How to Optimize the Disposal System With Staggered Analysis Using BLOWDOWN™ Technology

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Problem Statement

In this guide, you will be introduced to the tools in BLOWDOWN that can be used to perform staggered blowdown analysis. You will configure a simple analysis by using the Staggered Analysis tool, as well as a rigorous analysis using the Multi-Vessel Template.

The process consists of three blowdown systems and the flare header has a maximum capacity of 3.200E4 m3/h (4.831E6 barrel/day). The aim of this exercise is to determine if the flare capacity will be exceeded by the three blowdown systems all opening at t=0 and, if so, whether staggering the orifice opening times can rectify the problem.

This tutorial includes the following tasks:

- Task 1: Determine Orifice Opening Times to Meet Flare Capacity

- Task 2: Connect Multiple Blowdown Systems in Parallel

A plant may contain multiple blowdown systems and relief devices that tie into a common flare header system. Emergency scenarios and plant upsets can result in several of these devices opening and discharging materials into the flare network. To ensure process safety, it is crucial to ensure that the flare header can handle the flow rates that are encountered in the worst-case scenario.

Vessel depressurization is inherently a dynamic process. At the start of depressurization, higher pressures inside the vessel result in a higher driving force and thus higher mass flow though the orifice. As the pressure in the vessel decreases over time, so does mass flow. By "staggering," or implementing a time delay between the opening times of multiple orifices, you can reduce the peak mass flow to the flare header and prevent the system from being overloaded.

Staggered blowdown analysis is particularly useful for capital expansion and process revamp studies, where new process units may be added and tied into existing flare disposal systems. It can also be useful in front-end engineering and design to reduce the size of the flare header piping and thus save on capital expenditures.

Task 1: Determine Orifice Opening Times to Meet Flare Capacity

A file (StaggeredBlowdownStarter.hsc) has already been created for you that includes System 1, System 2 and System 3. The objective of this task is to identify an opening sequence for blowdown valves that discharge to a common header, such that the flare capacity is not exceeded.

The Staggered Blowdown tool imports the volumetric flow rate vs. time plots of individual BLOWDOWN analyses and superimposes them on a single plot. This is to approximate the total flow to the flare header. This tool is intended for quick, preliminary design calculations.

1. On the Home tab, click on the dropdown next to **BLOWDOWN and Depressuring** and select **Staggered BLOWDOWN** (*Figure 1*).

2. Change the name to **Simple Staggered Blowdown**.

3. In the Flare Capacity field, input the maximum rated capacity of the flare header: **3.200E4 m3/h (4.831E6 barrel/day)**.
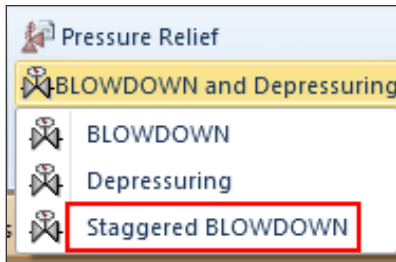

Figure 1:
Select Staggered BLOWDOWN in the drop down to use the functionality.

First, let's examine whether the flare capacity is exceeded if all systems open at the same time.

4. Ensure that the **Rating** radial button is selected.

5. Under the BLOWDOWN Analysis column, add the three single-vessel analyses in the following order: **System 2, System 1 and System 3**.

