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GE Energy

Steam Purity Recommendations for Utility Steam Turbines

This document does not apply to Nuclear Steam 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.

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I. INTRODUCTION

Steam purity can have a very significant influence on turbine output, efficiency and availability if impurity concentrations are not sufficiently controlled. Exposure of steam turbines to water droplets with high concentrations of the defined impurities can lead to corrosion damage including pitting, stress corrosion cracking, and corrosion fatigue. As the time of exposure and concentration of impurities increases, the likelihood of damage increases.

The overall objective in establishing appropriate water and steam cycle chemistry limits is to minimize deposits and corrosion throughout the entire steam plant, including the major components such as the boiler, turbine, and condenser. The recommendations in this document provide steam purity limits for normal operation of the steam turbine and action limits for steam purity excursions during transients or abnormal operating conditions or during commissioning. The steam purity limits and action levels in this document are based upon international industry experience and thermodynamic data for a variety of unit designs operating with the most common chemistry control practices.

II. STEAM PURITY REQUIREMENTS FOR UTILITY UNITS

Steam purity in drum type systems is a function of both vaporous and mechanical carryover of impurities from the water. In once through systems, it is equivalent to the purity of the inlet water. In addition, steam contamination may occur through use of contaminated superheater and reheater attemperation water.

Most of the serious instances of turbine corrosion damage for units supplied by either once-through or drum type boilers are associated with accidents or upset conditions. For example, in once-through systems, improper regeneration of deep bed polishers operated on the ammonia cycle can introduce caustic into the feedwater. In drum type systems, high drum levels, foaming, or defective steam separator baffles can significantly increase the amount of carryover. Operation of any boiler-turbine system with severe condenser leaks can eventually introduce chlorides into the turbine. Avoiding such instances requires constant attention to condenser leakage, demineralizer effluent purity, and steam purity.

Deposition of contaminants on steam path components roughens steam passage walls and reduces flow passage areas, thereby lowering steam flow, efficiency, and output. Excessive deposition can adversely affect mechanical performance of the steam turbine. The more common deposit forming contaminants in utility steam turbines include silica and silicates, iron and copper oxides, calcium and magnesium salts, phosphates, sulfates, and carbonates.

To minimize contamination deposition and possible corrosion damage to turbine components, concentrations of deposit forming contaminants and corrosion causing contaminants should be kept at or below the ‘N’ (Normal) levels provided in Sections IV through X. The different sections correspond to different plant designs and water treatment regimes, both of which affect the sensitivity of the system to impurities in the steam. It is critical that parameters such as sodium and cation conductivity be monitored continuously or frequently in superheated steam (plants without reheat) or reheat steam (plants with reheat). Note that for normal steam turbine operation, measurement of cation conductivity, not degassed cation conductivity shall be compared to the limits in Sections IV through X. Degassed cation conductivity is recommended for troubleshooting or for use during commissioning.

The system design and water treatment program all affect the severity of steam turbine corrosion for a given level of impurities in the steam. For this reason, the normal and action level requirements are different for each major class of steam plant design and water treatment regime. Operation at or below these ‘N’ (Normal) steam purity values has been consistent with long term equipment reliability. It is recommended that recording and alarms become implemented in control room alarms as a warning of steam cycle chemistry

excursions for sodium and cation conductivity. Appropriate corrective actions should be taken to minimize the duration and frequency of contaminant excursions. The maximum length of time that contaminant excursions are permitted in each action level for each design and water treatment regime are given in Section XI. Time spent in each action level removes time that may subsequently be spent at lower action levels during a single event or cumulatively for a 12 month period.

Steam purity action level time limits during commissioning are given in Section XII. Steam purity monitoring used in conjunction with a well managed and operated cycle chemistry program is necessary to provide maximum equipment reliability and performance.

Problems or questions regarding steam turbine purity limitations should be directed to Customer Service Technology via the Power Answer Center (678)-844-7747 or toll free 1-(888)-443-7747).

A. Once-Through Steam Supply Systems

Minimizing the level of feedwater contaminants is extremely important for once-through type boilers since essentially all the impurities dissolved in the feedwater remain dissolved in the steam and pass into the turbine. For these systems, the water purity input to the boiler is a good measure of the output steam purity. For these reasons the contaminant levels in the feedwater and therefore in the steam must be controlled more closely than in drum boilers.

