Plugs are set for many reasons – but mostly for isolation of pressures.

Not all plugs are a permanent seal. Sand plugs, cement plugs and inflatables have special requirements.
A typical plug showing seals, equalization ports and locking keys
Non-Selective Nipples

A single non selective nipple is usually all that is run in a well and it is usually at the bottom.

- Lock recess
- Seal bore
- No-go
Selective Nipples

- Lock recess
- Seal area
- Landing recess

Essentially full opening (about 0.1” less ID than pipe)

Allows running multiple profiles, each with same ID. Set is determined by running tool.
S Profile with plug installed. Showing locking section.
S profile, seal assembly in the polish bore section
Model "F" Seating Nipple
(Product No. 801-50 Alloy Steel)
(Product No. 801-51 Stainless Steel)
(Product No. 801-52 9 CR-1 MO)

[Uses Dog-Type or Collet-Type Locks]

[Uses Collet-Type Locks Only]

NO-GO BASE

NO-GO BASE

SEAL BORE

Sizes: 1.18-3.81 (except 3.12 and 3.31)

Sizes: 3.12, 3.31 and 4.00-5.95

*This also applies to all sizes of the Model "B" Safety Valve Nipple.

Courtesy of Baker
XN (left) and X profile (right). X profiles allow several to be run in series in the string (same size plug passes through each). Only one XN can be run (on the bottom).
Model "J" Ported Seating Nipple
(Product No. 800-20)

NO-GO BASE

SEAL BORE

Courtesy of Baker
Model “JSR-20” By-Pass Blanking Plug
Product No. 806-23
For use in Model “J” Seating Nipple

FEATURES/BENEFITS:
1. It straddles and packs off above and below the ports in the seating nipple allowing production or circulation through these ports while blanking off the tubing area below the nipple.
2. Can be held open to by-pass fluid while running and pulling.
3. Pressure can be equalized across the blanking plug by shifting the by-pass valve open or by breaking the secondary equalizing plug.

BY-PASS BLANKING PLUG

Model “JWR-20” (Product No. 806-26)
Same as Model “JSR-20” above except for the locks used.

APPLICATIONS:
- For zone isolation in a selective completion.
- To circulate or produce through the ported nipple.
- To kill the well by pumping kill fluid through the ported nipple.

A ported profile and plug.

For additional information, refer to Tab 480.30 of the Baker Packers Technical Manual.
Other Profiles

• Flow Couplings —
  – heavy wall tube, 1 to 6 ft long (0.3 to 2m), made of high allow steel.
  – same ID as tubing but similar OD to coupling
  – protection from internal erosion and corrosion
  – Used where excessive turbulence is expected
    • above and below some profiles
    • above crossovers
    • above bottom hole chokes
Other Profiles

• Blast Joints –
  – Similar to flow couplings but designed to resist exterior erosion and abrasion
  – 3 to 20+ ft long (1 to 6+m)
  – Used opposite perforations
  – Used opposite annular proppant entry point
  – Used in straddled intervals in dual completions
Other Equipment

• Downhole Chokes
  – a set diameter restriction in the tubing that takes some pressure drop downhole.
    • Used for up-hole hydrate prevention by taking some expansion of gas (cooling) in the downhole area where insitu temperatures are higher.
    • Used for production or injection limiting.
    • Stabilize bottom hole pressures
Model "FSC-20" Choke (with Steel Bean)
Product No. 807-03
For use in Model "F" Seating Nipple

FEATURES/BENEFITS:
1. They restrict fluid flow in the tubing string.
2. A wide range of orifice sizes are available for these chokes.
3. They can be used in non-ported seating nipples, upper bores of ported seating nipples, and sliding sleeves.

CHOKES

Model "FWC-20" with Steel Bean
(Product No. 807-07)

Model "FGC" with Steel Bean
(Product No. 807-72)

Model "FMC" with Steel Bean
(Product No. 807-76)

Same as Model "FSC-20" above except for the locks used.

APPLICATIONS:
- To reduce gas-oil ratios under certain conditions.
- To prevent freezing of surface controls by moving the point of pressure reduction to the lower portion of the wellbore.
- Prolong the flowing life of a well by maintaining bottom hole pressure.
- Lessening water encroachment under certain conditions by stabilizing bottom hole conditions.
- To reduce production when desirable.
Sliding Sleeves

open

closed
Other Equipment

• Downhole Regulators
  – a variable diameter restriction in the tubing that takes some pressure drop downhole according to the rate of flow.
    • Used for up-hole hydrate prevention by taking some expansion of gas (cooling) in the downhole area where insitu temperatures are higher.
    • Used for production or injection limiting.
    • Stabilize bottom hole pressures at variable rates
Model "FSR-20" By-Pass Blanking Plug
Product No. 806-06
For use in Model "F" Seating Nipple

FEATURES/BENEFITS:
1. Holds pressure from either direction.
2. Can be held open to by-pass fluid while running and pulling.
3. Pressures can be equalized across the blanking plug by shifting the by-pass valve open or by breaking the secondary equalizing plug.

