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GE Power Systems

Design Considerations for Heated Gas Fuel

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Introduction

Gas Fuel Performance Heating

As the need for higher efficiency power plants increases, a growing number of combined-cycle power plants are incorporating performance gas fuel heating as a means of improving overall plant efficiency. This heating, typically increasing fuel temperatures in the range of 365°F/185°C, improves gas turbine efficiency by reducing the amount of fuel needed to achieve desired firing temperatures. For fuel heating to be a viable method of performance enhancement, feedwater has to be extracted from the heat recovery steam generator (HRSG) at an optimum location. Boiler feedwater leaving the intermediate pressure economizer is commonly used. Using gas-fired, oil-fired or electric heaters for performance gas fuel heating will not result in a power plant thermal efficiency improvement.

Proper design and operation of the Gas Fuel Heating System is critical in insuring reliable operation of the gas turbine. Improper selection of components, controls configuration and/or overall system layout could result in hardware damage, impact plant availability and create hazardous conditions for plant personnel. This paper addresses the critical design criteria that should be considered during the design and construction of these systems.

Also included in this paper is the design of a "typical" GE Gas Fuel Heating System. This system has been developed taking into consideration the system requirements defined within.

Gas Compressor Heating

Gas compressors may be needed to meet specified minimum gas supply pressures levels. The use of a compressor adds heat to the gas and raises its operational temperature. The temperature level of the gas at the exit of the gas compressor is a function of its inlet conditions. This temperature may vary from site to site and should be evaluated against any combustion specific requirements defined in this document.

General System Requirements

The following section identifies general system requirements that apply to all gas fuel heating systems. These requirements, in addition to those described in the Combustion Specific System Requirements section shall be followed during the design and development of the system.

Gas Fuel Cleanliness

Gas fuel supplied to the gas turbine shall meet the particulate requirements as specified in the latest revision of GEI-41040, "Process Specification — Gas Fuels for Combustion in Heavy Duty Gas Turbines," (Reference 1). If the components in the Gas Fuel Heating System are constructed of materials susceptible to corrosion, a method of final filtration upstream of the gas turbine interface is required. Particulate carryover greater than that identified in GEI-41040 can plug fuel nozzle passages, erode combustion hardware and gas valve internals and cause damage to first stage turbine nozzles. The new gas piping system must be properly cleaned prior to initial gas turbine operation. Additional design considerations related to gas fuel cleanliness may be found in GER-3942, Gas Fuel Clean-Up System Design Considerations for GE Heavy Duty Gas Turbines," (Reference 2).

Gas Fuel Quality

As defined in GEI-41040, the fuel delivered to the gas turbine must be liquid free and contain a specified level of superheat above the higher of the hydrocarbon or moisture dewpoints.

Saturated fuels, or fuels containing superheat levels less than specified, can result in the formation of liquids as the gas expands and cools across the gas turbine control valves. The amount of superheat provides margin to compensate for temperature decrease due to pressure reduction, and is directly related to incoming gas supply pressure. (**Note:** Within this document, gas fuel heating strictly for dewpoint considerations is still considered to be in a "cold" state. Heating for performance purposes is considered "heated" fuel.)

The design of the Gas Fuel Heating System shall prevent carryover of moisture or water to the gas turbine in the event of a heat exchanger tube failure. Water entrained in the gas can combine with hydrocarbons causing the formation of solid hydrocarbons or hydrates. These hydrates, when injected into the combustion system, can lead to operability problems, including increased exhaust emissions and mechanical hardware damage. Proper means of turbine protection, including heat exchanger leak detection, shall be provided.

Gas Fuel Supply Pressure

Gas being supplied to the gas turbine interface point (customer connection FG1) shall meet the minimum gas fuel supply pressure requirements as defined in the proposal documentation. These minimum pressure requirements are established to insure proper gas fuel flow controllability and to maintain required pressure ratios across the combustion fuel nozzles. The Gas Fuel Heating System shall be designed to insure that these requirements are met during all modes of operation over the entire ambient temperature range.

The design of the Gas Fuel Heating System shall insure that the design pressure of the gas turbine gas fuel system is not exceeded. Overpressure protection, as required by applicable codes and standards, shall be furnished. In addition to minimum and maximum pressures, the gas turbine is also sensitive to gas fuel pressure variations. Sudden drops in supply pressure may destabilize gas pressure and flow control. Sudden increases in supply pressure may potentially trip the turbine due to a high temperature condition. Limitations on pressure fluctuations are defined in the gas turbine proposal documentation.

Gas Fuel Supply Temperature

The Gas Fuel Heating System shall be designed to produce the desired gas fuel temperature at the interface with the gas turbine equipment. Guaranteed performance is based on the design fuel temperature at the inlet to the gas turbine gas fuel module (FG1). The gas fuel heating and supply systems shall compensate for heat losses through the system. Compensation shall include but not be limited to elevated heater outlet temperatures, use of piping and equipment insulation, and minimization of piping length from heater outlet to turbine inlet.

The Gas Fuel Heating System shall be designed to support specified gas fuel temperature setpoints required by the gas turbine. These setpoints include high and low temperature alarms, gas turbine controls permissives, and gas turbine controls functions. These setpoints are derived by GE Gas Turbine Engineering and are based on operability requirements and/or design limitations of components within the gas turbine gas fuel system.

During specified cold and hot gas fuel turbine operating modes, the Gas Fuel Heating System shall attain and maintain the fuel at a temperature that corresponds to a Modified Wobbe Index (MWI) within ±5% of the target value.

