Parker Hannifin Plc
Product Training

Hoses

Level 1

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1.0 Introduction
Level One training has been devised as a 'self teach' module for persons who have no, or very little, prior knowledge of the subject matter. The aim is for persons to work through the information provided at their own pace and in their own time. When they have completed the module and feel confident that they have increased their knowledge they can complete a test that accompanies the module. Successful completion of the module test permits progress onto Level Two.

2.0 What is a hose?
A hose may be defined as a flexible tube for the transfer of fluids or gases from one point to another.

A hose may be made up of many different materials and constructions depending on the individual applications and environment. Hose is usually categorised into two main groups, (i) rubber hose (ii) thermoplastic hose. The basic construction of both types is very similar. Very simply, a hose consist of an inner tube, to convey the fluid or gas, a reinforcement of some kind, placed around the inner tube to enable it tube to be used at higher pressures without bursting, and an outer cover to protect the reinforcement and inner tube from the environment, working conditions, and anything else likely to cause damage to the reinforcement.

3.0 Rubber hose construction
Figure 3.1 shows the basic construction of a rubber hose, which will help the reader better understand some of the terminology used with hose makeup. Each part or layer is discussed below.

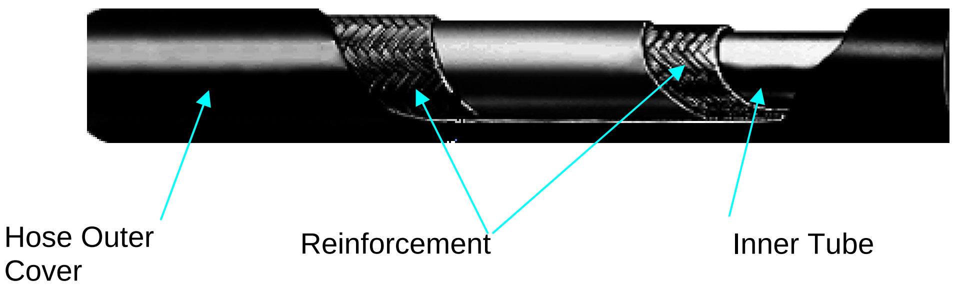


Figure 3.1 Basic hose construction

3.1 Inner tube
The innermost element of a hose is the tube or liner. The tube function is to contain and direct the flow of material either solid, liquid or gas. It also protects the outer elements of the hose from abuse or destruction by the materials being transferred.

Hose inner tube is made from a number of different types of synthetic rubbers, which are commonly referred to as tube stock. Listed below are some of the most common tube stocks and the desirable properties of each.

Table 3.1

MATERIALS	PROPERTIES
Neoprene	Oil and fuel resistant
Butyl	Resistant to synthetic fluids
Buna-N	Oil and fuel resistant
Teflon	High-temperature-, oil- and fuel-resistant
Silicone	Resistant to ethylene glycol antifreeze
Nylon	Resistant to synthetic fluids
EPDM	Resistant to synthetic fluids
Polyester Elastomer (PEL)	Resistant to most synthetic fluids

The application will determine the particular type of tube and reference to the compatibility charts will enable the correct selection to be made.

In the manufacture of tubes, the synthetic rubber stock is mixed to the desired blend and heated in a mill. A continuous strip is cut from the mill and fed into the extruder. A seamless rubber tube is then formed to the desired diameter and wall thickness by a continuous extrusion process, wherein the rubber stock is forced through the annulus of a pin and die combination by the pressure generated by a helical screw rotating in a cylinder.

The tube is either extruded directly onto mandrel, (see figure 3.1), or in some instances, such as large ID hose, the tube is made by the build-up method (see figure 3.2). Sheets or strips of tube stock are spirally wound around a mandrel, and then reinforced. During vulcanisation, the tube becomes a solid mass.

