GE Power Systems
Gas Turbine

Requirements for Water/Steam Purity in Gas Turbines

I. INTRODUCTION

Water/steam, fuel and air all carry contaminants which 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 (GEI 41047, for liquids, and GEI 41040, for gases), which identify all contaminants entering a gas turbine from all sources. The concern for any contaminants entering the hot gas path is two-fold. Will they cause hot corrosion, as for example do sodium and potassium salts, and will they cause deposits, as for example do calcium salts and silica.

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 which bring the fluids to the turbine.

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. Finally, water can enter a compressor as a result of carry-over 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 is discussed in GER 3601.

Of course, water of evaporation adds no contaminants to the incoming air, but carry-over water adds the contaminants contained in the water.

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

II. INJECTION WATER/STEAM SPECIFICATION

Table 1 gives criteria for acceptable water/steam for gas turbine injection. 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 fuel specification GEI 41047 states that the sum of the contaminants from all sources, referred to the fuel must satisfy the fuel specification. This part of the fuel specification, given in Table 2, forms the basis for contaminant levels entering the gas turbine from all sources.

Dissolved oxygen, pH, solids, and additives, all quantities considered in the water chemistry of boilers and steam turbines, must also be considered when water/steam is injected into gas turbines.

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 cause corrosion of the hot gas path components, and also 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, used sometimes for pH control. 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.

The preferred water sources are clean boiler condensate or demineralized make-up water. Preferred steam sources are from steam turbines. This steam should satisfy GEK 98965, which is a tighter restriction than given in Table 1. Steam from non-steam turbine sources must satisfy Table 1. Volatile additives are permitted for condensate pH control, such as ammonia, morpholine, and cyclohexylamine. These additives do not add to the alkali burden of the turbine, and will not accumulate in piping, valves, etc.

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 lead to combustion liner hole plugging and forced outages. Prevention of silica breakthrough requires longer regeneration times at higher temperatures, and effluent monitoring. *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.*

III. LIMITS ON WATER QUALITY FOR EVAPORATIVE COOLING SYSTEMS

Water quality must be maintained in evaporative coolers in order to ensure good long term system performance. Dirty water will foul the cooler media, eventually resulting in carry-over and possible damage to the gas turbine. Also, water which is very pure, such as demineralized make-up water, may degrade the materials of the cooler. *Consult the operation and maintenance manual for the evaporative cooler for specific details.*

To prevent excessive scaling of the cooler media water should be monitored to maintain one of the stability indices, such as Langelier or Ryznar (See Nalco Water Handbook, McGraw-Hill, 2nd edition, 1988).

When trace metals in the fuel, water or steam are not precisely known, a limit for these contaminants in the inlet air of 0.005 ppm is nominally set (GER 3419). Carry-over limits on contaminants may be obtained from a mass balance on the equivalent carry-over water for a specified contaminant level in the air[a]. Thus,

$$W = A(X_a / X_w) = 0.005\ (A / X_w) \tag{1}$$

where W and A are the flows of water and air , respectively, and X_w and X_a are the concentrations (ppm) of the contaminants in the water and air (1), respectively.

Figure 1 gives carry-over limits for gas turbine contaminants based on Equation (1) for several air flows. For example, if the concentration of Na in the make-up water is 100 ppm and the air flow is 300 lbs/sec, then 4 cc/sec would be the limiting carry-over rate.

IV. APPLICABLE REFERENCE DOCUMENTS

GEI 41047	Gas Turbine Liquid Fuel Specification
GEI 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
GEI 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

Nalco Water Handbook, Frank N. Kemmer, Editor, McGraw-Hill, Second Edition, 1988

(a) 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.

Table 1. Injection Water / Steam Purity Maximum Limits

		Method
Trace Metals:		
Sodium plus Potassium(1)	0.5 ppm	EPA 200.7
Calcium	1.0 ppm	EPA 200.7
Total Solids:	5.0 ppm	
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.

