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INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE

Application of a Heavy Duty F-Class Gas Turbine for Cogeneration MacKay River Cogeneration Plant

by

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Biography

Jack Szyszkowski is currently a Project Development Engineer with the Power Project Development group within TransCanada. Prior to his current position, his role was as the Owner's Project Engineer for the development, design, construction and start up phases of the MacKay River Cogeneration project. Jack graduated from the University of Saskatchewan in 1997 with a Bachelor of Science in Electrical Engineering.

Abstract
TransCanada owns and operates the 172 MW MacKay River Cogeneration Plant located adjacent to the PetroCanada MacKay River Enhanced Oil Recovery (EOR) Steam Assisted Gravity Drainage (SAGD) facility outside of Fort McMurray, Alberta. The Cogeneration plant is configured around a single GE 7FA gas turbine and a Deltak EOR Once Through Heat Recovery Steam Generator (OTHRSG). The produced power is provided to the PetroCanada facility, 3rd parties, as well as the Alberta market. All the steam generated by the plant is routed to the PetroCanada facility for use in their EOR SAGD process.

The project faced many technical challenges, including those associated with the extreme ambient conditions in Fort McMurray and the uniqueness of the EOR process. The project presented GE with the coldest GE 7FA installation in their fleet's history and also faced the challenges of installing one of the biggest EOR OTHRSG in operation and the only one behind an F-class engine.

The plant has been in commercial operation since February, 2004.

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1.0 Summary

TransCanada owns, operates, manages or is currently constructing approximately 5,700 megawatts of power*. This includes cogeneration, combined cycle, wind, hydro, and nuclear facilities. Of the TransCanada cogeneration facilities in Alberta, the largest electrical generator is the MacKay River Cogeneration Plant located in Fort McMurray, Alberta, Canada (see Figure 1).

Figure 1

In May, 2001, TransCanada and PetroCanada announced an agreement to build a 172 MW natural gas-fired cogeneration plant to be situated within PetroCanada's Mackay River oil sands development, 60 kilometres northwest of Fort McMurray, Alberta. The Cogeneration Plant would be an integral part of PetroCanada's Enhanced Oil Recovery (EOR) Steam Assisted Gravity Drainage (SAGD) process and would provide steam and electricity to the PetroCanada facility. The remaining electricity would be provided for sale to 3rd parties as well as to the Alberta market.

The plant is configured around a single 172 MW (ISO Rating), General Electric 7241 (FA) Industrial Combustion Gas Turbine equipped with a dry low emission system. The turbine exhaust gases, augmented by duct burners, then pass through a Deltak Once Through Heat Recovery Steam Generator (OTHRSG) to produce high pressure, 77% quality wet steam for use in PetroCanada's steam injection wells and production heaters. The OTHRSG operates in parallel with PetroCanada's steam generators as required to meet the steam need. The PetroCanada facility provides treated Boiler Feed Water (BFW) to the OTHRSG as well as mixed gas to the duct burners. Please refer to Figure 2.

* TransCanada announced the sale of TransCanada Power, L.P to EPCOR in May 2005, which is expected to close in the third quarter 2005. The LP owns 11 power plants in Canada and the U.S. generating more then 700 megawatts.

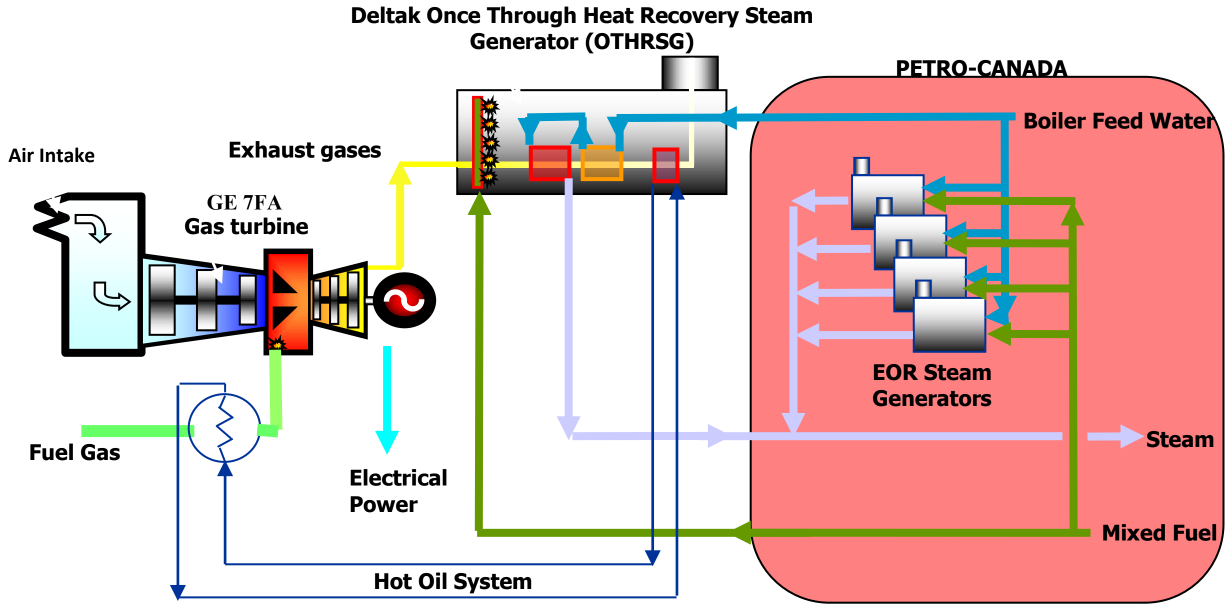

Figure 2.

