

PETE 4313

Handout #5

Rolling Cutter Bits (Rollercones or Tricones)



Read:

***Applied Drilling Engineering, Ch.5
(bits)***

HW#4:

Due Thursday February 21 in Class

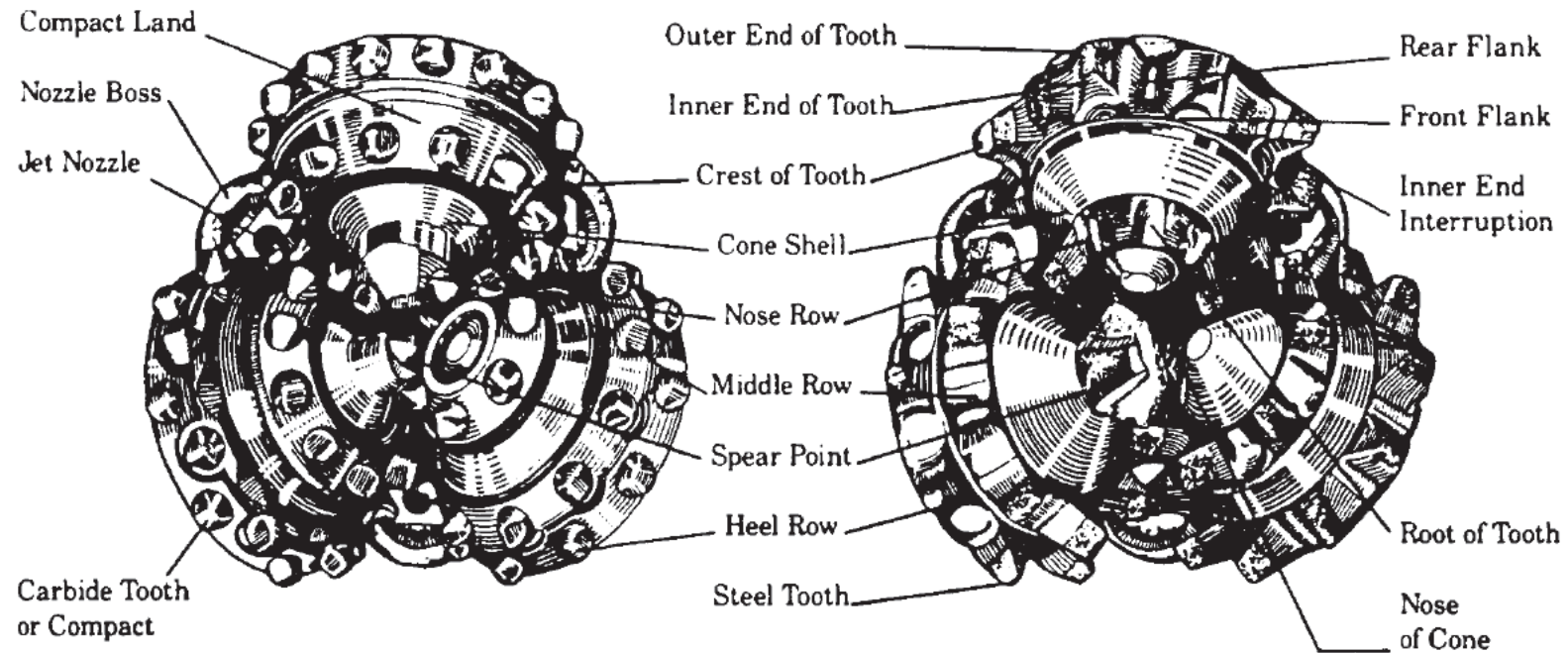


Handout #5 - Bits cont'd

- Rolling Cutter Bits
 - Steel Tooth (milled tooth)
 - Carbide Tooth (tungsten carbide insert)
- ▶ Grading of Worn Bits
- ▶ Bit Performance
- ▶ Buoyancy Again!



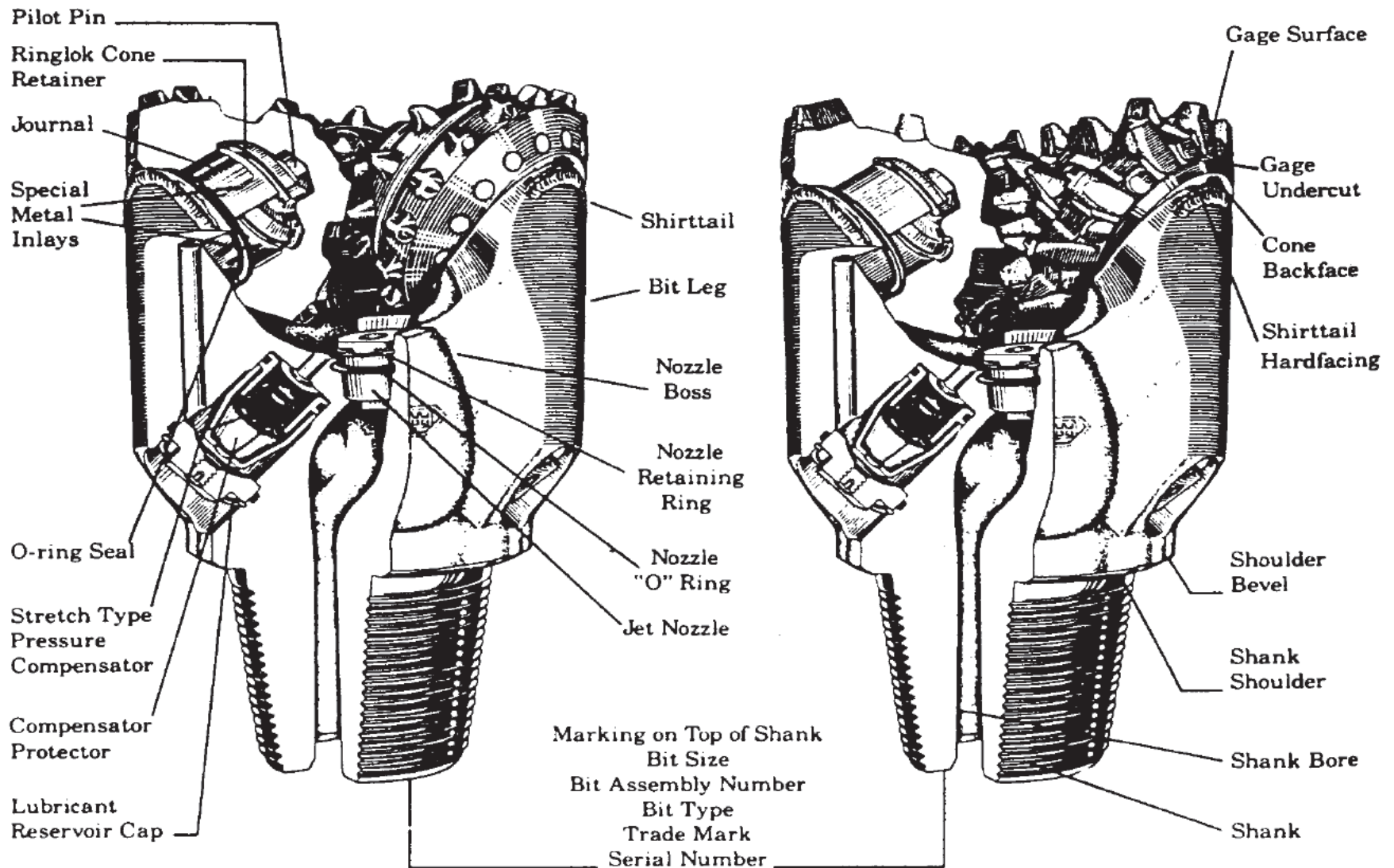
ROTARY DRILL BITS



ROCK BIT ELEMENTS

**Tungsten
Carbide Insert
Bit**

**Milled
Tooth
Bit**



Rock bit components. Bits have to be tremendously robust.

