Compressor blowdown calculations: Comparison of HYSYS BLOWDOWN vs the Depressuring Utility

Introduction

Fluid temperatures can drop significantly during depressurization events and the heat transfer between the fluid and the vessel wall causes a reduction in the temperature of the material, which can lead to fracture if the temperature falls below the minimum design metal temperature of the material. It is therefore important to accurately calculate these temperatures in order to select proper materials for construction.

AspenTech acquired the BLOWDOWN software technology in 2015, developed by Professor Stephen Richardson of Imperial College London and Dr. Graham Saville formerly of Imperial College London (Ref. 1). With this acquisition, the BLOWDOWN technology was made available in Aspen HYSYS V9 and above.

This tool performs rigorous calculations that can potentially help reduce CAPEX in greenfield and brownfield projects affected by modifications such as changes in compressor maximum discharge pressures. The tool has a more intuitive workflow compared to the depressuring utility (DPU) which is now a legacy tool still available in Aspen HYSYS. The Depressuring utility remains a useful tool that can still be used for initial screening studies; however, it is essential that the user correctly specifies PV work and/or recycle efficiencies which can be prone to error. The DPU often produces conservative results which is desirable from a safety point of view but can lead to a highly over-designed system.

On the other hand, the BLOWDOWN technology has been proven through experiments and across over 400 projects to more accurately represent reality. There are known limitations of using the DPU for low-temperature studies; for instance, the inner wall temperature prediction by DPU is not recommended to be used as it is not calculated using a rigorous heat transfer model. BLOWDOWN technology (Ref. 2):

- has improved modeling rigor
- has better vessel and pipe models
- has more rigorous orifice models
- has better handling of dense-phase fluids
- has more accurate heat transfer models across liquid and vapor phases (which don't need to be in equilibrium)
- is easier to use (no PV work term, recycle efficiency, or dense phase tuning factor).

BLOWDOWN Technology vs DPU in Aspen HYSYS V10

In this study, a comparison between the BLOWDOWN technology and the DPU in Aspen HYSYS V10 was performed. A scenario was defined to depressurize a compressor station including associated vessels and piping. It was assumed that the entire compressor station volume was depressurized using a single restriction orifice. For this reason, the compressor settle-out conditions were calculated using the compressor inlet pressure and the maximum compressor discharge pressure. The schematic for the BLOWDOWN inventory is shown below.

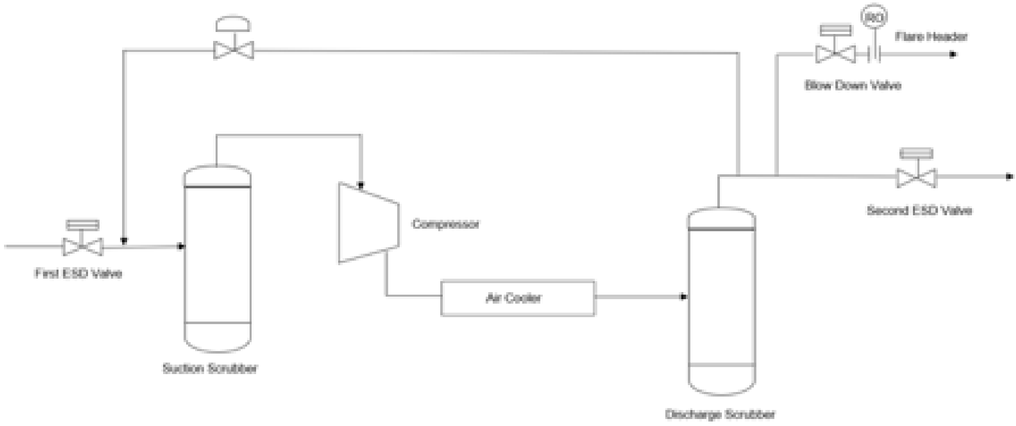

Figure 1: Compressor BLOWDOWN Inventory

The fire case (API 521) in BLOWDOWN was performed at the settle-out conditions considering the normal liquid level (NLL) in the vessel. The objective was to determine the restriction orifice (RO) size in order to reach a pressure of 100 psig in 15 minutes (Ref. 3). Once the RO size was established, another calculation was performed to determine the minimum temperature the fluid and wall would experience. This last calculation considers adiabatic heat transfer at the minimum ambient temperature and at isochoric pressure (obtained using the constant density approach). In order to be conservative, wind velocity, metal mass, and insulation were not considered.

Figure 2 below shows the input to DPU where the entire volume is lumped into a single vessel and the actual surface area of the inventory is adjusted in the top and bottom head area.

