WHITE PAPER
How Pressure, Temperature and Bend Radius Affect Hydraulic Hose Service Life

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INTRODUCTION

Hydraulic hose has a finite service life that can be reduced by many variable factors including: pressure cycles and pulsations, temperature extremes and the hose's minimum bend radius.

SAE Standard J517 establishes minimum hydraulic hose specifications for these three factors. However, there is often a large gap between ideal test conditions and the actual working environment in which a hose must perform.

Therefore, hydraulic system designers, and aftermarket technicians and machine operators must be aware of how variances from the ideal will affect hose life expectancy.

Engineers at The Gates Corporation offer the following examination of the effects of pressure, temperature and bend radius on hydraulic hose service life.

PRESSURE

When selecting a hydraulic hose, its working pressure must be greater than or equal to the maximum system pressure, including pressure spikes. Pressure spikes greater than the published working pressure will shorten hose life and must be considered.

NOTE: Gates DOES NOT recommend using hoses on applications that have pressure spikes greater than the published working pressure of the hoses.

In situations where equipment has been modified to perform special operations, it is not uncommon to see spikes in hydraulic pressure that the hose and coupling manufacturer did not anticipate. As a general rule, when choosing hose to transmit fluid under pressure, it's best to allow a generous margin of safety. Typically, for dynamic hydraulic applications, the minimum burst pressure rating is four times that of the maximum working pressure rating. Burst pressures are reference pressures and are intended for destructive testing purposes and design safety factors only.

A hose layline contains important information for specifying the replacement assembly: manufacturer, hose trade name, working pressure and hose ID.

The following general guidelines will help in choosing the correct hose for an application.

1) The minimum impulse cycle life found in SAE J517 can be used as an indicator of expected hose cycle life. NOTE: Different hose types, and in some cases hose sizes, have different expected cycle lives. Some hose manufacturers have products that far exceed SAE minimums.

2) Generally, spiral wire hoses exhibit longer impulse life than wire braid hoses.

3) Using a hose with a higher rated working pressure than the system pressure will generally increase the cycle life. Gates testing has shown that using a hose at 50% below its rated working pressure will approximately quadruple the cycle life.

4) Determining the pressure rating of the hose assembly is essential, but often overlooked. The pressure rating of a hose assembly is determined by the pressure rating of the component in the hose assembly with the lowest working pressure. To consider, therefore, only the pressure rating of the hose is NOT enough! Quite often the pressure rating of the fittings can lie below that of the hose.

PRESSURE DROP

Pressure drop occurs naturally in a hydraulic system. It also is important to allow for pressure drop that occurs between the pressure of a fluid as it enters one end of a hydraulic hose assembly and the pressure of that fluid as it leaves the other end.

However, it may be necessary to control the amount of pressure drop (by minimizing 90° bends in the routing, for example), so as not to adversely affect the performance of the equipment.

Pressure drop can be caused by the following:

<u>Friction.</u> Fluid rubbing against the inside walls of a hose and coupling creates friction, generates heat and causes pressure drop.

<u>Viscosity.</u> Different fluids behave differently under pressure. High viscosity (thicker) fluids don't move as readily as low viscosity fluids and exhibit a greater drop in pressure. Ambient temperatures also affect viscosity. In all cases, the idea is to allow the pump to move the fluid easily.

<u>Fluid Temperature.</u> As its temperature increases, the hydraulic fluid becomes thinner and allows the fluid to move more easily.

<u>Length of Hose Assembly.</u> The longer the hose assembly (surface area), the more friction will decrease pressure.

<u>Size (ID) of Hose.</u> The ID of the hose affects the fluid velocity for a given flow rate. Small IDs increase velocity, and high velocities result in greater pressure drop. Large diameter hose will produce less pressure drop.

<u>Couplings and Adapters.</u> Any change in bore or direction (such as with a 45° or 90° elbow) increases the amount of pressure drop. Hose assembly routing should be as straight as possible.

<u>Flow Rate</u>. Pressure drop increases with flow rate for the same size hose.

The importance of pressure drop.

When plumbing a system, OE engineers and aftermarket technicians must take any drop in pressure into account. If 4,000 psi of output is needed to run the equipment efficiently, the input pressure to the hose assembly must equal 4,000 psi, PLUS the amount of pressure drop inherent in the system.

Stated simply: Output pressure = input pressure + pressure drop.

Help in determining pressure drop is available from representatives of hose and coupling manufacturers. Be prepared to describe the type of application, fluid type and viscosity, fluid and ambient temperature, fluid flow rate, hose size and length, routing requirements, government and industry standards being met, and the number and type of fittings.

