An Introduction to Well Integrity

Presented at the Well Integrity Workshop, Norsk Olje og Gass, June 4, 2013

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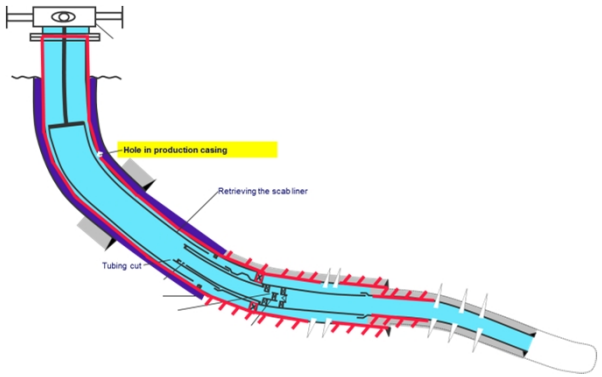

Compendium developed by:

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This presentation

- The objective of this presentation is to help people with limited background to understand the reasons for well integrity, and also how it is applied.
- NORSOK D-010 and OLF 117 are industry standards. They explain what to do, but not all the reasons behind
- The present kompendium is an attempt to give background knowledge to improve applications of standards and also well design and operations

Content list of compendium

- 1. What is well integrity?
- 2. Background and history
  - Failures, likelihood, consequences
  - 6 example cases of loss of integrity
- 3. Well construction and field development
  - Subsea, platform, well types
- 4. Well barriers
  - Diagrams, functions, requirements
  - Reliability, FMECA, fault tree analyses
- 5. Technical well barriers
  - Fail-safe, safety and fire systems
  - Drilling, completion, production, intervention and P&A phases
  - Barrier design for life cycle
- 6. Operational
  - X-mas trees and valves, SSSV, ASV aso…
  - Pressure monitoring
- 7. Organization
  - Roles, responsibilitie, competence and training
- Appendix
  - 4 exercises

Description of Compendium

- History of double barriers
- Why do we need double well barriers?
- Examples of well failures
- Some results from the PSA studies
- Well barriers
- Risk and reliability
- Well construction and field development
- Technical, Operational and Organizational aspects
- Summary

History of double barriers

- Two independent barriers have been used probably since 1970
- However, common for many applications
  - Dual circuit brake system in cars
  - Dual hull vessels
  - Double insulated electric drills
  - Three microporcessors runs in parallell
- Redundancy often applied to reduce economic or technical risk

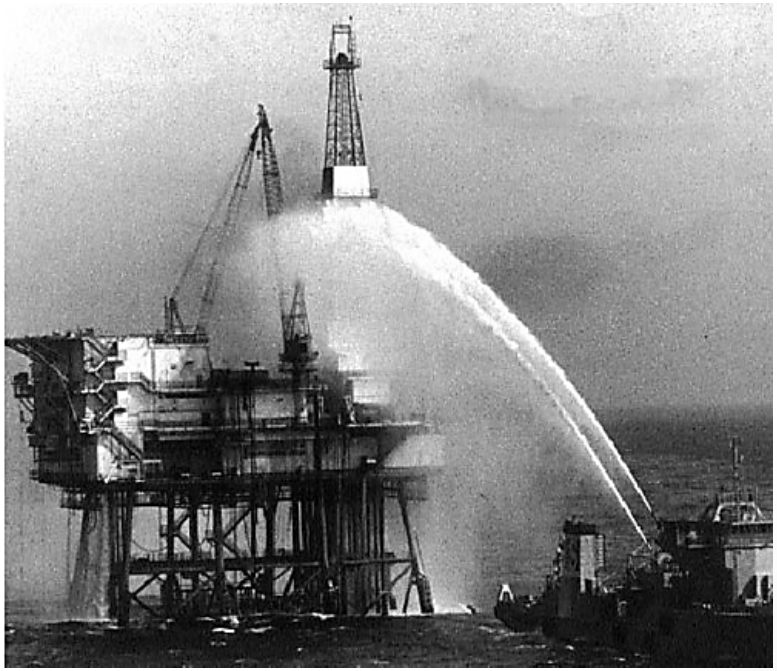
Shell Bay Marchand 1970 Well Blowout in the Gulf of Mexico

Jul 27th, 2010 by John Donovan.

