The *FASTEST* Solutions for Piping Design and Analysis.

# Readme Supplement

# CAEPIPE

## Version 7.30

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## Annexure A

# PCF Export

# PCF Export

CAEPIPE can export model data from inside the Layout window to a PCF file with the extension .pcf (piping component file). To export a model, select the menu command File > Export to PCF… from the Layout window.

This section brings out the details on how each element and data from CAEPIPE are exported to PCF file. The stress layout developed in CAEPIPE with Y axis vertical is automatically translated to be Z axis as vertical when the layout is exported to PCF file.

## Limitations

The Element types and Data types listed below are not transferred to PCF at this time.

### Element Types

1. Ball Joint
2. Beam
3. Elastic Element
4. Hinge Joint
5. Tie Rod
6. Comment and
7. Hydrotest Load

### Data Types

1. Concentrated Mass
2. Force
3. Harmonic Load
4. Jacket End Cap
5. Spider
6. Threaded Joint
7. Time Varying Load
8. User SIF and
9. Weld

## Units

The stress system will be exported to PCF in SI units, when the Length unit selected in CAEPIPE for a stress layout is “m” or “mm”. Otherwise, the stress layout will be exported to PCF in English units. The table below provides the details on English and SI units used while exporting to PCF.

| Sl. No. | Description of Units | English Units | SI Units |
|---|---|---|---|
| 1. | Length | inch | mm |
| 2. | Dimension | inch | mm |
| 3. | Angle | degree | degree |
| 4. | Weight | Lb | kg |
| 5. | Density | lb/in3 | Kg/m3 |
| 6. | Temperature | deg. F | deg. C |
| 7. | Pressure | psi | bar |
| 8. | Stiffness | lb/inch | N/mm |
| 9. | Rotational Stiffness | in-lb/deg | Nm/deg |

## Basic Header Information

The Basic Header Information attributes that defines the control file identifier and various Units that are used to specify Bores, Co-ordinates, Bolt Diameters, Bolt Lengths and Weights while exporting PCF file are provided below for both English and SI Units.

*ISOGEN-FILES ISOGEN.FLS*
*UNITS-BORE INCH / MM*
*UNITS-CO-ORDS INCH / MM*
*UNITS-WEIGHT LBS/KGS*
*UNITS-BOLT-DIA INCH/MM*
*UNITS-BOLT-LENGTH INCH/MM*

In addition to the above, the layout of stress system is always exported to PCF as a System Isometric using the identifier “SYSTEM-ISOMETRIC-REFERENCE” as the stress system may generally contain one or more individual pipelines that are physically connected in such a way that they form a network.

Additional optional attributes which relate to the “System” are not written to the PCF file at this time.

## Pipeline Header Information

Each “From” node defined in CAEPIPE is exported to PCF as a PIPELINE-REFERENCE attribute with its value set to “P” followed by the From Node number used in CAEPIPE.

The Temperature (T1) and Pressure (P1) defined in CAEPIPE for the element followed by the From node is written to PCF using the attributes “PIPELINE-TEMP” and ATTRIBUTE1 respectively in English or SI units as shown below.

For example, a From Node 10 in CAEPIPE with Temperature (T1 = 200 C) and Pressure (P1 = 10 bar) of the element following the “From” node is exported to PCF as

*PIPELINE-REFERENCE P10*
*PIPELINE-TEMP 200*
*ATTRIBUTE1 10*

## Component Identifiers

Each piping component from CAEPIPE is exported to PCF in a self-contained data block that consists of a “Component Identifier” together with a list of attributes that help to identify component location, size and specific requirements related to a physical component in a pipeline.

This section provides in details on how each piping component (element) from CAEPIPE is transferred to PCF along with their list of attributes. Each component from CAEPIPE is exported to PCF with Mandatory attributes, Material Information Attributes and Supplementary Information Attributes. The supplementary information attributes of each component will have eight (8) COMPONENT-ATTRIBUTES as shown in the table below.

| Sl. No. | Component Attribute in PCF | CAEPIPE Attribute | English Units | SI Units |
|---|---|---|---|---|
| 1. | COMPONENT-ATTRIBUTE1 | Section Outer Diameter | ‘inch’ | ‘mm’ |
| 2. | COMPONENT-ATTRIBUTE2 | Section Wall Thickness | ‘inch’ | ‘mm’ |
| 3. | COMPONENT-ATTRIBUTE3 | Section Corrosion Allowance | ‘inch’ | ‘mm’ |
| 4. | COMPONENT-ATTRIBUTE4 | Section Mill tolerance | % | % |
| 5. | COMPONENT-ATTRIBUTE5 | Section Insulation Density | ‘lb/in3’ | ‘kg/m3’ |
| 6. | COMPONENT-ATTRIBUTE6 | Section Insulation Thickness | ‘inch’ | ‘mm’ |
| 7. | COMPONENT-ATTRIBUTE7 | Temperature T1 | ‘deg. F’ | ‘deg. C’ |
| 8. | COMPONENT-ATTRIBUTE8 | Pressure P1 | ‘psi’ | ‘bar’ |

The co-ordinates for all components and supports are transferred in ‘inch’ for English Units and ‘mm’ for SI Units. Similarly, size attribute is transferred in ‘inch’ for English Units and ‘mm’ for SI Units. The material type and grade for each component is transferred to PCF through ITEM CODE.

## Element types from CAEPIPE

### Pipe

Pipe element from CAEPIPE is transferred to PCF as “PIPE” along with their attributes as shown below.

The absolute co-ordinate corresponding to “From” and “To” node is written to “END-POINT” attribute.

For standard pipe sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) defined for the element via section property is written to “Size” attribute in “inch” for English Units and “mm” for SI Units. For non-standard pipe sizes, OD defined for the element via section property is written to “Size” attribute.

The material properties (Name and Grade) defined for the element via “Material” property is written to PCF using the “ITEM-CODE” attribute.

Section properties of pipe element such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to “COMPONENT-ATTRIBUTE1” through “COMPONENT-ATTRIBUTE6” as explained in the Table above.

Temperature T1 and Pressure P1 defined for the pipe element via “Load” property is written to “COMPONENT-ATTRIBUTE7” and “COMPONENT-ATTRIBUTE8” respectively as explained in the Table above.

The element properties other than those listed above are ignored and not transferred to PCF at this time.

**Component Identifier**

***PIPE***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |

## Jacketed Pipe

The Core Pipe of Jacketed Pipe element of CAEPIPE is transferred to PCF as “PIPE” along with their attributes as explained above. The Jacketed Pipe details are not transferred to PCF at this time as there is no provision available in PCF.

## Bend

Bend element from CAEPIPE is transferred to PCF as “ELBOW” along with their attributes as shown below.

The co-ordinate corresponding to “Near” and “Far End” nodes (referred in CAEPIPE as Node number suffixed with A and B) are written to “END-POINT” attributes. The co-ordinate corresponding to “TIP” from CAEPIPE is written to “CENTRE-POINT” attribute of PCF.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) defined for the element via section property is written to “Size” attribute in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD defined for the element via section property is written to “Size” attribute.

The material properties (Name and Grade) defined for the element via “Material” property is written to PCF using the “ITEM-CODE” attribute.

The value of SKEY is written as “ELBW”.

Section properties of element (defined via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to “COMPONENT-ATTRIBUTE1” through “COMPONENT-ATTRIBUTE6” as explained above.

Temperature T1 and Pressure P1 defined for the bend element via “Load” property is written to “COMPONENT-ATTRIBUTE7” and “COMPONENT-ATTRIBUTE8” respectively as explained above.

Bend radius [inch/mm] and Angle [deg] defined for bend element in CAEPIPE are transferred to “BEND-RADIUS” and “BEND-ANGLE” respectively.

The properties other than those explained above are ignored and not transferred to PCF at this time.

**Component Identifier**

***BEND***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |

#### Material Information Attributes

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | |
| SKEY ELBW | |

#### Supplementary Information Attributes

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |
| BEND-RADIUS | data |
| BEND-ANGLE | data |

### Miter Bend

Miter Bend element from CAEPIPE is transferred to PCF as “ELBOW” along with their attributes as explained above. In addition, the value of SKEY is written as “BEBW” instead of ”ELBW”.

### Jacketed Bend

The Core Bend of Jacketed Bend element of CAEPIPE is transferred to PCF as “ELBOW” along with their attributes as explained above. The Jacketed Bend details are not transferred to PCF at this time as no provision is available in PCF.

### Valve

Valve element from CAEPIPE is transferred to PCF as “VALVE” along with their attributes as shown below.

The co-ordinate corresponding to “From” and “To” node is written to “END-POINT” attributes.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) defined for the valve element via section property is written to “Size” attribute in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD defined for the valve element via section property is written to “Size” attribute.

The material properties (Name and Grade) defined for the valve element via “Material” property is written to PCF using the “ITEM-CODE” attribute.

The value of SKEY is written as “VG**” for Gate and Globe Valve, “CK**” for Check Valve, “ZB**” for Butterfly Valve, “VC**” for Control Vale, “VB**” for Ball Valve and “VP**” for Plug Valve. For valve types other than those explained above, the SKEY is written as “VS**”.

Section properties of valve element (defined via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to “COMPONENT-ATTRIBUTE1” through “COMPONENT-ATTRIBUTE6” as explained above.

Temperature T1 and Pressure P1 defined for the valve element via “Load” property is written to “COMPONENT-ATTRIBUTE7” and “COMPONENT-ATTRIBUTE8” respectively as explained above.

Empty weight of valve is transferred to “WEIGHT” attribute in ‘lb’ for English Units and ‘kg’ for SI Units.

The valve properties other than those explained above are ignored and not transferred to PCF at this time.

#### Component Identifier

***VALVE***

#### Mandatory Attributes

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

#### Material Information Attributes

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | data |

#### Supplementary Information Attributes

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |
| WEIGHT | data |

### Reducer

Reducer element from CAEPIPE is transferred to PCF as "REDUCER-CONCENTRIC" along with their attributes as shown below.

The co-ordinate corresponding to "From" and "To" node is written to "END-POINT" attributes.

For standard component sizes, the Nominal Sizes (NS) corresponding to Outer Diameter 1 (OD1) and Outer Diameter 2 (OD2) of Reducer element are written to "Size" attributes in "inch" for English Units and "mm" for SI Units. For non-standard component sizes, OD1 and OD2 of reducer element are written to "Size" attributes.

The material properties (Name and Grade) defined for the reducer element via "Material" property is written to PCF using the "ITEM-CODE" attribute.

The value of SKEY is written as "RCBW".

Section properties defined for the Reducer element (via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to "COMPONENT-ATTRIBUTE1" through "COMPONENT-ATTRIBUTE6" as explained above.

Temperature T1 and Pressure P1 defined for the valve element via "Load" property is written to "COMPONENT-ATTRIBUTE7" and "COMPONENT-ATTRIBUTE8" respectively as explained above.

The reducer properties other than those explained above are ignored and not transferred to PCF at this time.

#### Component Identifier

***REDUCER-CONCENTRIC***

#### Mandatory Attributes

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

#### Material Information Attributes

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | RCBW |

#### Supplementary Information Attributes

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |

## Bellows / Slip Joint / Cut-Pipe

Bellow / Slip Joint / Cut-pipe from CAEPIPE are transferred to PCF as “MISC-COMPONENT” along with their attributes as shown below.

The co-ordinate corresponding to “From” and “To” node of the element is written to “END-POINT” attributes.

The mid-point computed using the “From” and “To” node of the element is written to “CENTRE-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element is written to “Size” attribute.

The material properties (Name and Grade) defined for the element via “Material” property is written to PCF using the “ITEM-CODE” attribute.

The SKEY attribute is written as EXPJ, SLIP and CUTP for Bellows, Slip Joint and Cut-Pipe respectively.

Section properties defined for the element (via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to “COMPONENT-ATTRIBUTE1” through “COMPONENT-ATTRIBUTE6” as explained above.

Temperature T1 and Pressure P1 defined for the element via “Load” property is written to “COMPONENT-ATTRIBUTE7” and “COMPONENT-ATTRIBUTE8” respectively as explained above.

Empty weight of bellow is transferred to “WEIGHT” attribute in ‘lb’ for English Units and ‘kg’ for SI Units.

The properties other than those explained above are ignored and not transferred to PCF at this time for Bellows / Slip Joint / Cut-Pipe.

**Component Identifier**

***MISC-COMPONENT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | EXPJ / SLIP / CUTP |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |
| WEIGHT | data [only for Bellows] |

## Flange

Rigid element (with length < OD) and Flange from CAEPIPE is transferred to PCF as “FLANGE” along with their attributes as shown below.

