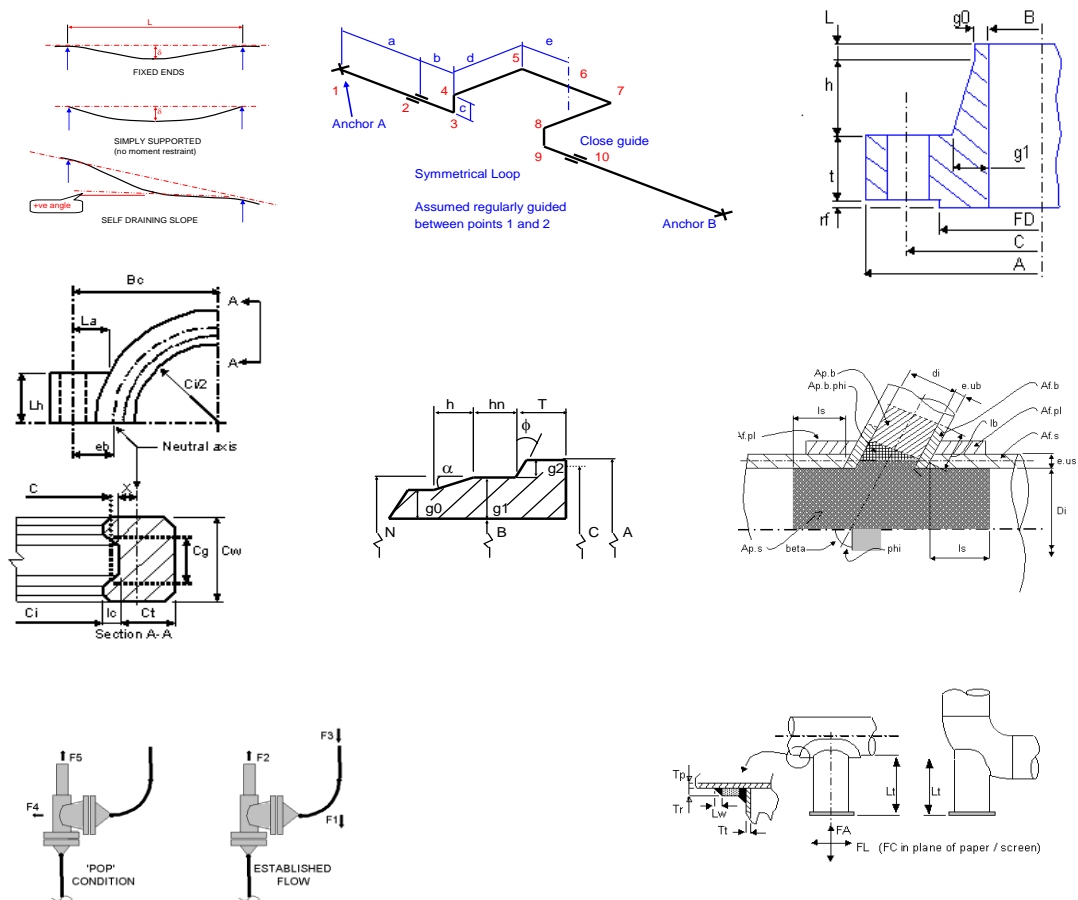


Pipemill

Engineering Software User Guide



Software designed to aid the Piping Engineer and
Piping Stress Engineer

Pipemill Engineering Software
User Guide, Version 4.00

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1.0 PROGRAM DESCRIPTION

PIPEMILL has been written to aid the piping design engineer and the piping stress engineer. Its purpose is to improve accuracy and speed in both complex and simple but repetitive calculations.

Extensive and wide ranging routines area available to assist in both commonly used and rarely used calculations.

Where possible, common functions are employed throughout all elements of the program.

Context sensitive help is provided where needed. It is expected that an experienced engineer would have little recourse to any literature whilst running the software.

The software is written in Microsoft Visual Basic and takes full advantage of the Windows environment to deliver clear, user friendly input and output screens, with helpful and informative graphics.

Pipemill is provided, loaded on a (USB) Stick memory. The software will run from this location only, on any compatible PC type computer.

Do not attempt to move execution software elsewhere as this will cause permanent corruption.

Refer to the section on Installation Instructions for further information.

Pipemill has been compiled under the Microsoft Windows 8 platform.

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1.1 LICENCE AGREEMENT

IF YOU DO NOT AGREE TO THE TERMS AND CONDITIONS OF THIS AGREEMENT, DO NOT USE THE SOFTWARE. **USING ANY PART OF THE SOFTWARE INDICATES THAT YOU ACCEPT THESE TERMS.**

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1.2 DISCLAIMER

Whilst each program within the PIPEMILL package has been carefully checked and tested, no guarantee is offered or implied with regard to accuracy or validity of results. The software must be used only by qualified personnel, familiar with the Codes of Practice and design rules implemented by the programs therein.

1.3 IMPORTANT NOTE CONCERNING NUMBER FORMAT:

Ensure that the number format on your computer is true decimal ONLY

USE THIS FORMAT: 123456.789

Decimal point with no spaces.

Any other format using commas or spaces such as below will cause fatal errors and will corrupt data read from the data bases:

Do not use these formats !

123 456,789	space and comma
123456,789	comma
123 456.789	space and decimal point

To change to the correct format select 'Regional and Language Options' from Microsoft Windows.

1.4 Technical Support

Technical support is available via e-mail. A description of the problem or query and any associated input files should be e-mailed to:

pipemill@lvysoftlimited.com

1.5 SYSTEM REQUIREMENTS

- A PC running at least the Windows XP operating system.
- Available USB port

1.6 COMMON FEATURES

1.6.1 File Manager

Where needed, file read and write facilities appear to be the same for all parts of the program. Files are stored in the directory named in the 'Data Files' window of the Set-Up file available from the main menu.

When saving a file, only the file name itself should be entered. Files from each individual program are identified by a unique trailer which is assigned by the program when the file is saved.

When reading files from a particular program, only those relevant will appear in the file list. Simply clicking on the required file name will load it and return to the populated input form.

Once saved with a particular units set, the retrieved file units cannot be changed.

1.6.2 Data Bases

Several data bases are coded into the software and accessed by the various programs. These include:

- Pipe sizes to ANSI B36.10, B36.19 and API 5L dimensions
- Flange dimensions to ANSI B16.5, ANSI B17.47A & B and API 6A
- Valve dimensions to ASME B36.10
- Material data curves relating to external pressure design
- Expansion characteristics of various materials to ASME B31.3

1.6.3 Help Files

Help files are available from most programs and are accessed usually by clicking on the yellow '?' button.

1.6.4 Calculator

A scientific type calculator is available from all elements of the program. It may be dragged and dropped to any location on the screen.

1.6.5 Design Codes

Calculations are generally in accordance with ASME and API UK codes of practice.

1.7 Future Developments

We encourage users to recommend future developments to Pipemill via the website.

2.0 INSTALLATION INSTRUCTIONS

Pipemill may be used on any compatible PC.

Plug the Memory Stick into an available USB port.

Either: Using Windows Explorer, click on the **PM-START.exe** file.

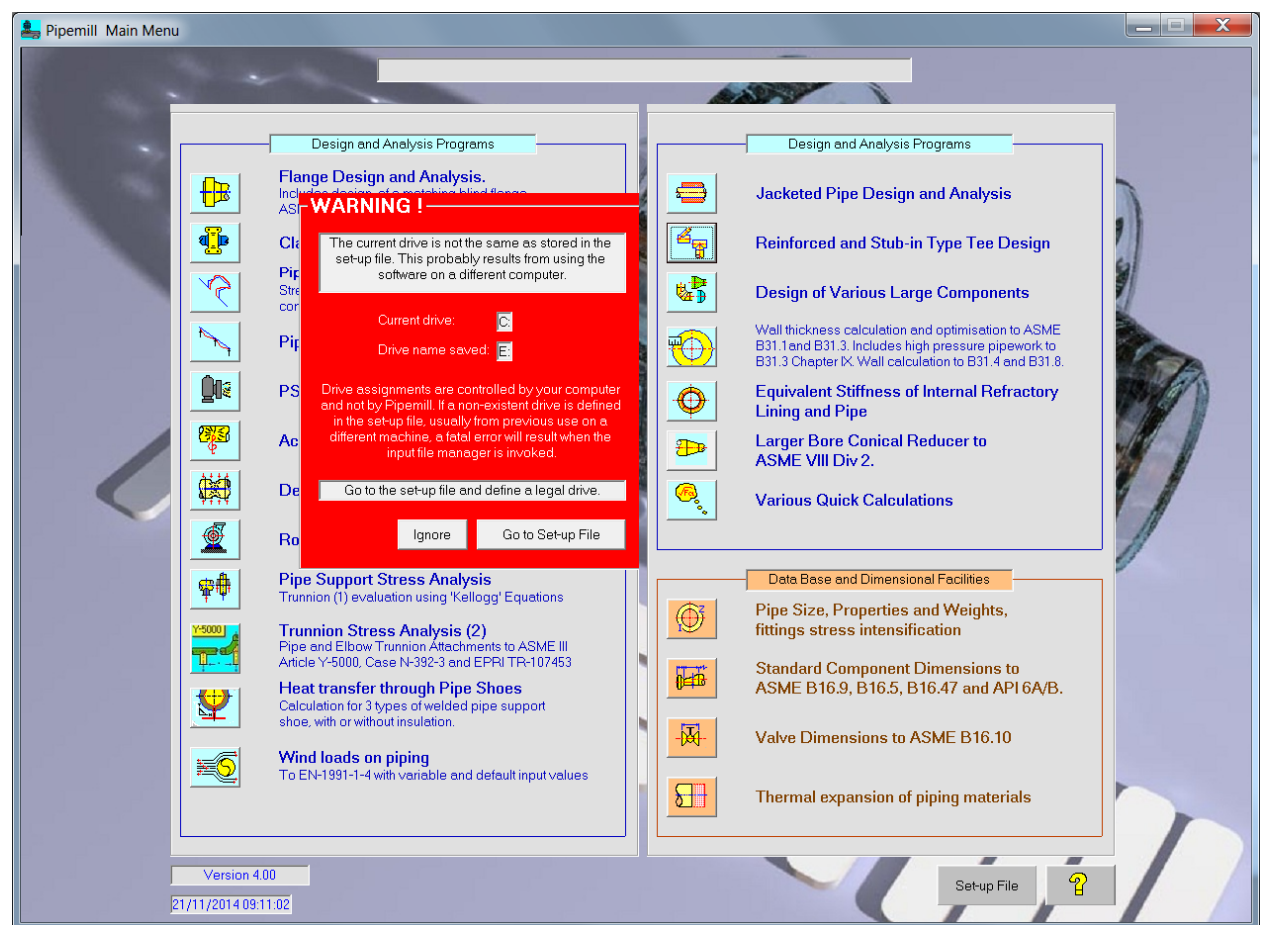
Using Windows Explorer, drag and drop the **PM-START.exe** file logo to your desktop and define a short-cut. Then use the short-cut.

Do not click on the Pipemill3.exe file, since this action will cause a file loading failure.

Allocated Drive Definition

If the Memory Stick has been used on a different computer, the USB port may not have the same name (E, F, G etc.) as the current installation. Whilst Pipemill will function normally under these circumstances, use of the file manager will cause a system abort.

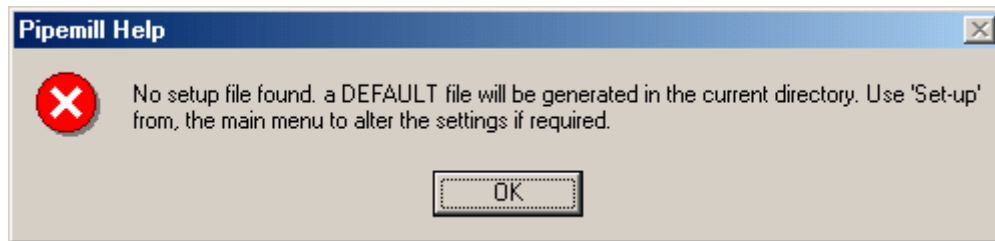
Pipemill will check the drive name and warn the user if necessary, giving the option of going directly to the set-up file, where the correct current drive location may be defined.



Input data files may be stored on any drive including the Pipemill stick memory itself.

2.1 Initial Start-up of Software

To operate normally the PIPEMILL system needs a set-up file to determine such as the system of units to be used and file structure. If the set-up file is accidentally deleted or moved, and at first start-up following installation, the following will appear:

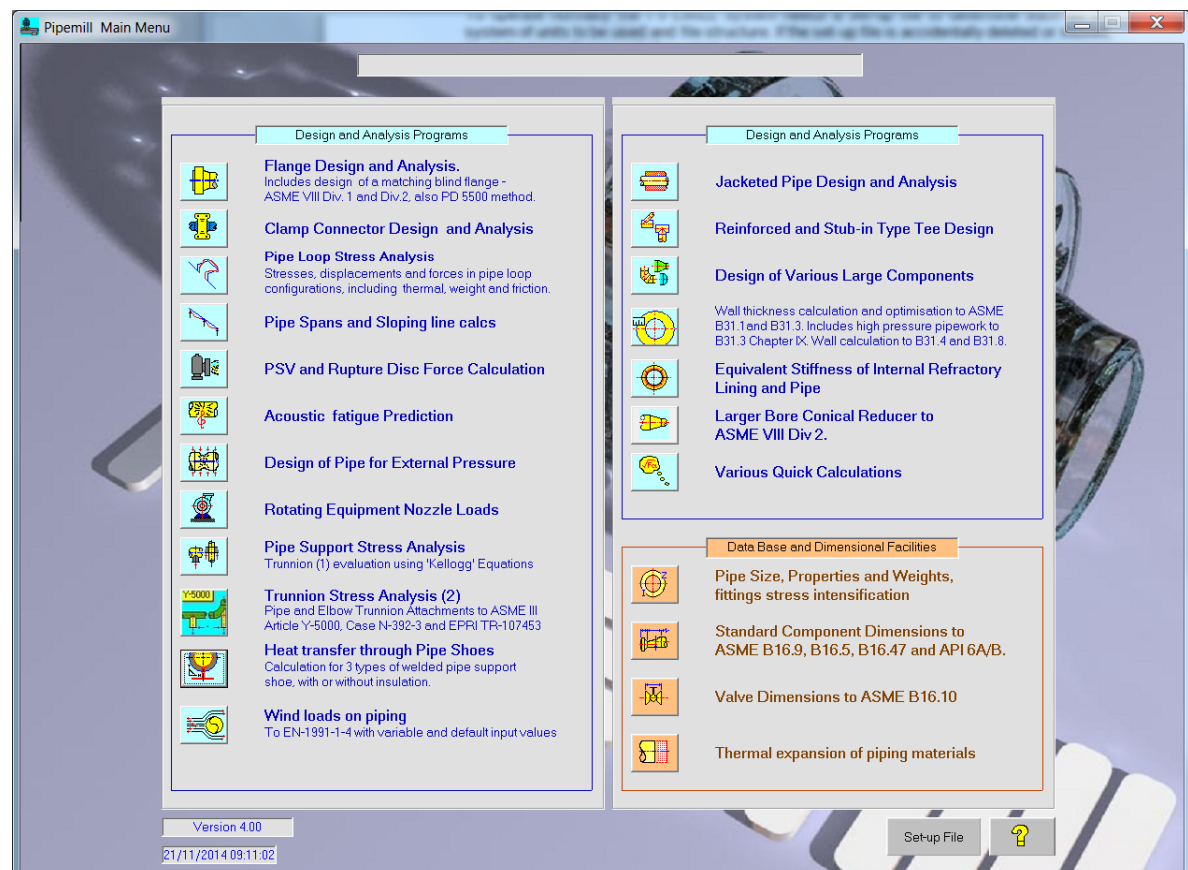


A system file will be created and the main menu will then appear.

All programs are accessed from the main menu screen as shown below.

The PIPEMILL system is designed to run one program element in memory. The running program and the main menu may be minimised to the tool bar and maximised without loss of data or any interference with other software in memory.

2.1.1 Main Menu Screen



2.2 The Set-Up File

Accessed from the main menu, the set-up file may be used to select the system of units to be used in calculations, the required paper size and file structure. Once defined, these settings are stored and used in all future work.

Pipemill Setup File

Define Location of Data Files

f\

f\
Pipemill-incr

Move to another existing Data File Directory:
f\Pipemill-incr
Click on 'Apply to confirm: Apply

Select System of Units
All programs will start up using the system of units defined here.
☒ SI Units
☐ English Units
Note that if a data file is read in differing units, the units in the data file will be applied and cannot be changed thereafter.

Select Paper Size:
All printed output will be set to this paper size.
☒ A4 (210 x 297mm)
☐ 8.5" x 11" (216mm x 279mm)
☐ 8.5 x 10.8" (215 x 275mm)

Current File Structure:
Source files: Source files MUST remain in the root directory of the Memory Stick
Data files: e:\V-4 Examples

Paper size A4
Current units: si
Current version Version 4.00

To accommodate large and multi-screen systems, when initially started Pipemill will locate at the top left of your screen area. The main menu may then be 'dragged and dropped' to any location, which the system will remember and use for subsequent start-ups.

Cancel OK - Use This Setup

3.0 FLANGE DESIGN AND ANALYSIS (INCLUDING BLIND FLANGES) to ASME VIII and PD 5500

3.1 INPUT DATA

Input data is common to ASME VIII Div. 1, ASME VIII Div. 2 and PD5500.

Typical Input Screen

Flange Design and Analysis

Select Units:
☐ English
☒ Metric (SI)

Design Basis:

Analysis Code:
☒ ASME VIII-1
☐ ASME VIII-2
☐ PD 5500
☐ EN 13445

Flange Type:
☒ Weld Neck
☐ Slip-on
☐ Lap Joint
☐ Flat Plate

Facing type:
☐ RF - Flat
☐ R.F Spiral
☒ R. T. J.
☐ Flat Face
☐ Full Face

Design Loads:
☒ Pressure
☐ Pres. + Wgt
☐ Combined

Project / Description:
 Calculation Details: 24in 1500# WN RTJ
 File: f:\V-4 Examples\V-4 FLG-ASME-01.flg

Geometry Diagram
 ASME B16.5
 1500 #
 24 in. nominal
 THL is the sum of L + h + t + rf (as appropriate) THL 427.0248 mm

Input Data

Flange Body:

A	1168.4	mm
B	559.6	mm
C	990.6	mm
PD0	609.6	mm
g0	25	mm
g1	101.2	mm
L	25.5325	mm
h	177.6675	mm
t	203.2	mm
rf	20.6248	mm
ca	3	mm
E. hot	199.95	MPa
E. cold	200.0	MPa

Gasket Data:

Ins Dia. Di		mm
Out Dia. Do		mm
Pitch Circle G	692.15	mm
Width W	34.925	mm
Factor m	6.5	
Factor y	179.26	MPa
Face Dia. FD	793.75	mm

Bolt Data:

No. of Bolts	16	
Bolt Dia.	88.9	mm
Bolt Area	5645	mm ²
Hole Dia.	91.948	mm

Units are GPa

Loads: Moment kNm
 Press. 250 Bar G. Axial Force kN

Allowable Stresses: Flange Bolts

Ambient Temp.	137.895	MPa	172.37	MPa
Operating Temp.	137.895	MPa	172.37	MPa

Execute ? Clear

3.1.1 Starting a New Input

To initiate a new flange design, either a standard or user defined design must be selected. If a standard flange is required, data bases of ANSI B16.5, ANSI B16.47A & B and API 6Aor 6B dimensions may be accessed.

In common with user defined data, the flange type and facing type must be defined before the main input data panel can be accessed.

A comprehensive help file may be accessed and is strongly recommended to new users. In addition to definitions and descriptions, dimensional data such as bolt and gasket parameters are available. Details of the help file are displayed below.

A local set-up file controls whether dimensional data is independent or related. If geometry cells are locked, when the g0 (hub small end) dimension is entered for a standard flange, all related dimensions will be updated. Related cells will not then be accessible.

Default data will be entered for allowable stresses, and dependent upon type, relevant gasket parameters. All these values may be revised if required.

3.1.2 Defining Load Cases

Loads applied to the flange must be defined. The selection controls assignment of allowable stresses in the calculation.

For ASME VIII Div. 1 and PD5500 calculations, load cases may be selected from:

Pressure only.	Allowable stresses as per the design code.
Pressure + weight.	Allowable stresses as per the design code. Primary stress case, assuming weight causes externally applied loads which are additional to pressure.
Combined.	Operating case, including primary and secondary stresses. External loads due to a combination of weight, thermal and other loads. In this case, allowable radial and tangential stresses and combinations including these are increased in the spirit of the ASME B31.3 piping code for secondary stresses including a safety de-rating factor of 0.8. Thus the allowable stress will be $0.8(1.25Sfa + 0.25 Sfo)$.

It is normal to run a pressure + weight case, whenever a combined case is run, to ensure that primary stress criteria are satisfied.

External loads are converted to an equivalent pressure and added to operating load sets in the calculation by default. A check box is accessible in the local set-up file, which allows the user to apply external loads to all pressure equations, including the gasket seating case.