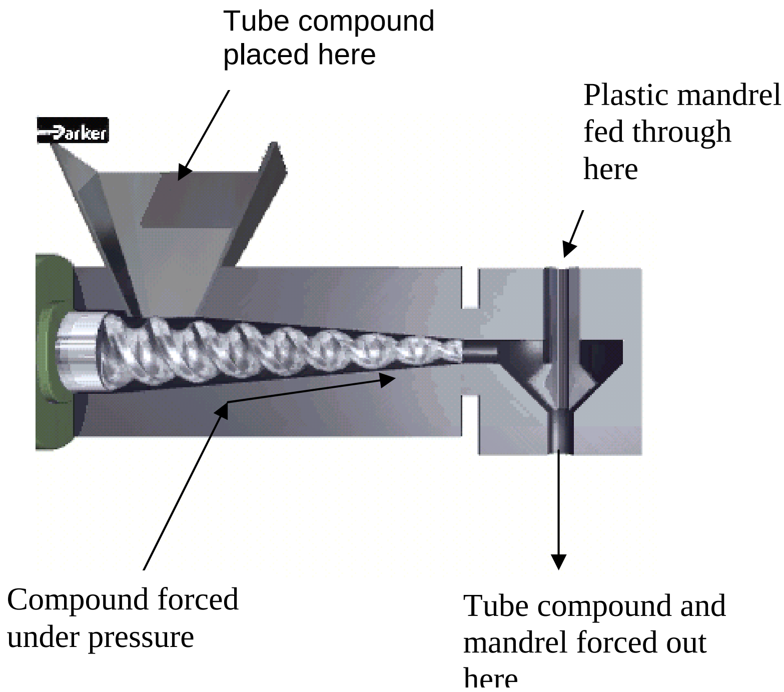


Figure 3.1 shows extruding directly on to a mandrel

Figure 3.2 Shows tube compound being wrapped on to a mandrel

3.2 The reinforcing

Fluids flowing through the inner tube exert pressure on the inner wall of the tube. Pressures may vary from vacuum to extremely high pressures. Since the inner tube is designed only for containing and directing the flow, another element known as reinforcement must be introduced about the tube to help it hold back internal pressures and thus increase the burst pressure of the hose.

3.3 Reinforcement materials

The magnitude of pressure determines the type of material utilised to reinforce the tube. For low-pressure applications, the reinforcement, or carcass, may be of cotton or synthetic material, such as nylon, rayon, Dacron or other polyester fabric woven, braided or wrapped about the tube. Higher pressures require stronger materials, such as carbon steel or stainless steel wire braided or spiralled about the tube. In some applications copper or bronze wire reinforcement may be used.

3.4 Reinforcement plies

Economy, flexibility and size must be considered when choosing a reinforcement material and arranging it about the tube for a given pressure range. Low-pressure applications may require a single ply or layer of fabric, while high pressures may require many layers of high tensile steel wire reinforcement.

3.5 Manufacture

Reinforcements are constructed about the tube using one of two methods – braided or spiral wrapped.

A machine containing carriers, each of which applies a number of strands around the tube, applies the braid. The carriers zig-zag about each other as they travel around the axis in a clockwise direction producing the braid. Several layers of wire or fabric braid may be required to produce the desired reinforcement.

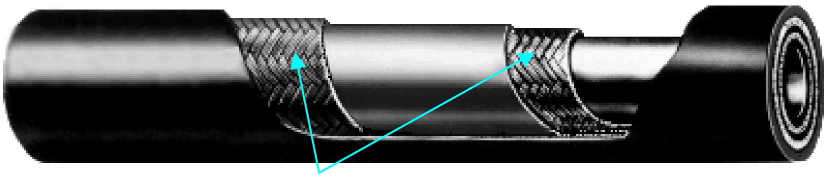


Figure 3.3 Two layers of braided reinforcing (2 wire hose)

It may be necessary to combine the spiral and braid methods to satisfy the pressure requirements of a hose. Two spiral wraps can occupy the same physical area as one braid because of the interlay of wires in the braid configuration. By using two spiral layers and one braid in the place of two braids, the pressure rating of the hose is increased while allowing the same end fitting to be used on both hoses. Layers of spiral and braid must work together to hold pressure. This is determined by the amount of tension applied during the manufacturing process.

