Maximizing equipment efficiency through proper hose/ tubing routing and advanced health monitoring techniques

By Mike P. Beining,
Product Manager, Eaton

The failure of high-pressure hydraulic hoses or tubing is responsible for high costs resulting from lost productivity, negative environmental effects, collateral damage and most importantly, safety. By using correct routing techniques and advanced technologies like Eaton's LifeSense® Hydraulic Hose Conditioning Monitoring System, the frequency and impact of hydraulic hose or tubing failures can be significantly reduced.

In hydraulically controlled and actuated machines, some components cannot be altered as their locations are controlled by the structure of the machine. However, other components can and should be placed where they are easy to connect, readily accessible and convenient to service.

System designers should endeavor to eliminate as many fluid conductors as possible by using manifolds to interconnect components. In most cases, external piping must be used. Minimizing potential leakage points and making maintenance as simple as possible should be the goals of any astute designer. When designing the basic machine, engineers should remember to:

- Provide adequate space to route hose and tubing
- Coordinate hydraulic system planning and design with other systems on the machine; i.e. electrical, fuel, lube ,torque converter, etc.

Coordinate hydraulic system planning and design with other systems on the machine; i.e. electrical, fuel, lube, torque converter, etc.

Parallel routing

Whenever possible, hydraulic lines should run parallel within the machine envelope and follow its contours. Smooth, parallel routing can be accomplished with a well-planned layout and proper clamping. To help keep lines parallel, study port positions on components and, carefully pre-plan the location of valves, filters, heat exchangers and reservoir.

Parallel routing can often save money by:

- Reducing line lengths and the number of adapters used
- Minimizing the number of sharp bends
- Making the machine more serviceable
- Protecting lines from external damage

Components should also be spaced far enough apart to provide room for proper installation of the adapters and fittings on connecting hoses and/or tubing.

Hose and tubing

System designers must first determine whether using hose, tubing or a combination of the two is best for a particular application. Hose and tubing should be viewed not as separate entities, but as companion items, each offering specific and unique benefits. For example, tubing can:

- Be bent to smaller radii than hose and installed in tighter spaces
- Be routed through areas of higher ambient heat
- Handle hotter fluids than hose
- Provide superior heat transfer characteristics

EATON
Powering Business Worldwide

On the other hand, tubing can be flattened or damaged when struck, whereas hose is resilient and more likely to return to its original shape after absorbing a blow. Tubing may also fatigue when connected to high frequency vibrating components, while hose will absorb the vibration.

Where lines are long, tubing may require a series of intricate, close-tolerance bends that may complicate installation and ultimately create service problems. The flexing properties of hose, on the other hand, allow it to follow desired contours and make hose installation easier. Hose can also absorb some high transient pressure shocks, providing more uniform flow patterns and smoother, quieter operation. Hose is not recommended when hydraulic rigidity is required due to its tendency to act as an accumulator.

Good designs foster good maintenance

To correctly route and properly install fluid conveying components during a machine prototyping, follow these 10 general rules. These guidelines are most useful during machine prototyping. Normal production procedures should be followed after all "bugs" have been removed.

1. **Start with large lines —** Install the larges ID lines first as they are the hardest to bend and maneuver, especially in tight spaces. Then, the toughest part of the job is done.

   Smaller lines provide more routing versatility and can be more easily worked in tight spaces, so route each line to conserve maximum space. This not only results in a neater-looking installation, but makes future modifications or additions of accessories easier, more convenient and more economical.

2. **Correct hose length —** The appearance and efficient operation of a system often depends on using proper length hoses. Excessive hose footage increases pressure drops and system cost. Hose assemblies are commonly manufactured to specified lengths as well as increments of lengths to minimize the size of the inventory, which must be carried. When computing hose length, remember that hose can elongate as much as two percent or contract as much as four percent.

3. **Hose flexing —** A hose assembly is designed to flex or bend, not twist. In fact, if a large-diameter, high-pressure hose is twisted seven degrees, its service life can be significantly reduced, in some cases by as much as 90 percent.

