Effects of Water Depth Workshop

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RP 96 Deepwater Well Design and Construction

Barrier Discussion

Session 3

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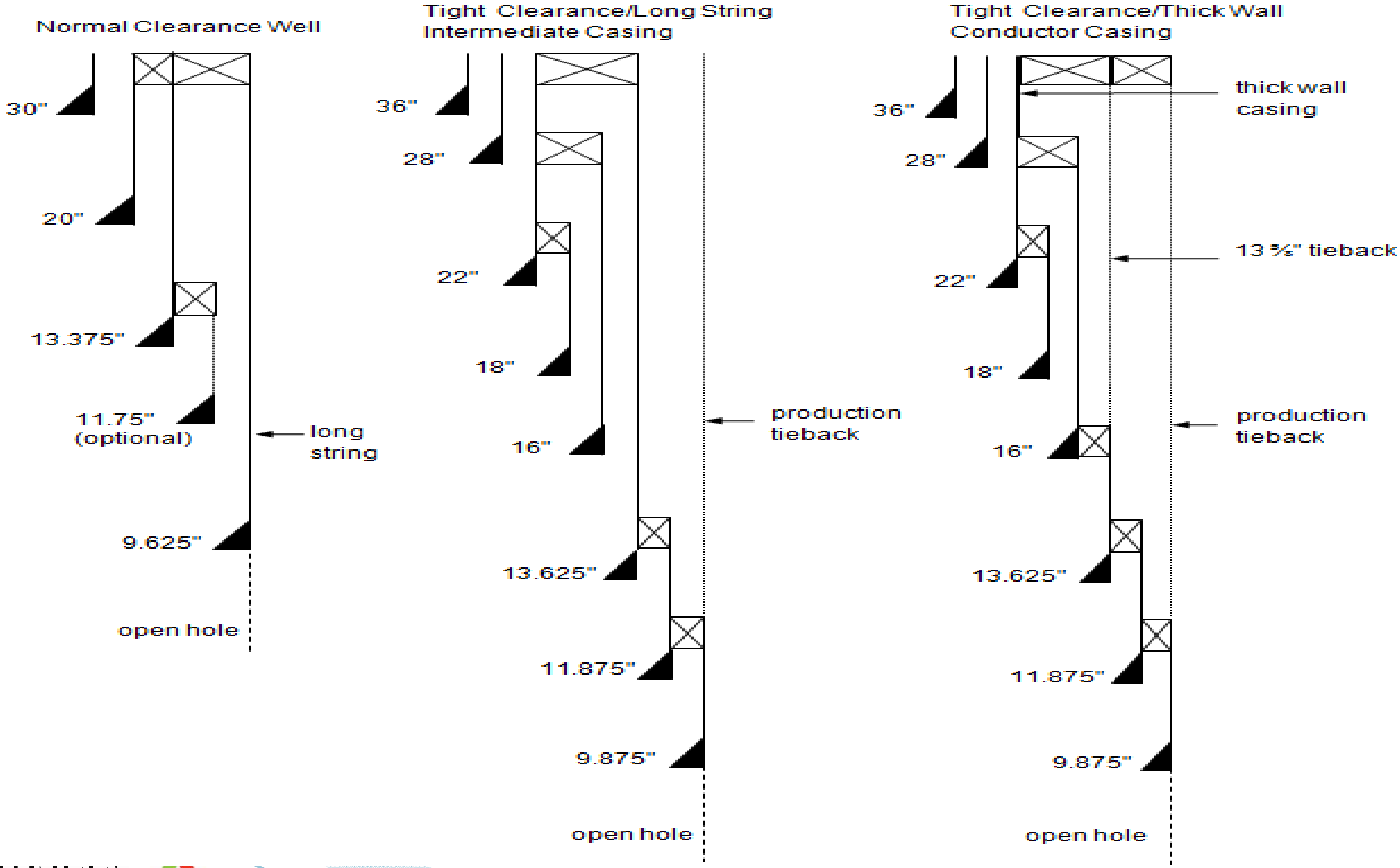
RP 96 –Barriers and Session 3

- Q1 What Challenges Exist in Casing and Equipment Design for Deepwater Wells?
- Q2 What are the Operational Challenges with Implementing Reliable Barrier Systems? (Drilling or Completion)
- Q3 What Challenges Exist in Deepwater Completion Designs?