For rigid element, the co-ordinate corresponding to “From” and “To” node is written to “END-POINT” attributes. On the other hand, for flange, the co-ordinate corresponding to flange node is written to “END-POINT” attributes. As the length of flange is zero in CAEPIPE (being a nodal property), both “END-POINT” attributes will have the same values.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the rigid element / flange defined via section property is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the rigid element / flange is written to “Size” attribute.

The material properties (Name and Grade) defined for the rigid element / flange via “Material” property is written to PCF using the “ITEM-CODE” attribute.

The SKEY attribute is written as “FL**”.

Section properties defined for the rigid element / flange (via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to “COMPONENT-ATTRIBUTE1” through “COMPONENT-ATTRIBUTE6” as explained above.

Temperature T1 and Pressure P1 defined for the rigid element / flange via “Load” property is written to “COMPONENT-ATTRIBUTE7” and “COMPONENT-ATTRIBUTE8” respectively as explained above.

Empty weight of rigid element / flange is transferred to “WEIGHT” attribute in ‘lb’ for English Units and ‘kg’ for SI Units.

The properties other than those explained above are ignored and not transferred to PCF at this time

**Component Identifier**

***FLANGE***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | FL** |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |
| WEIGHT | data |

## Rigid

Rigid element from CAEPIPE is transferred to PCF as “INSTRUMENT” along with their attributes as shown below when the length of the rigid element is greater than the outer diameter (OD) of the element. On the other hand, when the length is less than OD of the element, then the same is transferred as “FLANGE” to PCF as explained above.

The co-ordinate corresponding to “From” and “To” node of the element is written to “END-POINT” attributes.

The mid-point computed using the “From” and “To” node of the element is written to “CENTRE-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element is written to “Size” attribute.

The material properties (Name and Grade) defined for the element via “Material” property is written to PCF using the “ITEM-CODE” attribute.

The SKEY attribute is written as “INST”.

Section properties defined for the element (via section property) such as OD, Wall Thickness, Corrosion Allowance, Mill tolerance, Insulation Density and Insulation Thickness are written to "COMPONENT-ATTRIBUTE1" through "COMPONENT-ATTRIBUTE6" as explained above.

Temperature T1 and Pressure P1 defined for the valve element via "Load" property is written to "COMPONENT-ATTRIBUTE7" and "COMPONENT-ATTRIBUTE8" respectively as explained above.

Empty weight of rigid element is transferred to "WEIGHT" attribute in 'lb' for English Units and 'kg' for SI Units.

The properties other than those explained above are ignored and not transferred to PCF at this time.

**Component Identifier**

***INSTRUMENT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | INST |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |
| COMPONENT-ATTRIBUTE5 | data |
| COMPONENT-ATTRIBUTE6 | data |
| COMPONENT-ATTRIBUTE7 | data |
| COMPONENT-ATTRIBUTE8 | data |
| WEIGHT | data |

## Data Types from CAEPIPE

### Anchor

Anchor from CAEPIPE is transferred to PCF as "Support" along with the attributes as shown below. The co-ordinate value corresponding to Anchor node is written to "END-POINT" attribute.

The SKEY attribute is written as "ANCH".

The stiffnesses and specified displacements defined in CAEPIPE for Anchor are ignored at this time.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | ANCH |

## Branch SIF

Branch SIF with their sub-types are transferred from CAEPIPE to PCF as given below.

| Sl. No. | Sub-Type of Branch SIF | Component Identifier in PCF |
|---|---|---|
| 1. | Welding TEE | TEE |
| 2. | Reinforced Fabricated Tee | TEE-SET-ON |
| 3. | Unreinforced Fabricated Tee | TEE-SET-ON |
| 4. | Others | TEE-STUB |

As Branch SIF in CAEPIPE is assigned to a node, the co-ordinate value corresponding to “Branch SIF” node is written to “END-POINT”, “CENTRE-POINT” and “BRANCH1-POINT” attributes.

For standard component sizes, the Nominal Size (NS) corresponding to Run Pipe Outer Diameter (OD1) and Branch Pipe Outer Diameter (OD2) of the element is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD1 and OD2 of the element are written to “Size” attributes.

The material properties (Name and Grade) defined for the element via “Material” property on which the Branch SIF is located is written to PCF using the “ITEM-CODE” attribute.

**Component Identifier**

***TEE***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| END-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |
| *BRANCH1-POINT* | *E/W co-ords* | *N/S co-ords* | *Elevation co-ords* | *Size* |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | TEBW |

### Reinforced / Unreinforced Fabricated Tee

**Component Identifier**

***TEE-SET-ON***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| BRANCH1-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | TESO |

### Other Tees

**Component Identifier**

***TEE-STUB***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| BRANCH1-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | Size |
| CENTRE-POINT | E/W co-ords | N/S co-ords | Elevation co-ords | |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | TSSO |

### Guide

Guide from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Guide node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the guide is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The Friction, Stiffness [lb/in or N/mm] and Gap [in or mm] defined at Guide are transferred to “COMPONENT-ATTRIBUTE1”, “COMPONENT-ATTRIBUTE2” and “COMPONENT-ATTRIBUTE3” respectively.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | GUI |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |

### Hanger

Hanger from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Hanger node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the hanger is located is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The SKEY attribute is written as “SPRG”.

The hanger type and number of hangers entered in CAEPIPE are transferred to “COMPONENT-ATTRIBUTE1” and “COMPONENT-ATTRIBUTE2 respectively.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | SPRG |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |

### User Hanger

User Hanger from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to User Hanger node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the user hanger is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The SKEY attribute is written as “HANG”.

The Spring Stiffness [lb/in or N/mm], Number of hangers, Load [lb or N] and load type [HOT or COLD] defined at User Hanger are transferred to “COMPONENT-ATTRIBUTE1”, “COMPONENT-ATTRIBUTE2”, “COMPONENT-ATTRIBUTE3” and “COMPONENT-ATTRIBUTE4” respectively.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | HANG |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |

### Rod Hanger

Rod Hanger from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Rod Hanger node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the rod hanger is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The SKEY attribute is written as “ROD”.

The Number of hangers defined at Rod hanger of CAEPIPE is transferred to “COMPONENT-ATTRIBUTE1”.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | ROD |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |

### Constant Support

Constant Support from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Constant Support node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the constant support is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The SKEY attribute is written as “CS”.

The Number of hangers defined at this support in CAEPIPE is transferred to “COMPONENT-ATTRIBUTE1”.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | CS |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |

### Limit Stop

Limit Stop from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Limit Stop node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the limit stop is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The Upper Limit [in or mm], Lower Limit [in or mm], Stiffness [lb/in or N/mm] and Friction defined at Limit Stop are transferred to “COMPONENT-ATTRIBUTE1”, “COMPONENT-ATTRIBUTE2”, “COMPONENT-ATTRIBUTE3” and “COMPONENT-ATTRIBUTE4” respectively. The value of SKEY attribute is written as LSX when the direction is defined as (1.0, 0.0, 0.0), LSY when the direction is defined as (0.0,1.0, 0.0), LSZ when the direction is defined as (0.0, 0.0, 1.0) and LIM for other directions.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | LIM / LSX /LSY / LSZ |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |
| COMPONENT-ATTRIBUTE2 | data |
| COMPONENT-ATTRIBUTE3 | data |
| COMPONENT-ATTRIBUTE4 | data |

### Nozzle

Nozzle from CAEPIPE is transferred to PCF as “Nozzle” along with the attributes as shown below.

The co-ordinate value corresponding to Nozzle node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the nozzle is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

**Component Identifier**

***NOZZLE***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

### Restraint

Restraint from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Restraint node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the restraint is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The SKEY value will be filled with type of “Restraint” defined in CAEPIPE. For example, X and Z defined at a “Restraint” in CAEPIPE will be written to SKEY of PCF as “XZ”

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | data |

### Skewed Restraint

Skewed Restraint from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Skewed Restraint node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the skewed restraint is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

Translational Stiffness [lb/in or N/mm] or Rotational Stiffness [in-lb/deg or N-m/deg] defined in CAEPIPE will be transferred to COMPONENT-ATTRIBUTE1 of PCF. The value of SKEY is filled as TX, TY and TZ for Translational Restraint defined in X, Y and Z directions respectively. Similarly, for Rotational Restraint, the value of SKEY is filled as RX, RY and RZ for Rotational Restraint defined in X, Y and Z directions respectively. For Translational and Rotational Restraint defined in directions other than X, Y and Z, the value of SKEY is filled as “SKEW”.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | TX/TY/TZ / RX/RY/RZ/SKEW |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |

### Snubber

Snubber from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Snubber node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the snubber is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

Stiffness [lb/in or N/mm] defined in CAEPIPE will be transferred to COMPONENT-ATTRIBUTE1 of PCF. The value of SKEY is filled as XSNB, YSNB and ZSNB for snubber defined in X, Y and Z directions respectively. For direction of snubber other than X, Y and Z, the value is written as “SNUB”.

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | XSNB / YSNB / ZSNB /SNUB |

**Supplementary Information Attributes**

| | |
|---|---|
| COMPONENT-ATTRIBUTE1 | data |

### Generic Support

Generic Support from CAEPIPE is transferred to PCF as “Support” along with the attributes as shown below.

The co-ordinate value corresponding to Generic Support node is written to “END-POINT” attribute.

For standard component sizes, the Nominal Size (NS) corresponding to Outer Diameter (OD) of the element in which the generic support is defined is written to “Size” attributes in “inch” for English Units and “mm” for SI Units. For non-standard component sizes, OD of the element are written to “Size” attribute.

The stiffnesses defined in CAEPIPE for Generic Support are ignored at this time

**Component Identifier**

***SUPPORT***

**Mandatory Attributes**

| | | | | |
|---|---|---|---|---|
| CO-ORDS | E/W co-ords | N/S co-ords | Elevation co-ords | Size |

**Material Information Attributes**

| | |
|---|---|
| ITEM-CODE | data |
| FABRICATION-ITEM | data |
| SKEY | GNSP |

## Annexure B

# Pressure Design of Pipe and Pipe Fittings according to EN 13480-3 (2012)

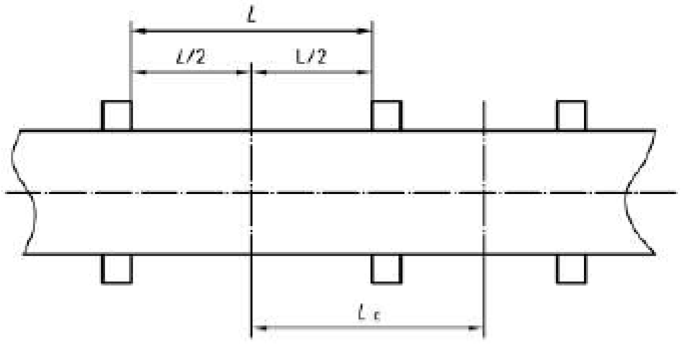
## Pressure Design of Pipe and Pipe Fittings according to EN 13480-3 (2012)

Pressure Design of Pipe and Pipe Fittings can be performed using the pre-processor modules added in CAEPIPE which are independent of the flexibility analysis.

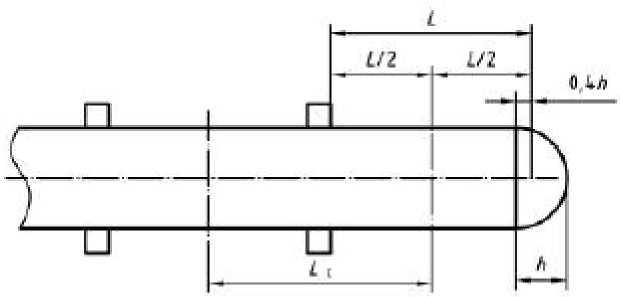
These modules can be launched through Layout frame > Misc > Internal Pressure Design: EN 13480-3 and Layout frame > Misc > External Pressure Design: EN 13480-3 respectively.

Internal pressure design calculations of pipe and pipe fittings according to EN 13480-3 are independent of lengths of pipes defined in CAEPIPE stress model. Hence, these calculations can be performed directly from the existing stress model developed for flexibility analysis.

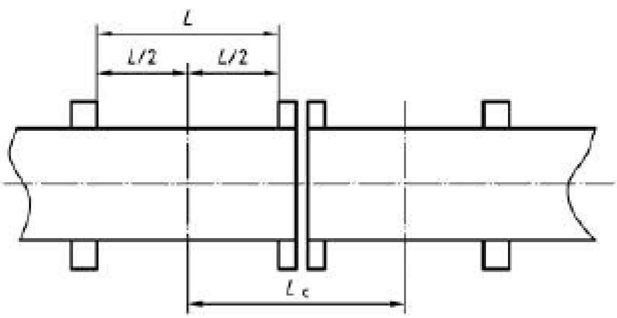
On the other hand, the external pressure design requires the calculation of collapse pressure, which is a function of length between the stiffeners placed on the piping (shown in figures below). Hence, ensure that the nodes are defined in CAEPIPE model only at locations where the stiffeners are provided along the piping in the field. In other words, the existing CAEPIPE stress model (developed for flexibility analysis) need to be edited before performing the external pressure design.



