all concerned to promote a diffusion of the best knowledge we have of the tire's virtues and shortcomings as it is designed and manufactured at the present time.

COST OF PRODUCTION HERE AND ABROAD

THE experienced student of the economics of production in an international sense is well aware that no process is more apt to give rise to misleading conclusions about the relative cost of national production and the relative ability of the various national industries to compete in the world's markets than that of comparing the bald figures of the wage rates or the other rates of compensation obtaining in the competing countries. The truth is that the question of the ultimate general cost of production in a given country is an extremely complex one, many other factors entering into the determination of this cost besides the amount of the remuneration which the productive workers derive from their services. Certain of the most important of these other factors, indeed, are antecedent to the wage element of cost and decisively affect the magnitude of that element itself.

This truth is well illustrated by the statistics compiled by English economists before the war in which comparisons were made between the mechanical equipment at the disposition of the workers in various British industries, as measured by the number of horsepower employed per 1000 workers, with that at the disposition of the workers in the same industries in the United States. It appeared from those statistics that in the American industries from two to five times as much machinery was in use for a given number of workers as in the same industries in Great Britain. And, what is more important still in the present connection, the statistics also demonstrated that the per capita production of the American workers is larger than that of the British workers in virtually the same proportion as the mechanical equipment of the former is greater than that of the latter. If British industry is taken as a whole the sum-total of capital invested per 1000 or per 1,000,000 workers is not much more than one-third of the similar investment in the industries of this Country. The necessary consequence, of course, is that British industrial production per 1000 or per 1,000,000 workers is correspondingly smaller than that in the United States, and that the relative remuneration which their productive services yield to the British workers follows the same rule. The assumption is warranted that, if the fundamental conditions of industrial production in Germany, France, Belgium and Italy were investigated statistically, it would be found that the industrial wage rates of these countries, except insofar as they have been temporarily distorted by the economic effects of the war, closely harmonize with the capital invested and employed in the countries' industries, proportionately to the number of wage-earners.

The average number of persons employed in American agriculture per 1000 acres of crop land is 41, whereas the corresponding number in England and Wales is 105; in France, 120; in Germany, 160; and in Italy, 235. That is, the land capital investment per 1000 or per 1,000,000 American farmers is greater than that in the other countries named in proportions very closely approximating those obtaining for our industries. Furthermore, it is matter of common knowledge that the capital investment of American farmers in farm machinery is likewise greater than that of British, French, German and Italian farmers by similar ratios. The economic effect of this larger capital investment in American agriculture in relation to the number of persons employed is unquestionably to increase the per capita production and the normal per capita remuneration of our farmers to a corresponding degree.—A. R. Marsh in *Economic World.*

AUTOMOTIVE EXPORTS

IN 1920, the United States had 73.0 per cent of the automotive export trade of the world; Canada, 9.8 per cent; and all other countries, less than 18.0 per cent. In the first 6 months of 1924, the United States' share was 54 per cent, Canada's 17 per cent, and other countries had increased their quota to nearly 30 per cent. The significance of this development lies in the quickness with which it has occurred. France, at present, due to the recent development of the small-type car, is selling more passenger cars in Belgium, United Kingdom, Germany, Switzerland and other countries than is the United States. Italy ships twice as many cars to Switzerland as we do, and many more to Austria, France and Egypt. The United Kingdom is directing its attention to Australia, for years the chief passenger-car customer of the United States, and is selling its motor vehicles in increasing numbers to its other colonial possessions. In 6 months of 1924, as many British made cars were sold as in the entire year of 1923.

In quantity of production and exports America still stands alone, our manufacturers having built in 1923 more than 4,000,000 cars and trucks, shipped 221,000 from the United States and Canada, and assembled 106,000 more abroad; while the rest of the world built 500,000 units at most and exported perhaps 70,000. Operating 90 per cent of the motor vehicles of the world and accounting for 80 per cent of its production, the United States and Canada lead the world in motor-transport development.—Percy Owen, chief of the automotive division of the Department of Commerce.

How Hard Does a Car Steer?

By F. F. CHANDLER[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

RELATIVE ease or difficulty of steering has in the past been largely a matter of psychology, of comparison rather than of measurement. One driver may find a car difficult to steer that another finds easy. Safety is the first essential, then comfort. Because the parts used in steering seldom break, present practice is considered safe, but the steering-ratio is very important. A low ratio that produces fast steering-effects may be entirely safe in the hands of a strong, safe, experienced driver, but absolutely unsafe in those of a weaker driver, even though he may be expert. Fatigue, however, will eventually affect the strong as well as the weak driver, so that comfort enters as well as safety.

With a view to eliminating the personal factor and determining by exact measurement the steering-effort exerted by a driver and the reactions termed road shock, road fight, shimmying and the like, instruments have been devised to produce a graphical record simultaneously of (*a*) the amount of steering-effort and the reactions at the steering-wheel, and (*b*) the stress imposed upon the drag-link; note is also made whether the steering-effort is to the right or to the left.

The details of construction and operation of these instruments are described and the results of tests made on roads of various types when the car is traveling at various rates of speed are discussed. A study also was made of the comparative effort exerted in making turns to the right and to the left, in suddenly reversing the direction of stress, and of the effect produced by striking a curbstone.

Statements are made that tests show that the drag-link stress of a car not in motion ranges from 400 to 600 lb., that balloon tires require 50 per cent greater steering effort than do high-pressure tires, that in some high-grade popular cars a difference of only a few ounces of steering-effort changes unsatisfactory conditions into very satisfactory results, that differences as great as 450 per cent have been found in the friction of the steering-knuckle thrust-bearings of current models of well-known cars, and that a difference is apparent between the steering-efforts required in cars having and in those not having center-point steering.

THE steering of automotive vehicles has always been a matter of comparison rather than measurement. A car that steers easily for one driver may steer hard for another. It has been and may always be largely a matter of psychology. As has been pointed out in a previous article,[2] safe steering is of the first importance. After safety, comes comfortable steering, the kind one individually likes.

Because the safety factor has heretofore been controlled by the making of steering parts that do not break and because these steering parts do not frequently fail, we look upon present practice as being safe. This view of safe steering is not altogether sufficient, however, because the low ratio that produces fast steering-effects may be entirely safe in the hands of a strong fast experienced driver and be absolutely dangerous in the hands of a weaker though expert driver. The weaker operator might drive safely for a short distance with a fast gear, but the manual labor thus imposed upon him would tire him to a point at which his driving might actually become unsafe. A strong driver contends that he cannot drive a high-reduction gear that produces slow steering-effects, because he cannot dodge obstacles quickly; and so the argument goes on, yet, if we bring in the factor of comfort, we must admit that even a strong driver eventually will become tired and a weak driver will become more tired; so, after all, do not the two factors, safety and comfort, go hand in hand?

NECESSITY FOR SECURING RELIABLE DATA

The trouble resulting from these differences of opinion usually begins with the designer. Being an expert, he thinks he knows how a car should steer. What he does know is, how a car should steer to suit him. He frequently overlooks the fact that he is a strong and experienced driver and usually a fast one, whereas the cars he produces are built for the public, most of whom are not strong, experienced or fast.

I have had a very strong feeling for many months that the best results in steering cannot be secured without considering certain well-defined facts which, up to this time, have not been known.

In designing the instruments used in the tests, in which H. A. Huebotter[3] played a prominent part, we desire to secure, if possible, an actual measurement of the steering-effort exerted by the driver, as well as a measured record of the unpleasant reactions usually termed road shock, road fight, shimmy and the like. As the actual steering-effort exerted by a driver is dependent upon the design of the steering-gear and its ratio of reduction, as well as upon the general set-up of all the steering linkages and the friction of those parts, it was quickly seen that two instruments had to be devised, one to record the steering-effort and the steering-reactions at the steering-wheel, and the other, the stress imposed upon the drag-link, and that both instruments had to be sufficiently efficient not only to record these things quickly and accurately, but to record definitely whether the steering-effort was made to the right or to the left.

It was finally decided that it was necessary to produce a third instrument; making one for application to the steering-wheel, one to the drag-link, and the third, a recording instrument, to produce simultaneously a chart record resulting from the action of the first two.

Figs. 1, 2 and 3 show views of the strip-chart recording-instrument. This consists of a conventional clockwork mechanism so modified that the strip-chart will move in a horizontal plane while two records are being made by two pens, as shown in Figs. 1 and 2. Each of these pens is operated by its own piston and spring-assembly. The pistons and springs are contained in cylinders mounted at either end of the instrument.

[1]M.S.A.E.—Chief engineer, Ross Gear & Tool Co., Lafayette, Ind.; trustee, Purdue University, Lafayette, Ind.

[2] See THE JOURNAL, June, 1924, p. 585.

[3] M.S.A.E.—Research assistant, Purdue University Engineering Experiment Station, West Lafayette, Ind.

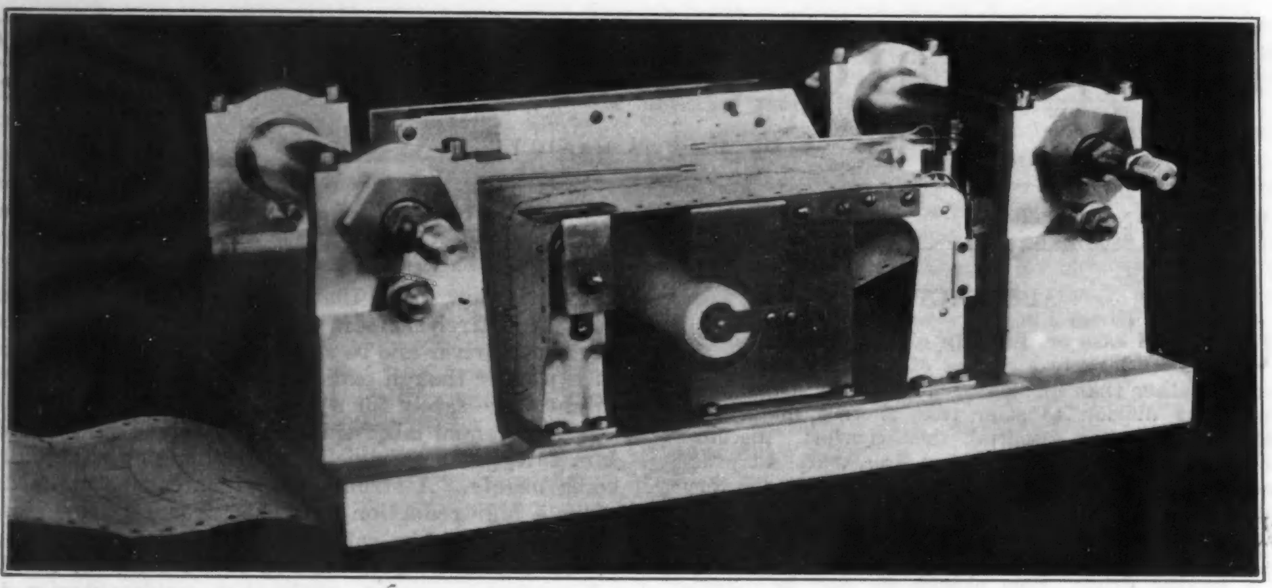


FIG. 1—FRONT VIEW OF THE RECORDING INSTRUMENT
This Instrument Consists of a Conventional Clockwork Mechanism That Has Been So Modified That the Strip Chart Moves in a Horizontal Plane and Records Are Made Simultaneously by the Two Recording Pens

The pistons are operated by hydraulic pressure carried through flexible tubes that are connected with the ends of the cylinders by the fittings shown. As one of the pens produces a record of the driver's effort applied at the steering-wheel, it must, therefore, not only record the time at which the effort is produced and its amount, but whether the driver is making a right-hand or a left-hand turn. As the instrument is held in the lap of an observer seated beside the driver, and as the strip-chart moves forward, or in the direction in which the car is traveling, to carry out the logical arrangement further, the recording-pens are designed to move to the right of a zero-line drawn through the middle of the strip-chart, when a right-hand steering-effort is being produced, and to the left of the zero-line, when a left-hand turn is made.

The arrangement of the parts is shown in Fig. 4. In the drawing at the left pistons *a* and *b* both lie in cylinder *c*. When pressure is admitted through openings *d* and *e*, these pistons move toward each other until the piston *a* meets the stud *f*, which projects from the piston *b*. The space left between the ends of the two pistons is just sufficient to allow the insertion of the pen-arm *g*.

Connected with piston *b* is a steam-engine indicator-spring, the opposite end of which is connected with the cylinder-head. If a preponderance of pressure is on piston *a*, the piston will move toward the left and, since it presses on the projection *f*, it will also move piston *b* toward the left, compressing the spring and pushing liquid out of the opening *d*. In this presumption, the part *g* of the pen-arm will also move to the left, moving

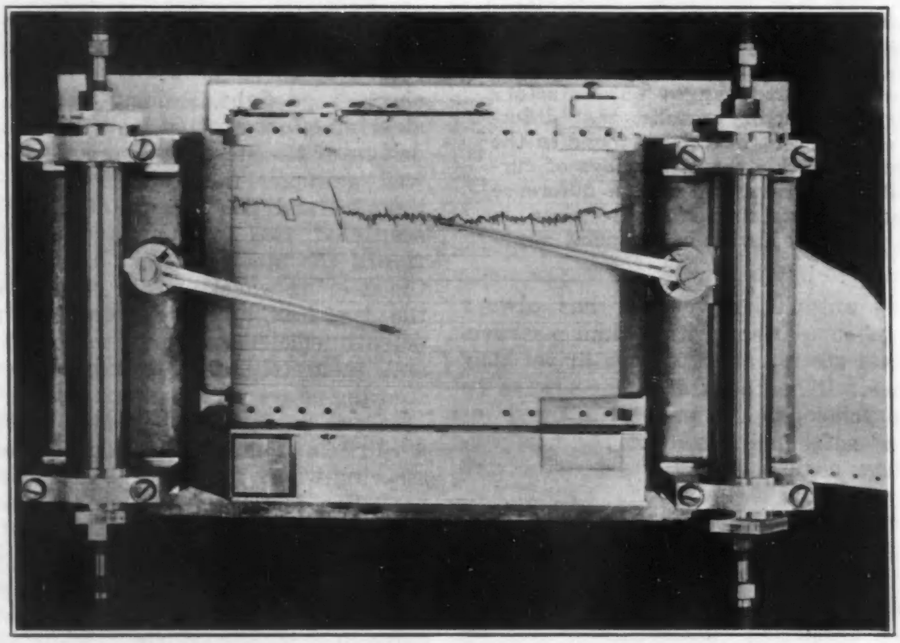


FIG. 2—VIEW LOOKING DOWN ON THE RECORDING INSTRUMENT
Each of the Recording Pens Is Operated by Its Own Individual Piston and Spring Assembly. These Operate in the Polished Cylinders Mounted at Each End of the Instrument. Hydraulic Pressure Regulates the Movement of the Pistons. One Pen Produces a Record of the Driver's Effort Applied at the Steering-Wheel and Indicates Whether a Right-Hand or a Left-Hand Turn Is Being Made

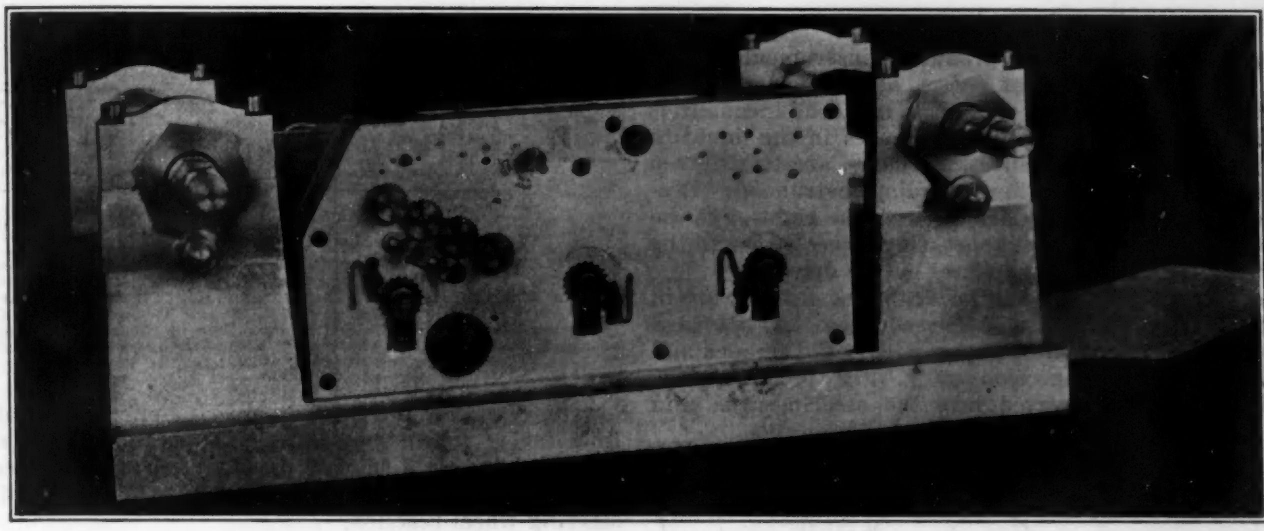


FIG. 3—REAR VIEW OF THE INSTRUMENT
The Clockwork Mechanism Is Shown as Well as the Connections for Admitting Pressure to the Cylinders That Actuate the Recording Pens

the pen itself to the right of the zero-line on the strip-chart. With a preponderance of pressure in the opposite direction, the pen will be moved to the left of the zero-line. The same result could be accomplished if the two pistons were made into one, but it was thought that better fits could be preserved by the method adopted.

The drawing at the right of Fig. 4 shows the mounting of the pen-arm and of the capillary tube which dips into the inkwell so that ink is fed to the glass penpoint.

WHEEL INSTRUMENT

The instrument attached to the wheel is shown in Fig. 5. This is an auxiliary steering-wheel made with a universal bracket so that it can be mounted on the driver's wheel by clamping it to the wheel rim. Portions *h* of this mounting move rigidly with the driver's wheel. At the point *k*, a bearing is turned on portion *h* on which turns the auxiliary wheel *j*. In the rim of the auxiliary wheel *j* is inserted a cylinder that moves whenever the auxiliary wheel is moved. In this cylinder is a piston with a ball-joint in the center and connections with the other portion *h*. Two flexible tubes are connected at points *l*, the opposite ends of the tubes being connected with the ends of the cylinder in the recording-instrument shown in Fig. 4.

If the cylinders in Figs. 4 and 5 and the tubes connecting them are filled with liquid, and if a steering effort to the right is imposed upon the auxiliary steering-wheel, pressure will be set-up in the instrument and will be recorded on the right side of the zero-line on the strip-chart. A left-hand steering-effort produces a record to the left of the zero-line.

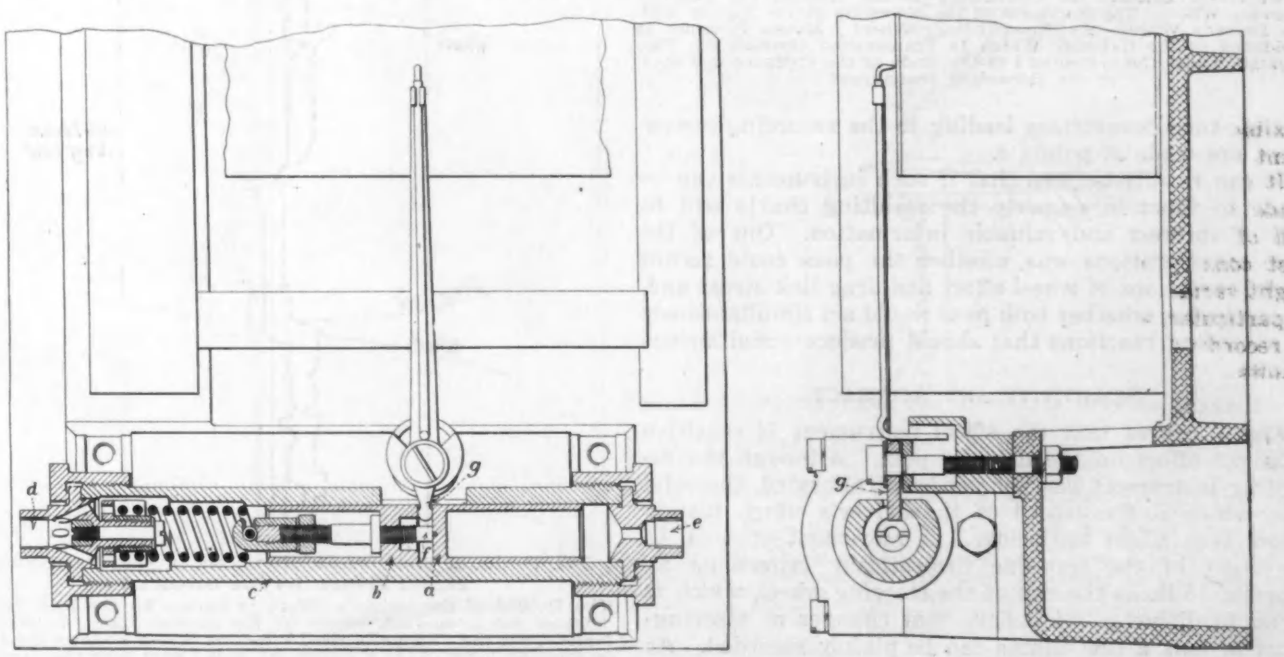


FIG. 4—SECTION THROUGH THE RECORDING-INSTRUMENT CYLINDER (AT THE LEFT) AND THE PEN MOUNTING (AT THE RIGHT)
The Movement of the Recording Pen Is Controlled by the Pistons *a* and *b* Which Move toward Each Other When Pressure Is Admitted to the Cylinder *c* through the Openings *d* and *e*. If the Pressure Admitted through *e* Is Greater than That Exerted by the Steam-Engine Indicator Spring Connected to the Piston *b*, the Stud *f* on the Piston *b* Is Forced to the Left and the End *g* of the Pen Arm Is Moved to the Left, Causing the Pen To Move to the Right of the Zero-Line on the Chart. Ink for Tracing the Records Is Fed from the Inkwell through a Capillary Tube to the Glass Pen-Point

Drag-Link Instrument

Fig. 6 shows a pressure-producing instrument for use with the drag-link so that stress, alternation of stress, steering-effort, the result of impact, and road inequalities all will produce corresponding pressures in the liquid in the cylinder. These pressures, similarly, are transferred to the other cylinder of the recording-instrument. Records of results are thus made either to the right or to the left of the zero-line on the chart, simultaneously with the effort put into the steering-wheel by the driver.

The reasons for making the drag-link instrument in the form shown are not of consequence. A standard drag-link, as used on the test-car, is cut off, threaded and screwed into the connection at *m*, Fig. 6, a separate steering-ball *n* is inserted into the steering-arm, and

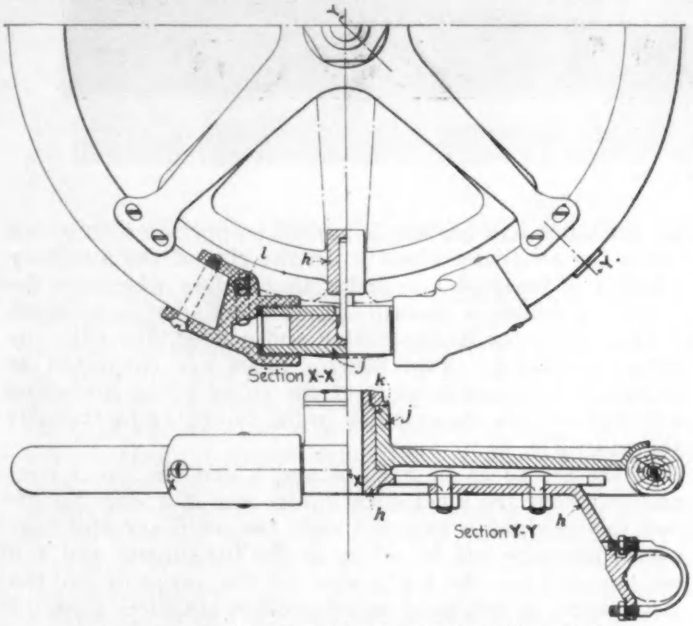


Fig. 5—The Steering-Wheel Pressure-Element

This Is in Reality an Auxiliary Steering-Wheel That Is Made with a Universal Bracket for Connection to the Rim of the Regular Steering-Wheel. The Portion *h* of the Mounting Moves Rigidly with the Driver's Wheel. As the Auxiliary Wheel *j* Moves, Pressure Is Produced in the Cylinder Which Is Transmitted through the Two Flexible Tubes Connected at *l* to the Ends of the Cylinder *c*, Fig. 4, of the Recording Instrument

flexible-tube connections leading to the recording-instrument are made at points *o*.

It can readily be seen that if such instruments can be made to function properly the resulting charts will be full of interest and valuable information. One of the first considerations was whether the pens could record slight variations of wheel effort and drag-link stress and, in particular, whether both pens would act simultaneously in recording reactions that should produce simultaneous results.

Sensitivity and Accuracy

Fig. 7 proves that the wheel instrument is sensitive to slight effort on the driver's part. Although the recording-instrument has not yet been calibrated, the solid line, which is the record of the driver's effort, plainly shows very slight variations. A movement of 1 in. to the right of the zero-line theoretically represents an effort of 15 lb. at the rim of the steering wheel, which is 18 in. in diameter. I believe that changes of steering-effort of only a few ounces can be plainly recorded. As steering-efforts of from 50 to 75 lb. can easily be produced by ordinary drivers, the minimum readings would seem to be very satisfactory.

Fig. 7 also proves that a change in drag-link stress fol-

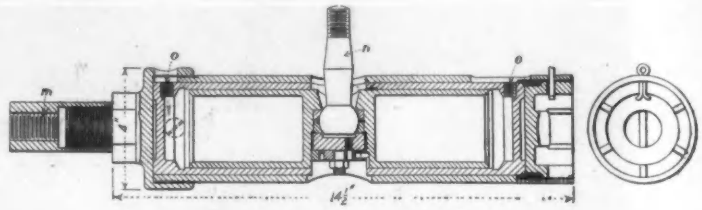


Fig. 6—The Drag-Link Pressure-Element

This Instrument Is Used with the Drag-Link and the Pressures Produced in the Cylinder by Stress, Alternation of Stress, Steering Efforts and the Result of Impact and Road Inequalities Are All Transmitted to the Other Cylinder of the Recording Instrument. Records of These Results Are Made either to the Right or the Left of the Zero-Line of the Chart and Simultaneously with the Efforts Put into the Steering-Wheel by the Driver

lows very closely a change in steering-effort. The drag-link line is shown by dashes. As the chart was made while driving on a smooth street, the drag-link stress is a result of the driving-effort and is not a cause of the steering-wheel reaction.

Theoretically, a 1-in. movement of the drag-link to either side of the zero-line represents a stress of 150 lb. in the drag-link; it will therefore be apparent that the set-up of the instrument is in the ratio of 10 to 1 with respect to the drag-link and the wheel readings. Results thus far secured indicate that changes of only a few pounds in the drag-link stress can be plainly recorded, and prove that the two pens will move simultaneously, as is demonstrated at a number of places on the chart shown in Fig. 8.

To do this, a rectifying template was made so that, when properly placed over the zero-line on the chart, two curves can be drawn, the lower one, marked "wheel," rep-

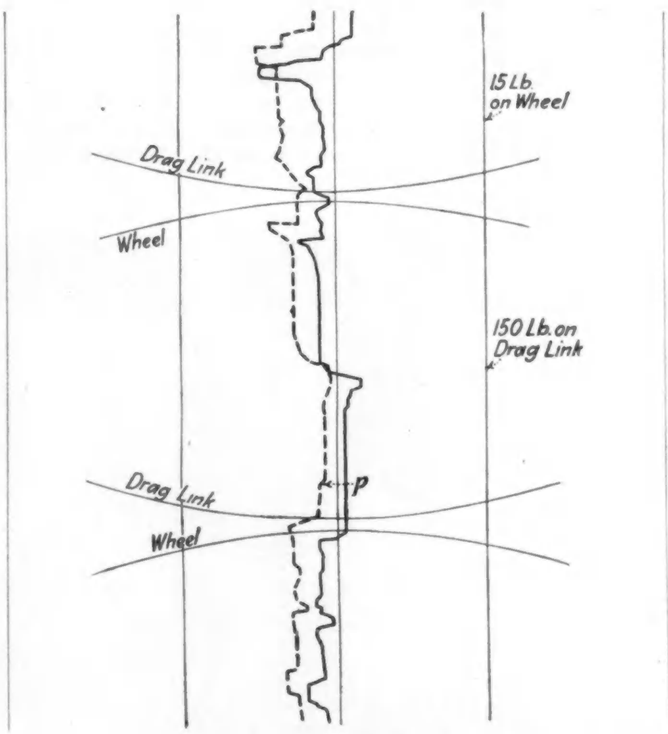


Fig. 7—Chart Showing Sensitiveness of the Instrument to Slight Efforts on the Driver's Part

The Record of the Driver's Effort Is Shown by the Full Line and That of the Drag-Link Stress by the Broken Line. It Should Be Noted That the Change in the Drag-Link Stress Follows the Change in Steering-Effort Very Closely. As This Chart Was Obtained while Driving on a Smooth Street, the Drag-Link Stress Is a Result of Driving-Effort and Is Not a Cause of Steering-Wheel Reaction. The Blur in the Drag-Link Line at *p* Was the Result of Some Imperfection in the Road Which Did Not React at the Steering-Wheel because of the Irreversible Characteristics of the Steering-Gear in the Car

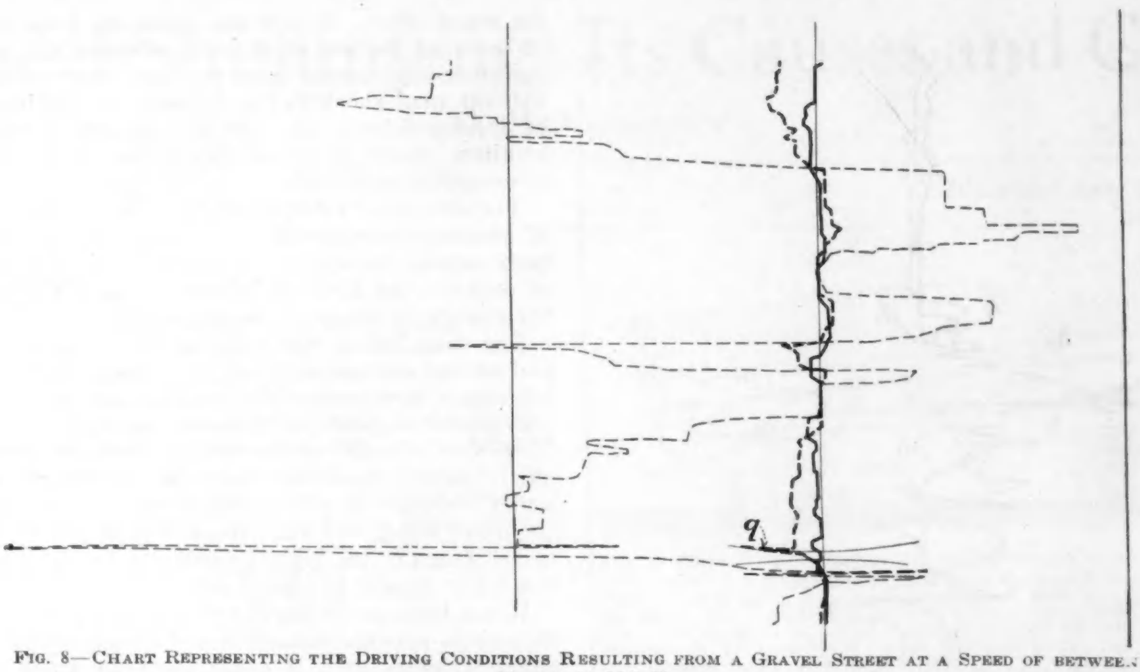


Fig. 8—Chart Representing the Driving Conditions Resulting from a Gravel Street at a Speed of Between 15 and 20 M.P.H.

On This Chart the Drag-Link Line Has Been Increased 10 Times To Show How a Chart Would Look If the Two Pens Were Recording in a Ratio of Unity instead of 10 to 1. As This Record Is One of Driving Conditions It Will, in This Modified Form, Picture More Accurately the Very Wide Variations of the Proportion between the Drag-Link Stress and the Wheel Effort. It Also Shows the Desirability of Securing Designs of Steering Systems Which Will Absorb the Drag-Link Forces To Make Comfortable Driving without Road Shock to the Driver

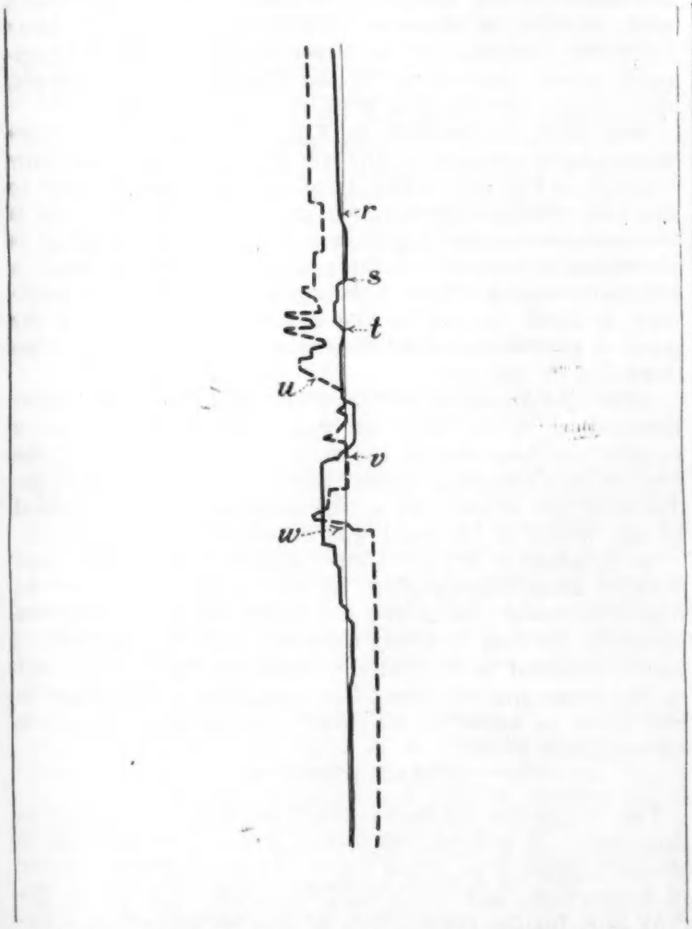


Fig. 9—Chart Showing the Effect of a Crowned Road

The Records of the Wheel Effort and the Drag-Link Stress Accompanying the Gradual Change in the Direction of a Car from the Right Side of a Crowned Gravel Street over the More or Less Rough Center Section to the Left Side Are Reproduced. The Maximum Wheel-Effort Was about 3 Lb. and the Maximum Drag-Link Stress about 30

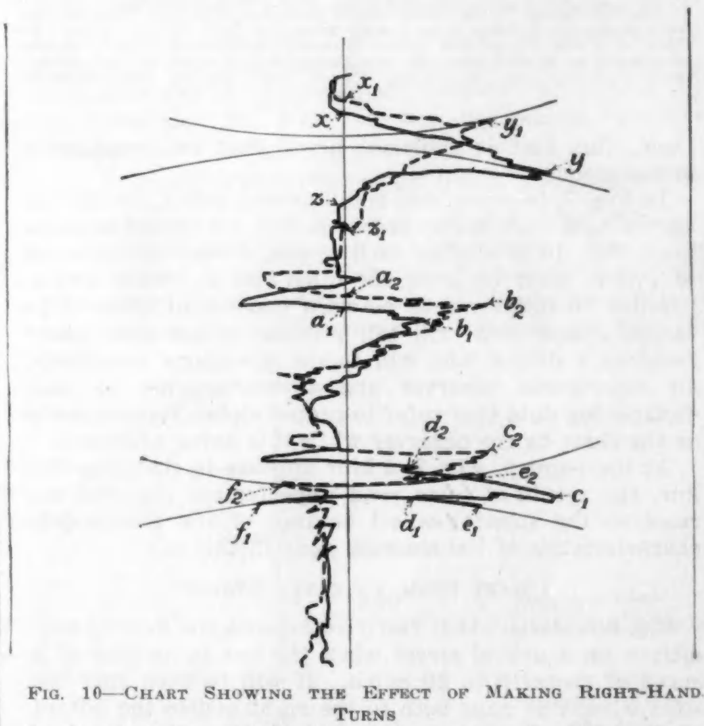


Fig. 10—Chart Showing the Effect of Making Right-Hand Turns

In the First Turn Which Was Rather Sharp the Effort of the Wheel from x to y Was Greater in Proportion than the Resulting Stress in the Drag-Link x_1-y_1; after the Turn Had Been Made the Wheel Effort from y to z Decreased Much More Rapidly than the Drag-Link Stress y_1-z_1, Thus Showing a Decided Self-Righting Tendency. In the Case of the Second Turn the Wheel Effort a_1-b_1 Is in a Proportion of Less than 10 to 1 when Compared with the Resulting Drag-Link Stress a_2-b_2 and the Self-Righting Effect Was Much Less. The Last Turn Is More Interesting as It Proves Not Only the Reversible Characteristics of This Particular Steering-Gear in the Extreme Position but Also the Speed of the Recording Instrument

resenting the arc through which the wheel-needle travels, and the upper one, marked "drag-link," representing the curve followed by the drag-link pen. If the wheel line and the drag-link line both show a similar change in contour at points where the rectifying curves intersect

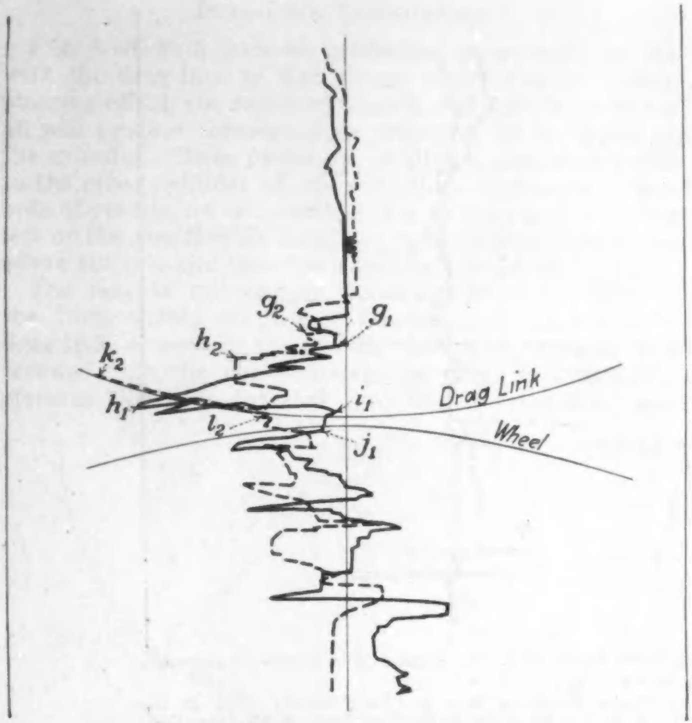


Fig. 11—Chart Showing the Effect of Running into a Curb
At the Beginning of the Chart the Car Is Traveling Down the Middle of a Street with Practically No Wheel-Effort or Drag-Link Stress. A Quick Turn to the Left Was Made from g_1 to h_1, the Drag-Link Stress Being Shown from g_2 to h_2. The Car Was Moving toward the Curb from i_1 to j_1 and when the Left Wheel Struck the Curb at j_2 the Drag-Link Stress Instantly Increased Greatly to the Maximum at k_2 and Immediately Dropped to l_2 and in Both Directions Followed the Rectifying Curve That Shows Instantaneous Action

them, this fact is sufficient proof that the reaction is simultaneous.

In Fig. 7, to prove this simultaneous action, rectifying curves have been drawn at two points. It should be made plain that, in producing such charts, a very accurate log of events must be kept, for otherwise it would be impossible to differentiate between cause and effect. To secure charts that will tell properly a complete story requires a driver who will follow directions absolutely, an experienced observer and a stenographer to take dictated log data that refer to proper cipher records made on the chart by the observer while it is being produced.

At the point *p*, Fig. 7, a blur appears in the drag-link line, the result of some road imperfection that did not react at the steering-wheel because of the irreversible characteristics of the steering-gear in this car.

Chart from a Gravel Street

Fig. 8 is a chart that fairly represents the driving conditions on a gravel street when the car is moving at a speed of from 15 to 20 m.p.h. It will be seen that the solid wheel-line runs both to the right and to the left of the zero-line, just as the steering-wheel is unconsciously moved slightly by the driver. At no point in the wheel line is a steering-effort shown that exceeds 1 or 2 lb. Also, at no point on the chart is there a pronounced similarity between the drag-link line and the wheel line. The drag-link line actually produced by the instrument is the dotted line nearest to the zero-line.

On the chart, the dotted drag-link line has been increased 10 times, to show how the chart would look if the pens were recording in a 1 to 1 instead of a 10 to 1 proportion. As this is a record of driving-conditions, it will, in modified form, depict more truly the very wide variations of proportion between the drag-link stress and the wheel effort. It will also show the great desirability of securing designs of steering-systems that will absorb the drag-link forces and produce comfortable driving without road shock to the driver. A steering-gear may be irreversible in one car and extremely reversible in another. Some gears are reversible in all cars; others irreversible in all cars.

The subject of reversibility of steering-gears is worthy of separate consideration. It includes overall efficiency, helix angles, the character and the shape of the surfaces in contact, the kind of lubrication, and the rapidity of the change of stress in the drag-link.

The drag-link at the point *q*, Fig. 8, shows a sudden and abrupt change in stress amounting to perhaps 75 lb., yet only a bare trace of the reaction, amounting to only a few ounces, appears at a similar point in the wheel line. This fact should be noted particularly, because the steering-gear under test had irreversible characteristics under ordinary straightaway driving-conditions, but, on the other hand, had very reversible characteristics when moved much to the right or much to the left, when making turns, as will be shown later.

It has been particularly gratifying to find that the instruments produce simultaneously curves having similar characteristics, and, in other cases in which conditions are different, produce curves of dissimilar characteristics.

Chart of the Crossing of a Crowned Road

Fig. 9 shows the gradual change in direction of a car from the right-hand side of a crowned gravel street over the more or less rough central section to the left-hand side. It must be remembered that the chart moves away from the observer, in the direction of car travel, or upward when observed as in the illustration; the record, therefore, must be read from the top downward.

Beginning at the top, in Fig. 9, it is seen that the wheel shows pressure to the left of the zero-line, but only slightly to the left. The drag-link also shows effort to the left, which is correct, for the tendency of the car is to crawl toward the right; a left-hand steering-effect is therefore necessary to counteract it. At the point *r*, a slighter steering-effort to the right is shown to be necessary to keep the car in the desired direction. At the point *s*, an effort to the left was produced, to change the direction of the car.

After the direction had been changed, the wheel effort lessened at *t*, but the car was then traveling over a rougher section, so that the drag-link pen reacted to the greater and changing stress; but no road shock was produced in the wheel. At *u*, the drag-link stress lessened as the crown of the road was reached.

At *v*, another left-hand steering-effort was made, but without drag-link reaction, as the car was about to go over the crown. At *w*, the car went over the crown, the stress in the drag-link was reversed, and the wheel effort again returned to zero as the smoother road to the left of the crown was reached. The maximum wheel-effort in the chart is about 3 lb. and the maximum drag-link stress about 30 lb.

Turning-Effects

Fig. 10, at the top of the chart, shows a sharp turn to the right. It will be noted that, during the making of the turn from x to y, the wheel shows an effort greater in proportion than the resulting stress x_1 to y_1 in the drag-link, for the reason that, in this particular steering-gear, the ratio changed rather quickly from 15.5 to 1.0 in the mid-position to 7.5 to 1.0 in the turns; conse-

(*Concluded on p.* 248)

Wheel Shimmying: Its Causes and Cure

By O. M. Burkhardt[1]

Annual Meeting Paper — *Illustrated with* Drawings

ABSTRACT

SHIMMYING is an oscillating motion produced by repeated impacts or forces in the linkage of a mechanism that lacks stability or has become loose because of wear. Although previously existent in chassis in which the steering gear was imperfect, it has become particularly noticeable since the introduction of low-pressure or balloon tires. But increasing the rigidity means increasing the unsprung weight, which, in turn, means greater impacts, hence, more shimmying. This is apparent in the effect produced by front-wheel brakes. Consequently, as the amount of looseness that can be removed is limited, the periodic forces that cause shimmying must be overcome.

The propensity of low-pressure tires for assuming periodic rebounds when traversing bumpy roads and for causing shimmying and tramping, as well as pitching and bobbing, is illustrated by an example involving the use of springs; and the deduction is made that in order to minimize its ill effects, the kinetic energy stored in the tires must be absorbed. Another example proves that only 76 per cent as much kinetic energy is stored in high-pressure tires as in balloon tires.

Lateral stability in a tire is a very desirable feature. The lack of it in balloon tires has a profound effect on the steering and produces shimmying. Backlash will cause the same result in cars having center-point or near center-point steering.

The use of a dash-pot, which prevents the lateral forces from synchronizing and, therefore, from gaining momentum, and of friction-discs mounted on the king-pin and the knuckle-shaft, to absorb kinetic energy, is recommended as having a beneficial effect. The three remedies for shimmying suggested by the author are:

(1) Design so that no slackness can develop
(2) Design for rigidity
(3) Use effective devices to absorb kinetic energy wherever it is likely to accumulate

SINCE the introduction of balloon tires, front-wheel shimmying has, under certain unfavorable conditions, become epidemic. The phenomenon was known to exist in some chassis before balloon tires came into prominence. Low-pressure tires, however, have accentuated the nuisance in chassis in which steering was already imperfect, and in chassis that were free from shimmying the symptoms have become noticeable because of their use.

To produce shimmying in the linkage of a mechanism, repeated impacts or forces must first be present. Secondly, inasmuch as shimmying is an oscillating motion, it is obvious that looseness and lack of rigidity of the mechanism are to blame for its occurrence.

In time, some wear will take place in any mechanism and this unavoidable property greatly increases the difficulty of permanently overcoming the evil under consideration. It is difficult to design a complete steering-mechanism of high rigidity and at the same time keep the unsprung weight low. Only reluctantly can we accept an addition to the unsprung weight, because this means greater impacts, hence, more shimmying. The effect produced by front-wheel brakes is sufficient proof of this line of reasoning. Being limited in regard to the amount of play and looseness that can be removed, we must endeavor to eliminate the periodic forces that, by supplementing the wear in the mechanism, produce shimmying.

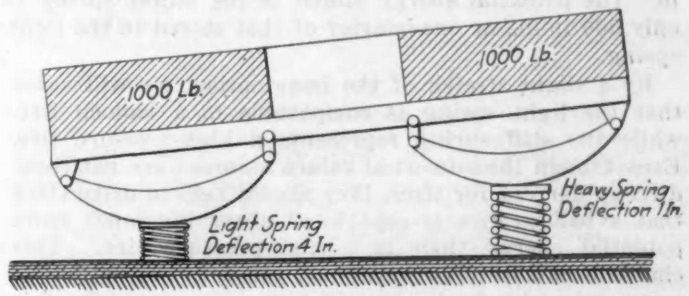


Fig. 1—Examples of Spring Deflection under the Same Weight
At the Left Is a Light Spring Having a Deflection Rate of 250 Lb.; That Is, It Deflects 4 In. under a Load of 1000 Lb. The Spring at the Right Has a Deflection Rate of 1000 Lb. and Deflects Only 1 In. under the Same Load. The Potential Energy Stored Up in the Two Springs Is 2000 and 500 In-Lb. Respectively. The Two Springs Are Readily Comparable to a Balloon and a High-Pressure Tire and the Numerical Values Help To Make Clear the Fact That a Balloon Tire Has a Much Greater Capacity for Absorbing Potential Energy than Has a High-Pressure Tire

Periodic Forces between Tires and Road

A low-pressure tire is capable of absorbing considerably more energy than is a high-pressure tire. For this reason, a balloon tire very readily assumes a periodic rebound on slightly bumpy roads. This characteristic is important because it is mainly responsible not only for

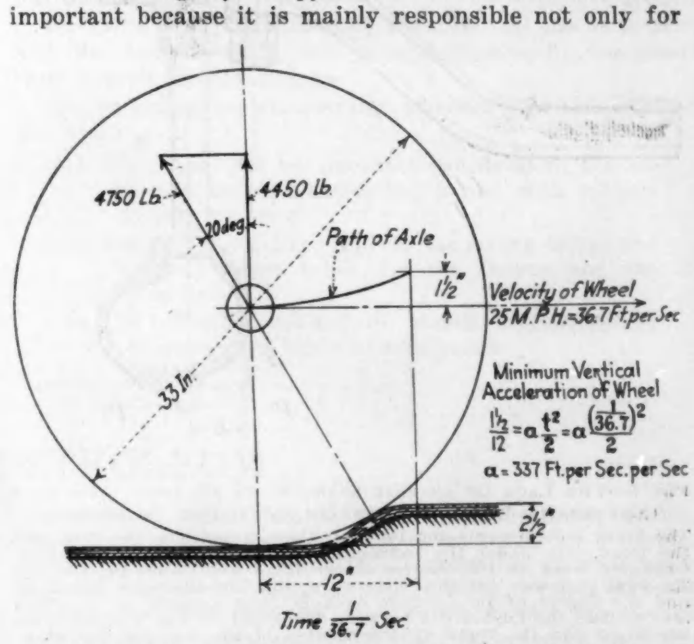


Fig. 2—Vertical Acceleration of a Wheel in Going Over an Obstacle 2½ In. High
In the Example Illustrated the Wheel Is Assumed To Have a Velocity of 25 M.P.H. or 36.7 Ft. per Sec., and in Traveling Forward 1 Ft. the Axle Rises 1½ In. The Acceleration Is Determined by the Formula $a(t^2/2)$ and Equals 337 Ft. per Sec. per Sec.

[1] M.S.A.E.—Consulting engineer, Pierce-Arrow Motor Car Co., Buffalo.

shimmying and tramping but also for the disagreeable phenomena known as pitching and bobbing.

To make this point clear, let us look at Fig. 1. At the left we have a light spring of 250-lb. rate, hence, it deflects 4 in. under a load of 1000 lb. The potential energy stored in the light spring is 2000 in-lb. We also have, at the right, a heavier spring of 1000-lb. rate, hence, this spring deflects only 1 in. under a load of 1000 lb. The potential energy stored in the stiffer spring is only 500 in-lb., or one-quarter of that stored in the light spring.

By a slight stretch of the imagination, we will agree that the light spring is comparable to a balloon tire, while the stiff spring represents a high-pressure tire. Even though the numerical values assumed are not those directly derived for tires, they should help to make clear that a balloon tire is capable of absorbing much more potential energy than is a high-pressure tire. This characteristic is very important yet very susceptible of being misunderstood. For instance, we may take two wheels of the same design, one shod with a high-pressure tire, the other with a balloon tire. If these two wheels are dropped from a given height, each will rebound a distance corresponding to the kinetic energy involved. In a motor car, however, we have springs above the wheels, and the springs carry the largest part of the load.

When a load falls on both the springs and the tires, if the tires are of the high-pressure type, the springs will absorb nearly all the kinetic energy, whereas, if they are of the balloon type, a large part of the kinetic energy will be stored in the tires.

