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GE Power Systems
Gas Turbine

F-Class Gas Turbine Compressor Washing

Liquid Washing Recommendations for Gas Turbines with Pulsed Water Wash Systems

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I. SCOPE

The scope of this document is to present the methods of compressor washing approved by General Electric. Two methods of liquid washing are employed – on–line and off–line. On–line washing is the process of injecting water into the compressor while the unit is running near base load with open IGV's. Off–line washing is the process of injecting cleaning solution into the compressor while the unit is rotating at part speed. The advantage of on–line washing is that it can be done without having to shut down the machine. On–line washing, however, is not as effective as off–line washing; therefore, on–line washing is used to supplement off–line washing, not replace it.

This document applies to all gas turbine models offered by Gas Turbine Division which have the capability to perform a pulse mode off–line water washing.

NOTE

It is recommended that a unit-specific procedure and checklist be created by each customer. The procedure and checklist should include configuring the unit for water wash, performing the wash and restoration following the wash. These procedures should conform to the enclosed general guidelines. It is recommended that the customer include a specific valve line–up before, during, and after the wash in their procedure. General Electric can provide technical assistance in preparing the unit specific procedures and checklists.

II. INTRODUCTION

A loss in gas turbine performance is detected by a decrease in power output and an increase in both heat rate and fuel consumption. The loss of performance is a direct result of fouling of the axial flow compressor. Fouled compressors result in reduced airflow, lower compressor efficiency and a lower compressor pressure ratio.

Compressor washing will assist in removing the fouling deposits and restoring performance. It should be noted that full power may not always be regained if significant fouling has occurred. Regular compressor washing will help maintain performance as well as allowing each wash to be more effective. Specific intervals shall be determined based on customer performance and site conditions. Compressor washing may also slow the progress of corrosion, thereby increasing blade life and reducing the contribution of corrosion products to the formation of fouling deposits.

III. TYPES OF FOULING

The type and rate of fouling of an axial compressor depends on the environment in which it operates and the inlet filtration present. Experience has shown that fouling deposits consist of varying amounts of moisture, oil, soot, water-soluble constituents, insoluble dirt and corrosion products of the compressor blading material. Fouling deposits are typically held together by moisture and oil. If corrosion of the blading is occurring, the corrosion products will promote and stabilize the deposit.

It is important to minimize fouling deposits by reducing oil leaks and the ingestion of oily constituents (lube oil fumes). Good filtration may greatly reduce fouling. Moisture formation cannot be reduced in humid environments. Moisture is formed in the compressor inlet when humid air is cooled below its dew point as a result of being accelerated to about Mach = 0.5. GER 3601, "Gas Turbine Compressor Operating Environment and Material Evaluation," discusses the factors influencing compressor fouling and corrosion.

IV. METHODS OF DETECTION

There are two basic methods for determining the cleanliness of the compressor. Visual inspection and performance monitoring. Both of these are described below.

A. Visual Inspection

Visual inspection involves shutting the unit down, removing the inlet plenum inspection hatch, and visually inspecting the compressor inlet, bellmouth, inlet guide vanes and early stage blading.

If any deposits, including dust or filmy deposits, can be wiped or scraped off these areas, the compressor is fouled sufficiently to affect performance. The initial inspection also reveals whether the deposits are oily or dry. For oily deposits, a water-detergent wash is required. Location of the source of the oil and correction should be accomplished before washing to prevent recurrence of the fouling.

If only dry deposits are found, water alone may be sufficient.

B. Performance Monitoring

A second method for detecting a fouled compressor is performance monitoring. Performance monitoring involves obtaining gas turbine data on a routine basis, which in turn is compared to base line data to monitor trends in the performance of the gas turbine.

The performance data is obtained by running the unit at steady-state BASE load and recording output, exhaust temperature, inlet air temperature, barometric pressure, compressor discharge pressure and temperature, and fuel consumption. The data should be taken carefully with the unit warmed up and running under normal operating conditions.