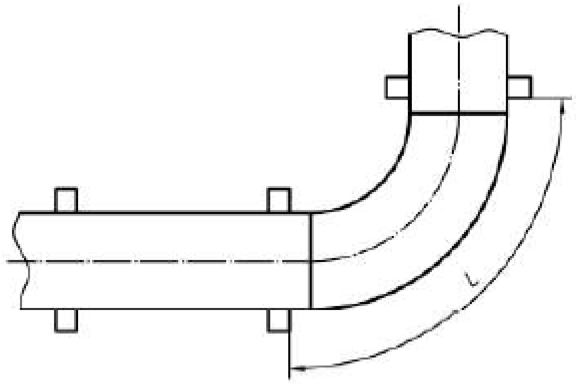

**Single Pipe**



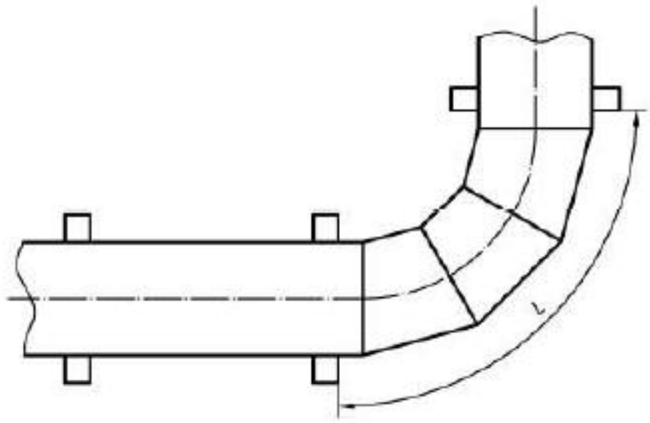

**Pipe with bend**




**Pipe with flange connections**




**Pipe with bend or elbow with ‘L’ measured on extrados**




**Pipe with mitre with ‘L’ measured on extrados**

The procedure given below will help in removing the additional nodes defined for support locations (for flexibility analysis) from the CAEPIPE stress model prior to External Pressure Design Calculations.

1. Create a copy of the existing CAEPIPE stress model (developed for flexibility analysis).
2. Navigate to the required element node in the layout window and use the option “Combine…” through Layout window > Edit.
3. Repeat Step 2 above and remove all other nodes where there are no stiffeners defined.
4. Upon completion, save the model.
5. Launch “External Pressure Design: EN 13480-3” through Layout window > Misc.

# Internal Pressure Design of Pipe and Pipe Fittings according to EN 13480-3 (2012)

# Design of pipe and pipe fittings under internal pressure according to EN 13480-3 (2012)

## Straight Pipes

The minimum required wall thickness for a straight pipe without allowances and tolerances, ep, is calculated from equation 6.1-1 and 6.1-3 depending on the ratio between inner and outer diameter as follows:

For $D_o/D_i$ <= 1.7

$$ep = \frac{P_c D_0}{2fz + P_c}$$

For $D_o/D_i$ > 1.7

$$ep = \frac{D_o}{2}\left[1 - \sqrt{\frac{fz - p_c}{fz + p_c}}\right]$$

where,

$D_o$ = outside diameter of pipe

$D_i$ = inside diameter of pipe = Do – 2 x $e_n$

$e_n$ = nominal wall thickness of pipe

f = Allowable stress for material at maximum temperature

z = weld efficiency factor = 1.0

$p_c$ = maximum pressure = maximum of CAEPIPE input pressures P1 through P10

$e_p$ = minimum required wall thickness

## Elbows

The minimum required wall thickness of the intrados and the extrados of the elbow without allowances and tolerances, ep1 / ep2, is calculated from equation B.4.1-3

ep1 = ep2 = e.B

$$B = \frac{D_0}{2e} - \frac{R}{e} + \sqrt{\left[\frac{D_0}{2e} - \frac{R}{e}\right]^2 + 2\frac{R}{e} - \frac{D_0}{2e}}$$

where

$D_o$ = outside diameter of elbow

e = minimum required wall thickness of corresponding straight pipe computed as per Eq. 6.1-1 or 6.1-3

R = radius of the elbow

ep1 = ep2 = minimum required wall thickness of the elbow

## Bends (formed by cold bending of straight pipes)

### Wall thickness of the intrados of the bend

The minimum required wall thickness of the intrados of the bend without allowances and tolerances, ep1, is calculated from equation B.4.1-1

ep1 = e . $B_{int}$

$$B_{int} = \frac{D_0}{2e} + \frac{r}{e} - \left[\frac{D_o}{2e} + \frac{r}{e} - 1\right]\sqrt{\frac{\left(\frac{r}{e}\right)^2 - \left(\frac{D_o}{2e}\right)^2}{\left(\frac{r}{e}\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)}}$$

r/e is calculated from

$$\frac{r}{e} = \sqrt{\frac{1}{2}\left\{\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right\} + \sqrt{\frac{1}{4}\left(\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)\left(\frac{R}{e}\right)^2}}$$

where

$D_o$ = outside diameter of bend

$D_i$ = inside diameter of bend = Do – 2 x $e_n$

e = minimum required wall thickness of corresponding straight pipe computed as per Eq. 6.1-1 or 6.1-3

R = radius of the bend

$e_{p1}$ = minimum required wall thickness of the intrados

### Wall thickness of the extrados of the bend

The minimum required wall thickness of the extrados of the bend without allowances and tolerances, ep2, is calculated from equation B.4.1-8

$$ep2 = e \,.\, B_{ext}$$

$$B_{ext} = \frac{D_0}{2e} - \frac{r}{e} - \left[\frac{D_o}{2e} - \frac{r}{e} - 1\right]\sqrt{\frac{\left(\frac{r}{e}\right)^2 - \left(\frac{D_o}{2e}\right)^2}{\left(\frac{r}{e}\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)}}$$

r/e is calculated from

$$\frac{r}{e} = \sqrt{\frac{1}{2}\left\{\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right\} + \sqrt{\frac{1}{4}\left(\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)\left(\frac{R}{e}\right)^2}}$$

where

$D_o$ = outside diameter of bend

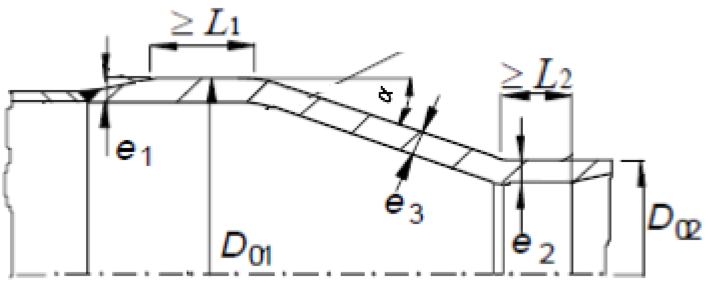
$D_i$ = inside diameter of bend = Do – 2 x $e_n$

e = minimum required wall thickness of corresponding straight pipe computed as per Eq. 6.1-1 or 6.1-3

R = radius of the bend

$e_{p2}$ = minimum required wall thickness of the extrados

## Reducers




### Junction between the large end of a cone and a cylinder without a knuckle

The minimum required wall thickness ($e_1$) of the larger cylinder adjacent to the junction is calculated from Subsection 6.4.6.2 as the greater of $e_{cyl}$ and $e_j$ where $e_j$ is determined from

$$\beta = \frac{1}{3}\sqrt{\frac{D_c}{e_j}}\frac{\tan \propto}{1+\frac{1}{\sqrt{\cos \propto}}} - 0.15 \qquad (Eq. 6.4.6-2)$$

$$e_j = \frac{p_{c\beta D_c}}{2f} \qquad (Eq. 6.4.6-1)$$

The value of $e_j$ is acceptable, if the value given by Eq. 6.4.6-1 is not less than that assumed in Eq. 6.4.6-2

$$e_{con} = \frac{p_c D_e}{2fZ + p_c}\frac{1}{COS(\alpha)} \qquad (Eq. 6.4.4-2)$$

$$\mathrm{e_{cyl}} = \frac{\mathrm{p_c D_{01}}}{\mathrm{2fZ+p_c}}$$

$$e_1 = thickness\ of\ larger\ cylinder = max(e_j, e_{cyl})$$

$$e_3 = thickness\ of\ cone\ shell = max(e_j, e_{con})$$

where

$D_e$ = outside diameter of the cone

$D_{01}$ = outside diameter of the larger cylinder

$D_{02}$ = outside diameter of the small cylinder

$D_c$ = mean diameter of the larger cylinder at the junction with the cone = $D_{01}$ - $e_n$

$e_n$ = nominal wall thickness of the larger cylinder at the junction with the cone

∝ = cone angle

$e_1$ = minimum required wall thickness for larger cylinder adjacent to the junction.

$e_3$ = minimum required wall thickness at cone.

f = Allowable stress for material at maximum temperature

$p_c$ = maximum pressure = maximum of CAEPIPE input pressures P1 through P10

Z = weld efficiency factor = 1.0

### Junction between the small end of a cone and a cylinder without a knuckle

The minimum required wall thickness ($e_2$) of the small cylinder adjacent to the junction is calculated according to Subsection 6.4.8.2 as follows.

$$s = \frac{e_3}{e_{j2}}$$

With $e_3$ already determined in the earlier section, assume value of $e_{j2}$ and calculate the values of $s, \tau$ and $\beta_H$

When s < 1.0, then

$$\tau = s\sqrt{\frac{s}{cos \propto}} + \sqrt{\frac{1+s^2}{2}}$$

When s >= 1.0, then

$$\tau = 1 + \sqrt{s\frac{1+s^2}{2cos \propto}}$$

$$\beta_H = 0.4\sqrt{\frac{D_c}{e_{j2}}\frac{tan \propto}{\tau}} + 0.5 \qquad (Eq.\ 6.4.8-4)$$

$$e_{j2} = \frac{p_c D_c \beta_H}{2fZ} \qquad (Eq. 6.4.8-5)$$

The value of $e_{j2}$ is acceptable, if the value given by Eq. 6.4.8-5 is not less than that assumed for Eq. 6.4.8-4

$$e_{cyl} = \frac{p_c D_{02}}{2fZ + p_c}$$

$$e_2 = max(e_{j2}, e_{cyl})$$

where

$D_{02}$ = outside diameter of the small cylinder at the junction with the cone

$D_c$ = mean diameter of the small cylinder at the junction with the cone = $D_{02}$ - $e_n$

$e_n$ = nominal wall thickness of the small cylinder at the junction with the cone

∝ = cone angle

$e_2$ = minimum required wall thickness of the small cylinder at the junction with the cone

f = Allowable stress for material at maximum temperature

$p_c$ = maximum pressure = maximum of CAEPIPE input pressures P1 through P10

Z = weld efficiency factor = 1.0

# Verification and Validation
# for Internal Pressure Design of Pipe and Pipe Fittings

## Straight Pipe due to Internal Pressure
## according to SS-EN 13480-3:2012 (E) Issue 1 (2012-06), Chapter 6.1

**General**

| | |
|---|---|
| Material | EN 10216-2 10CrMo9-10 W1.7380 |
| Design Temperature (Deg.C) | $T_d$ |
| Design Stress (MPa) | $f$ |
| Design Pressure (MPa) | $P_c$ |
| Weld efficiency factor for longitudinal weld (Z) | 1.00 |
| Outer Diameter (mm) | $D_o$ |
| Nominal Wall Thickness in Straight Pipe (mm) | $e_{nom}$ |
| Corrosion Allowance (mm) | $C_0$ = 1.00 |
| Negative Tolerance | $C_1$ |
| Thinning allowance due to manufacturing | $C_2$ |

Set parameter "Uniform Bend" below to "Yes" or "No" or "NA"

