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Air springs for vehicle suspension

The introduction of a completely pneumatic suspension for motor transport heralds a new era in comfortable travel. This article is the first in a series covering this revolutionary development from the viewpoint of the various firms who are pioneering it.

At some time or other we have all seen the odd package or crate being bounced about in a lightly loaded van or lorry, experienced an uncomfortable ride travelling in an almost empty bus, and had the unpleasant sensation of slipping sideways towards the gangway when negotiating bends, particularly on high-speed coaches. These sensations are all due either to insufficient or excessive deflection of the well-known leaf or coil springs at present in use on all types of road vehicles.

For many years suspension engineers have envisaged the replacement of these springs with some form of suspension incorporating the use of compressed air.

The Firestone Tyre & Rubber Company designed and manufactured a prototype air suspension for an automobile in 1934. It is not until recently, however, that the motor industry has started to develop schemes for their individual vehicles. Since 1934 this firm has investigated many types of air container and now have two basic types, one for commercial vehicles and the other for automobiles.

The writer had the opportunity, during a recent visit to the U.S.A., of riding on a coach fitted with air springs. The 85 miles outward journey was made on a coach fitted with steel springs with consequent upsetting vibration and " side slipping " on bends. The return journey was made on a Greyhound Coach fitted with Firestone Airide Springs. The improvement in comfort was remarkable—sitting with one's eyes closed, there was, except for the whine of the tyres, no evidence of motion at all, even at speeds up to 65 m.p.h.

The following comparison between air and steel springs makes the significance of the development clearer.

Comparison with steel springs

The normal type of leaf or coil spring has a linear load-deflection characteristic, *i.e.* equal increases in load give equal increases in deflection. Consequently, the natural frequency as calculated from $f = 188/\sqrt{d}$ (where f = natural frequency (c.p.m.) and d = static deflection (ins.)) will vary with static load on the spring.

Thus for a heavy load the frequency will be reasonably low. For a light load the frequency will be higher, and high frequency vibrations will be transmitted throughout the vehicle causing personal discomfort to driver and passengers, mechanical injury to the vehicle, and damage to fragile payloads.

Due also to the variable spring deflection with load, the distance of the centre of gravity of the

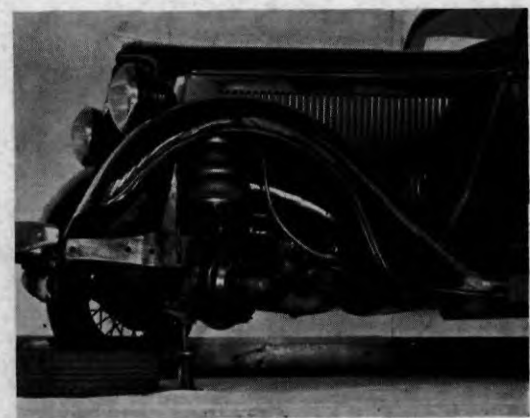

Fig. 1. *Airide springs fitted to 1934 Plymouth*

vehicle above the ground will increase as the load decreases, giving variable stability.

On cornering, say a left-hand bend, the body will tilt relative to the axle owing to load transference from the near-side to the off-side springs. This is particularly noticeable to coach passengers.

Steel leaf springs require periodic lubrication to minimise friction between the leaves. Replacement is necessary when sufficient permanent set reduces the amount of spring movement to bump stop to a low level.