6. Specify an Orifice Opening Time of **0 seconds** for each of the three systems.

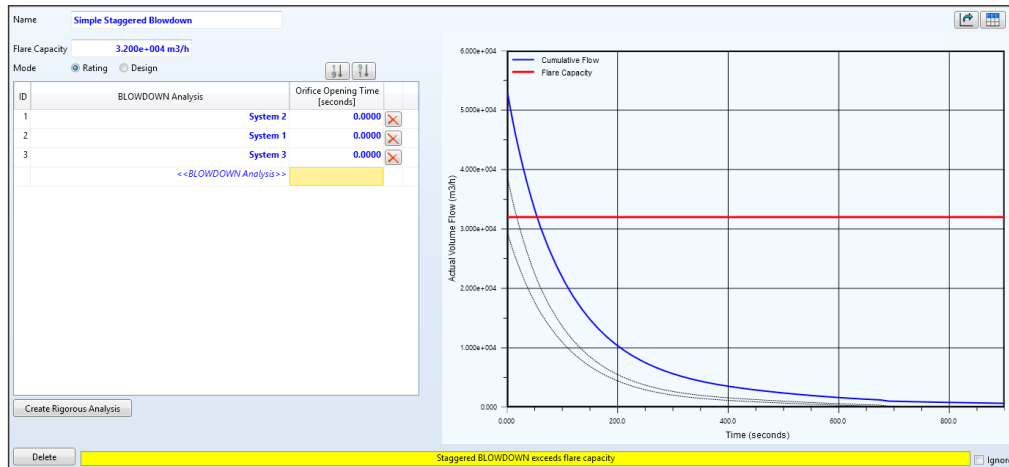With all of the blowdown systems opening simultaneously, the flare capacity is exceeded (*Figure 2*).

Figure 2:
Easily add blowdown valve analyses.

The Staggered Analysis tool provides a "Design" option, which can help to calculate opening times that will not exceed the flare capacity, while minimizing the flaring time (*Figure 3*).

The order in which the analyses are added is important in Design mode. The tool always assumes that the order of the analyses represents the order in which the systems must depressurize. Determining the order in which the systems should be depressurized is outside of the scope of this tutorial. Determining the order requires engineering judgment and a good understanding of the process.

7. Select the **Design** radial button.
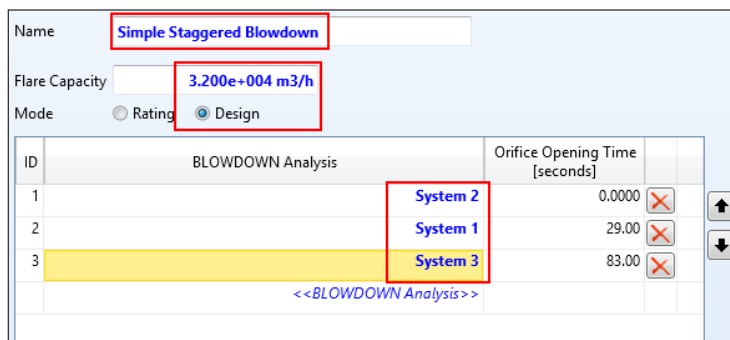
Figure 3:
Add the flare capacity to see if it is exceeded with the simple analysis option.

The calculation should complete. Assuming that System 2 must be the first system to depressurize, System 1 should open at 29 seconds and System 3 should open after 83 seconds in order to avoid overloading the flare. The tool generates a combined volumetric flow rate vs. time plot (*Figure 4*):
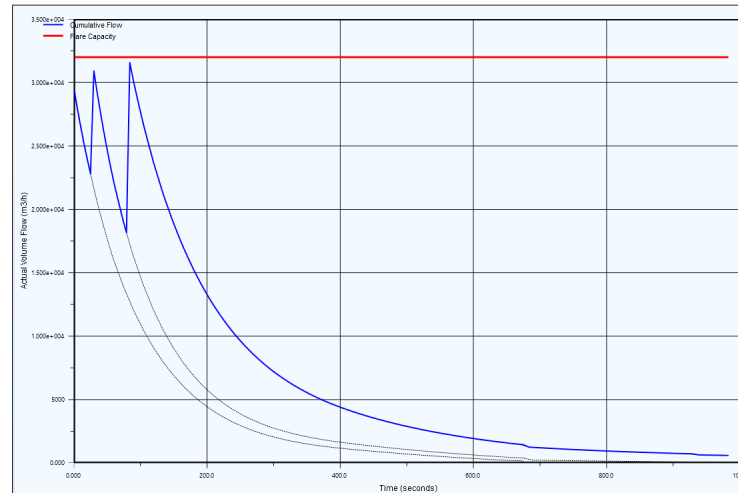

Figure 4:
The simple analysis superimposes the individual blowdown valve releases for a conservative result.

Bear in mind that results from the Staggered Blowdown tool should be treated as preliminary results to assess the feasibility of using a staggered blowdown for your system. Converting the simple staggered analysis to a rigorous multi-vessel BLOWDOWN analysis is always recommended.