The Modified Wobbe Index is a calculated measurement of volumetric energy content of fuel and is directly related to the fuel temperature and lower heating value (LHV). The Modified Wobbe Index is derived as follows:

$$MWI = \frac{LHV}{\sqrt{T_g \bullet SG}}$$

Where:

MWI = Modified Wobbe Index (temperature corrected)

LHV = Lower Heating Value of Fuel (BTU/SCF)

T_g = Absolute Temperature (°R)

SG = Specific Gravity of fuel relative to air at ISO Conditions

The ±5% Modified Wobbe Index range insures that the fuel nozzle pressure ratios are maintained within their required limits. If gas fuel constituents and heating value are consistent, the 5% tolerance can be based strictly on temperature variation. If the heating value of the fuel varies, as is the case when multiple gas suppliers are used, heating value and specific gravity must be considered when evaluating the allowable temperature variation to support the 5% Modified Wobbe Index limit.

For the use of gas fuels having a significant variation in composition or heating value, a permanent gas chromatograph shall be furnished in the plant's main gas supply line. LHV and specific gravity readings from the gas chromatograph are used to regulate the amount of fuel heating so that the ±5% Modified Wobbe Index requirement is satisfied. This control function shall be performed automatically by the plant control system.

Consideration shall be made to the location of the gas chromatograph relative to the inlet of the gas fuel module and the time delay from instrument reading to fuel gas control.

Combustion Specific System Requirements

The GE Gas Turbine product line incorporates the use of both Dry Low NOx (DLN) and Non-Dry Low NOx (conventional) combustion designs. Currently, there are five different DLN configurations offered by GE: DLN-1, DLN-2.0, DLN-2+, DLN-2.6 and DLN-2.5H. Each combustion design is applied to one or more gas turbine models. These designs have different hardware configurations and operability schemes and in turn have certain contrasting gas fuel heating requirements. Performance type gas fuel heating is not normally applied to conventional combustion systems, and thus will not be addressed in this document. *Table 1* identifies the combustion designs that are applied to the various turbine models. This section will detail the system design and operability requirements that apply to the specific DLN combustion design.

DLN-1 Requirements

On gas turbines that utilize DLN-1 combustion designs, the Gas Fuel Heating System and supporting control system shall be designed to provide either cold or heated fuel as based on the gas turbine's requirements.

The gas turbine control system will provide a permissive signal indicating when heated or unheated fuel is required. The plant control system shall use this signal to initiate gas fuel heating on start-up and to cease gas fuel heating on shutdown. For DLN-1 combustion designs, the fuel shall be in a cold state from ignition

Combustion Design	Applicable Turbine Models
DLN-1	PG5271R PG5371P PG6541B PG6561B PG6571B PG6581B PG7111EA PG7121EA PG9171E
DLN-2.0	PG6101FA PG7221FA PG7231FA PG9311FA PG9331FA
DLN-2+	PG9351FA PG7251FB PG9371FB
DLN-2.6	PG7231FA PG7241FA PG9231EC
DLN-2.5H	PG7371H PG9441H

Table 1. Combustion design to turbine model cross reference

(Primary combustion mode) through Lean-Lean and into Secondary Premix combustion mode. The fuel can be heated only after Premix steady state is achieved. The gas can be hot or cold in Premix Mode, but must be cold in Primary, Lean-Lean or Extended Lean-Lean Mode. The gas must be cold prior to transferring out of Premix Mode.

During a "hot gas restart," the DLN-1 combustion system has the ability to be fired on the hot fuel contained in the fuel supply system. Active heating of the fuel shall not be re-established until the combustion system reaches Premix Steady State Mode.

DLN-2.0 Requirements

On gas turbines that utilize DLN-2.0 combustion designs, the Gas Fuel Heating System and supporting control system shall be designed to provide either cold fuel or heated fuel as based on the gas turbine's requirements.

DLN-2.0 combustion systems are designed to operate on both unheated and heated fuels at ignition as well as Primary and Lean-Lean Modes. While in Premix Transfer, Piloted Premix, and Premix Modes, the system is designed to operate on heated fuels only. Permissives configured within the gas turbine controls permit or prevent changes in combustion mode until the gas is heated sufficiently in order to satisfy the Modified Wobbe Index requirements. Thermocouples located directly upstream of the gas turbine's Stop Speed Ratio Valve initiate this permissive.

During turbine shutdown, gas fuel heating shall be disabled only after transferring out of Premix Mode.

DLN-2+ Requirements (PG9351FA)

On gas turbines that utilize DLN-2+ combustion designs, the Gas Fuel Heating System and plant controls shall be designed to provide either cold or heated fuel as based on the gas turbine's requirements.