BY-PASS BLANKING PLUG

Model "FWR-20" (Product No. 806-09)
Same as Model "FSR-20" above except for the locks used.

APPLICATIONS:
- To shut in the well for:
  1. Surface equipment repairs.
  2. Moving rig on or off location.
- To test tubing by pressuring up or by bleeding down.
- To set a hydraulically actuated packer by pressuring up.
- To circulate above to displace well fluids and protect the lower formation from excessive pressure.
- For zone separations in selective completions (installed in a landing nipple below a sliding sleeve).

Courtesy of Baker

For additional information, refer to Tab 480.30 of the Baker Packers Technical Manual.
Side pocket Mandrel for gas lift or chemical injection

- Latch recess
- "Pocket"
- Port to annulus
- Access to tubular Flow Path

Indexing Groove
Seal Swelling Problems

• Gas permeation
• Solvent swelling of seals
Swollen seals on a plug retrieved from 10,000 ft

Left – one minute after pulling from the well, Right – after sixty minutes

Seal swell happens mostly on the trip up the hole as pressure is released and gas tries to leak out of the seal. It is not usually a cause of sticking.
Avoiding Profile Debris Problems

• Cementing - protect the nipple profile with a sleeve similar to an insert sleeve used in a downhole safety valve
When Sand Fill is Present

• “There was some sand present in the well, which gave us difficulties to run in hole at 63 deg dev. The problem was overcome by flowing the well slightly while running in, thus creating turbulences around the tool to flush away "sand dunes" building up in front of the tool.” – Charlie Michel, BP

North Sea operations comments – However, watch the potential for sticking with the sand washed above the tool.
The extension on the bottom of the plug (left side of picture) allows debris to fall through and away from the internal fishing neck.
Equalizing Prong with marks to differential contact on steel or sand.
Specialty plugs are available that will set in almost any type of tubular, regardless of the presence or absence of a profile, but a seal always depends on the integrity of the tubing in which the plug is set.
Slickplug - The Retrievable Bridge Plug

Available from 2 3/8” to 7” nominal sizes

Pressure ratings in excess of 5,000 psi working

Temperature ratings up to 350°F

Barrier for Tree change - outs

Contingency tubing plugging

Zonal isolation tool

Location of flow control devices
Retrievable Bridge Plugs

**Features:**

- Run and retrieved under pressure
- Straight pull to release
- Can be retrieved on coiled tubing
- Pressure differential is equalized with washover retrieving tool
- Electric wireline setting with industry standard setting tools

**Used for isolating zones during fracturing, acidizing or cementing operations or during wellhead removal**
Laying Sand Plugs

• Shut-in well for several hours to prevent crossflow disruption of plug.
• Don’t bury the BHA with dumped sand
• Tag frequently to avoid over-fill
• Use a gell spacer in front of sand to prevent sand roping or falling down the hole. Rapid sand fall out can cause bridge off inside the CT.
### Sand fall rates in various fluids

<table>
<thead>
<tr>
<th>Fluid</th>
<th>10/20 mesh sand</th>
<th>20/40 mesh sand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft/min</td>
<td>m/min</td>
</tr>
<tr>
<td>WF220</td>
<td>7.5</td>
<td>2.3</td>
</tr>
<tr>
<td>WF240</td>
<td>2.05</td>
<td>0.62</td>
</tr>
<tr>
<td>WF260</td>
<td>0.49</td>
<td>0.15</td>
</tr>
<tr>
<td>Diesel</td>
<td>21.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Water</td>
<td>21.9</td>
<td>6.7</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Fluid</th>
<th>10/20 mesh Bauxite</th>
<th>20/40 mesh Bauxite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft/min</td>
<td>m/min</td>
</tr>
<tr>
<td>WF220</td>
<td>14.4</td>
<td>4.4</td>
</tr>
<tr>
<td>WF240</td>
<td>4.1</td>
<td>1.2</td>
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<tr>
<td>WF260</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Diesel</td>
<td>33.7</td>
<td>10.3</td>
</tr>
<tr>
<td>Water</td>
<td>33.7</td>
<td>10.3</td>
</tr>
</tbody>
</table>
Setting a cement plug

• Position
• Setting in mud
• Effect of fluid loss and cross flow
Setting Cement Plugs

• A near 100% reliable system if cross flow can be stopped.

• Most cement plugs fail because of cross flow, density and viscosity mismatch, or failure to “break” the fluid momentum.

• Full plug method described and field tested in SPE 11415 (published in SPE JPT Nov 1984, pp 1897-1904) and SPE 7589.
Cement Plug Failure

Many cement plugs fail for the same 4 reasons:

1. Cross flow cuts channels into the plug.
2. Cement is higher density than the mud.
3. The mud is much lower viscosity than the cement slurry.
4. The open ended tubing produces a high momentum energy condition that the mud cannot stop.

The result of the last three is that the cement is spread out along the hole and a plug is never formed.
How?