   High-pressure hose must be routed to flex in only one plane. If plumbing requires that hose be routed through a compound bend, the hose should be "broken" into two or more sections so each will flex through only one plane. A spring guard will keep hose from bending beyond the minimum bend radius at the fitting, but it will not prevent the hose from twisting.

4. **Pivot points —** When hose must flex, route it through the pivot point around which the component is moving. This will result in the best and most efficient flexing of the hose line, use the least amount of hose and keep the hose within the contour of the machine.

   To achieve this, the hose should be positioned to bend like a hinge. Otherwise, the hose may have a tendency to take an S-bend, which is most likely to happen when the hose is pushed rather than bent. An S-bend installation results in excessive hose movement and reduced service life.

   When piping a flexible line through a pivot point, consider the relative positioning of the two end fittings to avoid an S-bend by following this procedure: Swing the moving component to its farthest point where the hose will experience its widest bend.

   If the fittings are placed in parallel planes at this point, the hose will tend to flex in a hinge-like manner when the component is swung back to the opposite end of its travel.

5. **Reciprocating motion —** In addition to flexing, the ends of the hose may have to reciprocate. There are several design methods to do this:

   - **Hose reels** — For use with high-pressure hydraulic hose, these reels are equipped with high-pressure swivel joints and a spring return to help rewind the hose.
   - **Festooning** — Hose is hung in loops from a steel cable. As one point of the loop moves away from the other, the loops open to form an almost straight line.
   - **Rolling** — Hose is arranged in an unbalanced U-shape with hinged tracks carrying the hose. One leg is left stationary and longer than the second, which is free to reciprocate parallel to the first.

6. **Rotary motion —** Swivel or rotary joints are commonly used to provide rotating motion. Where rotary movement is a continuous 360 degrees, use a rotary joint. If movement is reversing, a swivel joint would be the better choice.

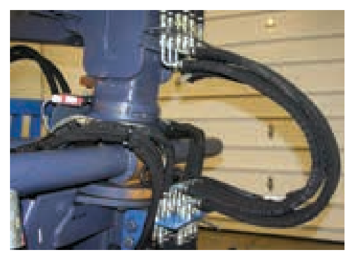
   When used with hose, a swivel joint will avoid hose twisting or bending at the fitting.

7. **Control oil spray —** Fire protection must be used where hydraulic lines are routed near hot, potentially hazardous areas. This prevents oil from a broken line from spraying onto any potential source of ignition. There are several ways to accomplish this:

   - Reroute the line through a tunnel made from steel tubing, channel, or angle iron
   - Install a sheet-metal baffle between the lines and potential ignition source
   - Route the lines through a large, open-ended hose or sleeve so the oil will flow out of the ends in case of line failure
   - Use fire sleeves either to fit over the hose or built into the hose cover
   - To guard against a failed hose that might whip and spray hydraulic oil over an ignition source, anchor the hose to the component to which it is hydraulically connected

8. **Minimum bend radii —** The hose must be routed to accommodate the minimum bend radii of that hose. Minimum bend radii for various size hoses can be found in SAE specifications and hose manufacturers' catalogs. These figures usually refer to the minimum bend radius at maximum operating pressure for a static line. Exceeding the minimum bend radius can result in kinking of the hose and/or most likely, extra stress at the hose or fitting interface. This causes the cover to become more easily cracked or the internal wire reinforcement to fatigue quicker, both of which will reduce service life.

9. **Avoid abrasion —** Most hydraulic hose is built with a tough outer cover to protect the hose reinforcement from abrasion or moisture damage. However, constant abrasion at one point will eventually puncture the outer cover and weaken the reinforcement. This is the number one cause of hydraulic hose failures in the field. To avoid abrasion as much as possible, properly route and clamp the hose or use a protective cover.



Choose from a variety of protective coverings:

- Coiled springs
- Coiled strap steel
- Spiraled plastic
- Nylon sleeves.

10. Clamping — A piping installation is not complete until it has been properly clamped. Clamp choice is very important, and often it can be critical to the installation. Common sheet metal clamps will not hold a large, high-pressure hose.

