SECTION 2

Bends

This section provides guidelines and recommended best practices for the modeling various bend geometries in CAESAR II.

NOTE For detailed information about using the software to define bend geometry, see "Component Information" in the *CAESAR II User's Guide*.

Bend Definition

A bend is defined by the element entering the bend and the element leaving the bend. The bend curvature is always physically at the **To** end of the element entering the bend.

The input for the element leaving the bend must follow the element entering the bend. The bend angle is defined by these two elements. The default bend radius is 1-1/2 times the pipe nominal diameter (long radius), but it can be changed to any other value. When you specify a bend, two additional intermediate nodes are automatically generated--one at the 0º location and one at the bend midpoint (M).

For stress and displacement output, the **To** node of the element entering the bend is located geometrically at the far-point on the bend. The far-point is at the weld line of the bend, adjacent to the straight element leaving the bend. The 0º point on the bend is at the weld line of the bend, adjacent to the straight element entering the bend.

The **From** point on the element is located at the 0º point of the bend (and no 0º node point is generated) if the total length of the element as specified by **DX**, **DY**, and **DZ** is equal to:

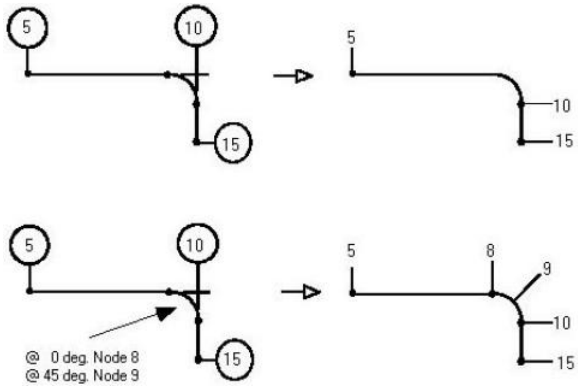
```
R tan (b / 2)
```

Where **b** is the bend angle, and **R** is the bend radius of curvature to the bend centerline.

Nodes defined by the **Angle** and **Node** properties are placed at the given angle on the bend curvature. The angle starts with zero degrees at the near-point on the bend and goes to **b** degrees at the far-point of the bend. Angles are always entered in degrees. Entering the letter **M** as the angle designates the bend midpoint.

Nodes on the bend curvature cannot be placed closer together than the angle distance specified by **Minimum Angle to Adjacent Bend** in the **Geometry** category of the **Tools > Configure/Setup** command. This includes the spacing between the nodes on the bend curvature and the near- and far-points of the bend.

The minimum and maximum total bend angle is specified by the **Minimum Allowable Bend Angle** and **Maximum Allowable Bend Angle** properties, also in the **Geometry** category of the **Tools > Configure Setup** command.



Single and Double Flanged Bends or Stiffened Bends

Single- and double-flanged bend specifications affect only the stress intensification and flexibility of the bend. There is no automatic rigid element (or change in weight) generated for the end of the bend. Single- and double-flanged bends are indicated by typing a **1** or **2** to define the **Type** in the bend auxiliary input. Rigid elements defined before or after the bend do not alter the stiffness of the bend or its stress intensification factors.

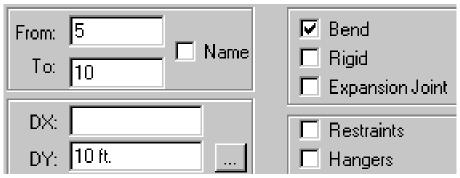
When specifying single-flanged bends, it does not matter on which end of the bend you place the flange.

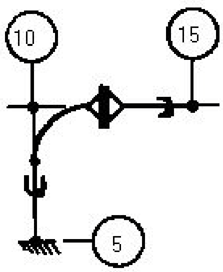
If you want to include the weight of the rigid flange at the bend ends, then put rigid elements (whose total length is the length of a flange pair) at the bend ends where the flange pairs exist.

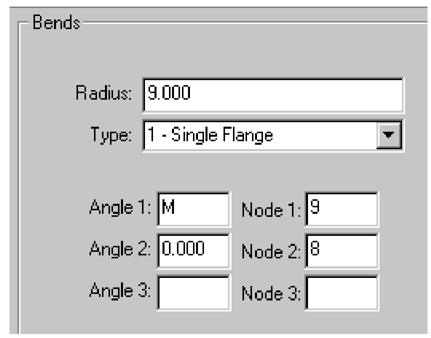
As a guideline, British Standard 806 recommends stiffening the bends whenever a component that significantly stiffens the pipe cross section is found within two diameters of either bend end.

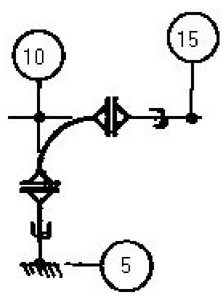
The flanges in the figures below are modeled only to the extent that they affect the stiff\-ness and the stress intensification for the bends.