External loads are converted using the familiar 'Kellogg' equation, also found in ASME III:

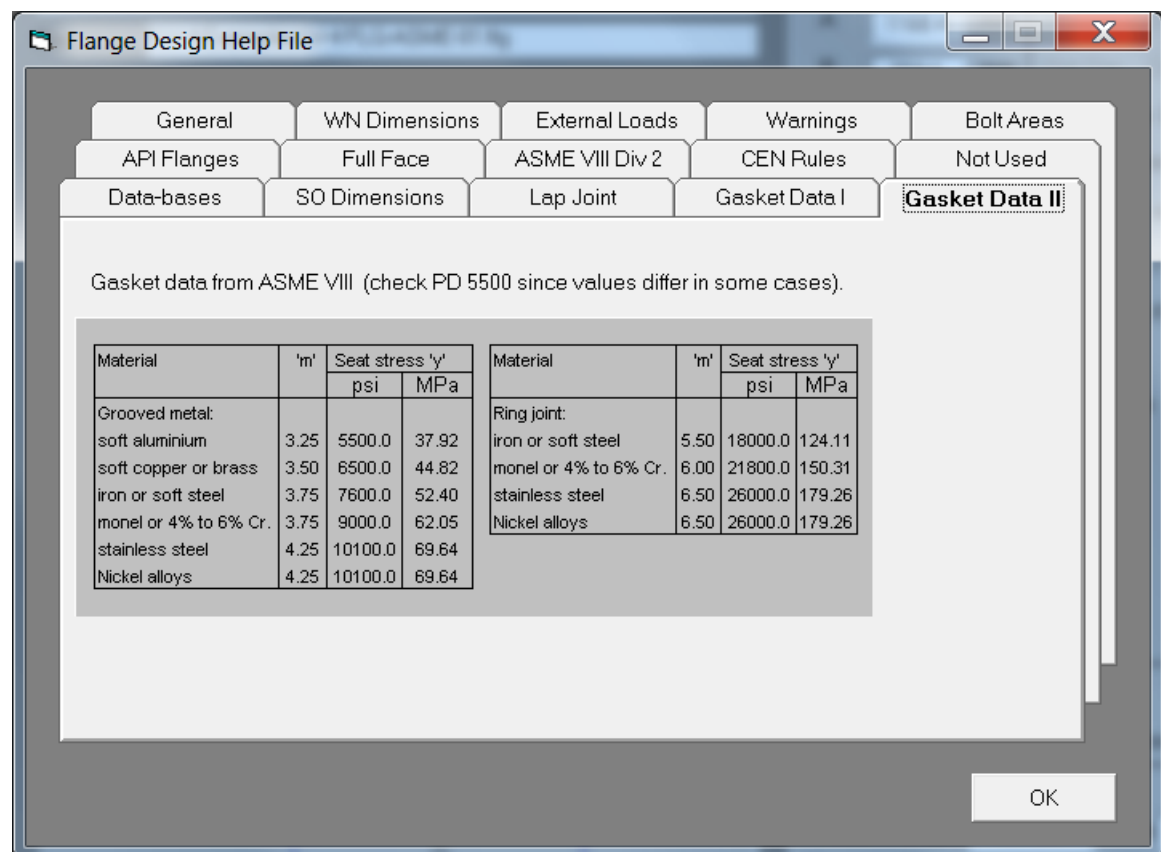
$$P_{eq} = 16.M/\pi.G^3 + 4.F/\pi.G^2$$

Where	P_{eq} =	Pressure equivalent of a longitudinal moment and axial force (MPa)
	M =	Longitudinal moment (Nmm)
	F =	Axial force (N)
	G =	Gasket reaction diameter (mm)

P_{eq} is added to flange design pressure P in equations as defined in the local set-up file.

For ASME VIII Div. 2 calculations, external loads are taken into account directly by the Code method. Thus the 'equivalent pressure' is not required.

3.1.3 Help file contents



3.2 EXECUTION

Prior to running the calculation, error checking will be carried out to ensure that the data set is both complete and feasible. An error message and the input will be returned if a fatal error is detected.

3.2.1 Non-Mandatory Checks

Several non-mandatory checks are carried out and reported. These are not directly code conflicts, but if shown they should be considered in the overall design process.

Rigidity Limit

If the calculation is to a code containing rigidity limits that have been exceeded, it will be reported. This is of particular relevance to high yield material such as duplex stainless. In some circumstances a design might meet the stress limitation criteria, but due to a thin flange ring section, sealing may be difficult to achieve in practice, due to local flexibility. If this may be a potential problem a lower allowable might be assigned, more appropriate to low carbon steel. It should be considered that the design approach is more appropriate to low carbon steel than newer high yield components.

Equivalent Pressure Check

The sum of an equivalent pressure due to external loads plus internal pressure should not normally exceed the hydrotest pressure, otherwise the condition will not be tested for prior to operation. Since hydrotest of pipework is normally a minimum of 1.5 x the design pressure,

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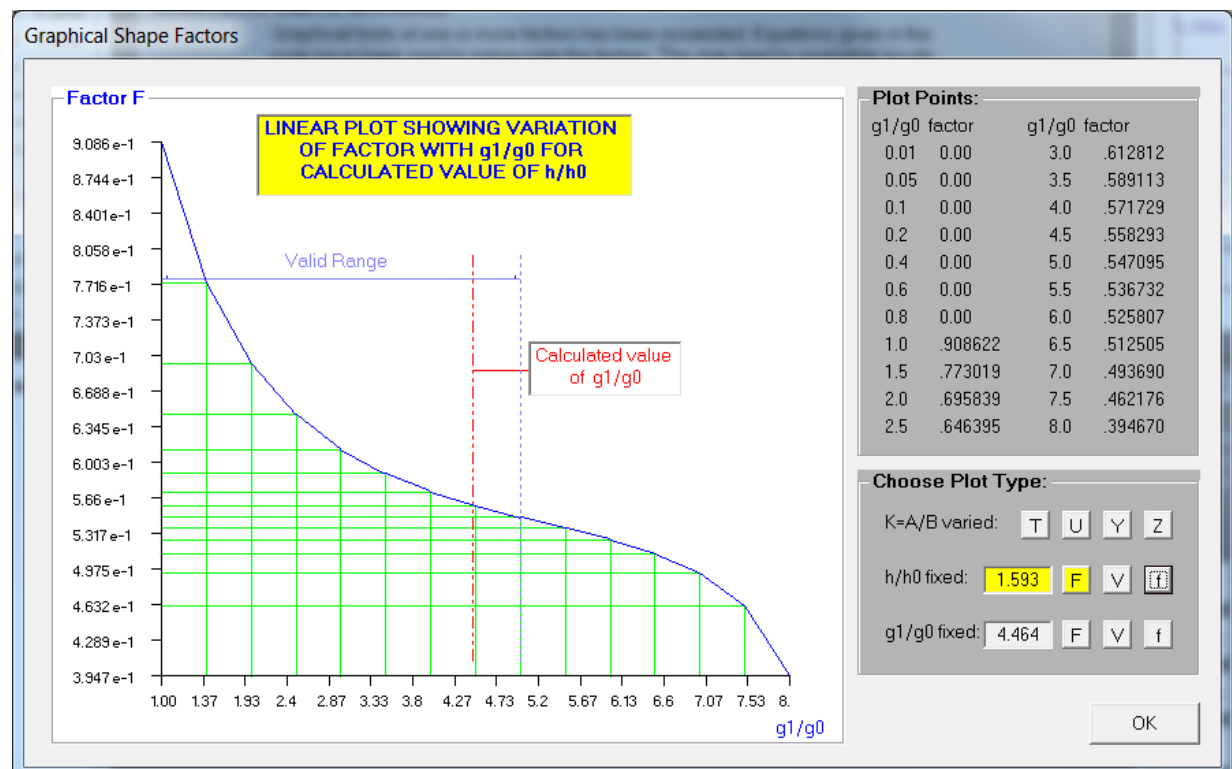
should the equivalent pressure due to external loads exceed 0.5 design pressure the condition will be flagged.

Graphical Limits warning

To solve geometrical shape factors, equations as presented in ASME VIII are used. The same functions are shown graphically in that and many other codes, including all those currently offered by PIPEMILL. The limits of application of these equations are clear in the codes, and to venture beyond the limits shown invites gross errors in results. To deal with this potential problem, PIPEMILL presents a warning that graphical limits have been exceeded, and allows the user to view the graphs in question by clicking on the view graph button. Graphs are plotted in linear fashion as opposed to log in the code.

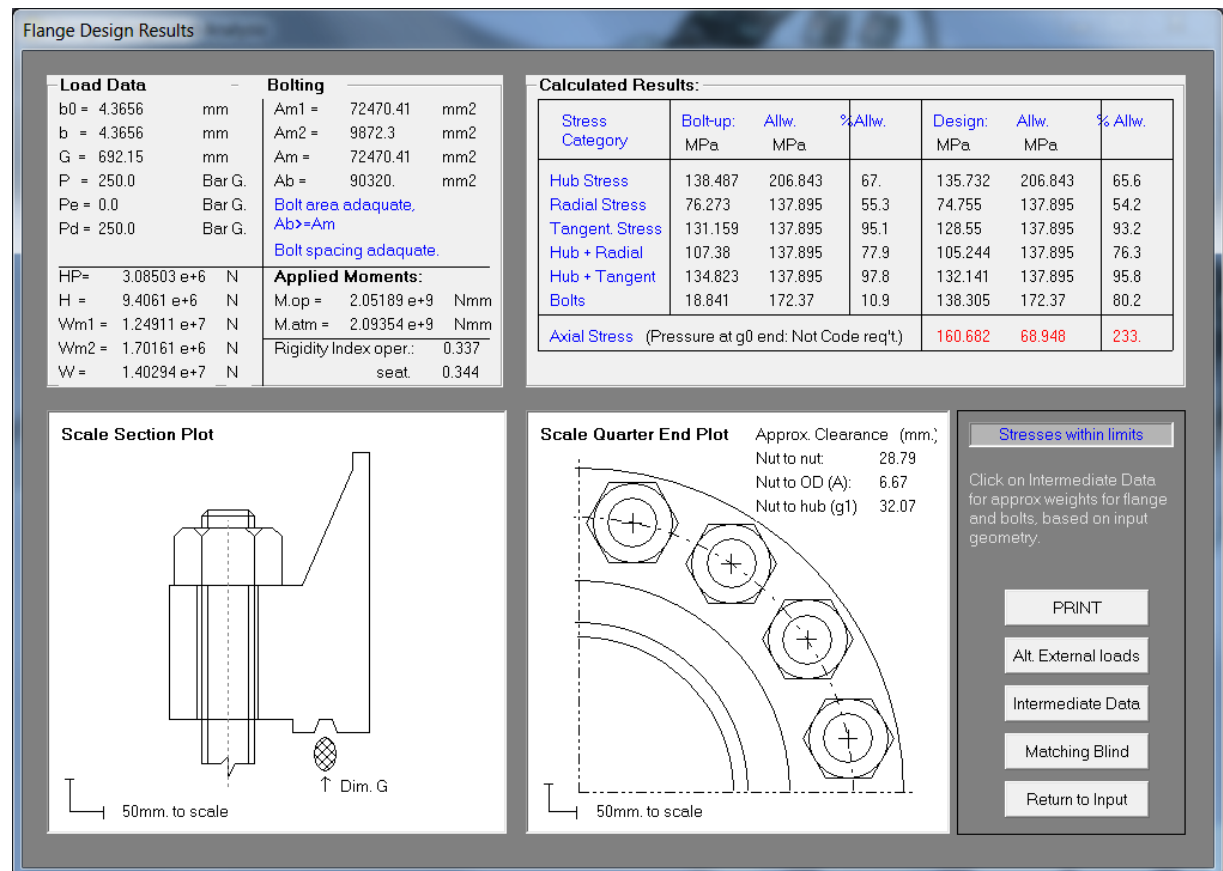
Graphs of all geometrical factors may be viewed, and a judgement then be made regarding the validity of results, from the direction and slope of the respective curves and the location of calculated data.

Graphical results will be presented as shown below.



3.3 RESULTS

Typical Flange Output Screen



Analytical results will be presented with further options available. Calculated and allowable stresses are shown together with primary system loads and associated data. Other intermediate data may be viewed. Flange and bolt weight will be presented, based on actual metal mass.

A matching blind flange may be designed, based on geometrical and other data extracted from the main flange body. Values such as allowable stresses for the blind may be revised.

Alternative methods of evaluating external loads may be accessed to compare with the equivalent method applied.

A scale section through the flange and a scale quarter end plot are presented to aid design and evaluation, particularly of custom designed items. These plots may be hard copied if required.

4.0 CLAMP CONNECTOR DESIGN AND ANALYSIS

Hub and clamp or 'Grayloc' type connectors may be designed and analysed in accordance with ASME VIII Div. 1 Appendix 24.

4.1 Clamp Connector Input

Input is similar to the flange design program, with input data panels specific to the hub, clamps and bolting & gasket.

To initiate design the user needs to define whether hub dimensions will be to match a standard pipe size, or dimensioned from the hub inside diameter.

Typical Clamp Connector Input

Clamp connector design and analysis

Select Units: ☐ English ☒ Metric (SI)

Get Dimensions From: ☐ Hub dims to match pipe ☒ Dims from hub ID (B)

Project / Description:

Calculation details:

File: f:\V-4 Examples\V-4 CLAMP-ASME-01.clm

Schematic Hub & Gasket Clamp

Hub Input Data

D =	273.05	mm	h =	25.4	mm	mu =	5	deg.
A =	317.5		hn =	19.05		phi =	15	
B =	234.95		g0 =	19.050		SA hub =	137.895	MPa
N =	284.48		g1 =	24.765		SO hub =	124.105	MPa
T =	25.4		g2 =	16.510				
Corrosion allowance	ca =	0						

Clamp Input data

Bc =	215.9	mm	La =	23.09	mm	Ct =	34.925	mm
Cw =	88.9		Lh =	50.8		SA clamp =	155.132	MPa
Ci =	298.45		Ic =	15.24		SO clamp =	133.069	MPa

Bolt and Gasket Data

Bolt Dia. Bd =	25.4	mm	Gasket OD =	260.35	mm
Bolt Area Ab =	354.838	mm ²	Gasket ID =	234.95	
Bolts per lug =	2		Gasket 'y' =	124.1055	MPa
SA bolt =	172.368	MPa	Gasket 'm' =	5.5	
SO bolt =	124.105	MPa	thk. tg =	5.08	mm

Load Data

Internal Pressure P =	96.526	bar G	Bending moment Mb =	0	kN.m
			Axial force Fa =	0	kN

Info: Include equiv. press. in all bolt and stress calcs. (See Help File) ☐
Denotes value in cell derived from other data

Design Loads: ☒ Pressure only ☐ Combined

Execute ? [File Icon] [Folder Icon] [Calculator Icon] Clear

Dependent upon the selection of dimensions source, some input data fields will be derived, and consequently not accessible.

A help file is available which describes some geometrical limitations imposed and accesses the flange program help file to obtain data such as bolt areas for use in this program.

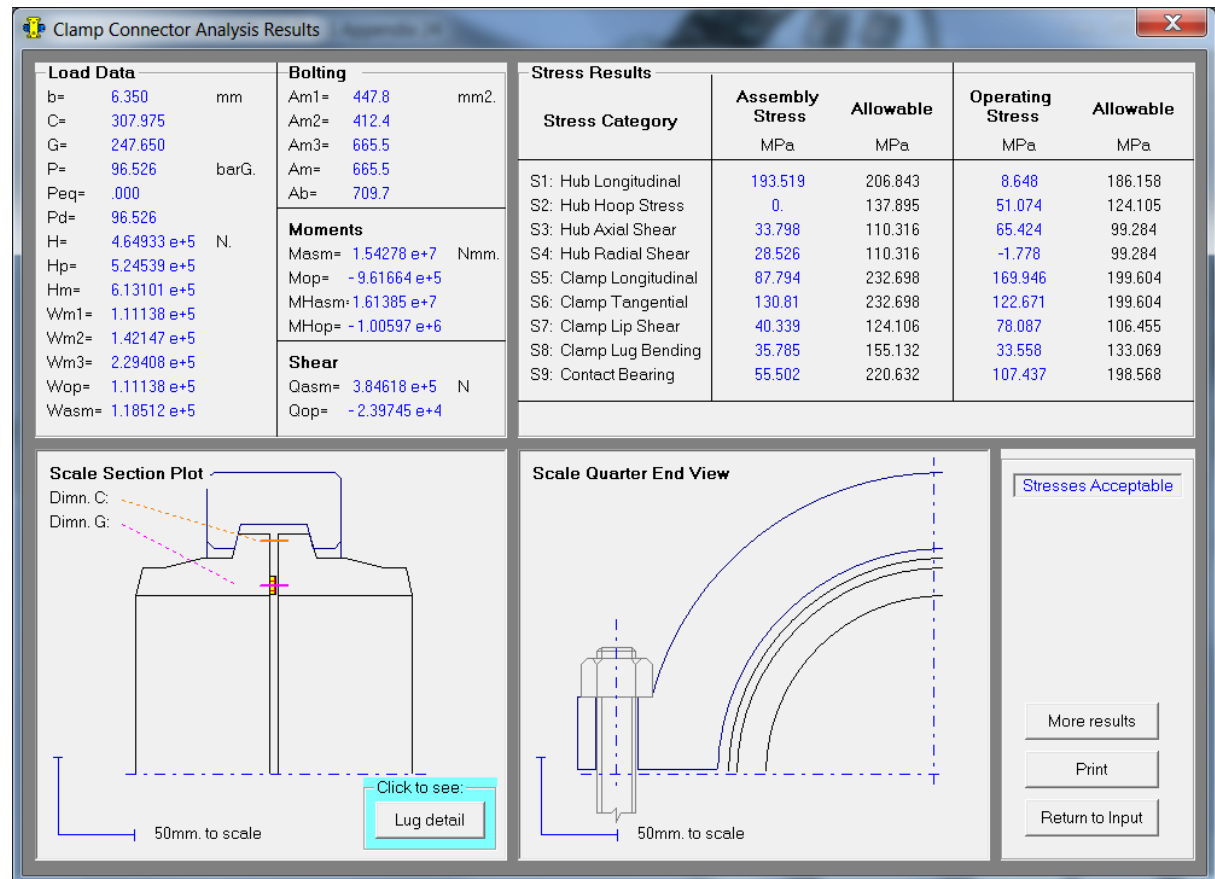
Similar to the calculation method employed for flanges, the user may choose whether or not external loads, converted to an equivalent pressure, are included or excluded from assembly stresses. The default is that these loads are excluded from assembly stresses and incorporated only in functional stress calculations.

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Prior to running the calculation, error checking will be carried out to ensure that the data set is both complete and feasible. An error message and the input will be returned if a fatal error is detected.

4.2 Clamp Connector Output

Typical Clamp Connector Output Screen



In addition to the views above, a scale section plot and additional calculated data may be viewed. Bolt spacing may be varied within allowable limits. The scale plots enable the design to be visualised and a better finished product obtained.

All loads and moment arms used in stress calculations are displayed in the output and 'more results' screen.

5.0 EXPANSION LOOP STRESSES, LOADS AND DISPLACEMENTS

Four different geometries are available, three requiring similar input data, and representing typical pipe loop arrangements found in pipe racks. The fourth is a simple three leg offset which may be loaded with thermal and end displacement conditions.

This program utilises a stiffness matrix solution and results will normally compare very closely to those from commercial pipe stress software.

Standard pipe sizes may be accessed from Pipemill's data base, and thermal expansion characteristics may similarly be quickly obtained.

Allowable stresses will be computed in accordance with ASME B31.3.

The solution assumes that pipe between loop region and anchors is properly guided, and in the close guide, rotation is negligible.

5.1 Typical Rack Type Expansion Loop Input

Pipe Loop Stresses and Loads

Project / Description: f:\V-4 Examples\V-4 LOOP type 1 .plp

Calculation Details

Units

- ☒ Metric
- ☐ English

Geometry

- ☒ 6 Ell. Loop
- ☐ 45 set-over loop
- ☐ Flat Loop
- ☐ Z-Offset

Input Data

Outside Dia. 457.2 mm Std. Pipe Size

Wall thk. 9.525 mm

Young's mod. 200000 MPa

Poisson's ratio 0.3

Allow. Stress, Cold 138 MPa

Allow. Stress, Hot 137 MPa f = 1.0

Base temp. 10 deg. C

Oper. Temp. 250 deg. C

Material Carbon Steel

Expansion 2.995e-3 mm/mm

Suppt Friction .3 Coeff.

Weights

	Mass kg/m3	Thk. mm
Pipe	7850	9.525
Fluid	1000	
Insulation	150	50
Cladding	8000	.8

Diagram

Symmetrical Loop

Assumed regularly guided between points 1 and 2

Close guide

Anchor A

Anchor B

Dimensions

a (1 to 2)	110	m
b (2 to 3)	5	m
c (3 to 4)	2	m
d (4 to 5)	8	m
e (5 to 6)	4	m
Bend radius	610	mm

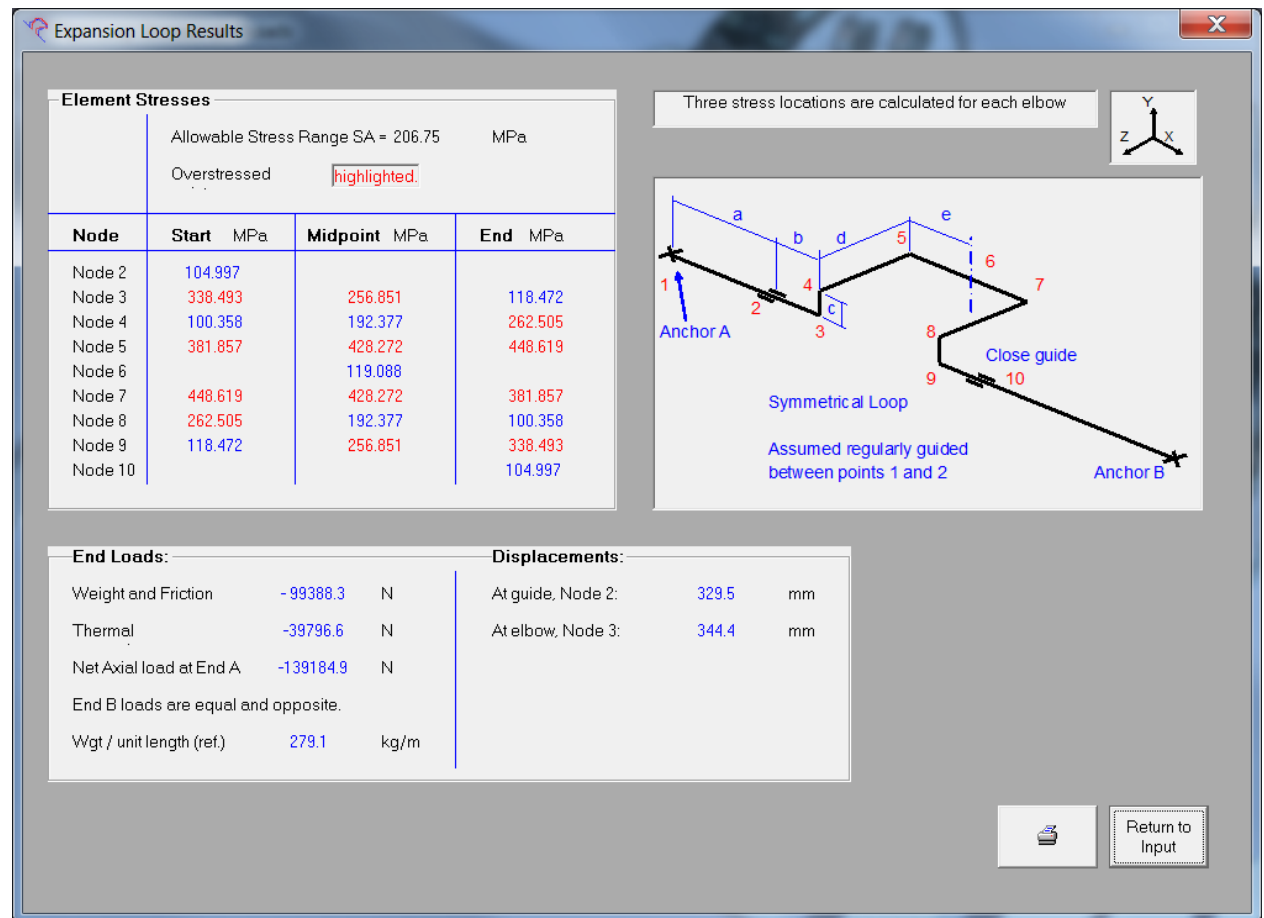
Execute [Calculator] [Help] [Save] [Delete] Clear

5.2 Typical Rack Type Expansion Loop Output

Calculated stresses through the system will be shown, and highlighted if excessive.

