RECENT DEVELOPMENTS IN SUSPENSIONS

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During the course of designing and manufacturing a heavy-duty truck/trailer suspension, the final configuration of the product is influenced by a variety of safety, regulatory, environmental, and technological demands, as well as the desires of the customer, and availability or unavailability of raw materials and components from suppliers. First on the list of design criteria is the demand for safety. The suspension must not contribute to instability of the vehicle during operation in what would be considered reasonably close to the vehicle's intended use.

Of course, customer's demands must be met as much as possible. The customer will always desire low cost, light weight, and reliability. Smooth ride and protection of driver, cargo and vehicle from shock is usually desired. Implicitly, other factors such as maintainability, ease of installation, and parts availability must be met. Longer and longer warranties are being asked for, and sometimes special performance requests such as a specific deflection rate or roll rate are made. The list of demands from customers is a long one.

Not having the proper material or component available in time to complete a delivery can be a big problem. Everyone wants to keep inventory costs as low as possible. Commonality of parts among products is therefore desirable. Steel and ductile iron are the primary ingredients in any suspension, and substitution of alternate materials must be cost effective. They will continue to be the primary materials in years to come. Secondary materials, such as rubber, plastics, and composites have been improving rapidly in truck applications and wider use of these materials will be made, but cost and lead time problems will surely plague these, as well.

Governmental regulations dictate many of the basic design parameters of a truck suspension, such as axle ground load, axle spacing, and number of axles in a group. Changes in regulations require diligent monitoring and sometimes quick response, but do not usually result in large costs to the suspension manufacturer (at least it hasn't so far). Not all changes cause a problem; for example, allowing wider trailers in the United Sates (and, therefore, wider spring centres to go along with them) dramatically improves the roll rate of any suspension, without adding weight or cost or degrading ride. Foreseeable legislation that could affect suspension manufacturers might be in the area of road damage caused by a particular type of suspension. If restrictions were placed on any particular configuration, this could result in some changes in market share for many suspension manufacturers.

Environmental considerations must be made, especially with regard to rubber and plastic parts, although corrosion of highly stressed steel parts such as springs is also a problem. High and low temperatures, dirt, salt, and chemicals are only some of the concerns to be addressed. Poor roads and off-highway use, when applicable, must be considered, although the end use of the suspension is not always known to the manufacturer, and misapplications do occur.

Advancing technology gradually changes trucks and the suspensions that support them. Improves tyres such as radial-ply improve traction and increase life. Brakes have improved with the advent of anti-lock systems and with non-asbestos linings that have a greater co-efficient of friction and therefore greater brake torque. The combination of better tyres and brakes means trucks can stop quicker, but at the same time this increases the braking loads on the suspension.

At the same time, empty weights of the vehicles have been reduced, which can degrade the ride of an empty vehicle, and, in conjunction with improved brakes, also has contributed to wheel hop during braking of lightly loaded trailers with a conventional spring suspension. Fortunately, technology such as computer aided design, computer modeling, and finite-element analysis along with physical testing, can be applied to prevent these problems.

The vast majority of suspensions in use today on heavy duty trailers are the spring type which consists of steel springs attached to axles and suspended from spring hangers with a mechanical equalizing device between axles. This is by far the most common suspension in use today because of its ease of maintenance, lightweight, and durability. The second most common suspension in use is the air ride suspension. The axle is attached and located by a trailing beam suspended by a solid hanger in front and an air spring at the rear. There is little inherent damping in an air ride suspension so shock absorbers are required. There are other suspensions such as rubber, solid mount, walking beam, and single point suspensions. These usually have more narrow applications and will not be discussed in this paper.

<u>Springs Composite</u>

The venerable four spring equalized suspension continues to be refined. One of the most interesting phenomenons is the increasing use of fibreglass/epoxy composite springs in place of steel leaf springs (see fig. 1). These springs are extremely light: they weigh approximately 18 pounds each, as opposed to 55 pounds each for the three leaf steel springs they closely mimic. Fibreglass has been the choice for springs because, although it is not as strong as other possible fibres, such as carbon, it is more flexible, and produces a softer ride. One problem to be overcome is that of wear on the spring ends where they contact the steel parts of the suspension. Two approaches to this problem are being taken by the two U.S. composite spring manufacturers. One uses a steel pad bolted to the top of the spring ends; the other is experimenting with Armid fibres on the spring ends. Another potential problem is that of crushing the spring centre when tightening U-bolts. One manufacturer limits the clamp force allowed on the spring, and one encloses the spring centre in a steel cap. The greatest problem to be solved, however, is that of price. The current composite spring costs about six times that of a three leaf steel spring, and no breakthroughs in this area are looming on the horizon.