Carbide Tooth Bit

Steel Tooth Bit

Rotary Drill Bits

Roller Cutter Bits - rock bits

- First rock bit introduced in 1909 by Howard Hughes
 - 2 - cone bit
 - Not self-cleaning



Rotary Drill Bits

- *Improvements*

- 3 - cone bit (straighter hole)
- Intermeshing teeth (better cleaning)
- Hard-facing on teeth and body
- Change from water courses to jets
- Tungsten carbide inserts
- Sealed bearings
- Journal bearings

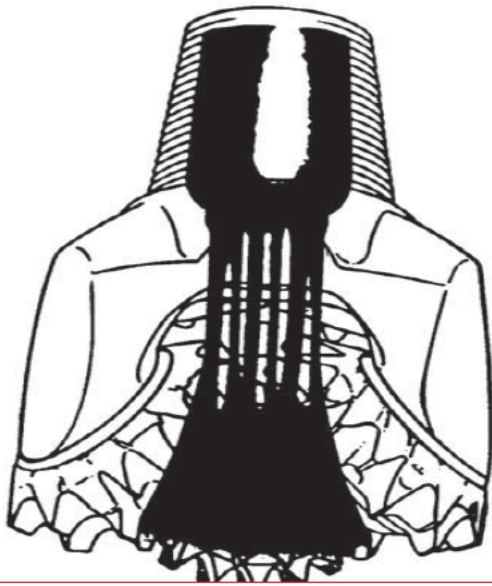


Rotary Drill Bits

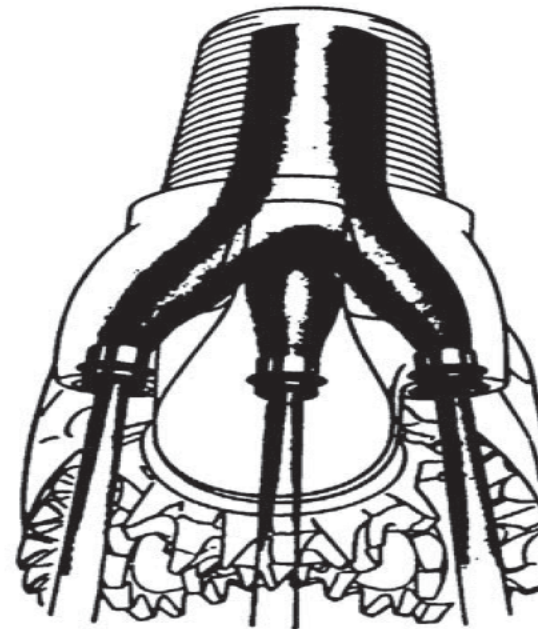
- *Advantages*

- For any type of formation there is a suitable design of rock bit
- Can handle changes in formation (PDC not?)
- Acceptable life and drilling rate
- Reasonable cost

**Proper
bottomhole
cleaning is very
important**



Fluid flow through water courses in old bit

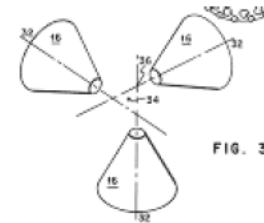


Fluid flow through jets in the bit (nozzles)

Rotary Drill Bits

➤ *Milled Tooth Bit (Steel Tooth)*

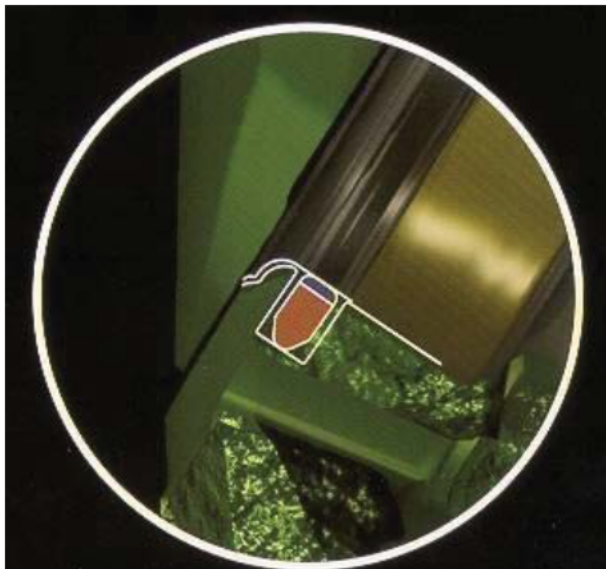
- Long teeth for soft formations
- Shorter teeth for harder formations
- Cone off-set in soft-formation bit results in scraping gouging action



- Self-sharpening teeth by using hardfacing on one side
- High drilling rates - especially in softer rocks



Milled Tooth Bit (Steel Tooth)



Rotary Bits

➤ *Tungsten Carbide Insert Bits*

- Long life cutting structure in hard rocks
- Hemispherical inserts for very hard rocks
- Larger and more pointed inserts for softer rock
- Can handle high bit weights and high RPM
- Inserts fail through breakage rather than wear

(Tungsten carbide is a very hard, brittle material)

