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GE Energy

Cleanliness Requirements for Power Plant Installation, Commissioning, and Maintenance

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

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I. INTRODUCTION

A. Purpose and Scope

To Provide general rules and guidance for field activity and Users regarding system cleanliness acceptance criteria for power plant installations, commissioning and maintenance when specific procedure are not available. Cleanliness issues during manufacturing, installation, and commissioning can cause delays in delivery, performance degradation, and unit damage. 182 cases involving cleanliness issues were submitted to the Power Answer Center (PAC) from the beginning of 1998 through June 2000. Analysis of the cases revealed a need for clear and specific acceptance criteria.

The present GEK is not applicable when specific procedure are available, eg: commissioning procedure, specification from MLI A125, etc.

B. General

Technological advancements in the field of power generation have raised the level of importance for maintaining system cleanliness during all phases of manufacturing, installation and operation. Each improvement to efficiency and reduction in emissions require a further tightening in clearances and reduction in the margins for error. The level of cleanliness control which the new power plant installations demand, require a change in the approach to maintaining system cleanliness.

System cleanliness must be a plant lifetime approach ranging from design to plant operations and maintenance. Strict, in-process controls to prevent contamination and to maintain the system cleanliness level are essential to the successful installation and long term reliability.

The best practices learned during installations have decreased the average amount of time required to deliver a cleaner, more robust system. Applying these practices is important to obtaining expected performance and equipment life.

II. DEFINITIONS AND CONTROL

The purpose of performing a flush or air/steam blow is to remove any and all foreign material from a system or component. Foreign material is defined as any material or object that should not be on or within the system hardware (Figure 1).

Figure 1. Metal Shavings found in piping following the Fitting Process

A. System Criticality Definitions

Cleanliness control levels will be defined in three categories: Critical, Controlled, and Foreign Material Exclusion (FME). If the system medium flows through components that can be considered to fall into more than one of these categories, the overall requirements for the entire system are categorized to the higher level of control.

Critical systems are defined as those systems where contamination of the system can cause a catastrophic failure. These systems require additional attention to ensure that system integrity is maintained.

Controlled systems are defined as those systems where contamination will cause degradation in unit or component performance or reduced component life.

Foreign Material Exclusion systems are defined as those connected to and have the potential to contaminate systems that are Critical or Controlled.

B. Control of Foreign Material

To most efficient method of maintaining system cleanliness is to prevent entry of foreign material into system piping or components during installation and maintenance. The following steps should be observed to prevent entry of foreign material into Power Plant systems:

- Temporary covers or plugs (FME covers) shall be installed on all system piping, components, or tank connections opened for work or inspections, except during the time the opening must be uncovered to perform the evolution. This requirement also applies to material in staging and lay down areas.
- FME covers shall be designed such that they cannot fit inside the system opening or have an installed capture device that guarantees their retrieval prior to component installation. The FME cover should cover the entire system opening. FME covers shall be constructed of a rigid, non-fibrous material. The use of wood, especially chip board or plywood, is not a recommended material as it can splinter or shed and deposit material within the system. The use of rags or foam is also not a recommended practice (Figure 2 and Figure 3). The soft material may be pushed into

a system opening thus becoming foreign material. Tape may be used to fasten the covers in place, but should not be used as a sole source of material exclusion.

- When the work is complete and prior to removal of the FME covers, inspect and thoroughly clean the work area to ensure that no foreign material is present. This includes the removal of loose or flaking rust and residue from grinding, chipping, welding, blasting, or other maintenance activities. It is important that FME devices be accounted for when system closeout is performed.
- Following fit-up of piping or installation of vital system components, a Quality Assurance or individual of supervisory authority should closeout and certify the cleanliness of that portion of the system.

Figure 2. 12” Piece of Foam Material used as an FME Cover, Removed from a Pipe Using Air Blows (Material was not detected during visual inspections)

Figure 3. Examples of FME Covers utilizing Paper, Linen and Plastic Bags (Not a Recommended Practice)

C. In-Process Controls

A pareto of system contamination PAC case root causes show inadequate in-process controls to be a leading contributor. Understandably, it is necessary to remove FME covers to perform different maintenance and installation related evolutions. When the covers are removed, appropriate measures should be taken to prevent the introduction of foreign material as a result of the evolution.

All tools and maintenance related material and debris should be removed from the work area and be accounted for prior to replacing the FME cover on the system opening. This requirement would also apply to any material that is to be installed into a system. During maintenance evolutions, care should be taken to prevent foreign material from entering areas that are inaccessible for cleaning and visual inspections. Finally, visual inspections remain an excellent traditional manner of detecting foreign material. This is discussed later in the article.

III. LUBRICATING/HYDRAULIC OIL FLUSHING AND ACCEPTANCE CRITERIA

Hydraulic Systems that operate at working pressures of greater than 3000 psi or are supply systems incorporating servo valves are critical systems. Combined lubricating oil and hydraulic systems that supply high pressure or servo valves are considered critical systems.

The values listed in this section (III) are representative of the requirements for clean operation, but specific requirements for cleanliness are defined in GE specifications (MLI A125, MLI A160, etc.) or in GE commissioning procedures and shall take precedence over this GEK.

Critical oil systems medium is to be maintained at an NAS class 6 specification (refer to Table 1and Table 2) with water content of <100 ppm (.01%).

Bearing Lubricating or Hydraulic systems that operate at working pressures of less than 3000 psi and do not have servo valves in the system are controlled systems.

Controlled oil system fluids are to be maintained at an NAS class 8 specification (refer to Table 1 and Table 2) with water content of <100 ppm (.01%).

Drain piping is an example of a foreign material exclusion system.

Foreign Material Exclusion oil systems are to be maintained free of debris with water content of <100 ppm (.01%).

Table 1. Cleanliness Level Particle Count

NAS 1638 (1964)	Based on 100 ml sample				
	5-15 micron	15-25 micron	25-50 micron	50-100 micron	>100 micron
12	1,024k	182k	32,400	5,760	1,024
11	512k	91,200	16,200	2,880	512
10	256k	45,600	8,100	1,440	256
9	128k	22,800	4,050	720	128
8	64,000	11,400	2,025	360	64
7	32,000	5,700	1,012	180	32
6	16,000	2,850	506	90	16
5	8,000	1,425	253	45	8
4	4,000	712	126	22	4
3	2,000	356	63	11	2
2	1,000	178	32	6	1
1	500	89	16	3	1

Table 2. NAS versus ISO

NAS	12	11	10	9	8
ISO	23/21/18	22/20/17	21/19/16	20/18/15	19/17/14
NAS	7	6	5	4	3
ISO	18/16/13	17/15/12	16/14/11	15/13/10	14/12/9

A. General Guidelines on Flushing

Flushes must take place after piping installation, but prior to system operation. The success of an oil flush is dependent on: Success of efforts to keep contaminants out, and the proper conduct of the flush. A successful flush means that system piping components and piping meet acceptance criteria in a minimum of time with a minimum of effort.

The proper performance of a flush depends on: the ability of the pump to provide sufficient flow rate to ensure turbulent flow in the system (typically two to three times normal velocity), control of the flushing fluid temperature (from 105°F [40°C] to 169°F [76°C] according to delivery state), the use of vibrations (Rawhide hammer, Rubber mallet, or Pneumatic Vibrator – Figure 4) to loosen solids, the actual condition of the material : storage condition, inside access for visual inspection, trace of rust, trace of grease, etc. The use of high velocity fluid in a properly sequenced flush is the most important of these flushing factors.

Figure 4. Pneumatic Vibrator

If 2-3 times normal flow is not achievable, turbulent flow must be ensured (Re > 4000).

Table 3. Example: Minimum flow to achieve turbulent flow

	For typical ISO VG 32 Oil at 170°F	
Flow (gpm) = 1.268 * ((4)*d)	6" pipe	75 gpm
(4)- Kinematic viscosity (in centistokes) of	4" pipe	50 gpm
flush fluid at 170°F	3" pipe	40 gpm
d - Pipe diameter measured in inches	2" pipe	25 gpm
	1" pipe	12 gpm

A minimum flushing time of 6 hours may be necessary to ensure cleanliness within a system or portion thereof. Review GE documentation to verify minimum flushing times, if applicable. System size and complexity will determine if additional flush time is required. It is impractical to flush through certain system components that are assembled, cleaned and sealed in the factory. Protect these components carefully against contaminants.

B. Recommendations

Air Blows - In an effort to remove debris resulting from fabrication, storage, and installation, sites should perform air blows on system piping during the installation process. The piping should be blown down during initial fit-up and prior to final installation. The air used for the blows can either be instrument air or clean dry air from an off-base air compressor. After the pipe is installed, any open ends should be capped using a suitable FME cover. This procedure can be applied to nearly any system during the fit-up phase of installation as a useful precautionary measure. Figure 5 and Figure 6 show the effect of proper air blows on flushing effectiveness.

Maintenance Practices - Cleanliness controls in maintenance practices are critical in preventing system contamination. The use of FME covers on system/pipe openings, good housekeeping/clean work areas (free of debris from related or non-related work) and visual inspections cannot be overstated.

Visual Inspections - Visual inspections are essential to ensuring that foreign material is not introduced into or left in the system. All piping and system openings should be inspected prior to final installation/closeout.

Filter Alignment - Sites should, where possible, align the flushing filters such that oil will not flow through the filter when the system is opened for inspection (Figure 7). Care must be taken when inserting filter baskets as the edges of the basket can rub on the filter body. This can introduce contaminates into the system and provide false positives. The basket should be inspected for this condition at each flush iteration. Temporary filter or basket shall not be installed in drain line to avoid risk of clogging and upstream overflowing-flooding.

