Assessing Well Integrity Risk; A Qualitative Model

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Jerry Dethlefs is a Well Integrity and Diagnostics Engineer, retired from ConocoPhillips after 27 years with the company and 36 years in the oil & gas industry. His experience includes well operations, intervention, production operations, and drilling.

For the past 18 years his focus has been on well integrity issues including policy, diagnostics, best practices, program management, risk assessments and regulatory compliance. Jerry has managed Well Integrity programs in both an operating unit (Alaska) and at the corporate level (Global Wells, Houston, Texas).

Jerry has been an active contributor to SPE and industry forums. He was a Distinguished Lecturer during the 2010-2011 tour season and is a Technical Paper Reviewer. In addition, he has authored or co-authored papers on well integrity issues, provided training seminars and has been an SPE Well Integrity conference committee member. Jerry was also a committee member for Well Integrity documents API 90 and 91, and ISO 16530.

Jerry has a Bachelor of Science (BS) in General Engineering, a Master of Science in Civil Engineering (MSCE, Environmental) and a Masters of Business Administration (MBA) from Oregon State University.

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AGENDA

- Introduction
- *Your* job responsibility and objectives
- Complications
- Well Integrity Risk Assessment method

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POLL

What is your primary job discipline?

WELL INTEGRITY

The application of technical, operational and organizational solutions to reduce the risk of uncontrolled release and/or unintended movement of well fluids throughout the lifecycle of the well *(NORSOK D-010)*

- Equipment, procedures and people working together
- Risk will be reduced, but not totally eliminated
- Goal is to keep all process fluids "in the pipe"
- Unintended movement may be within the well, not just external
- WI is a lifecycle process, from design to Plug & Abandon and beyond

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IN A NUTSHELL-

Well Integrity is the mechanical health of a well throughout it's lifecycle

Includes:

- Initial design elements that consider WI
- Clear requirements for proper operation
- Programs to monitor, investigate, and address WI issues
- Commitment of resources for the program
- Scope: Reservoir rock face to the downstream side of the wing valve

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ASSET INTEGRITY

An asset has integrity when it performs as intended and is operated and maintained within its design parameters at an acceptable risk over its entire service life ConocoPhillips

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SITUATION

Your job: Well Integrity Engineer

Your task: Ensure your company wells have integrity and the risk of an unintended release or incident is minimal

Your problem: Where do you start?

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GIVEN

- Limited resources
- Limited data
- High ***likelihood*** of an adverse well event
- High ***consequences*** of an adverse well event

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COMPLICATIONS

- Perceived risk versus actual risk; how do I focus on the right thing?
- How do you determine the risk of a well that has a problem?
- How do you determine the risk of a problem before it takes place?
- How do you know where your greatest risks are?
- How do you prioritize if you have limited resources?

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COMPLICATIONS

- What if you have 50, 100 or 1000 wells?
- What if there is a variety of well types?
- What if there are multiple field locations?
- How do you compare risk of different well types or locations?
- Where can you get the information you need?
- How can you present a plan to management?

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WELL INTEGRITY MANAGEMENT

Various methods for managing Well Integrity, depending on:
- Dedicated staff versus dual-role staff or contractors
- Historical record availability and data retention methods
- Ease of performing or obtaining diagnostic data
- Level of personnel experience available
- Use of Well Integrity Management System (WIMS) software
- Organizational structure and authority levels

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OPTION 1: REACTION

Act on known well problems, address future problems as they arise

- Reactive "shotgun" approach
- Ignores unknown or undiagnosed conditions
- Eliminates options for preventative interventions
- May result in unplanned releases or incidents

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OPTION 2: AOF PRIORITIZING

Use Absolute Open Flow potential as pseudo risk rank (loss of wellhead)

- Only valid if losing well control is a likely scenario
- Ignores risk conditions such as tubular corrosion, annular pressure, gas migration, subsidence, location, etc.
- May only apply to producers
- Will not produce accurate risk profile across all wells

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OPTION 3: SURVEY EVERY WELL

Perform diagnostics on all parts of all wells to determine status

- Minimal consideration for risk to implement
- Expensive
- Time consuming
- Labor intensive
- Impractical use of resources

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OPTION 4: PREFERRED

Determine risk profile of well inventory and apply resources to reduce high risk first

- Reduce high risk situations to an acceptable level
- Reduce overall risk, getting most "bang for the buck"
- Provides guidance for actions, basis of Well Integrity Program
- Understood by management, helps with acquiring resources

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POLL

How does your company manage/prioritize well integrity resources?

