Set Depressuring Model Dimensions to Get More Accurate Results

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28-Feb-2011

Introduction

As illustrated in Figure 1, Hysys depressuring model is single hold up model simply consisting of a flat ended vessel whereas actual system comprises different vessels and piping in vertical and horizontal orientations, containing gas and liquid in different percentages. This Hysys feature results in kind of limitation on how to prepare input data and how to apply final results into the design of such a complex system.

In view of this, the first step is to define Hysys depressuring model as similar as possible to actual system with respect to mass/heat contents and heat transfer specifications. The way Hysys results can be used for design purpose has been discussed in another note "Setting MDMT Based on Hysys Depressuring Results".

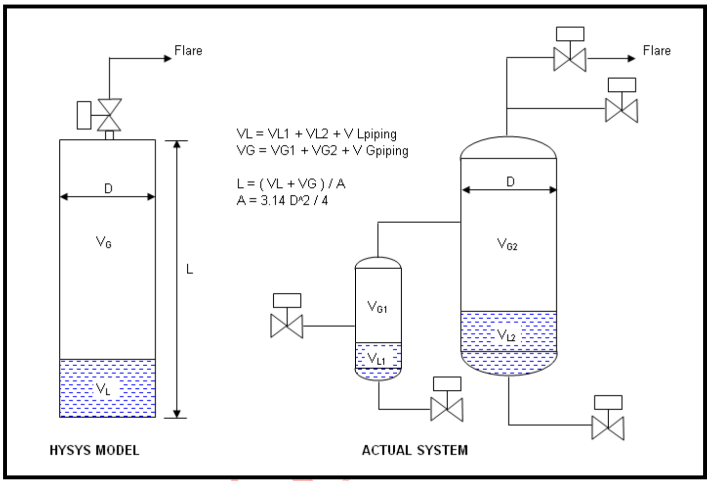

Figure 1 – Schematic of Hysys model vs. actual system

Hysys depressuring input data such as initial pressure and temperature, initial liquid level and depressuring time are project specific data and they may change form client to client and project to project. The effect of these parameters on depressuring results is outlined in technical note "Effect of Different Parameters on Depressuring Calculation Results". The main focus of this note is to match physical dimensions and dimension related parameters of the model with actual system.

Actual system

To define Hysys model similar to actual system, first you need to know the actual system parameters. Then you can match major Hysys inputs with actual system. Figure 2 is a snapshot of a spreadsheet developed for the same purpose called "Blowdown Facilitator". This software not only calculates actual system volume, surface and mass but also finds the dimensions of single flat ended vessel which is corresponding to the actual system. This is done by iteration on vessel diameter, length, liquid level, vessel head area and metal density as it will be explained later in this note. Using such spreadsheet helps user to define the actual process system accurately and get what is required for Hysys as input data.

Model input

There is no perfect way of matching model with actual system because the accuracy of model and its results will be limited by numbers of input data which can be entered into Hysys. In other words, it is not possible to define Hysys model 100% similar to actual system in all aspects where (unlike actual system) model have only one dimension, orientation, metal thickness and material. Actual system comprises different pieces of pipes and equipment with different specifications. In reality, these pieces will have different temperatures during depressuring so each of them will have different heat content (m Cp T) and heat transfer rate (U A ΔT) whereas Hysys model gives only two temperatures for entire system (metal in contact with gas and liquid). For complicated systems, using lump sum method will result in higher difference between Hysys results and what will be observed when system is being depressurized in reality. This is more important for cold depressuring calculation where Hysys results are used for the minimum design temperature of system.

Below paragraph proposes the method through which model parameters can be set if actual system parameters are known.

1. Vessel Volumes and Wetted Area

Gas and liquid volumes are one of the most important inputs for all types of depressuring as they define system mass content which needs to be depressurized. It has major impact on final results such as CV size and fluid/metal temperature as discussed in above mentioned technical note.

