GE Power Systems

Requirements for Water/Steam Purity in Gas Turbines

Does Not Apply to FB and H Gas Turbines

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.

I. INTRODUCTION

This document provides the requirements for water/steam purity for injection into all GE gas turbines except Classes FB or H. Impurity limits for water and steam injection into FB and H gas turbines, specified in GEK 107230, are more stringent than the limits in this document. Refer to GEK 107230 which provides the requirements for FB and H equipment.

Water and/or steam is injected into the combustion system for NOx control and/or power augmentation, in quantities comparable to fuel flow rates, and must meet strict criteria for purity similar to those required for gas turbine fuels. Furthermore, water/steam chemistries must be compatible with the materials used in the piping that bring the fluids to the turbine.

Water/steam, fuel and air all carry contaminants that can cause serious damage to hot gas path components if the levels at which they are present are not controlled. This document identifies the contaminant limits for water/steam entering gas turbines. Ultimately, the total contaminant loading allowed is determined by the fuel specifications (GEl 41047H, for liquid fuel, and GEI 41040G, for gas fuel), which identify all contaminants entering a gas turbine from all sources. The concern for any contaminants entering the hot gas path is two-fold: 1) will they cause hot corrosion, as for example do sodium and potassium salts, and 2) will they cause deposits, as for example, do calcium salts and silica.

Water also enters gas turbines with the compressor air. This may occur naturally as from water ingestion in coastal or marine locations, or from rain, or from water produced when humid air is cooled below its dew point at the compressor inlet and a fog develops. Water may be injected or fogged intentionally at the compressor inlet to cool the inlet air such as with the SPRITS system. Finally, water can enter a compressor as a result of carryover from such devices as moisture separators or evaporative coolers. Discussion of inlet air treatment is discussed in GER 3419. The effects of water on compressor materials are discussed in GER 3601.

Water of evaporation adds no contaminants to the incoming air, but carry-over water adds to the contaminants contained in the air/water/fuel stream. Sump water purity requirements for evaporative coolers are separate from the water quality requirements for water injection and are given in GEK 107158a.

Additional sources of water-born contaminants that enter the turbine are referenced in the following-documents: compressor and turbine washing (GEK 107122, GEl 41042 or GEK 103623), and water for dissolving Epsom salt, the heavy fuel vanadium inhibitor (GEK 28122).

II. WATER INJECTED AT THE COMPRESSOR INLET

The limit on the purity of water injected at the compressor inlet for the purpose of inlet air cooling (SPRITS) is imposed to prevent compressor degradation due to deposit build up and pitting or stress corrosion cracking. These requirements are much more stringent than for water washing. For inlet fogging, a maximum a water injection rate of 8 lbs water per 1000 lbs inlet air shall apply.

The limits on chloride and specific conductivity for water injected at the compressor inlet are given in Table 1. This requirement is for injected water purity only, and does not address other design requirements for SPRITS or other inlet fogging systems.

III. INJECTION OF WATER/STEAM AT THE COMBUSTOR INLET

The maximum total dissolved solids plus total suspended solids of injected steam or water (or a mixture) must be less than 5 ppmw. In addition, specific limits on impurities that could damage hot section components are applied

All flows (air, water/steam, and fuel) into the turbine contribute to the contaminants in the combustion gases, and hence to corrosion and deposits in the hot gas path. The allowable purity of water/steam for gas turbine injection is thus dependent upon the level of impurities in the fuel. Table 2 specifies the limits of the impurities in the air/water/fuel mixture that enter the combustors. Equation 1 provides a means of determining the total impurities in combustion gas mixture if the impurity contents of air, water/steam and fuel and their respective flow rates are know. Using the limits in Table 2 and Equation 1 to calculate the total impurity limit, one determines the maximum impurity limits for the water/steam.

Equation 1

$$(A / F) Xa + (W / F) Xw + Xf =$$ Total air+water/steam+fuel contamination (ppmw), referred to the fuel concentration

...where A, W, F are air, water and fuel flows (lbs/sec), respective; and Xa, Xw, Xf are air, water and fuel contaminant concentrations (ppmw), respectively. Water injected at the compressor inlet plus water or steam injected at the combustor inlet shall be summed to determine the total water injection rate. Examples of this calculation are shown in Appendices A and B.

Standard analytical methods for water and steam analysis are given in Table 3. Although no standard method exists for sampling compressor air, EPA 40 CFR 50 gives a number of methods for sampling particulate. Chemical analysis would be according to EPA 200.7 for particular contaminants.

If fuel purity is not known then the water purity equivalent to clean boiler condensate (with less than 0.2 µS/cm cation conductivity and less than 0.02 ppmw alkali metals) or demineralized make-up water (with less than 0.2 µS/cm specific conductivity and less than 0.02 ppmw alkali metals) is required. The injected steam must meet the requirements of GEK 98965. Volatile additives such as ammonia, morpholine, or cyclohexlamine are permitted for condensate pH control of the source of the steam. These additives do not add to the alkali burden of the turbine, and will not accumulate in piping, valves, etc.

Water treated with sodium compounds for pH or oxygen control should not be used for injection into gas turbines or for attemperation of steam used for injection into gas turbines. Such water can lead to high sodium in the air/water/fuel mixture and cause corrosion of the hot gas path components. It may also lead to stress corrosion cracking of piping equipment. It should be appreciated that very dilute solutions of some additives become concentrated during operation, through stagnation and evaporation.

This is especially true of NaOH. Attemperation water, containing NaOH, has produced caustic deposits in 316 stainless steel flex hose by evaporation, resulting in cracking. Units in which this has occurred have reported fuel nozzle deposits, first stage nozzle deposits, and bucket corrosion.

