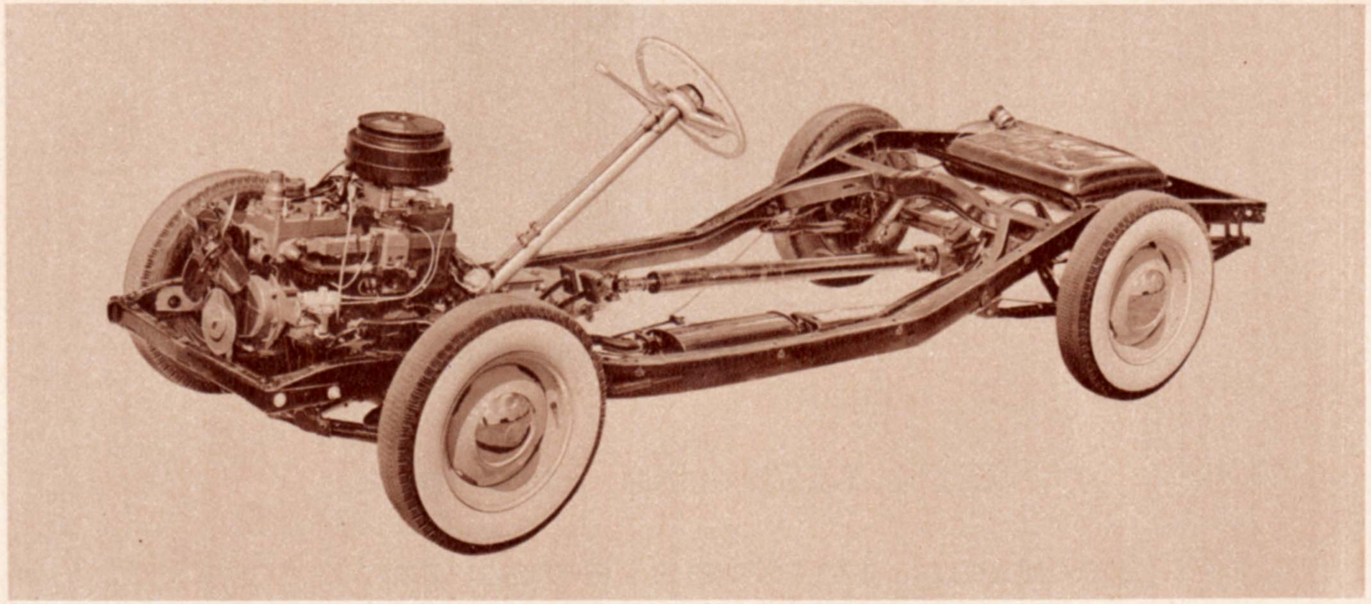


The 1951 Henry J Chassis with conventional Hotchkiss drive. As shown here this frame lacks the rigidity necessary for a successful open-sports type special.

SPORTS CAR DESIGN NO. 25

Advantages of the conventional type rear suspension

by John R. Bond

THERE is a strong tendency for automobile enthusiasts the world over to adopt the attitude that anything conventional (in automotive design) is to be sneered at—the rear suspension of 95% of the world's automobiles being an excellent example and a common target.

While no mechanical design can ever achieve perfection, the conventional rear suspension of most of today's passenger cars has evolved, through trial and error, into a very good all-around design compromise which fulfills the conflicting demands of low cost, durability and effectiveness. At the same time the c.r.s. has certain disadvantages which are well known and can be summarized as follows:

1. High unsprung weight. The complete differential assembly, axle housing, drive shafts and brake assemblies are an assembled unit, weighing in the neighborhood of 150 lbs on a 3400 lb. car. Add 85 lbs to this for a pair of 6.70-15 wheels and tires and we have 235 lbs of unsprung weight at the rear of an automobile. The problem of controlling this considerable mass as it bounces over road irregularities is not simple.