In once-through units, Oxygenated Water Treatment for the purpose of decreasing pre-boiler system corrosion has been used effectively internationally and conversions in the United States with GE turbines have also been successful. There are no defined limits for oxygen in steam purity documents, but careful impurity and oxygen control and monitoring is required for optimum corrosion protection of feedwater, boiler, and condensate systems.

B. Drum Type Steam Supply Systems

A major difference between drum type units over once-through designs is the drum boiler's ability to separate dissolved solids from the steam due to the strong affinity of the solids for the liquid phase. Control of feedwater chemistry is needed to minimize vaporous carryover of contaminants to the turbine, but precautions also need to be taken to limit mechanical carryover. High drum levels, high drum solids, rapid load changes, separator problems, chemical contamination, and separator overload affect mechanical carryover.

C. Steam Purity Monitoring

It is necessary to analyze steam with precision and accuracy consistent with the purity levels. Recommended sampling frequencies of reheat steam (plants with reheat) and superheated steam (plants without reheat) are included in the attached steam purity tables.

Proper design, operation, and maintenance of steam sampling and conditioning systems is critical to provide representative samples for monitoring the key chemical parameters in the cycle. Applicable ASME codes, ASTM methods, and instrumentation manufacturer's procedures for sampling and analysis should be followed.

D. Commissioning of a Heat Recovery Steam Generator or Fossil Boiler Plant

Commissioning a new heat recovery steam generator (HRSG) or boiler plant requires that steam be generated from water and piping that is contaminated by manufacturing, environmental exposure and

contamination from chemicals and impure water. During initial operation, piping, makeup water and drum water are cleaned by steam generation and purified by blowdown and/or condensate polishing until steam that is pure enough for admission to a steam turbine is generated. Prior to steam turbine admission, the steam generated by the evaporator must be bypassed directly to the condenser. Good storage and erection practice can minimize contamination and shorten this period of bypass and shorten commissioning to a few days.

Commissioning requires short-term operation in action level impurity levels to fully clean up the HRSG or steam generator. Steam purity during commissioning is characterized by Action levels defined in Sections IV through X. The time limits for admission of steam to the steam turbine at these action levels are given in Section XII.

Because of operation in action levels during commissioning, it is essential that the frequency of steam purity monitoring be greater than normal. Recommended steam purity sampling intervals are given in Section XIII. Commissioning time spent in each action level removes time that may subsequently be spent in lower action levels. For example, if half of the action level time limit in Section XII in Action Level 2 is expended at the start of commissioning, then only half of the allocation, or 168 hours, may be spent in Action Level 1. Because of this, it is recommended that the time in higher action levels be minimized.

A steam turbine is more susceptible to corrosion during layup after it has been operated with steam at action level concentrations than after normal operation. Because layup may be required during commissioning, LP steam turbine drying with dehumidified air is recommended to protect the steam turbine if a commissioning layup extends for longer than 5-7 days.

Following commissioning, the operational steam purity limits in Sections IV through X will apply. The time spent at action level steam purities during commissioning will not count toward the maximum annual exposure to contaminant conditions of Section XI.

III. MAINTENANCE RECOMMENDATIONS

A. Turbine Deposits

During turbine inspections the unit should be carefully inspected for deposits. Thorough chemical analysis of turbine deposits can provide an early warning that corrosive contaminants have been introduced into the unit. Deposit analysis can provide information required for logical recommendations regarding the nondestructive examination of critical turbine components and for formulating corrective actions to eliminate the source of contaminants.

GE recommends that if turbine deposits are present, samples should be taken and analyzed during every inspection. The results should be reviewed with local GE representatives.

A steam turbine is more susceptible to corrosion during layup if deposits are present that contain chloride or other acid contaminants. LP steam turbine and condenser blanketing with Nitrogen on spin down and drying the steam turbine with dehumidified air is recommended for any layup when known contaminants are present. Drying the steam turbine with dehumidified air is recommended for any layup that extends for longer than 7 days.

