PRESSURE PIPING THICKNESS AND FLANGE RATING CALCULATION

This case study demonstrates the use of a script and a Generic 4D chart to enable Flownex® to calculate standards-compliant wall thicknesses and flange ratings of piping used in high pressure flow applications.

OIL AND GAS INDUSTRY

Challenge:

The main challenge for this case study is the application of Flownex® to:

- Conveniently and easily check if the selected pipe wall thickness is adequate to safely contain the high pressure fluid by implementing ASME B31.3, AS 1210 and AS 4041 in a simple script.
- Determine the required ASME B16.5 flange rating by implementing the calculation in the same script.
- Use the Generic 4D chart facility to implement a simple library for the pipe and flange material tensile strength, working pressure-temperature ratings and other coefficients required by the calculations.

Benefits:

Flownex® is often used in a design environment to model high pressure flow systems with the aim of determining pressure losses, pipe velocities, heat transfer etc. However, in high pressure applications it is also necessary to design the pressure piping and associated connected flanges to safely contain the high pressure fluid. Since almost every country has its own pressure vessel and pressure piping standards, Flownex® does not offer this capability as part of a built-in component or script, but it is quite simple to implement using a script that may be connected to any Flownex® pipe component via a data transfer link (DTL).

Solution:

Using a simple script in any Flownex® model, pressure piping and flanges can be easily checked for compliance with any international standard.

"Using a simple script and Generic 4D chart combination, the design capability of Flownex® has been extended to include pressure piping wall thickness and flange rating. This enables the process engineer to account for various pipe wall thickness requirements during the thermo-fluid design phase and well before piping engineers are required to verify the structural properties of the piping system. This may potentially reduce the amount of rework as it will be less likely that the wrong pipe schedule and flange ratings are used during the process design phase and development of initial datasheets and Piping and Instrumentation Diagrams (P&IDs)."

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Introduction

In the oil and gas industry high pressure applications are mostly the norm rather than the exception. Process engineers may employ Flownex® to model liquid or gas piping systems as part of their heat and mass balance, and pipe sizing calculations. However, the process engineer often has to rely on others to determine the required pipe schedules (wall thickness) and flange ratings.

Flownex® has a very powerful facility in terms of its scripting capability. Combined with the Generic 4D chart library, all the tools required are available to implement pressure piping calculations according to any design standard. In fact, any data table oriented calculation procedure may be implemented using this approach. This case study demonstrates the implementation of three such international standards – ASME B31.3, AS 1210 and AS 4041 – in a simple script. It also further demonstrates how to use the Generic 4D charts as a material property library to be used by the script.

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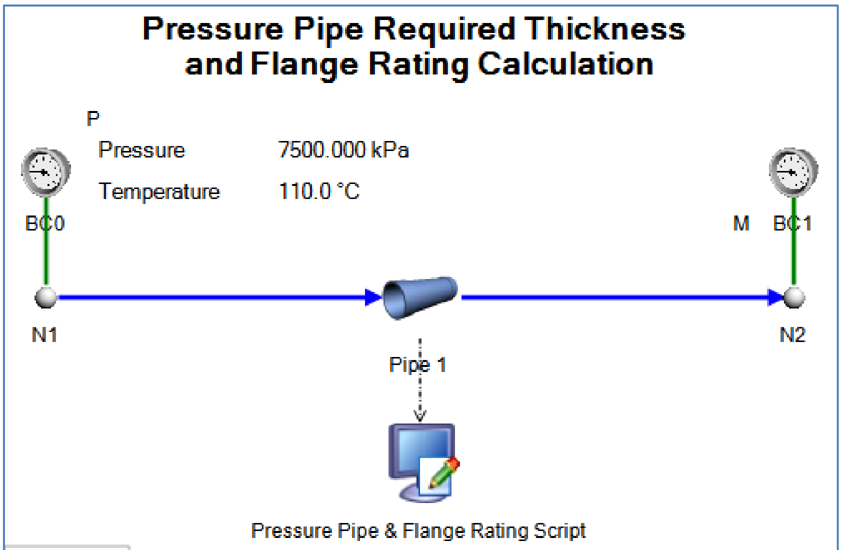
Flownex Model

Figure 1 shows the example network with a high pressure fluid flowing through the pressure pipe. The script obtains the pipe inside diameter and wall thickness as well as the operating (working) pressure and temperature from the pipe via the data transfer link (DTL). In the case demonstrated, the design pressure and temperature are entered directly into the script since the design values are often not the same as the working pressure and temperature. Typical values are shown in the inputs.