The entire platform burned. It was at the time the biggest production disaster in the history of the Gulf of Mexico. Shell let it burn rather than pollute the nearby delta. It took 9 months to drill all the relief wells to kill 23 boreholes.

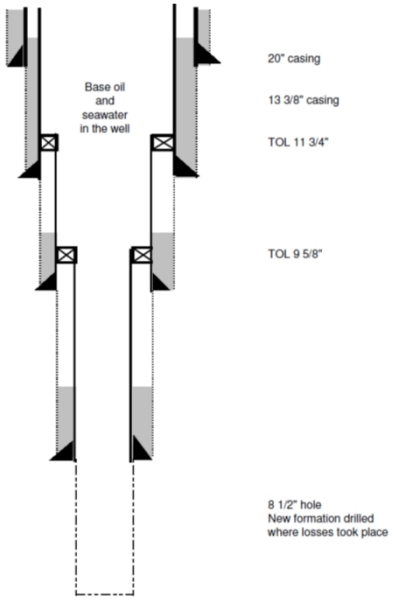
Why do we need double barriers?

- Petroleum production has high risk for HSE, actually a high danger potential
- Large failure potential in equipment, personnel and operations
- Barrier diagram is a check that all exposed components are safe. Testing verify strength, and key personnel knows status
- Barrier diagrams gives a common reference for all personnel



Examples of well failures

- 6 well failures on NCS form 2002-2005 presented
- Example 1: Loss of wellbore
  - Drilling below 9-5/8in csg, total losses occurred
  - LCM partly stabilized the well
  - Kick taken, well shut in
  - Well fully open in periods
  - Gunk pill plugged DP
  - Well killed through annulus
- Both well barriers lost at times
- Examples try to demonstrate loss of barriers

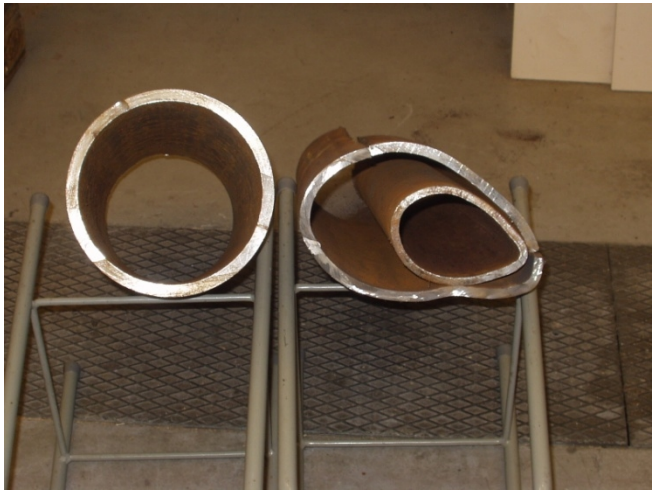


Examples of Well Failures

- 2) Collapse og production tubing and casing
  - Thermal expansion
  - Poor casing test, leak through PBR
  - Perforated with open well

