PROPERTIES OF MATERIALS

The construction, operation and maintenance of the mechanical systems involves matter in each of its three states and uses all of its properties. Each part of a machine is made of a material that has properties which allow it to do its job, figure 2-1.

The fuel that powers the machine to produce motion and the lubricating oils that reduce friction are examples of amtter that is essential to operation, but is not an integral part of the machine. The tools, equipment, and the atmosphere of a shop are also examples of matter. Hydraulic jacks and air compressors use matter in the form of liquids and gases.

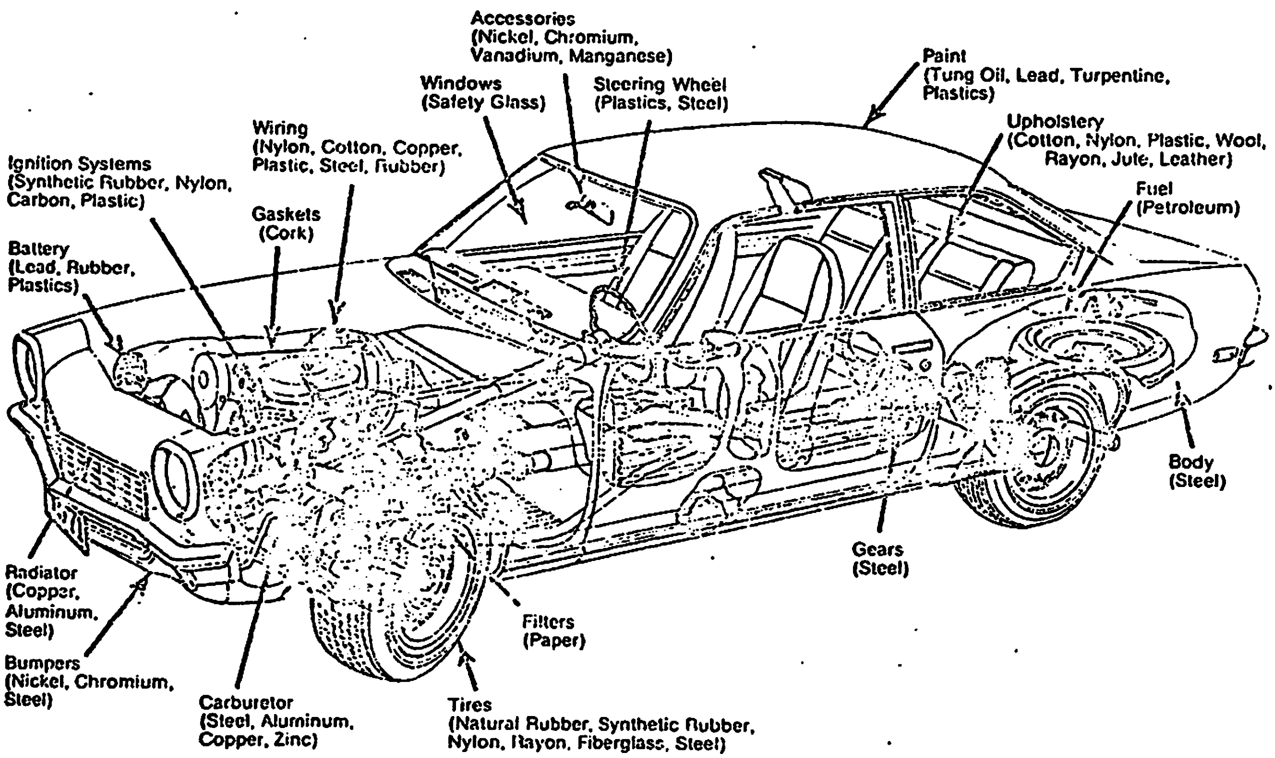


Fig. 2-1 How the world's resources are used in a modern automobile

Matter is practically everywhere. But what makes one solid or one liquid or one gas differ from another? The answer may be found in the molecular structure of each which is responsible for the characteristics or properties that each possesses. The terms used for these properties are explained in this unit. These terms should be understood and used by the automotive technician.