8. Save your case as StaggeredBlowdownSimple.hsc

Task 2: Connect Multiple Blowdown Systems in Parallel

Continue using the file created in Task 1.

Keep in mind that the Multi-Vessel Template can only be used for multiple vessels in parallel. It cannot be used to model blowdown in series (where the discharge of one vessel enters another vessel, etc.).

Notice that there are three BLOWDOWN analyses that are present in this simulation (*Figure 5*). Feel free to peruse them if you wish.
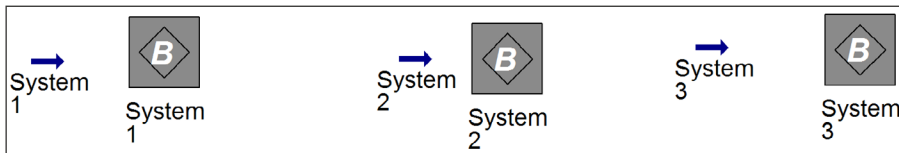
Figure 5:
Process flow diagram.

9. From the Staggered BLOWDOWN analysis created in Task 1, click the **Create Rigorous Analysis** button.

10. A new BLOWDOWN analysis will automatically be created using the **Multi-Vessel Template** and you will automatically be taken to the **Design** tab (*Figure 6*).

Figure 6:
After switching to a rigorous analysis, you will have the ability to add each individual blowdown system to the current flowsheet.

On the **Design** tab, construct the following flowsheet (*Figure 7*). You may attempt to reference the drawing and draw the flowsheet on your own in order to get some extra practice, or you may use the detailed directions that follow:
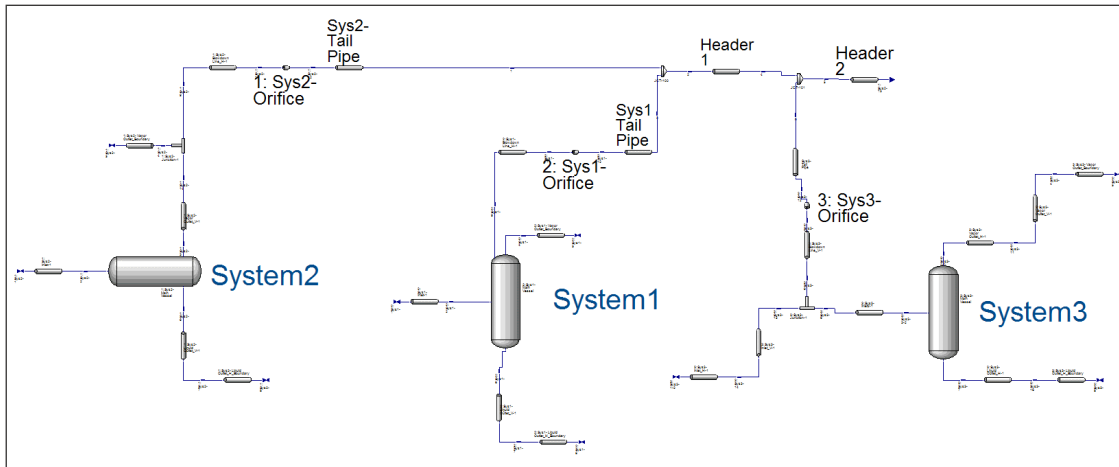

Figure 7:
Flowsheet of the disposal system.

11. Click the **Add Flowsheet** button for **System 2 @Main** and observe the changes in the flowsheet (*Figure 8*).

Figure 8:
Click "Add Flowsheet."

12. For **System 1 @Main**, select **1:Sys2- Tail Pipe_Boundary** as the downstream connection. Click the **Add Flowsheet** button and observe the changes in the flowsheet (*Figure 9*).

Figure 9:
Select the downstream connection.

13. Locate **PIPE-100** on the flowsheet (it should be yellow). Double-click on it and rename it **Header 1** (*Figure 10*).

Figure 10:
Open the header pipe.

