THOMPSON™
PIPE GROUP
PRESSURE

Steel Water Pipe Fittings – Design

Darren W. Dunker, PE
SPFA Member

Steel Water Pipe Fittings – Design

What is a fitting?

- AWWA M11
- AWWA C208
- ASME BPVC

Steel Water Pipe Fittings – Design

1. Design for Internal Pressure
2. Check for External Loads

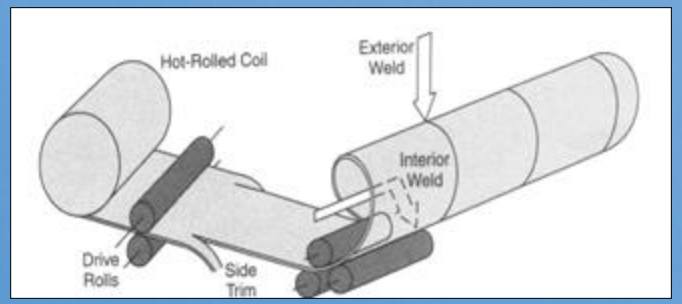
Steel Water Pipe Fittings – Design

$$t = \frac{P_w D_o}{2\,S}$$

t - Required thickness of steel
P_w - Working pressure
D_o - Outside diameter of pipe
S - Limited to 50% of the min. yield strength of steel