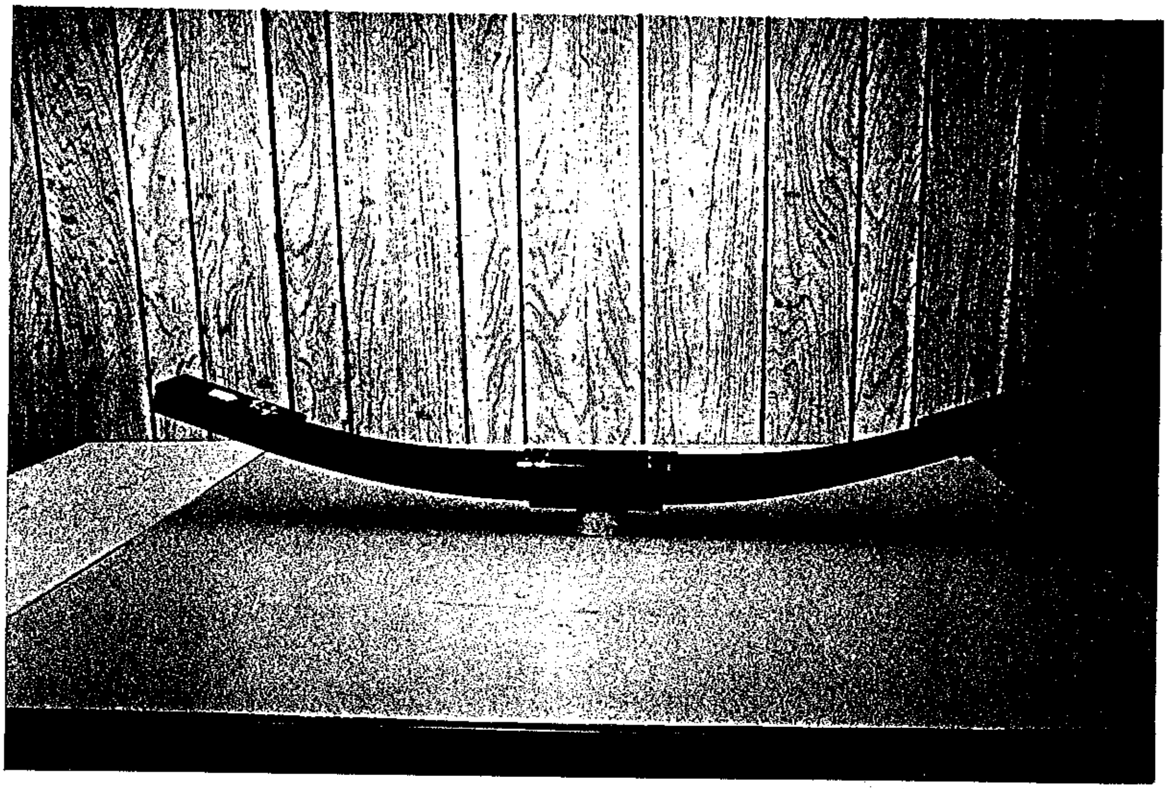

Figure 1. Composite Spring

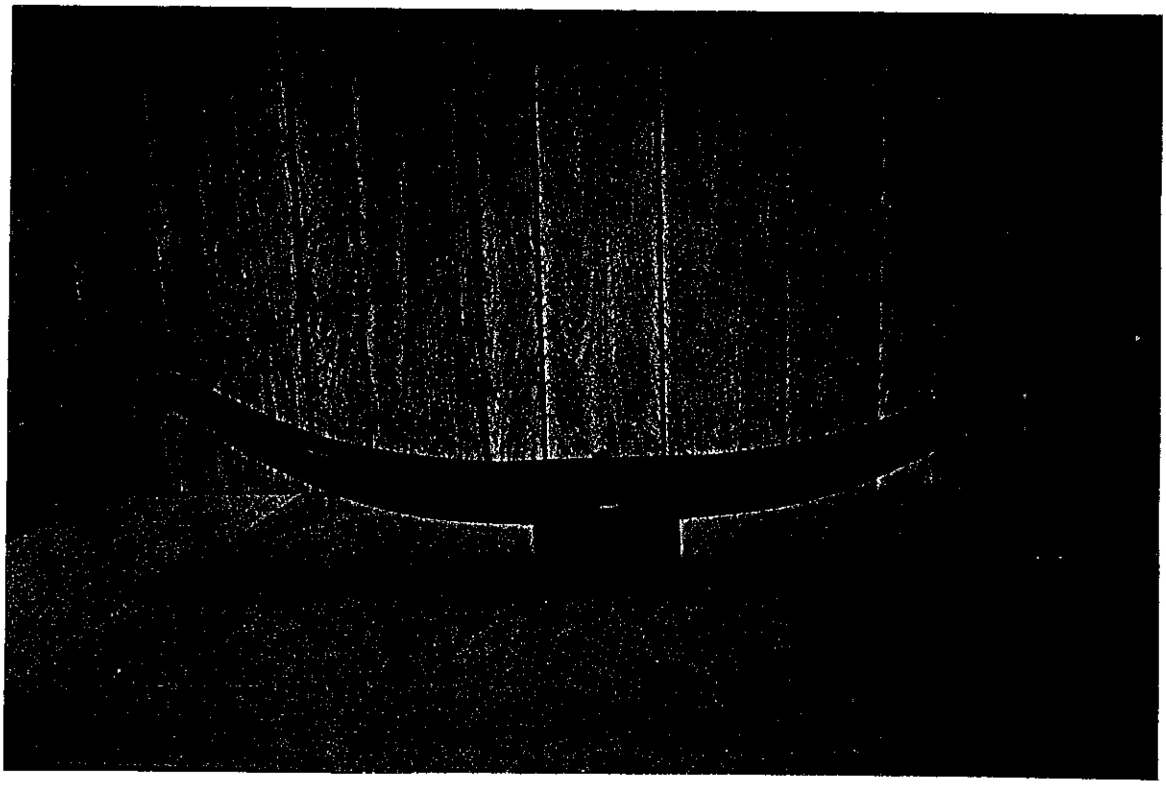

Figure 2. "Hi-Tech" Steel Spring

Springs - Hi-Tech

Uniform stressing of leaf springs by parabolically tapering the profile was developed in England over 20 years ago. The reason for tapering is to more effectively utilize steel by having more uniform stress along the length of the spring. The other aspect of hi-tech springs is enhanced durability. Inherent crack propagation is retarded by inducing residual compressive stresses in the tension surface of the spring. Enhanced spring life has brought about the need for better coatings to protect against corrosion. Fretting and corrosion are still the main cause for spring failures, but improved liners and auto-phonetic (and other) coatings have made major improvements in this area.

Hi-tech springs have an influence on ride, also. Because there are typically one to three leaves touching at the ends only, there is less interleaf friction. This allows improved response to some of the higher frequency inputs to the suspension, thus reducing the transfer of the inputs into the chassis.

So far, a three leaf hi-tech spring, weighing 64 pounds, has been able to equal the spring rate and exceed the test life of an eleven leaf conventional tractor spring weighing 118 pounds with about a 20% increase in price. Ride and durability tests are in progress.

Whatever spring is installed, it will tend to wear away the surfaces of the spring hangers and equalizers in which it operates. Liners made of ultra-high molecular weigh polyethylene have been used for several years and have had good success (see fig. 3). These pads are expensive, however, and an alternative is to use wear-resistant steel (see fig. 3). In laboratory tests, it gave seven times the life of the mild steel typically found in trailer suspensions.

Even as composite springs are gaining some use, the steel leaf spring is improving. Leaf spring weight is inversely proportional to the square of the design stress level, so if a highly stressed spring can be made to last, a large reduction in weight can be achieved. This is the basis behind today's "hi-tech" steel springs (see fig. 2). These springs start with a special steel alloy and then are heavily cold worked by bulldozing and stres-peening at a high stress level.

Urethane Bushings

In figure 4, some urethane bushings are shown. In the beam end bushing which has a steel inner and outer sleeve the urethane material actually is designed to slip on the steel inner sleeve. This cuts down enormously on the shear forces normally seen by a rubber bushing. In some environments, this bushing out performs its rubber equivalent. The bushings shown in fig. 4 are a direct replacement for standard rubber bushings and are designed identically, in that rotation is absorbed in the elasticity of the urethane and no slippage occurs.

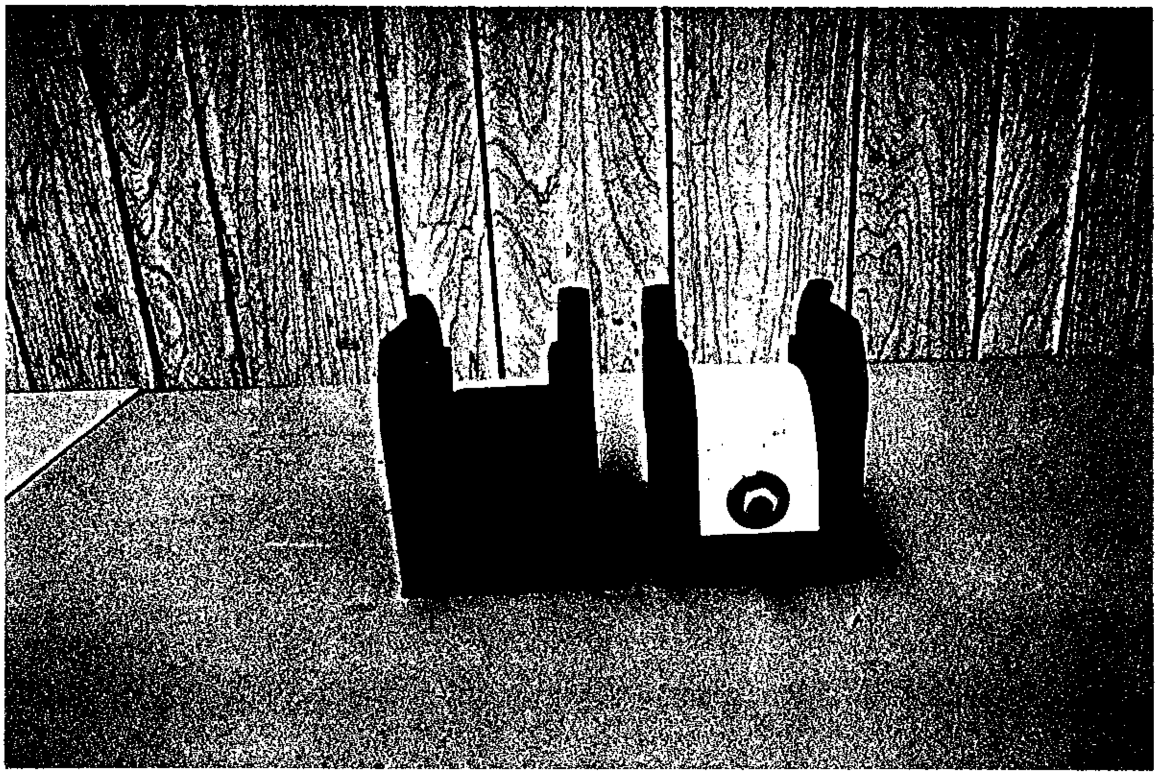

Figure 3. Hanger Wear Pads

Figure 4. Urethane Bushings

Air Suspensions

An air ride suspension is a very simple device. It consists of a trailing beam that supports and locates the axle, an air spring and a shock absorber. Despite its simplicity, this suspension is undergoing more evolutionary change than the other suspensions. The biggest difference between the types of air ride suspensions is the method employed in achieving roll stability. The three methods are:

(a) The use of the elasticity in rubber through bushings or pads (see fig. 5).

