13. Rotation of Fittings.

a. Rotation of Bends.

- 1) Bends can be rotated about the pipe axis to produce a simultaneous deflection or combined bend. This section covers the design of horizontal bends rotated in the vertical plane.
- 2) When labeling bends that will be rotated, refer to the amount of rotation as the horizontal and/or vertical <u>deflection</u> angle.
- 3) For the list of allowable bends, see Part One, Section 7 (Allowable Fittings). For ninety (90°) degree bends, the approaching line to the bend must be level (no slope).
- 4) Total deflection angle of the bend must equal the manufacturer's angle and will always be greater than either the horizontal plane (plan view) angle of the bend or the vertical plane (profile) angle of the bend.
- 5) When the rotation of the bend has a rotation angle greater than ten (10°) degrees for pipe sizes 12inch diameter and smaller and five (5°) degrees for pipe sizes larger than 12-inch diameter, special considerations must be given to restrain the horizontal and vertical components of the thrust force caused by the rotation of the bend. See Part Three, Section 27 (Thrust Restraint Design for Buried Piping).
- 6) <u>Formulas for computing the combined horizontal and vertical deflections</u> are provided below to obtain the required total deflection angle of the bend.
- 7) <u>Determine the vertical alignment (profile).</u> Set the station and invert elevation of the alignment through the bend. Then, use the Formula "C" below to establish the horizontal deflection in plan.

FORMULA "C"

To find VD or HD when either is known.

 $\cos B = ((\cos HD \times \cos V \times \cos V') + (\sin V \times \sin V'))$

Where:

- B = total manufacturer's deflection angle of the bend (45° , $22-1/2^\circ$, or $11-1/4^\circ$)
- V = vertical angle of the approaching line (incoming) of the bend with horizontal plane
- V' = vertical angle of the departing line (outgoing) of the bend with horizontal plane
- HD = horizontal deflection of the combined bend
- VD = vertical deflection of the combined bend

(Formula "C" is copied from Price Brothers Catalog, with some modifications)

<u>NOTE A:</u> V and V' are positive or negative if the pipe is sloping upward or downward, respectively, in the direction of laying. For positive V or V', sin V or sin V' and cos V or cos V' are positive. For negative V or V', sin V or sin V' is negative and cos V or cos V' is positive.



The following Sketch "D" is to define the different elements of the above formula.



To find the pipe slope of the approaching or departing line in degrees, use the following formula:

FORMULA "D"

V or V' = \tan^{-1} ((Difference between invert elevations) ÷ (Distance between invert elevations))

Example: Determine Pipe Slope

The pipe invert elevation station at 0+00 is 250.0 and at 2+00 is 251.0.

V or V' =
$$\tan^{-1} ((\text{Difference between invert elevations}) \div (\text{Distance between invert elevations}))$$

= $\tan^{-1} ((251.0 - 250.0) \div (2+00 - 0+00))$
= $\tan^{-1} (1.0 \div 200)$
= $\tan^{-1} 0.005$
V or V' = 0.28647651° or 00°17'11" (Pipe slope in degrees)

If V' and V are known then determine HD and VD using the following formula:

FORMULA "E"

 $HD = \cos^{-1} \left((\cos B - (\sin V \times \sin V')) \div (\cos V \times \cos) \right)$

FORMULA "F"

VD = V + V' See Note A, on previous page.



Example: Determine Vertical Deflection for a Horizontal Bend, Formulas "D", "E" and "F".

A 24-inch water main has a vertical alignment as shown in the profile below (Sketch "E") and in the horizontal plane we require a 45° horizontal bend. What will be the actual resultant deflection angle in the plan view?



The first step is to determine the vertical deflection angle (VD) for the 45° horizontal bend. Then, using Formula "D", find the pipe slopes for both the approaching line (V) and the departing line (V') in degrees.