GEK 28166, “Field Performance Testing Procedure,” can be used as a guide for assessing machine performance both before and after cleaning the compressor. The purpose of this particular document is to establish the performance of generator drive machines. The appropriate portions can, however, also be used for assessing cleaning effectiveness for other applications.

Output and heat rate can be corrected to a standard condition using the turbine performance curves, and an analysis may be made of compressor pressure ratio and efficiency. The current performance levels can be compared to base line data and will aid in determining the problem area.

If performance analysis indicates compressor fouling, it should be verified by a visual inspection.

V. WATER AND WATER AND DETERGENT WASHING METHOD

It is recommended that on-line water washing be addressed in the facility’s operating air permit. Regulators may interpret this as an additional short-term emissions source, requiring an exemption similar to that provided for start-up, shutdown and transient conditions.

General Electric does not recommend the use of detergents during on-line washing. For off-line washing, GE does recommend and encourages the use of detergents. The detergent effectiveness during an on-line wash is limited since there is no soak period as with the off-line wash. As the on-line washing practice has been found to be most effective when carried out daily, the specification on the liquid must be more restrictive for on-line washing than off-line washing. The duration of an on-line wash is limited to 30 minutes per day to minimize the potential for water erosion of the forward section of the compressor. The water specifications for on-line washing are given in Table 1. Likewise, the water or detergent solution being used during off-line

washing shall also meet the specifications in Table 1. The concentrated detergent which may be used for off-line washing must adhere to the Compressor Washing Detergent Specification in Appendix 1 of this document. Additional restrictions are required to ensure no harm will result to turbine components.

With the exception of the pH, the restrictions in these specifications are concerned with deposits and corrosion of the hot gas path. The pH restriction is concerned with corrosion in the water-handling system. High-purity demineralized water after contact with air will have a pH in the range of 5.0 to 6.0. Thus, allowance has been made in the pH level provided that this is the reason for the low pH.

In general, deposits will contain some water-soluble material and oils. The latter will be more amenable to removal by detergent, but the deposit may be removable by water washing alone, depending on the amount of water-soluble material present. Hot water at 150 to 200°F (66-93°C) is generally more effective than cold water, but is not required.

There are a number of detergents commercially available for the purpose of cleaning the compressor, some of which, along with the deposits that have been removed, may constitute a hazardous solid waste (as defined by the United States Environmental Protection Agency) when used for an off-line wash. Because of this possibility, local regulations should be considered for storing, handling and treating of the water wash effluent when the drain and containment system is designed.

VI. ALLOWABLE CONDITIONS FOR WATER WASH

For an on-line wash the compressor inlet temperature, CTIM from the Turbine Control Panel, must be greater than 50°F (10°C). This prevents the formation of ice at the inlet guide vanes and compressor inlet. CTIM must be measured with inlet bleed heat off.

On-line water washing shall not be performed while inlet bleed heat is operating for any reason. Do not force inlet bleed heat off to satisfy this restriction. If inlet bleed heat turns on for any reason while washing, the water wash procedure should be suspended.

For off-line water wash the operator must take appropriate precautions to prevent freezing in the compressor inlet, gas turbine, exhaust and drain system. Off-line water washing shall not be performed at compressor inlet temperatures, CTIM, less than 40°F (4°C), measured while cranking.

VII. TECHNICAL REQUIREMENTS FOR WATER WASH SKID

The following minimum technical requirements must be met in order for the water wash skid to interface with the turbine control panel for off-line pulse mode water wash applications:

A. Water Wash Skid outlet shall meet the flow, pressure, and temperature requirements defined in the Piping Schematic Diagram (MLI 0442).

B. The Turbine Control Panel shall cycle valve VA16–1, via solenoid driver 20TW–4, open and closed during the off-line water wash during the wash and rinse cycles. The valve shall not be open greater than one minute when sending water to the off-line manifold. In addition, the valve shall be closed for a minimum of 3 minutes and a maximum of 20 minutes between on/off cycles, depending on the wash mode.