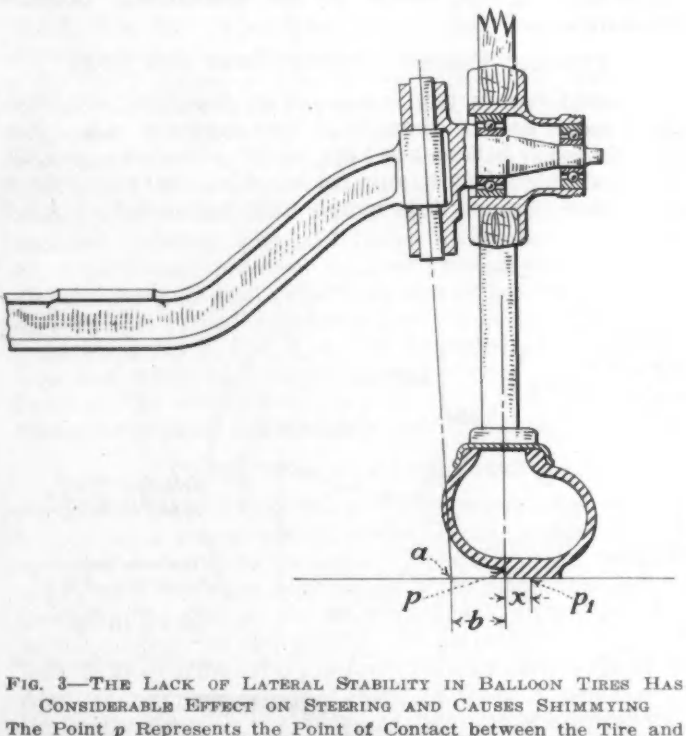


Fig. 3—The Lack of Lateral Stability in Balloon Tires Has Considerable Effect on Steering and Causes Shimmying

The Point p Represents the Point of Contact between the Tire and the Road, but, under the Influence of a Lateral Force That May Originate from an Unevenness in the Road and Cause the Chassis To Sway Sidewise for the Distance x, the Tire Becomes Distorted and the Center of Its Contact Area Is Now Located at p_1. This also Causes the Distance b between the Point of Tire Contact with the Road and the Point of Intersection of the Axis of the King-Pin with the Road, Which Represents the Length of the Lever-Arm through Which All Forces Acting between the Tire and the Road Impact a Turning-Moment to the Knuckle Shaft, To Increase or Decrease by x for Movement of the Chassis to the Left for Right and Left Wheels Respectively. This Change in the Length of the Lever-Arm Produces an Unbalance in the Steering Mechanism and Is Responsible to a Great Extent for Wheel Shimmying

Stiffness of Springs versus Inflation Pressure

The accumulation of energy increases in direct proportion to the stiffness of the chassis springs and decreases as a function of the inflation-pressure. This statement is borne out by observing that balloon tires, under the relatively stiff front springs, give much more trouble that do those under the rather flexible rear springs. Hence, the use of stiffer springs will not remove bobbing and tramping. Bobbing occurs when the deflection of the front spring synchronizes with the deflection of both front tires. If the tire and the spring of one side are one-half cycle behind the tire and the spring of the other side, tramping is produced.

From this analysis, the cure, of course, is obvious. We are dealing with kinetic energy and in order to minimize its ill effects we must resort to devices designed to absorb kinetic energy. As, however, we have no devices to absorb the energy stored in the tires, it cannot be good practice to use low-pressure tires and at the same time stiffen the springs. It is desirable that all road shocks should be absorbed by the tires and the springs, but at present the greater part of the shocks must be taken by the springs, because to them can be applied the means of absorbing the kinetic energy; and kinetic energy is the root of this evil.

In further support of this fundamental law, we have observed that balloon tires, when fitted to cars with four-wheel brakes, give more trouble than when fitted to cars with no brakes on the front wheels. In the light of our theorem, the answer is simple.

The unsprung weight of the front axle of a car having front-wheel brakes is about 425 lb. From Fig. 2, we note that the vertical acceleration, when going over an obstacle, is about 337 ft. per sec. per sec. This gives a pressure between the tire and the road of

$$P = (425 \div 32.16) \times (337 \div \cos 20 \text{ deg.}) = 4750 \text{ lb.}$$

The unsprung weight of the front axle of a car without front-wheel brakes is about 325 lb. The pressure between the tire and the road is, of course, in direct proportion to the unsprung weight; hence, without front brakes, we have only $100 \times (325 \div 425) = 76$ per cent as much impact and, consequently, only 76 per cent as much kinetic energy is stored in the tires.

Instability of Balloon Tires

Considerable attention has been called to the fact that lateral stability is a most desirable feature in a tire. The Dunlop Company was the first to realize the disadvantages of the balloon tire in this respect; and some users of balloon tires have also noticed that their cars roll when turning curves.

Lack of lateral stability has a profound effect on steering and causes shimmying. The following analysis will help to prove this contention.

Let us observe Fig. 3. Normally, the point p, being located in the plane of symmetry of the wheel, represents the point of contact between the tire and the road. But, under the influence of a lateral force, which may originate from an unevenness in the road, the chassis will sway sidewise a distance x. The tire has now become distorted with the center of the contact area at p_1. This distortion causes an unbalanced condition; consequently, according to the principle of simple harmonic motion, the chassis will sway in the opposite direction. Point a represents the intersection of the axis of the king-pin with the road. The distance $ap = b$ represents the length of the lever-arm through which all forces acting between the tire and the road impart a turning-moment to the knuckle-shaft.

The axis of the king-pin being the axis of rotation, it is now obvious from Fig. 3 that, if the chassis sways to the left, the lever-arm b for the right wheel will increase to $b + x$, whereas for the left wheel it will decrease to $b - x$. This change in the length of the lever-arm causes an unbalance in the steering mechanism that is very largely the cause of shimmying. By means of a sketch, we can analyze this a little better.

For instance, Fig. 4 represents a plan view of a primitive chassis. The dotted areas under the front wheels represent the tire contact, while the forces F represent the road resistance, or the retarding force, or both.

From the layout of the mechanism, it is obvious that, on a perfectly smooth road, we have in the tie-bar two equal and opposite forces $F\ (c/d)$, which hold each other in equilibrium. Through some disturbance, however, a lateral sway of the chassis may change the lever-arm b, as previously stated, so that on one end of the tie-bar we have a force

$$F_1 = F\,[(b + x)/c] = F\,(c/d) + F\,(x/d\,) \qquad (1)$$

and on the other end we have a force

$$F_2 = F\,[(b - x)/c] = F\,(c/d) - F\,(x/d) \qquad (2)$$

The difference between F_1 and F_2 is

$$F_1 - F_2 = F\,(c/d) + F\,(x/d) - F\,(c/d) + F\,(x/d) = 2F\,(x/d) \qquad (3)$$

This force $2F\ (x/d)$ causes the wheels to deviate in one direction. Immediately, as the chassis sways back, the force $2F\ (x/d)$ goes through zero to the negative maximum, causing the wheels to deviate in the opposite direction.

Effect of Alternating Forces

Such alternating forces will, of course, cause a shimmying, unless the parts are fitted so snugly that the alternating forces are absolutely prevented from gathering momentum. If, however, the slightest slackness exists in the linkage, the wheels will swing with an ever-increasing amplitude and, inasmuch as the steering mechanism is not irreversible, it is obvious that the steering-wheel will partake of the oscillation known as shimmying.

It will be noted that the force that induces shimmying is independent of the length of the lever-arm b. It is well known, however, that cars with center-point steering, or near center-point steering, shimmy very much worse than do others that have been designed so that a substantial lever-arm b exists between the king-pin axis and the center of the contact area. There is a very good reason that this should be so. In the case of center-point steering, the length of the lever-arm b may well be smaller than the sidesway. To give an example, let us take the values, $b = 1/2$ in. and $x = 5/8$ in. Substituting these values in equations (1) and (2), we have the force F_1 acting at one end of the tie-bar

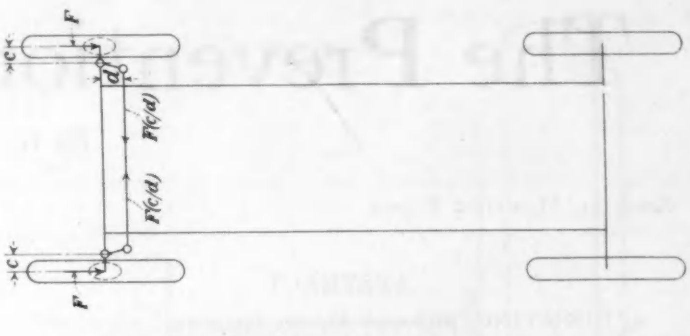


Fig. 4—Diagram for Analyzing Wheel Shimmying
This Drawing Represents a Plan View of a Primitive Chassis; the Dotted Areas under the Front Wheels, the Tire Contact; and F, the Road Resistance or the Retarding Force or Both. On a Perfectly Smooth Road Two Equal and Opposite Forces $F(c/d)$ in the Tie-Bar Hold Each Other in Equilibrium. If However a Lateral Sway of the Chassis Changes the Lever Arm b, the Forces then Differ by an Amount $2F(x/d)$ Which Causes the Wheels To Deviate in One Direction. As the Chassis Swings Back the Force Passes through Zero to the Maximum in the Opposite Direction, Causing the Wheels To Deviate in the Opposite Direction. These Alternating Forces Cause Shimmying unless Everything Is Fitted So Snugly That These Forces Are Prevented from Gathering Momentum

$$F_1 = F\,[(1/2 + 5/8)/d] = [(1\text{-}1/8)/d]\,F$$

and for force F_2, acting at the other end of the tie-bar,

$$F_2 = F\ \ [(1/2 - 5/8)/d] = [(1/8)/d]\,F$$

We note that F_2 has changed from a positive to a negative value. Inasmuch as we have chosen signs, the negative sign implies that F_2 is not opposing F_1, but both act momentarily in the same direction. The reversal of the force F_2 and the tendency of both forces to act in one direction remove all possible strain and backlash in the linkage. As we all must agree that backlash induces shimmying, this analysis should be sufficient to show why cars with center-point or near center-point steering will shimmy very easily.

We may now check our analysis with the results obtained with a dash-pot developed by the Goodyear Company. Even though this device acts on only one wheel, it prevents the lateral forces from synchronizing and, what is more important, prevents the forces from gaining momentum.

We know that friction-discs mounted on the king-pin and the knuckle-shaft will reduce shimmying, because they absorb kinetic energy.

The remedies for shimmying, according to this analysis, are

(1) Design so that no slackness can develop; for instance, use ball-and-socket joints, with springs to take up wear

(2) Design for rigidity; that is, use strong levers and large-diameter tubes for the tie-bar and the drag-link

(3) Use effective devices to absorb kinetic energy wherever it is likely to accumulate

PERUVIAN PETROLEUM

Peru is first in both the production and the exportation of petroleum in South America, and already takes eighth place among the petroleum producing countries of the world, having outranked Poland in both 1922 and 1923. The 1923 Peruvian production has been estimated at more than 6,000,000 bbl., a considerable increase over the figures for 1921 and 1922, and reports following exploratory surveys indicate a probability of the existence of its richest petroleum fields in a region as yet inaccessible for exploitation.

Consumption is small in Peru, owing to the low purchasing power of the people and the small industrial development of the country. Official statistics for 1921, the last available, show a per capita consumption of about 1 gal. for a population of approximately 4,500,000. Figures for previous years indicate that the consumption is increasing, but the increase in the production has been more rapid, so that exportation remains the principal petroleum trade influence in the country. Small imports of the refined products, largely from the United States, are recorded, the receipts of kerosene having steadily decreased through the last several years. Lubricants and paraffin form the largest items of importation.—*Commerce Reports.*

The Prevention of Shimmying

By R. B. Day[1]

Annual Meeting Paper *Illustrated with* Drawings and Photograph

ABSTRACT

SHIMMYING, although known for many years, did not become a serious problem until the arrival of the balloon tire and the four-wheel brake. Apparently, shimmying is of two kinds: the low-speed variety, which is merely a persistent front-wheel wabble without an abnormal bouncing of the axle, and the high-speed species, which is chiefly a persistent bouncing of the axle accompanied by wabbling of the wheels. The two most obvious effects are wheel wabble and axle bounce.

As low air-pressure seemed to be the cause, the attention of the tire makers was first devoted to stiffening the body of the tire in various ways, but the results obtained were not satisfactory; and the conclusion was reached that the solution lay in making the car control the tire rather than attempting to control the car through the design of the tire. These considerations led to a search for mechanical means of control. A form of stabilizer appeared to be efficacious in checking axle bounce, and an hydraulic damper, similar in principle to that of an ordinary door-check, in preventing wheel wabble. Although successful in preventing shimmying in open cars, these devices eliminated only from 60 to 70 per cent of the axle bounce in closed cars. This is believed to be a resonance effect between the tires with their unsprung weights and the body springs with their loads, and should be worked out mathematically. The author concludes that relief is to be found in the mechanical features that control the tires.

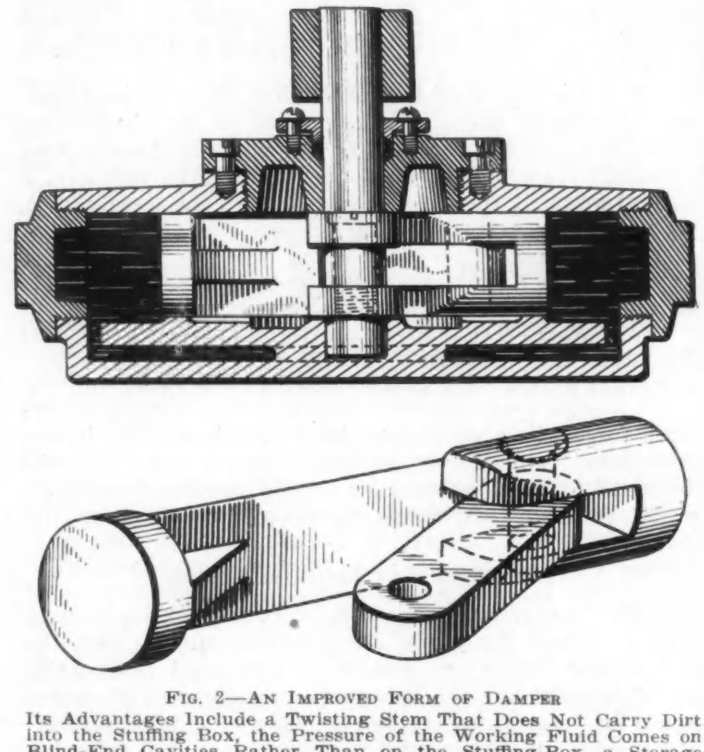


Fig. 2—An Improved Form of Damper
Its Advantages Include a Twisting Stem That Does Not Carry Dirt into the Stuffing Box, the Pressure of the Working Fluid Comes on Blind-End Cavities Rather Than on the Stuffing-Box, a Storage Chamber for Fluid and Less Leakage

SINCE the arrival of balloon tires and four-wheel brakes, the company with which I am associated has been interested in the violent shimmying that arrived with them. This form of trouble has been known for many years but has not heretofore been a serious problem because it never has been particularly violent. Natural friction in the parts of the steering-gear and the use of ordinary snubbers were sufficient to keep it under control. With the arrival of large low-pressure tires, however, shimmying became more prominent although not severe enough to demand serious attention. But four-wheel brakes, with their hammer-head weights inside the front tires, caused a startling increase in shimmy troubles.

It soon became apparent that shimmying is of two kinds, low-speed and high-speed. Low-speed shimmying is merely a persistent front-wheel wabble without any abnormal bouncing of the axle. High-speed shimmying, as commonly observed, is chiefly a persistent bouncing of the axle, accompanied by wabbling of the wheels. In reality, the subject is made clearer by speaking of two effects, wheel wabble and axle bounce. Pure wheel-wabble is found to occur at speeds ranging from 5 to 50 m.p.h.; axle bounce, mixed with wheel wabble, at speeds ranging from 45 to 75 m.p.h. Practically un-

[1] Research division, Goodyear Tire & Rubber Co., Akron, Ohio.

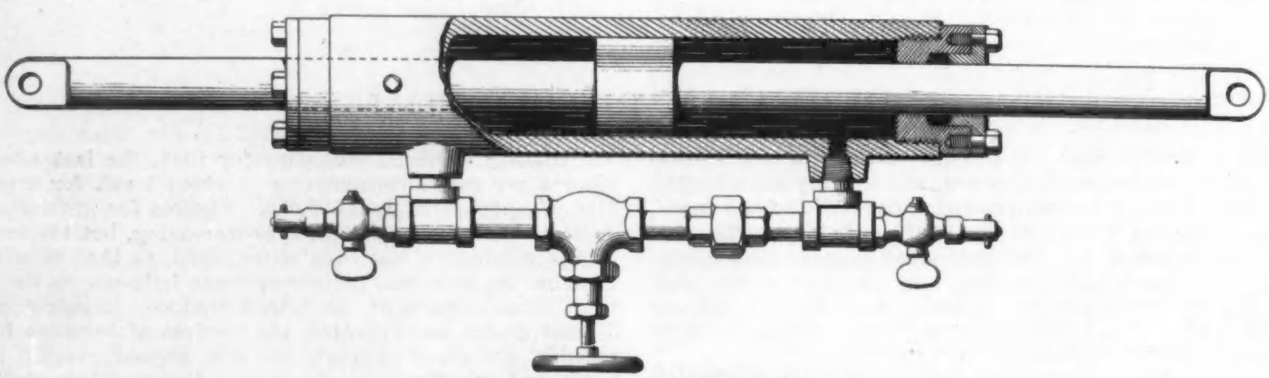


Fig. 1—Original Type of Damper Tested
Although Actually Built and Used, This Damper Was Found To Embody Several Undesirable Features

mixed axle-bounce may be obtained by preventing wheel wabble; but it is not common.

Car manufacturers naturally accuse the tires of being the cause of the trouble; and, naturally, the tire makers resented this accusation. They had observed the increase of wheel wabble that came with balloon tires, but this effect was negligible when compared with that which followed the use of four-wheel brakes. It was observed early that balloon tires with high inflation-pressures were practically free from wheel wabble and axle bounce. It was evident, therefore, that low pressure was one of their causes. Low pressure, however, could not be called a fault, because the sole purpose of the balloon tire is to carry the car on low-pressure air.

Changing the Tire Body

As nothing could be done to alter the characteristics of the air enclosed in the tire, the attention of the tire maker was devoted to changing the body of the tire. It was found that, by stiffening the tire in various ways, some favorable effect on wheel wabbling could be produced, but the effect on the bouncing of the axle was very small. On the whole, such attempts to mask the properties of the air confined in the tire have not yielded results that have been worth the effort. The reason, of course, is that the tire is very thin and flexible, relatively to the loads that the enclosed air must carry. Even though the tread and carcass be materially stiffened, the effect must be relatively small. The conclusion is, that the correction for wheel wabble and axle bounce can be found only in using higher air-pressure within the tire itself, thus partly or entirely defeating the fundamental purpose of the low-pressure tire. As stated, the correction is to be found in making the car control the tire rather than attempting to control the car through the design of the tire.

A Mechanical Means of Correction

Such considerations led our company to look for a mechanical means of correcting the trouble, that is, from the point of view of the car-builder. The clear distinction between wheel wabble and axle bounce suggested that each of these motions might be restrained by properly located damping-devices. A crude type that was actually built and used on our demonstration car is shown in Fig. 1. In Fig. 2 is a design that might be

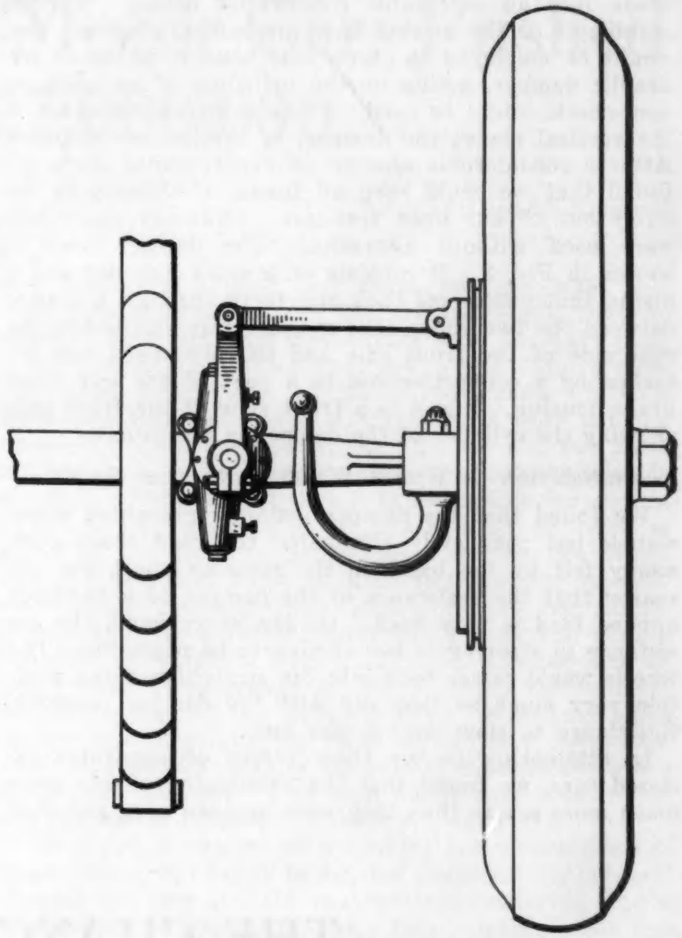


Fig. 3—Plan View of Damper
Showing Method of Mounting over the Front Axle and between the Left Front-Spring and the Wheel

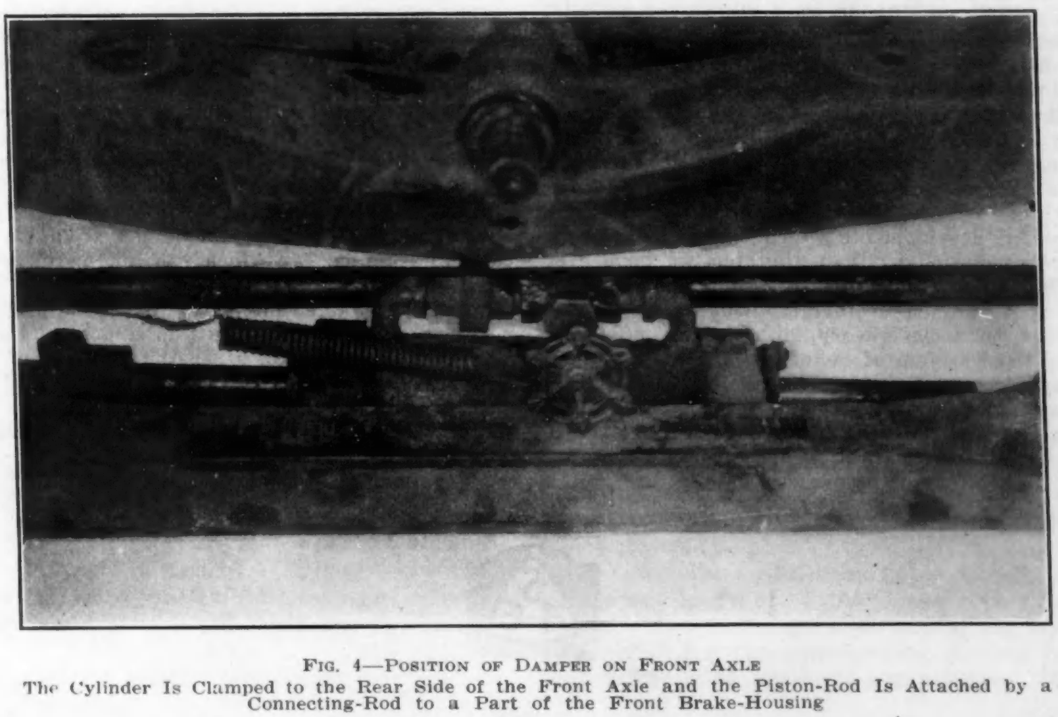


Fig. 4—Position of Damper on Front Axle
The Cylinder Is Clamped to the Rear Side of the Front Axle and the Piston-Rod Is Attached by a Connecting-Rod to a Part of the Front Brake-Housing

made into an acceptable commercial device. Various stabilizers on the market have mechanical elements that might be employed to check axle bounce, while an hydraulic damper, acting on the principle of an ordinary door-check, might be used. The stabilizers would act in the vertical plane; the damper, in the horizontal plane. After a considerable amount of experimental work, we found that we could keep all forms of shimmying entirely out of our open test-cars. Ordinary stabilizers were used without alteration. The damper used is shown in Fig. 3. It consists of a small cylinder and a piston that pumps oil back and forth through a bypass between the two ends. The cylinder was clamped to the rear side of the front axle and the piston-rod was attached by a connecting-rod to a part of the left front brake-housing. Fig. 4 is a front view of the front axle showing the cylinder of the damper in position.

Prevention of Wheel Wabble and Road Shock

We found that the damper not only prevented wheel wabble but completely eliminated the road shock commonly felt by the hand on the steering-wheel, for the reason that the resistance of the damper to a suddenly applied load is very high. On the other hand, the resistance to steering is low enough to be negligible. The wheels would caster back into the straight-running position very much as they did with the damper removed. Resistance to slow motion was low.

In attempting to use these pieces of apparatus on closed cars, we found that the shimmying effects were much more severe than they were on open cars, and that the stabilizers and dampers used on open cars would prevent only from 60 to 70 per cent of the axle bounce to which closed cars were subject. The closed body of a shimmying car, when placed on the chassis of a non-shimmying car, tended to carry the shimmying effect with it.

Even though these few experiences show that axle bounce is more difficult to handle on closed cars than on open cars, they serve to intensify the general belief that axle bounce is a resonance effect between the tires with their unsprung weights and the body springs with their loads. Each front-wheel brake is a hammer-head that strikes downward against the tire, then upward against the body springs. The impact against the springs moves the car body. When the impulses produced by the bounding of the axle attain a period that synchronizes with the natural period of the body and its springs, a resonance condition is reached in which the action is very severe. This action will be maintained as long as the car speed is maintained. Such interaction of the springs and the weights is subject to mathematical treatment. When the mathematical analysis has been completed, it should be possible to tell what effects may be expected from changes in tires, springs, weights of parts or weight distribution.

In conclusion, I wish to restate my belief that shimmying cannot be corrected by changing the design of the tire, nor can high pressure give a correction that will be really acceptable to a driver who desires the comfort of low-pressure air. The answer is to be found in the mechanical features that control the tires.

THE CHANGING WORLD

THERE are 600,000 men in the American colleges, which is 70 per cent as many men as have been graduated from the American colleges since the time when American colleges first were established. Obviously, the relationship of the college man to the community is going to be very greatly changed under any such circumstances as these. College men are not unusual in any community at the present time, and the further sad fact prevails that the man who holds a college diploma is not necessarily either a man of unusual attainment or one of unusual capacity.

It is only a little more than 100 years ago that it took only 12 horses and 2 coaches to take care of all the traffic between New York City and Boston.

Distance is not a matter of measured miles; distance is a matter of time consumed in getting somewhere or in communication with one in some place. We are almost certainly on the threshold of developments which will be even more rapid and more revolutionary than anything we have ever yet known. The world is changing so rapidly that we cannot safely tie up to any sort of rigid thought; we cannot accept in politics, in social theory, in religion, or in any other matter, a fixed system of belief, no matter how good that belief may seem to have been, without examining it and without attempts to understand whether that belief adapts itself to the needs of the present day and whether it can be applied to the developing problems of days before us. We need to keep before us recognition of the fact that the world is changing faster than it ever has changed before. All the extraneous aspects and internal attributes of the world being different from what they have been, it becomes exceedingly necessary that we examine and reexamine all that we have accepted as basic in a theory of life adjusted to entirely different circumstances.

The college course is the only open period of time that we have in adult life at the present day. I believe that the man will be a better specialist who utilizes the college course for studying those things which are going to be farthest away and most inaccessible when he gets outside. In a world where the pressure upon men is so heavy, in a world where limitations so fasten themselves upon the lives of men, and where the competitive features are so strong as they are at the present time, the man who is going to derive from his college course maximum benefit should get from his college course color and perspective which will not again be so generously available to him.

Life never was as interesting as at the present time. Life never offered the challenges that it does at the present time. The colleges, in spite of all their faults and of all their weaknesses and of all their mistakes, never offered to the student such opportunity for developing the intellect as they do at the present time.—From an address at Harvard University by President Hopkins of Dartmouth College.

Saturation-Point for Motor Cars Pushed Ahead to 27,000,000

By LEONARD P. AYRES[1] ANNUAL DINNER ADDRESS

ABSTRACT

ONE car per family is the measure of ultimate use of the automobile, for the same reason that one bathtub and one telephone serve the needs of the family unit in their respective fields of utility. Thousands of families will own more than one car and many business concerns will operate fleets of cars and trucks but the number of such extra machines will be offset by hundreds of thousands of families that cannot own even one because of poverty or circumstances of location which make an automobile useless to them. There are approximately 27,000,000 families in the United States and, as the present number of automobiles in use is about 17,000,000, there are still ample opportunities for salesmanship.

Insatiable demand for motor cars arises from the inherently competitive nature of the product. It is constantly being compared as to appearance and performance with other cars in the street and on the road, whether standing or running. The desire for possession is universal and, as cars wear out rather quickly, the desire for a new one is never remote. Whether the industry can continue to make and market automobiles at the present rate depends upon the number of cars the American people will use at one time and on the average length of service of the cars. The sustaining demand must come from the normal family, which has an average income not much in excess of $2,000 a year. If the number of cars in use should settle down to a constant of about 18,000,000, the average length of life of the cars will determine the number of new ones sold annually. If the average length of service were 6 years, the replacement requirement would be 3,000,000 a year, but, as cars become better and last longer, this figure tends to shrink so that, if the length of life is 8 years, the number required to replace worn out cars will be only 2,000,000.

These considerations are of real import, because the annual producing capacity of American factories is probably at least 5,000,000 cars and the industry has now entered the period of diminishing numbers of first purchasers, the potential replacement demand being cut down by the increasing length of service that is being built into new machines. This combination of conditions constitutes a hazard for the future of the industry and the solving of the problem depends upon the ingenuity, skill, enterprise and energy of the engineers and manufacturers. Because of the highly competitive nature of automobiles, the normal American citizen will continue to want new and better ones just so long as automotive engineers can continue to design new cars featuring genuine improvements, in which there is an open and boundless field.

Sales prospects for 1925 are distinctly good, owing to the balance of fundamental economic forces. The author forecasts a production of about 3,600,000 automobiles this year.

A LITTLE less than 25 years ago I bought an automobile. It was an Orient. It steered with a handle and had a one-cylinder engine over the rear axle. You could always tell when the dry-battery was producing a good, hot spark because, when you went around to the rear of the car and leaned down to crank it, your ear came into contact with the spark-plug.

Since that time we have produced in this Country some 24,000,000 automobiles, of which more than 1,000,000 have been exported, nearly 6,000,000 have worn out and about 17,000,000 are now in use. To buy and run these automobiles, we have spent more than $40,000,000,000, which is a sum so vast that it is impossible for anyone to realize how great it is. It is a sum almost twice as great as our military expenditures during the World War. It is almost twice as much as the entire expenditures of our National Government from the first administration of George Washington through the first administration of Woodrow Wilson. It is far greater than all the present indebtedness of our National Government, our States and all our municipalities. With that much money our Revolutionary War could have been kept running for 2000 years at the rate of expenditure which it actually involved. That sum would have restored all the devastated regions of France six times over.

During this quarter of a century the automobile has been getting constantly better and progressively cheaper, despite the fact that the raw materials entering into it have advanced greatly in cost. This amazing result has been brought about by enormous advances in the efficiency of manufacture. When my first car was built, the rate of output in automobile and parts factories was equivalent to each workman producing one car in 8 months. Now it is equivalent to each worker turning out one car a month.

In the entire history of industry there is no achievement comparable with that of the American automobile industry for rapidity of expansion, improvement in the quality of product and advance in the efficiency of operation. Two questions present themselves for answer. The first is: What has been the cause of this amazing development? The second is: Can comparable progress continue in the future?

INHERENT COMPETITION CREATES DEMAND

My own opinion is that the explanation for the insatiable demand for more and better automobiles is to be found in the fact that the automobile is the most inherently competitive article ever manufactured. I do not mean merely that the industry is competitive; I mean that every automobile is always in competition with every other automobile. Consider the inherent nature of the automobile. The desire to possess one is universal; so people constantly think about it. The cost is considerable; so they give it careful thought. It wears out rather rapidly; so the prospect of getting a new one is never very remote. The old one can always be sold; which makes the possibility of getting a new one appear more reasonable. When an automobile is not in use, it stands out in front of the house, where the neighbors compare its appearance with that of the one parked just ahead of it and the one standing directly behind it. At such times it is passively competitive. When it is in

[1] Vice-President, Cleveland Trust Co., Cleveland.

use, its owner compares its pick-up and acceleration with those of the other cars at every cross-street where traffic is halted and started by a police officer, and each time he goes up a hill he compares its power and speed with those of the cars that pass him. At these times the automobile is in active competition.

The result of this continuous competitive comparison is that everybody who does not own an automobile wants one and everybody who does own one wants a new one. No other manufactured article has ever produced so universal a covetousness. We are but mildly interested in other peoples' fountain pens or safety razors or watches. If we have a piano or a victrola, we do not worry that another similar instrument will come along and show it up as being inferior. I think that there have been, in our time, only three articles of ownership about whose virtues men have entered into discussion with a degree of sustained interest at all comparable with that with which they debate the relative qualities of automobiles. These are radio sets, which notoriously invite mendacious comparison of achievement, and, in former days, the horse and the bicycle, which, like the automobile, are means of individual transportation.

If we accept the uniquely competitive character of the automobile as being the controlling factor in its phenomenal popularity, we come to the second question, which is whether the industry can continue to make and market automobiles at the present rate. The answer to this depends on two factors, of which the first is the number of automobiles that the American people will use at one time, and the second is the average length of service of the cars. I do not, at this time, consider the export possibilities, because they represent, for the present, a secondary rather than a primary factor.

Number of Families the Limiting Factor

My own opinion is that the number of automobiles that this Nation will use at one time will tend to be about equal to the number of families in the population. The natural unit for automobile ownership for the great mass of our people, is the family, just as that is the natural unit for the possession of bathtubs and domestic telephones, and for fundamentally similar reasons. We know that bathtubs are not necessities, because our immediate ancestors did not have them. It is not many years since the installation of a bathtub in the White House evoked a storm of protest in the Congress. A little later a number of cities enacted ordinances forbidding their installation because they were considered to constitute a dangerous introduction of European luxury. Now they have become an integral item in the amenities of American civilization, and even houses occupied by the families of day-laborers do not find tenants unless they have bathrooms. The real explanation for this is, not that the bathtub is a hygienic necessity, but that it has become a social necessity. The fundamental reason even the man of deficient income insists on having a bathtub in his house is that he does not dare have his children tell the neighbors' children that their house does not have one. But the average American family that has one bathroom would not install a second or a third, even if it could purchase the entire equipment for $50. The reason for this is that it could not afford the upkeep, which is to say that it could not afford to give up the extra room for that purpose. The first one is an essential but the second and third are expensive luxuries. The same thing is true, in even greater degree, of telephones. The first is highly valuable and even necessary, but few families want a second or a third in the home.

It seems probable that similar principles will control the ultimate market for automobiles. Almost every normal family wants one automobile and will, if necessary, sacrifice a good deal to get it, but, having secured one, most families will not sacrifice much to purchase two or three. Of course, the families that own several machines are many thousands in number, as are the business firms that have delivery cars and trucks, but it is not from these sources that the great demand for automobiles has come and must continue to come. That sustaining demand must come, in the main, from the normal American family which has an average income not much in excess of $2,000 a year.

The number of families in this country is about 27,000,000, and the number of automobiles in use is about 17,000,000; so there are still large opportunities for salesmanship before this margin will have been covered. Included among these families are many thousands that will own more than one automobile, and in addition to them are commercial and industrial firms that will use many more thousands. On the other hand, there must be subtracted from them hundreds of thousands of families that cannot own even a single car. These include the indigents, many southern negroes, mountain whites, recent immigrants, and large numbers of soldiers, sailors, fishermen, lumbermen, lighthouse-keepers and others who are poor sales-prospects. It seems probable that the maximum number of automobiles that this Country can use is not far from equal to the number of families in the population and that selling new cars will become progressively more difficult as that number is approached and the influence of diminishing returns becomes more keenly operative.

Car Life Controls Replacement Market

The number of automobiles that the Country can use is one of two elements which determine how many can be sold each year, and the other is the average length of service of each car. The statistical principle involved is simple. If there were no export demand and the number of cars in use should settle down to a constant of about 18,000,000, and the average length of service were 6 years, the new cars required each year to replace those worn out would be 3,000,000, or the number in use divided by the average years of service. As cars become better and last longer, the number required for replacement tends to shrink. Thus, under these conditions of a steady 18,000,000 in use, if the average length of service should increase to 8 years, the annual replacements would be only 2,250,000; and if the average useful life of automobiles were 9 years, the annual replacement demand would be only 2,000,000.

These considerations are of real import, because the annual producing capacity of American factories is probably at least 5,000,000 cars and the average length of service of cars now being made will probably be as much as 8 years. If these figures are correct, they mean that the industry in this Country would now meet the replacement demand if 40,000,000 cars were in use, and that means that we have an excess of productive capacity.

This consideration brings us to the most serious problem confronting the automobile industry, which is that its most imminent danger is the product of its own splendid achievements in bettering the quality of its product and increasing the length of service of the cars manufactured. Careful estimates indicate that during the past 8 years the useful life, or length of service,

(*Concluded on p.* 208)

Officers of the Society

AT the Annual Meeting of the Society held last month a President, a First Vice-President, five Second Vice-Presidents representing motor-car, tractor, aeronautic, marine and stationary internal-combustion engineering respectively and three Councilors were elected, and the Treasurer was reelected. In addition to these officers the three Councilors elected at the 1924 Annual Meeting and the last Past-President are voting members of the Council for 1925. Such photographs of the officers and councilors as it was possible to secure are presented on the following pages and their careers are outlined below.

H. L. Horning

President Horning secured his early training in the modern classical course at Carroll College Academy and the scientific course at Carroll College, both at Waukesha, Wis. In 1901 he was in the chemical laboratory and operating department of the Milwaukee Gas Light Co., and later served for 2 years in the steam engineering department of the Crane Co. From 1904 to 1906 he was head of the mechanical engineering department of the Modern Steel Structural Co., his most important work at that time being the construction and mechanical operation of the Duluth steel bridge, one of three structures of the kind in the world. In 1906 he established the Waukesha Motor Co.

Mr. Horning has been a member of the American Society of Mechanical Engineers, and of the Association for the Advancement of Science. He was elected a Member of the Society of Automobile Engineers in 1910 and through his connection with the Society of Tractor Engineers and the National Gas Engine Association was active in the movement that resulted in changing the name of the Society to the Society of Automotive Engineers. Mr. Horning was elected third vice-president of the Motor & Accessory Manufacturers Association at the 1924 annual meeting and was elected first vice-president for the current year. He is also a member of the Street and Highway Safety Committee organized by Secretary of Commerce Hoover. A recent honor conferred upon him is his election as a Fellow of the Royal Society of London.

He was chairman of the automotive products section of the War Industries Board, Council of National Defense, during the war. He served as chairman of the Design Committee of Engineers that laid out the engines for the Class-B and Class-AA military trucks. He was the first chairman of the Tractor Division of the S. A. E. Standards Committee and was a member of the first Oil and Fuel Committee established by the Council of the Society.

Truck and Tractor Engines was the subject of a paper he presented in 1916 at a Mid-West Section meeting. At the 1917 Annual Meeting he presented a paper on the Ultimate Type of Tractor Engine and at the 1917 Semi-Annual Meeting he gave a paper on the Farm Tractor as Related to the Food Problem. He also presented a paper on Tractor Engines and Fuel Limitations before the Detroit Section in 1919, and at the 1921 Semi-Annual Meeting he gave a paper on Turbulence, and in 1923 at the Mid-West Section he analyzed the Effect of Compression on Detonation and Detonation Control.

As a representative of the Society, Mr. Horning accompanied the National Screw Thread Commission on its trip abroad during July, 1919, to make a study of foreign screw-thread practice. Together with Dr. Dickinson of the Bureau of Standards he visited Dr. Dixon of Manchester University and brought back to this Country a statement of the theory of engine knock and detonation.

He proposed and aided in the movement to bring the automotive and petroleum industries together for the purpose of dealing promptly with the fuel question. Mr. Horning was chairman of the Committee on Utilization of Present Fuels in Present Engines, whose first report was presented at the 1920 Semi-Annual Meeting of the Society. He also proposed the plan of inviting the leading internal-combustion engineers of Europe to visit this Country to take part in meetings of the Society. Mr. Horning was elected First Vice-President at the 1921 Annual Meeting. For the last year he has been Chairman of the Research Committee.

T. J. Lítle, Jr.

First Vice-President Lítle was born at Philadelphia in 1875. He received his elementary education at the public schools of his birthplace, including the Manual Training High School. He attended the Industrial Art School at Philadelphia and later the University of Pennsylvania, receiving the degree of mechanical engineer from the latter institution.

After being graduated Mr. Lítle entered the service of the Welsbach Light Co., Gloucester City, N. J. remaining there for over 10 years and holding the position of chief engineer when he left. During this time he was credited with over 100 inventions relating to the development of incandescent gas lighting in America and was awarded a gold medal at the Panama-Pacific Exposition at San Francisco for research and development work in gaseous combustion devices.

His connection with the automotive industry dates back to 1917 when he became associated with the engineering department of the Cadillac Motor Car Co. He was later made research and experimental engineer and left in 1918 to join the engineering staff of the Lincoln Motor Co., as research and experimental engineer. Subsequently he was made chief engineer of the latter company, a position that he still holds.

He was elected to Member Grade in the Society, March 8, 1919, and has taken a very prominent part in the activities of the parent Society and also of the Detroit Section. Mr. Lítle was a member of the Meetings Committee for the administrative year 1923 and served as its chairman last year. He was secretary of the Detroit Section for the year beginning May, 1922, and was elected chairman of the Section the following spring. He presented a paper entitled Spring Movement and Vibration Study of Cars in Action in the fall of 1923 at a meeting of the Indiana Section and outlined in a very interesting manner some of the methods used to record the movement of the springs of cars and the nature and amplitude of the various vibrations.

H. D. Church

Second Vice-President Church, representing motor-car engineering, was born at Waltham, Mass., April 16, 1883. He received his elementary education at public and private schools and entered the Massachusetts Institute of Technology.

His connection with the automotive industry dates back to 1905 when he became assistant chief-engineer of the Waltham Mfg. Co., Waltham, Mass., manufacturer of the Orient Buckboard. For a year after leaving this company he was engaged in experimental gasoline engine work. Subsequently he became associated with the Shawmut Motor Co., Stoneham, Mass., and later was chief engineer of the Mercer Motors Co. at Trenton, N. J. From 1909 to 1919 Mr. Church was associated with the Packard Motor Car Co., holding the position of chief engineer of the truck division for several years and being also chief engineer of the company during the World War. For the next 3 years he was vice-president of Hare's Motors, which had taken over the operation of the Locomobile Co. of America, the Mercer Motors Co. and the Kelly-Springfield Motor Truck Co. For the next year he was engaged in consulting engineering work on passenger cars and truck design, as well as general manufacturing, policy and management problems. On Sept. 1, 1923, he became associated with the Chevrolet Motor Co. at Detroit and after doing special engineering work for 10 months was made assistant chief-engineer in July, 1924.

Mr. Church has been a Member of the Society since Nov. 24, 1911. For a number of years he was a member of Truck Division of the Standards Committee and was also chairman of that Division. He was chairman of the Special Truck Committee of the Society which worked with the Government from 1915 on in an endeavor to develop a set of standard specifications for Army motor-transport.

Oliver B. Zimmerman

Second Vice-President Zimmerman, representing tractor engineering, was born at Galena, Ill., Sept. 2, 1873. He received his early education at the elementary and secondary schools of Milwaukee and in 1892 entered the University of Wisconsin, being graduated in 1896 with the degree of bachelor of science in mechanical engineering. In 1900 the degree of mechanical engineer was conferred on him by the university. Upon leaving the University Mr. Zimmerman taught in the Milwaukee West Division High School for 2 years as instructor of manual training, and from 1898 to 1900 was director of manual training. The next 5 years was spent in teaching at the University of Wisconsin, first as an instructor in descriptive geometry and elementary machine-design and latterly as assistant professor of machine design.

Although Mr. Zimmerman did some engineering work in summer vacation time, his professional engineering career really started in July, 1905, when he accepted a position as mechanical engineer and assistant superintendent with R. J. Schwab & Sons Co., Milwaukee. In March, 1906, he left there to accept a position as draftsman with the Hart-Parr Co., Charles City, Iowa, being successively inspector on finished parts, chief draftsman, chief tester, assistant mechanical-engineer and, when he left in February, 1909, mechanical engineer in charge of design and also supervisor of civil, electrical and architectural work. From February, 1909, to March, 1911, Mr. Zimmerman was associated with the M. Rumely Co., La Porte, Ind., as chief draftsman and mechanical engineer. Here he designed parts of the company's oil tractor, designed and selected heavy equipment of the new plant for the manufacture of tractors, superintended the erection of the buildings and acted in an advisory capacity on contracts, purchases and equipment. In March, 1911, he accepted a position as engineer in charge of estimates, design and construction with the contracting firm of M. Burner & Co., South Bend, Ind. After remaining there 7 months he became associated with the International Harvester Co., Chicago, and for 1 year was advisory engineer on sales and manufacture at the Tractor Works of the Company. From October, 1912, to March, 1915, he acted in a similar capacity with the European organization of the Company, having his headquarters at Brussels. Returning on account of war conditions, Mr. Zimmerman was reassigned to the Tractor Works at Chicago as engineer in charge of general experimental work, the complaint department and inspection of the sales force. In this capacity he also made general field reports on improvements in tractors and engines and conducted experimental and research work until September, 1916, when he resumed the duties of improving sales work on engines and tractors and directed the campaign of company schools in various parts of the Country until April 1, 1917.

During the war he was officer in charge of the mechanical civil equipment division of the Engineer Corps, from May 21, 1917, to August 1, 1918, his work there covering the selection, purchase and design of engineer mobile army and coast defense equipment. On the latter date he was appointed officer in charge of the research and development division and in this capacity supervised and developed new designs of equipment for mobile army and coast defense. He was also liaison officer between the General Engineer Depot and Bureau of Standards, from June 13, 1918 to April 16, 1919, and served as a member of the Bureau of Standards staff from June 14, 1918 to April 16, 1919. During a portion of this time he was also a member of the board of review of the General Engineer Depot and a member of the National Screw Thread Commission. In recognition of Mr. Zimmerman's war work, the Pennsylvania Military College, Chester, Pa., conferred the honorary degree of Doctor of Science upon him in June, 1919.

On May 8, 1919, Mr. Zimmerman returned to the engineering and experimental department of the International Harvester Co. and took up the work of standardizing and improving the specifications for materials and designs of machine elements and products of the Company. On Nov. 13, 1922, he was appointed assistant to the manager of the experimental and engineering department, a position that he still holds.

Mr. Zimmerman was elected a Member of the Society on Sept. 25, 1920. In addition, he is a member of the American Chemical Society, the American Society of Agricultural Engineers, the American Institute of Chemists and the Society of American Military Engineers. He has written a number of papers on various subjects, four of which dealing with tractors and one dealing with standardization, have been published in The Journal.

Charles A. Carlson

Second Vice-President Carlson representing marine engineering was born, July 8, 1879, at Summit, N. J. After receiving a public school education, he engaged in bicycle racing from 1893 to 1897.

H. L. HORNING

His connection with the automotive industry dates from 1898 when he became associated with the DeDion Bouton Co., which was the first company to assemble French automobile parts in this Country. Leaving this organization he went with the Ward Leonard Electric Co. and then with the Winton Motor Carriage Co. In 1903 Mr. Carlson engaged in business for himself at Brooklyn, N. Y., designing and building, it is stated, the first four-cylinder motor-truck in the United States and also marine engines using oil and gasoline as fuel. The Carlson Motor Vehicle Co., organized in 1909, to build motor trucks at Philadelphia, was his next business venture. In 1911 he designed and built two internal-combustion-engine-driven street-railway cars that were successfully used in the South.

In 1916 Mr. Carlson was called to the City of Washington to assist in truck and trailer designing for the Government. After the war he was elected president and general manager of the New Jersey Motors, Inc., Keyport, N. J. In December, 1923, he purchased the Remington Oil Engine Co., Stamford, Conn., and subsequently acquired the controlling interest in the New Jersey Motors, Inc., consolidating the two companies under the name of Remington Oil Engine, Inc., and holding the position of president and general manager.

Mr. Carlson was elected a Member of the Society on Sept. 10, 1917. For the last year he served on the Motorboat Division of the Standards Committee. He holds over 30 patents in connection with internal-combustion engines. In December, 1906, he received from a French association a diploma and gold medal for a design of four-cylinder four-cycle internal-combustion engine.

Paul G. Zimmerman

Second Vice-President Zimmerman representing aeronautic engineering was born at Iroquois, S. D., May 12, 1890. He received his education in the elementary schools of his birthplace and Sioux Falls, S. D., and at the high school in San Juan, P. R. After being graduated in 1904, Mr. Zimmerman entered the service of Swift & Co. at San Juan as salesman, a position that he held for 5 years. Returning to the United States in 1909, he entered Rensselaer Polytechnic Institute, Troy, N. Y.

Following his graduation in 1913 with the degree of mechanical engineer, he became associated with the Knox Automobile Co., Springfield, Mass., remaining there until November, 1914. While with that company Mr. Zimmerman was a student in the shops, a salesman and a branch manager at Rochester, N. Y. His next connection was with the Curtiss Aeroplane & Motor Co. at Buffalo and Hammondsport, N. Y., where he was successively chief draftsman and assistant aeronautical engineer. In November, 1917, Mr. Zimmerman resigned to accept the position of chief engineer with the Engle Aircraft Co., Niles, Ohio, remaining there until May, 1918. The next 5 months he spent exploiting a large airplane to be used in the war and in September, 1918, he accepted a position as chief aeronautical-engineer with the Aeromarine Plane & Motor Co., Keyport, N. J. Last year he left the Aeromarine Company and engaged in business for himself at Keyport in the design and construction of metal fuselages.

Mr. Zimmerman's work in the aeronautical industry includes the design of a number of Curtiss airplanes. He also designed the first cabin flying-boat used in this Country and converted and designed the passenger-cabin of the first flying-boat to be used on passenger service in this Country. The construction of the first two metal-hull flying-boats built in the United States is one of his achievements, as are also the construction of the first commercial flying-boats to make the trip between New York City to Porto Rico and the first American-built metal-fuselage airplane. Mr. Zimmerman also designed the first variable-thickness wing to be used on American military airplane.

He was elected a Member of the Society, June 19, 1922. For the last year Mr. Zimmerman has been a member of the Aeronautic Division of the Standards Committee.

C. F. Scott

Second Vice-President Scott representing stationary internal-combustion engineering was born at New York City on May 30, 1886. He prepared for college at the Haverford School, Haverford, Pa., for 4 years, and was graduated from the mechanical-engineering course at Haverford College in 1908.