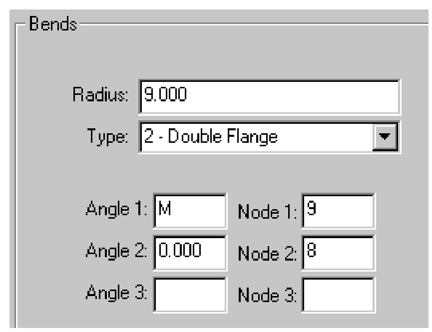
Flanges and Bends:







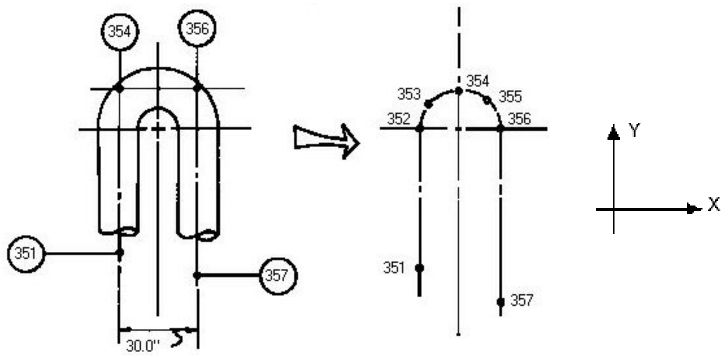


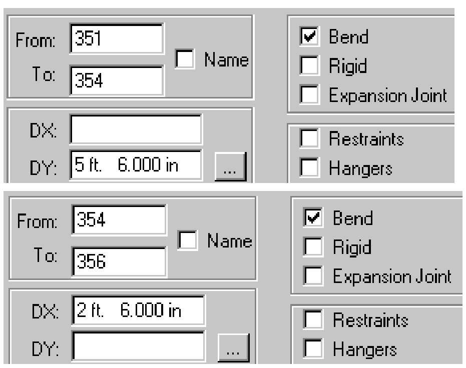


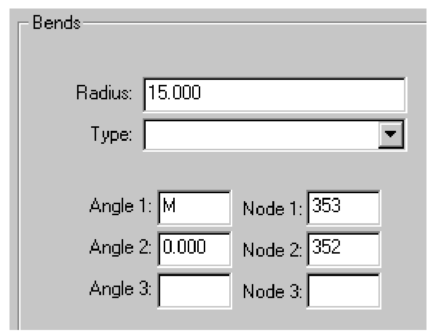
180º Return Fitting-to-Fitting 90º Bends

Separate two 90º bends by twice the bend radius. The far-point of the first bend is the same as the near-point of the second, or following, bend. Intergraph CAS recommends that you place nodes at the midpoint of each bend that comprise the 180º return.

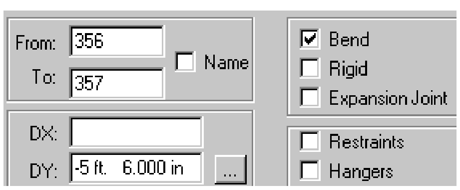
180º Bend:

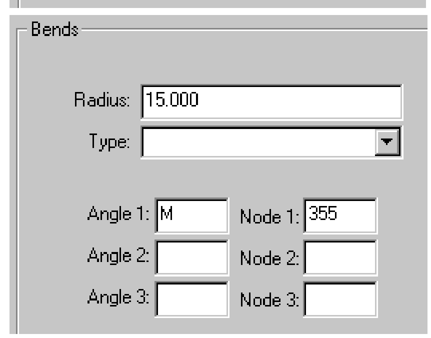






DX = 2R





Mitered Bends

Evenly spaced mitered bends, whether closely or widely spaced, are defined by two parameters:

- The number of cuts (changes in direction)
- The equivalent radius or miter spacing

For closely spaced miters, the equivalent radius is equal to the code defined as **R1** for B31.3 and **R** for B31.1. The equation for the equivalent radius to the spacing for evenly spaced miters is:

$$Req = S / [\, 2 \tan(\theta) \,]$$

Where:

Req = *equivalent miter bend radius*

S = *spacing of the miter cuts along the centerline*

θ = *code-defined half-angle between adjacent miter cuts:* $\theta = \alpha / 2N$

Where:

α = *total bend angle*

N = *number of cuts*

When using B31.1, an additional parameter, **B** (length of miter segment at crotch), is examined for closely spaced miters. The following equation is used to compute **B** for evenly spaced miters:

$$B = S\,[\, 1 - r_o / Req \,]$$

Where:

r_o = *outside radius of pipe cross-section*

Closely-Spaced Mitered Bend

Miter bends are closely spaced if:

$$S < r\,[1 + \tan(\theta)]$$

Where:

S = miter spacing

r = average pipe cross section radius: $(r_i+r_o)/2$

q = one-half the angle between adjacent miter cuts

B31.1 has additional requirements:

$B > 6\, t_n$

$\theta \leq 22.5$ *deg.*

B = length of the miter segment at the crotch.

t_n *= nominal wall thickness of pipe.*

Closely spaced miters, regardless of the number of miter cuts, can be defined as a single bend. CAESAR II always calculates the spacing from the bend radius. If you have the miter spacing but not the bend radius, the radius must be calculated as shown in the following example. The mitered bend shown below has four cuts through 90º and a spacing of 15.913 inches.

$$R_{eq} = S / [2 \tan(\theta)]$$

$$\theta = \alpha / 2N$$

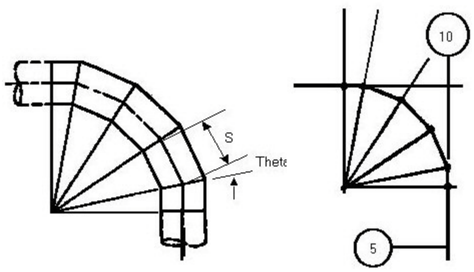
$$= 90 / [2(4)]$$

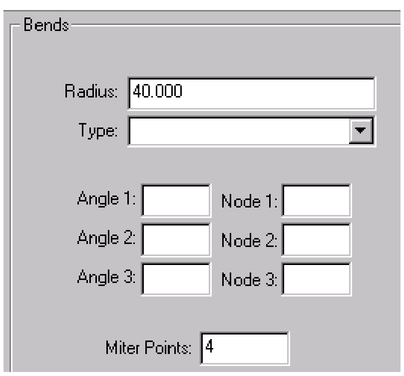
$$= 11.25^{o}$$

$$R_{eq} = 15.913 / [2 \tan(11.25^{o})]$$

$$= 40$$

Closely Spaced Miter Bend:





Widely-Spaced Mitered Bend

Mitered bends are widely spaced if:

$S^3 r * [1 + \tan(\theta)]$

Where:

S = *spacing between miter points along the miter segment centerline*

r = *average cross section radius* $(r_i + r_o)/2$

θ = *one-half angle between adjacent miter cuts*

B31.1 has the following additional requirement:

$\theta \leq 22.5º$

In CAESAR II, you must enter widely spaced miters as individual, single-cut miters, each having a bend radius equal to:

R = r [1 + cot (θ)*] / 2*

Where:

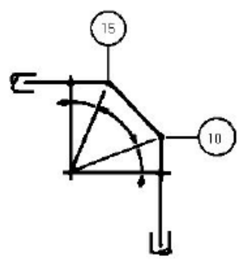
R = reduced bend radius for widely spaced miters.

During error checking, CAESAR II produces a warning message for each mitered component that does not pass the test for a closely spaced miter.

The following components should be re-entered as a group of single cut joints.

Widely Spaced Miter:

Pipe O.D. = 10.375 in.
Pipe Thickness = 0.500 in.
Bend Angle = 90º
Cuts = 2
Req = 45 inches



Assuming closely spaced:

$\theta = \alpha / 2N = 90/(2*2) = 22.5$ deg.

$S = R_{eq} 2\tan(\theta)$
$= 45[2\tan(22.5)]$
$= 37.279$ in.

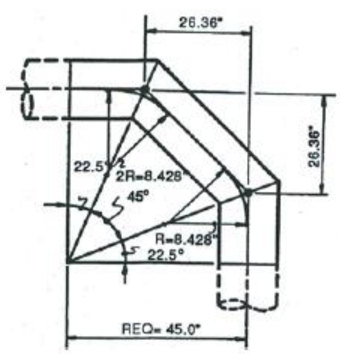
$r_2 = \frac{(D_o - t)}{2}$
$= \frac{(10.375 - 0.5)}{2}$
$= 4.9375$ in

Now check $s \geq r_2[1+\tan(\theta)]$

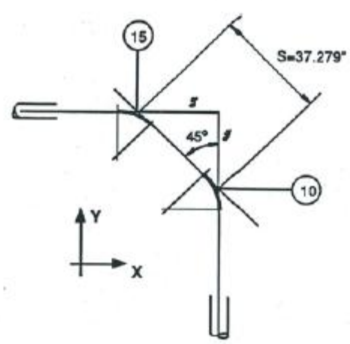
$r_2[1+\tan(\theta)] = 4.9375[1+\tan(22.5)] = 6.9\ 826$ in.

37.279>6.9826 The miter is widely spaced.

$R = \frac{r[1+\cot\theta]}{2} = 8.4288"$



$g = 37.279 \sin 45$ deg



Calculate the Δ coordinates to get from the tangent intersection point of the single cut miter bend at node 10 to the single cut miter bend at node 15.