End loads due to thermal expansion, weight induced friction and combined effects will be presented.

Thermal expansion at the close guide and first elbow will be provided, to allow a check of pipe support suitability and clearance.



The user can thus find the optimum dimensions for pipe expansion loops, without recourse to expensive commercial stress analysis software, and with much greater accuracy than chart form solutions and the like.

Pipemill Engineering Software

User Guide, Version 4.00

5.3 Thermal Offset Design

Material properties and end displacements (which may be zero) must be defined.

Pipe Loop Stresses and Loads

Units: ☒ Metric ☐ English

Geometry: ☐ 6 Ell. Loop ☐ 45 set-over loop ☐ Flat Loop ☒ Z-Offset

Project / Description:

Calculation Details:

Input Data

Outside Dia. mm Std. Pipe Size

Wall thk. mm

Young's mod. MPa

Poisson's ratio

Allow. Stress, Cold MPa

Allow. Stress, Hot MPa $f =$

Base temp. deg. C

Oper. Temp deg. C

Material

Expansion mm/mm

Suppt Friction Coeff.

End Displacements

	dX	dY	dZ	mm
Anchor A	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	
Anchor B	<input type="text" value="5"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	

Dimensions

a (1 to 2) m

b (2 to 3) m

c (3 to 4) m

Bend radius mm

5.4 Typical Thermal Offset Design Output

End forces and moments will be calculated. Stresses in accordance with ASM B31.3 will be provided, and highlighted if excessive.

Expansion Loop Results

Three stress locations are calculated for each elbow

Element Stresses

Allowable Stress Range SA = 206.838 MPa

Overstressed

Node	Start MPa	Midpoint MPa	End MPa
Node 1	25.289		
Node 2	82.210	80.745	76.363
Node 3	79.878	84.259	85.725
Node 4			29.415

Imposed Displacements

	dX	dY	dZ	mm
End A	0	0	0	
End B	5	0	0	

End Forces and Moments

	Fx	Fy	Fz	Mx	My	Mz
	N	N	N	Nm	Nm	Nm
End A	1479.0	.0	-137.0	.0	-1526.6	.0
End B	-1479.0	.0	137.0	.0	1775.7	.0

6.0 PIPE SPANS AND SLOPING LINE CALCULATIONS

6.1 Span Chart

Relevant data cells must be completed, and 'Create Span Chart' selected.

End conditions must be defined, using data in the 'Help' file.

The range of pipe sizes for which spans are needed must be defined. The option of selecting Standard pipe sizes and wall thickness is available. This will automatically load all pipe sizes from 0.5" nb to 30" using STD wall. All entries may be changed if required.

Since this is not a facility normally required on-screen, the printed output will be sent directly to your printer, which must of course be on-line.

Typical Span Chart input file

Pipe Span Calculation

Select units
☒ Metric (SI)
☐ English

Select action

End Conditions
See Help
☐ Simply supported
☒ Kellogg Section 8
☐ Fixed ends

Common Properties

Pipe Spec. Name:

Pipe description:

Pipe Density: kg/m³

Corrosion Allw.: mm

Tolerance: %

Allowable Stress Sh: MPa

Young's Modulus Eh: MPa

Fluid Density: kg/m³

Insulation Type:

Insulation Density: kg/m³

Insulation Thickness: mm

Cladding Type:

Cladding Density: kg/m³

Cladding Thickness: mm

Suppt. Contact Length: mm

Suppt. Contact Width: mm

Max Mid-span Defl.: mm

Project / Description:

Calculation Details:

Span Chart Pipe Sizes

Nom. Pipe in.	Pipe OD mm	Pipe WT mm	Nom. Pipe in.	Pipe OD mm	Pipe WT mm
0.5	21.336	4.775	12	323.85	9.525
0.75	26.67	5.563	14	355.6	9.525
1.0	33.401	4.547	16	406.4	9.525
1.5	48.26	5.080	18	457.2	9.525
2	60.325	3.912	20	508	9.525
3	88.9	5.486	22	558.8	9.525
4	114.3	6.020	24	609.6	9.525
6	168.275	7.112	26	660.4	9.525
8	219.075	8.179	28	711.2	9.525
10	273.05	9.271	30	762	9.525

Load NOMINAL pipe sizes and COMMON walls: (See Help)

6.2 Span for a Pocket Free Sloping Line

The intent of this program is to derive the maximum span for a pipe, whilst allowing free draining when sloping at some defined fall rate. This is important in two phase flow and similar systems, to avoid build-up of liquid slugs and consequent impact loads.

Similar input data to above is required.

Maximum allowable span for one pipe size will be calculated based on two criteria.

The calculations are based on two end conditions, either fully fixed or pinned with no moment restraint. Significant differences will be seen in results. The user must decide which condition is the more appropriate.

6.2.1. The slope required to allow the maximum allowed span will be calculated

Pipe Span Calculation

Select units
☒ Metric (SI)
☐ English

Select action

End Conditions
[See Help](#)
☒ Simply supported
☐ Kellogg Section 8
☐ Fixed ends

Sloping Line
☒ Find required slope for calc'd spans
☐ Find maximum span for user defined slope

Common Properties

Pipe Spec. Name: 1C5A

Pipe description: A106 Gr. B

Pipe Density: 7850 kg/m3

Corrosion Allw.: 1.5 mm

Tolerance: 12.5 %

Allowable Stress Sh.: 137.89 MPa

Young's Modulus Eh: 203390 MPa

Fluid Density: 1000 kg/m3

Insulation Type: Rockwool

Insulation Density: 140 kg/m3

Insulation Thickness: 50 mm

Cladding Type: St. Stl.

Cladding Density: 8000 kg/m3

Cladding Thickness: 0.8 mm

Suppt. Contact Length: 300 mm

Suppt. Contact Width: 10 mm

Max Mid-span Defl.: 12.5 mm

Project / Description: f:\V-4 Examples\V-4 SLOPE CALC 01.spn

Pocket Free Sloping Line

Pipe Outside Diameter: 219.075 mm

Wall Thickness: 8.179 mm

Required Slope for Max Allowed Spans:

Required Slope Data:	Simply Supported	Fixed Ends
Max Span	Slope	Slope
	m	m
Pipe Only:	10.027 0.399	13.984 0.209
Pipe + Insulation:	9.408 0.425	12.311 0.184

6.2.2. The maximum allowable span may be found for a defined slope

Pipe Span Calculation

Select units
☒ Metric (SI)
☐ English

Select action

End Conditions
☐ See Help
☐ Simply supported
☐ Kellogg Section 8
☐ Fixed ends

Sloping Line
☐ Find required slope for calc'd spans
☒ Find maximum span for user defined slope

Common Properties

Pipe Spec. Name:

Pipe description:

Pipe Density: kg/m³

Corrosion Allw.: mm

Tolerance: %

Allowable Stress Sh: MPa

Young's Modulus Eh: MPa

Fluid Density: kg/m³

Insulation Type:

Insulation Density: kg/m³

Insulation Thickness: mm

Cladding Type:

Cladding Density: kg/m³

Cladding Thickness: mm

Project / Description:

Calculation Details:

Pocket Free Sloping Line

Pipe Outside Diameter: mm

Wall Thickness: mm

User Specified Slope: m per 100m

Maximum Span for Defined slope:

Minimum wall thk. mm

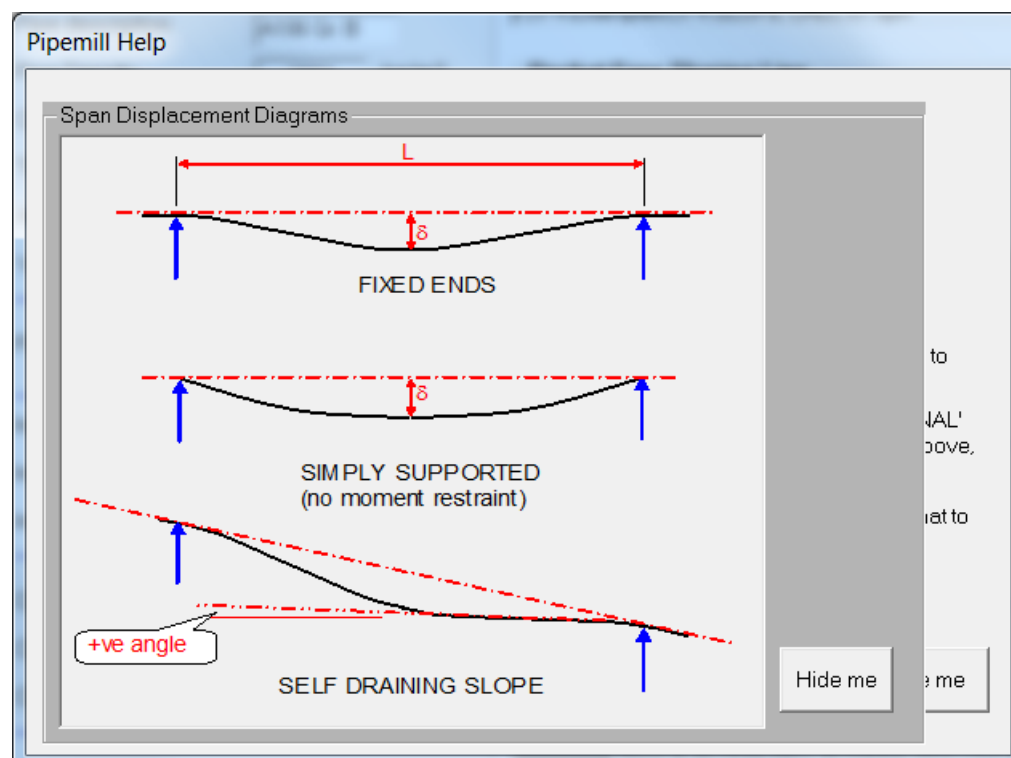
Pipe Only Weight kg/m

Insulation Weight kg/m

Maximum Span Data:	Simply Supported	Fixed Ends
	Max Span m	Max Span m
Pipe Only:	<input type="text" value="9.859"/>	<input type="text" value="17.050"/>
Pipe + Insulation:	<input type="text" value="9.056"/>	<input type="text" value="15.661"/>

SLOPE SPANS MAY EXCEED MAX NORMAL SPAN !

The Help file allows access to diagrams to assist in defining slope and end conditions.



7.0 PSV and RUPTURE DISC FORCE CALCULATION

Force calculations for the initial or 'pop' condition and under sustained flow may be carried out for gas and vapour PSV's (pressure safety valves), discharging into a closed header or directly to atmosphere. Forces present in a liquid relief valve and a rupture disc may be calculated, similarly for the initial and sustained conditions.

A data base of standard relief valve orifice sizes may be accessed in addition to the standard pipe data base which may be used to select outlet pipe size in an open discharge gas or closed discharge liquid PSV.

7.1 Gas / Vapour PSV

Gas and vapour PSV reactions are calculated in accordance with API RP 520 pt. II methods.

All equations used are presented, either on the input / output screen as shown below, or in the help file which follows.

7.1.1 Typical Input Screen and Output Results, Open Gas / Vapour PSV.

PSV and Rupture Disc Force Calculation

Calculation Basis

- ☒ Gas or vapour, with open pipe
- ☐ Gas or vapour, closed system
- ☐ Liquid, to closed system
- ☐ Rupture disc, gas or vapour

Based on API RP 520

Units

- ☒ Metric (SI)
- ☐ English

Orifice

- ☒ Standard Size
- ☐ User Defined

Standard Orifice Size

Label (in.2) (mm2)

Outlet Pipe

Outlet Pipe Outside diameter Do: 609.6 mm.

Outlet Pipe Wall Thickness t: 36.53 mm.

Input Data

Relief Temperature T: 55 deg.C

Set Pressure P: 250 bar G

Downstream Pressure Pd: 1 bar G

Required Mass Flow Rate W: 20000 kg/hr.

Molecular Weight M: 19

Ratio of Specific Heats kc=Cp/Cv: 1.3

Required Orifice Area Ar: 950 mm2.

Actual orifice Area Aa: 324.5 mm2. Orifice G

Dynamic Amplification Factor daf: 2

Project / Description:

PSV Tag No.: Rev.

PSV Data Sht. No.: Rev.

Stress Isometric No.: Rev.

Calculated Results

'POP' CONDITION

ESTABLISHED FLOW

Calculated Results

$$F1 := 0.0359 \cdot W \cdot \frac{Aa}{Ar} \left[\frac{kc \cdot (T + 273.15)}{(kc + 1) \cdot M} \right]^{10.5}$$

F1 = 766.27 N.

$$F2 := \frac{\left(\frac{W \cdot Aa}{3600 \cdot Ar} \right)^2 \cdot 98 \cdot R \cdot (T + 273.15)}{g \cdot (P + 1) \cdot Aa}$$






F2 = 63.42 N.

F3 := Pd · Ad F3 = 22609.66 N.

F4 := daf · F1 F4 = 1532.54 N.

F5 := daf · F2 F5 = 126.84 N.

F1+F3 = 23375.93 N.

Execute      **Clear**

t:\V-4 Examples\V-4 PSV GAS OPEN-02.psv

7.1.2 PSV Help File

PSV HELP FILE

In the case of gas flow close to sonic speed, the API 520 equations do not give reliable results. This situation is checked by Pipemill and if flow in the orifice area exceeds sonic a warning is issued. The forces calculated based on maximum possible gas flow should then be used.

Equations used to check and derive sonic force conditions:

Velocity at given conditions: $v := \frac{\left(\frac{W}{3600} \cdot \frac{A_a}{\rho \cdot A_a \cdot 10^{-6}} \right)}{\left(\frac{W}{3600} \cdot \frac{A_a}{\rho \cdot A_a \cdot 10^{-6}} \right)}$

Sonic velocity for gas: $V_s := \sqrt{\frac{(k_c \cdot P_{cr} \cdot 10^5)}{\rho}}$

Critical pressure: $P_{cr} := (P + 1) \left(\frac{2}{k_c + 1} \right)^{\left(\frac{k_c}{k_c - 1} \right)}$

Density at critical pressure: $\rho := \frac{(P_{cr} \cdot 10^5)}{R \cdot (T + 273.15)}$

Force based on maximum possible gas velocity v: $F := P_{cr} \cdot A_a \cdot k_c \cdot 10^5$

Other equations not shown on main screen:

Gas constant R is (Metric) $R := \frac{8314}{M}$ or (English) $R := \frac{1544}{M}$

Area of outlet pipe is $A_d := \left(\frac{\pi}{4} \right) (D_o - 2t)^2$

OK

7.2 High Gas Velocity PSV's

As gas flow approaches and exceeds sonic (Mach) velocity, the API equations will tend to predict higher forces than would exist if flow were limited to Mach speed.

The software will calculate the gas velocity in the valve orifice and compare it with the sonic velocity. If the flow exceeds sonic according to the API equations, and consequently forces may be over-estimated, the user has the option of accepting API results or re-calculating forces based on critical flow regime in the orifice.

7.2.1 Typical Output Showing Additional Calculation at Mach Speed

PSV and Rupture Disc Force Calculation

Calculation Basis

- ☒ Gas or vapour, with open pipe
- ☐ Gas or vapour, closed system
- ☐ Liquid, to closed system
- ☐ Rupture disc, gas or vapour

Based on API RP 520

Units

- ☒ Metric (SI)
- ☐ English

Orifice

- ☒ Standard Size
- ☐ User Defined

Standard Orifice Size

Label (in.2) (mm2)

K 1.838 1186.0

Outlet Pipe

Outlet Pipe Outside diameter Do: 457.2 mm. Std. Pipe

Outlet Pipe Wall Thickness t: 6.35 mm. Cancel

Input Data

Relief Temperature T: 230 deg.C

Set Pressure P: 55 bar G

Downstream Pressure Pd: 1 bar G

Required Mass Flow Rate W: 50000 kg/hr.

Molecular Weight M: 19

Ratio of Specific Heats $kc=Cp/Cv$: 1.3

Required Orifice Area Ar: 1120 mm2.

Actual orifice Area Aa: 1186 mm2. Orifice K

Dynamic Amplification Factor da_f : 2

Calculated Results

$F1 := 0.0359 \cdot W \cdot \frac{Aa}{Ar} \left[\frac{kc \cdot (T + 273.15)}{(kc + 1) \cdot M} \right]^{0.5}$ $F1 = 7353.78$ N.

$F2 := \frac{\left(\frac{W \cdot Aa}{3600 \cdot Ar} \right)^2 \cdot 98 \cdot R \cdot (T + 273.15)}{g \cdot (P + 1) \cdot Aa}$ $F2 = 7163.19$ N.

$F1 + F3 = 22871.7$ N.

Warning !!

These API loads result from a theoretical velocity which exceeds Mach speed.

Click here to re-calculate force due to limit velocity of Mach speed in orifice.

Mach Hide

Execute Print Calculator File Explorer Help Clear

If the user chooses to accept the directly calculated API forces rather than forces based on Mach speed, a note will be added to the printed output to this effect.

The principles above apply equally to open and closed outlet PSV's

7.3 Liquid Relief Valve

Forces generated by Liquid relief valves are not addressed in API 520, and tend to be smaller than gas discharge forces. Equations used in the program are based on change of momentum.

As the screen copy below shows, only the change of state as the valve initially operates causes an external reaction. Equilibrium is rapidly reached and no further external loads exist.

7.3.1 Typical Input Screen and Output Results, Liquid PSV.

PSV and Rupture Disc Force Calculation

Calculation Basis

- ☐ Gas or vapour, with open pipe
- ☐ Gas or vapour, closed system
- ☒ Liquid, to closed system
- ☐ Rupture disc, gas or vapour

Calc. based on Mass Momentum theory

Units

- ☒ Metric (SI)
- ☐ English

Orifice

- ☒ Standard Size
- ☐ User Defined

Standard Orifice Size

Label	(in.2)	(mm2)
K	1.838	1186.0

Inlet Pipe

Inlet Pipe Outside diameter Do: 168.28 mm.

Inlet Pipe Wall Thickness t: 7.11 mm.

Input Data

Liquid Density: Rho: 850 kg/m3

Set Pressure P: 45 bar G

Downstream Pressure Pd: 2 bar G

Required Volume Flow Rate: Qr: 0.07 m3/sec

Required Orifice Area Ar: 5500 mm2.

Actual orifice Area Aa: 7129 mm2. Orifice Q

Dynamic Amplification Factor daf: 2

Project / Description:

PSV Tag No.: Rev.

PSV Data Sht. No.: Rev.

Stress Isometric No.: Rev.

Diagram

Calculated Results

$$F1 := \sqrt{2} \cdot Qa \cdot Rho \cdot \left[\frac{(P - Pd) \cdot 10^5}{Rho} + \frac{Qa^2}{2 \cdot Ap^2} \right]^{0.5} \quad F1 = 7766.59 \quad N.$$

$$Qa := Qr \cdot \frac{Aa}{Ar} \quad F4 := daf \cdot F1 \quad F4 = 15533.19 \quad N.$$

$$Ap := \left(\frac{\pi}{4} \right) \cdot (Do - 2t)^2 \cdot 10^{-6}$$

Execute

f:\V-4 Examples\V-4 PSV LIQ CLOSED-03.psv

7.4 Rupture Disc

Rupture discs are normally used for gas and vapour. The calculation method used is simple, and originates in a paper from 'Hydrocarbon Processing'.

Once again a force will only be developed whilst there is a change of state existing. A sustained flow through failed disc will not cause any external force.

7.4.1 Typical Input Screen and Output Results, Rupture Disc

The screenshot shows the 'PSV and Rupture Disc Force Calculation' software window. The interface is divided into several sections:

- Calculation Basis:** Four radio buttons are present. The first three are 'Gas or vapour, with open pipe', 'Gas or vapour, closed system', and 'Liquid, to closed system'. The fourth, 'Rupture disc, gas or vapour', is selected.
- RUPTURE DISC:** A section header with no input fields.
- Units:** Two radio buttons: 'Metric (SI)' (selected) and 'English'.
- Validation:** A text box stating 'CALC DOES NOT REQUIRE INDEPENDENT VALIDATION.'
- Identification:** Three input fields for 'PSV Tag No.', 'PSV Data Sht. No.', and 'Stress Isometric No.', each followed by a 'Rev.' label.
- Diagram:** A schematic of a rupture disc installation in a pipe. A horizontal arrow labeled 'FORCE' points from the left towards the rupture disc. The vertical distance from the centerline to the top of the pipe is labeled 'CARRIER I.D.'.
- Input Data:** A section with four input fields: 'Carrier Inside Diameter CDi: 154 mm.', 'Set Pressure P: 20 bar G', 'Ratio of Specific Heats $kc=Cp/Cv$: 1.36', and 'Dynamic Amplification Factor def: 2'.
- Footer:** A file path 'f:\V-4 Examples\V-4 PSV RUPDISC-04.psv' and a row of buttons: 'Execute', a printer icon, a calculator icon, a folder icon, a question mark icon, and 'Clear'.

8.0 PREDICTION OF ACOUSTIC FATIGUE

8.1 General Features

The method proposed by Carruci and Meuller in ASME paper 82-WA/PVP-8 is applied to predict the risk of acoustic fatigue in pipework downstream of a pressure reducing valve.

