Recommended Practices for Ultra High Pressure (UHP) Hoses

Proven Methods To Improve Service Life

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Proven Methods To Improve Service Life

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Article contributed by Paul Webster, Program Manager for UHP Hose in Stafford Texas, Parflex Division, Parker Hannifin.

Dr. John Rogan, an entrepreneur in the bolt tensioning industry, realized the need for a "new hose" that offered higher operating pressures, increased impulse life and most importantly, lower volumetric expansion to allow for faster cycle times on the equipment. Polyflex Germany had begun developing such a hose which exceeded the current market offering of rubber hoses. News about the new Polyflex hose spread quickly beyond the bolt tensioning market and into other major industries, including water blasting and high-pressure test equipment. Companies realized it could easily replace rubber hose as well as steel tubing and it had excellent chemical resistance. As a result, the UHP hose industry was born.

Polyflex UHP hose is based on a ridged thermoplastic core tube reinforced with high strength steel wire and jacketed with a thermoplastic outer cover. Achieving the performance capabilities of a UHP hose is the result of methods used to apply the wire

History of UHP Hose

The origin of water blast UHP hoses can be found in the hydraulic tool industry. In the early 1980's, bolt tensioning equipment "pushed the envelope" of pressure which often was as high as 30,000 psi. This required higher working pressures and lower volumetric expansion that standard hydraulic hoses could not deliver.

UHP Hose

Today 55,000 psi water jetting equipment is a reality; therefore, it is more important than ever to follow safety guidelines and practices that extend the life of the high-pressure hose. Working pressures are much higher than 25 years ago when 40,000 psi equipment first became available. Advances in manufacturing techniques and the use of accessories have dramatically increased the life of the hose.

reinforcement. The wire spiraling process applies the high strength wire under higher tension than all other hoses. By varying the wire pitch and tension on each layer of reinforcement, the hoop stress is more equally distributed throughout the reinforcing layers, permitting the hose to function at higher pressures with minimal volumetric expansion and axial movement.

The water blasting industry has become the driving force of hose manufacturers and UHP equipment over the last four decades. The 1980's forced manufacturers to develop what some would now consider low-pressure equipment.

In the early 1990s, pressures increased to 36,000 psi and then 40,000 psi in the later part of the decade.

Historically, an increase in equipment pressure requirements was followed by an increase in flow rate. Thus, a 36,000-psi hose would be developed with a 3/16" ID, then a 3/10" ID and today a 1/2" ID 43,000 psi hose is available. In the year 2000, working pressures approached 45,000 psi with new pumps in development designed to operate at 50,000 and 55,000 psi. It has been challenging at times for manufacturers to develop technology and design equipment because of the stresses exerted on materials at these higher pressures. In the future, water-jetting pressures may reach 60,000 psi to 65,000 psi; however, significant R&D expenditures will be required in material science as current practices are reaching their design limits.

Factors That Can Reduce Service Life

Hose Fitting Stress

The most common type of damage to a UHP assembly is at the fitting, which is generally the weakest point of the hose assembly. To reduce bending directly behind the fitting, stiffeners and bend restrictors can be installed on the hose assembly. This reduces stress at the hose and fitting interface and prolongs hose service life. A stiffener keeps the hose straight behind the fitting and the pressure containment shield acts as a semi-stiff bend restrictor to let the hose gradually bend. A general rule of thumb is to keep the hose supported and straight directly behind the fitting for a minimum length of 4 times the hose O.D.

Another type of stress at the fitting is axial loading where the hose assembly is stretched or compressed at the fitting. One common application causing axial stress on the hose assembly is hanging one or more UHP assemblies from scaffolding or a wire rope. When a hose has a PVC outer abrasion or safety shield, the hose hangs freely within the shield. When the hose assembly is tethered off to a cable or fixture, the hose hangs inside the shield stretching the hose behind the topside fitting. Parker's new hose with TOUGHJacket™ eliminates this stretching because the actual hose is being supported rather than the shield.

Factors That Can Reduce Service Life (cont.)

Abrasion

Abrasion is regarded as damage to the outer cover and underlying reinforcement. When the outer cover becomes abraded to the extent that the reinforcement is visible, exposure to the environment will cause degradation and the reinforcement becomes the acting wear member. All reinforcing layers, whether steel or fiber, contribute to the strength of the hose. If the reinforcement becomes degraded, hose life will be reduced. The hose should always be visually examined prior to use for signs of abrasion. Hose assemblies with an abraded outer cover, exposing the reinforcements layers, should be removed from service as soon as possible.