***Tungsten
Carbide
Insert
Bits***



Cutting Elements Insert Bits



Soft

Shear and Compression



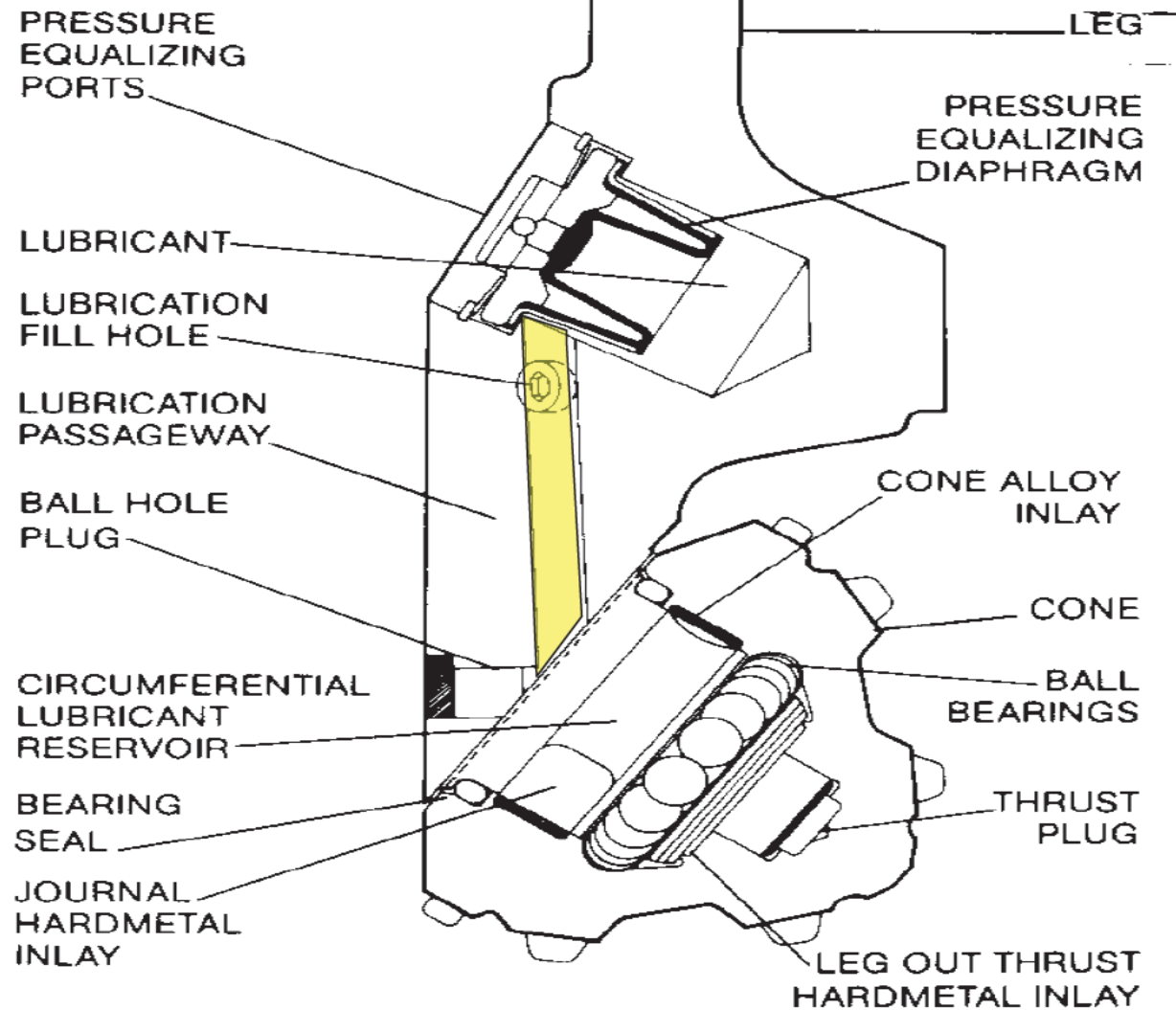
Medium



Hard

Compression

Sealed Bearing Lubrication System






What are Bearings?

Bearings are what make the cones on a Tricone spin.

There are four common types of bearings:

- 1- Standard open bearing roller bit**
- 2- Air-cooled roller bearings**
- 3- Sealed roller bearings**
- 4- Sealed journal (friction) bearings**

Bearings

- Ball Bearings (point contact) 
- Roller Bearings (line contact) 
- Journal bearing (area contact) 
- Lubrication by drilling fluid . . . or . . .

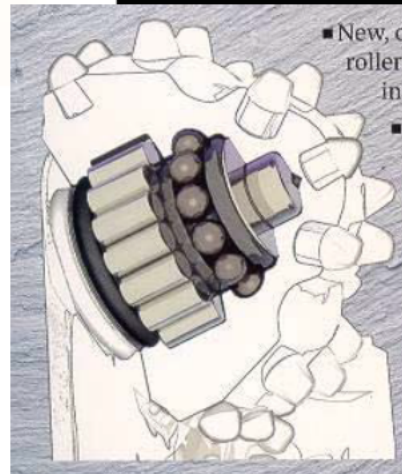
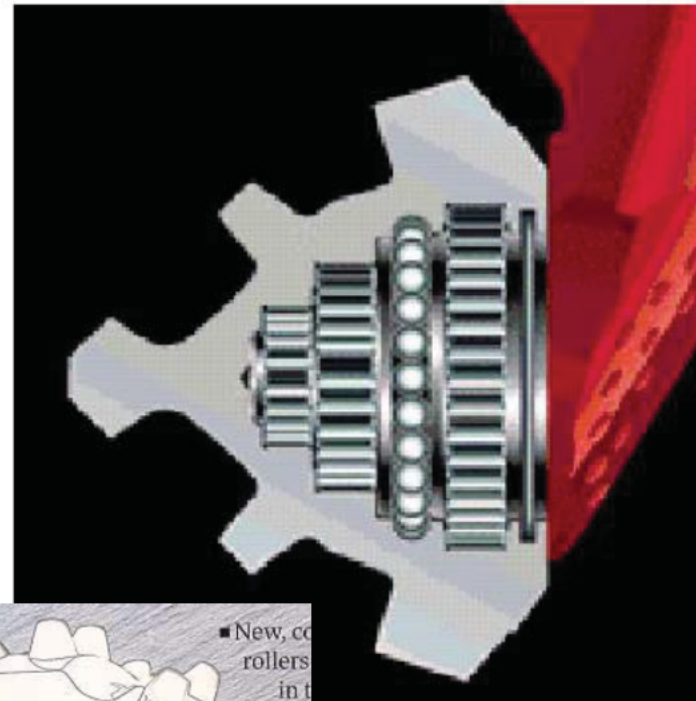


Roller Cone Bearings

Friction / Journal



Roller



Bearings

- ***Sealed Bearings (since 1959)***
 - Grease lubricant (much longer life)
 - Pressure surges can cause seal to leak!
- ***Journal Bearings (area contact)***
 - Wear-resistant hard surface on journal
 - Solid lubricant inside cone journal race
 - O - ring seal
 - Grease



Name: Quiz #3 Solution

Density of steel is 490 lbs/(ft³)

7.48 gallons is equal to one ft³

1. You have a vertical well with a depth of 12,000 ft. The well is filled with a 12 ppg mud. In the well you have a 12,000 ft drill string with only 5 inch OD drill pipe. (Neglect tool joints). The string weights 240,000 lbs in air. Assume the drill pipe is totally submerged in the mud and not in contact with the bottom of the hole - just hanging from the hook.

a. (3) What is the hook load?

$$K_0 = (1 - \frac{12}{65.5}) = 0.8168$$

$$H.L = W_{air} \cdot K_0$$

$$H.L = 240,000 \text{ lbs} \times 0.8168 = 196,036 \text{ lbs}$$

b. (3) What is the ID of the drill pipe?

$$W_{air} = \rho \cdot V = \rho \cdot L \cdot A = \rho \cdot L \cdot \frac{\pi}{4} \cdot (D_o^2 - D_i^2)$$

$$A = \frac{W_{air}}{\rho \cdot L} = \frac{240,000}{490 \times 12,000} \Rightarrow A = 0.0408 \text{ ft}^2$$

$$A = (\frac{\pi}{4}) (D_o^2 - D_i^2)$$

$$0.0408 \text{ ft}^2 = (\frac{\pi}{4}) ((\frac{5}{12})^2 - D_i^2) \Rightarrow D_i = 0.348 \text{ ft or } 4.18 \text{ in}$$

