Casing Design

The following topics will be discussed

- Functions of casing
- Casing types
- Casing specifications
- Casing design
- Bending effects
- Buoyancy effects
- Shock loads

Functions of casing

- To keep the hole open and to provide a support for weak, or fractured formations.
- To isolate porous media with different fluid/pressure regimes from contaminating the pay zone
- To provide a passage for hydrocarbon fluids; most production operations are carried
- To provide a suitable connection for the wellhead connection

Types of casing

1. **Stove pipe (Marine Conductor or foundation pile for offshore rigs)**
   - Run to prevent wash out of unconsolidated surface formation
   - Run to provide a circulation system for drilling fluids and to ensure the stability of the ground under the rig
   - Does not carry wellhead equipment
   - Can be driven into ground with a pile driver (26 in to 42 in per pile)

2. **Conductor pipe**
   - Run from surface to some shallow depth to protect near-surface unconsolidated formation
   - Provide a circulation for the drilling mud to protect foundation of the platform

- May be connecting of BOP or cut at surface or diverter connection
- Sizes from 18 5/8 in to 20 in

3. Surface casing (13 3/8 in.)
   - Run to prevent caving of week formation encountered at shallow depths
   - Should be set in competent rock like limestone: to ensure that the formation will not fractured at the casing shoe by high mud weight used later in the next hole
   - Protect against shallow blow-out, thus BOPs are connected to top

4. Intermediate casing (9 5/8 in.)
   - Usually set in the transition zone below or above pressured formation (salt and/or caving shale)
   - Need good cementing o prevent communication behind the casing between zones; multistage cementing may be used for long strings

5. Production casing (7 in.)
   - Isolate production zones
   - Provide reservoir fluid control
   - Permit selective production in multi zones production

6. Liner casing
   - A string of casing that does not reach to the surface
   - Hang on the intermediate casing, by use of suitable packer and slips called liner hanger

Types of liner

1. Production liner
   - Run instead of full production casing
   - Provide isolation across the producing or injecting zones

2. Tie-back liner
   - A section of casing extending upwards from top of an existing liner to the surface

3. Scab liner

- **A section of casing that does not reach the surface**
- **Used to repair existing damaged casing sealed from to and bottom by packers**

4. Scab-tie-back liner

- **A section of casing extending from the top of an existing liner but does not reach the surface.**

Strength properties

1. Yield strength

a. Pipe body yield strength

b. Coupling strength

- **API defined the yield strength as the tensile stress required to produce 0.5% of the gauge length**
- **Most common types of casing joints are threaded on both ends and fitted with a threaded coupling on one end only**
- **Joint strength may be lower or higher than the main casing, pipe body yield**
- **There are integral casing without coupling in which the threads are cut from internal-external upset**

2. Collapse strength

- **Defined as the maximum external pressure required collapsing specimen of casing**
- **Four types of collapse are observed:**
- **Elastic (fails before deforms)**

$$P_C = \frac{2E}{1-\mu^2} * \frac{1}{\frac{D}{t}\left[\frac{D}{t}-1\right]^2}$$

- **Plastic (certain deformation takes place)**

$$P_p = Y\left[\frac{A}{\frac{D}{t}} - B\right] - C$$

Y	**yield strength**
A,B,C	**constants depend on the grades and steel**
D/t	**diameter thickness ratio, should be calculated first and if fails in the range given in table then get A,B, &c and apply in equation**

- **Transition collapse (Elastoplastic collapse)**

A zone between elastic and plastic

$$P_t = Y\left[\frac{F}{\frac{D}{t}} - G\right]$$

$$F = \frac{46.95x10^6\left[\frac{3B/A}{2+B/A}\right]^3}{Y\left[\frac{3B/A}{2+B/A} - \frac{B}{A}\right] - \left[1 - \frac{3B/A}{2+B/A}\right]^2}$$

G = FB/A

3. Burst strength

a. Plain end

b. Coupling

- **It is defined as the maximum value of internal pressure required causing the steel to yield.**
- **It is calculated by Barlow's formula**

P = 0.875 (2Yt/D)

- **It gives the burst resistance for a minimum yield of 87.5% of pipe wall**
- **It allows 12.5% variation of wall thickness due to manufacturing defects.**

<u>Casing Specifications</u>

- **Casing is specified by: grade, weight per unit length, outside diameter and wall thickness, type of coupling, and length of joint.**
- **API defines three types of casing weight**
- **Nominal weight: normally based on the calculation, not exact, use for design and given in tables.**
- **Plain end weight: the weight of casing joint without inclusion of threads and couplings**
- **Threads and coupled weight**

