1905 GOLDEN ANNIVERSARY 1955

Number 537

THE NEW PACKARD TORSION LEVEL SUSPENSION

by

FOREST R. McFARLAND

Chief Engineer

Advanced Engineering

Studebaker-Packard Corporation

Detroit, Michigan

For presentation at the

SAE GOLDEN ANNIVERSARY

SUMMER MEETING

Chalfonte-Haddon Hall

Atlantic City, New Jersey

June 12-17, 1955

Written discussion of this paper will be accepted at SAE Headquarters until August 1, 1955. Three double-spaced copies would be appreciated.

SOCIETY of AUTOMOTIVE ENGINEERS, Inc., 29 West 39th Street, New York 18, N. Y.

THE NEW PACKARD
TORSION LEVEL SUSPENSION

by

FOREST R. McFARLAND
Chief Engineer
Advanced Engineering
Studebaker-Packard Corporation
Detroit, Michigan

For presentation at the
SAE GOLDEN ANNIVERSARY SUMMER MEETING
Chalfonte-Haddon Hall
Atlantic City, New Jersey

Presentation date:
June 15, 1955

THE NEW PACKARD
TORSION-LEVEL SUSPENSION

HISTORY

New developments in automobiles seem to appear in cycles. In the early thirties, helical gear transmissions and synchronizers were introduced which marked a new era in transmissions. In the early and middle thirties, independent suspensions appeared on American automobiles setting a new standard of riding comfort and control of vehicles. From 1939 to 1953, we have seen introduction of automatic transmissions by all makes of American cars. The second chapter of continued innovations is following from 1953 to the present time and apparently due to continue for some time into the future. We are all familiar with the engine programs resulting in the change from straight eights to V-8's which has swept the industry. Also the rapid adoption of power steering.

We have now reached the year 1955 with no change in basic principle, in the last twenty years, in the over-all design of suspensions on American cars. It would seem that a change in suspensions is overdue.

Since 1935, Packard Engineering has analyzed many ideas in search for something new in principle in suspensions that would be a definite step forward in improving the ride of our cars. We hoped to gain an improvement that would be apparent to a customer before he had driven the car more than a couple of blocks.

It has been generally known in the industry that a better boulevard ride could be obtained by lowering spring rates, but that stability on the road suffered. As a result, car suspensions have been compromised to give a certain amount of the former and a certain amount of the latter qualities, depending upon the judgment of the makers on customer desires. Any suspensions that would improve both boulevard ride and road stability would be a definite step forward.

Packard has had patent coverage on torsion bars connecting the front and rear wheel suspensions since the early thirties.Compensation for rear passenger load has been introduced by Daimler Benz on the Mercedes car but operated by manual control and for two positions only. American experimental cars and buses have been equipped with automatic self-leveling devices. In 1947 we were first exposed to the idea of combining the torsion bar suspension connecting the front and rear wheels with an automatic load compensator or levelizer, which, in addition, gave the necessary stability to the system. In 1951 an intensive development program was started that culminated with the introduction of the Torsion Level Suspension in the 1955 Packard. We feel this design does represent a step forward in accomplishing the objective of improving both boulevard and open road ride.

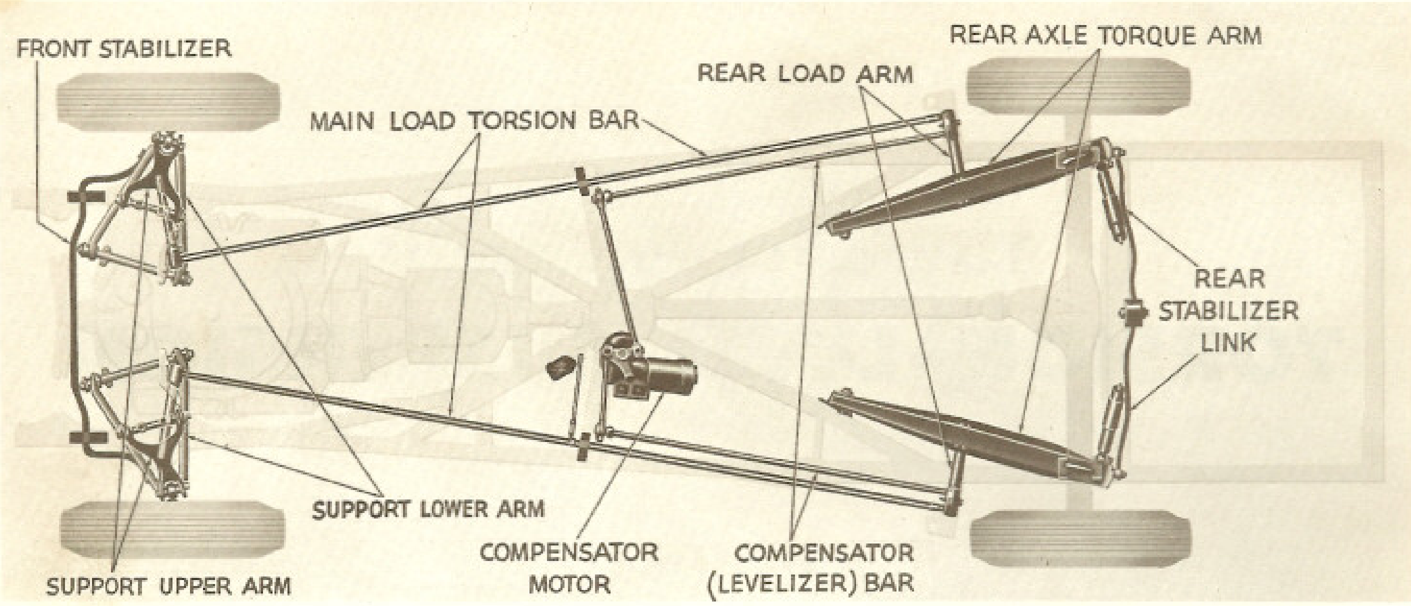


Fig. 1—Torsion-Level Suspension General Arrangement

GENERAL DESCRIPTION

The suspension in general consists of two features:

1. Long torsion bars connecting the front and rear wheels by suitable linkage that cause the car to ride level when passing over bumps and holes. These bars are also responsible for the "soft" ride.

2. Short torsion bars connecting the rear wheels to the frame together with an adjusting mechanism referred to as a compensator or levelizer that keep the car level at all times, whether it is empty or has six passengers and over three hundred pounds of baggage. These bars also give stability to the vehicle.

DESCRIPTION OF LONG TORSION BARS AND SUSPENSION STRUCTURE IN GENERAL

Let us now return to the description of the long bars in the general arrangement shown in Figure 1. These bars run from the front to the rear of the vehicle, are 111 inches long on the Packard model, and carry forged hexes at each end. The hexes fit into broached hex holes in levers mounted on needle bearings, on brackets attached to the front cross member and rear brackets welded to the outside of the frame.