Corrosion allowances typically range from 1.5mm to 3mm and are often specified separately for the pipe inside and outside surfaces. Manufacturing under-tolerances are often assumed 12.5% for good quality piping. For seamless piping the weld quality factor (joint efficiency) may be taken as 1.0. The weld joint reduction factor may be taken as 1.0 for cases where the temperature is less than 500°C. The example shows that the actual pipe wall thickness is approximately 25% more than the required thickness. An ASME B16.5 Class 900 flange is required for this design pressure and temperature and. The flange maximum allowable working pressure (MAWP) is 11988 kPa-g which is higher than the design pressure.



INPUTS

Tensile Strength Chart	ASTM A106B & A105| Pipe Material Strength (Generic 4D Charts)
Design Standard Option	ASME B31.3
Design Pressure (Gauge)	10200.0 kPa
Design Temperature	297.0 °C
Corrosion Allowance (Inside)	0.800 mm
Corrosion Allowance (Outside)	0.800 mm
Under-tollerance	12.5 %
Weld Quality Factor (Joint Efficiency)	1.000 0-1
Weld Joint Reduction Factor	1.000 0-1
Pipe Inside Diameter	97.180 mm
Pipe Wall Thickness	8.560 mm

RESULTS

Pipe Outside Diameter	114.300 mm
Design Tensile Strength	126.360 MPa
Table 304 Y-Coefficient	0.400 0-1
Required Pipe Nominal Thickness	6.828 mm
Pipe Design Strength Margin	25.4 %
ASME B16.5 Flange Class	900
ASME B16.5 Flange MAWP	11987.8 kPa

Figure 1: Example Flownex Pressure Pipe Network with Script

The inputs and results displayed on the canvas in Figure 1 can also be added directly via the script's property page. In fact, the Tensile Strength Chart and the Design Standard Option has to be selected via the script property page as the Flownex® canvas representations of dropdown options cannot be changed.

Figure 2 shows the script inputs and outputs. The user has to select the material library and the design standard from dropdown menus. Furthermore, the design pressure (in gauge pressure), design temperature and corrosion allowance must be specified. The DTL will import the pipe inside diameter and wall thickness as well as the operating pressure and temperature. The remaining factors will likely remain as given.

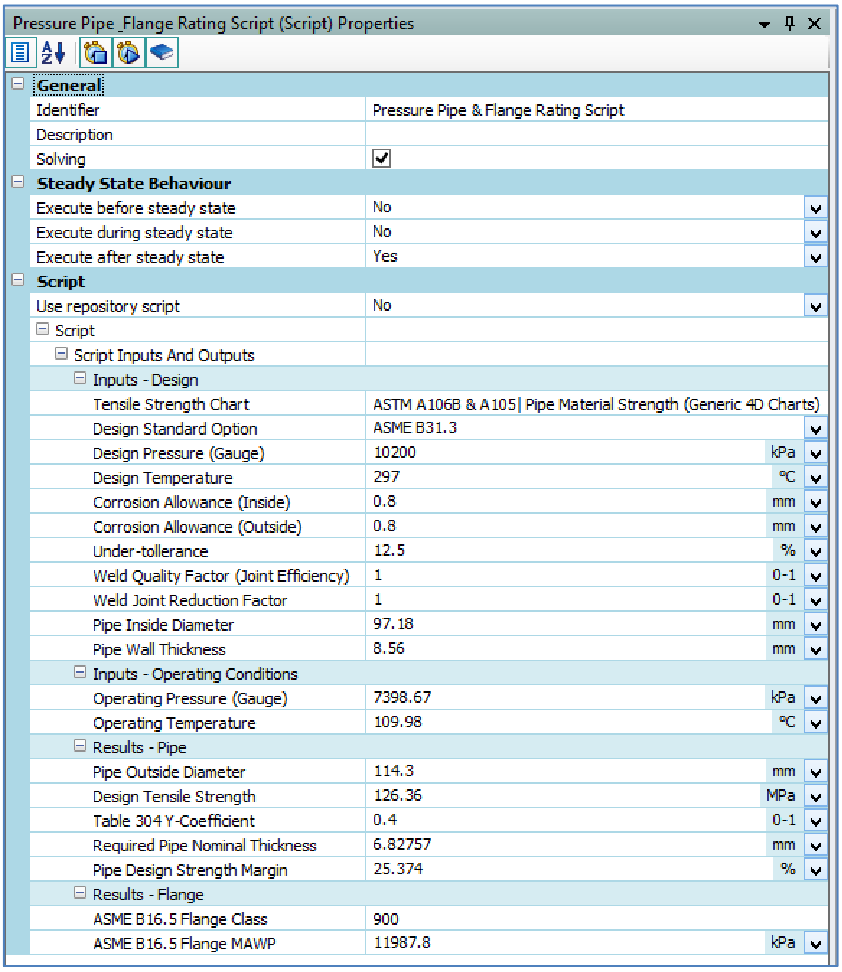


Figure 2: Pressure Piping and Flange Rating Calculation Script Inputs and Results

