November 18, 2002

# HOSE ASSEMBLY CLEANLINESS

## Preface

Hydraulic system cleanliness is a term used to describe the level of solid and liquid contamination found in hydraulic systems. "Contamination" may be defined as any substance that is not part of the hydraulic system's working fluid. Several sources claim that over 70% of hydraulic system failures are due to contamination. Cleanliness is becoming increasingly important to the marketplace because:

- With the introduction of more electronics in the system, pumps and valves are more sensitive to contamination.
- Equipment users are becoming more aware of the potentially damaging affects contaminants can have on their hydraulic systems.
- OEM's and service centers are looking more closely at filter residue and other signs of contamination as possible causes of hydraulic system failures. System filter residue is often analyzed to identify the contaminants and their sources. Responsibility for failures can be costly.
- Ability to supply hydraulic hose assemblies to a specified cleanliness level can be a powerful sales tool to help you grow your business.
- Your customers expect clean hose assemblies.
- Your competition will do it if you don't.

Contamination of hydraulic system fluid can come from many sources, including new, unfiltered oil, particles in the tank, abrasion wear of system components in use, and chemical degradation of components. Hose assemblies can also introduce contaminants into a hydraulic system. This document discusses some of the major contributing factors to <u>hose assembly contamination</u> with suggestions of possible measures to reduce the level of contaminates. The level of cleanliness that can be achieved with any cleanliness program depends in large part on how well the chosen procedures are implemented.

## Controlling Hose Assembly Contamination

A major contributor to hose assembly contamination occurs during cutting of the hose to length, typically done with a circular saw. As the saw blade cuts through the hose, particles of hose tube, reinforcement, and cover are thrown into the open hose end. This cutting debris is typically limited to a few inches of hose length at the ends. Different cutting processes can affect the amount of debris that is deposited in the ends of the hose.

- **Dry cutting:** This method generates more dust and debris and puts debris into motion more than wet cutting.

- **Wet cutting:** Water or other liquid lubricant is used and not only lengthens the service life of the saw blade, but the liquid suppresses dust and debris movement thereby reducing the amount of cutting contamination introduced inside the hose.

- A **vacuum system** aimed at the cutting site can draw dust and debris away from the ends of the hose as well as keep the work area cleaner.

- **Blowing air** through hose while cutting can prevent much of the cutting debris from entering the bore end of the hose. A possible issue with this method is cutting debris can be blown out into the work environment.

A combination of blowing air through the hose during cutting to direct debris away from the cut hose ends and vacuum to remove debris away from the work area can minimize contamination that occurs during cutting.

The saw blade can also make a significant difference in the amount of cutting debris that is generated.

- A sharp blade will cut more quickly and smoothly and generate less debris. Saw blades should be kept sharp and clean.

- Smooth blades generate less cutting debris than scalloped, serrated, or abrasive blades. However, smooth blades are not as effective at cutting spiral wire reinforced hose. Smooth blades become dull quicker.

- For wire-braided hose, serrated or scalloped blades cut hose better and faster. They also remain sharp longer since the blade can be reversed, positioning the other side of the notch for cutting. These blades are not recommended for cutting spiral wire reinforced hoses as they become dull rather quickly.

- Abrasive blades are recommended for cutting spiral wire reinforced hoses. The drawback is that not only do they produce more dust and hose particle debris, but also fine particles of the abrasive blade itself are added to the mass of potential contaminants flying about.

## Removing Hose Assembly Contamination

Even after concerted efforts to control hose assembly contamination during fabrication, there will still be a certain level of contaminants present inside the hose. These contaminants should be removed prior to attaching the couplings to the ends of the hose as they can become trapped between the hose coupling and the hose inner tube where they are not easily removed. Later, when exposed to pressure, vibration, flexing and the dynamics of hydraulic hose applications, they can be released into the hydraulic fluid inside the hose. As a result, it is recommended a post fabrication cleansing process be used. Commonly used hose assembly cleaning methods include:

- **Blowing shop air** through the hose bore after cutting it to length. The air should be clean, dry, and filtered. Typically the pressure from the air supply ranges from 90 psi to 120 psi. Be aware that debris from the cut end of a long piece of hose can be moved to somewhere in the middle without completely removing it. The longer the hose, the more likely this is to happen.

