GEK 107230b
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GE Energy

Specification for Alkali Metal Contamination in Fuels for Gas Turbines Using Lower Chromium Superalloys

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

In order to ensure that the expected parts lives are reached, the high strength, lower chromium content (<10%) superalloys (such as N5, N4 etc.) used in the airfoils of some advanced technology GE gas turbines require a controlled, low alkali metal environment in the turbine hot gas path.

This GEK specifies the alkali metal content limits for the gas fuel, liquid fuel, inlet air, injection water, compressor wash water, evaporative media cooler water, spray inlet temperature suppression water, fuel gas moisturization water, and injection steam as may be used in the 6C, FB and H gas turbines. For these and all other machines containing lower chromium superalloys, this GEK supersedes all other specifications that may refer to alkali metal content.

Other fuel property requirements for fuels for turbines containing lower chromium alloys are to be found in GEI 41040 "Process Specification Fuel Gases For Combustion in Heavy-Duty Gas Turbines" and GEI 41047 "Gas Turbine Liquid Fuel Specifications"[1,2].

At coastal sites, it may be more cost effective to treat fuel rather than procure the fuel per the requirements of this GEK, so it is recommended that fuel be purchased per GEI 41047 or ASTM D28803 and then treated to meet the requirements of GEK 107230. Table 6 in Appendix I gives the general requirements for liquid fuel treatment.

A list of applicable documents for alkali trace metal contaminants and other properties for fuel, inlet air, water and steam are also included in Appendix I.

II. NEED FOR A SPECIFICATION

Sulfur, which is present in gas turbine fuels as H2S, COS and complex organic compounds, burns to give a mixture of sulfur dioxide, (SO2) and sulfur trioxide (SO3) Sulfur trioxide combines with sodium and potassium compounds in the combustion gas to form sulfates, pyrosulfates, and trisulfates, which deposit on airfoil surfaces. In turbines operating at inlet temperatures above 1,200°F (650°C) these sulfates are molten and cause severe corrosion of the turbine airfoils. The molten salts destroy the ability of the superalloy material to maintain a protective oxide scale that acts as the barrier against further reaction with the environment per GER 3597 "High Temperature Coating for Improved Oxidation-Corrosion Protection"[4,5].

Sodium and potassium can also combine with vanadium pentoxide to form low melting eutectics, which can in turn combine with sulfur trioxide to form sulfates with melting points in the operating range of the gas turbine. These compounds also cause severe corrosion.

Since it is not practical to limit the sulfur content of the fuel to the very low levels that would be required, these types of corrosion must be controlled by limiting the sodium and potassium content of the fuel, air, water, steam and any other flow streams to the turbine.

III. SOURCES OF CONTAMINANTS

Contributions to the alkali content of the combustion gases can come from any of the flow streams supplied to the combustor; fuel, air, water or steam. The basic parameter that can be used to track the total alkali metal concentration admitted to the turbine is Xt, and is defined as the combined sodium and potassium content of the combustion gas at the entry to the first stage of turbine.

Equation 1, given below, expresses this concentration.

$T*(Xt) = A*Xa + F*Xf + S*Xs + W*Xw$……. (EQ 1)

Where T = total flow to turbine = (A + F + S + W) in lb/s:

Xt= alkali contaminant concentration in total flow in ppbw

A = Air flow in lb/s,

Xa= contaminant concentration in air in ppbw

F = Fuel flow in lb/s,

Xf= contaminant concentration in fuel in ppbw.

S = Steam flow in lb/s,

Xs= contaminant concentration in steam in ppbw.

W = water flow in lb/s.

Xw= contaminant concentration in water in ppbw.