The front levers bear upon the lower A frames of the front suspension through struts shown in Figure 2. The bearings are of an anti-friction type which will be described in detail later. The front suspension structure is the same as our previous standard front suspension except for a change in the caster and camber adjustment and slightly looser fits in the threaded bushings to minimize friction, particularly at small amplitudes.

The rear axle is located fore and aft and against rotation by torque arms as shown in Figure 3. The levers at the rear end of the long torsion bars are attached to the torque arms by the stirrups shown in Figure 4. At the top and bottom ends of the stirrups are anti-friction bearings shown which are the same as those on the front struts except the upper and lower bearings are changed to satisfy the geometry.

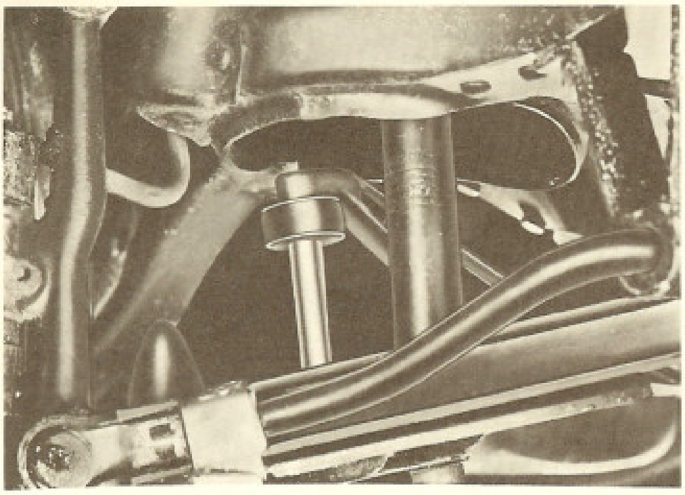


Fig. 2—Front Suspension Construction Showing the Front Strut Location

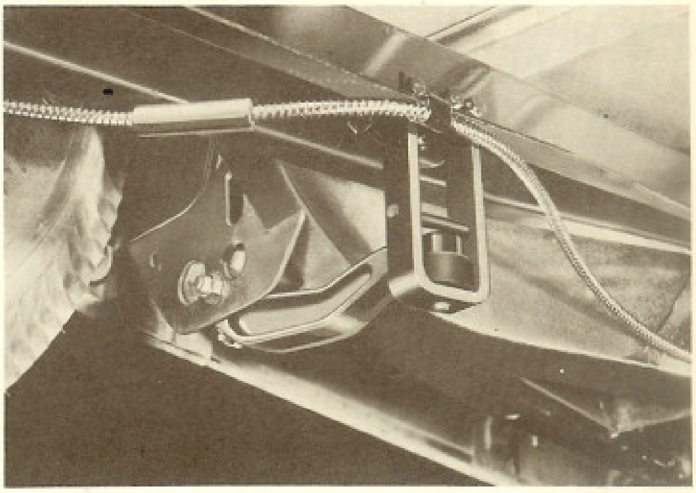
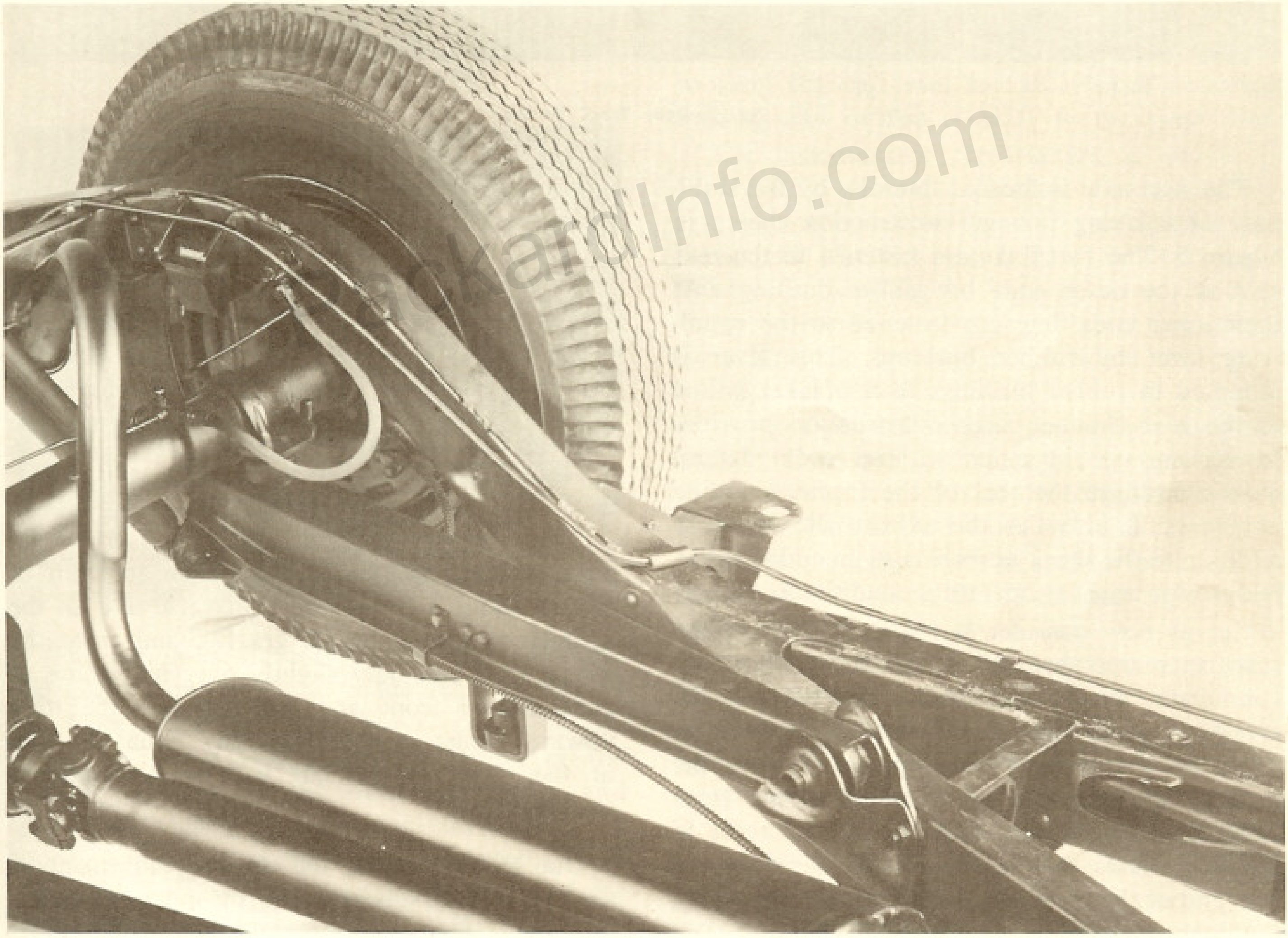