Calculations According to Piping Standards

ASME B31.3 (2014)

ASME B31.3 is a widely used US Standard for pressure piping. The required pressure piping wall thickness may be calculated according to ASME B31.3-2014 section 304.1.2 as follows:

$$t = \frac{PD}{2(SEW + PY)} \quad (1)$$

where:

t = the pressure design thickness for internal pressure
P = internal design pressure (gauge)
D = outside diameter of the pipe
S = stress value of material (pipe design tensile strength)
E = weld quality factor (weld efficiency)
W = weld joint strength reduction factor
Y = coefficient from Table 304.1.1, valid for $t < D/6$

AS 1210 (2010) & AS 4041 (2006)

AS 1210 is an Australian and New Zealand Standard for pressure vessels and AS 4041 is the pressure piping equivalent. Both standards are heavily based on ASME B31.3 although AS 1210 is more conservative due to its nature as a pressure vessel standard. Since they are based on ASME B31.3, the calculations are quite similar and although the AS standards use slightly different symbols, this case study will reuse the ASME symbols in the AS section and only add additional symbols as needed.

In accordance with AS 4041:

$$t = \frac{PD}{2SEMW + P} \quad (2)$$

where:

M = the class design factor (taken as 1.0 for Class 1 and 2 piping)

In accordance with AS 1210:

$$t = \frac{PD}{2SE + P} \quad (3)$$

Mechanical Allowances – All Standards

The above expressions provide the required wall thickness to contain the design pressure. No other mechanical allowances have been made. The mechanical allowances most frequently being used are those for corrosion, erosion, thread or groove and under-tolerance. In this example only corrosion and under-tolerance are considered. The required thickness of straight sections of pipe may then be determined as follows:

$$t_m = t + c \quad (4)$$

where:

c = sum of all mechanical allowances

Hence for the allowances considered, the following relationship is used:

$$t_m = (t + ca) \times (1 + ut) \quad (5)$$

where:

ca = the corrosion allowance
ut = the under-tolerance as a fraction (typically 0.125 or 12.5%)

ASME B16.5 (2009) Flange Ratings

Flange ratings for a particular application are selected according to the working pressure-temperature ratings for the specific material as given in the tables in ASME B16.5-2009. ASME flange classes are Classes 150, 300, 600, 900, 1500 and 2500.

Implementing a Material Strength Library By Using a Generic 4D Chart

Each of the standards considered provides tables of the pipe material design tensile strength as a function of design temperature. The tensile strengths given for ASME B31.3 and AS 4041 are similar since they are both pressure piping standards whilst the tensile strengths given for AS 1210 are somewhat lower owing to its more conservative approach as a pressure vessel standard. All these tables of design tensile strengths are implemented in a Generic 4D chart.

Pipe wall thickness calculations according to ASME B31.3 also uses a *Y*-coefficient given in Table 304.1.1 of the standard which is valid for cases where $t < D/6$. These factors will also be implemented in the same Generic 4D chart.

The ASME B16.5 flange rating is done by implementing the flange material pressure-temperature ratings in a table in the same Generic 4D chart.

For this case study, the piping and forgings (flanges) material pairs implemented in the Generic 4D charts are:

- ASTM A106 Grade B with ASTM A105
- ASTM A312 TP304 with ASTM A182 Gr.F304
- ASTM A312 TP316 with ASTM A182 Gr.F316
- ASTM A790-S31803 with ASTM A182 Gr.F51

To implement other materials would simply require a duplicate Generic 4D chart with the correct design tensile strengths, coefficients and pressure-temperature ratings for the new materials.

