Controlled Rapid Autoclave Blowdown

By

Kevin Jackson

MOGAS Industries, USA

Presented by

Kevin Jackson
kjackson@mogas.com

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14330 E. Hardy St. Houston, TX, USA 77039-1405 **www.mogas.com**
ph +1.281.449.0291 **fax** +1.281.590.3412 **email** mogas@mogas.com

SEVERE SERVICE BALL VALVES

Background

Traditionally brick-lined autoclaves used in the High Pressure Acid Leach (HPAL) and Pressure Oxidation (POx) leaching processes of minerals, such as nickel, gold and copper, have a requirement to be depressurized or “blown down” due to process upsets, emergency situations, to allow access for essential maintenance, equipment replacement or failure.

The autoclave is fitted with a vent line that maintains the pressure in the autoclave. The vent line should not be confused with the “discharge” line that maintains the liquid level in the autoclave.

The vent line consists of isolation valves (Fig. 1 a) and a control valve (Fig. 1 b). Typical vent line sizes are four to eight inches, ANSI 600 class that contain two eight-inch high integrity severe service metal seated isolation ball valves that hold pressure in the autoclave when required and a four- or six-inch angle pattern globe control valve with actuator and 4/20mA control signal that controls the release of the elevated gas pressure from the autoclave into the quench vessel. This maintains desired pressure and prevents overpressurization of the autoclave.

Autoclave blowdown takes place using the vent line. The blowdown rate is governed by two factors: 1) the brick lining is subject to thermal shock if the temperature inside the autoclave changes too quickly and 2) the capacity of the control valve.

Generally the limiting factor for autoclave blowdown has not been the thermal shock of the brick lining as you would expect, but, the capacity of the globe control valve.

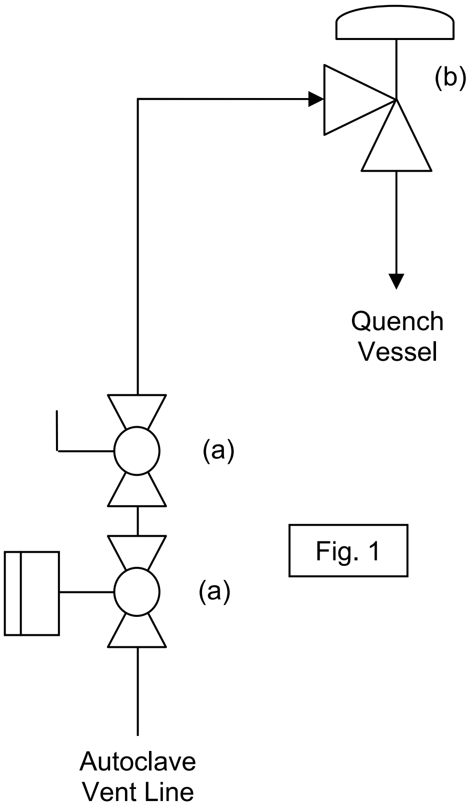
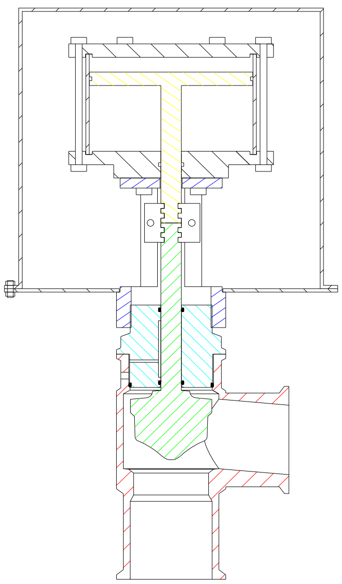


Fig. 1

The initial design pressure in the POx autoclave is approximately 3600 kPag at 180–240 C. HPAL autoclaves operate at approximately 6000 kPag at 240–270 C and pressure in the quench vessel is atmosphere, so the capacity of the control valve to handle flow rates at this ΔP needs to be small, around 25 to 35 C_v.


