FLOWNEX®
SIMULATION ENVIRONMENT

REGULATOR TEMPERATURE ANALYSIS

Pressure regulators are to be employed at a gas-fired power station to reduce upstream gas pressures from a maximum of 15 MPa to approximately 3.5 MPa. Due to the Joule-Thompson effect, the resulting gas temperature drops could be in the region of 55 °C. The dew-point temperature of the hydrocarbons (gas) flowing through is -15 °C and the minimum ambient temperature of the area is -6 °C. Thus the regulators could potentially be subjected to gas at -61 °C at start-up. According to the valve manufacturer, temperatures as low as -20 °C can be tolerated for some time, provided that condensation does not occur.

POWER INDUSTRY

CHALLENGE:

The client needed to know:

- The temperature profile of the regulator seat during start-up operations.
- The effect of proposed measures to prevent the seat from experiencing such low temperatures.

BENEFITS:

Analysis of the regulator seat temperature over time and exposure to low temperatures were calculated. The simulation results will allow the client to determine what measures are needed to prevent adverse effects.

SOLUTION:

Operation of the pressure regulators during the start-up of the turbines at a gas-fired power station was studied and simulated in Flownex®. The major advantage of using Flownex® is that the capacitance of the pipe material and the full Joule-Thompson effect could be simulated. The simulations established that the regulator internals would be exposed to extremely cold gas for an extended period of time. The model was also able to determine if the proposed trace heating and insulation system would be sufficient to prevent the valve internals from cooling below their minimum temperature limit of -20°C, with a reasonable safety factor taken into account.

"Anyone familiar with transient heat transfer of flow systems with complicated geometries will tell you that such an analysis would be beyond the capability of most engineering houses. Flownex enabled me to obtain reliable ball-park results in a matter of a few hours. When the potential cost of equipment failure is tens of millions of dollars, this is an amazing result which highlights the incredible power and flexibility of Flownex"

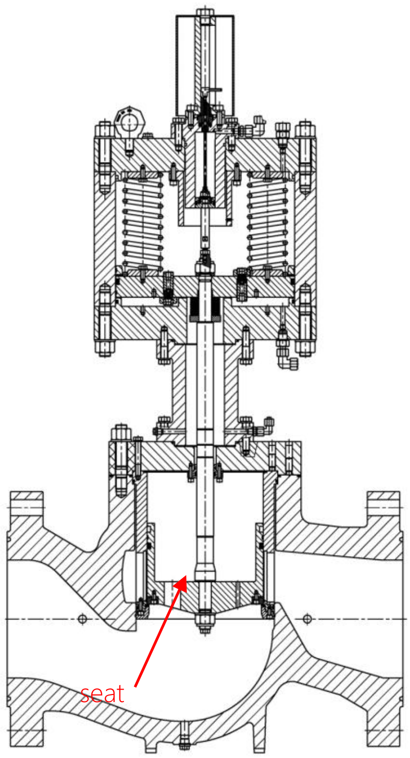
Hannes van der Walt
Senior Thermal & Process Engineer

REGULATOR TEMPERATURE ANALYSIS

INTRODUCTION

Pressure regulators are to be employed at a gas-fired power station to reduce upstream gas pressures from a maximum of 15 MPa to approximately 3.5 MPa. Due to the Joule-Thompson effect, the resulting gas temperature drops could be in the region of 55 °C. The dew-point temperature of the hydrocarbons (gas) flowing through is -15 °C and the minimum ambient temperature of the area is -6 °C. Thus the regulators could potentially be subjected to gas at -61 °C at start-up. According to the valve manufacturer, temperatures as low as -20 °C can be tolerated for some time, provided that condensation does not occur.

It was important to the client to analyse the regulator seat temperature over time and evaluate the exposure to low temperatures. The metal-alloy seat has an O-ring incorporated into its design to achieve proper sealing. At very low temperatures, the O-ring can deteriorate, become brittle and break. The seat itself may also become brittle and be susceptible to warping and/or breakage. The simulation results will allow them to determine what measures may be needed to prevent these adverse effects.



JOULE-THOMPSON EFFECT: Temperature change of a gas or liquid when it is forced through a valve or porous plug whilst no heat is exchanged with the environment (adiabatic expansion).

Figure 1: Cross section of a Pressure Regulating Valve.

BACKGROUND

At normal operations, the gas is heated up to 65 °C by heat exchangers upstream of the regulators. It then flows to the gas turbine where it is used as fuel (See Figure 2). However in the first minute of the start-up process, the mass flow rate is a lowly 1.5 kg/s per gas turbine. Thus the potentially cold gas contained in the pipe spool between the heat exchanger and the regulator will expose the regulator seats to extremely low temperatures for an extended period before the heated gas arrive at the regulators.

