CES

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Casing Design

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About Me

- Studied Petroleum and Natural Gas Engineering in METU 2006-2011
- Working at BP 2011- now.

What is Casing ?

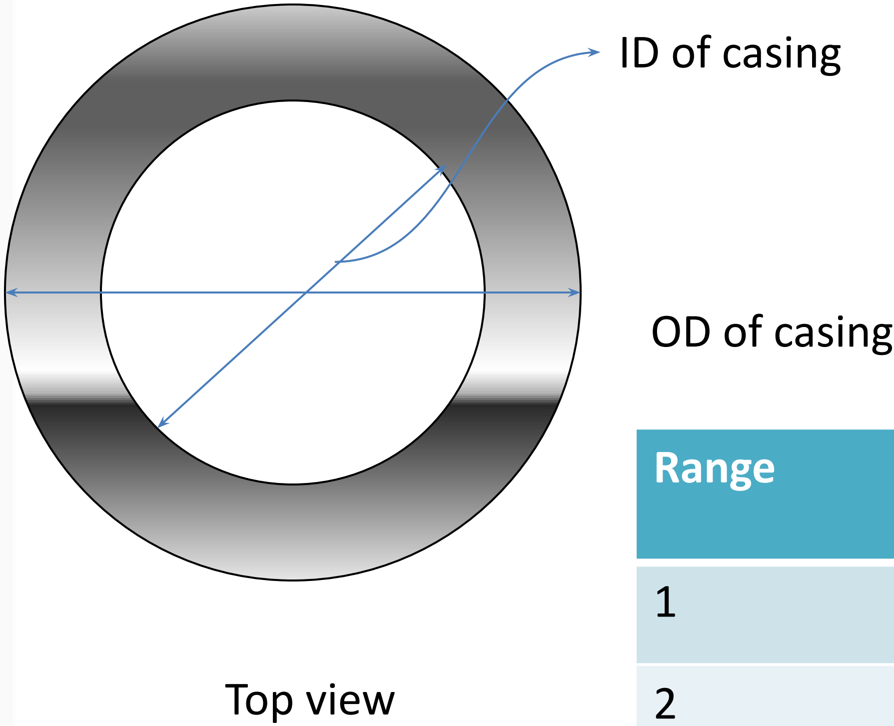
Main purpose of casing is to sustain cylindrical shape of hole by withstanding external & internal forces

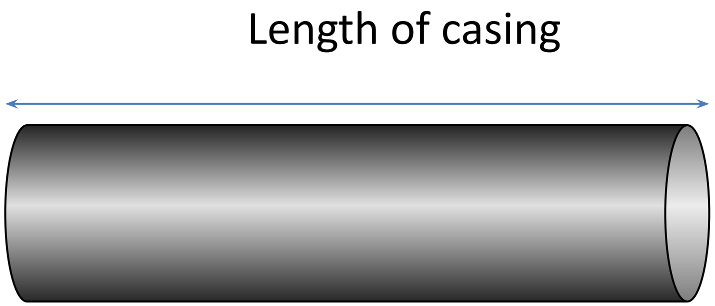
Key Topics

- Properties of Casing
- API specifications
- Casing Connections
- Casing Setting Depth Selection
  - PPFG curve
  - Class problem
- Burst , Collapse & Tensile Design
- Load Cases
- Class Problem

Properties of Casing

- Dimensional Properties

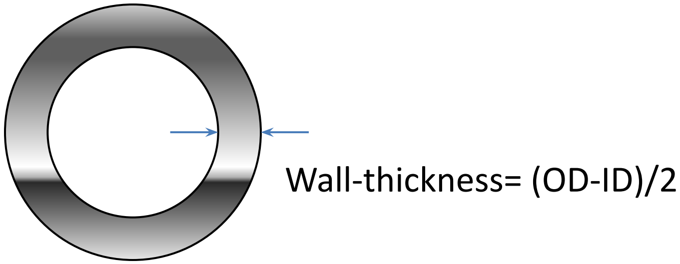




Range	Length (ft)	Average Length (ft)
1	16-25	22
2	25-34	31
3	34+	42

Properties of casing

- Drift Diameter
- Weight of casing
- Wall thickness



Weight (ppf)	OD (in)	ID (in)	Wallthickness (in)	Drift Diameter (in)
53.5	9.625	8.535	0.545	8.379
47	9.625	8.681		8.525
43.5	9.625	8.755		8.599
40	9.625	8.835	0.395	8.679

Properties of casing

- Material properties.
- API specifies grades to material of casing with different chemical properties.
- For example : N - 80

Shows cehmical properties of material

Shows minimum yield strength of casing material.

API Grade	Yield Strength (psi)		Tensile Strength (psi)
	min	max	
J-55	55000	80000	75000
K-55	55000	80000	95000
C-75	75000	90000	95000
L-80	80000	95000	95000
N-80	80000	110000	100000

API Specifications

- Standardization institute
- Several publications to standardize equipment and procedures.

Casing Related Publications :

- API SPEC 5CT – Specification for casing and tubing
- API STD 5B
- API RP 5A5
- API RP 5B1
- API RP 5C1
- API RP 5C5
- API BULL 5C2 – Bulletin on performance properties of casing and tubing
- API BULL 5C3 – Bulletin on formulas and calculations for casing, tubing, drill pipe and line properties.

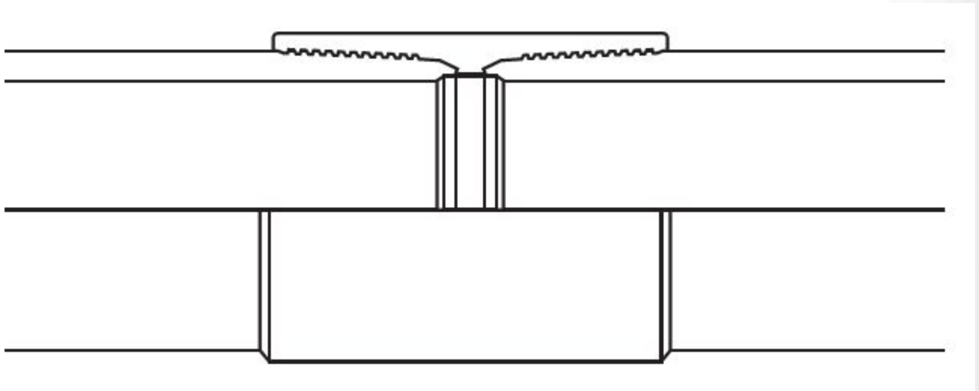
Casing Connections

- Casing Strings are connected together by connections

- API
- Premium
- Gastight
- Metal-to-Metal seal

Casing Connections

- API connection (couplings)
- Short Thread Connection STC
- Long Thread Connection LTC
- Buttress Thread
- Extreme Line



Casing Connections

- Long thread connection
- Short Thread connection
- Long thread connection has better sealing capacity.
- Short thread connection has 8 thread per inch

Casing Connections

- Long & Short Thread connections are as round type.