Table 2. Trace Metal Contaminant Specification Maximum Limits, All Sources

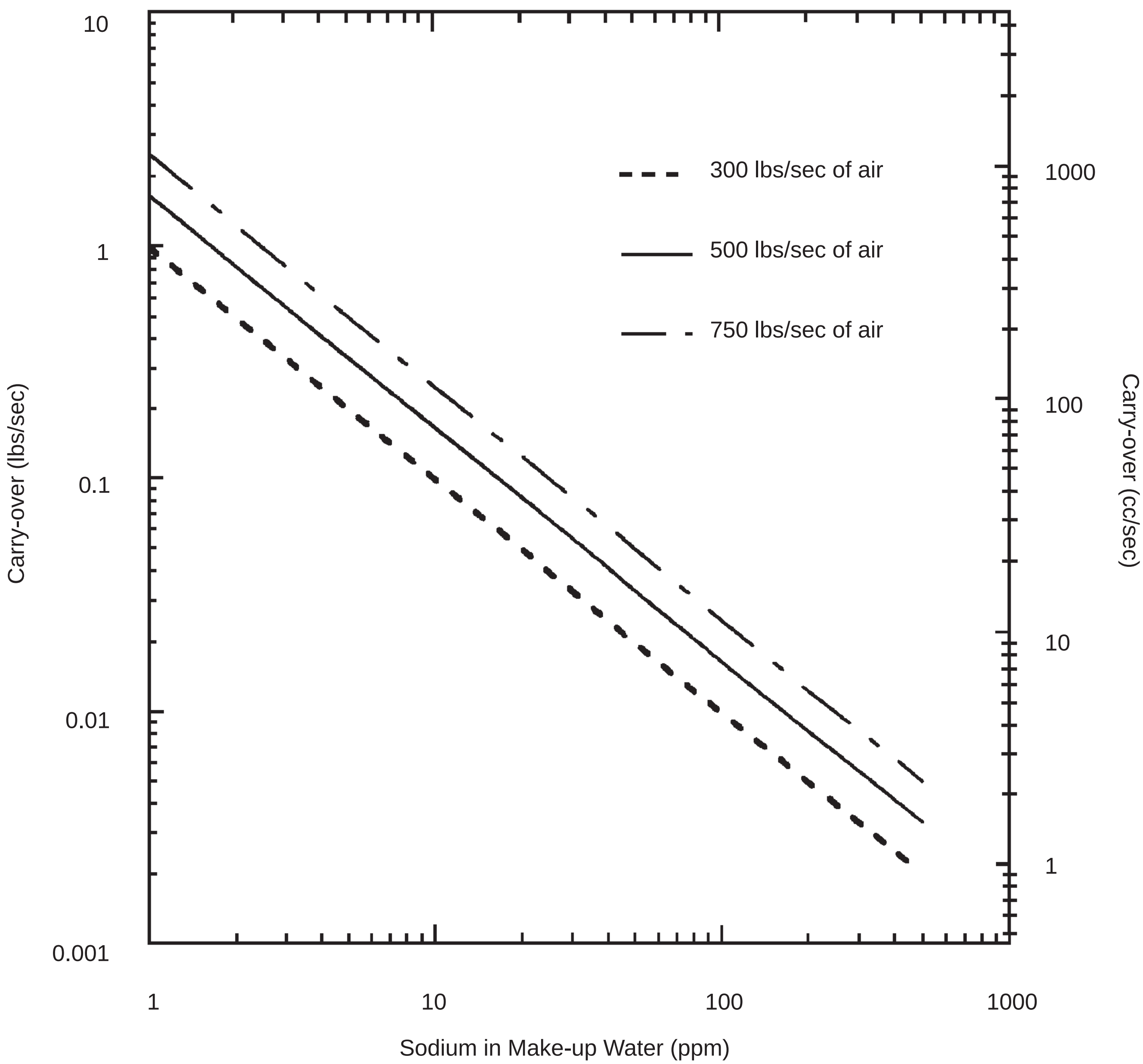
Contaminant	Contaminant Limit (ppmw) Referred to the Fuel(1)
Sodium plus Potassium	1.0
Lead	1.0
Vanadium	0.5
Calcium	2.0

(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 the equation:

$(A / F)\, X_a + (W / F)\, X_w + X_f$ = Contamination (ppmw), all sources, referred to the fuel,

where A, W, F are air, water and fuel flows (lbs/sec), respective; and X_a, X_w, X_f are air, water and fuel contaminant concentrations (ppmw), respectively.

Figure 1. Limiting Carry-Over for Minimizing Turbine Hot Corrosion



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