APPLICATION AND INSTALLATION GUIDE

FLUSHING AND CLEANING OF SYSTEM PIPING

CAT®

Contents

Foreword

This section of the Application and Installation (A&I) Guide defines the cleanliness level of Caterpillar engine systems and describes possible methods to clean and flush engine systems. Additional information about engine systems, components and dynamics are addressed in other sections of this Application and Installation Guide.

This section of the A&I guide is intended to provide the reader with cleanliness specifications for different components, assemblies, and systems present in Cat® engines. Adherence to the specifications outlined in this guide is crucial to ensure that engines achieve their design performance, reliability, and durability. The engine installer is responsible for the design, fabrication, installation, and commissioning of all external equipment that interfaces with the engine. Likewise, the installer is responsible to ensure that all engine systems operate at the cleanliness level required by the specifications in this guide. This can be achieved by cleaning procedures when cleanliness levels are not compliant with Caterpillar specifications.

Additionally, this guide provides possible methods by which an end-user can clean and flush engine systems and ancillary equipment to the cleanliness specification described in this guide. There are multiple methods that the industry utilizes to flush and clean internal equipment systems. Caterpillar does not recommend, endorse or approve specific methods to clean engine systems and ancillary equipment. The choice of method used for cleaning engine systems is at the discretion of the installer.

Cat dealers stand ready to assist installers with all aspects of engine application, installation, and commissioning. Your local Cat dealer can be found at http://www.cat.com/dealer-locator

Engine-specific information and data are available from a variety of sources. Refer to the Introduction section of this guide for additional references.

Systems and components described in this guide may not be available or applicable for every engine.

Cleanliness Specifications

The following specifications define the cleanliness level applicable to finished engine components and assemblies for the different systems on Cat engines. These specifications are applicable to individual components and to assemblies that become in contact with engine fluids during normal operation. A component may be exposed to one or more of the following fluids:

- Fuel (filtered and unfiltered)
- Engine lube oil (filtered and unfiltered)
- Inlet air
- Exhaust gas
- Coolant

Different cleanliness levels are required depending on individual requirements for components or assemblies. Therefore, cleanliness level requirements are divided into 6 groups. The components and assemblies that are governed by each cleanliness level are defined below:

1. Cleanliness group A
    a. Engine components or assembly surfaces in contact with filtered fuel
    b. All common rail components between the primary and secondary fuel filters and all common rail return components such as low pressure return lines
    c. The primary filter base, HEP pump, fuel pump, and transfer pump
    d. CRS, or other emissions system regeneration devices, components, or assemblies between the primary filter and final filtration or screening point, prior to the fuel nozzle.
2. Cleanliness group B
    a. Component or assembly surfaces (except those covered by cleanliness group E) in contact with filtered engine lube oil
    b. Component or assembly surfaces in contact with inlet air
3. Cleanliness group C
    a. Component or assembly surfaces in contact with unfiltered fuel
    b. Component or assembly surfaces in contact with unfiltered engine lube oil
    c. Component or assembly surfaces in contact with exhaust gases to the turbocharger

4. Cleanliness group D
    a. All fuel system component or assembly surfaces not covered by cleanliness group A
    b. All new electro-hydraulic control valve systems
5. Cleanliness group D_a
    a. Note: all new electro-hydraulic control valve systems shall be covered by cleanliness group D
    b. Intake valve actuator (IVA) component surfaces
    c. Variable valve actuator (VVA) component surfaces
6. Cleanliness group E
    a. Component or assembly surfaces in contact with filtered engine lube oil that lubricates crankshaft bearings or feeds supply oil to electro-hydraulic control valve systems

Note: Cooling system cleanliness specifications are specific for each engine platform and application. Contact your local Cat dealer to obtain cleanliness specifications for cooling system and any components or assemblies not present in the cleanliness groups above.

Refer to **Table 1** for cleanliness specifications for each group.