Figure 3.4 Spiral reinforced hose

3.6 Spiral wound hose

Figure 3.4 depicts a hose with successive layers of spiral wrap. Using a machine similar to the braider, the wire is spiralled around the tube. One layer is applied in one direction and the next layer is applied in the opposite direction, alternating until the desired number of layers is obtained. This type of reinforcement allows very high pressures.

3.7 Wire angle

Each layer of spiral or braid will have a natural position it will seek when the hose is pressurised. This is due to the angle that the reinforcing wire is wound or braided. A hose can be designed to expand or contract along its length as it is pressurised, by altering the angle of the reinforcing.

3.8 Interlay strip

Between each layer of both types of hose reinforcement, a breaker strip, or interlay is applied as a void filler and bonding agent. The strip is normally of the same material as the inner tube. It also acts to prevent frictional wear between successive layers of reinforcement wire.

4.0 The cover

The outermost element of the hose is called the cover. It protects the reinforcement from abuse by man, machine and environment. In many applications the type of

hose cover may mean the difference between a long service life and the early failure of a hose. The specific application and environmental conditions determine the type of cover required.
It may be necessary to cover the hose with a steel guard to protect it from severe abrasion caused by flexing in a confined area or a fire resistant sheathing to protect it for a short duration from the extreme heat generated in some applications.

4.1 Hose Cover Types
There are four basic types of hose cover. Each is designed to satisfy certain requirements of an application. These requirements may be related to economy, safety, corrosion, abrasion, chemical resistance, identification, tolerance, etc. Regardless of these many considerations, the major function of the hose cover is to protect the reinforcement and the inner tube. Covers can be further subdivided into skive and non-skive types which deals with the thickness of the outer cover.

4.2 Fabric Braided Cover
This type of cover consists of braided fabric often impregnated with a rubber adhesive. The cover is lightweight and permits heat dissipation. The cover is usually applied to low or medium pressure hose.

4.3 Coverless Type
The reinforcement acts as the cover in the coverless type. Hoses of this type are usually reinforced with corrosion-resistant metals, such as stainless steel, copper or bronze.

