White Paper

Blowdown Analysis Improvements With the UniSim® Design Blowdown Utility

Executive Summary

Blowdown, the emergency or planned depressuring of process equipment, is a critical process safety operation. It may be necessary, in the event of a fire, leak, pipe rupture or other hazardous situation, as well as for a planned shutdown. Devices such as control valves, relief valves, restriction orifices, rupture disks, and safety valves transfer the potentially dangerous contents of process equipment to a safe lower-pressure location, or to the flare system for controlled combustion.

To ensure blowdown can be executed safety and effectively, a number of design concerns must be addressed. Rapid depressuring and gas expansion can result in very low temperatures, potentially putting equipment at risk of brittle fracture if the construction material goes below its ductile-brittle transition temperature. In addition, the entire pressure relief system, including safety valves, relief orifices, flare piping and knockout drums, must be sufficiently sized to handle the flowrates that occur during blowdown, in addition to the piping and capacity of the flare system.

For new installations, accurately predicting the minimum vessel wall temperature during blowdown is important for selecting the appropriate construction material, for helping reduce overdesign and consequently for lowering project cost. Similarly, having an accurate prediction of the maximum flow rate during blowdown reduces overdesign associated with the relief valve/network, without compromising on safety. For existing facilities, blowdown studies can lead to changes in operating procedures or process equipment material or capacity in order to avoid brittle fracture during blowdown.

To obtain these predictions, software simulation tools are used to model the depressuring behavior of process equipment, and support design decisions such as:

- At what rate must gas be released from each equipment item to meet the required depressuring times?

- What is the required total flare capacity?
- What is the lowest metal temperature experienced in each equipment item and in the flare system?
- Which low-temperature materials are required?
- What size restriction orifice or other flowrate-controlling device and flare connections are required for Depressuring in each section of the plant?

Conventional simulation tools, such as the legacy UniSim® Design Depressuring Utility, employ equilibrium-based calculation methods that rely on a number of assumptions and approximations. These tools are widely used and they provide acceptable results when used appropriately. However, they often give rise to overly-conservative predictions, resulting in costly over-design. For example, specifying stainless steel where carbon steel would have been adequate could double or triple capital expenditure.

The UniSim Design Blowdown Utility addresses the shortcomings of the legacy Depressuring Utility. It incorporates a much more rigorous vessel unit operation model based on non-equilibrium calculations, simultaneous solution of the model equations, and a clear, straightforward, interface to configure the model. The Blowdown Utility has been extensively validated and tuned against both proprietary and open-literature experimental data.

This white paper presents the improvements made with the UniSim Design Blowdown Utility and validates the models against published experimental data.

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The Blowdown Operation

Emergency and Planned Depressuring

The term 'blowdown' denotes the emergency or planned depressuring of process equipment, such as vessels, heat exchangers, distillation columns, and compressors, in order to remove combustible hydrocarbons and protect against excessively high pressures or temperatures. This may be necessary, for example, in the event of a fire, leak, pipe rupture, or other hazardous situations, as well as for a planned shutdown.

During blowdown, devices such as relief valves, orifices, rupture disks, and safety valves are used to remove the potentially dangerous contents of process equipment in a controlled manner and transfer them to a safe lower-pressure location, or burn exhaust gases through the flare system to dispose of them in the environment. Reducing the process pressures in this way decreases the propensity for leaks and the risk of vessel or pipe rupture. This in turn diminishes the risk of event escalation with the release of explosive, combustible, or toxic substances.

For the purposes of depressuring, a process plant is typically isolated into a number of independent blowdown segments. The blowdown of the entire plant will then consist of the simultaneously or sequentialy depressuring all the pressurized gas (and/or in some cases liquid) in each segment by routing it to a lower-pressure location or to one or more flare tips for controlled combustion.

A typical example of an independent blowdown segment is a high-pressure separator in an oil and gas separation process (see Figure 1). During depressuring in the high pressure separator, the vessel's inlets and outlets (gas, liquid and/or water) are blocked by closing isolation valves (also called emergency shutdown valves or ESDVs). The gas is directed to the flare (or vent) system by means of an isolation valve and restriction orifice or through a manual valve. Instead of using a restriction orifice to set the flowrate, some installations use depressuring valves with a known flow coefficient.

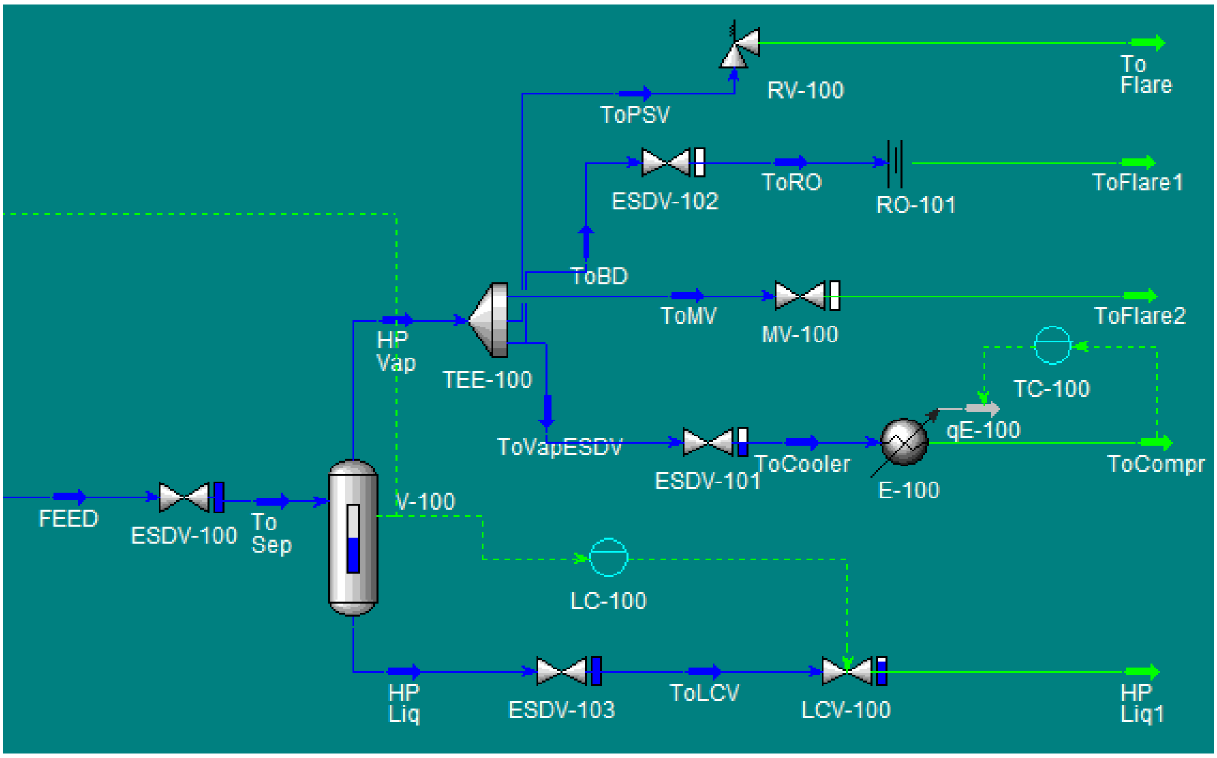

FIG 1. Typical Pressure Vessel.