TEMPERATURE RATING

Fluid power system designers and technicians must be cognizant of both the ambient external temperature and the internal hydraulic fluid temperature in which the hose will be operating.

It is important not to expose the hose to internal or external temperatures that exceed the hose specifications. The hose and couplings must be capable of withstanding both minimum and maximum temperatures of the system. All hoses are rated with a maximum working fluid temperature of 200° to 400°F . Using a hydraulic hose at a temperature of 18°F above maximum rated temperature of the hose may cut the hose life in half.

When selecting a hose for its maximum temperature, take care that the temperature stated is not an intermittent value.

Excessive heat can quickly damage hose not specifically compounded for extreme temperatures. In most cases, synthetic rubber compounds will harden when exposed to temperatures in excess of their rated maximum temperature (generally 200°F). These hoses become less flexible and prone to cracking, leading to significantly reduced service life.

However, special high temperature resistant compounds are available. These can be found in most manufacturers' catalogs. Temperature ratings of as high as 300°F are common.

On the other hand, minimum temperature must also be considered. Depending on materials used, hoses may accommodate temperatures as low as -65°F (Hytrel and winterized rubber compounds) or as high as 400°F (PTFE).

In situations where hose must operate in extremely low ambient temperatures (-40°F and lower), the designer also must be aware that hose tends to become brittle, less flexible and may crack. Special compounds can be specified for applications that require operation in extremely low temperatures.

When hoses are exposed to high external and internal temperatures concurrently, there will be a considerable reduction in hose service life, and extreme operating temperatures can affect the hose's ability to firmly retain its fittings.

Insulating sleeves can help protect hose from hot equipment parts and other high temperature sources that are potentially hazardous. In these situations, an additional barrier is usually required to shield fluid from a possible source of ignition.

Options for monitoring pressure and temperature

Until recently, there were two preventive maintenance strategies for monitoring pressure cycles and pulsations and temperature extremes:

1) Schedule regular external visual inspections for hose cover wear, damaged connectors, fluid leaks and excessive corrosion,
2) Maintain records of part numbers and product installation and replacement cycles.

Now, equipment operators have the option to use Gates Corporation's Sentry™ Services hydraulic hose diagnostic and monitoring systems.

Gates Sentry IQ predictive maintenance technology service monitors pressure and temperature in a hydraulic hose to gauge remaining hose life. The system is designed for equipment and processes in applications where unexpected hose failures can cause expensive downtime, compromise safety and require costly repair and clean-up. The technology is suited for both new equipment designs and aftermarket applications.

Gates other proactive maintenance tool, Sentry ID, is a radio frequency tagging system that identifies and tracks specific hose assemblies operating worldwide. High-radio frequency tags (pictured, left) contain pertinent information about hoses, allowing maintenance technicians to electronically read and identify the exact hose needed when the time comes for replacement. The tags not only speed turnaround, but also provide information about hose performance and inventory to guide future hose selections.

Information is available from Gates Fluid Power distributors and at www.gates.com/sentry.

BEND RADIUS

Subjecting a hose to a bend radius smaller than the minimum recommendation places excessive stress on the reinforcement, opens larger gaps between strands of reinforcement and severely reduces the ability of the hose to withstand pressure, thereby reducing hose assembly life.

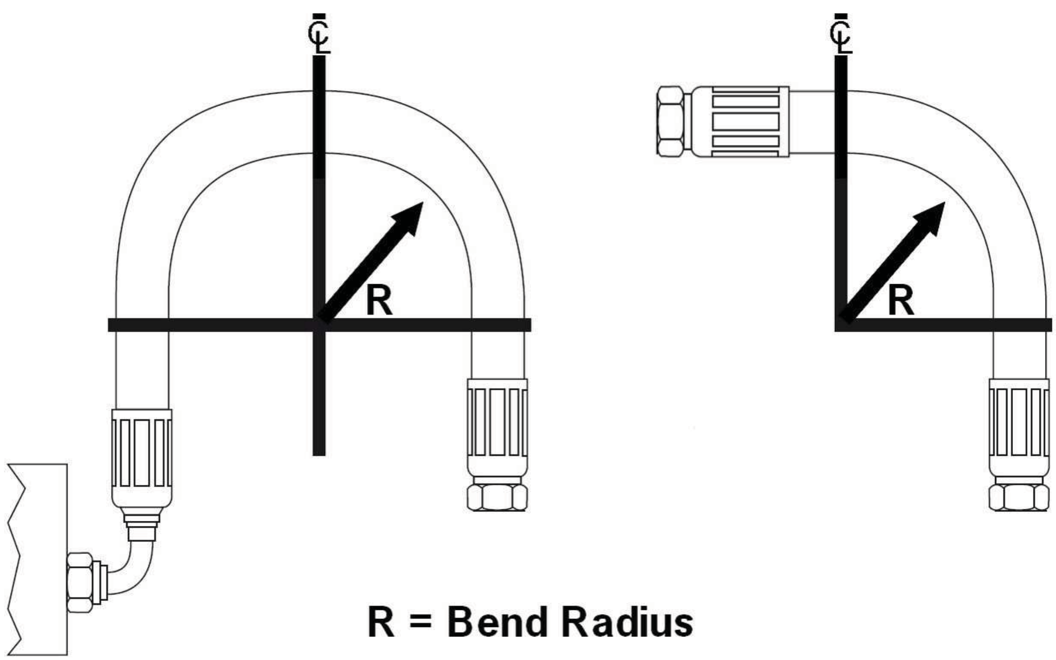
The number of bends and the degree to which hydraulic hoses are bent greatly affect the life and reliability of a hydraulic hose. This problem is compounded by the increasingly high-pressure application in which these hoses are expected to perform.

