SPE DISTINGUISHED LECTURER SERIES

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Overview

- New loads and limitations
  - Thermal effects – annular pressure build-up
  - Designing with limited casing bore
  - Extreme landing tools
- Beyond “API designs”
  - Probabilistic design considerations
  - ISO 10400
Annular Pressure Build-up (APB)
Annular Pressure Buildup (APB)

- Origin of APB loads
- Mitigating APB
  - Principles and solution categories
  - Specific well construction tools

16 in. casing collapse from APB during circulation
The origin of APB

What do we do about this hydrocarbon bearing zone?
APB depends on

- Mechanical and thermal properties of fluid
- Flexibility of the confining boundary
- Temperature increase

Considering the fluid component,

\[
\Delta V_f = V_f \left[ \alpha_f \Delta T - \frac{1}{C_f} \Delta p \right]
\]
Mitigating APB

**Brute Force**
- Thick-walled casing

**Fluid Properties**
- Foam spacer
- Fluids with low psi/F
- Cement entire annulus

**Control the Load**
- Vacuum Insulated Tubing (VIT)
- Nitrogen blanket
- Gelled brine
- Connection leak integrity
- Initial annulus pressure

**Container Flexibility**
- Vent the annulus
  - Active path to surface
  - Relief mechanism
    - Formation fracture/TOC
    - Rupture disks
    - Grooved casing
- Annulus communication
- Syntactic foam
- Avoid trapped pressures external to annulus
Mitigating APB

**Fluid Properties**

- **Foam spacer**
- Fluids with low psi/F
- Cement entire annulus

![Graph showing pressure vs. quality of total trapped system.](image)
Mitigating APB

Container Flexibility

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Mitigating APB

Control the Load

- **Vacuum Insulated Tubing**
- Nitrogen blanket
- Gelled brine
- Connection leak integrity
- Initial annulus pressure
Mitigating APB – Vacuum Insulated Tubing (VIT)

![Diagram showing temperature variations and brine phases with depth and connections](image-url)
Designing within wellbore limitations
Deepwater HPHT wells, maintaining hole size

- Geometric constraints
  - Minimum → production tubulars, SSSV
  - Maximum → 18-3/4 in. bore

- Possible solutions
  - Riserless drilling
  - Managed pressure drilling
  - Designer muds
  - **Revisit casing risk profile**
    - Probability x consequence
    - Recovery
    - Empirical validation
      - Solid expandable liners
Maintaining hole size - example

- 8-1/2 in. hole on bottom
- Production tubulars with 18,000+ psi internal yield
- 5-1/2 in. tubing
- 9-3/8 in. upper tieback drift (subsurface safety valve)
- Clearance outside tieback for APB mitigation (syntactic foam)
Extreme landing loads
Landing strings and slip crushing

- Landing string static loads approaching 1.5 mm lbs
  - Impulse load during tripping
  - Heave induced excitation
- Applicability of Reinhold-Spiri
  - To current systems?
  - To other slip problems?
Understanding slip systems

- Strain gauged samples indicate
  - Non-uniform loading
  - Worst loading may be between inserts

![Graph showing axial tensile load and pipe yield](image_url)

- AXIAL TENSILE LOAD = 100,000 lb
- AXIAL TENSILE LOAD = 300,000 lb
- AXIAL TENSILE LOAD = 500,000 lb
- AXIAL TENSILE LOAD = 700,000 lb
- AXIAL TENSILE LOAD = 900,000 lb

- NUMBER OF LINE LOADS = 3
- YOUNG'S MODULUS = 30 x 10^6 psi
- POISSON'S RATIO = 0.3
- YIELD POINT = 100,000 psi
- WALL THICKNESS = 0.5 in
- MEAN RADIUS = 3.0 in

Uniaxial Yield Strain 5014 psi

Distance from Slip Line in...

Solid Line - Hoop Strain
Dashed Line - Axial Strain
Probabilistic design considerations
Detailed inspection data
Application – calculation of cross-sectional area

Pipe Identifier: 02356
Application – detailed collapse prediction

- Line pipe samples
  - X65, D/t 16-18+
- Detailed input
  - Wall, diameter
  - Axial, hoop $\sigma$-$\epsilon$ coupons
  - Residual stress
- Full scale tests
  - Pressure with bending
  - Collapse, propagation
- Excellent results (<3% no bending, 0-9% with bending)
Probabilistic advantage using rupture disks

- Disk pressures have tight, controlled tolerances (± 5% on rupture pressure)
- Contrast with 12.5% wall tolerance and 10-30 ksi tensile strength variation for casing body
  - Wide uncertainty of casing rupture and collapse pressures
  - Cannot count on outer string failing first
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Conclusions

• No lack of challenging problems
  – Continuing research on annular pressure mitigation
  – Rethinking old solutions

• Design stretch via probability
  – Increasing support from standards