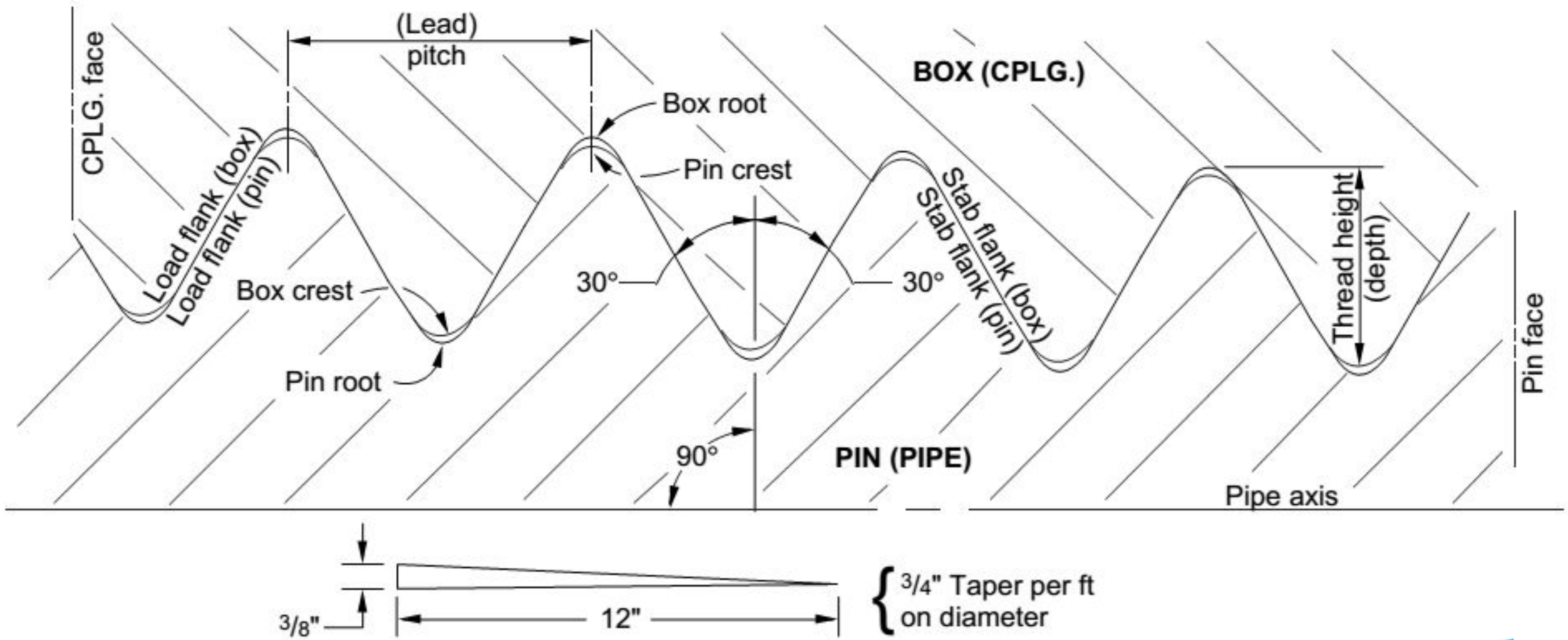


Figure 4—Round Thread Casing and Tubing Thread Configuration

Reference : API 5B1

Casing Connections

- Buttress thread connection

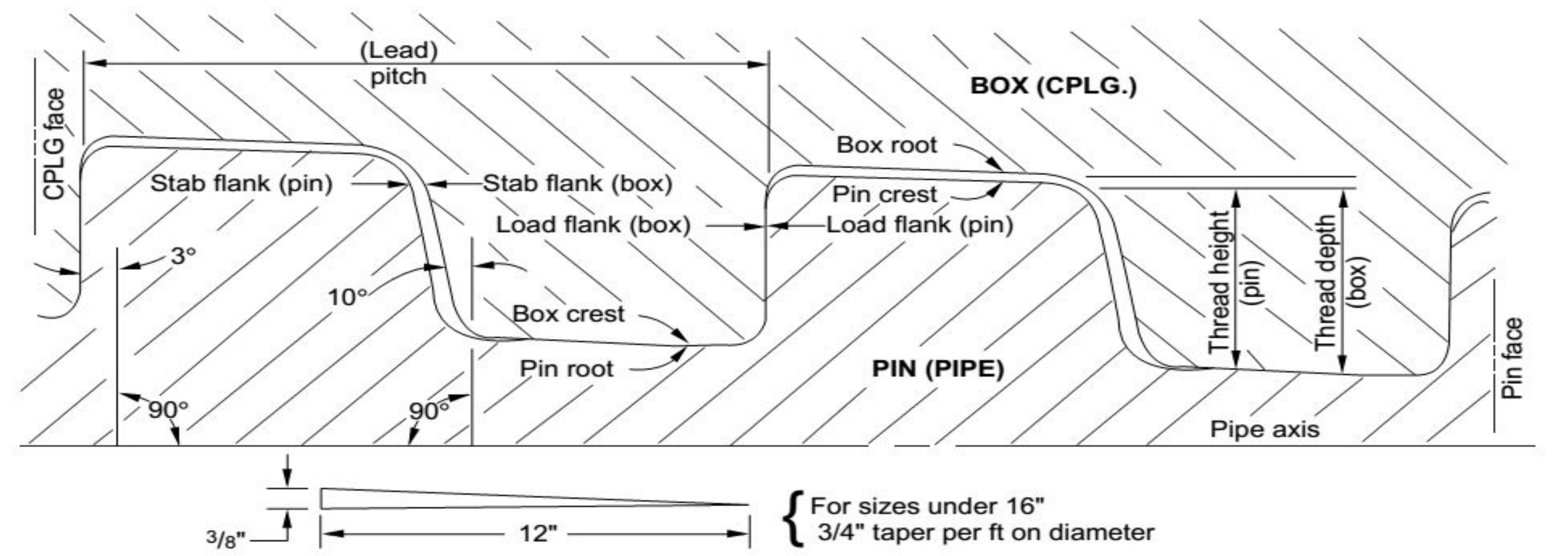