The Project faced many technical challenges, including those associated with the extremely cold winter weather in Fort McMurray and the uniqueness of the EOR process. The Project presented GE with the coldest GE 7FA installation in their fleet's history. This drove some necessary changes and additional features within GE's scope of supply that will be discussed later in this paper.

The uniqueness of PetroCanada's SAGD process also drove the use of an unconventional HRSG design. Due to the nature of operation in a SAGD process, the OTHRSG is designed to operate with Boiler Feed Water (BFW) having high dissolved solids content. For this reason saturated steam is generated at an average of 77% quality, thereby resulting in the concentration of the feedwater impurities in the liquid portion of the wet steam. If this OTHRSG was allowed to continuously operate much above 77-80% quality, let alone with superheated steam, the result would be deposits on the tubing and potential failures. Although once through steam generators are commonly used for this type of application, the use of heat recovery steam generators has only matured over the past several years. In addition, the heat recovery steam generators that are in operation abroad are all of smaller capacities, primarily in the aero derivative as well as 7EA and 6FA range. The project's Deltak OTHRSG is one of the biggest in operation and the only one behind an F-class industrial gas turbine.

Construction of the Mackay River Cogeneration Plant began in July 2002, with Commercial in Service attained in February 2004.

2.0 Steam Host Process

The TransCanada Cogeneration Plant supplies wet steam to the 30,000 barrel per day, PetroCanada MacKay River Steam Assisted Gravity Drainage (SAGD) bitumen extraction facility. SAGD has much less surface impact than traditional oil sands mining. The SAGD process is a proven technology that involves drilling pairs of parallel horizontal wells into the oil-bearing formation. As shown in Figure 3, the top pipe carries saturated steam into the deposit to emulsify the viscous bitumen, while the lower pipe transports the recovered emulsified bitumen product to the surface. This recovered product is a mixed stream of softened bitumen, produced water (condensed steam return) and reservoir gas. The PetroCanada MacKay River SAGD facility includes pairs of these horizontal wells approximately 5 metres apart and 120 metres deep. Approximately 90% of the steam is recovered as produced water. The PetroCanada SAGD process is a relatively constant demand and pressure process that utilizes the latent heat of the injected steam. This process differs from other SAGD facilities that use pressurization and release batch process utilizing both the latent and sensible heat of the steam.

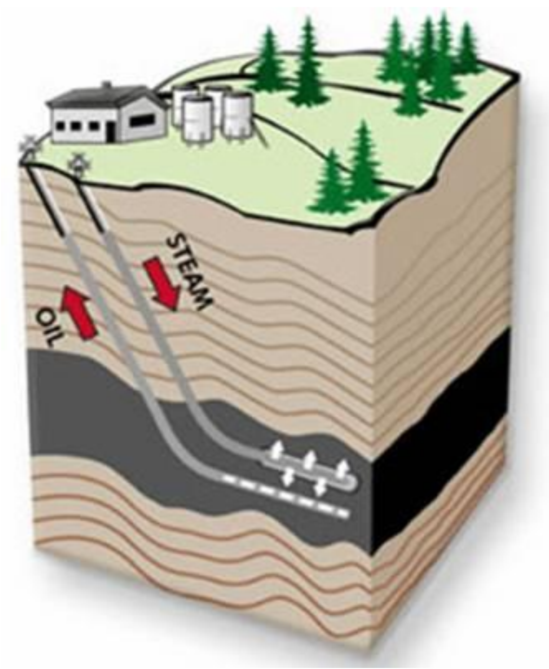

Figure 3

The PetroCanada facility is a zero liquid discharge (ZLD) facility and thereby recovers and recycles the produced water from the emulsified bitumen product. The produced water is separated from the bitumen, combined with make-up from an aquifer and sent to their water treatment facilities prior to reuse for steam generation. The PetroCanada facility uses a series of oil removal techniques, warm lime softeners, filters and weak acid cation beds to manage the boiler feedwater quality.

The PetroCanada facility also operates four gas-fired EOR steam generators, producing 80% quality steam. The Cogeneration Plant OTHRSG operates in parallel with the PetroCanada steam generators. The wet steam from the PetroCanada steam generators and/or the Cogeneration Plant is then routed to a set of high pressure steam separators that provide relatively dry steam for injection to the wells. The blowdown from the high pressure separators is then routed to low pressure steam separators. The low pressure separators provide steam to the ZLD evaporator as well as steam for plant utilities. The blowdown from the low pressure separators is then split and sent as feed to the ZLD, as well as recycled back into the process through the water treatment facility.

In addition to the produced water, the PetroCanada facility also separates reservoir gas from the emulsified bitumen product recovered from the wells. This reservoir gas, which may contain low content of H2S, is scrubbed and mixed with clean natural gas prior to delivery to the PetroCanada steam generators and/or the Cogeneration Plant. The Cogeneration Plant then uses this mixed gas as fuel for the OTHRSG duct burners for supplementary steam production.

3.0 Cogeneration Plant Fundamentals

3.1 Capacity and Process

To meet the high steam requirement of the PetroCanada facility, a heavy duty F-Class gas turbine was needed as the prime mover. Selection of a large heavy duty gas turbine would provide the Project with the efficiencies and economies of scale necessary to be viable. The expected steam demand forecast for the PetroCanada facility aligned very well with the steam generation capabilities associated with the GE 7FA. When the project entered into commercial operation, the plant was supplying the PetroCanada facility with their total steam requirement, while only operating with the duct burner at 10-20% capacity. As additional wells are brought into service, the PetroCanada facility steam demand will increase. With the additional available steam generation capacity from the operation of the duct burners, the plant will have the ability to provide PetroCanada with a large portion of their total demand for years to come.

The plant is also capable of operating the duct burners with the gas turbine at part-load operation. This mode of operation enables TransCanada to manage the spread between natural gas and power price, while maintaining steam production to the PetroCanada facility.