Kinks & Crushes

Kinks and crushes are due to mishandling and improper installation. Several scenarios cause kinking. Dragging the hose around a sharp corner or pulling the hose when it is in a coiled state and not letting the hose naturally un-twist may cause the hose to kink. With a pressure containment shield or abrasion shield, damage is not easily detectable.

Crushes may occur if heavy equipment is dropped on the hose assembly or if special clamping accessories are improperly attached to the assembly. Crushes are visibly detected as oval, flattened areas along the length of the hose. Both kinks and crushes will significantly reduce service life or may lead to immediate failure when pressurized.

Impulse & Flex Fatigue

Hose fatigue is similar to that in high-pressure steel tubing and adapters. The main component that causes hose fatigue is pressure cycling and, to a lesser extent, hose flexing. The steel wire reinforcement is cold worked every time it is pressurized (stressed) and depressurized (un-stressed). Pumps where pulsation dampeners are not used cause the hose to expand and relax at very high frequencies. The magnitude of pressure change has the greatest impact on hose reinforcement fatigue since the wire is stressed and un-stressed to a higher degree. If the pressure is constant with very little cyclical pulsation, hose service life will increase. High frequency flexing will cause the wire reinforcement to fatigue. However, these cases are very rare and only occur in applications where the hose is under constant flexing. High frequency flexing of UHP hose should be avoided.

Flexing and Twisting

When hoses are being continually flexed or twisted, service life is reduced. In one extreme application, the hose is oscillated side to side in a 60-degree arc at frequencies upwards of 60 cycles per minute. The extreme flexing causes the wire reinforcement to fatigue and there is considerable loss in service life.

Another hose application is found in rotary devices for internal tube cleaning. The hose is rotated to assist in the cleaning action of the water jet. Hoses in these applications often have extreme cover damage and the hose/fitting interface is usually twisted to the point of failure.

Chemical Attack

UHP hoses use very tough materials that resist fatigue and abrasion but can still suffer chemical attack. In water jetting applications, chlorine and fluorine are the two main chemicals of concern and are present in all city municipalities. If these chemicals are concentrated, then the core tube may experience crazing. Crazing is a condition where the core tube has longitudinal cracks in the core tube. Unfortunately, at this time not enough data has been collected to know what concentration levels will chemically attack the tube or what circumstances allow chlorine and fluorine to be present in these concentrations. Future tests will help understand this problem and offer guidelines to detect and control chemical attack.

Practices That Improve Service Life

Hose Fitting Stress

Operators can reduce stress at the fitting by using stiffeners or supporting the hose so it remains straight for a minimum length of 4 times the hose O.D. Also, installing adapters that let the hose hang straight down, as opposed to having the hose exit the pump or gun horizontally will extend hose life. If the hose is hanging from an elevated height, use support grips to support the weight of the hose rather than having the fitting support the weight.

Often, the hose safety shield pulls away from a fitting. Safety shields are heavy and less flexible than hose. When it pulls away from the fitting there is now a gap between the shield and the fitting which creates a bending point. The bending is magnified by the weight and stiffness of the safety shield and unduly stresses the hose. Keep the hose assembly straight a minimum of 4 times the hose O.D.

Pressure Spikes and Pulsations

Minimize pressure spikes and pressure pulsations as much as possible. Pressure spikes are internal to water jetting systems and cause internal damage to all working components of the system including the hose assembly. Pressure spikes are often created when the gun or lance is pressured up. The release of pressure by the relief valve is not instantaneous so there is a moment when the pressure exceeds the relief set point and creates a pressure spike. Pressure spikes are often higher than the rated working pressure of the hose assembly and overly stresses the hose reinforcement.

UHP hose may contract upwards of 2%. For each pressure pulsation, the hose contracts and elongates. Use accumulators or pressure pulsation dampeners if available from the manufacturer to smooth out the pressure wave. Operate the pump at the manufacturers recommended settings.

Photo of a hose assembly with the pressure containment shield pulled away from the fitting. The red arrow shows the point where hose hinges.

Abrasion

A primary source of hose failure is abrasion resulting from cuts and abrasion caused by the hose rubbing on the ground or against objects in the operating environment. Prevention of cover abrasion is critical to hose life. New hoses coming onto the market may have two layers of dissimilar colored covers. When the outer cover is worn down to the sub-layer, the color change becomes evident and immediate action can be taken to prevent further abrasion.