**Input**

| | | | |
|---|---|---|---|
| | 25 | | 221 |
| | 50 | | 221 |
| DN := | 150 | Td := | 221 |
| | 200 | | 221 |
| | 300 | | 221 |
| | 350 | | 221 |
| | 400 | | 221 |
| | 500 | | 221 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25 | | | 132.8 | | | 2.26 |
| | 50 | | | 132.8 | | | 2.26 |
| DN := | 150 | | f := | 132.8 | | Pc := | 2.26 |
| | 200 | | | 132.8 | | | 2.26 |
| | 300 | | | 132.8 | | | 2.26 |
| | 350 | | | 132.8 | | | 2.26 |
| | 400 | | | 132.8 | | | 2.26 |
| | 500 | | | 132.8 | | | 2.26 |
| | | | | | | | |
| | 25 | | | 33.7 | | | 2.6 |
| | 50 | | | 60.3 | | | 2.9 |
| DN := | 150 | | Do := | 168.3 | | enom := | 4.5 |
| | 200 | | | 219.1 | | | 6.3 |
| | 300 | | | 323.9 | | | 7.1 |
| | 350 | | | 355.6 | | | 8 |
| | 400 | | | 406.4 | | | 8.8 |
| | 500 | | | 508 | | | 11 |
| | | | | | | | |
| | 25 | | | 0.325 | | | 0 |
| | 50 | | | 0.3625 | | | 0 |
| DN := | 150 | | $C_1$ := | 0.5625 | | $C_2$ := | 0 |
| | 200 | | | 0.7875 | | | 0 |
| | 300 | | | 0.8875 | | | 0 |
| | 350 | | | 1 | | | 0 |
| | 400 | | | 1.1 | | | 0 |
| | 500 | | | 1.375 | | | 0 |
| | | | | | | | |
| **Result** | | | | | | | |
| | | | | | | | |
| **Straight Pipe** | | | | | | | |
| | | | | | | | |
| Minimum required wall thickness | | | $e_p$ | | | | |
| Analysis wall thickness | | | $e_a$ | | | | |
| Utilization factor shall be less than or equal to 1 : | | | Up = ep/ea | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25 | | | 1.28 | | | 1.18 |
| | 50 | | | 1.54 | | | 1.11 |
| DN := | 150 | | $e_a$ := | 2.94 | | $\frac{D_0}{D_0-2e_{nom}}$ := | 1.06 |
| | 200 | | | 4.51 | | | 1.06 |
| | 300 | | | 5.21 | | | 1.05 |
| | 350 | | | 6.00 | | | 1.05 |
| | 400 | | | 6.70 | | | 1.05 |
| | 500 | | | 8.63 | | | 1.05 |

if $\frac{D_0}{D_0-2e_{nom}} < 1.7, then\ e = \frac{P_c D_0}{2fz+P_c}$ (6.1-1) else $e = \frac{D_0}{2}\left[1-\sqrt{\frac{fz-p_c}{fz+p_c}}\right]$(6.1-3)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 25 | | | 0.28 | | | 0.22 |
| | 50 | | | 0.51 | | | 0.33 |
| DN := | 150 | | $e_p$ := | 1.42 | | $U_p$ := | 0.48 |
| | 200 | | | 1.85 | | | 0.41 |
| | 300 | | | 2.73 | | | 0.52 |
| | 350 | | | 3.00 | | | 0.50 |
| | 400 | | | 3.43 | | | 0.51 |
| | 500 | | | 4.29 | | | 0.50 |

## Elbows with Uniform Thickness due to Internal Pressure according to Chapter 6.2.3.3 of SS-EN 13480-3:2012(E) Issue 1 (2012-06)

**General**

| | | |
|---|---|---|
| Material | EN 10216-2 10CrMo9-10 W1.7380 | |
| Design Temperature (Deg.C) | $T_d$ | |
| Design Stress (MPa) | $f$ | |
| Design Pressure (MPa) | $P_c$ | |
| Weld efficiency factor for longitudinal weld | z | 1.00 |
| Outer Diameter (mm) | $D_o$ | |
| Nominal Wall Thickness in Straight Pipe (mm) | $e_{nom}$ | |
| Nominal Wall Thickness of bend intrados (mm) | $e_{intnom}$ | |
| Nominal Wall Thickness of bend extrados (mm) | $e_{extnom}$ | |
| Bend Radius (mm) | R | |
| Corrosion Allowance (mm) | $C_0$ = | 1.00 |
| Negative Tolerance | $C_1$ | |
| Thinning allowance due to | $C_2$ | |

Set parameter "Uniform Elbow" below to "Yes" or "No" or "NA"

**Input**

| | | | | | |
|---|---|---|---|---|---|
| | 150 | | Yes | | 221 |
| DN := | 200 | Uniform Elbow := | Yes | Td := | 221 |
| | 300 | | Yes | | 221 |
| | 350 | | Yes | | 221 |
| | 350 | | Yes | | 221 |
| | 400 | | Yes | | 221 |
| | 500 | | Yes | | 221 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 150 | | | 132.8 | | | 2.26 |
| DN := | 200 | | f := | 132.8 | | Pc := | 2.26 |
| | 300 | | | 132.8 | | | 2.26 |
| | 350 | | | 132.8 | | | 2.26 |
| | 350 | | | 132.8 | | | 2.26 |
| | 400 | | | 132.8 | | | 2.26 |
| | 500 | | | 132.8 | | | 2.26 |
| | | | | | | | |
| | 150 | | | 168.3 | | | 4.5 |
| DN := | 200 | | Do := | 219.1 | | enom := | 6.3 |
| | 300 | | | 323.9 | | | 7.1 |
| | 350 | | | 355.6 | | | 8 |
| | 350 | | | 355.6 | | | 8 |
| | 400 | | | 406.4 | | | 8.8 |
| | 500 | | | 508 | | | 11 |
| | | | | | | | |
| | 150 | | | 229 | | | 0.5625 |
| DN := | 200 | | R := | 305 | | $C_1$ := | 0.7875 |
| | 300 | | | 457 | | | 0.8875 |
| | 350 | | | 533 | | | 1 |
| | 350 | | | 356 | | | 1 |
| | 400 | | | 610 | | | 1.1 |
| | 500 | | | 762 | | | 1.375 |
| | | | | | | | |
| | 150 | | | 0 | | | |
| DN := | 200 | | $C_2$ := | 0 | | | |
| | 300 | | | 0 | | | |
| | 350 | | | 0 | | | |
| | 350 | | | 0 | | | |
| | 400 | | | 0 | | | |
| | 500 | | | 0 | | | |
| | | | | | | | |
| | | | | | | | |
| Minimum required wall thickness | | | $e_p$ | | | | |
| Analysis wall thickness | | | $e_a$ | | | | |
| Utilization factor shall be less than or equal to 1 : | | | $U_f$ | | | | |
| | | | | | | | |
| | 150 | | | 2.94 | | | 1.04 |
| DN := | 200 | | $e_a$ := | 4.51 | | $\frac{D_0}{D_0-2e_a}$ := | 1.04 |
| | 300 | | | 5.21 | | | 1.03 |
| | 350 | | | 6.00 | | | 1.03 |
| | 350 | | | 6.00 | | | 1.03 |
| | 400 | | | 6.70 | | | 1.03 |
| | 500 | | | 8.63 | | | 1.04 |

if $\frac{D_0}{D_0 - 2e_{nom}} < 1.7, then\ e = \frac{P_c D_0}{2fz + P_c}$ (6.1-1) else $e = \frac{D_o}{2}\left[1 - \sqrt{\frac{fz - p_c}{fz + p_c}}\right]$(6.1-3)

| | | | | | | |
|---|---|---|---|---|---|---|
| | 150 | | 1.42 | | | |
| DN := | 200 | $e_p$ := e = | 1.85 | | | |
| | 300 | | 2.73 | | | |
| | 350 | | 3.00 | | | |
| | 350 | | 3.00 | | | |
| | 400 | | 3.43 | | | |
| | 500 | | 4.29 | | | |

**Result**

**Elbows with Uniform Thickness**

$e_{int} = e_{ext} = e_p\ B$

$$B = \frac{D_0}{2e} - \frac{R}{e} + \sqrt{\left[\frac{D_0}{2e} - \frac{R}{e}\right]^2 + 2\frac{R}{e} - \frac{D_0}{2e}}$$ (B.4.1-11)

| | | | | | | |
|---|---|---|---|---|---|---|
| | 150 | | 161.27 | | | 59.26 |
| DN := | 200 | $R/e_p$ := | 164.99 | | $D_0/2e_p$ := | 59.26 |
| | 300 | | 167.23 | | | 59.26 |
| | 350 | | 177.65 | | | 59.26 |
| | 350 | | 118.66 | | | 59.26 |
| | 400 | | 177.90 | | | 59.26 |
| | 500 | | 177.78 | | | 59.26 |
| | | | | | | |
| | 150 | | 1.28 | | | 1.82 |
| DN := | 200 | B := | 1.27 | | $e_{int} = e_{ext}$ := | 2.35 |
| | 300 | | 1.27 | | | 3.46 |
| | 350 | | 1.24 | | | 3.73 |
| | 350 | | 1.48 | | | 4.44 |
| | 400 | | 1.24 | | | 4.26 |
| | 500 | | 1.24 | | | 5.33 |
| | | | | | | |
| | 150 | | 0.62 | | | |
| DN := | 200 | $U_f$ := | 0.52 | | | |
| | 300 | | 0.66 | | | |
| | 350 | | 0.62 | | | |
| | 350 | | 0.74 | | | |
| | 400 | | 0.64 | | | |
| | 500 | | 0.62 | | | |

## Bend with Uniform Thickness due to Internal Pressure according to Chapter 6.2.3.3 of SS-EN 13480-3:2012(E) Issue 1 (2012-06)

**General**

| | | |
|---|---|---|
| Material | EN 10216-2 10CrMo9-10 W1.7380 | |
| Design Temperature (Deg.C) | $T_d$ | |
| Design Stress (MPa) | $f$ | |
| Design Pressure (MPa) | $P_c$ | |
| Weld efficiency factor for longitudinal weld | Z | 1.00 |
| Outer Diameter (mm) | $D_o$ | |
| Nominal Wall Thickness of bend intrados (mm) | $e_{intnom}$ | |
| Nominal Wall Thickness of bend extrados (mm) | $e_{extnom}$ | |
| Bend Radius (mm) | $R_1$ | |
| Corrosion Allowance (mm) | $C_0$ = | 1.00 |
| Negative Tolerance | $C_1$ | |
| Thinning allowance due to | $C_2$ | |

Set parameter "Uniform Bend" below to "Yes" or "No" or "NA"

**Input**

| | | | | | |
|---|---|---|---|---|---|
| | 150 | | Yes | | 221 |
| DN := | 200 | Uniform Bend := | Yes | Td := | 221 |
| | 300 | | Yes | | 221 |
| | 350 | | Yes | | 221 |
| | 350 | | Yes | | 221 |
| | 400 | | Yes | | 221 |
| | 500 | | Yes | | 221 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 150 | | | 132.8 | | | 2.26 | | |
| DN := | 200 | | f := | 132.8 | | Pc := | 2.26 | | |
| | 300 | | | 132.8 | | | 2.26 | | |
| | 350 | | | 132.8 | | | 2.26 | | |
| | 350 | | | 132.8 | | | 2.26 | | |
| | 400 | | | 132.8 | | | 2.26 | | |
| | 500 | | | 132.8 | | | 2.26 | | |
| | | | | | | | | | |
| | 150 | | | 168.3 | | | 4.5 | | |
| DN := | 200 | | Do := | 219.1 | | $e_{intnom}$ =<br>$e_{extnom}$ := | 6.3 | | |
| | 300 | | | 323.9 | | | 7.1 | | |
| | 350 | | | 355.6 | | | 8 | | |
| | 350 | | | 355.6 | | | 8 | | |
| | 400 | | | 406.4 | | | 8.8 | | |
| | 500 | | | 508 | | | 11 | | |
| | | | | | | | | | |
| | 150 | | | 229 | | | 0.5625 | | |
| DN := | 200 | | R1 := | 305 | | $C_1$ := | 0.7875 | | |
| | 300 | | | 457 | | | 0.8875 | | |
| | 350 | | | 533 | | | 1 | | |
| | 350 | | | 356 | | | 1 | | |
| | 400 | | | 610 | | | 1.1 | | |
| | 500 | | | 762 | | | 1.375 | | |
| | | | | | | | | | |
| | 150 | | | 0 | | | | | |
| DN := | 200 | | $C_2$ := | 0 | | | | | |
| | 300 | | | 0 | | | | | |
| | 350 | | | 0 | | | | | |
| | 350 | | | 0 | | | | | |
| | 400 | | | 0 | | | | | |
| | 500 | | | 0 | | | | | |
| | | | | | | | | | |
| Minimum required wall thickness of pipe | | | e | | | | | | |
| Analysis wall thickness | | | $e_a$ | | | | | | |
| Utilization factor shall be less than or equal to 1 : | | | $U_f = ep / ea$ | | | | | | |
| | | | | | | | | | |
| | 150 | | | 2.94 | | | 1.04 | | |
| DN := | 200 | | $e_a$ := | 4.51 | | $\frac{D_0}{D_0-2e_a}$ := | 1.04 | | |
| | 300 | | | 5.21 | | | 1.03 | | |
| | 350 | | | 6.00 | | | 1.03 | | |
| | 350 | | | 6.00 | | | 1.03 | | |
| | 400 | | | 6.70 | | | 1.03 | | |
| | 500 | | | 8.63 | | | 1.04 | | |

if $\frac{D_0}{D_0 - 2e_a} < 1.7, then\ e = \frac{P_c D_0}{2fz + P_c}$ (6.1-1) else $e = \frac{P_c D_i}{2fz - P_c}$ (6.1-2)

| | | | | |
|---|---|---|---|---|
| | 150 | | 1.42 | |
| DN := | 200 | e := | 1.85 | |
| | 300 | | 2.73 | |
| | 350 | | 3.00 | |
| | 350 | | 3.00 | |
| | 400 | | 3.43 | |
| | 500 | | 4.29 | |