DLN-2+ combustion systems are designed to operate on heated or unheated fuel in Diffusion and Sub-piloted Premix Mode. Diffusion and Sub-piloted Premix Mode operation consists of ignition, acceleration to Full Speed No Load, and up to approximately 10% load. (*See Figure 1.*) During Piloted Premix Mode operation, from approximately 10% load to 25% load, the gas fuel temperature can be hot or cold. However, the gas must satisfy the Modified Wobbe Index hot temperature limits, in Piloted Premix Mode, from approximately 25% to 50% load. During Premix Mode operation, the gas temperature must be sufficient to satisfy the Modified Wobbe Index limit. In

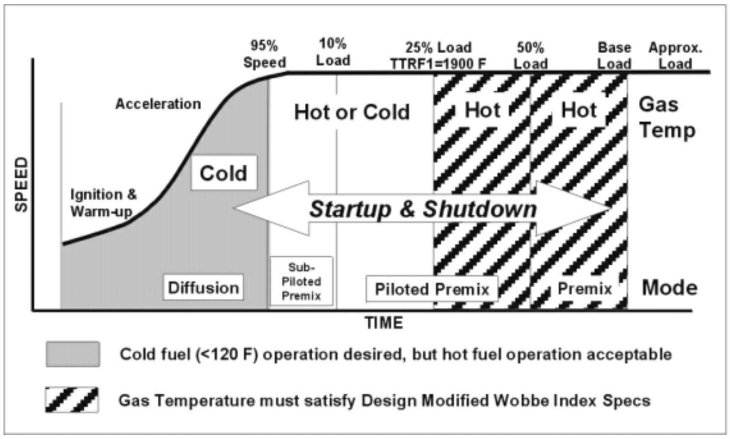

Figure 1. DLN-2+ (PG9351) fuel heating operational requirements

addition, Extended Piloted Premix Mode, from 50% load to Baseload, requires the gas to meet the Modified Wobbe Index hot limit. Permissives set within the gas turbine controls, prevent a transfer into the appropriate Piloted Premix load or Premix Mode, during loading, until the required temperature is attained.

Thermocouples located directly upstream of the gas turbine's Stop Speed Ratio Valve initiate this permissive.

During turbine shutdown, gas fuel heating shall be ceased only after transferring out of Piloted Premix Mode at approximately 25% load.

DLN-2+ FB Requirements (PG7251FB & PG9371FB)

On gas turbines that utilize the DLN-2+ FB combustion system design, the Gas Fuel Heating System and plant controls shall be designed to provide either cold or heated fuel as based on the gas turbine's requirements. (*See Figure 2.*)

DLN-2+ FB combustion systems are designed to operate on heated or unheated fuel in

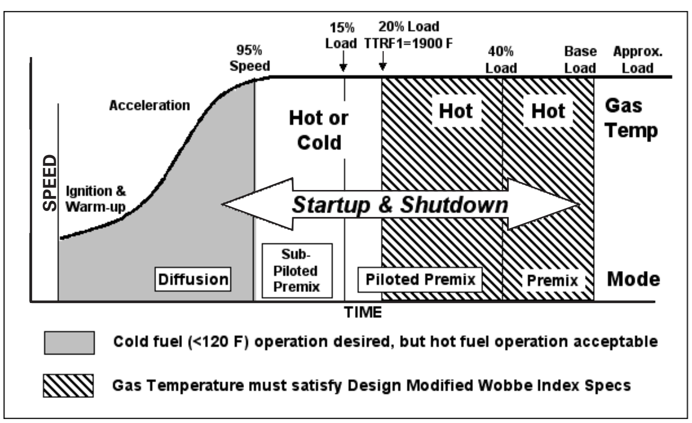

Figure 2. DLN-2+ FB (PG7251FB & PG9371FB) fuel heating operational requirements

Diffusion and Sub-piloted Premix Mode. Diffusion and Sub-piloted Premix Mode operation consists of ignition, acceleration to Full Speed No Load, and up to approximately 10% load. (*See Figure 2.*) During Piloted Premix Mode operation, from approximately 15% load to 20% load, the gas fuel temperature can be hot or cold. However, the gas must satisfy the Modified Wobbe Index hot temperature limits, in Piloted Premix Mode, from approximately 20% to 40% load. During Premix Mode operation, the gas temperature must be sufficient to satisfy the Modified Wobbe Index limit. In addition, Extended Piloted Premix Mode, from 40% load to Baseload, requires the gas to meet the Modified Wobbe Index hot limit.

Permissives set within the gas turbine controls prevent operation in Premix Mode or in Piloted Premix Mode until the required fuel temperature is attained. Thermocouples located directly upstream of the gas turbine's Stop/Speed Ratio Valve initiate this permissive.

During turbine shutdown, gas fuel heating shall be ceased only after reducing load below 20%.

DLN-2.6 Requirements

On gas turbines that use DLN-2.6 combustion designs, the Gas Fuel Heating System and plant controls shall provide either cold or heated fuel as based on the gas turbine's requirements. (*See Figure 3.*)

DLN-2.6 combustion systems are designed to operate on heated or unheated fuel in Modes 1, 2 and 3. Heated fuel operation in Modes 1, 2 and 3 is permitted, but not recommended, for normal operation. The gas must be heated to satisfy the Modified Wobbe Index hot temperature limits prior to transferring to combustion Mode 4, at approximately 25% load. Thermocouples located directly upstream of the gas turbine's Stop Speed Ratio Valve initiate a permissive to transfer into Mode 4.