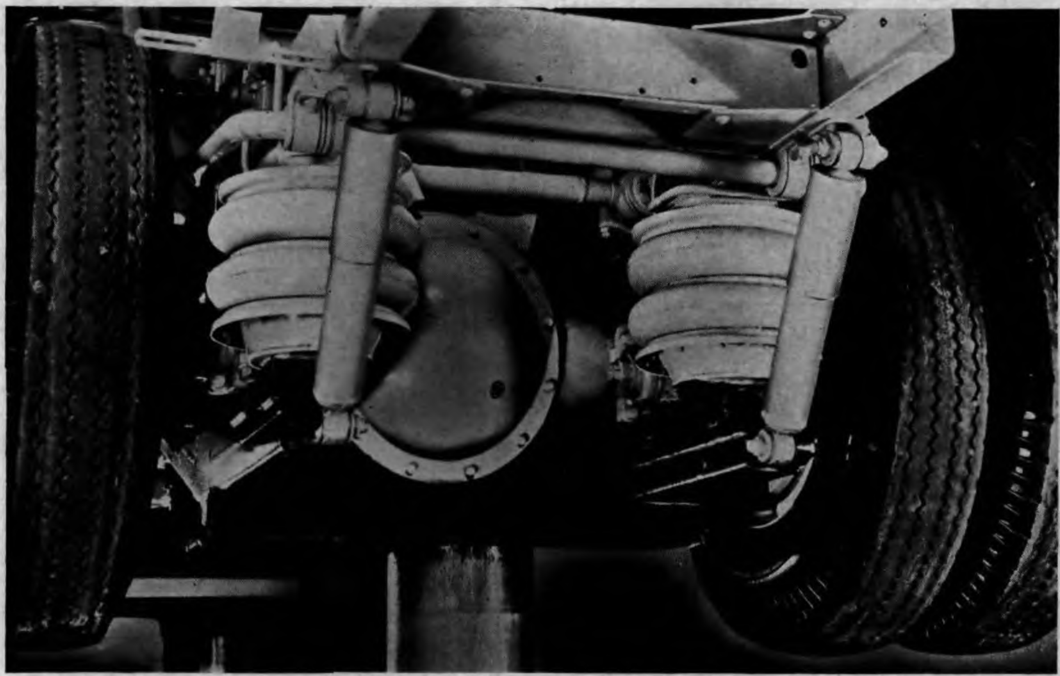

Fig. 2. *Airide springs fitted to rear of a General Motors Tractor*

Air springs

A typical spring installation for one axle showing the various items is shown diagrammatically in Fig. 3.

This will be seen to comprise two air springs placed between the axle and suitable body strut. (The actual number will be dependent on the space available and the static load being supported.) To each set of air springs is connected a height control valve actuated by relative movement between axle and body caused by changes in load. Thus an increase in load will tend to compress the spring, but this movement operates the valve and admits air to the spring which returns to its normal height. Conversely a reduction in load is compensated by exhausting air from the bellows in order to maintain the same height. Thus, irrespective of load it is possible to maintain the centre of gravity of the vehicle at a constant height above ground level.

Keeping a constant spring height means that for normal road driving a constant natural frequency is achieved, with the resultant improved ride characteristics. With regard to the bellows themselves, there is no maintenance required and in normal use they will out-last the life of the vehicle. As no moving parts are involved the necessity for lubrication is eliminated.

The Firestone Airide Springs have been successfully used in the U.S.A. for many years on coach, truck and trailer applications, having now been in service for many millions of miles. The application to automobiles has been developed in the past two years and two major American companies will be fitting air springs later this year. Figs. 4 and 5 show typical Airide installations for a commercial vehicle and an automobile.

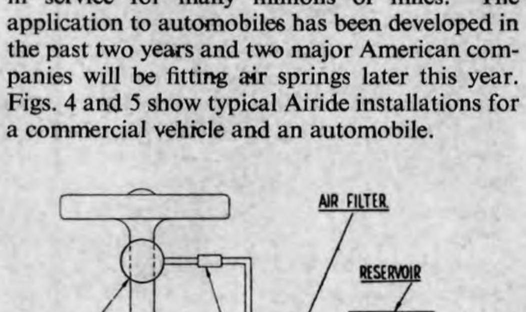

Fig. 3. *Diagrammatic arrangement of the various components required for an air suspension system*

When fitted in place of existing independent suspension coil springs the Airide installation is relatively simple, since the means of axle location are already supplied. However, when replacing leaf springs, as the Airide spring has no horizontal