Fig. 4—Rear Suspension Construction Showing the Rear Stirrup Location

Fig. 3—Rear Suspension Construction Showing the Attachment of Rear Axle to the Frame



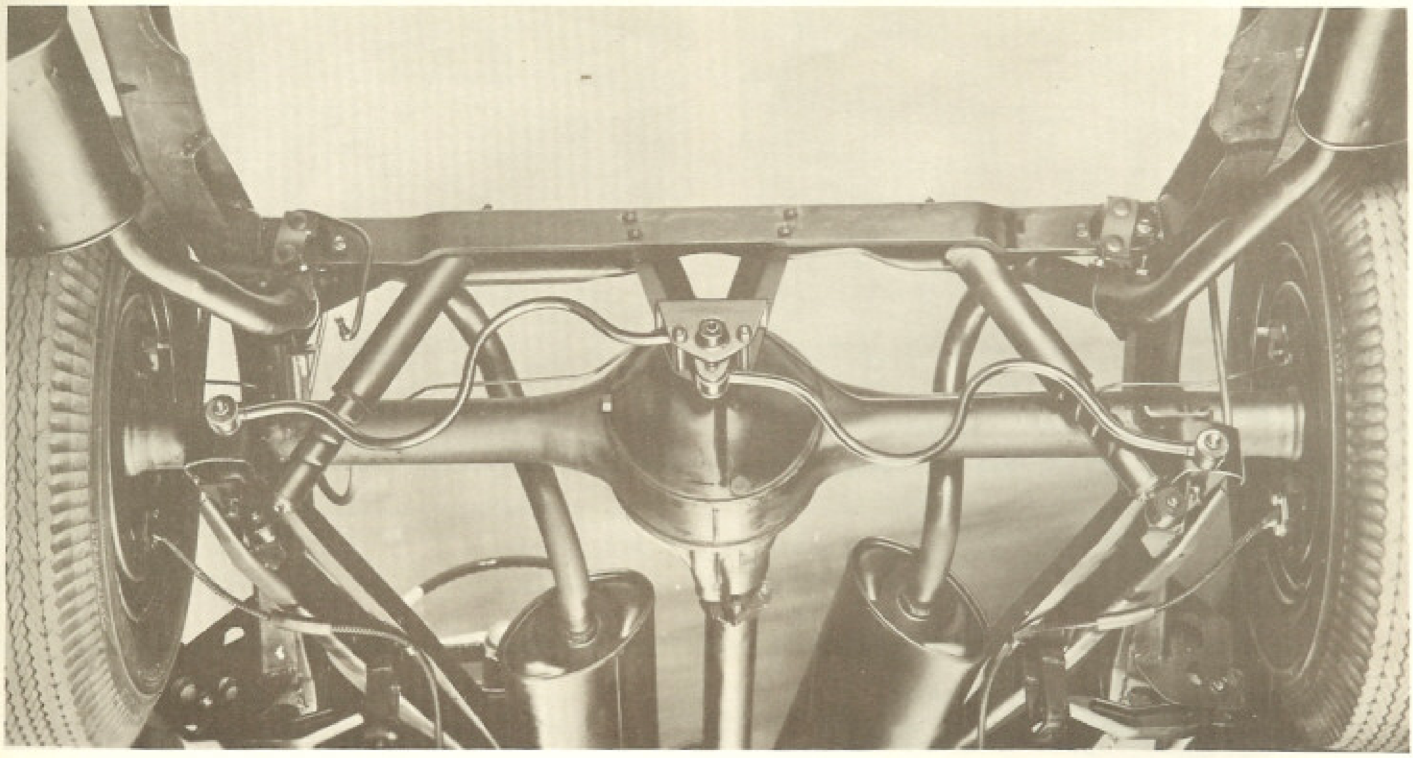


Fig. 5—Rear Track Linkage

The rear axle is located laterally by the stabilizer or tracking linkage construction shown in Figure 5. The two links are fastened to the rear axle at the outer ends by rubber bushings. At their inner ends they are fastened to the equalizing lever by rubber bushings. This lever is mounted in rubber bushings to a bracket bolted to the rear channel. This construction provides for vertical axle movement without feeding lateral movements into the rear of the frame, avoiding harshness. It also ties the axle to the frame in addition to the shock absorbers as an added safety feature for unusual operating conditions.

Let us now consider how this portion of the suspension operates. When the front wheel encounters a bump, the wheel rises, twisting the torsion bar by the front suspension linkage, causing an increase in the upward load at the torsion bar lever bracket attached to the front channel of the frame. The increase in twist in the bar causes the loading of the lever at the rear end of the bar to increase, thereby increasing the loading of the rear wheel on the ground. The net reaction of the rear torsion bar lever and torque arm appears on the rear of the frame upwardly at the point of attachment of the rear lever. This increase in upward loading is simultaneous with the increase in upward loading at the front channel. The result of these two loads appears near the center of gravity of the car fore and aft, tending to lift the car without an appreciable pitch effect.

Since the inertia of the car in translation upward is high compared to its polar moment of inertia about a horizontal transverse axis in the vicinity of the center of gravity, and since the spring rates are only slightly over half those of conventional front and rear springs, the total upward thrust is approximately equal to that at the front of the car with a conventional suspension.

Due to these facts, the upward movement of the car is small compared to the pitch occurring in a car with a conventional suspension.

