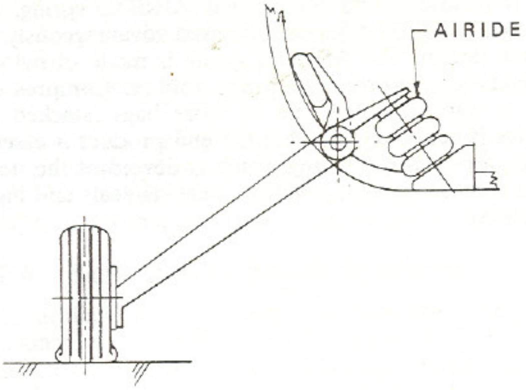
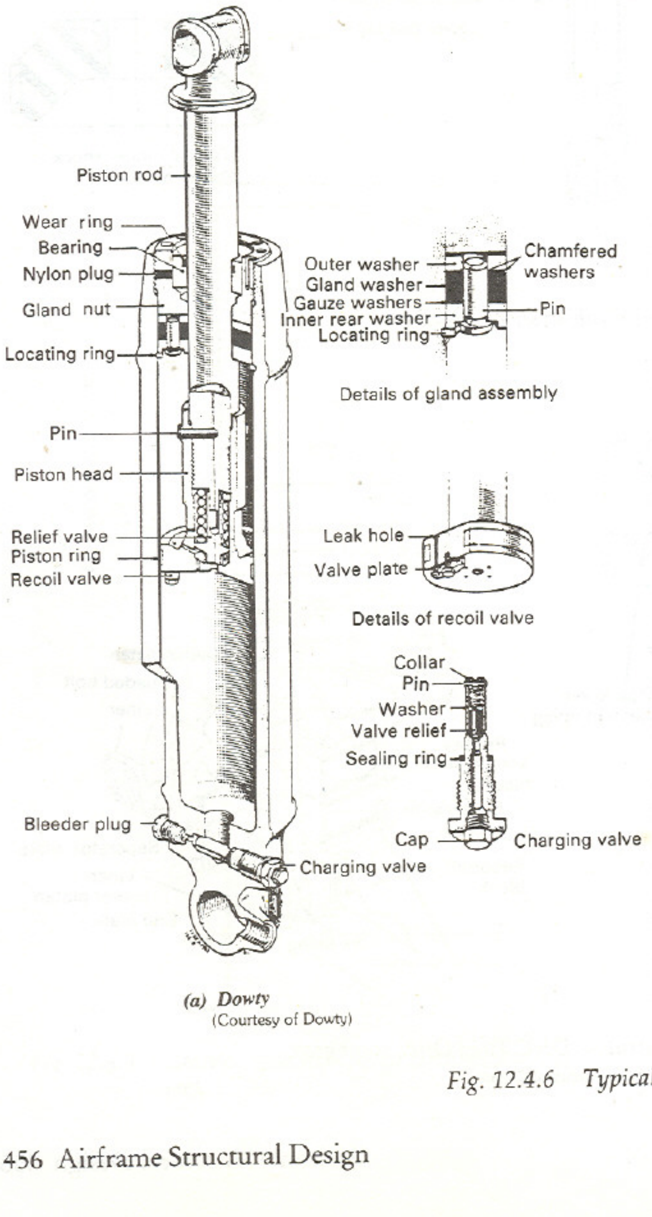


Fig. 12.4.5 Possible AIRIDE spring application.