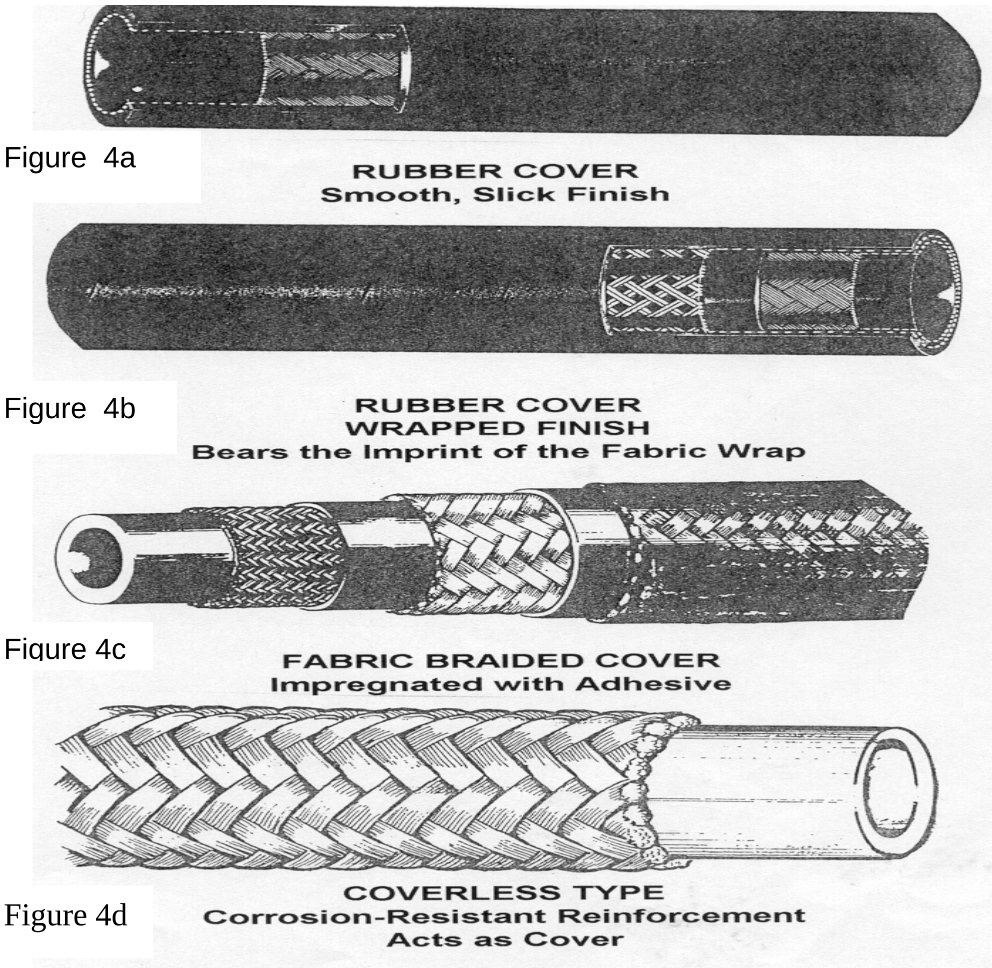


Fig 4 Examples of cover types

5.0 Hose skiving

When very high pressures occur in a system, hose assemblies have to be manufactured to take this pressure. Due to some hoses not having an equal cover thickness around the circumference, an operation called hose skiving has to be carried out. This operation is completed to ensure that the teeth on the ferrule have a direct bite into the hose reinforcement.

The operation is very simple and can be completed manually or by machine, it involves the removal of the rubber cover from the end of the hose for a length just short of the length of the ferrule. The reason why the skiving is not the same length as the ferrule is that a seal is needed between the end of the ferrule and the hose cover to stop any corrosive fluids contacting the reinforcement and corroding the wires. A skived hose is shown in figure 5.1

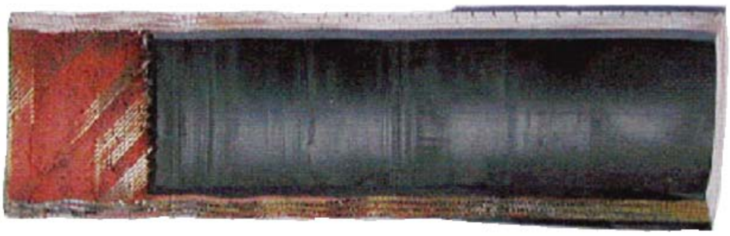


Figure 5.1 Showing an internally and externally skived hose

6.0 Hose selection

When selecting a hose for a particular application, the following information will be required:

6.1 Operating Pressure

This determines the hose reinforcement/construction. Select a hose with a Working Pressure greater than the system operating pressure. If pulsing or peak pressures are encountered, select a hose with a Working Pressure at least equal to the Peak pressure. The hose can accommodate occasional pressure rise above Working Pressure, but continual or frequent working at these pressures will shorten the hose life and cause premature failure.

6.2 Flow Rate

This determines the bore or internal diameter of the hose. Find the maximum recommended flow rate for a hose then refer to the Flow Rate Nomogram in the Technical Data section of any manufacturers catalogue. Select a hose bore size within the velocity limits indicated on the nomogram.

Caution: *The maximum Flow Rate of a hydraulic pump in a system may not be the maximum flow required to be carried by the hose. For example, a hydraulic ram may be allowed to descend rapidly under the influence of its load, causing a much higher rate of flow in the hoses connected to the cylinder than that encountered during the lifting cycle when only the pump Flow Rate is seen.*

6.3 Fluid to be carried by the hose

This will help determine the hose tube material. Select a suitable hose and fitting material, compatible with the fluid to be carried.

6.4 Temperature Range of Fluid/Gas
This will help determine the hose tube material. Select a hose that will accommodate the fluid temperature range encountered.

6.5 Temperature Range & Type of Surrounding Atmosphere
This will help determine the material of the outer cover, the temperature range of which is usually equal to that of the hose liner. If the hose is likely to be in a fire hazard area, a fire resistant sleeve should be considered.