Steel Water Pipe Fittings – Design

Steel Water Pipe Fittings – Design
Helical Forming and Weld Machine

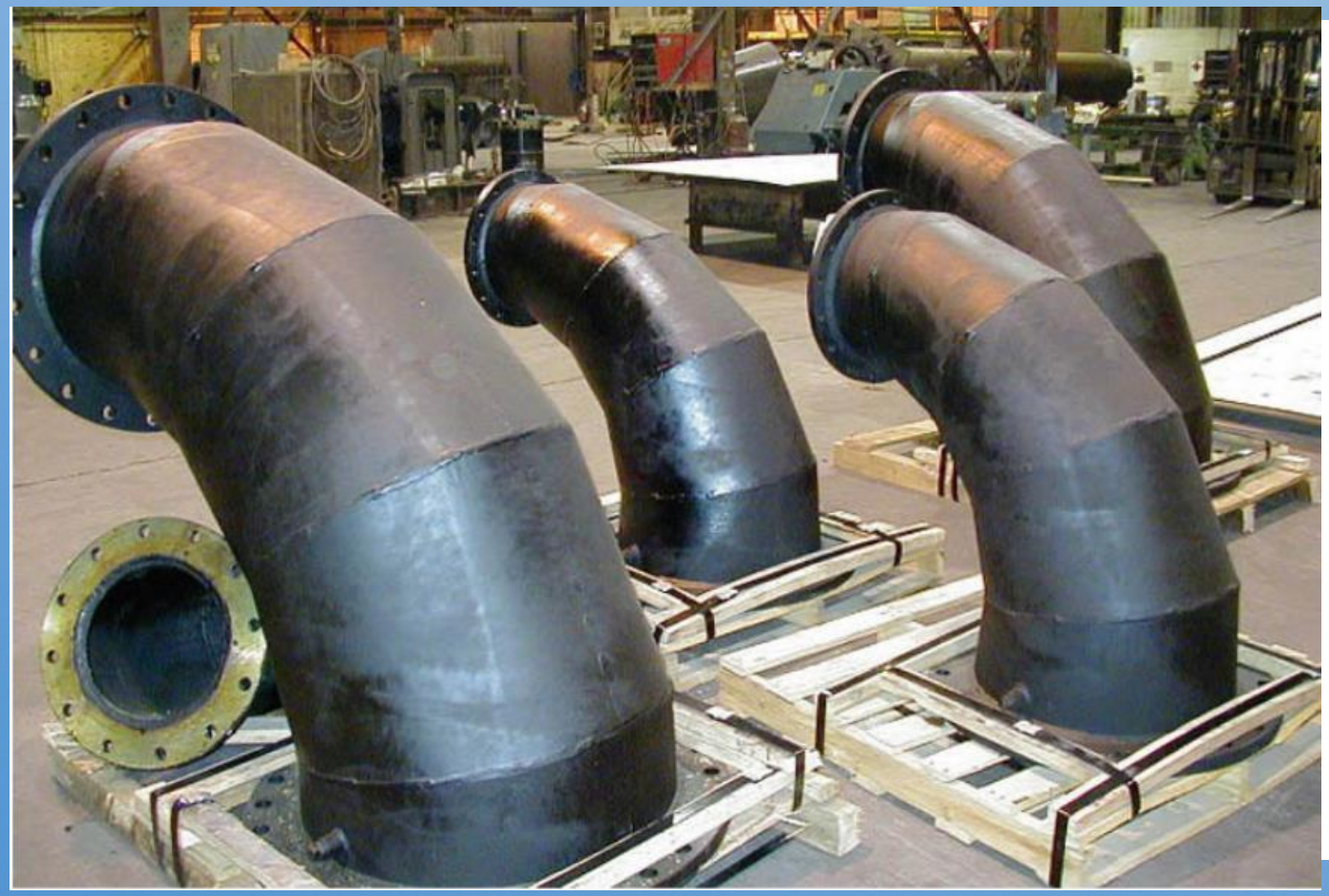


Steel Water Pipe Fittings – Design

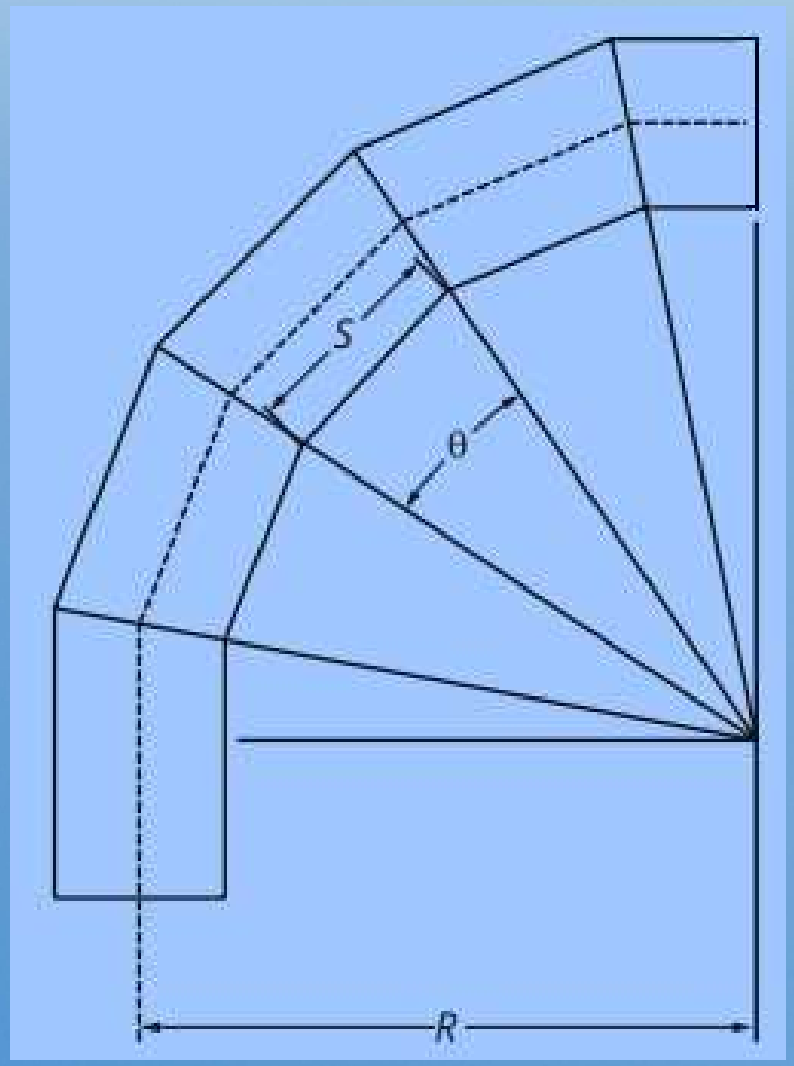
Elbows

Steel Water Pipe Fittings – Design

Elbows/Bends



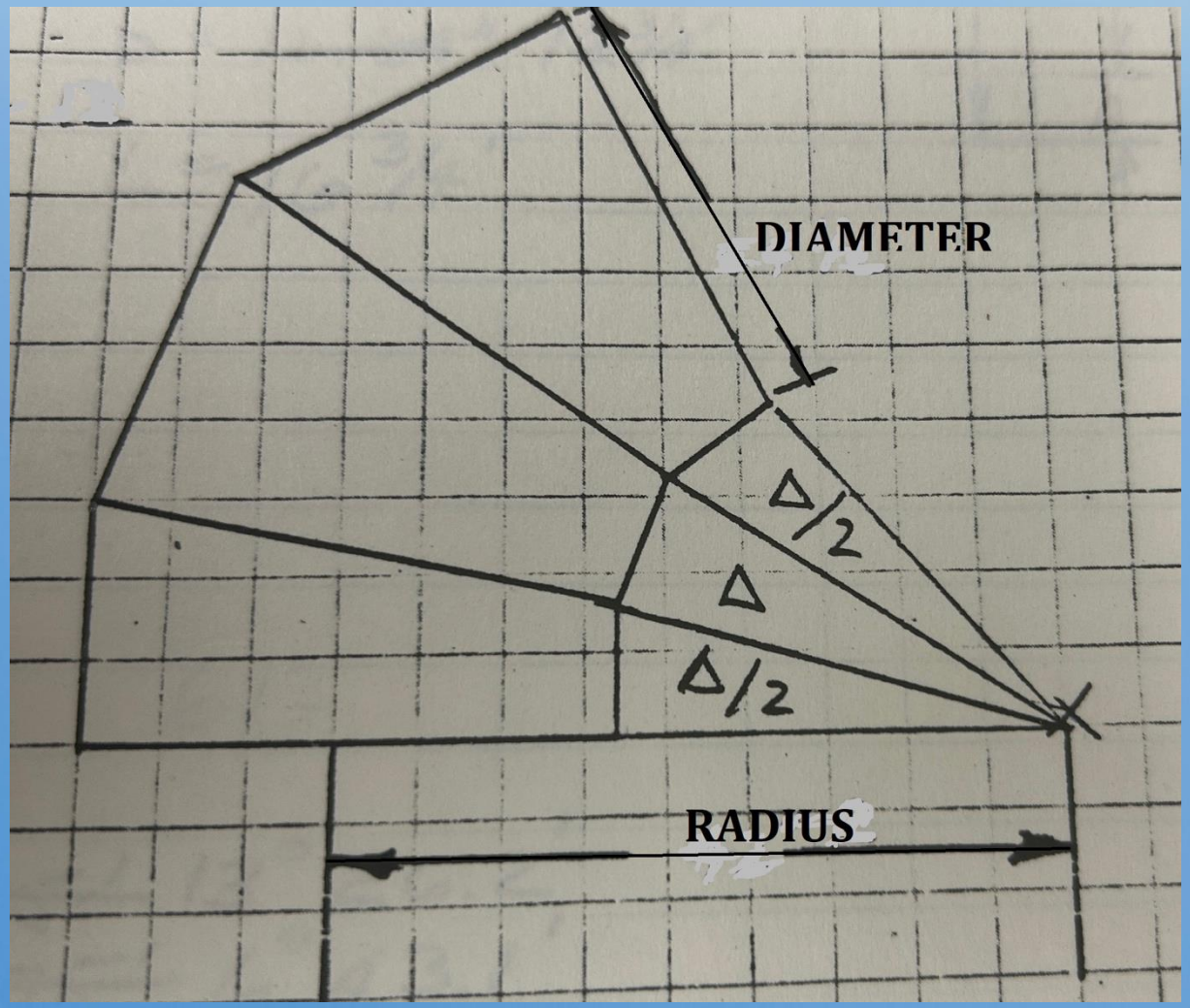
Steel Water Pipe Fittings – Design



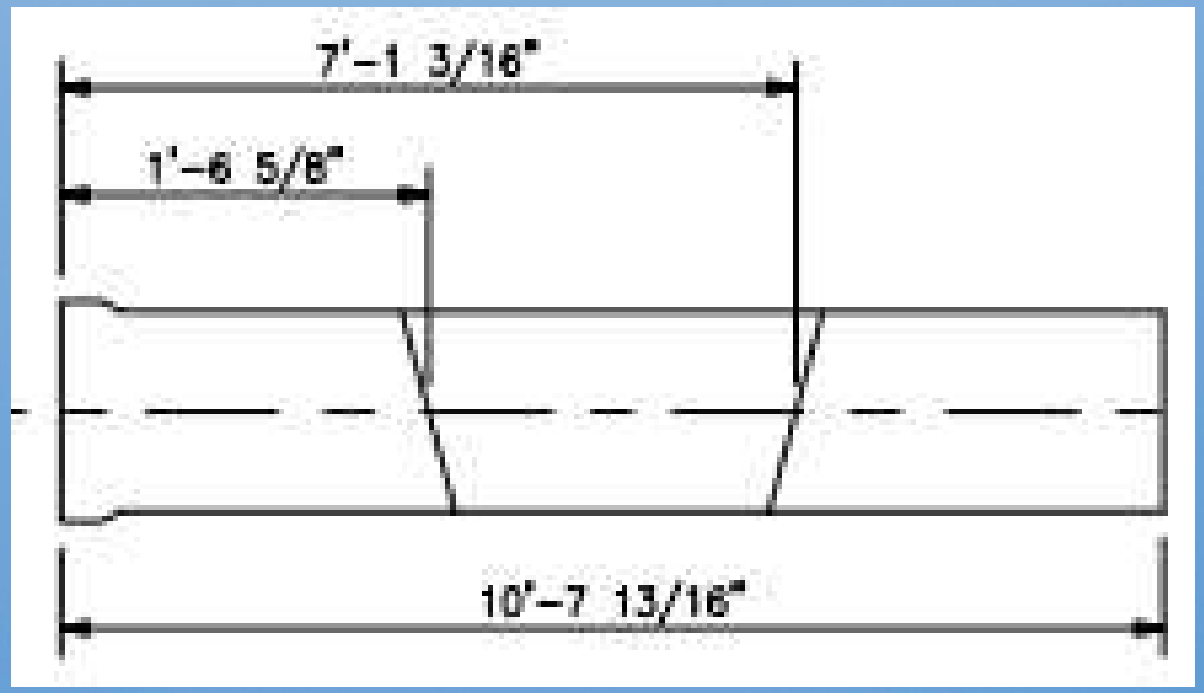
Elbow Leg Lay Length

At 90°, LL = R

Steel Water Pipe Fittings – Design



How many segments will an elbow have?