<u>Types of Threads and Couplings</u>

- **In general, the casing and coupling are specified by the type threads cut in the pipe or coupling.**

  - **API round thread (LTC, STC)**
  - **Buttress thread**
  - **VAM thread**
  - **Extreme line threaded coupling**

<u>Casing Design</u>
<u>Design Criteria</u>

- **Tensile force**
- **Tensile forces in casings originate from its weight, and shock loading.**
- **In casing design the upper most joint of the casing string is considered the weakest point in tension, as it has carried the total weight of casing strings.**
- **Safety factor ST = 1.6-1.8**

<u>Collapse pressure</u>

- **Considered as the hydrostatic pressure applied on outer surface of casing**
- **Zero at top and maximum at bottom**

- **Collapse pressure Pc = $\rho_m gh$**
- **Pc never exceeds the collapse resistance of the casing**
- **In designing for collapse, the casing is assumed empty for surface and production and partially empty for intermediate casing**

Burst pressure

- **At the top of the hole the external pressure due to mud is zero and the internal pressure must be supported entirely by casing body.**
- **Burst is the highest at the top and least at the casing shoe. When production tubing at shoe can be higher than burst pressure at surface.**

Compression load

- **A compression load arises in casings that carry inner strings.**
- **Thus production casing do not develop any compression, since they do not carry inner strings.**

Other Loading

- **Bending with tongs during make up**
- **Corrosion and fatigue failure**
- **Pipe wear due to running wire line tools and drill string assembly**
- **Squeeze cementing, acidizing and hydraulic fracturing.**
- **Only tensile forces, collapse pressure, burst pressure, and compression load will be considered in casing design**
- **Other loading accounted by use of "safety factors"**

Combination String

- **The requirement for burst and tension criteria are different from the requirement for collapse and a compromise must be reached when designing for casing**

Biaxial Effects

- **The combination of stress due to the weight of the casing and external pressures are referred to a "biaxial stress"**
- **Biaxial stress reduces collapse resistance of the casing in plastic failure mode and must be accounted for designing for**

deep wells or combination strings, Pcc under tensile load is given by:

$$P_{CC} = \frac{1}{K}\sqrt{\left(K^2 - 3W^2\right)} - W$$

$$K = 2AS_O$$

Where $A = \pi t(D_0 - t)$

S_0 **= Average yield stress of steel**

- **A graphical solution of this equation in Figure 2.18; it can also be represented in a tabulated form in Table 10.8 showing the percentage reduction in collapse resistance for a given unit weight carried by the casing.**
- **After determining the reduction in collapse resistance for the top joint only, calculate the hydrostatic head due to the mud at joint and compare this with the net collapse resistance of the top joint.**
- **A minimum safety factor of 0.85 should be obtained, otherwise replace this joint by a heavier grade.**

Graphical Method for casing design

1. **A graph of pressure against depth is first constructed at zero depth zero pressure to max. collapse pressure.**
2. **Strength values of available grades in collapse and burst are then plotted as plotted lines.**
3. **Selection is made such that the casing chosen has strength properties, which are higher, the maximum collapse and burst pressure.**

Collapse line

$C = H - H_1$

H, external mud load, and H_1 **internal mud load usually 60 of filled casing.**

<u>**Burst line**</u>

1. **Calculate external load due to mud column of 0.465 psi/ft as salt water.**
2. **Internal load due to formation pressure (P_f for the next hole section)**
3. **Calculate burst as the difference.**

- **Example**

At casing shoe

Burst pressure = internal pressure – external pressure

External pressure = CSD x G_m

Internal pressure = (P_f - (TDC- CSD) G

- **Burst at surface**

External pressure = 0 -

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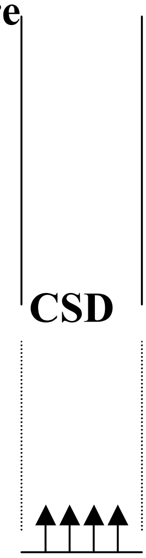

Internal pressure = P_f - TD x G P_f

- **Tensile forces**

a) **Calculate the weight of casing in air (positive)**

b) **Calculate the Buoyancy force (negative)**

c) **Calculate the bending force (positive)**

d) **Calculate the shock load due to arresting casing**