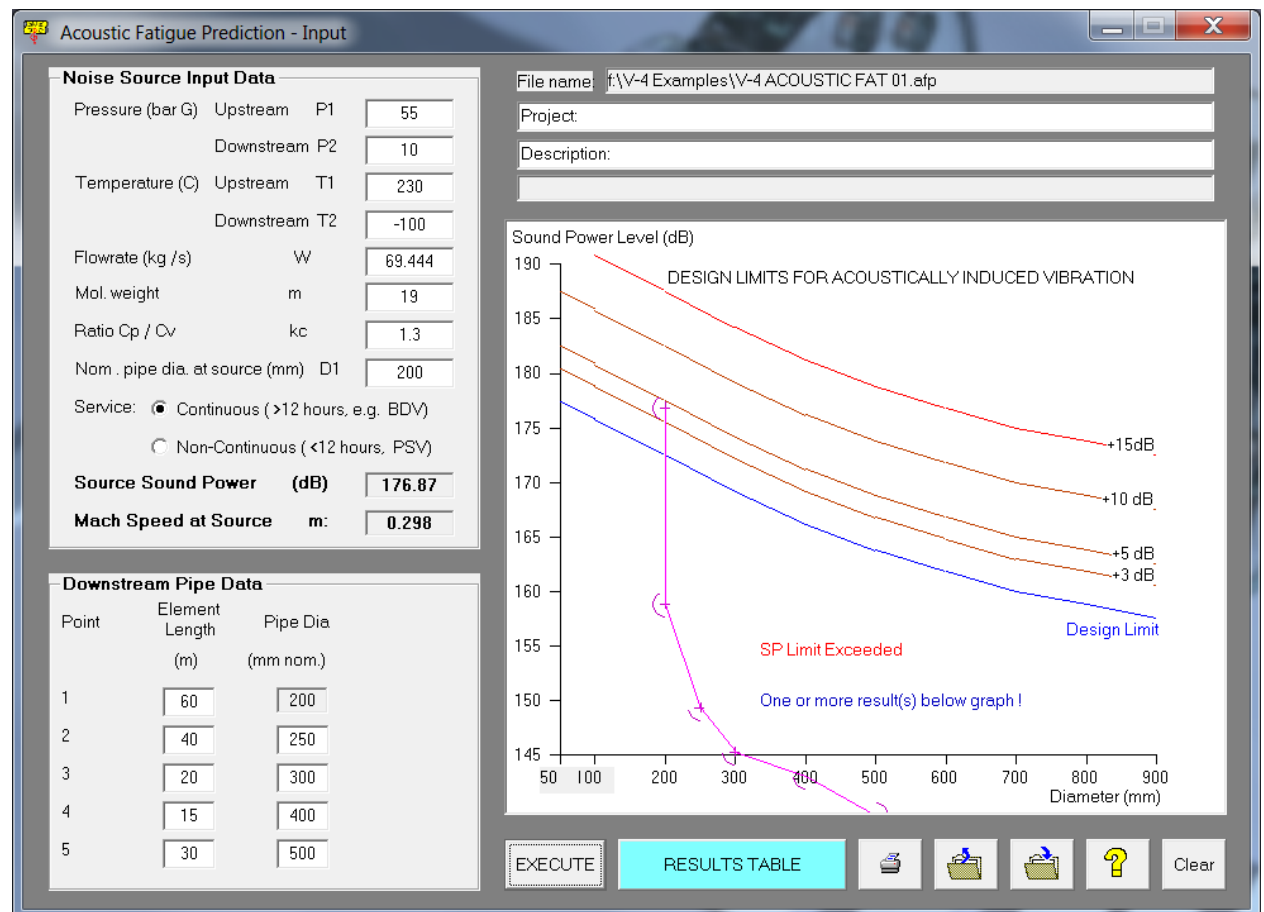
Up to five sections of pipe, generally of increasing diameter may be entered in the analysis.

Results will be displayed graphically and in table form for easy reference.

The results screen records calculated sound power level and predicted Mach speed. This is compared with acceptability criteria and modifications are recommended if required.

Recommendations regarding further action will be presented, depending upon the acceptability of results.

8.2 Typical input with output data overlaid on the graph



8.3 Typical acoustic fatigue output data

Acoustic Fatigue Recommendations

Pipe Section:	Sound Power Level (dB)	Db's over Design Limit	Recommended Action Code	Downstream Length Applied (m)	Velocity (m/s)	Mach No.	Velocity Limit (M/S)
Source	176.87	4.37	Action B	14.60	159.2	0.298	267.5
Source to Point 1	158.87	0.0	None	0.0	159.2	0.298	267.5
Point 1 to Point 2	149.27	0.0	None	0.0	101.9	0.191	267.5
Point 2 to Point 3	145.27	0.0	None	0.0	70.8	0.132	267.5
Point 3 to Point 4	143.02	0.0	None	0.0	39.8	0.074	267.5
Point 4 to Point 5	139.42	0.0	None	0.0	25.5	0.048	267.5

RECOMMENDED ACTION - SOUND POWER LEVEL

Modify, Action Code A to D:

Remove or brace all vents, drains etc.

Action Codes A, B and C: Minimum wall thickness recommended is 12.7mm (0.5")

Action Code D: Minimum wall thickness recommended is 19.1mm (0.75")

Apply at least to recommended downstream length.

RECOMMENDED ACTION - FLUID VELOCITY

Fluid velocities acceptable

Summary:

Sound power level EXCEEDED

Fluid velocity limits are complied with.

Return

8.4 Help screen

Acoustic Fatigue Help

This procedure is based on the work of Carruci and Mueller and relates to sound power generated by pressure reducing valves in piping service.

The procedure is relevant to continuous service such as blow-down valves and compressor recycle systems, and intermittent service such as PSV's.

The method was originally presented in an ASME paper no. 82-WA/PVP-8, and has been further refined by various oil producing companies based on experience.

The method is intended to be a guide only and not a definitive statement. It limits both sound power level and fluid velocity for gas service.

The basic equation for sound power level (metric units) is:

$$PWLO = 10 \cdot \log \left[\left(\frac{\Delta P}{P1} \right)^{3.6} \cdot W^2 \cdot \left(\frac{T1}{m} \right)^{1.2} \right] + 126.1$$

OK

9.0 DESIGN FOR EXTERNAL PRESSURE AND VACUUM

9.1 Description

Pipes and cylinders may be evaluated for their resistance to collapse under external pressure, and reinforcement may be designed to prevent collapse. Evaluation is in accordance with ASME VIII Div. 1.

Certain paragraphs of the design code allow use of nominal wall where clearly the actual minimum should be considered. **PIPEMILL always uses the minimum wall thickness.**

9.2 Materials Data

In most cases there will be no need to read or interpret material data curves in ASME II, referenced in ASME VIII. The three most commonly used curves are pre-programmed and available via a mouse click:

CS-2	Carbon steel with a minimum yield strength of 30 ksi
HA-1	Austenitic stainless steel, low chrome
HA-2	Austenitic stainless steel, high chrome

Alternatively, user defined material data may be entered.

If shell parameters entered result in (length / diameter) $L / D_o > 50$ a limit of 50 will be imposed in the calculation.

The shell may be un-stiffened, stiffened with standard section material or with a user defined section. Heavy wall shells with $D / t < 10$ may also be evaluated.

In analysis of a stiffened section, the pipe wall may be included or excluded from the calculation by selecting the desired option from the Stiffener Type panel.

There are many help files associated with this program, accessed from the relevant data input panel.

9.3 Typical External Pressure / Vacuum Input and Output

External Pressure / Vacuum

ASME VIII Div. 1 UG-28 and UG-29

Project / Description: _____

Calculation Details: _____

f:\V-4 Examples\V-4 EXT-PRES-03.exp

Select Units:
☐ English
☐ Custom
☒ SI (Metric)

Stiffener Type:
☐ None
☐ Standard
☒ User

Select Chart:
☒ Chart CS-2
☐ Chart HA-1
☐ Chart HA-2

Input Data

Outside Diameter	Do:	2500	mm.
Wall Thickness	t:	7.9375	mm.
Corrosion Allow.	ca:	1.5	mm.
Tolerance	tol:	1.3	mm.
Element Length	L:	990.6	mm.
Young's Mod. (hot)	E:	171679.18	MPa
Temperature	T:	371	deg. C.

Material Data Source: ☒ Use System Data
☐ User Defined A & B

External Pressure P.ex: 1.0342 bar
 (P.ex is entered only when reinforced)

User Designed Stiffener

Dim. x4	50.8	mm.	Dim. y4	6.35	mm.
Dim. x3	9.53	mm.	Dim. y3	60	mm.
Dim. x2	50.8	mm.	Dim. y2	6.35	mm.

Help

User Defined Section - Scale Plot

50mm. to scale

Intermediate Data:

Stiffener component: S

Factor A Interpolation: A

Factor B Interpolation: B

Output Data

Ratio Do/t	486.62
Ratio L/Do	.3962
Factor A	.3666e-3
Factor B	4417.95

Moment of Inertia: (mm.⁴)

Available	Required
1.521e+6	1.326e+6

Pipe wall stiffness INCLUDED.

Calculate Required Moment of Inertia in Wall and Stiffener

Factors A and B from charts.

9.4 Non-stiffened Shell

If a non-stiffened shell is analysed, a maximum allowable external pressure will be calculated. If the resulting value is close to or below atmospheric pressure, a warning will be issued.

9.5 Heavy Wall Shell

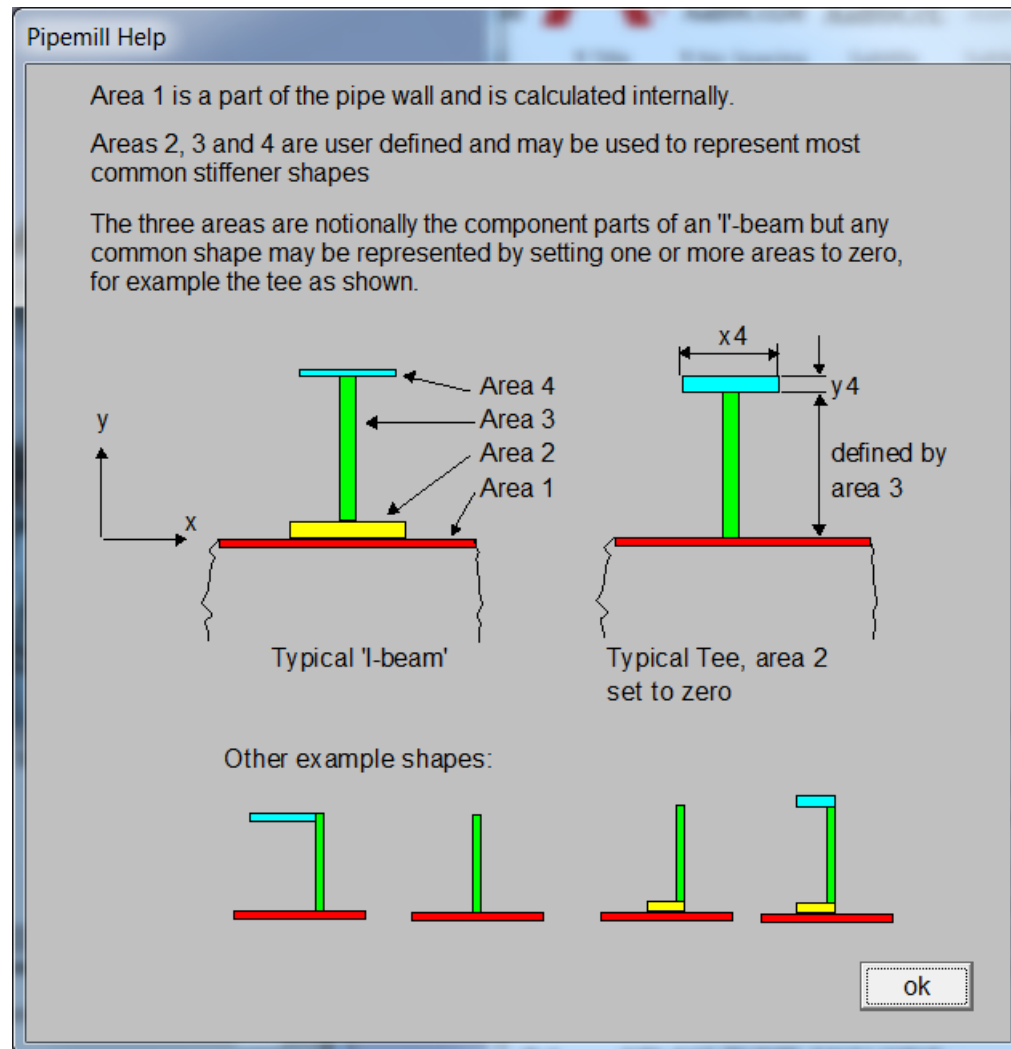
If the (diameter / wall thickness) D / t ratio is less than 10, special heavy wall rules are invoked. Reinforcement is excluded and the yield stress is required.

9.6 Standard Section Stiffener

To carry out a calculation for a shell stiffened with a standard section, in addition to the shell data, only the stiffener properties, moment of inertia, area, neutral axis distance and section width at the shell wall are required. The moment of inertia available in the combined defined section will be calculated and compared to that required to resist collapse. Unacceptable results will be clearly identified.

9.7 User Defined Section

A user defined section may be defined, consisting of three component parts in addition to the shell itself. The relevant help file clearly defines the areas used to build up a section, as shown below.



If for example, a section comprises only two components, only areas 2 and 3 would be defined and area 4 dimensions set to zero.

Operation of the program with user defined stiffeners is practically the same as with a standard section stiffener. A scale plot of the stiffener section will be presented, to aid in selection of a realistic shape.

The program does not currently consider radial buckling of a stiffener, or external loads caused for instance, by integration of a stiffener with a pipe support.

10.0 ROTATING EQUIPMENT NOZZLE LOADS ANALYSIS

Acceptability of nozzle loads applied by piping to various types of pump and compressor may be analysed with this program. The following codes are covered:

API 610	Centrifugal Pumps
API 611	Refinery Steam Turbines
API 617	Centrifugal Gas Compressors
NEMA SM-23	Steam Turbines

10.1 API 610 PUMP ANALYSIS

Typical API 610 Input Screen

Rotating Equipment Nozzle Loads

API 610 (11th EDITION)

Units
☐ Metric (SI)
☐ English

Loads and Vectors are entered using:
☒ Global Axis System
☐ Local Axis System

Shaft axis and nozzle direction must be defined before vector and load entries are allowed.

Select Pump Type
☒ Front Suction, Top Discharge
☐ Side Suction, Side Discharge
☐ Top Suction, Top Discharge
☐ Vertical In-line, Fixed Base
☐ Vertical In-line, Support by Pipe

Diagram shows local axis system in accord with API 610

Orientate the pump in the Global Axis System:
 Shaft Axis is: ☒ In 'X' plane
☐ In 'Z' plane

Vector FROM suction nozzle TO pump centre:
☐ +X
☒ -X

Stress Calc.	Data Point	NB (in.)	Vector X mm.	Vector Y mm.	Vector Z mm.	Force X N.	Force Y N.	Force Z N.	Moment X Nm.	Moment Y Nm.	Moment Z Nm.
Suction Nozzle			-267	0	0	12900	-8852	0	-1356	-7458	4879
Suction 100 10			-267	0	0	12900	0	-8852	-1356	-4879	-7458
Discharge Nozzle				-381	-311	7117	8674	445	678	-4882	3390
Discharge 200 8			0	311	-381	7117	-445	8674	678	-3390	-4882

API Factor 'Fn'
 Applied to all limits (default =2) 2.00

f:\V-4 Examples\V-4 API 610 CALC F4.1.1.eqp

Execute [Icons] Clear

10.1.1 API 610 Input Data

Two axis systems are available, one using the API local axis system (Z upward) and one utilising the more common global axis system used in piping stress analysis (Y upward).

If the API (local) axis system is used, only the pump type needs to be defined, prior to load and nozzle dimensional data entry, and subsequent analysis. If the global axis system is applied, the shaft axis orientation and the cardinal vector from suction nozzle to pump centre must also be selected, as shown above. If the global axis system is used, all nozzle data is entered with respect to the global axis. The program will re-orientate each data item to the local axis system on the line below, as it is entered.

If the analysis concerns a vertical in-line pump, the axis system must be carefully applied to avoid confusion, since the 'Y' axis points into the suction nozzle and out of the discharge.

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The help file clearly defines action of the pump multiplier factor, Fn.

10.1.2 API 610 Output Data

Output is presented with respect to the various clauses in the code. Each calculated load combination is presented with its respective allowable value, and acceptability or failure will be highlighted.

10.2 API 611, API 617 and NEMA SM-23 Code Analysis

API 611 and API 617 are similar and both refer to NEMA SM-23. The analysis methods are identical with the exception of differing factors employed as dictated by the respective code.

For purposes of the User Guide, operation in accordance with the NEMA SM-23 code will be described.

10.2.1 Typical NEMA SM-23 Input Screen

Rotating Equipment Nozzle Loads

NEMA SM-23 (2002 Edition.)

Units: ☐ Metric (SI) ☐ English

NEMA Factor: Allowable loads x

No. of Nozzles: ☐ 2 - Nozzles ☐ 3 - Nozzles ☒ 4 - Nozzles

Orientation: ☒ Global Axis ☐ Shaft direction

Reference node no. for Balance Point: BP node:

Note: Direction vectors are entered FROM the nozzle face centre TO the balance point.

f:\V-4 Examples\V-4 NEMA SM-23 CALC 01.eqc

Stress Calc. / nozzle ID	Data Point	N.B. (in.)	Vector X mm.	Vector Y mm.	Vector Z mm.	Force X N.	Force Y N.	Force Z N.	Moment X Nm.	Moment Y Nm.	Moment Z Nm.
Nozzle 1											
suction 1	500	14	-600	400	0	-6000	5000	-1000	16000	-5000	4000
Nozzle 2											
discharge 1	600	10	-100	400	-400	1500	-1000	-500	3000	-2000	1000
Nozzle 3											
suction 2	700	12	600	400	0	-2000	1000	1500	-2500	1500	-1500
Nozzle 4											
discharge 2	800	8	100	-500	300	-1000	750	-1500	1500	-1250	1000

For two nozzle machines it is normal practice to resolve loads at the largest nozzle face, usually the exhaust in the case of a turbine. Three and four nozzle machine loads are usually resolved at a central point on the shaft. Location should be agreed with equipment supplier.

Execute Clear

10.2.2 NEMA SM-23 Input description

Up to four nozzles may be analysed. The location of the point around which all forces and moments are resolved should be agreed with the equipment supplier. Commonly when NEMA SM-23 is applied to a two nozzle compressor, the suction (larger) nozzle face and centre-line intercept is used, and the shaft centroid of a two stage, four nozzle machine. This is not mandatory however.

The shaft axis will default to the global X direction, but may be changed.

The dimension Dc (equivalent circular opening equal to all nozzles) is normally interpreted as being based on the nominal diameter, and this is applied by PIPEMILL. The user has the option prior to analysis, of entering a different Dc value if desired, as shown below.

NEMA SM-23 Input Screen – Definition of Dc

The screenshot shows a software window titled "NEMA SM-23 Output". Inside, a dialog box titled "Equivalent Nozzle Area" is displayed. The dialog box contains the following text: "The program calculates the equivalent circular opening Dc, based on nominal nozzle diameters, in common with normal interpretation of NEMA. If you wish to input a user figure representing a different equivalent area, do so at the cell below, otherwise leave blank." Below this text, there are two input fields. The first is labeled "Calculated equivalent area Dc =" and contains the value "13.48" followed by "in.2". The second is labeled "User entered value Dc =" and is currently blank, followed by "in.2". To the right of the second input field is a button labeled "Continue".

Leaving the 'User entered ...' cell blank and pressing 'Continue' applies the value of Dc as calculated by PIPEMILL.

10.2.3 NEMA SM-23 Output

Output data is organised with respect to the code paragraphs and sections. Acceptability or failure of each element will be clearly identified.

A summary of results will be provided, and if code limits have been exceeded a diagnostic chart may be accessed. The diagnostic chart allows the user to identify which load and direction vector(s) is responsible for the over-load condition, in order to solve the problem most effectively.

Screens plots of output data and diagnostic screens follow.

10.2.4 Typical NEMA SM-23 Output Screen

NEMA SM-23 Output

Each Individual Nozzle:

	Resultant Force N	Resultant Moment Nm	FR + (MR/3) (English Units)	Allowable Load (English Units)	
				De	Allowable
Nozzle 1	7874.	17233.7	6006.6	10.000	5000.
Nozzle 2	1870.8	3741.7	1340.4	8.667	4333.3
Nozzle 3	2692.6	3278.7	1411.3	9.333	4666.7
Nozzle 4	1952.6	2193.7	978.2	8.000	4000.

Individual nozzles: (SM-23 para 8.4.6.1) Limit = (500 / 3) . De . fn
fn = 3.000

Combined Resultants at Balance Point:

Resultant Force	Resultant Moment	Fc + (Mc/2) (English Units)	Allowable (English Units)
9568.8 N.	18992.3 Nm.	9154.3	5056.2
2151.3 lbf.	14006.1 lb.ft.		

Combined Resultants: Fc +(Mc /2) <= 125 . Dc . fn
(SM-23 para 8.4.6.2)

Over-load Diagnostics

Use this chart to determine the source of a moment over-load.
Each force-distance set and a moment summation is available.

Diagnostic

Directional Resultants at Balance Point:

	Resultant Force N	Allowable Force N	Resultant Moment Nm	Allowable Moment Nm
X dir.	-7500.	8996.1	17875.	13712.5
Y dir.	5750.	22490.2	-4450.	6856.3
Z dir.	-1500.	17992.1	4625.	6856.3

Directional Resultants: Fx <= 50.Dc.fn.fc Mx <= 250.Dc.fn.mc
(SM-23 para 8.4.6.2) Fy <= 125.Dc.fn.fc My <= 125.Dc.fn.mc
Fz <= 100.Dc.fn.fc Mz <= 125.Dc.fn.mc

Dc = 13.480 fc = 4.448 mc = 1.356

SUMMARY - LOADS ARE NOT ACCEPTABLE.

Individual nozzle(s) overloaded.

Directional resultants at balance point are excessive.

