Well Integrity Life Cycle

Mohamed Hassan
Outline

• Macondo accident (Lessons learnt & Response)
• Petronas TIPS House
• Well Integrity Life cycle
• Managing Major Accident Hazards, overview
• Summary and conclusion
Why focus on Process Safety?

- High Frequency:
  - Struck by/against objects
  - Slips & Trips, Falls
  - Road Transport
  - Marines
  - Aviation

- Process Safety Accidents

- High Impact:
  - Jul 1988, Piper Alpha, 165 died
  - Sept 2005, Texas City, 15 died
  - Apr 2010, Macondo, 11 died
MACONDO Accidental Model

- Focus on commercial risk, not major hazard risk
- Heavy focus on personal safety as opposed to process safety
- Failure to adapt process safety to drilling

Poor (engineering & operation) decision-making

Multiple Fatalities

Environmental disaster

Gas diverter

Ignition control

Blowout response plan

Oil spill response plan

Hydrocarbon

Cement

Cement evaluation tool

Monitoring

Well integrity test

BOP
Process Safety in drilling

• The blindness to major hazard risk is not a unique to MACONDO drilling

• The concept of process safety was developed for process industries – refining and the like

• The fact is that process safety is not directly applicable to drilling operations and needs to be adapted to deal with blowout risks.

• BP had not recognized the need to make this adaption. So it was that major hazard risk and process safety tended to disappear from view.
Response to Macondo Accident

- BP, Safety and operation risk (SOR) assurance and audit structure, 2011
- NORSOK D-010: Well Integrity in Drilling Well Operations, Revs 4, Jun 2013
- ISO/DIS 16530-1: Life cycle governance, 2017
- Petronas, Technical Integrity Process Safety (TIPS assurance program), 2012 - 2017
TIPS House

Vision

Our assets are safe and we can prove it

Mission

Ensure and enhance the E&P integrity of assets across the entire lifecycle to prevent major accidents

Objective

Design it right, Operate it right, Maintain it right

HSE Case TIPS 2

Maintenance Integrity TIPS 3

Operational Integrity TIPS 4

Wells Integrity TIPS 5

Project Engineering Integrity TIPS 6

Pillars

To set the HSE Case standard and identify the MAHs & the hardware barriers to prevent LOC
To maintain the hardware barriers effectively and be able to assure it
To strengthen the soft barriers, and ensure we work within Operational Envelopes
To assure the wells are safe through its life cycle
To design and build facilities so that risks are ALARP

System Support

Integration of IT Systems TIPS 7

Enhancing Safety Leadership

Developing Generative HSE Culture

Building Asset Integrity Capability
Well Integrity Definition

Well Integrity is a condition where subsurface fluid are contained within designed boundaries throughout well lifecycle.
Well Integrity Management System (WIMS) is an application of combined solutions to prevent / reduce the risk of uncontrolled release of well fluids throughout well life cycle.
Well Integrity Life Cycle

Common Elements to all Phases
- Well Integrity
- Well Integrity Policy
- Well Integrity Management System
- Risk Assessment
- Organizational Structure
- Well Barriers
- Performance Standards
- Well Barrier Verification
- Reporting & Documentation
- Management of Change
- Continuous Improvement
- Audit / Independent Verification

Well Integrity Life Cycle Phases

As – built well integrity
- Basis of design phase
- Design phase
- Construct phase

Managing ongoing well integrity
- Operational phase
- Intervene phase
- Abandon phase

Continuous Improvement
- Identify Hazards
- Define mitigating barriers against hazards
- Build controls / barriers and verify against hazards
- Provide assurance of barrier and barrier elements
- Assure barriers are reinstated / maintained
- Restore natural barriers

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Management of Major Accident Hazards

Managing **MAH** in wells means ensuring **WI** throughout well lifecycle.
Hazards and Well Life Cycle Risk Consideration

- **Subsurface hazards:**
  - Hydrocarbon
  - Faults, pore pressures

- **Surface hazards:**
  - Location, urban planning
  - Proximity to rivers, subsea, offshore

- **Activities, that can influence well integrity:**
  - Future intervention
  - Change of use

- **Corrosion and erosion risks:**
  - CO2 & H2S corrosion
  - Sand / solid production

- **External and environmental Hazards:**
  - External corrosion of structure
  - Compaction & subsidence loads

- **Individual and combined loads :**
  - Pressure, temperature, tension
  - Drilling, production, injection
Safety Critical Elements (SCEs)