Typical angle pattern valve layout

When the autoclave needs to be blown down the angle pattern control valve releases pressure in the autoclave as it does in normal operating conditions, however as the pressure in the autoclave reduces the ΔP (difference in pressure in the autoclave and the quench vessel) the capacity required to pass the flow rate increases beyond the capacity of the angle pattern globe valve and therefore takes longer to completely depressurize the autoclave.

Globe control valves by design have limited rangeability (the ratio of the maximum controllable flow to the minimum controllable flow), this is because of their linear construction. Their ability to handle large scale differences in flow and/or pressure parameters inhibits their use in blowdown and other applications that require rangeability above 40:1.

The rangeability for the rapid autoclave blowdown is approximately 70:1.

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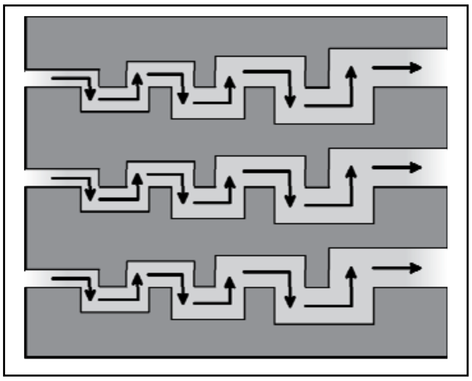
Within the oil & gas industry it has long been the practice to let pressure down across a multiple number of stages. There are a number of reasons for this, but primarily it is done when controlling gas flow to reduce velocity, noise, erosion and vibration. Of course, this multi-stage letdown or tortuous path technology has been applied in the past to relatively clean gases.



The principle operation of the tortuous path for gas flow is to control the pressure drop at each right angle turn, limiting the velocity and noise. With less velocity there is less erosion and vibration.

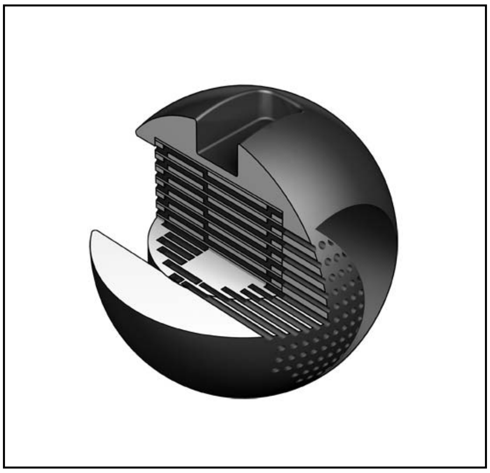
The number of right angel turns in the FlexStream® Technology trim can vary from two to 36, the number is dependent on the ΔP across the valve and flow rate.

The autoclave blowdown gas has some solid particle carryover, so by controlling the velocity the FlexStream trim is limiting the speed at which the particles collide with the trim and therefore limits the amount of potential erosion. It is crucial that velocity in the flow passages is not reduced to a level where solids can stall in the trim because they don't have sufficient speed to pass through the path.

It is important that the size of the path is sufficient to allow the volume of particles to pass through the trim. The solids content for this particular application is estimated at a maximum of 200kg/hr or greater than two percent by volume. Any particle that is too large to travel through the trim will gather at the bottom of the ball and be discharged when the valve is in its fully open position.

Because of the manufacturing techniques used in the production of the FlexStream trim, path sizes can be changed by simply changing the thickness of the plates that make up the trim element.

Rangeability is the key issue, as stated before, and any additional control valve added into the piping arrangement must be capable of handling the changing pressure drop and flow rates associated with the depressurization of the autoclave. The unique design benefit of FlexStream is to have rangeability in excess of 300:1.