Fuel temperature must be maintained within the hot gas temperature limits at all modes

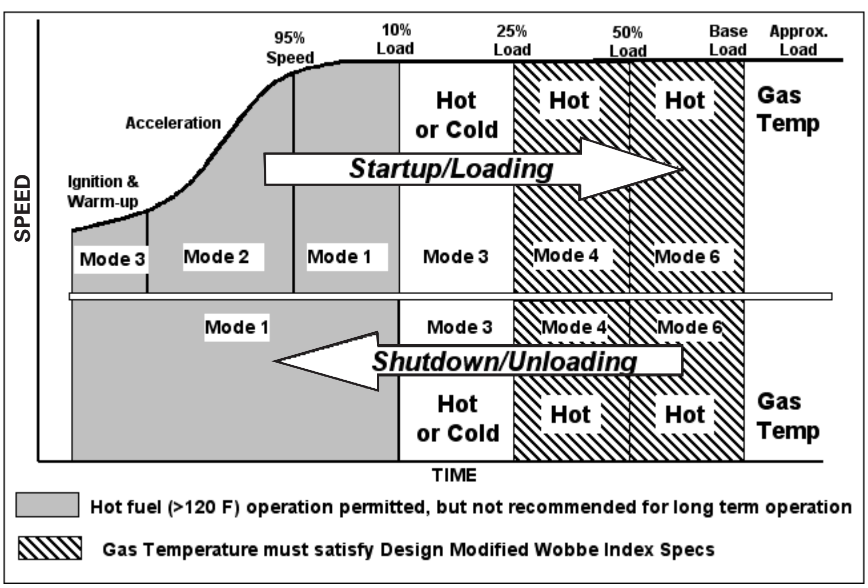

Figure 3. DLN-2.6 fuel heating operational requirements

above Mode 3 (approximately 25% load) during both unit operation and shutdown. During turbine shutdown, gas fuel heating shall be ceased only after transferring out of Mode 4 and into Mode 3. The gas fuel temperature is recommended, but not required, to be less than 120°F/49°C before transferring from Mode 3 to Mode 1.

DLN-2.5H Requirements

On gas turbines that operate with DLN-2.5H combustion designs, the Gas Fuel Heating System and plant controls shall provide either cold or heated fuel based on the gas turbine's requirements.

The DLN-2.5H combustion systems are designed to operate on both unheated and heated fuels at ignition through Diffusion Mode and into Piloted Premixed Mode. The gas must be heated in order to satisfy the Modified Wobbe Index hot gas temperature limits prior to transferring to Premixed Mode.

Typical GE Gas Fuel Heating System

The following section details the mechanical design and operational features of the typical GE Gas Fuel Heating System. The design intent of this system is to produce gas fuel that meets all requirements previously specified in this document. In addition to supporting heated fuel to the gas turbine, the typical system pro-vides safeguards that prevent gas fuel from entering the HRSG system. This commonly ignored condition can occur when a tube leak is present during gas turbine operation or unit shutdown.

This typical design is provided as a reference to the customer. Deviations from this design may be acceptable, providing that the requirements of the gas turbine are met.

System Description

Figure 4 identifies the equipment, instrumentation and piping configuration of the typical Gas Fuel Heating System. This system, as described, was initially applied to the MS9001H combined cycle power plant, which used intermediate pressure feedwater as the medium for fuel heating. The design criteria utilized during the development of this system shall be followed during the detailed design of all gas turbine gas fuel heating systems that utilize feedwater or steam as the heating medium. Job specific gas heating systems may deviate from this design based on gas conditions and interfacing balance of plant systems.

Design Criteria

The standard Gas Fuel Heating System design meets the following design criteria:

- Provide heated fuel that meets the Modified Wobbe Index requirement of the gas turbine's combustion system.
- Prevent water from being admitted to the gas turbine combustion system following a heat exchanger tube leak or rupture.
- Provide early indication of heat exchanger tube failure.
- Prevent gas fuel from entering the feedwater system following a heat exchanger tube failure.
- Remove gas entrained particulate as specified in the latest revision of GEI-41040, Process Specification — Gas Fuels for Combustion in Heavy Duty Gas Turbines (Reference 1).
- Provide overpressure protection to the gas turbine Gas Fuel Heating System piping and components.
- Ensure water pressure is higher than gas pressure during gas turbine operation and shutdown.