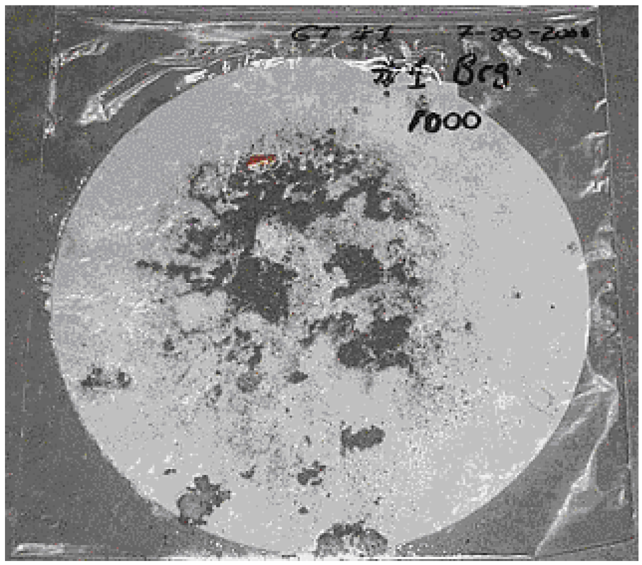


Figure 5. Initial #1 Bearing Flush Results from Lube Oil Piping without Air Blow. Flushes required 18 days

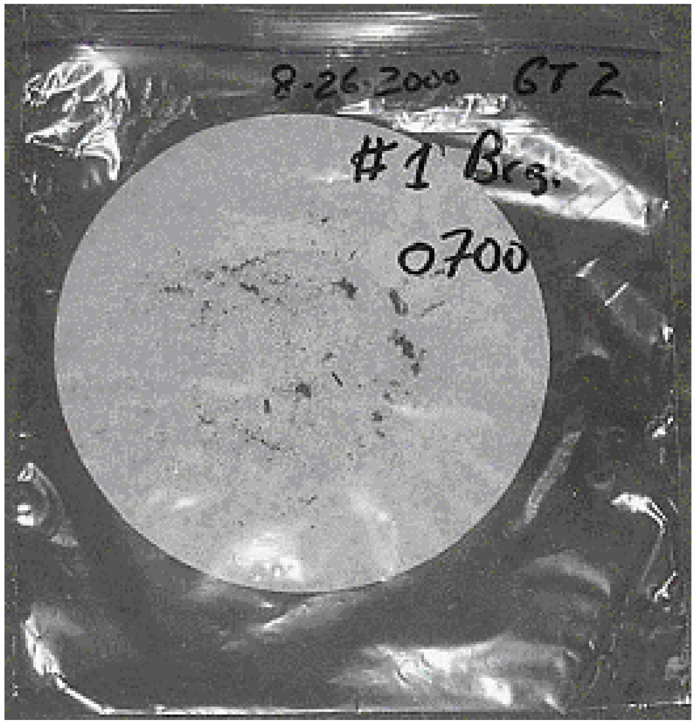


Figure 6. Initial #1 Bearing Flush Results from Lube Oil Piping after Air Blow. Flushes required 10 days

Figure 7.

C. Contamination Measuring Technique

Sites should use the following guidelines to measure flush performance and system cleanliness:

WARNING

A CUP OF BRAKE SOLVENT CAN DESTROY THE CHEMICAL PROPERTIES OF A 3000 GAL OIL SUMP. CARE MUST BE TAKEN TO ENSURE THAT ELEMENTS ARE CONTAMINATE FREE WHEN RETURNED TO THE SYSTEM.

- The sample should be free of visual contamination and debris for an acceptable level of cleanliness (Figure 8). Two acceptable samples, obtained at least two hours apart, are required to verify the cleanliness of the system or portion of the system that is being flushed. Specific sampling requirements may take precedence over this GEK.
- At the conclusion of a successful whole system flush, if the flush oil is removed the tank must be cleaned with lint free rags. Use of a truck as storage or source of replenishment fluid should be scrutinized closely. A typical sample of replacement fluid from a truck yields a contamination level of NAS class 10. This is a common source of post-flush contamination. When feasible, replenishment fluid should be polished prior to introduction into the system. It is the responsibility of the installer to insure that proper filtration, on the order of $\beta_{10} = 200$, is installed between the tanker truck and the oil reservoir to insure the installed oil meets a minimum cleanliness level. Although, the practice of reusing oil is strongly discouraged by engineering, it is recognized that this practice is occasionally utilized in the field. In the event that the site personnel, end user, and oil vendor all concur that reusing oil is acceptable, it shall not be done without reconditioning. Reconditioned oil shall meet the requirements of the applicable GEK's by full spectrum oil analysis by the Original Equipment Manufacturer (OEM) of the lubricant or a qualified third party.
- After the operating oil is charged back into the system, oil analysis should be performed. The quality of the oil shall meet the requirements defined in the appropriate GE specifications.
- Fill oil must be verified to meet cleanliness specifications of the system. Sampling and analysis should be performed at the beginning, middle and end of a oil transfer to verify cleanliness level. Typical refresh oil is several NAS classes less than required.

Verifying and maintaining a clean oil system will help to ensure proper operation and gain maximum performance of the system and components.

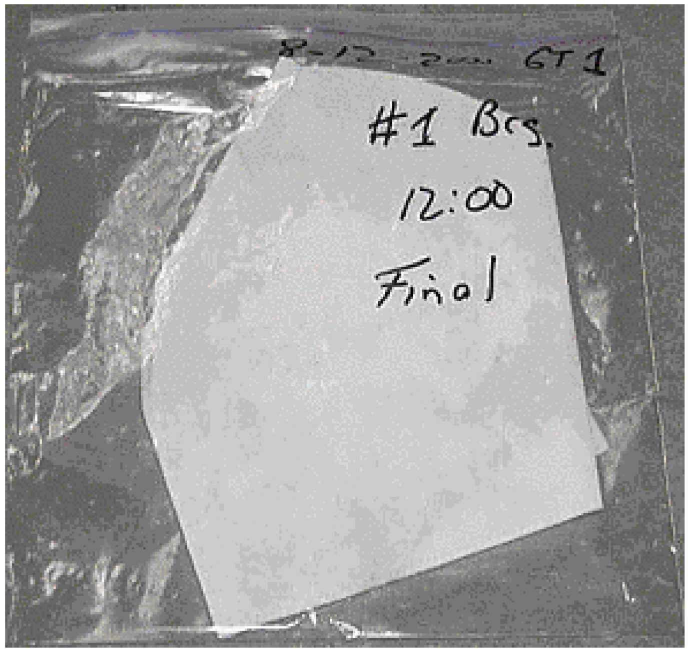


Figure 8. Visually Acceptable Filter Sample Unrelated to NAS Class

IV. LIQUID FUEL OIL FLUSHING AND ACCEPTANCE CRITERIA

Liquid Fuel Oil systems are controlled systems.

Controlled fuel oil system fluids are to be maintained at an NAS class 10 specification (refer to Table 1 and Table 2) with water content of <1.0 vol. %.

Drain piping is an example of a foreign material exclusion system.

Foreign Material Exclusion fuel oil systems are to be maintained free of debris and water.

A. Contamination Measuring Technique

Sites should use the following guidelines to measure flush performance and system cleanliness:

- Remove the filter element from the system and place on a clean coffee filter or lint free rag. The coffee filter/lint free rag will provide an area for sample collection and inspection.
- The sample should be free of visual contamination and debris for an acceptable level of cleanliness. Two acceptable samples obtained at least two hours apart, are required to verify the cleanliness of the system or portion of the system that is being flushed (Figure 9).

Figure 9. Acceptable Filter Sample - Unrelated to NAS Class

- If normal system fuel oil is used for the flush, the fuel oil may be pumped back to the holding tanks during the course of the flush to be used for subsequent system operation.

Verifying and maintaining a clean fuel oil system will help to ensure proper operation and gain maximum performance of the system and components.

V. GAS FUEL SYSTEM CLEANLINESS AND ACCEPTANCE CRITERIA

Gas Fuel systems are controlled systems.

A. Gas Fuel System Air Blow Procedure

A recommended method of blowing down the gas fuel system is to purge the off-base and on-base piping separately. For the off-base piping, blows should be performed from first through the customer's piping up to the fuel gas skid, FG-1. Once complete, blows should continue through the accessory module and the interconnect piping by stroking the fuel gas valves. Blows should last approximately 10 seconds and should be performed at least 3-5 times per gas line and until the gas lines are verified as clean. Following the blows the flanges should be inspected and either connected to downstream piping or covered with temporary FME covers.

For the on-base gas fuel piping, the gas manifolds and each pig tail line to the end-cover assembly connection is to be air pressure tested and blown in order to ensure all lines are free of contaminants. The following procedure should be followed for each gas manifold.

1. The individual pigtails are disconnected from the end-covers and blanked. This is done for one gas manifold system at a time.

2. FME covers are placed on the exposed combustion end-cover openings.

3. An air source is connected upstream of the on-base piping with a fast actuating valve installed to control the airflow. Air source examples are: a pressurized receiver, the CO_2 tank pressurized with air or the upstream piping up to the customer's control valve (in this case the control valve is opened and the stop valve acts as the fast actuating valve).

4. Prior to performing the blows, the piping system should be air pressure tested for leaks.

5. Each manifold is then blown for approximately 10 seconds per blow. Blows should be performed at least 7-12 times for each manifold and until the gas lines are verified as clean. Air velocities can be increased, as needed, by performing blows on half of the manifold pigtails at a time while the other half is blanked.

6. Once a gas manifold is complete, the pigtails and end-covers should be inspected and re-connected immediately prior to moving to the subsequent manifold. This should prevent delays in startup associated with debris fouling fuel nozzles.

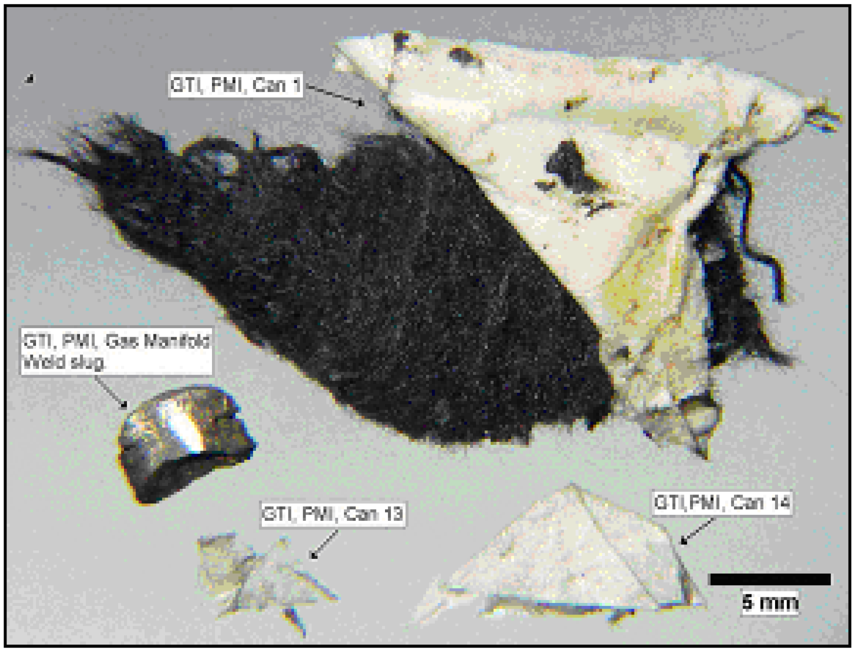


Figure 10. Example Contaminants found in Gas Piping

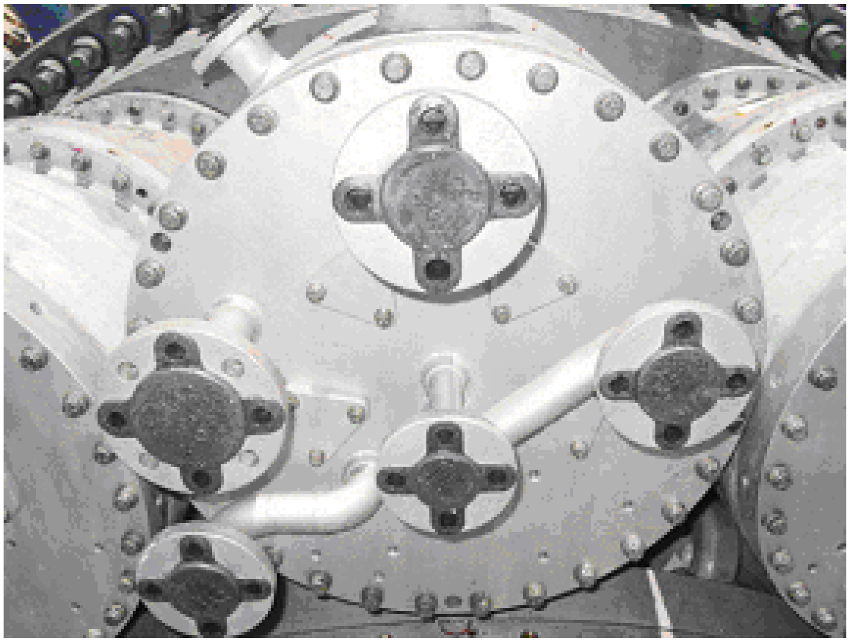


Figure 11. FME Covers On A Combustion Can End-Cover

B. Contamination Measuring Technique

Sites should use the following guidelines to measure and verify system cleanliness:

- During the performance of an air blow to either establish or verify cleanliness, a 100-mesh strainer (140 µm) should be placed in the discharge path to collect any debris from the piping or system. When performing blows of individual gas piping pig tails, a clean white cloth placed at the exit may be used in lieu of the strainer.
- The sample should be free of visual contamination and debris for an acceptable level of cleanliness. Two consecutive acceptable samples are required to verify the cleanliness of the system or portion of the system that is being air blown.
- The piping ends should also be swabbed by wiping the internal surfaces with a white cloth to verify cleanliness.
- Additionally, the gas fuel should be analyzed to ensure GEI 41040 specifications are met.

Verifying and maintaining a clean fuel system will help to ensure proper operation and gain maximum performance of the system and components.

VI. AIR SYSTEM CLEANLINESS AND ACCEPTANCE CRITERIA

All air systems; excluding service or shop air are controlled systems.

Service/shop air systems are foreign material exclusion systems.

The blowdown of air systems should be conducted.

A. Contamination Measuring Technique

Sites should use the following guidelines to measure and verify system cleanliness:

- During the performance of an air blow to either establish or verify cleanliness, a 100-mesh strainer (140 µm) should be placed in the discharge path to collect any debris from the piping or system.
- The sample should be free of visual contamination and debris for an acceptable level of cleanliness. Two consecutive acceptable samples are required to verify the cleanliness of the system or portion of the system that is being air blown.

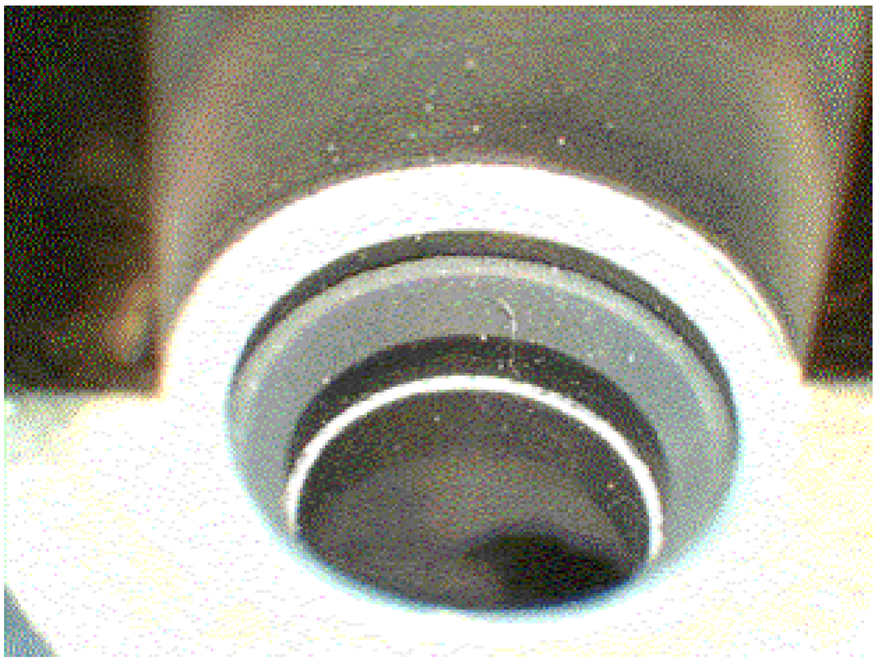


Figure 12. Fine Contamination causing a purge check valve to fail

B. Recommendations

Air Blows - In an effort to remove debris resulting from fabrication, storage, and installation, sites should perform air blows on system piping during the installation process. The piping should be blown down during initial fit-up and prior to final installation. The air used for the blows can either be instrument air or clean dry air from an off-base air compressor. After the pipe is installed, any open ends should be capped using a suitable foreign material exclusion (FME) cover.

The air blows will significantly reduce the amount of debris in the piping. Air blows have proven successful in removing debris when using a 200-gallon receiver charged to 100-125 psig and discharged through a two-inch hose. The blow should last between 5-10 seconds and should be repeated 4-5 times unless cleanliness levels dictate that more blows should be performed. The size of the hose used for the blows should be such that the hose is able to fit into the pipe opening and still allow the maximum flow rate possible. For example, a two-inch hose used to blow a six-inch pipe proved to be successful.

Maintenance Practices - Cleanliness controls in maintenance practices are critical in preventing system contamination. The use of FME covers on system/pipe openings, good housekeeping/clean work areas (free of debris from related or non-related work) and visual inspections will reduce the possibility of introducing foreign material or debris into a piping system.

Visual Inspections - Visual inspections are key to ensuring that foreign material is not introduced or left in the system. All piping and system openings should be inspected prior to final installation/closeout. Inspections should be performed using a flashlight and a mirror where practical and a borescope if required. A visual inspection, with no contamination visual to the naked eye, is sufficient to call an air system "clean".

Obtaining a smear of a dry area of piping near an exit and comparing the smear sample to the examples in paragraph 10 of reference 1 is an option to further confirm the cleanliness of air systems. This is not required but represents another opportunity to verify system cleanliness. Table 2 of reference 1 provides recommended contamination levels in mg/m2 for air systems.

Verifying and maintaining a clean air system will help to ensure proper operation and gain maximum performance of the system and components.

VII. STEAM PIPING CLEANING AND ACCEPTANCE CRITERIA

First stage cooling steam used in the H-type gas turbine is a critical system.

Procedures and criteria that are recommended in this document are not applicable to an H-type installation as it pertains to conducting a liquid flush of steam piping. Consult Dwg 362A2412 for further guidance regarding this matter.

Steam Supply and Steam Seal systems are controlled systems.

Experience has shown the importance of thoroughly cleaning the main steam, reheat steam, and steam seal systems prior to turbine operation or after the completion of a new installation or major repair work to the steam system. Debris left in the system would otherwise be blown into the turbine and cause serious damage to the steam path parts. The temporary fine mesh screens installed on the main stop and combined reheat valves during initial startup are not intended to be a substitute for cleaning the steam lines.

The objective of a chemical cleaning and air or steam blowdown is to minimize the possibility of damage to the turbine by removing pipe scale and other foreign material, which might otherwise be carried over into the machine.

The following equipment and steam piping should be chemically cleaned and air blown or steam blown prior to undertaking plant startup testing.

1. Each heat recovery steam generator and its steam lines.
2. The main steam lines and header from each heat recovery steam generator through to the turbine bypass piping just upstream of the turbine bypass desuperheater valve. The turbine bypass desuperheater valve must not be in the steam path during blowdown. The Purchaser shall supply temporary piping including a blowdown valve to be connected at a point just upstream of the turbine bypass desuperheater valve.
3. The main steam lines and header through to the turbine stop valve(s).
4. The steam seal piping. Acid cleaning of steam seal piping is not recommended.

A. General Guidelines on Chemical Cleaning of Steam System Piping

Chemical cleaning of the piping upstream of the main stop valve or combined reheat valve will require the installation of special chemical cleaning hardware to protect the turbine and valve internal parts. General Electric can supply the hardware as extra cost items when required.

The acids or caustics used during chemical cleaning attack certain materials commonly used in these turbine assemblies and must be protected. Hydrostatic tests should be completed prior to the installation of the chemical cleaning fixture(s). The chemical fixture may collapse if installed during the hydrostatic tests. The fixture should be installed during the blowdown in order to prevent foreign matter from depositing adjacent to the valve seat and plug.

B. Chemical Cleaning Process

One proven chemical cleaning process for steam system piping consists of a three-phase process that accomplishes alkaline degreasing, corrosion product and millscale removal, and passivation of active metal surfaces; all in a single fill of the system.

The system is initially filled with demineralized water and heated, the alkaline degrease chemistry is injected into the system. The alkaline degrease stage may be considered complete when the Sodium hydroxide concentration has leveled out and the minimum contact time of 12 hours has been met. Following completion of the alkaline degrease stage, a corrosion inhibitor is injected into the system. After a ninety minute circulation period, additional chemistry adjustments are injected into the circulating system to affect the removal of millscale and corrosion products. This is followed with a circulation of a passivation solution.

C. General Guidelines on Air Blowdowns

There are several proven methods available for cleaning steam pipes by blowing down with either steam or air. A method of cleaning that has been used with success is the compressed air blowdown. This procedure is similar to a saturated steam blowdown, except that compressed air is used as the cleaning medium. General Electric has studied the theoretical potential cleaning ability of air versus steam and found that for the same initial boiler pressure the cleaning force with either would be about the same. Although thermal cycling is not present, experience has shown that cleaning with compressed air, when specifically preceded by a proper chemical cleaning, is nearly as effective as steam blows. It is during the chemical cleaning that the millscale removal is achieved, which is the value of the thermal cycling found in the steam blows. Compressed air blowdown is preferred by some because it allows for increased construction scheduling flexibility. This is particularly applicable in the case of combined cycle gas and steam power plants.

A log sheet should be used to record data for each blow. Data that should be recorded includes air blow number, date, time, blow starting pressure, blow ending pressure, blow duration, and visual observation (wet, some moisture, dry, debris, etc.). One log sheet should be kept for each system being blown down.

The HP steam system and LP steam system will be air blown to targets.

D. General Guidelines on Steam Blowdowns

Blowing down the steam piping with saturated steam is a cleaning method that has traditionally been the method of choice in the power industry. The use of steam causes thermal cycling which helps to loosen debris, allowing it to be blown out. The procedure consists of pressurizing the boiler, terminating firing, and rapidly opening the temporary blow valve to depressurize the system. This cycle is repeated until the system is judged to be clean. The steam is essentially saturated as the water stored in the boiler flashes as pressure decays. The procedures and sample calculations in reference 14 are based on the saturated steam blowdown procedure.

Certain considerations that might not make this the procedure of choice include scheduling restrictions that do not allow for work stoppage during steam blows. Also, if the risk of encountering heat-related injuries from potential steam leaks outweighs the benefit of conducting a steam blow instead of an air blow, a steam blowdown may not be the preferred method. However, one advantage of a steam blow is that opportunities exist to run the plant, test the plant, and discover system flaws that might require attention before official startup.