The overall level of alkali contamination entering the gas turbine depends upon the machine type, the fuel type and site conditions and must be controlled. The upper spec limits in fuel, water and steam have been derived in a way that combined with air contamination, a target value of 20ppbw for total alkali at the turbine inlet, is not exceeded. Exceptions to this limit are observed if the air has unusually higher alkali contamination of more than 15ppbw. A typical value of total alkali, calculated using EQ1, is shown in Appendix-II and is well below the target value of 20ppbw. The impact of individual contribution from air, fuel, water and steam is discussed below:

A. Air

1. Contamination in Air

The salt content of air is very dependent on location, with the highest values being on or immediately adjacent to the sea. An average value of 2.6ppbw of Na, based on measurements at 41 inland sites has been quoted[6]. Inland locations that are close to dry lakebeds or situated in heavily industrial areas may experience higher than average concentrations for inland regions. The value for a coastal area (defined as within 12 miles of a coast) is dependent upon the distance from the coast. As an example the average salt contents approximately 5 miles from the coast is 7ppbw, as referred in GER 3419.

In ambient air, the trace metal contaminants are present in water droplets and these can be removed by air filters and moisture droplet separators (if installed in the inlet system). The range of sodium levels downstream of filters and moisture separators is, therefore, expected to be lower than the concentrations mentioned above, depending upon the removal efficiency of such equipment. Thus, for applications in extreme dry climates, the air alkali concentration at the compressor inlet may be less than the ambient air concentration due to filtration and removal of dry salt particles. However, for climates where the relative humidity exceeds approximately 70%, the salt particles and deposits will deliquesce forming concentrated brine droplets that will pass through the air inlet filtration

system. Therefore, it should be assumed that filers do not reduce the salt concentration in the inlet air.

If an evaporative media cooler or a spray inlet temperature suppression system (SPRITS) is provided with the inlet air system, then these cooler systems[7,14] will also make a contribution to the sodium and potassium content of the inlet air. The alkali metal contribution allowed in inlet air, which has been cooled by evaporation of water or SPRITS, should be minimized and the purity of the water used for cooling must be controlled. The alkali requirements for 6C, FB and H for this water, expressed as sodium, are given in Table 4 of Appendix I.

B. Steam

1. Specification/Contamination in Steam

The maximum alkali metal (sodium plus potassium) content of steam to be used for injection and for Gas Turbine cooling steam is 5ppbw, expressed as sodium. Steam for turbine injection is typically taken from a suitable extraction point on a system steam turbine or HRSG and the sodium level is generally in the range of 3 to 6 ppbw[8, 9].

In some cases, the extracted steam may not be at the exact condition needed for injection and the temperature and pressure are adjusted by spraying water into it. This process, called attemperation or desuperheating, must use water of controlled purity. Typically, this water will be condensate or boiler feed water, which has been polished as described in section C. The steam, after attemperation, must meet the alkali metal content specification of 5ppbw.

C. Water

1. Specification/Contamination in Water

The maximum alkali metal (sodium plus potassium) content of water to be used for injection is 20ppbw, expressed as sodium, and is more stringent than allowed for other machines. Water that meets this requirement will generally have a cation conductivity of 0.2–0.3 µS/cm. To obtain water with this level of purity, steam turbine condensate may be passed through a mixed bed ion exchange (polishing) system or raw water may be processed through a membrane pretreater followed by a multiple bed demineralization and polishing system. Each of these processes will be capable of producing water that will meet the sodium requirement and also meet the conductivity value[10].

The concentration of sodium in steam and water, at the levels specified, can be measured directly using an on-line sodium analyzer or, in the laboratory, with an ion or pH meter fitted with a “sodium specific” electrode or by an atomic absorption spectrometer fitted with a graphite furnace.

If fuel moisturization is offered as an option, the quality of the moisturized fuel should meet the quality of the fuel. The blow down of the water in the moisturization unit should be set in a manner that moisturized fuel does not exceed the alkali limits expected from the fuel without moisturization. Periodic sampling of the moisturized fuel at suitable locations of the moisturization unit be made and analysis should conform to the requirements in Section IV.

The requirements for compressor wash water for machines containing lower chromium superalloys has been set at limits similar to the limits for other machines and included in Table 4 of Appendix I.