- Production casing was 53.5# N80
- Collapse joint was 47#N80

- Root causes, weak csg. joint, poor csg. test and loss of barriers



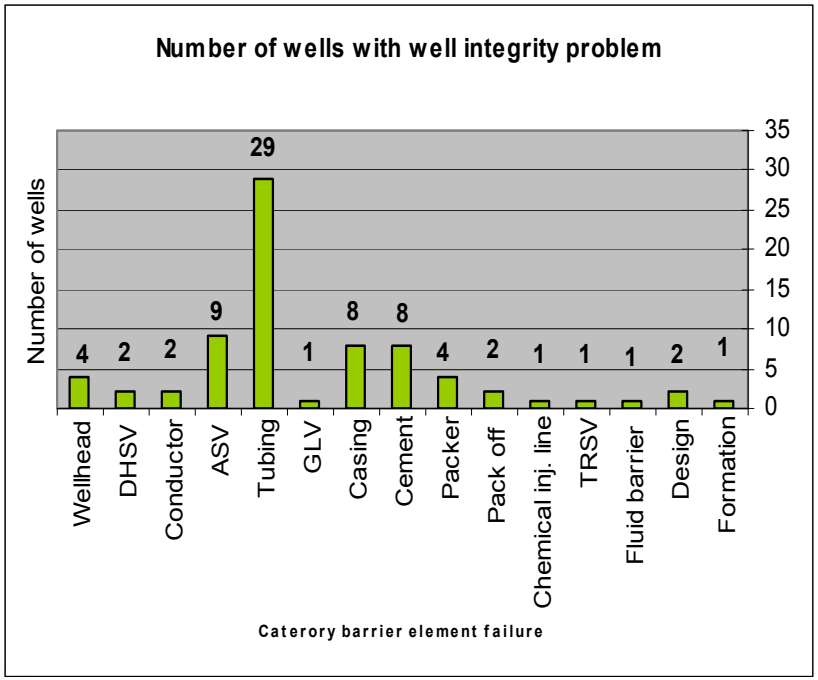
Other examples of well failures

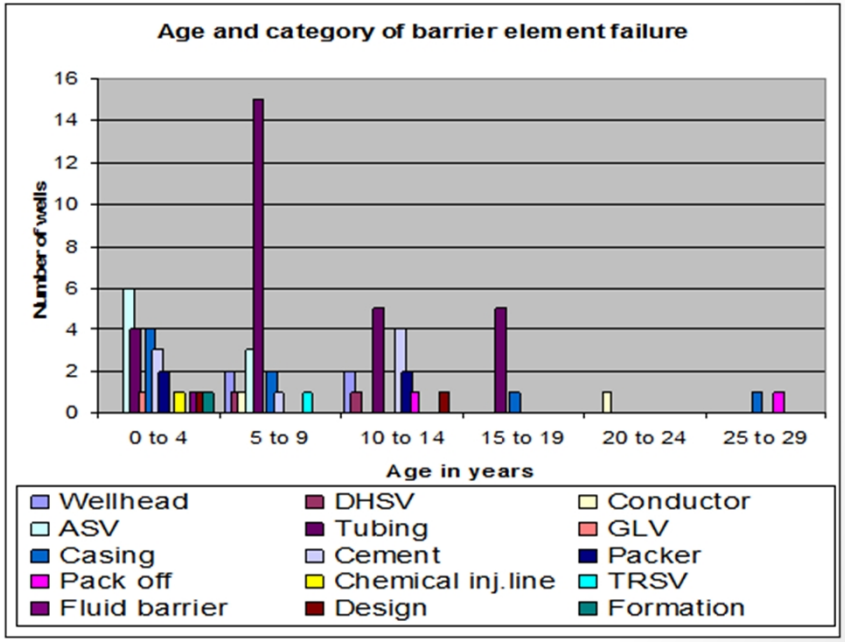
- 3. Workover
  - Surface casing failed due to corrosion
- 4. Casing and tubing hanger failure
- Other examples also included
- Analyzing well failures is very important for fundamental understanding of well integrity

- Root cause: cement port left open
- Root causes: poor design(8^{o}taper), axial overload, uprating wrongly accepted

Some results from the PSA studies

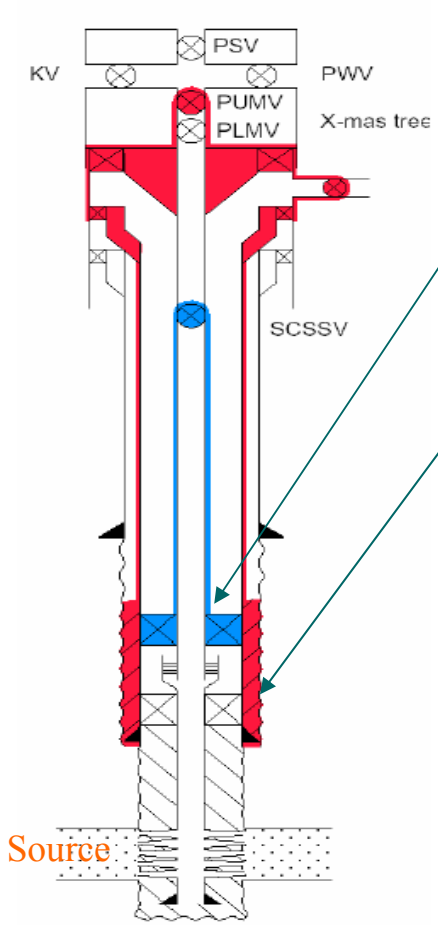
- From 2006 PSA performed several studies on Well Integrity