Wetted area is not the Hysys input. It is calculated by Hysys based on given dimensions and liquid volume. Although Hysys considers the wetted area of both heads of horizontal vessel, it ignores wetted area of both heads of vertical vessel. Wetted area is also a major factor in fire depressuring calculation. It is also important for cold depressuring because heat transfer thought wetted part of system is much higher than gas portions. Model main dimensions can be specified using below equation and guidelines:

- Set the model orientation same as orientation of vessel upstream of depressuring valve (main vessel) in actual system.
- Change model diameter, height and liquid level to get model's vessel total volume, liquid volume and wetted area same as actual system. Below equations can be used for horizontal flat end vessel:

$$V = \frac{\pi D^2}{4} L \qquad V_L = \frac{\pi D^2}{4} L f_1\left(\frac{H}{D}\right) \qquad A_w = \left(\pi D L + \frac{\pi D^2}{4}\right) f_2\left(\frac{H}{D}\right)$$

For vertical flat end vessel, iteration is not required as $V_L = \frac{\pi D^2}{4} H$ and $A_w = \pi D H$ where:

D: Hysys model - Vessel diameter
L: Hysys model - Vessel length
H: Hysys model - Liquid level height
V: Actual system - Total volume (known)
V_L: Actual system - Liquid volume (known)
A_w: Actual system - Wetted area (known)
f_1 and f_2: Mathematical function

Model diameter and length are outcomes of this stage.

2. Total Surface Area

Since the model diameter and length have been fixed in previous stage, model surface area (cylindrical + top and bottom heads based on hemispherical head) is calculated by Hysys which may not be same as total surface area of actual system. Surface area is very important parameter as heat transfer takes place from it and model metal mass is calculated by multiplying total surface area by metal density and thickness. This is not important for fire case but it is quite essential for cold depressuring. Hysys has two additional input boxes ("Top head area" and "Bottom head area") which can be used to match the surface area of model with actual system. Each head's area can be calculated using below relation.

<u>Heat transfer back ground</u>

Actual system heat transfer:
Q other vessels = $U_o A_o \Delta T_o$
Q piping = $U_p A_p \Delta T_p$
Q main vessel = $U_m A_m \Delta T_m$
Q = Q other vessels + Q piping + Q main vessel

During depressuring (in reality):
$\Delta T_m > \Delta T_p$ & ΔT_o
$U_m > U_p$ & U_o

Model heat transfer can be correlated by:
$Q = U_m (A_m + 0.7 A_o + 0.4 A_p) \Delta T_m$

o, p and m stand for "other vessels", "piping" and "main vessel" respectively.

Figure 2 – depressuring heat transfer background

$A_H = (A - A_C) / 2$

A: Actual system – Total surface area (known, see below note)
A_C: Hysys model – Cylindrical area (calculated by Hysys)
A_H: Hysys model – Head cap area (each)

<u>Note</u>

As mentioned before, during system depressurization in reality, the temperature of those parts of system which are farther from depressuring valve will have much higher temperature than pipe and vessel directly upstream of depressuring valve. Higher temperature is corresponding to lower heat absorption from surroundings. Adding other vessel's surface areas to the main vessel area in model ends up with more heat gain than what they do in reality. This is because main vessel will reach very low temperature in Hysys. In other words, this approach leads to higher temperature during depressurization in Hysys than reality. Since this approach is totally in conflict with the purpose of cold depressurization, the heat transfer contribution of other parts of system (other than main vessel) can be reduced by considering a correction factor of 70% and 40% for other vessels and piping area respectively (see below equation). These coefficients are based on case study published in note "<u>Validation of Hysys Depressuring Utility</u>". The lower coefficients are more conservative (causing lower temperature during depressuring).

$A = A_{main\ vessel} + 0.7\ A_{other\ vessels} + 0.4\ A_{piping}$

Refer to Figure 2 which shows the heat transfer background of this assumption.