Cleanlines Group	* Largest Particle Allowed			Maximum Number of Particles Allowed Per Given Particle Length		Maximum Mass Allowed		** Abrasives (Oxides) > 40 µm
	X(µm)	Y(µm)	Z(µm)	#	X(µm)	mg/m2	mg	
A	1200	500	150	4	50 - 1200	170	10	*** Allowed
B	1200	1200	200	4	500 - 1200	230	16	Allowed
C	2000	2000	200	4	1000 - 2000	535	-	Allowed
D	750	75	75	2	500 - 750	8	1	Not Allowed
D_a	1200	250	100	2	500 - 1200	24	2	Not Allowed
E	1200	500	100	2	500 - 1200	170	10	Not Allowed

* Refer to Figure 1.
** Not applicable to 3500 and 3600 engines.
*** For fuel system components only.

Table 1

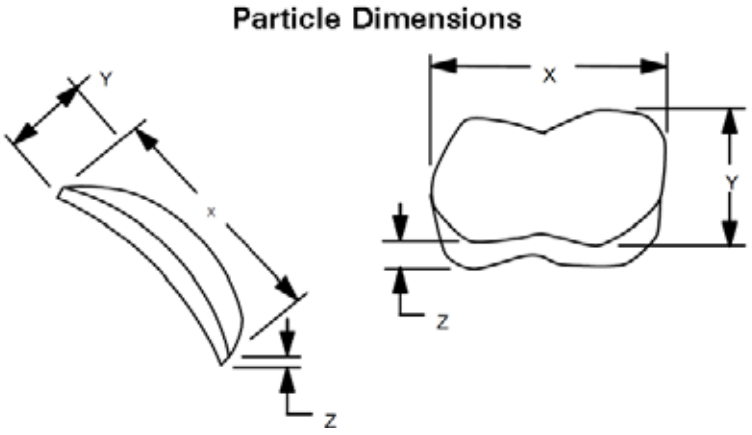

Figure 1

Flushing and Cleaning of System Piping

This guide provides procedure details the flushing process, pickling process, and cleanliness requirements as related to system piping external to the engine and ancillary equipment. At the time of publishing, this data is correct; updates will be included periodically and this section republished. Dealers may use the Technical Marketing Information system for the most current data.

This procedure is to be used as a guideline and should not be considered a substitute for good engineering practices.

General

The quality of the flushing medium is essential in ensuring the performance and longevity of the Cat engine and ancillary equipment. Prerequisites for proper equipment performance are:

- A well-designed system
- The use of a quality flushing medium

These prerequisites are meaningless unless the system piping is initially cleaned sufficiently to prevent equipment damage on initial startup or when debris may dislodges due to vibration or other piping disturbance.

Cleaning and flushing new and existing piping is accomplished by essentially the same procedure. New system piping emphasizes the removal of contaminants introduced during the manufacture, storage, field fabrication, and installation of the system piping. The flushing of existing piping emphasizes the removal of contaminants that are generated during normal operation, failures that may have occurred causing contamination, or debris introduced during overhaul.

All cleaning and flushing procedures must be done through the cooperative efforts and agreement of the equipment manufacturer, installer, operator, and flushing medium supplier. No portion of these procedures should be done without a thorough understanding of the possible effects of improper system preparation. The installation, cleaning, and flushing of the system piping must not be undertaken by persons lacking in experience.

Flushing Program for System Piping

Note: Do not flush through valves, instrumentation, or other critical components. Instead, use temporary bypasses as required.

Note: All flushing medium must be disposed in a responsible manner and according to environmental regulations.

For a system that is field assembled, keeping the piping sufficiently clean so that flushing is not necessary is economically and practically impossible. Thus, flushing is a necessary process for any system that has been completely installed, but prior to system start-up. The success of flushing depends on the following:

- The success of the effort to keep particles out initially
- The proper attention to flushing
- The design of the system

A successful flushing procedure means that piping and system components are clean and without damage from piping debris.