Following his graduation he entered the service of the Sprague Electric Works in the engineering department. After serving 1 year as designing engineer he was appointed commercial engineer of electric motor and control applications. He has been identified with the development and application of the electric dynamometer almost from its inception in 1909. In connection with his work on dynamometers Mr. Scott specialized for some years in the adapting of the electric dynamometer to testing automobile engines and in other automotive and internal-combustion engine problems. He developed and installed the first electric dynamometer for testing a complete automobile chassis. Mr. Scott is now manager of the Sprague Apparatus Products Section of the General Electric Co. and has charge of a number of special electrical applications.

Mr. Scott was elected to Junior grade in the Society Oct. 24, 1911, and was transferred to Member grade Sept. 11, 1912. He was elected Chairman of the Metropolitan Section in 1918 and became Vice-Chairman the following year. He was a member of the Society Nominating Committee, representing the Metropolitan Section in 1918, 1919 and 1923, was secretary of the Committee in 1919 and 1923 and a member at large of the 1920 committee. He has been a member of the Meetings Committee of the Society from 1919 to 1924 and served as chairman of the Committee in 1921 and 1922. Mr. Scott was elected a Councilor of the Society at the 1922 Annual Meeting.

A. K. Brumbaugh

Councilor Brumbaugh was born at Hagerstown, Md., Dec. 29, 1883. He received his education at the Baltimore Polytechnic Institute, Baltimore, and at Lehigh University, receiving the degree of electrical engineer at the latter institution in 1909.

Mr. Brumbaugh's experience is varied, dating from March, 1898, when he entered the service of the Crawford Mfg. Co., bicycle manufacturer at Hagerstown, Md., as a toolroom apprentice. Here he remained for a little over 3 years, leaving in April, 1901, to become a fireman on the Western Maryland Railroad. After serving in that capacity for 7 months, Mr. Brumbaugh was transferred to the civil engineering department of the railroad. He resigned in September, 1902, to enter the Baltimore Polytechnic Institute, where he studied until June, 1904. From that time until September of the following year and from February to September, 1906, he was connected with the electrical department of the Baltimore & Ohio Railroad.

O. B. ZIMMERMAN

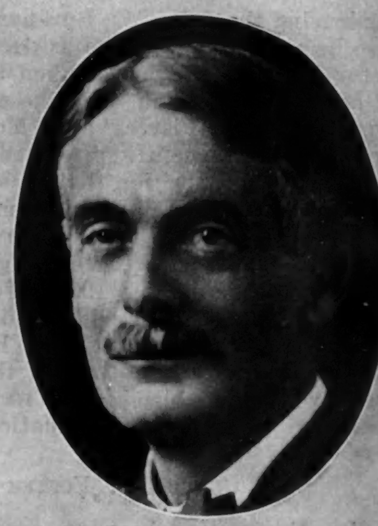
P. G. ZIMMERMAN

C. A. CARLSON

T. J. LITLE, JR.

H. D. CHURCH

C. F. SCOTT



H. M. CRANE

His connection with the automotive industry dates from 1907, when he became associated with the Loane Hiltz Engineering Co., motorboat builder, where he did designing, testing and sales work. In 1909 and 1910 Mr. Brumbaugh was engaged in the development of vehicle motors by the Westinghouse Electric & Mfg. Co., leaving in June of the latter year to become engineer for the Maryland Casualty Co. of Baltimore. He remained with this organization until February, 1914, being engaged in the bonding department and also doing construction and executive work. In February, 1914, Mr. Brumbaugh went with the Consolidated Gas & Electric Co., also of Baltimore, where he had charge of the administration and maintenance of transportation equipment. In 1915 he entered the service of the Autocar Co. as assistant engineer, doing sales and engineering work. This connection has been continued to the present time, his appointment as electrical engineer for the Company having been made in the fall of 1923.

Mr. Brumbaugh was elected to Member grade in the Society, Feb. 16, 1916. He was chairman of the Truck Division of the Standards Committee in 1921, has served as a member of the Division for the last 2 years and on the Storage Battery Division for 1924. In 1922, Mr. Brumbaugh was chairman of the Sections Committee of the Society. He was a member of the Automobile Insurance Schedule Committee last year.

Otto M. Burkhardt

Councilor Burkhardt was born at Meissen, Germany, Jan. 21, 1888. He received his elementary education in the schools of his birthplace and at the age of 17 entered the Technical Academy of Chemnitz, Germany, being graduated from there in 1908. The next year he worked as a designer in the Saechsische Maschinenfabrik Chemnitz, a plant that is noted for its fine locomotives. Mr. Burkhardt then entered the Technische Hochschule of Dresden. and was graduated in March, 1909, with the degree of engineer. After being graduated from Dresden he accepted a position as designer of electrical apparatus with the firm of Karl Flohr, of Berlin, but left shortly afterward to become a designer for Junkers & Co., remaining there until October, 1910, when he served for 1 year in the Engineering Corps of the German Army.

After leaving the army Mr. Burkhardt came to Toronto where he accepted a position as designer for the Russell Motor Car Co., which was then beginning to build Knight engines. In March, 1912, he accepted a position as designer with the Pierce-Arrow Motor Car Co., Buffalo and was subsequently promoted to mathematical research engineer, a position that he still holds.

Mr. Burkhardt was elected to Member Grade in the Society, Jan. 10, 1917. He has been prominent in the Buffalo Section of the Society, serving as its Treasurer, for the year beginning May, 1922. Two papers entitled Problems of Crankshaft Design and Progressive and Retrogressive Designing respectively have been presented by Mr. Burkhardt at meetings of that Section. Both of these have been published in THE JOURNAL, as has also his contribution entitled Valuation of Engine Performance.

Claude H. Foster

Councilor Foster was born on a farm at Brooklyn, Ohio, Dec. 23, 1873. He spent his early years in the usual pursuits of farm life and received his education in the elementary and high schools in the vicinity of his birthplace.

In the late 1890's he established a small machine-shop and bicycle business in Cleveland and gradually drifted into experimental work in the automobile field about 1898. This resulted in his becoming associated with the Winton Motor Car Co. in the early days of the industry.

After extensive experimenting and testing in 1903, Mr. Foster invented and patented a motor-car horn operated by the exhaust gas from the engine and having a musical or pleasing tone. The following year he organized the Gabriel Mfg. Co. to manufacture and market this horn and has been president of the company since its organization. He has invented and patented a number of shock-absorbing devices of various types which were marketed between 1906 and 1911 and in the following year invented and patented the Gabriel Snubber. His inventions include a special type of snubber to meet the requirements imposed upon such a device by balloon and low air-pressure tires.

Mr. Foster was elected to Member Grade in the Society, Feb. 6, 1911.

J. H. Hunt

Councilor Hunt was born at Saranac, Mich., March 24, 1882. He received his technical education at the University of Michigan, being graduated from that institution in 1905 with the degree of bachelor of science in electrical engineering.

After graduation Mr. Hunt went with the Western Electric Co., first in the power apparatus apprentice department and later in the engineering department. Entering educational work, a year was spent in the department of electrical engineering at Washington University and 5 years with the electrical engineering department at the Ohio State University. Mr. Hunt entered the engineering department of the Packard Motor Car Co. in 1912, working on the application of electrical equipment. In 1913 he became research engineer for the Dayton Engineering Laboratories, working on all problems of electrical installations on motor cars with special attention to ignition. Since 1920 he has been head of the electrical division of General Motors Research Corporation.

Mr. Hunt was elected to Member Grade in the Society, Jan. 14, 1916. He has been active in the Dayton Section since its organization, serving as Chairman for the administrative year of 1922. He was chairman of the Sections Committee for 1924 and also vice-chairman of the Lighting Division of the Standards Committee.

Mason P. Rumney

Councilor Rumney was born in Detroit, Dec. 4, 1883. He attended school in Detroit and Kalamazoo and was graduated from the high school of the latter city. He entered the University of Michigan in the fall of 1903 and was graduated as a mechanical engineer 4 years later. In addition, Mr. Rumney specialized in metallurgy and chemistry.

After leaving college he entered the service of the Detroit Steel Products Co. and was sent to Europe for 8 months to learn the manufacture of a new product. On his return to the United States, he entered the engineering and sales department, introducing this product. After this he became superintendent, works manager and assistant general-manager and is now vice-president of the Detroit Steel Products Co. During the war he was a Major in the office of the Chief of Ordnance at the City of Washington in charge of the production of vehicles and the assembly of field artillery.

Mr. Rumney was elected to Associate Grade in the

J. H. HUNT

A. K. BRUMBAUGH

M. P. RUMNEY

C. B. WHITTLESEY

O. M. BURKHARDT

C. H. FOSTER

E. P. WARNER

Society on May 17, 1912, and transferred to Member Grade, Jan. 9, 1923. He has been a member of the Meetings Committee since 1922 and in 1923 served as its chairman. Mr. Rumney has been a member of the Iron and Steel Division of the Standards Committee for the last 3 years. He is also a member of the American Society for Testing Materials and the Detroit Chapter of the American Society of Steel Treaters.

E. P. Warner

Councilor Warner was born in Pittsburgh, on Nov. 9, 1894. He was educated at the Volkman School, Boston, and after being graduated from Harvard University with the degree of bachelor of arts in 1916, attended the Massachusetts Institute of Technology, receiving the degree of bachelor of science in 1917 and that of master of science in 1919.

During the war he was employed as aeronautical engineer for the Air Service in connection with research and also as instructor in the military course in aeronautical engineering at the Massachusetts Institute of Technology. From January, 1919, to June, 1920, he served the National Advisory Committee for Aeronautics as chief physicist, directing aeronautical research work at Langley Field; and for 3 months after that time he continued with the Committee as acting technical assistant in Europe. Since the fall of 1920 he has been a member of the faculty at the Massachusetts Institute of Technology where he is now associate professor of aeronautical engineering.

Professor Warner was elected to Member Grade in the Society in 1917. He is also a member of the American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers, the American Physical Society and an associate fellow of the Royal Aeronautical Society. He is the author of about 60 published reports and papers, including one on Commercial Aviation in the Eastern Hemisphere that was presented at the Annual Meeting in 1921; Airplane Performance Formulas, at the 1922 Semi-Annual Meeting; Design of Commercial Airplanes, at the 1923 Annual Meeting, and Commercial Aviation, at the November, 1923, meeting of the Metropolitan Section. Professor Warner has served as chairman of the Publication Committee for the last 2 years.

Charles B. Whittelsey

Treasurer Whittelsey has been connected with the Hartford Rubber Works Co. since 1901, beginning as its purchasing agent. In 1905 he was made assistant to the general manager; in 1906, superintendent; in 1911, secretary and factory manager; in 1915, vice-president and factory manager; and in 1916, president and factory manager. He served as president of the Hartford Chamber of Commerce and of the Hartford County Manufacturers' Association of Connecticut, and at present is a director of the Manufacturers' Association of Connecticut.

Mr. Whittelsey was elected to Member Grade in the Society in 1910. In 1916 he was elected a Life Member. He was a member of the Standards Committee for several years, beginning in 1911, and served as chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913 and was elected Treasurer in 1918, being reelected each year since. At the 1912 Annual Meeting he delivered a paper on Solid Motor-Tires, and at the 1915 Annual Meeting presented a paper entitled the Pros and Cons of Tire Inflation.

H. M. Crane

Past-President Crane was born on June 16, 1874. He received his education in private schools, with the final year at Phillips Exeter Academy, being graduated in 1891. He was graduated from Massachusetts Institute of Technology in 1895 with the degree of bachelor of science in mechanical engineering and in 1896 with a similar degree in electrical engineering.

After graduating he joined the laboratory force of the American Telephone & Telegraph Co. in Boston and worked there 2 years. In 1898 he was transferred to the engineering department of the Western Electric Co. in New York City, where he worked first on the preparation of telephone switchboard installation specifications and later on the development of apparatus and circuits. In 1905 he left the engineering department to become engineering assistant to H. B. Thayer, general manager of the company, and the following year resigned from the company.

In 1906 Mr. Crane organized the Crane & Whitman Co., in Bayonne, N. J., for the development of gasoline automotive machinery and especially motor cars. This company later became the Crane Motor Car Co., and in 1914 was consolidated with the Simplex Automobile Co. He was president of the Crane Motor Car Co. and vice-president of the Simplex Automobile Co.

In 1916 the Wright-Martin Co. was organized and absorbed the Simplex Company. Mr. Crane became vice-president in charge of engineering and remained in this position after the reorganization of the company as the Wright Aeronautical Corporation, about Jan. 1, 1920. He resigned from the latter company in March, 1920, and for the remainder of the year was not engaged in any regular business but did some consulting work. During 1922 he was engaged in the development of a new passenger car. On July 30, 1923, he was appointed technical assistant to the president of the General Motors Corporation.

Mr. Crane has taken a prominent part in the work of the Fuel Committee of the Society and as chairman of its Research Committee and the Aeronautic Division of the Standards Committee.

He was a member of the Tire and Rim Division for 1924. At the 1920 Annual Meeting of the Society he was elected Second Vice-President representing aviation engineering, and a Councilor at the 1922 Annual Meeting of the Society, and served as First Vice-President for the administrative year 1923 and as President for the administrative year that has just recently been brought to a close.

Vol. XVI February, 1925 No. 2

Effects of Balloon Tires on Car Design

By J. W. WHITE[1]

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPHS

ABSTRACT

INASMUCH as the use of low-pressure tires has become established, the conditions of car design affected by them are reviewed, particular reference being had to the members of the chassis included under the term unsprung weight, namely, the axles, the wheels and the tires.

Referring to the principles that underlie basic design, the author first investigates the effect on the steering of such changes and compromises from the perfect structure as failure of the king-pin to coincide with the vertical load-plane, the inclination of the king-pin toward the wheel, or the wheel toward the king-pin, or both, and the giving of a toe-in to the front wheels. Further modifications have served to reduce the car shock, to add to the strength of all the parts by increasing the dimensions, to improve the spring-suspension, and to reduce the car weight per passenger. But four things remain to be done, namely, to stop the angular rotation of the axle because of the flexing of the springs, to eliminate backlash in the steering linkage, to construct a positive-steering mechanism that will be absolutely neutral, and to divorce the steering mechanism from all influences except those that occur from the road.

In the opinion of the author, all these objectives can be reached, but then looms prominently the question of lateral stability. This is to be expected unless the width of the rim is increased. In high-pressure tires, the normal ratio of the width of the rim to that of the tire is about 62 per cent, but ratios of from 50 to 55 per cent are common. Lack of lateral stability has amplified the errors of present design until a point has been reached at which shimmying has become prevalent.

By studying the footprints of tires, it is found that the side-slip per revolution is 60 per cent greater with balloon tires than with high-pressure tires. As the forward rake of the king-pin exerts a leverage that tends to turn the wheels still farther in the same direction, these two forces are said to be sufficient to cause shimmying even though the geometry of the steering mechanism were neglected.

The conclusion reached is that, in order to avoid shimmying, all backlash must be taken out of the steering-mechanism, and that, so far as possible, all rake of the king-pin outward leading of the wheels, and toe-in should be eliminated. The introduction of an hydraulic steering-gear is suggested as a means of accomplishing these results.

WITH the assurance that low-pressure tires have become established, we should study the conditions of car design and the calculations that have been affected by them. It is apparent that the advance in car construction caused by the use of balloon tires is of more value than was the main objective, riding-comfort.

Lower air-pressures were first regarded as something intended merely to please the purchaser, and too little attention was paid to the fact that they offered an opportunity through redesigning to add materially to the life and performance of the car and, at the same time, to reduce the cost, up-keep, and road shocks.

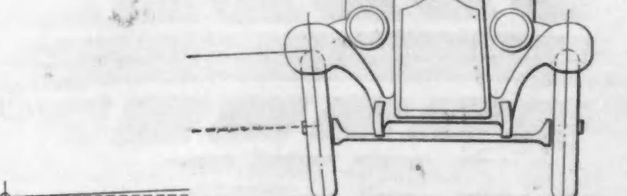


FIG. 1—DRAWING SHOWING HOW A DISHED WHEEL CAN BE CONSIDERED AS THE BASE OF A CONE LYING ON ITS SIDE

The Natural Path of Such a Wheel Rolling Free Is a Circle Having a Radius Equal to the Apex Distance of the Cone

Time being the variable factor in all shock calculations, it is patent that if the tire pressure were cut in two, the deflection of the tire would approximately be doubled and, consequently, the time factor in both the shock-absorbing and the rebounding periods, insofar as the unsprung weight is concerned, would also be doubled. It follows that, inasmuch as the cushioning effect is doubled by the increased time-period, the shock will vary inversely as the square of the time and will, therefore, be one-fourth of that formerly considered as the basis of design.

I shall confine my remarks exclusively to those members of the chassis that are included in the term unsprung weight, that is, the axles, the wheels and the tires.

Let us therefore go back to basic design and consider how our present standards of design have been built up, and why.

CONDITIONS AFFECTING STEERING

First, let us consider the axle and, particularly, the conditions that affect steering, that is, the load and shock stresses, vibration, backlash and wear.

Under these limitations, the steering was compromised by the following changes from a perfect structure:

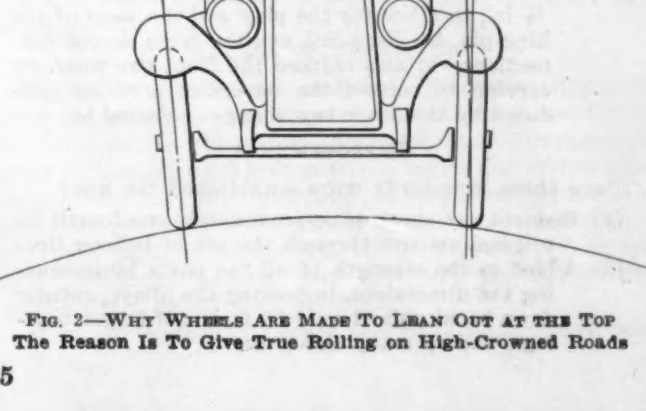


FIG. 2—WHY WHEELS ARE MADE TO LEAN OUT AT THE TOP

The Reason Is To Give True Rolling on High-Crowned Roads

[1] M.S.A.E.—Chief engineer, disc wheel division, Wire Wheel Corporation of America, Buffalo.

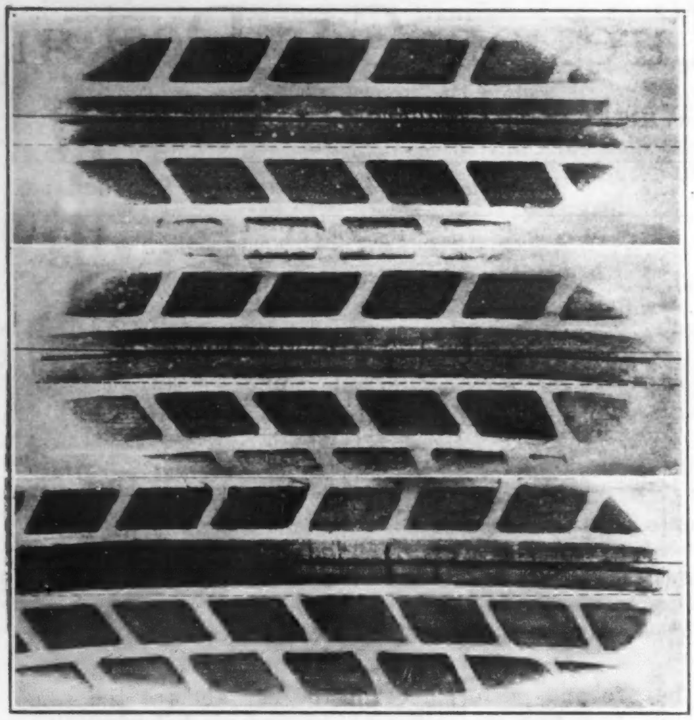


FIG. 3—THREE TREAD-MARKS OF A 32 X 6-IN. BALLOON TIRE ON THE RIGHT FRONT WHEEL OF A CAR WEIGHING 2800 LB.
In the Top View the Car Is Level and the Tire Makes Contact with Ground in Its Normal Position. The Tendency to Circular Travel Is Evidenced by the Arc of the Imprint. In the Middle View the Car Is Resting on a Laterally Inclined Plane of 6½ Deg. In Both of These Views the Inflation-Pressure Is 25 Lb. per Sq. In. The Bottom View Illustrates the Print Made by the Tire when the Car Is Resting on a Laterally Inclined Plane of 6½ Deg. and the Inflation-Pressure Is 20 Lb.

(1) It was not practicable on front axles to allow the king-pin to coincide with the vertical load-plane because of backlash and the bending of the axle, because of the changing of the spring angles under excessive spring movement, and because the resultant of the combined load, due to the weight on the axle and to road resistance, is a slightly inclined plane. It was principally because the car would cramp in going into or coming out of a turn, if the king-pin were in the same plane as the road contact, that early engineers gave the axle a rake or caster effect to make the wheels track and recover. At that time, this seemed to be the practical solution
(2) The king-pin was inclined toward the wheel, or the wheel toward the pin, or both, to take care of the axle deflection and the wear of the king-pin, to keep the stress in a dished wood wheel in one direction as much as possible, and to make correction for high-crowned roads. Two degrees from the vertical plane was the accepted standard that was adopted as far back as 1910, and it is still the practice
(3) The front wheels were also given a toe-in of ¼ to ½ in., to allow for the play and the wear of the king-pin, the drag-link and the cross tie-rod connections. It also reduced the front-tire wear, by serving to correct the imperfect tracking produced by the other two changes referred to

IMPROVEMENTS

Since these standards were established we have
(1) Reduced car shock to approximately one-fourth its original amount through the use of balloon tires
(2) Added to the strength of all the parts by increasing the dimensions, improving the alloys, cutting down backlash and wear by means of larger bearings, and by many closer fits
(3) Improved the spring-suspension and the wheel construction
(4) Reduced the proportional car-weight per passenger, and the vibration in the chassis

In the meanwhile, roads have been so greatly improved that the very conditions that brought about these standards have been largely reduced.

Four things remain to be accomplished
(1) To stop the angular rotation of the axle because of the flexing of the springs
(2) To eliminate backlash in the steering-linkage
(3) To construct a positive-steering mechanism that shall be absolutely neutral
(4) To divorce the steering mechanism from all influences except those which occur from the road and can be damped out in the axle itself

LATERAL STABILITY

All these objectives can be overcome; but a new problem has arisen with the introduction of balloon tires, and that is, lateral stability. The standing height has been increased about 25 per cent; the air-pressure and the number of plies have been reduced 50 per cent; but, as the width of the rim has not been increased proportionately, lack of lateral stability is only to be expected in so radical a departure from previous practice.

The only possible change of material value, with the exception of the carcass construction within the tire, is the increased width of the rim.

The normal ratio of the width of the rim to that of the tire in high-pressure tires is about 62 per cent, but, with few exceptions, ratios of from 50 to 55 per cent are common in balloon tires.

The only real indication of a return to normal proportions is shown in the new standards of rim widths

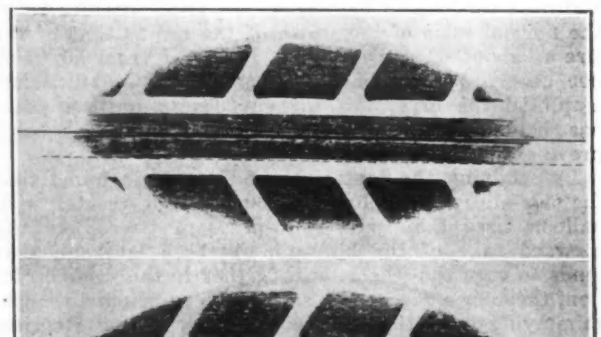


FIG. 4—THREE TREAD-MARKS OF A 32 X 4½-IN. STANDARD TIRE ON THE RIGHT FRONT WHEEL OF A 2800-LB. CAR
The Three Views Illustrate the Same Car-Positions as the Corresponding Ones in Fig. 3. In This Case the Inflation-Pressure Is Double That of the Other Illustration, Being 50 Lb. for the Top and Middle Views and 40 Lb. for the Bottom View

TABLE 1—RESULTS PRODUCED BY DOUBLING THE AIR-PRESSURE

Fig. No.		Size and Type of Tire, In.	Air-Pressure, Lb. per Sq. In.	Footprint Area, Sq. In.	Footprint Area, Per Cent	Footprint Length, In.	Footprint Length, Per Cent	Side-Slip per Revolution, In.	Side-Slip per Revolution, Per Cent
3	(Top View)	32 x 6.0 Balloon	25	16	30.0	9.00	20	0.875	25
4	(Top View)	32 x 4.5 Standard	50	12		7.50		0.705	
3	(Middle View)	32 x 6.0 Balloon	25	18	38.5	10.00	29	1.710	36
4	(Middle View)	32 x 4.5 Standard	50	13		7.75		1.250	
3	(Bottom View)	32 x 6.0 Balloon	20	26	85.5	11.75	31	2.000	60
4	(Bottom View)	32 x 4.5 Standard	40	14		2.00		1.250	

adopted by the Tire & Rim Association for drop-center rims; and this is largely responsible for very favorable performance.

It is well known that a wheel that leans out at the top can be considered as the base of a cone lying upon its side, as shown in Fig. 1. The natural path of such a wheel, when rolling free, is a circle having a radius equal to the apex distance of the cone.

Another reason for making wheels lean out at the top has been to give true rolling on high-crowned roads, a thing they do, as is indicated by Fig. 2. The rigidity of high-pressure tires is such that they do not lop over. In low-pressure tires the rigidity is proportionately less, and they lop over, as is evidenced by the fact that an increase in the bulge can be noticed on the inside of balloon tires as compared with the outside, when a car is standing on the low side of a road.

Lack of lateral stability of the balloon tire therefore introduces a new problem, which has amplified the errors in present design until a point has been reached at which shimmying has become prevalent.

The top view in Fig. 3 shows the footprint of a 32 x 6-in. balloon tire on the ground in the normal position. The tendency to circular travel is well shown by the arc of the footprint. The area of contact of tires and, therefore, the line of contact on the ground, is inversely proportional to the pressure within the tire.

In high-pressure tires, therefore, the length of the arc is shorter, and there is less tendency for the tire to scuff or for the road to exert so much control over it.

Increase in Size of Footprints

In low-pressure tires the footprint is increased in area about 60 per cent; consequently any change in the alignment of the wheel from a true-running course will affect the steering and the shimmying more than it will in high-pressure tires.

This is well shown by Figs. 3 and 4, which are footprints of tires taken on the right front wheel of the same car. The weight of the car was 2800 lb. and the toe-in ¼ in., a 4-in. rim being used in both cases. In both illustrations the top view shows the normal footprint of the tire.

The middle view of Fig. 3 shows a footprint of the same 32 x 6-in. right front tire on a car resting on a laterally inclined plane of 6.5 deg. It was found that this car could be rocked back and forth by one man, in the natural period of the car, so that the lateral movement of the rim because of the rolling of the tires was ½ in. either way, or a total of 1 in.

Side-Slip

I have assumed, for sake of discussion, that a lateral influence of this kind could be easily developed by the car at normal speeds on an ordinary road. The car was inclined on a platform until the natural side-slip of the car allowed the rim to move more than ½ in. from the normal position of the tire. The middle footprint in Fig. 3 is the result.

The bottom view shows the same tire under the same conditions with 20 lb. of air-pressure, but the same results would show at 25 lb. of air-pressure, if the lateral impact were increased.

It will be apparent that lack of lateral stability in balloon tires is the cause of the above-mentioned condition and that the effect has been to reduce the apex distance, or the outward rolling radius, as shown in Fig. 1.

It can also be seen that the center of the footprint is practically straight for about 4 in. (See the middle view of Fig. 3), so that there must be an actual shifting of the tire surface under the load that results in angular tread-wear or "scuffing" and represents the energy that tends to make the tire follow the apex circle instead of the normal path.

The three views of Fig. 4 show the same conditions as in Fig. 3 with high-pressure tires, but the pressure has been doubled, and some remarkable results are set forth in Table 1.

In Table 1 it will be seen that the side-slip of a balloon tire is 25 per cent greater than that of a high-pressure tire, according to the measurements taken of the two footprints resting normally on the ground. On the 6.5-deg. lateral incline of the car, the side-slip is 36 per cent greater.

When the pressures have been reduced to 20 and 40 lb. per sq. in., respectively, on the same incline, the side-slip per revolution is 60 per cent greater with balloon tires. It will also be noticed that the length of the footprint increases much faster with balloon tires, because of side-sway, and that the area of the footprint does likewise. We can logically assume, therefore, that lower pressures will allow greater side-sway, area of contact, and length of contact, and that these factors will increase in a greater proportion as the pressure in the tire diminishes.

As the angle of the king-pin is raked forward of the vertical from the point of contact with the road, a leverage is exerted, when the car sways to the right, that tends to turn the right wheel farther in the same direction. Mr. Burkhardt has brought out this point in his paper; and this effort is superimposed on the influence of the road over the tire, as has been stated before.

If the footprint of the tire on the road were a circle, the conditions would be ideal, but the footprint of a balloon tire is quite a departure from that of theoretical contact, when compared with the footprint of a high-pressure tire.

Causes of Shimmying

These two forces are sufficient to cause shimmying even though the geometry of the steering mechanism were neglected. Therefore, to secure any comparatively good results, all backlash must be taken out of the steering-mechanism; and pumping of the steering-arm, because of spring and drag-link geometry, is included as backlash in this connection, for it represents the relative movement between the axle and the car chassis, which itself constitutes backlash.

It would seem that, aside from the corrections possible in spring construction, shackling, and drag-link location, the ideal condition for steering would be the elimination, so far as possible, of all king-pin rake, outward leaning of the wheels, and toe-in. But this cannot be done until the backlash has been taken out of the steering-mechanism and an irreversible gear can be provided.

It is my firm belief, however, that the introduction of an hydraulic steering-gear will eliminate backlash and allow the corrections suggested. But, in order to do this, the actuation of the front wheels must be divorced from the chassis, and this would make it necessary to locate the piston that actuates the mechanism on the front axle.

SATURATION POINT FOR MOTOR VEHICLES PUSHED AHEAD

(*Concluded from p.* 196)

of the average automobile tire has been increased from 1 year to 2, or doubled, while that of the average automobile has advanced from 5 years to 7½ years, or an increase of 50 per cent. This means that the potential replacement demand for tires has been cut in half, while that for automobiles has been reduced by one-third. Moreover, these figures relate only to the tires and cars now going out of service. No one knows how long those sold this year are going to last but I have no doubt that the average service of the new cars will be at least 8 years, even when the cheapest cars are included in making up that average. How long the best cars will last, no one knows. I have a Pierce-Arrow that was built some time after the Spanish-American War, but well before the World War, that has not, so far as I can see, yet begun to show signs of wear.

The prospects for the industry in the year that has just begun appear to be distinctly good, because it is entirely probable that this year is going to be one of general business prosperity in this Country. The influence which has always determined the fortunes of the automobile industry has been, and still is, the general prosperity of the American people.

Over a long series of years, periods of sustained prosperity have come in this Country when certain fundamental economic forces have been operating in effective balance with one another. Most important among these forces has been the combination of increasing industrial production, farmer prosperity, good export trade and easy credit conditions. As this new year begins, these fundamentals are all effective and well-balanced. Industrial output is expanding, farmers are better off than they have been for a long time, export trade is increasing and credit conditions are easy and sound. Hopes for prosperous general business seem thoroughly justified and confidence in a good year for the automobile industry seems well-founded.

Output of 3,600,000 This Year

Forecasts of output for the industry in 1925 have been numerous and most diverse. They have ranged from a minimum of 2,500,000 passenger cars and trucks to a maximum of 5,000,000. My own estimate is that the total output will probably be about 3,600,000.

The year 1925 will mark the completion of the first quarter of the Twentieth Century. During this period the American automobile industry has achieved an unparalleled record in expansion of output, improvement of product and reduction of cost. The industry has now entered a period in which the number of possible new first-purchasers is rapidly diminishing and the potential replacement demand is being cut down by the increasing length of service that is being built into the new machines. This combination of conditions clearly constitutes a hazard for the future of the industry and that thrusts forward the question as to how the problem can best be met and crowded for solution.

If my analysis of the situation is correct, the solving of the problem depends on the skill and enterprise, and ingenuity and energy of you, the members of the Society of Automotive Engineers. If the phenomenal growth of the industry up to this time has resulted from the competitive nature of the product, then its future depends on keeping it competitive. There are clearly two sets of qualities of automobiles that make for continuous competitive comparison. The first is the combination of economy and convenience, and in supplying these the Ford has gone so far that it is almost within the bounds of accuracy to say that it has preempted the field. The second set of qualities is the combination of appearance and performance, and in this direction there is an open and boundless field.

So long as the automotive engineers can continue to design new cars featuring genuine improvements, the normal American citizen will continue to be imbued with intelligent discontent toward his present car and with a covetous desire for a new and better one. So long as that keeps on, the export market will grow, the problem of the traded-in car will never become quite hopeless, the dreaded saturation-point will recede still further into the future and the industry will continue its triumphant march forward.

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Metal Airplanes

By W. B. Stout[1]

Annual Meeting Paper *Illustrated with* Photographs

ABSTRACT

Although America holds practically all the world's records for aircraft, no attempt has been made in this Country to commercialize the engineering knowledge and organizing ability that have been acquired. Heretofore, development has been mainly in the direction of military airplanes and engines. No industry can continue to exist that is not self-supporting; and aviation in America is just beginning to emerge from the charity class. To be self-supporting, airplanes must support themselves financially as well as mechanically. Previous analyses having been made from the standpoint of Army or Navy business, Detroit, following its experience with the automobile, has visualized a commercial industry based on quantity production. With the slogan, "Build one 'airship' and stick to it," the project of building metal airplanes has been launched.

The reasons for determining the type of engine to be used, as well as the size, capacity, cruising-speed, maximum speed, climb and other features of the airplane are explained in detail. Inasmuch as safety is regarded as the fundamental requirement for money-making, adequate strength and unfailing control are essential; no point of instability, no tendency to stall or to spin, and an ability to fly under all conditions, whether the engine is on or off, to slow-down to less than flying-speed without becoming unbalanced, and to come out of a stall by itself without the use of controls and without falling off on a wing into a spin being qualities that are considered requisite.

As earning capacity is a function of the ton-miles in the air, it is placed second only to safety, minimum preliminary operating schedule of 4 hr. per day being expected, with a maximum ultimate requirement of 20 hr. per day.

With these ideas in mind, the type finally chosen was an all-metal internally-trussed Liberty-engined monoplane, carrying the maximum load at a cruising-speed of 100 m.p.h. or better. The considerations that led to the decision to build a metal thick-winged type of airplane, rather than one of wood, the advantages of duralumin and of the method of construction by box sections are discussed, the arrangement of the interior for the accommodation either of passengers or of freight is described, and illustrations are shown of both the exterior and the interior of the airplane. Because a useful pay-load of 1000 lb. can be carried by the metal airplane of the approved design, as compared with the 250-lb. pay-load carried by the Air Mail, a corresponding increase of revenue is forecast, and advantageous developments are anticipated. As a result of the progress of the work, the civic spirit of Henry Ford has led to his providing the airplane company with a location for a new plant and a landing-field at Dearborn, near his engineering and research building.

America today leads the world in aircraft. We hold practically every world's record, except that of altitude, a purely military requirement, and have proved that in aviation the American engineer need not take a back seat. Our engines are vastly superior to any foreign products.

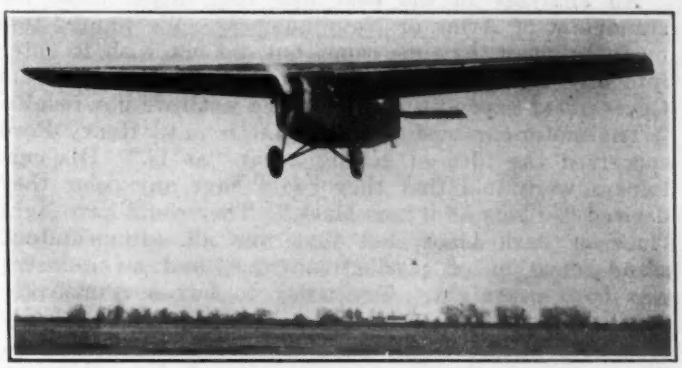


Fig. 1—The Original Maiden Detroit in the Air
Carrying 2700 Lb. of Ammunition for the Army, the Round-Trip from Detroit to Oscoda, 150 Miles, Was Made in 3 Hr.

As to air-lines, our own New York City-to-San Francisco Air Mail flies more miles per day than do all the European air-lines combined; and it is the only air-line operating both by night and by day on a regular schedule. With all this happening, no attempt has been made in America to commercialize the engineering knowledge and organizing ability that this Country possesses; but the hour for such a move has now come.

Flying got its major start during the war, but all the development was in the direction of military airplanes and engines, and all lines of thought and effort centered on military types. That habit of mind has continued, and no definite effort on the part of any concern has been made to translate the facts of flying into dividends.

An industry that is not self-supporting is a charity. Faith and hope may be its sisters, but it is still a charity. We are just making a beginning toward taking aviation out of the charity class and making it self-supporting. From now on in America, an airplane, to be commercially successful, must be able to support itself in the air financially as well as mechanically, and in some measure to repay in flying the sacrifice that the industry has been making during lean years to the accompaniment of sneering encouragement.

Quantity Production of Airplanes

When Detroit tackled the airplane problem she had, perhaps, a different viewpoint from that of all the rest of America. In the first place, her vision of this new

Fig. 2—Three-Quarter View of the Original Demonstrator
Taken in the Spring of 1924 on the Army Field at Mount Clemens, Mich. Since then the Airplane Has Carried More Than 1000 Passengers and Has Been Purchased by the Government for Use in the Night-Flying Air Mail Service between Chicago and Cleveland

[1] M.S.A.E.—President, Stout Metal Airplane Co., Detroit.

transportation was that of an industry self-supporting and on a quantity basis. Detroit was not interested in making money on Government contracts. Post-war experience had made such a procedure impossible with the banks and with the prospective investors of the type necessary for such a move. The plan had to be a commercial not a military one, in order to interest Detroit capital at all.

All analyses in the past had been made from the standpoint of Army or Navy business. We wanted this business when the time came, but did not wish to enter into any experimental program that would necessitate Government expenditure unless and until we got results.

The motor-car business was chaotic until Henry Ford conceived the idea of selling a car "as is." His customers were told that they could have any color they desired "so long as it was black." They could have light black or dark black, but that was all. Immediately, standardization of production came, and an industry was born overnight. Try today to buy a Studebaker with a wider chassis or a larger bore or stroke, or Ivory soap in a different-shaped cake, and see what it costs. Why not apply the same idea to aircraft by making an airplane that is right, and sticking to one design? This would lead to a better airplane, developed month after month, a cheaper airplane, as production went on, and an airplane that could be serviced at the minimum cost, which, after all, is the foundation of commercial flying.

This was the first analysis and it was adopted as a policy: Build one airship and stick to it. The next step was to design the ship.

Henry Ford says that business is like sorting potatoes. Instead of climbing on top of the pile, sort the potatoes nearest to you, letting the rest alone, and as you work they will roll down on you fast enough in their proper order. The building of a commercial airplane was the next potato that offered itself for sorting.

The Engine

The first problem to be considered in an airplane is the engine. We had built a number of different airplanes for various purposes during the last 6 or 8 years, and had found this fact to be fundamental. We had only recently built a small "air sedan," as we called it, but inability to get engines had absolutely stopped progress. The Liberty engine was the best available, and so, Liberty it was; I shall not go into engine analysis here.

The airplane must therefore be Liberty-engined, and of a size and capacity to pay a dividend on air-line work. Its cruising-speed must be 100 m.p.h., and the load the greatest that can be carried at this speed. Maximum speed was not an object, but the climb with full load must be at least 500 ft. during the first minute. This dictated wing areas, total weight and light weight, and set the first figure to "shoot at." We aimed at a 1-ton useful load with this performance.

Check was made with Air Mail figures, since foreign air lines, as then constituted, were too short to give accurate data. The final performance figures were far in advance of what was being done, hence were thought to be adequate for the start of the development work. In other words, if we could do this with the first ship, we could add to it many per cent after a few months of flying experience.

The best commercial airplane is the one that can earn the most money per fiscal year. Whether this would be in passenger, express, freight, mail or photographic work, was still hidden among the pile of potatoes, and had not yet rolled down on us, or on the industry, for solution.

The fundamentals of this airplane had to be:

(1) Maximum safety
- (a) Maximum reliability
- (b) Extreme structural strength
- (c) Extreme controllability

(2) Most ton-miles per dollar
- (a) Low insurance rates
- (b) Maximum engine-life
- (c) Quick serviceability
- (d) Minimum take-off and landing dangers

Irrespective of the airplane itself, it is still realized that 80 per cent of the safety of operation of any aircraft depends on the ground organization and the equipment.

Safety

Safety is the first requirement for money-making with aircraft. This means safety on the ground, in the air, and under all conditions of wind, weather and vision. It means safety in a crash, if a crash should occur, for the same reason that railroad coaches are made of steel. It means a structure that cannot fail in the worst hurricane, and controllability that will enable the pilot to handle the ship in any storm or wind.

The airplane should have no point of instability, no tendency to stall or to spin, but an ability to fly "hands off" under all conditions, with the engine on or off. It must be able to slow-down to less than flying-speed without tending to anything but an even keel. It must come out of a stall by itself without the use of controls, and without falling off on a wing into a spin. Its reliability must ensure it against forced engine-landings and its vision must allow it to continue during the most adverse snow and weather conditions.

Earning-capacity is a function of ton-miles in the air. The ship must be designed for an earning-capacity that is secondary only to safety. This item involved a survey and study of all operating conditions, routes, types of service, cabin capacity, distance range, and the like.

An airplane on the ground is a financial white-elephant. An airplane in the air is a service to mankind. Every minute spent on the ground is entered in the book in red. The ship must operate a minimum of 4 hr. a day in the air and eventually will be able to do 20 hr. a day. Only on this basis can aircraft pay dividends. The minimum number of hours per day spent in inspection and repairs therefore became imperative, and the type of structure dictated was metal.

Every pound on the airplane is worth 7 cents per hr. in the air during a 6-hr. day. One hundred pounds of weight saved means $42 a day of increased earnings because of greater load-carrying capacity. For the carrying of loads at the highest cruising-speeds no other airplane can compare with the monoplane, so, this type was chosen in spite of initial sales-resistance, in the belief that facts would eventually prevail. More monoplanes would be used in America if the makers had the sales nerve to start.

The Type Selected

Thus, we finally decided on the type: An all-metal internally-trussed Liberty-engined monoplane, carrying the maximum load at a cruising-speed of 100 m.p.h., or better.

The first study was structure. In studying structures, the two major considerations were (a) the material to be used and (b) the structural arrangement.

In airplane work, of course, the lightest material of the greatest strength in any given case should be used, and such an arrangement of structural shape should be made as will give the least possible weight per unit of area or volume, with the most extreme strength per pound.

MATERIAL: WOOD VERSUS METAL

No one has yet developed the proper way of inspecting wood. No man in the world can take a piece of spruce spar and tell within 40 per cent what the piece will stand without breaking; the only way to tell is to break it. When it breaks, its structure is entirely destroyed and, in a compression test, is splintered into many sharp penetrating pieces.

The strength of a piece of metal is known within 5 per cent. In other words, before it is put to the test, one can tell very easily just what a piece of metal will endure. Metal, therefore, is a much more inspectable and dependable material for minimum-weight structures than is wood, even when factors of safety many times beyond the actual requirements are assumed. Lack of knowledge of the actual strength of any wooden piece is the reason for much extra weight in wooden airplanes.

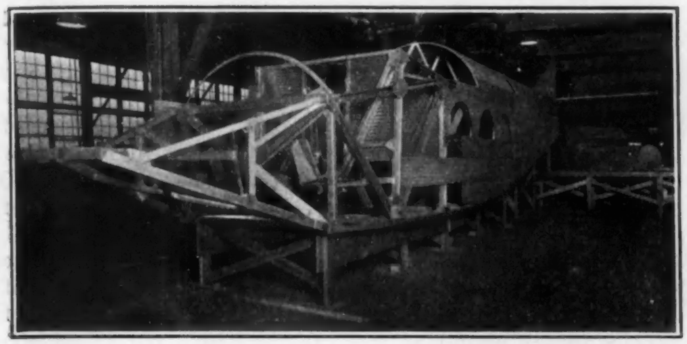


FIG. 3—PARTLY COMPLETED FUSELAGE SHOWING THE ENGINE SUPPORT AND WING-SPAR ATTACHMENTS
The Framework Is of Heavy Box-Sections, Riveted into Bulkheads, with Double Gusseting. The Detachable Wing-Tips Are Clearly Visible

STRUCTURAL ARRANGEMENT

In making an airplane of metal, it is a distinct mistake to try to copy a wood-and-cloth design. If metal is to be used, a structural arrangement suited to known metal structures should be chosen, even at the expense of new aerodynamics and the cost of additional development. To copy the old-type biplane in metal is too expensive in both material and money, so that the saving in weight is very little. If, however, a design is chosen to suit the metal, airplanes can be made lighter in proportion to the load carried than can the old types.

Type of service will dictate design. For mail and express service, the structure is arranged for major protection to the pilot and extreme vision in every direction. In this work, flights must be made in rain, snow, sleet and fog, and the actual limitation of the days on which these airplanes can operate depends on vision, one of the most deterrent features of the present-day Air Mail De Havilands.

An airplane for passenger service is an entirely different affair. It must have plenty of reserve power and climbing ability for safety; and the passenger cabin as well as the pilot's compartment must be armored and protected against all danger of a crash. For this reason, when it comes to carrying passengers in the air, metal cabins will be more important than ever, and the requirements will be as essential as is steel in railroad coaches.

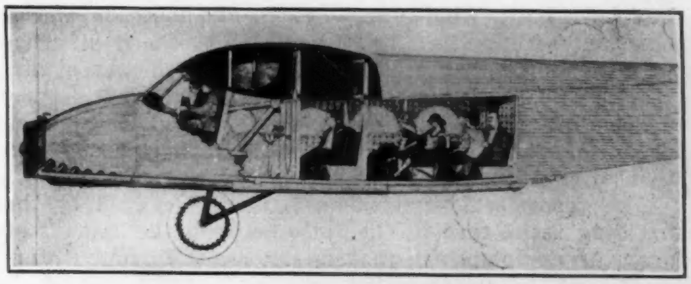


FIG. 4—GENERAL ARRANGEMENT OF SEATING AND STRUCTURE
The Dual-Control Three-Spar Wing-Construction and the Partition Bulkheads Are also Visible. The Windshield Is Part of the Lift Surface

ARMORED WALLS

A steel-frame structure covered with cloth is not sufficient protection; the walls, and particularly the floor, must be armored against forced landings of unusual character, such as might involve contact with fences, rocks or stumps.

Many Air Mail pilots have been flying for several years, thousands of miles every month, with no forced landings, except those caused by weather. When one does come down, however, it is well to know that he is in a crash-proof ship and that he will not be hurt no matter how severe the landing may be.

It is easy to design an airplane having better aerodynamic characteristics than those of any airplane flying today. Models in the wind-tunnel can show a very much increased performance. Of what use, however, is perfect aerodynamics, if a structure cannot be evolved for a design that will enable the wings to stay on in the air?

The best airplane design, therefore, is the one that absolutely and completely solves the structural problems with the very best possible aerodynamic compromise to fit those structural problems. Our analysis of this subject was, that it is just as sensible to put outside the struts, wires and structures that will resist the air without giving lift, as it would be to put the keel, ribs, and perhaps the engine, of a motorboat, outside in the water, instead of inside the hull where they belong.

THICK-WING AIRPLANES

During the war, before this organization was completed in Dayton, I outlined some of the possibilities of thick-wing airplanes. This was at a time when no thick-wing curves were known or had been developed, and when, so far as was known in America, no one else was working on this type. The wind-tunnel of that day showed no particular advantage of the thick-wing over the thin-wing type; but, after airplanes of the thick-wing type

FIG. 5—FRAMEWORK OF THE FRONT END, SHOWING THE ENGINE-MOUNTING AND LANDING-GEAR SUPPORTS
The Engine Mounting Is Built of Box-Sections Riveted Together and Is Detachable by Removing Four Bolts

had been built, wind-tunnel figures and methods of calculation were revised by Prandtl and others in order to make the tunnel results coincide with the actual air-results of later full-scale ships of the thick-wing type. Thick-wing curves have now been developed, so that the design of a thick-wing airplane is even more exact than that of previous thin-wing biplane types.

The general efficiency of an airplane is gaged by the lift-drag ratio, that is, the ratio between the amount of drag, or engine-power that is necessary to pull it forward, and the resultant lift.

By eliminating struts, wires and all possible parts that do not lift when resisting the air, our airplane showed a remarkable record in the tunnel over any previous commercial designs with which we were familiar. The wind-tunnel work was done at the Massachusetts Institute of Technology.

The ship was constructed of duralumin. We were averse to the use of steel or other metals with duralumin on account of electrolysis, and were prejudiced against the use of tubing on account of the weight of the fittings as well as the expense of that type of manufacture.

The metal airplane, therefore, is built mostly of box sections of duralumin riveted together, with all the rivets placed where they can immediately be inspected, inside the wings and out. The box sections were tested for their strength characteristics by outside testing-laboratories and from these figures the structural work proceeded.

Mock-ups

The first step was the building of a "mock-up" of sticks, shingle-nails and building paper, until all the plans and structures had been taken care of in the simplest possible manner. We found that this method saved many days of calculation, and led to a far more accurate result than could be obtained on the drafting-board.

Drawings were made from the complete "mock-up," the stresses in each piece analyzed and calculations made. When structures were indeterminate, sections were built and sand-loaded. Most of the structure, however, was of roof-truss or bridge design, with the maximum of known factors to work with.

This work has eliminated the drafting-room, for the drafting-tables are located in the shop, the draftsmen of any assembly being the foreman of construction of that assembly; so, if a rivet is hard to put in, or cannot be inspected after it has been put in, the drafting-room cannot condemn the shop, nor the shop the drafting-room. The man who creates an idea is responsible for the building of it, and it is his duty to make it right. This has led to extreme simplification of the metal design, and proportionately lessened costs.

Box sections are developed in dies in a 14-ft. power-brake; and all parts of the ship are designed to be complete, so far as bending operations go, within 15 min. of the time the metal comes from the heat-treating furnace. An automatic electric type of heat-treating furnace is used that keeps the temperature accurate within 1 deg. fahr. The metal is quenched in cold water before being straightened and worked. Production methods, metal, jigs, assembly tables and the rest are separate topics outside the scope of this paper.

By completing all bending operations at once after the heat-treatment, the development of cracks in the structure naturally is avoided. After some 3 years' work with this metal, we can now make it do everything but talk.

The Maiden Detroit

The photographs reproduced in Figs. 1 and 2 show our first airplane, Maiden Detroit, which has been used during the last year in and about Detroit as our original demonstrator, and has been purchased by the Air Mail for night-flying between Chicago and Cleveland. This airplane carried more than 1000 passengers during its year's work with us, and made intercity trips on which it carried with ease 2700 lb. of load.

When one considers that the De Haviland Air Mail airplanes can carry only 450 lb. of mail, and fuel sufficient for 3 hr., and that the metal airplane has carried nearly 2000 lb. of pay-load with the same fuel, the same engine, and at approximately the same speed, the advantage of the latter is obvious.