C. Interface points:

   1. Piping connection to PC WW1 on MLI 0442.

2. Contact output from turbine control panel to water wash skid identifying start/stop of pump during wash/rinse cycles.

3. Contact output from water wash skid to turbine control panel indicating water flow to turbine.

4. Control output from water wask skid to turbine control panel indicating trouble.

If a customer or AE provides the water wash skid, then the party providing the skid shall be responsible for the proper function and operability of the water wash skid.

VIII. WASHING AND RESTORATION OF PERFORMANCE

A. Off-Line Compressor Wash

The intention of this portion of this recommendation is to isolate all air extraction points and drain all low points to prevent water wash effluent from entering the piping systems. General Electric recommends that all piping, which may come in contact with water, have a continuous slope to a drainable low point without traps. It is recognized that additional isolations and drains may be required depending on specific systems, equipment and customer supplied equipment and interconnect piping. It should be further recognized that valve and control logic nomenclature may vary. It is recommended that the customer develop a customized checklist for the preparation and restoration of the gas turbine for an off-line water wash, especially a valve line-up before, during and after a wash. The approximate volume of drain water collected during a complete off–line wash cycle can be found in Table 2.

Off-line compressor water wash is recommended if compressor performance due to fouling degrades 10% or greater.

1. Preparation

   a. Off-line washing solution must meet the requirements of Table 1 and the detergent concentrate must meet the requirements of Appendix 1.

   b. The cooldown procedure must be continued until the second stage wheelspace temperature has been lowered to at least 150°F (65.6°C) when measured at 30 RPM or less. See TIL 1236-2 for details.

CAUTION

To prevent thermal shock, the average wheelspace temperature must be no more than 120°F (67°C**)** greater than the water wash temperature.

   c. If the unit is equipped with off-base atomizing air compressor(s), the operating compressor should be de-energized during the pulse mode water wash cycle.

   d. If necessary, close flame detector valves or blank-off, based on both the type of flame detector and gas turbine model. Water may foul the flame scanners and make start-up difficult.

   e. Fuel manifold low point drains are to remain closed during the pulse mode wash cycle. Open at the end of the rinse cycle, prior to the start of the drying cycle to ensure that no water is present in the manifold(s).

   f. Manually isolate systems, open drains and divert drains as follows:

- The flow through the false start drain valves (VA17) must be diverted from the sludge tank to a water wash effluent tank on turbines that operate on liquid fuel or have the capability to do so. On gas-only machines there may be no false start drain valves, only manual water wash drain valves.

NOTE

The false start drain flow or any flow that goes normally to the sludge tank must be diverted from its "normal" path into the sludge tank to the water wash effluent drain system to prevent an overflow of the sludge tank. In addition, the false start drain effluent should be visible to evaluate the effectiveness of the wash cycle.

- Open the inlet plenum water wash drain valve at or near the bottom of the inlet plenum.
- Open the water wash drain valve(s) in the combustion chamber water wash drain header as well as the water wash drain valve in the manway cover.
- Close the isolation valve in the gas vent line off of the false start drain header, if applicable.
- For gas-only machines, open the main water wash drain valves in the turbine shell and exhaust frame drains.
- Close valve installed in the AD–2 lines (MLI 0417) supplying compressor discharge air to the false start drain valves, if applicable, and open downstream drain.
- Switch motor controller for the turbine exhaust frame cooling fan motors, 88TK–1 and 88TK–2 in the manual "ON" position (if provided).
- Open the exhaust plenum water wash drain valve at or near the bottom of the exhaust plenum.

NOTE

This step is necessary to prevent wash water from entering the exhaust frame cooling system during the wash cycle.

g. The atomizing air system (refer to MLI 0425), if provided, is to be isolated in the following manner:

- Close isolation valve on the inlet side of the atomizing air system from AD–8 line.
- Open atomizing air separator drain valve (if provided).

h. The cooling and sealing air circuitry (refer to MLI 0417) is isolated in the following manner:

- Close isolation valves in AE–9 and AE–13 lines. Open all low point drains just upstream of these isolation valves (CA52 and CA53).
- Close valves in all compressor discharge pressure transducer supply lines (AD–4).
- Close isolation valve upstream of AD–6. Open low point drain (CA54) on inlet side of AD–6.