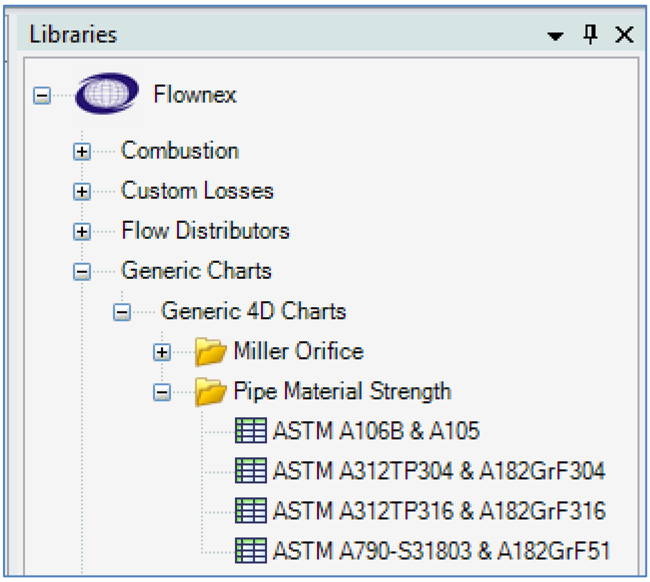


Figure 3: Piping and Flange Material Strength Library

The pipe and flange material strength library is provided to the script via a Generic 4D chart as shown in Figure 3. The user should add similar charts for all the piping and flange materials used.

The material library could have been implemented several different ways using Generic 4D charts. For simplicity and conciseness it was decided to implement all the data for a specific piping material and flange material pair required by the script in a single chart.

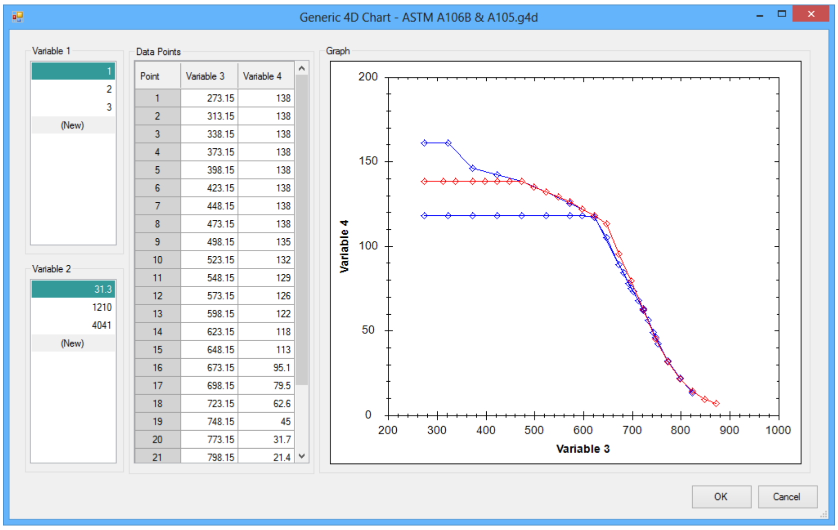


Figure 4: Piping Design Tensile Strength Table for ASME B31.3 Calculations for ASTM A106 Gr B Material

As shown in Figure 4, the Generic 4D charts provide for 4 variables to be plotted against each other. The implementation of the material strengths and other factors do not actually require a 4D chart, however it will be shown that having 4 variables available made this implementation simple. Variable 1 is used to store the different datasets as will be demonstrated in the following discussions.

Under Variable 1, Variable 2 has three (3) entries - each of which implements the temperature-tensile strength tables using Variable 3 and Variable 4 respectively for the three standards implemented. Note that the temperature (Variable 3) is in Kelvin and the basic allowable stress (or tensile strength) (Variable 4) is in MPa. The ASME B31.3 table is selected in Variable 2 and is therefore shown in red in the graph and clearly falls between AS 4041 and AS 1210 as discussed before.

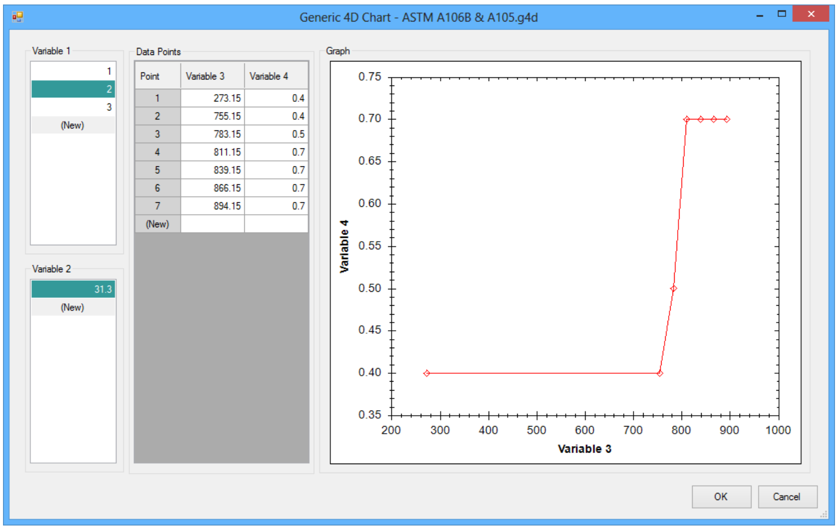


Figure 5: ASME B31.3 Y-Coefficient from Table 304.1.1

The second entry in Variable 1 (Figure 5) is used to store the ASME B31.3 *Y*-coefficient from Table 304.1.1 of that standard. Variable 3 lists the temperature (in Kelvin) whilst Variable 4 lists the *Y*-coefficient (dimensionless).