Thorough conduct of either an air (in conjunction with a chemical cleaning) or steam blowdown can produce a clean steam system. Specific procedural guidance for a steam blow are contained in References 14 and 15.

Maintenance Practices - Cleanliness controls in maintenance practices are critical in preventing system contamination. The use of foreign material exclusion (FME) covers on system and pipe openings, good housekeeping/clean work areas (free of debris from related or non-related work), and visual inspections will reduce the possibility of introducing foreign material or debris into a piping system.

Visual Inspections - Visual inspections are essential to ensuring that foreign material is not introduced or left in the system. All piping and system openings should be inspected prior to final installation/closeout. Inspections should be performed using a flashlight and a mirror where practical and a borescope if required.

External Vibration - Vibration is not necessary in cleaning or blowing down the steam system because the medium reaches near supersonic speeds during the air or steam blow, thereby creating a greater vibrating force. For a typical steam piping diameter (16”), external attachments to produce a viable vibration would be cumbersome and redundant and, most likely, would add little to no value.

E. Contamination Evaluating Technique

Contained within this section are two evaluating techniques. Both utilize steel targets to evaluate the cleanliness of the steam system at maximum blowing pressures during a steam or air blow. The first target assembly is in-line to the temporary piping (Figure 10), and the second assembly is attached to the discharge end of the piping, without the use of a silencer. Certain noise ordinance restrictions or personal choice may dictate which method is employed.

The targets used for the in-line target assembly should be 1” square mild steel polished on two opposite sides with the length fitted to just greater than the diameter of the temporary piping (most likely 16”). Dimensions of the targets for the open-discharge method are contained in Figure 11.

Figure 13. In-Line Target Assembly

Assuming that sufficient mass velocity has been achieved in the blowdown, the progress of the blow-down should be monitored by placing polished targets in the blowdown flow. Particles carried with the flow will cause pitting of the targets. The conduct of the blowdowns and calculations governing the determination of sufficient mass velocity can be found in References 14 and 15.

Once a plume, clear of moisture or debris, is observed discharging from the silencer or end of the piping, a polished target should be inserted in the target assembly. The target strips used in the open discharge method should be made of steel, polished on both sides to obtain double use from each. In accordance with reference 15, the strips can be made of steel, aluminum, or copper, but steel is recommended. Figure 11 shows the second possible target assembly and a suitable method for fastening this type of target to the open discharge end of the blowdown piping. Both of the target arrangements shown (Figure 10 and Figure 11) permit easy replacement of the target.

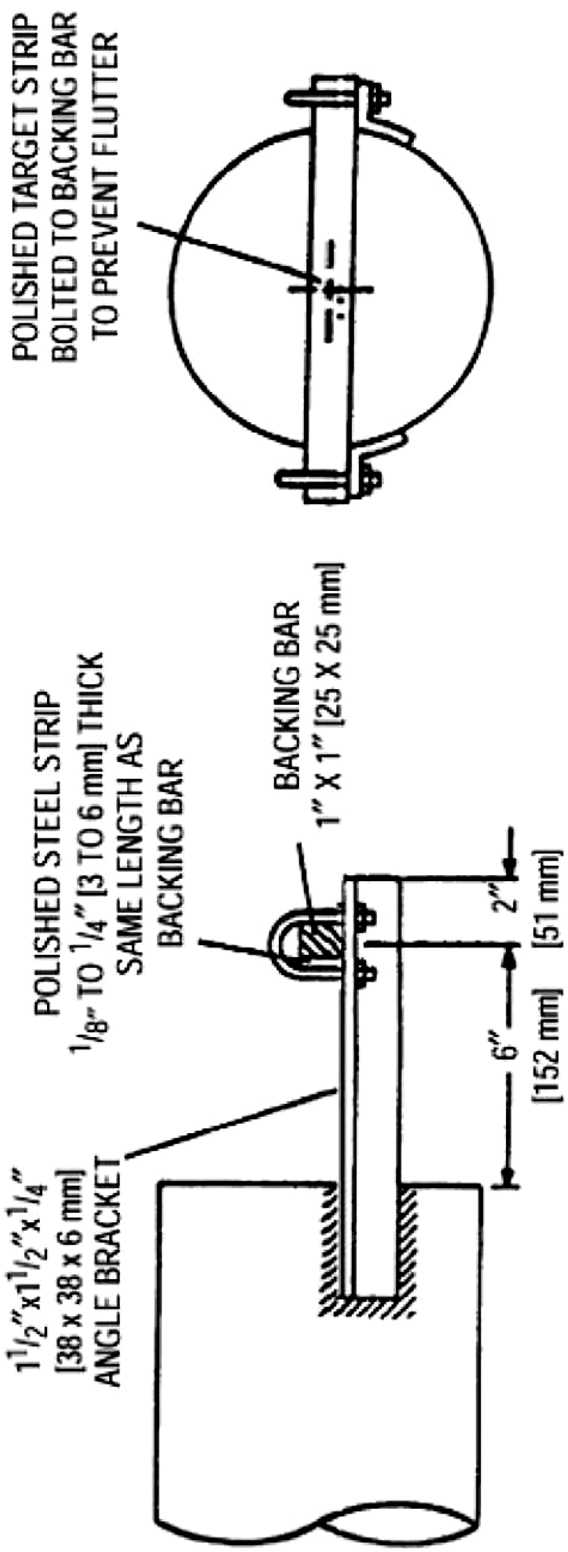


Figure 14. Open-Discharge Method Bracket Support for Polished Target

Following the initial evaluated blow, three to four cycles for each particular pipe run should be completed prior to performing an evaluated blow with, another polished target. Evaluation intervals for subsequent blows are at the discretion of the evolution manager.

The number of polished targets required to ascertain that the steam piping is adequately clean will vary dependent on the interpretation of the targets taken from the previous blows. Two consecutive targets are required to achieve final acceptance of each run of targeted steam systems.

General Electric recommends that the Cleaning Force Ratio (CFR) be greater than or equal to 1.5 at the start of the piping run that is the focus of the cleaning cycle and no less than 1.03 throughout the entire length of the pipe.

CAUTION

Must be taken to prevent piping configurations that require excessive inlet CFR's. Inlet CFR's, that significantly exceed 1.5 (i.e., 1.8 or greater), may cause system damage and should be avoided.

CFR is calculated using where:

$$CFR = \left(\left(\frac{Q_c}{Q_{\max}}\right)\right)^2 x \frac{(PV)_c}{(PV)_{\max}} x \frac{(P_{\max})}{(P_c)}$$

Q_c = calculated flow during cleaning (lb/hr)

Q_{max} = max load flow (lb/hr)

$(PV)_c$ = pressure-specific volume product during cleaning at boiler outlet (ft^3/in^2)

(P_{max}) = pressure at max load flow at boiler outlet (psia)

(P_c) = pressure during cleaning at boiler outlet (psia)

$(PV)_{max}$ = pressure-specific volume product at max load flow at boiler outlet (ft^3/in^2)

GE recommends that the acceptance criteria for the completion of air blow be no gouge of 40 mils (.040 in [1.0 mm]) or more in length or depth per 6 square inches [38 cm^2] of surface area on a 1 inch [25 mm] wide polished mild steel (A36, ASTM 1006) target that spans the entire diameter of the pipe, a general clear background is required, whereby the target polish is not fogged. These criteria shall be met for two consecutive targets taken. Data verification records of these targets are to be submitted to Product Services during the Red Flag Review. The targets shall be placed as close to the end of the permanent piping but prior to the temporary piping, as possible.

In addition, there shall be no more than 5 hits visible to the naked eye of any size Greater than .010 in a six square inch area [0.25 mm in a 38 cm^2 area]. No raised surface hits, no irregular pockmarks or raised pits and no embedded material visible to the naked eye on the target. A 5X magnification triplet should be used in classifying the size of the any hits in question.

Deviating from this standard, thereby falling short of meeting these acceptance criterion, could endanger the safe and efficient operation of the steam turbine and associated components, shorten the operating life cycle of the turbine or components, and negatively impact the long-term performance of the turbine.

F. Safety Considerations

Among many other safety items to bear in mind in an industrial environment, the following apply to the material discussed in this article. Low point collection of chemical cleaning solution in valves and drains can be a personnel hazard. Site management should be aware of it, and supervisors should prevent craft labor from putting themselves in such a position to be endangered by that possibility. During air blows, there exists a danger when purging low point drains due to the very low temperatures that could cause cold-related injuries. Conversely, during steam blows, personnel should be aware of the inherent danger in working with and around the high temperatures of steam.

VIII. WATER SYSTEM CLEANLINESS AND ACCEPTANCE CRITERIA

Water wash, water injection, and cooling water are all controlled systems. Water wash and systems should be maintained at NAS 10 level, water injection at NAS 8 level, cooling water systems should be maintained at NAS class 12 level (refer to Table 1 and Table 2).

A. Contamination Measuring Technique

Sites should use the following guidelines to measure system cleanliness.

During system flushes, flushing effluent should be captured through a flushing cloth (lint free rag) until no debris is found. A water wash flushing procedure for F class units is contained in reference 16. This section serves as contamination measuring augmentation to that procedure.

- The effluent sample is measured against Table 1 to ensure the system meets NAS level requirements.
- The sample should be free of visual contamination and debris for an acceptable level of cleanliness. Two consecutive acceptable samples obtained are required to verify the cleanliness of the system or portion of the system that is being certified.

Verifying and maintaining a clean water system will help to ensure proper operation and gain maximum performance of the system and components.

IX. SUMMARY

The values listed in table 4.System Summary Chart are representative of the standard requirements for clean operation.

Specific requirements for cleanliness written in GE specifications (MLI A125, MLI A160, etc.) or in GE commissioning procedure might be different from the table below according to product factory cleanliness and scope of work at site and shall take precedence over the present GEK.