RA METHODS

There are several methods to assess risk, each has advantages and disadvantages. In general---

- ***Quantitative*** methods require information, statistics, failure data, all of which is limited for Well Integrity failures
- ***Qualitative*** methods rely on the experiences and knowledge of personnel; a multi-disciplined group can provide a thorough analysis and assessment of risk

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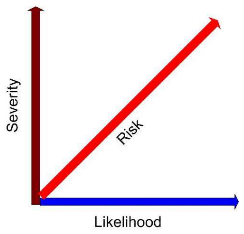
WHAT IS RISK?

Mathematically speaking:

Risk is a combination of the ***Severity*** of the consequences of an unfavorable event and the ***Likelihood*** that the event will occur.

Risk = Severity X Likelihood



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QUALITATIVE RA – PROVEN METHOD

A process to evaluate Well Barriers:

- Evaluates all types and number of wells to a single risk scale
- Can sort by risk rank, identify high risk scenarios
- Helps determine resources required
- Provides suggestions for mitigation actions
- Provides reference for barrier failures that may actually occur
- Documents RA process, participants and outcomes
- Provides guidance for WI program
- Communication tool for management

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FORMAT

- Qualitative, team-based, facilitated brainstorming process
- 'What-If' Method to identify well barrier failure modes
- Assess one well barrier failure at a time, not multiple failures
- Consequences and likelihood determined for each mode
- Relies on experience and knowledge of participants
- Results are recorded in Risk Register

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RA TEAM MEMBERS

Sponsor: Management role providing resources, support, expectations

Facilitator: Keeps large group on task and productive

Scribe: Captures the issues, risk rank information, mitigation suggestions

Technical Resource: Coordination of RA process, team selection, logistics, data preparation, and details for each well type to be assessed

Technical Experts (6-12): Variety of disciplines for different perspectives, experienced, including members from outside of the asset

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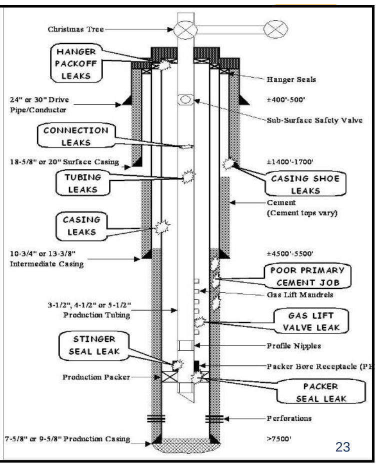
FAILURE MODES

Potential Leak Paths in a Well

Each segment requires evaluation



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WELL BARRIER

An envelope of one or several barrier elements which act together to prevent fluids or gases from flowing unintentionally from the formation, into another formation or to surface.

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Examples of well barriers include:

- Tubing, packer and casing below packer
- Tubing, packer and casing above packer ('A' annulus)
- Production casing, Surface Casing and casing shoe ('B')
- Inability for well to "flow to surface" without artificial lift
  - Well will die if flows to atmosphere

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WELL BARRIER

Conditional Barrier: A combination of barrier elements that constitutes a containment envelope where:
- Barrier elements cannot be tested or has not been tested to envelope pressure rating; and/or
- Barrier elements positively tested where a leak is known to exist (less than the test detection threshold)

Administrative Controls: A policy, procedure, or program in place to detect, prevent, mitigate, or control consequences.
- Considered a Conditional Barrier

Note: Only used in assessment process, not in real life!