IV. STEAM PURITY GUIDELINES FOR ONCE-THROUGH BOILERS

Table 1. Reheat Steam Purity for Once Through Boilers

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤3	>3 ≤6	>6 ≤12	>12
Cation Conductivity, µS/cm*	C	≤0.15	>0.15 ≤0.25	>0.25 ≤0.45	>0.45
Silica, ppbw, as SiO_2	C or S	≤10	>10 ≤20	>20 ≤40	>40
Chloride, ppbw, as Cl	C or S	≤3	>3 ≤6	>6 ≤12	>12
Sulfate, ppbw, as SO_4	D	≤3	>3 ≤6	>6 ≤12	>12
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	C	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

V. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITH REHEAT USING PHOSPHATE TREATMENT WITH NA/PO_4 MOLAR RATIO LESS THAN 2.6

Table 2. Reheat Steam Purity for Drum Boilers With Reheat Using Phosphate Treatment with $Na/PO_4 < 2.6$

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤5	>5 ≤10	>10 ≤20	>20
Cation Conductivity, µS/cm*	C	≤0.3	>0.3 ≤0.55	>0.55 ≤1.0	>1.0
Silica, ppbw, as SiO_2	T	≤10	>10 ≤20	>20 ≤40	>40
Chloride, ppbw, as Cl	T	≤3	>3 ≤6	>6 ≤12	>12
Sulfate, ppbw, as SO_4	T	≤3	>3 ≤6	>6 ≤12	>12
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

VI. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITH REHEAT USING PHOSPHATE TREATMENT WITH NA/PO_4 MOLAR RATIO GREATER THAN 2.6

(Operation at Na/PO_4 molar ratios in excess of 3.0 is not recommended because of the possibility of free caustic and serious damage to the steam turbine.)

Table 3. Reheat Steam Purity for Drum Boilers With Reheat Using Phosphate Treatment with Na/PO_4 > 2.6

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤3	>3 ≤6	>6 ≤12	>12
Cation Conductivity, µS/cm*	C	≤0.15	>0.15 ≤0.25	>0.25 ≤0.45	>0.45
Silica, ppbw, as SiO_2	T	≤10	>10 ≤20	>20 ≤40	>40
Chloride, ppbw, as Cl	T	≤3	>3 ≤6	>6 ≤12	>12
Sulfate, ppbw, as SO_4	T	≤3	>3 ≤6	>6 ≤12	>12
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

VII. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITH REHEAT USING ALL VOLATILE TREATMENT

Table 4. Reheat Steam Purity for Drum Boilers With Reheat Using All Volatile Treatment

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤3	>3 ≤6	>6 ≤12	>12
Cation Conductivity, µS/cm*	C	≤0.15	>0.15 ≤0.25	>0.25 ≤0.45	>0.45
Silica, ppbw, as SiO_2	T	≤10	>10 ≤20	>20 ≤40	>40
Chloride, ppbw, as Cl	T	≤3	>3 ≤6	>6 ≤12	>12
Sulfate, ppbw, as SO_4	T	≤3	>3 ≤6	>6 ≤12	>12
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

VIII. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITHOUT REHEAT USING PHOSPHATE TREATMENT WITH NA/PO_4 MOLAR RATIO LESS THAN 2.6

Table 5. Superheat Steam Purity for Drum Boilers Without Reheat Using Phosphate Treatment with Na/PO_4 < 2.6

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤10	>10 ≤20	>20 ≤40	>40
Cation Conductivity, µS/cm*	C	≤0.35	>0.35 ≤0.65	>0.65 ≤1.25	>1.25
Silica, ppbw, as SiO_2	T	≤20	>20 ≤40	>40 ≤80	>80
Chloride, ppbw, as Cl	T	≤6	>6 ≤12	>12 ≤24	>24
Sulfate, ppbw, as SO_4	T	≤6	>6 ≤12	>12 ≤24	>24
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

IX. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITHOUT REHEAT USING PHOSPHATE TREATMENT WITH NA/PO_4 MOLAR RATIO GREATER THAN 2.6

Table 6. Superheat Steam Purity for Drum Boilers Without Reheat Using Phosphate Treatment with Na/PO_4 > 2.6

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤6	>6 ≤12	>12 ≤24	>24
Cation Conductivity, µS/cm*	C	≤0.25	>0.25 ≤0.45	>0.45 ≤0.85	>0.85
Silica, ppbw, as SiO_2	T	≤20	>20 ≤40	>40 ≤80	>80
Chloride, ppbw, as Cl	T	≤6	>6 ≤12	>12 ≤24	>24
Sulfate, ppbw, as SO_4	T	≤6	>6 ≤12	>12 ≤24	>24
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