(b) The use of a spring beam which is nothing more than a steel leaf spring. (see fig. 6).

(c) Torsion bars not usually used in trailer air suspensions but sometimes in truck air suspensions (see fig. 7).

Another difference is the use of one height control valve versus two. Today's air ride suspensions are much more roll stable than suspensions of years ago, and more and more air ride suspension manufacturers are recommending one height control valve over two. Reyco recommends one valve in most cases. The advantages of one height control valve are: (see fig. 8).

(a) One valve means fewer parts so that you have reduced cost and lower maintenance.

(b) One valve eliminates the possibility of having the entire payload supported by one air bag as a result of valve failure or differences of timing between the two valves.

The advantage of two height control valves are: (see fig. 9).

(a) A quicker response to load changes in the trailer.

(b) The suspension is better able to maintain trailer attitude during off-centre loading.

Height control valves cannot be designed to maintain vehicle attitude during negotiation of curves. Any height control valve that would move air fast enough to be able to respond to "G-forces" during turning or lane change manoeuvres could result in an oscillating type of instability in the trailer. For this reason height control valves are designed with time delays and/or small orifices to limit response times. This reduces the use of air volume and puts less demand on the compressor of the power unit.

The quality of air rides today are good but the rideability and reliability of air ride suspensions would be greatly improved with advances in technology in three areas.