3. Metal Weight

Metal mass is usually ignored for fire rate calculation but it should be specified correctly for cold depressuring. Defining total surface area of model, Hysys is able to calculate model weight if metal thickness and density is provided. In actual system, pipes usually have less thickness than vessels and vessel head is thinner than shell. Considering the fact that those parts of system with lower thickness and closer to depressuring valve will reach lower temperature during cold depressuring, it is recommended to use:

- The thickness of equipment which is upstream of depressuring valve in actual system. The reason is that Hysys model results most probably match with the temperature of this vessel in reality. This vessel in reality and Hysys Model is the closest equipment to depressuring valve. The result of Hysys will be more applicable to this vessel rather than other ones. Therefore, it is better to define model more similar to the vessel upstream of depressuring valve to get more realistic results for at least one the equipment in the depressuring section. Hysys results will be finally used as minimum design temperature of entire system in the same depressuring section. Since other vessels and piping will reach higher temperature in reality, using same design temperature for them will be safe design approach.
- Since model surface area and thickness have been fixed, the only way to match Hysys model weight with actual system is to change metal density of model. Metal density does not have any effect on heat transfer and other important parameters so it can be manipulated to get model mass same as actual system.

Contact

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PROJECT :		DATE :	02-Aug-10
PROJ. NO.:		BY :	S. Rahimi
CLIENT:		REV :	A
UNIT :		DOC NO.:	

Blowdown Facilitator

Input Data								Volume		Surface					Weight
Actual System	Orient. (H / V) (H /E)	Vessel ID / Nominal Diameter	Length / Height	Vessel Liquid Level / Pipe Filling	Shell Thickness + cladding	Head Thickness + cladding	Metal Density	Total Vessel Volume	Total Liquid Volume	Surface Area of Shell	Surface Area of each Head	Total Surface Area	Wetted Surface Area	Gas Surface Area	Total metal Mass
	----	m/ inch	m	m / %	m	m	kg/m3	m3	m3	m2	m2	m2	m2	m2	kg
VESSEL															
V-4808 (main vessel)	HH	4.5	16.0	0.838	0.141	0.073	7860	302.03	37.05	226.1	31.8	289.7	85.0	204.6	287039
-	VE	0.0	0.0	0.000	0	0	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0
-	VH	0.0	0.0	0.000	0	0	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0
-	VH	0.0	0.0	0.000	0	0	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0
-	HH	0.0	0.0	0.000	0	0	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0
PIPING															
20"-P 21001	H	20	55.0	0.00%	0.03554		7860	8.25	0.00			75.5	0.0	75.5	21078
16"-P 21002	H	16	11.0	0.00%	0.02919		7860	1.05	0.00			12.0	0.0	12.0	2758
6"-P 21003	H	6	55.0	0.00%	0.01097		7860	0.74	0.00			22.5	0.0	22.5	1943
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
-	H	0	0.0	0.00%	0		0	0.00	0.00			0.0	0.0	0.0	0
TOTAL								312.06	37.05	226.1	31.8	333.7	85.0	248.6	312818

Hysys Model	Orient.	Vessel Internal Dia.	Length / Height	Vessel Liquid Level	Shell Thickness + cladding	Head Thickness + cladding	Metal Density	Total Vessel Volume	Total Liquid Volume	Surface Area of Shell	Surface Area of each Head	Total Surface Area	Wetted Surface Area	Gas Surface Area	Total metal Mass
	----	m	m	m	m	m	kg/m3	m3	m3	m2	m2	m2	m2	m2	kg
Horizontal Vessel	HF	4.72	17.83	0.83	0.141	0.141	6649	312.06	37.05	264.3	34.7	333.7	85.0	248.7	312818

HH	Horizontal vessel - Hemispherical head	VH	Vertical vessel - Hemispherical head
HE	Horizontal vessel - Flat head	VH	Vertical vessel - Elliptical head
HF	Horizontal vessel - Elliptical head	VF	Vertical vessel - Flat head

Figure 2 – Spreadsheet snapshot for generating correct input data for Hysys depressuring utility

Note: Green and white cells are input and results respectively.
Red figures are input data to Hysys depressuring model.