2. Vibration problems. Because of the considerable weight and non-independent geometry we find shake, tramp and ride-harshness difficult to control, particularly at critical speeds over certain types of surfaces which tend to excite vibration.

From these two principal disadvantages we can deduce, logically, that some form of independent rear suspension is inevitable, if and when the customer is convinced that the extra cost is necessary or worthwhile.

However, with few exceptions, today's automobile buyer is well satisfied with the ride of the car of his choice, if only because he knows no better. Of course, in the past 30 years, the ride engineer has accomplished wonders with c.r.s., despite the fact that the general arrangement appears to be unchanged. Here is a case where a number of seemingly small changes have made a very considerable improvement, and we can safely say that these small modifications have been so effective that adoption of i.r.s. has been delayed by many years. In fact, the American car designer though readily admitting that i.r.s. is the ultimate answer, also feels that i.r.s. is the "easy way out" and will always be expensive to manufacture.

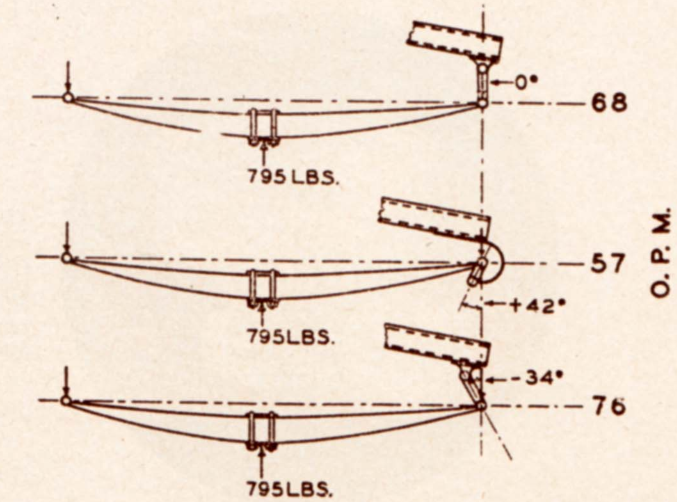
To combat the inherent evils found in c.r.s. systems we find the approach to be about as follows (not necessarily in sequence):

1. *Better coordination of ride frequencies, front to rear.* Studies of mass distribution and ride rates, both experimentally and mathematically, have resulted in the modern "flat" ride, virtually free from pitching.

2. *Better spring geometry.* A conventional pair of semi-elliptic leaf springs for 1955 may look the same as used in 1925, but there is a tremendous difference in the application. Under full design load the modern spring is no longer flat, but concave (in side view). The position of the spring eye is very critical, since the main leaf acts as radius rod, and as a result the motion of the rear wheels can be controlled as desired and yet the severe wind-up stresses of acceleration and braking are cushioned. The designers can arrange for varying degrees of rear-end roll-steer, merely by raising or lowering the front attachment point of the rear spring eye. In this way he can develop any amount of desired understeer (within reason) to match the understeer-oversteer characteristics of his front end geometry.

The metallurgist has also played a very important part in the continued popularity of semi-elliptic leaf springs at the rear. Spring breakage was not at all unusual prior to 1925. Today it is almost unknown, yet an average rear spring for a given car weighs less than half of its 30-year-old counterpart and does nearly twice the work (stress loads) due to the much greater rear wheel travel (bump plus rebound) of the modern car. This has been done through the use of better materials, improved knowledge and control of heat treatment, specially rolled sections, improved knowledge of the application (to reduce peak stresses) and new surface treatments such as controlled shot-peening.