Steel Water Pipe Fittings – Design

T_y - Required steel thickness
R - Elbow Radius
D - Outside diameter of pipe
p - internal design pressure
σ - *allowable design stress*

Cylinder Thickness for bends < 2.5 x D

$$T_y = \frac{pD}{2\sigma}\left(1 + \frac{D}{3R-1.5D}\right)$$

Steel Water Pipe Fittings – Design

Δ - Required elbow angle
R - Elbow Radius
D - Outside diameter of pipe
p - internal design pressure
σ - *allowable design stress*

Example: 48” OD x 90° Elbow with a standard radius (1 x D) at 150psi, 36ksi steel

$$T_y = \frac{pD}{2\sigma}\left(1 + \frac{D}{3R - 1.5D}\right)$$

Steel Water Pipe Fittings – Design

Δ - Required elbow angle
R - Elbow Radius
D - Outside diameter of pipe
p - internal design pressure
σ - *allowable design stress*

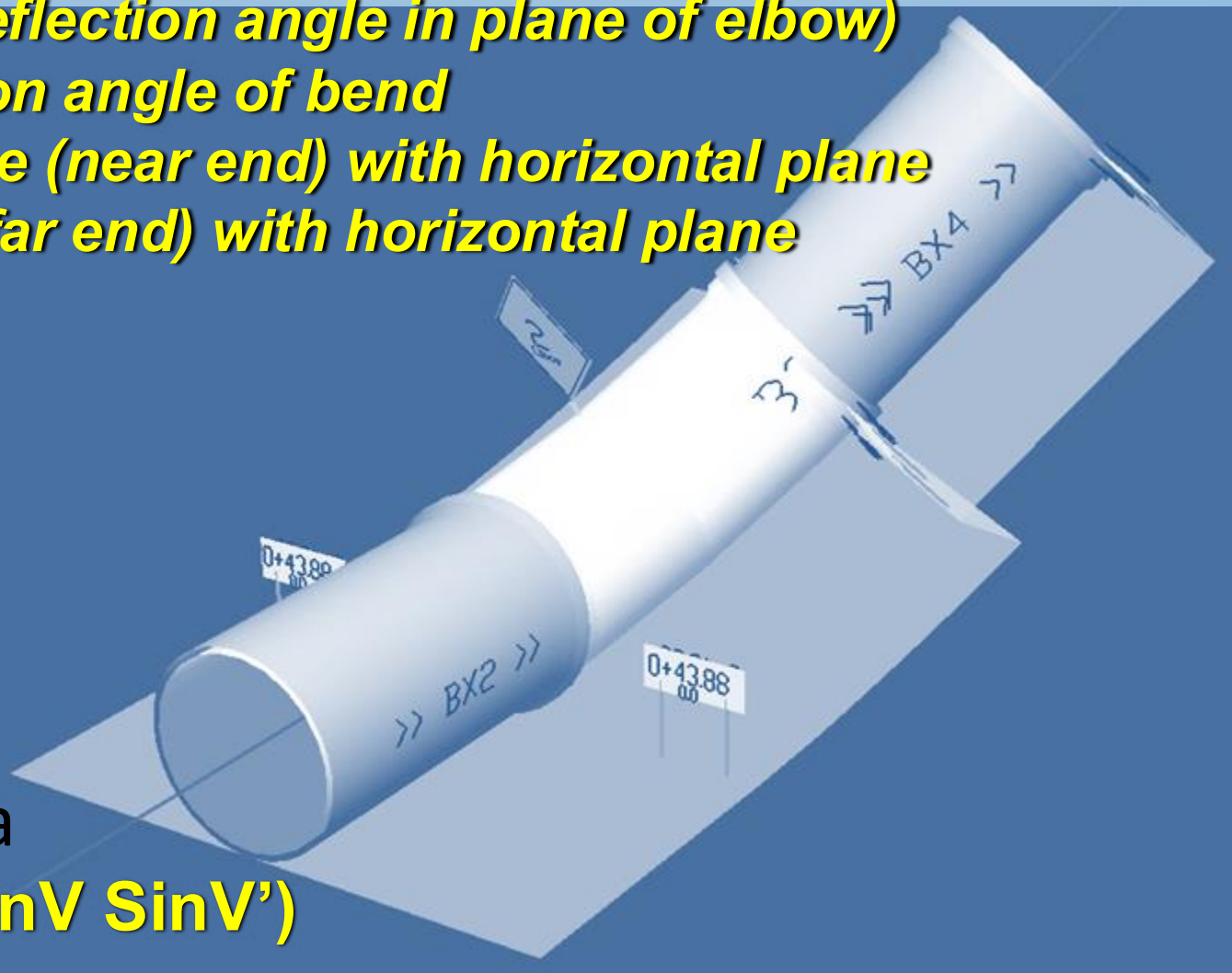
Example: 48” Dia x 90° Elbow with a standard radius (1 x D) at 150psi, 36ksi steel

$$T_y = \frac{150\ x\ 48}{2\ x\ 18{,}000}\left(1 + \frac{48}{3(48) - 1.5(48)}\right)$$

$$T_y = 0.333"$$

Steel Water Pipe Fittings – Design

C = Manufactured angle of elbow (deflection angle in plane of elbow)
H = Horizontal projection of deflection angle of bend
V = Vertical angle of approaching line (near end) with horizontal plane
V'= Vertical angle of departing line (far end) with horizontal plane



Compound bend formula

Cos C = (CosH CosV CosV') + (SinV SinV')