The fibrous tissues used to clean windshields and wipe up oil or grease have a high degree of *porosity*. This means the spaces between the molecules of these tissues are large. Such tissues also have the property of *adhesion*. Adhesion is an attractive force between molecules of different materials.

The *density* of a material is its weight per unit of volume. An iron alloy cylinder head differs in weight from an aluminum alloy cylinder head of the same size because of the difference in densities of the two materials. If these two cylinder heads are the same size, they have the same volume.

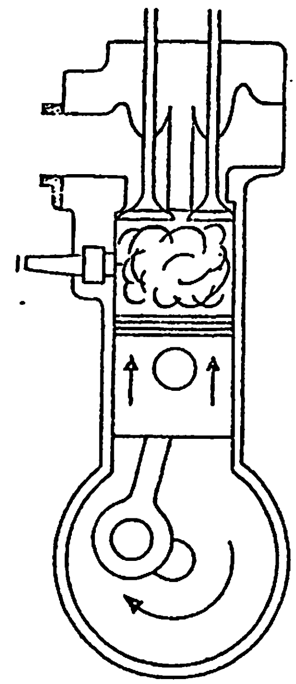


Fig. 2-2 A piston compresses the gas

It is easy to see the *impenetrability* of matter when a hammer strikes an anvil, or when any metal attempts to occupy the same space as another metal, as in the case of two automobiles meeting head on. It is also true that, whether the matter is solid (steel), or liquid (oil), or gas (air), the space it occupies cannot be occupied by other matter at the same time. When the piston rises against the gas vapor in the combustion chamber, it does not penetrate the gas, but merely compresses it, figure 2-2. When the pedal on hydraulic brakes is pushed down, the force against the hydraulic fluid is transmitted against the brake shoes and, in turn, against the drums. The fluid, unlike the gas, cannot be compressed and the space it occupies cannot be occupied by another material at the same time.

Notice that when a drop of oil is spilled it seems to form a ball shape while a drop of antifreeze spreads out to a pancake shape. This difference is due to the property of *cohesion*. Cohesion is the tendency of the molecules to stick together. Oil has greater cohesion than antifreeze.

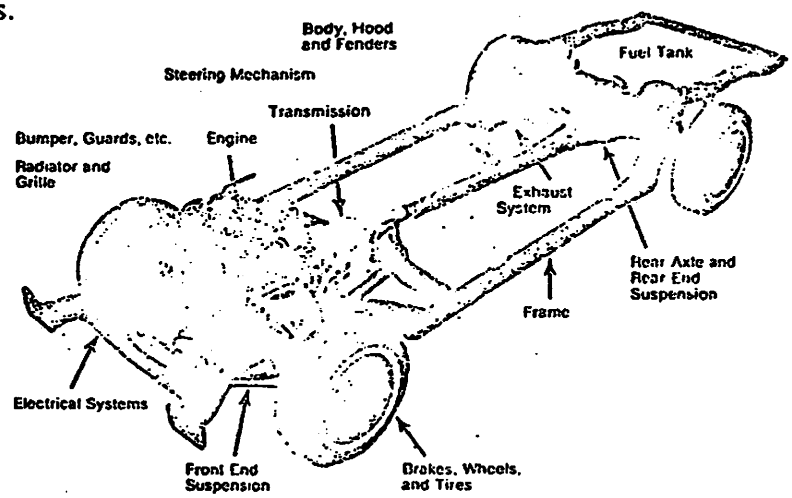
Oil also has a high degree of adhesion. It tends to stick to other materials. Notice that it is almost impossible to wipe oil completely from a bearing. The attraction between the molecules of the oil and the molecules of the bearing is very strong. This is one of many desirable qualities of lubricating oil.