D. Contamination in Fuel

The final source of contamination to be considered is the fuel. Most cases of alkali metal contamination and corrosion of hot gas path components are related to fuel contamination. The issues and requirements with gas and liquid fuels are discussed in the following section. This limit includes all alkali metals, e.g. potassium and lithium as well as sodium. Experience, however, has shown that sodium is generally by far the preponderant metal.

IV. GAS TURBINE FUELS

Both gas and liquid fuels may be burned in advanced technology turbines. A brief description of the fuel types is included here while a more extensive description of gas turbine fuels, their properties and requirements is to be found in GEI 41040 and GEI 41047[1, 2].

A. Gas Fuels

Advanced technology turbines using lower chromium superalloys have the ability to burn a wide range of gaseous fuels as shown in Table 2 (Appendix I). These gases present a broad spectrum of properties due to both active and inert components.

1. Natural and Liquefied Petroleum Gases

Natural gas is predominantly methane with much smaller quantities of the heavier hydrocarbons, ethane, propane and butane. As produced, natural gas contains varying degrees of nitrogen, carbon dioxide, hydrogen sulfide, and contaminants such as salt water, sand and dirt. Processing by the supplier normally reduces and/or removes these non-hydrocarbon constituents and contaminants prior to use. The presence of excessive amounts of alkali metals in natural gas is unusual but not unknown. Dependent on the geographical location and the means of transportation there is the potential for a natural gas supply to contain sodium from salt water.

Prior to commissioning the power plant, a complete analysis of the fuel gas, as described in this specification and in GEI 41040, should be provided to GE Energy. From time to time during operation, regular gas analyses should be performed to ensure that the fuel supply to the gas turbine continues to meet the alkali metal requirements of this specification. Liquefied Petroleum Gas (LPG) is rarely used as turbine fuel because of its high commercial value. It has been used as backup fuel and during periods of temporary over supply.

2. Synthesis and Process Gas Fuels

Synthesis and process gas fuels are not normally burned in advanced technology gas turbines using lower chromium superalloys. Consult GE for special recommendations if they are to be used.

3. Alkali Metal Contaminants in Gas Fuels

Assumptions:

1. Alkali contamination in air = 2.6ppbw for inland sites (>12 miles from sea)

2. Alkali contribution from evaporative cooler, fuel moisturization and SPRITS system are controlled by controlling either water quality or moisturized fuel quality per this GEK.

3. Alkali contribution from water/steam injection (when offered) is controlled by controlling the purity of steam/water per the requirements of this GEK.

Recommended Gas Fuel Specification: Maximum alkali metals 0.2ppmw for inland and trace levels for coastal sites.

This limit is considered to include all alkali metals, e.g., potassium as well as sodium. Experience, however, has shown that sodium is generally by far the preponderant alkali metal. For inland sites, which are located in heavily industrial areas, sometimes, the air alkali contamination is likely to exceed 2.6ppbw. For sites like this, GE should be contacted for additional recommendations.

B. Liquid Fuels

1. True Distillate Fuels

Advanced technology gas turbines have the ability to burn a range of liquid fuels as shown in Table 3 (Appendix I). **These fuels are limited to true distillates.** Within the true distillates, fuels vary in hydrocarbon composition, physical properties, pollutants and trace metal contaminant levels.

2. Ash-Bearing Fuels

The ash bearing fuels comprise the Crudes, blended residual fuels and heavier residual fuels, as described in GEI 41047 and currently must not be used in advanced technology gas turbines.

3. Specification for Alkali Metal for Liquid Fuels in the 6C, FB and H Turbines

Assumptions:

1. Alkali contamination in air = 2.6ppbw at inland sites (>12 miles from sea coast)

2. Alkali contribution from evaporative cooler, fuel moisturization and SPRITS system are controlled by controlling either water quality or moisturized fuel quality per this GEK

3. Alkali contribution from water/steam injection is controlled by controlling the purity of steam/water per the requirements of this GEK

4. A 2000 hour maximum operation time on liquid fuel per one hot gas path inspection interval (24000 hours, assuming a maintenance factor of 1) applies. All other applicable maintenance factors should be taken into account depending on the application. If it is anticipated that the operation with liquid fuel could exceed 2000 hour, GE should be consulted for additional recommendations.