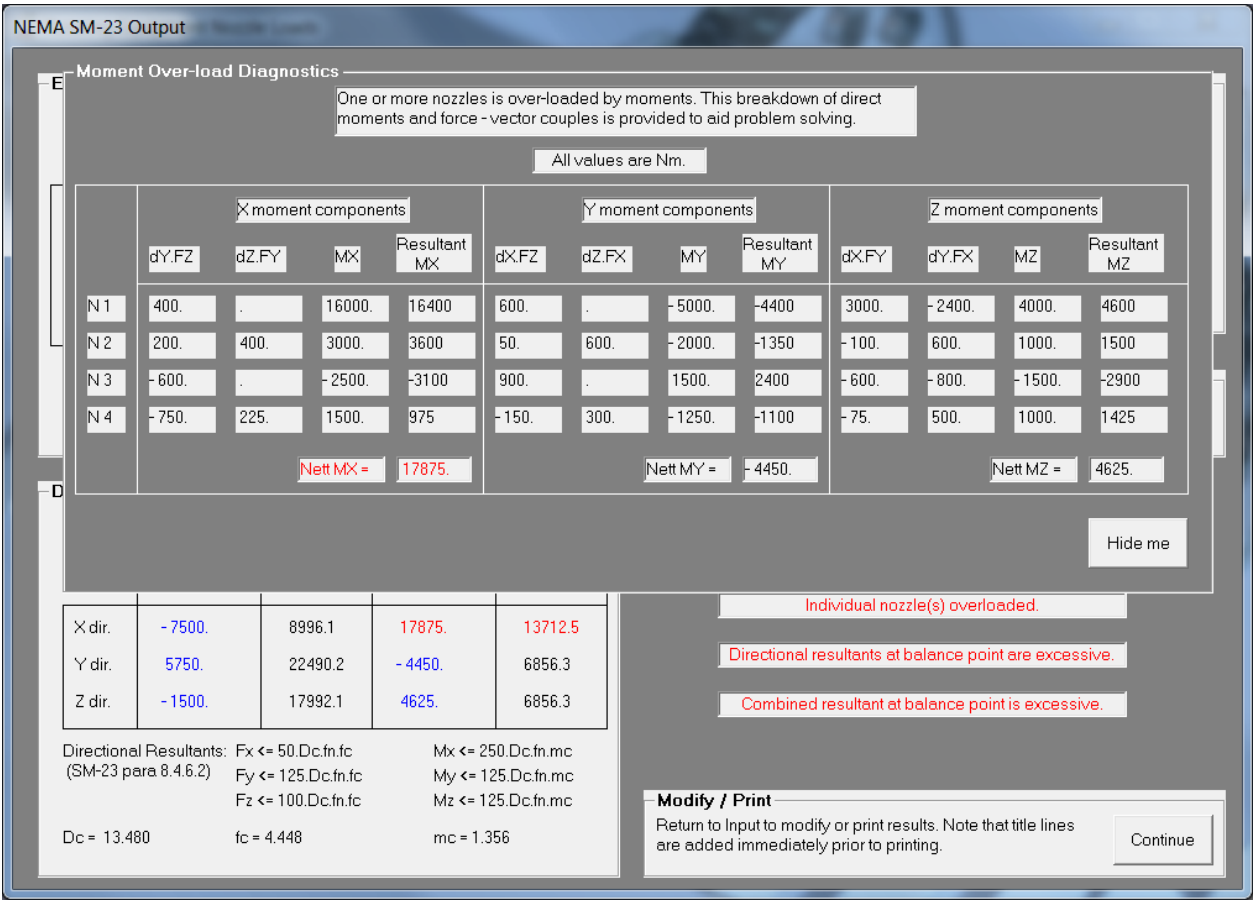
Combined resultant at balance point is excessive.

Modify / Print

Return to Input to modify or print results. Note that title lines are added immediately prior to printing.

Continue

10.2.5 Typical NEMA SM-23 Output Screen with diagnostic chart



10.3 Pump Nozzle Loads to ISO EN 5199

Nozzle loads for all configurations of pumps found in EN 5199 may be analysed.

The user will be warned if any data is outside the allowed range or exceeds and allowable load value.

10.3.1 Typical ISO EN 5199 Input and Results Screen

EN 5199 - PUMP NOZZLE LOADS

Units

☐ Metric only.

☒ Metric (SI)

Material

☐ Cast steel

☒ Cast Iron

Select Pump Type

Shaft Axis Horizontal

☒ Front Suction, Top Discharge

☐ Side Suction, Top Discharge

☐ Side Suction, Side Discharge

Shaft Axis Vertical

☐ Discharge Nozzle Only (Submerged suction)

☐ Suction and Discharge Nozzle

In-Line Pump

☐ Supported by Pipe

☐ Supported by Base Plate

Select Global or Local Axis

☒ Global Axis System

☐ Local (EN 5199) Axis System

Global Axis Orientation

Shaft Axis

☒ X-direction

☐ Z-direction

Global Axis

Validation calculation

f:\V-4 Examples\V-4 EN 5199 Option 1A.enp

Nozzle Limits

Pump type (ref. Table B1 and B2)

Size range: Min: Max:

Nozzle Data

	Data Point	Nozzle dia. (DN)
Suction	<input type="text" value="1"/>	<input type="text" value="100"/>
Discharge	<input type="text" value="3"/>	<input type="text" value="80"/>

Local axis loads:

Allowable loads:

Load Data

	fX N	fY N	fZ N	res.F N	mX Nm	mY Nm	mZ Nm	res.M Nm
Suction								
	700	800	900		1000	1100	1200	
Local axis loads:	700	900	800	1393.	1000	1200	1100	1910.
Allowable loads:	1108.	993.	893.	1737.	579.	414.	480.	860.
Discharge								
	550	650	750		850	950	1050	
Local axis loads:	550	750	650	1135.	850	1050	950	1652.
Allowable loads:	744.	678.	827.	1307.	529.	380.	430.	777.

Pump Body Data

Cold E Mod. MPa

Hot E Mod. MPa

Load Factor

INITIAL CHECK: SUCTION NOZZLE OVERLOADED

INITIAL CHECK: DISCHARGE NOZZLE OVERLOADED

INDIVIDUAL NOZZLE LOADS EXCEED para. B 4.4 (1.4 x ALLOW.)

11.0 PIPE SUPPORT STRESS ANALYSIS

Trunnion type and vertical riser (stack) type support structures may be analysed with the program. Section 11 deals with Trunnion design in accordance with the well-known 'Kellogg' method found in Kellogg, 'Design of Piping Systems'.

Note that a more comprehensive method of analysis for Trunnion type attachments to pipe and elbows may be found in section 12.

Trunnions in accordance with 'Kellogg' may be with or without a stiffener ring and on straight pipe or attached to an elbow.

Riser supports may include or exclude horizontal stiffener rings. Both calculation routines include the effects of external loads and internal pressure. Riser support analysis is based on Blodgett 'Design of Welded Structures'.

11.1 Trunnion Type Pipe Support Analysis

A standard pipe size for both the parent pipe and the trunnion may be selected from a database. Alternatively, user defined diameter and wall thickness may be entered. If specified, corrosion will always be deducted from the pipe wall thickness prior to calculation.

Mill tolerance may be included or excluded from the calculation by use of a check box.

As shown in the screen print below, the analysis assumes that reinforcement will be in the form of a ring, full welded on the inner and outer edges.

Since global axes are not used, the trunnion may be in any orientation. Direct load is axial in the trunnion and longitudinal in the plane of the parent pipe.

Two output panels are available, one providing local stresses at the pipe / trunnion juncture in accordance with the 'Kellogg' method and another giving global bending and shear stress in the trunnion. Local deflections are not calculated, however a significant global bending stress might suggest that trunnion and local pipe wall flexibility be considered, particularly if the trunnion is intended as a restraint local to equipment.

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11.1.1 Typical Trunnion Stress Analysis Input and Output Screen.

Pipe Support Stress Calculation

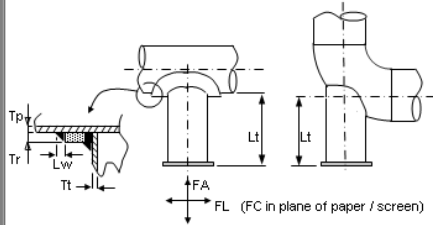
Units
☒ SI Units
☐ English Units

Calculation
☒ Trunnion stresses
☐ Stack Support
☒ Include Mill Tolerance

Pipe Properties:
Parent Pipe Outside dia. Dp: 323.85 mm
Wall thk. Tp: 9.525 mm
Corrosion Allowance: 1.5 mm
Mill Tolerance: 12.5 %
Design Pressure P: 24.8 bar G.
Hot allowable stress Sh: 117.0 MPa

Trunnion Data:
Trunnion: Outside dia. Dt: 219.075 mm
Wall thk. Tt: 8.1788 mm
Mill Tolerance: 12.5 %
Length Lt: 600 mm
Applied Loads: Longitudinal FL: 25306 N.
Circumferential FC: 6103 N.
Axial (direct) FA: 4516 N.
Reinforcing pad thk Tr: 9.525 mm.
Attachment weld length Lw: 6 mm.

TRUNNION DESIGN - GLOBAL AND LOCAL STRESSES



Local stress acceptable. Global stress acceptable.

Local Stresses
Dimensions: (mm.)
Pipe radius R = 161.93
Trunnion radius r = 109.54
Corr. pipe + pad thk. Tc = 16.36
Line loads: (N/mm.)
FFI = FL.Lt/(pi.r^2) FFI = 402.81
FFc = FC.Lt/(pi.r^2) FFc = 97.14
FFa = FA/(2.pi.r) FFa = 6.56
Pressure stress: (MPa.)
SCP = P.R/Tc SCP = 24.55
SLP = P.R/2.Tc SLP = 12.27

Local stress: (MPa.)
fac = (R^0.5) / (Tc^1.5)
SL = 1.17 FFI.fac SL = 90.63
SC = 2.34 FFc.fac SC = 43.72
SA = 1.75 FFa.fac SA = 2.21

Combined local stresses:
SL + SA + SLP = 105.12 MPa.
SC + SA + SCP = 70.47 MPa.

Allowable local stress: (1.5 Sh)
SAL = 175.5 MPa. **Global**

File Name: f:\V-4 Examples\V-4 SUPPORT TRUN 01 .spt

Execute

11.2 Riser (stack) Type Pipe Support Analysis

Input of data for the parent pipe is the same as used in trunnion analysis. The number of, and plate dimensions for the vertical plates must be defined, and parameters of any stiffening ring supplied. The calculation assumes that if any stiffening is defined, it will be in the form of two identical rings.

Local moments and consequently stresses will be evaluated and combined into a maximum shear stress. This will be compared to a notional limiting shear stress of 1/3 hot yield stress by the program. **The user is cautioned that some design codes specify differing limits for shear stress.**

11.2.2 Typical Riser (stack type) Support Stress Analysis Input and Output Screen.

Pipe Support Stress Calculation

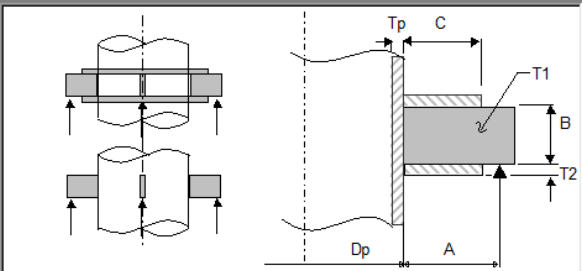
Units
☐ SI Units
☒ English Units

Calculation
☐ Trunnion stresses
☒ Stack Support
 ☒ Include Mill Tolerance

Pipe Properties:
 Parent Pipe Outside dia. Dp: 60 in.
 Wall thk. Tp: 0.5 in. Standard Pipe size
 Corrosion Allowance: 0.0125 in.
 Mill Tolerance: 12.5 %
 Design Pressure P: 25 psi. G.
 Hot YIELD stress Sy: 29000 psi.

Riser / Stack Support Data
 Number of support points: ☐ 2 ☐ 3 ☒ 4 ☐ 6 ☐ 8
 Dimn. pipe wall to support point A: 8.5 in.
 Height of vertical plate B: 4.0 in.
 Radial Width of ring C: 6.5 in.
 Thickness of Vertical Plate T1: 0.5 in.
 Thickness of each stiffener ring T2: 0.5 in.
 Net vertical load on all points Fv: 38000 lbf.
DESIGN INCLUDES RING STIFFENER PLATES

VERTICAL RISER / STACK SUPPORT - LOCAL STRESSES



Results





Stiff. ring / wall	ϵA in ²	ϵM in ³	ϵI_x in ⁴	ϵI_y in ⁴
Pipe wall:	1.7247 e+0	1.1577 e+1	7.771 e+1	2.596 e-2
Pipe ring:	3.25 e+0	1.0563 e+1	3.4328 e+1	1.1443 e+1
Sum values:	4.9747 e+0	2.2139 e+1		1.2351 e+2

Component stresses (psi)

	σ_{Cp}	σ_{Ct}	σ_{Cb}	Allowable
At hanger loc.	6.0747 e+2	2.029 e+3	1.4572 e+4	1.9333 e+4
At mid-point:	6.0747 e+2	2.869 e+3	-7.6074 e+3	1.9333 e+4

Max shear stress $0.5 (\sigma_{Cp} + \sigma_{Ct} + \sigma_{Cb}) = 8.6042 e+3$ psi
 Allowable shear stress = (1/3) Sy = 9.6667 e+3 psi
All calculated stresses are acceptable.

Code Check! Some Design Codes require differing allowable values.

Execute     Clear

File Name: f:\V-4 Examples\V-4 SUPPT-STACK 02 .spt

12.0 PIPE AND ELBOW TRUNNION STRESS ANALYSIS TO ASME III Section Y-5000

The method employed originated in ASME III Code Case N-392 (1994) and is embodied in ASME III Div. 1(2007) Appendices, Article Y-5000. The work is the conclusion of extensive finite element analysis of many straight pipe models employing a perpendicular trunnion type attachment.

The method was extended to cover a Trunnion attached to an elbow by EPRI under report TR-107453. This method applies to a maximum bend radius of 1.5D.

Pipemill deals with both straight pipe and elbow attachments. Two sets of input are available. The user may define all forces and moments that apply at the intersection, or only define forces at the end of the trunnion. In the latter case Pipemill will determine respective moments from imposed forces. This is considered the most relevant loading case to a typical piping application, since whilst trunnion supports often resist lateral forces, they rarely also fully restrain moments at the base.

There is no direct input for a reinforcing ring since it is not addressed in the base documents.

It is considered appropriate to include a reinforcing ring as an equivalent total wall thickness, provided the ring is of the accepted proportion of a net diameter close to the 2x the trunnion diameter.

12.1 Fully defined moment input

Trunnions to ASME III Y-5000, Case N-392-3 and TR-107453

Units
☐ English
☒ SI Units

Location
☒ Pipe
☐ Elbow

Weld Data
☒ Full Pen.
☐ Fillet

Moments
☐ Calc'd
☒ Define

Service Level
☒ Normal
☐ Upset
☐ Emergency
☐ Faulted

Project:
Calculation Details:
f:\V-4 Examples\V-4 N392 TRUN 01.ytr

Pipe / Elbow Properties
Outside Diameter PD: 355.6 mm. Standard Pipe Size
Nominal Wall tP: 9.525 mm.
Internal Corrosion ca: 0 mm.
Mill Tolerance MTP: 0 %
Design Pressure PR: 31.0264 barG
Max. Op. Pres. PRmax: 36.1975 barG
Cold Allw. Stress ScP: 137.895 MPa
Hot Allw. Stress ShP: 137.895 MPa
Yield Str. at Temp SyP: 241.316 MPa
Stress Red. Factor f: 1

Trunnion Data
Outside Diameter TDo: 219.075 mm. Standard Trun. Size
Nominal Wall tT: 8.1788 mm.
Mill Tolerance MTt: 0 %
Cold Allw. Stress ScT: 137.895 MPa
Hot Allw. Stress ShT: 137.895 MPa
Yield Str. at Temp SyT: 241.316 MPa

	Imposed Forces			Moments		
	Q1 N.	Q2 N.	W N.	MN Nm	ML Nm	MT Nm
Sustained	499	7904	1512	262	4713	1000
Occasional	7598	663	222	4518	388	1500
Expansion	2825	3483	49	1650	2035	1800
Settlement	1000	2000	3000	500	1500	2500
Max Loading	10871	3759	1237	6430	2290	2000

ML = in plane of page

Execute Clear

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12.2 Forces defined, moment derived input

Trunnions to ASME III Y-5000, Case N-392-3 and TR-107453

Units
☐ English
☒ SI Units

Location
☒ Pipe
☐ Elbow

Weld Data
☒ Full Pen.
☐ Fillet

Moments
☒ Calc'd
☐ Define

Pipe / Elbow Properties
Outside Diameter PDo: 355.6 mm.
Nominal Wall tP: 9.525 mm.
Internal Corrosion ca: 0 mm.
Mill Tolerance MTP: 0 %
Design Pressure PR: 31.0264 barG
Max. Op. Pres. PRmax: 36.1975 barG
Cold Allw. Stress ScP: 137.895 MPa
Hot Allw. Stress ShP: 137.895 MPa
Yield Str. at Temp SyP: 241.316 MPa
Stress Red. Factor f: 1

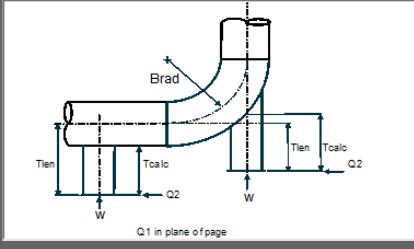
Trunnion Data
Outside Diameter TDo: 219.075 mm.
Nominal Wall tT: 8.1788 mm.
Length to C.L. Tlen: 800 mm.
Mill Tolerance MTt: 0 %
Cold Allw. Stress ScT: 137.895 MPa
Hot Allw. Stress ShT: 137.895 MPa
Yield Str. at Temp SyT: 241.316 MPa

Service Level
☒ Normal
☐ Upset
☐ Emergency
☐ Faulted

Project:
Calculation Details:
t:\V-4 Examples\V-4 N392 TRUN 03.yr

Imposed Forces

	Q1 N.	Q2 N.	W N.
Sustained	499	7904	1512
Occasional	7598	663	222
Expansion	2825	3483	49
Settlement	1000	2000	3000
Max Loading	10871	3759	1237



Execute

12.3 Typical Trunnion calculation output

PIPE TRUNNION TO ASME III App. Y-5000(2008a) and Case N-392-3

ref input

Min. Pipe Wall Thk:	9.525	mm.
Pipe Area Ap:	10355.834	mm ²
Pipe Modulus Zp:	872635.067	mm ³
Pipe Inertia Ip:	1.5515 e+8	mm ⁴

Trunnion Properties

Trunnion Area At:	5418.864	mm ²
Trunnion Modulus Zt:	275451.790	mm ³
Trunnion Inertia It:	3.0172 e+7	mm ⁴
Factor Beta	0.616	
Factor Gamma	18.667	
Factor Tor	0.859	

Limit Stresses

Service Level: Normal (A)

Min. Cold Allw. Stress	137.895	MPa
Min. Hot Allw. Stress	137.895	MPa
Min. Yield Stress	241.316	MPa
Factor Applied to Sh:	1.800	
Factor Applied to Sy:	1.500	
Stress Limit Sh:	137.895	MPa
Stress Limit Sy:	241.316	MPa

Full Penetration Weld - Local Stresses:

Y-5300 Component Moments: N.mm Y-5410(a) Component Stresses: MPa

Moment MA:	4825040.207	Stress SMT:	45.884
Moment MB:	4776281.817	Stress SNT:	88.666
Moment MC:	3178635.714	Stress SPT:	159.599
Moment MD:	2958039.892		

Y-5410 (b) Ref. Stress Dir. Value Allowed MPa

NC-3652 eq.8	SSL:	80.371	206.843	OK
NC-3653.1 eq. 9	SOL:	90.671	248.211	OK
NC-3653.2 eq. 10	SE(MC):	83.442	206.843	OK
NC-3653.2 eq. 10a	SE(MD):	83.189	413.685	OK
NC-3653.2 eq. 11	STE:	162.430	344.738	OK
Y-5410 (c)	SNTS:	302.029	482.632	OK
	Shear:	12.660	241.316	OK

DESIGN IS ACCEPTABLE.

NOTES:

The method assumes that elbows are short radius 1.0D or long radius 1.5D

In contrast to the Code, all calculations are based on the MINIMUM wall thickness, including corrosion and tolerance. This is a conservative approach.

13.0 Heat Transfer Through Welded Pipe Support Shoes

Heat transfer through a welded attachment is calculated using methods from ASTM C680-04 and Escoe's 'Piping and Pipeline Assessment Guide'.

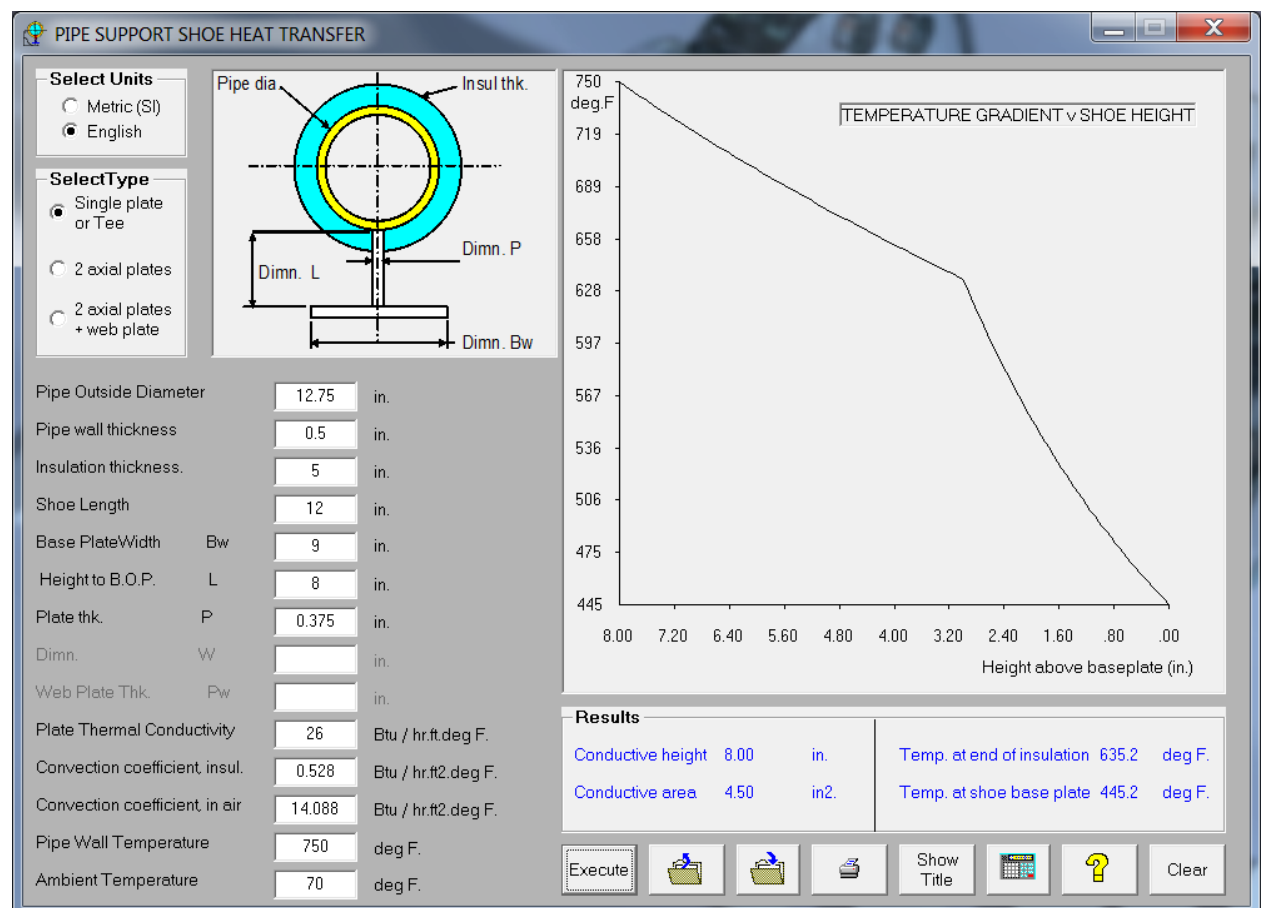
Typical values for thermal conductivity and convection coefficients are presented in the help file.