3. A drill bit which costs \$30,000 drilled from 6,000 ft to 8,400 ft with an average rate of penetration (ROP) of 20 ft/hr. The connection time is 5 min per 30 ft connection, the tripping time is 1 hr/1,000 ft and the rig rate is 72,000 \$/day.

a. (4) What is the \$/ft for this bit run?

$$t_r = \frac{(8400 - 6000) \text{ ft}}{20 \text{ ft/hr}} = 120 \text{ hr}$$

$$\# \text{ connections} = \frac{(8400 - 6000) \text{ ft}}{30 \text{ ft/conn}} = 80 \text{ conn}$$

$$t_{\text{conn}} = 80 \text{ conn} \times \left(\frac{5 \text{ min}}{\text{conn}} \right) \times \left(\frac{1 \text{ hr}}{60 \text{ min}} \right) = 6.67 \text{ hr}$$

$$t_{\text{trip}} = \frac{(8400 + 6000) \text{ ft}}{1000 \text{ ft}} \times \frac{1 \text{ hr}}{1000 \text{ ft}} = 14.4 \text{ hr}$$

$$C_f = \frac{(120 + 6.67 + 14.4) \text{ hr} \times \frac{\$72,000}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hr}} + \$30,000}{8400 - 6000 \text{ ft}}$$

$$= 188.8 \text{ $/ft}$$

Grading of Dull Bits

How do bits wear out?

- **Tooth wear or loss**
- **Worn bearings**
- **Gauge wear**

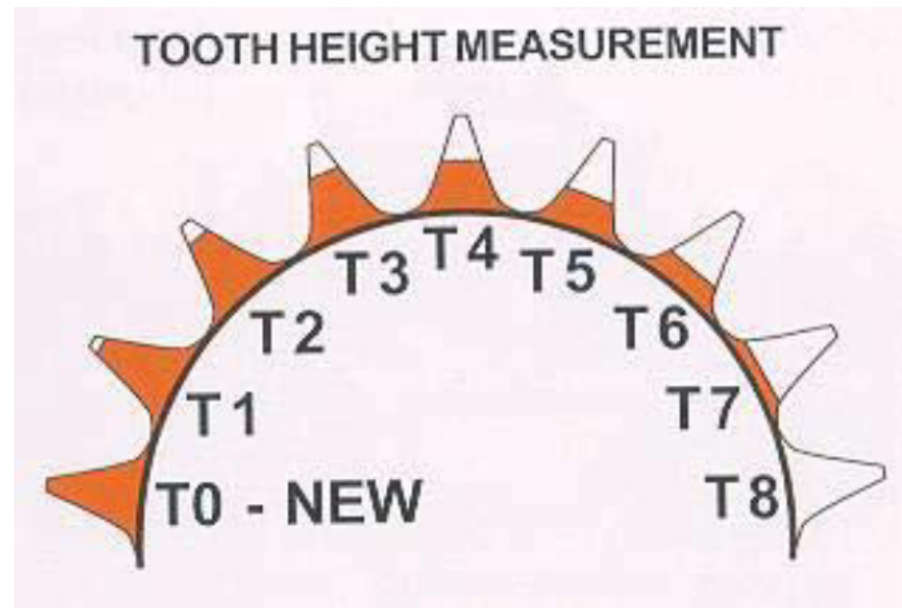


Grading of Dull Bits

How do bits wear out?

- **Steel teeth** - graded in eights of original tooth height that has worn away

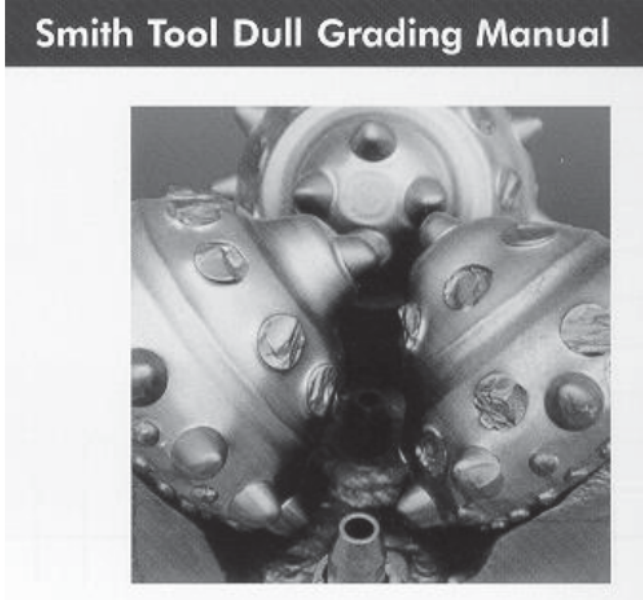
e.g. **T3** means that **3/8** of the original tooth height is worn away



Grading of Dull Bits

Broken or Lost Teeth

- *Tungsten Carbide Insert bit*

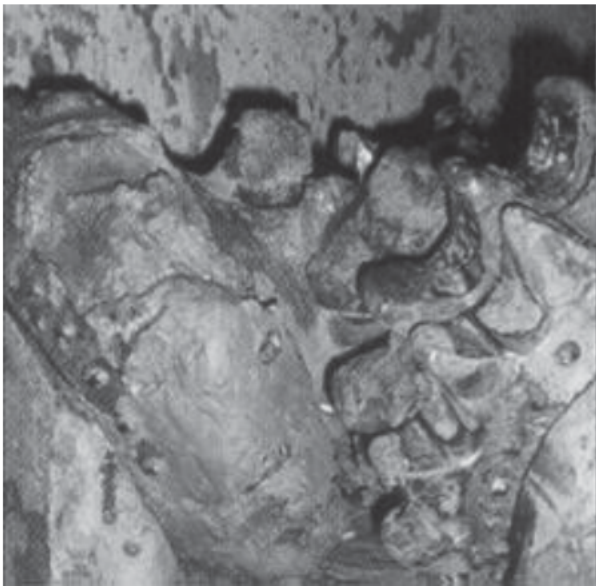


e.g. **T3** means that **3/8** of the inserts are broken or lost

Grading of Dull Bits

How do bits fail?