Figure 5—Buttress Thread Configuration for $13^3/_8$-in. OD and Smaller Casing

Reference : API 5B1

Casing Connections

- Extreme Line Connection

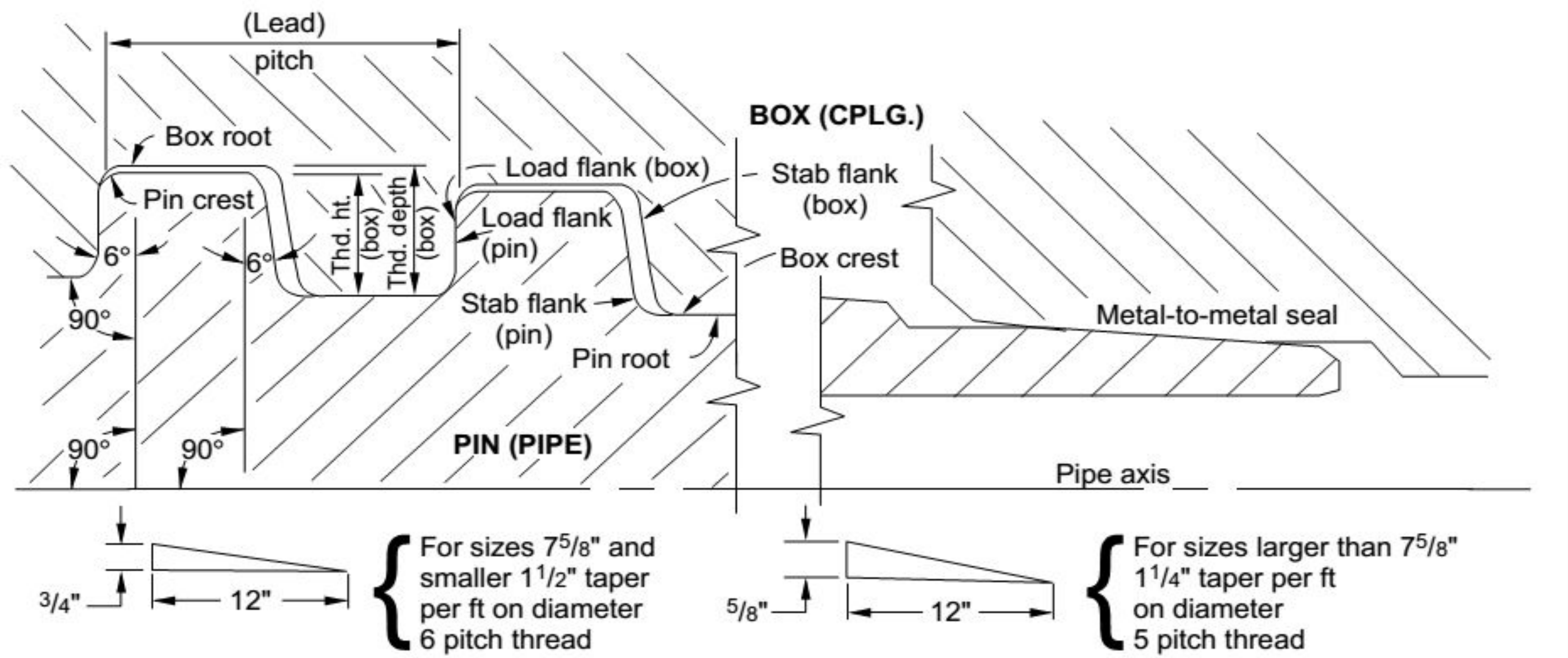
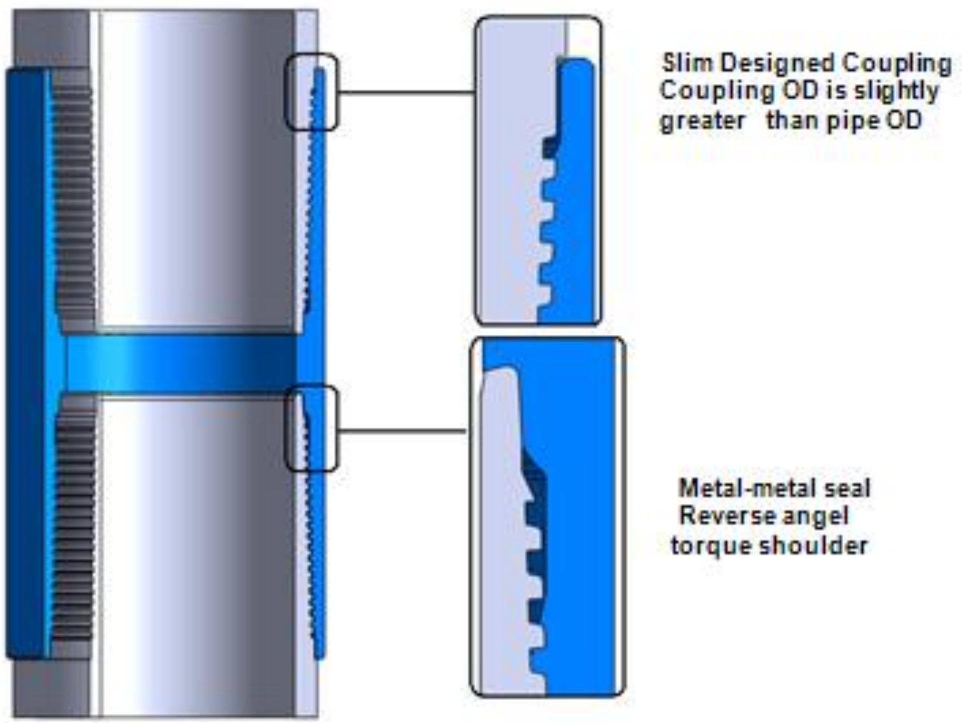