This airplane flies as designed. When it has climbed to a stall, it merely slows-down, settling at the nose until it regains its flying-speed, with no tendency to fall off on one wing or to go into a spin. It is under complete control, even though considerably below the landing-speed. We have settled for 1000 ft., when flying at less than a supporting-speed, with perfect control at all times and with a ton of load on board.

As completed, the airplane is a step farther ahead of previous monoplanes built by us in the last 6 years of experimental work, during which time some $500,000 has been spent and an equivalent amount learned of what not to do as well as what to do.

Weights have been reduced to the minimum, yet the structures are very simple and have the full factor of safety. The airplane shown in Fig. 1 has a factor of safety of six, which is more than is required of an airplane of the type described in the Army and Navy specifications. Flights in Air Mail work, through storms that have wrecked shipping on the Lakes and a trip on Dec. 14, 1924, the roughest day in the history of the Air Mail, have proved the structure against any sign of weaving or distress, even in bumps of the most extreme violence. The rivets certainly hold. Our own confidence is shown by the fact that we and our families occupy the ship on every opportunity, when factory airplanes go on cross-country tours.

The fuselage or body of the airplane is square in section, as shown in Fig. 3, with the engine section fastened to the front end by the quick-detachable method. The framework is of heavy box-sections, riveted into bulkheads with double gusseting. The cabin part, that is, the section from the engine to the back of the cabin, is framed to take all stresses without regard to the strength of the skin. The three main bulkheads are arranged to coincide with the three wing-spars above, and are fastened to them, as shown in Fig. 4, which also shows the seating and structural arrangement very plainly.

Engine Compartment

The engine compartment, depicted in Fig. 5, is of course in the front. Behind the fire-wall, which forms the front of the body proper, is the pilot's compartment where two pilots sit side by side on either side of an aisle, each pilot having his individual Deperdussin control. This is standard in every way except that pedals replace the former crude footbar.

Space is provided in the freight ships, or "air trucks," for the wearing of seat-type parachutes by the pilots, and for quick egress from the ship, since these airplanes are to be used in night-flying and under conditions of weather and fog in which it would be foolhardy to carry passengers. As passenger ships are intended for fair-weather flying under ideal circumstances, parachutes are not a part of their equipment.

A central door, shown in Fig. 6, leads from the pilot's room back to the wash-room which contains toilet and washing equipment. One may stand in this room, look out into the wings on either side and back through the tail of the ship, and inspect everything. On either side is a gasoline-tank provided with a sight-gage and holding 150 gal. of gasoline, a capacity sufficient for 6 hr. flying at cruising-speed, or about 600 miles.

Another central door leads from the wash-room into the cabin, shown in Fig. 7. This is some 14 ft. long and reminiscent of the interior of a modern intercity motor-bus. Seats are side by side on either side of an aisle. In the air-truck, this room is without seats but has rings in the floor for fastening loads into position. The backs of the middle seats fold down on the rear seats,

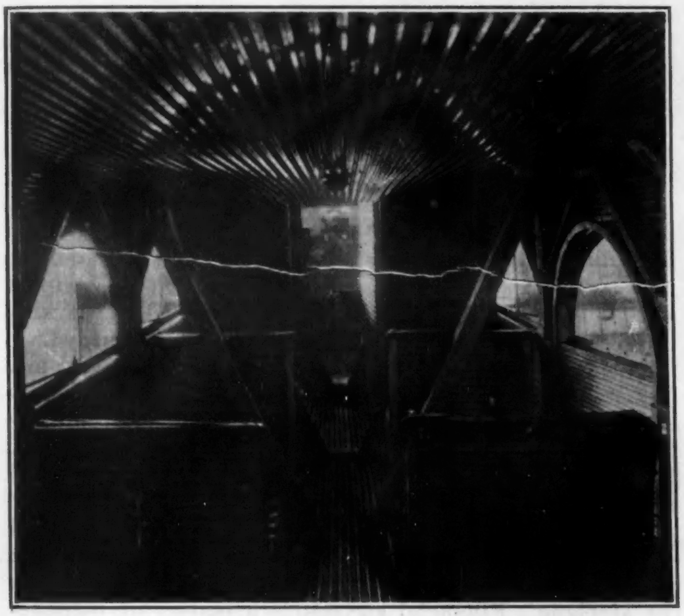


Fig. 6—View of Main Cabin Looking Forward
The Pilot's Room and the Wash-Room Are Also Shown. The Air-Speed Indicator and the Altimeter Are Mounted on the Front Wall. The Exit Door Is at the Right

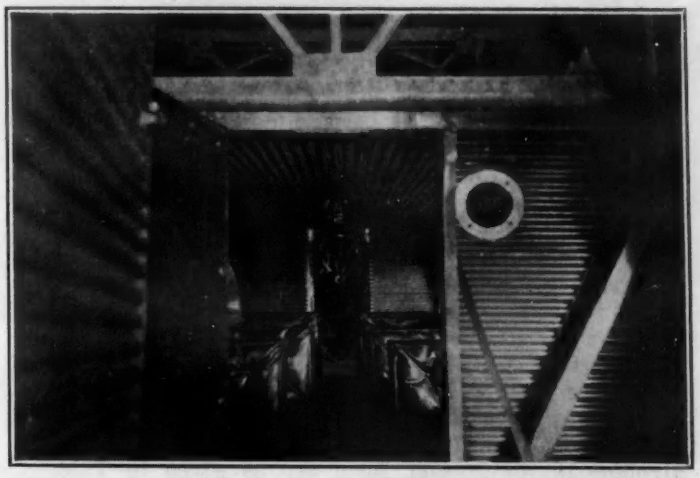


Fig. 7—Looking Aft through Main Cabin and Rear Door
The Wing-Spars and the Luggage Space Can Be Seen Above. All Parts Can Be Reached for Inspection from the Inside of the Ship

forming benches at the side so that passengers can face inward. A table can then be set between the seats for serving meals, for reading or for playing cards; or the benches can be used at night as berths, when the crew sleeps in the ship when in strange fields.

Cabin

The appointments of the cabin are those of a limousine, heating being provided for winter work, so that an even temperature can be maintained at all times. The windows open on an arc for ventilation in summer. Since three walls intervene between the engine and the load, no fumes of gas or oil can come through to bother the passengers.

The landing-gear below is fastened to the two major bulkheads, as shown in Fig. 4. It is of the split-axle type and is arranged for 12 in. of spring-action. The tires are 36 x 8 or 44 x 10 in., depending on the operating conditions involved.

Above the fuselage are the wings. These are built in three sections, a central section and the wing-tip sections, for handiness in shipping and for ease of replacement and storage. Three spars are fastened to the three

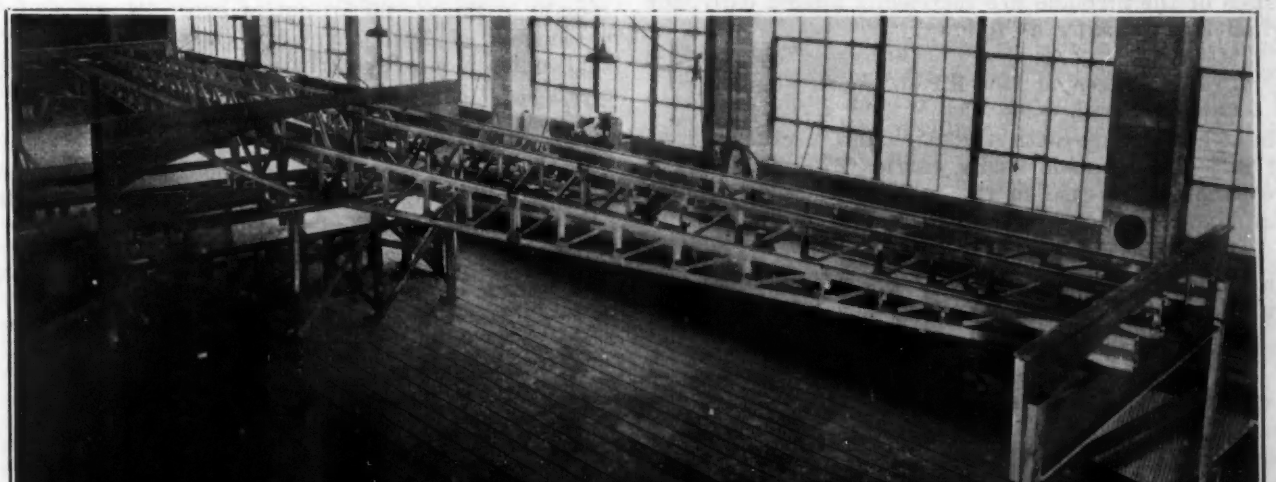


Fig. 8—Wing-Spar Arrangement Showing Method of Construction before Metal Covering or Skin Has Been Put On
The Crude Type of Wooden Jigs Originally Used Has Been Replaced by Permanent Metal Jigs and Tools

main bulkheads of the body. These spars are tapered, and are of cantilever bridge-type construction, with double gussets, as shown in Fig. 8.

Six bays, transversely braced with cross-bracing, take the torque. The skin is corrugated and forms the ribs proper. When complete this makes the strongest wing against torque and flutter that has been built and is a reason for the extreme rigidity in flight.

The wing is of double camber, a type used in this Country on our first airplane that is very stable in center of pressure movement.

The tail assembly is of high aspect-ratio, to save work on the part of the pilot, and the stabilizer is adjustable from the pilot's seat. No trouble is experienced in the air when passengers move about, for the tail can be set to compensate.

The general design and performance features of the airplane in its present form are as given in Table 1.

TABLE 1—DIMENSIONS AND PERFORMANCE

Span, ft. in.	58– 4
Length, Overall, ft. in.	45– 8
Chord, Maximum, ft. in.	12–10¾
Height, at Rest, ft. in.	11–10
Wing Area, sq. ft.	600
Wing-Tip Clearance, ft. in.	9–11
Engine, Liberty, hp.	400
Weight, per Sq. Ft., lb.	9.85
Weight per Hp., lb.	14.8
Total Weight, lb.	6,017
Weight, Empty, with Water, lb.	3,638
Useful Load, lb.	2,379
Fuel, gal.	150
Oil, lb.	96
Duration at Cruising Speed, hr.	5½ to 6

The airplane is stable with the engine on or off. We can fly it "hands off" on a calm day and cut-off the engine without touching the controls. It then takes its own flying-angle without a tendency to go into a nose-dive. When diving, "hands off," the machine goes into a normal glide by itself. When landing in a side wind, it has no tendency to ground-spin and, in taxying on the ground, the controls are extreme.

The take-off with 2000 lb. of load is between 600 and 800 ft., depending on the wind. We have climbed more than 1 mile in 10 min., with 1 ton of mail load. Characteristics of the airplane are increasing almost daily, the original figures being as follows:

Maximum Speed, m.p.h.	115.0
Cruising Speed, at 1450 R.P.M., m.p.h.	96.8
Landing Speed, m.p.h.	52.0

These figures are with the Air Mail useful load of 2000 lb. The airplane easily carries 2700 lb., with a corresponding increase in the take-off and decrease in the climb.

New Plant at Dearborn

As a result of the progress of this work, announcement has recently been made of our new plant at Dearborn, on the new landing-field known as Ford Airport, which Henry and Edsel Ford have constructed for us, close to the new Ford engineering and research building. I wish to mention this on account of some misconstruction that has appeared in the newspapers.

Mr. Ford has announced no plans of going into the airplane business, nor of building the so-called "air flivver," about which the newspapers seem to be so insistent. The field and factory, upon which about $250,000 has been spent, have been arranged for our use merely as an encouragement to the air industry around Detroit.

This civic spirit on the part of the Fords and others is the main thing that will make Detroit, we hope, the center of airplane manufacturing and, as a National move toward increasing the interest in aviation in America, cannot be too highly commended.

Further developments are beginning to accrue to us. Our plan tentatively is to operate our own airplanes on subsidiary air-lines between given cities.

By operating our own airplanes, we can control the safety of operation and the method of handling, so that we can work to a dividend point in strictly commercial operation in the type of carrying that proves to be the most profitable, be it fancy express, mail, or passengers.

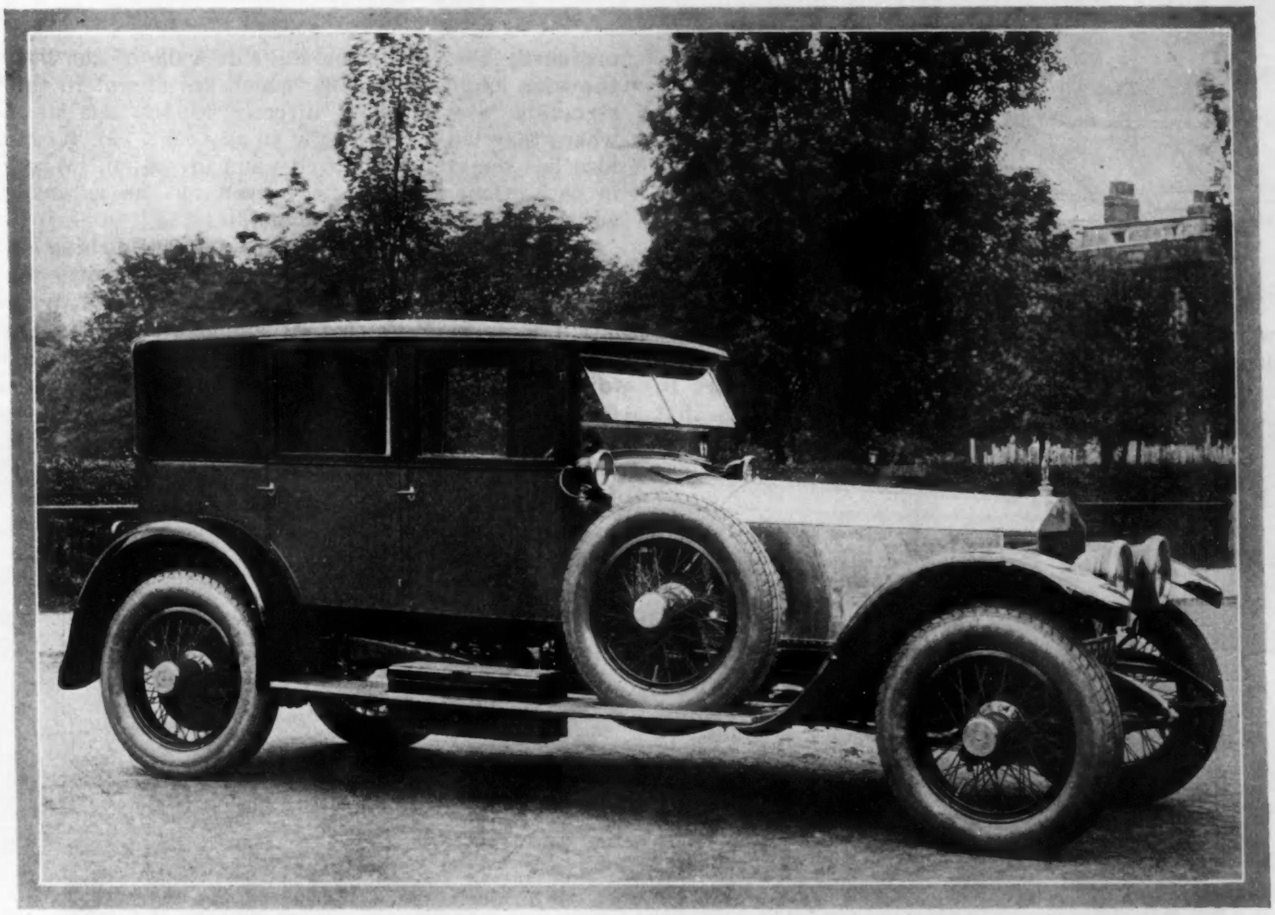
Visualize airplanes of this kind leaving Detroit and Chicago every hour. Ten passengers could be carried on each trip, and $25 per passenger would be a reasonable fare. The trip, including overhead expense, and the like, would cost about $150, leaving a profit per trip of $100. From four to six single trips per day per ship could be made, once full load had been accomplished.

The Air Mail today meets all expenses of its night and day flying from New York City to San Francisco, including the searchlight stations, emergency landing-fields, and all the equipment, with a pay-load of 250 lb. One can see the margin of profit that could be developed in this service with a pay-load of only 1000 lb.

It has been said by many persons that commercial airplanes cannot pay. As they have been operated in the past, they could not pay, no matter what might be the airplane. Financial success is a matter of management and of working from facts.

When we fly at night between civic centers with airplanes that safely carry passengers, freight, collateral, money, antiques, films, and the like, and the ships can remain in the air 20 hr. out of every 24, we shall carry passengers cheaper than first-class railroad fare and shall make money by carrying goods at express rates at a profit. It is purely a question of business men putting business fundamentals into airplane operation, a thing as yet undone.

A great deal of faith and hope still remains to be expended, in actual cash and energy, before the charity side will be overcome and aviation really will become self-supporting. Meanwhile, Detroit is letting the dollars fly, believing that eventually they will return like Noah's dove, carrying something more than their bill.



The Weymann Silent Flexible Body

By GEORGE W. KERR[1]

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPHS

ABSTRACT

BODY construction, of a character such that the wooden framework is secured by suitably shaped steel joining-plates and bolts that separate the wooden members ⅛ in. at the joints, is illustrated and described. The outer surface of the body is then completely covered with flexible textile fabric or leather-cloth. It is claimed that the effect is to impart to the finished body an easy deformability and to permit it to accommodate itself to distortions of the chassis frame, to which it is rigidly attached.

A portion of the English patent specification is quoted, and details of the actual construction practised at the inventor's factory in Paris, France, are stated. Due to the absence of steel and to the extreme slenderness of the wooden parts, these bodies are very light. The required wood-working operations are few and simple. Only the minimum machine equipment is needed to fabricate the framework, and no great skill is demanded in its erection. As no paint is used, the artistic success of the body largely depends upon the skill of the upholsterer.

ALTHOUGH the outer surface of the Weymann body is completely covered with flexible textile fabric or leather-cloth, its chief interest lies in the novel and revolutionary character of its construction. The wooden framework is not fastened together rigidly by mortise and tenon, or other close-fitting joints secured by glue, screws and pins, as is customary in conventional vehicle-body construction, but is secured by suitably shaped steel joining-plates and bolts in such a manner that none of the wooden members are in direct contact at the joints, but are separated approximately ⅛ in. The effect of this peculiar frame construction, together with the flexible outer covering of woven fabric, is to impart to the finished body an easy deformability and to permit it to accommodate itself to distortions of the chassis frame, to which it is attached rigidly, due to inequalities in the road or other causes. Offering practically no resistance to such distortions, it suffers no harm therefrom, which is an effect wholly the opposite of that caused by a rigidly framed metal-covered body-shell and a more or less limber chassis-frame.

Obviously, with its flexible skin and universally yieldable joints, the distortion at any single joint must be the minimum. Also, whereas extreme rigidity of some sections of the conventional body causes exaggeration of distortion and strain in weaker places such as doorways and upper front-corners, this body exhibits an opposite condition. The virtual absence of resonant material in the form of wood and metal under tension must go far to support the claim of silence advanced by its

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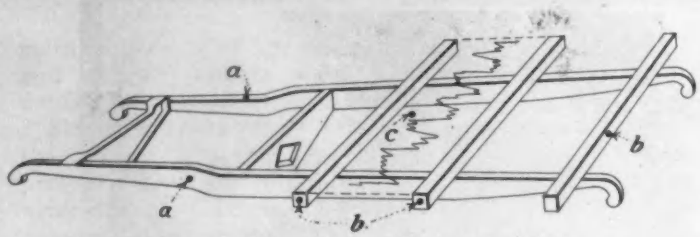


FIG. 1—BARE CHASSIS AND CROSSBARS
The Crossbars Form Supports for the Bodywork

inventor. Further, since the seats of this body rest upon the floor, the weight of the passengers is carried directly upon the chassis through the intervening crossbars to which the standing pillars are attached. Strains that ordinarily are carried by the side-walls of the body and the wide longitudinal sills, which are absent in this construction, are diverted directly to the chassis frame where they must rest finally in any case. M. Weymann's idea has the virtue of novelty and invention. Whether it is revolutionary must be proved by the extent of its adoption and usage by the public.

The Weymann body rapidly is establishing a permanent standing in the automotive industry on the European Continent and in Great Britain. M. Weymann has a factory in Paris that employs about 450 people. Under the Weymann patents, licenses have been issued to upward of 30 automobile and body builders in Great Britain. Bodies are being fitted to chassis of all classes,

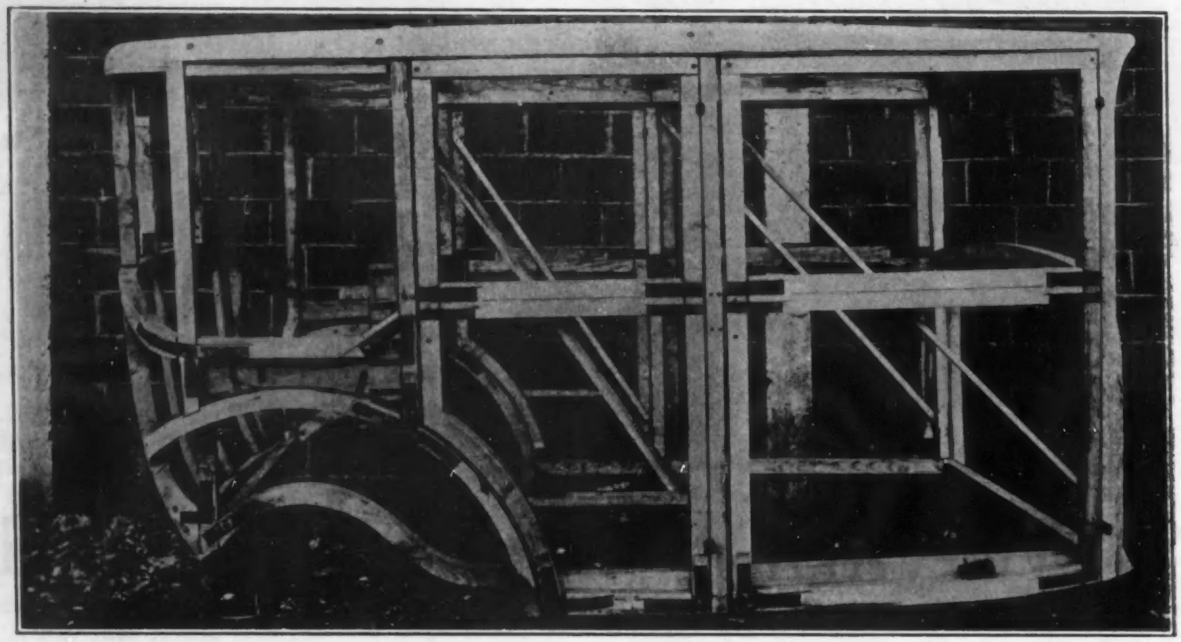


FIG. 3—SIDE VIEW OF BODY FRAME
Illustrating the Method of Connecting the Frame Members

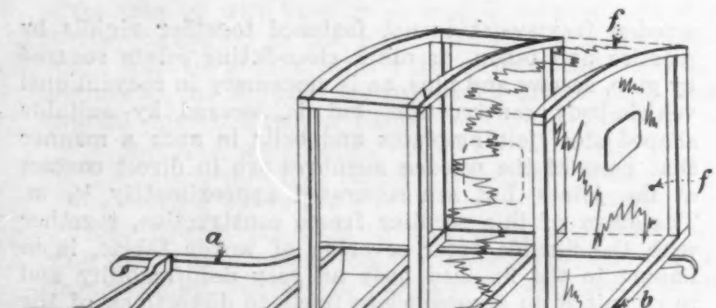


FIG. 2—BODY CONSTRUCTION
Vertical Frames Form the Skeleton of the Bodywork. The Usual Two Longitudinal Beams Bearing on and Secured to the Metal Longitudinal Members *a* of the Chassis Are Dispensed With. Independent Crossbars *b* Preferably Arranged Parallel to Each Other and Secured to the Longitudinal Members *a* Are Connected by a Flooring or Panelling, *c*, of Say Thin Boards and Permit Their Relative Displacements in Case of the Warping of the Members *a*. The Crossbars *b* Support the Upright *d* of the Bodywork. The Skeleton Is Therefore Constituted by a Series of Parallel Vertical Frames *e* Which Can be Equidistant or Not and Which Are at Right Angles to the Longitudinal Axis of the Chassis. These Frames *e* Are Also Connected by a Panelling, *f*, of Say Thin Boards Constructed So As To Permit Their Relative Displacements and To Constitute the Walls of the Bodywork. Connection of the Frame Members Is Effected by Using Iron Fittings Which Are Rigidly Secured on One of the Elements of the Skeleton Framework and Carry One or More Axes on Which the Associated Element Can Fit and Relatively Move

including those highest in price. Some of the bodies have very elaborate interior finish. This body has been patented in France and in England, and a United States patent, dated Dec. 9, 1924, has been issued to M. Weymann. The following excerpt from the English patent is presented:

ENGLISH PATENT SPECIFICATIONS

Fig. 1 illustrates a bare chassis on which are arranged crossbars, forming supports for the bodywork. Fig. 2 is a corresponding view showing the method of construction of the vertical frames forming the skeleton of the bodywork. In the vehicle bodies, according to this invention, the usual two longitudinal beams bearing on and secured to the metal longitudinal members *a* of the chassis are dispensed with and independent crossbars *b* preferably arranged parallel to each other and secured to the said longitudinal members *a* are provided. These crossbars *b* are connected by a flooring or panelling, *c*, of, for instance, thin boards, permitting their relative displacements in case of warping of the members *a* and support the uprights *d* of the bodywork. The skeleton of the latter is therefore constituted of a series of parallel vertical frames *e* which can be equidistant or not and are at right angles to the longitudinal axis of the chassis of the vehicle. These frames *e* are also connected by a panelling, *f*, of, for example, thin boards, constructed so as to permit their relative displacement and to constitute the walls of the bodyworks.

The framework is therefore formed of juxtaposed cells capable of relative distortions without antagonistic strains taking place at the points of connection and, consequently, without fear of the various members becoming disjointed. It is obvious that, in certain cases, one or more of the cells may be made so as to form a rigid and undeformable whole, while the adjacent cells are made flexible as hereinbefore described. These rigid cells can constitute abutments or stops limiting the amplitude of the resilient distortions of the juxtaposed flexible cells.

It will be noted that, to perfect the flexibility of the

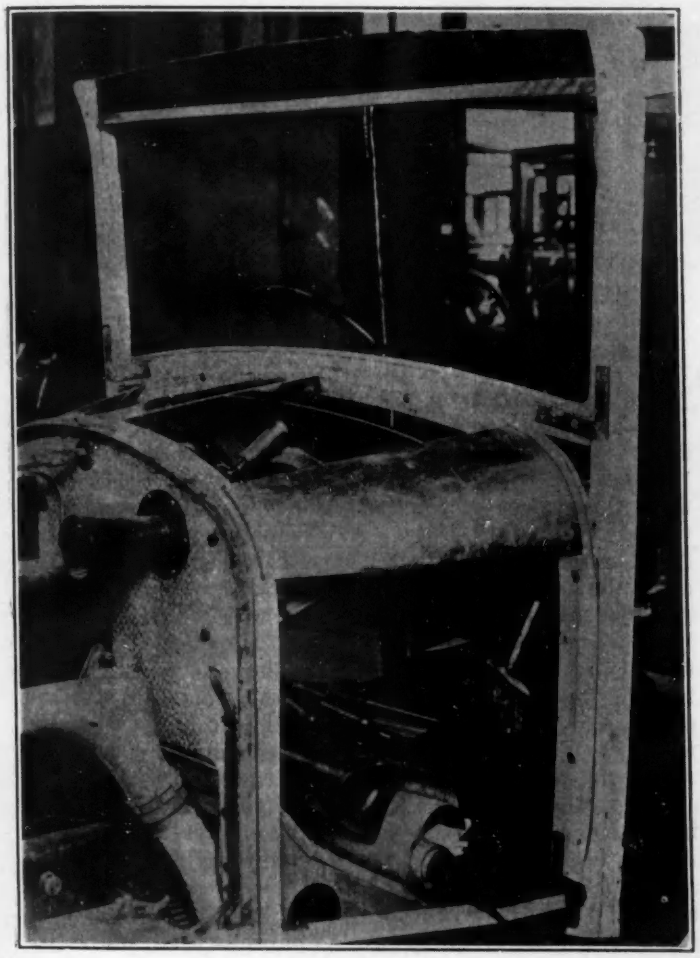


FIG. 4—THE COWL FRAME
Showing Its Construction and Manner of Attachment to the Chassis

whole, the elements of the skeleton of the bodywork, namely, the crossbars, uprights and the like, are not rigidly connected by a wooden assemblage such as mortises, pegs or the like, but the connection is effected by means of iron fittings which are rigidly secured on one of the elements of the skeleton framework and carry one or more axes on which the associated element can fit and relatively move.

DETAILS OF CONSTRUCTION

Fig. 3 shows a side view of the frame of the Weymann body. As practised at the plant of M. Weymann, at Paris, France, its construction is as follows: There are no longitudinal main-sills. The main sub-structure consists of cross-sills, bolted on top of the chassis frame. These sills are located at the ends of the body and at the standing pillars, each pillar passing down outside the cross-sill and being attached thereto by L-shaped

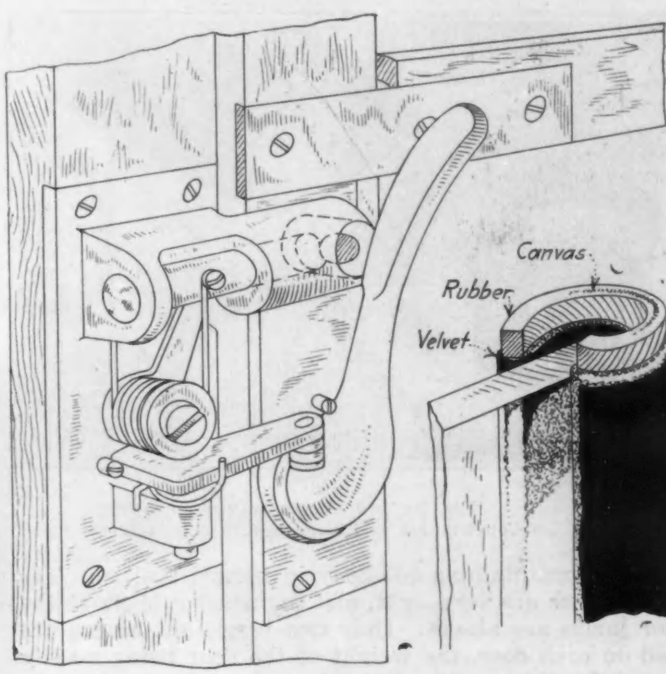


FIG. 5—SPECIALLY DESIGNED DOOR-LOCK
The Door Frames Are Very Light. The Usual Rabbets at the Door-Jambs Are Absent. Only Two Very Light Hinges Are Used On Each Door, Because the Weight of the Door is Carried Mainly by the Lock. A Section of the Glass-Runway Is Shown at the Right

steel-plates and four bolts; there are plates on both sides of the joint and two bolts pass through each member. This means of attachment of parts, or its equivalent, is used throughout the body. The lower outer edge of the body is formed by suitably shaped pieces of wood, cut in between the cross-frame and similarly fastened.

The body frame is assembled upon the chassis piece by piece, where it remains until the job is completed. The cowl frame and its attachment to the dash of the chassis, shown in Fig. 4, seem to constitute the principal

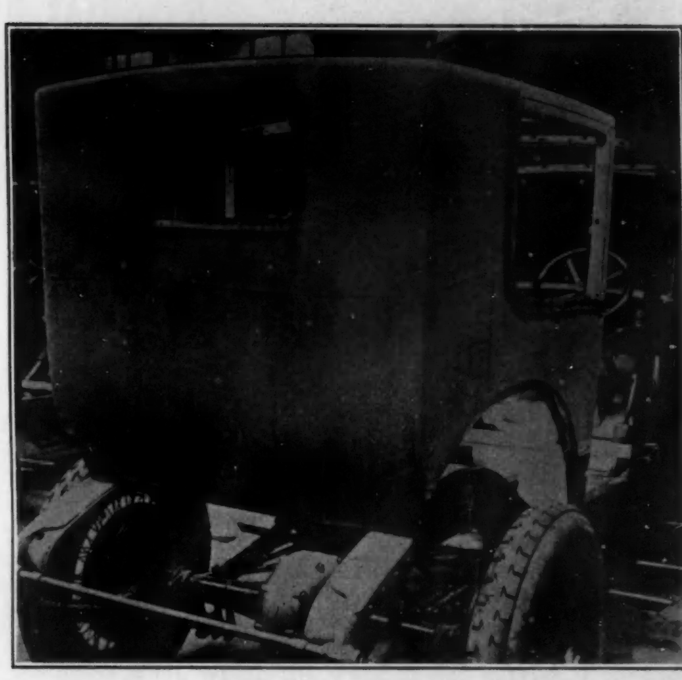


FIG. 6—FABRIC COVERING
Light and Strong Canvas Is Stretched Over the Assembled Frame To Form a Foundation for the Padding That Is Needed To Provide a Swelled Surface on Which To Apply the Outer Covering of Leather Cloth

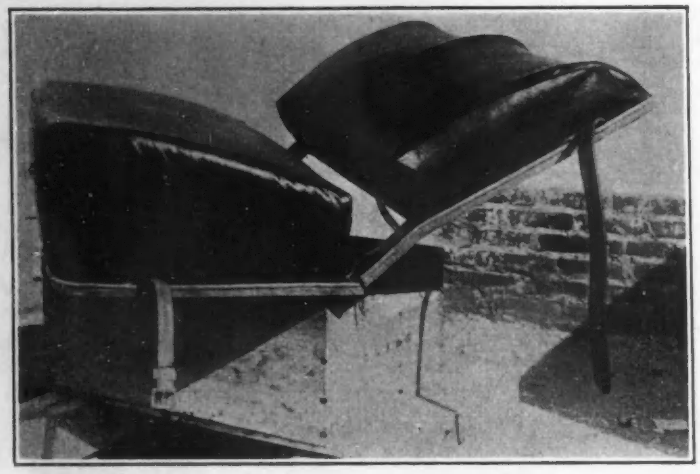


FIG. 7—THE FRONT SEAT
Indicating Its Construction and Showing Its Adjustable Backs

means of maintaining the body in normal position. The door frames are very light, and the usual rabbets at the door jambs are absent. Only two very light hinges are used on each door, the weight of the door being mainly carried by the peculiar lock, shown in Fig. 5, which is arranged to hold the door in suspension. There are no dovetails or bumpers on the door pillars; the doors close against fabric-covered rubber-tubing across the top and the bottom of the door. The molding covering the joint at the lock side of the door is of half-oval rubber, covered with leather-cloth to form a section similar to a tee molding. It is tacked to the edge of the door, and the tacking flange is covered with a thin strip of plated metal about 1½ in. wide and 1/32 in. thick extending from the top to the bottom of the door. No covering molding is provided at the hinge side of the doors. There is a small radius in the corners of the windows and a radius on the edges of the framework of the windows.

FIG. 8—THE COMPLETED BODY
A Two-Color Effect Is Easily Obtainable As the Leather Cloth Is Made in Varied Colors. As No Paint Is Used, the Artistic Success of the Body Depends Largely upon the Skill of the Upholsterer

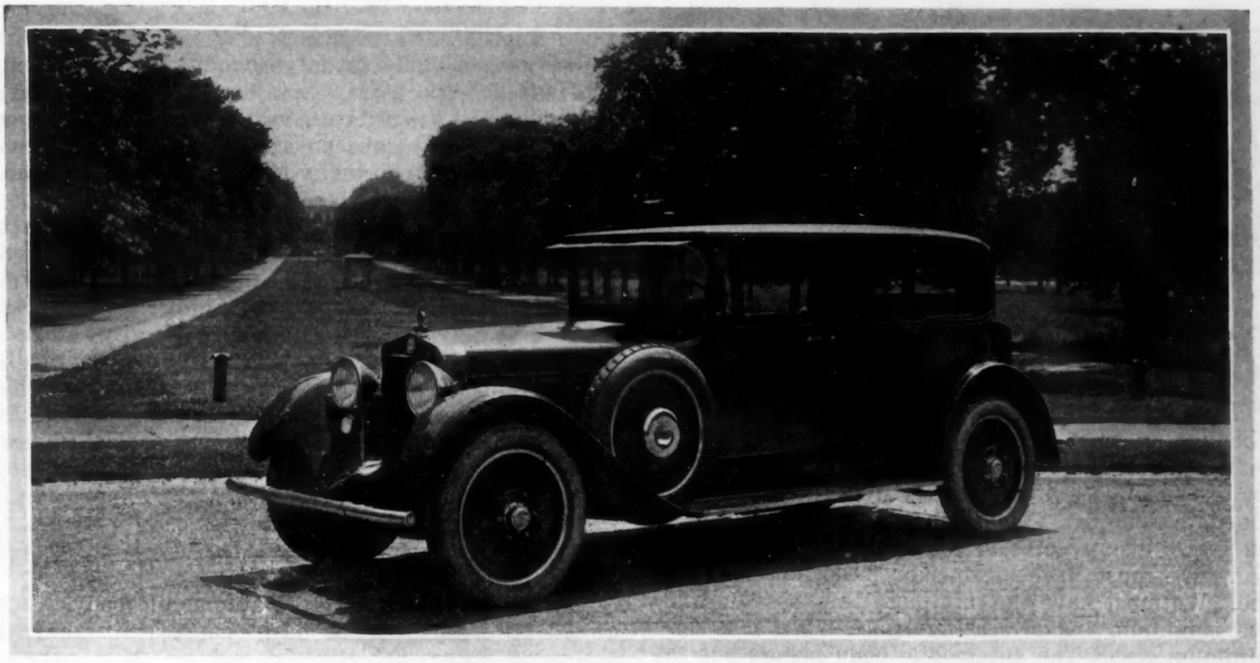
OUTER COVERING AND FINISH

Light but strong canvas is stretched over the assembled frame, as shown in Fig. 6, to form a foundation for padding; this is needed to provide a swelled surface on which to apply the outer covering of leather cloth. This canvas is also used upon the inside of the upper back and side quarters, the space between being filled with hair to swell the outer surface slightly. Mill board is also a resort for maintaining the contour of such places as the corner of the cowl, the lower back panel and the upper back of round-cornered bodies. The front-seat construction is indicated in Fig. 7, and the completed body is shown in Fig. 8.

The leather cloth is applied in the simplest manner possible, being drawn and tacked underneath the body, turned into the doorways, drawn across the face of the pillar and tacked on the inside of the body. It is stretched into the window openings and tacked in the glass rabbets. Lead-filled molding is used to cover the tacking and to carry out the design, where necessary, upon the outside of the body and across the cowl where the cowl joins the body. A wheel-house panel of very light metal, hammered to form, is attached by nailing after the body has received the outer covering. This is perhaps the only sheet metal used in the body and, from its location and shape, can have little effect in adding rigidity to the structure. A two-color effect is common; it is obtained easily, as leather cloth is made in various colors and shades. It is interesting to note that the material most favored by the Weymann works is of American manufacture.

Due to the absence of steel and to the extreme slenderness of the wooden parts, these bodies are very light. As the required wood-working operations are very few and simple, only the minimum machine equipment is needed to fabricate the framework and no great skill is demanded in its erection. As no paint is used, the artistic success of the body depends largely upon the skill of the upholsterer in producing not only a luxurious and inviting interior but an exterior free from irregularities of line and surface. The cost of the Weymann body is believed to be about 75 per cent of that of other custom-built bodies of equal finish and quality; it ranges in France from $900 to $1,500 and, in England, from $700 to $1,600 for four and for six-passenger bodies, according to size and finish.

As practically all the accessory fittings such as window regulators, glass channels, hinges, locks, door stops and joining plates are of special design and are supplied by Weymann, this body as a whole constitutes a wide departure from the established practice of automobile-body construction.



Building of All-Steel Vehicle Bodies

By EDWARD G. BUDD[1] AND J. LEDWINKA[2]

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPH

ABSTRACT

ALL-STEEL automobile bodies are lighter, stronger, roomier and cheaper than composite bodies having wood framing and metal panels. They are free from squeaks, afford better vision of the road and scenery, take a superior finish with less preliminary work and permit marked economies in quantity production. Steel has 40 times the strength to resist breakage that wood has and, in bending, may be stressed 7 times as much as wood, hence the cross-sectional area of steel members may be only a small fraction of that of wood members having equal strength. This makes for lightness of construction and reduction of the size of frame members, thereby affording more space in the interior of the body for the passengers and reducing the amount of obstruction to vision.

Whereas joints between sills and posts in a wood-frame body are weakened by the cutting away of a large part of the wood and consequently require reinforcing with irons and the use of glue and screws, corresponding joints in the pressed-steel body are strengthened by flanges and riveting and the formation of box section. Such joints are not loosened by shrinkage and vibration and do not become noisy. Steel members lend themselves readily to riveting and welding, which methods of fastening may produce the strength of continuous or integral metal. This is important because space limitations often prevent proper use of screws, braces and stiffeners in wood bodies so that they are sometimes weakest in the planes of greatest stresses.

In steel construction, where the formation is hollow, as in the doors, hardware such as locks has been designed which does not require the removal of any metal at points where the members are in tension or compression. Side panels and the rear panel of closed bodies are formed in one piece from floor to roof, including the formation of the rear window, thus avoiding the expensive and objectionable horizontal joint at the belt line and making it possible to assemble the entire side structure of the body in one piece for shipment as a unit. The panels may be joined together along their vertical lines by in-turned flanges, leaving an open joint, or the panels can be welded so as to avoid the open seam.

A factor of great economy in original manufacture has been the design of removable upholstery, which is also a great advantage in the case of repairs. The development of methods of working sheet metal by which stampings can be produced that are correct as to contour and free from surface defects has made it possible for finishing to be done without filling or rubbing and without the use of many preliminary coats of paint. It is the practice of some car manufacturers to finish the bodies with three coats of japan, without any filling and rubbing, and to bake the japan on at a high temperature. The steel body is also especially adaptable to the use of lacquers for getting hard finish with various colors.

EVERY structural advantage is possessed by the builder of steel bodies. Moreover, he finds that the earlier body builders have already incorporated in their wood bodies almost enough steel to make a steel body and, by putting certain in-turned flanges on the old-type panels and by certain rather inexpensive additional interior bracings, he can make the outer shell, which the wood frame carries, a strong structure that will justify elimination of the wood frame. This has less weight, the joints are strongly welded and riveted, and the posts will not shrink nor warp. Thus the objectionable rattles and squeaks which

[1] M.S.A.E.—President, Edward G. Budd Mfg. Co., Philadelphia.
[2] Chief engineer, Edward G. Budd Mfg. Co., Philadelphia.

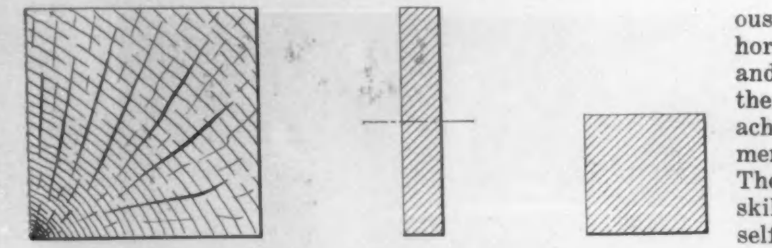


FIG. 1—COMPARATIVE AREAS OF CROSS-SECTIONS OF WOOD AND STEEL OF EQUAL STRENGTH
Steel May Be Stressed Seven Times as Much as Wood and Its Lower Section Modulus Makes Possible the Smaller Sections Shown in the Center and at the Right

are evident in the composite body are eliminated in the steel body.

The automobile body is a structure in which light weight is most essential. Strength is necessary and continued resistance to vibration must be secured if broken glass, disagreeable creaks and rattles are to be avoided. We must have a superior finish on the outer surface. We must have the minimum thickness of walls to give maximum inside seating space. We must get the minimum cost. The automobile body brings out the very highest development of the sheet-metal workers' art. Expensive die and tool equipment has deterred many from undertaking it. However, the advantages are so great and the economies in quantity production so marked that the die cost becomes an insignificant factor to those who view the matter in a broad light.

AN OUTGROWTH OF STRUCTURAL DEVELOPMENT

The analogy between all-steel automobile-body construction and earlier structural developments is so close as to be obvious to even the casual observer. Let us review those developments briefly. Man has always hungered for a change of scene. From the beginning, he has been the one form of animal life to whose desire for movement there have been no bounds. There is no place so far north, so far south, so high or so low, that men do not earnestly desire to reach it. They travel great distances by their own physical efforts, but the desire for ease or for more continuous travel led men to devise vehicles; first, those carried by other men; afterward, those supported on runners or wheels and propelled by the efforts of other men or animals, and, finally, they perfected a vehicle propelled by a mechanism within itself. In each of these steps the requirements have been speed, protection and comfort.

The sedan of the Middle Ages was a beautiful car, in many cases exemplifying the most skilful workmanship, decorated in a most elaborate style and giving the extreme of protection, seclusion and comfort to the rider.

As luxury increased throughout the civilized world, the demand for greater speed and comfort was continuous. In the early manhood of those now living, a fast horse with a finely made carriage, often fully enclosed and fitted with glass, and luxuriously upholstered in the most delicate fabrics, reached the acme of possible achievement and gave an air of luxury and dignity to men of wealth and taste which seemed unsurpassable. The artisans were a class to themselves, proud of their skill and honored by their fellow men. At this stage, the self-propelled vehicle was developed and those skilled carriage builders were called upon to put a proper body on this new and energized running-gear. Naturally, they, in great measure, copied the designs and methods of workmanship which were so suitable to the horse-drawn vehicle. These designs were quickly modified to meet more nearly the new requirements. The bodies were enlarged, doors of different type were designed, the lines of the body were changed materially and, step by step, the automobile body became in appearance more in harmony with the new conditions.

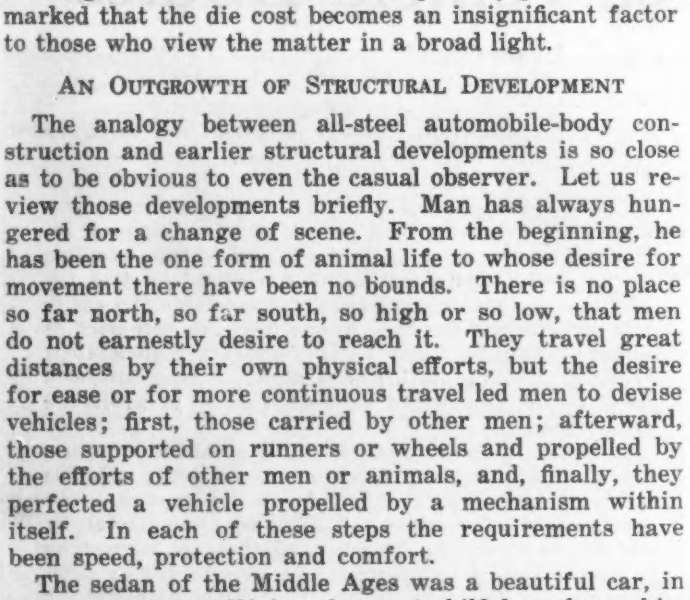


FIG. 2—STEEL SHAPES OF EQUIVALENT SECTION MODULI
Equal Strength in Steel Members Can Be Secured with Less Material by Allowing the Greater Part of the Material To Lie Within Planes of Maximum Stresses

WOOD BODIES ARE SHEATHED WITH METAL

The outside surface of the automobile body was made of wooden panels in the early days, as in the case of the horse-drawn vehicle. In making these panels, the early body builder used the finest kind of wood, which was most carefully seasoned and glued and jointed so that it would preserve its shape. Over this was placed the finish, consisting of many coats of filler, paint and varnish. It was soon found, however, that this surface would not stand the severe racking which the body received and, to secure a more durable finish, the body builder first put sheet metal over the surface of the cowl and, later, of the doors. Then, finally, the entire outer surface of the body below the belt was covered with a number of small pieces of sheet metal. This metal was not intended to strengthen the body but simply to give a better surface on which to lay the paint.

The process of arriving at a complete metal finish has extended over some years. Within the last 2 years the posts above the belt on the closed jobs have been covered with metal and within the last year the door jambs of the closed cars have been covered with metal, until now, on moderate-price cars, the entire body is sheathed. The composite-body builder has left the wood in place and this shell is added weight.

METAL-WORKERS' PROGRESS PAVED THE WAY

This development of the automobile body has been going on during a period of 25 years. Meanwhile, there has been another great development in the mechanic arts in this Country. The forming of sheet metal into careful shapes and, at the same time, in such a way as to give great strength to the formed structure has had its beginning and entire development in this period. The development has been a stupendous one.

Steel manufacturers have contributed greatly by constantly improving their methods until they are now marvelously suited to the demands. The taking of 50 lb. of rough, heavy, obdurate metal and, with a few dollars' cost, transforming it into a sheet of glistening steel 48 in. wide, 120 in. long and 0.04 in. thick, no part varying more than 0.003 or 0.004 in. in thickness, and every part of the sheet reflecting light as a mirror, and the whole sheet lying in an almost perfect plane, is one of the modern miracles.

The users of sheet metal have not been behind in their skilfulness. One man makes a seamless collar-button from this material and another man has learned to make a ball out of it with absolutely no seam. The Chinese workman who produces one ball of ivory within another is not comparable in skill with the sheet-metal worker who takes a flat sheet of metal and makes it into a seamless ball. One group of men makes furniture out of sheet steel and another group has made belt pulleys.

Going back 50 years, we find the beginning of another great development, the use of what is known as structural steel to obtain strength and lightness where previously only wood had been used: first in ships—the heavy metal gave greater buoyancy and strength to resist storms than did the much lighter oak and pine timbers. Steel bridge construction followed shortly after—a small bridge built of steel will weigh less than if built of wood. Where great strength in proportion to weight is necessary, as in the long spans which our engineers erect, steel is indispensable and no combination of wood would serve the purpose. Then quickly after the bridge conquest came the building conquest. Steel has supplanted wood in building construction for the reason that it is safer, stronger, lighter and cheaper.

About 20 years ago, in the face of great opposition, the most far-sighted railroad people of the United States began building railroad coaches of steel. Here they combined the art of the steel bridge builder with the art of the sheet-metal interior-finish maker. Conservative men of that day predicted that the new cars would be noisy, cold, ugly and heavy. We know that the Prophet of Evil was wrong in each prophecy. With this picture as a background, we will consider the present status of the automobile body.

Problems of the Body Builder

To bring the subject to a point at which it can be discussed intelligently, it is assumed that the engineering group is thoroughly familiar with wood body construction but is not as familiar with metal body construction. We make this assumption only for the purpose of inducing discussion at the end of this talk.

To begin with, the problems of the body builder are to

(1) Give the passenger a comfortable and strong support on which to seat himself
(2) Protect him from the weather, using an enclosure which can be opened readily
(3) Give the passenger the utmost possible view of the landscape and to give the driver the utmost possible view of the road
(4) Protect the occupants from personal injury in case of collision or overturning of the car
(5) Attain freedom from noise due to vibration of the chassis when moving over rough roads
(6) Accomplish these results with the least weight
(7) Last, but far from least, is to incorporate all of these in an extremely attractive form so as to be pleasing to the eye.