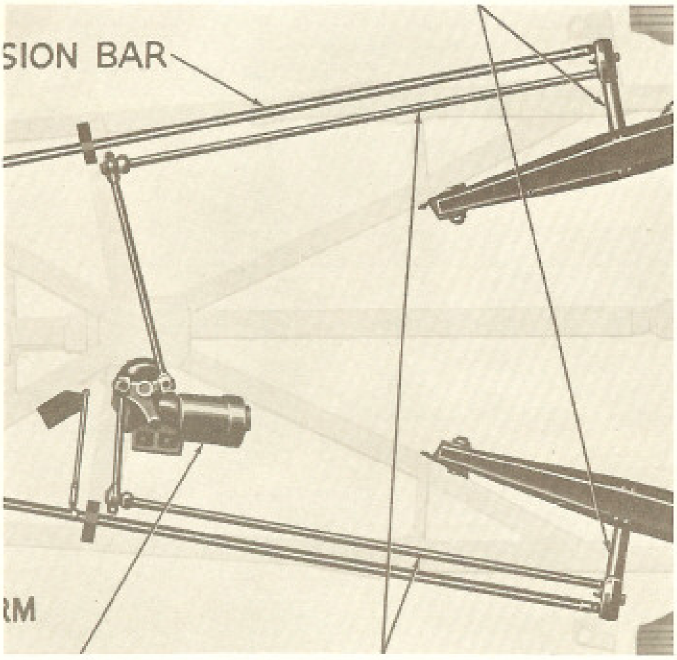
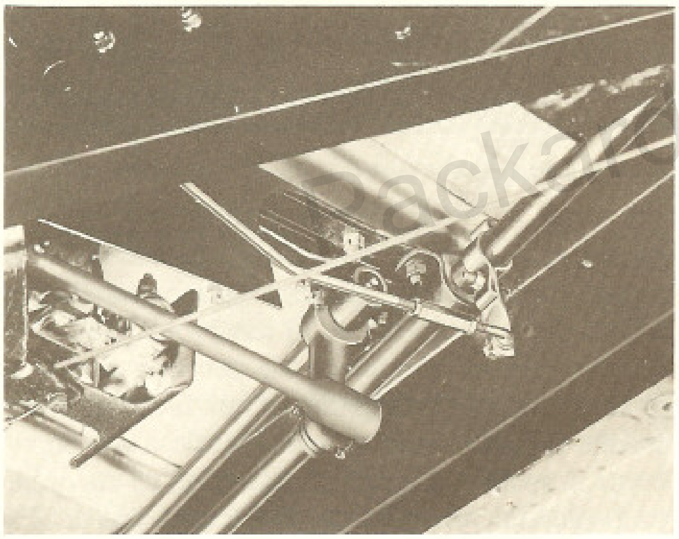


Fig. 6—Enlargement of Figure One Showing the Compensator Construction

Fig. 7—Lever and Linkage from Left Main Torsion Bar Leading to the Compensator Control Switch



The action of the suspension when the rear wheel goes over a bump is the same as that of the front wheel just described.

In the above description the action of the rubber bushings on the front suspension, and the rubber bushings and compensator bars on the rear suspension have been omitted. Their rates will be given later in the description of the technical details.

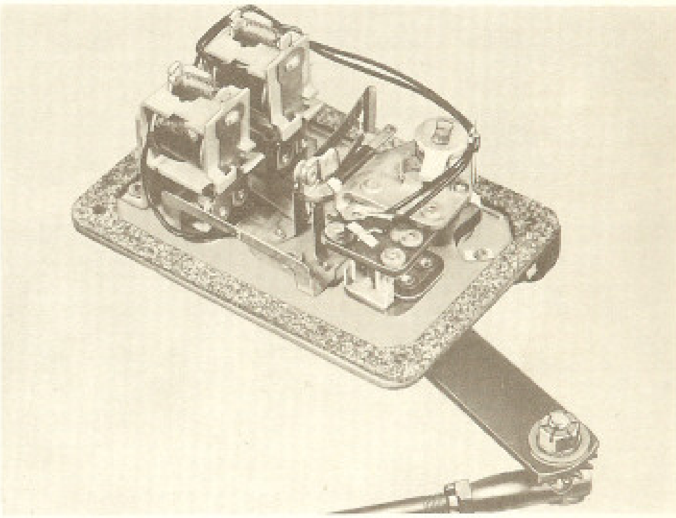


Fig. 8—Compensator Control Switch with Cover Removed and Linkage to Lever on Main Bar

DESCRIPTION OF SHORT TORSION BARS AND COMPENSATOR OR LEVELIZER LINKAGE

The function of the compensator or levelizer is to keep the car level for all normal passenger loading and furnish stability to the suspension.

The compensator construction is shown in Figure 6. In general it consists of two short torsion bars attached to the rear axle linkage and frame, an electric motor, gear reduction and linkage for winding the bars in either direction to raise or lower the car, and a sensing means for telling the leveling means when the car is out of level.

The torsion bars are clamped at their rearward ends in broached hex holes in the same levers that carry the rear ends of the long torsion bars. The short bars at their front ends are clamped in hex holes in levers and located in brackets attached to the frame. Both left and right levers carry ball joints to which links are attached. These links in turn are attached to the ball joints on two arms of a central lever mounted on a shaft which is the output of a planetary and worm gear reduction of 2762 to 1, 86 to 1 being in the worm. Driving the worm is an electric motor, a conversion of a high production generator, responsive through solenoids to a control switch which in turn is actuated by the sensing lever located on the long left torsion bar.