**Result**

**Pipe Bend with Uniform Thickness**

$e_{int} = e\ B_{int}$

$e_{ext} = e\ B_{ext}$

$$B_{int} = \frac{D_0}{2e} + \frac{r}{e} - \left[\frac{D_o}{2e} + \frac{r}{e} - 1\right]\sqrt{\frac{\left(\frac{r}{e}\right)^2 - \left(\frac{D_o}{2e}\right)^2}{\left(\frac{r}{e}\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)}} \quad \text{(B.4.1-3)}$$

`

$$\frac{r}{e} = \sqrt{\frac{1}{2}\left\{\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right\} + \sqrt{\frac{1}{4}\left(\left(\frac{D_o}{2e}\right)^2 + \left(\frac{R}{e}\right)^2\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)\left(\frac{R}{e}\right)^2}} \quad \text{(B.4.1-4)}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 150 | | 161.27 | | 59.26 | | 161.48 |
| DN := | 200 | R/e := | 164.99 | D0/2e := | 59.26 | r/e := | 165.20 |
| | 300 | | 167.23 | | 59.26 | | 167.43 |
| | 350 | | 177.65 | | 59.26 | | 177.84 |
| | 350 | | 118.66 | | 59.26 | | 118.99 |
| | 400 | | 177.90 | | 59.26 | | 178.09 |
| | 500 | | 177.78 | | 59.26 | | 177.97 |

| | | | | | |
|---|---|---|---|---|---|
| | 150 | | 1.29 | | 1.83 |
| DN := | 200 | Bint := | 1.28 | eint := | 2.36 |
| | 300 | | 1.27 | | 3.48 |
| | 350 | | 1.25 | | 3.75 |
| | 350 | | 1.49 | | 4.47 |
| | 400 | | 1.25 | | 4.28 |
| | 500 | | 1.25 | | 5.35 |

| | | | |
|---|---|---|---|
| | 150 | | 0.62 |
| DN := | 200 | Uf1 := | 0.52 |
| | 300 | | 0.67 |
| | 350 | | 0.62 |
| | 350 | | 0.75 |
| | 400 | | 0.64 |
| | 500 | | 0.62 |

$$B_{ext} = \frac{D_0}{2e} - \frac{r}{e} - \left[\frac{D_o}{2e} - \frac{r}{e} - 1\right]\sqrt{\frac{\left(\frac{r}{e}\right)^2 - \left(\frac{D_o}{2e}\right)^2}{\left(\frac{r}{e}\right)^2 - \frac{D_o}{2e}\left(\frac{D_o}{2e} - 1\right)}}$$ (B.4.1-9)

| | | | | | |
|---|---|---|---|---|---|
| | 150 | | 0.86 | | 1.23 |
| DN := | 200 | Bext := | 0.87 | eext := | 1.60 |
| | 300 | | 0.87 | | 2.37 |
| | 350 | | 0.87 | | 2.62 |
| | 350 | | 0.83 | | 2.50 |
| | 400 | | 0.87 | | 3.00 |
| | 500 | | 0.87 | | 3.75 |

| | | | |
|---|---|---|---|
| | 150 | | 0.42 |
| DN := | 200 | Uf2 := | 0.36 |
| | 300 | | 0.46 |
| | 350 | | 0.44 |
| | 350 | | 0.42 |
| | 400 | | 0.45 |
| | 500 | | 0.43 |

| Reducer without knuckle due to Internal Pressure according to SS-EN 13480-3 (2012), Chapter 6.4 | | |
|---|---|---|
| **Input** | | |
| Material | EN 10216-2 10CrMo9-10 W1.7380 | |
| Design Temperature (Deg.C) | $T_d$ | |
| Design Stress (MPa) | $f$ | |
| Design Pressure (MPa) | $p_c$ | |
| Weld efficiency factor for longitudinal weld (Z) | 1.00 | |
| Large Pipe Outer Diameter (mm) | $D_{01}$ | |
| Small Pipe Outer Diameter (mm) | $D_{02}$ | |
| Nominal Wall Thickness in Large Pipe (mm) | $T_1$ | |
| Nominal Wall Thickness in Small Pipe (mm) | $T_2$ | |
| Semi Angle of Reducer at Apex | $\alpha$ | |
| Weld effeciency factor for Longitudinal Weld | Z | 1.00 |
| Corrosion Allowance (mm) | $C_0$ | 1.00 |
| Negative Tolerance in Large Pipe | $C_{l1}$ | |
| Negative Tolerance in Small Pipe | $C_{s1}$ | |
| Negative Tolerance in Reducer | $C_1$ | |
| Thinning allowance due to manufacturing | $C_2$ | |
| Enter "Reducer Type" as E for "Eccentric" and C for "Concentric" | | |

| Input | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | 200x150 | | E | | 221 | | 132.8 |
| | 400x200 | | E | | 221 | | 132.8 |
| DN := | 400x350 | Reducer Type := | E | Td := | 221 | f := | 132.8 |
| | 500x300 | | C | | 221 | | 132.8 |
| | 500x300 | | E | | 221 | | 132.8 |
| | 500x400 | | E | | 221 | | 132.8 |
| | | | | | | | |
| | 200x150 | | 219.1 | | 6.3 | | 6.3 |
| | 400x200 | | 406.4 | | 8.8 | | 8.8 |
| DN := | 400x350 | D01 := | 406.4 | T1 := | 8.8 | enom := | 8.8 |
| | 500x300 | | 508 | | 11 | | 11 |
| | 500x300 | | 508 | | 11 | | 11 |
| | 500x400 | | 508 | | 11 | | 11 |
| | | | | | | | |
| | 200x150 | | 168.3 | | 4.5 | | 152 |
| | 400x200 | | 219.1 | | 6.3 | | 356 |
| DN := | 400x350 | D02 := | 355.6 | T2 := | 8 | L := | 356 |
| | 500x300 | | 323.9 | | 7.1 | | 508 |
| | 500x300 | | 323.9 | | 7.1 | | 508 |
| | 500x400 | | 406.4 | | 8.8 | | 508 |
| | | | | | | | |
| | 200x150 | | 31.00 | | 0.7875 | | 0.5625 |
| | 400x200 | | 46.00 | | 1.1 | | 0.7875 |
| DN := | 400x350 | $\alpha$ := | 8.00 | Cl1 := | 1.1 | Cs1 := | 1 |
| | 500x300 | | 20.00 | | 1.375 | | 0.8875 |
| | 500x300 | | 32.00 | | 1.375 | | 0.8875 |
| | 500x400 | | 18.00 | | 1.375 | | 1.1 |
| | | | | | | | |
| | 200x150 | | 0.7875 | | 0 | | 2.26 |
| | 400x200 | | 1.1 | | 0 | | 2.26 |
| DN := | 400x350 | C1 := | 1.1 | C2 := | 0 | Pc := | 2.26 |
| | 500x300 | | 1.375 | | 0 | | 2.26 |
| | 500x300 | | 1.375 | | 0 | | 2.26 |
| | 500x400 | | 1.375 | | 0 | | 2.26 |
| | | | | | | | |
| | 200x150 | | 1.55 | | 4.51 | | 2.94 |
| | 400x200 | | 4.12 | | 6.70 | | 4.51 |
| DN := | 400x350 | $ej$ := | 0.96 | ea1 := | 6.70 | ea2 := | 6.00 |
| | 500x300 | | 2.53 | | 8.63 | | 5.21 |
| | 500x300 | | 3.71 | | 8.63 | | 5.21 |
| | 500x400 | | 2.33 | | 8.63 | | 6.70 |

**Result**

**Reducers Concentric and Eccentric**

**6.4.6 Junction between the large end of a cone and a cylinder without a knuckle**

**6.4.6.2 Design**

$e_j = \frac{p_c D_c \beta}{2f}; \beta = \frac{1}{3}\sqrt{\frac{D_c}{e_j}}\frac{tan\propto}{1+\frac{1}{\sqrt{cos\propto}}}$

$e_{cyl} = \frac{p_c D_{01}}{2fZ + p_c}$

$e_{con} = \frac{p_c D_e}{2fZ + p_c}\frac{1}{COS(\alpha)}$

$e_1 = \max(e_j, e_{cyl})$

$e_3 = \max(e_j, e_{con})$

**6.4.8 Junction between the small end ofa cone and a cylinder**

**6.4.8.2 Design**

$s = \frac{e_3}{e_{j2}}$ when s < 1; $\tau = s\sqrt{\frac{s}{cos\propto}} + \sqrt{\frac{1+s^2}{2}}$ when s >= 1; $\tau = 1 + \sqrt{s\frac{1+s^2}{2cos\propto}}$

$\beta_H = 0.4\sqrt{\frac{D_c}{e_{j2}}}\frac{tan\propto}{\tau} + 0.5$

$e_{j2} = \frac{p_c D_c \beta_H}{2fZ}$

$e_{cyl} = \frac{p_c D_{02}}{2fZ + p_c}$

$e_{p2} = \max(e_{j2}, e_{cyl})$

Conditions of Applicability

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 200x150 | | Valid | | 1.68 | | |
| | 400x200 | | Valid | | 4.48 | | |
| DN := | 400x350 | Equ. 6.4.1-1 := | Valid | $e_j$ := | 1.04 | | |
| | 500x300 | | Valid | | 2.75 | | |
| | 500x300 | | Valid | | 4.04 | | |
| | 500x400 | | Valid | | 2.53 | | |
| | | | | | | | |
| | 0.933672 | | 1.69 | | 1.85 | | 2.16 |
| | 1.328222 | | 4.49 | | 3.43 | | 4.94 |
| $\beta$ := | 0.306872 | $e_j$ := | 1.04 | ecyl := | 3.43 | econ := | 3.46 |
| | 0.652824 | | 2.76 | | 4.29 | | 4.56 |
| | 0.957547 | | 4.05 | | 4.29 | | 5.05 |
| | 0.59948 | | 2.54 | | 4.29 | | 4.51 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Reducer at the Junction to the Larger Pipe :** | | | | | | | |
| | | | | | | | |
| | 200x150 | | 1.85 | | 2.16 | | **0.41** |
| | 400x200 | | 4.49 | | 4.94 | | **0.67** |
| DN := | 400x350 | | 3.43 | | 3.46 | Uf1:= e1/ea1 | **0.51** |
| | 500x300 | e1 := | 4.29 | e3 := | 4.56 | | **0.50** |
| | 500x300 | | 4.29 | | 5.05 | | **0.50** |
| | 500x400 | | 4.29 | | 4.51 | | **0.50** |
| | | | | | | | |
| **Reducer at the Junction to the Small Pipe :** | | | | | | | |
| | | | | | | | |
| | 200x150 | | 2.16 | | 2.10 | | 1.03 |
| | 400x200 | | 4.94 | | 2.93 | | 1.68 |
| DN := | 400x350 | | 3.46 | | 2.27 | | 1.53 |
| | 500x300 | e3 := | 4.56 | ej2 := | 2.86 | s:= | 1.59 |
| | 500x300 | | 5.05 | | 3.84 | | 1.32 |
| | 500x400 | | 4.51 | | 3.71 | | 1.21 |
| | | | | | | | |
| | 200x150 | | 2.11 | | 1.51 | | |
| | 400x200 | | 3.16 | | 1.62 | | |
| DN := | 400x350 | | 2.60 | | 0.77 | | |
| | 500x300 | z := | 2.73 | Bh := | 1.06 | | |
| | 500x300 | | 2.46 | | 1.42 | | |
| | 500x400 | | 2.26 | | 1.10 | | |
| | | | | | | | |
| | 200x150 | | 2.10 | | 1.42 | | |
| | 400x200 | | 2.93 | | 1.85 | | |
| DN := | 400x350 | | 2.27 | | 3.00 | | |
| | 500x300 | ej2 := | 2.86 | ecyl := | 2.73 | | |
| | 500x300 | | 3.84 | | 2.73 | | |
| | 500x400 | | 3.71 | | 3.43 | | |
| | | | | | | | |
| | 200x150 | | 2.10 | | | | **0.71** |
| | 400x200 | | 2.93 | | | | **0.65** |
| DN := | 400x350 | | 3.00 | | | | **0.50** |
| | 500x300 | e2 := | 2.86 | | | Uf2:= e2/ea2 | **0.55** |
| | 500x300 | | 3.84 | | | | **0.74** |
| | 500x400 | | 3.71 | | | | **0.55** |