Although the blowdown process is intended to ensure the safe operation of the plant, it is itself a potentially hazardous operation, during which a number of concerns arise. The three main factors to consider for the safe design of a pressure relief and blowdown system are:

- Construction material selection for low temperatures
- Sizing of the relief valves, orifices, piping, and vessels
- Connections and capacity of flare system

These design considerations are discussed in the following sections.

Construction Material Selection for Low Temperatures

During rapid depressuring, auto-refrigeration effects can result in very low fluid temperatures which are then transferred to pipe or vessel walls, potentially putting them at risk of brittle fracture if the construction material goes below its ductile-brittle transition temperature. Also, rapid temperature changes lead to non-uniform temperature distributions in pipe and vessel walls, causing differential expansion and contraction that places further stress on construction materials. For this reason, it is important to be able to correctly predict the temperatures of piping, valves, and other components, to avoid metal material cracking in both the process and flare system, with potentially serious consequences. For example, in a hydrocarbon processing facility, a brittle fracture of a pressure vessel or pipe segment could cause the release of flammable material, with a significant risk of harm to people and the environment. Similarly, the low temperatures that occur during blowdown can also pose a threat to the mechanical construction of the flare system. Avoiding these risks requires the use of materials suited to very low temperatures, which are, however, expensive and difficult to procure. Accurately predicting blowdown temperatures makes it possible to minimize the use of special low-temperature materials without compromising safety.

The 6th edition of the API 521 Guidelines on Pressure Relieving and Depressuring Systems [1] highlight the requirement to consider the mechanical design and risk of brittle failure of process equipment and piping during depressuring.

Sizing of Relief Valves, Orifices, Piping, and Vessels

To ensure that depressuring can take place safely, rapidly and effectively, all the components of the blowdown system, including safety valves, relief orifices, flare piping and knockout drums, must be sufficiently sized.

Connections and Capacity of Flare System

The flare system must also be correctly sized to handle the material vented during depressuring, especially peak flow. During the blowdown operation, a large amount of material must be disposed of simultaneously. It is necessary to ensure that there is sufficient flare discharge capacity to do this without violating hydraulic constraints in the flare piping, causing overpressures or excessive vibrations or exceeding radiation limits from the flare tip. It is also necessary to accurately determine what size of restriction orifices or other flow-controlling devices and flare connections are required for depressuring each section of the plant.

Simulation Tools

To meet these design challenges involved in the safe design of a blowdown system, calculation and simulation tools are generally employed. Their purpose is to determine:

- The minimum temperatures that will be experienced throughout the process and pipework metal walls, in order to select construction materials accordingly.
- The blowdown times and the relief loads entering the flare network.
- Valve sizing, for example the blowdown valve sizes required to achieve pressure reduction within a specified time or the relief valve sizes to prevent overpressure.
- The temperature of the fluid entering the flare system (which may contain evaporating entrained liquids), in order to select the appropriate construction material for the flare system tailpipes, sub-headers and headers.

However, the accuracy of these simulation tools may vary significantly depending on the fidelity of the modeling approach that they employ. Inaccurate simulations pose the risk of either over-designing the system (which unnecessarily elevates costs) or under-designing the system (potentially making it unsafe).

UniSim Design Blowdown Utility

UniSim Design introduces the Blowdown Utility, which achieves improved fidelity by adopting a modeling approach consistent with the new recommended practices set out in the 6th edition of the API 521 *Guide for Pressure Relieving and Depressuring Systems*[1]. This utility enables engineers to:

- Simulate emergency plant depressuring of process equipment within the UniSim Design flow sheeting environment.
- Rigorously handle non-equilibrium three-phase (gas, liquid, water) systems.
- Use a wide variety of rigorous thermodynamic models.
- Improve the heat-transfer modeling across metal by incorporating better correlations for heat transfer coefficients.
- Accurately incorporate rigorous formulas for volumes, and for surface and interfacial areas.
- Evaluate different configurations of vessel orientations.

Flowsheeting Environment

The Blowdown Utility can be easily attached to a single stream (or multiple streams combined with a mixer) on the process flowsheet. This initializes the vessel holdup. The Blowdown Utility is accessed from the Utilities menu in UniSim Design:

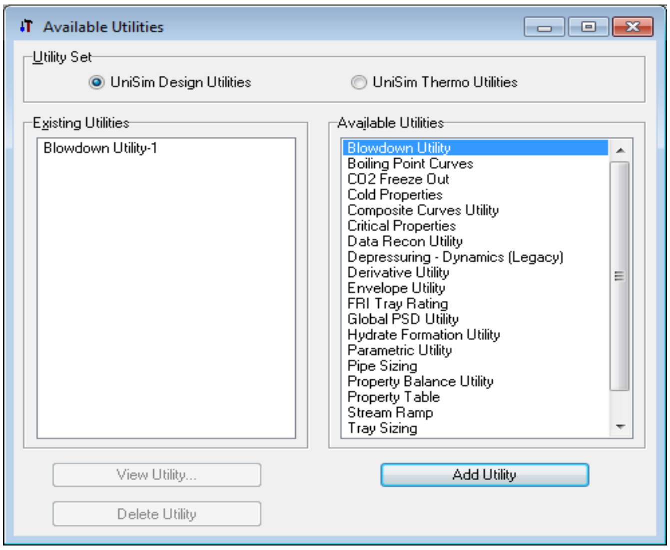

FIG 2. Accessing the Blowdown Utility.

Non-Equilibrium Model Method

A major change in the Blowdown Utility is the adoption of a new, significantly more accurate, holdup model that is able to represent the non-equilibrium conditions that actually occur during depressuring. To accomplish this, the Blowdown Utility uses a three-phase non-equilibrium model that divides the vessel into up to three zones, roughly corresponding to: vapor, liquid and heavy liquid phases. Within each zone, the fluid is in equilibrium, so that vapor bubbles can be formed in the liquid zones and liquid droplets in the vapor zone. The bubbles then move dynamically to the vapor zone and similarly droplets move dynamically to the liquid. However, the zones are not in equilibrium with each other, and the holdup model calculates both mass and energy transfer between the zones. An important part of this model is a rigorous calculation of the holdup volume, wall surface area and interfacial area. The model predicts how the zone volumes and areas change dynamically as the phase distribution changes.

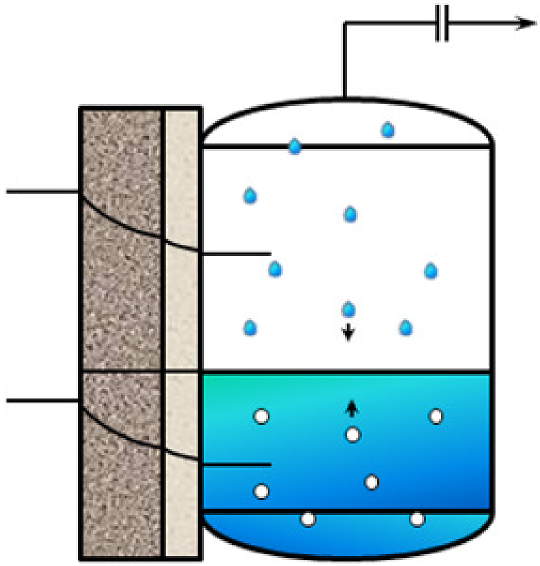

FIG 3. Vessel with Three-Phase Non-Equilibrium Model.

