Plug and Abandonment – Producing Well. Slides for very basic education only!

- Different from drilling P&A operations.
- Specific regulations set by governing bodies.
- This presentation covers the “intent” of P&A:
  - Isolate and protect all fresh and near fresh water zones;
  - Isolate and protect all “commercial” producing horizons for future development;
  - Prevent leaks from or into the well;
  - Remove surface equipment and cut and plug pipe below ground level or fishing net level or, depending on requirements, mark the surface location so identification can be made at any time after abandonment.
- P&A responsibility does not usually end with the P&A activities and not even with sale of the property . If it leaks, you will likely be held responsible for damage and to repair and remediate the well and the site.
- **Do it right the first time.**

Abandonment Types: TA and P&A

- TA – temporarily abandoned:
  - During a long shut-down.
  - Waiting on a workover.
  - Waiting on field development or redevelopment.
  - Opinion – do not delay abandonments that need to be done. In many cases, delays have increased P&A cost by 1 to 2+ orders of magnitude.

⇒**Set plugs to prevent cross flow and production. Isolate all flow and protect from pressures. Test and monitor the well and keep good records.**

Abandonment Types

- P&A – plugged and abandoned:
  - End of current economic operations.
  - Well problem that cannot be economically repaired.
  - Moving the bottom hole location – P&A the bottom and reuse the top part of the well.

  ⇒**Set cement and mechanical plugs to prevent cross flow and production. Isolate all flow and protect from pressures. Follow governing body regulations.**

  ⇒**Opinion – exceed the regulations and make sure it doesn't leak. Regulations change and companies might be held liable for further repairs even if the well was properly P&A'd under existing laws of the time.**

P&A Costs

- On Shore: nothing to low expense.
  - Well equipment recovered often offsets cost of P&A.
- Off-Shore: $100k to millions.
  - Depends on whether isolated wells or whole campaign to decommission a platform.
  - Depends on depth, pressure and potential to endanger fishing, shipping, coast line, etc.
  - Significantly increased by platform damage from storms, ship impact or corrosion.

Well damage increases the P&A cost sharply – 100k to 10's of millions

Pipe damage may necessitate pulling operations not in the original plans. Cement plugs generally need to be circulated into place – a functional tubing string is required.

Special Conditions and considerations:

1. Collapsed or burst pipe – repairs are difficult because the tubing has to be fished, often in pieces. Burst sections have to be sealed and isolated. Setting effective cement plugs is critical.

2. Channels and fractures in annulus cement or shoe areas. Setting long cement plugs requires effective sealing of fractures.

Legislative Drivers

- Safe Water Drinking Acts
- Numbers of abandoned wells – both hydrocarbon and water (>3mm in US since 1859) and reliability of the abandonment seals.
- Changing government regulations on fresh and near fresh waters.
- Protection of resources for the future (fields are often abandoned with 60 to 80% of oil and 10 to 20% of the gas still in place) – waiting on technology development – often for decades.

Main targets that must be sealed

- Isolation:
  - open hole,
  - separate pay zones,
  - perforations,
  - liner tops and channels in cement,
  - surface locations (3’ or 1m on land to 10 to 15’ or 3 to 5m, below ML offshore)
  - damaged sections (wear points, milling, perfs, etc.),
  - multi-laterals,
  - corrosive zones (highly corrosive salt water?) ,
  - special cases (clearing sea floor, rigs to reefs, geothermal, etc.).

Requirements

- Plug thickness (height).
- Tag to validate plug position.
- Pressure tests to validate seal.
- Well Identification(?).
- Marking of lost radioactive source tools.