**Internal Pressure Design Results from CAEPIPE**

## Pipe material 1: EN 10216-2 10CrMo9-10 Seamless

Density = 7850 (kg/m3), Nu = 0.300, Joint factor = 0.80, Type = CS
Tensile strength = 229.8 (N/mm2)

| Temp (C) | E (kN/mm2) | Alpha (mm/mm/C) | ff (N/mm2) | fCR (N/mm2) |
|---|---|---|---|---|
| 20 | 211 | 11.51E-6 | 137.1 | |
| 50 | 209 | 11.78E-6 | 136.9 | |
| 100 | 206 | 12.10E-6 | 136.5 | |
| 150 | 203 | 12.43E-6 | 132.8 | |
| 200 | 199 | 12.75E-6 | 132.8 | |
| 250 | 196 | 13.08E-6 | 132.8 | |
| 300 | 192 | 13.22E-6 | 132.8 | |

## Pipe Sections (8)

| Name | Nom Dia | Sch | OD (mm) | Thk (mm) | Cor.Al (mm) | M.Tol (%) | Ins.Dens (kg/m3) | Ins.Thk (mm) | Lin.Dens (kg/m3) | Lin.Thk (mm) | Soil |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 25 | 3 | 33.7 | 2.6 | 1 | 12.5 | | | | | |
| 50 | 50 | 3 | 60.3 | 2.9 | 1 | 12.5 | | | | | |
| 150 | 150 | 3 | 168.3 | 4.5 | 1 | 12.5 | 150 | 100 | 2700 | 1 | |
| 200 | 200 | 3 | 219.1 | 6.3 | 1 | 12.5 | 150 | 120 | 2700 | 1 | |
| 300 | 300 | 3 | 323.9 | 7.1 | 1 | 12.5 | 150 | 140 | 2700 | 1 | |
| 350 | 350 | 3 | 355.6 | 8 | 1 | 12.5 | 150 | 140 | 2700 | 1 | |
| 400 | 400 | 3 | 406.4 | 8.8 | 1 | 12.5 | 150 | 140 | 2700 | 1 | |
| 500 | 500 | 3 | 508 | 11 | 1 | 12.5 | 200 | 140 | 2700 | 1 | |

## Pipe Loads (1)

| Name | T1 (C) | P1 (bar) | T2 (C) | P2 (bar) | Specific gravity | Add.Wgt. (kg/m) | Wind Load |
|---|---|---|---|---|---|---|---|
| 1 | 221 | 22.6 | 20 | -1.00 | 0.003 | | |

Internal Pressure Design: EN 13480-3 (2012) (179)

| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 20 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 356 | | 6 | 6 | 4.4417 | 4.4417 | 0.74 | 0.74 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 356 | | 6 | 6 | 4.4824 | 2.4943 | 0.75 | 0.42 |
| 20 | 30 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 30 | 40 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 40 | 50 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 50 | 60 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 60 | 70 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 70 | 80 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 80 | 90 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 90 | 100 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 100 | 110 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 120 | 130 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 140 | 150 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 150 | 160 | Reducer | 221 | 22.6 | 132.8 | 406.4 | 355.6 | 1 | | 8 | 6.7 | 6 | 3.4289 | 3.0003 | 0.51 | 0.50 |
| 160 | 170 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 170 | 180 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 180 | 190 | Reducer | 221 | 22.6 | 132.8 | 406.4 | 219.1 | 1 | | 46 | 6.7 | 4.5125 | 4.4882 | 2.9294 | 0.67 | 0.65 |
| 190 | 200 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 200 | 210 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 210 | 220 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 220 | 230 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 230 | 240 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 240 | 250 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |

Internal Pressure Design: EN 13480-3 (2012) (179)

| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 250 | 260 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 260 | 270 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 280 | 290 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 300 | 310 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 310 | 320 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 320 | 330 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 330 | 340 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 340 | 350 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 350 | 360 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 360 | 370 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 370 | 380 | Reducer | 221 | 22.6 | 132.8 | 219.1 | 168.3 | 1 | | 31 | 4.5125 | 2.9375 | 1.8486 | 2.0994 | 0.41 | 0.71 |
| 380 | 390 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 390 | 400 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 400 | 410 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 410 | 420 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 420 | 430 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 360 | 500 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 500 | 510 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 510 | 520 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 1000 | 1010 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 356 | | 6 | 6 | 4.4417 | 4.4417 | 0.74 | 0.74 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 356 | | 6 | 6 | 4.4824 | 2.4943 | 0.75 | 0.42 |
| 1010 | 1020 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |

Internal Pressure Design: EN 13480-3 (2012) (179)

| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1020 | 1030 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 1030 | 1040 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1040 | 1050 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1050 | 1060 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 1060 | 1070 | Elbow | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7316 | 3.7316 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | 533 | | 6 | 6 | 3.7468 | 2.6225 | 0.62 | 0.44 |
| 1070 | 1080 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1080 | 1090 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1090 | 1100 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1110 | 1120 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1130 | 1140 | Pipe | 221 | 22.6 | 132.8 | 355.6 | 355.6 | 1 | | | 6 | 6 | 3.0003 | 3.0003 | 0.50 | 0.50 |
| 1140 | 1150 | Reducer | 221 | 22.6 | 132.8 | 406.4 | 355.6 | 1 | | 8 | 6.7 | 6 | 3.4289 | 3.0003 | 0.51 | 0.50 |
| 1150 | 1160 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 1160 | 1170 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 1170 | 1180 | Reducer | 221 | 22.6 | 132.8 | 406.4 | 219.1 | 1 | | 46 | 6.7 | 4.5125 | 4.4882 | 2.9294 | 0.67 | 0.65 |
| 1180 | 1190 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1190 | 1200 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1200 | 1210 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1210 | 1220 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1220 | 1230 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1230 | 1240 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1240 | 1250 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1250 | 1260 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1270 | 1280 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |

| Internal Pressure Design: EN 13480-3 (2012) (179) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
| 1290 | 1300 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1300 | 1310 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1310 | 1320 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1320 | 1330 | Elbow | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3525 | 2.3525 | 0.52 | 0.52 |
| | | Bend | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | 305 | | 4.5125 | 4.5125 | 2.3634 | 1.6025 | 0.52 | 0.36 |
| 1330 | 1340 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1340 | 1350 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1350 | 1360 | Pipe | 221 | 22.6 | 132.8 | 219.1 | 219.1 | 1 | | | 4.5125 | 4.5125 | 1.8486 | 1.8486 | 0.41 | 0.41 |
| 1360 | 1370 | Reducer | 221 | 22.6 | 132.8 | 219.1 | 168.3 | 1 | | 31 | 4.5125 | 2.9375 | 1.8486 | 2.0994 | 0.41 | 0.71 |
| 1370 | 1380 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 1380 | 1390 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 1390 | 1400 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 1400 | 1410 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 1410 | 1420 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 1350 | 1500 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 1500 | 1510 | Elbow | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.821 | 1.821 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | 229 | | 2.9375 | 2.9375 | 1.8298 | 1.2277 | 0.62 | 0.42 |
| 1510 | 1520 | Pipe | 221 | 22.6 | 132.8 | 168.3 | 168.3 | 1 | | | 2.9375 | 2.9375 | 1.42 | 1.42 | 0.48 | 0.48 |
| 170 | 1600 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 1600 | 1610 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2629 | 4.2629 | 0.64 | 0.64 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2803 | 2.9976 | 0.64 | 0.45 |
| 1610 | 1620 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 1160 | 1850 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 1620 | 1800 | Reducer | 221 | 22.6 | 132.8 | 508 | 406.4 | 1 | | 18 | 8.625 | 6.7 | 4.2861 | 3.7079 | 0.50 | 0.55 |

| Internal Pressure Design: EN 13480-3 (2012) (179) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
| 1800 | 1810 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1810 | 1820 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1820 | 1830 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1830 | 1840 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1840 | 1850 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1850 | 1860 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1860 | 1870 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1870 | 1880 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1880 | 1890 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1890 | 1900 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1900 | 1910 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1910 | 1920 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1920 | 1930 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1930 | 1940 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1950 | 1960 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1960 | 1970 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 1970 | 1980 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1980 | 1985 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1985 | 1990 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1990 | 2000 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 2000 | 2010 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 2010 | 2020 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 2020 | 2030 | Reducer | 221 | 22.6 | 132.8 | 508 | 406.4 | 1 | | 18 | 8.625 | 6.7 | 4.2861 | 3.7079 | 0.50 | 0.55 |
| 2030 | 2040 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |

| Internal Pressure Design: EN 13480-3 (2012) (179) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Element Type | Max.Temp (C) | Max.Press (bar) | All.Stress (N/mm2) | OD1 (mm) | OD2 (mm) | Cor.All (mm) | Radius (mm) | Cone Angle (deg) | ea1 (mm) | ea2 (mm) | ep1 (mm) | ep2 (mm) | Uf1 (ep1/ea1) | Uf2 (ep2/ea2) |
| 2040 | 2045 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2045 | 2050 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2050 | 2055 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2055 | 2060 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2629 | 4.2629 | 0.64 | 0.64 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2803 | 2.9976 | 0.64 | 0.45 |
| 2060 | 2070 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2629 | 4.2629 | 0.64 | 0.64 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2803 | 2.9976 | 0.64 | 0.45 |
| 2070 | 2080 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 406 | | 6.7 | 6.7 | 5.083 | 5.083 | 0.76 | 0.76 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 406 | | 6.7 | 6.7 | 5.1299 | 2.8498 | 0.77 | 0.43 |
| 2080 | 2090 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2090 | 2100 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2110 | 2120 | Reducer | 221 | 22.6 | 132.8 | 508 | 406.4 | 1 | | 18 | 8.625 | 6.7 | 4.2861 | 3.7079 | 0.50 | 0.55 |
| 2120 | 2130 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 2130 | 2140 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 2010 | 2200 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2629 | 4.2629 | 0.64 | 0.64 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 610 | | 6.7 | 6.7 | 4.2803 | 2.9976 | 0.64 | 0.45 |
| 2200 | 2220 | Elbow | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 406 | | 6.7 | 6.7 | 5.083 | 5.083 | 0.76 | 0.76 |
| | | Bend | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | 406 | | 6.7 | 6.7 | 5.1299 | 2.8498 | 0.77 | 0.43 |
| 2220 | 2230 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2230 | 2240 | Pipe | 221 | 22.6 | 132.8 | 406.4 | 406.4 | 1 | | | 6.7 | 6.7 | 3.4289 | 3.4289 | 0.51 | 0.51 |
| 2250 | 2260 | Reducer | 221 | 22.6 | 132.8 | 508 | 406.4 | 1 | | 18 | 8.625 | 6.7 | 4.2861 | 3.7079 | 0.50 | 0.55 |
| 2260 | 2270 | Elbow | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3297 | 5.3297 | 0.62 | 0.62 |
| | | Bend | 221 | 22.6 | 132.8 | 508 | 508 | 1 | 762 | | 8.625 | 8.625 | 5.3514 | 3.7467 | 0.62 | 0.43 |
| 2270 | 2280 | Pipe | 221 | 22.6 | 132.8 | 508 | 508 | 1 | | | 8.625 | 8.625 | 4.2861 | 4.2861 | 0.50 | 0.50 |
| 1990 | 2500 | Pipe | 221 | 22.6 | 132.8 | 60.3 | 60.3 | 1 | | | 1.5375 | 1.5375 | 0.50877 | 0.50877 | 0.33 | 0.33 |
| 2000 | 2600 | Pipe | 221 | 22.6 | 132.8 | 60.3 | 60.3 | 1 | | | 1.5375 | 1.5375 | 0.50877 | 0.50877 | 0.33 | 0.33 |
| 2090 | 2700 | Pipe | 221 | 22.6 | 132.8 | 33.7 | 33.7 | 1 | | | 1.275 | 1.275 | 0.28434 | 0.28434 | 0.22 | 0.22 |
| 2230 | 2800 | Pipe | 221 | 22.6 | 132.8 | 33.7 | 33.7 | 1 | | | 1.275 | 1.275 | 0.28434 | 0.28434 | 0.22 | 0.22 |