Three configurations may be considered as shown below.

The screen print of a stiffened shoe shown below demonstrates typical results for a cryogenic support.

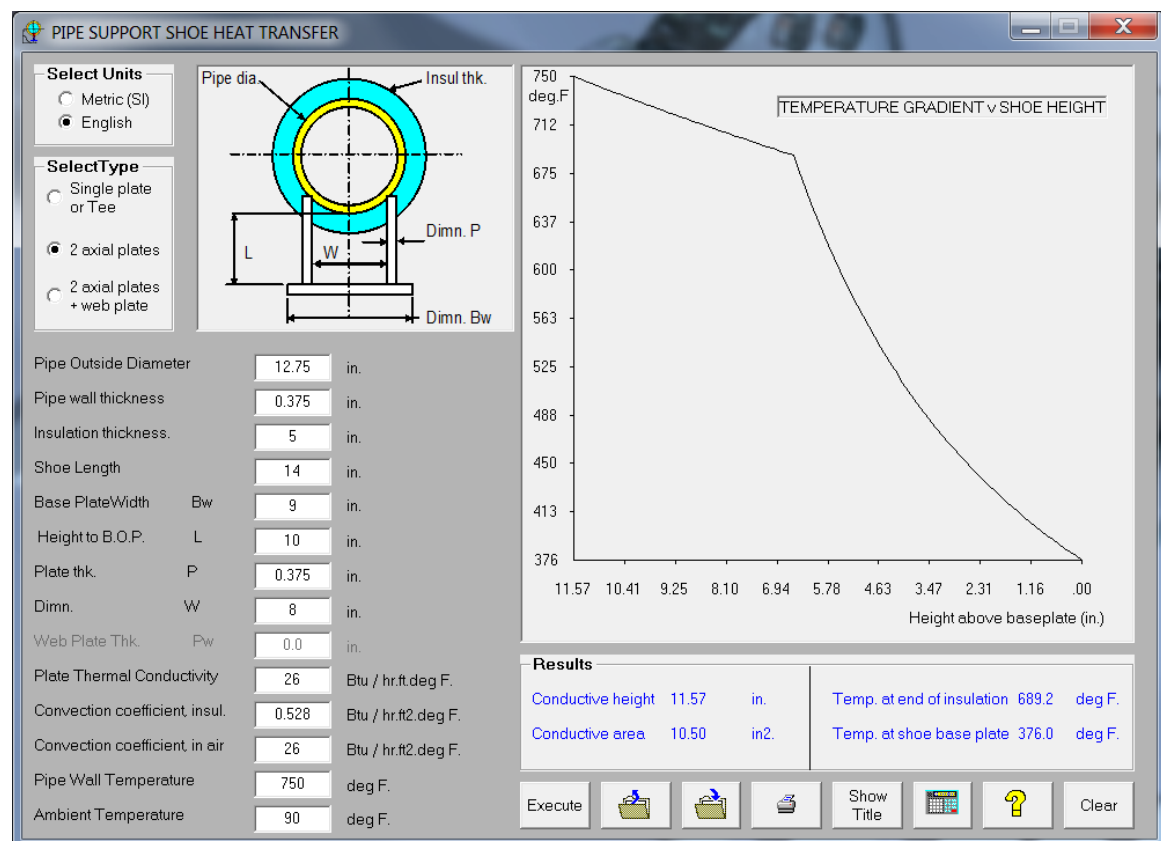
The intent of the program is to allow assessment of support contact temperature to aid material selection.

13.1 Simple Inverted Tee Shoe

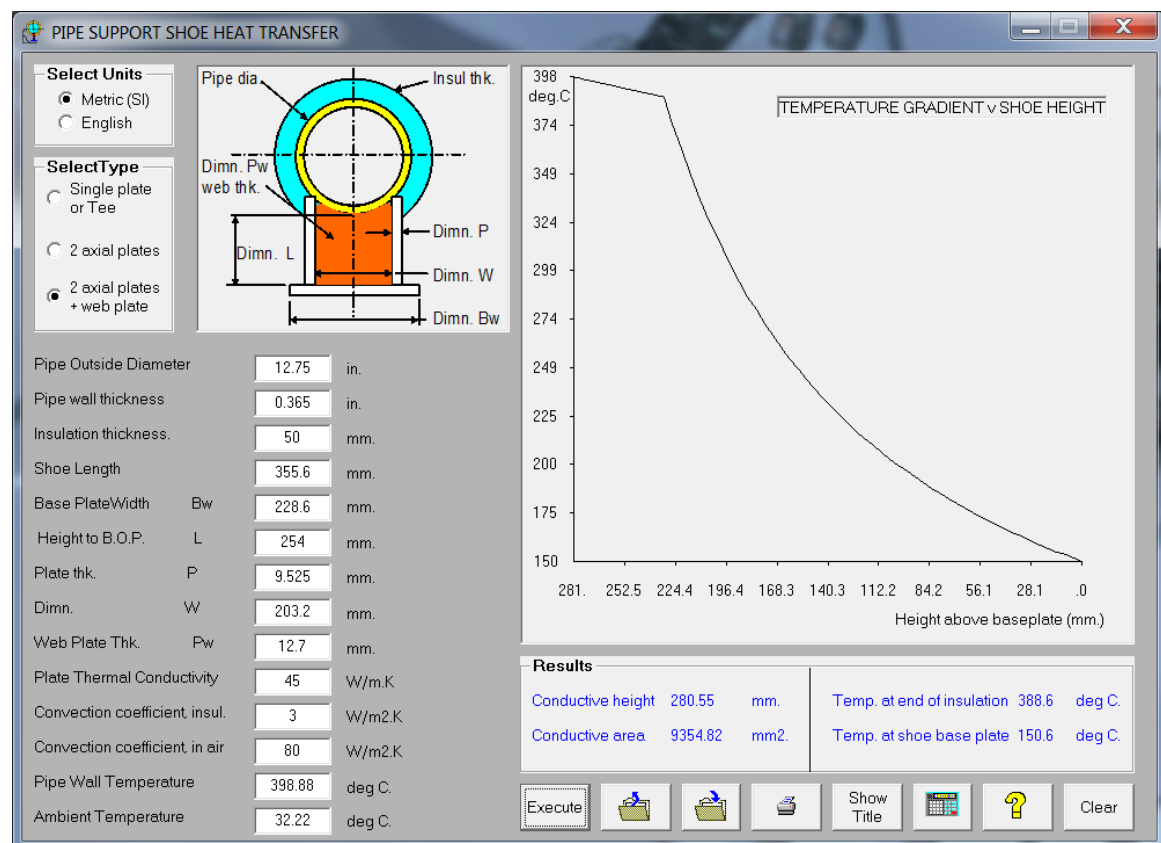


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13.2 Two Plate Shoe



13.3 Stiffened Shoe



14.0 Wind loads on Piping to EN-1991-1-4

14.1 General Notes on Wind Loads

This program element is specifically written to evaluate wind loads on piping and should not be applied, for example to buildings or other structures.

The EN-1991 method is complex, covering a large array of wind load situations. The intent of this element of Pipemill is to simplify the work as far as possible and to identify only that data needed for piping.

Predicted wind velocity and consequently force may vary significantly with height above ground. The user might consider carrying out a number of calculations representative of elevation change if piping is for example attached to a tall tower.

The EN-1991 Code which is copyright protected and some data cannot be reproduced in the program. Thus the User will need to obtain an official copy of this document.

Help file data contains guidance for certain factors, based on British criteria.

14.2 Typical EN-1991-1-4 Wind Load Calculation Input and Output

Copyright Note:
Since copyright law prevents reproduction of diagrams from the EN1991 Code, you will need a copy of the Code to read essential information from diagrams therein.

Project / Description:
Calculation Details:
f:\V-4 Examples\V-4 WIND LOAD 01.wnd

Basic Wind Velocity
Basic wind speed (Ref. Fig. NA-1) 23 m/s
Altitude above sea level 10.0 m
Height above ground (Ref. Fig 6.1 or 7.4) 2.0 m

Mean wind and roughness
Terrain category (Ref. Table 4.1) z0 1 m
See HELP Zmin 10 m
Distance to shore (Ref NA.2.11 for UK) 0.1 km
Roughness factor (from Fig NA-3 for UK) cr(z) 0.85

Wind turbulence
Basic turbulence factor l(z)flat 0.21
(Ref. Fig NA.5 for UK)
Town or built up terrain factor kIT 1.0
(Ref Fig NA.6 for UK)

Peak velocity pressure
Air density rho 1.226 kg/m3
Exposure factor (Fig. NA-7) ce(z) 2.0

Wind pressure on surfaces
Pipe or Insulation O.D. 214 mm
Kinematic viscosity of air mu 0.000015 m2/s
Equivalent roughness (Table 7.13) k 0.05

Output Data
Peak velocity at height ze vze 32.852 m/s
Peak velocity pressure qpz 661.6 N/m2
Reynold's Number Re 468691.1
Force coefficient Cf0 (factor) 0.65453
Calculated Wind Pressure 433.03 N/m2

Execute [Print] [Save] [Open] [Help] [Calculator] [Clear]

14.3 Typical EN-1991-1-4 Wind Load Calculation Output with help File

Copyright Note:
Since copyright law prevents reproduction of diagrams from the EN1991 Code, you will need a copy of the Code to read essential information from diagrams therein.

Basic Wind Velocity
Basic wind speed (Ref. Fig. NA-1)
Altitude above sea level
Height above ground (Ref. Fig 6.1 or 7.4)
Mean wind and roughness
Terrain category (Ref. Table 4.1)
See HELP
Distance to shore (Ref NA.2.11 for UK)
Roughness factor (from Fig NA-3 for UK)
Wind turbulence
Basic turbulence factor
(Ref. Fig NA.5 for UK)
Town or built up terrain factor
(Ref Fig NA.6 for UK)
Peak velocity pressure
Air density
Exposure factor (Fig. NA-7)

EN 1991 Help
Ref. Fig. NA.1. Basic wind speed in the UK varies from 22 m/s in central England to 31 m/s in Shetland Islands.
Where factors in UK and general versions of the EN1991 Code differ, the most onerous is used in default values.
Wind directional factor (Cdir) is set to 1.0
Season factor (Cseason) is set to 1.0
Orography factor (c0z) is set to 1.0
End effect factor (para 7.9.1) is set to 1.0
External pressure factors Cp0 and CpE (para 7.9.1) are set to 1.0
Terrain categories:

	z0 (m)	zmin (m)
0 Sea or coastal	0.003	1.0
I Lakes or flat with negligible obstacles	0.01	1.0
II Low vegetation, isolated obstacles	0.05	2.0
III Regular cover, buildings, villages, forest	0.3	5.0
IV Min 15% buildings, avg height >15m	1.0	10.0

Project / Description:
Calculation Details:
D 01.wnd

mu214mm
0.000015m2/s
0.13) k0.05

vze32.852m/s
qpz661.6N/m2
Re468691.1
0 (factor)0.65453
433.03N/m2

rho1.226kg/m3
ce(z)2.0

Execute

Clear

15.0 Jacketed Pipe Design and Analysis

15.1 General Features

Jacketed pipe is tedious and complex to model correctly in piping stress analysis software. The program is intended to aid and supplement such work.

Frequently problems with jacketed pipe concerns force and moment reactions on connected equipment. The first section of the program will generate for a given diameter, equivalent wall thickness and equivalent mass representative of core pipe, jacket, contents and insulation. This allows accurate evaluation of loads on supports and connected equipment using a normal single string of pipe elements in a stress analysis program. Calculated stresses will be approximate.

The second section evaluates internal forces in the jacket and core due to relative expansion, calculates all internal stresses and loads and the critical buckling length. Expansion rates can be extracted from the PIPEMILL internal data base.

The third section of the program assumes the worst case end closure, a flat plate, is in use and calculates stresses in the plate due to imposed expansion or contraction forces.

Comprehensive help files are available for all three sections.

15.2 Typical Input Screen

Jacketed Pipe Input

Selected Units
☐ English
☒ Metric (SI)

Project / Description: _____
Calculation Details: f:\V-4 Examples\V-4 JKT-PIPE-01.jkt

1. Compound Stiffness and Weight

	Jacket Pipe	Core Pipe	Insulation	Cladding
Outside Diameter mm	610	508		
Nom. Thickness mm	9.525	9.271	100	6
Material density kg/m3	7850	8200	150	8000
Contents Density kg/m3	200	1790		

2. Axial force, Stress and Buckling Calculation

Elastic Mod. MPa	202990	202990
Pressure bar G	16	25
Corrosion Allw. mm	1.5	3
Mill Tolerance %	12.5	12.5
Temperature deg.C	300	260

Expansion mm/mm/deg C: 1.29093e-5 1.74757e-5
Read from data base (Click):

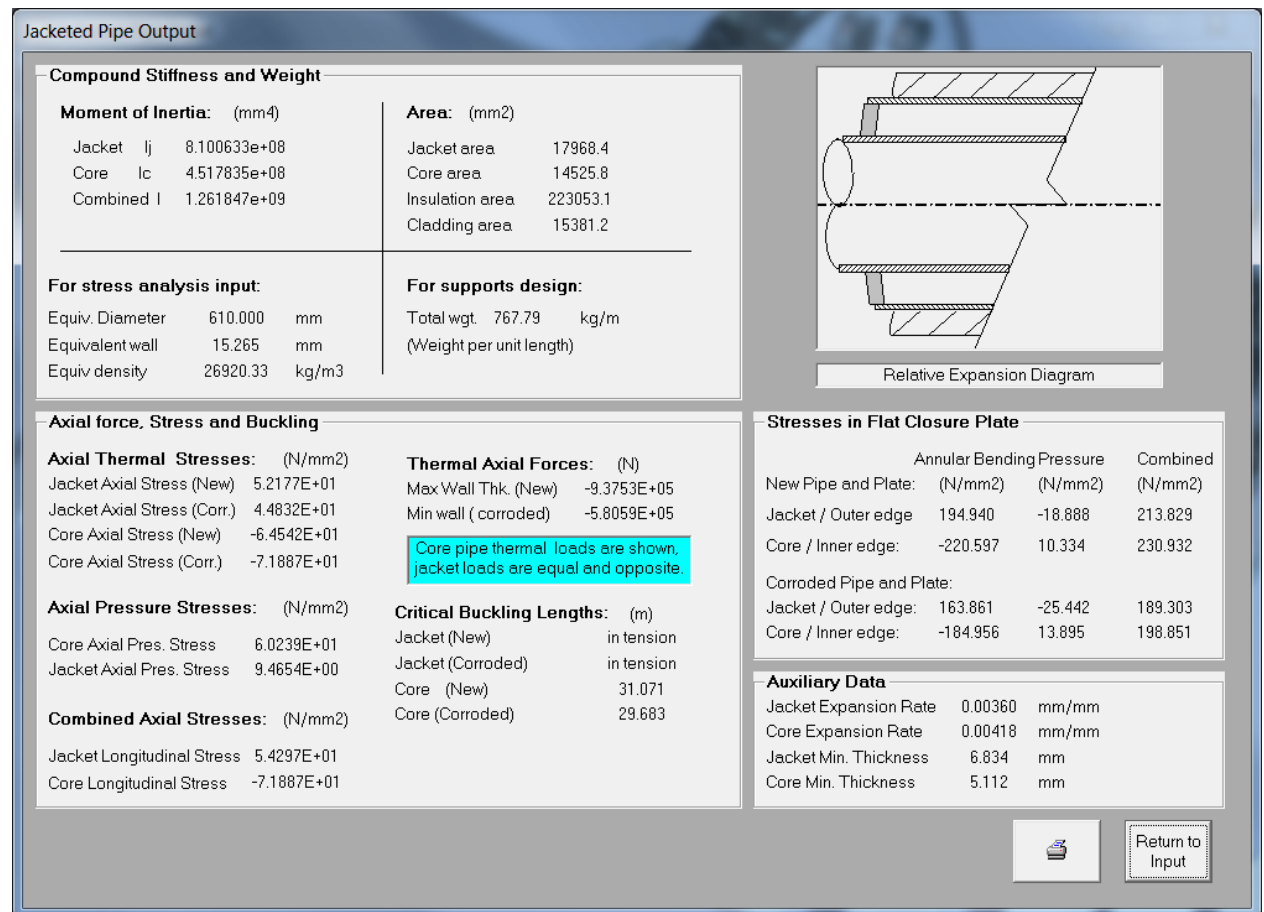
Ambient temp. deg.C: 21

3. Closure Plate Stresses

Nom. Plate thk. t mm	20
Poisson's Ratio	0.3
Corrosion Allw. mm	3

This part of the calculation assumes a flat closure plate. Many alternatives are available such as a reducing flange.

15.3 Typical Output Screen



16.0 REINFORCED AND STUB-IN TYPE TEE DESIGN

This program caters for the design of tees manufactured from plate or straight pipe. Lateral branch connections are allowed to an angle from the perpendicular of 45 degrees.

The tee connection may include inherent reinforcement within the wall of the header or branch pipe, or reinforcement may be in the form of a fully welded ring.

For both header and branch, a standard pipe size may be selected from a data-base, or user entered dimensions may be used.

Stress intensification factors will be calculated, based on the design code. If a lateral connection with an included angle less than 90 degrees has been defined, the stress intensification factor will be modified in accordance with the Codeti (French) code, which increases the *sif* as the branch angle reduces from 90 degrees. This is documented in the program help file.

Commonly a tee analysis would be run initially without a ring, to establish the minimum requirements for reinforcement. The program will define the minimum thickness and diameter bounds for an acceptable ring. Results will be presented on a full screen, and will be summarised on the input screen when it is returned.

A series of screen images follows from the same problem. These show a non-reinforced input data screen, a related comprehensive output screen and an input screen with reinforcement, where results are acceptable.

Pipemill Engineering Software

User Guide, Version 4.00

16.1 Non-reinforced Tee Input and Summary Output (results not acceptable)

Tee Design

Units: ☒ SI Units ☐ English

Design Code: ☒ ASME B31.3 ☐ BS EN 13480

Tolerances: Select (dimension) or (%):

Reinforcing Ring: ☐ Specified ☒ Not Specified

TEE Ref. ASME B31.3 Section 304.3 (2012)

Input Data

HEADER:		BRANCH:	
Outside Dia. Dh:	219.075 mm.	Db:	114.3 mm.
Nom. Wall Thk. Th:	8.1788 mm.	Tb:	6.0198 mm.
	Standard		Standard
Factor y yh:	0.4	yb:	0.4
Factor E Eh:	1	Eb:	1
Allowable Stress Sh:	110 MPa.	Sb:	110 MPa.
Tolerance tol(h):	12.5 %	tol(b):	12.5 %

Internal Pressure P: 30.68 bar G. Branch Weld Leg Lwb: 6 mm.

Corrosion Allowance ca: 2.5 mm. Design Temperature Td: 200 deg C.

Branch Angle beta: 90 Deg. Weld Factor W: 1

Results Summary (from previous calculation)

Min. ring dia. for thk. Tr: 275.9
Max allowed ring dia. (2.d2): 217.5
Min. ring thk for dia. Dr: 9.38

Errors and warnings:

Insufficient Reinforcement area. Increase wall or add / increase ring.

16.2 Comprehensive Output Data Screen (results not acceptable)

B31.3 Tee - Results

Dimensional limits:

Ratio Tnh / Dh: 26.8
Ratio Db / Dh: 0.5
Dh/Tnh and Db / Dh within limits

Branch Weld details

Minimum weld leg: 6.0 mm.
Run weld length: 6.0 mm.
Branch weld area: 36.0 mm2.

Wall thickness for pressure containment:

Header - min. wall for: 3.02 mm.
Header - Min. actual wall: 4.66 mm.
Branch - min. wall for pressure: 1.58 mm.
Branch - Min. actual wall: 2.77 mm.

Intermediate dimensions:

Dimn D1 108.8 mm. Dimn L41 11.6 mm.
Dimn D21 61.8 mm. Dimn L42 6.9 mm.
Dimn D2 108.8 mm. Dimn L4 6.9 mm.

Area requirements

Replacement Area Req'd A1: 328.6 mm2. Area A2: 177.8 mm2.
Area A3: 16.5 mm2.
Area A4 (weld): 36.0 mm2.
Min. Area req'd in ring + weld: 98.3 mm2.
Area available in ring + weld: 0.00 mm2. Area in Walls and Weld: 230.3 mm2.
(Ring to header pipe weld only) (Weld around branch pipe only)

Reinforcing ring data:

Min. ring dia. for thk. Tr: 275.9 mm. Weld leg length: 0.0 mm.
Max allowed ring dia. (2.d2): 217.5 mm. Ring edge weld area: 0.0 mm2.
Min. ring thk for dia. Dr: 9.38 mm.

Stress Intensification Factors:

Note that B31.3 takes no account of branch angle.	ASME B31.3 App. D:		Codeti for <90 deg.:	
	sifi	sifo	sifi	sifo
Unreinforced	3.961	4.949	3.961	4.949
Ring reinforced	3.961	4.949	3.961	4.949

Errors and warnings:

Insufficient Reinforcement area. Increase wall or add / increase ring.

Modify / Print

Note that title lines are added immediately prior to printing.

16.3 Input Screen with Reinforcement and Acceptable Results Summary

Units

☐ SI Units

☒ English

Design Code

☒ ASME B31.3

☐ BS EN 13480

Tolerances

 Select (dimension) or (%).

Reinforcing Ring

☒ Specified

☐ Not Specified

Input Data

	HEADER:		BRANCH:	
Outside Dia.	Dh:	16 in.	Db:	6.625 in.
Nom. Wall Thk.	Th:	0.5 in.	Tb:	0.28 in.
		Standard		Standard
Factor y	yh:	0.4	yb:	0.4
Factor E	Eh:	1.0	Eb:	1.0
Allowable Stress	Sh:	14400 psi.	Sb:	14400 psi.
Tolerance	tol(h):	12.5 %	tol(b):	12.5 %

Internal Pressure P: 500 psi.
 Branch Weld Leg Lwb: 0.375 in.
 Corrosion Allowance ca: 0.1 in.
 Design Temperature Td: 371 deg C.
 Branch Angle beta: 60 Deg.
 Weld Factor W: 1

Reinforcing Ring

Ring Diameter Dr:	12 in.	Ring Weld Leg Lwr:	0.375 in.
Min. Ring Thk. Tr:	0.5 in.	Allowable Stress Sr:	14400 psi.

