WHITE PAPER

Understanding Hydraulic Hose Reinforcement: Performance Characteristics, SAE Specs for Wire Braid and Spiral Wire

Introduction

While modern hydraulic hoses may have varying pressure ratings, temperature ranges and stock materials, all have similar construction features.

A hose consists of three basic components:

- The tube is made from several different rubber compounds and composites that must chemically resist the fluid being conveyed. The tube must also resist corrosion, deterioration and the effects of high or low temperatures.
- The reinforcement must resist fluid pressures, pressure spikes and hose bursts. It determines the working pressure of the hose. The reinforcement can be a braid or spiral wrap and can be made of natural fibers, synthetic materials or steel wire. Some hoses use a combination of fiber and steel wire or multiple layers of steel wire braids or spirals.
- The cover is designed to protect the tube and reinforcement from heat, abrasion, corrosion and environmental deterioration. The cover can be made from synthetic rubber, fiber braids or a combination of both depending on the application.

This may sound simple enough, but today's advanced hydraulic hoses are engineered with considerably more technology.

For example, the composition of the tube (typically a synthetic rubber compound) must be compatible with a wide range of petroleum-based and biodegradable fluids. Special compounds may be required to handle fire-resistant fluids or those that run at extreme temperatures. Likewise, the cover, made of various materials, must be designed to resist the effects of oil, abrasion, corrosion, heat, cold, UV light and ozone.

Braided reinforcement can be made of wire or textile, and can have one or multiple layers. It is light-weight and flexible for medium and low-pressure hose applications.

The type of reinforcement a hose incorporates typically varies with its rated working pressure. Hoses with low working pressures normally use fabric reinforcement, while those handling higher pressures use high-strength steel wire.

Steel-reinforced hose, in turn, falls into two categories: braid and spiral. Braided hose, which can handle working pressures up to 6,000 psi, depending on size, can have one braid layer or two, depending on applications and pressure requirements. If two layers are used, they are separated with a layer of rubber to ensure good adhesion throughout the wall of the hose.

Spiraled reinforcement is typically wire and has four or six layers (plies). It is designed to handle more severe applications with longer impulse service life.

By contrast, spiral hose, which generally handles high pressures in larger diameters, has the wire wrapped around its tube on a bias, with successive layers laid at an angle

opposite to the one beneath. Typically, either four layers or six layers of steel are used, and these constructions normally are known respectively as “four-wire” and “six-wire” hose. Rubber adhesion layers separate the layers of steel wrap.

When selecting a hydraulic hose, Gates Corporation engineers say it’s important to understand the relationship between hose reinforcement and pressure ratings.

Very and Extremely High Pressure Hose

Very high and extremely high-pressure hose is used for off-highway equipment and heavy-duty machinery where extremely high impulse or pressure surges are encountered. The oil-resistant synthetic tubes in these hoses are reinforced with four or six layers of spiraled, high-tensile steel wire. This spiral reinforcement is particularly well suited to high-pressure impulse applications because the individual wires are parallel and each layer is separated by a thin adhesion layer of rubber which keeps the wires from cutting one another. Each layer provides a level of reinforcement that works in conjunction with the other layers of reinforcement, leading to more efficient use of the wire strength, increased service life and improved flexibility.

The spiral reinforcement arrangement allows for a tighter pack of reinforcement for the tube than braid reinforcement, and therefore, more support. Individual ends or strands can be bound tightly together as opposed to the over-under gaps with braiding. Some flexibility is sacrificed, however.

Braided hose is generally more flexible than spiral hose. Spiral reinforcement is built over the tube in alternating, even-numbered layers to balance the forces of pressure and containment.

These hoses are often called “four-wire” for very high pressure and “six-wire” for extremely high-pressure hose, yet the actual number of spiral wire layers varies by the hose I.D. Most spiral hose with an I.D. of one inch or less has four layers.

High-Pressure Hose

These hoses are often called “two-wire” braid hose because they generally have a reinforcement of two-wire braids of high-tensile strength steel. They are frequently found in high-pressure hydraulic applications such as construction equipment. Operating pressures range from 6,000 psi for a 3/16” I.D. to 1,825 psi for a 2” I.D. Some proprietary hoses such as Gates M3K® and M4K® have the same pressure rating for all sizes.