The MacKay River Cogeneration Plant is designed to operate with the GE 7FA gas turbine at base-load or part-load operation. Given the ambient conditions in northern Alberta, this is equivalent to a gross output range of approximately 90MW to 190MW. Of the total power generated by the facility, approximately 2 MW is used internally to the Cogeneration Plant, while 10MW is provided to the PetroCanada EOR SAGD facility. The remaining power is available for arrangement with 3rd parties as well as sold to the Alberta market.

Figure 4

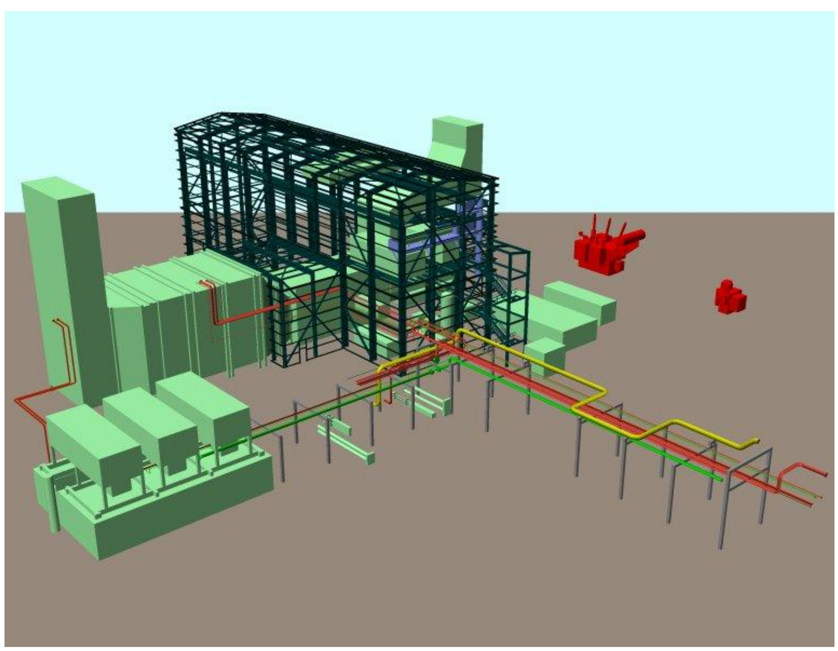

Figure 5

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As mentioned above, the facility is also designed to supply wet steam to the PetroCanada EOR SAGD facility. The PetroCanada facility delivers treated boiler feed water (BFW) to the Cogeneration Plant at approximately 12000 kPag and 160 degrees C. This BFW is then routed through the OTHRSG where it is converted to wet steam, and exported to the PetroCanada facility at saturated conditions of 77% steam quality, 9750 kPag pressure and 311 degrees C temperature. The reference to 77% quality is based on the mass ratio of steam and water in the generated steam/water bulk flow. The bulk flow contains 77% steam and 23% saturated water on a mass basis. The design concept is to have the impurities from the incoming BFW concentrating in the saturated water portion of the bulk flow and exiting the OTHRSG accordingly. As such, the steam quality is critical in ensuring that the impurities remain soluble in the flow and exit the OTHRSG without depositing on the tube walls and causing excessive tube temperatures and potential failures. This topic is discussed in more detail later in the paper.

With the gas turbine operating at base load operation with no supplementary duct firing, the plant will supply approximately 400 metric tonnes per hour of wet steam to PetroCanada. With supplementary duct firing up to a maximum of 816 degrees C, the plant can increase steam export up to approximately 700 metric tonnes per hour. Under these operating scenarios, the plant demonstrates a higher heating value (HHV) efficiency between 72-76%.

3.2 Daily Operation

The Cogeneration Plant is primarily operated from the main PetroCanada control room. The plant controller is integrated with the PetroCanada master steam pressure controller, thereby allowing the OTHRSG to automatically react to sudden changes in header pressure and steam demand. The PetroCanada operators have the ability to manage steam generation from the Cogeneration Plant by adjusting the OTHRSG duct burner level. In the event of a Cogeneration Plant trip, the operators have the ability to quickly start and ramp up the four PetroCanada steam generators, and thereby maintain a level of steam production.

4.0 Enhanced Oil Recovery Once Through Heat Recovery Steam Generator (EOR OTHRSG)

EOR SAGD projects impose different requirements on the design of heat recovery steam generators (HRSG) than those of more conventional process or utility steam generation applications. The common feature of most EOR SAGD projects is the lack of large quantities of clean, high quality utility grade water. For such applications, both permit requirements and economics drive the HRSG design to be able to effectively operate on recycled, produced water that is associated with EOR SAGD operations. As per figure 6, Boiler Feed Water within such processes contains high levels of dissolved solids (typically 5,000 to 8,000 ppm TDS) as well as trace levels of hardness, silica and iron.

Comparison of typical BFW values

Key Parameters	Conventional Steam Generation (Boiler Water)	EOR Steam Generation
Conductivity	<100 uS/cm	8,000 – 16,000 uS/cm (approximately equivalent to 5,000 – 8,000 ppm as CaCO3 TDS)
Hardness	0 ppm	< 1.0 ppm
Silica	< 1 ppm	< 150 ppm

Figure 6

The design and use of conventional steam generators is well documented due to an extensive number of units in current operation worldwide. Several operating standards and practices have been developed by well recognized groups such as the American Society of Mechanical Engineers (ASME) and the American Boiler Manufacturers Association (ABMA).