Heater Leak Detection Protection Philosophy

The heat exchanger leak detection scheme

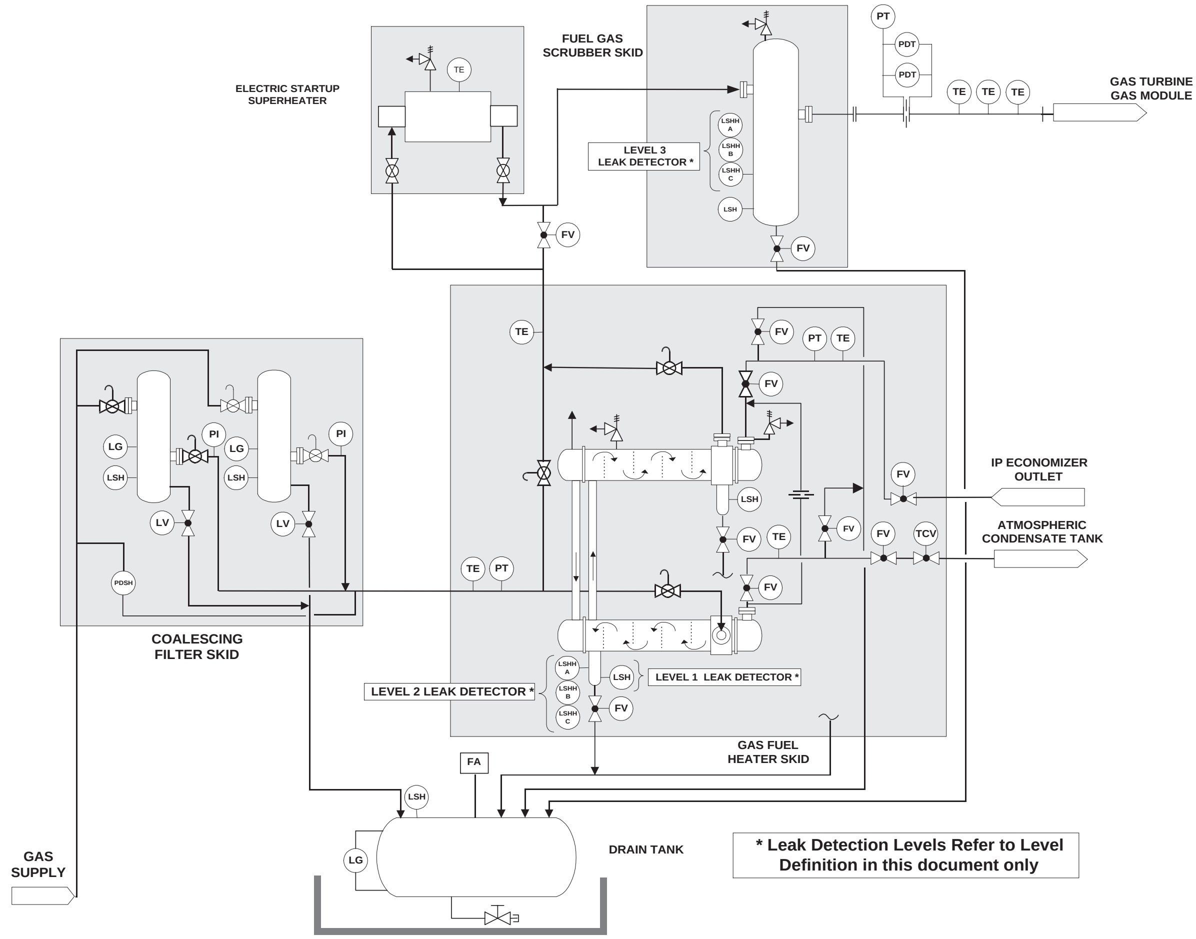

Figure 4. Typical Gas Fuel Heating System Flow Diagram

shall incorporate three levels of alarms or automated control. These three levels have been established to prevent the admission of water into the gas turbine while preventing inadvertent trips or load decreases due to failure of a single sensing instrument. (*See Figure 5*.)

The heater leak detection controls have been established to provide early detection of a heat exchanger leak and to mitigate the effects of both the leak on the gas turbine and the balance of plant systems.

Each gas fuel heater shell is furnished with a low point drain pot. The two drain pots house a series of level switches used in the tube leak detection controls. The lower heat exchanger drain pot is furnished with a single high level switch and three triple-redundant high-high level switches. A drain pot will open upon activation of the corresponding high level switch.

When two out of the three high-high level switches are activated, the feedwater to and from the heat exchanger will isolate. This action will quickly reduce the temperature of the gas fuel and initiate a transfer of the gas turbine to a cold mode of operation. Specifically for the typical Gas Fuel Heating System, the details of the three levels are as follows:

Level 1. At a minimum, a single sensing instrument (i.e., level switch) is implemented to alarm and evacuate the heating medium from

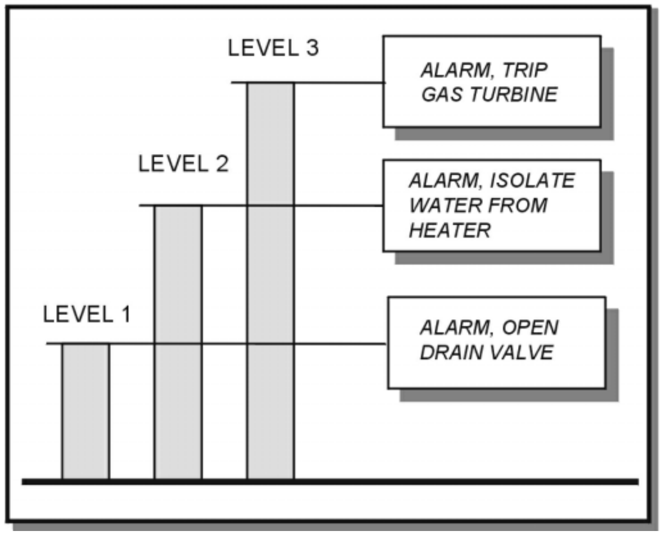

Figure 5. Heat exchanger leak detection control scheme

the gas stream/liquid collection sump following a tube leak/rupture. This provides initial indication that the heat exchanger tube leak/rupture is present.

Level 2. At a minimum, triple redundant sensing instrumentation is implemented and set at a level higher than that of Level 1. Output from these signals shall alarm and automatically isolate the heating medium from the gas stream, (i.e., isolating the feedwater from the heat exchanger). This provides secondary indication that the heat exchanger leak/tube rupture is present and that action taken based on Level 1 has failed. Automatic isolation of the heating medium from the gas stream will initiate a transfer of the gas turbine to a cold mode of combustion operation and/or lower turbine load.

Level 3. At a minimum, triple redundant sensing instrumentation is implemented and set at a level higher than that of Level 2. Output from these signals shall be integrated into the customer's master trip signal. This provides a final level of indication/mitigation following a rupture/leak event. Activation of these level switches prevents water from being admitted to the combustion system by either isolating the gas supply or tripping the gas turbine.