X. STEAM PURITY GUIDELINES FOR DRUM BOILERS WITHOUT REHEAT USING ALL VOLATILE TREATMENT

Table 7. Superheat Steam Purity for Drum Boilers Without Reheat Using All Volatile Treatment

		Targets			
Target Parameter	**Sample**	**N**	**1**	**2**	**3**
Sodium, ppbw, as Na	C	≤6	>6 ≤12	>12 ≤24	>24
Cation Conductivity, µS/cm*	C	≤0.25	>0.25 ≤0.45	>0.45 ≤0.85	>0.85
Silica, ppbw, as SiO_2	T	≤20	>20 ≤40	>40 ≤80	>80
Chloride, ppbw, as Cl	T	≤6	>6 ≤12	>12 ≤24	>24
Sulfate, ppbw, as SO_4	T	≤6	>6 ≤12	>12 ≤24	>24
Total organic Carbon, ppbw, as C	W	≤100	>100	-	-
Specific conductivity	T	-	-	-	-
*Conductivity measured at 25°C					
Legend Sample Frequency		**Targets** (see Table 8 for Cumulative Hours per year and Action Level Criteria)			
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning		N = Normal 1 = Action Level 1 2 = Action Level 2 3 = Action Level 3			

XI. MAXIMUM ANNUAL EXPOSURE TO CONTAMINANT CONDITIONS†

Table 8. Maximum Annual Exposure To Contaminant Conditions

Targets	Cumulative Hours per Year		Action Level Criteria
	Base Load	Cycling	
N (Normal)	-	-	Values consistent with long term reliability
1 (Action Level 1)	336 (2 weeks)	672 (4 weeks)	Potential for contaminant deposition and corrosion; Return parameter to normal range within 1 week
2 (Action Level 2)	48 (2 days)	96 (4 days)	Contaminant deposition and corrosion; Return parameter to normal range within 24 hours
3 (Action Level 3)	8	16	Potential for rapid corrosion damage; Shutdown unit within 4 hours

†Exposure during a rolling 12 month period, not by calendar year.

XII. COMMISSIONING ACTION LEVEL REQUIREMENTS†

Table 9. Commissioning Action Level Requirements†

Steam Purity Action Level	Cumulative Hours During Commissioning	Action Level for the Applicable Steam Purity Guideline
Action Level 1	336 (2 Weeks)	Consistent with industry experience during commissioning.
Action Level 2	48 (2 Days)	**Potential for contamination and corrosion.** Mid to lower Action level 2 is preferred. Stay in this level only if steam purity shows a trajectory to Action Level 1 within 12 hours.
Action Level 3	8	**Potential for rapid corrosion**. To avoid exceeding Action level allocation, steam purity should tend to Action Level 2 within 1 hour. Otherwise, lower steam pressure to return to Action Level 2 or 1.

† During commissioning, either degassed cation conductivity or cation conductivity may be measured to establish cation conductivity action level.

During commissioning only, the full two weeks time in Action level 1 may be utilized if time in Action level 2 has not exceeded the limits in this Table. Time spent in Action level 3 during commissioning does reduce time allowed in Action Level 2 as discussed in Section II.

The time permitted in Action Level 1 during commissioning is increased to four (4) weeks if SiO_2 is the only remaining steam parameter at Action Level 1 condition and all others are normal.

XIII. RECOMMENDED COMMISSIONING STEAM PURITY MONITORING FREQUENCY*

Table 10. Recommended Commissioning Steam Purity Monitoring Frequency*

PARAMETER	MONITORING FREQUENCY	NOTE
Sodium	C	
Cation or Degassed Cation conductivity	C	Measurement of Degassed Cation Conductivity is recommended during commissioning.
Chloride	S	Chloride should be analyzed by grab sampling and laboratory analysis when the Degassed CC action level exceeds the action level for Na.
SiO_2	D or S	Analysis per shift if SiO2 Action Level Exceeds the action level for Na.
Total Organic Carbon	D	
Sulfate	D	

Legend Sample Frequency
C = Continuous S = Grab, once per shift D = Grab, once per day W = Grab, once per week T = Troubleshooting and Commissioning

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