Medium-Pressure Hose

These hoses are used for hydraulic applications requiring operating pressures of 300 psi to 3,000 psi. They may be one-wire braid or multiple wire and/or textile braid construction.

In addition to being used on medium-pressure hydraulic

equipment, medium-pressure hoses are often used in heavy-duty truck and fleet vehicle applications. In the early 1940s, there were no flexible hoses on the market designed specifically for the fleet user. Truck mechanics discovered a high-working pressure hose used for hydraulic lines on aircraft and applied it to fleet applications. Soon this hose replaced the rigid copper tubing originally used on trucks. This truck hose is often called flexline, TWT (textile-wire-textile) or C5 hose after the Society of Automotive Engineers (SAE) designation of 100R5.

Low-Pressure Hose

Low-pressure hydraulic hoses are designed for use in various applications with operating pressures less than 300 psi. Their reinforcement is usually textile. They are used on low-pressure hydraulic equipment or they are used to transmit petroleum-based fluids, diesel fuel, hot lubricating oil, air, glycol antifreeze and water. Some low-pressure hose such as Global MegaVac® (GMV) is also rated for suction applications.

Specialty Hydraulic Hose

Some of these hoses do not fit well into a particular pressure category. Examples of special applications are conveying refrigerant or LPG gas, operating at temperature extremes or requiring non-conductivity of electricity. They may be used where weight is a concern or when long continuous lengths are required. Reinforcement is mostly non-metallic, and is usually a rubber-impregnated fabric.

SAE Hose Constructions

To bring a measure of uniformity to the manufacture of hydraulic hose, minimum standards for its construction and performance have long been established in North America by SAE.

In similar fashion, in other parts of the world, organizations such as the European Norm/Standard (EN), Deutsch Industrie Norm (DIN) and the International Standards Organization (ISO) also set standards, which may have different specifications than those of SAE. Governmental agencies also may set standards. Among them are the Mine Safety & Health Administration (MSHA) and the Department of Transportation with its Federal Motor Vehicle Safety Standards.

Most USA-manufactured hydraulic hose is built to conform to SAE requirements for size, tolerances, construction and minimum performance characteristics of each major hose type. SAE standard J517 provides general, dimensional and performance specifications for the 100R hose series, which are the most common hoses used in hydraulic systems. See SAE specifications below:

SAE 100R1

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

Type AT – Same construction as Type A, except it has a cover designed to assemble with fittings which do not require removal of the cover or any portion of it.

Type S – This hose has the same construction as Type AT and working pressures of ISO 436-1, Type 1SN.

SAE 100R2

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

It consists of an inner tube of oil-resistant synthetic rubber, steel-wire reinforcement according to hose type as detailed below, and an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

Type AT – Same construction as Type A, except it has a cover designed to assemble with fittings which do not require removal of the cover or any portion of it.

Type S – This hose has the same construction as Type AT and working pressures of ISO 1436-1, Type 2SN.

SAE 100R3

This hose should be used in low pressure and vacuum applications with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

It is constructed with an inner tube of oil-resistant synthetic rubber, a reinforcement consisting of a ply or plies of woven or braided textile fibers with a suitable spiral of body wire, and an oil- and weather-resistant synthetic rubber cover.

SAE 100R5

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

It is constructed with an inner tube of oil-resistant synthetic rubber reinforced with two textile braids separated by a high-tensile strength steel-wire braid. All of the braids are impregnated with an oil- and mildew-resistant synthetic rubber compound.

SAE 100R6

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

It consists of an inner tube of oil-resistant synthetic rubber, one braided ply of suitable textile yarn and an oil- and weather-resistant synthetic rubber cover.

SAE 100R7

This thermoplastic hose should be used for synthetic-, petroleum- and water-based hydraulic fluids in a temperature range from -40° to 93°C.

It consists of a thermoplastic inner tube resistant to hydraulic fluids with suitable synthetic-fiber reinforcement and a hydraulic fluid- and weather-resistant thermoplastic cover. Nonconductive 100R7 is identified with an orange cover and appropriate layline. Its pressure capacity is similar to that of 100R1.

SAE 100R8

This high-pressure thermoplastic hose should be used with synthetic-, petroleum- and water-based hydraulic fluids within a temperature range from -40° to 93°C.