Table 4. System Summary Chart

System Noun Name	Criticality	NAS Class	Specifics
Lubricating Oil	Controlled	NAS 8	H_2O content <100 ppm (.01%).
Hydraulic Oil	Critical	NAS 6	H_2O content <100 ppm (.01%) High Pressure, Servo Valve use.
Liquid Fuel	Controlled	NAS 10	H_2O content <100 ppm (.01%).
Gas Fuel	Controlled	NAS 10	Gas Fuel Specs in GEI 41040F
Air Systems-General	Controlled	N/A	
Air Systems-Service/Shop Air	FME	N/A	
Steam-First Stage Cooling (H-Type)	Critical	N/A	
Steam-General	Controlled	N/A	
Water Wash Systems	Controlled	NAS 10	
Water Injection Systems	Controlled	NAS 8	
Cooling Water Systems	Controlled	NAS 12	

References

1. D 6439-99, Standard Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems.
2. ISO TR 10949, Hydraulic Fluid Power-Methods for Cleaning and for Assessing the Cleanliness Level of Components.
3. ML A125, Lubricant Oil System Flushing Instruction
4. GEK 37971D, Flushing Procedure for Steam Turbine Lubrication and Hydraulic System Piping
5. GEK 46506D, Steam Turbine Lube Oil (Recommended Properties & Maintenance Practices)
6. Global Filtration Technology Handbook of Hydraulic Filtration, Parker Filtration
7. GEI 41047H, Turbine Liquid Fuel Specifications
8. GE specification 362A2412, Gas turbine System and Component Cleanliness Requirements
9. GEI 41040F, Process Specification Fuel Gases for Combustion in Heavy-Duty Gas Turbines
10. TIL 1192-2, DLN: Fuel Gas Cleanliness
11. DWG 366A2803, General Piping Cleanliness, Pipe
12. DWG 361A6439, Cleanliness Spec, On-Base Piping

13. TIL 1278-2, Steam Supply Piping and Steam Seal Piping Blowdown Criteria
14. GEI 69688E, Cleaning of Main Steam Piping and Provisions for Hydrostatic Testing of Reheater
15. GEK 41745A, Cleaning of Main Steam Piping for Combined Cycle Plant
16. Dwg 363A4220, Water Wash Flushing Procedures
17. PFI Standard ES-5, Cleaning of Fabricated Piping
18. National Aerospace Standard (NAS) Bulletin 1638

GE Energy
General Electric Company
www.gepower.com

HYDAC FILTERTECHNIK

Particle Measurement Technology in Practice.

From Theory to Application.

E 7.605.2/05.08

1 Introduction to Particle Counting

1.1 Physics Fundamentals

1.1.1 Light Obscuration

In optical contamination sensors, a beam of light is transmitted through the oil flow.
On the reception side, the light is obscured by the particles.

Fig. 1
No obscuration of the light beam

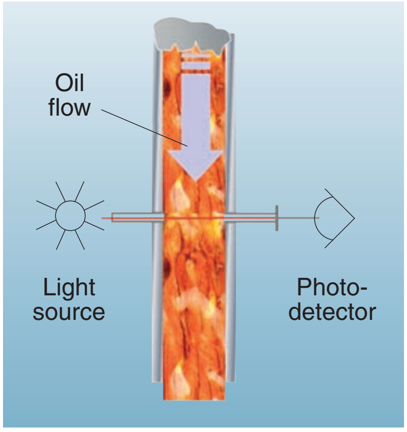
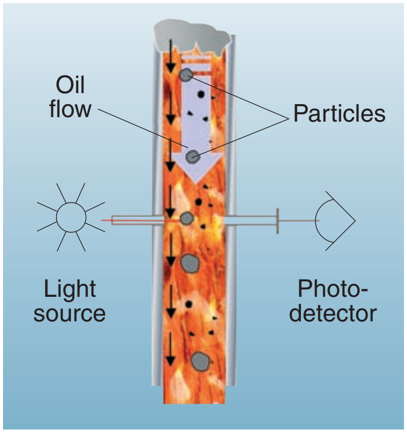
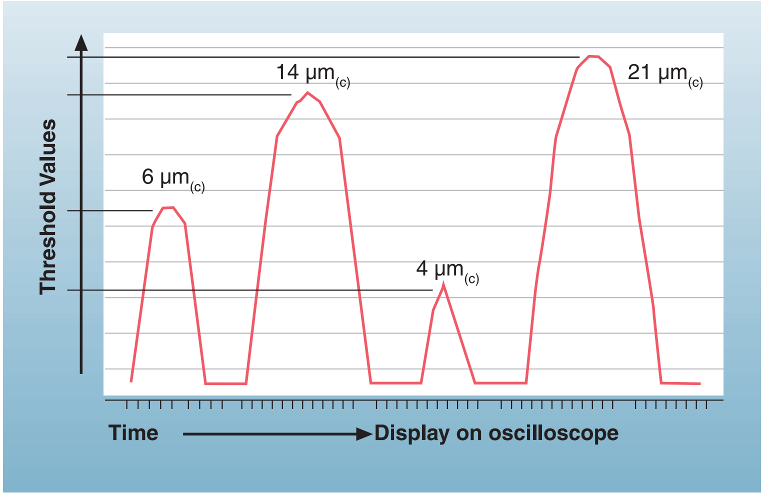


Fig. 2
Obscuration of the light beam by particles



The reception signal looks like this on an oscilloscope:

Fig. 3
Reception Signal



Signal conversion:

- Each of the signal peaks corresponds to obscuration by a particle.
- The signal height or amplitude reflects the particle size.
- The breakdown into 2, 5, 15, 25 µm and 4, 6, 14, 21 µm$_{(c)}$ is determined via the threshold values.

The principle of particle counting via light obscuration is used in the sensors presented in section 2.

1.1.2 Mesh Blocking Process

The fluid flow is conveyed through one or more meshes. In so doing, the particles contained in the fluid are retained by the mesh, thus generating a pressure differential (Δp) at the site of the mesh inlet and outlet.

Increases in Δp over time (t) provide information about particle loading.

Fig. 4
MeshBlockage Sensor MBS 1000

Advantages:
Mesh Blocking Process can be used for

- emulsions
- high particle loading
- opaque fluids

Disadvantages:

- only trend monitoring is possible
- no information on particle counts possible
- no particle distribution measurement possible
- no traceability to a calibration standard offered

1.1.3 Process Limits

When measuring particulate contamination using the sensors described in section 2, the oil cleanliness may not be above or below specific limits.

If the oil is "too clean" no particle readings can be captured. The lower process limit is approximately ISO 9/8/7.

Excess contamination leads to coincidence (= temporal meeting of two or more signals caused by several particles aligned in the same plane), rendering particle measurement no longer possible. This problem is encountered with cleanliness classes over ISO 25/24/23.

Particle counting in emulsions is not possible employing optical methods. The principle of light obscuration is limited to particles over 1 $\mu m_{(c)}$ in size.

For oil cleanliness classes of less than ISO 14/12/10, the direct comparison of an online measurement with an oil sample is not always possible. Additional error sources when taking oil samples:

- contamination of environment
- altered flow conditions at sampling point
- variable contamination at different sampling points (tank, pressure line, offline circuit)
- procedure for oil sampling (e.g. cleanliness of sampling adapter, fluid volume, machine cycle)

1.2
Test Dust

1.2.1
ACFTD / ISO MTD

Until 1992 ACFTD (Air Cleaner Fine Test Dust) was valid as test dust.

Starting in 1997, a new test dust, ISO MTD (ISO Medium Test Dust) was stipulated in ISO 12103-A3. ISO MTD forms the basis for the SRM 2806 (Standard Reference Material) developed by the NIST (National Institute of Standards and Technology, USA).

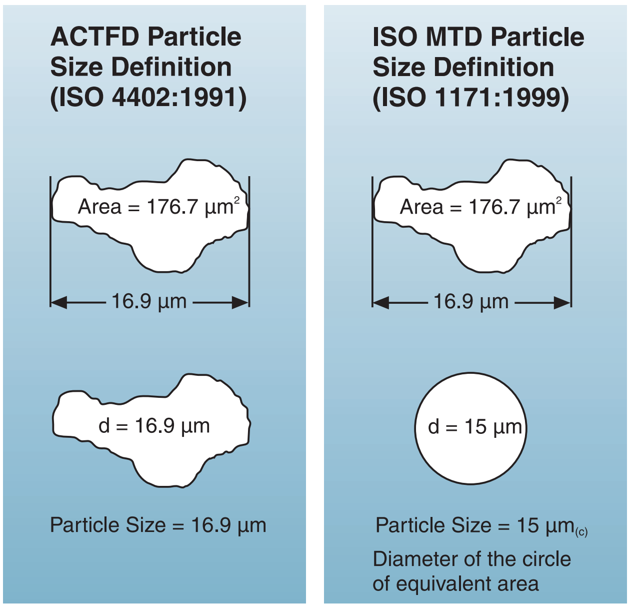
The ISO MTD dust is used for calibrating automatic particle counters subject to calibration standards ISO 11171:1999 and ISO 11943:1999.

1.2.2
Particle Sizes

In ACFTD dust the longest particle dimension is used to specify size.

With the introduction of ISO 11171:1999, a new definition of particle sizes was stipulated. The standard defines the diameter of an area-equivalent particle of ISO MTD dust as the particle size.
Particle size specifications according to ISO 11171:1999, the new calibration standard, contain the index $_{(c)}$, example: 4 µm $_{(c)}$, designating the calibration material used, certified and traceable to a national standard.
This notation is also used in the revised ISO 4406:1999 and the new ISO 11943:1999.

Fig. 5
Particle size definition



1.2.3
Calibration standard ISO 11171:1999

The ISO 11171:1999 calibration standard covers the calibration of automatic particle counters for fluids. This standard is applied in the primary calibration of laboratory particle counters. A suspension containing ISO MTD contamination is used for calibration.

The reference particle counters used by HYDAC and the ALPC Automated Laboratory Particle Counter are calibrated on the basis of ISO 11171:1999.

Fig. 6
ALPC Automated Laboratory Particle Counter

1.2.4 Calibration standard ISO 11943:1999

The ISO 11943:1999 calibration standard covers the calibration of automatic online particle counters for fluids.
This standard is applied in the secondary calibration of online laboratory particle counters.

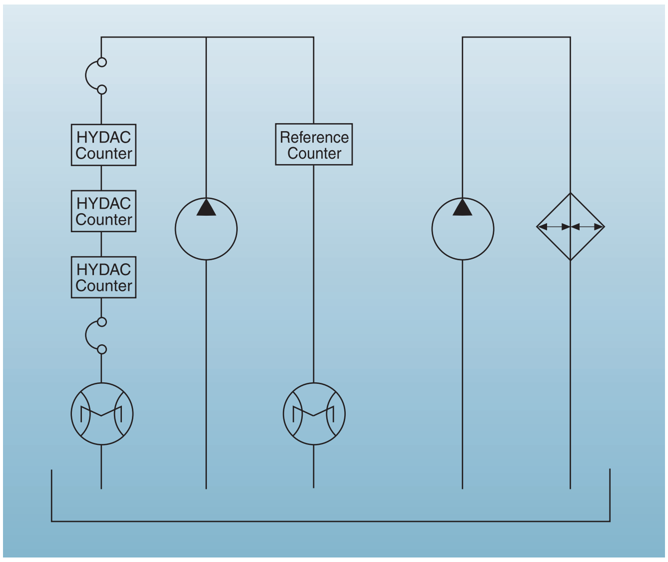
Fig. 7
FluidControl Unit FCU 2000

Fig. 8
ContaminationSensors CS 1000 and CS 2000

The same ISO MTD contamination is used as in ISO 11171:1999.

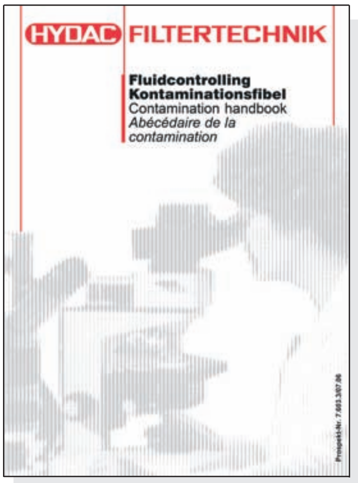
ISO 11943:1999 stipulates that online particle counters are connected in a hydraulic circuit with reference particle counters calibrated according to ISO 11171:1999.