NOTE The straight pipe section coming into and going out of the bend must be ≥ $R_{eq}\sin(\theta)$.

$R = \frac{r^2}{2}[1+\tan(\theta)]$
$= \left[\left(4.9375/2\right)\right][1+\cot(22.5)]$
$= 8.4288$ in.

$DX = S \times \cos(45)$
$= 37.279 \times \cos(45)$
$= 26.360$ in.

$DY = S \times \sin(45)$
$= 37.279\sin(45)$
$= 26.360$ in.

Enter widely spaced miters as individual straight pipe elements, with bends specified, having one miter cut.

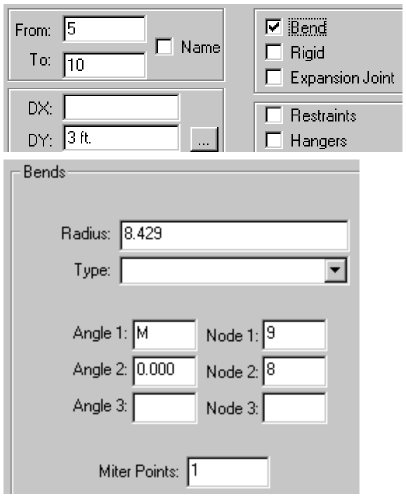


Figure 1: Coming Up to the First Cut

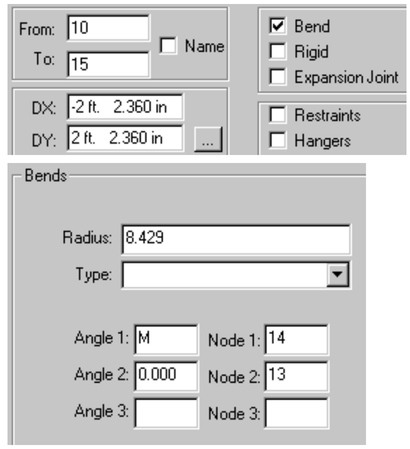


Figure 2: Between the First and Second Cuts

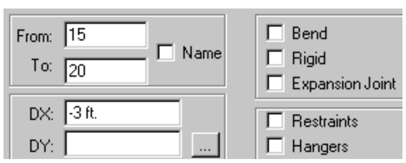


Figure 3: Coming Out of the Second Cut

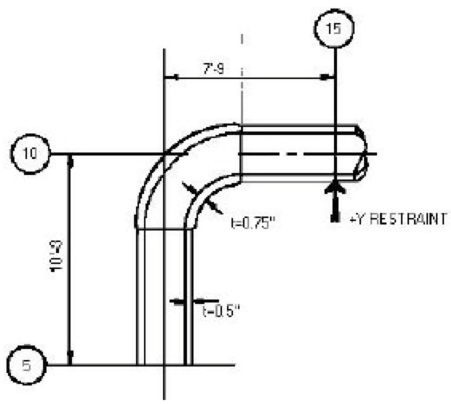
Elbows - Different Wall Thickness

When you define the fitting thickness for the bend, CAESAR II changes the thickness only of the curved portion of the bend element. The thickness of any preceding or following straight pipe is unaffected.

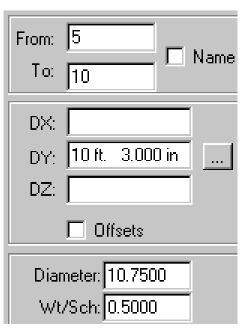
The specified fitting thickness applies only for the current elbow and is not persisted to any subsequent elbows in the job.

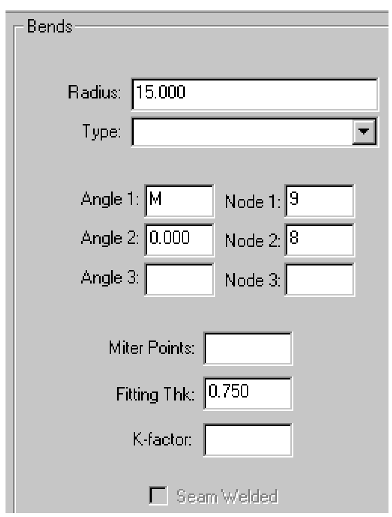
Stresses at the elbow are calculated based on the section modulus of the matching pipe as specified in the B31 codes. However, stress intensification factors and flexibility factors for the bend are based on the elbow wall thickness.

Thick Elbow:



NOTE The elbow at node 10 has a thickness larger than the matching pipe wall. The matching pipe has a thickness of 0.5.





Bend Flexibility Factor

Usually, bend flexibility factors are calculated according to code requirements. However, you can override the code calculation by typing a value for the **K-factor**. For example, if you type **1.500**, then the bend is 1.5 times as flexible as a straight pipe of the same length.