Good clamps can be inexpensive, yet highly effective for high-pressure surge lines. Anticipate and plan for a possible length change ranging from an increase of two percent to a decrease of four percent for high-pressure lines.

Properly sized clamps should grip the hose in a positive manner. To keep the clamp from abrading the hose, the ID of the clamp should be about 1/32 inches smaller than the OD of the hose.

Good installation techniques are essential to efficient operation and obtaining the maximum life of a hydraulic system. However, hydraulic hose and tubing are fatigue items with a finite service life. Eventually these wear items will fail. Typically, basic maintenance techniques are not enough to sufficiently prevent failures from occurring, whether it be visual inspection or time-based preventive schedules.

The Mean Time to Failure (MTTF) of a component can vary widely based on the duty cycle, installation of the product, environment and robustness of the product. If one chooses to replace a component every 3 years, there is no guarantee that the product will last 3 years. Alternately, that particular component may last six years – meaning that the component was replaced when it had 50 percent of its useful life left. Figure 5 is an example of a hydraulic hose and how the MTTF can vary. With this range of performance, it is difficult to determine the exact interval at which hydraulic hose should be replaced without (1) discarding a good hose or (2) without preventing a failure from occurring.

Eaton's LifeSense Hose is a true condition-based hose monitoring system that is designed to detect failure-related events both inside and outside of the hose, notifying the appropriate person to replace the hose before it actually fails.

This hose monitors both internal fatigue and external abrasion, which, as mentioned earlier, is the number one cause of hose failure in the field. Once impending failure is detected, the next step is the notification of that impending failure. There are two options available, a wired system and a wireless system.

The wired system consists of a sensor connected on the hose assembly with a wire routed from the sensor to a hose diagnostic unit. The hose diagnostic unit is then able to interpret the data and alert the operator if a hose needs to be replaced. The wireless system includes a sensor connected on the hose assembly that communicates wirelessly via a high frequency radio signal to a hose diagnostic unit. The hose diagnostic unit also doubles as a gateway where it can communicate this information to the cloud via Ethernet or Wi-Fi. With the information in the cloud, it can be sent via text message or e-mail. The wireless system also provides a customer portal that can serve as a user interface for remote monitoring. Now, the true condition of that hydraulic hose can be monitored anywhere anytime.

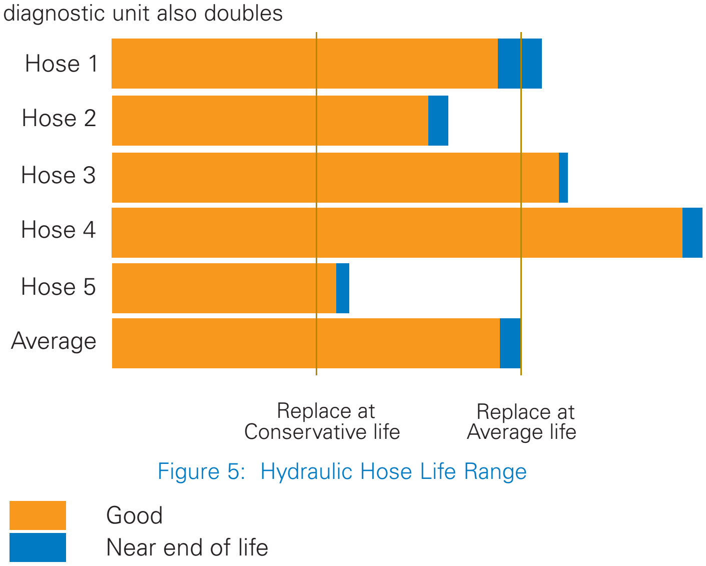


Figure 5: Hydraulic Hose Life Range

By combining good hose routing practices and advanced health monitoring technology like Eaton's LifeSense Hose, the frequency and impact of hydraulic hose failures can be significantly, if not completely eliminated. This results in maximum equipment efficiency and reduced safety concerns.

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

May 2016

Powering Business Worldwide