These are the engineer's problems. What should his material be? It should be material that gives the greatest strength with least weight for a body of a given size or volume. One group of body builders has selected wood. We have selected steel. Wood was a natural selection in the beginning. A great group of able engineers still pin faith to the wood and their arguments deserve serious and thoughtful consideration by the steel workers and no doubt will be strongly presented in the discussion.

Steel Sections Have Smaller Area

The physical properties of steel are so much higher than those of wood that the cross-sectional area of the steel member may be only a small fraction of that of wood having equal strength and the weight may be less.

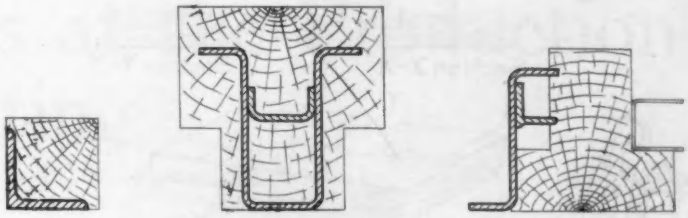


Fig. 3—Steel and Wood Shapes Compared To Show Relative Adaptability for Assembly
In Each Case the Design of the Steel Section To Meet Conditions of Assembly Design Also Increased the Strength of the Member

In bending, steel may be stressed seven times as much as wood and, in shear, it may be stressed more than this amount. Considering transverse bending stresses, which are in most cases the primary stresses acting, it is seen that the section modulus of a steel section need be only one-seventh that of a wooden section for the same strength. A cross-section of wood at the left of Fig. 1 is compared with two sections of steel of equal strength, shown in the other two views. The general character of section is the same, emphasizing the reduced areas in the steel made possible by virtue of the higher section modulus of steel.

A still greater advantage is obtained with steel sections by allowing the greater part of the material to lie within the planes of maximum stress. This, of course, results in the use of less material for the same section modulus. This fact is demonstrated in Fig. 2, in which steel sections of equivalent section moduli are shown. This type of section is distinctly a function of the material and cannot be obtained with wood.

Apart from the strengthening effect of such sections, the fact of their adaptability to conditions of assembly design may be utilized. The three views in Fig. 3 show steel sections superposed on wooden sections of equal strength. The fact is of interest that in each case the designing of the steel section to meet conditions of assembly also increased the strength of the member. In the view at the left of Fig. 3, much space occupied by the wooden section is offered for structural utilization and at the same time the shape affords a high section modulus. The two other views are sections similar to those of a post and door-rail slightly above the belt line of a sedan body. The compactness of the steel members affords for vision much of the valuable space which is occupied by the wooden members. The glass run, although of insignificant section, meets conditions of

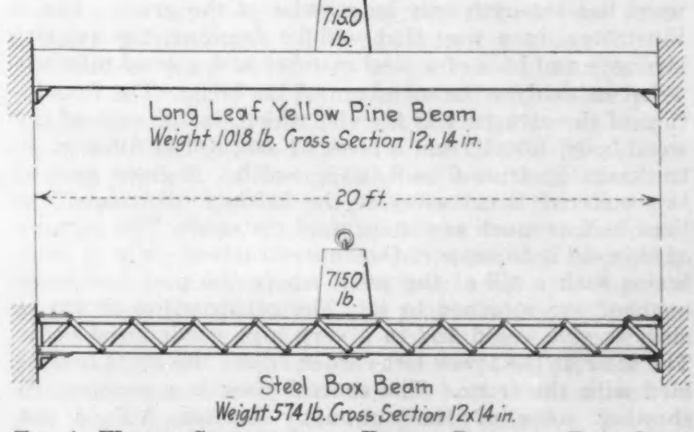


Fig. 4—Weight Comparison of Yellow Pine and Truss-Steel Beams of Equal Size and Strength
Distribution of Metal in the Steel Beam Permits Reduction of the Weight by 43.61 Per Cent

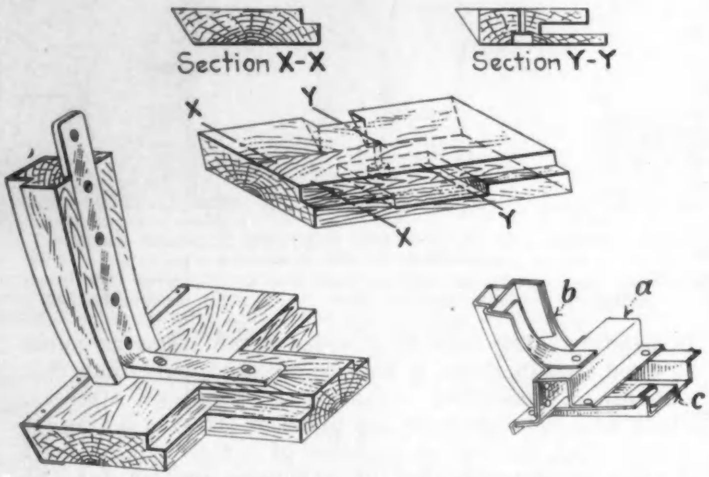


Fig. 5—Sill-and-Post Joint Construction in Wood and Steel
One-Third of the Wood of the Sill Is Cut Away as Shown at *Y Y* in the Central and Upper Right Views, Weakening It at This Vital Point So That Reinforcement with an Iron Knee Is Necessary, as in the Lower Left View. There Are No Cut-Outs of the Rail in the Corresponding Steel Construction Shown at the Lower Right. The Post Gets Full Support on Three Faces of the Rail and Attachment of the Cross Member Forms a Rigid Box-Section

assembly design neatly and at the same time increases the strength of its adjoining member materially.

Steel members lend themselves to fastening possibilities to a greater extent than wooden members. Apart from affording facilities in construction operations, steel fastenings, such as rivets or welds, may duplicate the strength of continuous metal. This condition cannot be realized with wooden members. The way in which the wood is fastened often results in maximum shearing stresses on planes of weakness. Space limitations may often prevent the proper use of screws, braces and stiffeners. Apart from the direct consequence of fastening, upon shear, the bending stresses are considerably affected. A simple illustration is that of a beam supported freely at both ends and loaded at center of span as compared with a built-in beam similarly loaded. The latter is twice as strong as the former. The glass-run of the wooden door-rail has little effect as a stiffener, due to inadequate fastening.

Greater Strength with Less Bulk

The modulus of elasticity of steel is from 15 to 30 times that of wood, with the consequence that, under a given deflection, steel offers from 15 to 30 times more resistance than wood of the same cross-section. Bear in mind that steel has equal strength in all directions and wood has strength only lengthwise of the grain. Fig. 4 illustrates, in a way that will be familiar, the relative strength and bulk of a steel member and a wood member.

Let us analyze the members of the body. The foundation of the structure is the sill, which, in the case of the wood body, is cut from a piece of ash, 8/4 or 10/4 in. in thickness by from 6 to 8 in. in width. A great part of this material is cut away so the finished sill weighs less than half as much as the original material. The purpose of this sill is to support the superstructure. Fig. 5 illustrates such a sill at the point where the post and cross member are attached to it. The construction shown is such as you would find in a very high-grade wood body. The view at the lower left corner shows the units assembled with the irons. The central view is a perspective showing some of the cut-outs. Section *XX* is cut through the sill, as designated, showing sections adjoining. Section *YY* is cut through the sill, as designated, at the point where the post is attached.

It will be noted that at this vital point the wood is greatly reduced in area, there being actually 6 sq. in. of wood remaining out of the original 9 sq. in. This shows clearly the handicap under which the wood-worker operates. He can secure a sound structure only by putting in a heavy iron knee. The real dependence for strength in the composite body is not in the mortise and tennon, together with the glue and screws which are put in, but in the ironing which has been added. The corresponding section in the steel body is shown in the lower right corner. The rail *a* extends straight through, having no cut-outs whatever. The post *b* extends at its full section clear down to the rail, gets a full support on three faces or flanges of the rail and, by means of the out-turned flanges, covers a substantial length of the rail, being secured to it by rivets. Such a connection is more flexible than one of wood and will maintain its strength indefinitely. The glue and screws in the wooden joint become loosened by vibration and shrinkage, in the course of time, as we all know, with the result that these joints are noisy.

In connecting the wood cross member to the wood sill, a large part of the sill and also the greater part of the cross member are cut away. In the steel section, none of the sill is cut away but attachment of the cross member *c* to the sill greatly strengthens the latter by tying the two legs of the sill together, thus making a box section at this point of extreme strain. By this method our sill is much better able to stand the strains put upon it by the posts.

When placing the hardware, especially the locks, in the wood door, great sections of the wood have to be removed just at the point where strain is greatest, thus giving again the condition which results when joining the post and the sill. The door is only so strong as the section may be at the lock. Heavy chunks of wood above and below do not contribute to the strength of the job and are waste weight. In the case of steel, where the construction is hollow, we are able to design hardware which does not require removal of any metal at points where the members are in tension or compression.

Closed-Body Panels Formed in One Piece

It has been the custom from the beginning of closed body building, to have a horizontal joint running from one of the rear doors all the way around the back to the other rear door at the belt, dividing the metal into upper and lower panels. This is expensive and objectionable for many reasons. Our common practice is to make the rear quarters in one piece from sill to roof, including the integral wheel-housing. This makes possible the assembling of the entire side structure in one piece for the shipment of units. Then the rear panel is one piece from the roof to the floor, including the formation of the rear window. These panels may be joined together by in-turned flanges, leaving an open joint which we think is attractive in appearance and which is, from the finishing standpoint, very satisfactory. However, if it is the desire of the customer, these panels can be welded at this point, avoiding the open seam, but the unit is rather a cumbersome one to handle if welded.

We have found it possible, as we progressed with development of the steel structure, to reduce the cross-section of the vertical posts greatly, thus giving a better view from within the car, and this has stimulated us to further effort in door construction.

The design of removable upholstery has been carried to

(*Concluded on p.* 231)

Discussion of Papers at the Production Meeting

THE discussion of two of the papers presented at the Production Meeting held Oct. 22 to 24, 1924, at Detroit is printed herewith. The authors were afforded opportunity to submit written replies to points made in the discussion of their papers. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with the minimum of effort.

UTILIZATION AND PREVENTION OF WASTE

BY C. B. AUEL[1]

ABSTRACT

SAVINGS that might be effected by the utilization of waste material and by the prevention of unnecessary waste, though frequently discussed, do not seem to be fully appreciated. Manufacturers are too prone to start with the assumption that a certain amount of waste is unavoidable and consequently have treated the subject in a perfunctory manner, their efforts being largely centered on items of design, workmanship and material. Even less scrutiny is sometimes given to the so-called expense materials. But improvement in the reduction of waste is as surely possible as is improvement in the products. A full recognition of the importance of salvaging would mean the opening of a new field of engineering, that of the consulting salvage engineer.

The customary assumption that no one is so well qualified to determine the waste in design or manufacturing as the actual designer or builder should be true but sometimes is the reverse. The question is whether the best disposition is being made of the unavoidable waste in design, workmanship and material, as well as in the expense materials. If it is possible to sell the waste from one's own plant for more than the customary scrap value it should also be possible to use some of the waste products of other concerns, instead of new materials, in one's own plant.

The duties of a salvaging engineer would be the studying of a plant for the purpose of (*a*) preventing or minimizing waste items, (*b*) reclaiming as much of the unavoidable waste as possible, (*c*) disposing of the waste to the best advantage, and (*d*) applying the wastes of other manufacturers to one's own products.

In the Westinghouse Company three committees devote their attention to this subject: The standards division of the engineering department, the standards committee, and the disposition department; and, indirectly, also, the materials and process division of the engineering department.

The activities of the standards division deal largely with the standardization of most of the production and many of the expense materials; the materials and process division with the preparation of purchasing and process specifications; the standards committee, with the standardization of complex matters; and the disposition department, not only with the salvaging of waste but with the reduction and elimination of waste of all kinds. It gives the greatest share of its attention to inactive stocks, raw, semi-finished and finished, with a view to preventing their becoming obsolete. Under this department also come the clean-up inventories and the general inspection.

Many instances are cited in which waste from one department or plant has been utilized in another. [Printed in the November, 1924, issue of THE JOURNAL.]

THE DISCUSSION

QUESTION: Where can one get a handbook on factory management?

C. B. AUEL: One is published by the Ronald Press Co., 20 Vesey Street, New York City, and is worthwhile.

CHAIRMAN K. L. HERRMANN[2]: When you prepare a specification do you make that specification stand for a definite period for that particular material, or is it subject to revision at any time?

MR. AUEL: Specifications are subject to revision at any time but often go 4 or 5 years without change. We have approximately 800 such specifications and 800 approved material cards which are, in effect, brief purchasing specifications. This makes a total of approximately 1600 more or less complete purchasing-specifications, and we have also about 1200 process-specifications. On the approved-material cards we list the item by trade name and by manufacturer's name; if we buy none of his material in 18 months and the matter comes up again and we want to give him a chance, we will ask him to submit an additional sample of his previously tested goods just to make sure that he has not changed the quality within that entire time. If carried to too great extreme, purchasing requisitions may react to one's disadvantage. For example, regarding a certain size of wire which our inspection department rejected, and properly so from the standpoint of our purchasing department's specification, the wire was of larger size than that specified but we had 30,000 lb. After making a study of its application, we found that the resistance was approximately correct and that the apparatus into which this material was to go had ample room to permit use of the larger wire; so, no reason existed why it should not have been used. Intelligence must govern the application of a purchasing specification.

QUESTION: Do you maintain what might be considered a master sample room where representative parts about which specifications are written are held for examination and used later if any question should arise?

MR. AUEL: Yes. Certain things cannot be purchased advantageously except after comparison with a sample. For instance, we have samples of wool waste for bear-

[1] Manager of employe's service department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

[2] M.S.A.E.—Assistant manager, methods and standards division, Studebaker Corporation of America, Detroit.

ings, of felt, and of such things as marble. We have to make certain that marble does not contain mineral veins, because they would reduce its electrical resistance; but also, we have to buy marble according to color, and therefore it must match our samples.

CHAIRMAN HERRMANN: Do you find it practicable to launder your own rags and to reclaim belting?

MR. AUEL: When we laundered our own rags, we had fires due to spontaneous combustion. If the rags were not reclaimed the same night, we would have a fire before the night was over or the next day. That necessitated discarding our apparatus for rag cleaning. One of our companies sends all its old rags to a laundry, which reclaims what it can and we buy back all the reclaimed rags at 5 cents per lb., although the price varies. As to our belting, in our East Pittsburgh works we find it generally cheaper to reclaim our belting but, in one of our plants, the old belting is sent to a company that cleans it and sells the reclaimed belting to us at 75 per cent off the list price.

HENRY W. ABBOTT[3]: Visits to some of the largest automobile manufacturing plants, particularly the sheet-metal-stamping plants, showed considerable variance in waste. There was a distinct contrast in two of the largest shops which were capable of about equal production. One shop was scrapping 5 lb. of sheet metal to each 1 lb. scrapped by the other shop. The economy of the more economical shop was due to the cooperation of the shop superintendent and the designing department. Examples of this cooperation were that oil-can supports, radiator supports, horn brackets and the like may have been correctly specified by the designer to be made of No. 16-gage material. Without figuring stresses or strains on the particular piece, No. 16 gage would meet the requirements very well. There were many of these small pieces to be made, necessitating the purchase of No. 16-gage material for the purpose. The shop superintendent pointed out unavoidable cuttings of Nos. 14 and 18-gage sheets that would make the pieces. The designer cooperated by adding to the drawings of the pieces that No. 16 gage be purchased if new stock was required; but, if the pieces could be made from shop waste, the superintendent had the option of using No. 14 or No. 18 gage. Another designer examining the details of that car might feel that he could cut down on the weight of certain small pieces; but, in so doing, he would cause new lighter weight material to be purchased that would increase the cost of the car. Throughout the design of that car, the shop man and the engineering department had cooperated in a commendable manner.

JOHN YOUNGER[4]: Some 25 years ago we used recut files in the shop. When working in brass and bronze, we preferred a recut file. In a certain plant in Ohio that is grinding and machining and doing all sorts of work, a briquetting machine is used for steel reclamation. Each bit of steel scrap goes into that briquetting machine again and again, becoming more and more refined; so, for 100 tons of material used, 100 tons of finished product results and there are no scale or pickling losses.

RICHARD C. DANIELS: What is the method of salvaging used buffing wheels?

R. L. INGRAM: Several lamp companies make very good use of the 14-in. buffing-wheels after they wear down to 8 or 9 in. in diameter. If we have no use for this small size, we find a ready outlet for them there.

MR. ABBOTT: A novel practice of one company is to take a 14-in. buffing wheel that has worked down to say 8 in., tear the wheel apart, punch a new hole, lay a template on the 8-in. buffing, punch new holes off center, assemble it, make it out to 14 in. and press it tight.

MR. DANIELS:—We must have from 40 to 50 bbl. of buffing wheels that we have not been able to reclaim to advantage. Tearing them apart seems such a lengthy and expensive process that I think we have not profited very much by it; therefore, they have been accumulating for the past several months.

QUESTION: How is the valuation of salvaged tools ascertained?

L. A. CHURGAY[5]: When a tool is rejected or scrapped, it is turned over to the salvage department and its value is the market value of scrap steel. To reclaim or salvage such tools a company work-order is issued to cover the necessary labor cost. This labor cost, the departmental overhead and the market value of the scrap steel added, make up the total cost. These tools are accepted by the stores as new and are charged according to the market value. Deducting the salvage cost from the market value of the tool, the salvage department is credited with the difference.

CHAIRMAN HERRMANN: What is the perishable-tool cost per car?

MR. CHURGAY: It depends upon conditions, such as the design of the car, the number of pieces to be machined, the method of machining, the quality of workmanship required and the like. The tool cost per car can be determined from the records of the central stores covering a period of from 6 to 12 months.

CHAIRMAN HERRMANN: The discussion indicates that the tool allotment has been based on experience for 3, 6 or 12 months. That method has many faults. If a foreman has been careless in the last 3 months he is likely to be careless in the next 3 months, and to have his allotment increased to cover it. Is there a possibility of predetermining for various sized drills the number of inches that a drill should drill in cast iron and various alloy steels heat-treated in certain ways? If this is done, the number of inches of drill that need be allotted to a given department for its year's production can be calculated. What should be the procedure for drills, counterbores or other important shop tools?

MR. CHURGAY: We prepare departmental charts showing the perishable-tool cost per car on a weekly basis. These charts furnish definite information of past performance. With an increase or decrease in production, there is a proportional increase or decrease in tool expense. If we notice that the charts show a tendency toward rising tool costs, an immediate effort is made to return to what is considered normal.

MR. ABBOTT:—Budgeting a shop for tool maintenance is, no doubt, splendid practice and I can see no possibility of danger from establishing a budget figure based on the record of the past 3 or 6 months. Regardless of whether or not the past record was a poor one, any management that is keen enough to budget such expenses will bear down sufficiently to see that the budget figure is bettered thereafter.

J. J. HARTLEY[6]:—The drill is the tool on which the most money can be wasted. Possibly, an inspection is needed as a general rule in manufacturing to determine when a drill is dull. If an inspector were to stop a multiple-spindle drilling machine to inspect the drills, coun-

[3] By-products section, General Motors Corporation, Detroit.
[4] M.S.A.E.—President and editor, *Automotive Abstracts*, Cleveland.
[5] Engineer, production division, Maxwell Motors Corporation, Detroit.
[6] Factory manager, The Borg & Beck Co., Chicago.

terbores and reamers, it might save the tool or prolong its life several hundred per cent. Some workmen on piece work are so avaricious for earnings that they will continue to use a drill until it is dulled back from the lip, edge or corner as much as 1/16 in. That increases the expense of getting the drill back to size. If the drill were kept sharp all the time, the workman would produce more and, consequently, would earn more.

CHAIRMAN HERRMANN:—On a recent inspection in our plant, we found some excessively dull drills, some that should have been sharpened and others that had been sharpened before they were dull. All drills receive the same grinding treatment; most could be sharpened by grinding 1/64 in. off the end, but from 1/32 to 3/64 in. was ground off.

MR. ABBOTT:—There seems to be considerable uncertainty as to when a drill is dull and needs grinding. That problem is no longer a complicated one for some shop foremen who have caused their entire grinding proposition to be handled according to a systematic routine.

When is a drill dull? The answer is that a drill is dull 1 min. after it has been put to work. Then when is it dull enough to be reground? It is dangerous to work too close to the point of ruination of the drill. A drill that is overly dull requires more power from the machine tool, increases the maintenance cost of the machine, drills a poor hole and, if used too long, requires an expensive regrinding, not to mention a waste of good tool-steel. Therefore, on production drilling, according to the size of the hole and the material being drilled, a definite schedule can be adopted to change drills every hour, third hour, fifth hour, twice a day, and the like, whether they need it or not. That insures reasonably sharp drills on the job and results in restoring dull drills to their best condition at minimum expense.

MR. INGRAM:—What is done with grinding wheels after they become undersize?

MR. CHURGAY:—Nothing can be done except to turn them over to the by-product department and dispose of them as best one can.

MR. AUEL:—We have sold some undersized grinding wheels back to the manufacturers; otherwise, they are scrapped.

MR. YOUNGER:—A machine tool[7] just brought out in England has for the grinding wheel a circular disc of steel into which are inserted pieces or segments of grinding wheels. That would allow the grinding wheel to be used right down to its last bit.

THE ECONOMIC ASPECT OF TOOLING FOR INTERCHANGEABLE PRODUCTION

BY JOSEPH LANNEN[8]

ABSTRACT

WHEN the volume and the variety of the parts produced by a plant increase beyond the point at which the shop mechanic is capable of devising the methods and building the tools for accomplishing the desired results, it becomes necessary to make a division of labor, and a special department on tool division is needed to determine the proper sequence of operations and the suitable equipment to produce the required quantity with the required degree of accuracy. It is necessary that the men be informed regarding the daily and the ultimate numbers of parts to be produced and the tolerances that will be allowed.

The foremost consideration of the production engineer should be economy of production. In this phase of tool engineering, the ultimate number of parts to be produced plays an important role and equipment should be selected that will give the maximum production. All known methods of production should be compared and the most economical one chosen. Rules are given for governing economic tooling and an illustrative problem is worked out for the production of bearing-caps. By means of charts, calculations are made to determine the comparative economy of drilling holes in 100,000 bearing-caps by the use of single-spindle vertical drilling-machines, of single-spindle vertical drilling-machines equipped with four-spindle multiple drill-heads, and of multiple-spindle vertical drilling-machines.

Having determined the economical method of selecting equipment, the tools must be produced economically. This involves accurate knowledge of the result to be accomplished, care in the preparation of the preliminary drawings, and the avoiding of unnecessarily difficult pattern-work and unnecessary machining operations. As the principal value of a tool estimate is the paying of bonuses in the toolroom, the group-bonus wage-payment plan employed by the Paige-Detroit Motor Car Co. is described. [Printed in the January, 1925, issue of THE JOURNAL.]

[7] See *The Engineer*, (London), Sept. 12, 1924, Supplement p. xv.

[8] Tool and equipment engineer, Paige-Detroit Motor Car Co., Detroit.

THE DISCUSSION

CHAIRMAN EUGENE BOUTON:—One point that interested me in Mr. Lannen's paper is the fact that the savings are spread over 100,000 pieces. Often, the first piecework-rate of a very expensive tool will show an enormous saving, but the initial cost of the tool equipment is so great that it will be a long time before the tool will be paid for. One of the principal things to be considered in making tools and changes is, will they pay for themselves in a given length of time?

G. A. SCHREIBER:—How long have you been using the bonus system?

JOSEPH LANNEN:—We put it into effect in June. Since that time the toolmakers have earned the bonus up to the last pay-period, and during this period they have worked a great deal of overtime. We purposely included overtime hours in the bonus to discourage overtime, so that, at present, the men are not earning a bonus. It is simply a period of trial, the work that we have done having demonstrated that the thing is feasible. We expect to make provision for overtime. Up to the present pay-period, the toolmakers who have earned the bonus have done better than was estimated. Previous to that time, they were as high as 75 per cent above the tool estimate.

MR. SCHREIBER:—I suppose that the men whose business it is to estimate tool costs can help the company a great deal, especially in the sketching of tools.

MR. LANNEN:—We have not followed that out to any great extent, possibly because of the fact that the system is fairly new; but there are possible savings along those lines. We make an effort to have the tools in good shape before they get to the production stage, because that is a rather poor time to fix them. If possible, they should be corrected when the sketch is first made. When a tool is brought back to be redesigned, it is doubtful whether the saving is great, but it is possible to watch standardization.

At present we have probably 30 tool designers and 30 toolmakers; one estimater takes care of all the estimating, so that he does not have a great deal of time in which to do much else than keep his work up.

L. A. CHURGAY:—How does Mr. Lannen take care of estimates of jigs, fixtures and the like, without preliminary sketches? In considering important changes to be adopted, or the building of an entirely new engine, the management will call for an estimate covering in detail the required equipment such as the machinery, tools, and gages needed to produce the engine or the proposed changes. As the preparation of such estimates does not permit the making of sketches, how will such estimates compare with estimates made later on after the tools have been designed?

MR. LANNEN:—When the management wishes to know what the possible cost of the tooling will be, in making a large change, the matter is gone over by several experienced men who have a good knowledge of costs based on previous performances. They will look over a job and say, "Here is a certain operation that we made on another part; the tools for that part cost so much"; then we add a little to be safe, going through the whole situation in that way and arriving at the approximate cost.

It is not possible to give the final analysis on an estimate; we simply make a good guess; but the method of estimating that I have described is used to squeeze the last drop out of the work after operation has actually begun.

A. L. DELEEUW[9]:—For a number of years I had charge of the manufacturing operations as chief engineer of the Singer Mfg. Co., where frequently a new kind of sewing-machine was brought out and had to be tooled up. The method pursued there to get some idea of the cost of tooling was as follows: The parts of the old machine were brought to my office and the heads of the various departments that were to make the various pieces were consulted, as was also the head of the tool department. As a rule, the head of some department could remember some piece similar to the new piece, for which he had already some fixtures or tools; and he would mention the fact. If the tool or fixture was small, it would be brought to the office and inspected. We found out the difference between this tool and the tool that was to be designed, and then would look up the cost of the old tool and make an estimate of the difference between that tool and the new one. If, for instance, the old tool had cost $150, the new tool might cost $10, $15 or $20 more. That $10, $15 or $20 was, if you wish to call it so, merely an intelligent guess, but it was a guess just the same; the error of $10, $15 or $20 in the guess was only a small percentage of the total cost of $150 or $170.

Then, to clinch the matter, the head of the toolroom was asked whether the conditions in the shop were such that he could, perhaps, no longer make the old tool for what it had cost originally. You can readily see that if the old tool had been made 10 years ago, the cost of $150 would no longer apply, so that one piece of definite knowledge and two pieces of intelligent guess work made up the estimate. We had no particular plan of rewarding the toolmakers, but most of the men in the toolroom had been with the company a long time and, as a rule, the tools came fairly close to the estimates.

One other thing I should like to mention is the standardization of certain parts. A complete tabulation had been made of all the parts that could be used again and again on various jigs and tools. When a new part that was not yet on the list had to be designed and we thought that that part might become a standard tool, it too was added to the list, with certain marks of reservation, so that it was not made a standard, perhaps, until some time later. Notice went out to the tool designers, that in no place were they allowed to use parts for the same purpose for which the standard parts had been designed, except under special authorization.

Bushings, clamps, levels, feet, and all such parts as enter into the make-up of tools, had to be standardized and used again and again.

Up to the close of the 5 years, during which the system was in existence, we did not add more than 2 or 3 per cent to the number of parts that we had on the list when we first made it.

QUESTION:—Who estimates the time to be allowed for the making of the jigs or the fixtures? Is this estimate placed on a conservative basis?

MR. LANNEN:—We have an estimater. I do not know whether an estimater is a new profession; but if a job is sent out to a tool shop on contract, an estimate is made of the cost of the tool. A man may develop a high degree of accuracy in estimating; in fact, the last two estimates that we have had average within 10 per cent, in many cases the estimates are within 5 per cent of the cost of the tool. That type of estimating is largely a state of mind. The man that does it has no standards that amount to anything. He may do it unconsciously, but it is surprising how close men, by training and practice, can estimate tools. The tool estimate that we use compares favorably with the average estimate. We attempt to have it compare with what we should get from an outside concern for the same tool.

CHAIRMAN BOUTON:—That is, less the overhead charges.

MR. LANNEN:—Overhead charges are usually included in the rate per hour.

CHAIRMAN BOUTON:—What happens when the jig or fixture estimate is low?

MR. LANNEN:—When it is low the toolroom loses. It really is based on an average. One could hardly expect an estimater to hit every estimate on the nose; he will have an occasional high one and an occasional low one. Even over the pay-period they average remarkably well. When the total estimate that is given of the jobs turned in or completed during a pay-period and the total time are taken on all the jobs, which include all the tools, if one is high, it is buried; if one is low, it is buried; but the average should come pretty close to the right amount at all times, and it does. The toolmakers are guaranteed a standard day-rate; we simply give them more money for working faster.

QUESTION:—Does the Paige-Detroit Co. employ 30 tool designers to 30 toolmakers?

MR. LANNEN:—Roughly. That does not mean that all the toolwork is done in the toolroom. Our policy has been to use the toolroom as a repair shop and supply it with enough new work to keep it busy. We feel that if this estimating theory develops properly we might be justified in increasing the size of our toolroom; but we send out a large amount of work when we are busy.

CHAIRMAN BOUTON:—Both tool designing and tool making?

MR. LANNEN:—No; just tool making.

QUESTION:—In computing the bonus to toolmakers, is the cost of whatever changes may be made after the estimate has been given, or while it is in process, included in the cost of the fixture?

MR. LANNEN:—An additional estimate would be made

(*Concluded on p.* 242)

[9] Consulting engineer, New York City.

Front-Wheel Shimmying

By W. R. Strickland[1]

Annual Meeting Paper *Illustrated with* Drawings

ABSTRACT

ALTHOUGH wheel wabble, even with high-pressure tires, is of ancient origin and the general methods of controlling it have been well understood, its importance among present-day problems is due to the fact that the recognized specific for its treatment, namely, increasing the air-pressure in the tires, has been denied. Shimmying, as generally applied, includes wabble, or the sidewise vibration of the front wheels about the knuckle-pin, and tramping, or the bouncing of the wheels vertically, alternately on the two sides.

In addition to discussing the advantages and disadvantages of the low-pressure tire, the author has enumerated the results of tests, some of which have been obtained from original research work by himself, others from the literature on the subject, with a view to determining whether shimmying is caused by defects in design, and what are the effects when certain modifications are introduced. Among these modifications are the use of moderate pressures and flexibility, wider rims, reversed caster-angle, increased weight on the front wheels, shock-absorbers, and hydraulic dampers on the steering-mechanism, and changes in the geometry of the steering-gear.

The conclusions reached are that the low pressure and the thin side-walls of balloon tires are the chief factors contributing to front-wheel shimmying and that no acceptable changes in chassis design can be made to control it. A perceptible improvement in riding comfort and freedom from shimmying can be obtained, however, by the use of a moderate design of balloon tire, not too thin a side wall, proper width of rim, and medium air-pressure.

WHEEL wabble is an old story, even with high-pressure tires; and the general requirements for controlling it have been well worked out and understood by both the engineering profession and the service department. The predominating reason that front-wheel shimmying has become the present-day problem is that, of the known expedients used to cure the trouble, the most important one, namely, raising the air-pressure, has proven unsatisfactory. Low air-pressure in the tires was known to produce wheel wabble years before the balloon tire was introduced; and caster angle, toe-in, stiff and tight connections were known to be the cure, with an occasional raising of the air-pressure when it dropped too far below the then high standard, but during the last 3 or 4 years, the pressure cure has become more important because

(1) Tire-builders began to furnish all tires over size, the next larger nominal-size being expected to be used on the smaller rim

(2) The public drove with lower pressures than those specified

(3) Cord tires with more flexible side-walls were used

These practices reduced the leeway between the permissible pressure and the shimmying pressure from, say, 75 to 35 lb. per sq. in., a working margin of 40 lb., to between 55 and 45 lb. per sq. in., a working margin of only 10 lb.

In many cases, when the load was heavy and the tires were twice the size of the rim, pressures of 55 and 60 lb. per sq. in. had to be maintained in order to prevent shimmying at high speeds. This wiped out the leeway, except for city driving, unless the old higher standard-pressures were used. A 10-lb. drop of pressure, after the tire had been blown up, was small indeed, not to mention the zero leeway. Proper practice should demand from 15 to 20 lb. per sq. in. for the present high-pressure tire and an equal percentage of leeway for the lower pressure tires now being used.

High Air-Pressure a Recognized Cure

As stated above, the shimmying that occurred, even on well-designed chassis, was practically cured by raising the air-pressure to the required amount. With the introduction of the balloon, or low-pressure, tire and the shimmying action that accompanied it, the higher pressure cure was not acceptable, and extensive research work was started with a fixed low-pressure as a basis, in the endeavor to find some other panacea for these ills.

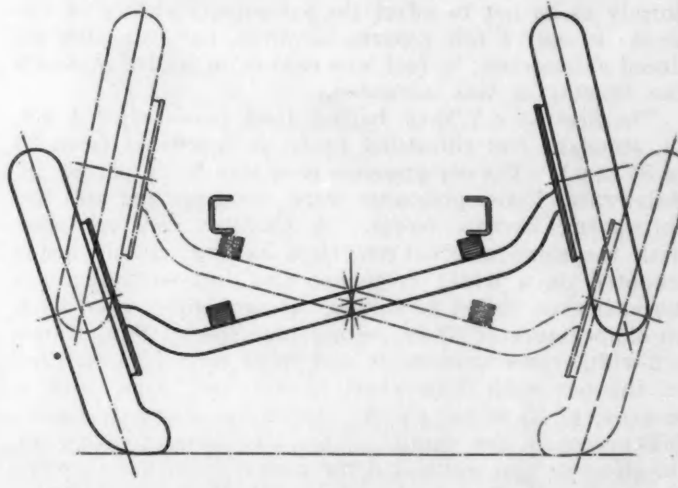


Fig. 1—Spring-Deflection Cycle During Tramping Action
The Tramping Effect Is Produced by the Bouncing of the Wheels Vertically, Alternately on the Two Sides

This search has not been completed, but many contributing causes have been studied with partial success and sufficient information has been deduced to indicate the immediate safe steps that should be taken in order that the balloon tire may be used commercially. To date, air-pressure control remains the dominating factor and the restraining influence against the extensive use of the full or exaggerated type of balloon tire.

The devices or changes that have been tried as a result of the research work on shimmying and of the information that has been published are given herewith, as are also the results of tests, and discussions as to their pertinence or possibilities.

The word "shimmying" is used in a general way; "wabble" means sidewise vibration of the front wheels about the knuckle-pin; and "tramping," Fig. 1, means

[1] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

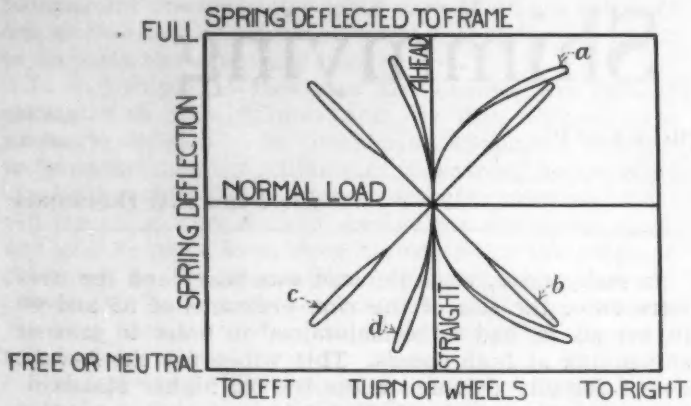


FIG. 2—FRONT-WHEEL MOVEMENTS, SHOWING SPRING-DEFLECTIONS AND GEOMETRY

A Turning of the Front Wheels to the Right Occurs on Either Side of the Central or Normal Position

the bouncing of the wheels vertically, alternately on the two sides, the axle, of course, working with them because of the flexibility of the front springs or frame. Cadillac chassis were used in most of the tests.

TESTS AND DISCUSSIONS

The balancing of the tires and the wheels will, of course, give a smooth-running car in any case; the tubes and if necessary, the wheels should be balanced uniformly so as not to affect the interchangeability of the tires. In only a few reports, however, has balancing reduced shimmying; in fact, one case is on record in which the shimmying was increased.

The first 34 x 7.30-in. balloon tires mounted on a 4.5-in. standard rim shimmied badly at speeds of from 35 to 50 m.p.h. The air-pressure used was 30 lb. per sq. in. Afterward, lower pressures were recommended and the shimmying became worse. A Cadillac car, equipped with the same nominal-size tires having outside beads mounted on a wider drop-base rim, but without four-wheel brakes, failed to shimmy at any speed, even with an air-pressure of 17 lb. per sq. in. Special 7-in. standard-width rims were made and tried with 7.30-in. tires on the car with four-wheel brakes and, even with a pressure of 25 lb. per sq. in., the wheels shimmied badly. Differences in the details of the two tests, considering the effective rim-width and the distance from the center of gravity of the wheel and tire to the center of the knuckle-pin, with and without considering the brakes and the make of tires, leave the matter still open as to the proper width of the rim on the 7.30-in. tire.

With 6.60 or 6.75-in. tires, the rim-width tests were absolutely comparative with the same geometry and four-wheel brakes. These tires work well on 6-in. rims (See Table 1) and, with the pressures recommended, an increased speed of 10 m.p.h. can be maintained over rough roads with greater comfort than with high-pressure 33 x 5-in. tires.

[2] See THE JOURNAL, December, 1924, p. 501.

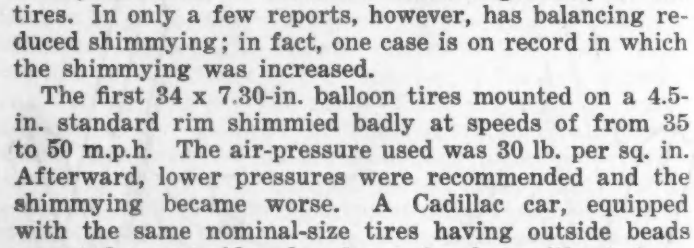


FIG. 3—GEOMETRY OF THE STEERING-GEAR

When the Steering-Gear Is Clamped, the Front Wheels Move by Flexing the Front Springs from Zero Deflection to the Loaded Position on Extreme Deflection

GEOMETRY OF THE STEERING-GEAR

The geometry of the steering-gear has been attacked severely, but many designs and tests have been tried without tangible results, except when reversed shackles were used, and then only by using what would previously have been called poor geometry. The first tests demonstrated that, when the steering-wheel was clamped, the front wheels moved by flexing the front springs from zero deflection to the loaded position and to the extreme deflection. Such a curve was shown in J. E. Hale's paper[2] on shimmying delivered before the Buffalo Section. (See curve a of Fig. 2 and Fig. 3) These measurements and the diagram referred to show that a turning of the front wheels to the right occurred on either side of the central or normal position.

Analyzing this movement, the front wheels must of necessity move to the right and back twice per cycle of spring deflection. This double movement does not exist, so far as has been learned from reports or from public discussion. The wabble or tramping action, or a composite action of the two, synchronizes with the spring-deflection cycle. This has been observed from all angles and has been well corroborated. Motion pictures could provide more tangible evidence.

TABLE 1—SHIMMYING TEST WITH 33 X 6.60-IN. SIX-PLY TIRES

Pressures,[3] Lb. per Sq. In.	Rim Sizes 4½-In.	6-In.
15	50 to 55 m.p.h. Tramped badly but not so severely as with 7.30-in. tires	58 to 60 m.p.h. Tramping of a moderate degree
25	55 to 60 m.p.h. Tramped badly	63 to 66 m.p.h. Passable tramping
35	60 to 65 m.p.h. Tramped badly	Trace at 65 m.p.h. occasionally, but on high percentage of installations, no shimmying up to top speed

[3] Minimum pressure recommended 35 lb. For heavy loading, higher pressures to suit driver.

Further, if the steering-wheel on a reversible steering-gear be freed, it will move in the same cycle as the shimmying action and not twice as fast. The deduction from the above facts is that, theoretically, the forces produced by this type of geometry are of a secondary nature and are overcome by the greater force that causes the wheel-wabble to synchronize with the spring-deflection cycle.

BLOCKING THE SPRINGS

The conclusion that the steering-gear geometry is not the cause of shimmying is borne out by the test that has been made by several persons, of clamping a block of wood between the spring and the frame to prevent the movement that was supposed to produce shimmying because of the geometry of the steering-gear. With the springs blocked, the front wheels shimmied as before but it was mostly a wabble, the tramping action being considerably less; the flexibility of the frame was the limit of the movement.

Other types of steering-gear geometry were tried, two of the types being wheel movements resulting from the spring cycle that synchronizes with them; in one, the movement, being from right to left, as shown in Fig. 4, corresponds to the free-spring position to the fully-compressed point, and in the other, which is from left to right, as shown in Fig. 5, it corresponds to the spring deflection cycle.

The geometry used in Fig. 4 gives a wheel movement that is synchronized with the spring-deflection cycle and might, theoretically, produce the wabble. Further, this movement of the wheels to the right and to the left during the cycle is what actually occurs on cars that shimmy, but this layout is difficult to obtain and cannot be blamed for present-day shimmying. On the contrary, our trials of this type gave better results and less

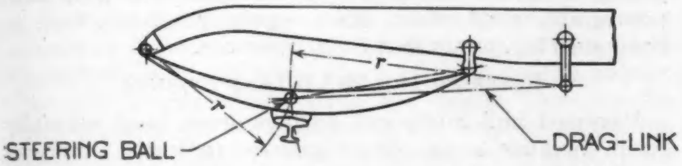


Fig. 4—Wheel Movement Resulting from Synchronizing with the Spring-Deflection Cycle
When Moved from Right to Left It Corresponds to the Free Spring Position to the Fully Compressed Point

shimmying than those of the first or conventional type.

The third type, shown in Fig. 5, gave mixed results and is still being investigated. It will be discussed further under reversed shackles, which were used to give this geometry.

Reversing the Shackles

A very popular layout is the reversing of the shackles and the making of the drag-link arc and the steering-knuckle arc coincide as nearly as possible. With this arrangement (See Fig. 6), very little movement of the wheels takes place, probably a small amount from straight ahead to the left, both above and below the normal line, because the length of the rear left of the spring is shorter than the length of the drag-link, and the two arcs struck through the same point about the long and short centers must diverge. This arrangement, shown in curve *b* of Fig. 2 and Fig. 6, solves

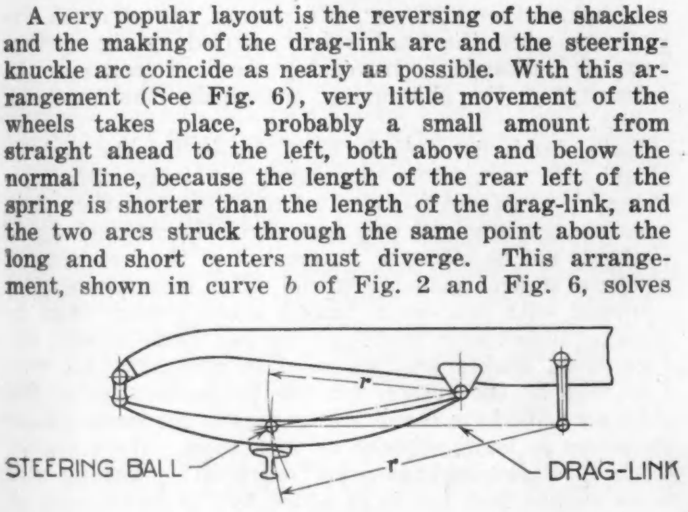


Fig. 5—Wheel Movement Similar to That Shown in Fig. 4 When Wheel Is Moved from Left to Right
This Corresponds to the Spring-Deflection Cycle

neither the shimmying nor the kick-back on the wheel when encountering severe or choppy bumps.

Three cars have been equipped with reversed shackles. The first installation, which was made with the layout shown in Fig. 5, with the forces opposed, was free from shimmying at high speeds, but instead shimmied at low speed. The second installation, similar to the first, so far as is known, was less satisfactory.

In the third trial layout, we could vary some of the geometrical conditions for experimental purposes by changing the length of the shackle, steering-sector arms, spring camber, and the like.

Perfect Geometry

The most important determination made was that with the so-called perfect geometry, Fig. 6, in which the wheel movement was the minimum, (See curve *d*, Fig. 2), the shimmying began at 50 m.p.h. and was so bad at

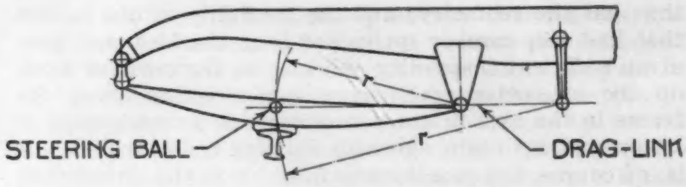


Fig. 6—Layout in Which the Shackles Are Reversed
The Drag-Link Arc and the Steering-Knuckle Arc Nearly Coincide, Producing Very Little Movement of the Wheels

57 m.p.h. that one could not drive through it. While decelerating, the shimmying continued until 45 m.p.h. was reached. This occurred with 7.30-in. tires, having 25 lb. pressure per sq. in. With 15 lb. pressure per sq. in., the shimmying was severe at 50 m.p.h. and continued down to 40 m.p.h. The caster angle was reversed about 1/4 deg.

The next and possibly the most important finding was that the same car, having the layout as shown in

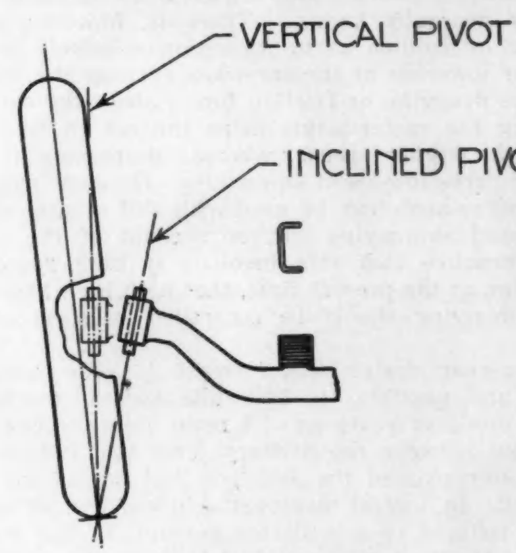


Fig. 7—Method of Locating the Pivot
Variation of the Length of the Lever-Arm Is Reduced by the Vertical-Pin Design

Fig. 5, notwithstanding that other conditions were the same, shimmied worse at a lower speed. The reason for the importance of this finding is that the type of layout in Fig. 5 gave better results on the first two cars. The principal differences were that springs with standard camber were used on the first two cars, which were the best, and that flat springs were used on the third car, which was worse, the shimmying being bad at 45 m.p.h. and continuing down to 17 m.p.h.

The differences in the spring and shackle design in the tests just described have more influence on shimmying

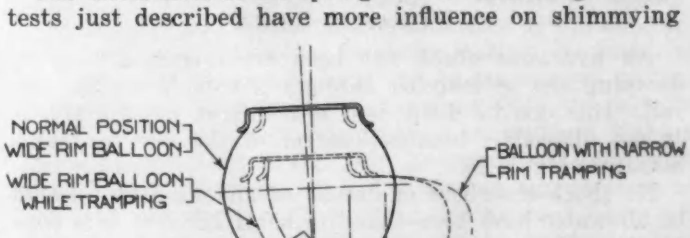


Fig. 8—Effect of Tramping Action
Greater Variation in the Length of the Lever-Arm Occurs with Balloon Tires Because of Their Greater Lateral Instability

than has the geometry; and the flexibility of one system that had deep-camber springs or long shackles may have given sufficient instability sidewise to damp-out or slow-up the crosswise reactionary forces acting from the frame to the axle that are necessary as an anchorage to set-up and maintain sidewise shimmying or wabble. It is, of course, the reactionary force from the shimmying that is felt by the passengers.

The importance of the flexibility theory was heightened by the action of two separate and differently designed chassis in which, with known greater flexibility in all directions, with flat or cambered springs, standard-steering geometry and shackles, the shimmying was reduced as much as in any other tests, such, for instance, as that of the reversed shackle and Fig. 3 geometry, and those with long shackles and cambered springs, in which the high-speed shimmying was eliminated.

Caster Angle

The influence of the caster angle on low-speed wabble is pretty generally known. There is, however, some difference of opinion as to its action relatively to the raising or lowering of the car when turning the wheels and to the dragging or friction forces about the spindle. Increasing the caster angle helps the car to hold the road at the higher speeds, whereas decreasing it improves or cures low-speed shimmying. On some axles, a reverse caster-angle can be used with still greater effect on low-speed shimmying but, on account of the questionable practice that this involves at high speed, it would seem, at the present time, that both high and low-speed shimmying should be controlled in some other manner.

Steering-gear design was thought to offer another solution; and, possibly, the hydraulic dash-pot might be used, but doing so leaves us with many joints to wear or hammer-out between the primary force that causes the wheel to shimmy and the dash-pot that damps out the shimmying. In a great many tests, in which shimmying has been reduced to a moderate amount, it was found that, when the gear is reversible, letting go the steering-wheel will damp-out the shimmying action, whereas holding the wheel tightly will increase the action. It was hoped that this principle could be utilized, but a reversible gear cannot be successfully used when shimmying or lumpy roads cause a kick-back through the steering-wheel. Consequently, a semi-reversible gear is found to give the greatest satisfaction over 99 per cent of the driving range; and this seems to be true regardless of the type of gear. The present tendency is toward a greater reduction in the gear, to provide ease of handling of low pressures and to reduce the kick-back, regardless of the certainty that by so doing shimmying will be increased.

Hydraulic Check

An hydraulic check has been tried with a view to damping the shimmying through a control on the tie-rod. This can be done, but, although it is effective, it is not allowable, because control of the car for quick maneuvering is lost.

No shock-absorbers or checks of any kind that would be allowable have been found to be of interest as a cure for tramping.

Tight joints in the steering and axle connections have been found to be necessary to stop mild forms of shimmying that develop when the joints become loose, but when they are produced by other causes, such as the geometry of the tire and the wheel, another phase of the problem must be considered.

Wabble or tramping action is a vibration akin to the action of a pendulum. It is an action against and a reaction from a force or anchorage. If the force could be reduced, the trouble would be cured at the source; but if not, anchorage should be taken away or a flexible, yielding, or damping anchorage provided, to kill the shimmying as near its point of inception as possible. Mild forms of shimmying can be cured by using plain bearings in the steering-knuckle or, possibly, by providing loose joints transversely on the spring-eyes, or deep camber-springs and long spring-shackles, or rubber joints, to reduce the wabble. These have been tried with appreciably good effect. Here, again, reactions, such as hard steering, occur that limit their use.

Reversed and Multi-Leaf Springs

Reversed and multi-leaf springs have been carefully tried, because some investigations indicated improvement, but the future must decide this question after more work has been done. A reversed-camber spring changes the geometry of the steering, reversing the movement of the joint, similarly in a slight degree to that of the reversed shackle. The friction in multi-leaf springs is not sufficient to produce a result, although, by clamping the leaves together, severe tramping can practically be stopped in the same way that it is stopped when a block of wood is used between the spring and the frame; but a wabble still remains to be taken care of.