Fig. 9
Schematic of a Calibration Test Rig



1.3 Contamination Classification

For a concise reference containing reference photographs, please refer to our Contamination Handbook on fluid monitoring (stock no. 349339).



1.3.1 ISO 4406

In ISO 4406, particle counts are determined cumulatively, i.e. > 4 µm$_{(c)}$, > 6 µm$_{(c)}$ and > 14 µm$_{(c)}$ (manually by filtering the fluid through an analysis membrane or automatically using particle counters) and allocated to measurement codes.
The goal of allocating particle counts to codes is to facilitate the assessment of fluid cleanliness ratings.
In 1999 the “old” ISO 4406:1987 was revised and the size ranges of the particle sizes undergoing analysis redefined.

The counting method and calibration were also changed. This is important for the user in his everyday work:

Even though the measurement codes of the particles undergoing analysis have changed, the cleanliness code will change only in individual cases. When drafting the “new” ISO 4406 care was taken to ensure that not all the existing cleanliness provisions for systems had to be changed (Lit. ©HYDAC, “Filters- Power Fluid Technology, New Test Dust, New Calibration, New Filter Testing Methods – How This Impacts Everyday Work”).

Overview of the changes:

	“Old” ISO 4406:1987	**“New” ISO 4406:1999**	
Size ranges	> 5 µm > 15 µm	> 4 µm$_{(c)}$ > 6 µm$_{(c)}$ > 14 µm$_{(c)}$	
Dimension determined	Longest dimension of a particle	Diameter of the area-equivalent circle ISO 11171:1999	
Test dust	ACFTD-dust	1-10 µm ultrafine fraction	ISO 12103-1A1
		SAE Fine, AC-Fine	ISO 12103-1A2
		SAE 5-80 µm ISO MTD Calibration dust for particle counters	ISO 12103-1A3
		SAE Coarse Coarse fraction	ISO 12103-1A4
Comparable size ranges	Old ACFTD-Calibration	Comparable ACFTD dusts	New NIST calibration
		< 1 µm 4.3 µm 15.5 µm	4 µm$_{(c)}$ 6 µm$_{(c)}$ 14 µm$_{(c)}$

Allocation of particle counts
to cleanliness classes:

No. of particles / ml		Cleanliness class
Over	**Up to**	
2,500,000		> 28
1,300,000	2,500,000	28
640,000	1,300,000	27
320,000	640,000	26
160,000	320,000	25
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	**2,500**	**18**
640	1,300	17
320	640	16
160	**320**	**15**
80	160	14
40	80	13
20	40	12
10	**20**	**11**
5	10	10
2.5	5	9
1.3	2.5	8

The reproducibility of the results in cleanliness class 8 depends on the concentration of particles in the sample undergoing analysis. If the number of particles counted in the sample is fewer than 20, the result has to be reported with ≥.

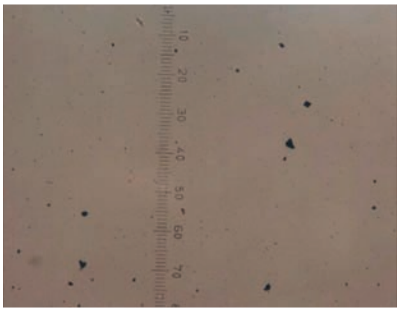
Example: 14/12/≥8

Note: increasing the measurement code by 1 causes the particle count to double.

Example: ISO class 18 / 15 / 11 says that the following are found in 1 ml of analyzed sample:

1,300 - 2,500 particle > 4 µm$_{(c)}$
160 - 320 particle > 6 µm$_{(c)}$
10 - 20 particle > 14 µm$_{(c)}$

Fig. 10
Microscopic Examination
of an Oil Sample (100 ml),
Magnification 100x
(ISO 18/15/11)



1.3.2
SAE AS 4059

Like ISO 4406, SAE AS 4059 describes particle concentrations in liquids. The analysis methods can be applied in the same manner as ISO 4406:1999 and NAS 1638.

The SAE cleanliness classes are based on particle size, number and distribution.
The particle size determined depends on the measurement process and calibration, consequently the particle sizes are labeled with letters (A - F).

The following table shows the cleanliness classes in relation to the particle concentration determined:

		Maximum particle Concentration [particles/100 ml]					
Size ISO 4402 Calibration or optical counting*		> 1 µm>	5 µm	>15 µm	> 25 µm	> 50 µm	> 100 µm
Size ISO 11171, Calibration or electron microscope**		> 4 µm(c)	> 6 µm(c)	> 14 µm(c)	> 21 µm(c)	> 38 µm(c)	> 70 µm(c)
Size coding		**A**	**B**	**C**	**D**	**E**	**F**
Classes	000	195	76	14	3	1	0
	00	390	152	27	5	1	0
	0	780	304	54	10	2	0
	1	1,560	609	109	20	4	1
	2	3,120	1,220	217	39	7	1
	3	6,250	2,430	432	76	13	2
	4	12,500	4,860	864	152	26	4
	5	25,000	9,730	1,730	306	53	8
	6	**50,000**	**19,500**	**3,460**	**612**	**106**	**16**
	7	100,000	38,900	6,920	1,220	212	32
	8	200,000	77,900	13,900	2,450	424	64
	9	400,000	156,000	27,700	4,900	848	128
	10	800,000	311,000	55,400	9,800	1,700	256
	11	1,600,000	623,000	111,000	19,600	3,390	1,020
	12	3,200,000	1,250,000	222,000	39,200	6,780	

* Particle sizes measured according to the longest dimension.

** Particle sizes determined according to the diameter of the projected area-equivalent circle.

The SAE cleanliness classes can be represented as follows:

1. Absolute particle count larger than a defined particle size

Example:

Cleanliness class according to AS 4059:6

The maximum permissible particle count in the individual size ranges is **bold-faced** in the above table.

Cleanliness class according to AS 4059:6 B

Size B particles may not exceed the maximum number indicated for class 6.

6 B = max. 19,500 particles of size of 5 µm or 6 µm(c)

2. Specifying a cleanliness class for each particle size

Example:

Cleanliness class according to AS 4059: 7 B / 6 C / 5 D

Size B (5 µm or 6 µm(c)):
38,900 particles / 100 ml

Size C (15 µm or 14 µm(c)):
3,460 particles / 100 ml

Size D (25 µm or 21 µm(c)):
306 particles / 100 ml

3. Indication of the highest cleanliness class measured

Example:

Cleanliness class according to AS 4059:6 B - F

The 6 B - F specification requires a particle count in size ranges B - F.

The respective particle concentration of cleanliness class 6 may not be exceeded in any of these ranges.

1.3.3 NAS 1638

Like ISO 4406 and SAE AS 4059, NAS 1638 describes particle concentrations in liquids.

This standard is now obsolete but often used in practice.
The analysis methods can be applied in the same manner as ISO 4406:1999.

In contrast to ISO 4406, certain particle size ranges are counted in NAS 1638 and allocated to these measurement codes.

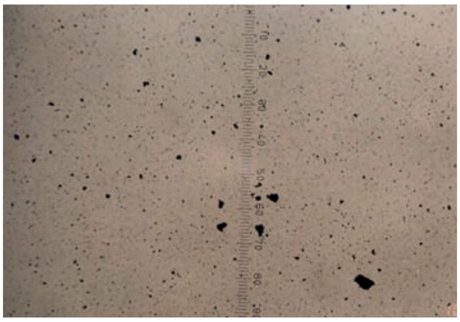
The following table shows the cleanliness classes in relation to the particle concentration determined.

		Particle size [µm]				
		5-15	15-25	25-50	50-100	>100
		No. of particles in 100 ml sample				
Cleanliness class	00	125	22	4	1	0
	0	250	44	8	2	0
	1	500	89	16	3	1
	2	1,000	178	32	6	1
	3	2,000	356	63	11	2
	4	4,000	712	126	22	4
	5	8,000	1,425	253	45	8
	6	16,000	1,850	506	90	16
	7	32,000	5,700	1,012	180	32
	8	64,000	11,600	2,025	360	64
	9	128,000	22,800	4,050	720	128
	10	**256,000**	**45,600**	**8,100**	**1,440**	**256**
	11	512,000	91,200	16,200	2,880	512
	12	1,024,000	182,400	32,400	5,760	1,024

Increasing the class by 1 causes the particle count to double on average.

The maximum particle counts of class 10 are **bold-faced** in the above table.

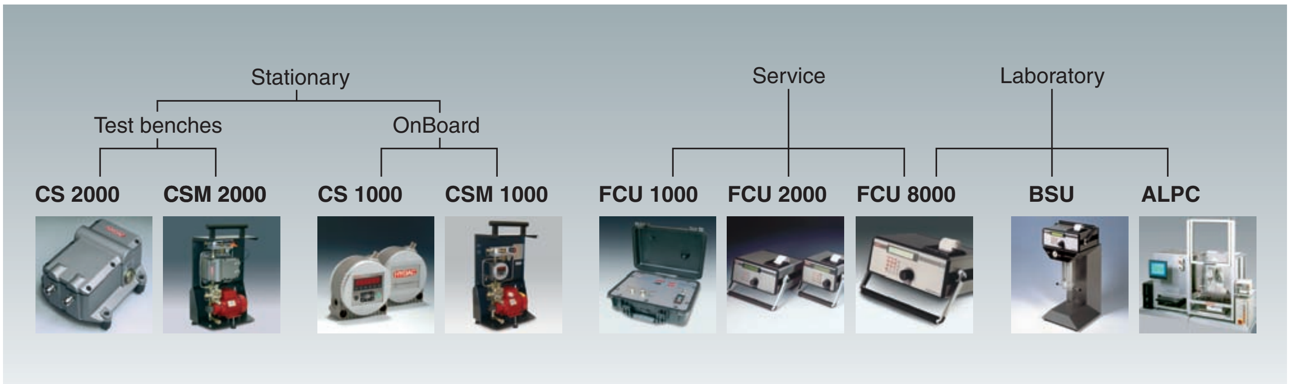
Fig. 11
Microscopic Examination of an Oil Sample (100 ml), Magnification 100x (NAS 10)