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WELL BARRIER PHILOSOPHY

- Every well should have at least two barriers between the reservoir and atmosphere
- Primary well barriers must be strong enough and tested to contain the highest expected pressure from the well
- Backup barriers should be tested and have the ability to contain the maximum expected pressure present in the adjacent interior envelope
- If the primary barrier develops a leak, the secondary barrier will contain the well fluids and pressure

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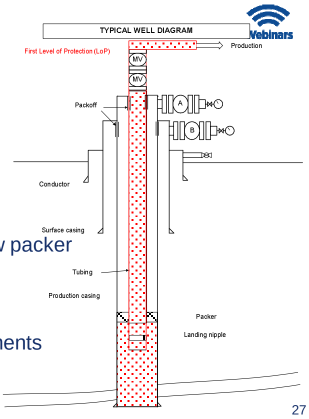
PRIMARY BARRIER

Well in service

Note: Some areas may use a slightly different primary barrier plan



Barrier Elements:
- Casing and cement below packer
- Packer
- Tubing string
- Tubing packoff assembly
- Tree and flowline components

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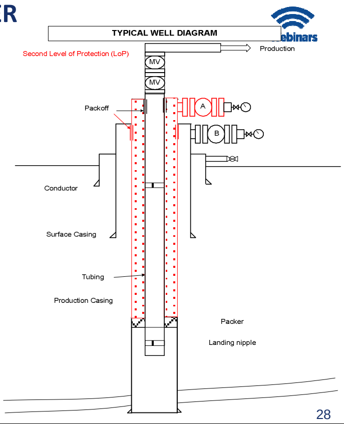
SECONDARY BARRIER



Barrier Elements:
- Production casing
- Packer
- Casing packoffs
- A annular valve

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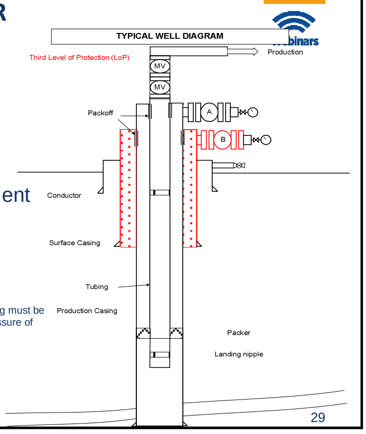
TERTIARY BARRIER



Barrier Elements:
- Surface casing and cement
- Casing packoffs
- B annular valve

Note: To be considered a barrier the pressure rating must be high enough to contain the maximum expected pressure of adjacent annulus

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HAZARD ANALYSIS

- Divide well barrier envelopes into segments
- “Fail” each segment, one at a time
- Determine consequences of failure
- Determine likelihood of failure
- Calculate risk (likelihood x consequence)
- Suggest mitigation options to reduce risk
- Continue until every segment is assessed
- Compile all data in risk register tables

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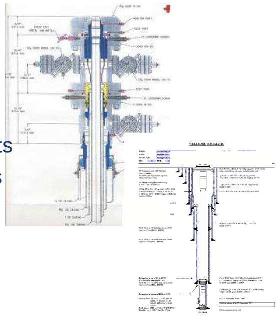
REFERENCE INFORMATION

- Wellbore schematic diagrams
- Well barrier diagrams
- Drilling and completion reports
- Production data
- Intervention and diagnostic reports
- Wellhead / facility / flowline specs
- Operations SOPs / policies
- Regulatory requirements



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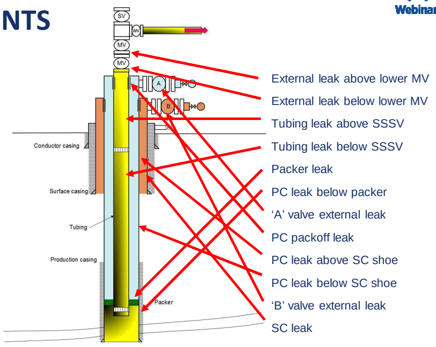
EXAMPLE SEGMENTS