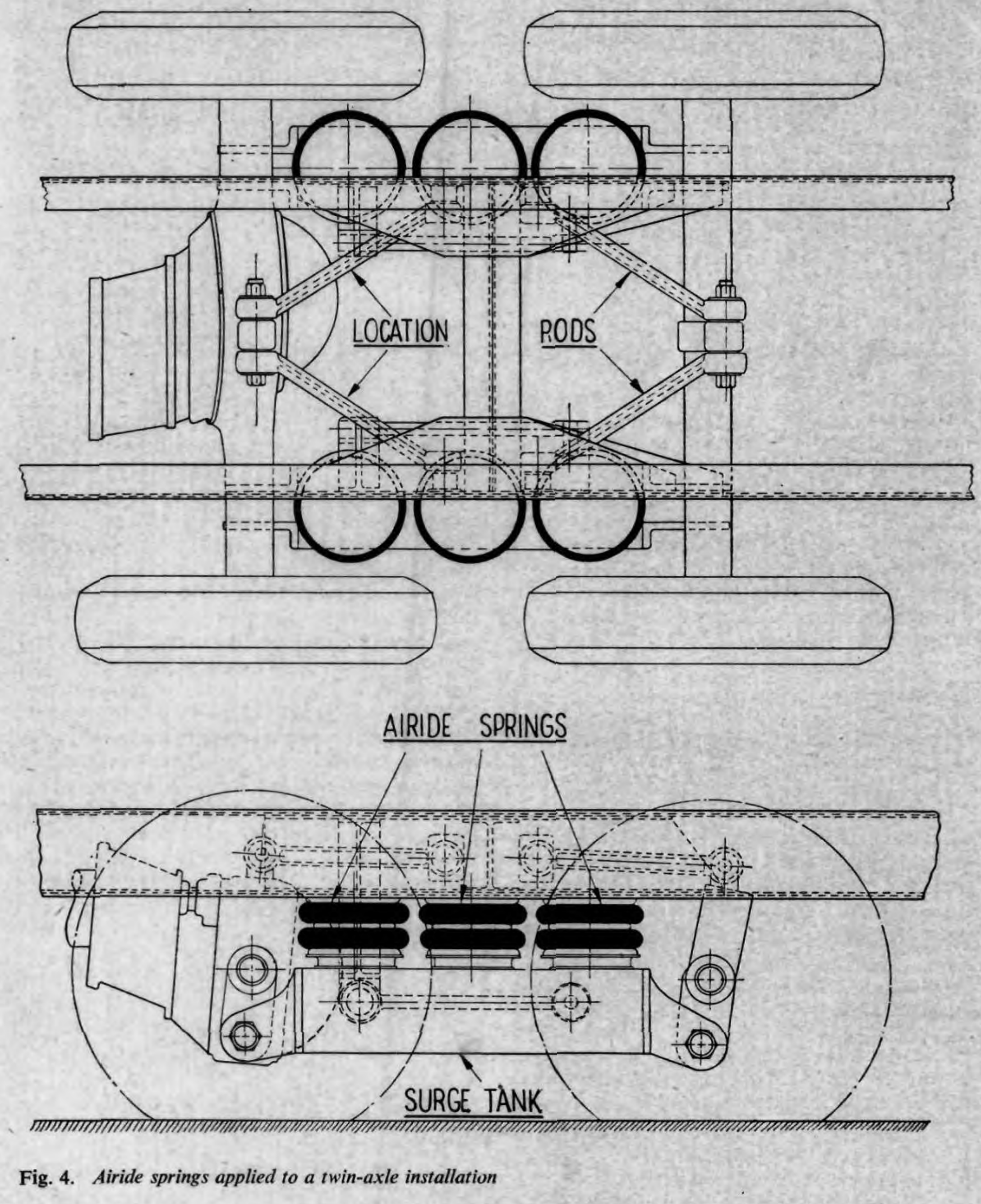

Fig. 4. *Airide springs applied to a twin-axle installation*

stability it is necessary to provide means for locating the axle relative to the body.

Briefly, the theory of air suspension is as follows. Due to bellows deflection between full bump and full rebound typical " effective area " and volume curves will be as shown in Fig. 6.

Thus, from a knowledge of these curves and the pressure in the bellows (from consideration of adiabatic compression and expansion according to $P_1V_1^{1.38} = P_2V_2^{1.38}$) it is possible to calculate a dynamic load-deflection curve as shown in Fig. 7.

We now have sufficient information to calculate the rate curve as shown in Fig. 8.