Well integrity

Well barriers



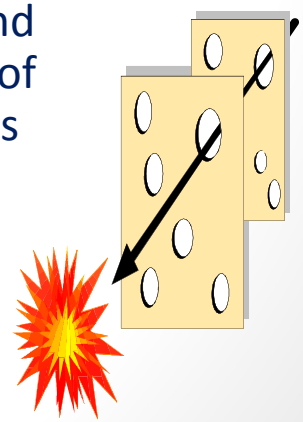
Common production well with two "barrier envelopes"

Source: NORSOK Standard D-010 (2004)

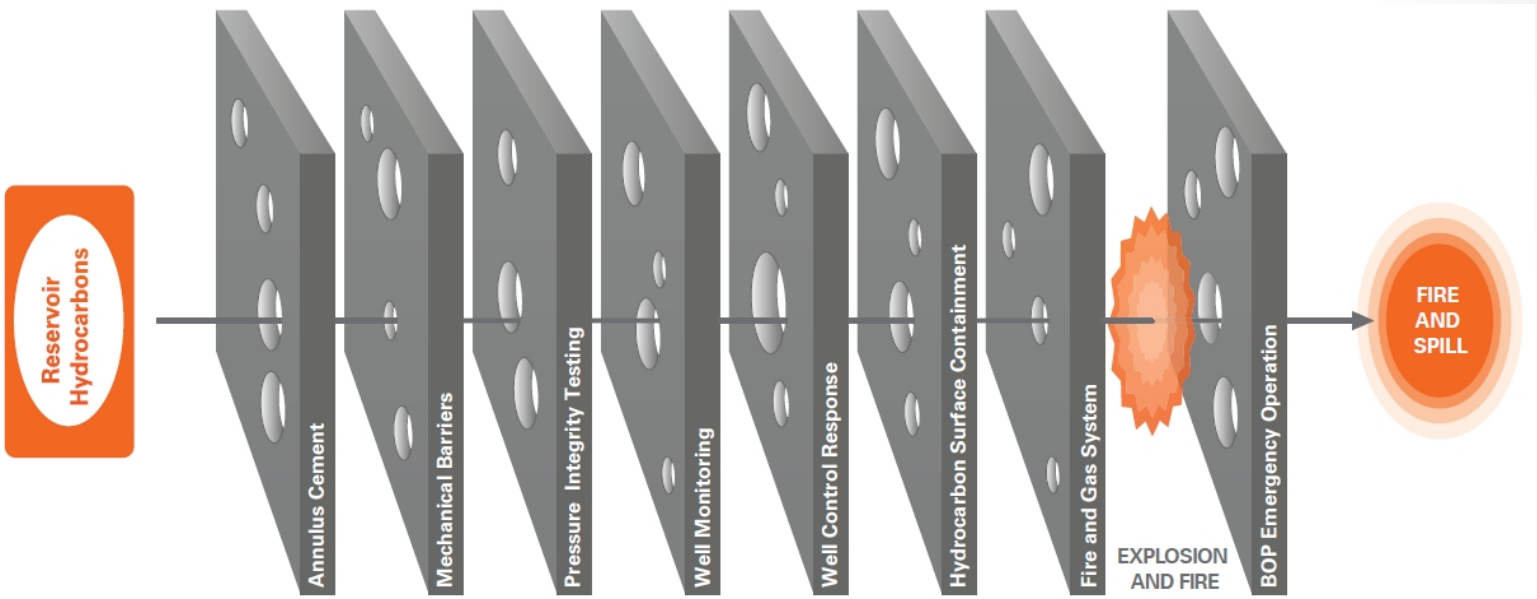
The Primary well barrier is the first object to prevent unintentional flow from the source

The Secondary well barrier prevents further unintentional flow if the primary well barrier should fail

Well integrity ref NORSOK D-010
Application of technical, operational and organisational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of the well.