RP 96 Brief History/Update

- API (Gary Luquette and David Payne) committed to 2nd phase of JITF Operating Procedures for "new standards for DW well designs". June 2010
- Document intent
  - Outline barrier and load case considerations
  - Supplement API 65-2 and 90.
  - Discuss design features and risks for various scenarios to prevent loss of well control
- Passed first ballot, however ~1100 formal comments. Addressed ~1300 comments and 96 is out for reballot at present.
  - Is not a text book for novices, does not state safety factors, but does give examples/considerations of current DW well architecture, load cases, barrier philosophy , survival design and operational considerations (displacements, negative tests, etc)

Example of DW well designs



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RP 96 Barrier Definitions

- **Barrier --**Component or practice that contributes to the total system reliability by preventing formation fluid or gas flow.
- **Barrier Plan --**The operator's specific operating procedure for barrier placement, verification, and removal.
- **Barrier System--**A combination of barriers acting in conjunction along a given potential failure path to prevent formation fluids or gases from unintentionally flowing from one side of the system to the other side.
  - NOTE: The barrier system includes both physical barriers and operational practices.

RP 96 Definitions (cont)

- **Mechanical barrier--**Subset of physical barriers that features mechanical equipment. Examples include: permanent or retrievable bridge plugs, downhole packers, wellhead hanger seals, and liner hanger seals.
  - NOTE: Does not include set cement or a hydrostatic fluid column
- **Physical barrier--**Material object or set of objects intended to prevent the transmission of pressure and fluid flow from one side of the barrier to the other side.
  - NOTE 1 The barrier is designed to withstand all anticipated pressures at its relative position in the wellbore. It may be verified by testing to its full-anticipated load or verified by alternative evaluation (see Section 5.3.2. c).
  - NOTE 2 Includes mechanical barriers, cement barriers, and hydrostatic barriers.
  - NOTE 3 Does not include operational barriers.

RP 96 Definitions (cont)

- **Operational barrier--**Practices that enhance the total system reliability through human behavior and result in the activation of a physical barrier. Operational barriers by themselves do not constitute a physical barrier.
  - EXAMPLE: Process to close BOPs or detect an influx.

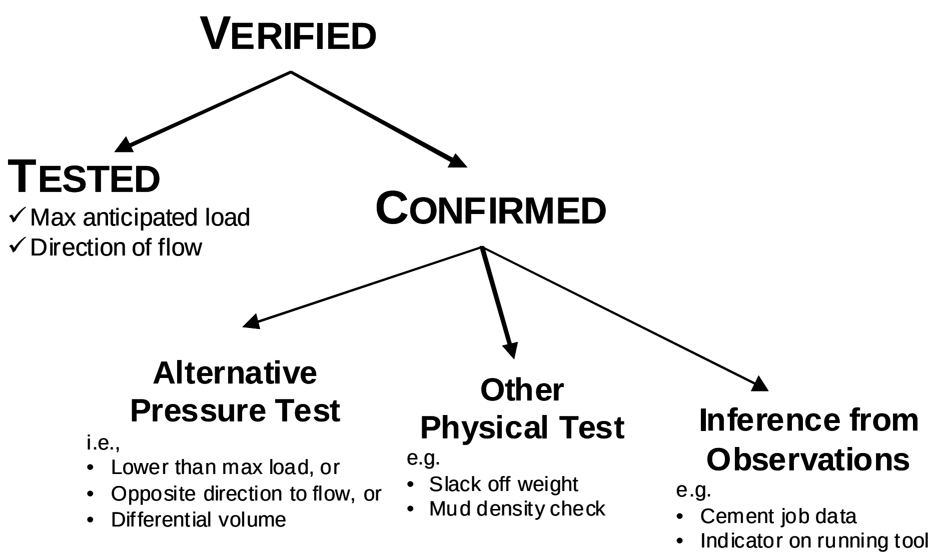
RP 96 Definitions (cont)

- **Tested barrier --** A barrier whose performance has been verified through meeting the acceptance criteria of a pressure test. The test is in the direction of flow and to a pressure differential equal to or greater than the maximum differential pressure anticipated during the life of the barrier.
- **Verified barrier--**Barrier whose proper deployment has been substantiated through a post-installation assessment or through observations recorded during its installation.
  - EXAMPLE: Cement in the casing annulus that had proper displacement and observed lift pressure.
  - NOTE: A tested barrier has the greatest level of assurance.

RP 96 Definitions (cont)

- **Confirmed barrier--**A barrier whose performance has been verified through meeting the acceptance criteria of a post-installation evaluation other than that of a tested barrier, or through evaluating data collected during installation. A confirmed barrier has a lower level of assurance than a tested barrier.
  - EXAMPLE: A barrier pressure tested in the direction opposite of flow would be considered a confirmed barrier.