Inertia is the resistance of an object to change its direction or state of motion. When pushing a car by hand, notice how difficult it is to get it started and how, once it starts to roll, it is easier to keep it rolling. This is mainly due to inertia. When the brakes are applied suddenly, passengers are thrown forward. The passengers' inertia tends to keep them moving in the same direction and speed as that of the car before the brakes are applied. The force of inertia is also illustrated by the rapid motion of the piston which must be stopped at the end of each stroke by the crank connection. This is similar to a rapidly moving automobile hitting a solid object.

BASIC PROPERTIES OF SOLIDS

Few people realize the variety of materials that go into the manufacture of an automobile. For example, there may be 160 separate varieties of steel in a car. This steel appears in over a thousand combinations of form, composition, size, and quality.

Some of the uses of steel in a typical four-door sedan, together with its forms and weights, are shown in figure 3-1. The total weight of steel is 3,542 pounds, excluding weight allowance for scrapped parts.



	Steel Bars			Strip Steel		Sheet Steel		Wire Products	Steel Plates	Terne Plate	Structural Shapes	Pipe & Tubes (Seamless)	Totals
	Hot Rolled	Cold Rolled	Forgings	Hot Rolled	Cold Rolled	Hot Rolled	Cold Rolled						
Steering Mechanism	20.5	10.3	1.2	1.4	0.9	6.2	7.2	3.6	0.3				51.6
Engine and Clutch	28.4	34.8	137.5	31.6	23.7	42.7	22.1	17.4	7.9	10.8			356.9
Front End Suspension	47.2	7.7	57.4	9.5	2.2	18.2	0.2	2.6					145.0
Brakes, Wheels and Tires	3.5	10.1	0.4	146.4	1.5	69.3	11.0	13.6					255.8
Bumpers, Guards, Etc.	5.4	1.4	25.1	26.7	78.2	7.4	51.7	3.4			5.8		205.1
Fuel Tank and Exhaust System	1.1	0.7		1.6	23.8	3.4	20.6	0.5		17.3		0.7	69.7
Frame						248.5	45.4	5.7					299.6
Electrical System	0.5	2.9		5.1	5.3	3.1	17.4	2.8		0.1			37.2
Transmission	4.6	22.4	42.9	1.0	2.1	0.4	4.1	2.1					79.6
Radiator and Grille	0.5			4.2	1.8	14.7	51.1	0.9		5.3		0.4	78.9
Body, Hood and Fenders	7.5	8.3	0.9	53.9	115.7	160.2	1185.7	96.1		22.9		0.1	1651.3
Rear Axle & Rear End Suspension	84.9	15.8	54.9	10.8	2.4	94.6	13.1	6.7	18.2			9.8	311.2
Totals	204.1	114.4	320.3	292.2	257.6	668.7	1429.6	155.4	26.4	56.4	5.8	11.0	3541.9

Fig. 3-1 Allocation of steel in a typical four-door sedan

The remaining solids required to meet the vast manufacturing needs of the automobile are: rubber, glass, aluminum, copper, leather, diamonds, platinum, tungsten, mica, plastics, carbon, wood, wool, cotton, lead, iron, tin, nickel, zinc, manganese platinum, and abrasives. All of these materials, used alone or in combination, have very definite properties which make them particularly well suited for certain parts of automobiles or for their manufacture.

Science, research and engineering develop new materials or improve existing ones to meet new or more severe requirements of the modern motor vehicle. Metals are changed through metallurgy to improve their basic properties. Synthetic rubber and plastics are developed through chemistry to meet new and varied uses. The efficiency, speed, power, comfort and safety of today's automobile is ample proof that the scientists and engineers are successful in developing and utilizing the basic properties of solids.

Plastics are often used in automobiles because they have the properties of hardness, toughness, ductility, and tenacity. Fiberglass is used for many car bodies and several kinds of plastics are used for automotive accessories and structural parts. The use of these materials results in less weight and reduced cost.

Hardness is the ability of a material to resist forces that tend to push the molecules apart.

Toughness is the property of a material to withstand a permanent change.

Ductility refers to the ability of a material to be drawn into shape without losing other mechanical properties.

Tenacity is the cohesive ability to resist forces which tend to pull a material apart.