Figure 7—Extreme-Line Casing Thread Configuration

Reference : API 5B1

Casing Connections

- Metal to Metal and Gas tight Connections

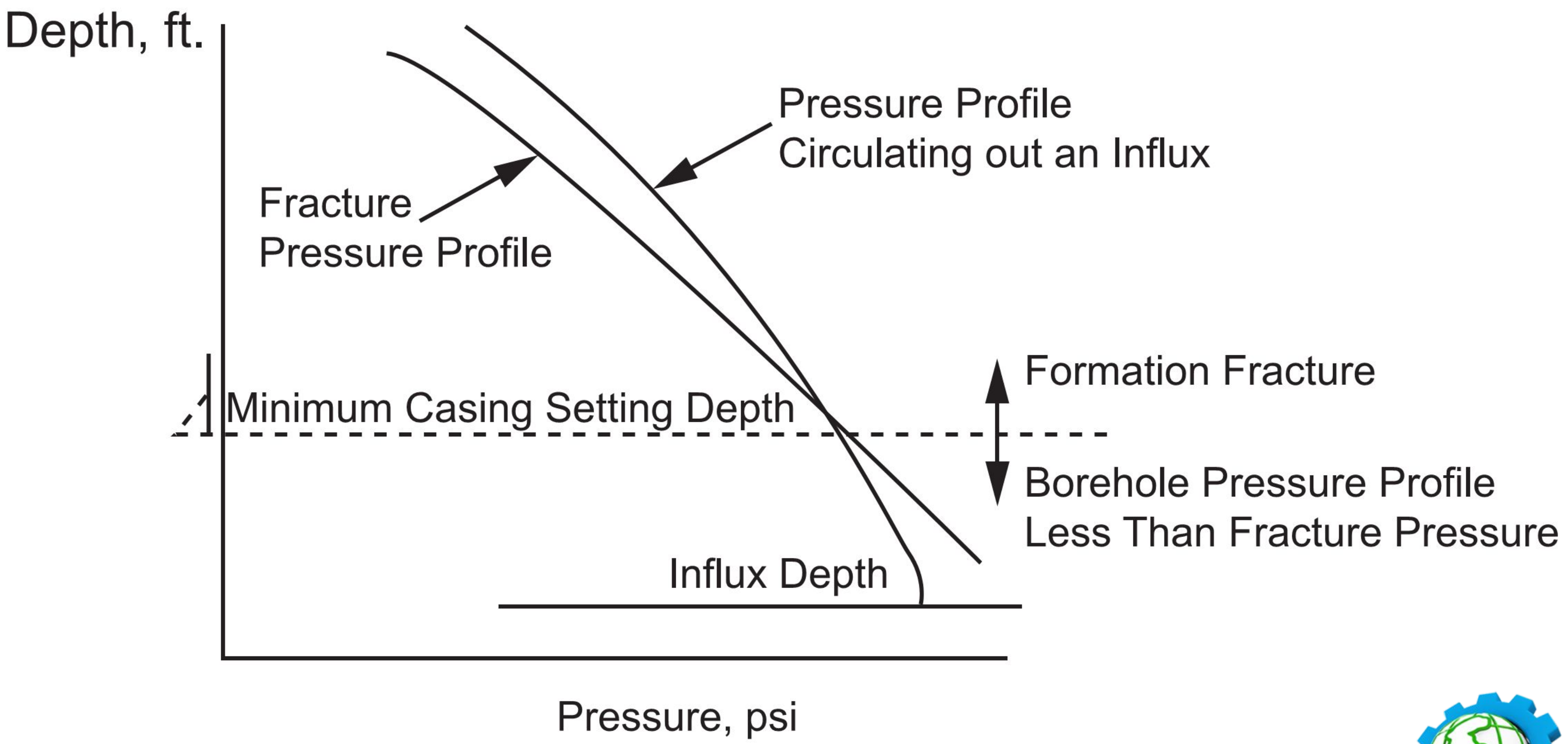


Reference : API 5B1

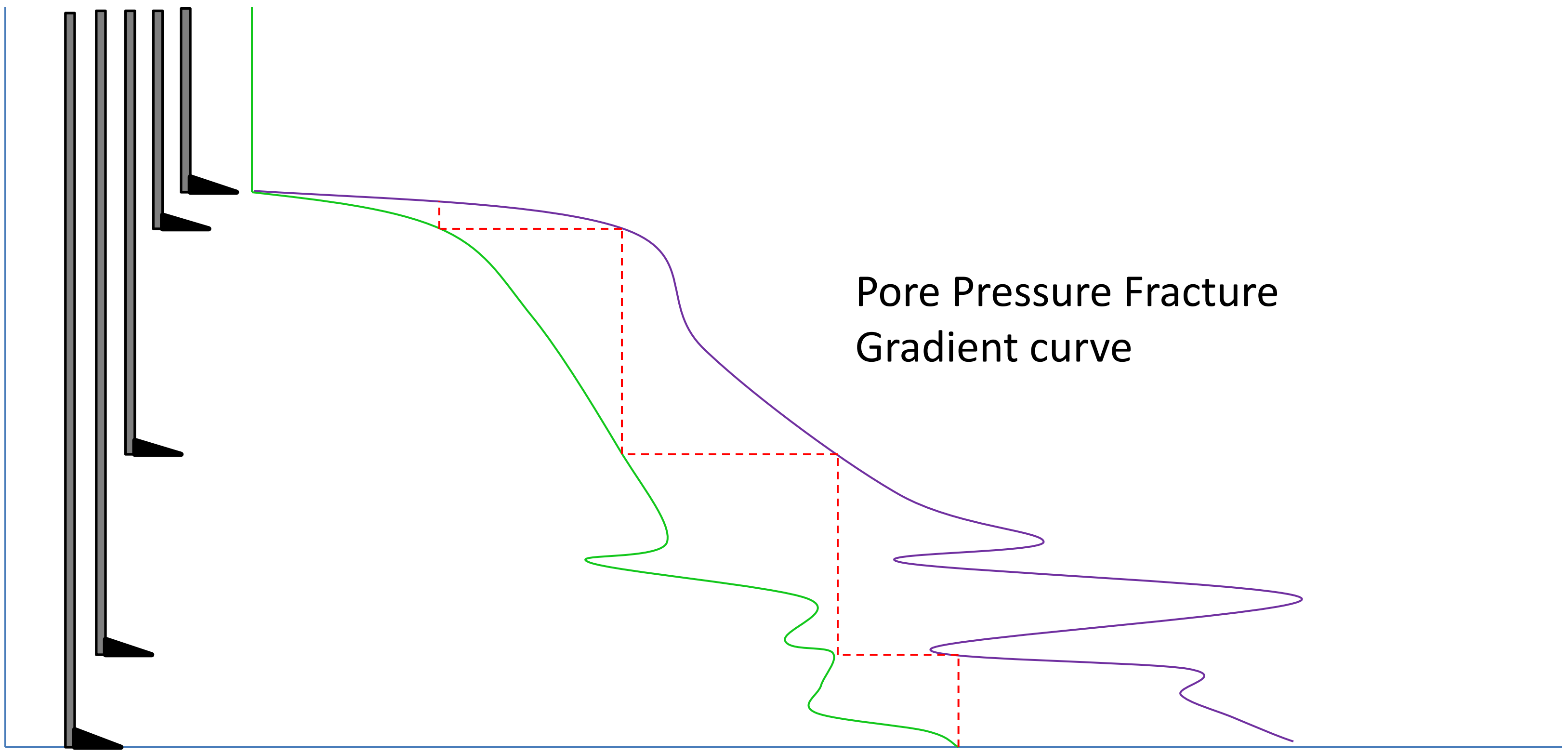
Casing Setting Depth Selection

- Ability to drill next hole section while maintaining stable wellbore.
- Consider formation strength using PPFG curve
- PPFG = Pore Pressure & Fracture Gradient