Although not nearly as evolved as that of conventional steam generation, operating experience for steam generators in EOR SAGD processes as well as other heavy oil steam injection projects has developed over the last several years. This operating experience has predominantly come out of Fort McMurray, Alberta and Bakersfield, California. Boiler Feed Water limits for EOR steam generator operation is addressed by the API 11T, Recommended Practice for Installation and Operation of Wet Steam Generators

Unfortunately, operating experience with the use of an EOR HRSG for such applications has not yet matured to the same level as for the EOR steam generator. API 11T can be used as a good guideline for HRSG operation; however, one needs to be aware of the distinct differences between the two configurations and take that into consideration when designing the facility.

The key differences between EOR steam generators and EOR HRSGs are:

- higher heat fluxes in the EOR HRSG than EOR steam generators. Although an EOR steam generator may be fired at a higher temperature, since the EOR HRSG design incorporates significant finned tubing in the critical areas, the resulting heat fluxes in those areas are higher;
- the gas turbine exhaust flow distribution is often erratic and non uniform, and varies with changing gas turbine load conditions;
- typically HRSGs have a much larger number of circuits, making the control system more difficult to manage.

4.1 General Design Concepts

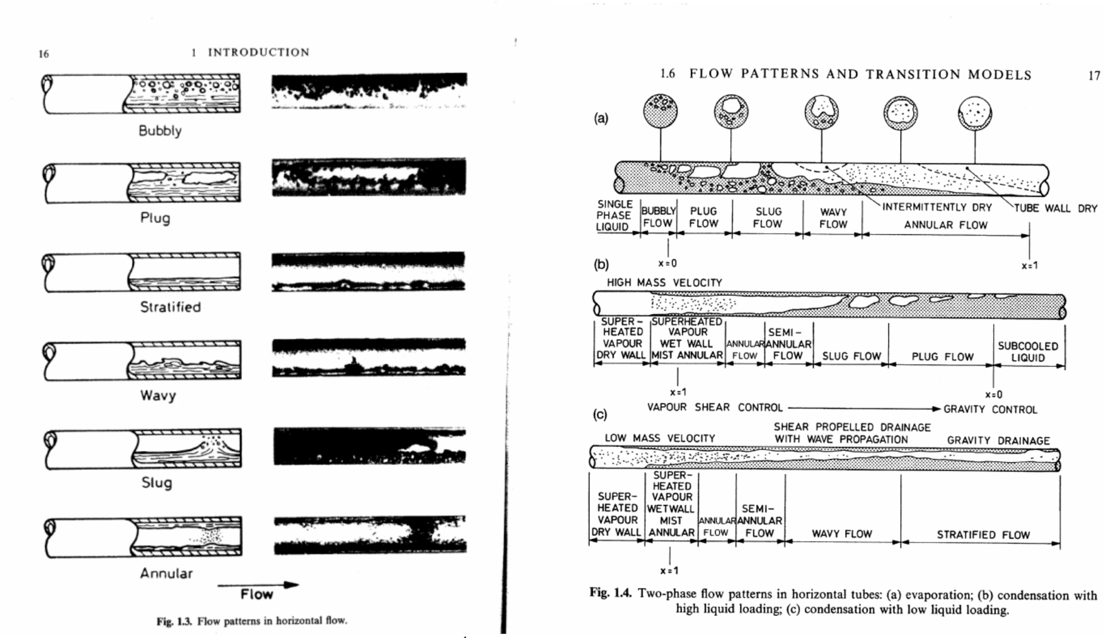
Due to the quality of the Boiler Feed Water used in the EOR SAGD process, the HRSG design is that of a once through forced circulation configuration, hence the name Once Through Heat Recovery Steam Generator (OTHRSG). The key elements of the OTHRSG design include heat flux, proper two-phase flow regimes and velocities, exit steam quality, and flow distribution in a multi-pass OTHRSG unit.

Since this is a once-through design and there is no steam drum, all Boiler Feed Water solids and impurities stay in the liquid phase of the water/steam mixture. The general concept in this case is to vaporize the maximum amount of the boiler feed water flow while still maintaining sufficient liquid at the outlet of the OTHRSG as required for the following objectives:

1) Maintain sufficient liquid in the bulk flow to ensure adequate cooling of the inner tube walls. This is to manage the boiling heat transfer coefficient and to keep the tube metal temperature down at a safe level.
2) Maintain the water soluble solids in solution to ensure they exit the OTHRSG

Objective 1: As the Boiler Feed Water proceeds through the OTHRSG circuit, the flow quickly goes through several flow regimes, namely bubble flow, slug flow, annular flow and dispersed or mist flow. Please refer to Figure 7

As nucleate boiling begins to occur (bubble flow regime), the approach to and formation of slug flow results in the acceleration of the feed water flow due to the increase in specific volume of the fluid. The increase in velocity tends to limit the slug flow regime prior to the formation of an annular flow pattern. Annular flow is basically a core of vapor traveling through an annulus of liquid.



Reference: Convective Boiling and Condensation – 3rd Edition by John G. Collier and John R. Thome

Figure 7

Due to the influence of gravity on horizontal tubes, the areas of low feed water/vapor velocity conditions (i.e., low steam quality) experience phase separations with the vapor flowing along the top of the tube and the liquid along the bottom. These conditions are not desired in high heat flux areas as they would cause tube dry-out conditions. The annular flow regime, specifically with the presence of a liquid film, does help maintain low tube metal temperature, nevertheless it is still not a desired operating condition due to the high solids content in the fluid (see Objective 2 below). As the bulk flow transitions through the annular flow regime and into the dispersed flow regime, the velocity increases, and the liquid film layer on the tube surface becomes thinner and will eventually disappear. The desired operating condition is a dispersed flow regime where the heat transfer takes place throughout the mixture, and the bulk fluid has sufficient liquid component to reach the inside tube wall, as required to maintain appropriate tube metal temperatures.