Malleability refers to the ability of a material to withstand mechanical processing, such as hammering and rolling.

SUMMARY REVIEW

1. Place an X in the appropriate square, or squares, which best describes the basic property or properties of each of the automotive parts listed. The column on the right indicates the number of properties that should be marked.

		Hardness	Toughness	Malleability	Elasticity	Ductility	Machinability	Tenacity	Fusibility	Conductivity – heat	Conductivity – electric	Number of Properties
1.	Tires											3
2.	Body, hood & fenders											1
3.	Frame											4
4.	Springs											3
5.	Electrical wires											2
6.	Radiator											2
7.	Bumper											3
8.	Aluminum piston											2
9.	Crankshaft											3
10.	Fan belt											2
11.	Connecting rod											2
12.	Babbitt bearings											2
13.	Storage battery lead											2
14.	Rear axle housing											3
15.	Fuel tank											1
16.	Head gasket (copper)											2
17.	Gears											3
18.	Axle shaft											2
19.	Ball & roller bearings											2
20.	Exhaust valve seats											2
21.	Muffler											1
22.	Piston pin											2
23.	Bushings (bronze)											2
24.	Cylinder block											2
25.	Cylinder head (aluminum)											2

BASIC PROPERTIES OF LIQUIDS

A number of different liquids are used in the operation and servicing of the automobile. Without these liquids and their properties, the automobile would be an impossibility. The modern auto mobile with its automatic transmission, power steering, and hydraulic brakes and shock absorbers uses many of the properties of liquids. This unit is concerned only with the basic properties of liquids, leaving the mechanics of liquids (pressure and force) to be studied in another unit.

The basic properties of liquids can be seen by their use in the automobile. A lubricant adheres to a bearing surface and is also partially absorbed by the surface. The oil itself is held together by the cohesive action of its molecules.

When a crankshaft journal turns in its bearings or a piston slides up and down within a cylinder, the oil adheres to both moving and stationary parts. Pressure is built up in the oil between the bearing surfaces. It is this pressure that supports and floats the moving body, thereby preventing actual contact between the moving parts and reducing the friction.

The cohesive property of the oil must hold the molecules together as pressures build up between bearing surfaces or when friction develops high temperature. A breakdown of the oil film would mean metallic contact between bearing surfaces and therefore excessive wear or possible damage to the bearing surfaces.

Oil must have enough *viscosity* (the measure of resistance to flow) to keep the bearing surfaces separated under all conditions.

Since viscosity is one of the most important properties of a lubricating oil, different viscosity oils are recommended to meet varying operating conditions. These conditions include air temperatures, operating temperatures of the engine, and the age and condition of the engine. The viscosity numbers 5W, 10W and 20W represent winter oils; numbers 20, 30, and 40 are summer oils. The proper grade to use at any season depends on engine condition and design, and on an approximate temperature range. Since the rate of viscosity change with change in temperature varies widely with different types of oils, a standard of measurement of

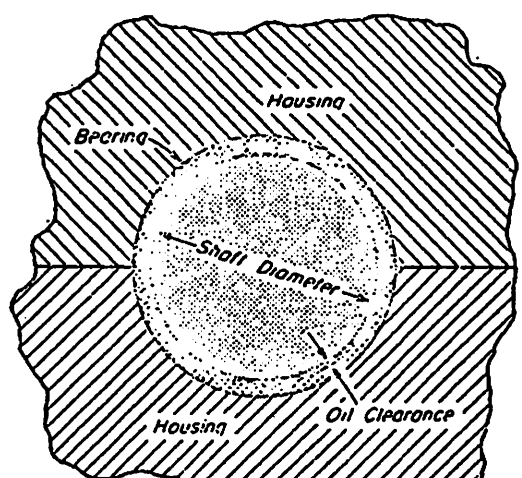


Fig. 4-1 Cross-sectional diagram of a bearing assembly

this rate of change, known as *Viscosity Index*, has been established. A high Viscosity Index number (as 90 or above) indicates a relatively low rate of viscosity change with change in temperature, while a low Viscosity Index number (50 or lower) indicates the reverse. An engine requiring an S.A.E. (Society of Automotive Engineers) 20 oil in summer would require an S.A.E. 10 or 10W oil in winter or in cold climates. Dual-graded oil meets the viscosity requirements of a grade at 0° F. and at 210° F. For example, 5W-20, 10W-30 or 10W-40 oils will meet all-season requirements.