- Consider also influx circulation out (kick) as a well control scenario.

Casing Setting Depth Selection



Casing Setting Depth Selection

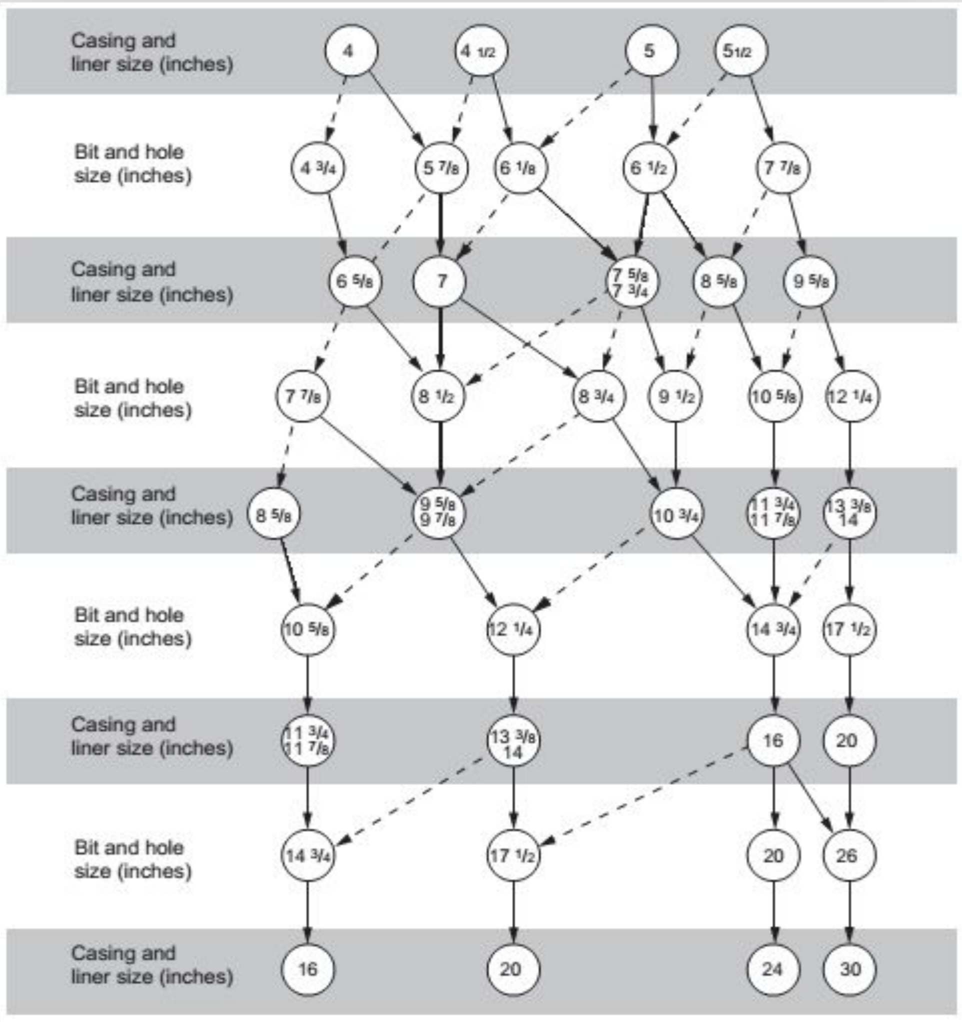


Class Problem 1.

Depth (m)	PP (sg)	FG (sg)
0	1.08	1.49
2700	1.08	1.49
2896	1.14	1.53
3048	1.32	1.65
3200	1.41	1.71
3353	1.47	1.75
3505	1.55	1.80
3658	1.59	1.83
3810	1.62	1.85
3962	1.68	1.89
4115	1.80	1.97
4267	1.92	2.05
4420	1.94	2.06