Recommended Liquid Fuel Specification: Maximum alkali metals 0.5ppmw for inland sites and 0.2ppmw for coastal sites.

This limit is considered to include all alkali metals, e.g., potassium as well as sodium. Experience, however, has shown that sodium is generally by far the preponderant alkali metal. For inland sites, which are located in heavily industrial areas, sometimes, the air alkali contamination is likely to exceed 2.6ppbw. For sites like this, GE should be contacted for additional recommendations.

V. LIQUID FUEL HANDLING, TREATMENT AND STORAGE

True distillate fuel, as refined, contains levels of water, dirt, and trace metal contamination well within the requirements of GE fuel specifications as given in GEI 41047. These levels can be maintained with careful transportation, handling, and storage methods. Contamination of fuel occurs most frequently during transportation and usually involves sea water or industrial process water.

When barges or other bulk modes of transportation supply liquid fuel, it should be pumped directly into raw fuel storage tanks, and conditioned or treated before being placed in clean fuel storage tanks from which the gas turbine will be supplied. After filling any tank or adding fuel to it, a settling time of 24 hours should be allowed before burning fuel from that tank. Initially, water and sludge should be drained from all storage tanks on a daily basis. After experience is gained with a given fuel and fuel source, the frequency of draining may be adjusted by the customer.

After filling the clean fuel storage tanks and allowing a 24-hour settling time, fuel samples should be analyzed to ensure that the fuel discharged from these tanks meets the fuel specification. At least two tanks of clean, “settled” fuel should be available at all times. in this way it will be possible to switch to a new tank if successive analyses show contamination in the fuel going to the turbine.

Contamination during transportation may raise the allowable alkali above the limit for turbines using lower chromium superalloys. Under these circumstances a fuel treatment system must be installed between the delivery tank and the clean fuel storage tank. The fuel treatment system will remove water and dissolved alkali salts. In some cases a small quantity of de-mineralized water may be required by the fuel treatment system if the delivered fuel is ‘dry’, that is has a water content less than approximately 0.1% but exceeds the alkali limit. Up to 0.2 % water may be required for dilution purposes. A smaller quantity is required for periodic flushing of the fuel treatment equipment. If a fuel treatment system is installed, there is no need for a delivered fuel settling period prior to treatment. This relaxation will reduce the size of the delivered fuel tank if the fuel can be processed immediately on delivery.

VI. FUEL SAMPLING AND ANALYSIS

A. Methods of Sampling

The sodium and potassium salts, which are the common alkali metal contaminants present in fuel, are not soluble in hydrocarbons and they will be present in fuels in solution in liquid water particles or adsorbed on the surfaces of solid particles.

The sampling of gas turbine fuels, whether gaseous or liquid, for alkali metal contamination, presents two challenges:

1. getting a representative two phase sample from the fuel storage vessel or fuel supply stream and then

2. getting a true sample, including the contaminant, into the analyzer.

B. Sampling and Analysis of Gas Fuels

The ASTM sampling procedure for gas fuels is given in D-5287. This method is designed for single phase flow and may not give representative results for liquid and solid materials suspended in the gas. Since alkali metals will be present in liquid water particles or adsorbed on the surfaces of solid particles the method of sampling needs to be valid for gas/liquid or gas/solid two phase flow.

The use of an isokinetic sampling nozzle will give a representative sample and will allow a sample to be removed from the fuel supply pipe such that there is no change in gas velocity as the sample enters the nozzle[11]. EPRI has designed a suitable nozzle for steam sampling but it can be used for other gases. Information on the design of is given in reference 11 or can be obtained from GE Energy.