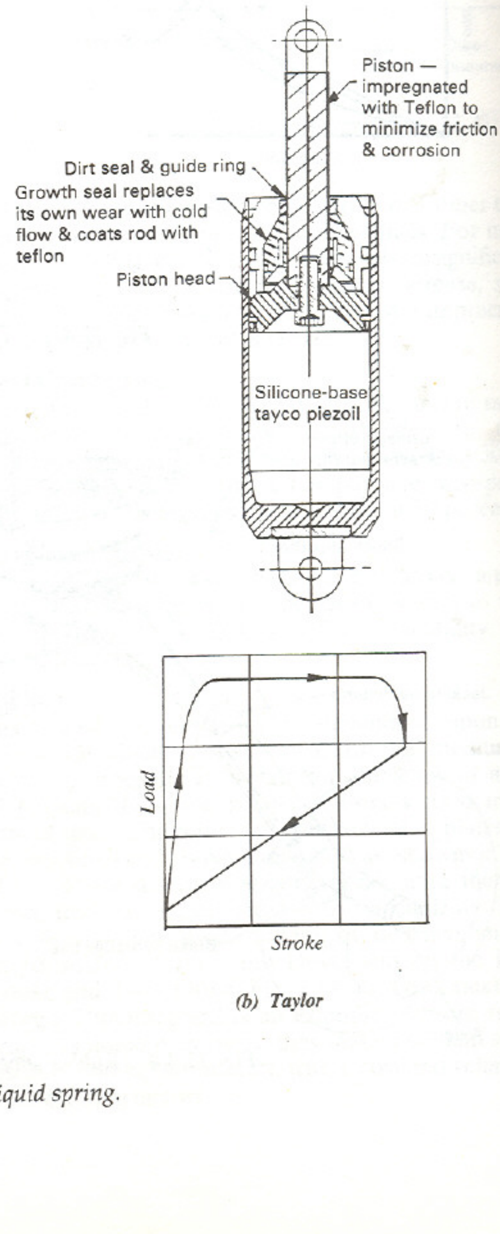
Oil (Liquid Spring)

Fig. 12.4.6 shows a typical liquid spring. These have about 75 to 90 percent efficiency; they are as reliable as an oleo-pneumatic unit, but slightly heavier due to the robust design necessitated by high fluid pressures. The advantages of a liquid spring are: few fatigue problems due to robust construction, elimination of inflation/deflation, and relatively small size. Disadvantages are: fluid volume changes at low temperature affect shock absorber performance; the shock absorbers can only be pressurized while the aircraft is on jacks (i.e., with gear extended) due to the pressure levels required; high pressures must be sealed; and the unit has high mechanical friction and stick-slip action.

The liquid spring, as the name implies, uses the compressive properties of liquids as a springing medium. The same fluid volume is used in a dash-pot effect to control the recoil stroke. The liquid spring,



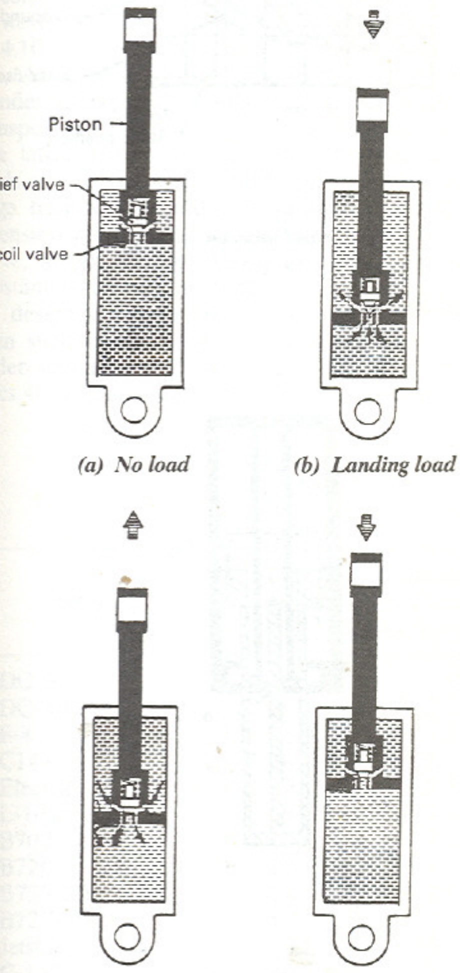
(a) Dowty
(Courtesy of Dowty)



(b) Taylor

Fig. 12.4.6 Typical liquid spring.

trated in Fig. 12.4.6, is simple in construction, nprising a cylinder, piston rod, piston, and gland. ng motion is accomplished by forcing the piston into the cylinder, displacing fluid volume thereby npressing the liquid. Energy is dissipated during compression stroke by transferring fluid to the osite side of the piston passing the central spring-led valve and a smaller open orifice in the piston. the recoil stroke, the spring-loaded valve closes, ricting flow to the small open orifice, thus damp-the outward movement of the piston rod (see Fig. .7).