The leading factor in obtaining clean piping is to keep particulates out initially. This is achieved through the cooperation and diligence of many parties. A few examples of these efforts are the following:

- A system design which allows for successful cleaning
- Properly cleaned and preserved piping and equipment prior to installation
- The prevention of any contaminants from entering during any modifications

This list is not comprehensive but emphasized that the manufacturer, shipper, installer, and operator play a role in assuring that no contaminants enter the piping or equipment. These efforts to prevent the entrance of contaminants make the flushing procedure easier, safer, shorter, and less costly.

The success of flushing depends on the ability of the pump to provide a substantial flow rate, this giving a turbulent flow within the system piping. A turbulent flow is required for flushing and can be maintained with a Reynolds number greater than 20,000. When necessary, an outside pump is recommended to achieve this flow. Temperature level, temperature cycling, and vibration contribute to the success of a flush. However, high velocity (two to three times the normal system velocity) is the most important component to a successful flush.

Solids loosening will be promoted by hammering or inducing vibration at pertinent points in the system piping. These points include all welded joints, flanges, bends, low points, beneath welds, or any place where work was

done on the system. After the solids are broken loose, the solids will either settle in the main tank, become trapped by the temporary screens, or be filtered out by the user's bypass or full-flow filtration system.

It is not normally necessary to flush through certain systems and devices that have been assembled, cleaned, and sealed before shipment to site. Such equipment must be carefully protected against contaminants. In this flushing procedure, blank off or bypass such equipment until the attached systems are clean.

For assemblies that will undergo the flushing process, this flushing procedure does not have the ability to flush out all conceivable contaminants. Therefore, during system installation, carefully prevent the intrusion of unnecessary impurities that cannot be easily removed by flushing. These contaminants will cause problems in subsequent operations when dislodged by vibration or operational effects.

Although flushing will be performed prior to startup, this must not lead to the perception that contaminants entering the system piping are not harmful because they will be removed by the flush.

Preparation of System Piping for Flushing

Prior to the flushing operation, thoroughly inspect all accessible areas of the system piping. If any evidence of contamination is encountered, the contamination should be removed manually.

The Cat engine and ancillary equipment must be blanked off or bypassed as closely as possible to the connection point with the piping being flushed. Jumpers must be installed to bypass the Cat engine, ancillary equipment, actuators, and instrumentation; however, they must be installed such that the minimum portion of piping and flow passages are bypassed. Any other area in the system piping that will not be flushed must be blanked off with numbered blanking plates. At the end of the flushing period, remove the numbered blanking plates and account for them via a check-off list.

In all system piping, install temporary strainers of 80 to 100 mesh on the suction side of the flushing pump. Also, install temporary fine mesh strainers (no finer than 100 mesh) on the discharge side of gravity and pressure systems (just upstream of the flushing tank). Use auxiliary filters (non-reactive type) to increase the rate of filtration, and to decrease the maximum particle size of contaminants in the flushing medium.

When a flushing medium heater has not been installed, or when the heater is inadequate, supply heat to the flushing medium with the aid of electrical heaters in the tanks. Hot water run through coolers is recommended; however, when low-pressure steam is used, check it against the manufacturer's recommendation.

Heat the flushing medium to 60 to 82°C (140 to 180°F) either by means of low-pressure steam 34.5kPa (5 psig) maximum on the water side of the flushing medium cooler (when it is designed for such service), or by electrical resistance heaters in the main tank. Make sure to circulate the fluid during this period.

The flushing medium selected for flushing the system piping can be either the system operating fluid or flushing oil. If flushing oil is used, special attention must be given in ensuring that the flushing oil is compatible with the entire system (valves, seals, etc.). The selection of the type of flushing medium to be used is based on the judgment of experienced personnel after thorough inspection of the system piping.