Steel Water Pipe Fittings – Design

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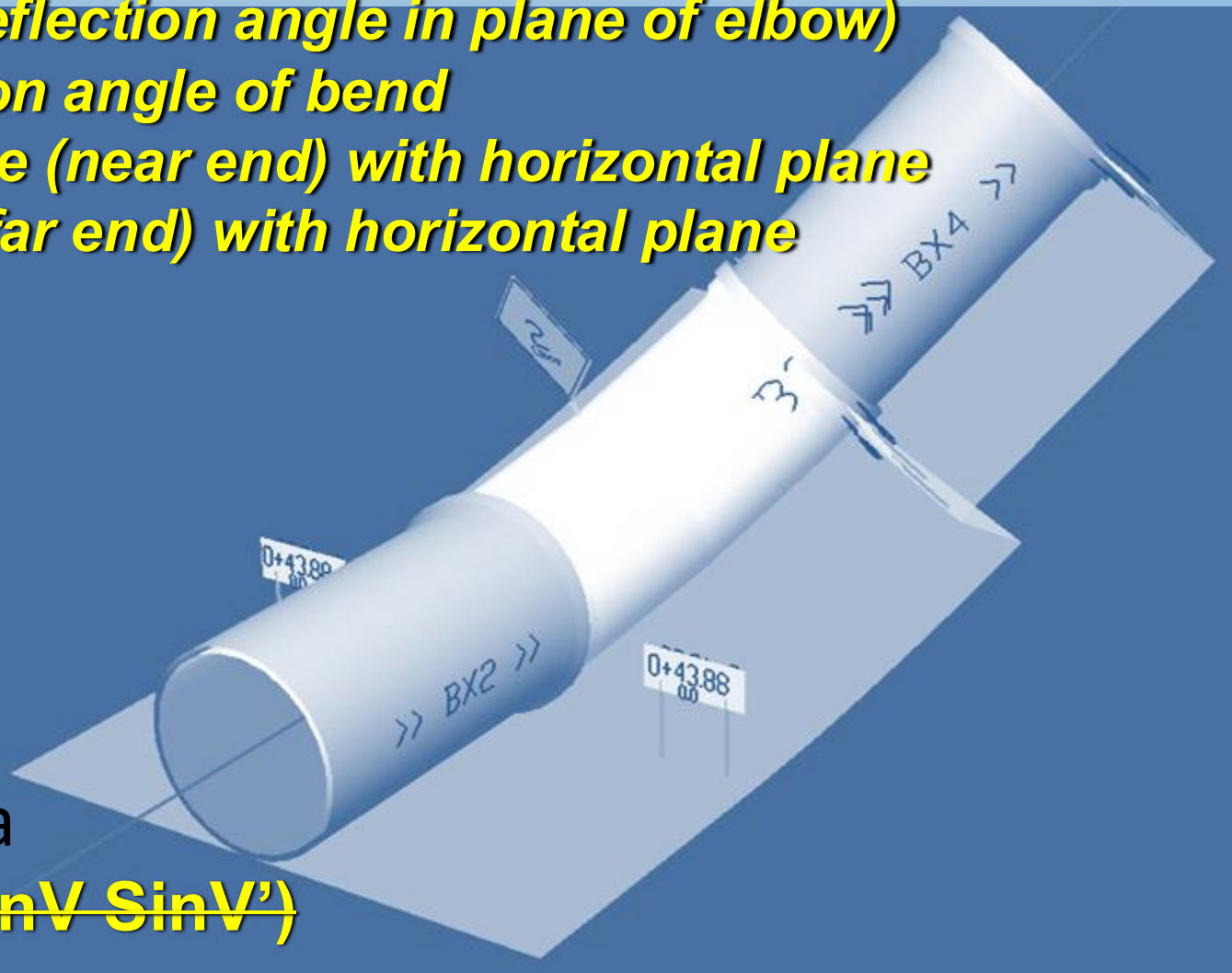

Compound bend formula

Cos C = (CosH ~~CosV~~ CosV') ~~+ (SinV SinV')~~

Steel Water Pipe Fittings – Design

Reducer Lay Length

$$LL = 4 \times (D_L - D_S)$$

Steel Water Pipe Fittings – Design

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Tees, Outlets & Laterals

Steel Water Pipe Fittings – Design

$$PDV = \frac{Kpd_o^2}{D_o(\sin^2\Delta)}$$

K = 1.0 except for full-size cross(1.5)
p = design pressure, psi
d_o = outlet outside diameter, in.
D_o = main pipe outside diameter, in.
Δ = outlet angle of deflection, degrees

Steel Water Pipe Fittings – Design

$$PDV = \frac{Kpd_o^2}{D_o(\sin^2 \Delta)}$$

K = 1.0 except for full-size cross(1.5)
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Do = main pipe outside diameter, in.
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Steel Water Pipe Fittings – Design

$$PDV = \frac{Kpd_o^2}{D_o(\sin^2 \Delta)}$$

Example: 48” x 8” outlet at 150psi

K = 1.0
p = 150 psi
do = 8.625 in.
Do = 49.75 in.
Ty = 0.375”
Δ = radial or 90 degrees

Steel Water Pipe Fittings – Design

Example: 48” x 8” outlet at 150psi

$$PDV = \frac{1.0(150)(8.625)^2}{49.75\,(\sin^2 90)}$$

PDV = 299

Steel Water Pipe Fittings – Design

$$PDV = \frac{Kpd_o^2}{D_o(\sin^2 \Delta)}$$

PDV	Reinforcement
< 6,000	C
6,000–9,000	ICT, W, or C (M = 0.000167xPDV)
> 9,000	Crotch Plate

Steel Water Pipe Fittings – Design

Allowable stress,σ = 0.5 x Pw or 0.75 x Pw +Pt or :P_{ft}

Input variables

D_o = run pipe OD, in.

Ty = run cylinder thickness, in.

d_o = outlet pipe OD, in.

t_y = outlet cylinder thickness, in.

Δ = outlet deflection angle, degrees

Output variables

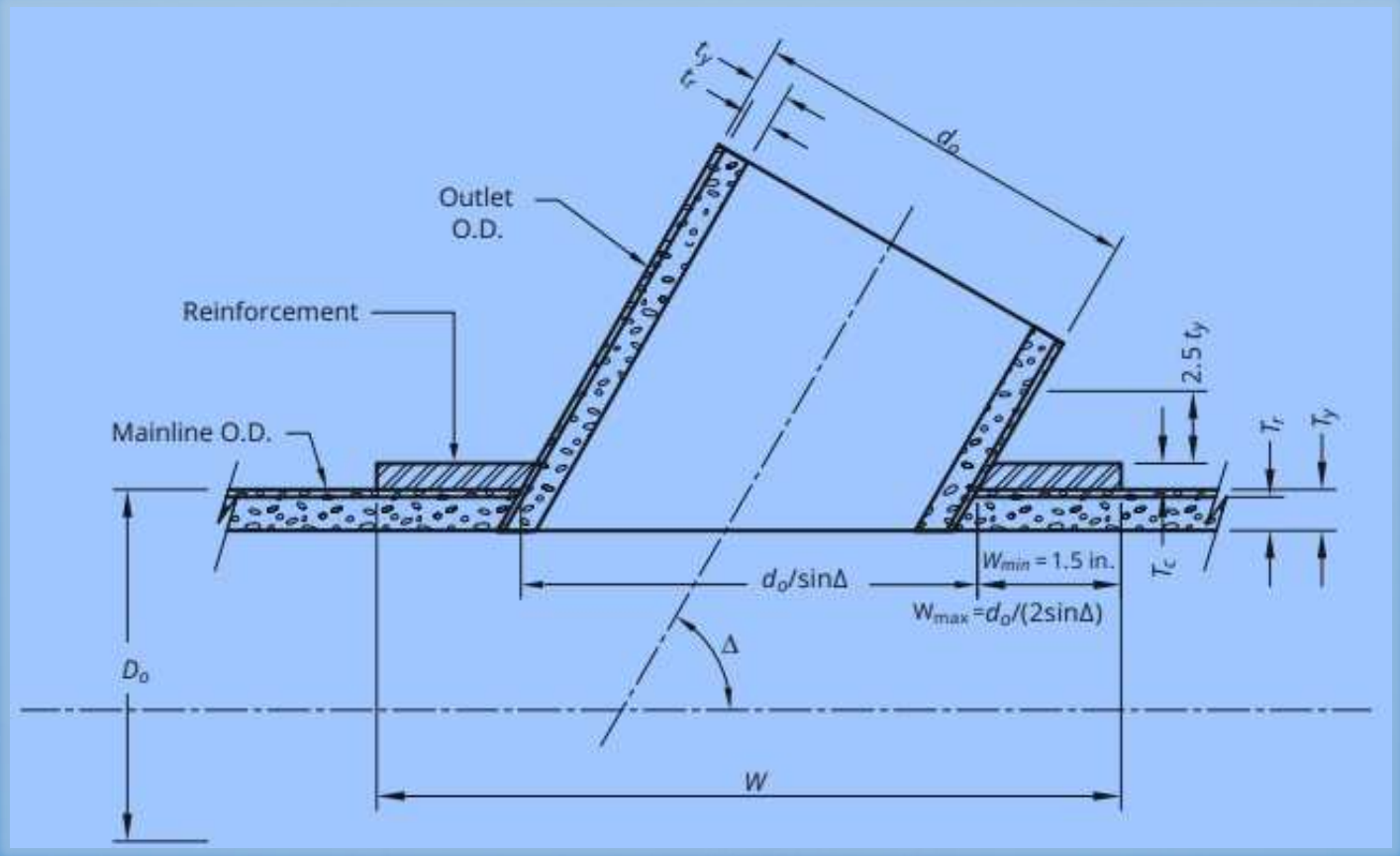
t_r = required outlet cyl thickness, in.