2 The Right Tool for the Job

2.1 Product Overview and Applications

Fig. 12
Product Overview

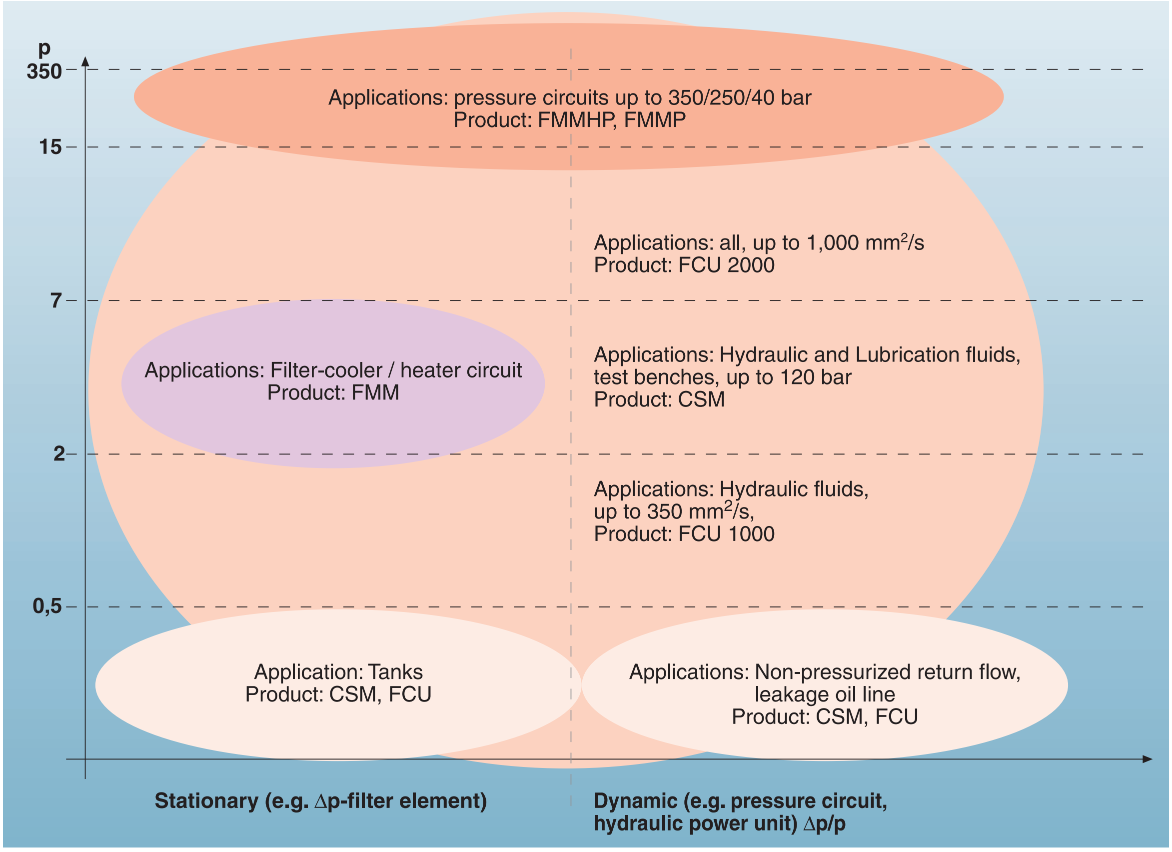


FluidControl Units (FCU) are offered for temporary measurement and fluid service purposes. The Contamination Sensors (CS) are designed for stationary applications in hydraulic/lube systems and test rigs. These sensors are also available as units featuring a motor-pump assembly, patented air suppression, and optional installation for the AS 1000 AquaSensor and HYDACLab®.

The Bottle Sampling Unit (BSU) combined with the FCU 8000 is used for analyzing oil samples. Simplified oil sampling can be done with FCU 2000 and FCU 1000. The Automated Laboratory Particle Counter (ALPC) can be used to analyze up to 500 samples/day. The following table shows the key differences between the individual units:

	FCU 1000	FCU 2000	FCU 8000	CS 2000	CS 1000	CSM 2000 / CSM 1000
Optical measurement cell	Glass block →higher pressure stability	Glass fiber	Glass plates Lens system	Glass fiber	Glass block →higher pressure stability	Depends on sensor
LED	Infrared	Infrared	Laser	Infrared	Infrared	Depends on sensor
Determination of flow rate via	Particle signal	Integrated flow rate sensor	Integrated flow rate sensor	Particle signal	Particle signal	Depends on sensor
Regulation of flow rate via	Motor-pump assembly	Control knob on the front for setting the flow control valve	Control knob on the front for setting the flow control valve	- Internal hydraulic conditioning selectable in the model/type code - External modules (see 2.4.3)	External modules (see 2.4.3)	Motor-pump assembly

Fig. 13
Typical Applications
and Suitable Products
(and Modules)



The various applications are subdivided below into:

- Temporary Measurement and Fluid Service
- Continuous Online Analysis in Test Rigs for Determining Surface Cleanliness
- Continuous Online Measurement in Hydraulic and Lubrication Systems for Condition Monitoring
- Laboratory Equipment

2.2 Temporary Measurement and Fluid Service

Portable FluidControl Units (FCU) (series 2000) are available for temporary measurement and fluid service purposes.
The FCU is available in various calibrations and models.
All models feature a display with a keypad, a knob for adapting the flow rate, and an integrated miniature dot-matrix printer. Models are also available with/without an internal pump for automatically suctioning fluids from oil samples or the tank. The FluidControl Units are user-friendly and provide for reliable measurement results.

The following table provides a comparison of the various models:

	FCU 1000	FCU 2000	FCU 8000
			
Brief description	- Portable particle counter	- Portable particle counter	- Laser particle counter
Features	- 4 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - With internal pump - Data output on display or via connection to a PC - Analysis and storage of measurement data - M12x1 and Bluetooth interface - Rugged design	- 4 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Type with internal pump available - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 or RS485 interface - Continuous online measurement - Rugged design	- 6 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 interface for data output - Laser particle sensor - Extended measurement range for fluids down to NAS 0
Competitive advantages	- Optical infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own FluMoS software possible (FluMoS light available as freeware)	- Patented fiber optic infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)	- Can be used in the field as a portable measurement unit and in laboratory - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)
Applications	- Hydraulic systems - Maintenance and servicing - Tank analysis	- Hydraulic and lubrication systems - Maintenance and servicing - Test rigs - Bottle sampling analysis - Tank analysis	- In laboratories and at service centers - Field applications - Bottle sampling analysis

The following prerequisites apply to using the FCU:

Pressure range	1 - 350 bar (depending on viscosity)
Permissible viscosity range (continuous operation)	5 - 1,000 mm^2/s (pressure port) 5 - 150 mm^2/s (suction port, FCU 2000-4 only)
INLET port (pressure)	FCU 2000: Minimess coupling, type 1604 (including high-pressure inlet hose DN 4 (type 1604 - type 1620, 2 m long)) FCU 8000: Minimess coupling, type 1620 (including high-pressure inlet hose DN 2 (type 1620 – type 1620, 2 m long))
OUTLET port (suction)	Plug connector DN 6.4 with shut-off
OUTLET port	Plug connector (low-pressure outlet hose DN 7 (2 m long))

2.3 Continuous Online Analysis in Test Rigs for Determining Surface Cleanliness

Using online particle counters for checking component cleanliness is described in detail in ISO 18413. In the process, the test oil is analyzed subsequent to component cleanliness analysis. Test rigs possess several factors which render continuous online analysis difficult:

- short measurement cycles
- changing flow rates
- air bubbles
- oil mixtures
- grease
- assembly lubricants

Stationary units, i.e. the Contamination Sensor Modules (CSM), are available for ensuring stable measurement conditions, thus enabling continuous online analysis. The CSM 2000 and CSM 1000 models differ by virtue of the sensors used.
The CSM is a standalone unit featuring a motor-pump assembly and a contamination sensor. This enables the fluid to be suctioned out of lines and non-pressurized tanks and conveyed through the sensor for measurement.

The module also possesses a patented air suppression feature. This causes air present in the oil to be dissolved by applying pressure and thus not counted as particles in the optical contamination sensor. A moisture sensor, the AS 1000, or an oil level sensor, the HYDACLab®, can be integrated in the oil stream. The HYDACLab® is a multi sensor for

- temperature
- moisture
- viscosity changes
- permittivity alterations

Fig. 14
CSM 1000

Fig. 16
CSM 1000 integrated in test rig

Fig. 15
CSM 2000

The following prerequisites apply in order to enable simple integration in the test rig, the CSM is used to suction oil in the vicinity of the return-flow line and convey it through the particle counter.
The CSM 1000 is used for standard hydraulic applications.
The CSM 2000 – combined with a supplementary CM-FS flowmeter – is available for difficult-to-count fluids (gear lubrication fluids, oil mixtures, grease concentrates and assembly lubricants).

The following prerequisites apply to the use of the CSM:

INLET pressure range	-0.4 – 0.5 bar (standard pump) or -0.4 – 120 bar (pump, inlet pressure stability, with leakage oil line)
Pressure OUTLET	5 bar
Permissible viscosity range	10 - 3,000 mm²/s
Permissible viscosity range for measurement operation	10 - 1,000 mm²/s
INLET port (pressure)	Thread G 1/4, ISO 228
OUTLET port	Thread G 1/4, ISO 228

The CSM contains a 400 µm protective mesh (CM-S).

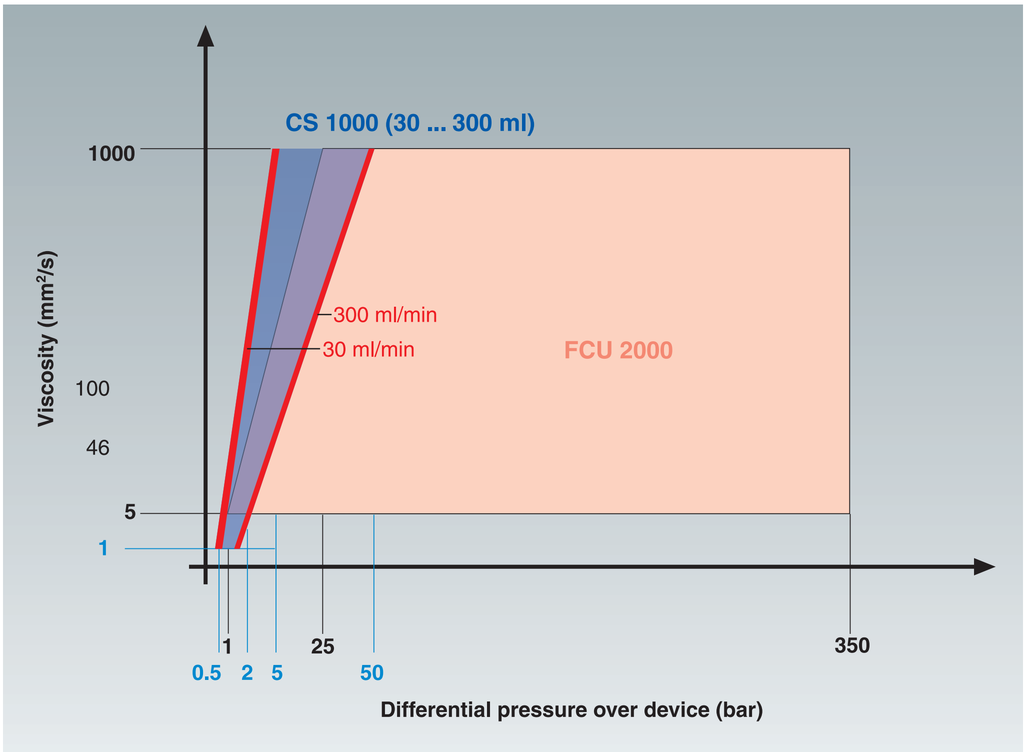
2.4
Continuous Online Measurement in Hydraulic and Lubrication Systems for Condition Monitoring

The series 2000 and 1000 Contamination Sensors (CS) are available for continuous online measurement in hydraulic and lubrication systems, the sensors being integrated permanently in the system. To this end, the flow rate has to be precision-adjusted in the respective measurement range via the sensor.
The Contamination Sensor is an orifice (hydraulically speaking).