Liquids have a tendency to spread over any surface in proportion to their viscosity. Lubricating oil is drawn into the space between a piston and the cylinder wall by *capillary action*. Penetrating oil spreads between the leaves of an automobile spring by capillary action. Oil penetrates as a film in the space between a bearing and a shaft, no matter how small, in exactly the same manner as water climbs in a capillary tube. Films as thin as one-millionth of an inch (thinner than the walls of a soap bubble) are possible. Theoretically, a film of oil may be spread out until it is only one molecule in thickness. Capillary action, therefore, is partly responsible for the efficient lubrication of moving parts of an automobile.

Oil has less *surface tension* than water. When oil is poured on water, it spreads over the water forming a thin film. This characteristic of low surface tension causes it to spread in a thin film over solids. This property is very important in the lubrication of an automobile.

The *boiling point* of a liquid is an important consideration in some applications. Some liquids might give good protection against freezing when used as an antifreeze but do not have high enough boiling points for summer use, figure 4-2. Glycerine and ethylene glycol have a high boiling point, hence do not boil away easily. This is one requirement of a good permanent antifreeze.

The electrolyte used in a storage battery is a solution of chemically pure sulfuric acid and distilled water. The proportion is about two parts of acid to five parts of water by volume. The proportion of water and acid should be such that the density of the solution will be at a specific gravity of 1.265 to 1.290 at 80° F.

The sludge in the crankcase of all internal combustion engines is a product of contamination from both outside and inside sources. It is brought about by the presence of water, fuel dilution, acid formation, metal dust, and carbon churned together into an emulsion by the operation of the engine. This emulsion is very harmful to the engine. It will foul piston rings, accelerate carbon formation, restrict or even close oil lines, and eventually lead to lubricating system failure.

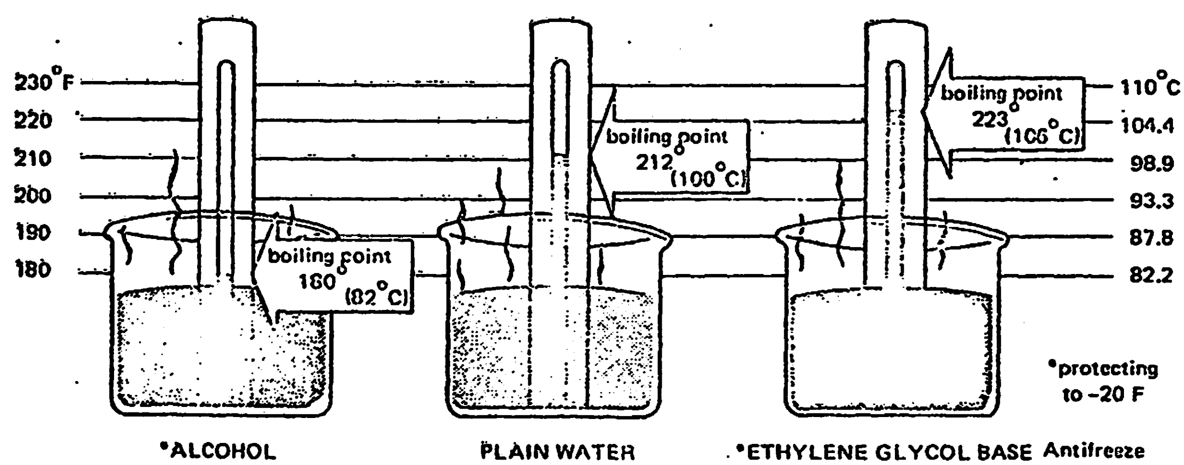


Fig. 4-2 A good permanent antifreeze requires a high boiling point.