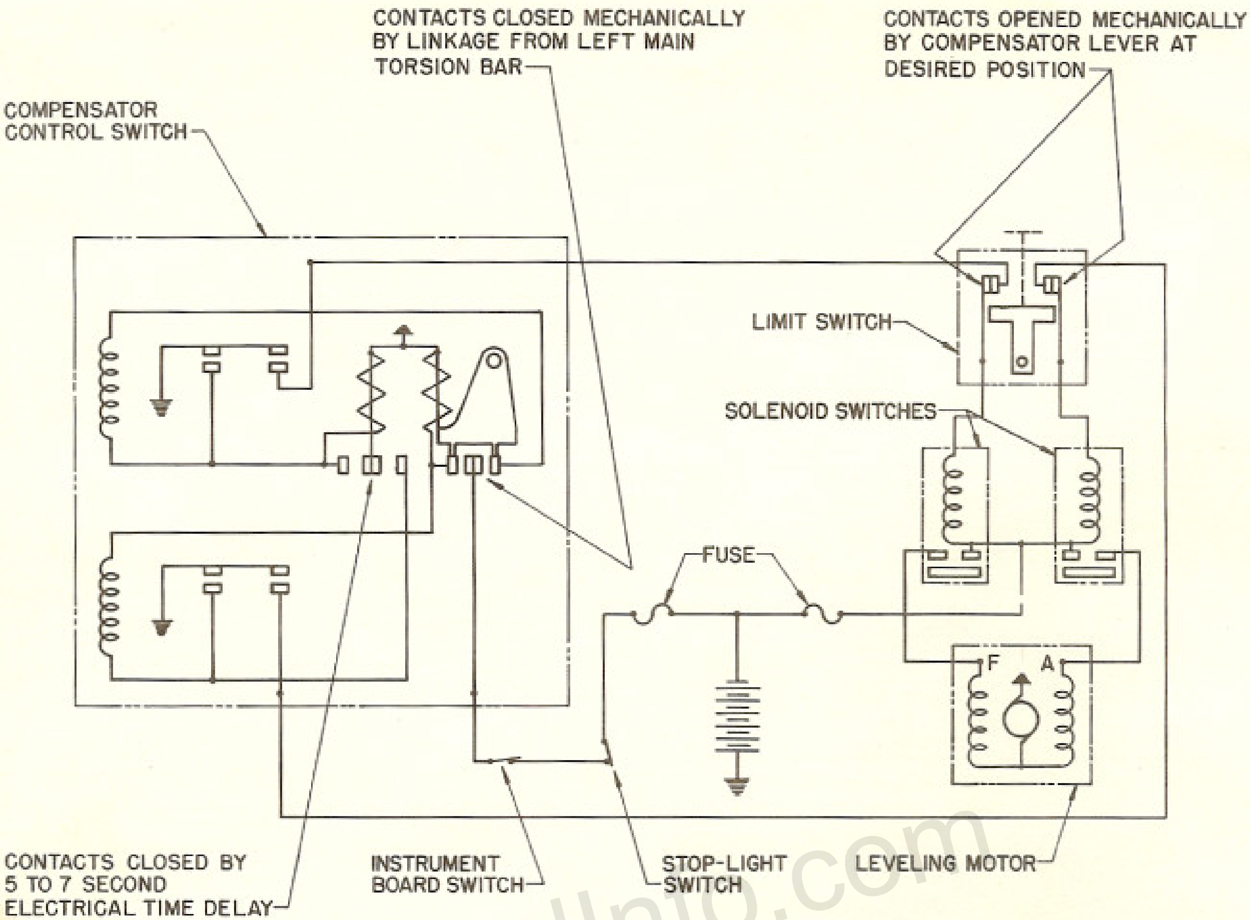


Fig. 9—Compensator Electrical Circuit Diagram

The operation in detail is as follows. The sensing lever is located at the node of the left bar at a "6 o'clock" position as shown in Figure 7. As long as the car is level even though its vertical height changes, the nodal point does not rotate, so the lever remains at 6 o'clock. If the rear of the car is low the lever moves to a position slightly earlier than 6 o'clock viewed from the rear. If the rear is high, the lever moves to a position slightly later than six. The moving lever on the long left bar then moves the lever in the control switch mounted on the front X-member of the frame. Figure 8 shows this switch with cover removed and operating rod. As soon as the car is out of level with the ground by approximately five-eighths of an inch, contact is made inside the control switch, shown diagrammatically in Figure 9, which heats a bimetal element. After a 5 to 7 second delay, the bimetal element closes a contact actuating a small relay that supplies current to the motor solenoid operating the motor. The motor through the reduction gears and linkage winds the two short bars in the proper direction, bringing the car back to level. As soon as the car is level within five-eighths of an inch, the lever on the long torsion bar moving the lever on the control switch cuts off the current to the relay and solenoid, which stops the electric motor. The slight over-run of the motor brings the car close to the ideal position.

Operation of the compensator in the opposite direction is the same as described except the opposite leg of the bimetal switch is heated, causing the bimetal element to make contact with the switch operating the relay and solenoid that runs the motor in the reverse direction, thereby lowering the car.

The electrical diagram is believed to be self-

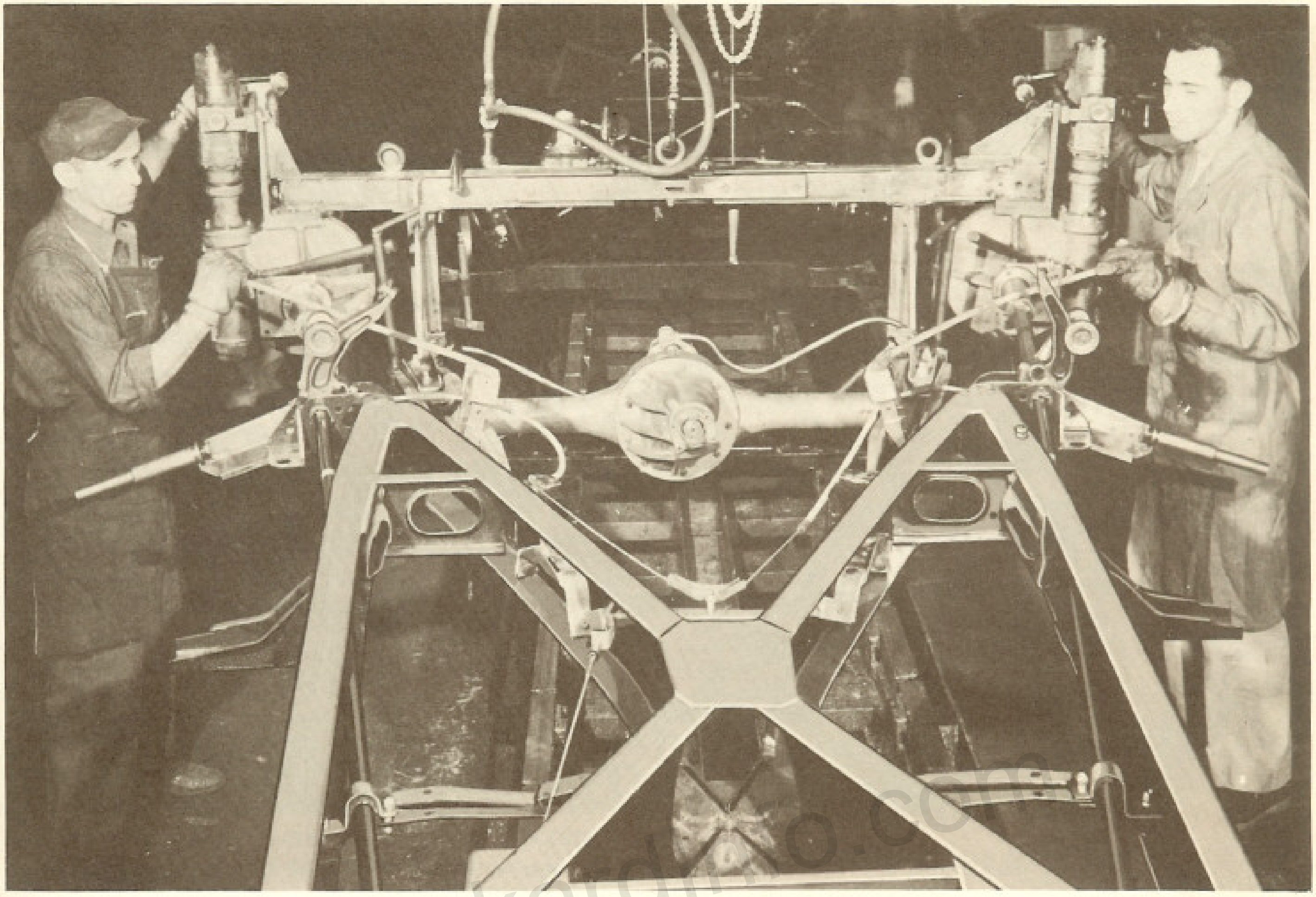


Fig. 10—Production Fixture for Winding the Long Torsion Bars

explanatory. One point of particular interest is the design of the bimetal element shown in Figure 9. This element can be heated on one leg causing it to move in one direction, and on the other leg causing movement in the opposite direction. Ambient temperature differences, however, act on both legs, causing the unit to be substantially temperature insensitive with respect to the gaps between the points. Use of the bimetal element solved a troublesome problem of eliminating most of the variation in delay time due to temperature variation. A switch combined with the stop light switch opens the circuit to the compensator controls when the brakes are applied, preventing compensator action during this operation.