The gas sample is passed from the isokinetic nozzle through a pressure-reducing valve into high purity water, (18 megohm resistance or conductivity < 0.06 µs/cm) where the alkali metals are absorbed. The gas flow is monitored accurately, with a flow meter downstream of the absorption solution, until 10–11 cubic feet of gas has passed through the absorber.

The water solution is then analyzed for alkali metals using ASTM methods D-4191 or D-6071. To achieve the level of sensitivity for detection of Na + K to the level required, method D-6071 which uses a flameless (graphite furnace) atomic absorption spectrometer may be necessary.

C. Sampling of Liquid Fuels

Sampling of liquid fuels may be done manually or automatically as described in ASTM methods D 4057 and D 4177.

A period of 24 hours of settling, following the fuel delivery, is recommended before sampling the fuel tanks for analysis. For storage tanks receiving the fuel, the sampling and analysis should be done whenever a new supply is obtained. Samples may be taken at different levels from large volume tanks per ASTM D 4057. For all fuel sampling, sufficient samples (a minimum of 3) must be taken to ensure that a representative sample is obtained. For guidelines for the general requirements of the sampling probes for manual sampling of tanks as well as pipelines, refer to details in ASTM D 4057.

For advanced technology gas turbines at coastal sites, a fuel treatment system is required between the delivery tank and the clean fuel storage tank. Although the fuel treatment system will remove water and dissolved alkali salts from the fuel, within the specification, some samples must be taken at the fuel skid immediately upstream of the flow divider. Initially the frequency of sampling and analysis may be set to a higher level (say 4-8 hours), after gaining experience this frequency may be lowered. For automatic sampling, ASTM D-4177 provides guidelines for the probe design, sampling frequency and probe location to obtain a representative sample.

To avoid contamination, all samples must be obtained in clean, rigid plastic bottles. Metal cans flexible plastic bottles and all containers with elastomer seals should not be used. The container should only be filled to about two-thirds so that the sample may be well shaken before analysis.

For alkali metal analysis the volume of the sample taken should be 200–400 ml.

D. Analysis of Liquid Fuels

Water Washing Method:

The oil sample should be taken from full flow in a supply pipe, as oil is being delivered to the turbine or to a storage tank. When received for testing the entire sample (200–400 ml) should be shaken well in its container and transferred to a separating funnel. It should then be extracted with two 20–25 ml portions of high purity water (18 megohm resistance or conductivity < 0.06 µs/cm). The water extracts should be combined and diluted to exactly 50 ml. The volume of the oil should then measured in a graduated cylinder to the nearest 2–4 ml.

The water solution should then be analyzed for alkali metals using ASTM methods D-4191 or D-6071.[12]

To analyze for Na + K, to the detection level required, method D-6071, which uses a flameless (graphite furnace) atomic absorption spectrometer, may be necessary.[13] If the analysis result is higher than specification additional, duplicate fuel samples should be taken.

If three successive analysis results are out of specification, investigation for cause and corrective action should be undertaken.

Digestion Method:

In this method a representative sample of the liquid fuel is digested with acid in a closed microwave transparent vessel, using microwave heating. The digestate is then analyzed by direct aspiration or injection by flame atomic absorption spectrophotometry (FAAS), inductively coupled plasma emission technique (ICP), direct current plasma emission technique (DCP), or graphite furnace atomic absorption (GFAAS) method, or a combination of methods.

The analysis is carried out per ASTM D 4309 and D 5673.

Other Methods:

Other methods may be used but their accuracy should be established relative to the two methods recommended above.

VII. WATER/STEAM SAMPLING AND ANALYSIS

Water and steam sampling and analysis are covered in the documents listed in Appendix-I but test methods controlling the quality of water and steam are listed in the following table.