Through mainly operating experience, the industry accepted critical steam quality level where the liquid content in the bulk fluid is such that tube wall is subject to dry-out conditions has been determined to be around 80% by mass. This number is believed to be a maximum rather than an average. Operating proximity to 80% is dependent on the stability of operation as well as control accuracy and philosophy. The MacKay River OTHRSG is designed to operate at an average of 77% steam quality.

Objective 2: Since the Boiler Feed Water entering the OTHRSG has high levels of dissolved solids and other components, the quantity of the liquid in the bulk fluid exiting the OTHRSG has to be sufficient enough to carry all the impurities, within the acceptable limits of concentration, out of the OTHRSG so that significant deposition and scaling on the tube walls is avoided. As mentioned above, once steam quality begins to reach higher levels, annular flow regime is not desired because of the thin liquid film on the tube wall. In this case, heat transfer takes place through the liquid film, vaporizing a portion and leaving solids at the tube wall. This can result in deposition, increased tube temperatures, reduced performance and eventual tube failure.

Based on the 80% steam quality limit mentioned above, the impurities exiting the OTHRSG would be concentrated by a factor of five. For example, if the Boiler Feed Water entering the OTHRSG has a TDS level of 8000 ppm, the bulk fluid at the discharge would contain levels of 40,000 ppm when operating at 80% steam quality.

Based on the two objectives above, the fundamental design philosophy is therefore to control the flow regime and the maximum heat flux to the OTHRSG tubes. The flow regime is directly dependent on the tube side mass velocity, heat flux and steam quality. The maximum heat flux and its location relative to the steam quality condition is a very critical design consideration.

4.2 MacKay River OTHRSG

The MacKay River Cogeneration plant incorporates an OTHRSG designed and supplied by Deltak LLC. The unit is one of the largest EOR OTHRSGs in the world and the only one operating behind an F-class gas turbine.

The MacKay OTHRSG is designed under the ASME Section I Code and has 14 individual horizontal circuits, each one approximately 1.4 kilometres in length. The serpentine circuit configuration results in the economizer and evaporator sections of each circuit not having a fixed delineation point. The economizer/evaporator transition location will vary over the circuit length based on the theoretical point where the fluid begins initial evaporation. This point will move with changing operating conditions such as firing level, steam pressure, BFW temperature or steam quality.