- **A fluid flush with liquid** can be effective as a means of cleaning the hose bore. Usually this is not done until after the couplings are attached which can leave contaminants trapped between the coupling and the hose tube. It is important that the cleaning liquid must be chemically compatible with the hose tube. It must also evaporate quickly so the cleaning fluid itself does not become a contaminant. Naptha is one such solvent cleaner. It can also dissolve other residues such as manufacturing lubricants that may adhere to the hose tube wall. Following the flushing process with a clean, dry, filtered air flush can promote solvent drying and further clean the hose bore. This method involves safe, responsible disposal of used cleaning fluid.

- **Blowing a cleaning projectile** such as a sponge pellet through the cut hose with clean, dry, filtered shop air can not only remove cutting debris, but also any mandrel lubricants or other manufacturing residues. Soaking the projectile in a cleaning solvent can enhance the cleaning process. This is a very fast method of cleaning. Cleaning projectiles are most effective when used before the hose couplings are attached. As the projectile passes over the bump end of the coupling inserted into the hose bore end it could result in wiping off the collected debris and leaving it deposited there. Blowing a cleaning projectile through a finished assembly can possibly introduce new contamination into the system as pieces of the projectile can be peeled off and trapped as the projectile goes past the coupling

- Using a brush and suction at the hose end can loosen and remove debris from the inside surface at the coupling end of a hose assembly where most contaminants are found.

None of these methods guarantee results under all conditions, which can vary considerably. The various cleaning methods offer the potential of providing an acceptable level of cleanliness. Success depends highly upon awareness of contamination sources, how much attention is given to detail, and how carefully the cleaning procedure is carried out.

## Avoiding Contamination Outside of the Fabrication Process

Being aware of contamination sources in your particular fabrication environment and taking steps to avoid contamination in the first place will also assist in providing clean hose assemblies to your customers.

- Hoses and couplings should be stored in a clean, dry environment. Hoses should have the ends capped or remain in shipping cartoons or sealed plastic wrap. Couplings should be kept in sealed bags, boxes, or closed bin drawers until they are to be used.

- Completed, cleaned hose assemblies should have the ends capped or be placed in sealed bags or shipping boxes until they are attached to equipment and put into use.

## Assurance of Cleanliness

Despite efforts to totally remove all of the contaminant in a hydraulic hose assembly, some contamination remains even after the most robust cleaning or flushing techniques are applied. Contamination can be quantified to better understand the resulting cleanliness level of the hose assembly. The customer may require a specified cleanliness level.

The International Standards Organization (ISO) has established three principal methods to measure the contamination level within a component, circuit, or system. These three methods are widely used for cleanliness quantification. These methods are gravimetric measurement, particle size counting (distribution analysis), and maximum particle size analysis. All of these methods involve sloshing a liquid solvent back and forth through a completed hose assembly and then pouring it through a filter to isolate the contaminants. Contamination particles are usually sized using a metric unit of measure called a micrometer, otherwise known as a micron.

<u>It is important to understand that there is absolutely no correlation between cleanliness levels of gravimetric vs. size/distribution methods</u>. A clean hose by weight (gravimetric) may have many small, lightweight particles that result in a worse level of cleanliness using the particle distribution analysis methodology.

Periodic sample testing to verify continuing compliance to a given level of cleanliness being produced by your system can be done at an independent lab. Be sure that the lab test method used satisfies your customers' needs. (i.e. What standard or level of cleanliness must be met?).