Sludge also forms in the cooling system of a motor. Water solutions tend to corrode cooling system metals when the metals are not protected by inhibitors in the antifreeze or in antirust preparations added to water for summer driving. Loss of metal by corrosion may result in parts failure or leakage. The formation of corrosion products on the surface of the metal will reduce heat transfer at the walls of the engine water jacket and in the tubes of the radiator even before clogging occurs.

Corrosion of some metals in the cooling system, such as stainless steel, brass, solder, aluminum and copper, may be the result of direct attack by the liquid but more often it is caused by galvanic corrosion. *Galvanic action* (electrolytic corrosion) is a form of corrosion which can occur when unlike metals, in contact with each other, are immersed in a liquid which will carry an electric current. It is an action similar to that occurring in a storage battery.

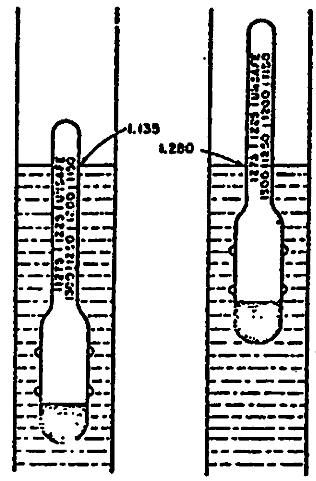


Fig. 4-3 High float means high specific gravity.

The tendency of a liquid to produce an upward force on an object in the liquid is known as *buoyancy*.

The buoyant force is used to determine the specific gravity of liquids. Specific gravity can be measured quickly by using an instrument called a hydrometer, figure 4-3. The *hydrometer* used for determining the state of charge of a storage battery should include a thermometer for making a temperature correction to the specific gravity reading. The temperature correction amounts to .004 specific gravity. This is sometimes referred to as four points of gravity for each 10°F. change in temperature.

Most battery manufacturers adjust the acid in their batteries so that the specific gravity readings are accurate only when the acid temperature is at 80° F., figure 4-4.

Special hydrometers are used to test antifreeze solutions and are marked to read in freezing points for the standard types of antifreeze.

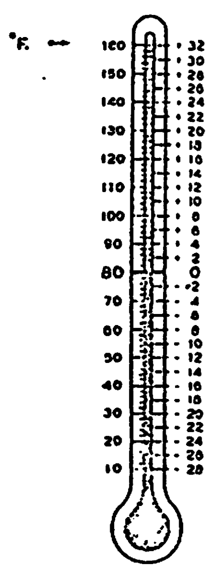


Fig. 4-4 The specific gravity of battery acid is measured at 80° F.

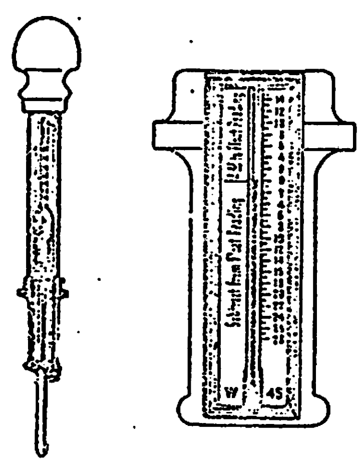


Fig. 4-5 Thermometer built into hydrometer

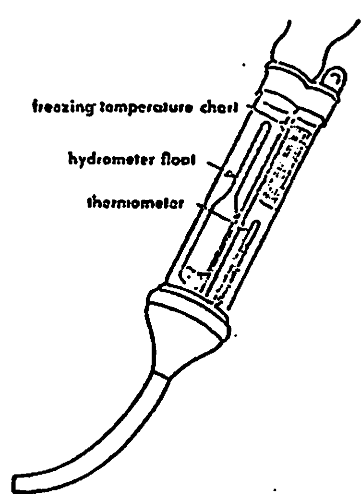


Fig. 4-6 Special hydrometer for antifreeze

BASIC PROPERTIES OF GASES

The internal combustion engine used in the automobile is essentially an air engine; it pumps air. In traveling a distance of less than 50 miles, a 330-cubic inch engine pumps enough air to fill an eight-room house. The fuel (gasoline) is suspended in the air. Gasoline engines operate on the principle of the compressibility of gases. Gases expand to produce extremely high pressures when ignited. Each power stroke may produce as much as 12,000 pounds of force. However, we are now concerned with the basic properties of gases and not with the operation of the internal combustion engine, which will be studied later.

