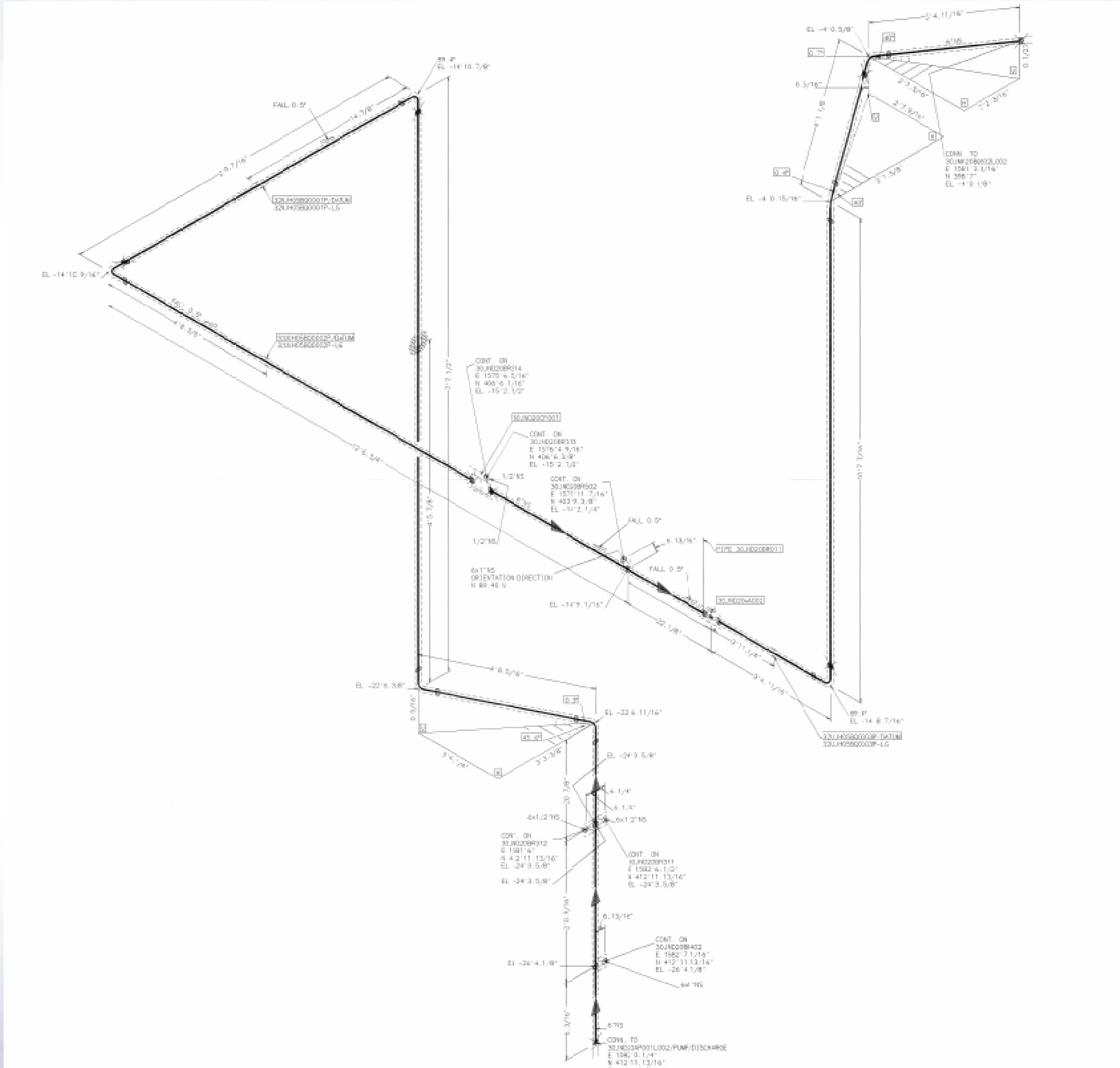
ASME

SETTING THE STANDARD

Case Study

- Small Segment of a Piping System
  - Medium Head Safety Injection Discharge
  - Class 2 portion between pump and penetration (see Page 3)
  - Code plus additional requirements must be met
- Code design ensures pressure boundary integrity, not functionality of the pipe or other components