(a) No load (b) Landing load (c) Recoil (d) Static load

Fig. 12.4.7 Liquid spring operation.

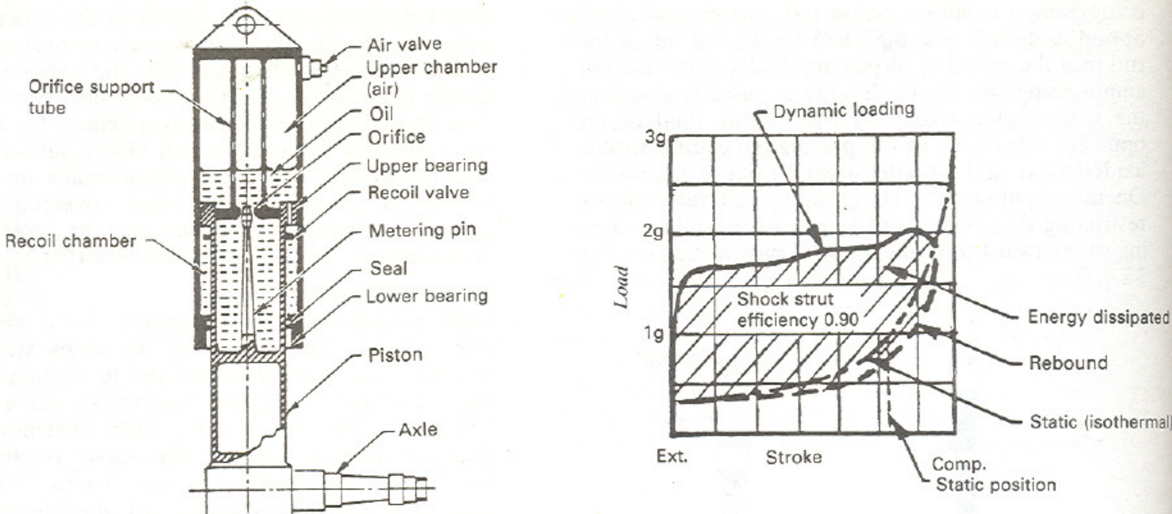
he spring-loaded valve gives the shock absorber rent spring characteristics for high and low mic loading. This is especially important on wheel landing gears, which require a hard shock rber when taxiing to prevent a slow pitching ement while requiring a softer shock absorber to d exceeding the maximum permissible airframe tion on landing. The velocity of shock absorber ure when taxiing is low, of the order of 1-2 feet second. Consequently, the pressure drop across the small open orifice is not large, since the pressure drop is proportional to the square of the velocity. This pressure differential is not enough to overcome the spring behind the valve, and thus the orifice used for taxiing is the small one; the shock absorber is hence hard and can successfully resist pitching. On landing, the velocity of closure is much higher, and the pressure differential across the piston builds up until it reaches a predetermined value, overcoming the spring. The valve then opens and the large orifice comes into use, giving a soft shock absorber.

Air/Oil (Oleo-Pneumatic)

Most aircraft use oleo-pneumatic shock absorbers (Fig. 12.4.8). The purpose of the shock strut is to alleviate load on the airframe and to cushion impact. Fig. 12.4.8(a) is a typical load/stroke curve for an oleo-pneumatic unit, and the high efficiency under dynamic conditions means that stroke is minimized for a given sink speed and load factor. With efficiencies as high as 90 percent, it is an almost perfect device for absorbing the kinetic energy due to sink speed. The oleo-pneumatic unit not only has the highest efficiency of all types of shock absorbers, but it is also the best in terms of energy dissipation. Unlike a coil spring, it does not store the energy and then release it, causing the aircraft to bounce down the runway. Instead, the oil returns to its normal static condition at a controlled rate such that rebound does not occur [see Fig. 12.4.8(b)]. The ideal situation is one in which an aircraft can make a hard landing, after which the rebound characteristics of the shock strut will ensure that the wheels stay on the ground.