If a gas is confined, so that it cannot expand when it is heated, it will exert a greater pressure. An automobile tire may seem underinflated in the cool of early morning, yet due to the heat of the road and travel, it may expand until a blowout occurs. Suppose the tires on an automobile are inflated to 25 lb. pressure when the temperature is 32° F. When the temperature rises to 68° F., the pressure in the tires increases to approximately 28 lbs. When the thermal energy of a gas increases, the speed of the molecules increases. They bombard the inner walls of the tire more vigorously, increasing the pressure exerted by the gas.

Gas pressure is measured by a number of different types of gages. The Bourdon-type gage, figure 5-1, is often used in motor vehicles to indicate oil pressure and engine temperature. The temperature indicator is a remotely controlled thermometer which tells the temperature of the engine coolant. A Bourdon temperature gage has a capillary tube and a bulb attached to the unit. This tube and bulb are filled with a *volatile* liquid (one which evaporates easily), such as ether, and sealed. When the bulb is heated by the engine coolant, the confined liquid generates vapor pressure. This pressure is transmitted through the capillary tube to the Bourdon tube in the gage.

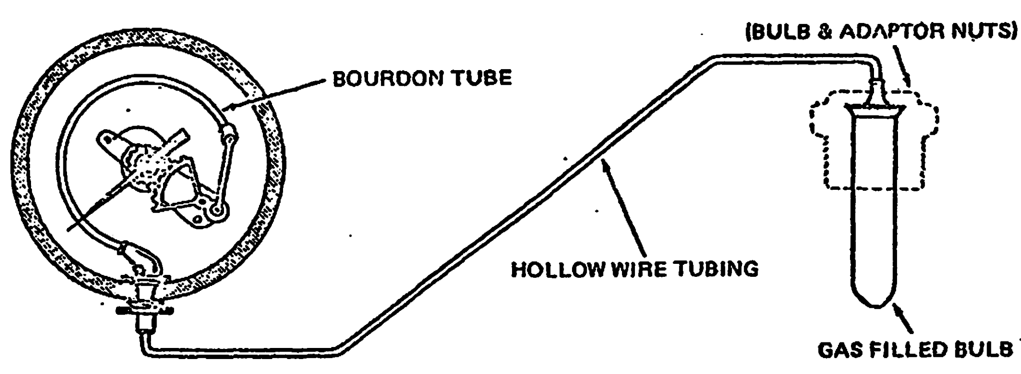


Fig. 5-1 The bourdon tube tends to expand with increased vapor pressure.