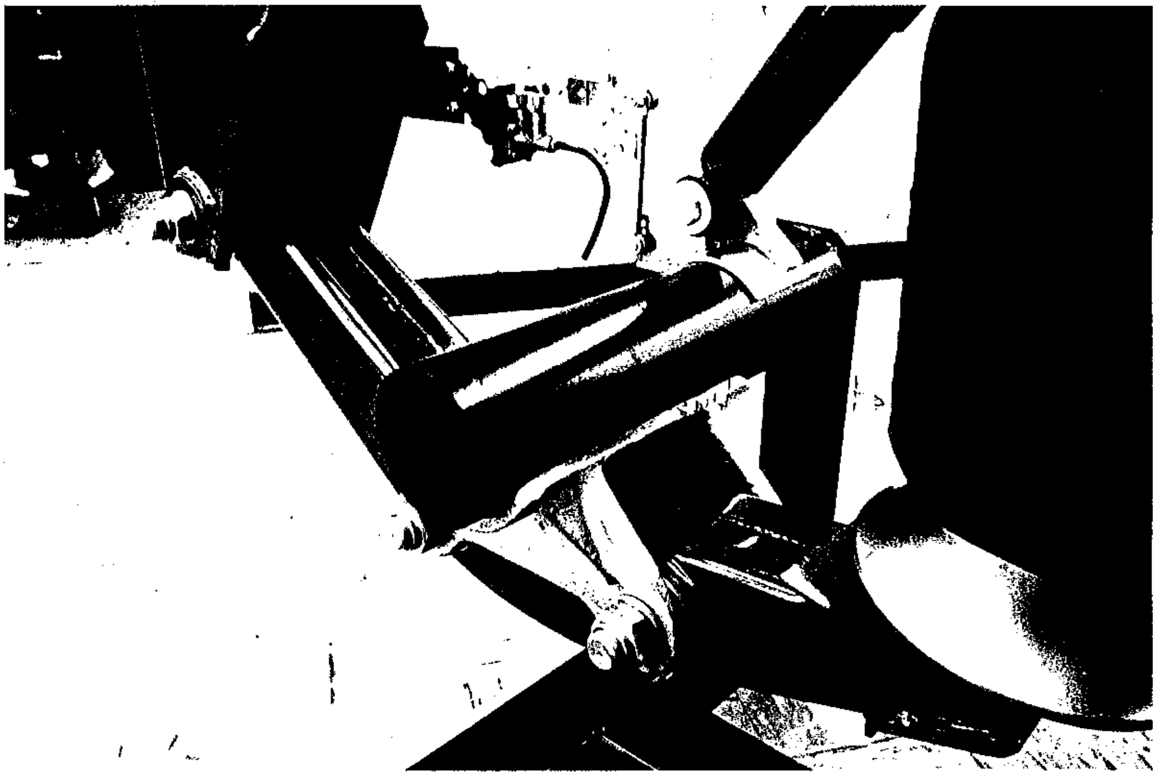

Figure 5. Air Suspension With Rubber Bushings For Roll Stability

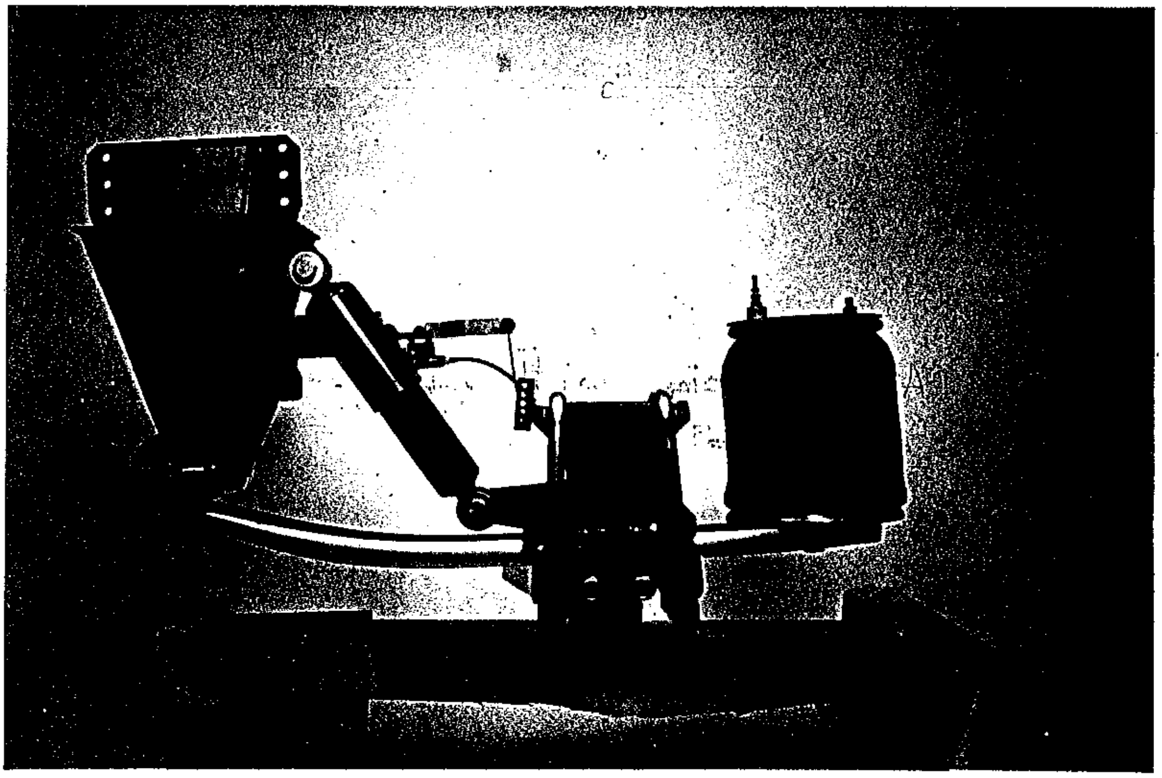

Figure 6. Air Suspension With Spring Beam For Roll Stability

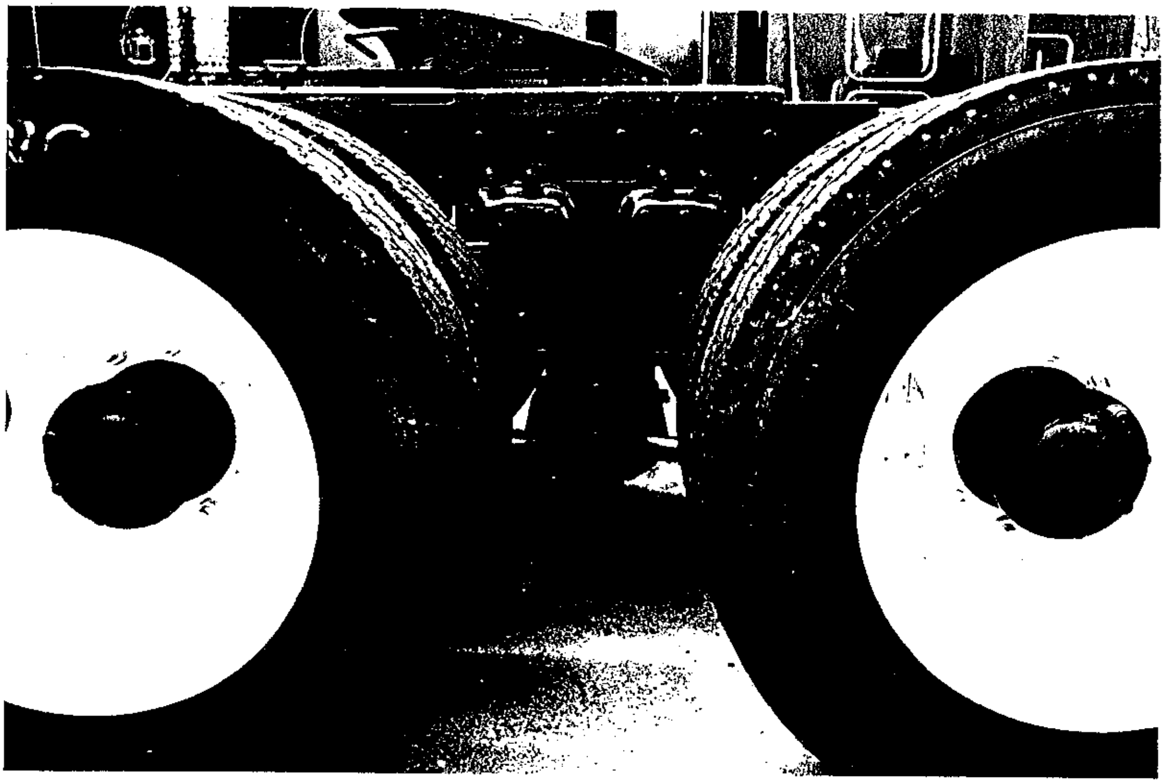

Figure 7. Air Suspension With Torsion Bars For Roll Stability

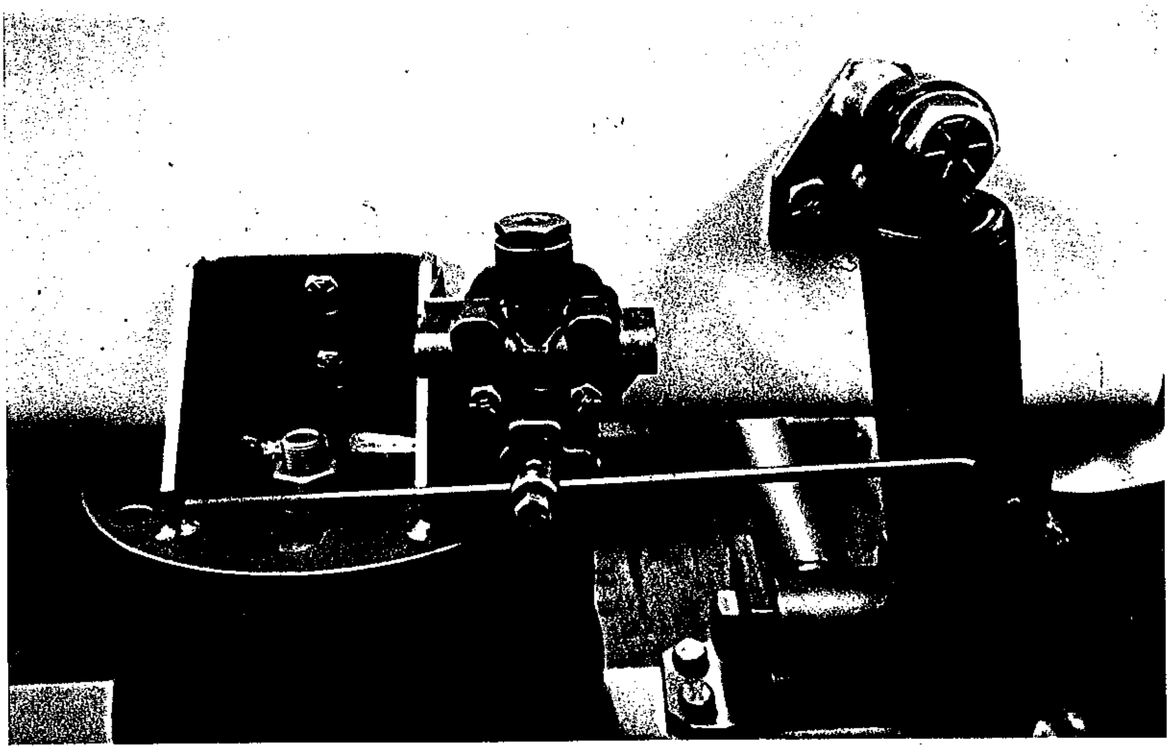

Figure 8. One Height Control Valve

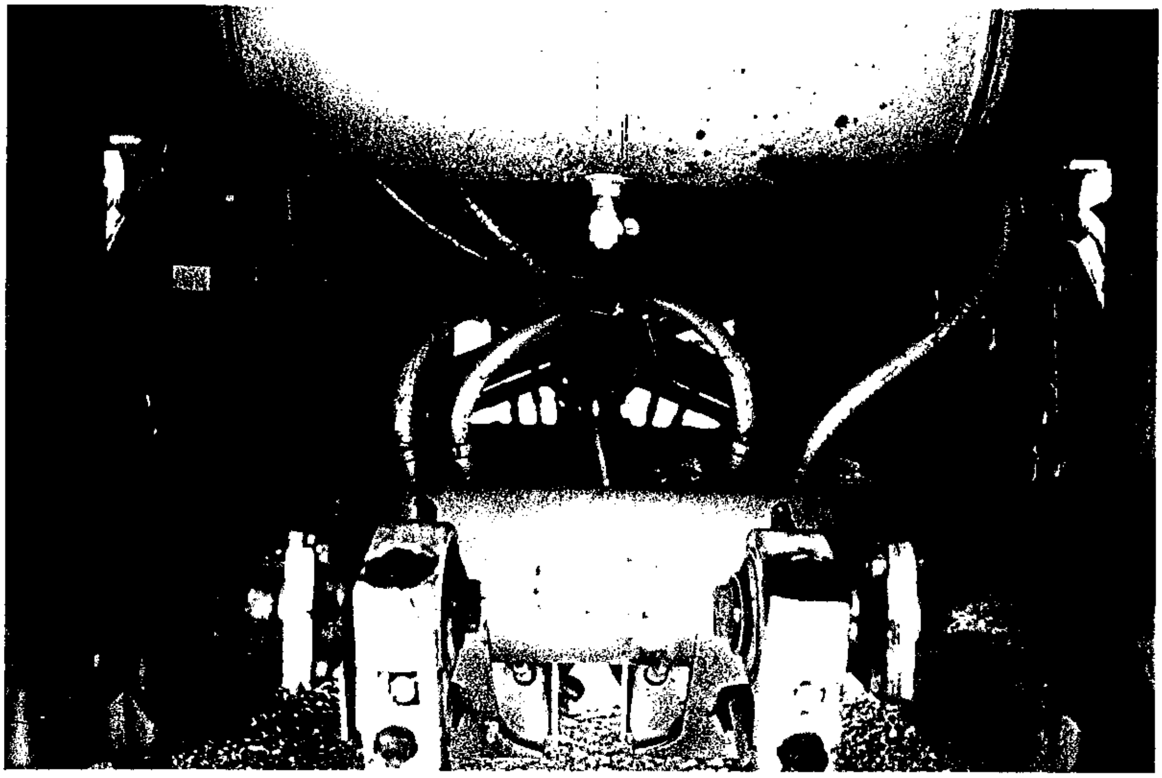

Figure 9. Two Height Control Valves

(a) Better shock absorbers - Because of cost considerations, the most common shock in use today is the old hydraulic twin-tube shock which is the type that is original equipment in most automobiles. This shock is a common replacement item on heavy duty air ride suspensions. When negotiating severe contour road surfaces for any length of time, this shock will steadily lose performance. There are at least two companies that are into initial production of mono-tube gas shocks for heavy duty vehicles (see fig. 10). While expensive, they represent a significant step forward in performance. There are also shocks that automatically vary damping rate based upon air bag pressure. This enables the shock to be more closely tailored to any particular payload from empty to full load.

(b) Improved height control valve - This valve is basically a three-way valve with its handle mechanically attached to the axle beam. As long as the trailer is at ride height the valve neither feeds nor bleeds air from the air springs. If there is a load placed on the trailer, the increased load will compress the air spring and the frame will move closer to the axle. This rotates the valve handle and the system will feed air into the air spring until the desired ride height is again reached. The opposite happens when load is removed. As long as the load on the axle is constant there is no need for there to be any operation in the height control valve. The problem with the valve used today is that it is always in a harsh environment and it is mechanically linked to the axle which is in a constant oscillating state during operation which means the valve handle is constantly rotating.

It is not surprising that the height control valve is the most troublesome component on an air ride suspension. Many valves are built with a time delay mechanism so that the transient small up-and-down movement of an axle as the trailer is travelling down the road does not involve the addition or deletion of air from the air spring thus depleting air supply from the brake system air tanks. There is also a "dead band" area in the valve of two or three degrees of rotation so that