6.6 Type of Application
Note any information relating to flexing, abrasion, hose support, accessibility, etc. Consideration of these factors can help decide hose construction, type of end fittings and accessories. *Example*: the application may require small bends radius, wire guard, re-usable end fittings, smooth outer cover, etc. The more information that can be gained about the actual application, the better the hose specification will meet the requirements.

7.0 Hose sizing
The nomogram chart Figure 7.1 is provided as an aid in determining the correct hose size. Hydraulic hoses are measured using the bore size. This can be stated or described in three ways.

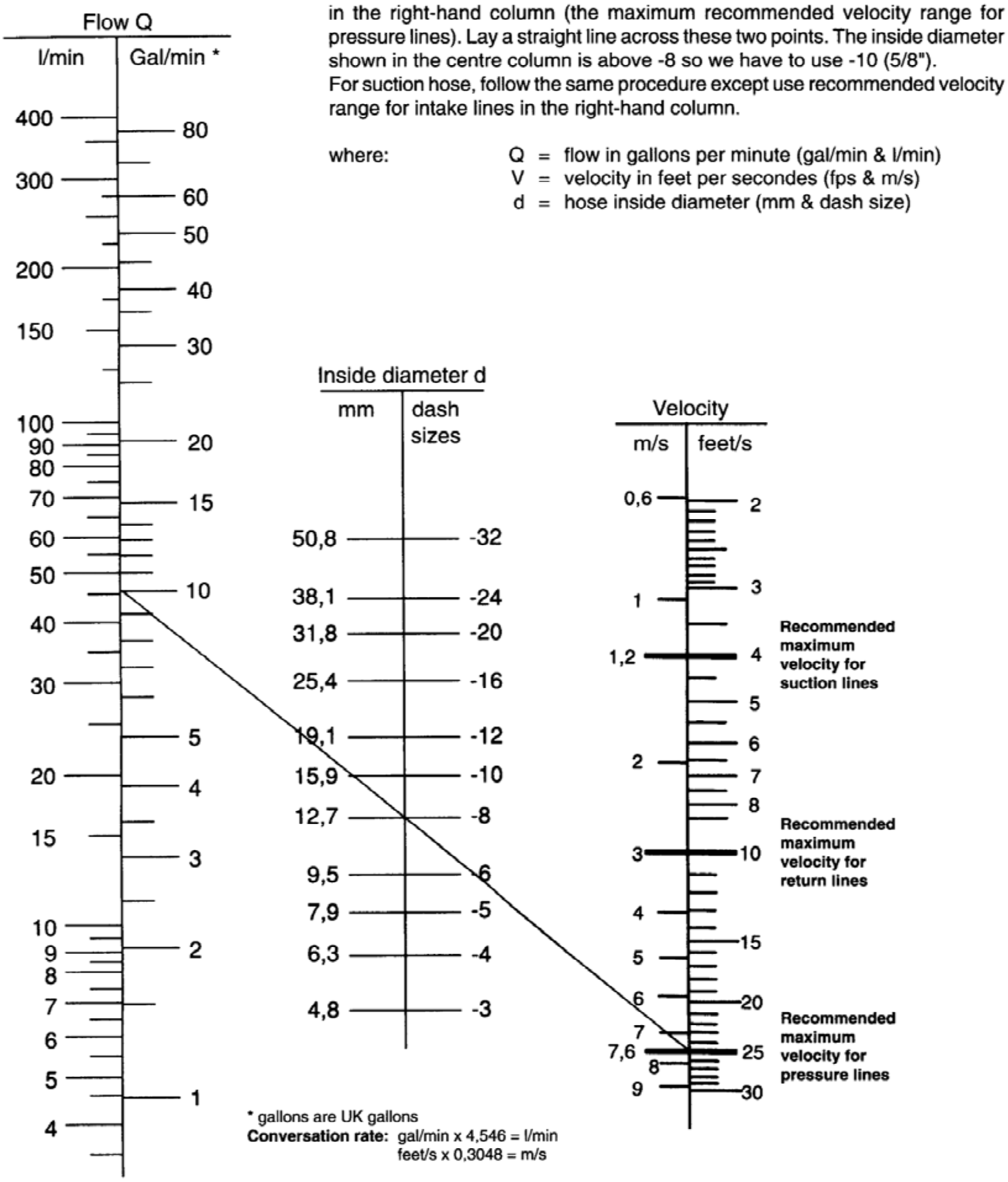
1. Imperial size, a hose would be stated as having a bore of ½”
2. DIN size, A hose would be stated as having a bore size of DIN 12, this is the closest metric size to ½”
3. SAE sizing using the dash (-) system based on the number of sixteenths the bore equates to, this is the most common way of describing a hose size, a ½” hose would be shown as – 8 (Dash 8).