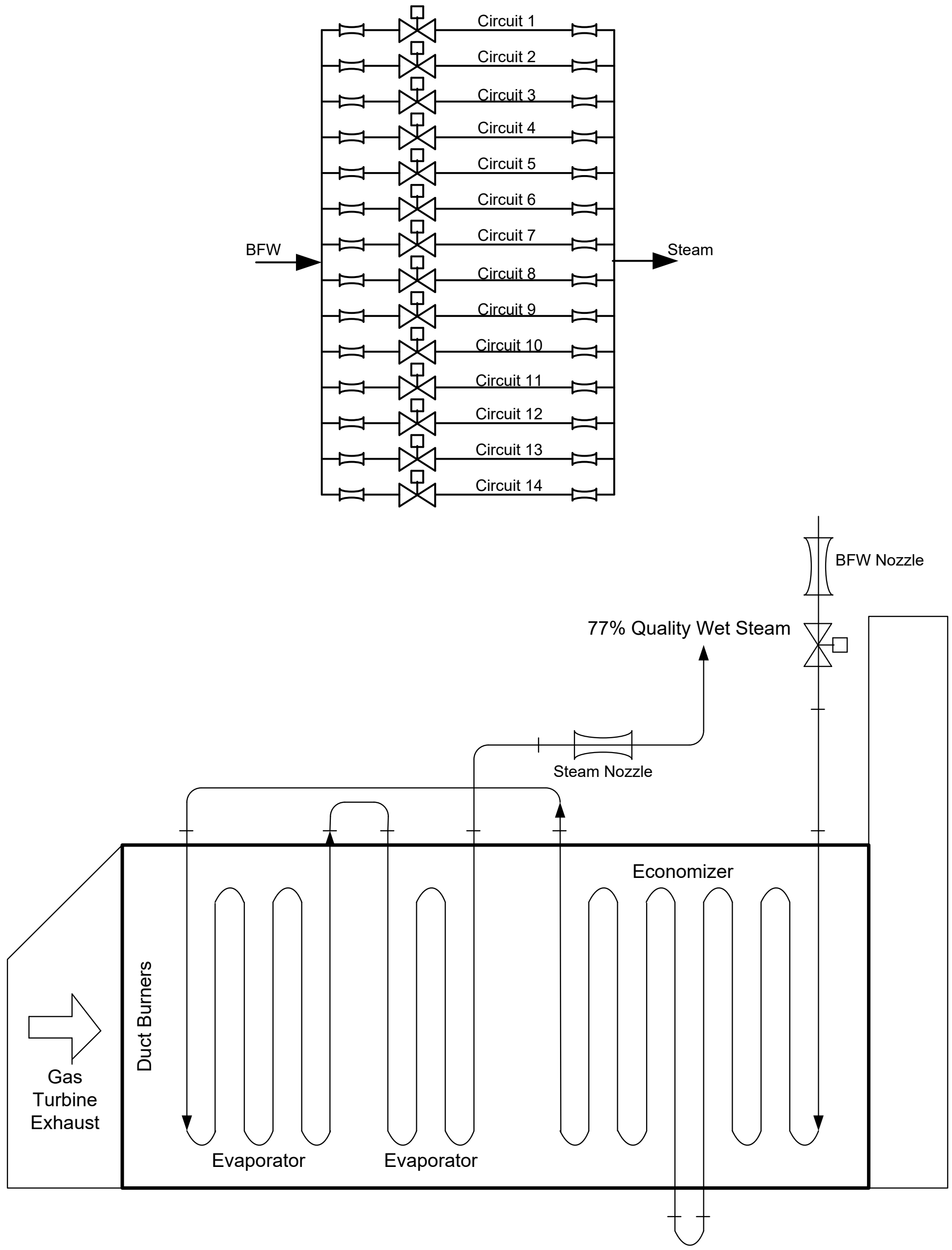


Figure 8

As per Figure 8 and Figure 9, the circuits are of counter-current/co-current flow arrangement. The economizer section is predominantly counter-current, while the evaporator section is co-current. The economizer section being counter-current to the exhaust flow takes advantage of the available temperature differential between the gas temperature and the fluid temperature while the evaporator section being co-current to the exhaust flow prevents local tube overheating by having the decreasing gas temperature matched with increasing steam quality. To provide further safeguards against tube overheating, the arrangement of the circuit is such that the maximum steaming formation occurs within the evaporator section located several rows back from the hot gas inlet.

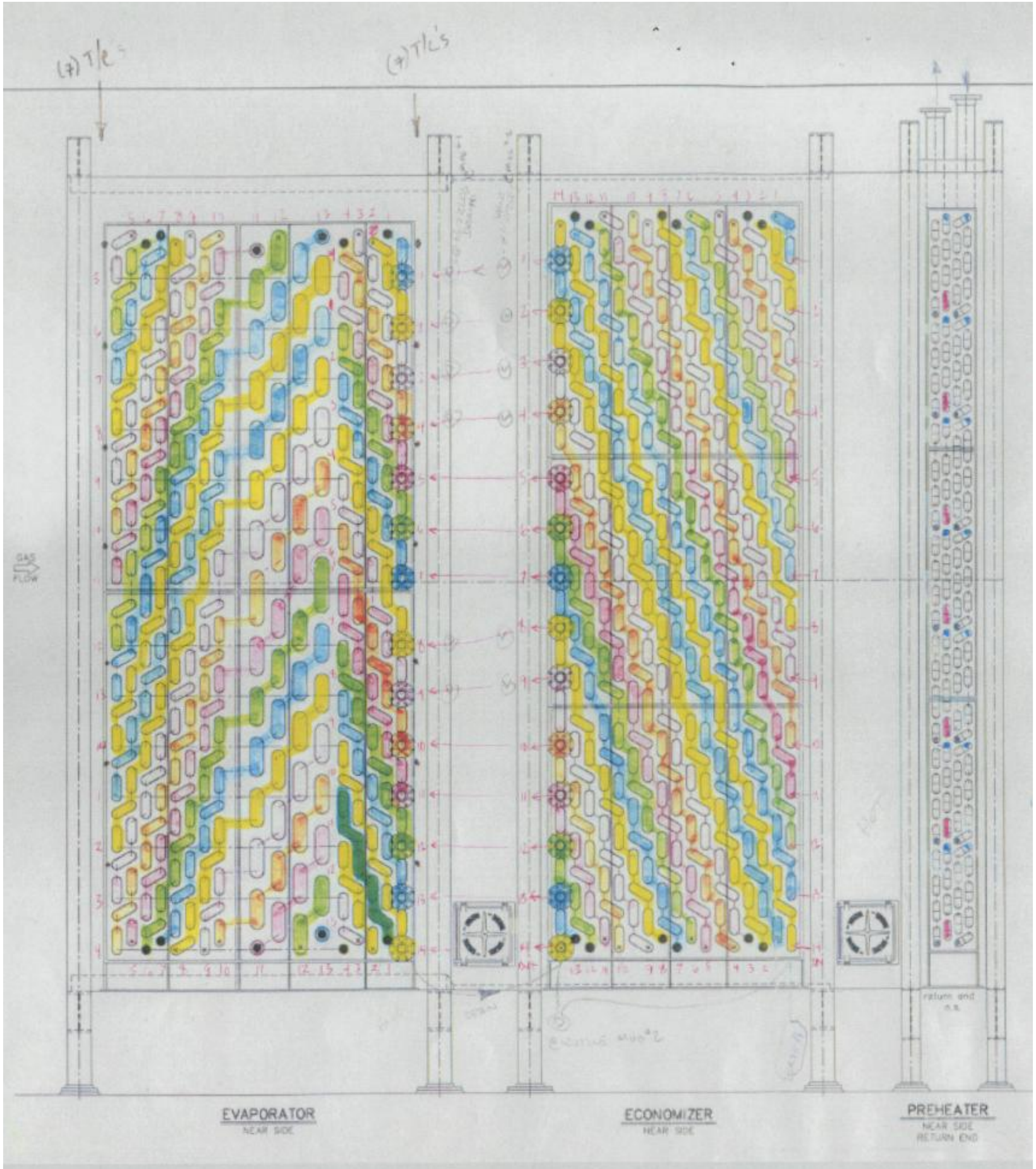


Figure 9

The economizer sections are all standard SA-106 Schedule 80 piping material, while the evaporator sections are made up of both SA-106 Schedule 80 and SA-210 material. In order to maintain steam velocities to appropriate levels to limit erosion, the tube diameter in the last several rows of the evaporator is increased.

Figure 10

Figure 10 shows the installation of one of the economizer modules. The modules are installed perpendicular to the exhaust gas flow.

In addition to the 14 economizer and evaporator circuits, the OTHRSG also has a separate coil dedicated to heating a hot oil medium. This hot oil is routed to heat exchangers for the purpose of heating the gas turbine fuel gas to 185 degrees C prior to the gas turbine skid, thereby reducing the gas turbine fuel consumption. The separate hot oil circuit also further increases the efficiency of the plant by extending waste heat utilization and decreasing the exhaust stack temperature.