minor changes in ride height do not cause the valve to operate. This "dead band" area and time delay are mechanical systems that have a high degree of variation from valve to valve. This makes it very difficult for dual air valve systems to function well. An electronic device or a simple on-off switch could add to reliability and functionality of this valve because electronical switches are more capable of withstanding millions of cycles and a numerically controlled time delay can be manufactured with negligible differences from valve to valve.

(c) Better bushings - rubber bushings in most suspensions, especially steel spring suspensions serve two functions:

1. Eliminates need for lubrication. The rubber bushing eliminates metal-to-metal contact.

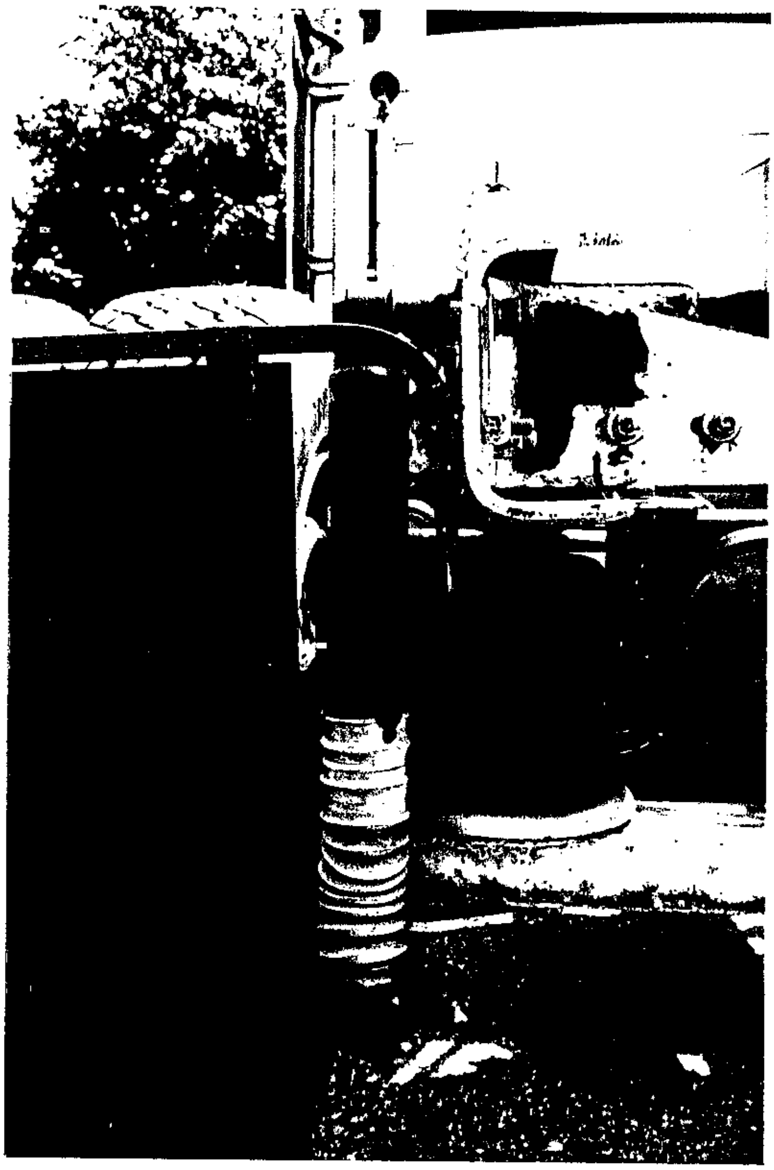

Figure 10. Gas Shock Absorbers

2. Out-of-plane rotation. The pin connection on torque arms and other joints allow for rotation in one plane only. During diagonal walk or other manoeuvres involving twisting the suspension the rubber bushing allows for a minimal amount of rotation in plates normal to standard rotation.

In addition to these two items, the rubber bushings in some air ride suspensions must be also dependent upon to supply the elasticity necessary to resist roll. There is room for better materials and better design in this area. In fig. 11 we show Reyco model 246SF beam suspension with a superior alternate to rubber bushings. The beam end bushing shown is made of urethane instead of rubber as discussed earlier. The composite bearing shown in the centre is a superior replacement for either bronze or rubber bushings. This bearing only required an initial lubrication and none is required during its lifetime. In tests it out performs bronze bearings 5 to 1.

Air Suspensions - Truck

The Reyco model 102AR air ride suspension is a Z-shaped steel spring beam type of air ride (see figure 12). This type of air ride suspension is being used by most of the major OEM truck/trailer companies. Because of the tall air bags it has excellent axle travel and stepping ability. There are several interesting design features about this suspension:

(a) Vertical mounting of the shocks outboard of the frame. This allows the shock to act parallel to the direction of axle movement. This and the fact that the shocks are mounted closer to the tyres gives the shock absorber maximum mechanical advantage in damping out oscillation and resisting roll.

(b) Turn-buckle type of alignment feature. The axles can be easily re-aligned without the use of shims by simply loosening two bolts and re-adjusting torque arm length.