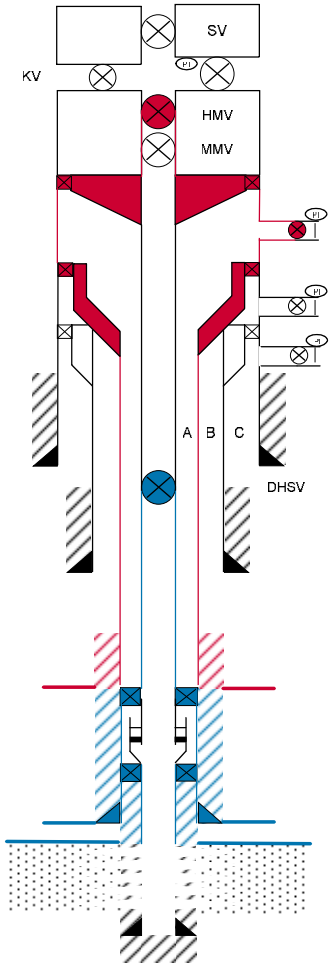


Ref. "Swiss cheese model"
Reason (1997)



13Swiss cheese model - barriers breached in Macondo field (Ref. BP report).

Example of Well Barriers



This well has six *primary* well barrier elements:

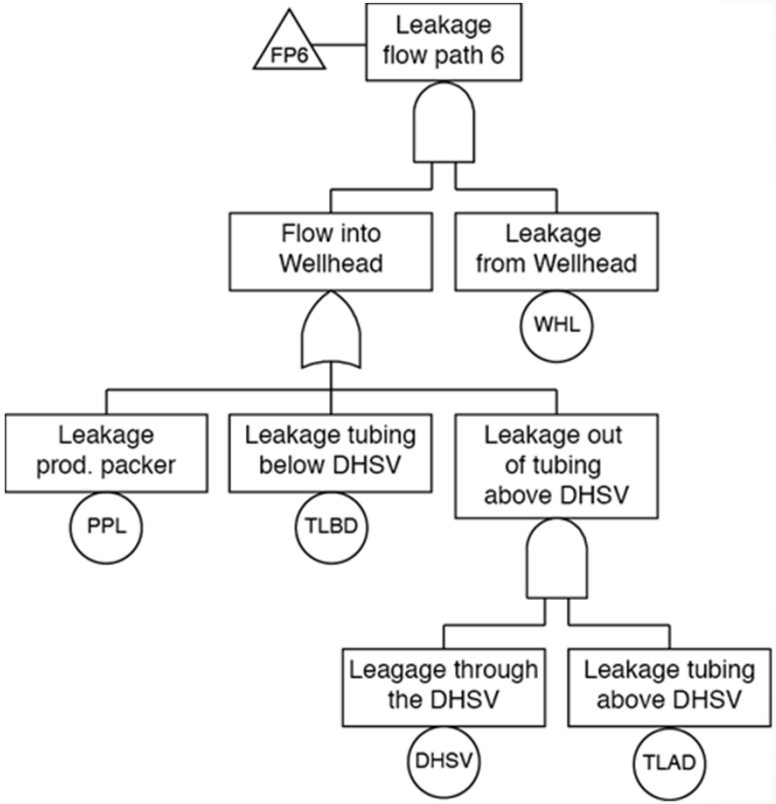
- Formation /cap rock above reservoir
- Casing cement
- Casing
- Production packer
- Completion string (below the DHSV)
- Surface controlled subsurface safety valve (DHSV)

And six *secondary* well barrier elements:

- Formation above production packer
- Casing cement
- Casing with seal assembly
- Wellhead
- Tubing hanger with seals
- Annulus access line and valve
- Production tree (X-mas tree) with X-mas tree connection