Travel of the levers is controlled by limit switches indicated in Figure 9 which cut off the current supply when the levers have moved to their maximum desired positions. A dash switch also indicated in Figure 9 is provided to cut out compensator action when changing tires. Within a few days after our mechanics had been exposed to this mechanism, they found two of them could sit on the rear bumper, let the compensator raise the car to level, then immediately turn off the compensator switch, leaving the rear of the car in the air, thereby saving themselves considerable work jacking up the rear of the car to change rear tires.

TECHNICAL DETAILS OF CONSTRUCTION

The long torsion bars are of SAE 5160 steel of 1 inch diameter precision rolled and upset at each end into hexagons to size without any further finishing. The hexes are straight. Considerable thought was given to crowning them or making the hex

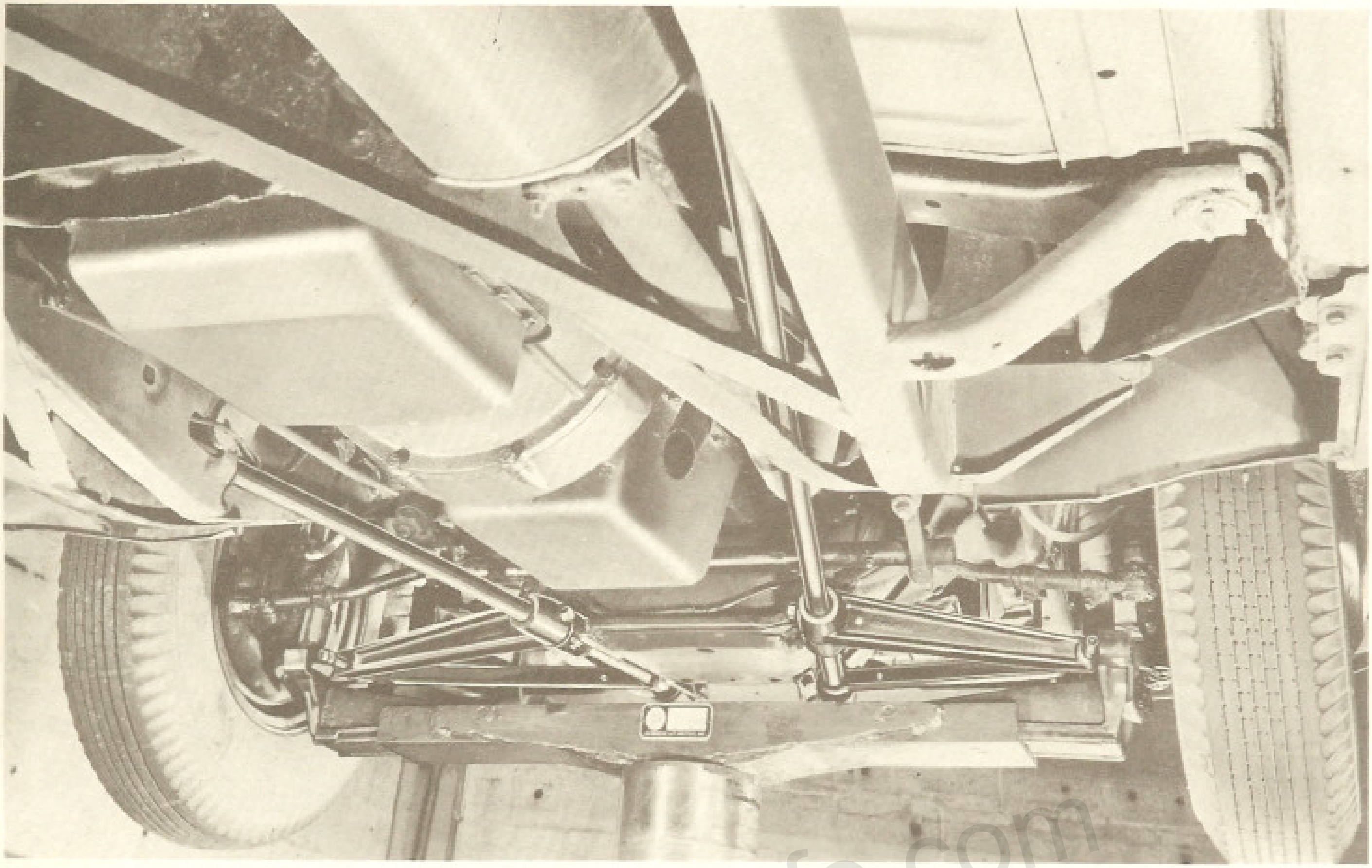


Fig. 11—First Design of Torsion Level Suspension, Showing the Connection of Long Torsion Bars and Lower Pivots in Front Suspension

larger at its extreme end to "flow" the stress out of the bar more uniformly. To date no bars have broken at the hex ends, indicating the present method appears to be satisfactory. The bars are shot peened and then pre-twisted 100% to properly index the hexes and also pre-stress the outer fibres to further insure against breakage. The bars are stressed to a maximum of 130,000 lbs. per sq. in. under full simultaneous bottoming at front and rear wheels, which is a rare condition. This compares very favorably with the combined stresses on front coil springs of the majority of present production cars under bottoming loads at the front wheels only, which would occur much more frequently.

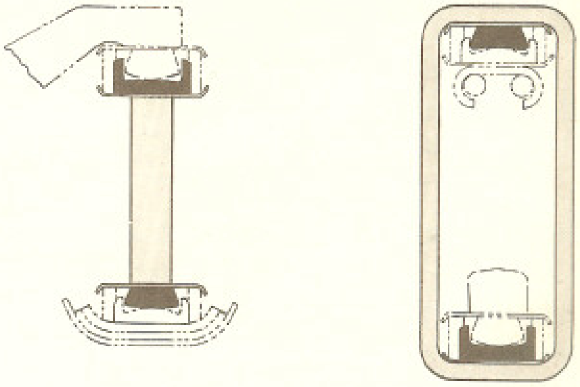
Assembly of the long torsion bars in the chassis is one of the problems worked out with Production during development. A winding fixture was designed as shown in Figure 10 and used to wind up the bars on engineering cars as a pre-production check on the procedure. The fixture consists of two air motors, each driving a gear reduction unit. The output shafts of the reduction units have pilots fitting into the broached holes in the rear levers carrying the hex ends of the long torsion bars, and driving arms that bear against the torsion bar levers. After assembling the fixture to the bar in the free state, the bar is twisted approximately 120 degrees, the stirrup dropped over the end of the lever and the lever backed up, seating the bearing end of the lever into the bearing in the stirrup. Production now states assembly of these bars is preferred to the assembly of the conventional coil and leaf springs. This was a happy ending to one element of the problem that had concerned us at the start.