Thus, the oleo-pneumatic unit has the highest efficiency, and it is also an excellent energy dissipator with good rebound control. They are obviously more complex than other types of units, but constant refinement during the last 60 years has resulted in high reliability. As illustrated in Fig. 12.4.8, oil (Such as MIL-H-5606) is poured in with the strut compressed. The space above the oil is then pressurized with dry air or nitrogen. When the aircraft lands, fluid is forced from the lower chamber to the upper chamber through an orifice. Although this orifice could be merely a hole in the orifice plate, most American designs have a pin extending through it, and by varying the pin diameter the orifice area is varied. This variation is adjusted so that the strut load is fairly constant under dynamic loading [Fig. 12.4.8(b)]. If this could be made constant, the dynamic load curve would be a rectangle, and efficiency would be 100 percent. In practice, this is never obtained and efficiencies of 80 to 90 percent are more usual. The final value is not known until the completed strut has been drop tested, and possible adjustments have been made to the metering pin size.

Fig. 12.4.9 illustrates various types of oleo-pneumatic shock absorbers. They absorb energy by pushing oil in the lower chamber and compressing air in the upper chamber. Energy is dissipated during this process by oil being forced through one or more orifices. After initial impact, rebound must be controlled. During rebound, the expanding air pressure causes oil to flow back into the lower chamber through one or more recoil orifices. If oil flows back too quickly, the aircraft will be bounced back into the air again. If oil does not flow back quickly enough, the



(a) Oleo-pneumatic shock absorber

(b) Strut load variation

Fig. 12.4.8 Oleo-pneumatic shock absorber.

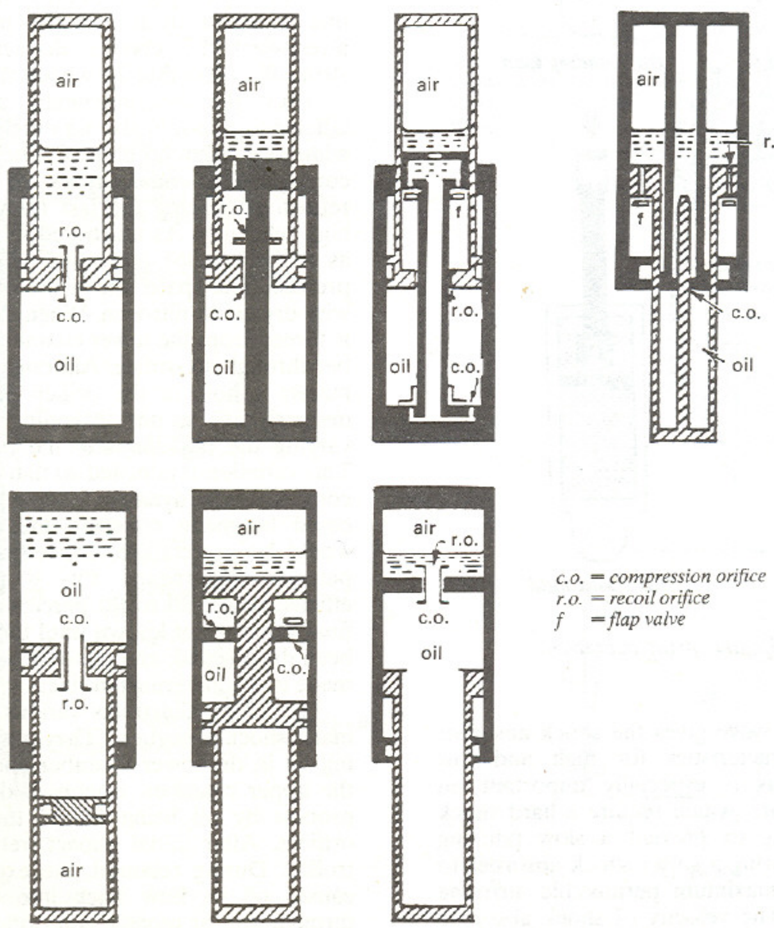


Fig. 12.4.9 Oleo-pneumatic shock absorber types.

ent short wavelength bumps encountered during g will not be adequately damped, since the shock ber will not respond quickly enough in restoring heels to their static position. The objective then lesign recoil damping such that the tires stay in ct with the runway upon landing impact, and espond quickly enough to taxiing conditions.