3. *Shock absorber design.* There have been only two major improvements in the basic design of shock absorbers in the past 20 years. The first was the Delco "inertia valve" (used at one time by Cadillac and the larger Buicks, see cut) and the second was the direct acting shock absorber. The d.a. type of absorber (the British prefer the term damper, which is much more accurate terminology) has many advantages such as lower unit pressures, less sensitivity to wear and leakage, plus little or no tendency to "fade" after an hour or two on a very rough road. However, the method of application is our primary concern and here experimental work and studies of rear axle hop, shake



Effect of shackle angle on oscillations per minute where lower o.p.m. indicates a "softer" ride. Tension-type shackle is shown in the center.

and tramp have made it possible to mount the shock "dampers" much more effectively.

4. *Tire design.* As has been pointed out many times the advent of e.l.p. (extra low pressure) tires tends to alleviate the problem of handling high unsprung axle weight. The tire absorbs the blow before it is transmitted to the unsprung axle assembly.

5. *Links and other accessories.* Some form of track bar or Panhard rod is now universal with c.r.s. Such members allow rubber bushed spring eyes and shackles, since they tend to keep the chassis and rear axle in a fixed transverse relationship. The transverse track bar also allows some latitude in locating the rear roll center up or down, as desired, but the bar cannot be too rigid if ride harshness is to be avoided. Side links or rods which in effect convert the wheel geometry to a trailing-link parallelogram system are occasionally used, primarily to reduce axle wind-up. However these auxiliary upper "arms" must be flexible enough to avoid binding when the chassis rolls.

Sometimes the front halves of the leaf springs are modified by auxiliary leaves to improve the radius rod function of the spring. However it is now general practice to make the front half of the spring as much as 6" shorter than the rear "half." This accomplishes the same purpose as auxiliary leaves and has one other seldom appreciated advantage. A study of the 3-link equivalent motion of such a modified spring (see Sports Car Design No. 16, Dec., 1954) will show that the axle housing must twist when the chassis rolls in a corner. Since the housing cannot twist, and since the 3-link equivalent is actually a non-symmetrical leaf spring, roll is resisted or reduced by the spring geometry. This resistance to roll is in addition to the normal resistance of a flat leaf spring to twisting movements, as viewed from the rear of the vehicle. This explains, partially, why no American car now uses a rear anti-roll bar—it already has one, built-in. However a rear anti-roll bar is not used today, primarily because it tends to create oversteer and also because too much roll-stiffness in the rear suspension lifts the inside wheel off the ground in a severe corner. A Ferrari Monza for example, under the same condition always lifts its inside front wheel showing that the rear suspension has little or no roll-stiffness. This in turn explains why the Ferrari accelerates out of a corner without inside rear wheel spin, though a limited slip differential is employed to further enhance accelerating ability under this condition.

Other "accessories" often found on c.r.s. systems include spring interleaves; usually small pads located near the end of each leaf. One of the oft-repeated advantages of the leaf spring is its built-in friction damping, but this damping is ordinarily most effective just where it is undesirable, static rather than dynamic. For small wheel movements caused by bumps it is desirable that there be no static friction, for a good boulevard ride. Friction pads give controlled