- Close isolation valves to AD–1, 3 and if provided, AD–5, AD–7, AD–10, AD–11 lines.
- Close isolation valve on the inlet side of the gas purge system from PA3 line, if provided.
- Close valve in bearing sealing air supply line AE–5 from air extraction (if provided).

i. The inlet heating system (refer to MLI 0432), if provided, is isolated in the following manner:

- Close VM15–1 manually, or if motorized valve is provided, ensure it is closed.
- Open low point drain (CA20) in interconnecting piping.

2. Washing Procedure

Prior to installing the on–line and off-line nozzles and using the water wash system for the first time in the field, a preliminary flushing procedure shall be performed on the water wash supply lines to free the system of burs, dust, weld fragments, etc. The flushing recommendations may be found in 363A4220, “Water Washing Flushing Procedure.”

Prior to initiating the wash, the bellmouth, struts, and IGV’s should first be hand cleaned to prevent these deposits from being washed into the compressor during the cleaning. Refer to procedure 361A6297, “Water Washing Hand Cleaning Procedure.”

The off-line water wash flow rate is specified by the off line flow tag located on the on-base water wash system schematic (MLI 0442).

NOTE

The orifice upstream of the pneumatic injection valve VA16–1 shall be sized by the customer in order to supply the proper pressure, and thus flow, to the off-line spray nozzles. Verification that this orifice has been resized should be performed prior to washing.

The following steps shall be performed on the water wash skid (if provided by General Electric) prior to initiating the pulse mode water wash:

a. Turn on the skid breaker panels.

b. Set the HANDS/OFF/AUTO switch in the **AUTO** position in order to enable starting of the skid pump 88TW–1 via the PLC.

c. PLC on the skid will check skids required parameters.

Utilize the detergent pulse mode water wash procedure which follows:

a. On the Turbine Main Control Display Screen, place the Master Select Switch in the **CRANK** position. Select the Water Wash Control User Defined Display on the turbine control panel CRT. Select **OFF-LINE WATER WASH ON** (L43Bwon_CPB).

At this time, the turbine is prohibited from firing.

b. From the Main Control Display, initiate a turbine **START** signal. This command will crank the turbine to water wash speed via the LCI once the temperature permissives (wheelspace and inlet temperatures) have been met.

c. When cranking speed and no flame detection signals are detected, IGV's will go to full open position. The IGV's will remain in the full open position throughout the wash cycle. The sequencing will now initiate the pre-wash cycle.

A pre-wash will be initiated in order to flush all the loose contaminates such as dust and dirt from the compressor prior to applying detergent during the detergent cycle. This is a water only application which reduces the amount of dirt particles which may become entrained in the detergent foam.

NOTE

The pulse mode sequencing shall operate 3-way solenoid valve 20TW–4 such that the 2-way air actuated VA16–1 is open during the pre-wash pulse(s) and all other pulses that follow. Likewise, 20TW–4 shall close VA16–1 between pulses.

At the conclusion of the pre-wash cycle, the water wash pump will fill the supply piping with a water/detergent mixture in preparation for the detergent cycle.

d. Place the 3-way customer supplied (if applicable) valve upstream of PC WW1 to the drain position.

e. On the water wash skid, place the normally closed ball valve upstream of the venturi, in detergent line, to the open position.

f. Set the HANDS/OFF/AUTO switch in the **HANDS** position which shall manually start the wash skid motor/pump. Allow the pump to run for the appropriate time required for flushing (each site may have a different time based on the pump flow and piping arrangement).

g. When a consistent water/detergent mixture is present at the drain port of the 3-way valve or at the nozzle per visual inspection, return the HANDS/OFF/AUTO switch in the **AUTO** position.

h. Return the 3-way valve to the normal position.