A new development coming up shortly in this suspension is a 60-40 axle split for 6x2 applications. By the use of different size air bags on the front tandem axle over the rear, load can be biased on the front axle. A longer term project is underway where Reyco is working with two valve manufacturers to develop an air pressure regulating system that could be controlled from the cab. It would allow the shifting of weight from one axle to another via electronic control of air pressure. There is also developmental work on a off-road air ride suspension. It will use much heavier duty components and will be designed for up to 44,000 lbs maximum load on a single axle! Because of the reliability of these types of suspensions, we are doing development work on a similar type of suspension for trailers.

Air Suspension - Trailer

Trailer air ride suspensions have always been heavy, with, typically, a large welded beam, attached by a large pivot bushing, to a heavy front hanger, which is welded to a heavy sub-frame which features six large crossmembers. These parts are large because ALL fore-and-aft and lateral loads are reacted through the load path described above. If a track bar is added to the system, however,

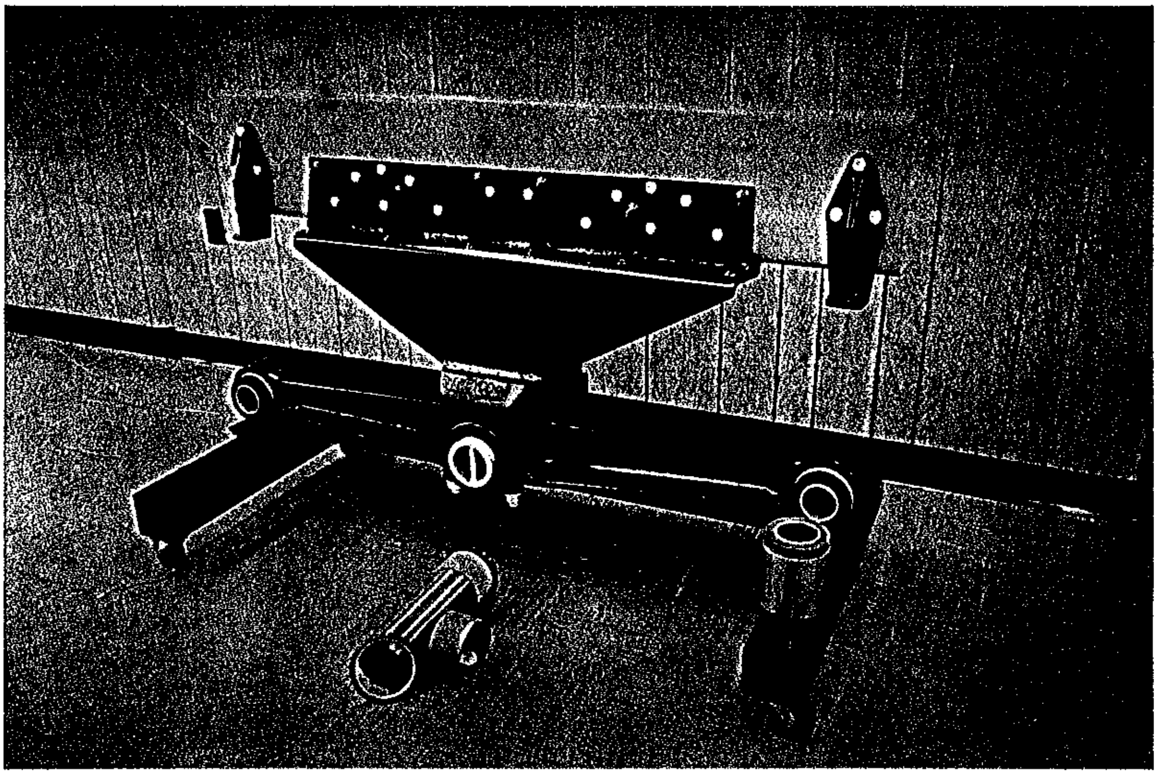

Figure 11. Use Of Urethane And Composite Bushings

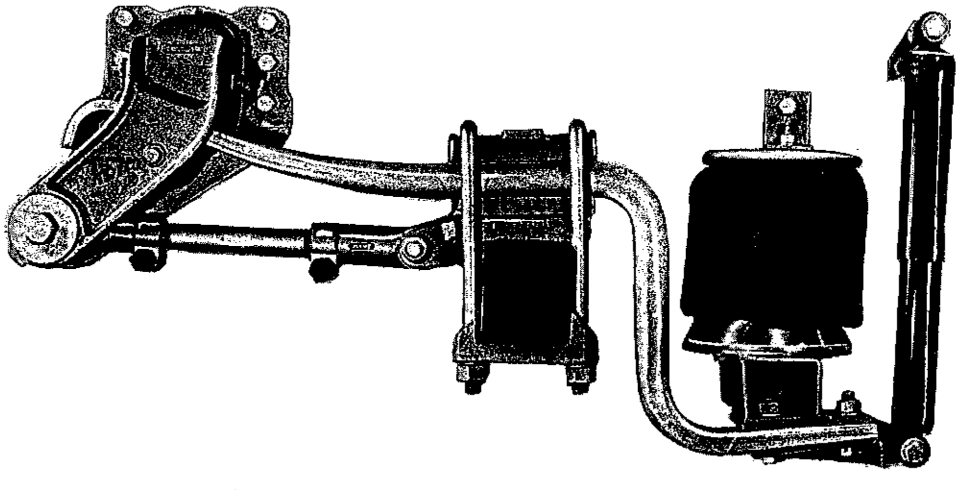

Figure 12. Reyco Model 102AR Suspension

a dramatic reduction in front hanger loads, both lateral and fore-and-aft, is achieved (see fig. 13). So much load reduction takes place, in fact, that a standard leaf spring type front hanger torque arm, and axle seat can be used. This is the basis behind the Reyco model 88AR, which is currently in the experimental prototype stage (see fig. 14).

This suspension requires the addition of only one cross member and two light air spring cross tubes to the standard four spring suspension slider (see fig. 15). Packaging has been the biggest problem on this project, which was aided tremendously by using computer-aided-design to position and design components. Efficient utilisation of the existing strength of the sub-frame has yielded a very light weight assembly. The total of the slider and suspension assembly is 1,080 pounds as compared to an approximate weight of ______ pounds for most air ride frame and suspension assemblies.

The model 87 is Reyco's second generation air ride (see fig. 16), following the development of the model 81, and stems from the desire for a lighter weight, lower cost air ride suspension. It features a welded, dia-formed beam which is common to all mounting heights from 6½" to 17" while still maintaining the same basic air ride and frame structure. The beam goes under the axle, allowing brake camshafts to be positioned in a variety of places both fore-and-aft of the axle. Attachment of the beam to the axle is achieved without the use of U-bolts. Design integrity was assured by finite-element-analysis and comprehensive testing. The result is a light, simple, durable air suspension. By modification of the length of the trailing beam, this suspension can be made to fit self-steer axles.

<u>Air Suspension - Front Axle</u>

The model 1212 is Reyco's newest suspension currently being marketed (see fig. 17). It is a front steer axle suspension designed for buses and motor homes. This suspension or one similar to it can be used on Class 8 tractors and trucks. It has ratings up to 12,000 lbs. The air ride suspension will come to the steer axle of tractor suspensions for the following two reasons:

(a) The spring rate and damping co-efficients can be more closely tailored to the air ride suspensions that are now very common on the rear axle or power units.

(b) Air ride suspensions allow for constant ride height. In a very short time most larger trucks will be equipped with some types of air ride suspension. One of the benefits of air ride suspensions is the constant ride height for all graduations of loading from empty to full. With the present long tapered steel spring on the front of a truck, the difference in height from empty to full can vary the height of the frame at the front of the truck by 50-75 mm. This will put a forward slope to the frame. This of course will also change the pinion angle. Correct pinion angles are necessary for drive line life and to combat drive line induced vibrations. Peterbilt, a Paccar company in the U.S., has already introduced a front steer axle air ride.