Case Study - Input

- Design Specification defines:
  - Code of Record
  - Design Pressure and Temperature
  - Loadings (Service and Test)
  - Load Combinations and Service Conditions (Level A/B/C/D, Test)
  - Operability (via reference to other documents)

Case Study - Input

- NC-3112:
  - Design Pressure = 1525 psig
  - Design Temp = 340^{o}F/250^{o}F
- Material:
  - SA-312 Type 304L (pipe)
  - SA-403 WP304L (fittings)
  - S (ASME II, Part D) = 16.3/16.7 ksi

NC-3112 Design Loadings

The Design Loadings shall be established in accordance with NCA-2142.1 and the following subparagraphs.

NC-3112.1 Design Pressure. The specified internal and external Design Pressures to be used in this Subsection shall be established in accordance with NCA-2142.1(a).

NC-3112.2 Design Temperature. The specified Design Temperature shall be established in accordance with NCA-2142.1(b). It shall be used in conjunction with the Design Pressure. If necessary, the metal temperature shall be determined by computation using accepted heat transfer procedures or by measurement from equipment in service under equivalent operating conditions. In no case shall the temperature at the surface of the metal exceed the maximum temperature listed in the applicability column of Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, nor exceed the maximum temperature limitations specified elsewhere in this Subsection.

Case Study - Input

- Design Specification requires:
  - Flanges per ANSI B16.5
  - Fittings per ANSI B16.9
  - Meets NC-3132 requirements
    - Need to check against NC-3612 requirements (matching fittings, rated flange pressure at temperature)

ASME SETTING THE STANDARD

NC-3132 Dimensional Standards for Standard Products

Dimensions of standard products shall comply with the standards and specifications listed in Table NC-3132-1 when the standard or specification is referenced in the specific design Subarticle. However, compliance with these standards does not replace or eliminate the requirements for stress analysis when called for by the design Subarticle for a specific component.

Case Study – Input

- Piping and fittings are 6 inch NPS
  - No corrosion allowance specified
  - Material is 304L
  - Dimensions per SA-312
  - Manufacturer's under tolerance 12.5% per Table 3, SA-312 (attached)
  - Branch Connections (1/2" and 1") made using socket half couplings

TABLE 3
PERMITTED VARIATIONS IN WALL THICKNESS

NPS Designator	Tolerance, % from Nominal	
	Over	Under
1/8 to 2 1/2 incl., all *t/D* ratios	20.0	12.5
3 to 18 incl., *t/D* up to 5% incl.	22.5	12.5
3 to 18 incl., *t/D* > 5%	15.0	12.5
20 and larger, welded, all *t/D* ratios	17.5	12.5
20 and larger, seamless, *t/D* up to 5% incl.	22.5	12.5
20 and larger, seamless, *t/D* > 5%	15.0	12.5

where:

t = Nominal Wall Thickness
D = Ordered Outside Diameter

Case Study – Input

- Loads
  - Weight (pipe, contents, insulation)
  - Thermal Load Case (N) Normal
  - Thermal Load Case (F) Faulted
  - Reactor Building Pre-Stress
  - Reactor Building Creep/Shrinkage
  - Reactor Building Pressure Test
  - Safe Shutdown Earthquake

Case Study - Input

- Loads (con't)
  - Test Pressure – 1906 psig at 70^{o}F
    - Test = 1.25*P_D per NC-6221
  - Thermal anchor movements at pump
  - Seismic anchor movements at penetration, pump, and supports (if applicable)

Case Study - Input

- Other Considerations
  - Functional Capability
  - Break Postulation
  - Nozzle Loads/Valve Accelerations
  - Penetration Loads
  - Support Loads
  - Displacements/clearances

Case Study

- Since this is Pipe under internal Pressure, we can skip:
  - NC-3133 (External Pressure)
  - NC-3200 (Vessels/Alt. Rules)
  - NC-3300 (Vessels)
  - NC-3400 (Pumps)
  - NC-3500 (Valves)