Deposit formation in the turbine from contaminants in injection water is also a concern. In demineralization ion exchange systems, a special situation may arise in the case of silica. Silica absorbed by the anion exchanger may not be completely removed during regeneration causing it to accumulate. Eventually, leakage will occur, allowing silica discharge into the effluent and into the turbine. Such occurrences have led to combustion liner hole plugging and forced outages. Prevention of silica breakthrough requires longer regeneration times at higher temperatures, and effluent monitoring.

NOTE

Ion exchange manufacturers should be-consulted.

Another problem arises if silica is present in a colloidal form. In this form it can pass through ion exchangers and it cannot be detected by conductivity measurements. Water treatment experts should be consulted. They can make recommendations concerning proper treatment.

IV. APPLICABLE REFERENCE DOCUMENTS

- GEI 41047 Gas Turbine Liquid Fuel Specification
- GEl 41040 Process Specification, Fuel Gases For Combustion in Heavy-Duty Gas Turbines
- GER 3419 Gas Turbine Inlet Air Treatment
- GER 3601 Gas Turbine Compressor Operating Environment and Material Evaluation
- GEl 41042 Gas Turbine and Compressor Cleaning
- GEK 103623 Gas Turbine Compressor Washing
- GEK 28122 Specification For Magnesium Sulfate For Gas Turbine
- GEK 98965 Steam Purity For Industrial Turbines
- GEK 107158 Water Supply Requirements for Gas Turbine Inlet Air Evaporative Coolers
- Nalco Water Handbook, Frank N. Kemmer, Editor, McGraw-Hill, Second Edition, 1988

TABLE 1. WATER PURITY REQUIREMENTS FOR INLET FOGGING (SPRITS)

Choride (as Cl)	300 ppbw*
Specific Conductivity	2 microSiemens/cm

* parts per billion by weight

TABLE 2. TRACE METAL CONTAMINANT SPECIFICATION MAXIMUM LIMITS, ALL SOURCES

Contaminant	Contaminant Limit (ppmw) Referred to the Fuel(1)
Sodium plus Potassium	1.0
Lead	1.0
Vanadium	0.5
Calcium	2.0

(1) The tabulated limits in parts per million by weight (ppmw) are for A / F = 50. For other A / F ratios multiply the tabulated limits by ((A / F + 1) / 51). The total contamination referred to the fuel from all sources is determined from Equation 1.

TABLE 3. STANDARD ANALYTICAL METHODS FOR WATER/STEAM

	Method
Trace Metals:	
Sodium plus Potassium(1)	EPA 200.7
Calcium	EPA 200.7
Total Solids:	
Total dissolved solids	EPA 160.1
Total suspended solids	EPA 160.2

(1) Other metals not normally encountered in water/steam but found in fuel oils, such as vanadium and lead, or other alkali metals such as lithium, are also to be included.

V. APPENDIX A

WATER AND STEAM PURITY CALCULATIONS TO DETERMINE IF WATER PURITY IS ADEQUATE

Liquid Fuel with Water Injection with water/fuel ratio of 0.5 and air/fuel ratio of 50.

Example Liquid Fuel Impurity Content		Example Air Impurity Content		Example Water Impurity Content	
Na + K	0.5 ppmw	Na+K	0.001 ppmw	Na+K	0.25 ppmw
Lithium	0.05 ppmw	Ca	0.002 ppmw	Ca	1.5 ppmw
Lead	0.2 ppmw	Si	0.002 ppmw		
Vanadium	0.1 ppmw				
Calcium	0.5 ppmw				

Na+K (include other alkali metals):

Required: $(A / F)\,Xa + (W / F)\,Xw + Xf <= 1.0$ ppmw Na+K

The sodium plus potassium content of the water meets the requirement.

V:

Since there is no V content in the water, the water meets the requirement.

Ca:

Required: $(A / F)\,Xa + (W / F)\,Xw + Xf <= 2.0$ ppmw Ca

The calcium content of the water meets the requirement.

VI. APPENDIX B

WATER AND STEAM PURITY CALCULATIONS TO ESTABLISH MAXIMUM WATER LIMITS

Liquid Fuel with Water Injection with water/fuel ratio of 0.5 and air/fuel ratio of 50.

Example Liquid Fuel Impurity Content		Example Air Impurity Content	
Na + K	0.5 ppmw	Na+K	0.001 ppmw
Lithium	0.05 ppmw	Ca	0.002 ppmw
Lead	0.2 ppmw	Si	0.002 ppmw
Vanadium	0.1 ppmw		
Calcium	0.5 ppmw		

Na+K limit (include other alkali metals):

$(A / F) Xa + (W / F) Xw + Xf = 1.0$

$Xw = (F/W)(1.0 - (A / F) Xa - Xf)$

The maximum limit of Na + K plus other alkali metals in injected water is 0.8 ppmw.

V limit:

$(A / F) Xa + (W / F) Xw + Xf = 0.5$

$Xw = (F/W)(0.5 - (A / F) Xa - Xf)$

$Xw = (2)(0.5-0.1) = 0.8$ ppmw V

The maximum limit of V in injected water is 0.8 ppmw. (V is not usually found in water)

Ca limit:

$(A / F) Xa + (W / F) Xw + Xf = 2.0$

$Xw = (F/W)(2.0 - (A / F) Xa - Xf)$

$Xw = (2)(2.0-50*0.002-0.5) = 2.8$ ppmw Ca

The maximum limit of Ca in injected water is 2.8 ppmw

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