A standard quench control application to significantly improve the simple PID loop approach.
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QUENCH CONTROL
An advanced approach for temperature control

Quench control is used in applications where cooling of the hot recycle gas is achieved by direct mixing of a cold multi-phase gas/liquid. The liquids used for quenching are already produced by operation of the refrigeration compressor, so a separate cooler is not needed. Figure 1 shows a piping schematic for quench control on the first side-stream of a four-stage refrigeration compressor.

In its simplest form, a quench controller is a standard PID loop that maintains a given temperature at a set point by opening and closing a control valve to maintain the controlled temperature. However, this simple PID loop strategy has its shortcomings. The main issue is that the set point temperature of the quench controller depends on the pressure of the cooled stream. Since the pressure changes continuously, the setpoint needs to be continually adjusted as well.

Avoid Slow Loop Reaction
One of the shortcoming of the standard PID loop approach is its slow response. The quench loop dynamics will be slow relative to that of the pressure and flow controllers. The hot recycle flow demand will change rapidly as flow stability decreases near the surge control line. Therefore, PID control alone is not sufficient to keep pace with the changes in recycle flow.
Controlling Temperatures Logically

Another limitation of the standard PID approach is that the quench controller will continue its attempt to maintain a temperature set point even when the hot recycle valve is closed. As the quench controller tries to control an unpredictable temperature in a pipe with little or no flow, the quench valve can open spuriously.

A crucial element with quench control is allowing quench control only when it is necessary. If the hot recycle valve is closed or only has marginal amount of flow, then the best control strategy is to keep the quench valve completely shut. This control strategy applies even if the measured quench stream temperature strays from what would be the controlled set point. The quench valve should only be used to chill the hot recycle gas. Thus, the quench valve should only be open and controlling when a significant amount of hot recycle gas is flowing.

Set Point Calculation

The set point temperature depends on the pressure of the cooled stream because the drums located at the inlets of a multi-stage compressor contain a two-phase mixture. The separated gas in the upper portion of the drum is saturated, so the temperature of the gas is a function of the drum pressure. If the quench controller setpoint is much greater than the saturation temperature, the hot gas will potentially overheat the compressor. If the quench controller setpoint is too close to the saturation temperature, significant amounts of liquid may be drained and wasted from the main accumulator, leading to compression inefficiency. Additionally, excess liquid in the inlet drum has no chance to evaporate and may be carried over into the compressor, threatening impeller damage. Either scenario greatly disturbs the refrigeration process and needs to be avoided. Thus, the setpoint for the quench controller needs to be maintained near, but slightly above the saturation point of the inlet drum. See Figure 2 above.
Temperature Control Loop

Attempting to tune a temperature PID loop to keep pace with a changing flow control loop will certainly prove to be a wasted effort. The temperature control loop will continually struggle to maintain a temperature which is highly influenced by a rapidly changing hot recycle flow. The solution to this problem is to open the quench control valve, in addition to its closed loop response, directly proportional to the hot recycle valve opening (i.e. feed forward control). At any given drum pressure a ratio metric quench flow is needed to bring the flow mixture temperature to the quench control like. Feed forward control quickly sets the required quench to hot recycle ratio while PID control is only required to maintain zero steady state error.

Quench Control Strategy

The CCC Quench Application corrects the deficiencies of the standard PID loop approach through the following methods:

1. Calculation of the gas dew point to determine the temperature set point
2. Utilizing a feed forward signal from the antisurge controller to improve response time
3. Automatic sequencing the quench valve via coordination with the antisurge controller

By using CCC’s integrated approach, the end user gains powerful control strategies that avoid the dangers and hassles of simple PID control.
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