System Flowpath

As the incoming gas fuel supply enters the plant facility, it first passes through one of two 100% coalescing filters. These filters are required to remove both liquids and particulate from the customer's gas supply. The filters may not be required if similar equipment is installed upstream by the gas supplier. Liquids collecting in the Coalescing Filter Sump are automatically drained into the common Drain Tank. A differential pressure switch installed across the filters monitors pressure differential and alarms when cleaning or cartridge replacement is required.

Downstream of the Coalescing Filter, the gas fuel supply enters the Electric Startup Superheater. This startup heater is required when the gas supply does not meet the minimum superheat requirement.

The electric heater is turned off and then bypassed at the point when the Performance Gas Fuel Heater is capable of maintaining gas temperatures above the minimum superheat requirement.

As fuel exits the superheater, it enters the Performance Gas Fuel Heater. This system incorporates a stacked two-shell heater arrangement with the gas on the shell side and the feedwater on the tube side. Each of the heat exchanger shells is furnished with low point collection sumps. These sumps house level instrumentation that provide early indication of a heat exchanger tube leak or rupture and automatically control the sump drain valves.

Activation of a single high level switch indicates detection of a Level 1 leak, while triple redundant high-high level switches indicate a Level 2 leak (*See Figure 5.*) A full bypass/bypass valve is provided around the Gas Fuel Heater to allow for certain modes of operation when the heat exchanger is not in service. Dependent on combustion type and frame size, these "cold" modes of operation may be load and/or emissions limited. (Refer to the Combustion Specific Requirements.)

The gas fuel exiting the Gas Fuel Heater Skid enters the gas fuel scrubber. This "dry" scrubber performs two functions in that it a) provides the final level of particulate filtration upstream of the gas turbine, and b) removes gas-entrained water droplets present as the result of a minor tube leak (i.e., pinhole). Two levels of instrumentation within the scrubber monitor for the presence of liquids. A high level switch will generate an alarm and automatically open the scrubber drain valve that drains collected fluids to the drain tank. Two out of three high-high level switches indicate detection of a Level 3 leak, thus initiating a signal to trip the gas turbine. (*See Figure 5.*)

Downstream of the gas fuel scrubber, the gas fuel supply enters the gas fuel metering tube. The metering tube houses a flow orifice, two differential pressure transducers, three temperature elements and a pressure transducer. The gas turbine control systems read signals provided by these instruments to calculate a pressure and temperature-compensated fuel flow.

The typical Gas Fuel Heating System uses intermediate pressure feedwater as the heating medium. The feedwater enters the Gas Fuel Heater Skid and passes through a double block-and-bleed valve arrangement to the tube side of the heat exchanger. These automated block-and-bleed valves prevent gas from backflowing into the feedwater systems during unit shutdown if a tube leak is present. A similar three-valve block-and-bleed configuration is provided at the heat exchanger feedwater outlet. The gas temperature control valve is located directly downstream of the second isolation valve.

Component Description

The following section provides a detailed description of the hardware components within the typical Gas Fuel Heating System. Unit specific components may differ based on incoming gas conditions, heating requirements and over-all plant configuration. The component out-line drawings may differ depending on the equipment supplier:

Coalescing Filter Skid — The Coalescing Filter Skid is designed to protect the downstream gas fuel system against the entry of both liquid phase fuel and particulate contaminants. (*See Figure 6.*) At rated flow, the efficiency of the filter is 100% for solid and liquid particulate larger than 0.3 microns at rated flow. This skid is not designed to remove large quantities (i.e., "slugs") of liquids.

The skid, as shown, consists of two 100% gas flow coalescing filters. Each filter is designed for performing maintenance without removing the gas turbine from service. Peaking units may use a simplex arrangement, where the filter can be cleaned or maintained during unit down time.

Each filter house contains a liquid collection sump. The sump is furnished with a drain system that automatically removes liquids from the vessel. A high level switch is provided to monitor the sump level. (See Coalescing Filter Skid Controls.) (**Note:** If large quantities of gas entrained liquids are expected, a scrubber may be required upstream of the coalescing filter.)

Electric Startup Superheater — The Electric Startup Superheater is needed at ignition when the fuel supply does not meet the minimum required superheat level as defined in GEI-41040. (*See Figure 7.*) The heater's capacity is sized to provide this temperature rise for fuel flows up to the point where the performance heater can maintain the temperature. The heater's capacity will not maintain the super-heat level at fuel flows in excess of this value.

The heater is an industrial unit designed for natural gas application. A Silicon Controlled Rectifier (SCR) controls the heater. The SCR controller maintains a constant differential across the heater and over the entire range of gas fuel flows where superheating is necessary. (**Note:** Non-electric heat exchanger designs, i.e., gas-fired or oil-fired, may be used for this application. The startup superheater requires a heat source available at gas turbine ignition.)