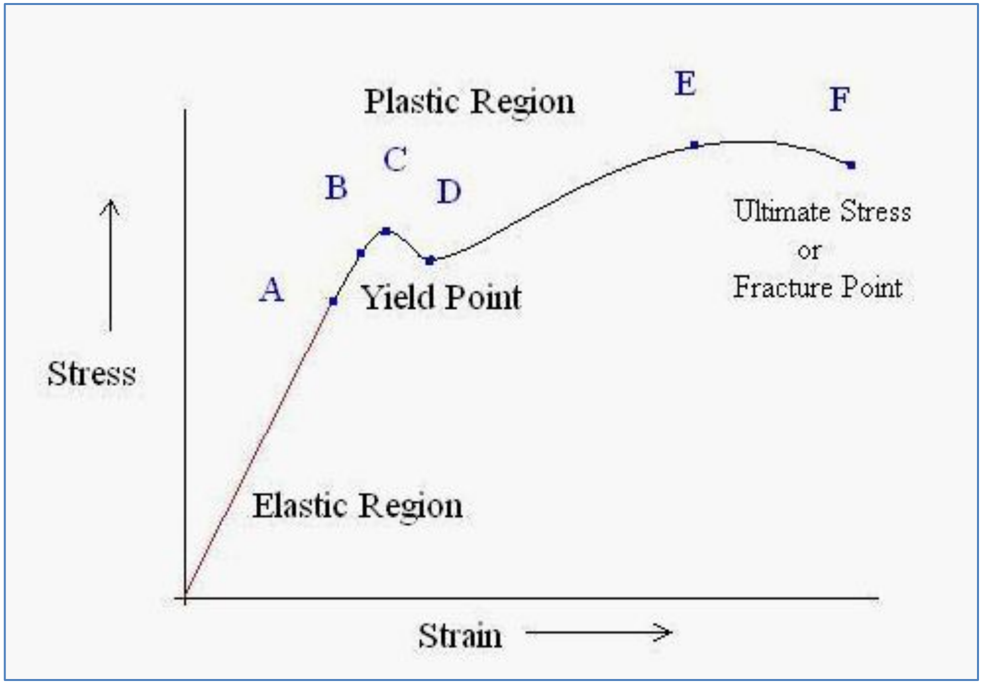
A. Plot the PPFG curve on cartesian sheet
B. Find Casing Setting Depths
C. Calculate PP and FG at each shoe
D. Select all possible casing sizes based on production tubing size 4 ½" and 5"

Casing Setting Depth Selection



Strength Properties of Casing

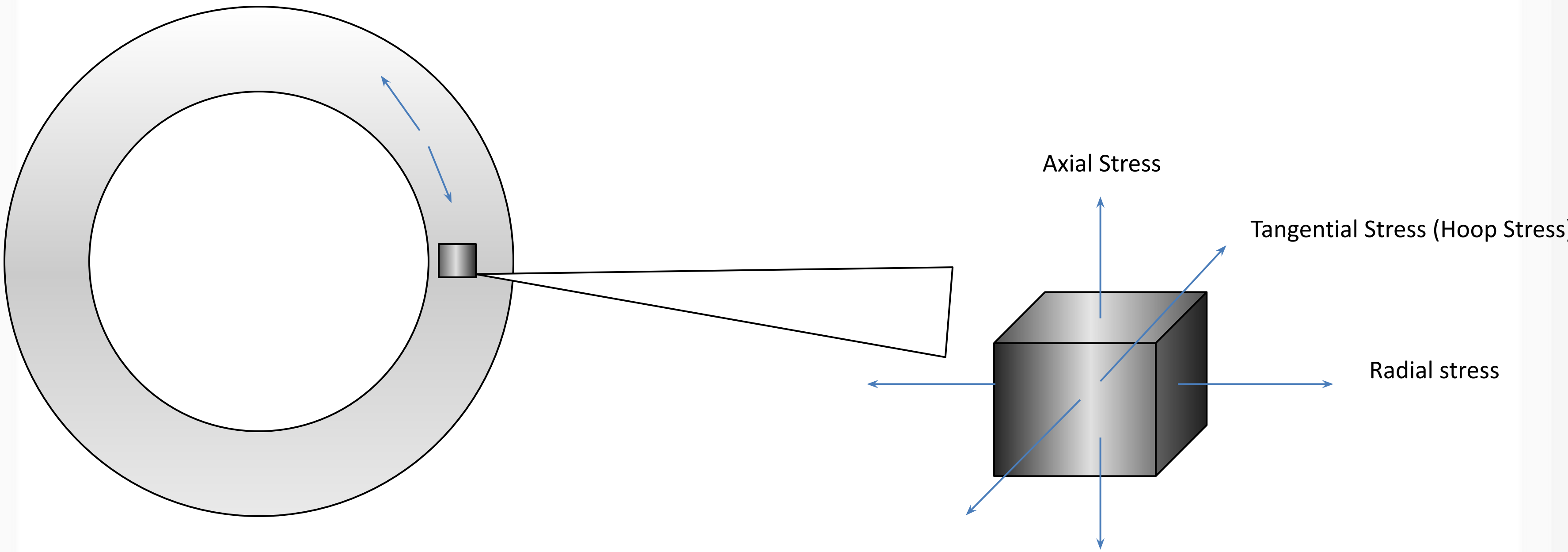
If we load any metal specimen slowly by tension or compression a gradual decrease or increase is observed in its length.



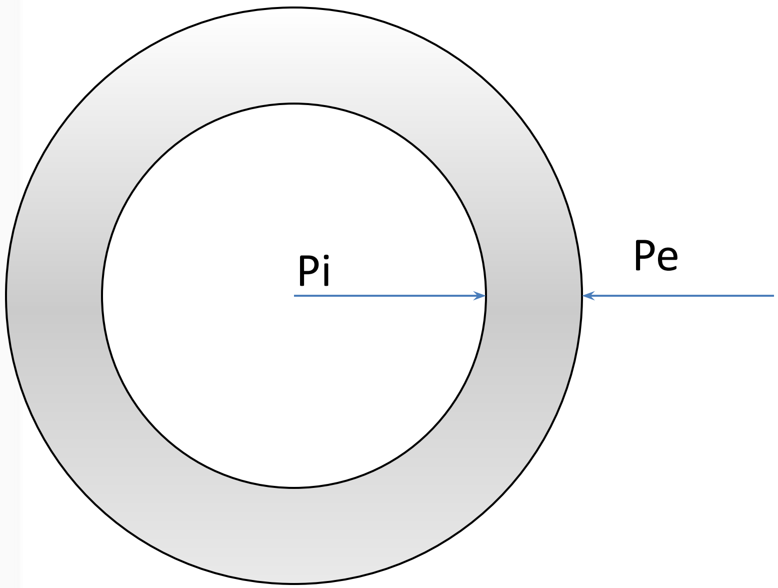
-From origin to point A obeys hook law
-From A to B slightly change in linear relationship between stress&strain.
-Point B called Yield Point
-From B to C stress strain relationship becomes nonlinear. Hence, lead to plastic deformation.
-From C to D called "necking", cross sectional area of the specimen is decreasing.