If the system operating fluid is used for flushing the system piping, it must not to be used for operation. In this case, it is necessary to fill the system with new fluid since incompatible flushing medium-soluble contaminants picked up during the flush may cause foaming, emulsification, reduced oxidation resistance, and premature components failure.

Prior to filling the system with the flushing medium, establish proper piping configuration to bypass the engine and components described above. Fill the

reservoir with flushing medium to the minimum operating level so the inlets of the system pump(s) are always below the reservoir level and operate properly. Start the pump(s) and circulate the flushing medium. Because the system pump cannot generally give adequate fluid velocity for effective flushing, use external pumps at two to three times the system pump flow rate (do not exceed system design pressures). Heat the flushing medium to 60 to 82°C (140 to 180°F) by the use of the cooler as outlined above. Continue circulation as long as necessary to flush the system piping.

Flushing time of at least 24 hours is necessary to ensure proper system piping cleanliness. The size of the system piping and complexity will dictate the extent of flush time. Throughout the flushing period, maintain the flushing medium in the system at to 60 to 82°C (140 to 180°F). This temperature is necessary to maintain low viscosity of the flushing medium, to dissolve soluble materials, and to aid in the loosening of adherent particles.

The system pump discharge pressure may need to be reduced for flushing purposes by lowering the relief valve of compensator settings to prevent possible damage.

Almost all of the foreign matter is collected in the temporary strainers during the first few hours of flushing. During this time, whenever a noticeable increase in pressure drop occurs across the strainers, the strainers should be cleaned. The frequency of this occurring may be as often as 15 minute intervals. The flushing medium contamination control devices must be inspected and cleaned frequently. Auxiliary filters must be operated within the pressure drop limits as specified by the manufacturer.

Flushing System

During the early phases of the flushing period, vibrate or hammer the piping, particularly at joints and flanges to dislodge any scale or weld spatter that has adhered to the surface. When inspection of the strainers and accessible parts of the system shows that there is no evidence of contaminants such as lint, welding beads, or other debris, then the system is considered clean.

After inspection of the strainers and temporary filters shows that there is no evidence of contaminants, flush other parts of the system by removing blanks and jumpers. Continue flushing the system until it is considered that the entire system is thoroughly cleaned. At this point, take a sample for verification of cleanliness.

Replace all inspection plates on openings except the ones in use. When no evidence of contaminants appears in the strainers and auxiliary filters, stop circulating the flushing medium and inspect representative components for cleanliness. The condition of these representative components is used as a guide as to determine whether further flushing is needed.

When flushing is completed, remove the flushing medium from the system. Open fluid lines at the lowest points in the system and allow the fluid to drain. After the system is completely drained and surfaces cleaned, the system piping is again thoroughly inspected for evidence of contamination. After cleanliness is verified, the system is rechecked to determine if it is safe for operation.

If the system will be idle for a long period of time, care must be taken to prevent corrosion. In cases such as this, the use of oil with a vapor space inhibitor can protect the system from corrosion by condensation. During this period of time, the system should be inspected frequently for signs of corrosion.

Pickling Information and Guidelines

General

Pickling is the process of removing mill scale by chemical reaction, electrolysis, or both. When completed, surfaces shall be free of all visible mill scale and rust when viewed without magnification. Pickling is not a cleaning process.

Prior to Pickling

Prior to pickling, remove heavy deposits of oil, grease, soil, drawing compounds, and foreign matter other than rust, scale or oxides. Small quantities of foreign matter specified may be removed in the pickling tanks provided no detrimental residue remains on the surface.

Pickling

WARNING: Add acid to water at normal room temperature. Do not add water to the acid. Add neutralizing agents to water. Do not add water to the neutralizing agents. There are many safety precautions when handling acid. Therefore, this should only be done by qualified personnel.

Note: All pickling solution must be disposed in a responsible manner and according to environmental regulations.