14. For **System 3 @Main**, select **Header 1** as the downstream connection. Click the **Add Flowsheet** button and observe the changes in the flowsheet (*Figure 11*).
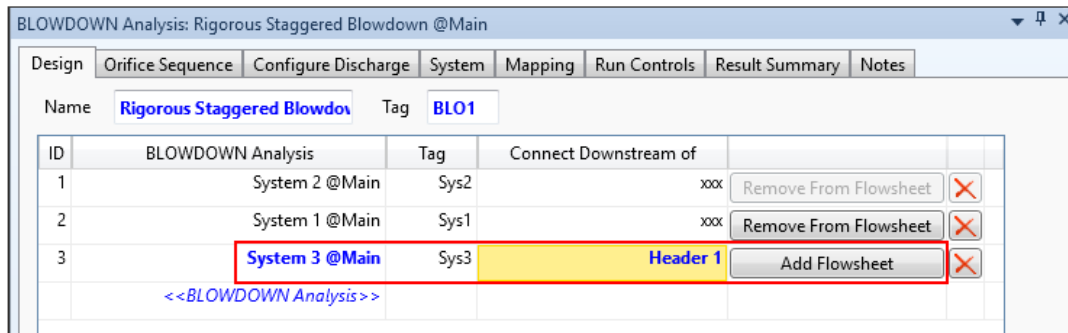
15. Locate **PIPE-100** on the flowsheet (it should be yellow). Double-click on it and rename it **Header 2**.

Your flowsheet should now resemble the drawing found in Figure 6. Notice that two new pipes were added: Header 1 and Header 2. These are downstream piping elements and will be yellow due to missing inputs. All other inputs are complete because they are imported from the pre-existing BLOWDOWN analyses.

Move to the **Orifice Sequence** tab (*Figure 12*). This is where you can define the time after the start of depressurization when each orifice will open.

Notice that the orifice opening times were imported from the calculated times in the Staggered BLOWDOWN analysis.

Figure 12:
Orifice opening times imported from simple Staggered analysis.

The **Configure Discharge** tab can be used to add additional piping elements downstream of each orifice (*Figure 13*). If you would like to add additional piping elements upstream of an orifice, you must do so on each individual BLOWDOWN analysis, before importing it into the Multi-Vessel Template.

Recall the best practices regarding additional piping. Try using as few piping segments as possible and only add additional piping segments if there is a significant change in piping diameter or metallurgy along the line.

Also, recall that BLOWDOWN calculates pressure drop in pipes that are downstream of the orifice. This applies to the additional piping elements that you add here and the ones that are created by the Multi-Vessel Template.
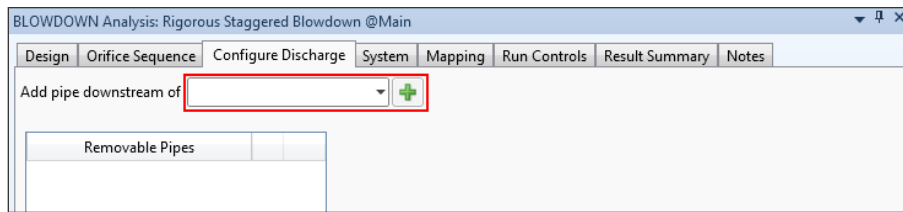

Figure 13:
Add pipelines downstream of the orifice.

The **System**, **Mapping** and **Run Controls** tabs are very similar to the ones found on the Single-Vessel Template. You should be familiar with navigating the forms on these tabs. Most of the information on the System tab has been filled out with what was on the pre-existing BLOWDOWN analyses. However, since two additional downstream pipe segments were added when you constructed the flowsheet, you must define inputs for these pipes.

16. Navigate to the **System** tab. Select **Pipes** from the left-hand pane. On the **Geometry** tab, input the following information for the headers:

	Header 1	Header 2
Pipe Schedule	40	40
Nominal Diameter	550 mm (22 inch)	550 mm (22 inch)
Length	55.78 m (183 ft)	68.28 m (224 ft)
Elevation Change	0 m (0 ft)	0 m (0 ft)

Table 1:
Geometry data for newly added header pipe segments

17. Move to the **Heat Transfer** tab and specify **25° C (77° F)** for the Ambient Temperatures and **0** for the Ambient Fluid Speeds (*Figure 14*).