Case Study – Pressure Design

- NC-3641.1 (Next Slide)

$$t_m = \frac{PD_o}{2(S + Py)} + A$$

  - A = Additional Thickness (Threading, corrosion) = 0.0 inches
  - P = Design pressure = 1525 psig
  - D_o = Outside diameter = 6.625 inches for 6” NPS (Table X1.1, SA-312)
  - y = 0.4, unless $D_o/t_m < 6$
  - t_m = Minimum required Thickness, which is increased later to account for tolerances
  - S = allowable stress at design temperature = 16.3 ksi at 340^{o}F
  - t_m = 0.3 inches
  - Tolerance = 12.5%
  - t_{req} = 1.125*0.3 = 0.34 inches
  - D_o/t_m = 19.4 > 6, therefore y = 0.4 is OK

NC-3641.1 Straight Pipe Under Internal Pressure. The minimum thickness of pipe wall required for Design Pressures and for temperatures not exceeding those for the various materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, including allowances for mechanical strength, shall not be less than that determined by eq. (3) as follows:

$$t_m = \frac{PD_o}{2(S + Py)} + A \qquad (3)$$

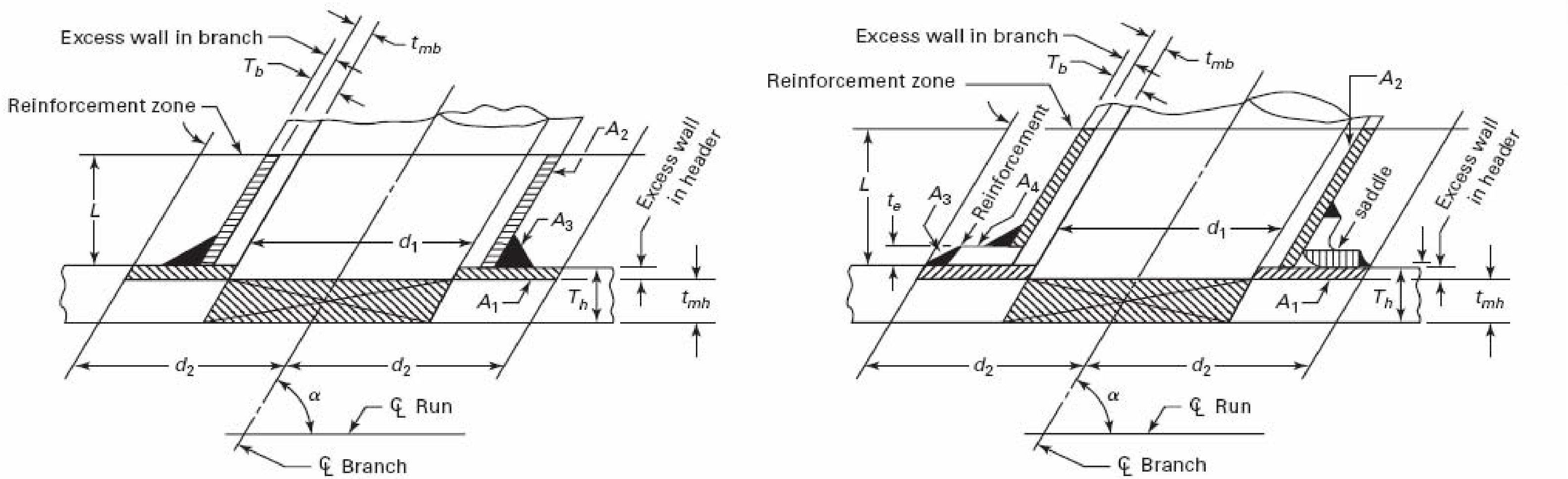
Case Study – Pressure Design

- Pipe normally bought to standard size (SCH 40, SCH 80, SCH 160)
- SCH 40 = 0.28” < 0.34”, NG
- SCH 80 = 0.432” OK, marginal
- SCH 160 = 0.719” is chosen ($D_o/t = 9.2 > 6$)
- NC3642.2 - Elbows purchased to B16.9 are acceptable without further review
- NC-3643 – Intersections – see attached figure

FIG. NC-3643.3(c)(1)-1 REINFORCEMENT OF BRANCH CONNECTIONS

Required reinforcement = $1.07(t_{mh})(d_1)(2 - \sin\alpha)$

Reinforcement areas = A_1, A_2, A_3, A_4



Example A **Example B**

Explanation of areas:

- Required reinforcement area
- Area A_1 – Excess wall in header
- Area A_2 – Excess wall in branch
- Area A_3 – Fillet weld metal
- Area A_4 – Metal in reinforcement

GENERAL NOTES:

(a) When metal is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered. Typical acceptable methods of meeting the above requirement are shown in Fig. NC-3643.3(c)(1)-2.