Tr = required run cyl thickness, in.

Tc = collar or wrapper thickness, in.

w = collar or wrapper edge width, in.

W = overall collar or wrapper width, in.



Steel Water Pipe Fittings – Design

✓ Theoretical cyl thickness of run pipe

$$Tr = \frac{pD_o}{2\sigma}$$

✓ Theoretical cyl thickness of branch

$$t_r = \frac{pd_o}{2\sigma}$$

Theoretical reinforcement area

$$A_r = M\left[Tr\left(\frac{d_o - 2ty}{\sin \Delta^\circ}\right)\right]$$

✓Available reinforcement

$$A_a = \frac{d_o - 2ty}{\sin \Delta}(T_y - T_r) + 5t_y\,(t_y - t_r)s_{r1}$$

Required Reinforcement

$$A_w = \frac{A_r - A_a}{s_{r2}}$$

Steel Water Pipe Fittings – Design

✓ Theoretical cyl thickness of run pipe

$$Tr = \frac{pD_o}{2\sigma} = \frac{150(49.75)}{2(18{,}000)} = 0.207”$$

✓ Theoretical cyl thickness of branch

$$t_r = \frac{pd_o}{2\sigma} = \frac{150(8.625)}{2(17{,}500)} = 0.037”$$

Theoretical reinforcement area

$$A_r = M[Tr(\frac{d_o - 2ty}{\sin \Delta^\circ})]$$

$$= 1[0.207(\frac{8.625 - 2(0.322")}{\sin 90^\circ})] = 1.656 in^2$$

Steel Water Pipe Fittings – Design

✓Available reinforcement $$A_a = \frac{D_o - 2ty}{\sin \Delta}(T_y\text{-}T_r) + 5t_y\,(t_y\text{-}t_r)s_{r1}$$

$$A_a = 8\,(0.375”\text{-}0.207”) + 5(0.322”\,)(.322\text{-}.037)0.972$$

$$= 1.79in^2$$

Required Reinforcement $$A_w = \frac{A_r - A_a}{s_{r2}} = \frac{1.656 - 1.79}{1} = -0.134in^2$$

Steel Water Pipe Fittings – Design

✓Min & Max reinforcement $$\boldsymbol{w} = \frac{d_o}{2\sin\Delta} = \frac{8.625}{2\sin 90°} = 4.312in$$

$$\boldsymbol{T_c} = \frac{A_w}{2w} = \frac{0.986}{2(4.312)} = 0.114in \text{ round up to } 0.125"$$

Min Reinforcement Width $$\boldsymbol{w} = \frac{\boldsymbol{A_w}}{2\boldsymbol{T_c}} = \frac{\boldsymbol{0.986}}{2\,(.125")} = 3.94in$$

Overall Reinforcement Width $$\boldsymbol{W} = 2\boldsymbol{w} + \frac{\boldsymbol{d_o}}{\boldsymbol{\sin\Delta}} = 2\boldsymbol{(3.94)} + \frac{\boldsymbol{8.625}}{1} = 16.5in$$

Steel Water Pipe Fittings – Design

Outlet Reinforcement Design Calculation

Per AWWA Manual M11 (5th Edition) - Chapter 7

48" Main Line with 8" Radial Branch

Mainline Pipe

Nominal diameter:	48	in	
Cylinder outside diameter:	49.75	in	D
Cylinder thickness:	0.375	in	T_y
Material minimum yield:	36,000	psi	

Branch Pipe

Nominal diameter:	8	in	
Cylinder outside diameter:	8.625	in	d
Cylinder Thickness:	0.322	in	t_y
Material minimum yield:	35,000	psi	
Branch type:	Radial		
Deflection angle:	90	degrees	Δ
Branch configuration:	Single		
Reinforcement material minimum yield:	36,000	psi	
Design pressure:	200	psi	P

Outlet type multiplier:	1.0		K
Branch pipe strength reduction factor:	0.972		sr_1
Reinforcement strength reduction factor:	1.000		sr_2
Pressure Diameter Value	299		PDV
	0.17		d/D
Reinforcement type:	Collar		
Multiplier Factor:	1.000		$M\text{-}factor$
Required mainline cylinder thickness:	0.276	in	T_r
Required branch cylinder thickness:	0.049	in	t_r
Theoretical reinforcement area:	2.203	in²	A_r
Run pipe excess area:	0.79	in²	A_1
Branch pipe excess area:	0.427	in²	A_2
Area available:	1.217	in²	$A_a = A_1 + A_2$
Additional reinforcement area required:	0.986	in²	$A_w = A_r - A_a$
Minimum reinforcement thickness:	0.114	in	$T(min)$
Minimum allowable width:	1.50	in	$w\ (min)$
Width based on reinforcement thickness:	2.63	in	$w\ (use)$
Maximum allowable width:	4.31	in	$w\ (max)$

3/16" THICK BY 14.00" LONG BY 14.00" CIRCUMFERENTIAL WIDTH COLLAR

Note: Required width/length dimensions rounded up to the nearest 1/4"