- ***Bearings:*** B3 means that an estimated 3/8 of the bearing life is gone



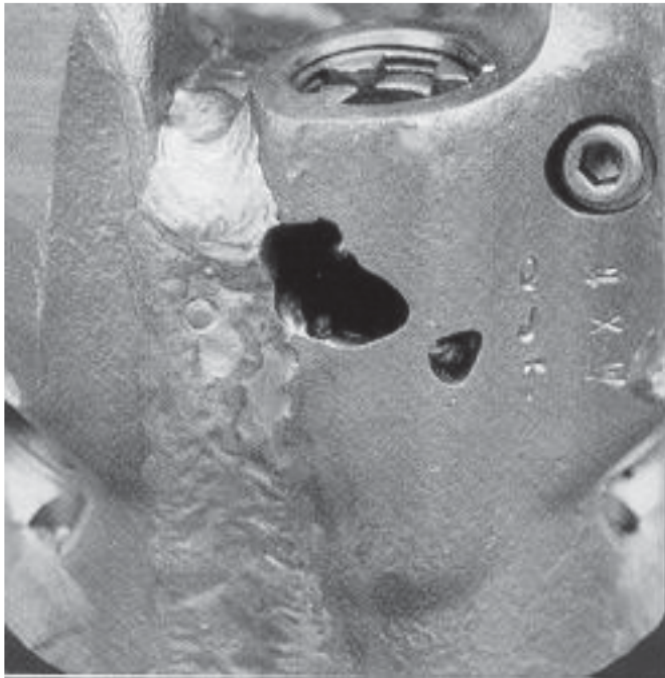
Balled up Bit



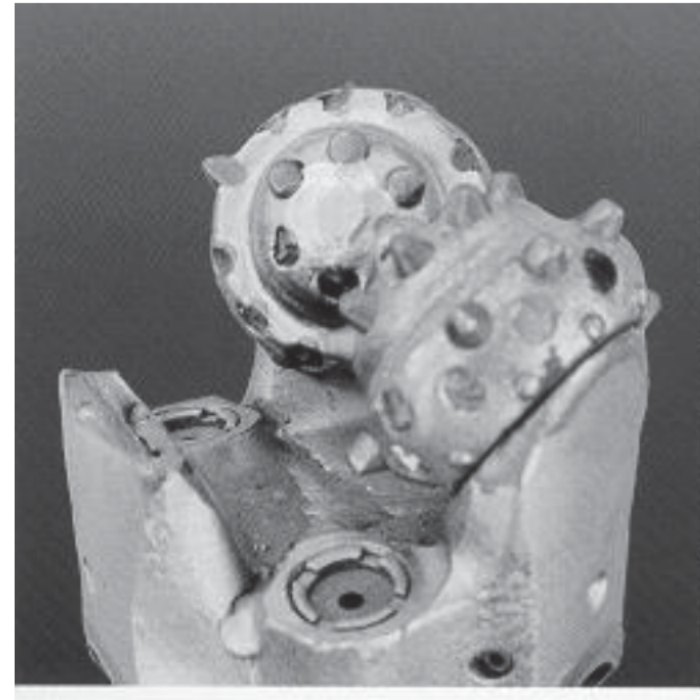
Cracked Cone

Grading of Dull Bits

How do bits fail?



Washed out Bit



Lost Cone

Grading of Dull Bits

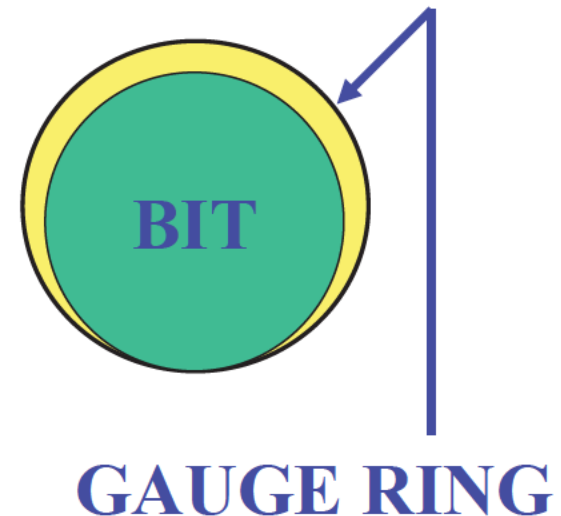
How do bits wear out?

➤ Gauge Wear:

- Bit is either in-Gauge or out-of-Gauge
- Measure wear on diameter (in inches), using a gauge ring

▶ Examples:

- T3 – B3 - 1
- T5 – B4 - 0 1/2



IADC ROLLER CONE BIT CLASSIFICATION SYSTEM



IADC System

- Operational since 1972
- Provides a Method of Categorizing Roller Cone Rock Bits
- Design and Application related coding
- Most Recent Revision
 - 'The IADC Roller Bit Classification System'
 - 1992, IADC/SPE Drilling Conference
 - Paper # 23937



IADC Classification

- 4-Character Design/Application Code
 - First 3 Characters are NUMERIC
 - 4th Character is ALPHABETIC

135M

or

447X

or

637Y



Sequence

135M or 447X or 637Y

➤ Numeric Characters are defined:

- Series *1st*
- Type *2nd*
- Bearing & Gage *3rd*

➤ Alphabetic Character defined:

- Features Available *4th*



Series

135M	or	447X	or	637Y
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- **FIRST CHARACTER**
- General Formation Characteristics
- Eight (8) Series or Categories
- Series 1 to 3 Milled Tooth Bits
- Series 4 to 8 Tungsten Carbide Insert Bits

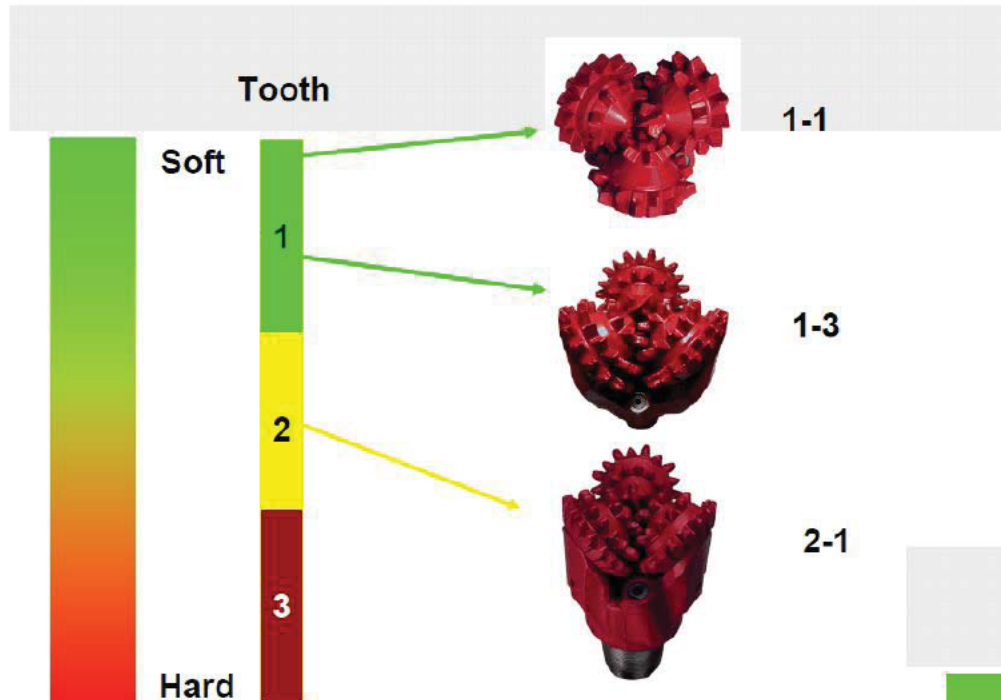
The higher the series number,
the harder/more abrasive the rock