Unlike a linear globe valve, the FlexStream trim is not linear and therefore it is not held by a bonnet assembly arrangement that compresses the trim and/or seat in place. The trim or seat is independently held within the ball by a removable retention ring. This means that the ball's inner diameter (ID) can be filled from 10 to 100 percent to ensure that the right amount of trim can be inserted to deal with the high ΔP and flow rate where required. As ΔP reduces, the ball is opened, producing the hydraulic diameter that allows low ΔP and high flow rates.

Transition across the flow may require less pressure letdown turns due to the reduced ΔP. This can be accommodated within the FlexStream trim element by changing the number of pressure letdown turns across each tortuous path, and in some cases, down to the drilled exit holes.

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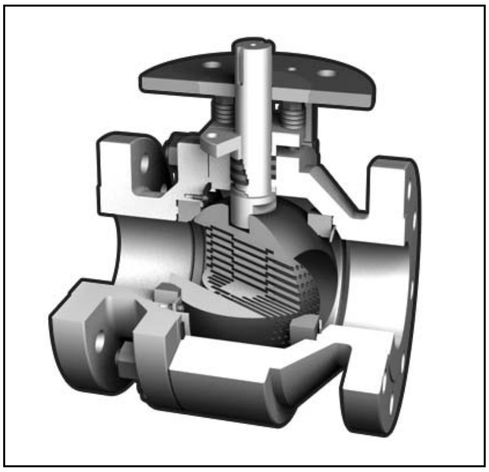
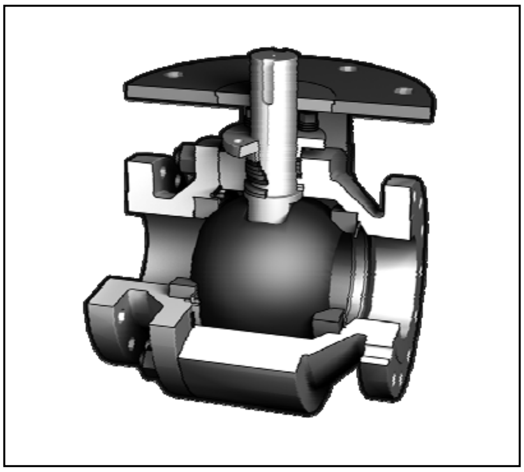
The advantage with the trim element being in the ball is that the surrounding valve body, stem, seals, gaskets and actuators are interchangeable with the existing isolation valves. This means less training for a site- or workshop-based maintenance staff.

Therefore, there is no introduction or concern surrounding the viability of the base valve design as it is already proven and in use.





The revised vent line system layout would include an additional 8-inch pipe run connecting the new rapid blowdown line to the quench vessel, the FlexStream control valve, actuator, 4/20mA positioner and additional I/O counts in the PLC/DCS.

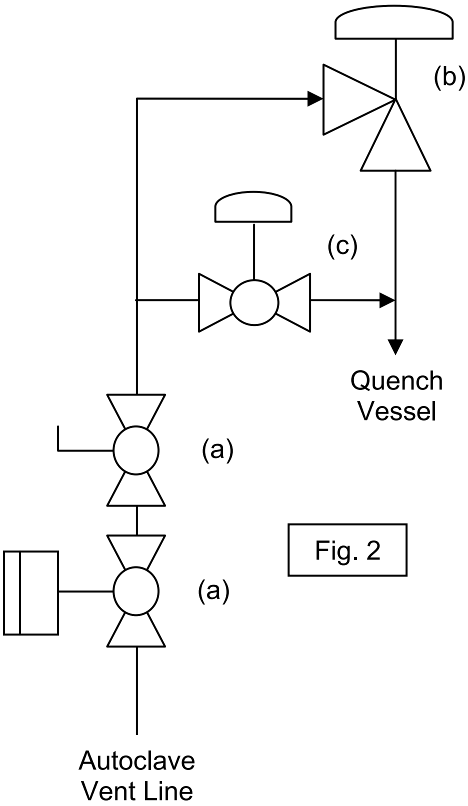


Fig. 2

The additional FlexStream rotary control valve would be fitted with an actuator capable of accepting a 4/20mA control signal for precise position control. This actuation can be achieved with pneumatic, hydraulic or electric power sources.