Steps d through h in this procedure ensure that both water and detergent are present in the line upstream of VA16–1 prior to initiating the washing cycle.

i. The water wash control logic will be in a hold position. After the previous step has been completed, select **CONTINUE WASH** push–button (L43DET_CPB).

j. The detergent/water solution will be injected into the unit during the wash cycle(s) followed by the appropriate soaking period between the wash cycle(s).

At the conclusion of the soaking period, the customer supplied piping shall be flushed with water prior to rinsing via steps k through o which follow.

k. Place the 3-way customer supplied (if applicable) valve upstream of PC WW1 to the drain position.

l. On the water wash skid, place the normally closed detergent ball valve upstream of the venturi in the closed position.

NOTE

Step k is important in preventing detergent from entering the off-line manifold during the rinse cycle.

m. Set the HANDS/OFF/AUTO switch in the **HANDS** position which shall manually start the wash skid motor/pump. Allow the pump to run for the appropriate time required for flushing (each site may have a different time based on the pump flow and piping arrangement).

n. When only water without detergent is present in the off-line water wash supply line, return the HANDS/OFF/AUTO switch in the **AUTO** position.

o. Return the 3-way valve to the normal position.

The previous steps k through o ensure that only water is allowed to enter the unit during the rinse cycle. The object of the rinse cycle is to remove detergent from the surface areas of the compressor blades and to rinse the remainder of the unit.

p. The rinse cycle will begin when the operator selects the **RINSE** Push-Button (L43RINSE_CPB).

q. After completing the initial rinse cycle, the operator will have the choice to select an additional rinse cycle via **PULSE** Push-Button (LOFL_XTR_CPB) or **END RINSE CYCLE** Push Button (LOFL_END_CPB). If the operator elects to choose additional rinse cycles, the choice still exists to add a rinse cycle to make sure that the unit is free of detergent/contaminants. The Rinse Mode will be terminated when the operator selects the **END RINSE CYCLE** Push-Button (LOFL_END_CPB).

r. After completing the rinse cycle(s), an operator will stop the unit by selecting the **STOP** push-button off of the Turbine Control Panel interface display. This will allow the unit to coast down to turning gear speed to drain any remaining water in the unit.

s. The **WATER WASH OFF** Push Button (L43BWOFF_CPB) should be selected at this time from the Turbine Control Panel interface display.

t. Open the Gas Fuel manifold low point drains.

u. Start the unit back up for the drying cycle. The drying cycle is designed to remove any residual water left in the unit that has yet to drain out. A Master Reset may be required before selecting **START** again.

v. At the end of the 20 minute drying cycle, an operator will have to visually check the various off-line water wash drain ports on the gas turbine to ensure that no water wash effluent is flowing out of the unit. All water wash low point drains should be open at this time including all low point drains in the gas fuel, atomizing air system, inlet bleed heat and purge systems to ensure that no water has entered these systems. Once it has been confirmed that no water is draining from the unit, the drying cycle can be brought to a close by initializing a turbine **STOP** signal.

NOTE

In the event of an aborted water wash, the unit shall not be re–started until the full rinse and drying cycle is completed.

w. To end the off-line water wash drying cycle, select the **OFF** Push-Button from the turbine control panel interface display. This step terminates your Off-line Water Wash.

3. Restoration

a. Open the hand valves or remove blank-off plates on flame detectors, if applicable.

b. If applicable, set off-base atomizing air compressor motor to **AUTO.**

c. Return the following manual valves to their previous position in the order listed:

- The flow through the false start drain valves (VA17) must be diverted back from water wash effluent tank to the sludge tank on turbines that operate on liquid fuel or have the capability to do so (not applicable to gas-only machines).

CAUTION

It is important that the line that allows waste fuel to drain to the sludge tank be kept open after water washing and during normal turbine startup and operation, so that fuel or water which may accumulate in the exhaust plenum can continuously drain out of the plenum. Accumulation of waste fuel in the exhaust plenum is potentially hazardous.