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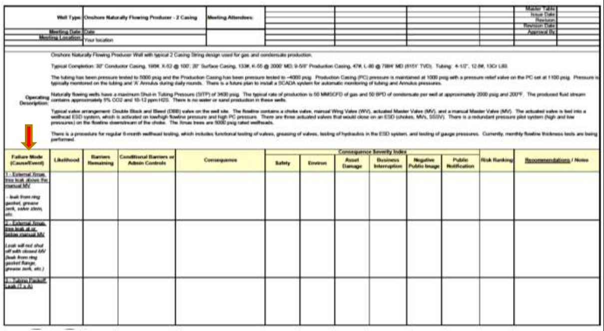
RISK REGISTER DATA



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CONSEQUENCE TABLE

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Category	Safety	Environment Impact (Remediation)
5	Fatality, Public Hospitalization, or Severe Health Effects	> $10 MM
4	Permanent Disability, Multiple Hospitalizations, or Major Health Effects	$1 MM to $10 MM
3	One or More Lost Time Workday Cases or Significant Health Effects	$100 M to $1 MM
2	Medical Treatment with Restricted Duty or Medium Health Effects	$10 M to $ 100M
1	Medical Treatment, Minor Health Effects, First Aid Case, or Less	$ 0 to $10 M

These categories are optional---

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LIKELIHOOD TABLE

Webinars

Category	Descriptor	Definition
5	Frequent	Occurs several times a year
4	Probable	Occurs once/10 years to annually
3	Occasional	Has occurred but rare (< once/10 years); heard of it in local area
2	Remote	Not expected nor anticipated to occur, but has happened before; heard of it in industry
1	Improbable	Virtually improbable and unrealistic but possible; never heard of it occurring

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RISK MATRIX

Webinars

Risk Matrix

LIKELIHOOD	CONSEQUENCE 1	2	3	4	5
5	II 5	II 10	III 15	IV 20	IV 25
4	I 4	II 8	III 12	III 16	IV 20
3	I 3	II 6	II 9	III 12	III 15
2	I 2	I 4	II 6	II 8	II 10
1	I 1	I 2	I 3	I 4	II 5

Risk: (Likelihood **X** Consequence)

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RISK CATEGORIES

Risk Categories		
IV 17-25	High	**High Risk**. Manage risk utilizing prevention and/or mitigation ***with highest priority***. Promote issue to appropriate management level with commensurate risk assessment detail.
III 12-16	Significant	**Significant Risk**. Manage risk utilizing prevention and/or mitigation ***with priority***. Promote issue to appropriate management level with commensurate risk assessment detail.
II 5-10	Medium	**Medium Risk with Controls Verified**. No mitigation required where controls can be verified as functional. **ALARP** should be evaluated, as necessary.
I 1-4	Low	**Low Risk**. No Mitigation Required

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RISK REGISTER

- One table per well type - complete description
- Reference for real wells that fit type category
- Documents all assessed failure modes
- Capture suggestions to reduce risk

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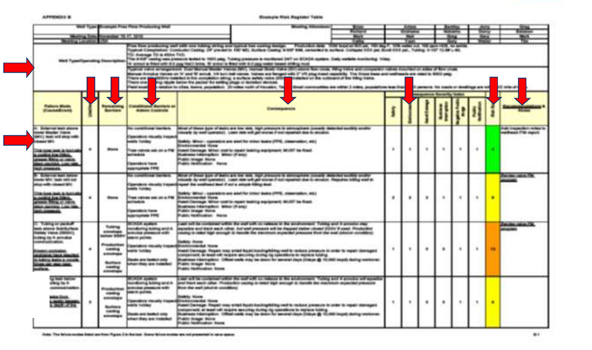
EXAMPLE RISK REGISTER