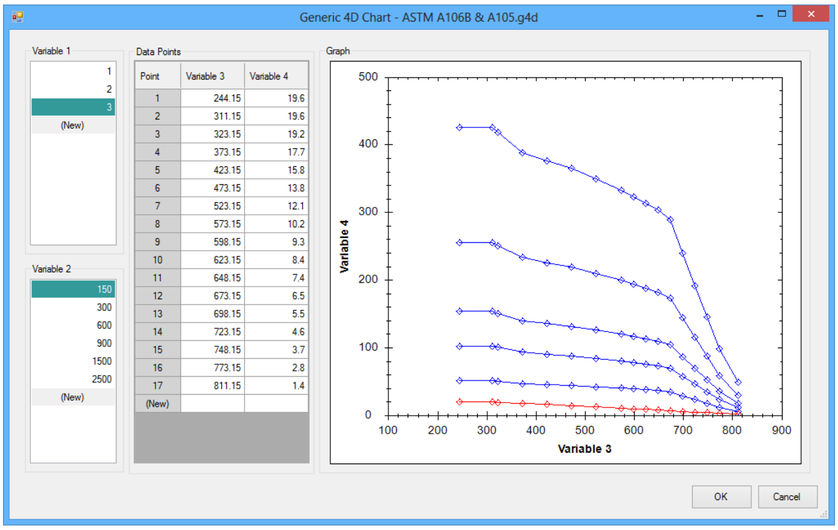


Figure 6: ASME B16.5 Pressure-Temperature Ratings for ASTM A105 Flanges

The third entry in Variable 1 (Figure 6) is used to store the ASME B16.5 flange pressure-temperature rating data. It is shown that Variable 2 is used to store each flange class with Class 150 shown as selected and displayed in red in the graph. Variables 3 and 4 store the temperature vs. working pressure respectively for each instance of Variable 2. Note that the temperature (Variable 3) is in Kelvin and the working pressure (Variable 4) is in bar-g (bar-gauge).

A facility where each of the 4 variables can be assigned a label to assist with the clarity of a chart is yet to be added to Flownex®.

Warning Reporting

The script has been updated to implement three basic warnings as shown below. The first warning informs the user that the Pipe Design Strength Margin as shown in Figure 2 is negative, i.e. there is no margin available. The second warning informs the user that the operating pressure (actual pressure in the pipe) is higher than the specified design pressure. Similarly, the third warning suggests that the operating temperature exceeds the design temperature.

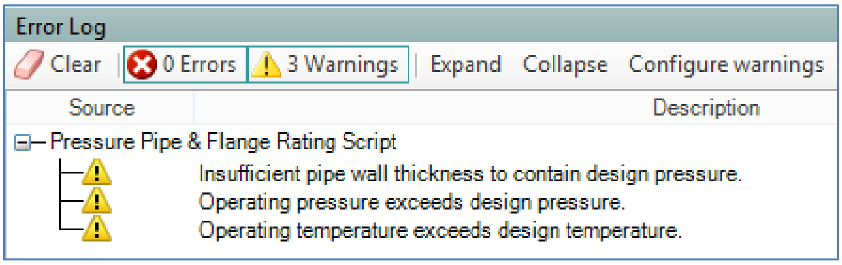


Figure 7: Warnings Generated by the Script

Summary

Using a simple script and Generic 4D chart combination, the design capability of Flownex® has been extended to include pressure piping wall thickness and flange rating. This enables the process engineer to account for various pipe wall thickness requirements during the thermo-fluid design phase and well before piping engineers are required to verify the structural properties of the piping system. This may potentially reduce the amount of rework as it will be less likely that the wrong pipe schedule and flange ratings are used during the process design phase and development of initial datasheets and Piping and Instrumentation Diagrams (P&IDs).

Case Study Flownex Model Availability

The Flownex® model discussed in this case study is available in the user project downloads area available from:

http://www.flownex.com/projectlibrary

The model demonstrates various simple scripting techniques such as:

- the implementation of dropdown menus;
- hiding and showing variables in the property page depending on selected options;
- accessing the Generic 4D chart libraries and
- reporting of warnings.