- Close the inlet plenum water wash drain valve at or near the bottom of the inlet plenum.

NOTE

This step is important in preventing the intake of dirt, etc., into the compressor.

- Close the water wash drain valve(s) in the combustion chamber water wash drain header as well as the water wash drain valve in the manway cover.
- Open the isolation valve in the gas vent line off of the false start drain header, if applicable.
- For gas-only machines, close the main water wash drain valves in the turbine shell and exhaust frame drains.
- Open valve installed in the AD–2 lines (MLI 0417) supplying compressor discharge air to the false start drain valves, if applicable, and close downstream drain.
- Switch motor controller for the turbine exhaust frame cooling fan motors, 88TK–1 and 88TK–2 in the manual “AUTO” position (if provided).
- Close the exhaust plenum water wash drain valve at or near the bottom of the exhaust plenum.

d. The atomizing air system (if provided) is to be restored to the normal start-up and running mode in the following manner:

- Close all low point drains in the atomizing air lines.
- Open isolation valve on the inlet side of the atomizing air system from AD–8 line.

CAUTION

It is critical that this valve be opened to prevent damage to the turbine.

- Close atomizing air separator drain valve, if provided.
- Open isolation valve on the inlet side of the gas purge system from PA3 line, if provided.

CAUTION

It is critical that this valve be opened to prevent damage to the turbine.

e. The cooling and sealing air circuitry is reengaged in the following manner:

- Open manual isolation valves in AE–9 and AE–13 lines.

CAUTION

It is critical that the 9th and 13th stage extraction valves are open prior to firing the unit in order to prevent damage to the turbine.

- Close all low point drains just upstream of these isolation valves in lines AE–9 and AE–13 (CA52 and CA53).
- Open valves in all compressor discharge pressure transducer supply lines (AD–4).

CAUTION

It is critical that these valves be completely opened to prevent damage to the turbine.

- Open isolation valve upstream of AD–6.

CAUTION

In configurations where AD–6 is used to supply gas purge, it is critical that this valve be completely opened to prevent damage to the turbine.

- Close low point drain (CA54) on inlet side of AD–6.
- Open isolation valves to AD–1, 3 and if provided, AD–5, AD–7, AD–10, AD–11 lines.
- Close valve in bearing sealing air supply line AE–5 from air extraction (if provided).

CAUTION

It is critical that this valve be opened to prevent damage to the turbine.

f. The inlet heating system (if provided) is restored to the normal start-up and running mode in the following manner:

- Open VM15–1 manually, or if motorized valve is provided, ensure it is opened.
- Close low point drain (CA20) in interconnecting piping.
- Close all manifold low point drains opened during drying cycle.
- Close all low point drains in purge, atomizing air, and inlet bleed heat systems if opened during drying cycle.

NOTE

When the OFF-LINE WATER WASH OFF is selected, the permissive is in place to allow the unit to fire and the permissive is removed to allow the VA16–1 valve to be opened.

NOTE

Within 24 hours of completing an off–line water wash and restoring the unit to the normal firing configuration, the unit should run at FSNL for 5 minutes.

B. On-Line Compressor Wash

The intent of on-line washing is to extend the period between off-line washes through frequent washings of short duration. When the compressor is suspected of being heavily fouled, an off-line wash should be performed.

In the past, on-line water washing may have resulted in a fogging over of flame detector lenses, based on the type of flame detector, gas turbine model, and combustion system. Operating experience has shown that this is not a problem with DLN 2.0, 2.0+, and 2.6 combustion systems. It is noted that the on-line wash may result in unacceptable emission output levels during the washing cycle.

Adding water for wash will increase the compressor pressure ratio and thus reduce the surge margin. Under normal circumstances, there is ample surge margin to allow for washing and steam or water injection for NOx control or power augmentation. However, the following steps are recommended prior to performing an on-line wash.