Spring flexibility affects some mild forms of shimmying, but neither stiff nor soft springs are of much importance when the total weight carried by the springs remains unchanged. Increasing the load increases the intensity of the shimmying, principally the tramping action.

Late standards of 1/8 to 3/8-in. toe-in for the conventional axle were found to prevent tire wear. Straightening up the front tires or toeing them out, therefore, even though it might help to control the wabble, would probably not be allowable on account of the tire wear.

There is some evidence to the effect that automobiles equipped with four-wheel brakes shimmy more than do those equipped with brakes on the rear wheels only, but four-wheel brakes are now used so generally that this fact may be the reason for the preponderance of the evidence. We have found that generally the same chassis shimmies as badly without as with them. As a matter of fact, shimmying has been controlled by adding still more weight than has been added by the installation of brakes.

Measure of Balloon-Tire Inertia

The inertia of the balloon-tire wheel-equipment has been measured and has been calculated to be less than that of high-pressure equipment; the weight with its inertia has been added to the rims and has been found to control the wabble. The weight necessary to do this is more than has been thought desirable to add to a rim or wheel for this purpose, but the test points to it as one of the factors for deadening shimmying.

Gyroscopic action should resist shimmying but, if the revolving wheel or tire is struck, the wheel will turn in accordance with the law. As the two wheels strike alternately in tramping, there would be two blows or tendencies to turn in the same direction per cycle of spring-deflection. The vibration per cycle should thus be double, but this was not the case in the test, even though the steering-gear geometry had been corrected, as it was in Fig. 5, to oppose this gyroscopic tendency, and the tramping at high speeds was eliminated. It should be pointed out also that what force is developed by the deranged steering geometry acts against one wheel and with the other wheel, so that no action should result.

Center-point or near center-point steering, as shown in Fig. 7, has been used to a considerable extent on four-wheel-brake designs, but shimmying has not been confined to them. Tests indicate that in any one axle the greater the distance from the center of gravity of the wheel to the center-line of the pivot, the less will be the intensity of the shimmying.

A vertical pivot-pin, Fig. 7, with near center-point steering, has made an improvement by reducing the variation of the lever-arm from the center of the ground contact to the center of the pivot-pin with the change in the deflection of the tires, which is greater with balloon than with high-pressure tires, for balloon tires are depressed more on the bottom as the wheels strike the pavement from side to side in the deflection cycle. This variation is overcome through the vertical pivot-pin design, which is a noticeable improvement, even with the shorter lever-arm between the center of gravity and the center of the piston-pin, but it does not take care of all the variations and requires other expedients to produce a cure.

Variable-Point Steering

With variable-point steering, it is certain that, in the gyrations of the front wheels when tramping, Fig. 1, a greater variation of the various lever-arms takes place on balloon than on high-pressure tires, because of the greater instability of the tires transversely, Fig. 8, in which direction it is necessary that considerable force should be applied in order to hold the chassis in a straight line; if this is not done a great variation will occur in the lever-arms that synchronizes with the deflection cycle. From an analysis of these forces it appears that the moment of force about the pin center-line, Fig. 8, would diminish, or in some cases would reverse, at the end of the deflection cycle when the tire is compressed and distorted to the greatest extent, and that the algebraic leverage at the neutral point in the cycle will be the minimum when the reacting pressure of the tire begins to lift the wheel at the beginning of a new cycle. Meanwhile, the movement of the chassis and the action of the springs have stored-up energy through the distortion and displacement of the tires, and the rolling of the wheel has carried this displaced point to the rear of the pivot-pin center-line and pulls in on the rear, throwing the front end violently out as it bounds up on the first half of the spring-deflection cycle. The pull-in on the tire and the rim on a lever-arm may attain a length of 6 or 7 in.

This action is also conveyed through the cross-rod, which turns the opposite wheel in on the second half of the cycle and prepares it for a repeat on the other side. The lever-arm to the rear of the pivot-pin, being so much greater because of the larger contact area of low-pressure tires, can be shortened by reducing the caster angle, or, by giving it sufficient reverse castr action, the turning effect before and behind the pivot-pin can more nearly be equalized. The side drag, of course, can be reduced slightly by straightening-out the toe-in, or by actually toeing out somewhat; but the most important and practicable reduction of these forces can be attained by using stiffer sections of tire. On any given chassis, a limit will be found to the tire size, number of plies, rim width, and pressure.

Stiff Tread

It seems self-evident that a stiffer or better supported tread would better resist the forces that produce shimmying. Even in high-pressure tires, we find a variation in speed of 10 m.p.h. between the points at which shimmying occurs.

Closed cars have been known to increase shimmying, probably on account of the extra weight and greater stiffness of the frame. Their increased production consequently aggravates the problem, but a chassis equipped with balloon tires upon which to conduct tests is difficult enough.

Many combinations still remain to be tried. It is hoped, however, that this review of the subject will be of value in enlarging the use of moderate-size balloon tires and of a moderate reduction of pressure on the heavier cars, say to 35 lb. per sq. in. initial pressure and 25 lb. per sq. in. before shimmying appears. This would give a leeway of 10 lb. per sq. in.

BUILDING OF ALL-STEEL VEHICLE BODIES

(Concluded from p. 222)

completion in connection with the development of the steel framework. This is a great factor for economy in original manufacture of the product.

Finishing Requires Less Preliminary Work

It was evident in the beginning to certain customers that finishing could be done without the great number of preliminary coats which were necessary on the cruder stampings used on the wood body. It has been the practice of certain of the larger and better producers to finish these bodies with three coats of japan, without filling or rubbing, and bake them on at high temperature. This gives durability of finish which has not been equaled by any process developed heretofore. Lacquers have come into common use of late, because of the possibility of getting a relatively hard finish with various colors. Our steel body is especially adapted to the use of lacquers as it is not necessary to do so much knifing and filling as is required on a composite body. It is true that a somewhat better appearance and a great depth of color can be secured by some filling, but at most, the amount of filling need be only a fraction of that required for other products, whether the final coating is varnish or lacquer.

To summarize: Given the requirements of the automobile body, as outlined, and selecting steel as the material with which to operate, a body can be constructed so that the posts or reinforcements, together with the outside panel, form a system of interbracing and support, making the whole structure of the body, internally and externally, play a part in resistance to the strains and stresses of service. By the use of welding, the various parts are united integrally and form a coordinated structure that is durable and lasting, presenting an outer surface which receives the finish to the best advantage and presenting an inner surface on which the upholstery can be hung securely yet, at the same time, be readily removed. Every piece or part has a definite function in the strength-design of the body.

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Foreign Material in Used Oil: Its Character and Effect on Engine Design

By G. A. Round[1]

Annual Meeting Paper *Illustrated with* Photographs

ABSTRACT

STUDIES of samples of used engine-oil under the microscope show that the carbonaceous material is extremely finely divided and that the particles are held together loosely by oxidized oil. Dust particles in the oil can be distinguished from other foreign material by means of photographs taken with polarized light. Examination of a number of samples shows that the dust particles circulating with the oil are small in comparison with those drawn in through the carbureter intake, indicating that they have been pulverized on the cylinder-walls.

The results of tests indicate that air-cleaners are of direct benefit, but the use of other devices to prevent dilution and to keep the oil free from foreign material is equally desirable. Oil-screens cannot be expected to remove any but the coarsest material, such as lint; hence they should be of fairly coarse mesh and of liberal area, in order to provide a free flow of oil at low temperatures. They should also be self-cleaning.

EXAMINATION of a large number of samples of used oil from the crankcases of a wide variety of automotive units shows practically the same foreign material present in every instance, although in proportions that differ greatly with the unit and the conditions under which it has been operated. The usual constituents of the foreign material are oxidized oil, carbon, metallic particles and road dust, with occasionally some fibrous material or lint. Although all these substances are insoluble in the oil itself, they are, with the exception of the lint, of such a character that they do not separate quickly from the lubricant.

Statements to the effect that used crankcase-oil sometimes contains as high as 25 per cent of foreign material have occasionally been made. While not denying that analyses of some samples may have shown this amount, we are quite certain that such samples were not truly representative of the oil circulated to the bearings. It is unfortunate but true that, in most instances, crankcase-oil samples are taken from the drain-plug as the contents of the reservoir are drained off. Under such conditions, much of the sediment that gradually collects in the base is carried away, hence, is caught in the sample. An analysis of used oil obtained under such conditions might show a very high content of insoluble material but would not give a true picture of the conditions affecting the lubrication of the engine from which the sample was taken. In any test involving lubrication, the oil samples should be drawn from the lubricating system while the engine is running.

Analyses of a large number of samples of used oil, taken from passenger cars and motor trucks operating under widely varying conditions, show that the entire quantity of insoluble material will seldom exceed 1.25 per cent, while the average is less than 0.50 per cent. Of this amount, about one-fifth, or 0.1 per cent of the whole, usually comprises metals and road dust, the latter varying considerably in its proportion with the conditions of operation.

Although comparatively simple methods of analysis will give a reasonable approximation of the quantities of the various foreign materials to be found in used oil, they do not give a real clue to the physical characteristics of these materials. Yet they are of the greatest interest and importance to the engineer, because they have a direct bearing on engine design. The object of this paper is to show what has been learned concerning these characteristics.

Carbon Content

When the oil comes into contact with the heated undersides of the piston-heads, some oxidation takes place tending to thicken small portions of the oil, making them somewhat gummy and, incidentally, insoluble in the main body of the oil. If the temperatures are high enough, that is, 600 deg. fahr. or above, some cracking takes place, forming carbon. The carbon produced in this way is extremely fine and should not be confused with the deposits that often build-up inside the piston-heads. These are caused by the gradual and progressive stewing down, or oxidizing, of the oil into a hard mass. With such deposits, however, we are not concerned, because, if any of them flake off and drop into the oil, they are separated very quickly by gravity and the action of the oil-screen.

Because of its character, oxidized oil tends to collect any finely divided material that may be contained in the oil, including the carbon caused by cracking or coming from the blow-by in the form of soot, fine metal particles, and some, if not all, of the road dust. Collectively, this material is opaque and only a very small amount, less than 0.05 per cent, is sufficient to make the oil look black.

Some proof of this "conglomerate" theory regarding the nature of so-called carbon in crankcase oil is found when samples are examined under the microscope. Using white transmitted light, some of the particles of carbon appear to be slightly translucent and of a reddish color. Examination with blue light causes these particles to show up strongly, whereas with red light the smaller particles do not appear because they transmit red light.

Referring to the photomicrograph shown in Fig. 1, which was taken with blue light, it will be noticed that the foreign material occurs largely in groups of small particles, the size of which may be judged from the fact that the distance between the two horizontal lines is equivalent to 0.001 in., when magnified 150 diameters. If this illustration is compared with Fig. 2, which is of the same sample when photographed with red light, it will be seen that part of the dark material apparent in Fig. 1 has disappeared, showing that it is not solid, as is usually supposed to be the case.

It must be admitted that red light does not show up

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the fine detail in a photograph that blue light does and is much more difficult to handle, so, to a certain extent, this and other photographs that have been taken with red light should be considered only as indicative that the conglomerate theory is correct. Examination of this sample, however, and of a number of others under much higher magnification, shows that the groups that appear to be solid in either light are themselves composed of extremely fine particles apparently held together in the same way.

FIG. 1—PHOTOMICROGRAPH OF OIL SAMPLE TAKEN BY BLUE LIGHT SHOWING THE CLUSTER FORMATION OF THE INSOLUBLE MATERIAL

It Will Be Noticed That the Foreign Material Occurs Largely in Groups of Small Particles, the Size of Which Can Be Judged by the Fact That the Distance between the Two Horizontal Lines Is Equivalent to 0.001 In. before Being Magnified 150 Diameters

As a further check on the oxidized oil's forming the bulk of the so-called carbon, if a sample of used oil is treated with chloroform, a large part of the "carbon" will be dissolved. It is also interesting to note that, as the oil becomes diluted by fuel, the various groups tend to coalesce and to become more readily separated from the oil by gravity or by centrifugal force.

From the standpoint of promoting wear, it is obvious that no ill effects need be expected from the material under discussion, for the individual particles are too fine to take effect with the normal oil-film thickness, even

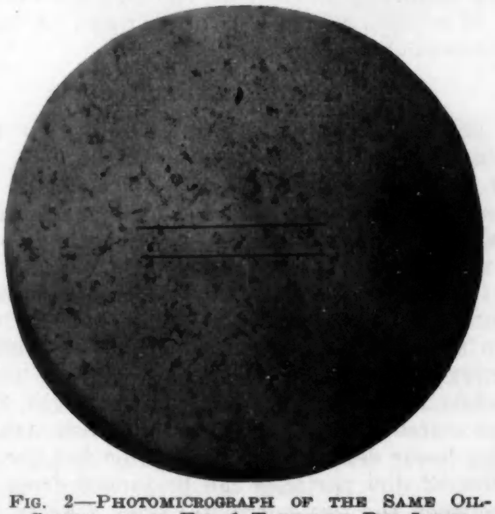


FIG. 2—PHOTOMICROGRAPH OF THE SAME OIL-SAMPLE AS IN FIG. 1 TAKEN BY RED LIGHT

A Comparison of These Two Illustrations Will Show That Much of the Dark Material Shown in Fig 1 Has Disappeared, Proving That the Particles of Foreign Matter Are Not as Solid as Is Usually Supposed To Be the Case

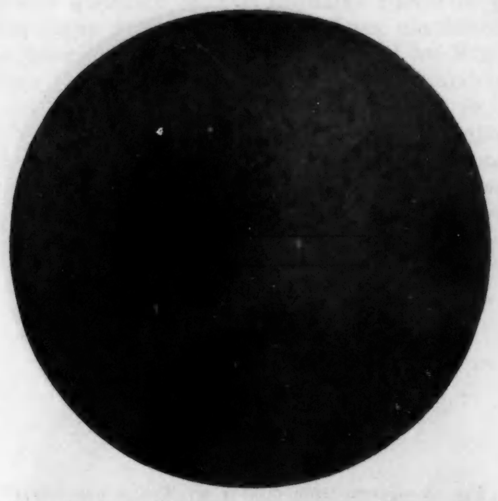


FIG. 3—PHOTOMICROGRAPH OF THE SAME OIL-SAMPLE WITH POLARIZED LIGHT, THE WHITE SPOTS INDICATING THE PRESENCE OF ROAD DUST

Some of the Patches of Insoluble Material Shown in Fig. 1 also Show in This Illustration. A Comparison of the Two Will Show That at the Points Where the Road Dust Appears in Fig. 3, No Evidence of Its Presence Can Be Found in Fig. 1. This Is Due to the Fact That Road Dust Is Fairly Transparent and Consequently Does Not Show in the Average Photograph. However, This Material, Which Is Fine Sand, Does Possess the Property of Rotating Polarized Light so That Nearly All the Particles, and Particularly the Large Ones, Show Bright on a Dark Field, While the Rest of the Insoluble Material Remains Dark

were they of an abrasive character, which is not the case, insofar as the carbon particles from soot or cracking are concerned. The presence of such material in

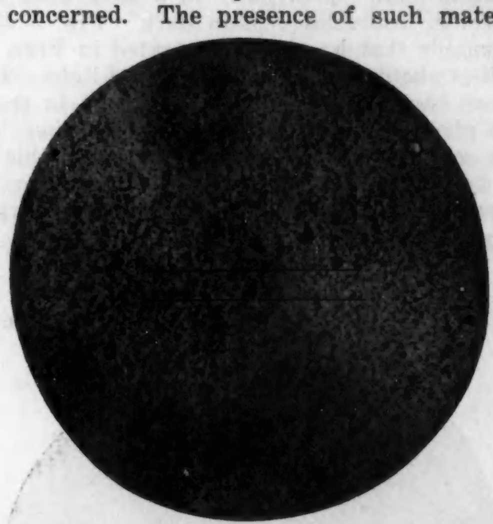


FIG. 4—PHOTOMICROGRAPH UNDER BLUE LIGHT OF AN OIL SAMPLE HAVING A HIGH INSOLUBLE-CONTENT

The Presence of Road Dust Which Constituted Approximately One-Half of the Insoluble Content Is Not Definitely Indicated. The Carbon Is Considerably More Dense Than in Fig. 1

engine lubricating-oil is, nevertheless, undesirable for other reasons that will be mentioned later.

HOW ROAD DUST MAY BE DETECTED

Examination of either Fig. 1 or Fig. 2 does not show any particles that could be identified as road dust or metallic particles. Insofar as the latter are concerned, it is obvious that, considering the rate at which wear takes place in an engine, even under the worst conditions, the particles worn off would be extremely fine, hence, too small to have any abrasive action. In all probability, some of the finest particles that make up the

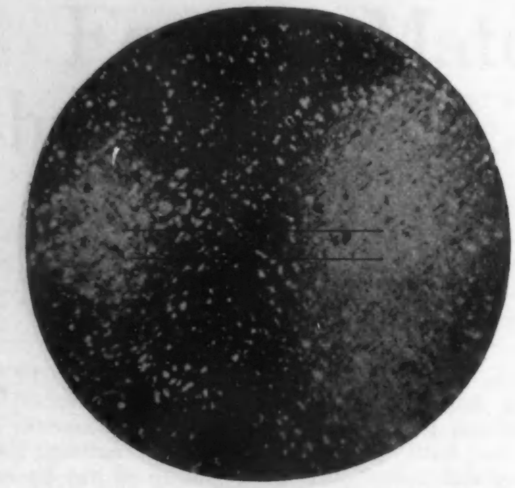


FIG. 5—PHOTOMICROGRAPH BY POLARIZED LIGHT SHOWING THE ABNORMALLY LARGE DUST-CONTENT OF THE SAMPLE ILLUSTRATED IN FIG. 4

This Sample Was Secured from a Motor Truck as the Crankcase Oil Was Being Drained. The High Dust-Content Was Due to the Washing Out of the Accumulated Grit in the Oil Reservoir and Did not Indicate the True Condition of the Oil in Service

groups in Fig. 1 are actually worn metal. Occurring in so fine a form, some of the iron may possibly be dissolved by the acids that usually develop in crankcase oil.

Road dust is fairly transparent, hence does not show in an average photograph. This material, however, which is fine sand, has the property of rotating polarized light, so that nearly all the particles, particularly the large ones, show up brightly in a dark field, while the rest of the insolubles remain dark. Fig. 3 shows the same sample that has been illustrated in Figs. 1 and 2, when it is photographed with polarized light. The white spots are caused by specks of road dust in the sample.

This photograph has been fogged by other light just enough so that some of the patches of insoluble material shown in Fig. 1 also show in Fig. 3. When they are compared, it will be found that, at the points where road dust appears in Fig. 3, there is no evidence of it in Fig. 1.

The analysis of this sample showed a total insoluble content of 0.75 per cent, 0.20 per cent comprising metals

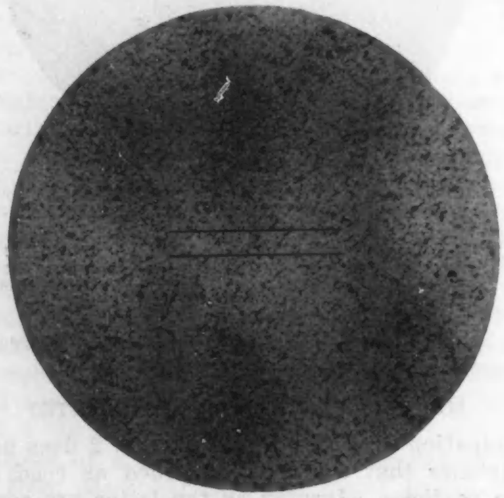


FIG. 6—PHOTOMICROGRAPH OF A WEAR-TEST OIL-SAMPLE UNDER BLUE LIGHT

The Degree of Magnification in This Case Is Not as High as in the Previous Ones. However, the Relative Proportions of the Dust Particles Can Be Judged from the Distance between the Two Horizontal Lines Which Indicates 0.001 In. as in the Previous Illustrations

and road dust. The latter was approximately 0.04 per cent of the total. As a matter of contrast, Fig. 4 is a photomicrograph with blue light of a sample showing an insoluble content of 1.2 per cent, of which approximately 0.6 per cent is road dust. The carbon is considerably more dense than that shown in Fig. 1; but a much more striking contrast is shown by Fig. 5, which is the specimen of Fig. 4 taken with polarized light. The far greater dust-content is indicated by the very large number of brilliant white spots that appear, even though the photograph has been fogged to a certain extent by white light.

A point of much interest in connection with these samples is that the one having the very large dust-content was secured from a motor truck as the crankcase oil was being drained, while the other was taken from the oil circulating in the lubricating system of another truck operating under similar conditions of service. It is therefore apparent that the high dust-content of the former does not indicate the true condition of the oil in service but is caused by the washing out of the accumulated grit in the oil reservoir. This emphasizes the need of taking all the samples from the oil in circulation, if reliable indications are desired in connection with lubrication problems.

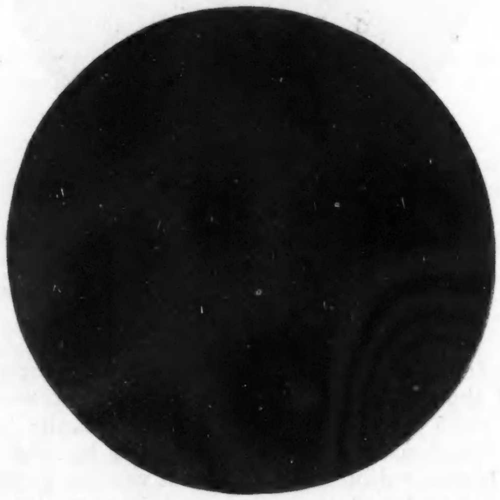


FIG. 7—PHOTOMICROGRAPH OF THE WEAR-TEST SAMPLE BY POLARIZED LIGHT

This Illustration Should Be Compared with Fig. 5, Keeping in Mind the Likeness of Appearance of Figs. 4 and 6

RESULTS FROM OTHER SAMPLES

The photographs thus far discussed were the first made in connection with these investigations. To get further information regarding the character of the dust actually circulating with the oil, a number of others have been taken of samples secured from engines operating under varying conditions. Table 1 shows the analysis of the insoluble content of a sample taken from an engine running under load, into the carbureter-intake of which a measured amount of road dust was introduced to aggravate the wear. Fig. 6 shows the oil under blue light, while Fig. 7, taken with polarized light, indicates the dust-content. These photographs were taken with a slightly lower degree of magnification but the relative proportion of dirt particles can be judged from the distance between the two horizontal lines. As in the previous illustrations, this distance indicates 0.001 in.

The size and the character of the particles of road dust fed into the engine are shown by Figs. 8 and 9, the

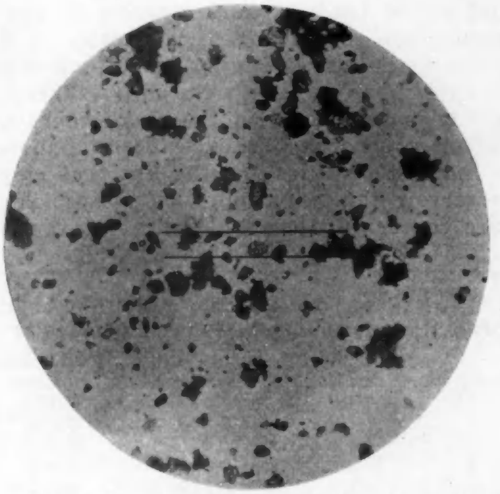


FIG. 8—PHOTOMICROGRAPH OF ROAD DUST TAKEN BY TRANSMITTED LIGHT

This Shows That Many of the Crystals Are Fairly Transparent. The Magnification in This Case Is the Same as in Figs. 6 and 7, So That a Direct Comparison Can Be Made of the Size of the Particles Going into the Engine and Those Found in the Crankcase. While Some of the Particles Are Fairly Small, Most of Them Are Far Larger than Those Showing in Fig. 7

first having been taken with white transmitted light, the second with polarized light. The magnification in these photographs is the same as in Figs. 6 and 7, so a direct comparison can be made of the size of the particles entering the engine with those found in the crankcase.

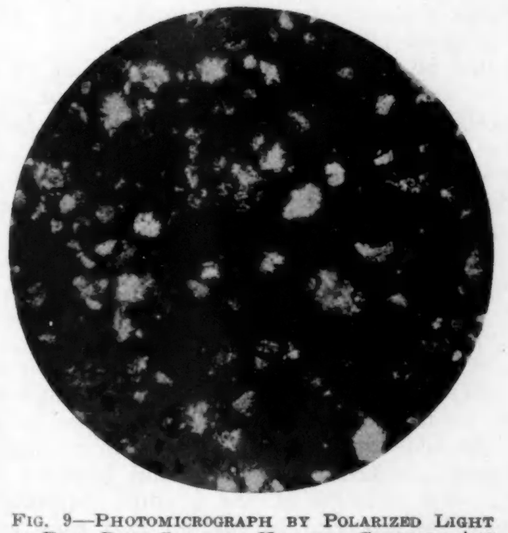


FIG. 9—PHOTOMICROGRAPH BY POLARIZED LIGHT OF ROAD DUST SHOWING HOW THE CRYSTALS ARE MADE VISIBLE AGAINST A DARK FIELD WITH THIS METHOD OF ILLUMINATION

In This, as in the Other Photomicrograph Taken with Polarized Light, Nearly One-half of the Dust Crystals Do Not Appear in the Photographs, Since They Do Not All Rotate the Light into the Proper Plane for Visibility with One Setting of the Polarizing Prisms. This, However, Does Not Affect Their Value in Showing the Character and the Average Quantity of Abrasive Material Present

Although some of the particles in Fig. 8 are fairly small, most of them are much larger than those showing in Fig. 7.

It should be said, regarding these photomicrographs taken with polarized light, that nearly one-half the dust crystals do not appear in the photographs, since they do not all rotate light into the proper plane for visibility with one setting of the polarizing prisms. This, however, does not affect their value in showing the character and average quantity of the abrasive material present. Of all the many samples that have been examined, none, with the exception of the one illustrated by Fig. 5, has ever shown the presence of any large dust particles comparable in size with the larger ones shown in Figs. 8 and 9. Figs. 10 and 11, showing a sample taken from

A motor truck after 30 days' use of the oil in suburban service near New York City, show only a few very fine dust particles and are indicative of what has been found generally in the study of oil samples under the microscope. The analysis of this sample is given in Table 2.

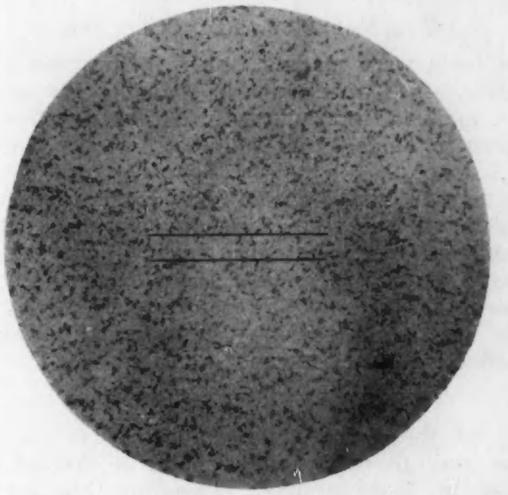


FIG. 10—PHOTOMICROGRAPHS UNDER BLUE LIGHT OF A SAMPLE OF OIL FROM A MOTOR TRUCK AFTER 30 DAYS' USE

This Truck Has Been in Suburban Service near New York City

The presence of this extremely fine dust in the lubricating oil seems to indicate that the grit drawn in through the carbureter has been more or less pulverized by the piston and ring action, while at the same time promoting wear of these parts. The results of the "wear test" also indicate that the ground-up particles are coarse enough to cause wear of the bearings, if the lubricating oil becomes thinned out.

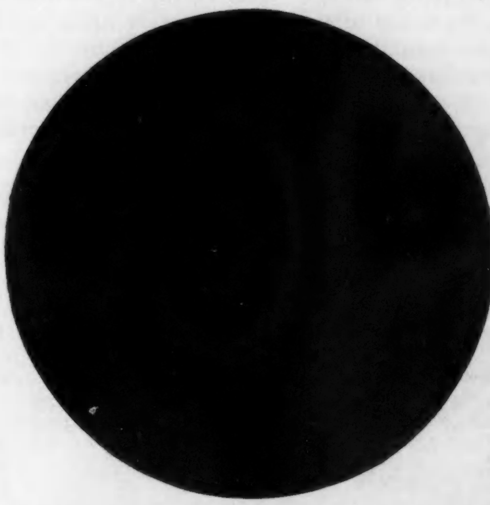


FIG. 11—PHOTOMICROGRAPH BY POLARIZED LIGHT OF THE OIL SAMPLE SHOWN IN FIG. 10

It Should Be Noticed That Only a Few Very Fine Dust Particles Can Be Seen. The Presence of This Extremely Fine Dust in the Lubricating Oil Seems To Indicate That the Grit Which Was Drawn In Through the Carbureter Was More or Less Pulverized by the Piston and Ring Action, at the Same Time Promoting Wear of These Parts

TABLE 1—ANALYSIS OF INSOLUBLE MATERIAL TAKEN FROM AN OIL SAMPLE FROM THE ENGINE ON THE WEAR TEST IN WHICH DUST WAS FED INTO THE CARBURETER INTAKE

Material	Per Cent
Oxidized Oil	15.5
Carbon	7.7
Iron	58.2
Silica and Silicates	18.6
Total	100.0[a]

[a] This total represents only 0.96 per cent of the total sample and was insoluble in petroleum ether.

The Value of an Air-Cleaner

Some tests were made recently to determine the effectiveness of an air-cleaner in reducing the amount of abrasive material in crankcase oil. The results obtained are shown in Table 3 and indicate that such a device is helpful.

Obviously, if dust is drawn in through the carbureter, some of it will adhere to the cylinder-walls in the path of the piston travel and cause wear, unless the oil-film thickness is sufficient to float the particles. The latter seems doubtful in the vicinity of the top ring, even if it were the case in the bearings; therefore the desirability of an effective air-cleaner is indicated.

The Importance of Clean Oil

Study of these photomicrographs seems to indicate that the foreign or insoluble material present in the crankcase oil, dust included, is so fine that very little bearing wear need be expected, so long as the percentage of dilution is relatively low. Service records of engines operating under widely varying conditions prove this beyond question. But some very real objections to the presence of any foreign material in the oil exist, whether it be of an abrasive character, or otherwise.

In the first place, it always tends to separate from the oil either by gravity or by centrifugal action, and frequently collects in the vicinity of oil-holes that feed main or camshaft bearings, gradually blocking off the flow of oil. Not infrequently the crankshaft oil-passages become clogged, particularly if they are sufficiently large so that the oil flow is relatively slow and not sufficient to cause a scouring action. The result is a failure of the bearing, the cause of which may not be apparent because the dirt accumulation would be loosened by the pounding of the bearing that failed and would be washed out by the flow of oil. Another objection to insoluble material in the oil is the fact that it is a first-class emulsifying agent and would tend to cause trouble if any water should accumulate in the engine crankcase.

Many engines have been equipped with extremely fine-mesh screens, apparently with the idea of keeping the oil clean. It is obvious from the photographs that no system of oil-screens can be expected to remove more than the coarsest particles and the lint that may reach the oil reservoir through carelessness. Insofar as the former are concerned, they will settle out very quickly and not give trouble, if the pump intake is well away from the bottom of the crankcase. Any lint will be caught by a relatively coarse-mesh screen, the large mesh being desirable from the standpoint of providing an unrestricted oil-flow in cold weather.

It cannot be emphasized too strongly that all screens should be either readily accessible for cleaning or as nearly self-cleaning as possible, preferably both. To give the self-cleaning characteristic, the flow through the screen should be vertically upward or horizontal, never downward; and the screen area should be large. It is a common experience to find the down-flow type of screen clogged and then punctured by the mechanic in the field who cleans it, so that trouble from that source will not again be encountered. Especially troublesome is this type of screen when it is of fine mesh.

Holding the dilution down to the minimum by a rectifier or other device that will get rid of the fuel will undoubtedly be helpful in reducing wear caused by dust in the oil. In addition, it will probably allow longer periods between crankcase drainings and improve the oil economy. But because of the gradual building-up of other insoluble material in the oil that may separate from it and cause trouble, draining will eventually be required. This could be obviated by some form of filtering or separating device that would take out the insoluble material.

From a purely lubrication standpoint, any foreign material in the oil is objectionable. Until grit, fuel, water and insoluble materials of all kinds have been removed, we cannot expect to get a full measure of service from either the engine or the lubricating oil. Hence, any device that tends to prevent the entrance of dust or to eliminate fuel, water or foreign matter is bound to be beneficial.

TABLE 2—ANALYSIS OF INSOLUBLE MATERIAL IN A SAMPLE OF OIL USED FOR 30 DAYS IN A MOTOR TRUCK IN SUBURBAN SERVICE NEAR NEW YORK CITY

Used-Oil Analysis	
Flash-Point, deg. fahr.	220
Pour-Test, deg. fahr.	0
Viscosity at 210 deg. fahr, sec.	50
Fuel, per cent	6.9
Water	Trace
Material Insoluble in Petroleum Ether, per cent	0.97
Analysis of Material Insoluble in Petroleum Ether	
Oxidized Oil, per cent	21.4
Carbon	65.6
Iron	12.4
Silica	0.6

TABLE 3—ANALYSIS OF SAMPLES TAKEN FROM UNITS OPERATING WITH AND WITHOUT AIR-CLEANERS

Sample No.	Fuel, Per Cent	Insolubles, Per Cent	Road Dust, Per Cent
1[b]	1.2	0.030	0.001
2	1.8	0.500	0.015
3[b]	1.0	0.015	0.001
4	2.0	0.430	0.010
5	1.7	0.540	0.015
6	3.3	0.550	0.013
7[b]	1.6	0.240	0.006
8[b]	3.6	0.340	0.008
9	3.5	0.370	0.012
10[b]	1.7	0.280	0.006
11[b]	3.0	0.350	0.009
12	1.6	0.460	0.016

[b] These samples are from engines equipped with air-cleaners. The results indicate that air-cleaners tend to reduce the dust content of the crankcase oil.

Recent Cooperative-Fuel-Research Progress

By S. W. Sparrow[1] *and* J. O. Eisinger[2]

Annual Meeting Paper *Illustrated with* Drawing and Charts

ABSTRACT

THIS report deals with further progress in the cooperative fuel research. General factors underlying starting ability are discussed and experiments showing the effect of changes in spark character and of gas leakage are described. The probable mechanism of crankcase-oil dilution is treated, and further experiments with reference to this subject are explained. One experiment deals with operation with oil as a cooling medium to obtain high jacket-temperatures. Other experiments show the effect of change in piston clearance, and in the number of piston-rings employed.

Factors influencing the rate at which the diluent is eliminated from the diluted oil are shown to be of importance, and methods of examining these factors are stated.

IN December, 1924, the President of the United States created an oil-conservation board consisting of the Secretaries of War, of the Navy, of the Interior and of Commerce. In his letter to these secretaries, announcing the creation of the Board, the President made these two statements: "Developing aircraft indicate that our National defense must be supplemented, if not dominated, by aviation. It is even probable that the supremacy may be determined by the possession of available petroleum and its products" and ". . . . the oil-industry's welfare is so intimately linked with the industrial prosperity and safety of the whole people that Government and business can well join forces to work out this problem of practical conservation." It must be a source of satisfaction to the members of the Society, to the members of the American Petroleum Institute and to those of the National Automobile Chamber of Commerce that they authorized the Bureau of Standards to undertake this cooperative fuel-research, the object of which was, most assuredly, "practical conservation," in the summer of 1922.

Direction and Scope of the Research

The direction of this research has rested very largely in the hands of a steering committee composed of members of the cooperating societies. To this committee, frequent informal reports of progress have been submitted. Formal reports have been presented at the annual meetings of the American Petroleum Institute and at both the Annual and the Semi-Annual Meetings of the Society. Reference is made to publications of these reports[3]. No attempt will be made here to discuss in detail any work done prior to the Semi-Annual Meeting of the Society in June, 1924. The steering committee, in a resolution adopted with reference to the carrying on of the investigation from July, 1924, to July, 1925, recommended:

> First, that the factors contributing to crankcase-oil contamination be investigated; second, that the factors contributing to easy starting be investigated; third, that an investigation of vaporization be made to coordinate design of internal-combustion engines and the volatility of fuel.

The starting-point of an investigation of the subject of vaporization consists of obtaining more exact knowledge of what constitutes effective fuel-volatility in both the temperature range governing crankcase-oil dilution and in the initial range which determines starting characteristics. Such work is in progress, but definite conclusions have not been reached. The limitations of the distillation curve as a criterion for judging fuels have been recognized by many investigators, and what are quite generally recognized as being better methods

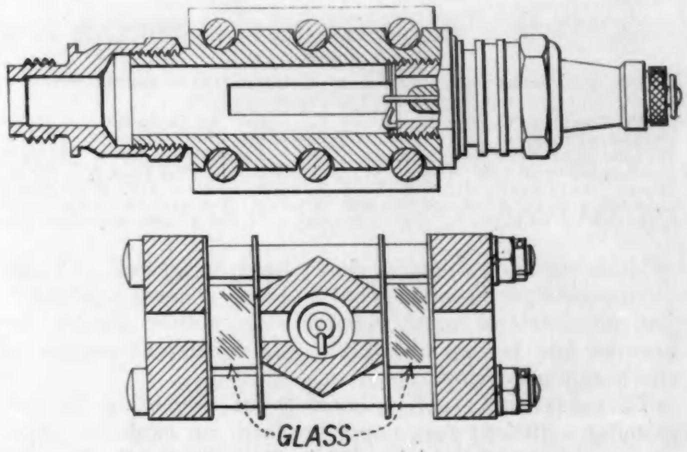


Fig. 1—Spark-Plug Enclosed in Glass Tube
Since the Electrodes and the Spark Were Visible through the Glass of the Tube, Means Were Afforded for Determining Whether the Spark Actually Occurred

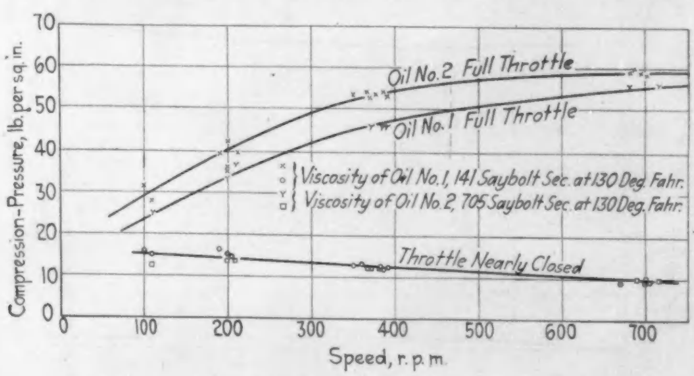


Fig. 2—Comparative Tests with Two Different Oils
Oil No. 1, of 141-Saybolt Sec., and Oil No. 2, of 705-Saybolt Sec. Viscosity, Both at 130 Deg. Fahr., Were Used. The Highest Pressure Was Obtained When Gasoline Was Not Allowed To Enter the Cylinder and the Lowest Jacket-Water Temperature and the Most Viscous Oil Were Employed

[1] M.S.A.E.—Mechanical engineer, Bureau of Standards, City of Washington.

[2] Jun. S.A.E.—Assistant mechanical engineer, Bureau of Standards, City of Washington.

[3] See The Journal, February, 1923, p. 139; July, 1923, p. 3; March, 1924, p. 267; July, 1924, p. 69; October, 1924, p. 333.

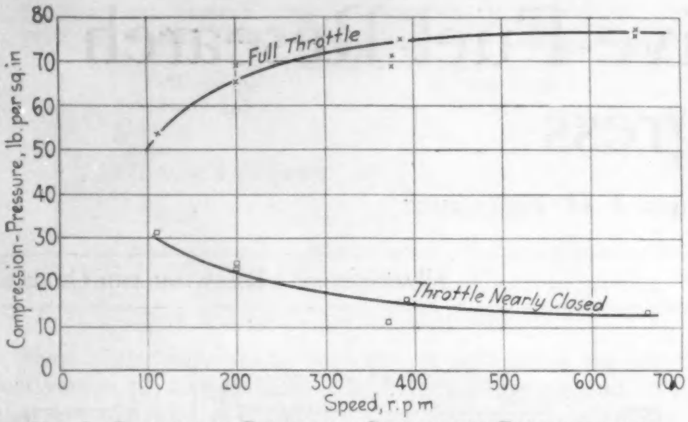


FIG. 3—PERCENTAGE CHANGE IN COMPRESSION-PRESSURE WITH CHANGE IN THROTTLE-OPENING

With Throttle Nearly Closed, as the Speed Is Reduced the Compression-Pressure Increases; Whereas, at Full Throttle, It Decreases. At Very Low Speeds, Change of Throttle-Lever Position Accomplishes Little Except an Alteration of the Fuel-Air Ratio. Hence, an Engine Having Valve-Timing Chosen for High-Speed Operation May Develop Starting Trouble Because an Insufficient Quantity of Charge To Turn the Engine Over Enters the Cylinder

of judging fuel volatility have been suggested. It can be appreciated, however, that to be of general applicability, any method must require only rather simple apparatus and be capable of yielding consistent results in the hands of various observers.

The starting problem consists of providing in the cylinder sufficient fuel vapor to form an explosive mixture and a spark which will fire the mixture. The influence of the character of the spark upon its ability to ignite a mixture has long been a favorite topic for discussion. Insofar as actual experiments are concerned, most investigators appear to have reached the conclusion that the spark furnished by any of the conventional types of ignition system is adequate to fire the charge, and that differences in spark character have no significance with reference to the starting problem. In this connection, the following experiment is of interest, although it was not made as a part of this investigation.

The essential part of the experiment consisted of inserting a resistance in the spark-plug circuit which could be varied at will, thus varying the character of the spark. It was found that, when this resistance was sufficiently high, the spark obtained would not fire the charge in the cylinder. To make sure that a spark was

[4] See THE JOURNAL, July, 1924, p. 69.

[5] See *Automotive Industries*, Nov. 27, 1924, p. 928.

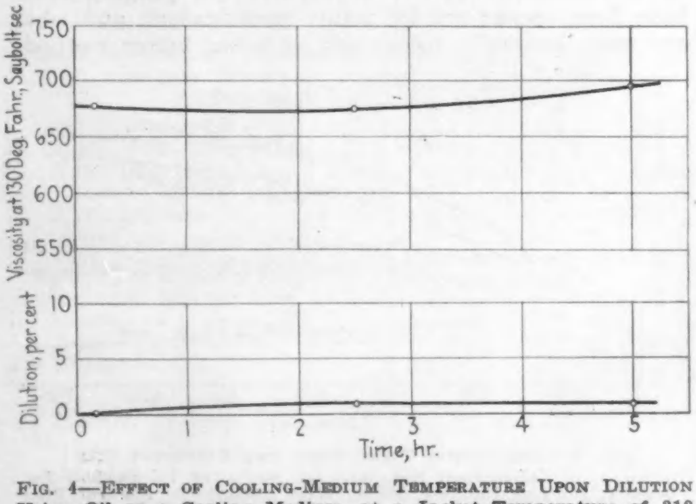


FIG. 4—EFFECT OF COOLING-MEDIUM TEMPERATURE UPON DILUTION

Using Oil as a Cooling Medium, at a Jacket Temperature of 212 Deg. Fahr. the Amount of Dilution Was Extremely Small and the Oil Viscosity Actually Increased during the Run

actually occurring under such conditions, the spark-plug was enclosed in the glass-sided tube shown in Fig. 1, which was screwed into the hole normally occupied by the spark-plug. The electrodes, and the spark as it jumped across them, could be seen through the glass sides of the tube. Such a tube provides a more or less dead pocket around the spark-plug and, in this respect, gives a condition somewhat worse than is found in the ordinary engine. This was offset to some extent by the fact that the engine was of the overhead-valve type and operating at a much higher speed than is employed normally in cranking an engine. Hence, it is probable that there was more turbulence around the spark-plug, in spite of its unfavorable position, than is found in many motor-car engines during the starting period. It may be added also that this same effect was found with a spark-plug mounted in its normal position in the cylinder, although in this case an auxiliary spark-gap was utilized as a means for indicating whether the spark actually occurred.

Sufficient work was not done to determine definitely upon what characteristics the efficacy of the spark as a source of ignition depended. It appeared, however, to be related to the "duration" of the spark. Such devices as are employed for indicating the position in the cycle at which the spark occurs indicate also its "duration," or the number of degrees of crank angle over which it persists. The description of this experiment, however, has not been introduced for the purpose of recommending any particular type of spark or spark-plug position, but merely as furnishing definite proof that, under certain circumstances, the character of the spark may determine whether the charge is ignited.

AMOUNT OF FUEL

The amount of *fuel* which must be introduced into the cylinder to furnish sufficient *fuel vapor* to form a combustible mixture depends upon its temperature and its volatility. As was shown in the report presented in June, 1924, and published later[4], at 32 deg. fahr., to get a mixture rich enough to fire, it is necessary to provide more than 10 times as much fuel as is required to make a mixture too rich to fire at 200 deg. fahr. That portion of the fuel which is not vaporized dilutes the oil and, in many cases, the chief source of crankcase-oil dilution may be the large quantities of fuel it is necessary to take into the engine to start it. The choke valve is a means commonly employed for getting these large quantities of fuel into the cylinder, and it is rather common to hear it blamed for much of the dilution trouble. So long as fuel in large amounts is needed, the choke is a blessing rather than a curse, as no one desires freedom from dilution at the price of inability to start.

To decrease the quantity of fuel that it is necessary to take into the cylinder, heat can be applied to the charge in its passage to the cylinder or in the cylinder itself. Some of the methods which have been employed to heat the charge in the carbureter or in the intake-manifold have been described by P. M. Heldt[5]. The only heat that the charge is likely to receive in the cylinder itself is that derived from compression. Leakage from the combustion-chamber is important because of its influence upon the amount of heat that is developed. Some of the factors which influence this leakage were investigated by rotating an engine, mounted in a car, at various speeds and throttle-openings and measuring the compression-pressures in the cylinder.

It had been anticipated that the best piston-seal and, therefore, the highest compression-pressure, might be obtained with an oil of rather low viscosity. In these tests, however, the highest pressures were obtained under conditions which made the oil upon the cylinder-walls most viscous. The lowest pressure was obtained when gasoline was admitted into the cylinder and the highest jacket-water temperature and the least viscous oil were employed. The highest pressure was obtained when gasoline was not allowed to enter the cylinder and the lowest jacket-water temperature and the most viscous oil were employed. Jacket-water temperatures of 25 and 80 deg. cent. (77 and 176 deg. fahr.) were obtained, while the oils used had viscosities at 130 deg. fahr. of 141 and 705 Saybolt sec. Fig. 2 shows the result of comparative tests with the two oils.

A fact that may or may not be of importance is brought out in Fig. 3. This shows that, with throttle nearly closed, as the speed is reduced the compression-pressure increases; whereas, at full throttle, it decreases. At very low speeds, a change in the position of the throttle lever would accomplish little except an

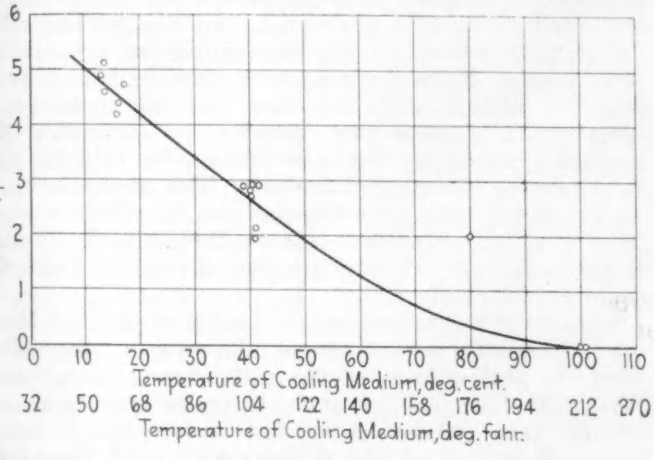


FIG. 5—RELATION BETWEEN TEMPERATURE OF COOLING MEDIUM AND RATE OF DILUTION
Based Only Upon Tests with One Engine over a Rather Restricted Range of Conditions

alteration of the fuel-air ratio. This suggests that engines with a valve-timing chosen for high-speed operation may give trouble in starting solely because of the difficulty of getting a sufficient quantity of charge into the cylinder to turn the engine over.

At the 1924 Semi-Annual Meeting of the Society, Dr. Dickinson discussed briefly the probable mechanism of dilution and this discussion, somewhat amplified, was published[6]. It seems desirable to repeat the salient points of this discussion as summarizing the general conclusions reached thus far in the investigation of crankcase-oil dilution. It should be noted that the first portion of the explanation deals with what happens during normal operation and not with what happens during the starting period when large quantities of unvaporized fuel are introduced into the cylinder.

In normal operation, conditions are somewhat as follows: (*a*) the cylinder-walls, particularly the side-walls, are covered with a film of oil, not more than a few thousandths or perhaps a few ten-thousandths of an inch thick, which is at a temperature not far from that of the metal of the cylinder-walls; (*b*) the fuel-air mixture entering the cylinder is within the range of combustibility, and the fuel that it contains is at least partly vaporized, any liquid that remains being in small droplets distributed with some degree of uniformity throughout the charge; (*c*) the fuel in the mixture is made up

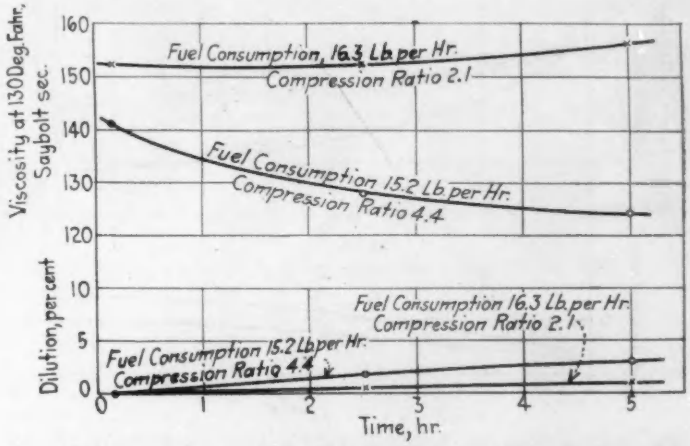


FIG. 6—RELATIVE DILUTION AT TWO DIFFERENT COMPRESSION-RATIOS
Compression-Ratios of 2.1 and 4.4 Were Employed. The Marked Improvement Shown Is Not, Necessarily, Due Entirely to Change in Pressure. The Change in Ratio Involved Other Changes Whose Influence Would Be Expected To Decrease the Rate of Dilution

of various constituents of differing volatility and, when vaporizing in the presence of its own vapor, it has a definite dew-point temperature for any given mixture proportion, the existence of a dewpoint temperature above which the fuel will vaporize entirely having been shown by different experimenters and the temperature having been determined for various grades of gasoline; and (*d*) the oil-film on the cylinder-walls is being interchanged with oil from the crankcase by the motion of the piston.

On entering the cylinder during the intake stroke, the charge probably, though perhaps not always, contains some liquid spray. If present, the spray or part of it strikes the cylinder-walls, piston-head and other parts, and attempts to mix with the film of oil. Will the fuel actually mix with the oil or not?