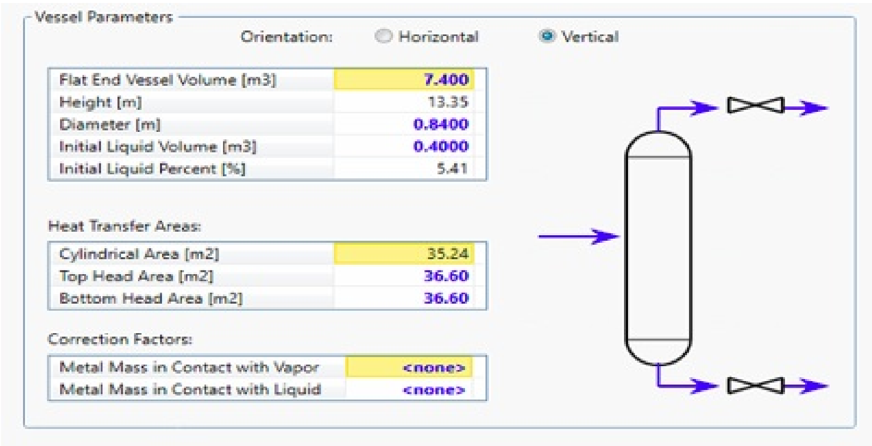

Figure 2: Input to DPU where entire system inventory (pipes and vessels are lumped into a single vessel)

On the other hand, the system inventory is specified individually as pipes and vessel in BLOWDOWN. The BLOWDOWN tool only allows one vessel to be defined in a single calculation, therefore suction and discharge scrubber volumes are combined into one vessel. Figure 3 below shows the input to BLOWDOWN, and Figure 4 shows a schematic generated by BLOWDOWN.

Geometry	Heat Transfer	Initial Condition		
	Inlet-1	Vapor Outlet_Boundary	Blowdown Line_V-1	Tail Pipe_Boundary
Wall Material	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Wall Thermal Conductivity [Btu/hr-ft-	24.96	24.96	24.96	24.96
Wall Thermal Diffusivity [m2/s]	1.180e-005	1.180e-005	1.180e-005	1.180e-005
Pipe Schedule	40	40	40	40
Nominal Diameter	8 inch	6 inch	6 inch	8 inch
Inner Diameter [in]	7.981	6.065	6.065	7.981
Wall Thickness [in]	0.3220	0.2800	0.2800	0.3220
Wall Roughness [in]	xxx	xxx	xxx	1.969e-003
Length [m]	30.48	127.0	10.00	100.0
Elevation Change [m]	0.0000	0.0000	10.00	0.0000
Volume [m3]	0.9838	2.367	0.1864	3.228
Model Pressure Drop	☐	☐	☐	☑
Model Mass Accumulation	☑	☑	☑	☐
Min Design Metal Temperature [C]	<Unbounded>	<Unbounded>	<Unbounded>	<Unbounded>
Max Design Metal Temperature [C]	<Unbounded>	<Unbounded>	<Unbounded>	<Unbounded>

Geometry | Internals | Heat Transfer | Simple Fire | Initial Condition	
	Main Vessel
Orientation	Vertical
T/T Length [m]	6.700
Cylinder Inner Diameter [m]	0.8400
Wall Material	Carbon Steel
Wall Thermal Conductivity [Btu/hr-ft-	24.96
Wall Thermal Diffusivity [m2/s]	1.180e-005
Cylinder Wall Thickness [in]	2.000
Head Geometry	Hemispherical
Head Wall Thickness [in]	1.000
Total Vessel Volume [m3]	4.023
Min Design Metal Temperature [C]	<Unbounded>
Max Design Metal Temperature [C]	<Unbounded>

Figure 3: Input to BLOWDOWN where system inventory (pipes and vessels) are entered individually

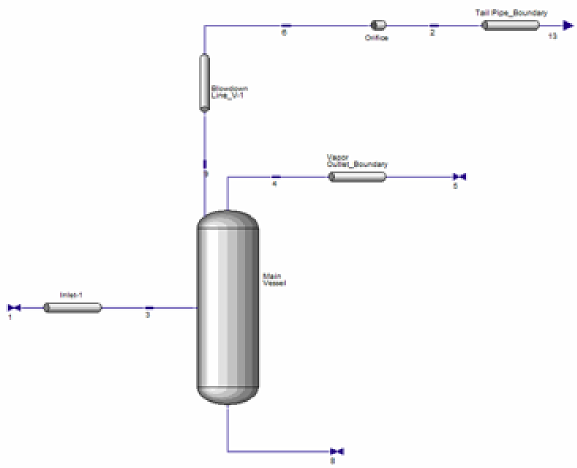

Figure 4: BLOWDOWN graphical interface

Results

BLOWDOWN predicts that a smaller orifice is required which would result in the reduction of the peak depressurization rate when compared to DPU.

Scenario	DPU - Fire	BLOWDOWN - Fire
Initial Pressure (psig)	728	728
Initial Temperature (°C)	74	74
Final Pressure (psig)	100	100
Depressurization Time (min)	15	15
Orifice Size (in.)	0.38	0.36
Peak Depressurization Gas Flowrate (MMSCFD)	2.4	2.0

Table 1: Fire Case Results for DPU and BLOWDOWN

Using the orifice size calculated above, a minimum design metal temperature (MDMT) scenario was then performed using both options.

The minimum fluid temperature predicted by DPU is conservative when compared to the minimum wall temperatures the BLOWDOWN tool has predicted. If MDMT is fixed based on the fluid temperatures predicted by DPU, this would lead to a highly conservative design. The better approach here would be to select the minimum design metal temperature based on the minimum wall temperatures predicted by the BLOWDOWN tool.