Threats From Improperly Abandoned Wells

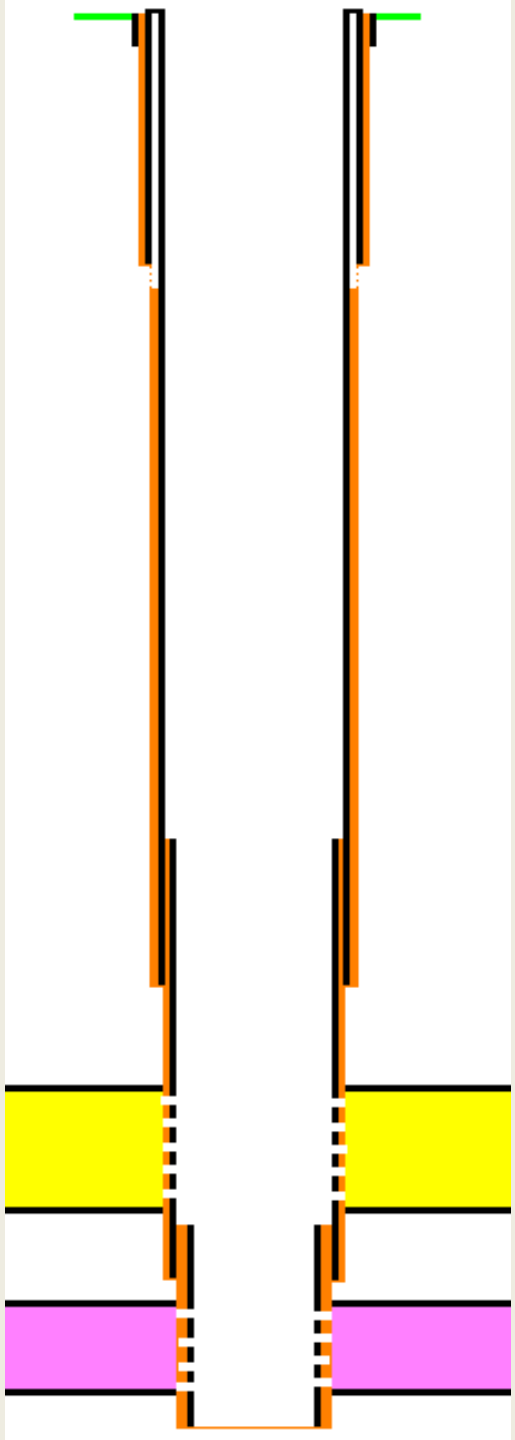
- Contaminated surface water entry (minerals, bacteria, waste, etc.).
- Surface leakage from shallow zones through well or leaking cement sheath.
- Leakage form an aquifer to surface.
- Leakage from surface to an aquifer.
- Danger of open well to surface egress (falling down the well).

Materials Used in Abandonment

- Cement slurries.
- Gelled pills (bentonite and others).
- Spacers to protect cement slurries.
- Mechanical plugs (incl. cement retainers).
- Inflatable plugs.
- Sand plugs (as base for cement).

P & A Concerns

- Knowledge of the well – where are plugs needed?
  - Perforations
  - Wear areas in the casing
  - Multilateral junctions
  - Overlap seal stability
  - Channels and fractures in cement sheath
  - Fracturing far out of zone (probably rare?)
  - Etc.
- Placement accuracy and seal reliability of plugs.
- Reliability of the cement sheath.
- Reliability of the overall P&A system.



Cement Plugs

- Cement slurry design.
  - Cement type and additives.
    - API class
    - Extenders, shrinkage, gas control, fluid loss control, formation and pipe adherence, spacers.
    - Volumes and excesses.
- Placement method.
  - Location identification,
  - Depth control,
  - Spotting method (bailer, circulation, etc.),
  - Contamination control,
  - Testing requirements.

Cement Plug Placement

- Balanced method.
- Modified balanced method.
- Displacement from surface.
- Two plug circulation.
- Grouting – various.
- Mechanical assistance.