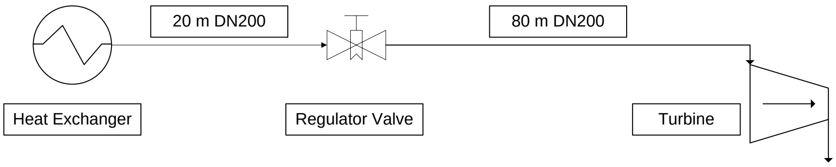


Figure 2: Flow path of the gas

SOLUTION

A Flownex® model in Figure 3 was developed to model the flow from the outlet of the heat exchangers through 20 m of piping to the outlet of the regulators. Temperatures vary along the length of the pipe. Thus to ensure sufficient accuracy of heat transfer from the gas to the pipe, it is subdivided into 20 increments. Gas flows through the system at the initial start-up flow rate of 1.5 kg/s for the first 60 seconds by opening the regulator orifice to 9 mm to achieve this. The Reynolds number using the fluid properties from the orifice were calculated. The convective heat transfer coefficient at the regulator exit through use of the Dittus-Boelter equation was then determined.

The benefits of using Flownex® for the simulation were:

- Heat conduction was simulated in 2D, lateral and cross conduction in the pipe wall.
- The thermal capacitance or ability of a material to store and release heat during transient events can be modelled to determine the actual start up conditions and the temperatures experienced by the regulator valve.
- Piping data could be obtained from the built-in pipe schedule tables. This ensure less time was spent on the setting up of the model and more time was available to evaluate and improve the design and operation of the

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system to protect the turbine from over pressurisation and low temperatures.

- User coding could be used to calculate the heat transfer coefficient of the gas at the regulator exit to accurately model the Joule-Thompson effect on the valve seat.
- The temperature profiles can be displayed graphically in Flownex® for easier interpretation of results.

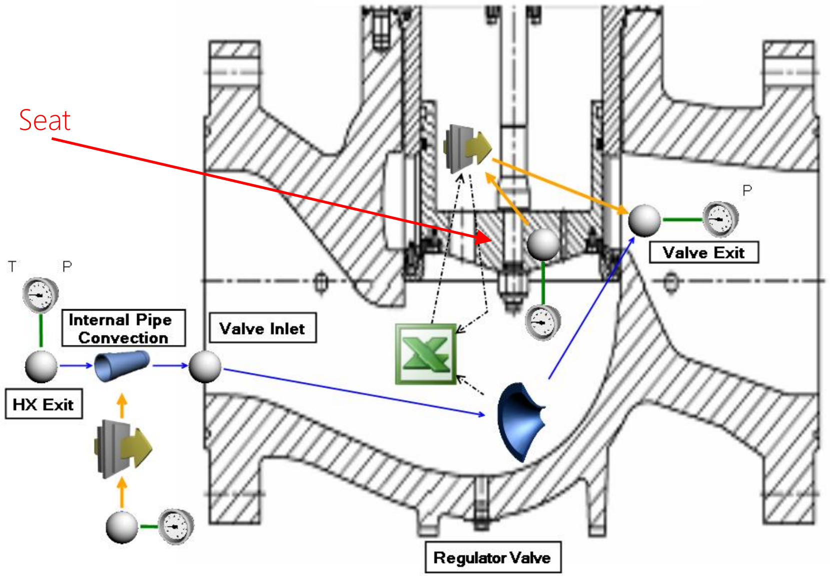

Figure 3: The Flownex® model used for analysis.

- A simulation run without trace heating and a simulation run with trace heating around the piping could be saved as snaps within one model. This feature can be used where different materials, fluids, boundary conditions, etc are to be compared on the same model without needing to set up each scenario and results from scratch each time or in different networks.
- The client could determine that the minimum temperature limit for the regulator seats would be exceeded due to the cold gas if no trace heating was used. Preventative measures were taken and in doing so, the client avoided a potentially disastrous equipment failure incident.

The model initialises all material and the contained gas to -6°C and then allows gas at 60°C to enter the upstream piping from the heat exchanger exit. Temperatures determined from the analysis are shown in Figure 4.

It is thus possible for the average regulator seat temperature to drop to unacceptably low temperatures (-40°C) for some time

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during start-up. The regulator inlet gas temperature will remain at -6°C for approx. 40s before heated gas from the heat exchangers arrive. The figure also shows that the regulator exit temperature is predicted to be at -63°C for about 40s before it starts to rise, and it will still be sub-zero after two minutes. These extremely low temperatures can have very catastrophic consequences.