Table 1. Water and Steam Control Parameter Test Methods

Target Parameter	ASTM and other Methods[15-31]
Specific Conductivity, µS/cm	D 4519
Sodium, Na	D 2791
Cation Conductivity, µS/cm*	D 4519
Silica, SiO_2	D 4517
Chloride, Cl	D 4327
Sulphate, SO_4	D 4327
Phosphate, PO_4	D 4327
Iron, Fe	D 1068
Total Organic Carbon	D 4779
PH*	D 5128
*Conductivity and pH measured at 25C	

VIII. REFERENCES

1. GEI 41040 “Process Specification Fuel Gases For Combustion in Heavy-Duty Gas Turbines”.
2. GEI 41047 “Gas Turbine Liquid Fuel Specifications”.
3. ASTM D 2880-96a Standard Specification for Gas Turbine Fuel Oils.
4. GER 3597 “High Temperature Coating for Improved Oxidation-Corrosion Protection”.
5. Superalloys II C Sims ed. Chapter 12 “Hot Corrosion” F.S. Petit and C.S. Higgins.
6. GER 3419 “Gas Turbine Inlet Air Treatment”.
7. GEK 101944 “Requirements for Water/Steam Purity in Gas Turbines”, April 1995.
8. GEK 72281 “Steam Purity Recommendations for Utility Steam Turbines”.
9. GEK 106669 “Specification for Cooling Steam Purity for Closed Circuit Steam Cooled Gas Turbine”.
10. ASME Handbook “Water Technology for Thermal Power Systems” Chapter 12.
11. “Development of a Steam Sampling System.” EPRI report TR-100196.
12. ASTM D-4191 “Test method for sodium by atomic absorption spectrophotometry”.
13. ASTM D-6071 “Low Level Sodium in High Purity Water by Graphite Furnace Atomic Absorption Spectroscopy.
14. GEK 107158 “Gas Turbine Inlet Evaporative Coolers”.
15. ASTM D 4309 “Standard Practice for Sample Digestion Using Closed Vessel Microwave Heating Technique for the Determination of Total Metals in Water”.
16. ASTM D 5673 “Standard Test Method for Elements in Water by Inductively Coupled Plasma-Mass Spectrometry”.
17. ASTM D 4057 “Standard Practice for Manual Sampling of Petroleum and Petroleum Products”
18. ASTM D 4177 “Standard Practice for Automatic Sampling of Petroleum and Petroleum Products”
19. ASTM D 5287 “Standard Practice for Automatic Sampling of Gaseous Fuels”
20. ASME Power Test Code Section 19.11.
21. ASTM D1066 - "Standard Practice for Sampling Steam."
22. Development of a Steam Sampling System. EPRI. Palo Alto, CA. TR-100196. December 1991.
23. ASTM D1068 - "Standard Test Methods for Iron in Water."

24. ASTM D2791 - "Standard Test Methods for Continuous Determination of Sodium in Water."

25. ASTM D4309 - "Sample Digestion Using Closed Vessel Microwave Heating Technique for the Determination of Total Metals in Water.

26. ASTM D4519 - "On-line Determination of Anions and Carbon Dioxide in High Purity Water by Cation

27. Exchange and Degassed Cation Conductivity."

28. ASTM D5391 - "Standard Test Method for Electrical Conductivity and Resistivity of a Flowing High Purity Water Sample."

29. ASTM D5542 - "Standard Test Methods for Trace Ions in High Purity Water by Ion Chromatography."

30. ASTM D1068 - "Standard Test Methods for Iron in Water".

31. ASME Power Test Code 31 Section 4.3 "Sampling for Suspended Solids."

APPENDIX 1

Table 2. Gas Fuels

FUEL	LHV (Btu/SCF)	MAJOR COMPONENTS
Natural Gas (NG)	800–1200	Methane
Liquefied Petroleum Gas (LPG)	2300–3200	Propane, Butane
Gasification Fuels		
- Air Blown	100–150	Carbon monoxide, Hydrogen, Nitrogen, Water Vapor
- Oxygen Blown	200–400	Carbon monoxide, Hydrogen, Water Vapor
Process Gases	300–1,000	Methane, Hydrogen, Carbon monoxide, Carbon dioxide