The compensator bars are assembled with no load so offer no assembly problem. These bars operate at comparatively low stress values but are shot peened as an additional precaution.

The front struts between the front torsion bar levers and the front suspension lower A frames come in four lengths in half-inch increments which vary the standing height of the car in three-eighth inch increments to handle manufacturing variations. Parts are coming through production uniformly enough so that one length has been used almost entirely. Experience to date indicates less loss in riding height in service than present in standard suspensions.

The question has come up, "Why weren't the bars run directly off the pivot point of the front suspension?" The answer to that question is shown in Figure 11, which represents our first design in which exactly this was done. We found the present design worked in much better on several counts using the extra arm in front, besides permitting use of the present front suspension substantially as is.

One of the problems in this development was the minimizing of friction in the system. The inner bearings of the front suspension structure and all joints of the rear suspension structure are of rubber. The torsion shaft levers operate on needle bearings. The bearings in the struts at the front, and stirrups at the rear represented one of the problems in the development. These bearings had to operate substantially without friction. Various needle bearings, ball seats of bronze and nylon and rubber arrangements were tried without success. The final design, cut through center, is shown in Figure 12 for front and rear. This design bears some resemblance to one we had previously used to take friction out of a standard clutch linkage. The bearings located in the ends of the front and rear torsion bar levers are spherical. The bearings in the plates cushioned in rubber in the lower front suspension arms and the bearings located in the stampings bolted into the rear torque arms also are spherical. The front struts originally had flat bearings which "clicked" under full jounce or rebound due to the spread of the load contact lines, as shown in Figure 13, causing the bearings to slide under load and hit the sides of the cups. Addition of a radius tangent to the flat of the bearings at a .375 inch diameter



FRONT STRUT

REAR STIRRUP

Fig. 12—Cross Section of Front Strut and Rear Stirrup

reduced the spread of the contacts, eliminating clicking under normal conditions. As the angle of the rear arms was only approximately one-half that of the front arms, these same bearings were first used in the rear stirrups. Since the stirrups, however, are tension members whereas the struts are compression members, it was found desirable to alter the design of the stirrup bearings by suitable radii to control the spread of the load contact lines to eliminate clicking.

Hertz maximum shear stresses in the bearings under full load are approximately 400,000 lbs. per sq. in. Ball and roller bearing makers have advised us these figures are in line with stresses in ball and roller bearings where proper service life was obtained. Endurance testing on the bench and in cars has indicated this stress is satisfactory.

Bearings were run dry and without rubber seal rings for many thousand miles satisfactorily. It was considered safer, however, to start with the bearings sealed and filled with a moly disulphide grease due to possible sliding with the sides of the cups.

It would appear that considerable time has been spent in describing a small detail of this design. It is felt to be justified as it presented one of the definite problems in the development.

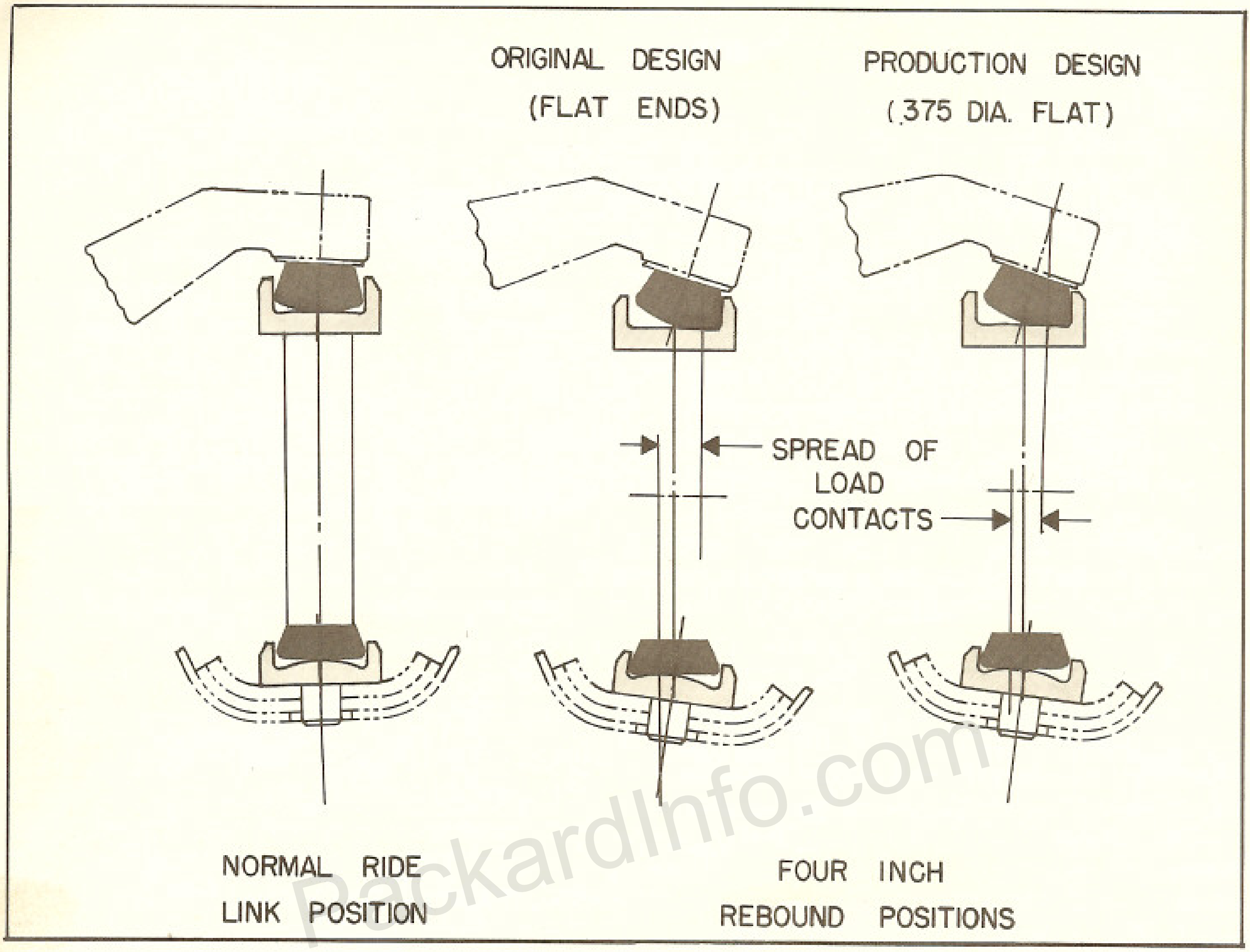


Fig. 13—Front Strut Anti-Friction Bearing Geometry, Showing First Design and Final Design

FUNCTIONING OF DESIGN

Individual wheel rates on the Packard car are 66 pounds per inch front and 69 pounds per inch rear. Ride rates are approximately 3 pounds per inch less. When the front and rear wheels are deflected in equal amounts simultaneously, the front wheel rate is approximately 100 pounds per inch and the rear wheel rate, 104 pounds per inch. Ride rates are approximately 7 pounds per inch less. The front wheel and ride rates include 26 pounds per inch due to the front suspension and stabilizer rubber bushings. The rear wheel and ride rates include 40 pounds per inch due to the rates of the compensator bars and the torque arms and track linkage rubber bushings. These rates contribute toward pitch but are low compared to the equivalent standard suspension rates, making the car relatively pitch free under most normal conditions. Pitch frequency is approximately 40 cycles per minute and bounce frequency approximately 54 cycles per minute for the Packard car with 4.5 passenger load.