1. Preparation

a. On-line washing solution must meet the requirements of both Table 1 and Appendix 1.

b. Turbine must be running at full speed and not in the process of shutting down.

c. Compressor inlet temperature, CTIM, must be greater than 50°F (10°C). Refer to TIL1153–3 for information on cold weather on-line water wash. On-line water washing should not be performed while inlet bleed heat is operating for any reason. Do not force inlet bleed heat off to satisfy this on-line wash requirement.

d. For units operating with water or steam injection for NOx control or power augmentation, the water or steam injection should be selected off or reduced to 3% maximum of compressor inlet flow.

2. Washing Procedure

a. The unit should be operating at base load.

b. Once the permissives have been satisfied, the operator is to select **ON-LINE WATER WASH ON** push button (L83WWON_CPB). The unit should be unloaded (approximately 3%), slightly off base load, transitioning from temperature control to speed control. This will prohibit the unit from "peaking" during the wash cycle.

NOTE

Selection of On-Line wash is not sealed in if the permissives are not met at any time. On-Line Water Wash On will have to be reselected once the fault or permissive is clear.

c. The unit controller will then open the on-line water wash inlet valve VA16–3 and signal the water wash pump to start.

d. If all permissives are met, the on-line wash cycle will begin and continue for approximately 30 minutes.

e. The operator can abort the on-line wash at any time by selecting **ON-LINE WATER WASH OFF** (L83WWOFF_CPB).

f. At the end of the cycle the on-line wash will automatically select off.

g. At the conclusion of the on-line wash, the operator is to select **BASE LOAD** or some other desired load target to return the unit to normal service.

C. Results of Washing

After cleaning, there should be a noticeable increase in performance based on the site conditions and gas turbine models. Increase in performance is a function of how fouled the compressor was initially. An increase in BASE load power of 10% is not uncommon following an off-line wash. This can be confirmed by comparing restored performance data to levels of performance before washing, utilizing the procedure in GEK 28166 for generator drive machines and the appropriate procedure for other applications as previously described under Performance Monitoring. It should be noted that full power may not always be regained once significant fouling occurs. Regular compressor washing will help maintain performance. Specific intervals must be determined based on customer performance.

TABLE 1

QUALITY SPECIFICATION

OFF-LINE WASHING (for water only or detergent and water applications)	
TOTAL SOLIDS (dissolved and undissolved)	100 ppm
TOTAL ALKALI METAL	25 ppm
OTHER METALS WHICH MAY PROMOTE HOT CORROSION (i.e. lead, vanadium)	1.0 ppm
pH (determined by glass electrode)	6.5 to 7.5
See Table A1 in Appendix 1 for chemical specifications.	
ON–LINE WASHING (for water only applications)	
TOTAL SOLIDS (dissolved and undissolved)	5 ppm
TOTAL ALKALI AND OTHER METALS WHICH MAY PROMOTE HOT CORROSION	0.5 ppm
pH (determined by glass electrode)	6.5 to 7.5

TABLE 2

APPROXIMATE WATER USAGE DURING AN OFF–LINE COMPRESSOR WASH

Gas Turbine	Total Volume	Volume of Five Additional Rinse Pulses
MS7001FA+e	1650	250
MS9001FA+e	2400	300

Total volume represents the minimum volume of water that may be used during a complete off–line compressor wash. Total volume will vary based on the operator's decision to perform or bypass additional rinse pulses following the rinse sequencing.

APPENDIX

COMPRESSOR WASHING DETERGENT SPECIFICATION

I. SCOPE

A. This specification is for cleaning compounds for use in compressor washing. It is required that these compounds will not cause harm to gas turbine components. Thus, their purity and composition must be such that they do not cause aqueous corrosion or stress corrosion of compressor materials. Also, it is required that they do not cause hot corrosion in the turbine. Furthermore, they must not lead to compressor fouling. With regard to the cleaning agents themselves, they must be chemically stable in themselves and in their mixtures with water. Also, they must not form combustible mixtures and they should satisfy all local codes relative to health and safety requirements. Compliance with this specification does not imply a cleaning compound improves the cleaning of a compressor over and above what can be obtained from water alone.