Several accessories offer additional protection to the hose cover. Abrasion shields are commonly installed on the hose at the factory. Nylon spiral guards, which can be applied in the field, are especially good at preventing initial abrasion or stopping further abrasion once it has begun. Other types of shields can be wrapped around the

Practices That Improve Service Life (cont.)

hose and secured with tie wraps for localized abrasion resistance. Ask your hose supplier what abrasion accessories are available for the hose you are using.

Pressure Cantonment Shields

The safety or pressure containment shield is designed to resist a hose burst or pinhole leak at the rated working pressure and offers abrasion resistance to protect the hose from external damage. The pressure containment shield is clamped directly onto the hose fitting using a retaining sleeve.

Typically, a stiffener or bend restrictor is used to prevent the hose from bending directly behind the fitting, which decreases the stress at the hose/fitting interface. In addition, a relief hole drilled into the crimp shell acts as an early leak indicator and offers some protection from pressure build up within the fitting or threaded connection. With the safety shield attached in this manner, additional pressure relief holes are added to the shield to relieve any pressure build up and indicate leakage.

Pressure containment shields are used to protect the user in the event of a high-pressure fluid leak. Sometimes the end user chooses their own pressure containment shield which may or may not be rated for the full pressure of the hose. When hoses have an abrasion shield, there is often a mis-understanding that the abrasion shield offers protection from a high pressure fluid leak. It does not.

Abrasion Shields

Cuts, tears and punctures are common sources of hose damage causing lower service life. An abrasion shield is a flexible PVC thermoplastic cover designed to prevent these common causes of hose damage. An abrasion shield, like the safety shield, is clamped directly onto the hose fitting using a retaining sleeve. However, an abrasion shield does not have relief holes to vent pressure build up nor does it offer operator protection from hose burst or high-pressure fluid leakage.

Abrasion shields offer no resistance to high-pressure fluid leaks and are only used to protect the hose from abrasion. Never let the hose come in contact with any part of the body unless a safety shield is installed on the hose assembly or the operator is wearing properly rated personal protective equipment. Make sure the equipment manufacturer has approved the safety shield based on the hose size and working pressure. Do not use an un-approved safety shield or protective shields that have pulled away from the fitting exposing the hose.

A properly rated shield will resist a burst and the resultant waterjet at the system's rated working pressure. A pressure containment shield can run the entire length of the hose assembly or it can be

Photo showing the ColorGard™ feature (yellow liner) with abrasion resistant TOUGHJacket. Here the outer TOUGHJacket is abraded down to the yellow under

Practices That Improve Service Life (cont.)

a short five to six-foot whip that is affixed to one or both fittings. A pressure containment shield may also serve as a bend restrictor lessening the bending moment behind the fitting.

Containment Grips, Support Grips and Bend Restrictors

Containment grips are used to reduce hose "whipping" in the event the hose uncouples from the fitting under pressure. Additionally, it can act as a support grip.

Containment grips grab onto the hose as the grip is pulled. The harder the grip is pulled, the tighter it grips the hose. Like the pressure containment shield, the containment grip must be properly rated to the hose by specifying its breaking strength. We calculate the breaking strength by taking the area of the hose's inner diameter and multiply it by the working pressure. The breaking strength (BS) equation is $\pi * (\text{radius}^2) *$ working pressure. For a 20,000 psi 1-inch hose, the breaking strength needed would be BS = $3.14 * (0.5^2) *$ 20,000 psi which equals 15,700 lbs. A design factor must also be used. We usually use 1.5 times the calculated breaking strength; therefore, the required breaking strength needed would be 23,500 lbs.

Support grips are much shorter and have a lower breaking strength than containment grips. They are used to support the weight of the hose assembly such as a hose hanging from scaffolding. They should not be expected to contain whipping of the hose assembly.

Bend restrictors are used to prevent the hose from bending behind the fitting. These are different from the stiffeners. Bend restrictors are semi-ridged and allow the hose to bend gradually. They typically do not offer burst protection. For proper selection of containment grips, support grips and bend restrictors be sure to asked for assistance from your hose assembly supplier.