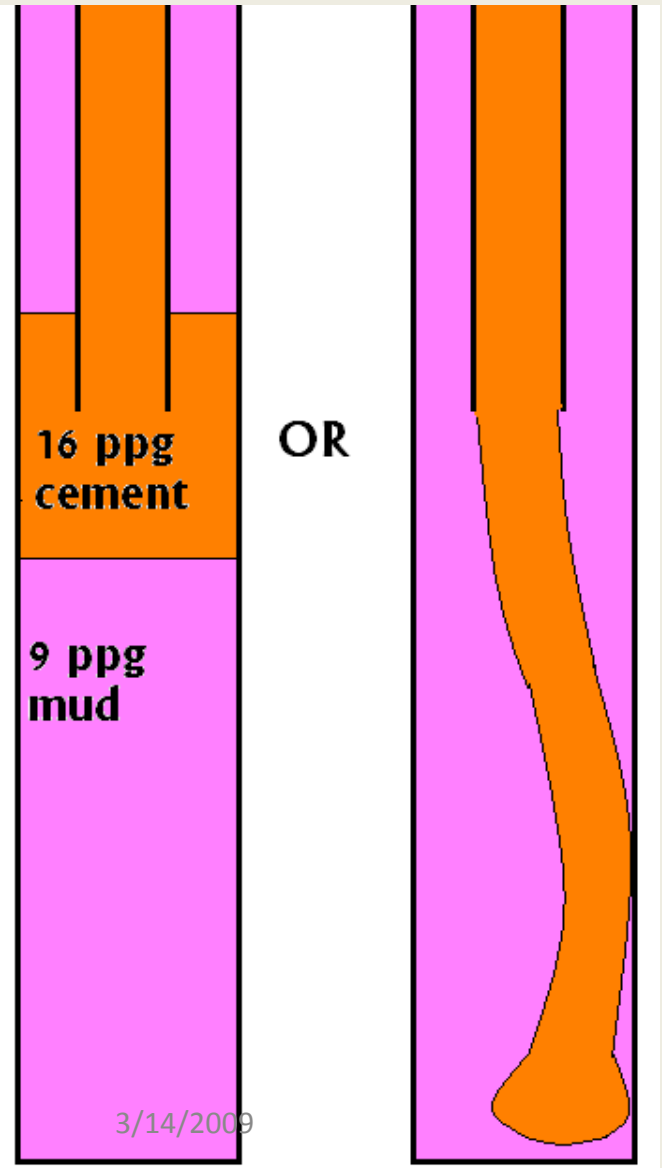
Setting a cement plug

- Not as easy as it may seem
- Position of the end of tubing (EOT) may not correspond to where the plug is actually set.
- What are the considerations of setting a cement plug in mud?
- Effect of fluid loss and cross flow on setting an effective cement plug?

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

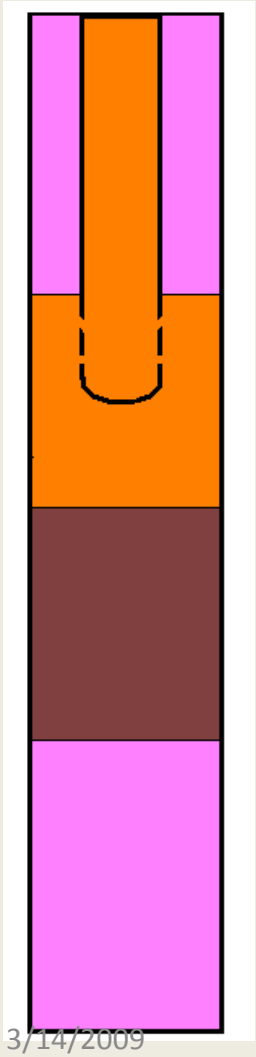


Many cement <u>plugs fail for the same 4 reasons:</u>

1. **Cross flow cuts channels into the plug.**
2. **Cement is higher density that the mud – cement falls through the mud. Mud contamination of the cement may keep it from setting.**
3. **The mud is much lower viscosity than the cement slurry – cement falls through the mud**
4. **The open ended tubing produces a high momentum energy condition that the mud cannot stop – thus cement falls through the mud.**

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

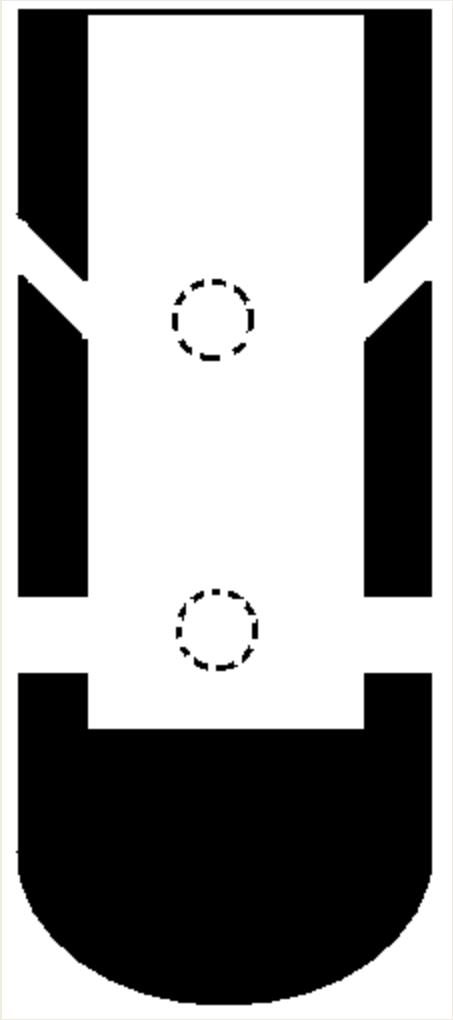
How?



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 ½ 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.

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 gel 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 plugs are often used as a base for more stable plugs.

Sand fall rates in various fluids

	10/20 mesh sand		20/40 mesh sand	
Fluid	ft/min	m/min	ft/min	m/min
WF220	7.5	2.3	2.2	0.67
WF240	2.05	0.62	0.49	0.15
WF260	0.49	0.15	0.11	0.03
Diesel	21.9	6.7	10.2	3.1
Water	21.9	6.7	12.6	3.8

	10/20 mesh Bauxite		20/40 mesh Bauxite	
Fluid	ft/min	m/min	ft/min	m/min
WF220	14.4	4.4	4.1	1.2
WF240	4.1	1.2	1	0.3
WF260	1	0.3	0.24	0.07
Diesel	33.7	10.3	16.9	5.2
Water	33.7	10.3	20	6.1

Source – D/S Field Book

Reasons for Cement Plug Failures

- Contamination of the cement slurry with drilling mud during or immediately after placement.
- Failure to place a viscous pill to stop downward movement of cement slurry.
- Inaccurate knowledge of volumes required.