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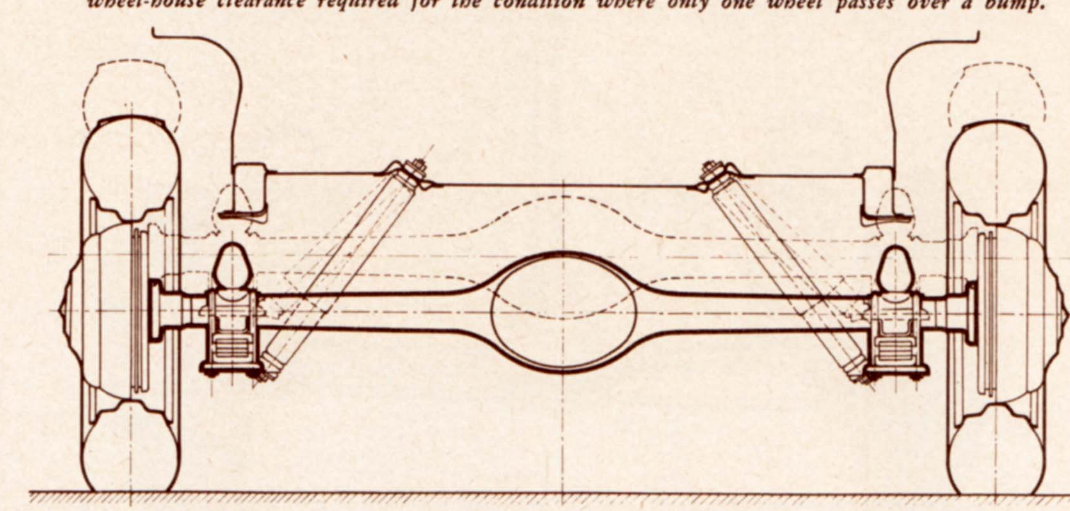
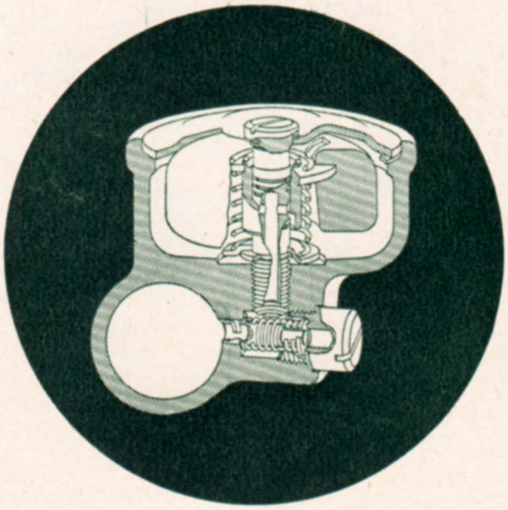
Rear view of a conventional solid axle type rear suspension with leaf springs. Note the large wheel-house clearance required for the condition where only one wheel passes over a bump.





This detail shows the Delco inertia control which automatically releases the axle when rebound control is not needed. It also eliminates the pull-down of the car body when a wheel drops into a rut.

friction which stays relatively constant without lubrication. The material used may vary from rubber to high-friction brake lining type to zinc or porous bronze.

The leaf spring also lends itself very readily to variable rate designs, desirable in order to give a soft boulevard ride without requiring excessive wheel movements over severe bumps. It has been shown that the arrangement of the rear shackle alone can give a pronounced variable rate effect; as much as 50% stiffer at full bump than at normal static load. We find many cars (Ford, Chevrolet, Mercury, etc.) using the so-called tension shackle while others like Pontiac, get a variable rate through a progressive leaf stack. Still other cars employ a rubber bumper attached to the frame so that it contacts the approximate middle of the front half of the spring at about one half of the bump travel. Regardless of the method employed to achieve a variable rate, the goal is to achieve a soft ride without too much loss in stability (the willowy-marshmallow ride).

The torque tube drive was, at one time, widely used, but has now fallen into disfavor because of cost and weight. Only Buick and Nash in this country employ such a design, possibly because the unit-assembly of axle and enclosed propellor shaft makes it a simple matter to use coil springs at the rear. Advocates of the torque-tube drive claim that the rigid assembly makes the driving wheels "behave" better under power and braking conditions, freeing the springs from all duties as radius rods. However the hotchkiss drive, with its inherent flexibility, tends to cushion these forces and more importantly, the hotchkiss drive allows rear axle roll-steer to be used to improve the overall handling of a car, something impossible to achieve with torque tube drive.

Summed up, the c.r.s. does a very good job at moderate cost. Nevertheless, once the advantages of i.r.s. become generally known, it will become universal, and for cost reasons it is very probable that the first American applications will be the "single-pivot-swing" types as described in the December, 1955 issue of R. & T. ●

The 1956 American Motors Rambler torque-tube drive assembly. The forward end of the tube is located by a pair of rubber bushings rather than the more usual ball-and-socket construction.