(b) Width to height of reinforcement shall be reasonably proportioned, preferably on a ratio as close as 4 to 1 as the available horizontal space within the limits of the reinforcing zone along the run and the O.D. of the branch will permit, but in no case may the ratio be less than 1.

(c) This Figure is to be used only for definitions of terms, not for fabrication details.

(d) Use of reinforcing saddles and pads is limited as stated in NC-3643.3(c)(7).

Case Study – Pressure Design

- Branch Connections – NC-3643
  - NC-3643.2 (next slide) – If made using half coupling, require no added reinforcement if:
    - D_{nom} < 2" NPS (1/2" and 1" are OK)
    - D_{nom} < D_{run}/4 = 1.5" NPS (1/2" and 1" are OK)
    - Weld in compliance with Fig NC-3643(b)-1 or 2, certain sketches
    - Coupling at least 3000 lb (used 6000 lb half coupling)
    - Therefore, no additional check required

ASME SETTING THE STANDARD

NC-3643.2 Branch Connections Not Requiring Reinforcement. Reinforcement need not be provided if the branch connection is made in accordance with the requirements of (a) through (c) below:

(*b*) by welding a coupling or half coupling directly to the run pipe, provided the nominal diameter of the branch does not exceed NPS 2 (DN 50) or one-quarter the nominal diameter of the run, whichever is less; the wall thickness of the coupling is not less than that of the branch pipe; the coupling is joined to the run pipe by one of the methods shown in Fig. NC-3643.2(b)-1, sketch (c)(1) or Fig. NC-3643.2(b)-2, sketch (e); and in no case is the thickness of the coupling less than extra heavy or 3,000 lb nominal rating;

Case Study – Pressure Design

- NC-3644, -3645, -3646 not applicable
- NC-3647 – Flanges (SA182, 304L)
  - Flanges purchased to B16.5
  - B16.5 provides ratings vs. temperature, since flanges resist pressure differently
  - Material and temperature dependent
    - 900 lb rated at 1330 psi at 340^{o}F (Table F2-2.3, att)
    - 1500 lb rated at 2210 psi at 340^{o}F (ibid)
    - 1330 < 1525 < 2210 psig; Choose 1500 lb
- NC-3648 (reducers) and -3649 (other) NA

ASME SETTING THE STANDARD

Table F2-2.3 Pressure–Temperature Ratings for Group 2.3 Materials

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316L		A 240 Gr. 316L
18Cr–8Ni	A 182 Gr. F304L (1)		A 240 Gr. 304L (1)

Working Pressures by Classes, psig

Class / Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	230	600	800	1200	1800	3000	5000
200	195	510	680	1020	1535	2555	4260
300	175	455	610	910	1370	2280	3800
400	160	420	560	840	1260	2100	3500
500	150	395	525	785	1180	1970	3280
600	140	370	495	745	1115	1860	3100
650	125	365	485	730	1095	1825	3040
700	110	360	480	720	1080	1800	3000
750	95	355	470	705	1060	1765	2940
800	80	345	460	690	1035	1730	2880
850	65	340	450	675	1015	1690	2820

NOTE:
(1) Not to be used over 800°F.

Case Study – Piping Analysis

- NC-3650 – Analysis of Piping Designs
  - Analysis side typically done using computer programs
  - Static analysis for weight, thermal expansion, anchor motion
  - Response Spectrum (usually enveloped) for seismic analysis
  - Result is bending moments at model joints, deflections, accelerations, support/nozzle forces and moments