Define Hardness

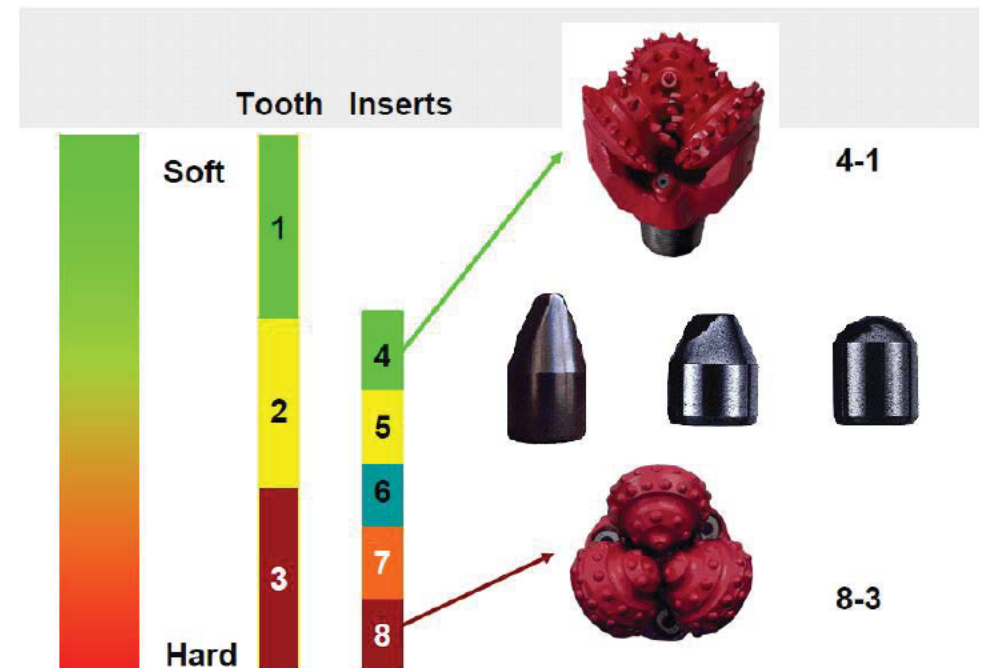
Hardness	UCS (psi)	Examples
Ultra Soft	< 1,000	gumbo, clay
Very Soft	1,000 - 4,000	unconsolidated sands, chalk, salt, claystone
Soft	4,000 - 8,000	coal, siltstone, schist, sands
Medium	8,000 - 17,000	sandstone, slate, shale, limestone, dolomite
Hard	17,000 - 27,000	quartzite, basalt, gabbro, limestone, dolomite
Very Hard	> 27,000	marble, granite, gneiss

UCS = Uniaxial Unconfined Compressive Strength

Milled Tooth



Insert Tooth



Type


135M

or

447X

or

637Y

- SECOND CHARACTER
 - Degree of Hardness
 - Each Series divided into 3 or 4 'Types'
 - Type 1 Softest Formation in a Series
- 
- Increasing Rock Hardness*
- Type 4 Hardest Formation in a Series

Bearing & Gage

135M	or	447X	or	637Y
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➤ THIRD CHARACTER

➤ Bearing Design and Gage Protection

➤ Seven (7) Categories

- 1. Non-Sealed (Open) Roller Bearing
- 2. Roller Bearing Air Cooled
- 3. Non-Sealed (Open) Roller Bearing Gage Protected
- 4. Sealed Roller Bearing
- 5. Sealed Roller Bearing Gage Protected
- 6. Sealed Friction Bearing
- 7. Sealed Friction Bearing Gage Protected

Features Available

135M	or	447X	or	637Y
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➤ **FOURTH CHARACTER**

➤ **Features Available (Optional)**

➤ **Sixteen (16) Alphabetic Characters**

➤ **Most Significant Feature Listed**

(i.e. only one alphabetic character should be selected).

IADC Features Available

- A - Air Application
- B - Special Bearing/Seal
- C - Center Jet
- D - Deviation Control
- E - Extended Nozzles
- G - Gage/Body Protection
- H - Horizontal Application
- J - Jet Deflection
- L - Lug Pads
- M - Motor Application
- S - Standard Milled Tooth
- T - Two-Cone Bit
- W - Enhanced C/S
- X - Chisel Tooth Insert
- Y - Conical Tooth Insert
- Z - Other Shape Inserts

135M

or

447X

or

637Y

Categorization - Summary

- Convenient Categorization System
- Design and Application Code
- Know its Limitations
- Use Carefully in Application Decisions
 - Consider other sources: offset bit records; dull grading; performance analysis.



Manufacturer	IADC Generalized Code Assigned	Manufacturers' Product Designation
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Hughes	5-1-7	J22
RBI	5-1-7	C2
Reed	5-1-7	FP51A
Sandvik	5-1-7	CFS20
Security	5-1-7	S84-F
Smith	5-1-7	F2

How to Improve Bit Performance

1. Stabilize the bit
2. Maintain minimum mud weight, sand and solids
3. Maintain adequate bottom hole cleaning
4. Protect the seals - avoid pressure surges
5. Thoroughly inspect bit before re-running
6. Keep oil from the mud, and from the seals
7. Follow manufacturers recommendations
(e.g. **6,000 lb/in** of diameter and **40-60 RPM**)