TEE Ref. ASME B31.3 Section 304.3 (2012)

Results Summary (from previous calculation)

Min. ring dia. for thk. Tr:	10.861
Max allowed ring dia. (2.d2)	14.630
Min. ring thk for dia. Dr:	0.369

Errors and warnings:
Reinforcement is acceptable.

17.0 DESIGN OF VARIOUS LARGE COMPONENTS

This program is intended for the design of large bore refinery type fittings where standard components may not be available. Mitre elbows with any number of cuts, reducers with or without end reinforcement, end caps and line blinds may be designed.

17.1 Mitre Elbow

The mitre elbow calculation checks whether the construction is by code definition wide or closely spaced and evaluates acceptability accordingly. The maximum allowable pressure is calculated and compared with the required pressure. Stress intensification factors are presented in accordance with the design code.

A comprehensive output screen will be presented, and results summarised on the input screen when it is returned.

17.1.1 Mitre Elbow Input Screen with Summary Output.

Various Large Component Design - Internal Pressure

Units: ☒ SI Units ☐ English Units

Design Code: ☒ ASME VIII / B31.3 ☐ BS EN 13480

Tolerance: Select (dimension) or (%)

Select the component to design:

Mitre Elbow to ASME B31.3 (2012) Section 304.2.3 (Internal Pres.)

Input Data

Pipe Outside Dia. D: mm

Wall Thickness t: mm

Quality Factor E:

Allowable Stress S: MPa

Tolerance: mm.

Weld Creep factor W:

Design Pressure P: barG

Corrosion Allw. ca: mm.

Bend radius R: mm.

Bend Angle theta: deg.

No. of Mitre Cuts:

Project / Description:

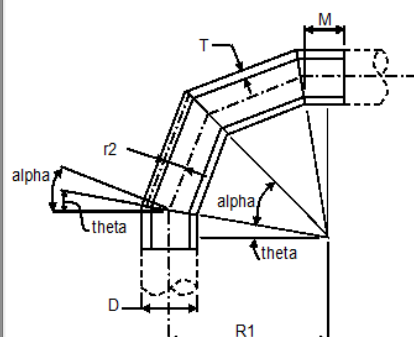
Calculation Details:

Results Summary - Mitre

Minimum wall 17.45 mm. Stress Intens. Factors:
Minimum rad. R1 1394.65 mm. App. D - close spaced
Mid wall rad. r2 1209.68 mm. sifi and sito: 7.492

Max Allowable Pressure 3.75 bar G.

Acceptable - Allowable pressure exceeds specified design pressure



17.1.2 Mitre Elbow, Comprehensive Output Screen

B313 Mitre Elbow - Results

Geometry			Stress Intensification Factors	
Minimum wall thk.	17.45	mm.	App. D - close spaced	
Minimum rad. R1	1394.65	mm.	flexibility factor h:	0.042
Mid wall rad. r2	1209.68	mm.	Element length s:	1272.24
Min. end length M:	395.50	mm.	$r2(1 + \tan(\theta))$	1450.29
			sifi and sifo:	7.492

Pressure Calculation:		
Allow. pressure, eq. 4a	3.75	bar G.
Allow. pressure, eq. 4b	5.94	bar G.
Allow. pressure, eq. 4c	2.52	bar G.
Max Allowable Pressure	3.75	bar G.

Acceptable - Allowable pressure exceeds specified design

Continue

17.2 Line Blind

The calculation of a line blind thickness to ASME B31.3 is straightforward. The program adds corrosion allowance to both sides of the blind if specified.

17.2.1 Line Blind Calculation and Results Panel

Various Large Component Design - Internal Pressure

Units: ☐ SI Units ☒ English Units

Design Code: ☒ ASME VIII / B31.3 ☐ BS EN 13480

Tolerance: Select (dimension) or (%)

Select the component to design:

Line Blind (trapped between flanges) to ASME B31.3 (2012) Section 304.5.3.

Input Data

Pipe Outside Dia. D: in.

Wall Thickness t: in.

Joint Eff. factor E: 1.0

Allowable Stress S: 20000 psi

Gasket Dia. Dg: 60.39 %

Weld Creep factor W: 1.0

Design Pressure P: 32.72 psi

Corrosion Allw. ca: 0.0625 in.

Results - Blind

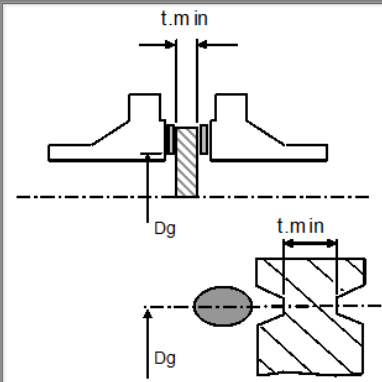
Corrosion allw. is added to BOTH sides of the blind.

$$t_{min} = D_g \sqrt{\frac{3 \cdot P}{16 \cdot S \cdot E \cdot W}} + 2 \cdot ca + tol$$

Minimum thk. t(min) = 1.183 in.

Project / Description:

Calculation Details:



17.3 End Cap

End caps are currently calculated in accordance with ASME VIII Div. 1. Currently only pressure on the concave side is addressed. The minimum required thickness will be calculated, also the related spherical and knuckle radii will be reported.

17.3.1 End cap Input Screen with Summary Output.

Various Large Component Design - Internal Pressure

Units: ☐ SI Units ☒ English Units

Design Code: ☒ ASME VIII / B31.3 ☐ BS EN 13480

Tolerance: Select (dimension) or (%)

Select the component to design:

Elliptical Cap to ASME VIII Div. 1 (2013) Section UG-32(d) (Pres. on concave side).

Input Data

Pipe Outside Dia. D: in.

Wall Thickness t: in.

Quality Factor E:

Allowable Stress S: psi

Tolerance: %

Design Pressure P: psi

Corrosion Allw. ca: in.

Project / Description:

Calculation Details:

Results - Cap

ASME VIII approximation of 2:1 elliptical head

Inside dia. $D_i := D - 2t = 29.188$ in.

Spherical rad. $R := 0.9 \cdot D_i = 26.269$ in.

Knuckle rad. $r := 0.17 \cdot D_i = 4.962$ in.

$$t_{min} := \frac{P \cdot D_i}{(2SE) - (0.2P)} + tol + ca$$

$t_{min} = 0.367$ in.

18.0 Large Bore Reducer to ASME VIII Div. 2

18.1 General Notes

The program carries out a rigorous analysis of any viable conical reducer in accordance with ASME VIII Div. 2 rules.

Checks are carried out to ensure that data is complete and representative of an acceptable geometry set.

Global and local stresses are calculated and presented in full and in concise form.

18.2 Large Bore Reducer - Typical Input Data

Large Conical Reducer - Input

Select Units

☒ English Units

☐ SI Units

Tolerance

☒ %

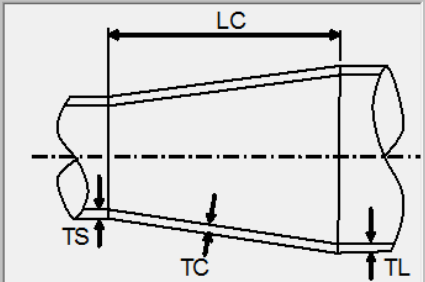
☐ in.

CONICAL REDUCER TO ASME VIII Div. 2 (2010) Section 4.3

Project / Description: Large Reducer

Calculation Details: CONICAL REDUCER DESIGN

f:\V-4 Examples\V-4 ASME VIII RED-01.lcr



Input Data

Large End Outside Diameter	D	60	in.	Allowable Stress, Ambient	Sa	25300	psi.
Large End Wall Thickness	TL	0.437	in.	Allowable Stress at Temp.	Sh	25300	psi.
Small End Outside Diameter	Ds	24	in.	Yield Stress, Ambient	Ysa	38000	psi.
Small End Wall Thickness	TS	0.322	in.	Yield Stress, at Temp.	Yst	38000	psi.
Cone Wall Thickness	TC	0.452	in.	UTS, Ambient	UTSa	75000	psi.
Cone Length Along Axis	LC	67.17691	in.	Weld Joint Factor	E	1.0	
Corrosion Allowance	ca	0	in.	Poisson's Ratio	nu	0.3	
Tolerance	tol	0	%	External Axial Force	FL	100000	lb.f.
Internal Pressure	intP	250	psi.	Net Longitudinal Moment	ML	83333.33	lb.ft
External Pressure	extP	15	psi.	Torsional Moment	MT	41666.67	lb.ft
Hot Young's Modulus	Eh	29505882	psi.				

Execute

Icons: Print, Save, Open, Copy, Paste, Calculator, Help, CLEAR

18.3 Large Bore Reducer - Typical Summary Output Data

Large Conical Reducer - Global Stress and Geometry Results

Geometry Checks:			
	Required	Actual	
Min wall thk., large cylinder (in.)	0.294	0.437	OK
Min wall thk., small cylinder (in.)	0.116	0.322	OK
Min wall thk., cone (in.)	0.304	0.452	OK
Half Apex Angle (deg.)	max 60	15.000	OK
Min Cone Length (in.)	10.712	67.177	OK
RL / tl ratio 20 <= RL/tl <= 500	67.650	4.311.4c	OK
tc / tl ratio 1 <= tc / tl <= 2	1.034		OK
RS / ts ratio 20 <= RL/tl <= 500	36.267		OK

Moment and Shear Force Resultants:	
4.3.3 L.End Moment Resultant, Pressure (lb.ft)	-1.173
4.3.3 L.End Shear Resultant, Pressure (lb.ft)	-4.442
4.3.4 L.End Moment Resultant, Line load (lb.ft)	-0.035
4.3.4 L.End Shear Resultant, Line load (lb.ft)	-0.132
4.3.5 S.End Moment Resultant, Pressure (lb.ft)	0.441
4.3.5 S.End Shear Resultant, Pressure (lb.ft)	-1.828
4.3.6 S.End Moment Resultant, Line load (lb.ft)	0.027
4.3.6 S.End Shear Resultant, Line load (lb.ft)	-0.125

Global Stresses:			
Hot Allowable Stress Sh	25300.000	psi	
Primary+Sec. Stress Limit sPs	76000.000	psi	

Compressive Stress Checks:			
Meridional Stress sigma sm (psi)	10812.765		
Allowable Compressive Stress Fxa (psi)	22386.416		
	OK		

Combined Stresses:			
	Actual	Allowed	psi
sigma theta m (psi)	17633.784		
sigma sm (psi)	10812.765		
tor (psi)	428.464		
Combined stress sigma (psi)	15534.427	25300.000	OK

Stress Results Summary

GEOMETRY AND STRESS LIMITS COMPLIED WITH.

Review local stresses at cylinder and cone intersections

Local Stress

Return to Input and Print

18.4 Large Bore Reducer - Local Stress Output Data

Large Conical Reducer - Local Stress Results

Internal Pressure + external loads, Local Stresses (psi):									
	Cyl. Large End		Cone Large End		Cyl. Small End		Cone Small End		Allowable
sigma sm pos	10521.612	OK	10171.660	OK	16014.526	OK	11367.805	OK	25300.000
sigma sm neg	6390.859	OK	6178.102	OK	-6947.756	OK	-4960.277	OK	
sigma theta m pos	2208.025	OK	2106.787	OK	21789.472	OK	20308.718	OK	
sigma theta m neg	7918.085	OK	7836.016	OK	1758.451	OK	2494.288	OK	
sigma sb pos + sigma sm pos	-15840.407	OK	-14469.700	OK	45964.430	OK	26567.340	OK	76000.000
sigma sb pos - sigma sm pos	-36883.632	OK	-34813.020	OK	13935.377	OK	3831.730	OK	
sigma sb neg + sigma sm neg	-9477.468	OK	-8654.493	OK	-21032.261	OK	-12108.143	OK	
sigma sb neg - sigma sm neg	-22259.186	OK	-21010.697	OK	-7136.749	OK	-2187.590	OK	
sigma theta b pos + sigma theta m pos	-5700.580	OK	-5285.622	OK	30774.443	OK	24868.578	OK	
sigma theta b pos - sigma theta m pos	-10116.631	OK	-9499.195	OK	-12804.501	OK	-15748.858	OK	
sigma theta b neg + sigma theta m neg	3157.587	OK	3386.238	OK	-2466.901	OK	349.928	OK	
sigma theta b neg - sigma theta m neg	-12678.583	OK	-12285.795	OK	-5983.802	OK	-4638.648	OK	

External Pressure + external loads, Local Stresses (psi):									
	Large End Cyl.		Cone Large End		Small End Cyl.		Cone Small End		Allowable
sigma sm pos	1558.002	OK	1506.286	OK	11209.138	OK	7971.815	OK	25300.000
sigma sm neg	-2572.751	OK	-2487.272	OK	-11753.144	OK	-8356.266	OK	
sigma theta m pos	-3158.813	OK	-3162.899	OK	9309.073	OK	8223.125	OK	
sigma theta m neg	2551.246	OK	2566.331	OK	-10721.948	OK	-9591.305	OK	
sigma sb pos + sigma sm pos	-2421.933	OK	-2213.878	OK	32750.380	OK	18903.966	OK	76000.000
sigma sb pos - sigma sm pos	-5537.938	OK	-5226.450	OK	10332.104	OK	2960.336	OK	
sigma sb neg + sigma sm neg	3941.006	OK	3601.329	OK	-34246.310	OK	-19771.517	OK	
sigma sb neg - sigma sm neg	9086.508	OK	8575.873	OK	-10740.022	OK	-3058.985	OK	
sigma theta b pos + sigma theta m pos	-4352.794	OK	-4278.948	OK	15771.446	OK	11502.770	OK	
sigma theta b pos - sigma theta m pos	1964.832	OK	2046.850	OK	-2846.700	OK	-4943.480	OK	
sigma theta b neg + sigma theta m neg	4505.373	OK	4392.911	OK	-17469.898	OK	-13015.880	OK	
sigma theta b neg - sigma theta m neg	-597.119	OK	-739.750	OK	3973.999	OK	6166.730	OK	

Return to Global and Combined Stresses

19.0 Wall Thickness Calculation and Optimisation to ASME B31 Codes

19.1 General Features

This routine calculates pipe wall thickness in accordance with ASME B31.1, B31.3, B31.4 and B31.8 codes and includes high pressure pipe wall thickness to ASME B31.3 Chapter IX.

The ASME B31.3 calculation may be run for a single pipe size or, more commonly, a range of pipe sizes may be run in one calculation. In this case the user may define a range of up to 18 pipe sizes. This would for example allow the normal range from 0.5" to 24" to be calculated in one run.

The bare minimum and minimum wall including allowances is evaluated. From the PIPEMILL internal data base, the nearest standard pipe size will be selected, if one exists.

Output is hard copied in a concise manner to enable, for example, construction of a Pipe Material Specification Table.

The ASME B31.4 and B31.8 methods are similar in that a single pipe diameter is considered and a bare minimum and minimum wall including allowances is calculated.

19.2 Typical ASME B31.1 Screen (Single Pipe Size)

Wall Thickness Calculation

Select Units: ☒ Metric(SI) ☐ English

Project/Description:

Code: ASME B31.1 (2012) para 104.1

Calculation details

Filename: f:\V-4 Examples\V-4 WALL THK B311-01.wtk

Design Code

☒ ASME B31.1

☐ ASME B31.3

☐ B31.3 Chapter IX

☐ ASME B31.4

☐ ASME B31.8

B31.1 and B31.3:

☒ Straight Pipe

☐ Elbow (Bend)

Req'd Output

☒ One pipe size

☐ Several sizes

Straight Pipe

Material (reference only): Reference only

Temperature: 538 Deg. C

Internal Pressure P: 4.7 bar G

Nominal Diameter D: 30 (in.)

Allowable Stress S: 17.237 MPa

Joint Efficiency E: 0.9

Yield factor Y: 0.4

Tolerance: 12.5 %

Corrosion Allowance: 1.5 mm

to =
$$\frac{(P \cdot D_o)}{2(S \cdot E + P \cdot Y)}$$

Basic thickness equation

Pipe Results

Bare minimum calculated thk.	11.405 mm
Min wall including corrosion and tolerance	14.748 mm
Nearest standard wall	15.875 mm
Nearest standard wall schedule or thk (in.)	Sch 30

EXCLUDES any thread cutting allowance

Execute ? [Icons] Clear

19.3 Typical ASME B31.3 Screen (Single Pipe Size)

Wall Thickness Calculation

Select Units:
☐ Metric(SI)
☒ English

Project/Description: _____
 Calculation details
 Filename: f:\V-4 Examples\V-4 WALL THK B313-01.wtk

Code: ASME B31.3 (2012) para 304.1.2

Design Code
☐ ASME B31.1
☒ ASME B31.3
☐ B31.3 Chapter IX
☐ ASME B31.4
☐ ASME B31.8

B31.1 and B31.3:
☒ Straight Pipe
☐ Elbow (Bend)

Req'd Output
☒ One pipe size
☐ Several sizes

Straight Pipe

Material (reference only): Reference only

Temperature: 1000 Deg. F

Internal Pressure P: 68.168 lb/in2

Nominal Diameter D: 30 (in.)

Allowable Stress S: 2500 lb/in2

Joint Efficiency E: .9

Weld Joint factor W: .954

Yield factor Y: .4

Tolerance: 12.5 %

Corrosion Allowance: .0591 in

Pipe Results

Bare minimum calculated thk.	0.470	in
Min wall including corrosion and tolerance	0.605	in
Nearest standard wall	0.625	in
Nearest standard wall schedule or thk (in.)	Sch 30	

Basic thickness equation

$$t = \frac{P \cdot D_o}{2(S \cdot E \cdot W + P \cdot Y)}$$

EXCLUDES any thread cutting allowance

Execute ? [Icons] Clear

19.4 Typical ASME B31.3 Input Screen (Several Pipe Sizes)

Wall Thickness Calculation

Select Units:
☒ Metric(SI)
☐ English

Project/Description: _____
 Calculation details
 Filename: f:\V-4 Examples\V-4 WALL THK B313-02.wtk

Code: ASME B31.3 (2012) para 304.1.2

Design Code
☐ ASME B31.1
☒ ASME B31.3
☐ B31.3 Chapter IX
☐ ASME B31.4
☐ ASME B31.8

B31.1 and B31.3:
☒ Straight Pipe
☐ Elbow (Bend)

Req'd Output
☐ One pipe size
☒ Several sizes

Straight Pipe

Material (reference only): Reference only

Temperature: 538 Deg. C

Internal Pressure P: 4.7 bar G

Allowable Stress S: 17.237 MPa

Joint Efficiency E: 0.9

Weld Joint factor W: 0.954

Yield factor Y: 0.4

Tolerance: 12.5 %

Corrosion Allowance: 1.5 mm

Basic thickness equation

$$t = \frac{P \cdot D_o}{2(S \cdot E \cdot W + P \cdot Y)}$$

Min. size
 0.5in nb.
 0.75in nb.
 1in nb.
 1.5in nb.
 2in nb.
 3in nb.
 4in nb.

Max. size
 12in nb.
 14in nb.
 16in nb.
 18in nb.
 20in nb.
 22in nb.
 24in nb.

0.5in nb. 24in nb.

No. of sizes to compute: 18

Execute ? [Icons] Clear

19.5 Typical ASME B31.3 Output Screen (Several Pipe Sizes)

19.6 Typical ASME B31.4 Screen

Wall Thickness Calculation

Select Units:
☒ Metric(SI)
☐ English

Project/Description: _____
 Calculation details
 Filename: f:\V-4 Examples\V-4 WALL THK B314-01.wtk

Code: ASME B31.4 (2009) para 404.1.1

Design Code:
☐ ASME B31.1
☐ ASME B31.3
☐ B31.3 Chapter IX
☒ ASME B31.4
☐ ASME B31.8

B31.1 and B31.3:
☒ Straight Pipe
☐ Elbow (Bend)

Straight Pipe

Material (reference only): Reference only

Internal Pressure P 98 bar G
 Outside Diameter D 30 (in.)
 Specified Yield Stress Sy 448 MPa
 Joint Efficiency E 0.9
 Factor F ref 402.3.1 (Default 0.72) 0.72

Tolerance 12.5 %
 Corrosion Allowance 1.5 mm

Basic thickness equation

$$t = \frac{P \cdot D_o}{2(F \cdot E \cdot S_y)}$$

Pipe Results

Bare minimum calculated thk.	12.862	mm
Min wall including corrosion and tolerance	16.413	mm

EXCLUDES any thread cutting allowance

Execute ? [Icons] Clear

19.7 Typical ASME B31.8 Screen

Wall Thickness Calculation

Select Units:
☒ Metric(SI)
☐ English

Project/Description: _____
 Calculation details
 Filename: f:\V-4 Examples\V-4 WALL THK B318-01.wtk

Code: ASME B31.8 (2010) para 841.11

Design Code:
☐ ASME B31.1
☐ ASME B31.3
☐ B31.3 Chapter IX
☒ ASME B31.8

B31.1 and B31.3:
☒ Straight Pipe
☐ Elbow (Bend)

Straight Pipe

Material (reference only): Reference only

Internal Pressure P 44.237 bar G
 Nominal Diameter D 30 (in.)
 Specified Yield Stress S 240 MPa
 Long. joint factor (841.115A) E 0.9
 Location factor (841.114B) F 0.6
 Temp derating factor(841.116A) T 0.867

Tolerance 12.5 %
 Corrosion Allowance 1.5 mm

Basic thickness equation

$$t = \frac{P \cdot D_o}{2 \cdot S \cdot F \cdot E \cdot T}$$

Pipe Results

Bare minimum calculated thk.	15.000	mm
Min wall including corrosion and tolerance	18.857	mm

EXCLUDES any thread cutting allowance

Execute ? [Icons] Clear

Wall Thickness Calculation

Select Units

☒ Metric(SI)

☐ English

Design Code

☐ ASME B31.1

☐ ASME B31.3

☒ B31.3 Chapter IX

☐ ASME B31.4

☐ ASME B31.8

B31.1 and B31.3:

☒ Straight Pipe

☐ Elbow (Bend)

Project/Description::

Calculation details

Filename: f:\V-4 Examples\V-4 WALL THK B313-IX-01.wtk

Straight Pipe

Material (reference only):	Reference only	
Outside diameter	141.3	mm
External Wall Tolerance c0	0.5	mm
Internal Wall Tolerance c1	0.5	mm
Corrosion allowance ca	3.0	mm
Manufacturing W.T. Tolerance	7.5	%
Sustained Internal Pressure	1034	barG
Fluctuating Internal Pressure	61	barG
Allowable Sustained Stress	265.841	MPa
Allowable Stress Intensity	100	MPa

Confirm Code Equation

The Code specifies a term for diameter in the equation of D - 2.c0 on which wall thickness is based. This is not conservative. Select preferred basis for calculation here:

☒ D + 2.c0

☐ D - 2.c0

Confirm Austenitic / Nickel / Steel Factor

Solution treated austenitic and similar nickel alloys requires a factor in the code equation of sta = 1.155, otherwise sta = 1.0 (ref. equation above)

☐ sta = 1.0

☒ sta = 1.155

Code: ASME B31.3 (2012) Ch. IX para K304.1.2

$$t_{34} := \left[\frac{(D_o + 2 \cdot c_0)}{2} \right] \cdot \left(1 - \exp\left(\frac{-sta \cdot P}{S}\right) \right)$$

Basic thickness equation

Pipe Results		
Bare minimum calculated thk.	25.748	mm
Min wall including corrosion and tolerance	32.160	mm
Min. Thk. for Fatigue	25.748	mm
Cyclic Fatigue Stress (ref. K304.8.3)	20.580	MPa

EXCLUDES any thread cutting allowance

Execute
?
Help
Print
Calculator
Clear

20.0 Equivalent Stiffness of Internal Refractory Lining and Pipe

20.1 General Notes

This calculation is intended to provide only modification of elemental stiffness in piping due to refractory lining, and provides data for input to typical stress analysis software.