Case Study - Piping Analysis

- 4 basic equations

$$NC-3652:\ B_1\frac{PD_o}{2t_n}+B_2\frac{M_a}{Z}\le 1.5\,S_h \qquad (8)$$

$$NC-3653.1:\ B_1\frac{P_{\max}D_o}{2t_n}+B_2\frac{M_a+M_b}{Z}\le lesser\ of\ 1.8\,S_h,1.5S_y \qquad (9a)$$

$$NC-3655:B_1\frac{P_{\max}D_o}{2t_n}+B_2\frac{M_a+M_b}{Z}\le lesser\ of\ 3S_h,2S_y \qquad (9a)$$

$$NC-3653.2:\frac{i\,M_c}{Z}\le S_a \qquad (10a)$$

$$NC-3653.2:\frac{PD_o}{4t_n}+0.75i\left(\frac{M_a}{Z}\right)+i\left(\frac{M_c}{Z}\right)\le S_h+S_a \qquad (11)$$

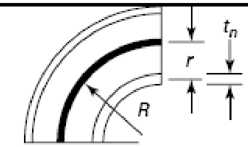
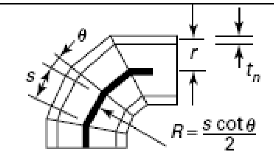
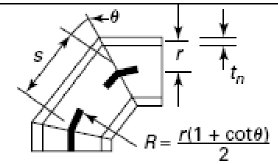
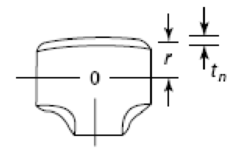
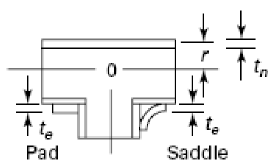
Case Study – Piping Analysis

- Nomenclature:
  - D_o – nominal OD
  - t_n = nominal thickness
  - Z = section modulus
  - B_1, B_2 = stress indices (Fig. NC-3673.2(b)-1
  - *i* = stress intensification factor (same figure)
  - M_a = moment due to weight, other sustained loads
  - M_b = Moment due to occasional Level B (or Level D) loads
  - S_h = stress allowable at temperature
  - S_A = allowable stress range (NC-3611.2)
  - S_y = yield stress at temperature
  - P, P_{max} = design or maximum pressure

Case Study – Piping Analysis

- Stress indices
  - Primary stresses (mechanical loads only)
  - “correct” straight pipe stresses to component/joint
- Stress Intensification Factors (SIFs)
  - Secondary stresses/fatigue (strain controlled)
  - “correct” the fatigue life of a standard butt weld to component/joint

FIG. NC-3673.2(b)-1 STRESS INDICES, FLEXIBILITY, AND STRESS INTENSIFICATION FACTORS [NOTES (1), (2), AND (3)]

Description	Primary Stress Index		Flexibility Characteristic h	Flexibility Factor k	Stress Intensification Factor i	Sketch
	B_1	B_2				
Welding elbow or pipe bend [Notes (4) and (5)]	$0.4\,h - 0.1 \le 0.5$ and > 0	$\frac{1.30}{h^{2/3}}$	$\frac{t_n R}{r^2}$	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	
Closely spaced miter bend [Note (4)] $s < r\,(1 + \tan\theta)$	[Note (6)]	[Note (6)]	$\frac{s t_n \cot\theta}{2r^2}$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	
Widely spaced miter bend [Notes (4) and (7)] $s \ge r\,(1 + \tan\theta)$	[Note (6)]	[Note (6)]	$\frac{t_n\,(1 + \cot\theta)}{2r}$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	
Welding tee per ASME B16.9 [Note (8)]	0.5	Branch end: $B_{2b} = 0.4\left(\frac{r}{t_n}\right)^{2/3}$ Run end: $B_{2r} = 0.5\left(\frac{r}{t_n}\right)^{2/3}$	$\frac{4.4\,t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$ For branch leg of a reduced outlet, use $\frac{0.9}{h^{2/3}}\left(\frac{T'_b}{T_r}\right)$	
Reinforced fabricated tee [Notes (8)–(10)]	0.5	[Note (6)]	$\frac{\left(t_n + \frac{t_e}{2}\right)^{5/2}}{r\,(t_n)^{3/2}}$	1	$\frac{0.9}{h^{2/3}} \ge 2.1$ For branch leg of a reduced outlet, use $\frac{0.9}{h^{2/3}}\left(\frac{T'_b}{T_r}\right) \ge 2.1$	