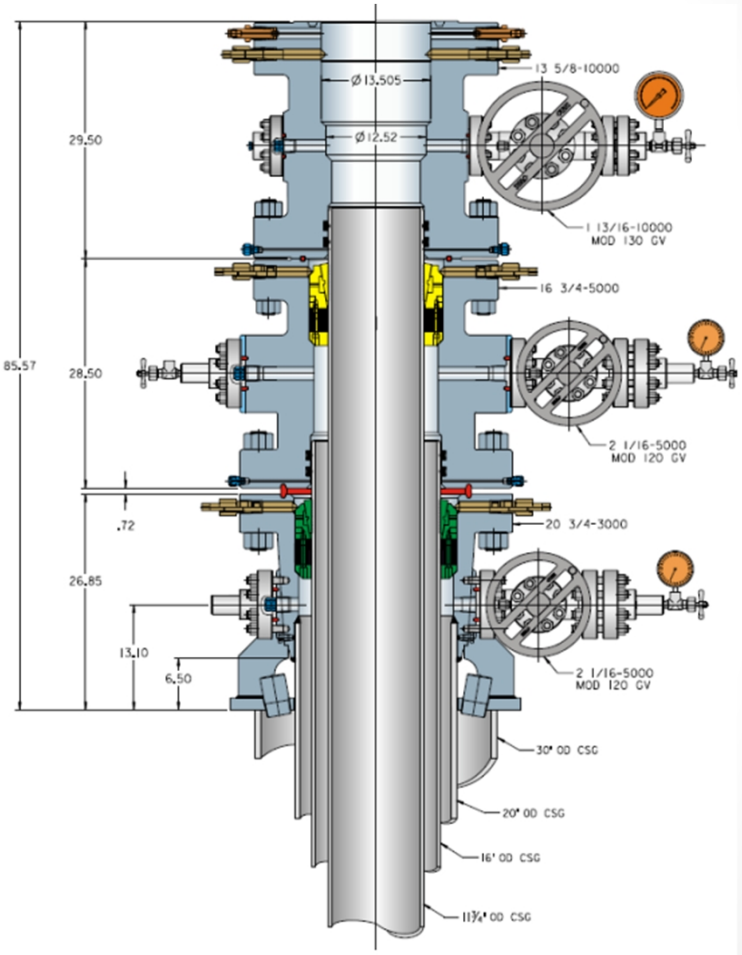
Risk and Reliability

- The compendium gives introduction to:
  - Reliability analysis
  - Failure analysis
  - FMECA methods
  - Fault tree analysis
- Efficient tools to:
  - Compare completion alternatives
  - Evaluate blowout risk
  - Identify barrier problems
  - Assess risk reducing methods
  - Identify barrier problems during well interventions