## Cleanliness Measurement Standards

The following ISO specifications are the main industry specifications involving hose assembly cleanliness. Copies of these standards can be obtained from the national source for standards, Global Engineering in Denver, Colorado. Phone number is (800) 854-7179 or find them on the internet at www.globalihs.com.

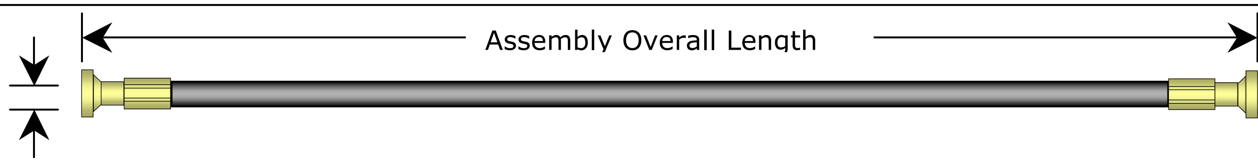
**ISO 4021**

Defines the testing procedure for fluid extraction of contaminants from hose assemblies for sample test measurement.

**ISO 4405 (Gravimetric Measurement)**

Gravimetric measurement is a reporting method that references the total mass of contaminant found in a hydraulic component. This total mass measurement is then normalized by the total internal component surface area of a hydraulic component. A fluid is used to dislodge contamination in a hose assembly and is then poured through a membrane catch filter. An analytical balance is used to measure the total mass of contaminate which has been flushed out of a component and is referenced to the surface area or volume of the assembly or component. The filtered particles are dried and weighed, and results are typically stated in milligrams of contaminant per square meter of internal surface area.

An example determining the contaminant level in the following example when 52 mg of contaminant is found on the filter is:




Hose Diameter = -12 (3/4”)
Assembly length = 246”
Surface Area (in) = Internal Circumference x Length
⇒Internal Circumference = 3.1416 x Inside Diameter
3.1416 x 0.75”
2.36 in.
2.36 in. x 246 in.
580.6 in.$^2$
Surface Area (m) = 580.6 in.$^2$ x (0.0006452) *(0.0006452 converts in.$^2$ to m$^2$)*
0.375 m$^2$

Contaminant Level = 52 mg / 0.375 m$^2$

<u>138 milligram per square meter (mg/m$^2$)</u>

## ISO 4406 (Particle Size Distribution)

Particle size distribution is a reporting method to gauge both the size and number of contaminant particles in a known quantity of fluid. A fluid sample is either taken directly out of a hydraulic system or a known quantity of fluid is used to dislodge contaminants out of a hydraulic component (in this case a hose assembly). This fluid is run through a particle counting instrument to size and count contaminant particles. These particle 'counts' can then be normalized by the total component volume to determine a corresponding ISO 4406 'Code' level of particle contamination.

The cleanliness code for fluid is reported as a series of numbers representing the number of particles greater than 2, 5, and 15 microns.

For example, a 1-milliliter sample of fluid containing:

1,254 particles >= 2 microns
132 particles >= 5 microns
29 particles >= 15 microns