Case Study – Piping Analysis

- Example Indices/SIF – Elbow

$$B_1 = 0.4h - 0.1 \le 0.5 \;\; but \ge 0; \quad B_2 = \frac{1.3}{h^{2/3}}; \quad i = \frac{0.9}{h^{2/3}}$$

$$h = \frac{tR}{r^2}$$

$$t = thickness = 0.719''$$

$$R = bend\ radius = 9''(1.5D_{nom})$$

$$r = mean\, radius = (6.625 - 0.719)/2 = 2.953''$$

$$h = 0.742$$

$$B_1 = 0.2$$

$$B_2 = 1.6$$

$$i = 1.1$$

Case Study – Piping Analysis

- Allowable stresses
  - Eq 8, 9 – Primary stress check
    - Prevent burst/collapse
    - Higher limits (lower margin) as load becomes less likely
  - Eq. 10, 11 – Secondary/Fatigue check
    - Prevents through wall crack
    - Allowable stress also provided to ensure "shakedown"
    - Allowable stress based on 7000 cycles, reduces as number of cycles increases (NC-3611.1)

ASME SETTING THE STANDARD

Case Study – Piping Analysis

- Sample Results entire system

Code Equation	Maximum Stress Ratio	SOP	DCP	Allowable Stress (psi)	Computed Stress (psi)	Load Cases Applied
Equation 8 $B_1 \frac{PD_o}{2t_n} + B_2 \frac{M_A}{Z} \leq 1.5S_h$	0.230	24W	150	24510	5646	DWT, PDES
Equation 9 (Level B) $B_1 \frac{P_{max}D_o}{2t_n} + B_2 \frac{M_A + M_B}{Z} \leq MIN(1.8S_h, 1.5S_y)$	0.203	24W	150	27780	5646	DWT, PDES
Equation 9F (Level D) $B_1 \frac{P_{max}D_o}{2t_n} + B_2 \frac{M_A + M_B}{Z} \leq MIN(3.0S_h, 2.0S_y)$	0.249	24W	150	37040	9205	DWT, SSE, PDES
Eq. 10 $\frac{iM_C}{Z} \leq S_A$	0.060	3W	110	24960	1497	TH1N, TH2F, RBPT

ASME SETTING THE STANDARD

Case Study – Piping analysis

- In addition, must meet pressure requirements
  - For Level B, < 1.1P_a per NC-3611.2(c)(1)
  - For Level D < 2P_a per NC-3655(a)(1)
  - P_a is the maximum allowable pressure calculated IAW Equation (5) of NC-3641.1:

$$P_a = \frac{2St}{D_o - 2yt}$$

  - t = actual wall thickness, less tolerance and corrosion/erosion/threading allowances

Case Study – Piping Analysis

- Flange Check (NC-3658) – based on work by Everett Rodabaugh for ORNL

6" 1500# Flange								
S =	25000	psi	Bolt Mat'l:SA193 Gr. B7			(> 20000 psi)		
S_Y =	18.52	ksi	Flange Mat'l: SA182 F304L					
C =	12.5	in	Reference ANSI B16.5					
A_B =	9.156	in^2	12 Bolts x	0.763	in^2	(1 1/8" Bolts)		
D_F =	8.5	in	Reference ANSI B16.5					
P =	1525	psi	Design Pressure					
Allowable Moment								
(3125/12) x (S_Y/36) x C x A_B =				15333	ft-lbs		LEVEL A/B - M_{fs}	
(6250/12) x (S_Y/36) x C x A_B =				30666	ft-lbs		LEVEL A/B - M_{fd}	
[(11250A_B)-(π/16)D_F^2P] x C x (S_Y/36)/12=				43605	ft-lbs		LEVEL C/D - M_{fd}	
		Level A/B - M_{fs}				Level D - M_{fd}		
DCP	Mx	Myz	Allow	Ratio	Mx	Myz	Allow	Ratio
130	1921	2262	15333	0.148	2455	12247	43605	0.281
140	1921	3613	15333	0.236	2455	11840	43605	0.272

Case Study – Other Items

- The pressure boundary design is complete
- Other items would still be checked:
  - Supports (NF)
  - Nozzle Loads (pump, penetration DS)
  - Valve Accelerations (Valve DS)
  - Clearances
  - Regulatory checks

YOUR QUESTIONS & COMMENTS