The cylinder, at the closing of the intake-valve, contains a charge of air at a pressure of from 6 to 14 lb. per sq. in., depending upon the throttle opening. This is mixed with fuel vapor, which, if all the fuel had been evaporated, would have a vapor pressure of something under 2 per cent of the air pressure. It follows from Dalton's law that the presence of the air can be neglected so far as the behavior of the fuel vapor is concerned, except that the evaporation or the condensation of the fuel may take place somewhat more slowly with air present.

At this time the fuel, partly liquid and partly vapor, is present in such an amount that the vapor pressure is something less than that indicated by ½ in. of mercury. For any given total amount of fuel present, as noted

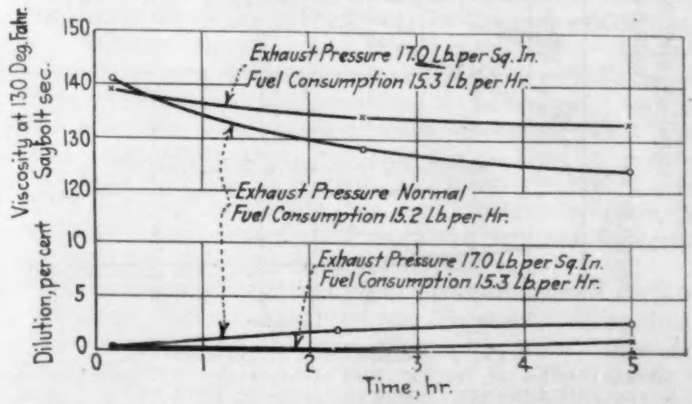


FIG. 7—EFFECT OF DIFFERENT EXHAUST-PRESSURES ON DILUTION
Increase of Back-Pressure When Operating with the High Compression-Ratio Resulted in a Considerable Decrease in Dilution

[6] See THE JOURNAL, October, 1924, p. 271.

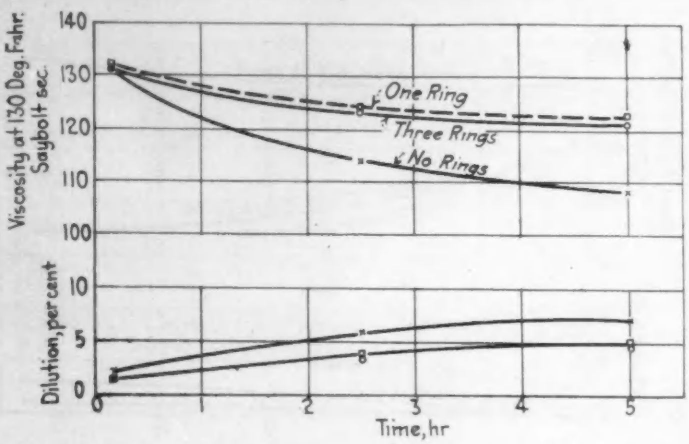


FIG. 8—DILUTION AS AFFECTED BY CHANGES IN PISTONS AND IN PISTON-RINGS

Two Experiments Were Made. One Showed a Marked Increase in Dilution When Operating the Pistons Without Rings, but No Appreciable Difference between Results with One Ring and with Three Rings; in the Second, Operating with Very Loose Pistons and Clearance Increased 1/32 In. on the Diameter, No Appreciable Increase in Rate of Dilution Resulted

above, a temperature exists which is known as the "dewpoint temperature," at which the first drops of fuel will condense on cooling or the last drop will evaporate on heating. This temperature depends upon the quality of the fuel and on the fuel-air ratio.

Assume for the moment that this dewpoint temperature is 100 deg. fahr. for the condition predicated above. When the surfaces are covered with oil, the dewpoint temperature may differ somewhat from that for dry surfaces of metal, but it is assumed that this 100-deg. fahr. dewpoint applies to oil-covered surfaces. If the temperature of the cylinder-walls is above 100 deg. fahr., any liquid fuel striking them will tend to evaporate and, in so doing, it will absorb heat from the oil-film and cool it below the original 100-deg. fahr. temperature. Indeed, were it not for this cooling, fuel could not go into solution in the oil.

AMOUNT OF EVAPORATION

The amount of evaporation of the fuel which can take place in the surface film of oil, therefore, will depend on how rapidly heat can be supplied to the oil-film and thus to the liquid fuel by conduction from the cylinder-walls and by contact with the gases in the cylinders. The average amount of dilution which will exist in the oil-film on the cylinder-walls will depend upon the relation

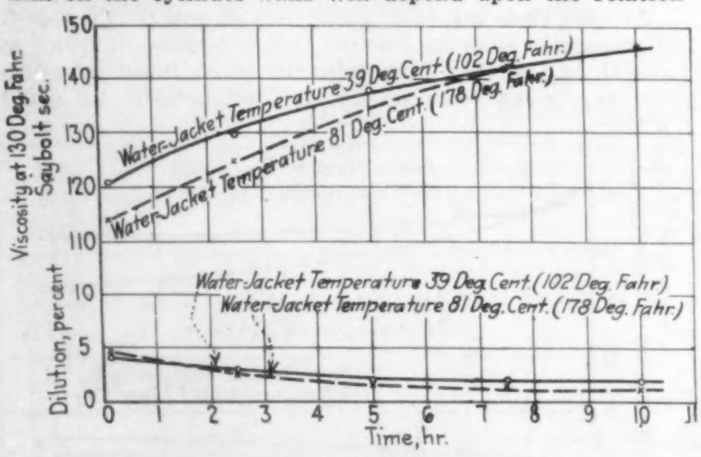


FIG. 9—ELIMINATION OF DILUENT

Actual Dilution of the Oil Was Accomplished by Operating the Engine with Ordinary Commercial Gasoline While Using a Rather Rich Mixture and Keeping the Temperature of the Jacket Water Rather Low. When the Oil Had Been Diluted Sufficiently, Aviation Gasoline Replaced the Commercial Gasoline as Fuel

between the rate at which the fuel strikes the walls and the rate at which heat is supplied to vaporize this fuel.

An estimate of these rates is furnished by the following: The evaporation of the fuel charge in the air will lower the air temperature about 60 deg. fahr., while the heat produced by the burning of the charge is sufficient to raise the temperature about 3600 deg. fahr. In other words, the amount of heat produced is about 60 times that required to vaporize all the fuel. Since some 20 per cent of the heat of combustion passes to the water-jacket through the cylinder-walls and the oil-film on their surface, it is obvious that, for each cycle, at least 12 times as much heat passes through the oil-film as would be required to vaporize all the fuel used in that cycle. It is evident, therefore, that plenty of heat is available to vaporize all the fuel striking the cylinder-walls.

If the temperature of the oil-film and the cylinder-walls is below the dewpoint of the fuel mixture, complete evaporation will not take place, because the available heat is absorbed by the water-jacket. The temperature of the cylinder-walls need be but slightly above the dewpoint, however, for the heat supply for evaporation to be ample. From this reasoning it would be concluded that the cylinder-wall, and therefore the jacket-water temperature, control very directly and definitely the average composition of the oil-film on the cylinder surfaces, as regards its fuel content. This seems to be in entire accord with experimental results. The average dilution of this oil-film would be the ultimate dilution of the crankcase oil, were no fuel eliminated from the oil in the crankcase itself.

Experiments described at the 1924 Semi-Annual Meeting indicated that crankcase-oil dilution is not dependent upon the temperature of the piston-head. This seems reasonable inasmuch as, under average operating conditions, the temperature of the piston-head is much higher than that of the cylinder-walls. If, therefore, the cylinder-walls are at a temperature anywhere near the dewpoint, the piston-heads are hot enough so that all the fuel which strikes them is evaporated. Naturally, a change in this temperature has little effect on dilution.

In the earlier stages of this research it was found that the rate of crankcase-oil dilution was higher with Grade *D* fuel than with Grade *B* fuel; in other words, that there is a close relationship between fuel volatility and the rate of dilution. This is in entire accord with the foregoing analysis. The dewpoint temperature of the fuel-air mixture depends on the fuel volatility, though not directly on the distillation end-points; therefore, the less volatile the fuel is, the higher will be the jacket-water temperature required to prevent dilution or, conversely, the greater will be the amount of dilution under the same operating conditions.

In a previous report, it was pointed out that the rate of crankcase-oil dilution varies almost directly with the fuel-air ratio. This would be expected, since the dewpoint temperature increases with fuel content as well as with decreased fuel-volatility.

In the same report it was shown that the temperature, and therefore, supposedly, the degree of vaporization of the incoming charge, have much less effect on the rate of crankcase-oil dilution than many had supposed. This, too, agrees with the foregoing analysis. The dewpoint temperature does not depend upon the intake temperature; hence, the temperature of the cylinder-walls at which dilution stops should not depend primarily on intake-charge temperature, nor should dilution depend upon it directly. In fact, even if the fuel were entirely evaporated before entering the cylinders, condensation on the cylinder-walls and consequent dilution would occur, if the cylinder-walls were below the dewpoint temperature. From this analysis, supported by the data derived from experiments, the conclusions reached are summarized as follows: Under average operating conditions, crankcase-oil dilution

(1) Depends primarily on the average temperature of the cylinder-walls
(2) Is likely to reach an equilibrium value if starting periods are not too frequent
(3) Depends directly on fuel volatility
(4) Is directly dependent upon the average fuel-air ratio
(5) Does not depend much upon the piston temperature
(6) Is not dependent much upon the charge temperature or the degree of vaporization.

Other Experiments and Results

By using oil as a cooling medium, the effect of jacket temperatures as high as 100 deg. cent. (212 deg. fahr.) has been investigated. Fig. 4 shows that, at this temperature, the amount of dilution was extremely small and that the viscosity of the oil actually increased during the run. It should be noted that, in the absence of dilution, the normal behavior of oils is to increase in viscosity with use. Perhaps it should be mentioned that oil was selected as a convenient means for studying the effect of high jacket-temperatures and no attempt was made to study its efficacy as a cooling medium. The experiment is of practical value, as temperatures of this order could be obtained with steam cooling-systems.

Fig. 5 suggests the relation between the temperature of the cooling medium and the rate of crankcase-oil dilution. Its value is limited by the fact that it is based upon tests with one engine over a rather restricted range of conditions. Moreover, with respect to the highest temperature, it is open to the objection that the difference between the wall temperature and that of the cooling medium may be different for oil than for water. Nevertheless, it is believed that it gives a picture of sufficient accuracy to be of interest.

Recently, some experiments have been made to investigate the effect upon dilution of reducing the compression-ratio. If dilution takes place according to the mechanism already described, that is, if it is dependent primarily upon the dew-point, then the effect of decreasing the vapor pressure should be the same as that of increasing the wall temperature. If the same amount of fuel is taken into the cylinder, the vapor pressure will be lower with a low-compression engine than with a high-compression engine, as the volume occupied by the vapor is greater.

While discussing this vapor pressure, it is well to mention a fact to which Professor Schweitzer has drawn attention, relative to the compression of wet mixtures, in his article entitled Another Aspect of Crankcase-Oil Dilution.[1] With adiabatic compression, fuel tends to evaporate rather than to condense as the pressure increases. This is due to the rise in temperature produced by such compression. Professor Schweitzer points out that the layer of gas adjacent to the wall may remain at substantially wall temperature, and that its compression may thus be nearly isothermal. Compression under such circumstances would tend to cause condensation.

The compression-ratio employed was about 2.0 as against a normal ratio of over 4.0. Fig. 6 shows the relative dilution with the two ratios. Had no decrease in dilution been shown with the low ratio, it would have disproved the theory already offered. It does not follow, however, that the marked improvement shown in the figure is entirely due to the change in pressure. The change in ratio involved other changes whose influence in every case would be expected to decrease the rate of dilution. For example, with the low compression-ratio, there is a much greater quantity of exhaust gas left in the clearance volume, which means much higher charge-temperatures at the beginning of the compression stroke. This condition was approximated to some extent by increasing the back-pressure when operating with the high compression-ratio, and this too resulted in a considerable decrease in dilution as shown by Fig. 7. It is of interest that, with the low compression-ratio, a spark-advance of nearly 100 deg. was required; whereas 30 deg. was sufficient with the normal ratio.

In previous reports, the effect upon dilution of certain changes in pistons and rings was discussed. Since then, two additional experiments have been made. The results of the first are shown in Fig. 8. This shows a marked increase in dilution when operating the pistons without any rings, but no appreciable difference between results with one ring and with three rings. The other

[1] See THE JOURNAL, January, 1925, p. 92.

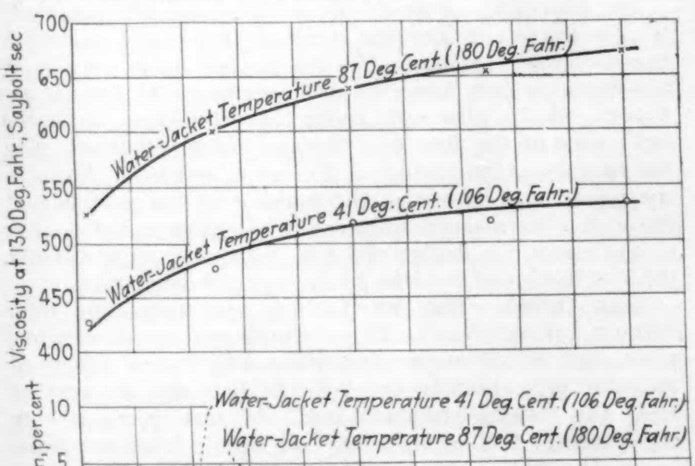


FIG. 10—ELIMINATION OF DILUENT
Showing Similar Curves to Those of Fig. 9 But at Different Temperatures

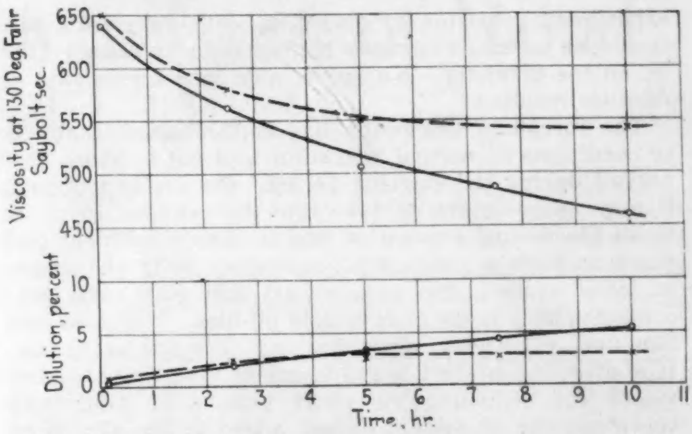


FIG. 11—RESULTS OF TESTS WITH DIFFERENT TEMPERATURES OF CRANKCASE OIL
The Importance of Crankcase-Oil Temperature in Its Influence upon Dilution Has Been Emphasized. Its Influence Probably Is Due to Its Effect upon the Rate of Elimination of the Diluent

experiment consisted of operating with very loose pistons, the normal clearance having been increased 1/32 in. on the diameter. No appreciable increase in rate of dilution resulted.

The foregoing discussion has applied almost entirely to conditions of normal operation, and not to those that prevail during the starting period. On a cold morning, it may be necessary to take into the cylinder 10 or 20 times the normal amount of fuel to obtain sufficient fuel vapor to form a combustible mixture. With the piston at lower center, this unvaporized fuel may come into contact with a large area of cold oil-film. It dilutes this film and, eventually, finds its way into the crankcase. It is evident that, in a type of service involving frequent starts and comparatively short periods of continuous operation, the amount of diluent added to the oil will be large and, unless the diluent is eliminated at a fairly rapid rate, the oil speedily will become of too low a viscosity to give satisfaction. It is of importance, therefore, to consider the factors that influence the rate at which diluent is eliminated from the crankcase oil.

To study this problem, tests were made in the following manner: First, actual dilution of the oil was accomplished by operating the engine with ordinary commercial gasoline while using a rather rich mixture and keeping the temperature of the jacket water rather low. When the oil had been diluted sufficiently, aviation gasoline replaced the commercial gasoline as fuel. It is not likely that this caused any material change in any of the engine temperatures. However, to all practical purposes it did stop the addition of the diluent to the crankcase oil. This was proved by engine tests in which no perceptible increase in dilution occurred over a 10-hr. period during which aviation gasoline was the only fuel employed. With no diluent being added, changes in the percentage of dilution must be due solely to the elimination of the diluent. Figs. 9 and 10 show such changes to be very marked. The figures cover two conditions of jacket-water temperature with two oils, No. 1 and No. 2, of widely different viscosities.

In the paper on Engine-Oil Dilution and Consumption[8], by Neil MacCoull, the importance of crankcase-oil temperature in its influence upon dilution was emphasized. Its influence probably is due to its effect upon the rate of elimination of the diluent. Fig. 11 shows the results of some Bureau of Standards tests made with different temperatures of the crankcase oil. The various stills and oil rectifiers on the market accomplish, in most cases, the elimination of the diluent by heating a portion of the oil to a high temperature.

[8] See The Journal, July, 1924, p. 93.

Remedies for Dilution

The various comments on the "disease" of dilution suggest certain remedies. It is well to mention what may prove to be disadvantages of the remedies. Increasing the maximum temperature is likely to involve increased trouble from detonation. Both high jacket-temperatures and high oil-temperatures mean that the oil must be of rather high initial viscosity in order that its viscosity shall be adequate at its normal operating temperature. Any increase in oil viscosity means increased difficulty in cranking the engine when it is cold, and greater friction-losses before the engine reaches its normal temperature. There do not seem to be any objections, however, to a decrease in the time required for the engine to reach its normal temperature, and such a decrease is greatly to be desired.

While no one would have the temerity to suggest that there is not a great deal more to be studied with relation to the factors influencing dilution, it appears that the more important factors have been examined fairly carefully and that further effort is likely to show "diminishing returns." It is the intention, subject of course to the desires of the steering committee, to devote the remainder of the year to other phases of oil contamination and the starting problem, rather than to dilution.

DISCUSSION OF PRODUCTION MEETING PAPERS

(Concluded from p. 226)

to cover the change. On repair work, we furnish two estimates, one of the cost of tearing-down the tool, for when the tool is taken apart, we can see absolutely what is wrong and what needs repair; the other for repairing the tool and putting it back into shape.

Question:—What is the ratio of the design and drafting-room cost to the total cost of the tool?

Mr. Lannen:—Over a period of 2 years, it has varied. You will find that when the volume of work is small and the designers are of good class, the ratio will drop; if the volume of work is large and must be done in a hurry, and if any Tom, Dick or Harry is hired to get it done and you take what he produces whether he produces efficiently or not, it will run high. As a wild guess, I would say that it will average pretty close to 80 per cent.

Chairman Bouton:—In making drawings of gages, that is, the simpler forms of gage, such as plug and snap gages, does the tool designer do all the work?

Mr. Lannen:—It is taken care of by the tool designer. Plug and snap gages have become pretty well standardized within the last 2 years.

Mr. Schreiber:—Are you using an experienced tool-designer or merely a good draftsman for estimating tools?

Mr. Lannen:—I would not say that we are organized in accordance with the best method; that is a thing which is constantly changing. At the present time, our chief tool-designer is a first-class tool-engineer; he has an assistant, who is also very good; these two men, with the assistance of the few men that we have developed, plan the operations according to the set of rules set forth in the paper, and supervise the making of the sketches of the tools. We attempt to have the sketch so complete that a draftsman can design the tool with very little further information; and we like to have rapid draftsmen.

Erik Oberg:—Has Mr. Lannen any figures on total manufacturing costs? These would not cover any one piece, but would cover practically the entire range of manufacture, showing the relation between the cost of tools and tooling-equipment and the cost chargeable to the machine-tool equipment. It would include three items: the cost of the regular machine-tool equipment, of the tools that are applied to the machine-tools, and of the labor. Has Mr. Lannen any figures that give those costs compared with one another?

Mr. Lannen:—No. It would be comparatively easy to get the machine cost and the tool cost, but the labor cost is constantly changing.

The Physical Characteristics of Road and of Field Dust

By C. E. Summers[1]

Annual Meeting Paper *Illustrated with* Charts and Photographs

ABSTRACT

In a study of the dust problem that has lasted more than 2 years, many observations, measurements and experiments were made to determine the nature and effect of dust and the best means for its elimination as a cause of engine wear. The results of these experiments, which seem to be of general interest, are reported, and cover briefly such matters as the chemical composition of road dust, its particle size, specific gravity and abrasive nature and the relative amounts of it to which an engine may be exposed under varied conditions. Curves are also submitted that show the average cylinder-wear on a number of test cars. The methods of testing air-cleaners are described, the principles underlying commercial air-cleaners are discussed and a list of what the author believes to be important elements of air-cleaners for passenger cars is given.

In connection with the development of the air-cleaner now being manufactured by the A. C. Spark-Plug Co., a large number of experiments were made and data from many sources were analyzed to determine with accuracy such facts as pertain to the dust problem. In pursuance of this idea, a number of dust samplers, constructed to retain all the dust caught and actually of nearly 100-per cent efficiency, were sent to various parts of the Country, mounted on engines, operated under known conditions and returned to us for determination of the quantity and quality of dust to which the engine was exposed under each set of conditions. By mechanically feeding definite quantities of dust of known particle-size and chemical analysis, several engines were worn-out to determine the relation of dust quantity to wear and to give measurements of wear on various parts and surfaces. In addition, cylinder-wear records covering 20,000 miles of car travel were made for 14 test cars of all makes in common use, and similar data were obtained on a number of privately owned cars. Further, the work included laboratory and road-tests of practically all air-cleaners now on the market, and a study of their effect on engine performance. The more detailed development work consisted of a study of the mechanics of dust-air mixtures, the controlling forces and resultant movements of solid particles through the air, recovery of the kinetic energy in whirling air and a large number of tests to determine the effect of changes in detail and proportions.

It is not our purpose to discuss the air-cleaner which resulted from this research and development, since that information is available from another source. The results of our experiments and measurements are given in the hope that they may be of value to those interested in this problem from any angle and that our work may contribute in its small way to the betterment of the industry.

[1] Special problems section, General Motors Research Corporation, Dayton, Ohio.

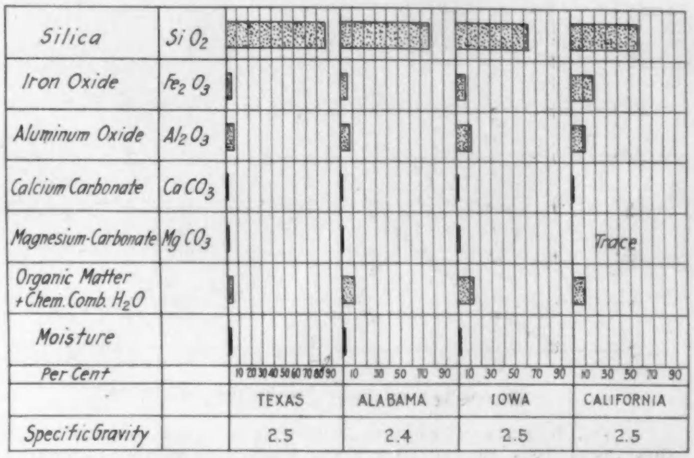


Fig. 1—Variation in the Chemical Composition of Dust

This Chart Gives the Chemical Analyses and the Specific Gravity of Air-Floated Field-Dust Caught in Air-Cleaners Operating in Four Different States. In These Samples More than Half the Mass Is Silica with Varying Quantities of Iron and Aluminum Oxides, the Remainder Being Small Percentages of Calcium and Magnesium Carbonates

The Dust Problem

The dust problem in some of its phases is much older than the automotive industry. In a number of industrial processes, dust becomes so dense as to endanger the health of the workmen and, if the particles are of combustible matter, constitutes a possible cause of explosion. The Government, through the Bureau of Mines, has been concerned with dust in coal mines, cement and flour mills, wood-working and leather-working factories, textile factories and other industries which have dust problems. In this connection, many determinations have been made that deal with such details as the rate of fall of dust particles of various densities and sizes, particle count per cubic foot, and time required for dust density to become maximum for different rates of agitation, fall and ventilation. Conditions have been remedied in many ways by ventilation, by removal of the dust at its source by a vacuum system and by the use of filters, air-washing devices and centrifugal separators, in conjunction with means for the protection of the individual who may inhale the particles.

The automotive industry is particularly interested in road and in field dust in its relation to the wear of engines and other operating machinery. Very early in the development of the automobile, it was found necessary to house-in all gears and bearings and operate them in an oil-bath. It is not possible thus to isolate the engine itself since, to operate, it must consume large volumes of air that makes contact directly with cylinder-walls, thus exposing these high-speed bearing-surfaces to any dust which may be present in the atmosphere. The only logical means of protecting the engine from this un-

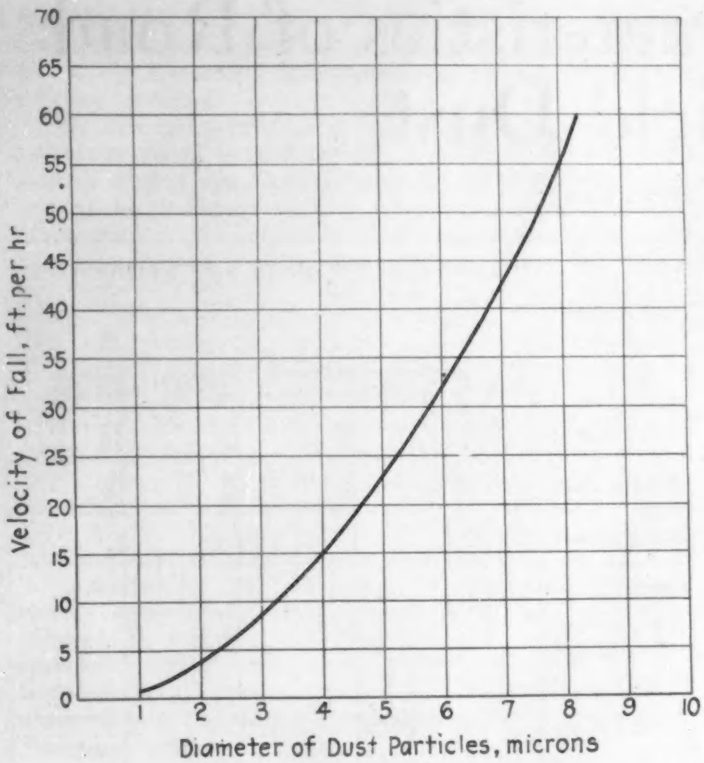


FIG. 2—RATE OF FALL OF PARTICLES OF LIKE DENSITY
This Curve Was Plotted from Data Furnished by the Bureau of Mines. The Particles Were of Various Sizes but of the Same Density, 2.5. The Relation Shown by the Curve Holds Only for Very Fine Particles

necessary wear is to remove the abrasives from the air before it enters the cylinders.

PHYSICAL DATA

Chemical analyses of road and of field dust show that samples taken from different States vary considerably in composition. Ninety to 98 per cent by weight is mineral matter. Road-dust particles of different chemical composition do not differ materially in abrasive character. Fig. 1 gives the chemical analyses of air-floated field-dust caught in air-cleaners operating in the States indicated. In these samples, more than half the mass is silica with varying quantities of oxides of iron and aluminum, the remainder being small amounts of carbonates of calcium and magnesium. Organic matter rarely exceeds 10 per cent in field dust, and forms a still lower percentage of road dust.

The specific gravity of dust particles varies somewhat, but it is about 2.5, which corresponds very closely to that of quartz. Contrary to popular opinion, therefore, dust is not in itself a light substance. The ability of dust to float in the air for a length of time is a function of its size, rather than of its specific gravity. This is due to the greater ratio of area to volume as the size of the particle grows less. The volume of a cube or a sphere varies as the cube of the lineal dimensions, while the

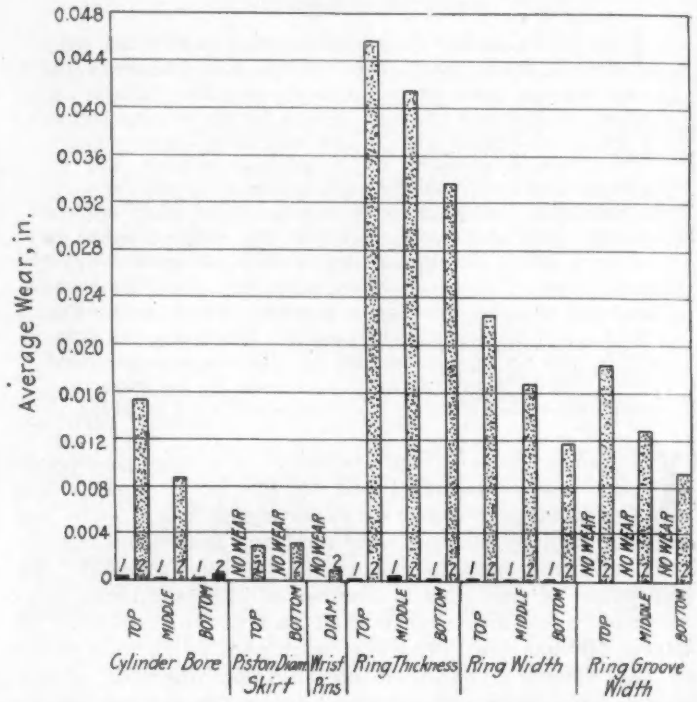


FIG. 4—RELATIVE WEAR OF A STANDARD FOUR-CYLINDER ENGINE WHEN OPERATED FOR 36 HR. WITHOUT DUST AND WHEN 300 GRAMS (0.661 LB.) OF DUST WAS FED TO IT IN THE SAME LENGTH OF TIME
The Engine Was Operated at Half-Load at a Speed of 1500 R.P.M. The Column Marked 1 Shows the Amount of Wear after 36 Hr. of Operation without Dust; Column 2 Gives the Same Information for 36 Hr. of Operation without an Air-Cleaner and after 300 Grams (0.661 Lb.) of Dust Had Been Fed to It. The Greatest Wear Occurred on the Top Piston-Ring and the Top of the Cylinder

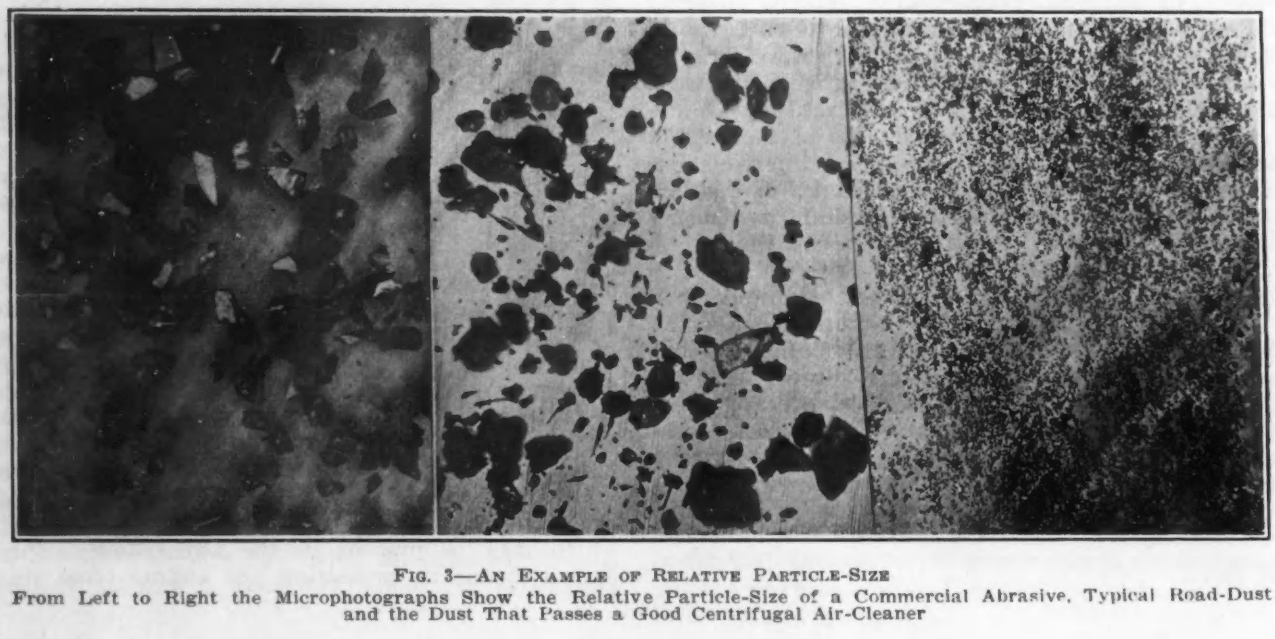


FIG. 3—AN EXAMPLE OF RELATIVE PARTICLE-SIZE
From Left to Right the Microphotographs Show the Relative Particle-Size of a Commercial Abrasive, Typical Road-Dust and the Dust That Passes a Good Centrifugal Air-Cleaner

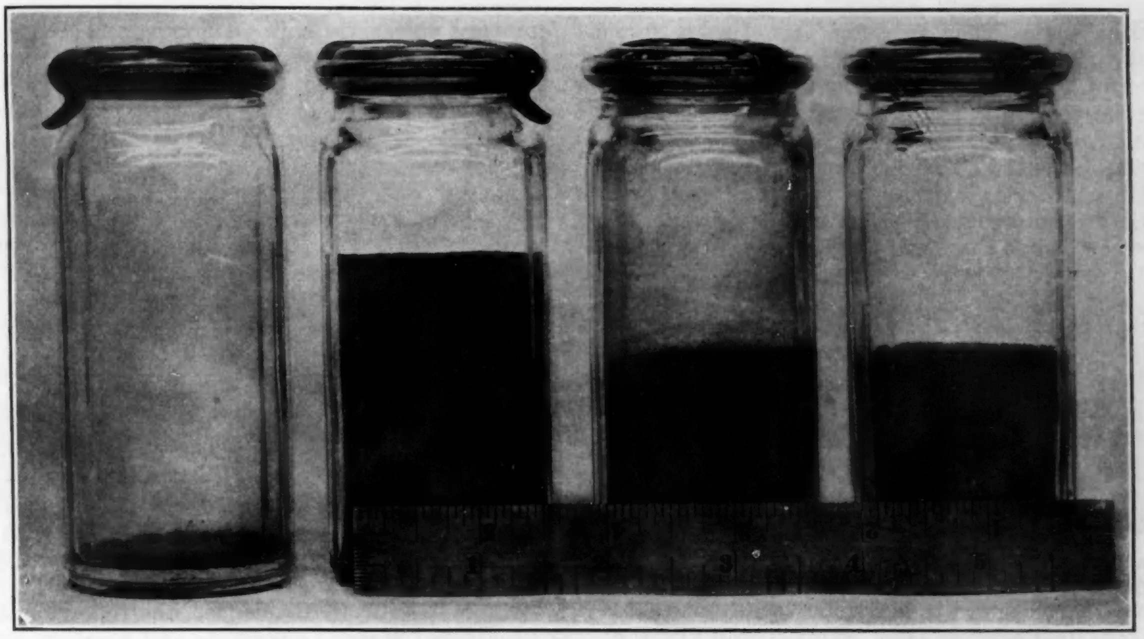


Fig. 6—Dust Caught in the Centrifugal Air-Cleaners Attached to Four Cars on a 2000-Mile Test Run
The Run Was Made through Oklahoma and Texas and for about One-Third of the Distance the Road Was Dusty. The Bottles from Left to Right Show the Order in Which the Cars Were Driven, the Cars Following Each Other Closely and the Second Car in Particular Keeping within a Few Yards of the Leader. The Air-Cleaner on the Leading Car Caught 0.13 Oz. of Dust. While That on the Second Car Caught 3.62 Oz. or More than 27 Times as Much

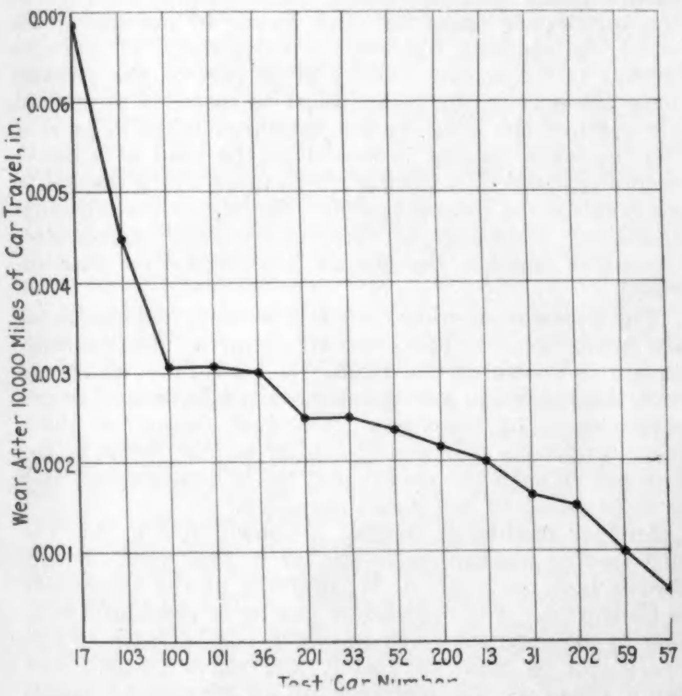


Fig. 5—Relative Cylinder Wear after 10,000 Miles of Car Travel
The Wear Was Measured on 14 Test-Cars, Including 10 Standard Makes, That Were Driven on Paved and Gravel Roads around Dayton, Ohio. This Chart Is Interesting Because of the Marked Difference in Cylinder Wear between the Cars of This Group. The Engine Showing the Greatest Wear Is That of a High-Grade Expensive Car and the One Showing the Least Is in a Moderate Priced Car

surface varies as the square of the dimensions. For very small particles, the viscosity of the air is an important factor.

Fig. 2 shows a curve of the rate of fall of dust particles of various sizes, but of the same density. It is noted that a size of particle is finally reached at which its weight is not sufficient to move it at any considerable velocity against the friction and viscosity of the air. Thus, when a large number of particles of varied sizes are thrown into the air by any violent agitation such as that caused by the wheels of a vehicle, the larger ones fall rapidly and remain suspended only a few seconds. The smaller the particles are, the longer will they remain suspended, until the very finest fall so slowly that the eddy currents of the wind tend to carry them upward; so, apparently, they float suspended in the atmosphere.

When dust particles are examined under a microscope, they are found to consist of crystals that appear to be very hard and have sharp edges. There is a difference in the color of dust coming from various localities but, otherwise, the dust possesses very much the same characteristics. So far as has been observed in practice, no dust exists which is harmless, due to its softness and

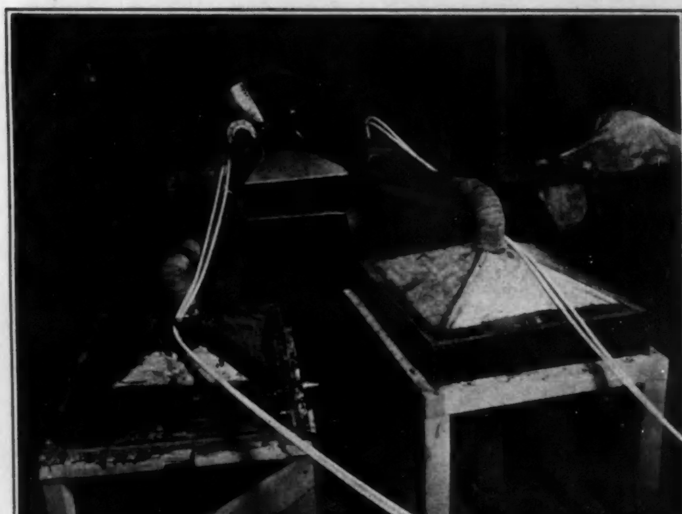


Fig. 7—Laboratory Dust-Room in Which Air-Cleaners Are Tested and Compared under Conditions That Are Very Similar to Those under Which They Must Operate in Practice
In This Method a Blower That Is Located in Another Corner of the Room Agitates the Dust to Any Desired Density. The Dust Formation under These Conditions Is Precisely Similar to That Found in the Field and on the Road except That the Laboratory Dust May Be Finer Owing to Less Direct Agitation

lack of cutting edges. The very fine particles are found to be somewhat less abrasive than an equal weight of coarse material. The microphotographs exhibited in Fig. 3 show the relative appearance of a commercial abrasive such as fine Grade A Cloverleaf grinding-compound, typical road dust and the dust which passes through a good centrifugal air-cleaner. Dust particles in all soils vary from the coarsest material down to tiny crystals that are just visible with a microscope of 500-diameter magnifying capacity, and no doubt even smaller particles are present.

The coarsest particles that an automobile engine may draw-in, when following closely or passing another car, may be 0.010 in. in diameter or even larger. Particles still in the air 2 min. after a vehicle has passed are approximately 0.00025 in. in diameter. The average particle-size of the bulk of the dust is about 0.001 in. in diameter.

Relation of Dust to Engine Wear

The abrasive action of dust depends upon its amount and coarseness, the material and the speed of the rubbing surfaces, and lubrication. It is evident that, to scratch the surface, the dust particle must be greater in diameter than the thickness of the oil-film. Where dust is present, it is always noted that more wear exists at the top than at the middle or the bottom of the cylinder. Undoubtedly, this is due to the fact that the surface is exposed to dust lodgment during a greater period of time; also, because the lubricating film is thinner in this region.

Fig. 4 shows the relative wear of the parts of a four-cylinder engine operated without dust, and operated when 300 grams (0.661 lb.), of dust was fed to it. It will be observed that the greatest wear is on the top piston-ring and at the top of the cylinder. The run being relatively short, the wear of parts when no dust was fed was practically nil. The fact that this quantity of dust completely wore the engine out shows that, in practice, great quantities of dust are not ordinarily drawn-in. It is known that an engine operated in a dustless atmosphere will not last forever. Under certain conditions of high temperature of lubricant, of high dilution and of heavy load, metal-to-metal contact exists at certain points and this results in wear.

The curve in Fig. 5 shows the cylinder wear for 10,000 miles of car travel on a number of test cars driven on paved and on gravel roads around Dayton, Ohio. We are unable to explain the marked difference in cylinder wear between the cars of this group. The engine showing the greatest wear is that of an expensive high-grade car; the one showing the least wear is in a moderate-priced car. Neither of these is a product of the General Motors Corporation. This test should not be made the basis of far-reaching conclusions concerning the merit of individual cars, but it serves to show that, under average good conditions, a cylinder wear of 0.002 to 0.003 in. can be expected in 10,000 miles. None of the cars in the test was equipped with an air-cleaner. Some less authentic figures which we have collected indicate that cars operated altogether on unpaved roads in the Southwest show an average wear in cylinder diameter of 0.005 in. per 10,000 miles.

The actual quantity of dust to which an automobile engine is exposed varies from practically nothing on paved roads to as much as 1 oz. per 100 miles when closely following another car on dusty roads. This latter condition is never realized except for test purposes; for personal reasons, the average driver does not make a practice of trailing another car closely in the dust.

Fig. 6 shows the dust caught in the air-cleaners of four cars driven through Oklahoma and Texas on a test run. From left to right, the bottles show the order in which the corresponding cars were driven. The roads were dusty and the cars followed each other closely, particularly the second car, which kept within a few yards of the leader. The air-cleaner on the leading car caught 0.13 oz. of dust; the air-cleaner on the second car caught 3.62 oz., or more than 27 times as much. No figure can be set for the average quantity of dust that an unprotected engine breathes-in during 1 year; but, from considerations of average wear and many measurements of actual dust caught, it can be approximated closely as being 0.5 oz. when the car is operated principally on paved roads and 2.0 oz. when the operation is largely on unpaved roads.

Methods of Testing Air-Cleaners

In comparing or developing air-cleaners, a great amount of quantitative testing is necessary. It is essential that test conditions either be identical with those to which the cleaner is subjected in practice or differ from the practical condition by a known factor. In making a laboratory test of an air-cleaner, the following apparatus is necessary: Means to regulate and measure the rate of airflow so that the cleaner can be operated at the extremes of the requirements of the engine which it is intended to serve; manometers connected to measure the resistance of the air-cleaner at each airflow; and accurate means for determining the amount of dust which the air-cleaner takes out and leaves in the air, from which its cleaning efficiency is calculated. If the air-cleaner tested depends wholly or in part on the airblast from the engine fan, means must be installed to give an air velocity the same as the measured velocity back of the fan when the car is driven on the road at a corresponding speed. In testing air-cleaners which depend to some extent for their proper functioning on the vibration of the car, installing and running an out-of-balance electric-motor supplies the cleaner with vibration thus induced.

Fig. 7 shows one corner of the dust room and apparatus set up for test, including two air-cleaners. The vibrator fixture is shown at the right. A blower by which the dust is agitated to any density desired is located in another corner of the room. The dust formation under these conditions is precisely similar to that found in the field and on the road, except that the laboratory dust may be finer owing to less direct agitation.

Another method of testing is shown in Fig. 8. The dust-feeding mechanism is similar to that used for air-cleaner tests by Prof. A. H. Hoffman at the University of California. This method of testing is especially valuable in development work in which comparisons in efficiency can be made accurately and conveniently. Any figure given as the efficiency of an air-cleaner means nothing unless it is accompanied by the size of dust particles with which the test was made. The usual fault in testing and rating air-cleaners is to use fine sand or other material much coarser than average road-dust and, thus, greatly to overestimate the practical cleaning efficiency. It is possible to go to the other extreme, use dust much finer than average road dust and, by this means, lose the perspective of the relative all-round value of the air-cleaners tested. It is most practical to test an air-cleaner with a quality of dust as nearly as possible like that with which it must operate on the road.

Principles Employed in Air-Cleaners

Various methods of separating dust from air have been in use in the industry for many years. Considera-

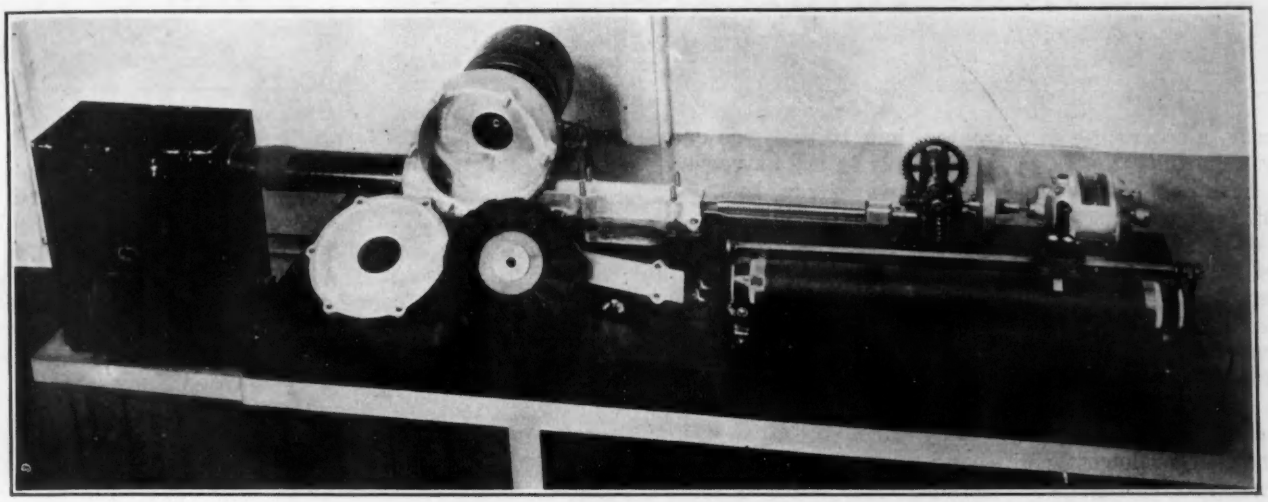


FIG. 8—ANOTHER METHOD OF TESTING AIR-CLEANERS
The Dust-Feeding Mechanism Employed Delivers a Carefully Weighed Quantity of Dust, Which Has Been Thoroughly Mixed, into the Airstream. This Method of Testing Is Especially Valuable in Development Work Where Comparisons in Efficiency Can Be Made Accurately and Conveniently

tion of the relative characteristics of air and of dust at once suggests the methods which have been employed successfully. If we draw a mixture of air and dust through water, oil or other liquid, a tendency exists for the dust to adhere to and sink in the liquid and for the air to flow on through. Again, if a mixture of dust and air be passed through a filtering material, such as specially prepared cloth, the air passes through the minute openings while the dust particles, being solid substances and having a definite size, remain entangled in the fibers of the material. When a mixture of air and dust is rotated rapidly, or is made to turn a corner sharply, the greater inertia of the dust particles, which are approximately 2140 times heavier than air, makes them tend to continue in a straight line while the air turns the corner. The dust, therefore, separates itself from the air by virtue of its difference in specific gravity. All these principles used for cleaning air have their strong points, which commend them under particular circumstances.

Passenger-Car Air-Cleaner Essentials

The qualities of an ideal air-cleaner are that: it offer no restriction; accomplish perfect cleaning; require no attention, renewals or service; be rattleproof, failure-proof, compact and adaptable; have a good appearance; and be light in weight and low in cost. Different types of air-cleaner possess various groups of these qualities but, so far as I know, no one air-cleaner embodies all of them. It becomes necessary then to determine which qualities are most essential for the particular use under consideration. The tractor, the truck and the passenger-car present distinctly different problems. A heavy, bulky air-cleaner, requiring daily attention, is acceptable on a tractor, provided the cleaner is efficient and reliable. It is evident that other qualities are needed for passenger cars.

Apparatus of this nature developed at the laboratory can have value only as it is applicable to motor cars. We must, therefore, look beyond the device itself, consider its relation to the motor car of which it is to become a part and measure its value in terms of the added utility, service and satisfaction which the purchaser will find in its use.

The reason for installing an air-cleaner is a desire to protect the engine against dust. The cleaner must, therefore, be high in cleaning efficiency; otherwise it does not fulfil its purpose. Another requirement of equally great importance is that the cleaner shall not under any circumstances reduce the power or economy, or interfere otherwise with the satisfactory operation of the engine. This means that restriction must be low and stable. An air-cleaner should fit directly into the carbureter, thus avoiding the complication and restriction of long conduits and bends. It should require attention not more than once a year, and must be neat, compact, light and inexpensive.

It is not expected that the application of an air-cleaner will result in enabling an automobile to operate 10 years instead of 5 years. The actual abandonment of a car is not, usually, due to the engine having worn beyond repair, but rather to the entire car becoming obsolete, shabby and uneconomical to run longer. A good air-cleaner can and does make the normal life of the engine more satisfactory. It eliminates the annoyance of oil-pumping, leakage and noise, which follow in the wake of wear, and thus leaves in the mind of the owner that background of satisfactory service which automobile builders do well to establish among their customers.

A large share of the experimental work and the collecting of the data reported in this paper was borne by H. G. Kamrath and M. L. Blair, then connected with the Laboratory prior to their transfer to the A. C. Spark-Plug Co. I wish also to express my appreciation of the help and counsel given by other members of the Laboratory, including J. F. Taylor, C. L. Lee, E. S. Patch, H. C. Mougey and C. H. Butts.

HOW HARD DOES A CAR STEER

(*Concluded from p. 188*)

quently, a steering-effort greater than 10 to 1 was necessary. Because this gear is reversible in the extremes, it will be noted that, after the turn was made, the wheel-effort from y to z decreased much more rapidly than did the drag-link stress from y_1 to z_1, thus showing a decidedly self-righting effect.

On the other hand, the right-hand turn made from a_1 to b_1, when compared with the resulting drag-link stress from a_2 to b_2, is in a proportion less than 10 to 1, because the part of the variable-ratio steering-gear that was used had a ratio greater than 10 to 1. In this case the self-righting effect is much less.