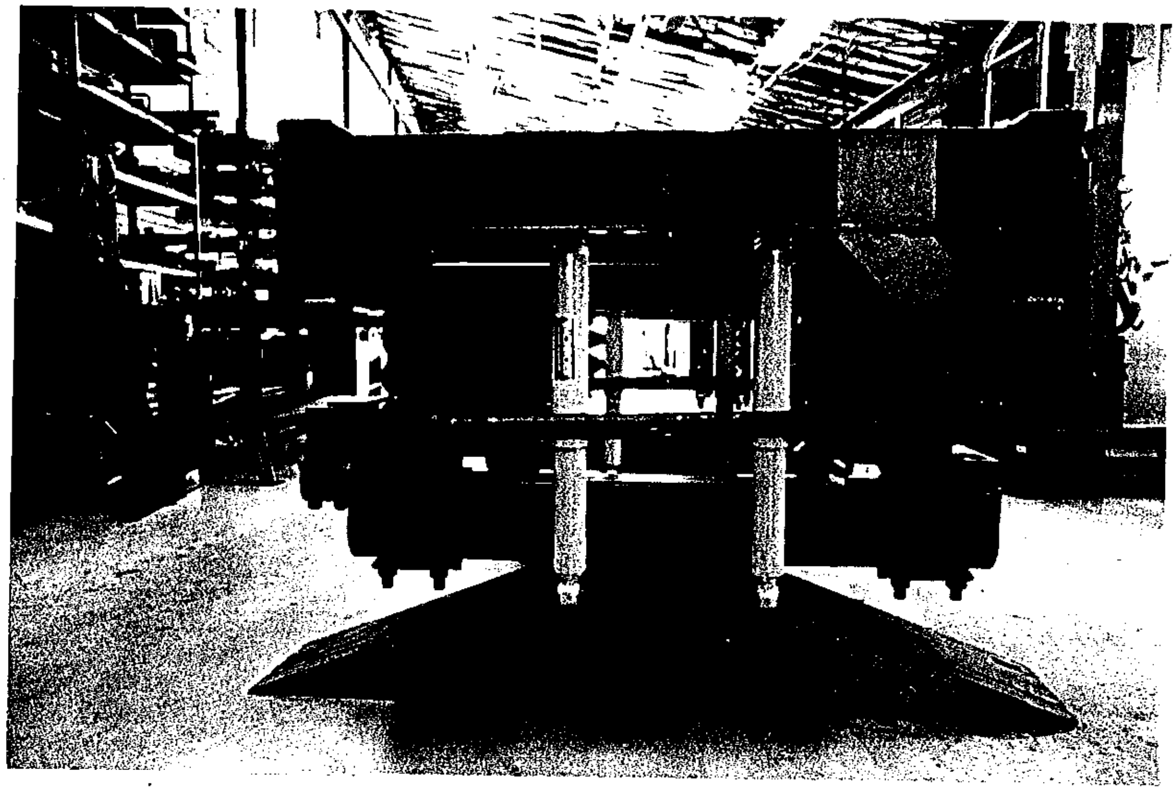

Figure 13. Track Bar

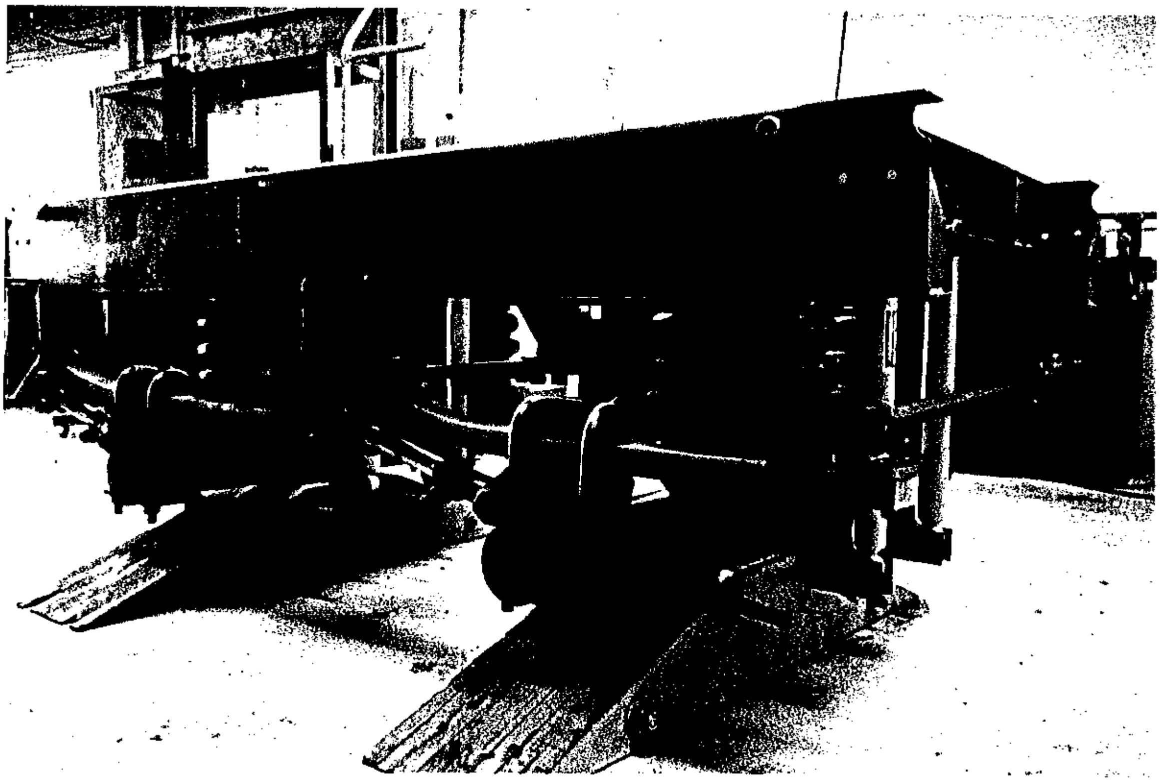

Figure 14. Reyco Model 88AR Suspension

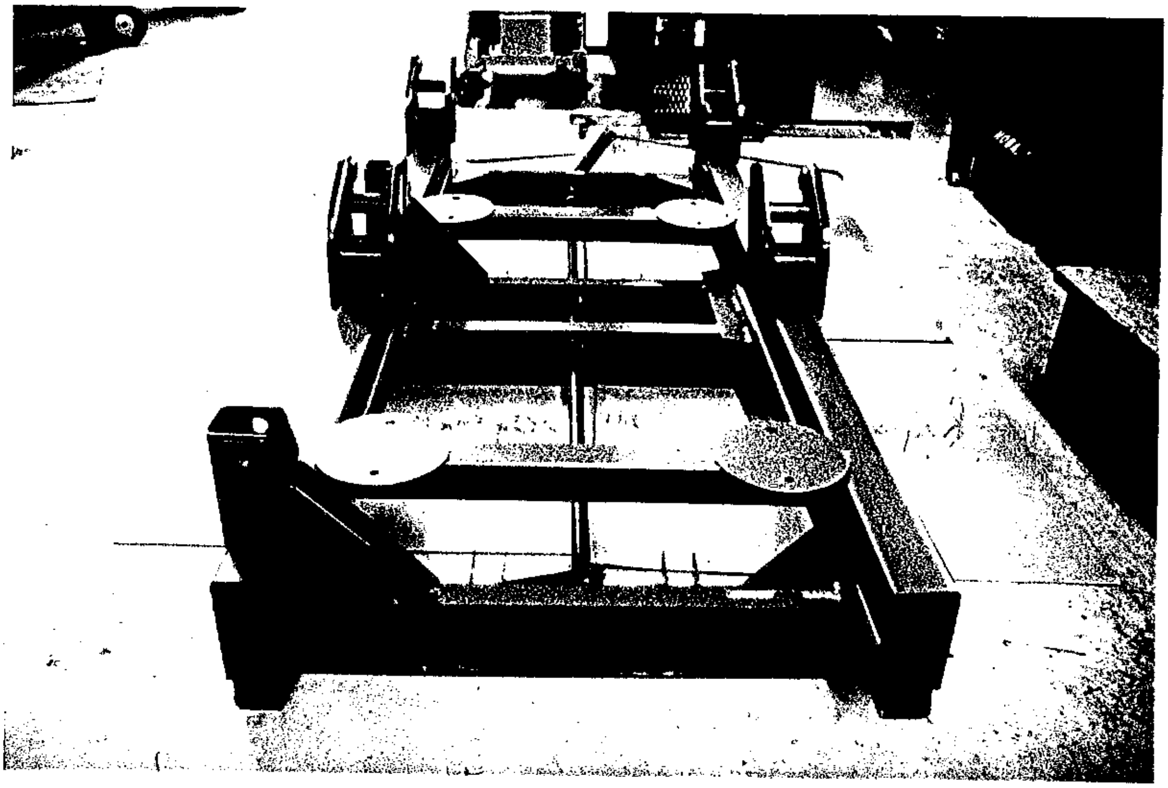

Figure 15. Light Weight Sub-Frame

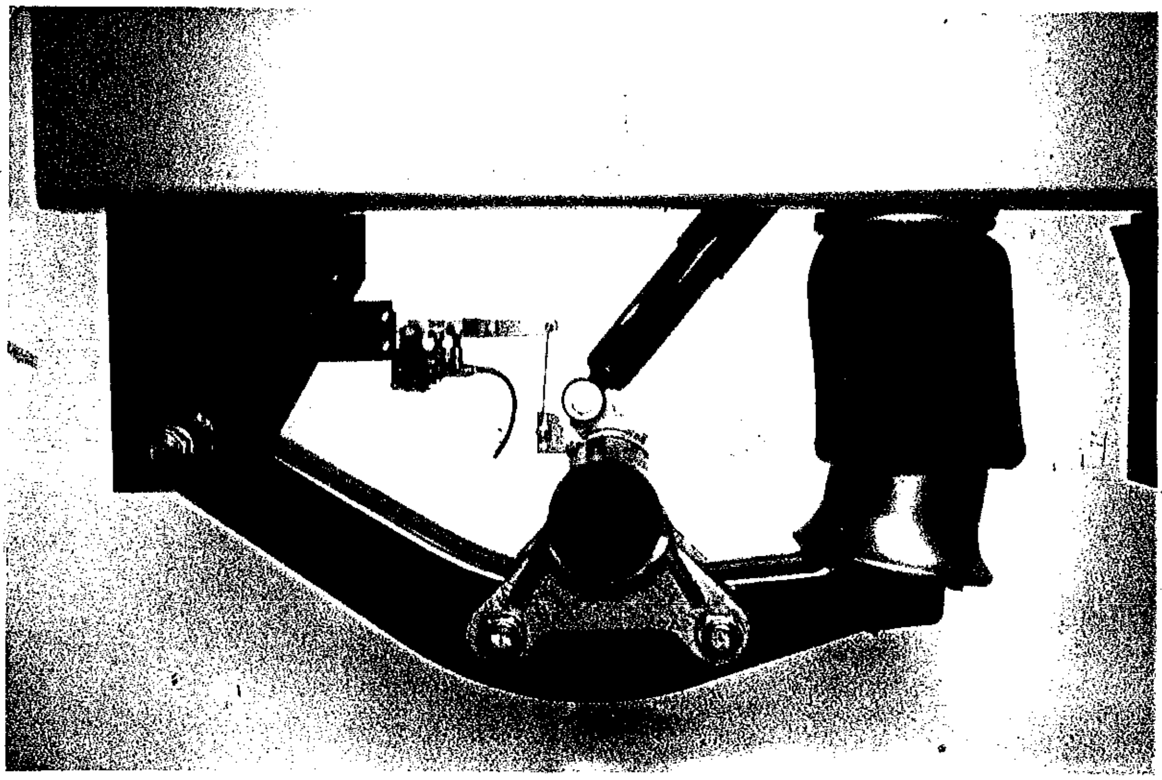

Figure 16. Reyco Model 87 Suspension

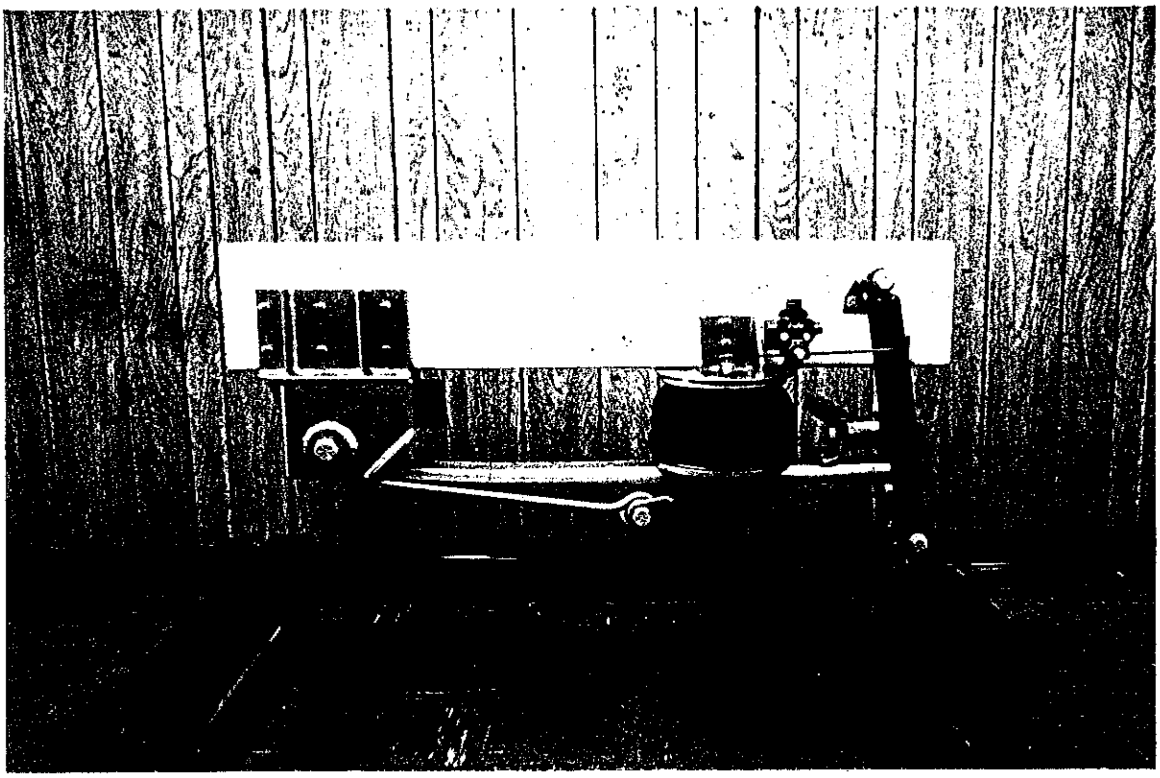

Figure 17. Reyco Model 1212 Suspension

We are currently working on a version of this model for straight axle application on small trailers. This suspension would have a rating of 12-14,000 lbs per axle. In the U.S., it is becoming very common to use small power units and small trailers that can haul up to maximum of 30,000 lbs for delivery purposes within a 500 mile radius. We hope this small air ride suspension will service this small trailer market.

In conclusion, the change from steel spring suspensions to air ride has been revolutionary, but the changes within the steel spring and the air ride suspension designs is evolutionary as new material and techniques are developed.