3/16” x 14” long x 14” wide

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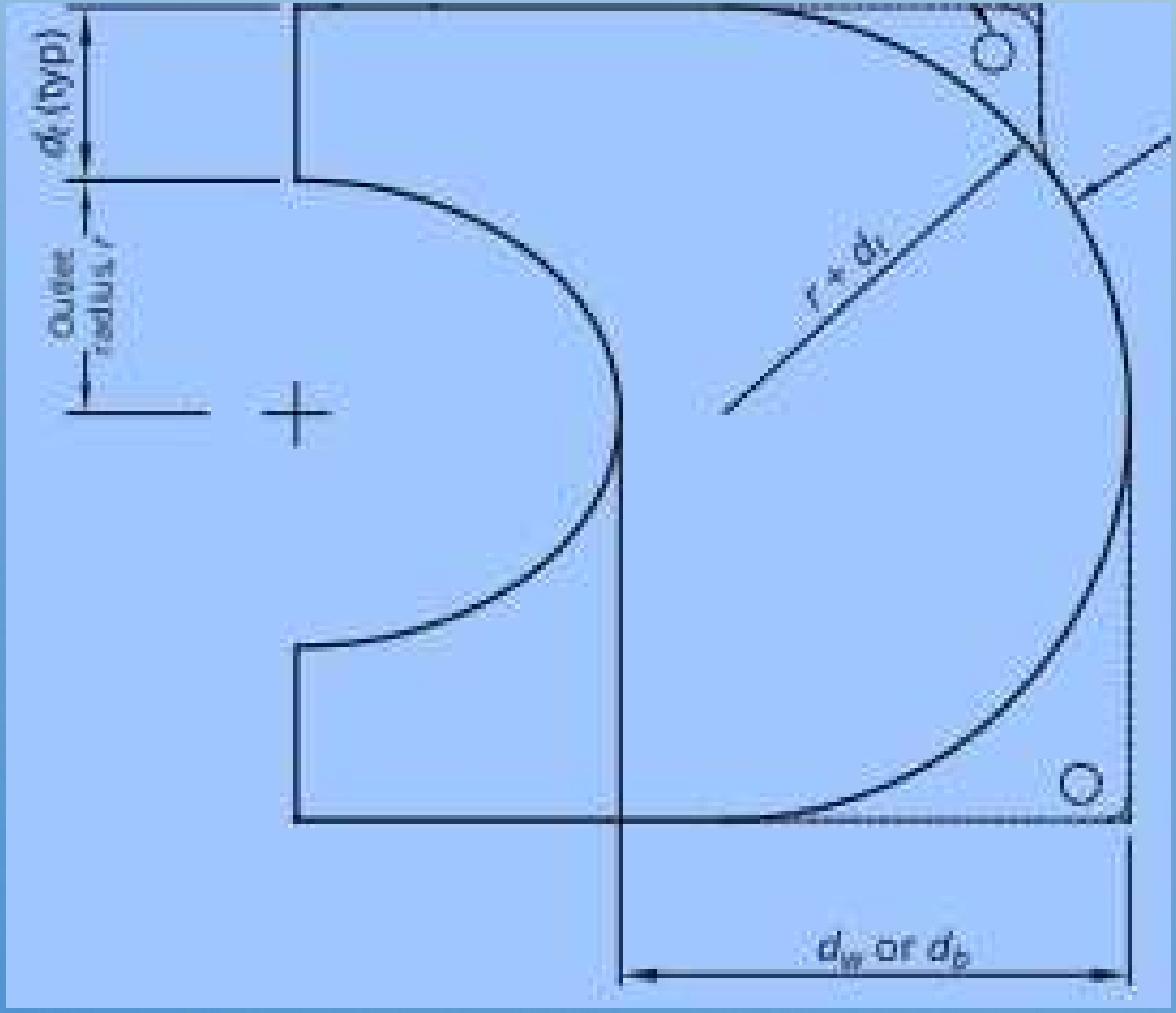
CROTCH PLATES