It is expected that the user's stress analysis software will accommodate added weight due to lining. This program provides a modified Young's modulus value representing both pipe wall and refractory lining. This may be entered directly to stress analysis software.

It may be necessary to carry out calculations for both ambient and operating conditions.

20.2 Typical Input and Output Data

Equivalent Refractory Stiffness

Select Units
☐ English Units
☒ SI Units

Project / Description:

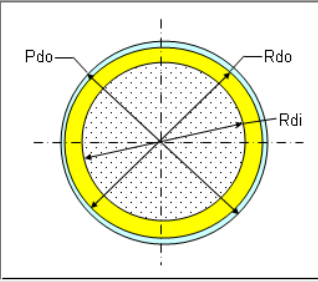
Calculation Details: Validation calculation






Input Data

Pipe Outside Diameter	PDo	<input type="text" value="2590.8"/>	mm.
Pipe Wall Thickness	Pwt	<input type="text" value="12.7"/>	mm.
Pipe Young's Modulus	Ep	<input type="text" value="206842.34"/>	MPa
Refractory Lining:			
Thickness	Rwt	<input type="text" value="139.7"/>	mm.
Weight (density)	Rwgt	<input type="text" value="961.11"/>	kg/m3
Average Rupture Modulus	Rarm	<input type="text" value="2.0684"/>	MPa

Results

Pipe Inertia	Ip	8.5462E+10	mm4
Refractory Inertia	Ir	7.8561E+11	mm4
Refractory Modulus	Er	1.83155E+03	MPa
Equivalent Modulus (Pipe + Refractory)			
Eq		2.23679E+05	MPa
Ratio of Moduli: Equivalent / Pipe Only:		1.08	



Execute      Clear

21.0 VARIOUS QUICK CALCULATIONS

This part of the program is intended to deal with those simpler calculations, which might be unreliable if written down from memory.

It is intended that the input screen is largely self explanatory.

Calculations include:

- Slug forces acting at a pipe elbow
- Linear interpolation of values
- Thermal expansion rates for common pipe materials
- Elongation of straight pipe due to internal pressure
- Methods of assessing external loads on flanged joints
- Vertical pressure vessel skirt expansion

21.1 Vertical Pressure Vessel Skirt Expansion

Vessel Skirt Expansion

Ambient deg C.
Temp at skirt top deg C.
Height h mm.
Wall thk. t mm.
Insulation K ☐ None ☒ Firebrick

Calculate average skirt temp
 Average temp deg C.

Get resulting skirt expansion
 mm/mm.
Net Skirt Expansion: mm.

When the initial calculation of average temperature has been made, the user will be prompted to select a material. From this data the net skirt expansion will be provided.

21.2 Slug Forces Acting at a Pipe Elbow

Slug Flow Forces

Diagram: A pipe elbow with flow direction and angle 'a' indicated.

Input Data

Line No.	1234-5	
Pipe Out. Dia.	323.9	mm.
Actual wall thk.	12.7	mm.
Velocity V	45	m/sec.
Density ρ	125	kg/m3.
Angle 'a'	45	Deg.
D.A.F. 'd'	2.0	

Equations:

$$F_x := d \rho \cdot A \cdot V^2 \cdot (1 - \cos(a))$$

$$F_y := -d \cdot \rho \cdot A \cdot V^2 \cdot \sin(a)$$

$$F_r := \sqrt{F_x^2 + F_y^2}$$

Results

Fx =	10.38	kN.
Fy =	-25.05	kN.
Fr =	27.12	kN.

Slug is assumed to fill the bend and to be of constant density.
Calculation is based on momentum.
Fr is the resultant force

Execute

This would normally be used to calculate a transient impact force due to the temporary passing of a liquid slug in a gas line. The dynamic factor of 2.0 is conservative and cannot be exceeded.

21.3 Linear Interpolation of Values

Interpolation of Values

This small program is intended to be used to interpolate values from tables such as ASME B31.3 allowable stresses, to obtain a value for stress at a particular temperature falling between given values.

Example:

ASME B31.3 Table A-1, A106 Gr. B at 730 deg F:

User value	Interpolate from table A-1:		Output:
730	700	16.5	14.4
	deg F	SE, ksi	
	750	13.0	

Interpolate

Input:	Interpolate between:		Output:
15460	16000	700	646.000
	15000	600	

Execute

The upper set of input cells is an example to guide the user.

21.4 Elongation of Straight Pipe Due To Internal Pressure

Pressure Elongation

This program calculates the axial pressure extension of a straight, uniform pipe subjected to internal pressure. It is assumed that longitudinal pressure stress may be simplified to $(Pd/4t)$

Base calc. on:

☐ Outside dia.

☒ Inside dia.

Outside Diameter Do mm

Wall Thickness t mm

Young's Modulus E MPa

Poisson's Ratio v

Internal Pressure P bar G

$$\epsilon = \left(\frac{P \cdot d}{2 \cdot t \cdot E} \right) \cdot \left(\frac{1}{2} - \nu \right)$$

Strain $\epsilon =$ mm/mm

Elongation of a 100m length of pipe = mm

The expansion of pipe due to pressure can be considerable and is not considered by some older stress analysis software.

This program allows a quick evaluation of the effect.

21.5 Methods of Assessing External Loads on Flanged Joints

Alternative Flange Moment Calcs
X

These calculation methods are included for completeness and for comparison with the equivalent pressure method .

Bolt Circle Dia.	C=	990.6	mm.	<div style="background-color: yellow; border: 1px solid black; padding: 5px;"> <p>Note that these methods do not address gasket type or seating stress, or loss of material due to corrosion or counterboring to match pipe</p> </div>
Area of one bolt	Ab(1)=	5645	mm2.	
Number of Bolts	nb=	16		
Gasket OD	Df =	727.1	mm.	
Design Pressure	P=	25	MPa.	
Flg. Yield Stress Sb, Sy=		245	MPa.	

ASME B31.8 Table E1 (14):

$$ML := \left(\frac{C}{4} \right) \cdot (Sb \cdot Ab - P \cdot Ap)$$

2.8896 e+6
N.m.

ASME III NB / NC-3658:

$$Mfd := \left[11250 \cdot Ab - \left(\frac{\pi}{16} \right) \cdot Df^2 \cdot Pfd \right] \cdot C \cdot \left(\frac{Sy}{36} \right)$$

4.28335 e+6
N.m.

$$Mfs := 3125 \cdot \left(\frac{Sy}{36} \right) \cdot C \cdot Ab$$

1.88988 e+6
N.m.

Execute

This program is provided for comparison purposes. It can be used as a stand-alone program here, or it can be called up from the flange analysis package when data will be loaded from the flange package.

22.0 PIPE DATA

22.1 Program Description

This program allows the user to click on a standard size pipe, or enter user defined data, and then calculates weight and technical data such a moment of inertia, pipe wall area and flow area for the given size.

Clicking on the SIF button provides stress intensification factors for the pipe defined, for elbows and various tees. A comparison is made between the ASME B31.3 values and CEN code values.

22.2 Typical Input and Data Screen

The screenshot displays the 'Pipe Data' software window. It features several sections for user input and data display:

- Units:** Radio buttons for 'Metric (SI)' (selected) and 'English'.
- Data Source:** Radio buttons for 'Standard dimensions' (selected) and 'User Input Dimensions'.
- Stress Intensification Factors:** A section with a 'Calculate Code sif's for various fittings' label and a yellow 'SIF's' button.
- Pipe Properties:** Fields for 'Pipe Area', 'Flow Area', 'Inertia I', and 'Modulus Z', each with a numerical input box and a unit (mm², mm², mm⁴, mm³).
- ANSI B36.10, B36.19 and API 5L Data:** A list of standard pipe sizes (1 in. Sch 5s, 1 in. Sch 10s, 1 in. Sch 40(s), 1 in. STD, 1 in. Sch 80(s), 1 in. XS, 1 in. Sch 160, 1 in. XXS, 1.5 in. Sch 5s) with a 'Selected pipe size:' label and a corresponding input field. Below this are 'Dia.' and 'Wt.' fields with numerical inputs and units (mm).
- User Input Dimensions:** Fields for 'Dia.' and 'Wt.' with numerical inputs and units (mm), and a 'Continue' button.
- Pipe Weights:** A table with columns for 'Dens. (kg/m3)', 'Thk. (mm.)', and 'Density and Thickness'. Rows include 'Pipe:', 'Fluid:', 'Insulation:', and 'Cladding:'. Each row has input fields for density and thickness. A yellow 'Density and Thickness' button is also present.
- Execute:** A button labeled 'Execute'.
- Net Weight:** A label 'Net Weight =' followed by a numerical input field and a unit (kg/m).
- Footer:** Includes an 'Add Titles and Print' button, a calculator icon, and a text box stating 'Calculated weights are quoted in kg/m (lb/ft) run of pipe.'

Bend Variables				Bend to ASME B31.3 App. D				Bend to CEN F1 and F3																																		
<input type="radio"/> 1.0 D <input checked="" type="radio"/> 1.5 D 533.4 mm <input type="radio"/> 3.0 D				<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>App. D calc.</th> <th>SIF's</th> </tr> </thead> <tbody> <tr> <td>Flex characteristic h</td> <td>0.359</td> <td></td> </tr> <tr> <td>Flex factor k</td> <td>4.598</td> <td>4.598</td> </tr> <tr> <td>In-plane SIFi</td> <td>1.782</td> <td>1.782</td> </tr> <tr> <td>Out of plane SIFo</td> <td>1.485</td> <td>1.485</td> </tr> </tbody> </table>					App. D calc.	SIF's	Flex characteristic h	0.359		Flex factor k	4.598	4.598	In-plane SIFi	1.782	1.782	Out of plane SIFo	1.485	1.485	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2">Table F-1</th> <th colspan="2">Table F-3</th> </tr> </thead> <tbody> <tr> <td>k</td> <td>4.598</td> <td>k</td> <td>4.598</td> </tr> <tr> <td>SIF</td> <td>1.782</td> <td>SIFi</td> <td>1.782</td> </tr> <tr> <td></td> <td></td> <td>SIFo</td> <td>1.485</td> </tr> </tbody> </table> <p>The CEN Code does not currently address the effects of pressure stiffening or flanged ends.</p>				Table F-1		Table F-3		k	4.598	k	4.598	SIF	1.782	SIFi	1.782			SIFo	1.485
	App. D calc.	SIF's																																								
Flex characteristic h	0.359																																									
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Table F-1		Table F-3																																								
k	4.598	k	4.598																																							
SIF	1.782	SIFi	1.782																																							
		SIFo	1.485																																							
User defined bend radius: <input type="radio"/> User 0.0 mm <input type="button" value="OK"/>				<input checked="" type="radio"/> No flanged ends <input type="radio"/> One flanged end <input type="checkbox"/> Include pressure stiffening <input type="radio"/> Both ends flanged																																						
Tees to 31.3 App. D																																										
		To ASME	Stub-in	Reinf. stub-in	Contour insert	Integral reinf.	Extruded																																			
Flex char. h		0.498	0.113	0.113	0.498	0.374	0.000																																			
In-plane SIFi		1.324	3.134	3.134	1.324	1.735	1.000																																			
Out plane SIFo		1.432	3.846	3.846	1.432	1.735	1.000																																			
Code notes		B16.9 tee note rx >= 0.125 x Db Tc >= 1.5 T		Contour insert note: rx >= 0.125 * Db Tc >= 1.5T		Extruded tee note: rx >= 0.05 x Db Tc < 1.5 x T																																				
Status		Not checked		Not checked		Not checked																																				
Tees to CEN Code Table F1 and F3																																										
Table F1 stress intensifications factors (one only for each type) are equal to ASME B31.3 App. D values for out of plane SIF's. Table F-3 values are equal to ASME B31.3 App. D values in all cases.																																										
Tee variables																																										
Crotch radius rx	0.0 mm																																									
rx is required to compute SIF's for an extruded tee to ASME B31.3																																										
Crotch thk. Tc	0.0 mm																																									
Reinf fab'd pad thk. Tp	0.0 mm																																									
Branch dia. Db	0.0 mm																																									
rx: 0.05Db =	0.																																									
rx: 0.125Db =	0.																																									
Tc: 1.5T =	28.58		<input type="button" value="OK"/>																																							
Pipe parameters																																										
Diameter	355.6 mm		Wall thk.	19.05 mm																																						

23.0 STANDARD COMPONENT DIMENSIONS

If the user clicks onto an equal size fitting alone, individual and compound dimensions for that pipe size to ASME B16.9 will be provided as shown below

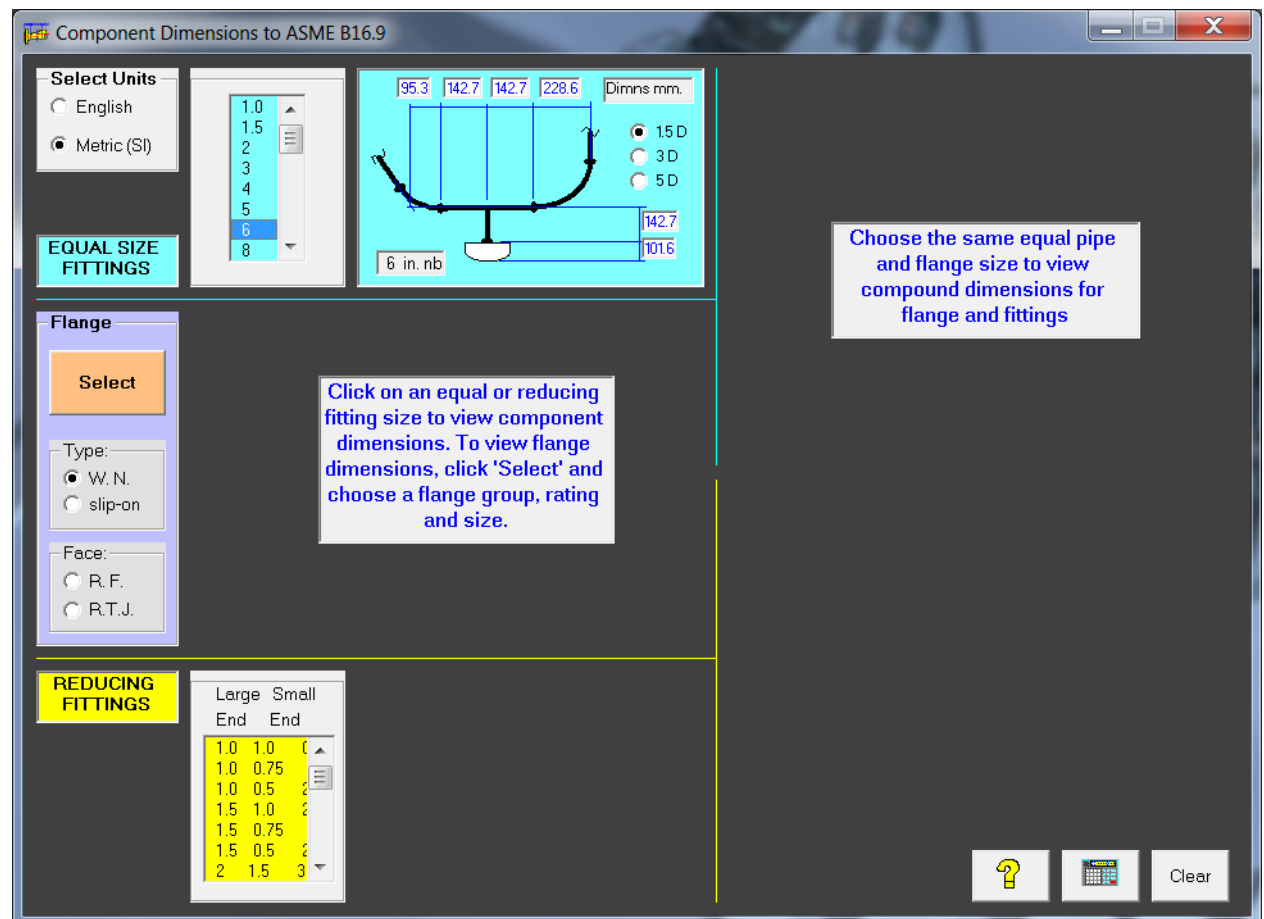
If a flange size alone is called up, dimensional data to ANSI B16.5, B16.47 or API 6A/B will be provided for that item alone.

Similarly, dimensions of reducing fittings may be obtained.

If a flange of the same nominal size as an equal fitting is called up, both the fitting and flange data will be provided on the same screen. In addition, fit-up dimensions for flanges and fittings will be available and shown below.

Also, if a reducing fitting small end matches the flange, compound dimensions will be available. This type of dimension string might well be expected at a control valve. Thus the ability to call up a trunnion support has been added to the dimension string

23.1 Equal Fittings Only



23.2 Equal Fitting and Flange Dimensions

Component Dimensions to ASME B16.9

Select Units
☐ English
☒ Metric (SI)

EQUAL SIZE FITTINGS

1.0
1.5
2
3
4
5
6
8

95.3 142.7 142.7 228.6 Dimms mm.
142.7 101.6
6 in. nb

Flange
Select

Type:
☒ W.N.
☐ slip-on

Face:
☒ R.F.
☐ R.T.J.

ASME B16.5
600 #
6 in. nominal
Raised face
Dimms mm.

355.600
292.100
215.900
6.350
47.803
69.545
12 bolts 25.400 THL= 123.698

REDUCING FITTINGS

Large End	Small End
1.0	1.0
1.0	0.75
1.0	0.5
1.5	1.0
1.5	0.75
1.5	0.5
2	1.5

352.298 218.998 323.9
266.398 6 in. 600 # 266.398 371.3
90+45 deg
Equal Size Compound dimensions (mm)

? Clear

23.3 Reducing Fitting and Flange Dimensions

Component Dimensions to ASME B16.9

Select Units
☐ English
☒ Metric (SI)

EQUAL SIZE FITTINGS

Flange
Select

Type:
☒ W.N.
☐ slip-on

Face:
☒ R.F.
☐ R.T.J.

ASME B16.5
150 #
12 in. nominal
Dimns mm.

14
16
18
20
22
24
26
28

482.600
431.800
381.000
1.524
31.750
81.026
12 bolts 22.225
THL= 114.3

REDUCING FITTINGS

Large End	Small End	
24	12	0
24	10	0
26	24	0
26	22	0
26	20	0
26	18	0
26	16	0

0.0 431.8 431.8 Dimns mm.

0.0 381.0
24 x 12 red. tee

Elbow dim's are based on 1.5D

24 x 12 reducing
150 #
0.0 Trunion

495.3

Red. Tee

Reducing Fitting Compound dimensions (mm)

Trunion ? Clear

24.0 VALVE DIMENSIONS TO ASME B16.10

A complete data base of all ASME B16.10 valve dimensions is included. The user needs only to click on a pipe size and valve type, to obtain in-line dimensional data for raised face and ring type joint constructions.

If a particular type or size is not available this will be flagged.

24.1 Typical Input and Data Screen

Valve dimensions to ASME B16.10

Select Units
☐ English
☒ Metric (SI)

Face
☒ R.F.
☐ R.T.J.

20 in. nb. 600 lb. Raised Face.

Dimensions in mm.

Select size and rating:

ASME B16.10	4	600
ASME B16.10	5	600
ASME B16.10	6	600
ASME B16.10	8	600
ASME B16.10	10	600
ASME B16.10	12	600
ASME B16.10	14	600
ASME B16.10	16	600
ASME B16.10	18	600
ASME B16.10	20	600
ASME B16.10	22	600
ASME B16.10	24	600

Select valve type:

Gate Valve	Swing Check
Plug valve	Wafer Check
Ball Valve	Angle Check
Butterfly valve	Lift Check
Angle Globe	Y-Type Globe
Std. Globe	Y-Type Check

Gate Valves

Solid Wedge Double Disc

Conduit

Short Pattern

1193.8

1193.8

1193.8

1193.8

1193.8

25.0 THERMAL EXPANSION OF PIPING MATERIALS

The data base contains thermal expansion data for common piping materials, extracted from ASME B31.3.

The base temperature and design temperature need to be entered and the relevant material must be clicked onto.

Expansion results are then produced in three forms.

This program is accessed by several other Pipemill routines.

25.1 Typical Input and Data Screen

The screenshot shows a software window titled "Thermal Expansion" with a close button (X) in the top right corner. The window contains the following elements:

- Units:** A section with two radio buttons: "English" (unselected) and "SI Units" (selected).
- Instructions:** A yellow text box stating: "Enter the Base Temperature, from which expansion (or contraction) will originate. Enter the Design Temperature for which the expansion rate is required. Select the required material from the list below. Values are taken from ASME B31.3."
- Design Temperature:** A text box labeled "DesignTemperature" containing the value "450" and a unit box labeled "Deg. C."
- Base Temperature:** A text box labeled "Base Temperature" containing the value "-5" and a unit box labeled "Deg. C."
- Material Selection:** A list box containing the following materials: "Carbon Steel", "Moly Steel", "Low Chrome to 3Cr-Mo", "5Cr-Mo thru 9Cr-Mo Steel", and "Austenitic Stainless". The "Austenitic Stainless" option is currently selected and highlighted in blue.
- Results:** Three rows of output data:
 - Lin. Thermal Expansion: 819.5800 mm. per 100m.
 - Lin. Thermal Expansion: 8.1958e-3 mm. per mm.
 - Unit Thermal Expansion: 1.80127e-5 per deg. C.
- Execute Button:** A button labeled "Execute" located in the bottom right corner of the window.