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WELL DATA

- **Offshore Naturally Flowing Producer** Well with typical 2 Casing String design used for gas and condensate production.
- Typical Completion: 30" Conductor Casing, 196#, X-52 @ 100'; 20" Surface Casing, 133#, K-55 @ 2000' MD; 9-5/8" Production Casing, 47#, L-80 @ 7984' MD (6151' TVD). Tubing: 4-1/2", 12.6#, 13Cr L80.
- The tubing has been pressure tested to 5000 psig and the Production Casing has been pressure tested to ~4000 psig. Production Casing (PC) pressure is maintained at 1000 psig with a pressure relief valve on the PC set at 1100 psig. Pressure is typically monitored on the tubing and 'A' Annulus during daily rounds. There is a future plan to install a SCADA system for automatic monitoring of tubing and Annulus pressures.
- Naturally flowing wells have a maximum Shut-in Tubing Pressure (SITP) of 3400 psig. The typical rate of production is 50 MMSCFD of gas and 50 BPD of condensate per well at approximately 2000 psig and 200 F. The produced fluid stream contains approximately 5% CO2 and 10-12 ppm H2S. There is no water or sand production in these wells.
- Typical valve arrangement: Double Block and Bleed (DBB) valve on the well site. The flowline contains a choke valve, manual Wing Valve (WV), actuated Master Valve (MV), and a manual Master Valve (MV). The actuated valve is tied into a wellhead ESD system, which is activated on low/high flowline pressure and high PC pressure. There are three actuated valves that would close on an ESD (chokes, MVs, SSSV). There is a redundant pressure pilot system (high and low pressures) on the flowline downstream of the choke. The Xmas trees are 5000 psig rated wellheads.
- There is a procedure for regular 6-month wellhead testing, which includes functional testing of valves, greasing of valves, testing of hydraulics in the ESD system, and testing of gauge pressures. Currently, monthly flowline thickness tests are being performed.

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HEADER - WELL DATA


Well Integrity Risk Register Table

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WELL TYPES

For multiple well assessments:

- Divide portfolio into category "types" of similar design and/or service
- Goal: Define categories so all wells are included for analysis
- Large number of wells in few categories

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WELL TYPES

- Water Injection Wells - 2 Casing Strings
- Oil Producer Wells: Sucker Rod Pump - 3 Casing Strings
- Naturally Flowing Gas Producer Wells - 2 Casing Strings
- Naturally Flowing Gas Producer Wells - 3 Casing Strings
- Subsea Naturally Flowing Gas Producer Wells - 2 Casing Strings
- Offshore Artificial Gas Lift Oil Producer Wells - 2 Casing Strings
- Offshore - Subsea Natural Flowing
- Offshore - Platform Natural Flowing
- Offshore - Platform Gas Lifted
- Offshore - Platform Non-Hydrocarbon Injector
- Onshore - Artificial Lift (Gas Lift)
- Onshore - Non-Hydrocarbon Injector
- Onshore – EOR water injector

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DELIVERABLES

- Risk register table for each well type
  - Failed well barrier scenarios
  - Risk ranking
- Potential mitigation actions to reduce risks
- Report of purpose, methodology, participants, and findings
- Participants benefit from process
  - Excellent learning tool

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POST RA – APPLY TO REAL WELLS

- Analyze real wells for fit with Risk Register
- Sort wells by risk rank
- Take action

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POST ASSESSMENT ACTIONS

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- Risk rank results considered by asset
- Evaluate and implement mitigations
- Potential for new or modified Ops procedures
- Influence Well Integrity Program
- Review and/or repeat at 3-5 year intervals

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SUMMARY

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WI RA provides an organized method to:

- Identify WI risk situations
- Rank risk exposure by severity
- Provide potential mitigation actions
- Focus resources for most benefit
- Reduce overall WI risk exposure
- Assist communication with management

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QUESTIONS?

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Thank-You for Your Interest and Participation!

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ACKNOWLEDGMENTS

Webinars

ConocoPhillips for understanding the importance of Well Integrity and incorporating it into the business culture

SPE for sharing and promoting Well Integrity throughout the industry

Reference:
SPE 142854-PP, "Assessing Well Integrity Risk, A Qualitative Model"
J.C. Dethlefs, SPE, ConocoPhillips; and B. Chastain, Arktis LLC

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