Also, hose bends immediately behind the couplings result in undue stress at the couplings. This is a very common cause of hose failures.

All bending affects hydraulic hose life to some degree. Even more damaging is hose twist. Twisting the hose distorts the angle of reinforcement, and drastically shortens hose life. Laboratory test show that even a 5° twist can reduce hydraulic hose life by as much as 70 percent.

Gates suggests that if the bend must be sharper than the minimum radius, adapters or angle fittings should be used. The hose manufacturer's specifications should be checked to determine the straight hose section, between the couplings, needed for a particular I.D.

The minimum bend radius of a hose is the smallest diameter the hose can be bent without internal damage or kinking. SAE requires all hydraulic hose manufacturers list the minimum bend radius for their hose, which is based on the hose construction, pressure rating, size and wall thickness. Bend radius is measured to the inside of the curvature as shown below.



The minimum bend radius is measured from the inside of the hose to the centerline of the bend.

As a rule of thumb, a 1/4-inch I.D. hose requires a five-inch minimum straight section, a 3/4-inch I.D. hose needs seven inches, and a two-inch I.D. hose must have at least 11 inches of hose length between the couplings.

The designer should also determine whether hose, tubing or a combination of the two is best for a particular application. Hose and tubing should be considered as compatible components.

Advantages of tubing include:

- Routed in higher temperature areas.
- Handle hotter fluids than hose.
- Can be bent in smaller radii than hose and installed in tighter spaces.

On the other hand, hose has advantages:

- Can be attached between moving and stationary components.
- More resilient than metal. Less likely to crack.
- More flexible.
- More resistant to vibration.

In addition to the 14 standard SAE hoses, manufacturers such as Gates produce hoses for which no SAE standard has been written. The standards are used as guidelines, but manufacturers have produced hoses that are superior in performance that have added benefits for the user.

For example, many manufacturers now produce a one-wire braid reinforced hose that can be used in many traditional two-wire braid applications. The advantages include:

Increased flexibility.

Reduced minimum bend radius.

Less hose needed to plumb a circuit, because of a smaller bend radius.

Lighter weight assemblies.

Less costly than the comparable two-wire hose.

Smaller hose O.D. for easier routing.

CONCLUSION

In summary, hydraulic hose technology has been developing much more rapidly than hose standards. For example, the specifications for SAE 100R13 hose were released in the late 1980's, even though the hose had been on the market since the early part of the century. And, the current trend is toward products rated in the 6,000-psi working pressure range, for which there are no SAE standards. More and more frequently, hoses are being developed to meet specific applications or to fulfill specific customer requirements.

The hose designer and technician must be aware of the effects of pressure, temperature and bend radius on hydraulic hose life. Many other guidelines for the use of hydraulic hoses can be found in SAE J1273. When in doubt, the best approach is to contact the hose manufacturer or distributor for current applications data.

ADDITIONAL INFORMATION

For technical assistance from Gates Fluid Power Product Application engineers, call 303-744-5070 or email Gates hotline @ HCPA0000@gates.com.

To learn more about Gates hose and coupling products and services, visit www.gates.com/hydraulics.

For information about Gates hydraulic maintenance and safety program, visit www.gates.com/safehydraulics.

SIDEBAR

Understanding Hydraulic Hose Reinforcement

Hydraulic hose 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 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 (pictured, right), they are separated with a layer of rubber to ensure good adhesion throughout the wall of the hose.

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. These constructions (pictured, right) 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.

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