Variety of Thermodynamic Packages

Software solutions based on conventional calculations are limited in the number of thermodynamic packages and components they can use. This is not the case with the Blowdown Utility, which can be used with a wide selection of thermodynamic property packages.

Heat Transfer/Wall Modeling

The heat transfer/wall model is also considerably more sophisticated than in the legacy UniSim Design Depressuring Utility and allows for highly accurate calculation of the temperature profile through the walls. Each holdup zone incorporates heat transfer with the vessel wall, heat transfer with adjacent zones and heat transfer with the environment through radial heat conduction in the vessel wall and insulation. Both the wall and insulation can each be modeled with up to two layers. The heat-transfer correlations take into account the phase and conditions of the fluid.

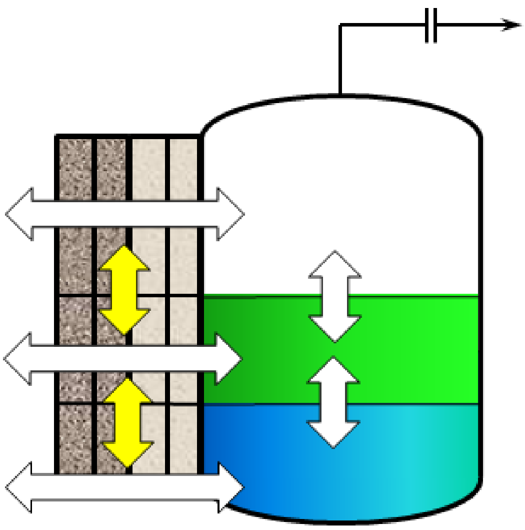

FIG 4. Heat-Transfer for Vessel with Three-Phase Non-Equilibrium Model.

Distributed Flowsheet Model

Conventional analysis adopts a 'lumping' approach whereby the entire segment is represented by a single notional vessel, with wall thickness chosen to approximate the entire metal mass of the original segment. This approach, although useful, has limitations as real systems are distributed in nature, so that metalwork and fluid temperatures may vary significantly within the blowdown segment. The next version of Unisim Design with Blowdown Utility due in November 2015 will allow multi-vessel and interconnecting pipeline design (see *Future Enhancements* section below).

Vessel Configuration / Geometry

In common with the legacy UniSim Design Depressuring Utility, the Blowdown Utility models a single, horizontally or vertically oriented, vessel (without a feed stream). The Blowdown Utility supports depressuring through a single outlet on the top, bottom or side of the vessel. The legacy utility supported simultaneous depressuring through two nozzles, although in practice this was rarely used. The Blowdown Utility allows the vessel to have no outlet (with the None option), to simulate the pressurization dynamics of a closed vessel.

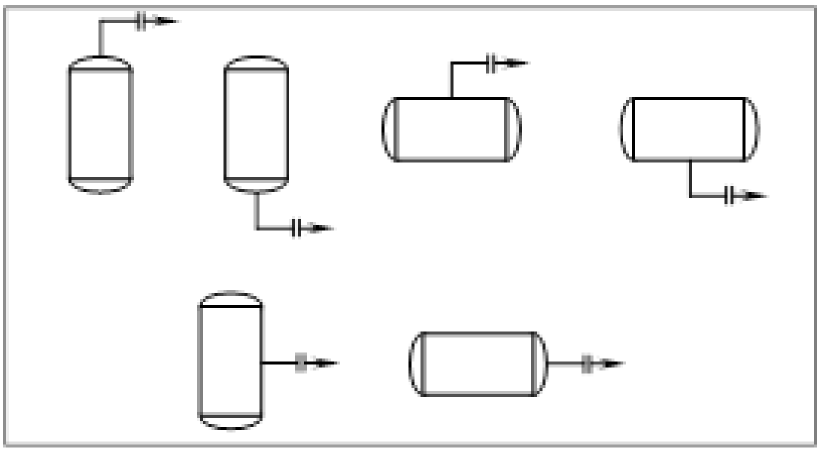

FIG 5. Different Vessel Orientations.

In the Blowdown Utility the top and bottom outlet options are truly located in the top and bottom surface of the vessel (in the legacy utility, by contrast, the top and bottom outlets occupied 5% of the vessel side wall by default). For a Side outlet the mixture in the outlet nozzle is determined by the proportions of the cross-sectional area of the nozzle covered by the aqueous, liquid and vapor zones of the vessel. Instead, the legacy model used a linear coverage rule.

As described above, accurate calculation of the interfacial area, as well as the vessel volume and surface area is very important. For this reason the Blowdown Utility includes a detailed representation of torispherical (dished) vessel heads. The user can select from a number of predefined head types (e.g. Hemispherical, 2:1 Semi-Elliptical) or supply custom Dish Radius and Knuckle Radius factors. The legacy utility used a much simpler flat-headed vessel assumption, and allowed the user to customize the Top Head Area and Bottom Head Area to account for the actual area of a non flat-ended vessel. This customization is no longer needed in the Blowdown Utility.

Comparison of Legacy Depressuring Utility and Blowdown Utility Functionality

The table below compares the capabilities of the UniSim Design legacy Dynamic Depressuring Utility with those of the UniSim Design Blowdown Utility:

	UniSim Design (Legacy) Dynamic Depressuring Utility	UniSim Design Blowdown Utility
Robustness	Fair	Good
Ability to Model External Fire	Yes	Yes
Model Vertical & Horizontal Vessel Orientations	Yes	Yes
Model Top/Bottom Depressuring Configurations	Limited	Yes
Interfaces with Spreadsheet Software	Yes	Yes
Limitations in the Number of Components in Simulation	No	No
Physical Property Package Options	Most UniSim Design Options	Most UniSim Design Options
User-Friendly Documentation	Yes	Yes
Rigorous Heat Transfer Model	No	Yes
Model Multiple Connected Vessels and Piping	No	No
Tested Against Measurements from Full Scale Experiments that Include HC Systems with Phase Change	No	Yes
Models 3-Phase Systems (Gas, HC Liquid, Water)	No	Yes
Includes Geometry of Vessel Heads	Limited	Good
Ability to Model Non-Equilibrium Cases	No	Yes
Modeling Rigor	Limited	Good

TABLE 1. Comparison of the legacy UniSim Design Depressuring Utility and the UniSim Design Blowdown Utility.

Dynamics Models & Validation with Experimental Data

Model Implementation

Blowdown dynamics for a number of vessels were modeled using the UniSim Design Blowdown Utility software. The vessel models covered top and bottom blowdown and a wide range of compositions, vessel orientations and orifice sizes.

It should be emphasized that UniSim Design Blowdown utility contains no adjustable parameters. If all the testing conditions are described fully, the UniSim Design Blowdown utility is completely predictive.

Model Testing

The dynamic models were subjected to tests that reflected experiments with data available on the public domain (references 1-6). The results were compared to the experimental data collected from the respective experiments.