a ½” hose	1/2" = 8/16 = -8
a 5/8” hose	5/8 = 10/16 = -10
a 2” hose	2” = 32/16 = -32

7.1 NOMOGRAM CHART

in the right-hand column (the maximum recommended velocity range for pressure lines). Lay a straight line across these two points. The inside diameter shown in the centre column is above -8 so we have to use -10 (5/8").
For suction hose, follow the same procedure except use recommended velocity range for intake lines in the right-hand column.

where:
Q = flow in gallons per minute (gal/min & l/min)
V = velocity in feet per secondes (fps & m/s)
d = hose inside diameter (mm & dash size)



* gallons are UK gallons
Conversation rate: gal/min x 4,546 = l/min
feet/s x 0,3048 = m/s

Figure 7.1 Nomogram chart

8.0 Maximum working pressure

All hydraulic hose are made to very exact standards; to achieve the pressure ratings given, all hose have a safety margin. This safety margin ensures that the hose will perform within its area of application.
For most hydraulic applications a 4-1-safety margin is manufactured into the hose. I.e. the pressure at which a correctly assembled hose will burst must be at least 4 times higher than the working pressure

The following ratings of the maximum working pressure are based on SAE test requirements J343b. But in some particular applications other factors e.g. safety, temperature-exceeding +100°C (212°F), tight bend radius, etc. may reduce working pressure.

$$\text{Design factor} = \frac{\text{Minimum burst pressure}}{\text{Maximum working pressure}} = \frac{4}{1}$$

This does not mean however that if a system is running at 200 bar, a hose with a working pressure rating of 100 bar can be used. Hydraulic systems have many pressure peaks and spikes; a system running at 200 bar must be fitted with a hose which has a minimum working pressure of 200 bar.

9.0 Thermoplastic hoses

As stated earlier in this manual, all hydraulic hoses are made using the same construction principles. The tube or liner carries the fluid/gas, the reinforcing holds the pressure and the cover protects the reinforcing. The main differences with thermo-plastic hoses are the compounds used during the manufacture. Rubber hoses are excellent in many applications. But rubber hydraulic hoses are not suitable in some applications and fluids.

10.0 Materials used in hose covers and tubes

The thermo-plastic hose tubes and covers are made from man made polymers; these have the advantage of being very stable in their design.

10.1 Polyamide

Polyamide is another name for nylon, it is often abbreviated as the following PA6, PA6/66,PA11 and PA12 nylon. Polyamides are used for both tubes and covers and have many advantages over other compounds. Smooth surface, resistant against paints solvents, ester based fluids and most chemicals. Added to this it has the advantage of being very low in permeability i.e. the fluid will not permeate in between the layers and blister the outer cover.

10.2 Polyester-Elastomer

Often identified as PE-E (Hytrel®). This compound has the advantage of having good flexibility at low temperatures. It is also a very clean hose (no plasticisers) and is also resistant to both synthetic and mineral oils. Hose with a cover made from PE-E are often manufactures into twin triple or even quadruple hose combinations due to the fact that it can be welded with ease. See figure 10.1

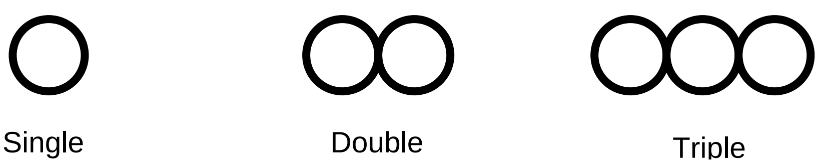


Figure 10.1 Showing various welded hoses

10.3 Polyurethane
Abbreviated to PUR. Well known as an additive to paints this material has excellent resistance to abrasion. It is very flexible, UV and Ozone resistant, and has an excellent resistance to hydrolysis and microbiological degradation. For this reason is often used as a cover on under sea pipelines.