Safety Critical Elements (SCE)
Any Part of an installation - The failure of which could cause to a major accident - or a purpose of which is to prevent or limit the effect of a major accident

Key Safety Plant:

Wells:
Equipment that falls within pressure boundary of the well
**Well Integrity Life Cycle**

Mohamed Hassan

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**Well Barrier Schematic**

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### Primary Well Barrier to Reservoir

<table>
<thead>
<tr>
<th>Barrier Element</th>
<th>Element Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap Rock</td>
<td>XXX Equivalent Mud Wt s.g.</td>
</tr>
<tr>
<td>7” Liner Cement</td>
<td>TOC xxx ft: Total Cmt length xxx ft</td>
</tr>
<tr>
<td>7” Liner Hanger/Packer</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>7” Liner</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>9-5/8” Casing [below Packer]</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>9-5/8” Production Packer</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>Gas Lift Valve</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>4-1/2” Tubing</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>TR SSV Flapper</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
</tbody>
</table>

### Secondary Well Barrier to the Reservoir

<table>
<thead>
<tr>
<th>Barrier Element</th>
<th>Element Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-5/8” Casing Shoe Strength</td>
<td>XXX Equivalent Mud Wt s.g.</td>
</tr>
<tr>
<td>9-5/8” Cement inside 13-3/8”</td>
<td>TOC xxx ft: Total Cmt length xxx ft</td>
</tr>
<tr>
<td>9-5/8” Casing</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>9-5/8” Casing Hanger seals</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>9-5/8” Wellhead section</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>9-5/8” Wellhead Annulus Valves</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>Tubing Hanger Seals</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>X-mas Tree Connector</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
<tr>
<td>Hydraulic Master Valve</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
</tbody>
</table>

### Secondary Well Barrier to the Lift Gas

<table>
<thead>
<tr>
<th>Barrier Element</th>
<th>Element Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-3/8” Casing Shoe Strength</td>
<td>XXX Equivalent Mud Wt s.g.</td>
</tr>
<tr>
<td>13-3/8” Cement</td>
<td>TOC xxx ft: Total Cmt length xxx ft</td>
</tr>
<tr>
<td>13-3/8” Casing</td>
<td>PT to xxx psi w/ MW yy s.g.</td>
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<td>13-3/8” Casing Hanger seals</td>
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<td>PT to xxx psi w/ MW yy s.g.</td>
</tr>
</tbody>
</table>

### Well Integrity Notes:

1. the 410ft of cement overlap inside the 13-3/8” is considered good cement
Typical Modes of Well Barrier Failure

1. Tubing Hanger/Sea Leak
2. Wellhead Seal Leak
3. Tubing Leak Above SSV
4. Intermediate Casing Leak
5. SSV Leak
6. External Leak Or Seep Outside Conductor
7. External Corrosion from Aquifer
8. Production Casing Leak
9. Tubing Leak Below SSV
10. Leak Through The SPM Accessory
11. Leak into an Outer Annulus From Casing Shoe
12. Leak into B-annulus From Casing Shoe
13. Leak Around the Production Packer
14. Leak Via Through Poor Cement or Micro Annulus Channel
15. Leak through the Liner Hanger or Liner Cement
16. Hydraulic Control Line Leak to A-annulus
17. Hydraulic Leak Line At Xmas Tree Void/Tubing Hanger
18. Leak At Wellhead Outlet
19. Leaks through Xmas Tree and Wellhead Valves to or from the Process Facilities
20. Stem Packing Leak
21. Bonnet Seal Leak
22. Flange Leak
23. Xmas Tree Body Leak
24. Xmas Tree Valve Leak
25. Xmas Tree Connector Leak
26. Leak Through Cap Rock

Note: Often two or more simultaneous modes of failure can complicate diagnosis and also lead to a significant worsening of the Well Integrity condition.
Performance Standards (PS)

- A set of specifications and qualification criteria
- For design phase:
  to define, design, procure WBE / SCE
- For construction phase:
  to test and verify WBE / SCE
- For operation phase:
  to monitor, maintain, inspect and test WBE / SCE
- Examples:
  - A defined barrier element selection process
  - Function test or pressure test to demonstrate valve’s functionality, availability and reliability
  - Cement qualification testing to define cement integrity
Summary & Conclusion

- Learn and act from the accidents lessons.

- Recognize that we work in a MAH environment.

- Familiarize ourselves with hazards and SCEs in our installation.

- Establish safety case regimes.

- Managing MAHs in wells means ensuring well integrity throughout well life cycle.

- Embedding the process safety concept into engineering and operation entities via standards and system.
Thank you

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