Gas Fuel Performance Heater Skid — The Gas Fuel Performance Heater Skid consists of two stacked shell and tube heat exchangers in series, gas and water side isolation valves, vent and drain valves, and instrumentation required

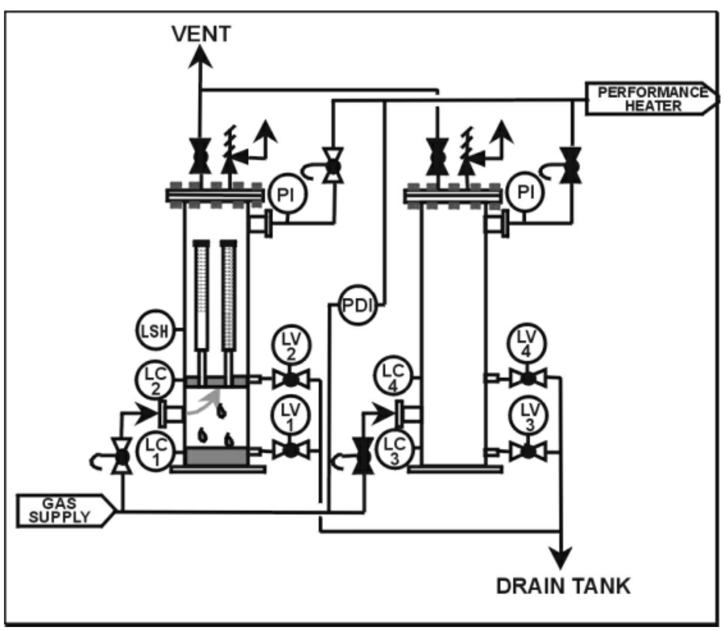

Figure 6. Standard Coalescing Filter Skid

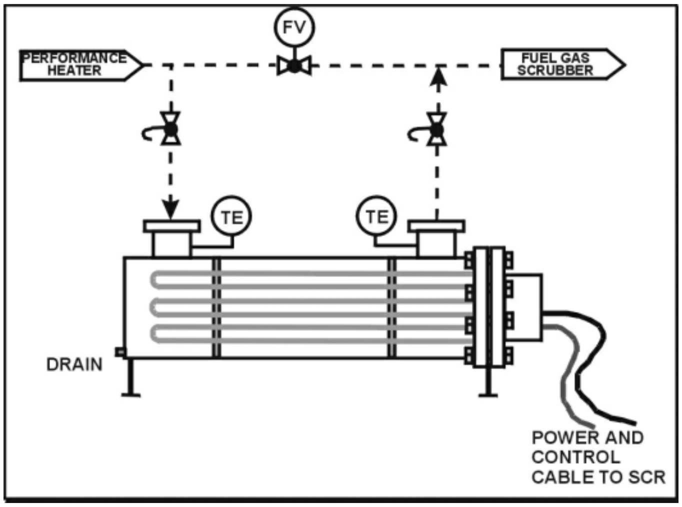

Figure 7. Standard Electric Startup Superheater

to support the operation of the gas fuel heater. (*See Figure 8.*) The heat exchangers are single pass, fixed tubesheet type, and include expansion bellows on the shell. The heat exchangers are mounted on a common base. The heat exchanger is designed for the intermediate pressure feedwater to flow within the tubes and the lower pressure gas fuel to flow through the shell.

With water pressure being higher than gas pressure, this configuration insures that gas will not enter the feedwater system following tube leak or rupture. The design of the system incorporates various safeguards designed to prevent water entering the gas from being admitted to the gas turbine combustion system.

Each heat exchanger is furnished with a drain pot at one end of the shell. These drain pots house level instrumentation that provide early indication of tube leak/rupture prior to and during gas turbine operation.

The physical configuration of the heat exchanger has the gas inlet at the side of the first stage heat exchanger and the outlet at the top of the second stage heat exchanger. The nozzles oriented in this manner prevent water from collecting in the inlet or outlet piping following a tube rupture event.

Each heat exchanger is furnished with a flow restrictive orifice plate located at the inlet and outlet tube sheets of each shell. This orifice plate controls the amount of water that exits as a result of catastrophic tube rupture. This design is required to both minimize the effect on the feedwater system and to limit the quantity of water entering the gas stream. The downstream orifices are non-concentric with the tubes to allow draining during shutdown. The Gas Fuel Heater is sized to accommodate temperature downstream of the heat exchanger and will be able to supply the desired temperature for all operating conditions.

It may be necessary to provide an automated by-pass system around the Gas Fuel Heater in order to satisfy the Combustion Specific Requirements defined in this document. The need for this by-pass will depend highly on the actual heater system applied to a unit.

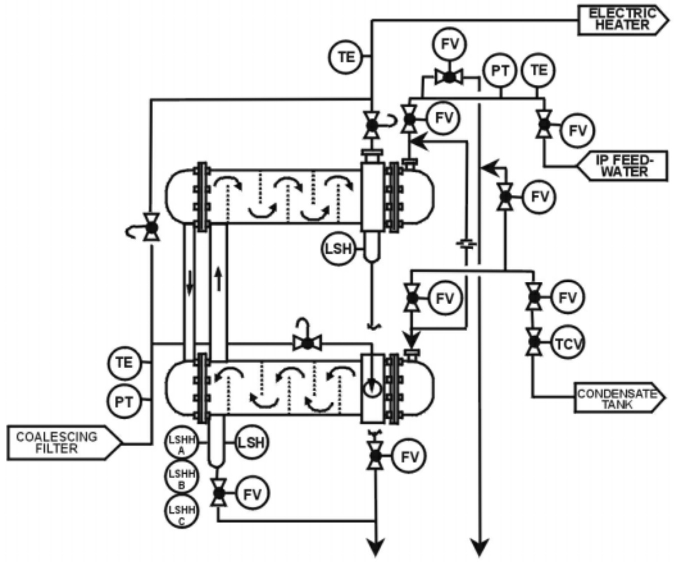

Figure 8. Standard Gas Fuel Performance Heater Skid

Gas Fuel Scrubber — The Gas Fuel Scrubber provides the final level of filtration directly upstream of the turbine. (*See Figure 9.*) The scrubber also removes water droplets from the gas stream following the event of a heater tube leak or rupture. For particulate 8 microns or larger, removal is 100% efficient at the design flow rate. The performance of the scrubber insures that the outlet gas will contain no more than 0.10 gallons of entrained liquid per million standard cubic feet of gas, at the rated flow. The scrubber is furnished with an automatic drain system that discharges to the Drain Tank.