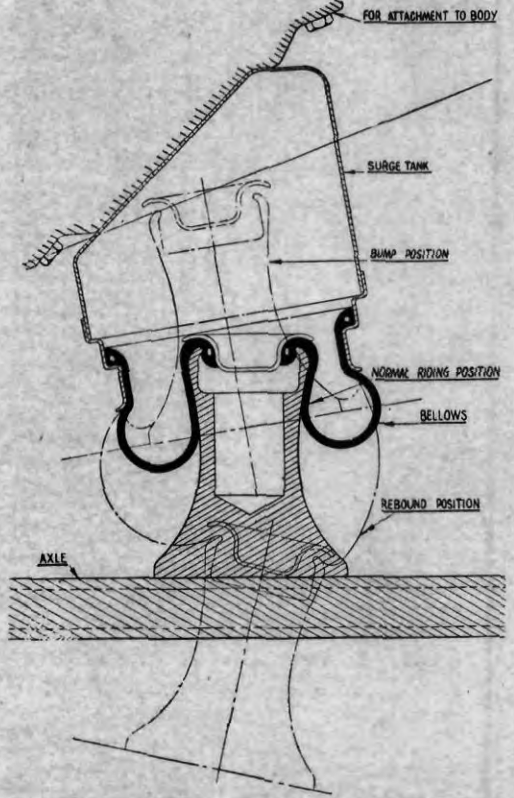

Fig. 5. *Typical Airide spring for automobile applications*

Thus, by adjusting the internal air pressure to suit the loading, the rate will be automatically adjusted to keep the frequency constant.

Height control valve

The height control valve is of special design incorporating a time delay element. This is necessary so that when riding on uneven roads the air in the bellows is allowed to compress and expand to give the variable rate curves referred to above. Consequently, when a change in static load is made, there is a short time delay before the valve operates.

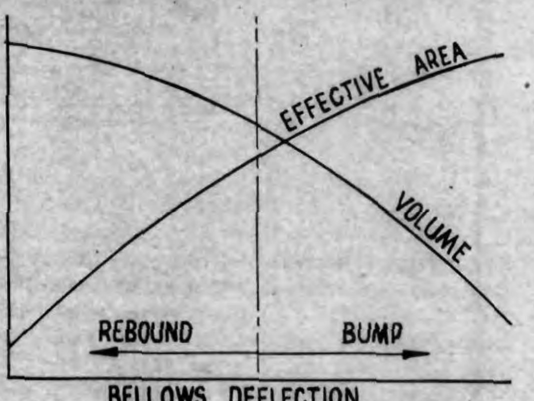

Fig. 6. *Effective area and volume characteristics*

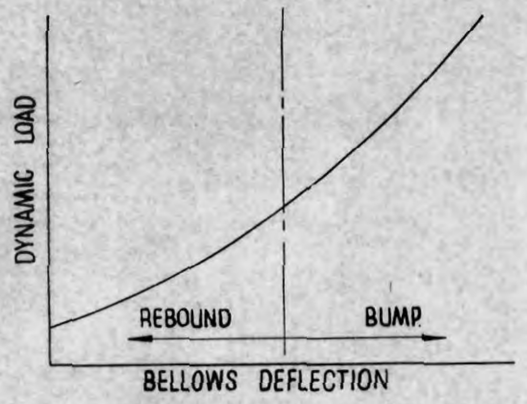

Fig. 7. *Dynamic load curve*

In order to cater for low frequencies and rates required by vehicle designers, it is necessary to attach the bellows to a surge tank. The effect of varying the size of the surge tank is shown on Figs. 8 and 9.

Thus, it will be seen that an Airide installation possesses many interesting characteristics which hitherto have not been available to suspension engineers. It is necessary to fit bump and rebound stops to ensure that the bellows is neither fully compressed nor fully extended. The use of shock absorbers is also necessary since the air system does not possess any inherent damping

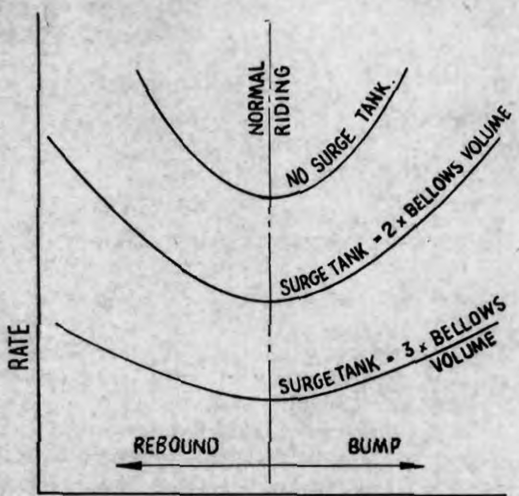

Fig. 8. *Effect of surge tank volume on spring rate*