e distance from the static to the fully com-d position is largely a matter of choice. It is practice to call for an inflation pressure giving ss than one-third extension at maximum weight ot more than one-half extension at light load. If nnot be arranged, then strut pressures must be ed to suit the prevailing weight conditions. ver, an examination of the values shown in Fig. 0 shows that aircraft such as the Piper Coman-ztec and Navajo, Beech 99, and Aero Com-er all have extensions of 35 to 45 percent, while ort aircraft have extensions of about 16 percent. atter gives a harder ride while taxiing, but it to prevent wallowing — an important factor in transport aircraft. In addition, with the static ion point being so far "up" the load-deflection weight changes during loading do not result in ntial deflections of the shock strut. To sum up, signer usually selects an extension which has successfully used on similar aircraft operating similar conditions. The shock strut character-re calculated and the original assumptions then

Airplane	Total Stroke (in.)	Distance (in.) Static to Compressed
-9	16	.88
-10	26	2.5
	15.9	1.5
41	28	3
ctra	20	2.2
011	26	3.5
07	22	3
20	20	3
37-200	14	2.1
27-200	14	2.5
tar	15.5	3.5
30	10.5	3
ch U-21A	10.8	3.3
er Turbo Navajo	8	2.8
er Aztec	8	3.1
ch 99	12	4.8
o Commander	8.8	3.5
04	13.8	5.6
er Comanche	6.1	2.8

The above values are approximate)

12.4.10 Shock strut static extension comparison (ref. 12.32).

modified as required.

Aircraft weight may change appreciably between take-off and landing, and to allow for this, calculations should be made for both conditions to verify that performance is satisfactory. In addition, calculations should be made to determine initial inflation pressures for varying airplane weights. This information is then quoted on a plate affixed to the shock strut so that ground crew can ensure that strut pressures are appropriate to the airplane weight.

It is almost impossible to stipulate a precise all-encompassing method for calculating the sizes and characteristics of an oleo-pneumatic shock absorber. Initial assumptions have to be made concerning some or all of the following: static position, compression ratio, air volume in the compressed position, maximum g-force applied to the strut, and maximum and minimum pressures inside the strut.

Piston diameters are generally chosen on the basis of having the maximum static strut pressure around 1,500 psig. Higher pressure will result in high dynamic pressures on the seals and also smaller diameters for the entire strut leg, thus providing a strut that is inefficient in bending and torsion. Lower pressures provide a strut of large diameter with thin walls resulting in efficient bending and torsion sections but lower bending allowables due to the high $\frac{D}{t}$ (where D = piston diameter and t = piston wall thickness). The thin wall strut also tends to ovalize and permit seal leakage.

Having selected the strut stroke and piston diameter, the designer can now determine what type of air spring, or air curve, is most suitable. Since one function of the air spring is to reliably push the piston out after take-off, it is apparent that the extended pressure must be high enough to overcome seal and bearing friction. The extended pressure of 65 psig is probably as low as practical. On the other hand, if the extended pressure is too high, the load required to begin the stroking of the strut on landing becomes excessive. Thus when a very low sink rate landing is made, the strut will compress only slightly and the airplane will bounce. Experience has indicated that the extended pressure should not exceed 250 psig, particularly for a single axle gear. A truck type (or bogie) gear, and also multi-main gears, will have less tendency to bounce since all the tires do not contact the ground simultaneously.

It is obvious that all the best features can not be combined in one strut having a simple air spring. If struts were built with double air chambers, double acting shock struts, or mechanical devices that provide all the desirable characteristics — low extended pressure, soft taxi ride, etc., they had seldom proved popular, especially for commercial transports, due to complicated servicing procedures, noise, leakage, and higher cost and weight.

However, landing gear design for the military cargo transports fulfill airfield roughness specifications for operation on both standard and substandard runways. Substandard conditions include three-inch high step bumps and 1-cosine wave bumps at specified wave length and amplitude. To minimize the transmission of these loads to the structure, double-acting shock struts (as shown in Fig. 12.4.11) are used in both main and nose landing gears. As the name imples, the double-acting shock strut [Fig. 12.4.11(c)] has two air chambers instead of the conventional single-chamber [Fig. 12.4.11(b)]. One chamber is the normal air chamber of a conventional air-oil shock absorber; the second chamber is inside the primary piston beneath a floating secondary piston. The chamber is preloaded by compressed air in excess of maximum static requirements.