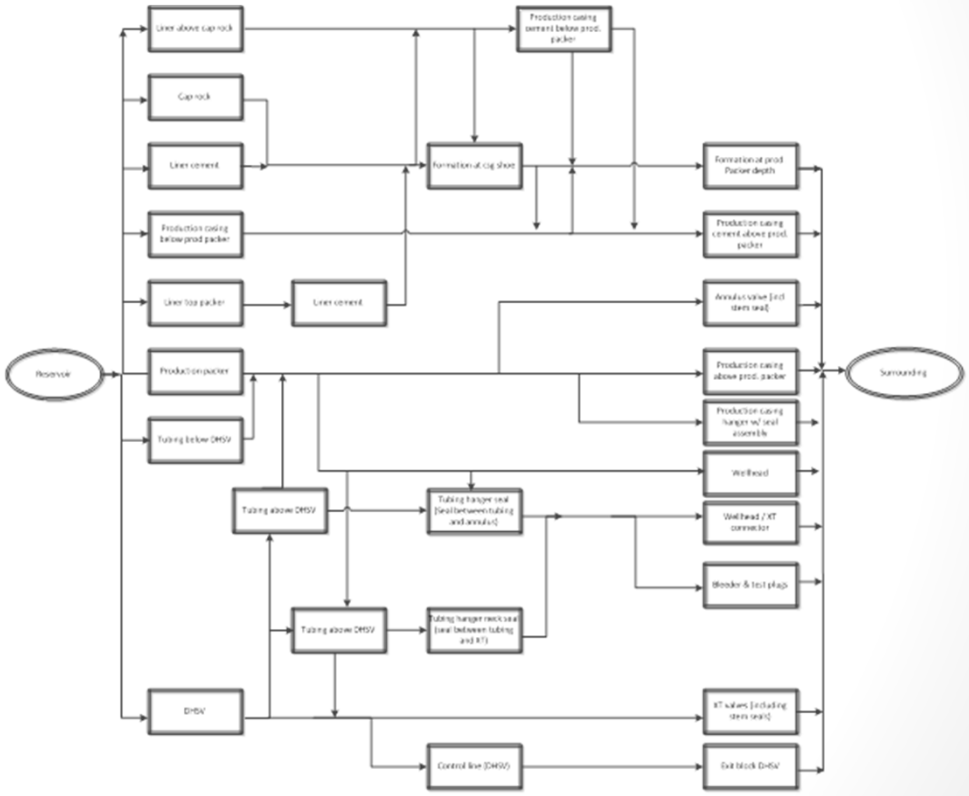
Well Construction and Field Development

- Subsea and platform drilling
- Vertical/horizontal X-mas trees
- Technical description of well



Technical Well Barriers

- Fail-safe functions
- Automatic open/close bleedoff
- Fire resistance
- Failure modes – barrier diagrams

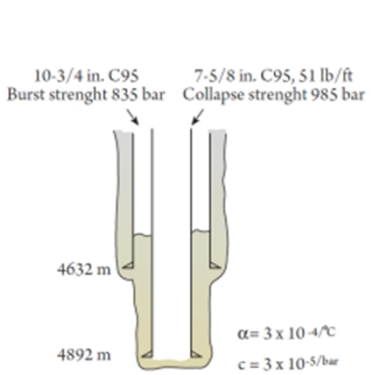


Operational factors

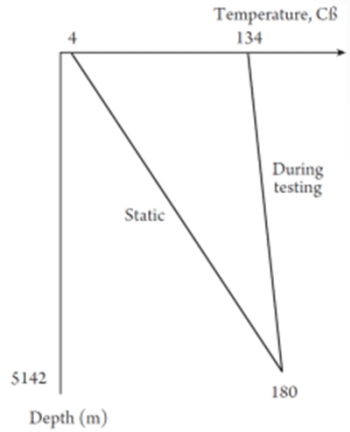
- X-mas tree and SSSV testing
- ASV in gas lift wells
- Pressure monitoring
- Types of annular pressures
  - Thermal effects, B-annulus pressure
- Sustained casing pressures

- Calculation of MAASP and MOP
- Calculation of MINAP in gas lift wells

- Management and control



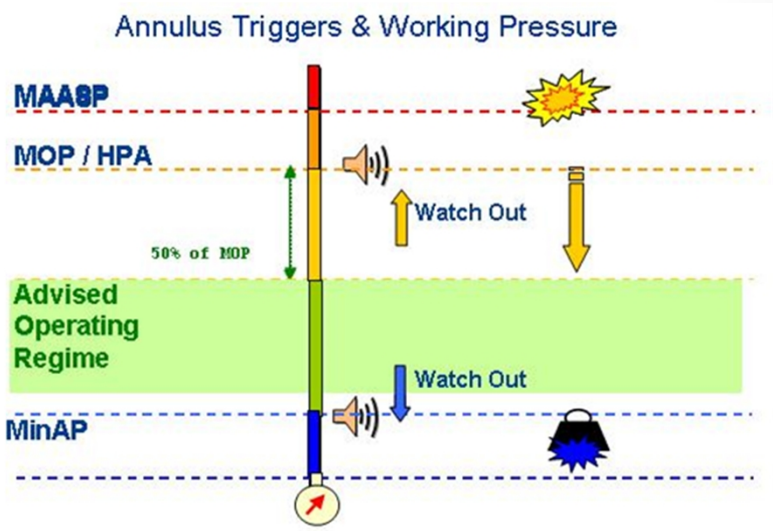
a) Well configuration



b) Temperature profiles

Organizational

- Organizational solutions are also required to ensure the required well integrity is maintained.
- This will include, amongst other things, that the operating company ensures that people with the right competence are working with well operations and that they are up to date with the latest well status.



Summary

- Compendium developed called: An Introduction to Well Integrity
- Introductory material for drilling people
- Based on NORSOK D-010 and OLF 117
- Objective is to introduce well integrity early and establish as a basis for all work
- The compendium is a pre-requisite for the standards, separate training in the standards must be done later

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