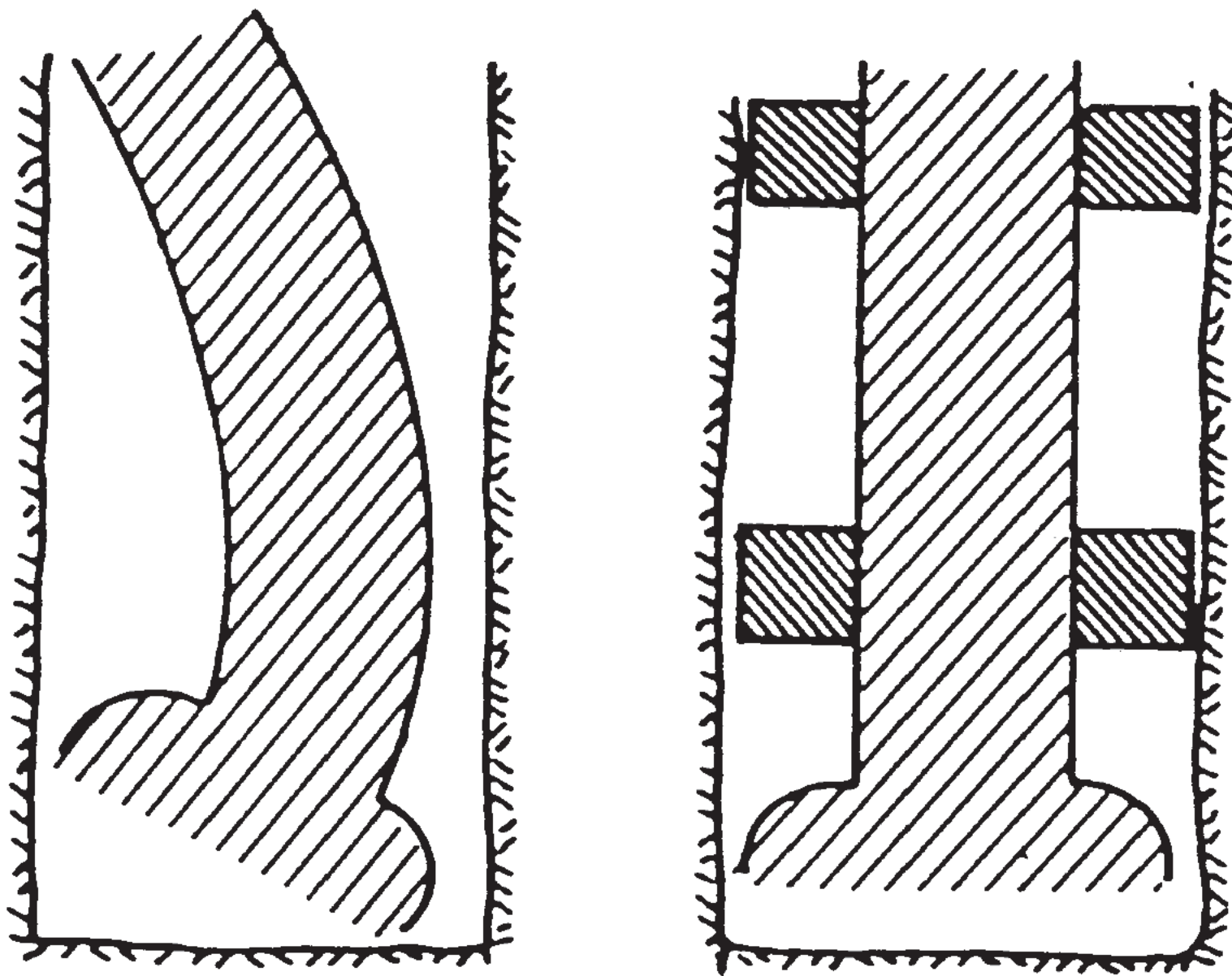


Fig. 5.52—Need for bit stabilizers.

Bit type?

1. **Roller cone**
2. **Drag bit**
3. **Natural diamond**
4. **PDC bit**
5. **Tri-cone bit**



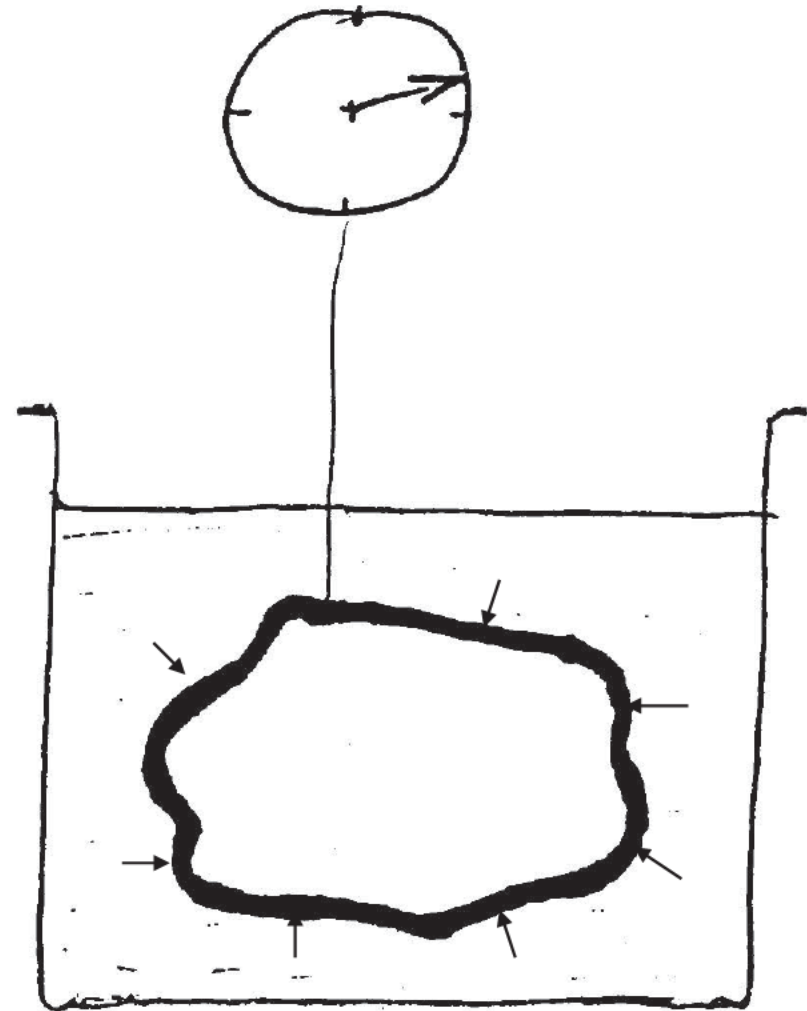
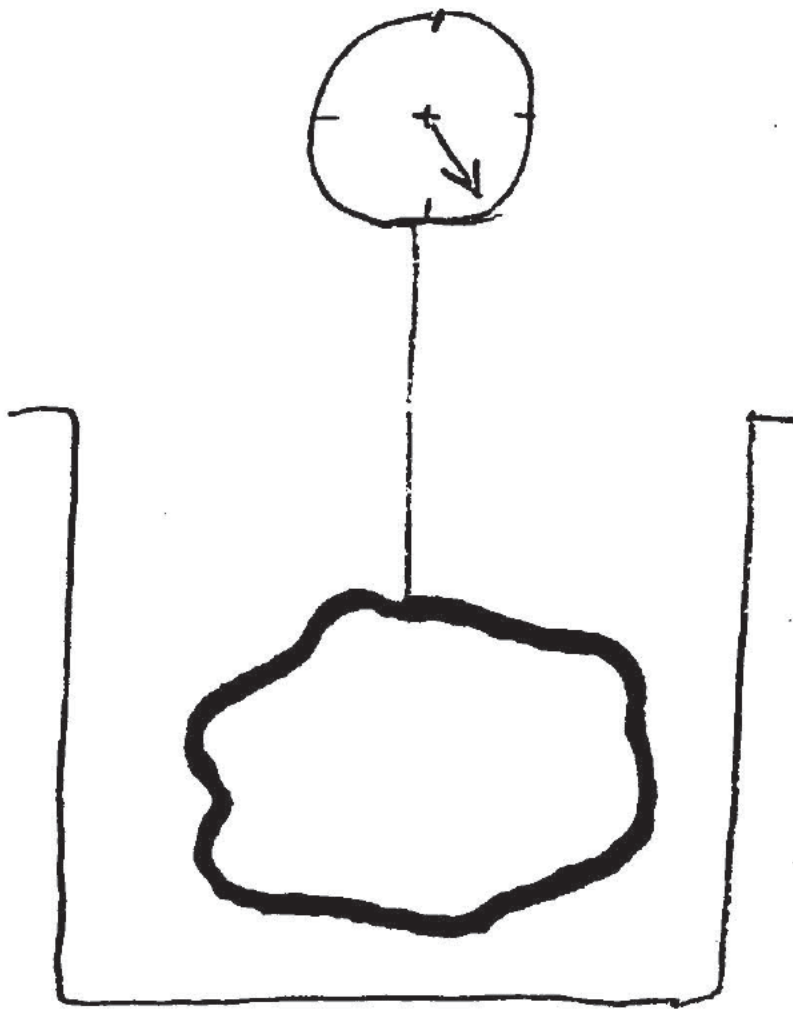
1. **1 series**
2. **5 series**

Buoyancy Again

➤ Archimedes' Principle:

“The upthrust (buoyancy force) experienced by a submerged body is equal to the weight of fluid displaced.”