The normal mode of operation would be exactly the same as before. The control valve (Fig. 2 c) would be closed and the control valve (Fig. 2 b) would be regulating pressure in the autoclave. If the autoclave was called upon to depressurize, the control valve (Fig. 2 c) would position itself using the control loop and based upon the temperature the valve would position itself to allow gas and pressure to pass into the quench vessel. This process would continue until the autoclave reaches atmospheric pressure and the normal safety procedures for entry could be made.

This system is best incorporated in the initial plant design and layout, but can also be retrofitted.

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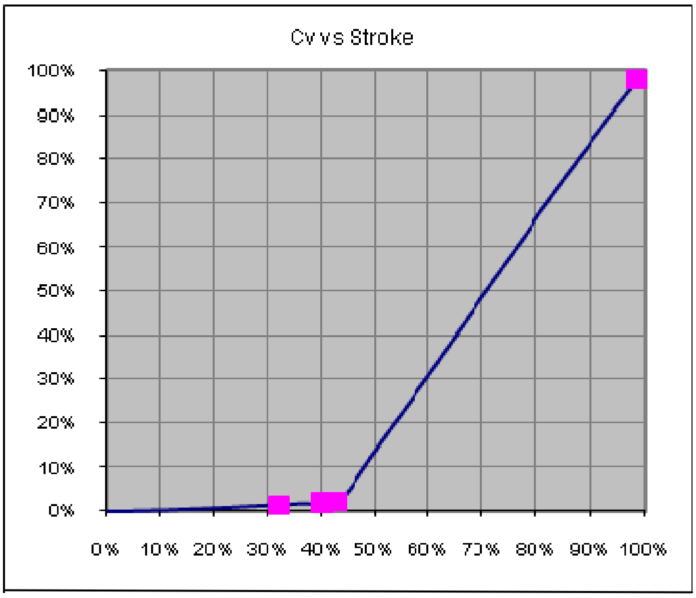
Sizing