Pickling in 5 to 10% (by volume) hydrochloric acid (HCl) at 40 to 50°C (104 to 122 °F), with 0.03% (by volume) hydroxyl amine hydrochloride (NH_4ClO) inhibitor to minimize attack on the base metal. Circulate the pickling solution until all mill scale is removed

Example:

929.7 liters clean water

70 liters hydrochloric acid

0.3 liters hydroxyl amine hydrochloride

100 liters total pickling solution

Pickling is then followed by a neutralizing rinse with a solution comprising of 10% sodium hydroxide (NaOH) and 50 grams/liter of trisodium phosphate (Na_3PO_4).

Example:

900 liters clean water

100 liters sodium hydroxide

50 kg trisodium phosphate

1000 liters total neutralizing solution

Add neutralizing solution as required maintaining a Ph ≥ 6.5. If checking the Ph is not possible, fill, circulate through piping, and drain the tank three different times, passing the total system volume through the piping, and drain the tank three different times, passing the total system volume through the piping five times or for 30 minutes (whichever is greatest) before changing.

Do not exceed a dissolved iron content of 10% in hydrochloric acid or 6% in the sulfuric acid pickling solutions. Only use clean water or steam condensate for solutions and rinses. Rinse tanks should be continuously supplied with new water as needed.

Flushing and Pickling System Piping

General

Note: Hydrostatic test the system piping prior to flushing and pickling.

1. All pipes that contain mill scale require pickling
2. Isolate the Cat engine and ancillary equipment from the system. Install jumpers around isolated equipment
3. Install the flushing pump and tank. As a rule of thumb, the tank should have a volume of 1.5 times the system capacity. The pump should have a capacity of approximately 2 times the maximum flow (do not exceed system design pressures) of the system (under no circumstances should the pump capacity be less than the maximum system flow rate). The heater must be able to heat the flushing medium to a minimum temperature of 60°C (do not exceed 82°C). An 80 to 100 mesh strainer must be installed prior to the flushing pump to protect the pump from foreign matter. Install a 100 mesh type strainer after the pump, just upstream of the flushing medium tank.

Initial Water Flush

1. The purpose of this flush is to remove large debris from the field fabricated piping prior to pickling the pipe.
2. Fill the system with clean water. If there is an excessive amount of grease in the pipes, an alkaline solution should be added to the water.
3. Flush the system (heating the water is not necessary), stopping as necessary to clean the strainer prior to and after the pump. During the flushing process, the piping should be vibrated and hammered at pertinent locations to break lose any material.
4. Monitor and clean the strainers as required, keeping the differential pressure across the strainers within the manufacturer's recommendations
5. The initial water flush is complete when the 100 mesh inspection strainer is clean after 30 minutes of flushing

6. Stop the pump and isolate the flushing tank
7. Drain the flushing tank
8. Clean the flushing tank
9. Open the vents and drains in the piping
10. Drain the piping
11. Close the vents and drains beginning at the air source
12. Disconnect the compressed air.

Pickling

Note: The piping must be flushed with water before pickling. The Cat engine and ancillary equipment MUST be isolated from the pickling process. Only field fabricated piping should be pickled.

WARNING: Add acid to water at normal room temperature. Do not add water to the acid.

Note: The pickling solution must be disposed in a responsible manner and according to environmental regulations.

1. Fill the tank with hydrochloric acid pickling solution, or functional equivalent
2. Open the isolation valves
3. Start the pump and begin heating the pickling medium. After the pickling solution reaches the minimum temperature of 40°C (50°C max), begin timing the pickling process.
4. Monitor the dissolved iron content. Do not exceed a dissolved iron content of 10% in hydrochloric acid or 6% in sulfuric acid pickling solutions.
5. Pickle the piping for 5 hours, checking the piping every hour for excessive iron removal.
6. Stop the pump and isolate the flushing tank
7. Drain the flushing tank
8. Clean the flushing tank
9. Open the vents and drains in the piping
10. Drain the piping
11. Close vents and drains

Neutralizing

WARNING: Add neutralizing agents to water. Do not add water to the neutralizing agents.