- From D to E with little increase in stress specimen elongates (strain increases faster)
- From E to F material strength increases then decreases until point F.
- Point F is called rupture point or ultimate point

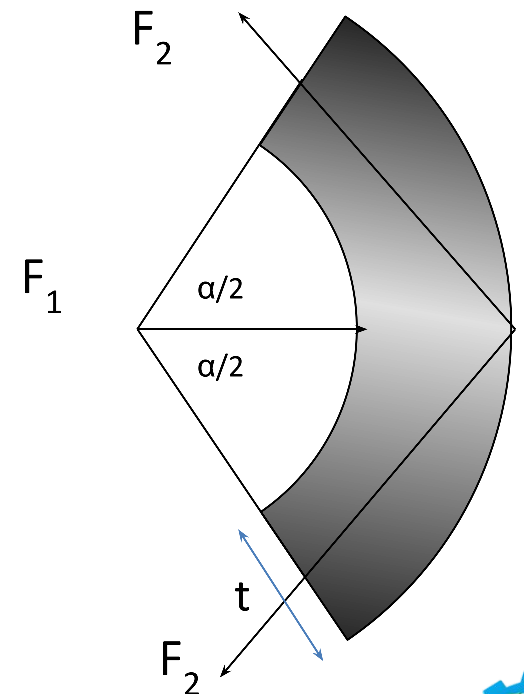
Burst , Collapse Tensile Design



Burst , Collapse Tensile Design



- Burst



Burst , Collapse Tensile Design

- Collapse

API COLLAPSE PRESSURE EQUATIONS

Yield strength collapse pressure:

$$P_y = 2\sigma_y \frac{\alpha - 1}{\alpha^2} \qquad (1)$$

The P_y domain: $2 < \alpha \leq \alpha_{yp}$

$$\alpha_{yp} = \frac{(A-2) + \sqrt{(A-2)^2 + 8(B + C/\sigma_y)}}{2(B + C/\sigma_y)} \qquad (2)$$

Plastic collapse pressure:

$$P_p = \sigma_y\left(\frac{A}{\alpha} - B\right) - C \qquad (3)$$

The P_p domain: $\alpha_{yp} < \alpha \leq \alpha_{pt}$

$$\alpha_{pt} = \frac{\sigma_y (A - F)}{C + \sigma_y (B - G)} \qquad (4)$$

Transition collapse pressure:

$$P_T = \sigma_y\left(\frac{F}{\alpha} - G\right) \qquad (5)$$

The P_T domain: $\alpha_{pt} < \alpha \leq \alpha_{te}$

$$\alpha_{te} = \frac{2 + BA/A}{3\,B/A} \qquad (6)$$

Elastic collapse pressure: $\alpha > \alpha_{te}$

$$P_E = \frac{2EK_E}{\alpha(\alpha-1)^2(1-\mu^2)} \approx \frac{46.98 \times 10^6}{\alpha(\alpha-1)^2} \qquad (7)$$

Factors and constants of the API collapse pressure equations:

$$A = 2.8762 + 1.0679 \times 10^{-6}\sigma_y + 21.301 \times 10^{-12}\sigma_y^2 - 53.132 \times 10^{-18}\sigma_y^3 \qquad (8)$$

$$B = 0.026233 + 0.50609 \times 10^{-6}\sigma_y \qquad (9)$$

$$C = 30.867 \times 10^{-3}\sigma_y - 10.483 \times 10^{-9}\sigma_y^2 + 36.989 \times 10^{-15}\sigma_y^3 - 465.93 \qquad (10)$$

$$F = \frac{27}{4} \times \frac{2EK_E}{1-\mu^2} \times \frac{(B/A)^3}{\sigma_y(1-B/A)^3} \approx \frac{317 \times 10^6 (B/A)^3}{\sigma_y(1-B/A)^3} \qquad (11)$$

$$G = F \times B/A \qquad (12)$$

Proposed collapse pressure equation (alternative to the API Equations 1, 3, 5, and 7)

$$\frac{1}{P^2} = \frac{1}{P_y^2} + \frac{1}{P_E^2} \qquad 13$$

$$P = \left\{\left[\frac{1}{2\sigma_y}\frac{\alpha^2}{\alpha-1}\right]^2 + \left[\frac{1-\mu^2}{2EK_E}\alpha(\alpha-1)^2\right]^2\right\}^{-1/2} \qquad 14$$

Derivation of Equations 13 and 14:

$$\frac{1}{P^n} = \frac{1}{P_y^n} + \frac{1}{P_E^n} \qquad 15$$

$$\Delta P = \frac{P - P_{API}}{P_{API}} 100\% \qquad 16$$

Nomenclature

- A, B, F, and G = API dimensionless factors that are a function of σ_y, expressed in psi
- C = API location factor (parameter) in psi that is a function of σ_y expressed in psi
- D = Tubing outside diameter
- E = Modulus of elasticity, E = 30 x 10^6 psi (207 GPa) for steel tubing
- K_E = Average-to-minimum elastic collapse pressure correction factor, K_E = 0.95 x 0.75 = 0.7125
- P = Collapse pressure as proposed by new formula
- P_{API} = Collapse pressure as defined by API: P_Y, P_P, P_T, or P_E
- P_Y = API yield strength collapse pressure
- P_P = API plastic collapse pressure
- P_T = API transition collapse pressure
- P_E = API elastic collapse pressure
- t = Tubing wall thickness
- α = Outside diameter-to-wall thickness ratio, α = D/t
- α_{yp} = Yield-to-plastic boundary D/t ratio
- α_{pt} = Plastic-to-transition boundary D/t ratio
- α_{te} = Transition-to-elastic boundary D/t ratio
- μ = Poisson's ratio, μ = 0.30 for steel tubing
- σ_y = Yield strength, psi