	Header 1	Header 2
Wall Material	Carbon Steel	Carbon Steel
Wall Thermal Conductivity [W/m-K]	43.20	43.20
Wall Thermal Diffusivity [m2/s]	1.180e-005	1.180e-005
Pipe Schedule	40	40
Nominal Diameter	550 mm	550 mm
Inner Diameter [mm]	527.0	527.0
Wall Thickness [mm]	15.87	15.87
Wall Roughness [mm]	5.000e-002	5.000e-002
Length [m]	55.78	68.28
Elevation Change [m]	0.0000	0.0000
Volume [m3]	12.17	14.89
Model Pressure Drop	☑	☑
Model Mass Accumulation	☐	☐
Min Design Metal Temperature [C]	<Unbounded>	<Unbounded>
Max Design Metal Temperature [C]	<Unbounded>	<Unbounded>

Figure 14:
The heat transfer tab.

18. Move to the **Initial Condition** tab and specify **25° C (77° F)** for the Temperature and **101.3 kPa (14.69 psia)** for the Pressure (*Figure 15*).

	Header 1	Header 2
Ambient Medium	Air	Air
Ambient Temperature [C]	25.00	25.00
Ambient Fluid Speed [m/s]	0.0000	0.0000
Include Ambient Heat Transfer	☑	☑

Figure 15:
The initial conditions tab.

19. Move to the **Run Controls** tab and select the Halt Conditions. Specify **900 seconds** (or 15 minutes) for the Time and **0 kPa (0 psia)** for the Pressure (*Figure 16*).

	Header 1	Header 2
Temperature [C]	25.00	25.00
Pressure [kPa]	101.3	101.3
Liquid Level (from bottom head) [m]	<empty>	<empty>
Liquid Volume [m3]	<empty>	<empty>
Liquid Volume Percent [%]	<empty>	<empty>

Figure 16:
The run controls tab.

20. Run the simulation. After it solves, move to the **Result Summary** tab and analyze the results (*Figure 17*).
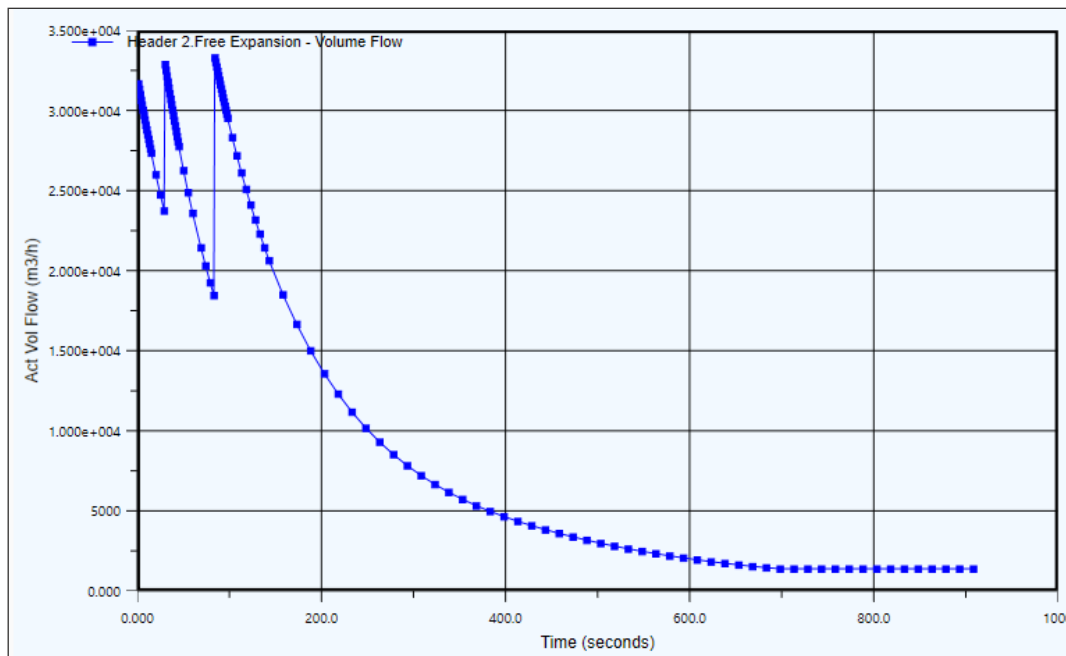

Figure 17:
The view of the results summary tab

21. Save your case as StaggeredBlowdownRigorous.hsc

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