10.4 Polyoxymethylene
Known as POM (Delrin®), POM is necessary for the ultra high-pressure hose applications, it is very hard smooth surface but it is not flexible.

10.5 Fluoropolymers
Often shown as PTFE, FEP or PFA. This compound has excellent chemical resistance, high working temperatures and non-stick. One advantage of this compound is that it is passed for food use.

11.0 Reinforcement materials
The materials used in the reinforcement of a thermo-plastic hose differ from those used in the manufacture of rubber hose. Still used is brass coated high tensile steel for economy and strength. But due to the applications that thermo-plastic hose is used in, more exotic reinforcement materials are used. These materials are still applied in the same format as with rubber hose, i.e. braided and spirally wound. These other compounds bring other qualities and are described below.

11.1 Polyester-Fibre
Polyester fibre has the advantage of being very light, flexible and resistant to kinking.

11.2 Aramid fibre
This material is better known as Kevlar®. It is used in thermo-plastic hoses primarily because of its lightweight and strength, 5 times higher tensile strength compared to steel wire. Aramid is very expensive and is sensitive to kinking.

11.3 Stainless steel wire
Stainless is used far more often in thermo plastic hoses than in rubber. Although higher in cost compared to high tensile steel, it has the advantage of have very good chemical resistance and temperature resistance. A hose using stainless wire reinforcement is often left without a cover due to these properties.

11.4 Measurement of Thermo-plastic hoses
Some confusion can arise from the way some thermo-plastic hoses are measured. All are measured using the bore size but some are stated using the SAE dash system
E.g. –8 = ½”. Some are stated as DIN sizes = Din 12 . If you order a DIN 12 instead of –12 you will receive a ½” hose instead of a ¾” hose. Care must be taken!

12.0 Advantages and benefits

Compared to some thermo-plastic hoses, rubber hydraulic hoses are heavier and more robust in their make up. But their working pressure rating is limited to aprox 450 bar, where as thermo plastic can be manufactured to perform at pressures in excess of 7000 bar.

Due to the manufacturing process used in thermo plastic hoses, they can be made to all most any length; rubber hoses are limited to aprox 300m.

Thermo-plastic hoses are available in very small-bore sizes due to the thinner section; rubber hoses on the other hand are only available down to – 4.

During the manufacture of rubber hoses carbon black is used, carbon conducts electricity so cannot be used when working on live electrical systems. Thermo plastic on the other hand does not contain any carbon and is non conductive. Non-conductive hose is always coloured orange; this type of hose must never be replaced with any other type of hose.

Rubber hose has a stated life cycle of 8 to 10 years; thermo plastic because of its compounds is stated as having an indefinite life.

Because rubber is a soft substance, when it is put under pressure it moves. Over a distance this will expand the hose in its diameter, this can be as much as 5%. Thermo plastic is very stable and is volumetric expansion can be as low as 0.5%. This is important for a pilot control hose as the volume of oil put in one end of the hose needs to be the same at the other end. Very important on hydraulically controlled valves.

Summery

1 Hoses are available with two types of reinforcing, braided and spiral wound

2 Tube material is matched to the fluid being moved

3 The reinforcing is matched to the pressure

4 There are two types of hose swaging processes skive and no skive

5 Orange hose dictate that the hose is non conductive

6 All hoses are stated with a minimum bend radius – manufacturer's catalogue

7 Stainless steel braided hoses are often made without a cover

8 Hose material should be matched to the temperature of the system

9 Suction and delivery hose is manufactured with a single or double coil of wire to stop the hose collapsing under vacuum conditions

10 Never mix different manufactures' parts when making a hose