The following cases, discussed in this white-paper, are a subset of the cases that were examined:

- Spadeadam Experiment S12 [2] [3]
- Gas N2 blowdown [2]
- Gas N2/CO2 blowdown [2]
- Gas C1/C2/C3/C4 blowdown [2] [4]
- CO2 Blowdown from Super-Critical Condition [5]
- CO2 Blowdown from Liquid State [6]
- Fire Engulfment Test of LPG Tank [7]

Model Validation

Spadeadam Experiment 12

This experiment represents a retrograde condensation, in which condensate forms even though the pressure is dropping due to Depressuring. The table below summarises the Spadeadam S12 experiment conditions:

Item	Value
Composition	
CH4	66.5 mol%
C2H6	3.5 mol%
C3H8	30 mol%
Initial Temperature	20 degC (293 degK)
Initial Pressure	120 bara
Vessel	
Diameter	1.13 m
Tan-tan Height	2.25 m
Orientation	Vertical
Head type	torispherical
Wall thickness	59 mm
Orifice Diameter	10 mm
Blowdown From	Top

Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 2. Spadeadam S12 Experiment Conditions.

The Blowdown Utility model predictions and the experimental results are displayed below:

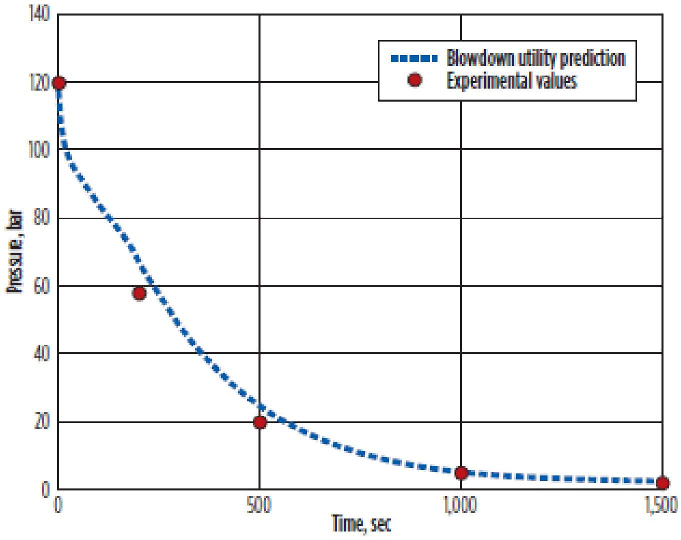

FIG 6. Pressure Profile for Spadeadam S12 experiment.

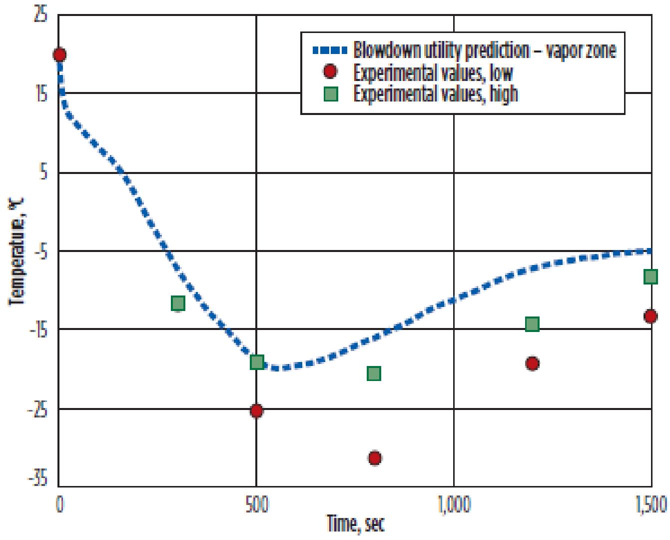

FIG 7. Vapour Temperature Profile Spadeadam S12 experiment.

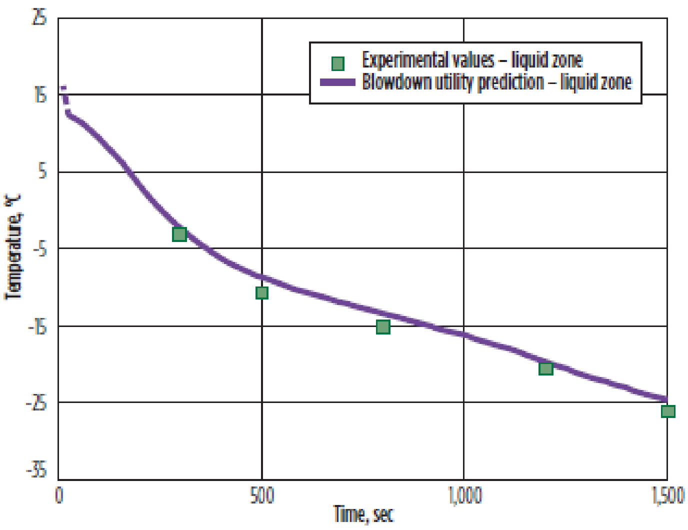

FIG 8. Liquid Temperature Profile for Spadeadam S12 experiment.

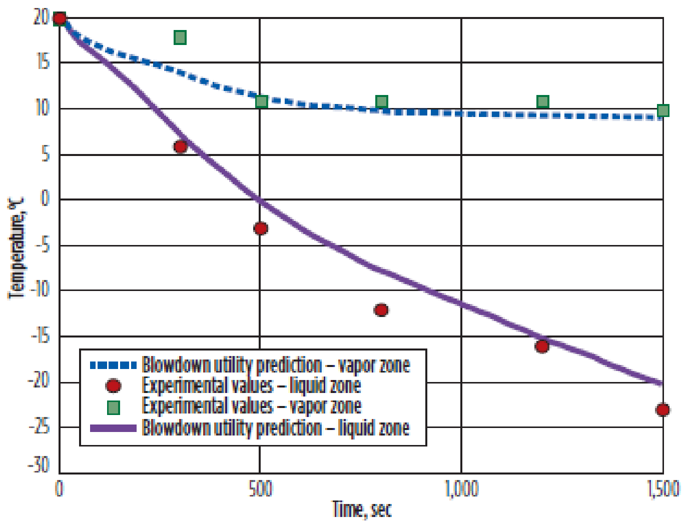

FIG 9. Wall Temperature Profile Spadeadam S12 experiment.

As can be seen from Figure 6, there is very good agreement in the pressure profile between the model prediction and the experimental data. Likewise, as it can be seen from Figures 7 and 8, the liquid and vapor temperature profiles are in good agreement between the model and the experimental data. Finally, as it can be seen in Figure 9, there is also good agreement in the inner wall temperature profiles for the liquid and vapor zones, between the model and the experimental data.

Gas N2 blowdown

The table below summarizes the Gas N2 blowdown experiment conditions and the figures that follow, report the validation test results:

Item	Value
Composition	
N2	100 mol%
Initial Temperature	20 degC (293 degK)
Initial Pressure	120 bara
Vessel	
Diameter	0.273 m
Tan-tan Height	1.524 m
Orientation	Vertical
Head type	Flat
Wall thickness	25 mm
Orifice Diameter	6.35 mm
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 3. Gas N2 Blowdown Conditions.

