INTERMEDIATE CASING SELECTION FOR COLLAPSE, BURST AND AXIAL DESIGN FACTOR LOADS EXERCISE

Instructions

Use the example well data from this document or the powerpoint notes handout to complete the following graphs.

- Intermediate Casing – Collapse Loads
- Intermediate Casing – Burst Loads
- Intermediate Casing – Axial Loads

When complete, scan or photograph your work and upload it. Post questions to the discussion board.
The design of the intermediate casing is done exactly as the design of the surface casing except we use the design load curves we made for the 9 5/8 inch intermediate casing. We will assume the following design factors for the intermediate casing.

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Design Factors for this Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapse</td>
<td>1.125</td>
</tr>
<tr>
<td>Burst</td>
<td>1.125</td>
</tr>
<tr>
<td>Tension</td>
<td>1.6 or 100,000 lb</td>
</tr>
</tbody>
</table>

These are the same factors we used for the surface casing, but we emphasize again that it is not necessary or even advisable in some cases to use the same design factors for all casing strings in a well.

It is not material as to whether we select to address the collapse or burst first. With some experience we can often determine that by starting with a particular load curve we can minimize the number of adjustments necessary to satisfy the next one. Looking at the load plots we can often tell which one will be the more critical and possibly save time by starting there. In this case we will start with the burst.

We will assume that we have the following 9 5/8 inch casing available in our inventory for use in this well.

Table 6-2 Intermediate Casing Inventory

<table>
<thead>
<tr>
<th>Wt lb</th>
<th>Grade</th>
<th>Connection</th>
<th>ID In.</th>
<th>Collapse Pressure psi</th>
<th>Internal Yield psi</th>
<th>Joint Strength 1000 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>K-55</td>
<td>ST&amp;C</td>
<td>8.921</td>
<td>2020</td>
<td>3520</td>
<td>423</td>
</tr>
<tr>
<td>40</td>
<td>K-55</td>
<td>ST&amp;C</td>
<td>8.835</td>
<td>2570</td>
<td>3950</td>
<td>486</td>
</tr>
<tr>
<td>40</td>
<td>K-55</td>
<td>LT&amp;C</td>
<td>8.835</td>
<td>2570</td>
<td>3950</td>
<td>561</td>
</tr>
<tr>
<td>40</td>
<td>N-80</td>
<td>LT&amp;C</td>
<td>8.835</td>
<td>3090</td>
<td>5750</td>
<td>737</td>
</tr>
<tr>
<td>43.5</td>
<td>N-80</td>
<td>LT&amp;C</td>
<td>8.755</td>
<td>3810</td>
<td>6330</td>
<td>825</td>
</tr>
<tr>
<td>47</td>
<td>N-80</td>
<td>LT&amp;C</td>
<td>8.681</td>
<td>4750</td>
<td>6870</td>
<td>905</td>
</tr>
<tr>
<td>53.5</td>
<td>N-80</td>
<td>LT&amp;C</td>
<td>8.535*</td>
<td>6620</td>
<td>7930</td>
<td>1062</td>
</tr>
<tr>
<td>58.4</td>
<td>N-80</td>
<td>LT&amp;C</td>
<td>8.435*</td>
<td>7890</td>
<td>8650</td>
<td>1167</td>
</tr>
<tr>
<td>43.5</td>
<td>P-110</td>
<td>LT&amp;C</td>
<td>8.755</td>
<td>4420</td>
<td>8700</td>
<td>1105</td>
</tr>
<tr>
<td>47</td>
<td>P-110</td>
<td>LT&amp;C</td>
<td>8.681</td>
<td>5300</td>
<td>9440</td>
<td>1213</td>
</tr>
<tr>
<td>53.5</td>
<td>P-110</td>
<td>LT&amp;C</td>
<td>8.535*</td>
<td>7950</td>
<td>10900</td>
<td>1422</td>
</tr>
</tbody>
</table>

*Note that since we elected to drill an 8 ½ inch hole from the bottom of the intermediate casing to total depth we may have a problem with some of the casing in this inventory. The 53.5 lb/ft casing will have to be specifically drifted for an 8 ½ inch bit. The 58.4 lb/ft casing cannot be used unless we use a smaller bit.

A precursory examination of the available pipe and the loads we can see most of the pipe will sustain the maximum collapse load at the bottom of 2071 psi. (If we rounded to the nearest 10 psi as API does, all of the 40 lb/ft pipe and heavier would satisfy the design.) Almost immediately we will find that the collapse loading is very small and the weakest pipe in our inventory will easily sustain the maximum collapse load. We also note that the burst load is relatively high and that the first three items in our inventory will not sustain the burst load at the bottom of the string where the burst load is the lowest. It looks like the best place to start on this design is with the burst design curve.
In looking at the burst loads we immediately see that the plug bump loading is not critical, so we discard it and look at the drilling kick loads. If we are drilling in an oil environment that does not produce gas then we would select the oil line as the critical load. But we have stated for our example that it is a potential gas environment so we will consider the two gas loads. The “maximum load” method with a 5000 psi BOP at the surface is used commonly as already mentioned. Many consider it a safety hazard, and we will too. So we will use the gas load line with a 1.125 design factor.
This selection requires five different weights of 9 5/8 in. casing. You will also note that the 53.5 lb/ft pipe must be special drifted for an 8 ½ in. bit, but the 500 ft top section will not allow an 8 ½ in. bit at all. This selection is not acceptable because of the internal diameter restrictions. An easy alternative would be to replace the top two sections with 43.5 lb/ft P110 grade pipe as in the next figure.
Some would object to this design as having too many sections thus increasing the chances of a mistake in the running process. A simpler alternative consisting of P110 and N80 is shown in the next figure. All the pipe in that selection has the same wall thickness.
Both of these last two would work, and most would favor the last. To keep things simple we will select the last one above.