1. Use a simple tubing end plug with circulation to the side and upward but not downward.

2. Spot a heavily gelled bentonite pill below the cement plug depth. Pill thickness of 500-800 ft (152-244 m).

3. Use a custom spacer to separate the pill and the cement slurry.

4. Use a viscous, thixotropic cement with setting time equal to the job time plus \( \frac{1}{2} \) hr. Plug thickness of 300 to 600 ft (91 to 183 m).

5. Rotate the centralized tubing (do not reciprocate) during placement and gently withdraw at the end of the pumping.

6. WOC = 4 hrs for every 1 hour of pump time.

Full details and field tests in SPE 11415.
Diverter Plug on End of Tubing

A simplified diverter tool can be made by plugging the end of tubing and drilling 8 holes – the bottom four straight out and the top four angled up at 45°.

Holes are 0.75 to 1” (2 to 2.5 cm) diameter.
1. Modify the tubing to bull plug the bottom and open a side port
2. Pump a 20 bbl pill of heavily gelled bentonite, same density as the mud in the hole
3. Spot the cement slurry on top of the pill while slowly withdrawing the tubing.
## Composite Plug Data – Drillable

<table>
<thead>
<tr>
<th>Plug Mkr</th>
<th>Plug Type</th>
<th>Plug Size</th>
<th>Csg wt range lb/ft</th>
<th>Max Csg ID</th>
<th>Min Csg ID</th>
<th>Length</th>
<th>Max Rec Temp</th>
<th>Max Pressure from above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halliburton</td>
<td>Std</td>
<td>4-1/2&quot;</td>
<td>9.5-13.5</td>
<td>4.09&quot; 103.9 mm</td>
<td>3.92&quot; 99.6 mm</td>
<td>28.62&quot; 726.9 mm</td>
<td>50-250F 10-121C</td>
<td>5,000 psi 34,474 kpa</td>
</tr>
<tr>
<td>Halliburton</td>
<td>Std</td>
<td>5-1/2&quot;</td>
<td>15.5 - 23.0</td>
<td>4.95&quot; 123.7 mm</td>
<td>4.67&quot; 118.6 mm</td>
<td>29.09&quot; 713.9 mm</td>
<td>50-250F 10-121C</td>
<td>5,000 psi 34,474 kpa</td>
</tr>
<tr>
<td>Halliburton</td>
<td>HTHP</td>
<td>4-1/2&quot;</td>
<td>9.5-13.5</td>
<td>4.09&quot; 103.9 mm</td>
<td>3.92&quot; 99.6 mm</td>
<td>27.92&quot; 709.2 mm</td>
<td>50-350F 10-177C</td>
<td>10,000 psi 68,947 kpa</td>
</tr>
<tr>
<td>Halliburton</td>
<td>HTHP</td>
<td>5-1/2&quot;</td>
<td>15.5 - 23.0</td>
<td>4.95&quot; 123.7 mm</td>
<td>4.67&quot; 118.6 mm</td>
<td>29.87&quot; 758.7 mm</td>
<td>50-350F 10-177C</td>
<td>10,000 psi 68,947 kpa</td>
</tr>
</tbody>
</table>

Note the temperature limits. These have proved optimistic in a few HT wells. Milling time to remove these plugs with CT milling tools will be about 1 hour or less with the right mills, equipment and operator.
Example of the force generated by pulling a plug without equalizing pressures below and above the plug

5-1/2” Csg
4.95” ID

Effective area of plug = $\pi \frac{\text{id}^2}{4} = 19.24 \text{ in}^2$

Do a net force balance:

upward: 2500 psi x 19.24 = 48,100 lb

downward: 500 psi x 19.24 = 9,620 lb

Net force (upward) = 38,480 lb

Now, what happens if plug anchors are released before pressure is equalized? With wireline as pulling tool?
Theoretical loads (in lbs) resulting from pressure differentials in various sizes of plugs.

<table>
<thead>
<tr>
<th>Pressure Differential (psi)</th>
<th>3-1/2&quot; tube</th>
<th>4-1/2&quot; tube</th>
<th>5-1/2&quot; tube</th>
<th>7&quot; tube</th>
<th>8-5/8&quot; tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>703</td>
<td>1253</td>
<td>1923</td>
<td>3737</td>
<td>4961</td>
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<tr>
<td>500</td>
<td>3514</td>
<td>6264</td>
<td>9617</td>
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<tr>
<td>1000</td>
<td>7027</td>
<td>12529</td>
<td>19234</td>
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<td>62643</td>
<td>96172</td>
<td>186869</td>
<td>248070</td>
</tr>
</tbody>
</table>

The common element on all plugs that must be pulled is that there must be a reliable way to release the pressure below the plug before releasing the locking mechanism on the plug.
Swab/Surge Forces

• “Plunger force” - tremendous force exerted event in small movements because of large area affected.

• Close clearances and high tool movement speeds increase the swab/surge force

• Circulation while pulling lessens swab/surge loads
Quiz – Plugs and Profiles

• What is one of the most common well problems that affects both setting and retrieving a plug?
• What seal material is acceptable for aromatics such as xylene?
• What problem does long term exposure to gas cause in pulling a plug?
• What type of device is recommended for hanging a short tailpipe from a profile with a No-Go shoulder?