General Requirements

- Onshore – 10 ft (3 m) plug on top of the well and casing cut 3 ft (1m) below the ground surface.
- Mud between plugs (9.5 lb/gal).
- Plug thickness minimum of 100 ft, plus 10% for each 1000 ft of zone.

Procedures

- Remove salvageable equipment.
  - NORM scale present? Leave the pipe in the well?
  - What pipe is needed for a barrier? How effective?
- Set, at minimum, plugs required by regulations. Don’t hesitate to go beyond requirements.
- Test to limits required.
- Cap and identify as specified.

Isolation of Open Hole

- Cement Plug 100ft (30m) above and below lower-most shoe in open hole.
- Cement retainer 50 to 100 ft (15 to 30m) above the shoe. Cement 100 ft (30m) below shoe and 50 ft (15m) of cement on top.
- Tested to 15,000 lbs load or 1000 psi.

Isolation of Perforations

- Cement Plug 100ft (30m) above and below perfs (or to next plug).
- Cement retainer 50 to 100 ft (15 to 30m) above the perfs. Cement 100 ft (30m) below shoe and 50 ft (15m) of cement on top.
- Permanent bridge plug within 150 ft (45m) of perfs with 50 ft (15m) of cement on top.

Isolation of lap joints or liner tops.

- Cement Plug 100ft (30m) above and below liner top (or to next plug).
- Cement retainer or permanent bridge plug 50 ft (15m) above the liner with 50 ft (15m) of cement on top.
- Cement plug 200 ft (60m) long within 100 ft (30m) of liner.

Finding and Repairing Channels in Cement

- Channels in cement occur from many causes:
  - Lack of effective pipe centralization,
  - Inadequate mud conditioning prior to cementing,
  - Ineffective cement displacement design and/or execution,
  - Excess free water in the cement, especially in a deviated hole (usually a cement mixing problem).
  - Excessive fluid loss from the cement slurry (generally results in low cement top),
  - Gas influx before the cement sets,
  - Cement shrinkage,
  - Etc.

Identifying Channels in Cement Sheath

- Numerous logging methods:
  - CBL and segmented CBL tools that scan around the wellbore,
  - Borax logging, Carbon-Oxygen logs, Sonic tools, etc.
- Plug and packers with perforating.

Repair of Channels - Cement Squeezes

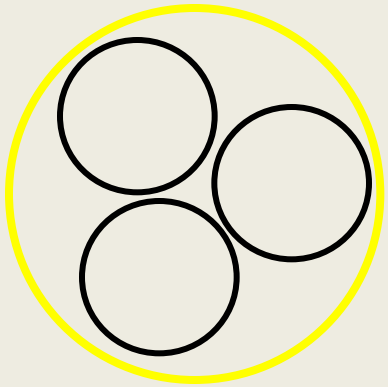
- Types (some names anyway)
  - Block squeeze
  - Cement Packer
  - Suicide squeeze
  - Breakdown squeeze
  - Running and Walking squeezes
  - Hesitation squeeze
- What is used depends on both what is needed and the experience of the operator.

Abandonment Gun Systems for Large Casing

- Can be designed to shoot through one very large diameter casing string without hitting the outer casing string.
  - 11.875”
  - 13.375”
  - 16”

- Key design factor: Inexpensive way to put charges near casing wall – does not require single body very large guns that are difficult to find and difficult to handle.

A grouped set of perforating guns within a large casing.



From Phil Snider

Surface Plug

- On-Shore – depends on local regulations.
- Offshore – cement plug 150 ft (45m) long within 150 ft (45m) of mud line. Placed in the smallest string of casing that extends to the mud line.

Testing of Plugs

- Location of the first plug below the surface plug shall be verified.
  - Pipe weight of 15,000 lbs on cement plug, cement retainer, or bridge plug.
  - Pump pressure of 1,000 psi with maximum 10% drop in 15 minutes.

Fluid Left in the Hole

- Fluid fill between plugs must exert a fluid density at least higher than the greatest formation pressure in the intervals between the plugs at the time of abandonment.

Disclaimer

- These slides are very basic slides for educational purposes on the very basic elements of the P&A process. To meet legal guidelines, consult an expert for interpretation of the laws, design and application of the P&A jobs.

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