Scenario	DPU - MDMT	BLOWDOWN - MDMT
Initial Pressure (psig)	570	
Initial Temperature (°C)	13	
Final Pressure (psig)	0	
Orifice Size (in.)	0.38	0.36
Fluid Temperatures		
Minimum Vessel Fluid Temperature (°C)	0.5	-5
Minimum Valve Outlet Temperature (°C)	-17.3	-14.4

Wall Temperatures		
Minimum Wall Temperature @ Main Vessel	11.4* Not recommended to be used	7.0
Minimum Wall Temperature @ Inlet-1		7.0
Minimum Wall Temperature @ Vapor Outlet_Boundary		7.6
Minimum Wall Temperature @ BLOWDOWN Line_V-1		0.70
Minimum Wall Temperature @ Tail Pipe_Boundary		-1.7

**DPU doesn't differentiate the inner wall temperature between upstream and downstream of orifice, unlike blowdown. The earlier practice from DPU was to consider the fluid temperature predicated upstream and downstream of orifice to select the material of construction.*

Table 2: MDMT Case Results for DPU and BLOWDOWN

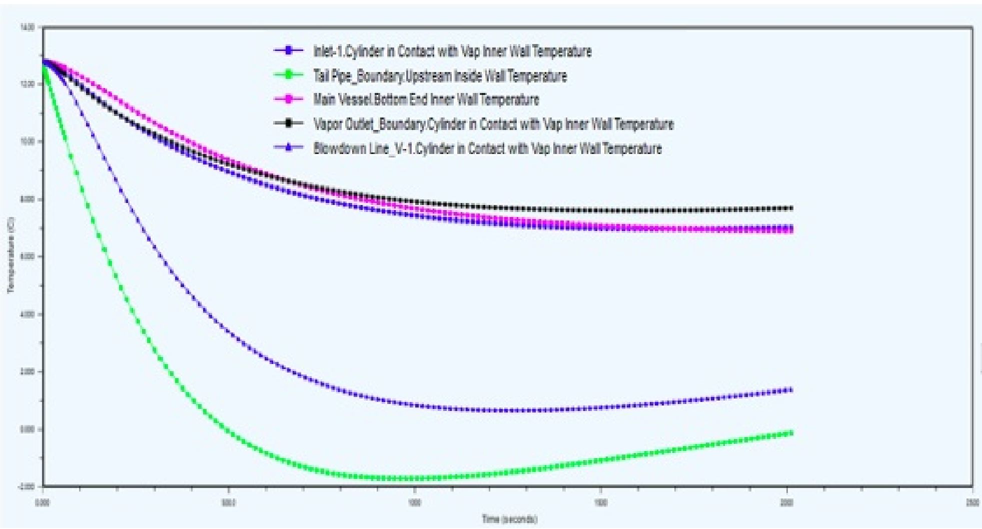

Figure 5: Wall Temperature Results for BLOWDOWN

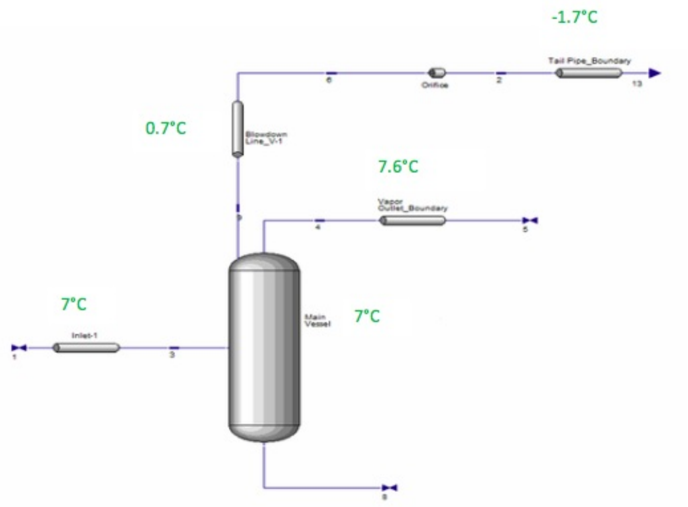

Figure 6: Minimum Wall Temperature predicted for BLOWDOWN

Conclusion

DPU models the entire volume of a system into a single vessel, and it does not consider restrictions to flow via valves, orifices, and fittings in piping between vessels. DPU estimates minimum metal temperature using simplistic heat transfer models and is not recommended to determine MDMT.

On the other hand, BLOWDOWN allows the user to input pipe segments and vessels individually and it uses more rigorous heat transfer models to predict minimum wall temperature and which have been validated against real data providing a more accurate estimation for MDMT. In this case, it would result in lower capital costs.

References

1. Validation of BLOWDOWN™ Technology in V9 of Aspen HYSYS, Dr. Benjamin Fischer and Dr. Souvik Biswas, R&D, Aspen Technology, Inc.
2. Top 10 Questions About BLOWDOWN™ Technology in Aspen HYSYS®
3. American Petroleum Institute, Pressure-relieving and Depressuring Systems, API Standard 521, Sixth Edition, January 2014.