<table>
<tr><td rowspan="16">PROCESS DATA</td><td>FLUID</td><td colspan="16">Autoclave Gas/Vapor</td></tr>
<tr><td></td><td>UNITS</td><td colspan="3">Max</td><td colspan="3">Norm</td><td colspan="3">Norm</td><td colspan="3">Norm</td><td colspan="3">Min</td></tr>
<tr><td>FLOW RATE</td><td>kg/s</td><td colspan="3">3.573</td><td colspan="3">3.573</td><td colspan="3">2.871</td><td colspan="3">1.989</td><td colspan="3">1.989</td></tr>
<tr><td>INLET PRESSURE</td><td>KPa(g)</td><td colspan="3">3618</td><td colspan="3">3352</td><td colspan="3">2352</td><td colspan="3">1352</td><td colspan="3">100</td></tr>
<tr><td>OUTLET PRESSURE</td><td>KPa(g)</td><td colspan="3">0</td><td colspan="3">2352</td><td colspan="3">1352</td><td colspan="3">100</td><td colspan="3">98</td></tr>
<tr><td>INLET TEMPERATURE</td><td>Deg. C</td><td colspan="3">230</td><td colspan="3">230</td><td colspan="3">165</td><td colspan="3">100</td><td colspan="3">100</td></tr>
<tr><td>MOLECULAR WEIGHT</td><td></td><td colspan="3">32</td><td colspan="3">32</td><td colspan="3">32</td><td colspan="3">32</td><td colspan="3">32</td></tr>
<tr><td>RATIO OF SPECIFIC HEAT</td><td></td><td colspan="3">1.54</td><td colspan="3">1.54</td><td colspan="3">1.42</td><td colspan="3">1.42</td><td colspan="3">1.3</td></tr>
<tr><td>COMPRESSIBILITY</td><td></td><td colspan="3">0.850</td><td colspan="3">0.850</td><td colspan="3">0.925</td><td colspan="3">1.000</td><td colspan="3">1.000</td></tr>
<tr><td>INLET DENSITY</td><td>lbm/ft3</td><td colspan="3">2.091</td><td colspan="3">1.941</td><td colspan="3">1.455</td><td colspan="3">0.936</td><td colspan="3">0.130</td></tr>
<tr><td>KINETIC ENERGY</td><td>Psi</td><td colspan="3">61.00</td><td colspan="3">3.44</td><td colspan="3">3.58</td><td colspan="3">8.47</td><td colspan="3">0.31</td></tr>
<tr><td>CALCULATED CV</td><td></td><td colspan="3">20</td><td colspan="3">30</td><td colspan="3">29</td><td colspan="3">27</td><td colspan="3">1303</td></tr>
<tr><td>STEM TRAVEL</td><td>%</td><td colspan="3">32.1%</td><td colspan="3">42.6%</td><td colspan="3">42.0%</td><td colspan="3">40.2%</td><td colspan="3">98.6%</td></tr>
<tr><td>SPL AT 1 METER</td><td>dBA</td><td colspan="3">89.4</td><td colspan="3">75.0</td><td colspan="3">75.0</td><td colspan="3">75.0</td><td colspan="3">75.0</td></tr>
<tr><td>OUTLET PIPE VELOCITY</td><td>Mach</td><td colspan="3">0.144</td><td colspan="3">0.011</td><td colspan="3">0.015</td><td colspan="3">0.060</td><td colspan="3">0.084</td></tr>
<tr><td>VALVE OUTLET VELOCITY</td><td>Mach</td><td colspan="3">0.148</td><td colspan="3">0.011</td><td colspan="3">0.015</td><td colspan="3">0.061</td><td colspan="3">0.087</td></tr>
<tr><td></td><td>Cv - Trim / Open / Turns</td><td></td><td>30</td><td>1302</td><td>8</td><td>30</td><td>1302</td><td>8</td><td>30</td><td>1302</td><td>8</td><td>30</td><td>1302</td><td>8</td><td>30</td><td>1302</td><td>8</td></tr>
</table>

The FlexStream Technology sizing that has been carried out in accordance with ISA S75-01. The chart above shows the five basic operating conditions of the valve. At each case the flow rate, ΔP, C_v, noise, kinetic energy and velocity is calculated to ensure they are not above the limits allowed by the standard or best practices for the industry.

The sizing shows that the maximum and normal cases have a C_v of 30 or less at a flow rate of between 3,573 and 1,989 kg/s with declining inlet and outlet pressures. These flow cases are passing through the eight-turn tortuous paths with velocity and noise control taking place due to the significant ΔP present.

This can be seen on the C_v – Stroke graph below.



The inlet pressure reduces as the pressure in the autoclave decreases and the outlet pressure to the quench system also decreases. The flow rate decreases but has less impact on C_v as the ratio of inlet to outlet pressure remains steady. As the pressure in the autoclave decreases the gas volume increases so it takes longer to release the gas through the restricted orifice in the angle control valve. With the high rangeability in the additional valve it simply opens further to allow the higher C_v to pass the increased gas volume.

At the minimum case the ΔP is 2 kPa (g) and requires a C_v of 1303 to be able to pass the flow rate of 1,989 kg/s, in this position, i.e. with the valve fully open, some of the flow will pass through the tortuous paths but the majority will flow down the hydraulic diameter.

Conclusion

By using the controlled rapid autoclave blowdown rotary control valve, blowdown times for the autoclave can be reduced from 24-plus hours to approximately 13 hours. This represents a significant reduction in turnaround times for the autoclave and can have dramatic impacts on run times and costs.

Irrespective of the process, HPAL or POx, the impact of this reduced depressurization time is reflected in increased production and will always be significant to the plant's efficiency. In the case of gold (our example) this is magnified due to the base metal price.

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