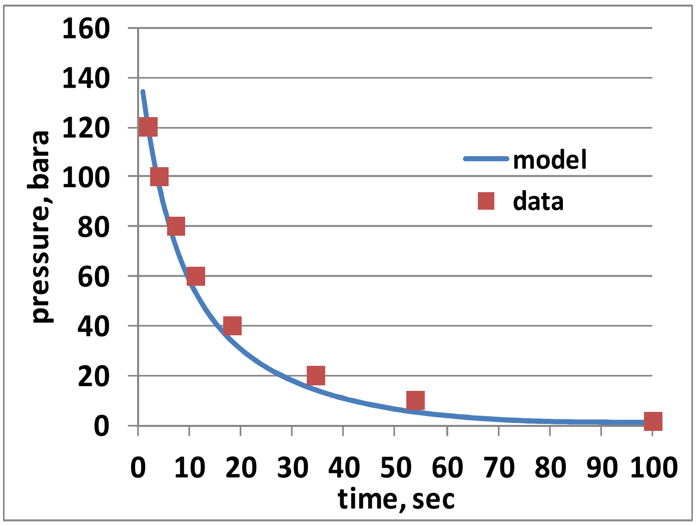

FIG 10. Pressure Profile for Gas N2 blowdown.

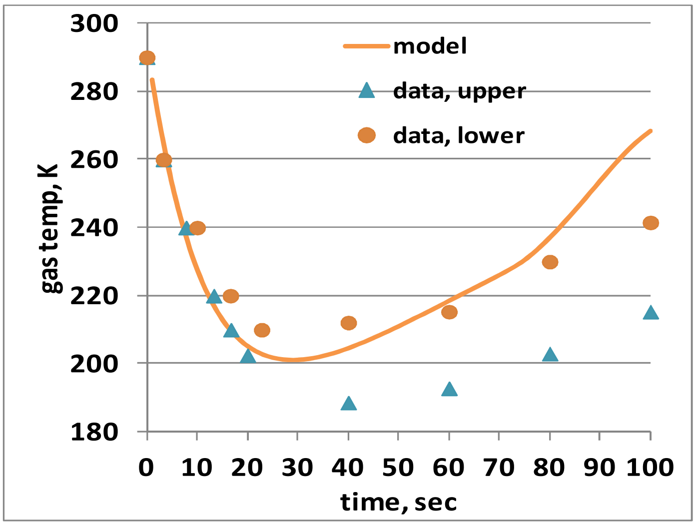

FIG 11. Vapour Temperature Profile for Gas N2 blowdown.

It is generally quite easy to predict the pressure profile if orifice diameter is given, as seen in Figure 10. The measured temperatures vary within the bulk fluid phase and the inside wall, which are denoted as upper and lower to bracket the data between the upper and lower locations of the vessel, in Figure 11. The model assumes uniform temperature within each phase and the wall. For the temperatures in Figure 11 & 12, the agreement between the data and the model prediction, at least in terms of trend, is quite good.

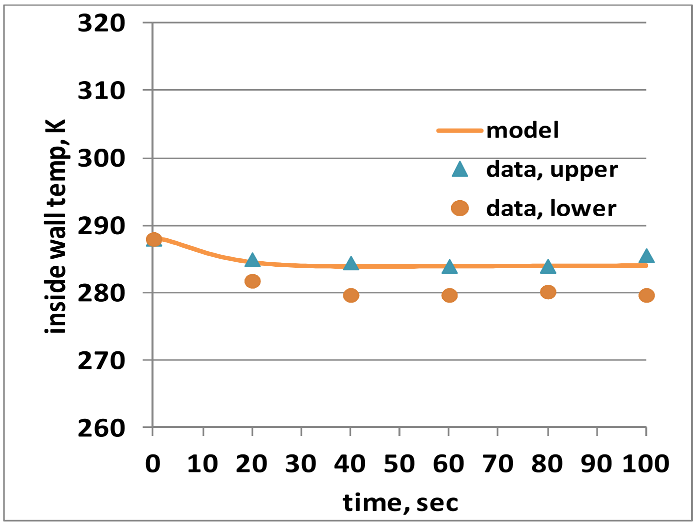

FIG 12. Pressure Profile for Gas N2 blowdown.

Gas N2/CO2 blowdown

The table below summarizes the Gas N2/CO2 blowdown experiment conditions and the figure that follows, reports the test results:

Item	Value
Composition	
N2	70 mol%
CO2	30 mol%
Initial Temperature	20 degC (293 degK)
Initial Pressure	150 bara
Vessel	
Diameter	0.273 m
Tan-tan Height	1.524 m
Orientation	Vertical
Head type	Flat
Wall thickness	25 mm
Orifice Diameter	6.35 mm
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 4. Gas N2/CO2 Blowdown Conditions.

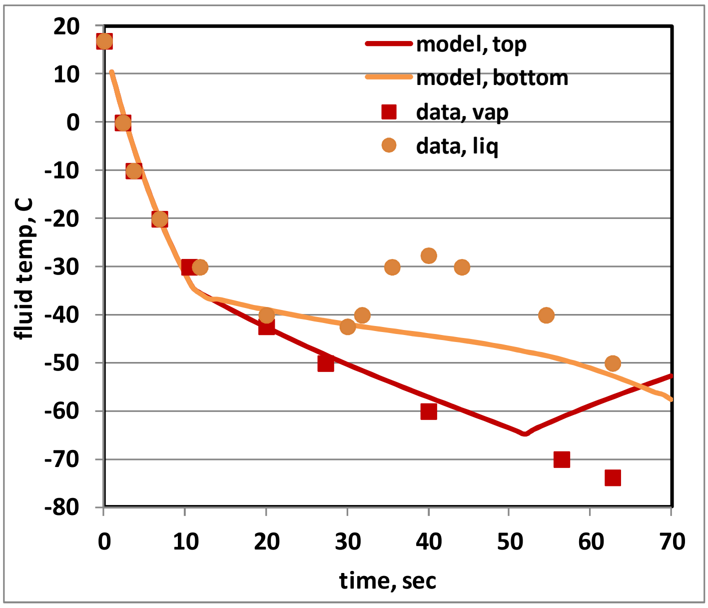

FIG 13. Temperature Profile for Gas 70/30 N2/CO2 blowdown.

The presence of CO2 leads to a possibility of liquid condensation or even solid CO2 formation. According to the authors [2], the fluid temperature at the top of the vessel continued to fall and remained as a gas phase shown as red square symbols. The temperatures measured near the bottom of the vessel, which was a liquid condensate with orange round symbols in Figure 13, showed a rise at about 30 sec and then a steady fall. The temperature rise was due to the relatively warm temperature of the bottom wall of the vessel initially. While some evaporation may have occurred, more condensate was formed from the upper part of the vessel due to expansion. Eventually the liquid temperature would continue falling due to evaporative cooling. The model follows the gas temperature data very well until about 50 sec, where solid CO2 may have appeared. The current UniSim Design Blowdown Utility does not consider formation of the solid phases. As a consequence, the predicted temperatures deviate from the data. From Figure 13, the gas temperature prediction is very accurate up to slightly beyond CO2 triple point (5.2 bar, -57C). Therefore, based on thermodynamic calculations, UniSim Design would predict a possible solid CO2 formation at about 40 or 50 sec.

The liquid temperature prediction is also very good until about 30 sec, after which the model misses the increase of the temperature.