Note: The neutralizing solution must be disposed in a responsible manner and according to environmental regulations.

1. Fill the flushing tank with sodium hydroxide/trisodium phosphate neutralizing solution, or functional equivalent
2. Open the flushing tank isolation valves
3. Start the pump and monitor the neutralizing solution (heating the solution is not necessary), keeping the Ph $\geq$ 6.5 by adding neutralizing solution as required. If checking the Ph is not possible, fill, circulate through piping, and drain the tank three different times, passing the tank volume through the system piping five times or for 30 minutes (whichever is greatest) before each change.
4. Circulate the neutralizing solution until the Ph$\geq$6.5 for a 30 minute period without adding neutralizing solution.
5. Stop the pump and isolate the flushing tank
6. Drain the flushing tank
7. Clean the flushing tank
8. Open the vents and drains in the piping
9. Drain the piping
10. Blow the piping with compressed air
11. Close the vents and drains beginning at the air source
12. Disconnect compressed air
13. Visually inspect the pipe at several different locations to ensure mill scale has been removed. If the mill scale has not been removed, the pickling procedure above must be repeated.

Final Flushing

Note: All piping with mill scale must be pickled before final flushing.

Note: All flushing medium must be disposed in a responsible manner and according to environmental regulations.

1. Bypass the engine and ancillary equipment so that only the field fabricated piping must is flushed.
2. Flushing can be performed with water or flushing oil
3. Fill the system with clean water or flushing oil

4. Flush the system, stopping as necessary to clean the strainers prior to and after the pump. During the flushing process, piping should be vibrated and hammered at pertinent points in the system.
5. Monitor and clean the strainers as required, keeping the differential pressure across the strainers within the manufacturer's recommendations.
6. The flush is completed when the 100 mesh inspection strainer is clean after 60 minutes of flushing.
7. Stop the pump and isolate the flushing tank
8. Drain the flushing tank
9. Clean the flushing tank
10. Open the vents and drains in piping
11. Drain the piping
12. Blow the piping out with compressed air to clean the low points for changing to system fluid
13. Close the vents and drains
14. Disconnect the air supply beginning at the air source
15. Fill the flushing tank with the following:
    a. Lube oil system – lube oil
    b. Heavy fuel oil system – distillate oil
    c. Distillate oil system – distillate oil
    d. Cooling water system – cooling water
    e. Compressed air system – water
    f. Steam system – water
16. Install the following filter equipment just prior to the flushing tank on the return line:
    a. Lube oil system: 20 micron filter after flushing pump
    b. Heavy fuel oil system (between day tank to engine supply and return): 10 micron filter after flushing pump
    c. Heavy fuel oil system (other than b): 100 mesh screen after flushing pump
    d. Distillate fuel oil system (between day tank to engine supply and return): 10 micron filter after flushing pump
    e. Distillate fuel oil system (other than d): 100 mesh screen after flushing pump
    f. Cooling water system: 100 mesh screen after flushing pump.
    g. Compressed air system: 100 mesh screen after flushing pump

h. Steam system: 100 mesh screen after flushing pump

17. Open the flushing tank isolation valves.
18. Start the flushing pump.
19. Flush for a minimum of 24 hours after the flushing medium has been heated to a minimum of 60°C (do not exceed 82°C)
20. Flush until no debris is found in the screen/filter during one hour
21. Stop the pump and isolate the flushing tank
22. Drain the flushing tank
23. Open the vents and drains in the piping
24. Drain the piping
25. Blow down the system piping with steam for the steam system, and air for all others
26. Close the vents and drains, and restore system completely.
27. Do not use the flushing medium in the engine under any circumstances

Note: If system piping is not to be placed into service within one week, fill the system with inert gas and seal off completely (this must be done with the Cat engine and ancillary equipment bypassed).

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