As detailed in the above sections, due to the criticality of controlling Boiler Feed Water flow and steam quality, each circuit is controlled individually by monitoring the outlet steam quality. Each circuit has an associated feed water control valve, feed water flow orifice and steam flow differential nozzle.

4.2.1 Steam Quality Control

Steam quality control is a critical component in the OTHRSG's operating philosophy. In addition to maintaining the operation within the constraints of the design, steam quality measurement is also used in the heat balance calculations and for the purposes of custody transfer.

Since the OTHRSG steam generation is at saturated conditions, the determination of steam quality cannot be accomplished through conventional means such as simple measurement of pressure and temperature. The smaller EOR steam generators have predominantly used manual sampling methods to determine steam quality. For instance, this can be accomplished by comparing conductivity or alkalinity of the steam sample with the conductivity or alkalinity of the incoming Boiler Feed Water sample. The concept is that since the boiler design does not incorporate a blow down component, the feedwater impurities concentrate in the liquid portion of the wet steam. Comparison of the two readings is used to provide a good representation of the steam quality, and the results are then used to periodically adjust inlet boiler feed water flow to maintain the boiler in the proper operating range.

Due to the relatively high heat flux design of the Mackay OTHRSG, the number of circuits and a high variability of the GT exhaust flow and duct firing rate, the Mackay OTHRSG design includes on-line steam quality measurement. The on-line measurement is not only used for automatic control of the OTHRSG, but also for commercial billing and custody transfer. Manual sampling is included in the design, however, it is not used for daily control and operation of the OTHRSG, but rather more for periodic validation and auditing of the on line measurements.

As per figure 8, the Mackay OTHRSG incorporates a feed water control valve, feed water flow nozzle and a steam flow differential nozzle. To ensure high measurement accuracy, each flow nozzle was a prefabricated and tested meter run manufactured to meet ASME MFC-3M-1989 standards. Each flow nozzle meter run was calibrated to determine the specific nozzle discharge coefficients (C_d) and beta ratios.

In order to accurately measure steam quality for the safe and reliable operation of the unit, as well as for the appropriate accuracy required for custody transfer, TransCanada, in conjunction with Charles G. Turner & Associates Ltd., Deltak LLC and Bantrel Co., incorporated an on-line algorithm based on ASME Fluid Meters Theory and Application reference. By measuring the differential pressure across both the Boiler Feed Water and steam nozzles, comparing the two, and assuming that the mass flow of the fluid is constant (i.e., BFW mass flow in = Wet Steam mass flow out), one can determine the steam density through general hydraulic equations. Steam quality is then derived from the calculated density.

With this methodology, steam quality is continuously calculated and operation adjusted accordingly to maintain a safe and reliable state.

4.2.2. OTHRSG Pigging

Even if the OTHRSG design is such that the flow regimes and velocities are optimized, and the control system and steam quality measurement are designed to ensure quick response time and high measurement accuracy, due to the nature of operation one cannot completely avoid tube scaling and deposition. Mechanical cleaning, or pigging, has to be considered a major component of operation and as such, taken very seriously during the design phases of the project.

The MacKay River OTHSRG is designed to be completely piggable, with removable spool pieces on the inlet and outlet of each circuit. However, with the number, size and location of the spool and transition pieces that must to be removed to accommodate pigging, this has proven to be a very tedious exercise taking several days. Figure 12 shows the pigging spool arrangement on a single circuit. Considering that there are 14 circuits stacked on top of each other, the resulting space constraints make the removal of certain spools very difficult and time consuming. Figure 11 shows the piping layout of each circuit (BFW spools already removed, with steam circuits in the background).