Next we look at the collapse load curves and decide which are the most critical – burst or collapse.
We have four collapse loading scenarios in this plot. The most severe is the case where the casing is completely empty. According to our formation pressure charts this is not a possibility with lost circulation unless some formation has been depleted by other wells. We will assume that is not the case, so the only other way that could happen would be the case of a gas blowout to the surface in which the open hole below the intermediate casing bridges and the gas pressure bleeds to atmospheric pressure at the surface. While this sort of thing has happened it is rare, and it is questionable as to whether we would want to consider it in a design. Perhaps in a populated area or environmentally sensitive area it might be critical, but for this example we are going to consider this possibility too remote to include in the design. So what should we select as the basis for our design? The only load on the chart that we are certain to encounter is the cementing load. The lost circulation curve based on the lowest formation pressure below the shoe with drilling mud is also a distinct possibility. Many designs would likely use the fresh water curve. But there is no real basis here for doing so, even though in this case it is a greater load than the cementing load. So, all that said, let us consider that we have highly reliable data and we will base our design on the cementing and known lost circulation load. The design line has been added to the chart using the collapse design factor of 1.125 and we have plotted the collapse rating of the preliminary burst selection we just made.

Figure 6-15 Intermediate casing collapse loads
The burst design also meets our collapse requirements. We have completed our preliminary selection for burst and collapse. Next, we address the axial loading.

**Intermediate Casing – Axial Load Design**

Now we look at the axial load. The casing is run in 11.8 ppg mud, and normally we use the true axial load of the casing just as we did for the surface casing. Some might use the un-buoyed weight, but we will continue to use the true buoyed load. The manual calculations for this string are simple since there is a single wall thickness.

**ALL CASES**

- Calculate the cross sectional areas

  \[ A_0 = \left(\frac{\pi}{4}\right) \left(9.625\right)^2 = 72.760 \text{ in}^2 \]

  \[ A_1 = \left(\frac{\pi}{4}\right) \left(8.755\right)^2 = 60.201 \text{ in}^2 \]
Calculate the un-buoyed weight of the string
\[ W_i = w_1 L_1 = 43.5(10500) = 456,750 \text{ lbf} \]

**RUNNING CASE**

- Calculate the external and internal pressures at the bottom
  \[ \hat{p}_0 = 0.052(11.8)(10500) = 6443 \text{ psi} \]
  \[ p_0 = \hat{p}_0 = 6443 \text{ psi} \]

- Calculate the section forces
  \[ F_1^\downarrow = -\hat{p}_0 \hat{A}_0 + p_0 A_1 = 6443(60.201 - 72.760) = -80,918 \text{ lb} \]
  \[ F_1^\uparrow = F_1^\downarrow + W_1 = -80918 + 456750 = 375,832 \text{ lb} \]

**PLUG BUMP CASE**

- Calculate the external and internal pressures
  \[ \hat{p}_0 = 0.052[(15.9)(1000) + (12.0)(9500)] = 6755 \text{ psi} \]
  \[ p_0 = 6755 + 1000 = 7,755 \text{ psi} \]

- Calculate the section forces
  \[ F_1^\downarrow = -\hat{p}_0 \hat{A}_0 + p_0 A_1 = -6755(72.760) + 7755(60.201) \]
  \[ = -24,635 \text{ lb} \]
  \[ F_1^\uparrow = F_1^\downarrow + W_1 = -24635 + 456750 \]
  \[ = 432,115 \text{ lb} \]

**POST PLUG BUMP CASE**

- Calculate the external and internal pressures
  \[ \hat{p}_0 = 0.052[(15.9)(1000) + (12.0)(9500)] = 6755 \text{ psi} \]
  \[ p_0 = 0.052(11.8)(10500) = 6,443 \text{ psi} \]
• Calculate the section forces

\[ F_1^\downarrow = -\hat{p}_0 \hat{A}_0 + p_0 A_1 = -6755(72.760) + 6443(60.201) \]
\[ = -103,619 \text{ lb} \]

\[ F_1^\uparrow = F_1^\downarrow + W_1 = -103619 + 456750 \]
\[ = 353,131 \text{ lb} \]

Had we done this with your spread sheet it would look like this.

![Spreadsheet axial load calculations](image)

**Figure 6-17** Spreadsheet axial load calculations (blue cells are input and yellow cells are output).

The figure above shows part of the spreadsheet. The blue cells are input data, and the yellow cells are output. We plot the three axial loads from the spreadsheet for the axial loads. We have also selected which of the four possible loads on which to base our axial design, un-buoyed, running, plug bump, post plug bump. In this case the post plug bump load was the critical load, so we selected 3 in the blue box to the right. Initially it does not make any difference which is selected, but after looking at the four possibilities we can select the critical load and then make the selection. The specified design and over pull are then applied to that load in the right two columns.
The plot below shows us that the plug bump is the greatest axial load so we will use it as the load line in our design.
The design now satisfies burst, collapse, and axial load and design factors.

![Casing Design Summary](image)

**Figure 6-20** Intermediate casing summary