Roll stability of the car is higher than that of our standard cars due to the location of the attachment points of the long torsion bar levers at the rear and the fact that the combined spring rates act on the body in roll.

The roll center is approximately on the ground surface at the front wheels and approximately 11.75 inches above the ground at the rear wheels.

Roll centers at the rear from 4 inches below standard to 4 inches above standard were evaluated by five engineers riding in a test car without knowing what was in the car. Four of the engineers preferred a higher roll center if a change from standard were to be made, and one preferred a lower roll center. This is an example of differences among experts.

Rear end steering has been given considerable attention. The design carries definite understeer due to the geometrical location of the front bearings of the torque arms. The torque arm-to-rear axle rubbers by their own geometry lessen the over-all understeer expected from the torque arms.

Measurement of understeer effect under roll shows a definite difference between understeer with reference to the body as compared to that with the front wheels due to the fact the roll center at the front of the car is lower than that at the rear.

Rear end lateral flexibility has an influence on understeer effect. Some personnel have questioned the rear end lateral softness with full passenger load although reaction from the field has been good. The Proving Ground drivers on a 25,000 mile run at an average speed of 104.7 miles per hour stated that they could drive the cars with the new suspension approximately five miles faster than our standard cars with the same feeling of stability. Several of our personnel have reported definitely more than the five mile differential on country roads. Less flexibility is easily obtained to give less lateral movement but at the cost of increased harshness.

A complete discussion on steering, including tire, wind, and other effects, will not be attempted as it could well be a full length paper in itself.

SUMMARY

The advantages felt present in the torsion level design suspension over the standard type are as follows:

1. Flat ride.

The suspension will stay definitely more level than a standard suspension with a minimum of pitching, resulting in a more comfortable and relaxed ride for the occupants of the vehicle.

2. Level ride.

Whether the car is empty or has six passengers and over 300 lbs. of baggage in the trunk, it is always level. Over-all height varies by a little over an inch. This is an answer to the stylist's prayer.

3. Soft boulevard ride with gain in stability on the highway.

The ride is definitely softer than conventional as the spring rates per wheel individually are only slightly more than half that of conventional. The great reduction in pitch which suspension engineers have been striving for and lessened roll permit the softer ride with the attendant gain in open road ride.

4. Headlights stay on the road.

A valuable safety feature.

5. No rear end squat on acceleration.

Bottoming under this condition is absent due to the torque arm action.

6. Less dive on stopping.

There is front end dive, but the effect of the torque arms tending to hold the rear down helps to lessen the over-all dive effect.

7. Better wheel traction.

Tests have indicated less wheel spin upon starting.

8. Reduced torsional stresses in frame.

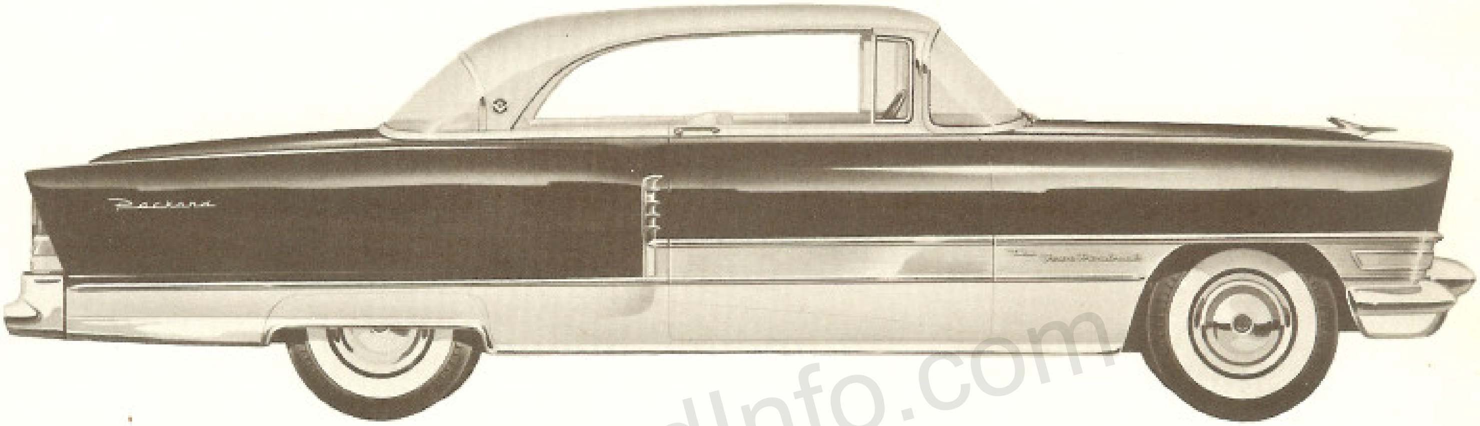
CONCLUSION

This discussion opened with mention of cycles of development of transmissions, engines, and steering. It is felt the time is ripe for a cycle of development in automotive suspensions. With the present knowledge of the various types of suspensions, including DeDion, rear independent, air, combination of air and hydraulic, rubber, and others, it would seem that within the next 2 to 5 years, we should see some radical changes in suspension design.

It is hoped the introduction of the Packard Torsion Level Suspension will serve to stimulate more activity in this field, resulting in a definitely better and safer ride for all future motor car owners.

ACKNOWLEDGMENT

Acknowledgment is made of the contributions to this development by the personnel of Studebaker-Packard Advance Engineering, Packard Engineering and Proving Ground. Mention in particular is made to the contributions of Mr. George Joly and our associate, Mr. W. D. Allison. Several of our suppliers have contributed in the engineering of the products they are furnishing. The Engineering, Manufacturing, and Corporate Management of Studebaker-Packard have been very receptive and understanding in this development. The combined cooperation of all concerned has made this project possible.



The 1955 Packard 400 with Torsion Level Suspension

NOTES

The Packard Chassis with Torsion-Level Suspension