Relief Holes

UHP hose fittings, high pressure adapters and even some quick connect couplers have relief holes. Relief holes are used principally as a leak indicator and to vent leaking fluid. If the leaking fluid is not vented, pressure may build up in the connection

Abrasion Shield and Pressure Containment Shield Comparison

Shield Type	Operator Protection	High Pressure Fluid Leak	Hose Abrasion
Abrasion Shield	x	x	✓
Pressure Containment Shield	✓	✓	✓
"TOUGHJacket"	x	x	✓

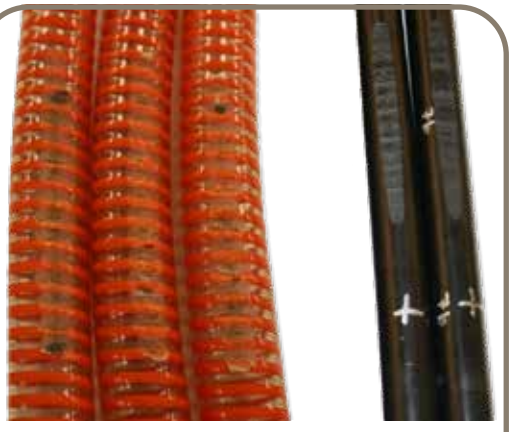

Photo comparing an PVC abrasion shield and TOUGHJacket™ hose. The TOUGHJacket hose went 740,100 cycles before wearing through to the wire reinforcement. The tests were performed to ISO6945 with 50N load.

Practices That Improve Service Life (cont.)

and may cause the parts to uncouple under pressure. Relief holes are found on Type M swivel nuts, female high-pressure ports, all large bore UHP hose fittings and 40,000 through 55,000 psi hose fittings. In the case of a swivel nut, or a gland nut & collar assembly, simply tightening the fitting may stop the leak. If the male or female cone is too far damaged or worn, then no amount of tightening will stop the leak. At ultra-high pressures, even a microscopic leak will quickly wear and become enlarged to the extent that the relief hole may not be able to fully dissipate the fluid and pressure. It is strongly recommended that if a leak is observed at a relief hole, replace the part at once.

Evaluation of Hose For Service

Make it a standard practice to inspect the UHP hose before placing them into an application. If the assembly is equipped with a pressure containment shield, make sure it has not pulled off the fitting or pulled out of the stiffener exposing the hose. Look for indications of leaks at relief holes. If the hose has an abrasion shield, inspect for areas that are worn through exposing the hose. These areas can be repaired inexpensively.
Look for exposed wires on every UHP hose assembly. This is a serious condition and demands immediate removal from service. Check if the cover is wrinkled behind the fitting, which indicates a kink. Also look for kinks and crushed areas along the length of the assembly.

Photo comparing a support grip (right) and a containment grip (left).

Inspect the fitting for damage. It may be oval from improper assembly or the waterjet has begun to wear away the fitting. Check for stiff sections along the length of the hose. This indicates the area is corroded and the hose must be discarded at once.

Implement a hose management program. A hose management program may look like this:

- **Record the serial number**
- **Record the length**
- **Record the equipment is was used on**
- **Record the operating pressure**
- **Record if the hose is directly connected to the pump or tool. Supply hoses would not be identified**

With this information you can determine if issues are at the pump or the tool or supply string.

The hose management program will help determine the expected service life of the assembly for each specific application. Factory built assemblies are now marked with unique serial numbers allowing the user to keep accurate information for each hose which will aid in identifying areas where improvements in hose routing and support are needed.

Photo of a hose that has been kinked behind the fitting. The cover is wrinkled and pulled away from the fitting. The wire is exposed and corroded.

Conclusion

Since the initial development of high-pressure hose, many technical advancements have been made. The core tube materials are tougher improving fatigue resistance. New manufacturing methods have improved quality by reducing material contamination, improving process control, and allowing the production of longer lengths. Advancements by wire manufacturers have improved the wire dramatically. The wire has improved fatigue life and allows even higher strength wire to be used. This extends service life, allows for higher working pressures and smaller hose diameters. Hose fittings are engineered to avoid leakage and offer increased service life. Outer covers are tougher and offer greater abrasion resistance and may be extra thick which eliminates the need for abrasion shields. These special covers are becoming standard on many of the large bore hoses and have multi-layer covers of different colors. If the outer cover is worn down to the sub-layer, then the color change is evident and added protection or hose replacement can be addressed at this point. Further study in chemical attack is planned, as are lighter safety shields. Manufacturers are investing in R&D to improve:

- **Process control**
- **Reduce weight**
- **Hoses with smaller outer diameters**
- **Increased flexibility**
- **Higher working pressures**
- **Longer lengths**
- **Longer and consistent service life**

Finally, safety is of utmost concern and manufacturers are actively improving and developing new accessories and equipment to protect the operator and offer a safe product that can be used with great confidence.

Review and understand the additional precautions outlined in the WJTA's "Industry Best Practices for the Use of High Pressure Waterjetting Equipment" available from the WJTA. DIN EN 1829-2 provides more information on high pressure jet machines, safety requirements for hose, hose lines and connections.

Do you have a specific application problem or need more information on Parker UHP hoses?

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