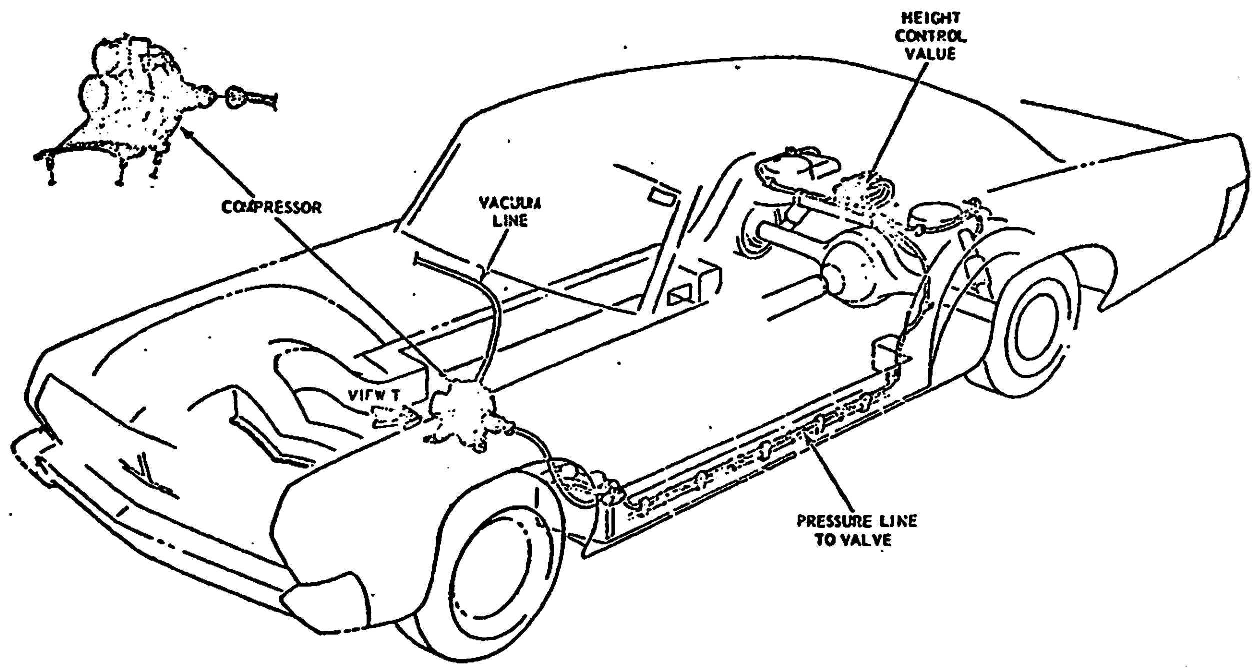


Fig. 5-2 Automatic load leveling system

The Bourdon tube is a slightly oval tube, bent in a circular shape and closed except for the connection to the bulb. When vapor pressure is applied to the tube it tries to expand and in so doing straightens out slightly. This straightening of the Bourdon tube causes the pointer, which is attached to it, to move.

Due to the springiness of air, automobiles are able to use air shocks for controlling the riding height. Air shocks operate on the principle of the compressibility of air. The basic parts of a typical automatic load leveling system, figure 5-2, include a vacuum compressor, height control valve and linkage, air sleeve shock absorbers, plus connecting lines and flexible hoses.

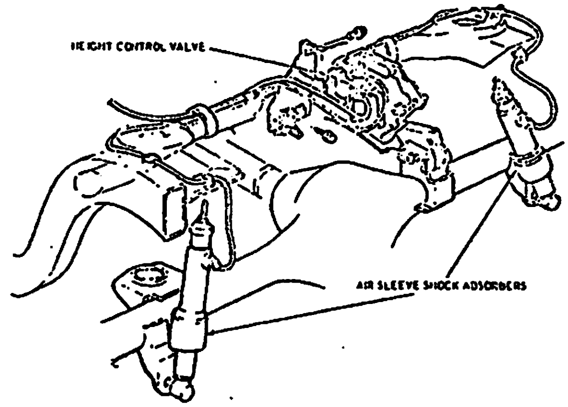


Fig. 5-3 Air sleeve shock absorbers

The air sleeve shock absorbers and adjacent related parts are shown in figure 5-3. The system is designed to raise the rear of the vehicle after a predetermined load is reached. When this extra load is placed in the vehicle, the vacuum operated compressor will produce the pressure required to inflate the shocks and extend them to raise the vehicle.

The vehicle is kept at the proper height by the action of the control valve. The shock absorbers deflate and collapse as the extra load is removed thus leveling the automobile. A time delay is included in the control valve so the system will not be activated by a slightly bumpy road surface. Pneumatic springs (air bags) replace steel springs on certain buses.. Pneumatic springs support the vehicle weight, absorb the shock from the uneven road surfaces, and maintain the correct height regardless of the load.