Figure 11

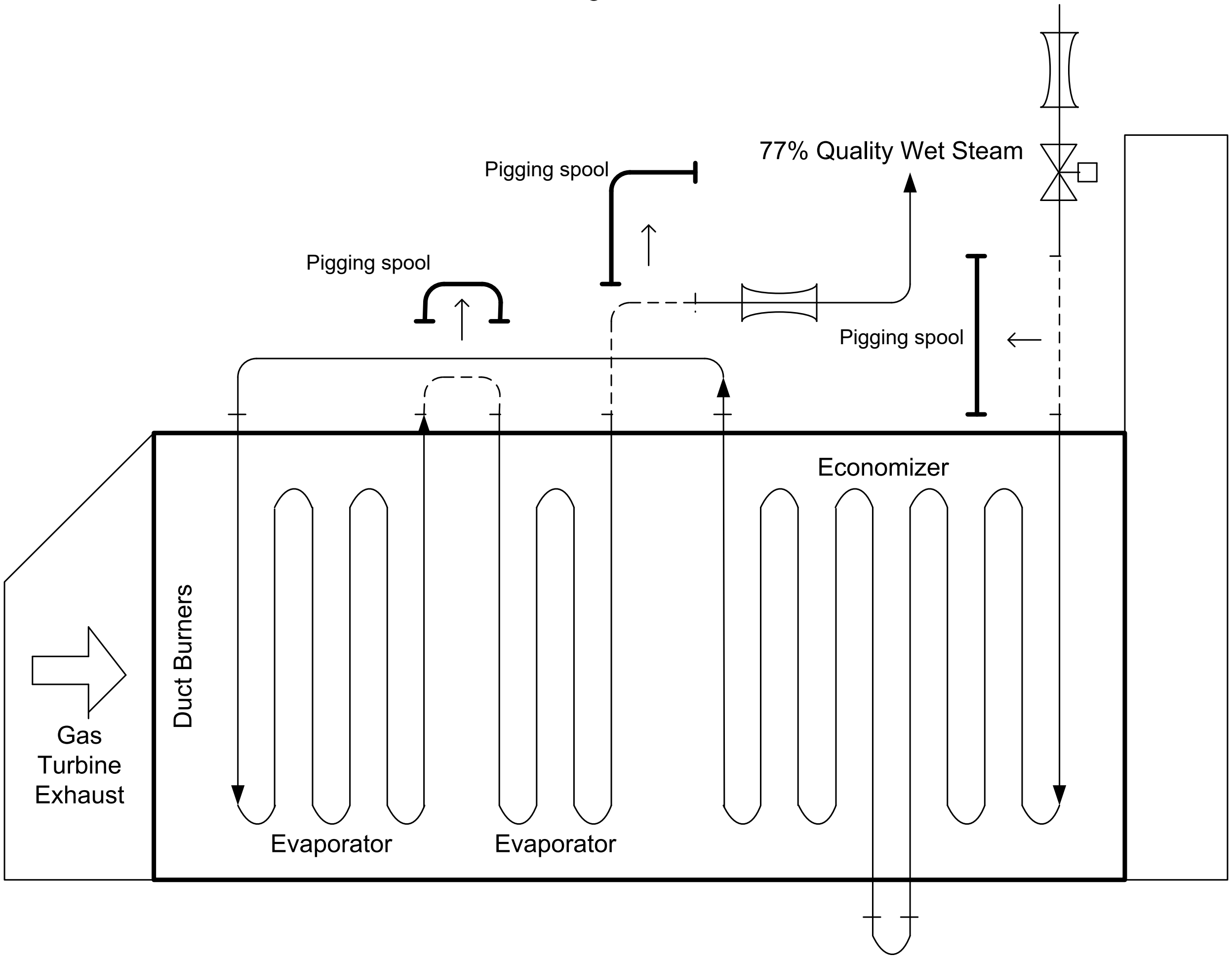


Figure 12

Third-party pigging experts get involved in the process, supplying hard polyurethane pigs, pig launchers, pumping rigs and tanks that store the collected scale and residue. Figure 13 demonstrates a typical cleaning pig, while Figure 14 shows connected pig launchers and recievers.

Figure 13

Figure 14

Due to the number of circuits, the time required to prepare the spool pieces, and the time required to relocate the pigging launchers, it is imperative that the pigging spool arrangement is optimized during the early design phases. TransCanada is currently evaluating different options for improving the current pigging process. Options include the relocation of certain pigging spool pieces to more accessible locations, as well as potential modifications to the existing spool pieces that would allow for easier and quicker removal.

The industry average has been to pig EOR steam generators and other the OTHRSGs at least once per year. The MacKay OTHRSG is currently above that average; however, this is primarily due to the relatively low amount of operating hours at the plant. Once OTHRSG operation and scaling characteristics are better understood, pigging frequencies will be adjusted accordingly.

5.0 Extreme Weather Challenges

One of the challenges that faced the design phase was extreme winter conditions that are predominant in northern Alberta. Historically, the region has witnessed ambient temperatures below -40 degrees C for an average of two weeks out of the year. The lowest temperature recorded in Fort McMurray was -51 degrees C. The MacKay River facility has the gas turbine generator installed within a turbine hall, while the OTHRSG is installed outside.

5.1 Gas Turbine Start-up and Shutdown

Since this was going to be the coldest location to which GE has ever supplied a 7FA gas turbine, operating experience was obviously at a minimum. These ambient conditions led GE to perform several studies in order to assess the implications of extreme cold weather on the various components and operation of the unit. The discussions concentrated predominantly on the 7FA compressor rotor. The compressor rotor is a relatively highly stressed part in the 7FA. The material property capability of some rotating components is reduced at extremely low temperatures and as such it was determined that the compressor rotor bore metal temperature must not fall below -31 degrees C. This was not considered a concern while the unit was operating, even with ambient temperatures as low as -51 degrees C, however, certain start-up scenarios were identified through simulations where it was possible for the compressor rotor temperature to reach the specified low limit temperature.

As a result of the extreme conditions in Fort McMurray, GE incorporated an inlet damper door into the design that would be used to block the inlet airflow through the gas turbine and minimize the convective heat loss due to the ‘stack effect’ during shut-down events. The operation of the damper door is a manual function. The damper can only be closed after the unit has reached turning gear speed and will be locked out otherwise.

During outages in extreme cold temperatures, the role of the inlet damper door becomes very critical, as it is imperative to close the damper door as soon as practicably possible. Depending on the position of the inlet damper door, the cooling rate of the compressor bore temperature changes. Should the door accidentally remain open, the cooling rate is significantly increased. If, during extreme cold temperatures, the position of the inlet damper door is neglected for a longer period of time, the result could be a potential lock-out of the start cycle.

The implemented logic also allows the operators to maintain the temperature of the compressor rotor above the critical limits through other non-conventional means, such as directing electric or gas fired heaters into the air plenum.

With the operator having the ability to manage the temperature inside the plenum, extreme cold conditions that are regularly experienced in Fort McMurray are not expected to impact availability of the unit.

6.0 Conclusion

The TransCanada MacKay River Cogeneration Plant was placed in Commercial Operation in the first quarter of 2004. The Plant faced many unique technical challenges such as those imposed by having one of the largest Enhanced Oil Recovery OTHRSG operating in the world as well as having the coldest installation for a GE 7FA gas turbine generator.

As expected for a first year of operation, there were a few design and commissioning issues that affected availability. The primary hit to availability was the increased duration of the planned outages that were required to address some of these issues. The duration and frequency associated with pigging of the OTHRSG is one of the largest contributors to the increased plant outage hours.

Operating Statistics (Year to Date)

Actual YTD Availability: 90% (includes a major outage in a 6 month operation window)
Planned or Budgeted YTD Availability: 93% (Based on planned outage duration)
Starting Reliability: 100%

TransCanada is actively pursuing to improve the OTHRSG pigging process and thereby increase the plant availability in the incoming years.