The Gas Fuel Scrubber is a vertical, multi-cyclone, high-efficiency dry-type separator. The scrubber vessel is manufactured of carbon steel and is designed to satisfy the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code (Reference 3). The outlet flange of the scrubber serves as the carbon-to-stainless steel interface point for the Gas Fuel Heating System. In other words, the piping and valves between the scrubber and gas turbine connection shall be stainless steel.

Drain Tank — The Drain Tank is an atmospheric horizontal tank constructed of carbon steel. The Drain Tank collects and stores liquids discharged from the Coalescing Filter Skid, the Performance Heater drain pots, and the Gas Fuel Scrubber. The vents from the performance heater also discharge to the Drain Tank. Due to the potential for collecting both gaseous and liquid hydrocarbons, a flame arrestor is mounted on the Drain Tank vent. The tank is mounted within a containment dike in order to protect the environment from hazardous discharges.

The Drain Tank is furnished with a local level gauge and a high level switch. Manual draining of the tank is required when the level reaches a specified setpoint. If excessive amounts of liquids collect in the drain tank, they should be analyzed and their origins determined.

System Controls

This section provides a detailed description of the controls hardware and software associated with the typical Gas Fuel Heating System. Unit

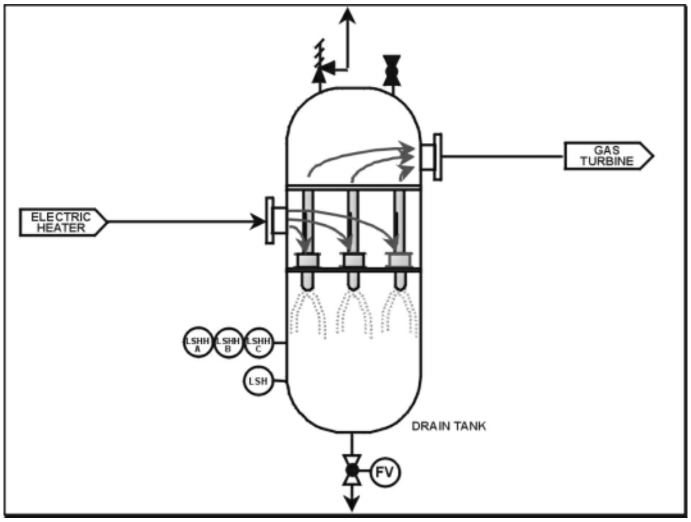

Figure 9. Standard Gas Fuel Scrubber

specific controls may deviate from the following descriptions based upon the specific plant configuration.

Coalescing Filter Skid Controls — Each of the two full capacity coalescing filters is furnished with a level controller and integral drain valve. The controller maintains a minimal level in the sump by continuously opening and closing the drain valve. Collected liquids are discharged to the Drain Tank. A single high level switch monitors sump level. An alarm within the plant's control system will initiate upon activation of this switch. Each filter is also furnished with a local level gage.

A high differential pressure switch monitors the pressure drop across the coalescing filter that is in use. Activation of this switch generates an alarm in the plant controls indicating that a switch over to the clean filter is required. The gas outlet of each filter is furnished with a local pressure gage.

Electric Startup Superheater Controls — The Electric Startup Superheater controls are configured to achieve the desired gas fuel temperature at the heater outlet based on the temperature differential across the heater. The controls are set to maintain a constant differential temperature with a maximum temperature limit.

The constant differential is the difference between the minimum supply gas temperature and the minimum superheat level above the fuel's dewpoint. All control functions are per-formed locally by a dedicated SCR controller.

Gas Fuel Heater Skid Controls — The gas temperature controls regulate and monitor temperature of the gas fuel supply to the turbine. Temperature elements and transmitters are furnished at the gas side and waterside inlets to the gas fuel heater and on the gas side outlet. Signals provided by these instruments are sent to the control system. These signals are used to modulate the flow control valve located at the waterside outlet of the heater in order to attain the desired gas fuel temperature.

Design Considerations for Heated Gas Fuel

Summary

This publication was developed to (a) identify the requirements of the gas turbine with respect to the gas fuel heating systems, and (b) provide a descriptive overview of GE's standard Gas Fuel Heating System. This standard system has been developed to meet these requirements, while insuring safe and reliable gas turbine and power plant operation.

Due to the nature of this system, it is imperative that the detailed system incorporates means of personnel protection. This includes, but is not limited to, the discharge direction of pressure safety relief valves, the inclusion of personnel protection insulation and the prevention of gas fuel from entering and "hiding" in the plant's steam and feedwater system.

References

1. "Process Specification — Fuel Gases for Combustion in Heavy Duty Gas Turbines," GE Power Systems, GEI-41040.

2. "Gas Fuel Clean-Up System Design Considerations for GE Heavy Duty Gas Turbines," GE Power Systems, GER-3942.

3. Section VIII, ASME Boiler and Pressure Vessel Code.

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