During taxi operations over moderate or long wavelength undulations, the double-acting shock strut acts as a conventional shock absorber. The secondary piston serves as the equivalent of a hydraulic surge chamber, absorbing unsprung mass momentum and attenuating peak loads.

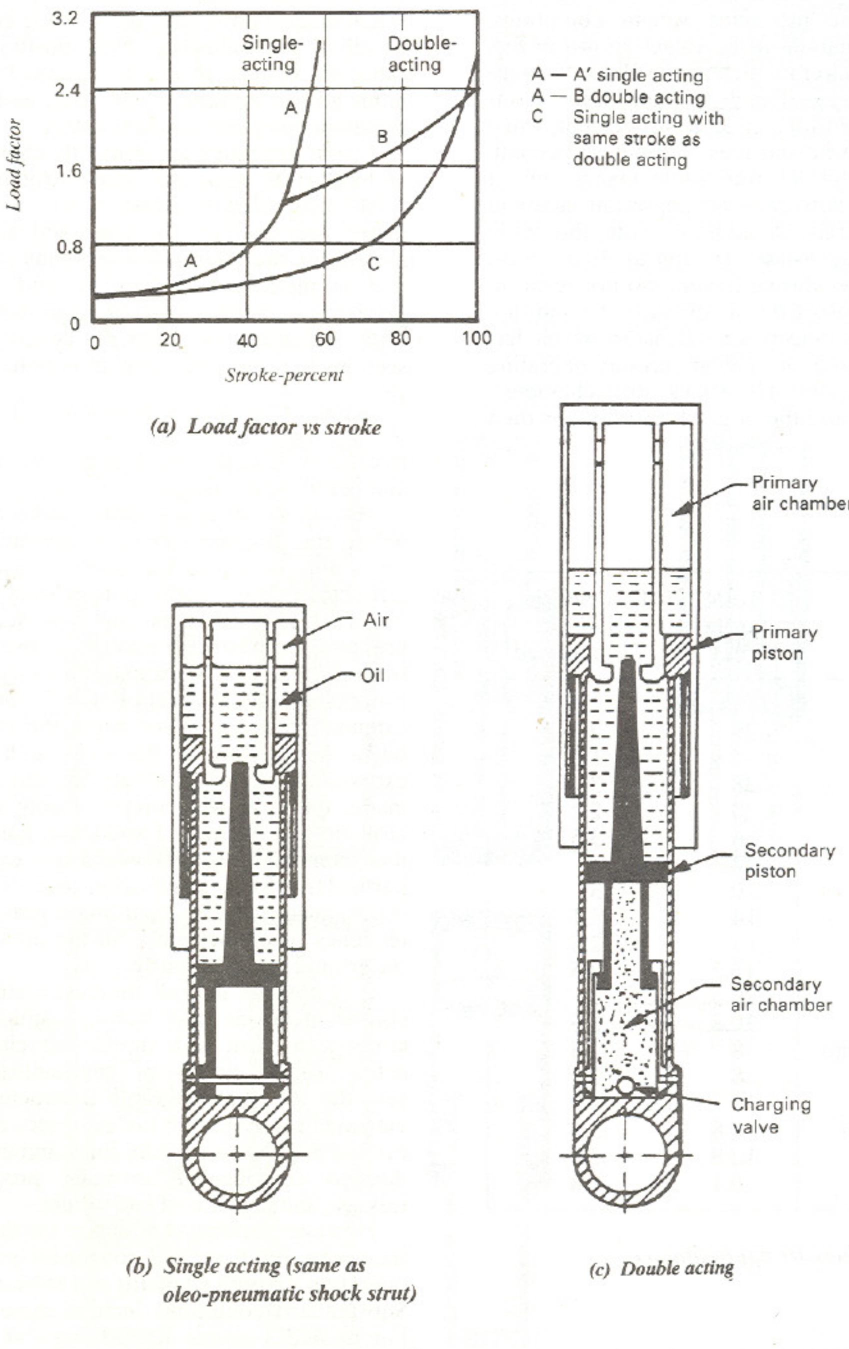


Fig. 12.4.11 Double-acting shock strut vs single-acting shock strut.