Burst , Collapse Tensile Design

Table 1—Yield Collapse Pressure Formula Range

(1) Grade[a]	(2) *D/t* Range[b]
H-40	16.40 and less
-50	15.24 and less
J-K-55	14.81 and less
-60	14.44 and less
-70	13.85 and less
C-E-75	13.60 and less
L-N-80	13.38 and less
C-90	13.01 and less
C-T-X-95	12.85 and less
-100	12.70 and less
P-G-105	12.57 and less
P-110	12.44 and less
-120	12.21 and less
Q-125	12.11 and less
-130	12.02 and less
S-135	11.92 and less
-140	11.84 and less
-150	11.67 and less
-155	11.59 and less
-160	11.52 and less
-170	11.37 and less
-180	11.23 and less

[a]Grades indicated without letter designation are not API grades but are grades in use or grades being considered for use and are shown for information purposes.
[b]The *D/t* range values were calculated from Formulas 2, 21, 22, and 23 to eight or

Table 2—Formula Factors and *D/t* Range for Plastic Collapse

(1)	(2)	(3)	(4)	(5)
	Formula Factor[b]			
Grade[a]	A	B	C	*D/t* Range[b]
H-40	2.950	0.0465	754	16.40 to 27.01
-50	2.976	0.0515	1056	15.24 to 25.63
J-K-55	2.991	0.0541	1206	14.81 to 25.01
-60	3.005	0.0566	1356	14.44 to 24.42
-70	3.037	0.0617	1656	13.85 to 23.38
C-E-75	3.054	0.0642	1806	13.60 to 22.91
L-N-80	3.071	0.0667	1955	13.38 to 22.47
C-90	3.106	0.0718	2254	13.01 to 21.69
C-T-X-95	3.124	0.0743	2404	12.85 to 21.33
-100	3.143	0.0768	2553	12.70 to 21.00
P-G-105	3.162	0.0794	2702	12.57 to 20.70
P-110	3.181	0.0819	2852	12.44 to 20.41
-120	3.219	0.0870	3151	12.21 to 19.88
Q-125	3.239	0.0895	3301	12.11 to 19.63
-130	3.258	0.0920	3451	12.02 to 19.40
S-135	3.278	0.0946	3601	11.92 to 19.18
-140	3.297	0.0971	3751	11.84 to 18.97

Burst , Collapse Tensile Design

Table 3—Formula Factors and *D/t* Range for Transition Collapse

(1)	(2)	(3)	(4)
	Formula Factors[b]		
Grade[a]	F	G	*D/t* Range[b]
H-40	2.063	0.0325	27.01 to 42.64
-50	2.003	0.0347	25.63 to 38.83
J-K-55	1.989	0.0360	25.01 to 37.21
-60	1.983	0.0373	24.42 to 35.73
-70	1.984	0.0403	23.38 to 33.17
C-E-75	1.990	0.0418	22.91 to 32.05
L-N-80	1.998	0.0434	22.47 to 31.02
C-90	2.017	0.0466	21.69 to 29.18
C-T-X-95	2.029	0.0482	21.33 to 28.36
-100	2.040	0.0499	21.00 to 27.60
P-G-105	2.053	0.0515	20.70 to 26.89
P-110	2.066	0.0532	20.41 to 26.22
-120	2.092	0.0565	19.88 to 25.01
Q-125	2.106	0.0582	19.63 to 24.46
-130	2.119	0.0599	19.40 to 23.94
S-135	2.133	0.0615	19.18 to 23.44
-140	2.146	0.0632	18.97 to 22.98
-150	2.174	0.0666	18.57 to 22.11
-155	2.188	0.0683	18.37 to 21.70
-160	2.202	0.0700	18.19 to 21.32
-170	2.231	0.0734	17.82 to 20.60
-180	2.261	0.0769	17.47 to 19.93

[a]Grades indicated without letter designation are not API grades but are grades in use or grades being considered for use and are shown for information purposes.
[b]The *D/t* range values and formula factors were calculated from Formulas 4, 6, 21, 22, 23, 26, and 27 to eight or more digits.

Table 4—*D/t* Range for Elastic Collapse

(1)	(2)
Grade[a]	*D/t* Range[b]
H-40	42.64 and greater
-50	38.83 and greater
J-K-55	37.21 and greater
-60	35.73 and greater
-70	33.17 and greater
C-E-75	32.05 and greater
L-N-80	31.02 and greater
C-90	29.18 and greater
C-T-X-95	28.36 and greater
-100	27.60 and greater
P-G-105	26.89 and greater
P-110	26.22 and greater
-120	25.01 and greater
Q-125	24.46 and greater
-130	23.94 and greater
S-135	23.44 and greater
-140	22.98 and greater
-155	22.11 and greater
-155	21.70 and greater
-160	21.32 and greater
-170	20.60 and greater
-180	19.93 and greater

[a]Grades indicated without letter designation are not API grades but are grades in use or grades being considered for use and are shown for information purposes.
[b]The *D/t* range values were calculated from Formulas 6, 21, and 22 to eight or more digits.

Burst , Collapse Tensile Design

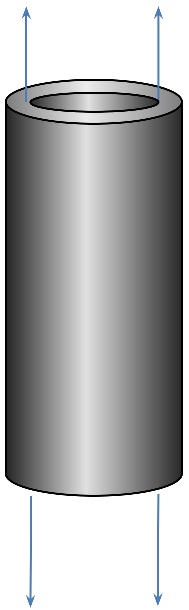
2.1.7 Collapse Pressure Formula Symbols

D = nominal outside diameter, inches.
t = nominal wall thickness, inches.
Y_p = minimum yield strength of the pipe, pounds per square inch.
P_Y = minimum yield strength collapse pressure, pounds per square inch.
P_P = minimum plastic collapse pressure, pounds per square inch.
P_T = minimum plastic/elastic transition collapse pressure, pounds per square inch.
P_E = minimum elastic collapse pressure, pounds per square inch.
P_e = equivalent external pressure, pounds per square inch.
P_i = internal pressure, pounds per square inch.
P_o = external pressure, pounds per square inch.
$(D/t)_{YP}$ = D/t intersection between yield strength collapse and plastic collapse.
$(D/t)_{PT}$ = D/t intersection between plastic collapse and transition collapse.
$(D/t)_{TE}$ = D/t intersection between transition collapse and elastic collapse.

Class Problem 2.

- Calculate Collapse pressure for pipe :
- OD=7”
- Weight = 26 ppf
- Wall Thickness = 0.362”
- P-110

Burst , Collapse Tensile Design



- Axial Tension

$F_{axial\ tension} = \sigma_{yield} \times A_s$