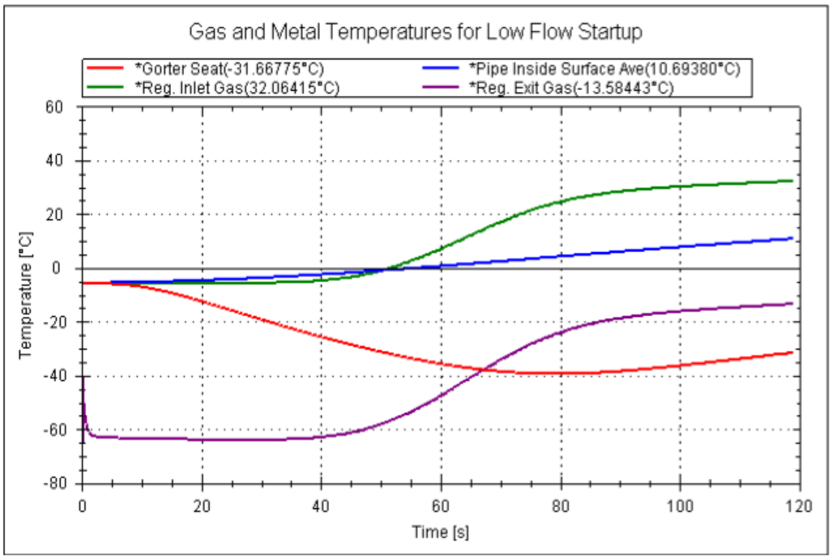

Figure 4: Flownex® temperature results of the gas and the valve seat.

"the Joule-Thompson effect causes the gas temperature in the regulator to drop to only about 12°C in the first 40s "

It was suggested that to prevent the gas from reaching subzero temperatures, trace heating be implemented on the pipe spool between the heat exchanger and the regulators.

The same Flownex® model was used for analysis, but all materials and the contained gas are initialised to 50°C and then gas at 60°C is allowed to enter from the heat exchanger exit. Figure 5 shows the predicted temperatures with trace heating installed.

None of the temperatures dropped below the regulator design temperature, and the Joule-Thompson effect causes the gas temperature in the regulator to drop to only about 12°C in the first 40s. The analysis shows that a trace heating system that will keep the gas temperature above 12°C would be adequate to protect the valve seats.

SUMMARY

Operation of the pressure regulators during the start-up of the turbines at a gas-fired power station was studied and simulated in Flownex®. The major advantage of using Flownex® is that the capacitance of the pipe material and the full Joule-Thompson effect could be simulated. The simulations established that the regulator internals would be exposed to extremely cold gas for an extended period of time. The model was also able to determine if the proposed trace heating and insulation system would be sufficient to prevent the valve internals from cooling below their minimum temperature limit of -20°C, with a reasonable safety factor taken into account.

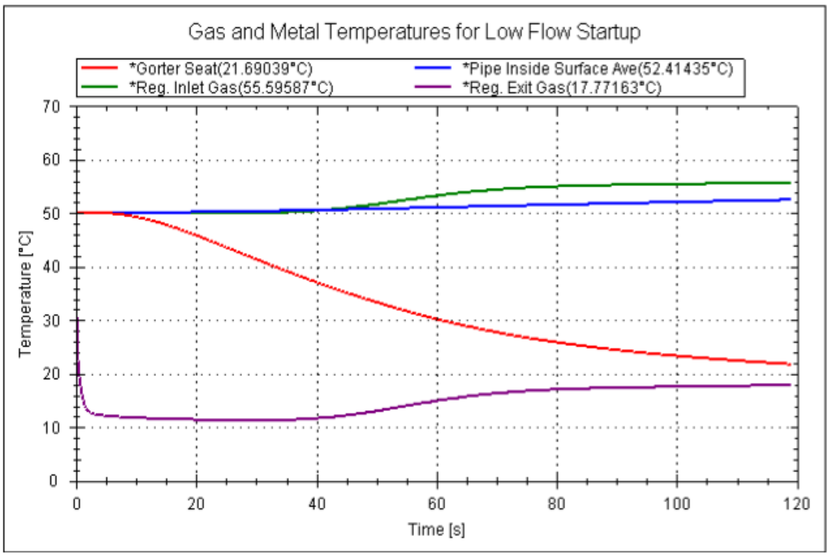

Figure 5: Flownex® temperature results of the gas and the valve seat (with trace heating).

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INDUSTRIAL GAS TURBINES BACKGROUND

A gas turbine, also called a combustion turbine, is a rotary engine that extracts energy from a flow of combustion gas. Energy is added to the gas stream in the combustor, where fuel is mixed with air and ignited.

The construction process for gas turbines can take as little as several weeks to a few months, compared to years for base load power plants. Their other main advantage is the ability to be turned on and off within minutes, supplying power during peak demand. Since single cycle (gas turbine only) power plants are less efficient than combined cycle plants, they are usually used as peaking power plants, which operate anywhere from several hours per day to a few dozen hours per year, depending on the electricity demand and the generating capacity of the region.

Natural gas is currently one of the most widely used fuel for new power plants, mainly due to attractive gas pricing, low emissions and the favourable capital costs of gas turbine power plants.