II. REQUIREMENTS

A. The cleaning compound when mixed with water in the manufacturer's prescribed concentration shall satisfy the water washing specifications for on-line and off-line water quality given in Table 1. In the pure state it shall satisfy the specification given in Table A1.

B. The residue or ash content of the cleaning compound shall not exceed 0.01%. See test IV A.

C. The storage stability of the cleaning compound shall show no marked color change, shall not separate and shall not corrode or stain the steel specimen when tested as specified in test 4.5.16 of MIL–C–85704A. This test is given in IV B.

D. The cleaner and its mixtures with water shall not form gums under compressor conditions.

E. The Pensky-Martens flash point of the cleaning compound shall be above 140°F (60°C) (ASTM D93).

III. MATERIAL COMPATIBILITY

A. Use of the cleaning compound shall not have adverse effects on engine system materials such as compressor or turbine materials.

IV. TESTS

A. Ash content: preparation of test samples

Approximately 10 g of cleaning compound shall be weighed to the nearest 0.1 mg in a tared porcelain crucible. The crucible shall be heated at 221° ± 2°F (105° ± 1°C) for 24 hours, then heated at 464° ± 4°F (240° ± 2°C) for the next 24 hours. Following this, the crucible and its contents shall be carefully ignited over a Bunsen-type gas burner. The crucible shall then be placed in a muffle furnace at 1,900°F (1,040°C) for 2 hours. The crucible shall be transferred to a desiccator, cooled and weighed until constant weight. The ash content shall be calculated as the percentage of the initial weight of cleaning compound.

B. Accelerated storage stability (from MIL–C–85704A)

1. Preparation of test sample

A 150-ml portion of a well-shaken cleaning compound shall be poured into each of two chemically clean 250-ml pressure-resistant clear glass bottles which shall be approximately 9.5 inches (24.1 cm) in height and 2.5 inches (6.4 cm) in outside diameter. One bottle shall be capped and stored in the dark for at least six days at room temperature. A strip of steel 6 by 0.5 by 0.02 inches (15.2 x 1.3 x 0.05 cm) conforming to MIL–S–7952 shall be polished to remove surface contamination and then cleaned by boiling for one minute in chemically pure isopropyl alcohol and one minute in mineral spirits. The steel strip shall be placed in the other test bottle and the bottle shall be capped. The capped bottle containing the steel strip shall be thoroughly shaken for one minute.

2. Procedure

The capped bottle containing the steel strip shall be placed in a water bath and heated at a uniform rate to a temperature of 140° ± 4°F (60° ± 2°C) over a period of five hours. It shall be held at this temperature for three hours. No heat shall be applied to the bath overnight. The above heating procedure shall be repeated each day for five days. (This test need not necessarily be attended if an interval time is used to regulate the temperature automatically. The test may be started on a Wednesday, Thursday or Friday and still have the pressure bottle removed on a normal workday.) On the morning of the sixth day, the bottle shall be removed from the bath, uncapped, examined for separation and the steel strip carefully withdrawn from the cleaning compound. Separation into layers shall be cause for rejection. The portion of the steel strip which had been immersed in the compound shall be examined for evidence of pitting, corrosion and uneven darkening. The open bottle shall be capped and the two bottles shall be thoroughly shaken for one minute, then allowed to remain undisturbed for one hour at room temperature and then examined. Any marked change in the color and uniformity of the aged sample shall be considered as showing unsatisfactory stability properties.

TABLE A1
CHEMICAL CONTENT OF WASHING DETERGENT

Total alkali metals	25 ppm max
Magnesium + calcium	5 ppm max
Vanadium	0.1 ppm max
Lead	0.1 ppm max
Tin + copper	10 ppm max
Sulfur	50 ppm max
Chlorine	40 ppm max

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