RP 96 Example of Barrier Verification



Q1 part 2 (selected barrier comments pulled from RP 96)

- **Long String versus Liner and Tieback (5.2.4)**
  - A liner with an optional tieback may be considered for intervals experiencing severe lost circulation with gas bearing intervals.
  - The liner option allows the casing to be hung at any depth if the string does not reach bottom. It also allows pipe rams to seal around drillpipe once the liner is past the BOP stack.
  - Close tolerance liner hangers (e.g., 13⅝ X 11⅞ and 11⅞ X 9⅝) may have reduced burst and collapse ratings, *(increased complexity)*
  - Effect of lost circulation during cementing . Wells that experience severe losses during cementing may need additional evaluation of slurry placement to verify the cement barrier (refer to Table B.3)
  - Casing hanger lock-down requirements (annular gas migration may cause additional loads

RP 96 Barrier Question 2-1

- **What are the Operational Challenges with Implementing Reliable Barrier Systems**
  - **In-situ Verification of Barrier.** ***Note: only one barrier in a series can be tested. (the second test on the second barrier may only be testing the first barrier if 2nd didn't seal.)***
    - **RP 96 has 4 examples for conducting negative tests.**
      - " Description of Example 1--an example of an inflow test using a retrievable packer for testing sub-mudline barriers, such as a newly set liner hanger. This test will not put a negative pressure differential across the stack, but does require a trip with a mechanical packer to isolate the annulus. It can be used to generate a higher downhole test pressures than a test which displaces fluid down the choke or kill lines".

RP 96 Question 2-2

- **Reliability of Mechanical Barriers-** The reliability of a mechanical barrier can be established by various factors including quality in design, manufacture, installation and testing.
  - RP 96: "The designer's objective is to achieve a high level of well reliability by combining operational and physical barriers. Physical barriers contribute to a high level of reliability".
  - "The reliability of any physical barrier is increased if its integrity is tested to anticipated loads (i.e., in the direction of flow), after the barrier is deployed. Sometimes testing cannot be used to verify barrier integrity because potential load directions or anticipated loads cannot be simulated within the well. In these situations, more emphasis is placed on maximizing the reliability of the barrier by increasing quality control during design, manufacturing, and installation".

Barrier reliability (2-2 cont)

- If a physical barrier cannot be verified by testing it to its full anticipated loads, consider one of the following alternative verification methods:
  - test the barrier to a lower load or in the opposite direction of the maximum design load
  - collect data or observations during physical barrier installation that confirm effective execution of the installation
  - perform post-installation inspection of the mechanical barrier
  - if placement of a physical barrier cannot be confirmed, additional operational barriers may be used to enhance the well system reliability in accordance with regulations. To enhance their effectiveness, operational barriers may be assessed with measurement, workflow, training, and drills
- Review the barrier plan as part of a management of change (MOC) process if well conditions change.
- Train personnel to understand that a decision not to deploy a planned operational or a physical barrier due to unexpected conditions may increase the likelihood of well system failure
- If a physical barrier is found to be deficient during the course of operations and it cannot be repaired, reassess the remaining well system reliability in accordance with regulations. The loss of a physical barrier may cause a significant reduction in the well reliability. Consider replacing the physical barrier if possible, or installing supplemental physical barriers or using operational barriers as a part of the MOC process

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RP 96 Question 2-3

- Reliability of Cement Barriers - The reliability of an annular cement barrier is in part a function of annular clearance and centralization. These attributes are particularly important in close tolerance casing programs.
  - RP 96:"For set cement in the annulus to serve as a physical barrier to the influx of formation fluids, the cement slurry shall be designed and laboratory-tested for the anticipated well conditions. Consider loads and environmental changes that may occur on a cement sheath over the life of the well. The cement slurry should be placed in the well using recommended practices and equipment per API 65-2."
  - RP 96 gives general guidelines, refer to 65-2, 10TR-1, and other documents for specific recommendations

RP 96 Question 2-4

- Mechanical Lock-Down of Hanger and Hanger Seal Assemblies
  - *Note: For drilling load calculations (Not WCD) the hanger will rarely lift off the wellhead since APB is minimal, and temperature change is small. Current software is not designed for this, workarounds are normally required.*
  - RP 96:"Consider performing an analysis of the forces on the casing hanger caused by thermal growth of the casing and the pressure differential loads across the seal assembly such as:
    - assessing the potential for casing hanger/seal assembly movement
    - determining the lock down force necessary to keep the casing hanger in place
    - verifying the rating of the lock-down component is greater than the predicted necessary lock-down force"

RP 96 Question 2-5

- Casing and Cementing Equipment Reliability–
  - reduce common equipment failure modes;
  - to increase the reliability of individual casing/cementing equipment components;
  - improve the integration of these components into highly reliable barrier systems
  - RP 96:
    - Table B-3 *Cement Behind Casing or Liner*
    - Table B-4 *Cemented Shoetrack*—refer to API 10F
      - *Some have noted that current API standards may be lenient, don't require testing with mud type that will be used (SBM), and one test can apply to many sizes.*
      - "One or more mechanical barriers shall be used to isolate the shoetrack from the mudline." RP 96 discounts the shoe track use as a mechanical barrier

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RP 96 summary

- Extensive review and examples for conducting displacement operations during drilling and completion operations
- Review of management of change, including Stop Work Authority
- 3 annexes (53 pages) provide multiple, detailed examples for barriers employed during common operations (annex (A), barrier definitions (B) and operational examples for negative testing (C)