Steel Water Pipe Fittings – Design

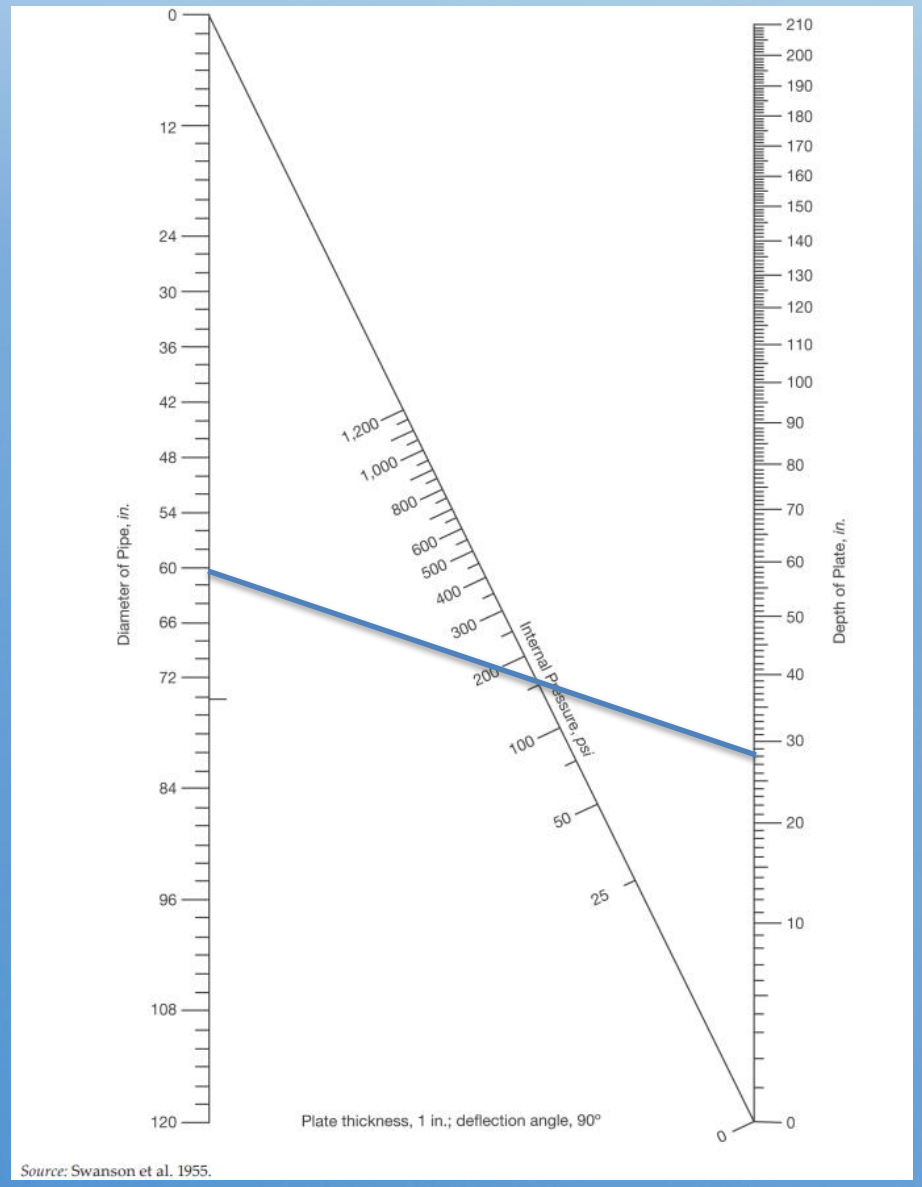


d_w and d_b = depth of plate

d_t = depth of plate between branch and mainline cylinder

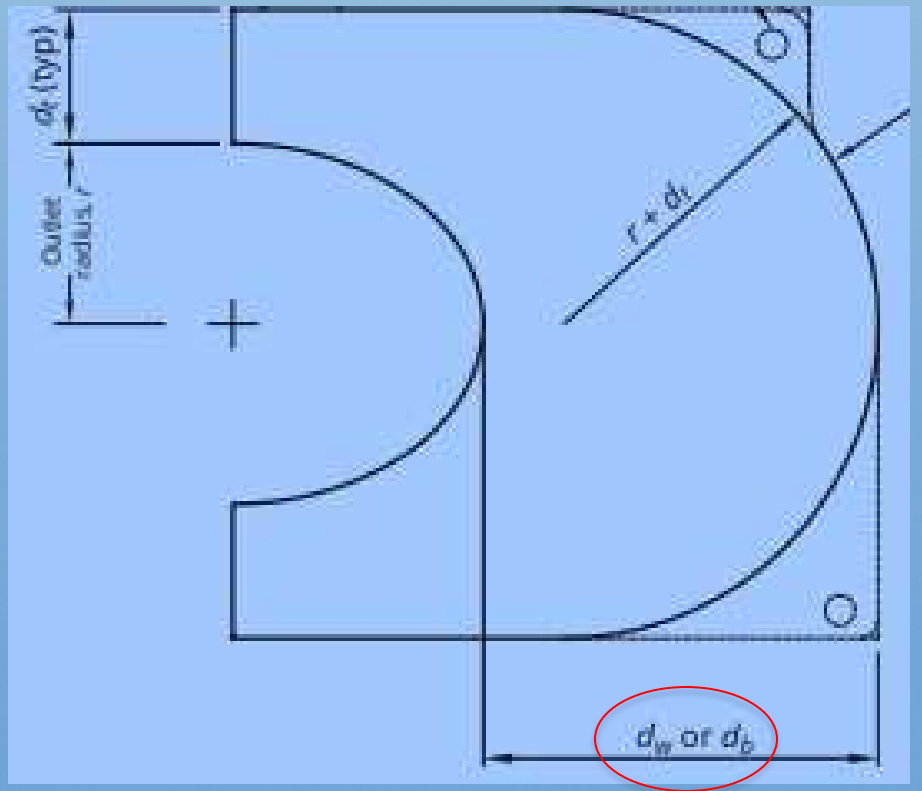
t = crotch plate thickness

Steel Water Pipe Fittings – Design



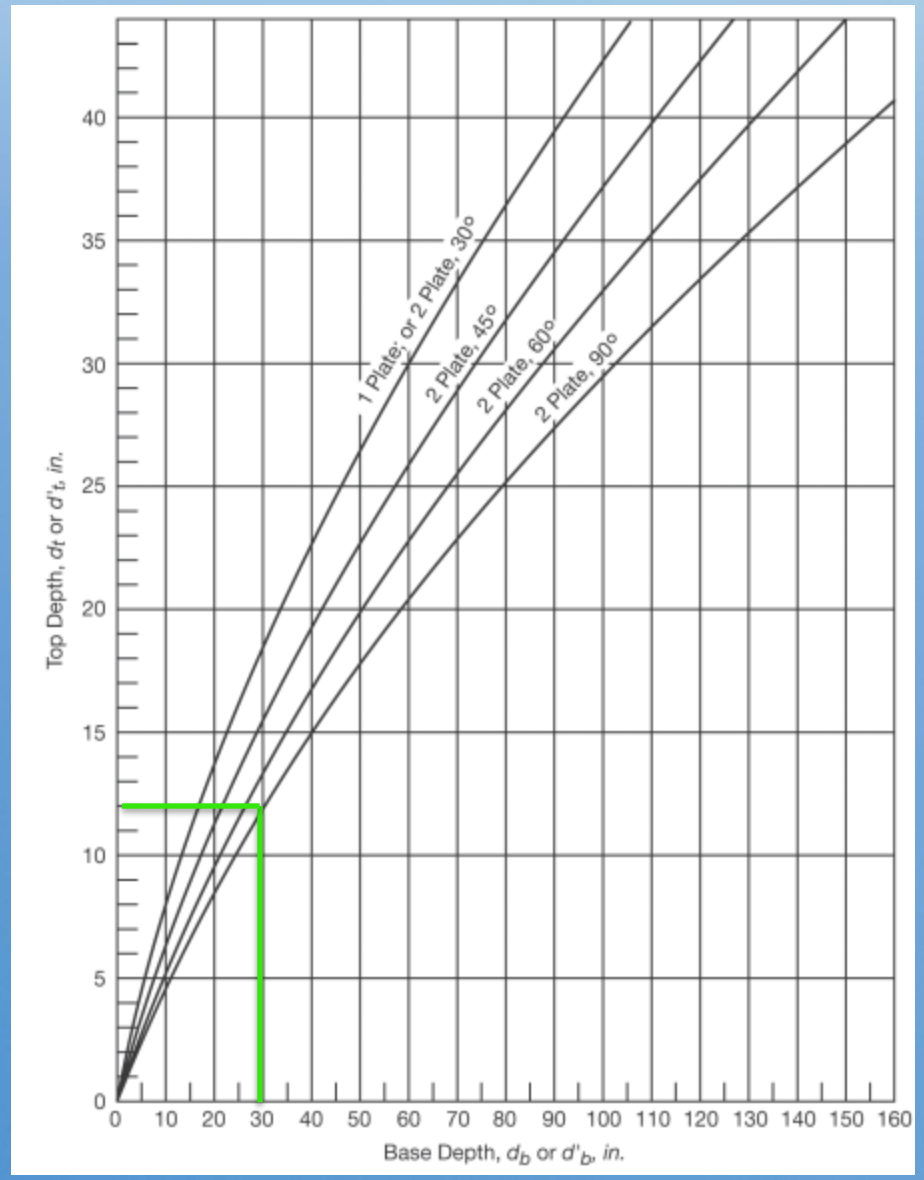
Dia, D =60 in, size-on-size tee, at 150psi