Gas C1/C2/C3/C4 Blowdown

The table below summarises the Gas C1/C2/C3/C4 blowdown experiment conditions and the figures that follow, provide the test results:

Item	Value
Composition	
CH_4	64 mol%
C_2H_6	6 mol%
C_3H_8	28 mol%
C_4H_{10}	2 mol%
Initial Temperature	20 degC (293 degK)
Initial Pressure	120 bara
Vessel	
Diameter	1.13 m

Tan-tan Height	2.25 m
Orientation	Vertical
Head type	torispherical
Wall thickness	59 mm
Orifice Diameter	10 mm
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 5. Gas C1/C2/C3/C4 blowdown Conditions.

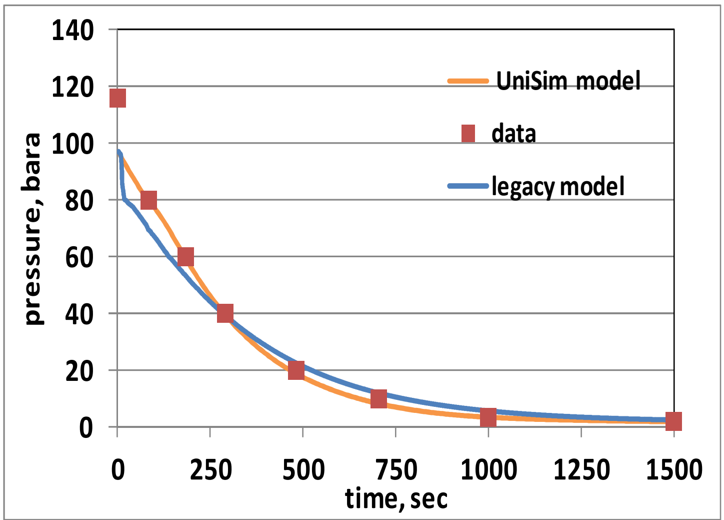

FIG 14. Pressure Profile for Natural Gas blowdown.

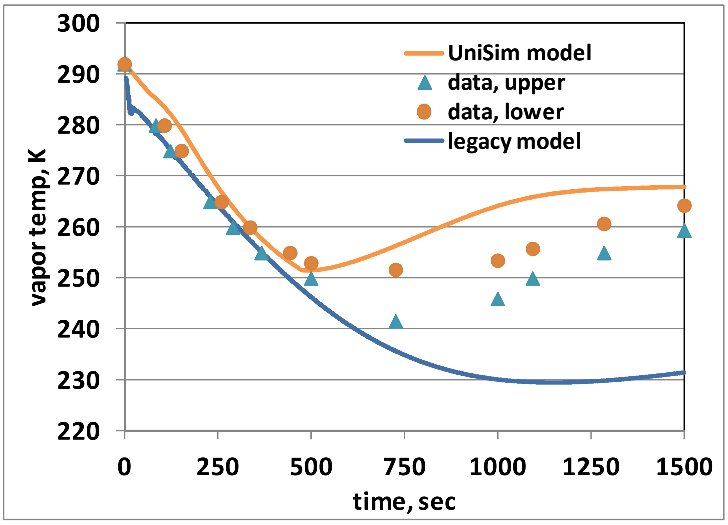

FIG 15. Vapour Temperature for Natural Gas blowdown.

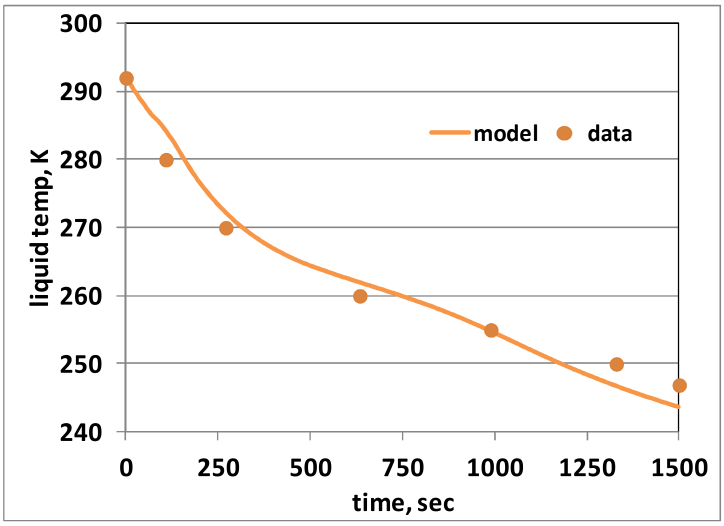

FIG 16. Liquid Temperature for Natural Gas blowdown.

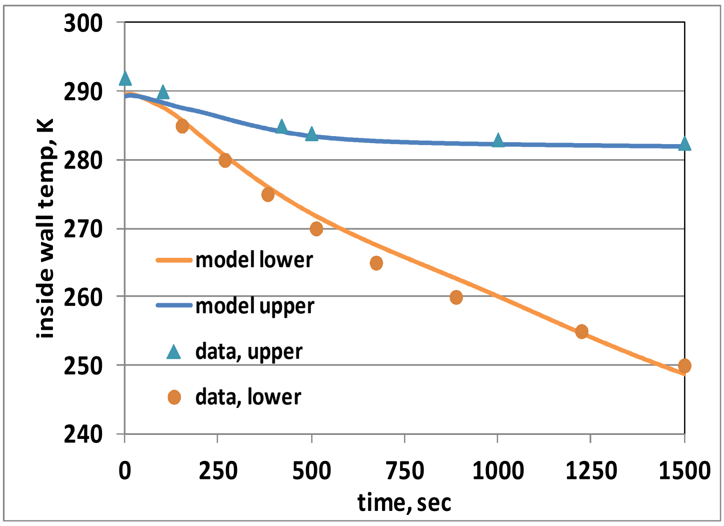

FIG 17. Inner Wall Temperature for Natural Gas blowdown.

Figure 14 shows that both UniSim Design Blowdown and Depressuring (Legacy) models can track the experimental pressure easily. For the vapor temperature in Figure 15, while some deviation from data exists, UniSim Design Blowdown model generally follows that data trend much better then UniSim Depressuring Utility. Furthermore, the UniSim Design Blowdown model shows excellent agreement with data for the liquid temperature in Figure 16, but legacy Depressuring

Utility model has only one temperature for both vapor and liquid, which is entirely incorrect. Again, the data indicated by "upper" and "lower" refers to the thermocouple positions in the vapor zone of the vessel. Figure 17 shows the excellent agreement between the measurement and the UniSim Design Blowdown Utility for the inside wall temperatures, where "upper" means vapor phase and "lower" means liquid phase.

CO2 Blowdown from Super-Critical Condition

The table below summarizes the CO2 blowdown from super-critical conditions and the figures that follow, the test results:

Item	Value
Composition	
CO_2	100 mol%
Initial Temperature	40 degC (313 degK)
Initial Pressure	150 bara (15 MPa)
Vessel	
Diameter	0.242 m
Tan-tan Height	1.1 m
Orientation	Vertical
Head type	Flat
Wall thickness	35 mm
Orifice Area	17 mm2
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 6. CO2 Blowdown from Super-Critical Conditions.