Table 3. Liquid Fuels - True Distillates

Fuel	Description	Other Names
Light True Distillates		
1. Naphtha	a. A light volatile fuel with a boiling range between gasoline and Light Distillate. The lower flash point and higher volatility require special safety considerations. Its very low viscosity may result in poor lubricity.	JP-4, Jet B O-GI Gas Turbine Fuel
	b. Very difficult to sample and analyze for alkali metals	
2. Kerosene	a. A light, highly refined and slightly more volatile fuel than Light Distillate.	1-GT Gas Turbine Fuel No.1 Burner Fuel 1-D Diesel Fuel JP-5, Jet A Range Oil Lamp Oil
	b. Difficult to sample and analyze for alkali metals.	
3. Light Distillate	a. Widely available volatile distillate fuel with good combustion characteristics, being readily atomized and clean burning.	2-GT Gas Turbine Fuel No. 2 Burner Fuel Diesel Oil Marine Gas Oil Domestic Fuel
	b. Difficult to sample and analyze for alkali metals.	
4. Diesel Fuel	a. Closely related to Light Distillate fuel except for additional requirements peculiar to diesel engine operation such as Cetane Number.	2-D Diesel Fuel
	b. Difficult to sample and analyze for alkali metals.	

Table 4. Guide to Applicable Documents

Parameter	Applicable Document for			
	6C, FB, H		Other machines	**Comments**
Alkali Metals in	Spec Limit (ppbw)	Document Number	Document Number	
Air	*	GEK 107230	GEI 3419	*Contamination in air varies from inland to coastal locations
Gas Fuel		GEK 107230	GEI 41040	**In coastal regions gas contamination higher than "trace level" may impact the life of hot gas path parts
Inland	200			
Coastal**	Trace level			
Liquid Fuel		GEK 107230	GEI 41047	Liquid fuel may need treatment to satisfy GEK 107230
Inland	500			
Coastal	200			
Injection Water	20	GEK 107230	GEK 101944	
Injection Steam	5	GEK 107230	GEK 101944	
Evaporative Cooler Water	200000 Re-circ water	GEK 107230	GEK 107158	Cycles of concentration would depend upon the quality of the make up water
SPRITS water	20	GEK 107230	GEK 101944	Additional requirement of 300ppbw Chloride
Fuel Moisturization Water	***	Under Preparation	Under Preparation	***Moisturized fuel should meet the fuel spec
Compressor Wash On line	500	GEK 107230	GEK 103623	GEK 103623 may also be used for off-line wash for turbines using lower chromium superalloys
Requirements other than alkali metals for air, fuels, water and steam	Existing Relevant Documents Applicable to Machines not using N5 type materials			

*Air quality is qualitatively defined in Table 5. Fuel can be treated to certain extent to lower its alkali levels in order to allow air with higher contamination levels. When fuel treatment reaches its capability limits, substantially contaminated air may impact the life of the hot gas path parts.

Table 5. Air Quality Values Considered in GEK 107230

	Site Location and Distance From Sea coast (miles)			
	Inland	**Coastal**		
	>12	6.2	4.2	0.8
Alkali level (ppbw)	2.6	5.2	7.8	15.2

Table 6. General Requirements for Fuel Treatment

Location/ miles from sea	**Fuel Treatment Required with level of alkali**		
	Poor quality fuel (> 0.5ppmw)	**Average fuel (0.2-0.5ppmw)**	**Good fuel (≤0.2ppmw)**
Inland (≥12)	Yes	No	No
Coastal (<12)	Yes	Yes	No

APPENDIX II

Calculation to estimate overall level of alkali contamination Xt entering the gas turbine

T*(Xt) = A*Xa + F*Xf + S*Xs + W*Xw……. (EQ 1)

Where T = total flow to turbine = (A + F + S + W) in lb/s:

A = 1350 lb/s,

Xa= 2.6ppbw

F = 40 lb/s,

Xf= 500ppbw.

S = 0 lb/s,

Xs= 0 ppbw.

W = 60 lb/s.

Xw= 20ppbw.

Xt= 17.04ppbw

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