# External Pressure Design of Pipe and Pipe Fittings according to EN 13480-3 (2012)

# Design of pipe and pipe fittings under external pressure according to EN 13480-3 (2012)

## Pipes, Elbows, Mitre Bends and Reducers

### Interstiffener collapse

The thickness of the pipe within the unstiffened length L shall not be less than that determined by the following.

$$P_r \geq k.P_c$$

$$P_y = \frac{Se_a}{R_m}$$

$$P_m = \frac{E_t e_a \varepsilon}{R_m}$$

$$\varepsilon = \frac{1}{n_{cyl^2} - 1 + \frac{Z^2}{2}} \left\{ \frac{1}{\left(\frac{n_{cyl^2}}{Z^2} + 1\right)^2} + \frac{e_{a^2}}{12 R_{m^2(1-v^2)}} \left(n_{cyl^2} - 1 + Z^2\right)^2 \right\}$$

$$Z = \frac{\pi R_m}{L}$$

using the calculated value of Pm/Py, Pr/Py is determined from Table 9.3.2.1 of Subsection 9.3.2

where

$n_{cyl}$ = integer >= 2 to minimize the value of $P_m$

$R_m$ = mean radius of the pipe

L = length between the stiffener, is calculated from CAEPIPE input as follows

for Pipe, L = length of pipe (= distance between the “From” and “To” node of CAEPIPE)

for Elbow and Mitre bend, L = arc length measured on extrados of elbow and mitre bend

for Reducer, L = Length of the reducer

$E_t$ = Young’s modulus of material at design temperature = max of CAEPIPE Temperature T1 through T10

$e_a$ = analysis thickness of reducer at smaller end = $e_n$ – corr.all – mill tolerance

$e_n$ = nominal thickness of reducer at smaller end

k = factor = 1.5

$P_c$ = external pressure = maximum negative CAEPIPE input pressures P1 through P10

S = elastic stress limits for pipe and stiffener

= $R_{p0.2,t}$ for non-austenitic steels

= ($R_{p0.2,t}$ / 1.25) for austenitic steels

$R_{p0.2,t}$ = minimum 0.2% proof strength at temperature of pipe (= Tensile strength of material from CAEPIPE)

## Additional check for Reducers

In addition to the above, as stated in Subsection 9.4.2 of EN 13480-3, the moment of inertia, Ix taken parallel to the axis of the cylinder, of the part of the cone and cylinder with a distance of $\sqrt{D_{eq}.e}$ on either side of the junction is not less than:

$$I_x = 0.18 D_{eq} L D_s^2 \frac{p_c}{E_t} \leq I_{xa}$$

where

$D_{eq}$ = equivalent diameter = $\dfrac{\frac{D_1+D_2}{2}}{\cos(\alpha)}$

D1 = outside diameter of larger end of reducer

D2 = outside diameter of smaller end of reducer

$\alpha =$ cone angle of reducer input in CAEPIPE

$I_{xa}$ = moment of inertia of reducer at smaller end

Ds = diameter of the centroid of the moment of inertia of the stiffening cross section calculated as shown below

$$I_{cone} = \left(\sqrt{D_{eq} e_1}.e_1\right)\left(\frac{D_{mcon}}{2}\right)^2 = (A_{cone})\left(\frac{D_{mcon}}{2}\right)^2$$

$$I_{Cyl} = \left(\sqrt{D_{eq} e_2}.e_2\right)\left(\frac{D_{mcyl}}{2}\right)^2 = \left(A_{cyl}\right)\left(\frac{D_{mcyl}}{2}\right)^2$$

$$I_{stiff} = \left(A_{cone} + A_{cyl}\right)\left(\frac{D_s}{2}\right)^2$$

From the above,

$$I_{cone} + I_{Cyl} = I_{stiff}$$

*and*

$$D_s = 2\sqrt{\frac{I_{stiff}}{\left(A_{cone} + A_{cyl}\right)}}$$

e1 = analysis thickness of reducer at larger end = $e_{n1}$ – corr.all – mill tolerance

e2 = analysis thickness of reducer at smaller end = $e_{n2}$ – corr.all – mill tolerance

$e_{n1}$ = nominal thickness of reducer at larger end

$e_{n2}$ = nominal thickness of reducer at smaller end

## Verification and Validation
## for External Pressure Design of Pipe and Pipe Fittings

## Calculation of Straight Pipe and Elbows due to External Pressure according to Chapter 9.3 of SS-EN 13480-3:2012 (E) Issue 1 (2012-06)

**General**

| | | |
|---|---|---|
| Material | EN 10216-2 10CrMo9-10 W1.7380 | |
| Type | Non-austenitic steels; Enter "NS" | |
| | Austenitic steels; Enter "AS" | |
| Design Temperature (Deg.C) | $T_d$ | |
| Yield strength at design temperature | $R_{p0.2T}$ | |
| Design Pressure (MPa) | $P_c$ | |
| Modulus of Elasticity at Design Temperature | $E_t$ | |
| Outer Diameter (mm) | $D_o$ | |
| Nominal Wall Thickness in Straight | $e_{nom}$ | |
| Bend Radius (mm) | R | |
| Corrosion Allowance (mm) | $C_0$ = | 1.00 |
| Negative Tolerance | $C_1$ | |
| Thinning allowance due to manufacturing | $C_2$ | |
| No. of circumferential waves for an unstiffned length of shell | $n_{cyl}$ | |
| Unstiffend length of shell | L | |
| Poisson's ratio | v | 0.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Input** | | | | | | | |
| | Pipe: 350 | | NS | | 221 | | 229.8 |
| | Elbow: 350 | | NS | | 221 | | 229.8 |
| DN := | Pipe: 350 | Material := | NS | Td := | 221 | Rp0.2T := | 229.8 |
| | Pipe: 400 | | NS | | 221 | | 229.8 |
| | Pipe: 500 | | NS | | 221 | | 229.8 |
| | Elbow: 150 | | NS | | 221 | | 229.8 |
| | | | | | | | |
| | Pipe: 350 | | 0.10 | | 198000 | | |
| | Elbow: 350 | | 0.10 | | 198000 | | |
| DN := | Pipe: 350 | Pc := | 0.10 | Et := | 198000 | | |
| | Pipe: 400 | | 0.10 | | 198000 | | |
| | Pipe: 500 | | 0.10 | | 198000 | | |
| | Elbow: 150 | | 0.10 | | 198000 | | |
| | | | | | | | |
| | Pipe: 350 | | 355.6 | | 8 | | 1467 |
| | Elbow: 350 | | 355.6 | | 8 | | 1116.52 |
| DN := | Pipe: 350 | Do := | 355.6 | enom := | 8 | L := | 467 |
| | Pipe: 400 | | 406.4 | | 8.8 | | 1500 |
| | Pipe: 500 | | 508 | | 11 | | 1000 |
| | Elbow: 150 | | 168.3 | | 4.5 | | 491.895 |
| | | | | | | | |
| | Pipe: 350 | | 1 | | 0 | | 2 |
| | Elbow: 350 | | 1 | | 0 | | 2 |
| DN := | Pipe: 350 | C1 := | 1 | C2 := | 0 | ncyl := | 2 |
| | Pipe: 400 | | 1.1 | | 0 | | 2 |
| | Pipe: 500 | | 1.375 | | 0 | | 2 |
| | Elbow: 150 | | 0.5625 | | 0 | | 2 |
| | | | | | | | |
| | | | | | | | |
| **Result** | | | | | | | |
| | | | | | | | |
| **Lower Bound Collapse Pressure** | | | Pr | | | | |
| | | | | | | | |
| **Utilization factor shall be equal to or greater than 1** | | | Pr/kPc | | | | |

**9.3.2 Interstiffener collapse**

$P_y = \frac{Se_a}{R_m}$ where $R_m = mean\ radius\ of\ the\ cylinder$ (9.3.2-1)

$P_m = \frac{E_t e_a \varepsilon}{R_m}$ (9.3.2-2)

$$\varepsilon = \frac{1}{n_{cyl}^2 - 1 + \frac{Z^2}{2}} \left\{ \frac{1}{\left(\frac{n_{cyl}^2}{Z^2} + 1\right)^2} + \frac{e_a^2}{12 R_m^2 (1 - \nu^2)} \left(n_{cyl}^2 - 1 + Z^2\right)^2 \right\}$$ (9.3.2-3)

$Z = \frac{\pi R_m}{L}$ (9.3.2-4)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pipe: 350 | | 6.00 | | 173.80 | | 229.8 |
| | Elbow: 350 | | 6.00 | | 173.80 | | 229.8 |
| DN := | Pipe: 350 | ea := | 6.00 | Rm := | 173.80 | S := | 229.8 |
| | Pipe: 400 | | 6.70 | | 198.80 | | 229.8 |
| | Pipe: 500 | | 8.63 | | 248.50 | | 229.8 |
| | Elbow: 150 | | 2.94 | | 81.90 | | 229.8 |
| | | | | | | | |
| | Pipe: 350 | | 7.93 | | 0.37 | | 0.000715316 |
| | Elbow: 350 | | 7.93 | | 0.49 | | 0.001387256 |
| DN := | Pipe: 350 | Py := | 7.93 | Z := | 1.17 | E := | 0.018177071 |
| | Pipe: 400 | | 7.74 | | 0.42 | | 0.000898377 |
| | Pipe: 500 | | 7.98 | | 0.78 | | 0.005725034 |
| | Elbow: 150 | | 8.24 | | 0.52 | | 0.001709149 |
| | | | | | | | |
| | Pipe: 350 | | 4.89 | | 0.62 | | |
| | Elbow: 350 | | 9.48 | | 1.20 | | |
| DN := | Pipe: 350 | Pm := | 124.25 | Pm/Py := | 15.66 | | |
| | Pipe: 400 | | 5.99 | | 0.77 | | |
| | Pipe: 500 | | 39.34 | | 4.93 | | |
| | Elbow: 150 | | 12.14 | | 1.47 | | |
| | | | | | | | |
| | | | | | | | |
| | Pipe: 350 | | 0.31 | | 0.15 | | 2.441618389 |
| | Elbow: 350 | | 0.58 | | 0.15 | | 4.604731871 |
| DN := | Pipe: 350 | Pr/Py := | 0.96 | kPc := | 0.15 | Pr := | 7.604026467 |
| | Pipe: 400 | | 0.39 | | 0.15 | | 2.990634655 |
| | Pipe: 500 | | 0.91 | | 0.15 | | 7.263678959 |
| | Elbow: 150 | | 0.67 | | 0.15 | | 5.522284799 |
| | | | | | | | |
| | Pipe: 350 | | 16.28 | | | | |
| | Elbow: 350 | | 30.70 | | | | |
| DN := | Pipe: 350 | Pr/kPc := | 50.69 | | | | |
| | Pipe: 400 | | 19.94 | | | | |
| | Pipe: 500 | | 48.42 | | | | |
| | Elbow: 150 | | 36.82 | | | | |