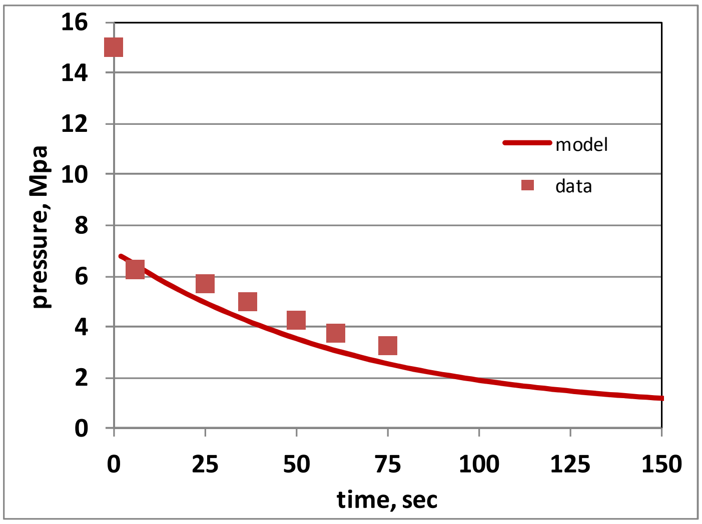

FIG 18. Pressure Profile for Super-Critical CO2 blowdown.

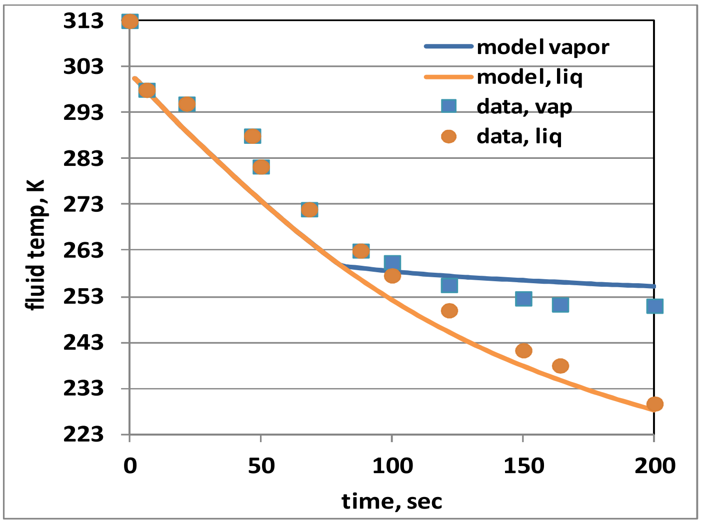

FIG 19. Fluid Temperature for Super-Critical CO2 blowdown.

Figures 18 & 19 show the comparison of measured data with UniSim Design Blowdown model prediction for the pressure profile. Very good agreement between the data and the model can be seen. At the onset of depressuring, the supercritical CO2 flashed so rapidly that the pressure dropped almost instantaneously. The CO2 fluid changed to a sub-cooled liquid and quickly turned into a liquid CO2 phase at its bubble point with continuous vapor flashing. The predicted liquid temperature follows the vapor-liquid equilibrium temperature at a given pressure, according to the UniSim Design model. Both the measured and the predicted vapor temperatures are higher than the liquid temperatures due to heat flow from the wall. No CO2 freezing was expected in the time scale shown in Figure 19, as the temperature is above -56C.

CO2 Blowdown from Liquid State

The table below summarises the CO2 blowdown from liquid state conditions and the figures that follow, the test results:

Item	Value
Composition	
CO_2	100 mol%
Initial Temperature	22 degC (295 degK)
Initial Pressure	62 bara (0.62 MPa)
Initial Level	86%
Vessel	
Diameter	0.242 m
Tan-tan Height	1.1 m
Orientation	Vertical
Head type	Flat
Wall thickness	35 mm
Orifice Area	17 mm2
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 7. CO2 Blowdown from Liquid State Conditions.

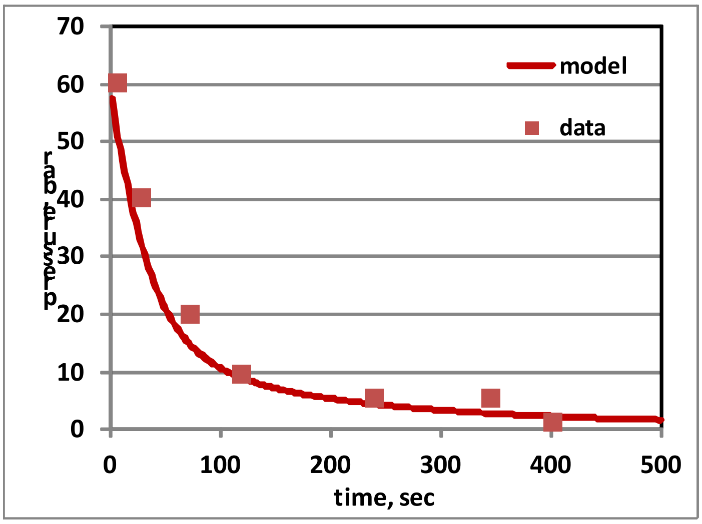

FIG 20. Pressure Profile for Liquid CO2 blowdown.

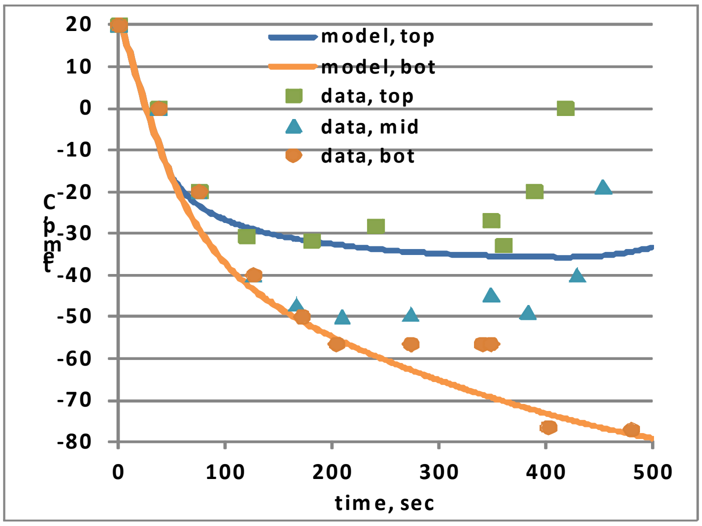

FIG 21. Fluid Temperature for Liquid CO2 blowdown.

Figures 20 & 21 show the pressure and temperature data and the model prediction by UniSim Design. The data indicated by "top", "mid" and "bot" in Figure 21 represent the thermocouple locations in the vessel, understandably with the vapor phase in the top and the liquid phase in the bottom. As can be seen, the model follows the vapor phase temperature quite well. The model accurately predicts the bottom or the liquid temperature until about 200 sec, where solid CO2 was formed at its triple point. While the data shows a constant bottom temperature, UniSim Design predicts a steady drop of the liquid temperature because the UniSim Design Blowdown calculations do not consider solid phase, as mentioned earlier. However, UniSim Design can correctly predict the time of solid CO2 formation.

Fire Engulfment Test of LPG Tank

The table below summarises the fire engulfment of LPG tank conditions and the figures that follow, the test results:

Item	Value
Composition	
LPG	100 mol%
Initial Temperature	6.4 degC (279.4 degK)
Initial Pressure	5.8 bara (0.58 MPa)
Initial Level	72%
Vessel	
Diameter	1.68 m
Tan-tan Height	4 m
Orientation	Horizontal
Head type	elliptical
Wall thickness	11.85 mm
Orifice Area	0 mm^2 (PSV closed under P = 14.7 bara)
Blowdown From	Top
Back Pressure	1.013 bar
Ambient Temperature	20 degC

TABLE 8. Fire Engulfment of LPG Tank Conditions.