	CS 1000	CS 2000
		
Brief description	- Contamination Sensor for measuring the solid particle contaminants in hydraulic and lubricating fluids	- Contamination Sensor for measuring the solid particle contaminants in hydraulic and lubricating fluids
Features	- Up to 300 bar - No data input - Switching output - Analog output: 4 – 20 mA or 0 – 10 V - RS485 port	- Max. 40 bar - 2 x 4 – 20 mA inputs for AquaSensor (AS) or other sensors - 3 dedicated and 3 optional outputs - RS232 for ISO code display - 2 alarm relays - Universal PLC output - Option: 4 – 20 mA, RS232, RS485 or Ethernet - Can be operated with an external flow sensor
Competitive advantages	- Recalibratable - IP 67 - Shock- and vibration-resistant - Compact design - 3-digit display - Data interfaces integrated in unit	- Recalibratable - Large number of data outputs - Wide range of hydraulic conditioning modules available - Electrical outputs
Applications	- Mobile hydraulics - Industrial facilities, e.g. machine tools, injection moulding equipment, presses, etc. - Filter carts - Scheduled maintenance	- Test rigs

In contrast to the fluid service unit FCU, the flow rate is not subsequently manually readjusted in the permanently integrated Contamination Sensors.
The limited flow range correlates with a restricted working range with regard to pressure and viscosity. The following graph shows the difference in hydraulic working range between the FCU and CS 1000.

Fig. 17
Working Ranges of the CS 1000 and FCU 2000

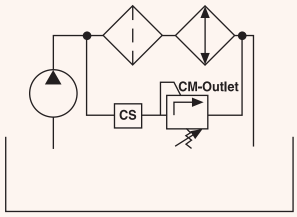
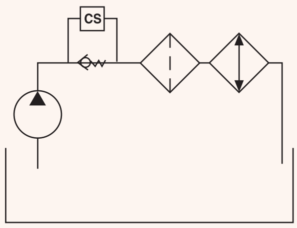
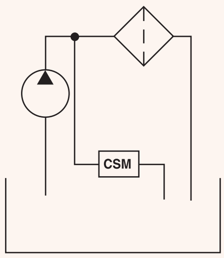


Various ConditioningModules (CM) are available for regulating the flow rate within the permissible range. The ConditioningModules enable the working range of the CS 1000 and CS 2000 to be adapted to the hydraulic conditions.
These units are presented in a number of typical installation examples.

2.4.1
Typical Installation Examples

2.4.1.1
Filter-Cooler / Heater Circuit

In a hydraulic circuit featuring a filter and cooler / heater unit, the CS can be integrated in the bypass.

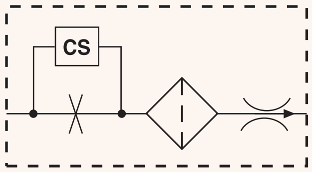
Modules Used	Circuit Diagram	Function Description	Significance for the operating point
CS + CM-O **FMM**		- Pressure upstream of the filter-cooler/heater is sufficient for creating a pressure differential (Δp) - Return flow conveyed into tank or downstream of cooler/heater, depending on pressure differential (Δp) - Throttling of (possibly) overly high flow rate through the CM-O	- Clean filter element: setting of the operating point in the lower part of the permissible flow range - Increasing contamination of the filter element → Increase of the pressure differential (Δp) → Shifting of the operating point upwards = increase of the flow rate through the CS - Contaminated filter element: If the flow rate continues to be within the permissible range, the static operating point suffices for regulating the flow rate through the sensor
Check valve **CS + CM-O** **FMM**		- System-specific check valve (2-3 bar) for generating a sufficient Δp via the sensor - Connection of the sensor via Minimess DN4 (minimum line length, inlet: 630 mm, max. 4 m)	- Setting a constant Δp → Working range of the sensor now only dependent on viscosity
CSM 2000 **CSM 1000**		- Pressure upstream of clean filter element is not sufficient for creating a pressure differential (Δp) - Use of a CSM	- Automatic imposition of the operating point by impressing a flow rate in the specified range of the CS

Industries / applications:

- Plastic injection molding machinery (OEM and MRO)
- Automotive / hydraulic presses (OEM and MRO)
- Steel manufacturing / paper manufacturing / power generation

2.4.1.2
Pressure Circuit

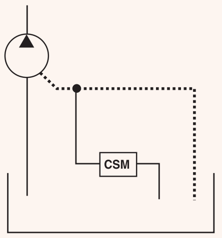
Integration is done via a pressure-compensated flow control valve for medium pressure applications and when good oil cleanliness ratings are present. In high-pressure applications it is recommended that a filter be used for protecting the flow control valve.

Modules Used	Circuit Diagram
FMMP **FMMHP** **CM-S + CM-I** **+ CS + CM-O**	

Industries / applications:
- Plastic injection moulding machinery (OEM)
- Mobile / agricultural machinery, forestry equipment, stackers and lifting trucks, conveying equipment, mining machinery, construction machinery (OEM)

2.4.1.3
Leakage Oil Flow Monitoring

In hydraulic circuits in which large, costly pumps are used it is important that the wear and tear posed to these pumps is measured. The optimal location for performing contamination measurement is the leakage oil line as particle concentrations build up here the fastest.

Modules Used	Circuit Diagram	Function Description	Significance for operating point
CSM 2000 **CSM 1000**		- Leakage oil line virtually non-pressurized - Pressure generation in the leakage oil line is not possible on account of possible damage to the main pump(s) - CSM used - Possibility of integrating an AS 1000 or HYDACLab® - Note: Maintain temperature range of CSM	- Automatic imposition of the operating point by impressing a flow rate in the specified range of the CS

- Industries / applications:
Large-scale systems (OEM and MRO)

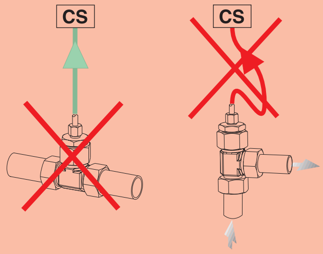
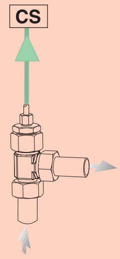
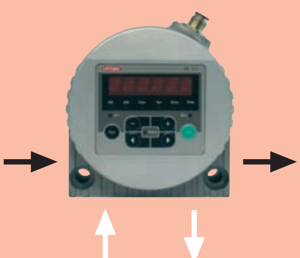
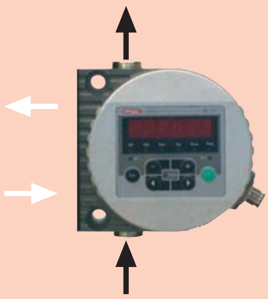
2.4.1.4
Lubrication Oil Monitoring

The ContaminationSensor Module CSM is available for lubrication oil monitoring. The pump provides a sufficient flow rate through the sensor.
The CSM possesses a patented air suppression feature. Hydraulic pressure precharging of 25 bar in the sensor is recommended for lubricating oil.

Industries / applications:
- Wind power generation systems and gear units
- Steel manufacturing / paper manufacturing / power generation

2.4.2 General Installation Recommendations

Certain criteria should be heeded when installing the sensors so that interference is reduced.

Installation recommendation	BAD	GOOD
		
Selection of the measurement point		- The measurement point has to be selected so that the measured volume is taken from a turbulent flow, e.g. at a pipe bend
Spacing with regard to measurement point		- The CS has to be installed in the vicinity of the measurement point in order to obtain precision-timed results - When precharging using the CM-O (recommended: 20 – 25 bar) an intake path of 630 mm (max. 4 m) is advisable between the measurement point and the CS
Prevent siphon trap		- While installing the measurement line, make sure that no "siphon trap" is created so as to prevent sedimentation buildup (formation of particle deposits in the line)
Diameter of connector lines		- INLET: Minimess hose DN4 or pipe with an internal diameter of 6 mm - OUTLET: Minimess hose ≥ DN4 or pipe with an internal diameter ≥ 6 mm - If a high viscosity is present, the cross-sections have to be accordingly larger
Direction of flow Horizontal or vertical?	- A horizontal flow direction is not advisable - Air bubbles may collect, particularly when the CS is installed at the highest point of the hydraulic circuit 	- A vertical flow direction is preferable over a horizontal one as no air bubbles will collect 

2.4.3 Conditioning Modules

For information on the Conditioning Modules, please refer to the brochure "Fluid Monitoring - Technical Information" (when ordering, please state language required: German or English).

2.5 Laboratory Equipment

Sample analysis in the laboratory:
the BottleSampling Unit (BSU), Automated Laboratory Particle Counter (ALPC) and FCU 2000 have been specifically developed for this purpose.
Overview of the key features of these units:

	FCU 2000	FCU 8000	ALPC
			
Brief description	- Portable particle counter	- Laser particle counter combined with a BottleSampling Unit for analyzing hydraulic fluid sampling bottles	- Automatic particle counter for analyzing fluid sampling bottles
Features	- Continuous online measurement - Rugged design - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Type with internal pump available - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 or RS485 interface - Calibrated according to ISO 11943	- 6 measurement channels - Cleanliness ratings according to ISO 4406, SAE 4059 and NAS 1638 - Integrated graphics-capable printer - Data output on display or via connection to a PC - Analysis and storage of measurement data - RS232 interface for data output - Laser particle sensor - Extended measurement range for fluids down to NAS 0	- Automated, controlled measurement and flushing cycles of hydraulic and lubrication fluids - Sample analysis performed quickly thanks to extremely short measurement and flushing times (up to 500 samples/day) - Calibrated according to ISO 11171 and ISO 4402 Consequently, analysis according to NAS1638 possible
Competitive advantages	- Patented fiber optic infrared measurement cell - Capturing, analysis and storage of measurement data - Evaluation via HYDAC's own CoCoS software possible (CoCoS light available as freeware)	- Easy to use - Can be used in the field as a portable measurement unit - Can be used in the laboratory with the BottleSampling Unit (BSU)	- Only small sampled quantity required (approx. 50 ml) - Automated sample feeding via multi-axis robot arm (ALPC 9000-2) - Enables convenient operation - Graphical analysis of measured results via ALPC software
Applications	- Hydraulic and lubrication systems - Maintenance and servicing - Test rigs - Bottle sampling analysis - Tank analysis	- Laboratories and service centers - Field applications	- Laboratories - Up to 500 samples/day

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