## Concentric and Eccentric Reducer without knuckle due to External Pressure according to Chapter 9.4 of SS-EN 13480-3: 2012 (E) Issue 1 (2012-06)

| | | |
|---|---|---|
| **Input** | | |
| Material | EN 10216-2 10CrMo9-10 W1.7380 | |
| Type | Non-austenitic steels; Enter "NS" | |
| | Austenitic steels; Enter "AS" | |
| Design Temperature (Deg.C) | $T_d$ | |
| Design Stress (MPa) | $f$ | |
| Design Pressure (MPa) | $P_c$ | |
| Yield strength at design temperature | $R_{p0.2T}$ | |
| Modulus of Elasticity at Design | $E_t$ | |
| Small Pipe Outer Diameter | $D_1$ | |
| Nominal Wall Thickness in Small Pipe (mm) | $e_{n1}$ | |
| Nominal Wall Thickness of Reducer | $e_{nom}$ | |
| Semi Angle of Reducer at Apex | $\alpha$ | |
| Corrosion Allowance (mm) | $C_0$ = | 1.00 |
| Negative Tolerance in Small Pipe | $C_{s1}$ | |
| Negative Tolerance in Reducer | $C_1$ | |
| Thinning allowance due to manufacturing, Small Pipe | $Cs_2$ | |
| Thinning allowance due to manufacturing, Reducer | $C_2$ | |
| Number of circumferential waves for an unstiffend part of the cylinder | $n_{cyl}$ | |
| Unstiffend length of shell | L | |
| Poisson's ratio | v | 0.3 |
| Enter "Reducer Type" as E for "Eccentric" and C for "Concentric" | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Input** | | | | | | | |
| | | | | | | | |
| | 200x150 | | C | | NS | | 221 |
| | 400x200 | | C | | NS | | 221 |
| DN := | 400x350 | Reducer Type := | C | Type := | NS | Td := | 221 |
| | 500x400 | | C | | NS | | 221 |
| | | | | | | | |
| | 200x150 | | 219.1 | | 6.3 | | 0.7875 |
| | 400x200 | | 406.4 | | 8.8 | | 1.1 |
| DN := | 400x350 | D := | 406.4 | en1 := | 8.8 | Cl1 := | 1.1 |
| | 500x400 | | 508 | | 11 | | 1.375 |
| | | | | | | | |
| | 200x150 | | 168.3 | | 4.5 | | 4.5 |
| | 400x200 | | 219.1 | | 6.3 | | 6.3 |
| DN := | 400x350 | D1 := | 355.6 | en2 | 8 | enom := | 8 |
| | 500x400 | | 406.4 | | 8.8 | | 8.8 |
| | | | | | | | |
| | 200x150 | | 30 | | 0.5625 | | 0.5625 |
| | 400x200 | | 46 | | 0.7875 | | 0.7875 |
| DN := | 400x350 | α ≔ | 8 | C1 := | 1 | Cs1 := | 1 |
| | 500x400 | | 18 | | 1.1 | | 1.1 |
| | | | | | | | |
| | 200x150 | | 0 | | 0 | | 0.1 |
| | 400x200 | | 0 | | 0 | | 0.1 |
| DN := | 400x350 | Cs2 := | 0 | C2 := | 0 | Pc := | 0.1 |
| | 500x400 | | 0 | | 0 | | 0.1 |
| | | | | | | | |
| | 200x150 | | 152 | | 2 | | 229.8 |
| | 400x200 | | 356 | | 2 | | 229.8 |
| DN := | 400x350 | L := | 356 | ncyl := | 2 | Rp0.2T := | 229.8 |
| | 500x400 | | 508 | | 2 | | 229.8 |
| | | | | | | | |
| | 200x150 | | 198000 | | 132.8 | | |
| | 400x200 | | 198000 | | 132.8 | | |
| DN := | 400x350 | Et := | 198000 | f := | 132.8 | | |
| | 500x400 | | 198000 | | 132.8 | | |
| | | | | | | | |

**Result**

**Reducers Concentric and Eccentric**

| | |
|---|---|
| **Lower Bound Collapse Pressure** | Pr |
| **Utilization factor shall be equal to or greater than 1** | Pr/kP |

**9.3.2 Interstiffener collapse**

$P_y = \frac{Se_a}{R_m}$ where $R_m = mean\ radius\ of\ the\ cylinder$ (9.3.2-1)

$P_m = \frac{E_t e_a \varepsilon}{R_m}$ (9.3.2-2)

$\varepsilon = \frac{1}{n_{cyl^2} - 1 + \frac{Z^2}{2}} \left\{ \frac{1}{\left(\frac{n_{cyl^2}}{Z^2} + 1\right)^2} + \frac{e_{2^2}}{12 R_{m^2}(1-\nu^2)} \left(n_{cyl^2} - 1 + Z^2\right)^2 \right\}$ (9.3.2-3)

$Z = \frac{\pi R_m}{L}$ (9.3.2-4)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 200x150 | | 4.51 | | 193.70 | | 223.6654943 |
| | 400x200 | | 6.70 | | 312.75 | | 450.2213078 |
| DN := | 400x350 | e1 := | 6.70 | Dm := (D+D1)/2.0 | 381.00 | Deq := | 384.7443051 |
| | 500x400 | | 8.63 | | 457.20 | | 480.7285289 |
| | | | | | | | |
| | 200x150 | | 2.94 | | 114.12 | | 229.8 |
| | 400x200 | | 4.51 | | 247.02 | | 229.8 |
| DN := | 400x350 | e2 := | 6.00 | Rm := | 181.54 | S := | 229.8 |
| | 500x400 | | 6.70 | | 226.73 | | 229.8 |
| | | | | | | | |
| | 200x150 | | 9.09 | | 2.36 | | 0.059300674 |
| | 400x200 | | 6.23 | | 2.18 | | 0.055178791 |
| DN := | 400x350 | Py := | 8.48 | Z := | 1.60 | E := | 0.036390344 |
| | 500x400 | | 8.74 | | 1.40 | | 0.027759249 |
| | | | | | | | |
| | 200x150 | | 464.30 | | 51.09 | | |
| | 400x200 | | 296.33 | | 47.54 | | |
| DN := | 400x350 | Pm := | 265.92 | Pm/Py := | 31.35 | | |
| | 500x400 | | 209.09 | | 23.92 | | |
| | | | | | | | |
| | | | | | | | |
| | 200x150 | | 0.96 | | 0.15 | | 8.709931526 |
| | 400x200 | | 0.96 | | 0.15 | | 5.974238107 |
| DN := | 400x350 | Pr/Py (from Table 9.3.2-1) := | 0.96 | kPc := | 0.15 | Pr := | 8.128947416 |
| | 500x400 | | 0.96 | | 0.15 | | 8.379055655 |
| | | | | | | | |
| | 200x150 | | 58.07 | | | | |
| | 400x200 | | 39.83 | | | | |
| DN := | 400x350 | Pr/kPc := | 54.19 | | | | |
| | 500x400 | | 55.86 | | | | |

## 9.4 Reducers (Conical Shells)

$$I_x = 0.18 D_{eq} L D_{s^2} \frac{p_c}{E_t} \quad \textbf{(9.4.2-1)}$$

$$I_{cone} = \left(\sqrt{D_{eq} e_1}.e_1\right)\left(\frac{D_{mcon}}{2}\right)^2$$

$$I_{Cyl} = \left(\sqrt{D_{eq} e_2}.e_2\right)\left(\frac{D_{mcyl}}{2}\right)^2$$

$$I_{stiff} = (A_{cone} + A_{cyl})\left(\frac{D_s}{2}\right)^2$$

**From the above,**

$$I_{cone} + I_{Cyl} = I_{stiff}$$

*and*

$$D_s = 2\sqrt{\frac{I_{stiff}}{(A_{cone} + A_{cyl})}}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 200x150 | | 214.59 | | 1650343 | | 514731.0597 |
| | 400x200 | | 399.70 | | 14697164 | | 2341465.127 |
| DN := | 400x350 | Dm,con:= | 399.70 | Icone:= | 13586469 | Icyl:= | 8808375.744 |
| | 500x400 | | 499.38 | | 34624396 | | 15186946.3 |
| | | | | | | | |
| | 200x150 | | 199.02 | | 122.4123 | | 514731.0597 |
| | 400x200 | | 345.37 | | 1738.027 | | 2341465.127 |
| DN := | 400x350 | Ds := | 377.54 | Ix := | 1774.869 | Ixa := | 8808375.744 |
| | 500x400 | | 461.47 | | 4727.797 | | 15186946.3 |
| | | | | | | | |
| | | | | | | | |
| | 200x150 | | Valid | | | | |
| | 400x200 | | Valid | | | | |
| DN := | 400x350 | Ix < Ixa := | Valid | | | | |
| | 500x400 | | Valid | | | | |

## External Pressure Design Results from CAEPIPE

## Pipe material 1: EN 10216-2 10CrMo9-10 Seamless

Density = 7850 (kg/m3), Nu = 0.300, Joint factor = 0.80, Type = CS
Tensile strength = 229.8 (N/mm2)

| Temp (C) | E (kN/mm2) | Alpha (mm/mm/C) | ff (N/mm2) | fCR (N/mm2) |
|---|---|---|---|---|
| 20 | 211 | 11.51E-6 | 137.1 | |
| 50 | 209 | 11.78E-6 | 136.9 | |
| 100 | 206 | 12.10E-6 | 136.5 | |
| 150 | 203 | 12.43E-6 | 132.8 | |
| 200 | 199 | 12.75E-6 | 132.8 | |
| 250 | 196 | 13.08E-6 | 132.8 | |
| 300 | 192 | 13.22E-6 | 132.8 | |

## Pipe Sections (5)

| Name | Nom Dia | Sch | OD (mm) | Thk (mm) | Cor.Al (mm) | M.Tol (%) | Ins.Dens (kg/m3) | Ins.Thk (mm) | Lin.Dens (kg/m3) | Lin.Thk (mm) | Soil |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 150 | 150 | 3 | 168.3 | 4.5 | 1 | 12.5 | 150 | 100 | 2700 | 1 | |
| 200 | 200 | 3 | 219.1 | 6.3 | 1 | 12.5 | 150 | 120 | 2700 | 1 | |
| 350 | 350 | 3 | 355.6 | 8 | 1 | 12.5 | 150 | 120 | 2700 | 1 | |
| 400 | 400 | 3 | 406.4 | 8.8 | 1 | 12.5 | 150 | 140 | 2700 | 1 | |
| 500 | 500 | 3 | 508 | 11 | 1 | 12.5 | 200 | 140 | 2700 | 1 | |

## Pipe Loads (1)

| Name | T1 (C) | P1 (bar) | T2 (C) | P2 (bar) | Specific gravity | Add.Wgt. (kg/m) | Wind Load |
|---|---|---|---|---|---|---|---|
| 1 | 221 | 22.6 | 20 | -1.00 | 0.003 | | |

| Internal Pressure Design: EN 13480-3 (2012) (13) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | Element Type | Temp (C) | Press (Pc) (bar) | All.Stress (N/mm2) | Yield (N/mm2) | E (kN/mm2) | OD1 (mm) | OD2 (mm) | Thk1 (mm) | Thk2 (mm) | Cor.All (mm) | Radius (mm) | Length (mm) | Cone Angle (deg) | Pr (bar) | K.Pc (bar) | (Pr/K.Pc) | Ix (mm4) | Ixa (mm4) |
| 10 | 11A | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 355.6 | 355.6 | 8 | 8 | 1 | | 1467 | | 24.4 | 1.50 | 16.28 | | |
| 11A | 11B | Elbow | 221 | 1.00 | 132.8 | 229.8 | 198 | 355.6 | 355.6 | 8 | 8 | 1 | 533 | 1116.52 | | 46.0 | 1.50 | 30.70 | | |
| 11B | 12 | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 355.6 | 355.6 | 8 | 8 | 1 | | 467 | | 76.0 | 1.50 | 50.69 | | |
| 12 | 20 | Reducer | 221 | 1.00 | 132.8 | 229.8 | 198 | 406.4 | 355.6 | 8.8 | 8 | 1 | | 356 | 8 | 81.3 | 1.50 | 54.19 | 1778.71 | 8.808376E+6 |
| 20 | 25 | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 406.4 | 406.4 | 8.8 | 8.8 | 1 | | 1500 | | 29.9 | 1.50 | 19.94 | | |
| 25 | 30 | Reducer | 221 | 1.00 | 132.8 | 229.8 | 198 | 508 | 406.4 | 11 | 8.8 | 1 | | 508 | 18 | 83.8 | 1.50 | 55.86 | 4738.02 | 1.5186949E+7 |
| 30 | 35 | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 508 | 508 | 11 | 11 | 1 | | 1000 | | 72.6 | 1.50 | 48.42 | | |
| 35 | 40 | Reducer | 221 | 1.00 | 132.8 | 229.8 | 198 | 508 | 406.4 | 11 | 8.8 | 1 | | 508 | 18 | 83.8 | 1.50 | 55.86 | 4738.02 | 1.5186949E+7 |
| 40 | 50 | Reducer | 221 | 1.00 | 132.8 | 229.8 | 198 | 406.4 | 219.1 | 8.8 | 6.3 | 1 | | 356 | 46 | 59.7 | 1.50 | 39.83 | 1741.79 | 2.3414655E+6 |
| 50 | 60 | Reducer | 221 | 1.00 | 132.8 | 229.8 | 198 | 219.1 | 168.3 | 6.3 | 4.5 | 1 | | 152 | 30 | 87.1 | 1.50 | 58.07 | 122.677 | 514731 |
| 60 | 70A | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 168.3 | 168.3 | 4.5 | 4.5 | 1 | | 2771 | | 12.6 | 1.50 | 8.41 | | |
| 70A | 70B | Elbow | 221 | 1.00 | 132.8 | 229.8 | 198 | 168.3 | 168.3 | 4.5 | 4.5 | 1 | 229 | 491.895 | | 55.3 | 1.50 | 36.83 | | |
| 70B | 80 | Pipe | 221 | 1.00 | 132.8 | 229.8 | 198 | 168.3 | 168.3 | 4.5 | 4.5 | 1 | | 2771 | | 12.6 | 1.50 | 8.41 | | |