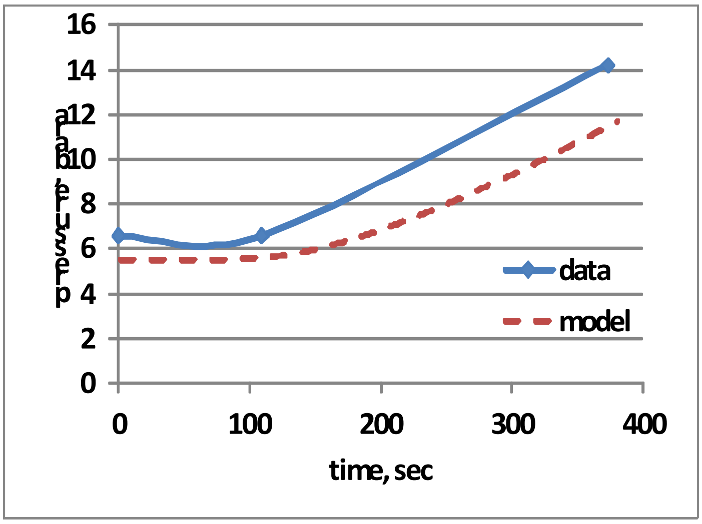

FIG 22. Pressure Profile for Fire Engulfment of LPG test.

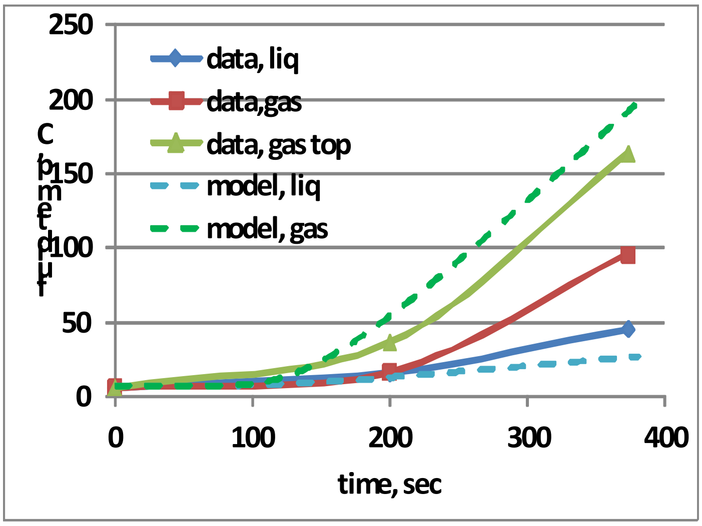

FIG 23. Fluid Temperature for Fire Engulfment of LPG test.

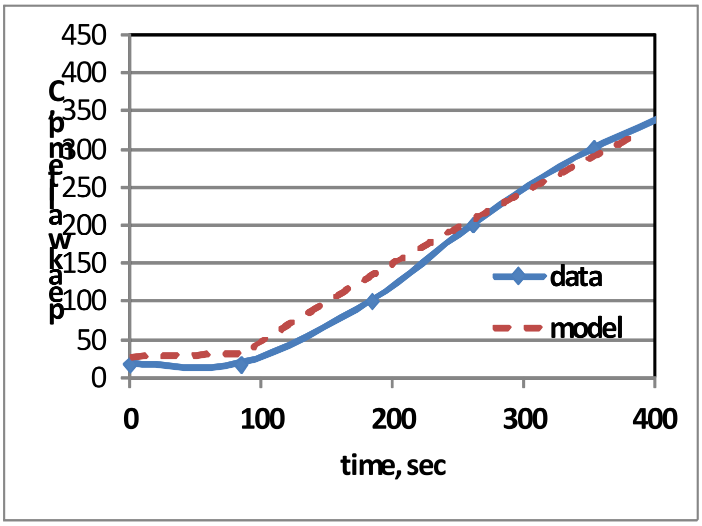

FIG 24. Wall Temperature Profile for Fire Engulfment of LPG test.

The data used to compare with the model was up to the point when the PRV opened at about 14.7 bara, as the UniSim Design Blowdown Utility does not yet model the actual control action of PRV. Figures 22-24 show the comparison of the data with the model. The pressure remained quite constant initially, then increased almost linearly with time, which was captured quite well by the UniSim Design Blowdown Utility. In the blowdown model, the blowdown orifice size was set to zero to simulate this fire engulfment test before the PRV opened. The model also tracked the measured liquid and vapour temperatures quite well. Finally, in Figure 24, it can be seen that the model predicts the wall temperatures very accurately.

Conclusions and Future Enhancements

Conclusions

The validation tests show that the UniSim Design Blowdown utility matches the experimental data from a variety of sources with desired accuracy for blowdown prediction. It correctly predicts the non-equilibrium nature of a blowdown vessel, i.e. different vapor and liquid temperatures, which the legacy UniSim Design Depressuring Utility does not distinguish. The UniSim Design Blowdown Utility requires no adjustable parameters in the model which means fewer user inputs. While it does not account for the solid phase in the model, it can accurately predict the incipient solid CO2 or hydrate formation temperature. The UniSim Design Blowdown Utility is clearly a better and more accurate tool for blowdown calculations than the legacy UniSim Design Depressuring utility.

Future Enhancements released in November 2015

The forthcoming release of UniSim Design, allows for modeling of multiple vessels with interconnecting piping, in an equation-based modeling (EO) environment. This enables the user to more accurately predict temperature profiles in vessels and surrounding piping, to integrate blowdown scenarios with process design and to configure the flowsheet to achieve optimization in the future with a single tool.

As a flowsheeting tool, UniSim incorporates a broad range of component databases and thermodynamic packages. Performing blowdown calculations in a flowsheeting tool such as UniSim Design also avoids the data/information transfer or export/import from a flowsheeting tool to a different blowdown tool. This has the benefit of minimizing the errors and reducing the number of iterations.

In addition, with the UniSim Design Blowdown Utility, the user is able to specify the time at which a pressure vessel begins depressuring, which may differ from vessel to vessel. In this way, it will be possible to test blowdown schedules, staggered blowdown, back-pressure build-up, and flare system capacity.

Finally, the upcoming UniSim Design Blowdown Utility has the following additional heat-transfer features:

a. Vessel may be subject to a user-imposed heat flux (other than fire) that can be applied to the external wall, the liquid(and/or water) or the vapour phase, independently

b. A new two dimensional heat conduction model of the wall and heads of the vessel for heat-exchange with the fluid-phases that the contact; and heat exchange by conduction in the radial and axial directions

c. Optional initialization of the wall temperatures of vessels and pipes using the environment and fluid temperature as boundary conditions

These features allow for more accurate temperature prediction in the vessel and allow for an even broader selection of test scenarios that can be applied.

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For More Information
Learn more about how Honeywell's UniSim Design Blowdown Utility can improve plant safety visit our website www.honeywellprocess.com or contact your Honeywell account manager.

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