It consists of a thermoplastic inner tube resistant to hydraulic fluids with suitable synthetic-fiber reinforcement and a hydraulic fluid- and weather-resistant thermoplastic cover. Nonconductive 100R8 is identified with an orange cover and appropriate layline. Its pressure capacity is similar to that of 100R2.

SAE 100R9

This hose type has been removed from the SAE standard.

SAE 100R10

This hose type has been removed from the SAE standard.

SAE 100R11

This hose type has been removed from the SAE standard.

SAE 100R12

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 121°C.

It consists of an inner tube of oil-resistant synthetic rubber, four spiral plies of heavy wire wrapped in alternating directions and an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

SAE 100R13

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 121°C.

It is constructed with an inner tube of oil-resistant synthetic rubber, followed by multiple spiral plies of heavy wire wrapped in alternating directions, and concluding with an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor

the synthetic rubber to the wire.

SAE 100R14

This hose should be used with petroleum-, synthetic- and water-based hydraulic fluids within a temperature range from -54° to 204°C.

Type A – This type consists of an inner tube of polytetrafluorethylene (PTFE) reinforced with a single braid of stainless steel.

Type B – This type has the same construction as Type A, but has the additional feature of an electrically-conductive inner surface to prevent buildup of an electrostatic charge.

SAE 100R15

This hose should only be used with petroleum-based hydraulic fluids within a temperature range from -40° to 121°C.

It consists of an inner tube of oil-resistant synthetic rubber, multiple spiral plies of heavy wire wrapped in alternating directions and an oil- and weather-resistant rubber cover. A ply or braid of suitable material may be used over or within the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

SAE 100R16

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C.

It consists of an inner tube of oil-resistant synthetic rubber, steel wire reinforcement of one or two braids and an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

SAE 100R17

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C. It has a constant working pressure rating of 3,000 psi.

It consists of an inner tube of oil-resistant synthetic rubber, steel wire reinforcement of one or two braids and an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

SAE 100R18

This thermoplastic hose should be used for synthetic-, petroleum- and water-based hydraulic fluids in a temperature range from -40° to 93°C.

It consists of a thermoplastic inner tube resistant to hydraulic fluids with suitable synthetic-fiber reinforcement and a hydraulic fluid- and weather-resistant thermoplastic cover. Nonconductive 100R18 is identified with an orange cover and appropriate layline. Its working pressure rating is 3,000 psi for all sizes.

SAE 100R19

This hose should be used with petroleum- and water-based hydraulic fluids within a temperature range from -40° to 100°C. It has a constant working pressure rating of 4,000 psi in all sizes.

It consists of an inner tube of oil-resistant synthetic rubber, steel wire reinforcement of one or two braids and an oil- and weather-resistant synthetic rubber cover. A ply or braid of suitable material may be used over the inner tube and/or over the wire reinforcement to anchor the synthetic rubber to the wire.

Hoses that Exceed SAE Specs

Some manufacturers like Gates have developed hose products that far exceed the performance and construction requirements of SAE specifications. These include higher pressure and temperature capability, greater flexibility and a bend radius equal to one-half of the SAE standard.

Gates newest advancement is its M-XP™ hydraulic hose, which combines the flexibility of wire-braid construction with the strength and performance of spiral-wire reinforcement. The result is a two-braid wire hose that is economical, yet can handle 4,000-psi high-impulse applications in all sizes.

M-XP hose has been tested at an industry-leading 1,000,000 impulse cycles (at 212°F; 100°C), which exceeds the SAE standard of 200,000 impulse cycles and the Gates minimum requirement of 600,000 impulse cycles for typical wire-braid hoses. The high-impulse cycle testing increases service life and makes M-XP hose ideal for out-of-sight and hard-to-reach applications such as boom arms and scissor lifts used in the mobile equipment and construction markets.

Gates M-XP hose is engineered with one-half the SAE bend radius requirement. This reduces hose length requirements up to 47 percent, and allows for greater flexibility and easier installation in confined spaces.

Rather than using expensive spiral-wire couplings, M-XP hose can be fitted with Gates economical one-piece MegaCrimp® couplings that also exceed 1,000,000 impulse cycle tests. M-XP hose assemblies meet MSHA flame-resistance requirements.

For additional information, please visit www.gates.com/mxp.

For information about Gates complete fluid power product line, visit www.gates.com/hydraulics.