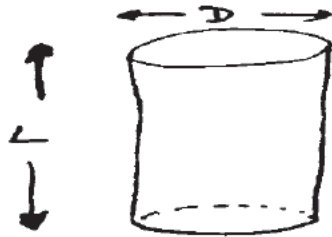


How would you prove this?

What is “buoyancy”?

Buoyancy Force (B)

B = Wt. Of fluid displaced

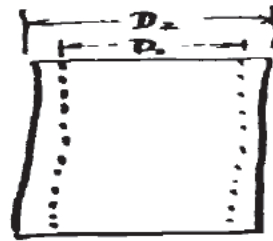


(i)
Solid

$$V_1 = \frac{\pi}{4} D^2 L$$

$$B_1 = \text{Vol.} * \text{Density}$$

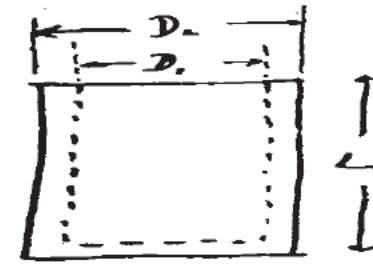
$$B_1 = \frac{\pi}{4} D^2 L \rho_f$$



(ii)
Hollow

$$V_2 = \frac{\pi}{4} (D_2^2 - D_1^2) L$$

$$B_2 = \frac{\pi}{4} (D_2^2 - D_1^2) L \rho_f$$



(iii)
Hollow but closed at
Bottom

$$V_3 = \frac{\pi}{4} D_2^2 L$$

$$B_3 = \frac{\pi}{4} D_2^2 L \rho_f$$



Float Shoe!

Note: L = Length of submerged section

Buoyancy Force

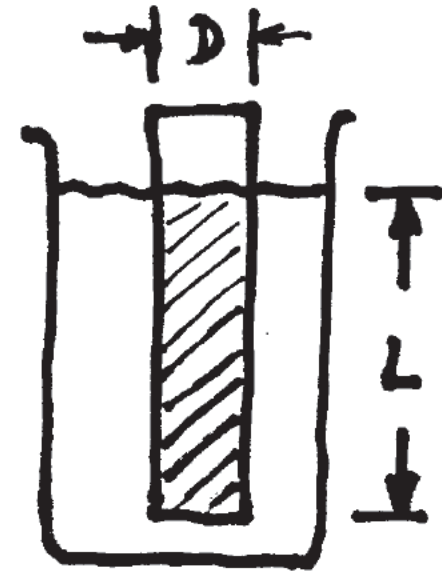
➤ Example: Case 1 (Solid Cylinder)

$$D = 7 \text{ in}$$

$$L = 12,000 \text{ ft}$$

$$\rho = 14.5 \text{ \#/gal}$$

➤ Calculate Buoyancy Force



Buoyancy Force

➤ Solution: B_1 = Weight of fluid displaced

= Volume of cyl * density of mud

$$= \frac{\pi}{4} D^2 L \rho$$

$$B_1 = \frac{\pi}{4} (7^2 \text{ in}^2) \left(12,000 \text{ ft} * 12 \frac{\text{in}}{\text{ft}} \right) \frac{\text{gal}}{231 \text{ in}^3} \frac{14.5 \text{ lb}}{\text{gal}}$$

$$B_1 = 347,860 \text{ lbf}$$



Alternate Solution (Assuming straight well/casing)

Hydrostatic pressure at bottom:

$$P_B = 0.052 * 14.5 * 12,000 = 9,048 \text{ psig}$$

$$\text{Cross-sectional area} = \frac{\pi}{4} D^2 = \frac{\pi}{4} (7^2) = 38.486 \text{ in}^2$$

$$\therefore B_1 = \text{force} = \text{pressure} * \text{area} = 9,048 * 38.486 \frac{\text{lb}}{\text{in}^2} * \text{in}^2$$

$$B_1 = 348,210 \text{ lbf}$$

$$B_1 = 347,860 \text{ lbf (?)}$$

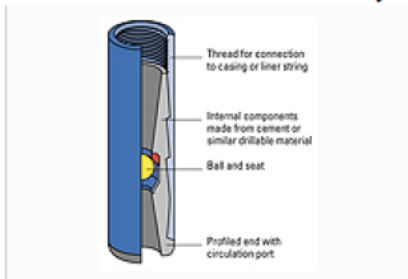
Typical Properties for 7" Casing!

Size O.D. In.	Grade	Wt. Per Ft. With Cplg., Lb.	Inside Dia. In.	Thread & Cplg.		Extreme Line		** Col'pse Resis- tance PSI
				Drift Dia. In.	O.D. of Cplg. In.	Drift Dia. In.	O.D. of Box In.	
7	*F-25	17.00	6.538	6.413	7.656	—	—	1,100
	H-40	17.00	6.538	6.413	7.656	—	—	1,450
	H-40	20.00	6.456	6.331	7.656	—	—	1,980
	J-55	20.00	6.456	6.331	7.656	—	—	2,270
	J-55	23.00	6.366	6.241	7.656	6.151	7.390	3,270
	J-55	26.00	6.276	6.151	7.656	6.151	7.390	4,320
	K-55	20.00	6.456	6.331	7.656	—	—	2,270
	K-55	23.00	6.366	6.241	7.656	6.151	7.390	3,270
	K-55	26.00	6.276	6.151	7.656	6.151	7.390	4,320
	C-75	23.00	6.366	6.241	7.656	6.151	7.390	3,770
	C-75	26.00	6.276	6.151	7.656	6.151	7.390	5,250
	C-75	29.00	6.184	6.059	7.656	6.059	7.390	6,760
	C-75	32.00	6.094	5.969	7.656	5.969	7.390	8,230
	C-75	35.00	6.004	5.879	7.656	5.879	7.530	9,710
	C-75	38.00	5.920	5.795	7.656	5.795	7.530	10,680
	N-80	23.00	6.366	6.241	7.656	6.151	7.390	3,830
	N-80	26.00	6.276	6.151	7.656	6.151	7.390	5,410
	N-80	29.00	6.184	6.059	7.656	6.059	7.390	7,020
	N-80	32.00	6.094	5.969	7.656	5.969	7.390	8,600
	N-80	35.00	6.004	5.879	7.656	5.879	7.530	10,180
	N-80	38.00	5.920	5.795	7.656	5.795	7.530	11,390

Does Casing Float?

A 12,000-ft string of K-55 7" 20 lb/ft casing would weigh $20 * 12,000 = 240,000$ lbf

A 12,000-ft string of N-80 7" 38 lb/ft casing would weigh $38 * 12,000 = 456,000$ lbf



Float shoe. A float shoe is used to guide the casing or liner into the wellbore. The check-valve assembly within the float shoe prevents the flow of fluids into the casing during the running process or following the cementing operation.

(float shoe is present)

Buoyancy force = 348,000 lbf !!



Does Casing Float?

Quiz#4 Thursday Feb. 23?

If you are given the depth, casing OD and mud weight as in this example.

- Again, Calculate lbs/ft from dimensions
- What is the weight of the fluid displaced if the casing is run (submerged) to TD (total depth)?
- Can you estimate what the minimum lb/ft of the casing must be to make sure it does not float?
- What would be the corresponding ID of the casing of the casing with the lb/ft calculation from above?