σ = 36,000psi



30/36 = 0.83” thick plate and from nomograph, depth of plate is 29in

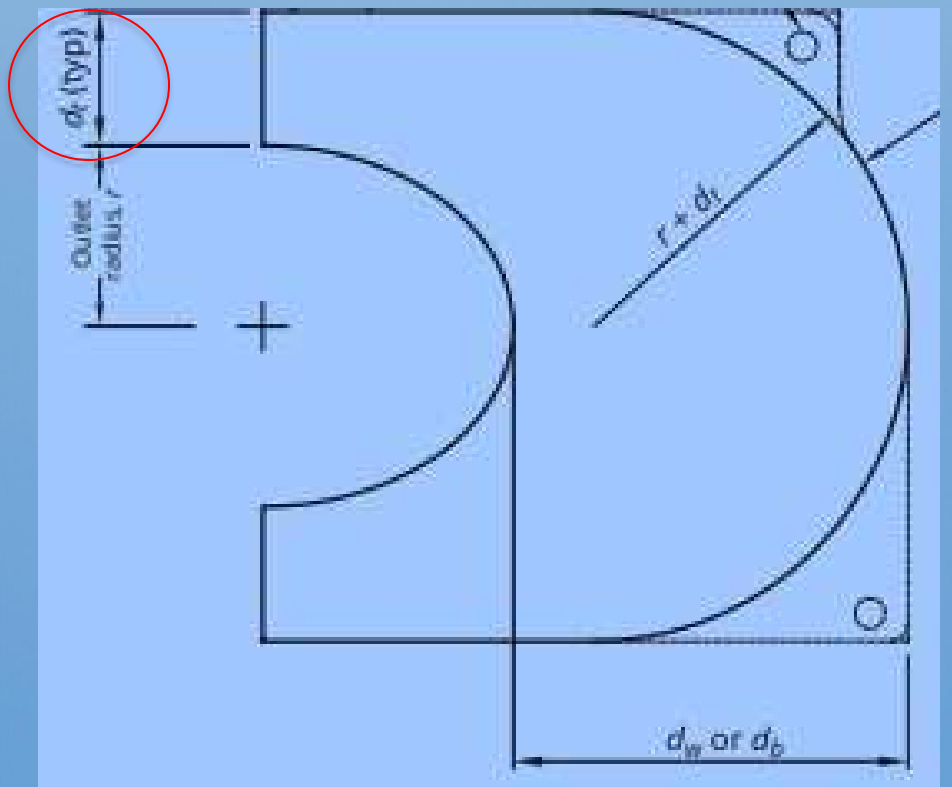
Steel Water Pipe Fittings – Design



Dia, D =60 in, size-on-size, at 150psi

σ = 36,000psi

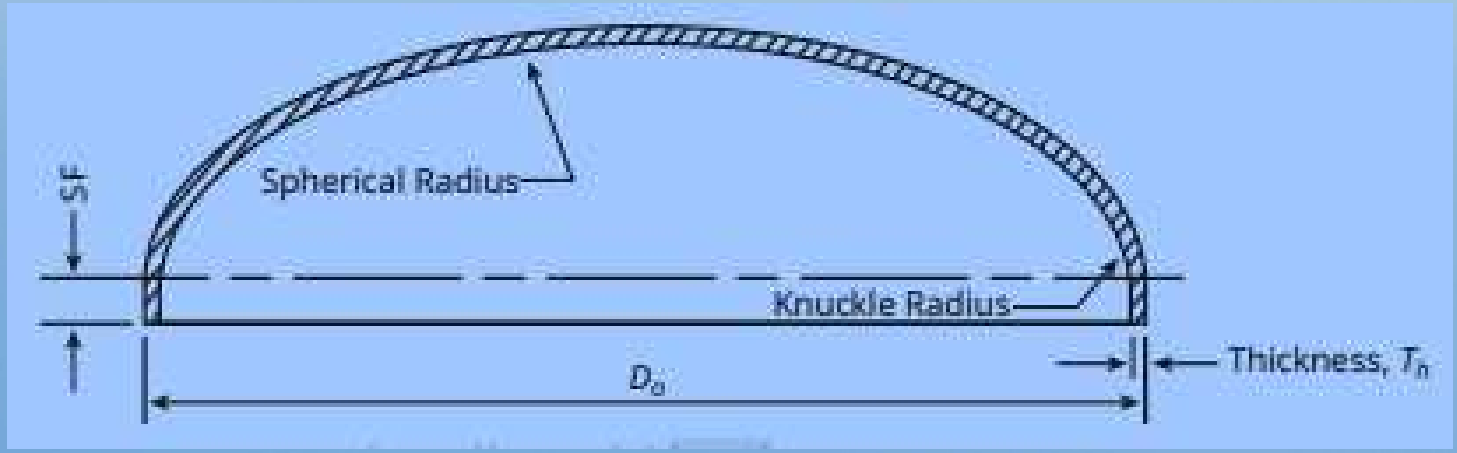
depth of plate, d_b is 29in, using this nomograph, d_t = 12”.



Steel Water Pipe Fittings – Design

Bulkheads

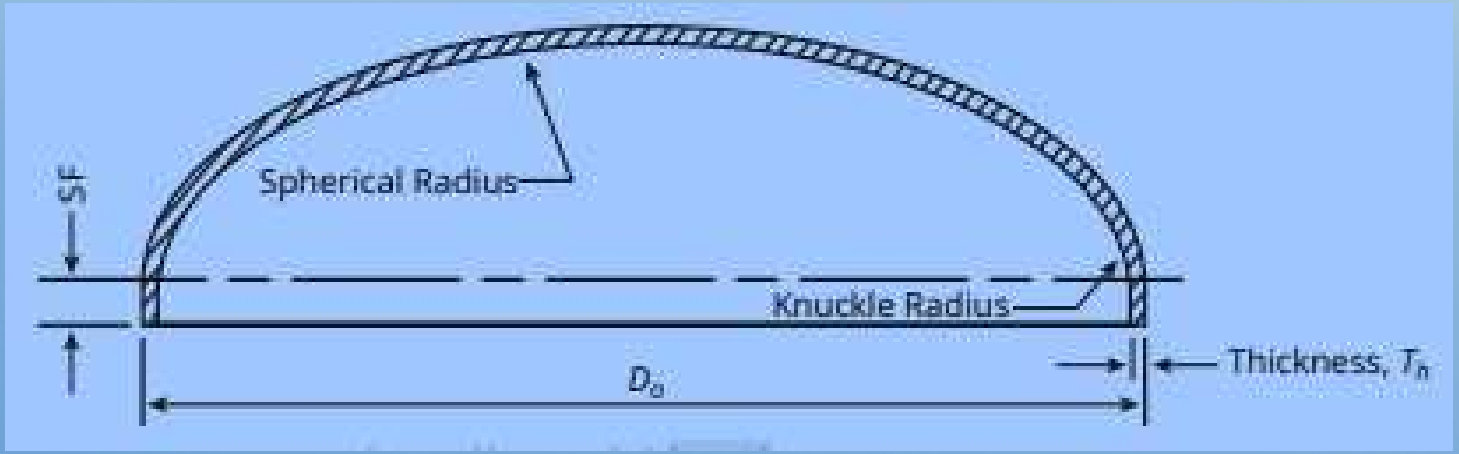
Steel Water Pipe Fittings – Design



T_h = min req'd thickness of head
p = design pressure, psi
D_h = dished head outside diameter, in.
σ = allowable design stress for dish, psi

$$T_h = \frac{pD_h}{2\sigma - 0.2p}$$

Steel Water Pipe Fittings – Design



$$T_h = \frac{pD_h}{2\sigma - 0.2p}$$

T_h = min req'd thickness of head
p = 150 psi
D_h = 49.75 in.
σ = 0.5 x 38,000psi

$$= \frac{150\ x\ 49.75}{2(19{,}000) - 0.2(150)}$$

$$= 0.197in$$

Steel Water Pipe Fittings – Design

What else? What other fittings are there?

Steel Water Pipe Fittings – Design

Questions?

Darren Dunker, Thompson Pipe Group Pressure ddunker@thompsonpipegroup.com