The last or lowest right-hand turn shown in Fig. 10 is more interesting, for it demonstrates not only the reversible characteristics of this particular steering-gear in the extreme position, but also the speed of the recording-instrument. After the right-hand cramp had been made, the wheel showed a rapid lessening of effort from c_1 to d_1, corresponding to the lessening of the drag-link stress from c_2 to d_2. At d_2, the front wheels struck some obstacle that reversed the stress suddenly from d_2 to e_2, and this line coincides with its rectifying curve. The wheel immediately reacted in the line d_1 to e_1, and this coincides with its rectifying curve. A resulting reaction in the drag-link occurred at e_2, again violently reversing the stress; this shows in the line from e_2 to f_2, and coincides with the rectifying line. The wheel line was instantly carried from e_1 to f_1 on its rectifying line. Therefore, as the lines d_2 to e_2, e_2 to f_2, d_1 to e_1, and e_1 to f_1 all follow coincident rectifying lines, any question as to the accuracy and the speed of the instrument should vanish. As the drag-link line, in this case, shows an instant reversal of stress of about 175 lb. and, as drag-links and joints are subjected to many hundreds of such changes, it shows why such parts do not always remain intact and why cars rapidly accumulate rattle.

The turns shown on this chart were made while driving on a straight street. The left-hand turns were made about as quickly as were those to the right. Just why the left-hand turns do not show so great effort as do the right-hand, I am not able to say, for the log is not clear as to this point. The effect is probably due to the fact that all left-hand-drive cars inherently steer more easily to the left than to the right by a considerable amount.

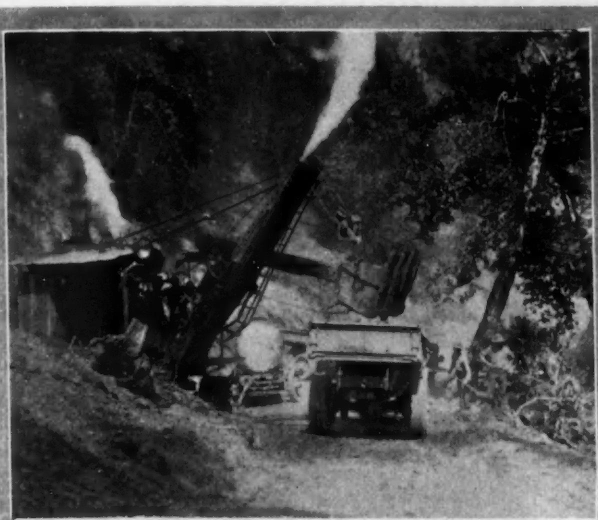
Effect When Car Hits Curb

Fig. 11 shows the effect when a car runs into an ordinary curb. Beginning at the top of the chart, while the car was in the middle of the street, practically no wheel-effort or drag-link stress is shown. From g_1 to h_1, a quick turn was made to the left. The drag-link reacted from g_2 to h_2. From i_1 to j_1 it ran straight at the curb. The left wheel struck at the point j_2, instantly increasing the drag-link stress at k_2 enormously. This stress immediately dropped to l_2 and followed the rectifying curve in both directions, showing instantaneous action. The car was then backed slowly and the instrument recorded what seemed to be an illogical production of curves caused by backward motion.

In other charts not shown, I have proved that, in ordinary cars, when not in motion, the drag-link stress ranges from 400 to 600 lb. or more. I have checked these results by disconnecting the drag-link and measuring the moments necessary to move the wheels on various kinds of street, with both high-pressure and balloon tires. I have proved that balloon tires require 50 per cent greater steering-effort than do high-pressure tires. As the accuracy of the instruments seems to be unquestioned, I suggest that reliable data relative to drag-link stresses should be secured. These might lead to a more satisfactory design of steering-gears, linkages and joints.

I have data proving that, in one high-grade popular car, a reduction of only a few ounces of steering-effort produced the difference between unsatisfactory and very satisfactory results. Such results should set-up certain standards of perfection, with data to show how they can be obtained. I also have data, secured in another way, that show differences of 450 per cent in the friction of steering-knuckle thrust-bearings as they are used today on cars of popular make.

Chart records should show the difference between the steering-effort required in cars having center-point steering and in those not having it. I am certain that such charts will show the story of shimmying, from the incipient causes through the subsequent violent stages. I have not yet had the fortune or misfortune to drive such a car. Manufacturers who may be interested in obtaining chart records of steering effects may, under certain conditions, obtain the use of these instruments.



Air-Cleaners on Trucks in Service

By A. H. Hoffman[1]

Annual Meeting Paper *Illustrated with* Photographs and Charts

ABSTRACT

UTILIZING an opportunity presented by a mountain-road construction-project in California, eight Class-B 3½-ton trucks were assigned to the work and a test of air-cleaners was conducted during its progress. Six trucks were each equipped with an air-cleaner; two were not. The trucks had dump-bodies and were specially prepared for the test, details of this preparation being specified.

Due to varied air-cleaner design, it was not feasible to locate the cleaners identically on all the trucks, and differences in mounting may have influenced the resulting air-cleaner efficiency, but mountings were made as nearly identical as possible. Tables of average wear of piston-rings, engine cylinders and crankpins, for 1000 hr. of use, are presented, and details of how the measurements were made are stated, together with a discussion of the "growth" of pistons and of the peculiarities of wear.

Other features of importance treated include statements of the amount of dust encountered, comparisons regarding oil consumption and analyses of carbon and sludge deposits. Seven essentials of a satisfactory road-test of air-cleaners are specified, and seven specific conclusions are reached.

AIR-CLEANERS are not particularly ornamental. Unless they can reduce engine wear by a considerable amount, the efficiency engineer will not install them. For some time, R. H. Stalnaker, equipment engineer of the California State Highway Commission, had been seeking a way to determine whether air-cleaners were worth installing on the hundreds of trucks under his supervision. In the spring of 1924, a requisition came in for eight dump-trucks for use on a mountain-road construction-job on the Redwood Highway near Cummings, Cal. Recognizing the opportunity for making a comparative test, he issued on the requisition eight Class-B 3½-ton trucks, and installed an air-cleaner on each of six of them, the commercial air-cleaner names being Pomona, Protectomotor, Stromberg, United, Wishon and Eiderdown. Two trucks were left unequipped with air-cleaners. The test was planned and executed by the Highway Commission, and the agricultural engineering division of the University of California cooperated.

Preparation of Engines for Test

The trucks were prepared in accordance with the following instructions:

(1) Select eight Class-B trucks, equipped with dump-bodies, that have been overhauled for delivery to this division. All to be in as nearly the same condition as possible

(2) Record truck and engine numbers, license numbers and odometer readings

(3) Equip each truck with an air-cleaner as directed

(4) Remove the pistons, clean them thoroughly with Oakite, dry and weigh them. Then measure their diameters both parallel to and at right angles to the wristpin hole, midway between the wristpin hole and the lower ring-groove and ½ in. above the lower edge of the skirt. Measure the width of the ring-grooves; the top, the second and the third

(5) Equip the pistons with new piston-rings. Weigh the rings and measure their width. Make the ring gage of 4.75 in. + 0.05-in. diameter bore, and measure the tip clearance of the rings when inserted in the gage

(6) Measure the cylinder diameter, parallel to and at right angles to the crankshaft; at the top, ½ in. below the extreme travel of the lower ring, and at the bottom ½ in. above the extreme travel of the upper ring. Make a hook gage to locate these points from the top surface of the cylinder-block

(7) Measure the crankshaft diameters at the crankpins, especially noting any eccentricity or flat spots

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Location of Air Intake

The intention was to locate the air intakes for all air-cleaners at the same relative place under the engine hoods. Because of the various shapes, sizes and operative characteristics of the several cleaners, it was not found feasible to make the locations identical. It seems entirely possible that, in several instances, these differences may have obscured entirely differences in air-cleaner efficiency. Thus, the outside placing and forward opening of the intake of air-cleaner No. 5, Eiderdown, probably was responsible in part for this cleaner's poor showing. The inlets, except that of air-cleaner No. 5, were all under the engine hoods. The heights above the ground were: No. 1, 58 in.; No. 2, 52 in.; No. 3, 46 in.; No. 4, 56 in.; No. 5, 48 in.; No. 6, 56 in.; and that of the two not having air-cleaners, 38.5 in. Fig. 1 shows the several positions. The two breather and oil-filler tubes on the engines of these trucks are covered by flap valves that open for outward pressures but seal against inward pressures. Hence dust could not enter by that route.

Inasmuch as air-cleaner No. 2, the Wishon, was broken before the end of the test, as shown in Fig. 2, and the time of the accident is unknown, all wear-data for truck No. 1188, which carried it, are omitted. The average wear for each part of each engine is given in Table 1.

Since the total time of use of the several trucks ranged from 1160 to 1345 hr., it seemed necessary to provide Table 2, which gives the average wear equivalent for 1000 hr. of use. The 1000-hr. basis was chosen rather than a mileage basis because several of the odometers were out of order either for the entire duration of the test or occasionally. At such times the driver estimated his mileage day by day. Tables 3 and 4 indicate that some estimates probably were higher, habitually, than others. As the work of all the eight trucks was similar and the engines of all were running almost without a stop during the 8 hr. of each shift, it seems that the 1000-hr. basis of comparison is as fair as can be had under the circumstances.

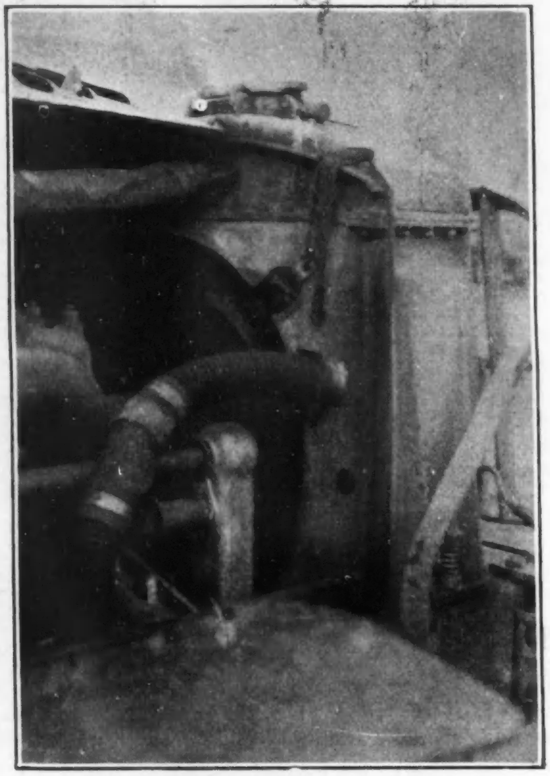

Fig. 2—Breakage During the Test
Due to Accident or to Vibration, the Tube Connection on the Wishon Cleaner Broke at Some Unknown Time during the Test and All Wear-Data for the Truck That Carried It Were Discarded

Fig. 1—Positions in Which Air-Cleaners Were Mounted
From Left to Right, Their Commercial Names Are United, Pomona, Stromberg, Protectomotor and Eiderdown. On the Engines Without Air-Cleaners, the Air Intakes Were Directed Backward, As Shown in the Lower Right-Hand Corner, and Had Their Inlets 38.5 In. above the Ground. On the Pomona, the Air Inlet Opened Forward until the Operator Added a Tin Elbow To Enable Him To Add Oil without Removing the Oil-Cup

TABLE 1—AVERAGE WEAR

Truck No.	Air-Cleaner No.	Ring-Grooves, In.			Rings				Cylinders, In.	Crankpins, In.
		1	2	3		Width, In.	Tip Clearance, In.	Weight, Grams		
1180	1	0.0008	0.0014	......	Top	0.0025	0.0170	2.340	0.0038	0.0021
	....	......	......	......	2	0.0008	0.0088	1.003	......	......
	....	......	......	......	3	0.0003	0.0073	0.715	......	......
1194	3	0.0036	0.0025	0.0025	Top	0.0028	0.0260	2.100	0.0033	0.0006
	....	......	......	......	2	0.0006	0.0103	0.853	......	......
	....	......	......	......	3	0.0007	0.0165	0.907	......	......
1744	4	0.0030	0.0016	0.0021	Top	0.0039	0.0451	3.788	0.0043	0.0014
	....	......	......	......	2	0.0013	0.0274	1.830	......	......
	....	......	......	......	3	0.0005	0.0244	1.355	......	......
1745	5	0.0050	0.0030	0.0045	Top	0.0076	0.0703	7.235	0.0042	0.0014
	....	......	......	......	2	0.0016	0.0338	3.070	......	......
	....	......	......	......	3	0.0008	0.0261	2.250	......	......
1746	6	0.0016	0.0010	0.0018	Top	0.0024	0.0274	2.700	0.0045	0.0004
	....	......	......	......	2	0.0008	0.0179	1.270	......	......
	....	......	......	......	3	0.0008	0.0120	1.000	......	......
1191	None	......	......	......	Top	0.0066	0.1248	9.778	0.0034	0.0011
	....	......	......	......	2	0.0019	0.0675	4.823	......	......
	....	......	......	......	3	0.0014	0.0525	3.348	......	......
1753	None	0.0055	0.0029	0.0025	Top	0.0059	0.0985	7.405	0.0034	0.0011
	....	......	......	......	2	0.0023	0.0438	2.905	......	......
	....	......	......	......	3	0.0014	0.0343	2.248	......	......

In Table 5 and in Fig. 3, the equivalent average wear for 1000 hr. is reduced to a percentage basis to facilitate comparison. The average wear, part by part, for the two engines unequipped with air-cleaners is taken as being 100-per cent wear.

In Table 3, hours of work, miles traveled, fuel consumption, oil consumption and the record of the number of drivers, troubles and the like are given as a total and also as the percentage each item is of the average. Table 4 gives the same data reduced to the equivalents for 1000 hr. of work. Fig. 4 shows the same data graphically. Table 6 gives the average data of the oils used in the crankcases of four trucks, three of which were equipped with air-cleaners, including mileage before draining, specific gravity at 60 deg. fahr., flash-point and burning-point temperatures, viscosities at 100 and at 210 deg. fahr., and percentage of dilution and similar data for the same oils unused are presented in Table 7.

TABLE 2—AVERAGE WEAR PER 1000 HR.

Truck No.	Air-Cleaner No.	Ring-Grooves, In.			Rings				Cylinders, In.	Crankpins, In.
		Top	2	3		Width, In.	Tip Clearance, In.	Weight, Grams		
1180	1	0.0006	0.0011	......	Top	0.0019	0.0127	1.754	0.0028	0.0016
	....	......	......	......	2	0.0006	0.0066	0.753	......	......
	....	......	......	......	3	0.0002	0.0055	0.535	......	......
1194	3	0.0028	0.0019	0.0019	Top	0.0021	0.0199	1.612	0.0025	0.0005
	....	......	......	......	2	0.0005	0.0079	0.654	......	......
	....	......	......	......	3	0.0005	0.0126	0.695	......	......
1744	4	0.0023	0.0012	0.0016	Top	0.0030	0.0347	2.911	0.0033	0.0011
	....	......	......	......	2	0.0010	0.0211	1.406	......	......
	....	......	......	......	3	0.0004	0.0188	1.041	......	......
1745	5	0.0042	0.0025	0.0038	Top	0.0064	0.0588	6.050	0.0035	0.0012
	....	......	......	......	2	0.0013	0.0283	2.568	......	......
	....	......	......	......	3	0.0007	0.0218	1.882	......	......
1746	6	0.0012	0.0007	0.0013	Top	0.0018	0.0204	2.007	0.0033	0.0003
	....	......	......	......	2	0.0006	0.0133	0.944	......	......
	....	......	......	......	3	0.0006	0.0089	0.743	......	......
1191	None	......	......	......	Top	0.0055	0.1032	8.075	0.0028	0.0009
	....	......	......	......	2	0.0016	0.0558	3.970	......	......
	....	......	......	......	3	0.0012	0.0434	2.765	......	......
1753	None	0.0047	0.0025	0.0022	Top	0.0051	0.0850	6.382	0.0029	0.0009
	....	......	......	......	2	0.0020	0.0378	2.505	......	......
	....	......	......	......	3	0.0012	0.0296	1.938	......	......
Average, No Air-Cleaner		0.0047	0.0025	0.0022	Top	0.0053	0.0941	7.229	0.0029	0.0009
		......	......	......	2	0.0018	0.0468	3.238	......	......
		......	......	......	3	0.0012	0.0365	2.352	......	......
Average, All Having Air-Cleaner		0.0022	0.0015	0.0022	Top	0.0030	0.0293	2.867	0.0031	0.0009
		......	......	......	2	0.0008	0.0154	1.265	......	......
		......	......	......	3	0.0005	0.0135	0.979	......	......
Average, All Having Air-Cleaner under Hood		0.0017	0.0012	0.0016	Top	0.0022	0.0219	2.071	0.0030	0.0009
		......	......	......	2	0.0007	0.0122	0.939	......	......
		......	......	......	3	0.0004	0.0115	0.754	......	......

TABLE 3—SERVICE RECORD; TOTALS AND PERCENTAGES OF AVERAGE

Truck No.	Air-Cleaner No.	Working Time, Hr.	Miles Traveled	Gasoline, Gal.	Oil, Qt.	Number of Drivers	Remarks
1180	1	1,334 105.3	3,409[a] 128.9	1,764 105.6	394 120.3	7	Air leak at carbureter inlet.
1188	2	1,296 102.3	2,885 109.2	1,946 116.5	310 94.5	6	Cleaner found broken at end of test. Air leak at carbureter inlet.
1194	3	1,304 102.9	2,767 104.7	1,592 95.2	302 92.1	6	
1744	4	1,301 102.7	2,420[a] 91.6	1,684 100.8	346 105.5	3	Cleaner found dismantled at end of test.
1745	5	1,196 94.5	2,007 76.	1,503 89.8	335 102.1	1	Pieces of valve head found in intake-manifold.
1746	6	1,345.5 106.3	2,338[a] 88.5	1,679 100.5	357 108.8	3	
1191	None	1,210.5 95.6	2,888 109.3	1,699 101.7	329 100.3	4	
1753	None	1,160 91.6	2,424[a] 91.8	1,504 89.9	254 77.4	5	
1191 and 1753 Average	None	1,135 89.6	2,656 100.5	1,602 95.8	292 89.1	4.5	
Totals Average		10,147 1,267	21,138 2,642	13,371 1,671	2,627 328	25 4.4	

[a]Mileage estimated day by day; odometer not working.

How the Measurements Were Taken

In addition to the usual micrometer measurements of piston, cylinder and crankpin diameters, and of widths of ring and of ring-grooves, the weights of pistons and of piston-rings were taken by balances. The tip clearance of the rings, when placed in a special ring-gage shown in Fig. 5, was obtained by taper gage or by thickness gages. This measurement was taken in lieu of ring thickness and, as was anticipated, it was found to give a distance relatively larger and therefore easier to measure accurately. Also, in this way, the need of measuring the distance between the outer and the inner curved surfaces of the rings was avoided. The use of a solid taper-gage was found necessary. A bunch of thickness-gage leaves used for this purpose proved unreliable. The original piston and piston-ring weights were taken on a Troemner-type balance. In the case of the former, the loss of weight by wear was found to be within the limits of error in the original weighings. Hence, the piston weights are omitted from the tables. The piston-ring weights were, relatively, more accurate.

The samples of used crankcase-oil were taken with engine hot and running for not less than 2 min. immediately before taking the sample. For the sampling, a special drain-cock was tapped-in at the lowest point of the oil-sump of each truck. These cocks were similarly placed; they were covered, to prevent mud from the out-

TABLE 4—SERVICE RECORD; TOTALS AND PERCENTAGES OF AVERAGE PER 1000 HR. OF WORK

Truck No.	Air-Cleaner No.	Miles Traveled	Gasoline, Gal.	Oil, Qt.	Remarks
1180	1	2,554[b] 122.7	1,322 100.2	295 114.0	Air leak at carbureter inlet.
1188	2	2,227 106.8	1,502 113.8	239 92.4	Air-cleaner found broken at end of test. Air leak at carbureter inlet.
1194	3	2,120 101.8	1,220 92.5	232 89.7	
1744	4	1,860[b] 89.4	1,294 98.1	255 102.8	Cleaner found dismantled at end of test.
1745	5	1,678 80.6	1,257 95.3	280 108.2	Pieces of valve head found in intake-manifold.
1746	6	1,737[b] 83.4	1,247 94.5	265 102.4	
1191	None	2,387 114.7	1,404 106.4	274 106.0	
1753	None	2,090[b] 100.3	1,297 98.4	219 84.7	
1191 and 1753 Average	None	2,214 106.4	1,355 102.7	238 92.0	
Average		2,081.6	1,318	258.8	

[b]Mileage estimated day by day; odometer not working.

TABLE 5—PERCENTAGE OF AVERAGE WEAR PER 1000 HR. AVERAGE WITHOUT CLEANERS TAKEN AS 100 PER CENT

Truck No.	Air-Cleaner No.	Ring-Grooves, In.			Rings				Cylinders, In.	Crankpins, In.
		Top	2	3		Width, In.	Tip Clearance, In.	Weight, Grams		
1180	1	12.8	44.0	......	Top	35.9	13.5	24.3	96.6	177.8
	....	......	......	......	2	33.3	14.1	23.3	......	......
	....	......	......	......	3	16.7	15.1	22.7	......	......
1194	3	59.6	76.0	86.4	Top	39.6	21.2	22.3	86.2	55.6
	....	......	......	......	2	27.8	16.8	20.2	......	......
	....	......	......	......	3	41.7	34.5	29.5	......	......
1744	4	49.0	48.0	72.7	Top	56.6	36.9	40.3	113.8	122.2
	....	......	......	......	2	55.6	45.0	43.5	......	......
	....	......	......	......	3	33.3	51.5	44.4	......	......
1745	5	89.4	100.0	172.5	Top	120.7	62.5	83.7	120.7	133.3
	....	......	......	......	2	72.2	60.3	79.4	......	......
	....	......	......	......	3	58.3	59.7	79.9	......	......
1746	6	25.6	28.0	59.1	Top	34.0	21.7	27.8	113.8	33.3
	....	......	......	......	2	33.3	28.4	29.2	......	......
	....	......	......	......	3	50.0	24.4	31.6	......	......
1191	None	......	......	......	Top	103.8	109.7	111.7	96.6	100.0
	....	......	......	......	2	88.9	119.3	122.7	......	......
	....	......	......	......	3	100.0	118.9	117.4	......	......
1753	None	100	100	100	Top	96.2	90.3	88.3	100.0	100.0
	....	......	......	......	2	111.1	80.3	77.5	......	......
	....	......	......	......	3	100.0	81.1	82.4	......	......
1191 and 1753 Average	....	100	100	100	Top	100.0	100.0	100.0	100.0	100.0
		......	......	......	2	100.0	100.0	100.0	......	......
		......	......	......	3	100.0	100.0	100.0	......	......

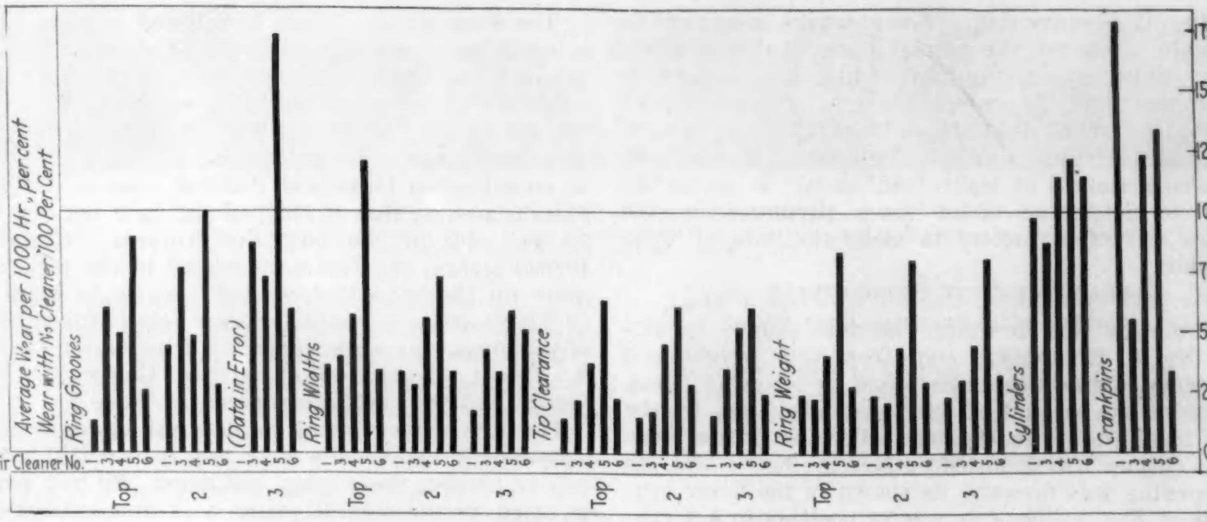

Fig. 3—Comparative Wear on a Percentage Basis
The Equivalent Average Wear for 1000 Hr. of Use Is Reduced to a Percentage Basis To Facilitate Comparison. The Average Wear, Part by Part, for the Two Engines Not Equipped with Air-Cleaners, Is Taken As Being 100-Per Cent Wear

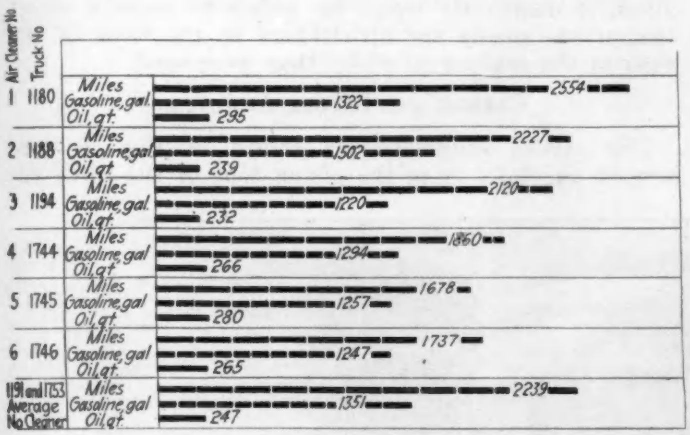

Fig. 4—Data of Table 4 Presented Graphically
Miles Traveled, Gasoline and Oil Consumption per 1000 Hr. of Work

side adhering to them and being washed into the sampling cans. The sample was, in each case, the first quart drained, and it was run directly into the can. The tests for viscosity and for flash-point and burning-point temperatures were made in accordance with the standard specifications of the Bureau of Mines, reported in one of its technical papers.[2] The percentage of dilution tests followed the transition method of M. E. Preble and T. S. Sligh, Jr., of the Bureau of Standards, which has been published.[3] The apparatus used for the dilution determinations was not altogether satisfactory and some of the values given may be in error. The specific gravities of the used oils were obtained by the submerged-body method. The sinker chosen displaced 29.22 grams of water at 60 deg. fahr.; hence, it was large enough to give readings of sufficient accuracy.

"Growth" of Pistons

It will be noted that the piston diameters are omitted from the tables of average wear. All or nearly all of the pistons were new when the original measurements were taken. Tests by others have shown that a new cast-iron piston will increase in size when subjected to the normal temperature-changes it encounters in use in an internal-combustion engine. In many cases, the final diameter-measurements of the pistons in this test were larger than the original. The "growth" evidently had exceeded the wear. We have no reason to think that this growth was apparent only; that is, caused by nearly constant errors in the original or final readings. The micrometers used were checked against secondary standards that, apparently, were in as good condition as when received from the well-known manufacturers.

Peculiarities of Wear

As can be noted, several cases exist in which cylinder wear was greater on diameters parallel to the wristpins than it was on diameters at right angles. This probably was due to lack of proper alignment of the several parts concerned. It will be observed that the actual wear, even in the engines not equipped with air-cleaners, was small as compared with what is often found in trucks operating in dust no more dense than was encountered by the trucks in this test. The chief reason seems to be found in the fact that the crankcases were drained once a week for the first 2 months and at about 10-day intervals during the remainder of the time. This promptly removed the accumulated dirt and maintained the viscosity high, as indicated in Fig. 6.

Oil Consumption Not the Same

The service records, presented in Tables 3 and 4, and the service graph of Fig. 4, show considerable differ-

Fig. 5—Special Ring-Gage
Tip Clearance Was Measured with the Piston-Rings Placed in a Ring Gage as Large as the Largest Over-size Cylinder on the Eight Engines

[2] See Bureau of Mines Technical Paper No. 323A.
[3] See The Journal, October, 1924, p. 334; January, 1925, p. 17.

ences in oil consumption. Some trucks required no additional oil between the regular times of draining and refilling, while others required additional oil more or less regularly. If the reason for low oil was a leaky crankcase, the constant addition of new oil would tend to maintain high viscosity and so reduce wear. The records show some instances of leaky crankcases. It seems impossible to determine under these circumstances the necessary correction factors to make the data of wear comparable.

Amount of Dust Encountered

The intention was to weigh the dust caught by air-cleaner No. 5, Eiderdown, and, from this weight and the efficiency of this cleaner as found by laboratory test, to determine the amount of dust contended with by the average truck-engine in the test. Because of its large size, this cleaner was mounted outside the hood; also, its intake opening was forward, as shown in the lower central view of Fig. 1. Thus, it was in position to get considerably more dust than the average amount entering the intakes under the hood. In addition, the appearance of the second layer of eiderdown indicated definitely that the cleaner had considerably lower efficiency on the long-time road-use than the 99.4-per cent efficiency it had shown in the laboratory tests of ½-hr. duration. The amount of dry dust caught was 160.52 grams in a mileage totalling 1733. This, uncorrected for the efficiency (unknown) of the cleaner, is equivalent to 0.0926 gram per mile.

The Pomona air-cleaner is believed to have furnished a much more accurate measure of the amount of dust encountered. This cleaner in its position under the hood as shown in the center of the upper row in Fig. 1 caught 188.1 grams of dry dust. The efficiency of this particular cleaner has not been tested but, from its similarity in construction to several Pomona cleaners tested, it is safe to assume that it stopped and held between 96 and 99 per cent of the dust that entered; assuming the former figure, the dust encountered in the total of 2550 miles for the truck that carried it would be 195.9 grams, or 0.0761 gram per mile. Screen and chemical analyses of this dust were made under the direction of Dr. Charles S. Bisson, division of chemistry, University of California, and the results are given in Table 8.

The air-cleaners having intakes well up under the hood undoubtedly had considerably less than 0.0761 gram per mile to handle; those lower had more. By how much less or more, in the several cases, it is impossible to determine at present. Since the several handicaps are unknown, yet were undoubtedly of very considerable weight in determining the amount of wear in the several engines, it manifestly would be unfair to make a direct comparison among the air-cleaners on the basis of the wear of the engines on which they were used.

Carbon and Sludge Analyzed

The carbon accumulations shown in Fig. 7 were scraped carefully from the piston tops of the three en-

Fig. 6—Condition of the Pistons after the Test
Actual Wear Was Small, Probably Because the Crankcases Were Drained Once Weekly for the First 2 Months and at About 10-Day Intervals Thereafter. This Removed the Dirt and Maintained a High Viscosity

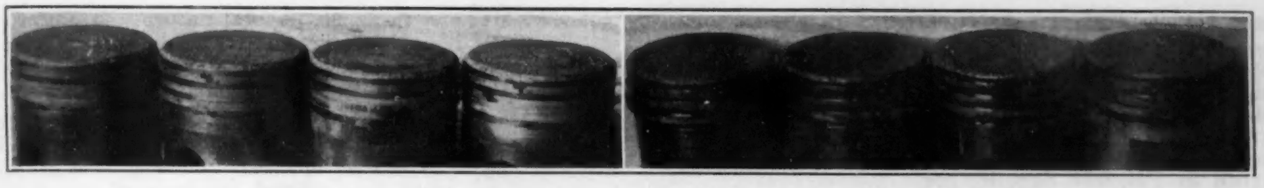

FIG. 7—CARBON DEPOSIT AFTER THE TEST
Three Engines Had Kept Their Cylinder-Heads in Place Thro ughout. No Outstanding Differences in the Amount of Carbon on the Tops of the Pistons Were Evident

gines that had kept their cylinder-heads in place throughout the test. A blunt putty-knife was used to prevent cutting the iron, and no attempt was made to get all the deposit. The amount left was approximately the same in each case. The results of Dr. Bisson's analysis are given in Table 9.

The screens in the oil-sumps of the four trucks whose crankcases had not been removed during the test were taken out carefully, and the accumulated sediment was collected. Analyses by Dr. Bisson are given in Table 10.

TABLE 6—DATA ON OILS USED IN CRANKCASES OF FOUR OF THE TRUCKS[4]

Truck No.	Oil No.	Mileage before Draining Crankcase	Specific Gravity at 60 Deg. Fahr.	Temperatures, Deg. Fahr.: Flash-Point	Temperatures, Deg. Fahr.: Burning	Viscosity, Saybolt Sec.: 100 Deg. Fahr.	Viscosity, Saybolt Sec.: 210 Deg. Fahr.	Dilution, Per Cent
1180	1	181.6	933.1	286.8	399.0	572.3	59.3	5.44
	2	111.0	928.9	266.4	363.6	630.9	62.6	6.14
1191	1	151.8	932.9	275.8	393.5	586.9	56.4	5.33
	2	103.5	930.5	275.0	380.7	603.1	59.0	4.93
1194	1	135.2	927.7	227.0	302.0	370.0	52.7	8.22
	2	116.0	923.5	213.5	272.1	405.1	54.8	9.22
1746	1	117.8	932.5	238.5	356.0	470.7	56.2	6.28
	2	70.6	927.1	227.9	320.7	502.4	59.1	6.64

[4] Trucks 1180, 1194 and 1746 were equipped with air-cleaners, truck 1194 was not.

OTHER DIFFERENCES UNACCOUNTED FOR

Accidents must be expected in any work. That there were not more from falling rocks and trees and from caving mountainsides is remarkable. Several accidents or troubles occurred that may have had a marked influence on the wear in the engines concerned, and two cases of leaks because of warped cylinder-heads. Five out of the eight engines had the cylinder-heads off for one cause or another. One had the cylinder-blocks removed. Two exchanged crankcases so that one of them might continue in service. The shovel fell on one truck and broke its frame, decreasing very considerably its mileage total and hours of service.

The different personalities of the 25 men who drove the 8 trucks enter as another indeterminable factor. One truck went through the season with a single driver; another had seven. Even if the carbureter adjustments had been sealed, it seems easily possible that the driver may have been the only reason for a case of greater dilution of oil and therefore greater wear. Some of the trucks were on the morning shift, from 4:00 a. m. to noon; the remaining trucks worked from noon to 8:00 p. m. This difference possibly had little, if any, effect.

As to the nature of the work, there was little difference. Other than hauling rock and earth from the shovels to the dumps at the edges of the fill, the work purposely was distributed among the trucks. This special work was infrequent and consisted of trips to town for cement, coal and steel, and to the rock crusher and gravel-washing plant for the aggregates to be used in the concrete work.

The curiosity of the American traveling public is another unknown factor that cannot be evaluated in this

TABLE 7—DATA ON UNUSED LUBRICATING OILS, BOTH OF WHICH WERE OBTAINED FROM WESTERN CRUDES

Oil No.	1	2
Specific Gravity at 60 Deg. Fahr.	939.9	935.3
Flash-Point, deg. fahr.	390.0	395.0
Burning Point, deg. fahr.	447.5	463.3
Viscosity at 100 Deg. Fahr., Saybolt sec.	646.2	964.7
Viscosity at 210 Deg. Fahr., Saybolt sec.	59.0	68.6
Dilution Subtrahend[5]	3.9	4.5

[5] See THE JOURNAL, October, 1924, p. 334.

case. Any newfangled contraption arrests the attention and interest of the passerby. Possibly this may account for the fact that one cleaner had been dismantled at some time during the test and was not reassembled properly, thus causing a considerable leak of dusty air. It would seem that, to guard against such contingencies and against possible malicious interferences, the engine hoods should be padlocked securely; but, on a test that is secondary to the main objective, this clearly would be out of the question.

AIR-CLEANER TEST SECONDARY

Moving earth at minimum cost and in maximum amount was the very laudable objective of the engineer in responsible charge of the road-construction job. The taxpayers footing the bill would require no less of him. The air-cleaner test was an interesting and worthwhile matter, but a secondary one. Hence, it would have been surprising had the test resulted in every respect as one might have hoped. No one in particular is to blame for the fact that direct comparisons of air-cleaners cannot be based with any fairness on the results of this test. On the contrary, the engineer in charge has undoubtedly made possible a considerable increase in the store

TABLE 8—CHEMICAL AND SCREEN ANALYSES OF DUST FROM DUST COLLECTOR ON ONE OF THE TRUCKS

Total Solids in Sample, grams	188.10
Screen Analysis on 50-Gram Sample	
Passed 200-Mesh Screen, grams	46.49
Passed 200-Mesh Screen, per cent	92.98
Passed 150-Mesh, but Retained on 200-Mesh Screen, grams	1.54
Passed 150-Mesh, but Retained on 200-Mesh Screen, per cent	3.08
Passed 100-Mesh, but Retained on 150-Mesh Screen, grams	1.05
Passed 100-Mesh, but Retained on 150-Mesh Screen, per cent	2.10
Retained on 100-Mesh Screen, grams	0.41
Retained on 100-Mesh Screen, per cent	0.82
Lost in Course of Analysis, grams	0.51
Lost in Course of Analysis, per cent	1.02
Chemical Analysis of Sample	
Weight of Sample, grams	0.5000
Weight after Ignition, grams	0.4499
Loss on Ignition, grams	0.0501
Loss on Ignition, per cent	10.02
Abrasives, grams	0.4263
Abrasives, per cent	85.26
Silica, grams	0.2367
Silica, per cent	47.34

TABLE 9—ANALYSIS OF CARBON DEPOSITS ON PISTON TOPS

Sample	1194	1746	1753
Total Weight, grams	9.030	13.500	12.740
Solids, grams	6.972	9.192	10.087
Solids, per cent	77.21	68.09	79.17
Carbon, grams	5.561	7.806	7.586
Carbon in Solids, per cent	79.75	85.05	75.25
Carbon in Original Sample, per cent	61.50	57.80	59.60
Abrasives, grams	0.119	0.184	0.341
Abrasives in Solids, per cent	1.707	2.004	3.380
Abrasives in Original Sample, per cent	1.317	1.363	2.675
Silica, grams	0.086	0.132	0.254
Silica in Solids, per cent	1.228	1.431	2.510
Silica in Original Sample, per cent	0.950	0.973	1.988
Copper	None	None	None
Iron, grams	0.105	0.122	0.379
Iron in Solids, per cent	1.510	1.330	3.760
Iron in Original Sample, per cent	1.160	0.900	2.970
Ratio of Abrasives to Silica	1.390	1.400	1.350

of knowledge on the subject, and he is certainly to be commended for the fine spirit of cooperation which was apparent throughout the tests.

Essentials of a Satisfactory Air-Cleaner Road-Test

(1) The test itself must be the main object in the operation of the vehicles

(2) The test must be in responsible control of one person who carries out a well-considered plan designed to secure uniformity of conditions in and for all the vehicles concerned

(3) The tests on any air-cleaner should be run at least in duplicate, preferably in triplicate

(4) The several drivers should exchange vehicles according to a definite plan. They should be instructed as to the general nature and objects of the tests, and particularly as to their part and its importance. Their interest and loyalty to the program are highly important

(5) All air-cleaners and unequipped carbureters must take their air from a standard place under the hood. The inlet opening, unless it be a multiple one, must face toward the rear of the vehicle. When necessary, flexible metal-tubing well taped can be used to extend from the inlet on the air-cleaner to the standard inlet-position

(6) Engine hoods must be sealed or locked against unwarranted interference

(7) Every vehicle and every air-cleaner must be inspected daily, and a complete record kept of any troubles or accidents. Air-tightness of all cleaner and carbureter connections is of prime importance. Accidental troubles or defects must be remedied before the vehicle re-enters the test

TABLE 10—ANALYSIS OF MATERIAL REMOVED FROM OIL STRAINERS

Sample	1180	1191	1194	1746
Total Weight, grams	21.950	66.870	48.800	55.700
Solids, grams	7.012	29.940	3.047	10.047
Solids, per cent	31.95	33.77	6.24	18.04
Abrasives, grams	1.006	6.187	0.268	1.488
Abrasives in Solids, per cent	14.36	20.65	8.82	14.81
Abrasives in Original Sample, per cent	3.15	9.25	0.55	2.67
Silica, grams	0.677	4.374	0.202	0.984
Silica in Solids, per cent	9.67	14.62	6.63	9.79
Silica in Original Sample, per cent	3.09	6.54	0.41	1.77
Copper, grams	0.117	0.628	0.015	0.240
Copper in Solids, per cent	1.67	2.10	0.49	2.39
Copper in Original Sample, per cent	0.37	0.94	0.03	0.43
Iron, grams	2.230	6.420	0.561	3.300
Iron in Solids, per cent	31.90	21.40	18.40	32.80
Iron in Original Sample, per cent	10.20	9.61	1.15	5.93
Ratio of Abrasives to Silica	1.49	1.42	1.33	1.51

Since, in a number of respects, as already has been pointed out, the tests here reported did not meet these requirements, it evidently would be unjust to make direct comparisons on the basis of the wear in the several engines. For this reason, the names of the air-cleaners have been withheld so far as comparisons are concerned. It was indicated by this test that:

(1) In a service test involving several uncontrollable variables, no just comparisons can be drawn among air-cleaners not differing greatly in efficiency

(2) Nevertheless, such a service test may yield valuable data, especially if, instead of one, several air-cleaners of a kind are entered and the results averaged

(3) Frequent changing of crankcase oil and consequent maintenance of higher viscosity markedly reduces engine wear

(4) Placing the air inlet high up and well back under the hood lessens the quantity of dust encountered

(5) The air inlet should face forward. A rearward opening acts as an inertia-type dust-separator

(6) An air-cleaner is a needed and worthwhile truck-engine accessory

(7) For certain types of air-cleaner, a short-duration laboratory-test of efficiency is inconclusive, unless supplemented by one or more long-time tests

After the tables had been made up and the graphs drawn, it was observed that the records did not include the 250-mile run in about 20 hr. which each truck made from the shops of the Highway Commission at Sacramento to the scene of the work about 45 miles beyond Willetts. Any exact comparisons that may be made should have these added mileages taken into account. However, as has been pointed out, exact comparisons on a mileage basis are inadmissible here since some of the odometers were not working, the mileages in such cases being estimated.

Applicants *for* Membership

The applications for membership received between Dec. 15, 1924, and Jan. 15, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLEN, JAMES G., engineer, Beneke-Kropf Mfg. Co., *Chicago.*

ALLMERS, DR. R., geheimrat, Hansa-Lloyd Werke A.-G., *Bremen, Germany.*

ALSBERGE, VICTOR L., garage foreman, Brooklyn Edison Co., Inc., *Brooklyn, N. Y.*

ANDREW, T. M., JR., treasurer, Robert H. Hassler, Inc., *Indianapolis.*

ASKE, IRVING E., president and general manager, Kase Electric Co., *Minneapolis.*

BAGGALEY, RALPH, JR., inspector, Durant Motors, Inc., of New Jersey, *Elizabeth, N. J.*

BLACKBURN, LEONARD ANDERSON, plant engineer, Olds Motor Works, *Lansing, Mich.*

BLAIR, F. R., treasurer and general manager, Edward V. Hartford, Inc., *Jersey City, N. J.*

BOLIN, C. H., automotive engineer, Pacific Telephone & Telegraph Co., *San Francisco.*

BROTZ, ANTON F., SR., research engineer, Kohler Co., *Kohler, Wis.*

BROWN, KNOX T., general service-manager, Packard Motor Car Co. of Boston, *Allston, Mass.*

BUNDY, JAMES A., chief engineer of motor trucks, Fort Wayne Works of International Harvester Co., *Fort Wayne, Ind.*

BUREN, NEWTON J., manager, Tsungani Piston Co., *Tacoma, Wash.*

BURLINGHAM, CHARLES S., JR., special engineer, West Penn Railways Co., *Pittsburgh.*

CHAPIN, W. R., metallurgist, E. C. Atkins & Co., *Indianapolis.*

CINCINNATI MILLING MACHINE CO., *Oakley, Cincinnati, Ohio.*

CLARKSON, WILLIAM STOUP, partner, R. W. Orrell Machine Co., *Flint, Mich.*

CORNELY, E. A., president, E. A. Cornely, Inc., *San Francisco.*

CRAMER, W. J., superintendent, General Piston Ring Co., *Indianapolis.*

CUMMINS, E. L., vice-president, Gambill Motor Co. and Michigan Avenue Chevrolet Co., *Chicago.*

DANIELS, H. M., New York branch manager, Four Wheel Drive Auto Co., *New York City.*

DONKIN, W. T., engineer, Cleveland Wire Spring Co., *Cleveland.*

DUBOIS, RALPH N., assistant mechanical engineer, Bureau of Standards, *City of Washington.*

EARNEST, STANLEY, instructor, Army Air Service, *City of Washington.*

EARNSHAW, WILLIAM B., head of dynamics research section, General Motors Research Corporation, *Dayton, Ohio.*

EMRICH, M. F., manager of industrial sales department, Glidden Co., *Cleveland.*

FABIAN, JULES, designer, General Motors Research Corporation, *Dayton, Ohio.*

FEELY, J. H., salesman, Autocar Sales & Service Co., *New York City.*

FERGUSON, IVAN P., superintendent of trimming, Murray Body Corporation, *Detroit.*

FOLBERTH, FRED G., president, Folberth Auto Specialty Co., *Cleveland.*

FRANCIS, WILLIAM C., president, Hall Wheel Corporation, *Philadelphia.*

GILCHRIST, BENJAMIN W., plating engineer, Ternstedt Mfg. Co., *Detroit.*

GLASNER, R. W., president, Marquette Tool & Mfg. Co., *Chicago.*

GRABFIELD, JOHN J., draftsman, Cadillac Motor Car Co., *Detroit.*

HARPER, DONALD A., commercial engineer, Tung-Sol Lamp Works, *Newark, N. J.*

HARRMAN, CHARLES R., mechanical engineer, Dodge Bros., *Detroit.*

HESSLER, J. A., secretary and sales manager, Western Felt Works, *Chicago.*

JAHNKE, CHARLES B., chief engineer, Beloit works, Fairbanks, Morse & Co., *Beloit, Wis.*

KARA, JOSEPH F., designer and draftsman, Northern Motors Co., *Chicago.*

KARMAZIN, JOHN, manager in charge of production, Flintlock Corporation, *Detroit.*

KATZ, JOSEPH B., president, Provident Machine Co., *Philadelphia.*

KLEPS, EDWARD W., service-manager, Lenk Electric Co., *Boston.*

LAWRENCE, W. H., lubrication engineer, Vacuum Oil Co., *Detroit.*

LIVERMORE, HARVEY J., engineer, National Lead Battery Co., *St. Paul, Minn.*

LORMOR, H. W., equipment manager, Willard Storage Battery Co., *Cleveland.*

MA, KAI YEN, training course, Ford Motor Co., *Detroit.*

MAXWELL, D. GRAY, salesman, Ferodo & Asbestos, Inc., *New Brunswick, N. J.*

MCADAMS, JOHN C., manager, J. C. McAdams Co., *Long Island City, N. Y.*

MCCLOSKEY, L. T., vice-president and Western manager, Diamond State Fibre Co., *Chicago.*

MCEVOY, JAMES, director of patent section, General Motors Corporation, *Detroit.*

MCGREGOR, HOWARD L., general manager, National Twist Drill & Tool Co., *Detroit.*

MINICH, HENRY D., consulting engineer, Greyledge, R.F.D. No. 3, *Troy, N. Y.*

MORGAN, DAVID M., mechanical engineer, Morgan Spring Co., Inc., *San Francisco.*

MORIARTY, JAMES, JR., service-manager, Williams & Hastings, *Detroit.*

NOWALK, ROBERT F., factory manager, John Warren Watson Co., *Philadelphia.*

OEHRLI, JOHN W., draftsman, Lycoming Mfg. Co., *Williamsport, Pa.*

PARSONS, CARL B., president, Parsons Mfg. Co., *Detroit.*

PEARCE, M. J., manager of technical service division, Glidden Co., *Cleveland.*

REID, VAUGHAN, president and manager, City Pattern Works, *Detroit.*

RICHARDSON, ELWOOD G., chief chemist and chemical engineer, Berry Bros., Inc., *Detroit.*

ROME WIRE CO., *Buffalo.*

RUTAN, ALOYSIUS J., designing draftsman, Elevator Supplies Co., *Hoboken, N. J.*

SMITH, GEORGE A., engineer on technical staff, American Bureau of Shipping, *New York City.*

SPRUANCE, F. P., sales manager, American Chemical Paint Co., *Ambler, Pa.*

STEWART, J. P., engineer, Vacuum Oil Co., *New York City.*

SUMMERS, C. E., research engineer, General Motors Research Corporation, *Dayton, Ohio.*

VALENTIN, DR. ERNST, consulting engineer, Westfalische Strasse 92, *Berlin-Wilmersdorf, Germany.*

VAN DER STEMPEL, TH. M., junior engineer, Chicago Motor Coach Co., *Chicago.*

WARD, AARON, miniature lamp department, Westinghouse Lamp Co., *New York City.*

WEAVER, GAILARD E., vice-president, Weaver Mfg. Co., *Springfield, Ill.*

WELLS, FRANKLIN H., engineer, Westinghouse Air Brake Co., *Wilmerding, Pa.*

WOOD, WALTER A., head of dynamometer testing, General Motors Research Corporation, *Dayton, Ohio.*

WUESTNER, C. J., planning engineer, Yellow Taxi Corporation, *New York City.*

YERGER, FRANK H., technical manager, Gomery-Schwartz Motor Car Co., *Philadelphia.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 10, 1924, and Jan. 10, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

BARNARD, DANIEL P., 4th (M) research chemist, Massachusetts Institute of Technology, *Cambridge, Mass.*

BILLINGS, WILLIAM ARTHUR (A) automotive engineer, Associated Oil Co., *Los Angeles*, (mail) West Gate Hotel, 445 South Western Avenue.

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CARTER, ROBERT HILL (A) secretary and general manager, Richmond Forgings Corporation, *Richmond, Va.*

CLARK, EUGENE C. (A) engineer in charge of road testing, International Motor Co., *New York City*, (mail) 233 West 230th Street.

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FAWICK, THOMAS L. (A) president, Twin Disc Clutch Co., *Racine, Wis.*

FISHER, URBAN A. (A) vice-president, Standard Motor Truck Co., *Detroit*, (mail) 4449 Oregon Street.

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HULL, R. WINTER, (J) branch plant manager, Rex Mfg. Co., *Connersville, Ind.*

JUNKERS, PROF. HUGO (M) possessor and director, Junkers Works, 21 Kaiserplatz, *Dessau, Germany.*

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LEBLOND, HAROLD R. (A) secretary and treasurer, G. A. Schacht Motor Truck Co., 8th and Evans Streets, *Cincinnati.*

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MANSUR, C. W. (A) assistant engineer in fabroil gear department, General Electric Co., Lynn, Mass., (mail) 32 Spruce Street, *Malden, Mass.*

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STEVENS, CARL A. (A) mechanical engineer, Pierce Petroleum Corporation, *Sand Springs, Okla.*, (mail) Box 526.

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WOOD, LAWRENCE (A) Detroit district sales manager, Colonial Steel Co., Pittsburgh, (mail) 5-253 General Motors Building, *Detroit.*