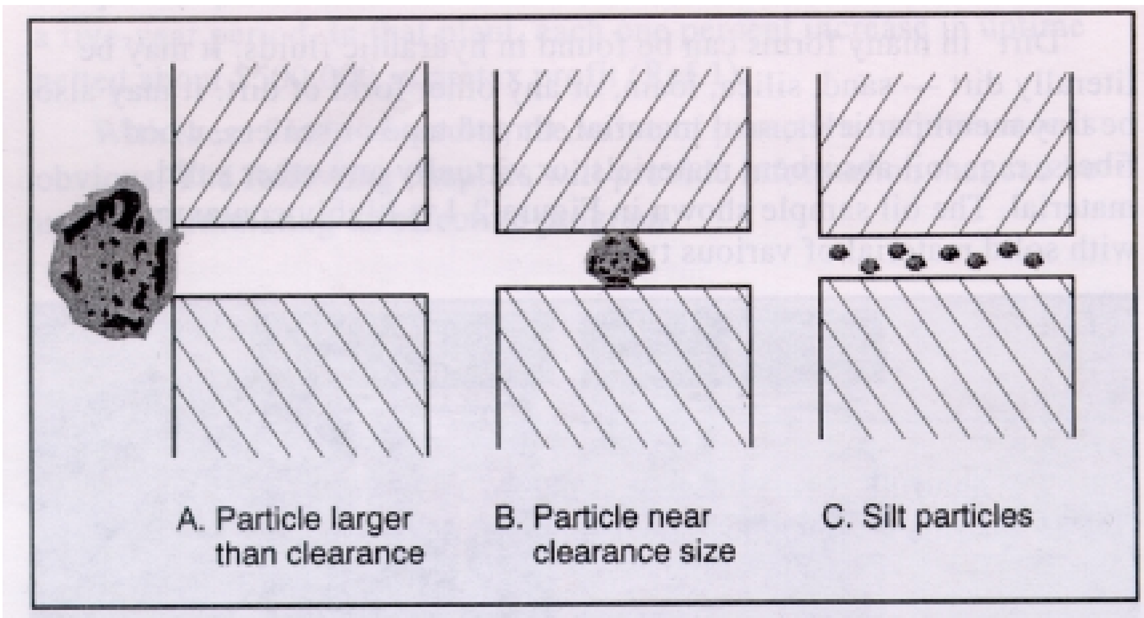
would have an ISO 4406 cleanliness level of 17/14/12. When only two numbers are reported, i.e. 17/14, only the 5 micron and 15 micron particles are counted.

**ISO 4406 Chart**

| Range Number | Particle Concentration (Number of particles per milliliter) | |
|---|---|---|
| | More than | Up to and including |
| 30 | 5,000,000 | 10,000,000 |
| 29 | 2,500,000 | 5,000,000 |
| 28 | 1,300,000 | 2,500,000 |
| 27 | 640,000 | 1,300,000 |
| 26 | 320,000 | 640,000 |
| 25 | 160,000 | 320,000 |
| 24 | 80,000 | 160,000 |
| 23 | 40,000 | 80,000 |
| 22 | 20,000 | 40,000 |
| 21 | 10,000 | 20,000 |
| 20 | 5,000 | 10,000 |
| 19 | 2,500 | 5,000 |
| 18 | 1,300 | 2,500 |
| 17 | 640 | 1,300 |
| 16 | 320 | 640 |
| 15 | 160 | 320 |
| 14 | 80 | 160 |
| 13 | 40 | 80 |
| 12 | 20 | 40 |
| 11 | 10 | 20 |
| 10 | 5.0 | 10 |
| 9 | 2.5 | 5.0 |
| 8 | 1.3 | 2.5 |
| 7 | .64 | 1.3 |
| 6 | .32 | .64 |
| 5 | .16 | .32 |
| 4 | .08 | .16 |
| 3 | .04 | .08 |
| 2 | .02 | .04 |
| 1 | .01 | .02 |

**ISO 4407 (Maximum Particle Size Analysis)**

Maximum particle size is an analysis on the maximum particle size that is found in the sample fluid is conducted with a microscope. A microscope is used to size individual pieces of contaminant. Customers may specify that the cleanliness level have a maximum particle size, for example 500 microns. Particle size is important in reference to maximum clearances of hydraulic components.




Whether hydraulic assembly cleanliness applies to you or not, it is worthwhile to understand the significant impact that low contamination levels can have on the life of hydraulic system components.

By establishing a contamination control program, costly repairs and downtime may be minimized. A contamination control program can be as simple as establishing an allowable level of contamination within a hydraulic system, supplying cleaned components for the system, and monitoring levels of contamination as part of a preventive maintenance promotion.

For assistance with cleanliness issues or programs, please feel free to contact Gates Hose & Connector Product Application Engineering department at 303-744-5070.