 $V' = \tan^{-1} ((\text{Difference between invert elevations}) \div (\text{Distance between invert elevations}))$ = $\tan^{-1} ((273.0 - 251.0) \div (3+00 - 2+00))$ = $\tan^{-1} (22.0 \div 100)$ = $\tan^{-1} 0.22$ $V' = 12.407418^{\circ} \text{ or } 12^{\circ}24'27''$ $V = \tan^{-1} ((\text{Difference between invert elevations}) \div (\text{Distance between invert elevations}))$ = $\tan^{-1} ((251.0 - 250.0) \div (2+00 - 0+00))$ = $\tan^{-1} (1.0 \div 100)$

$$= \tan^{-1} 0.005$$

 $V = 0.28647651^{\circ}$ or $00^{\circ}17'11''$

To find the vertical deflection angle (VD), use Formula "F".

VD = V + V'In above profile V and V' are positive because both lines are upward, see Note A. = 12.407418° + 0.28647651 VD = 12.693895° or 12°41'38"



Second, to determine the horizontal deflection angle (HD), use Formula "E".

$$HD = \cos^{-1} \left(\left(\cos B - (\sin V \times \sin V') \right) \div (\cos V \times \cos V') \right) \\ = \cos^{-1} \left(\left(\cos 45^{\circ} - (\sin 00^{\circ}17'11'' \times \sin 12^{\circ}24'27'') \right) \div (\cos 00^{\circ}17'11'' \times \cos 12^{\circ}24'27'') \right) \\ = \cos^{-1} \left(\left(0.7071068 - (0.0049984 \times 0.2148632) \right) \div (0.9999875 \times 0.9766442) \right) \\ = \cos^{-1} \left((0.7071068 - 0.001074) \div 0.976632 \right) \\ = \cos^{-1} 0.7229261 \\ HD = 43.703401^{\circ} \text{ or } 43^{\circ}42'21''$$

After determining the resultant horizontal deflection angle (HD), adjust the horizontal plane to suit the computed resultant horizontal deflection angle.

When the pipeline is 12-inches and smaller, Chart "A" can be used to determine the horizontal deflection angle (HD). When using this chart, the horizontal and vertical angles should be rounded to the nearest one-half degree $(1/2^{\circ})$. The approaching line must be laid almost level, not to exceed the maximum slope allowed for this chart, which is two (2°) degrees or three and one half (3.5%) percent.





 $\cos B = ((\cos HD \times \cos V \times \cos V') + (\sin V \times \sin V')), \text{ with } V = 0^{\circ}$



Example: Determine Vertical Deflection for a Horizontal Bend, Chart "A".

Using the example as previously stated and shown on the profile, determine the vertical deflection angle (VD) and horizontal deflection angle (HD) using Chart "A", for pipelines 12-inch and smaller diameter. Also, Chart "A" could be used as a <u>check</u> for pipelines larger than 12-inch diameter.

cos B = ((cos HD × cos V × cos V') + (sin V × sin V'))= ((cos HD × cos 0° × cos V') + (sin 0° × sin V'))= ((cos HD × 1.0 × cos V') + (0.0 × sin V'))= (cos HD × cos V'), (V' = VD = V + V' and V = 0)cos B = (cos HD × cos VD)HD = cos⁻¹ (cos B + cos VD)= cos⁻¹ (cos 45° + cos 12°30')= cos⁻¹ (0.7071068 + 0.976296)= cos⁻¹ 0.724275= 43.591429° or 43°35'29", round to nearest 1/2°

HD = $43^{\circ}30'$

b. Rotation of Tees.

- When the branch of a tee has a valve on the rotated section of the branch connection, the maximum allowable rotation of the branch connection at the tee is not to exceed three (3°) degrees. Exceptions can be submitted for approval using a maximum of five (5°) degrees for branch connections which are 14-inch and smaller. See Part One, Section 18 (Pipeline Valves).
- 2) When the rotation of a branch connection is ten (10°) degrees or more for pipe sizes 12-inch and smaller diameter or five (5°) degrees or more for pipe sizes larger than 12-inch diameter, special thrust blocking design must be provided for the vertical components of the thrust forces caused by the rotation of the tee. See Part Three, Section 27 (Thrust Restraint Design for Buried Piping).

c. Rotation of Other Fittings.

1) Rotation of any fittings other than bends or tees is not permitted.

