Success Paths: A Risk Informed Approach to Oil & Gas Well Control

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Outline

- Understanding and Characterizing Risk
- The Success Path Approach
- A Drilling Example using Success Paths
- A Coiled Tubing Example using Success Paths
  - Barriers; Success Path; FMECA support; Response
- Insights learned by applying the Success Path Approach to Coiled Tubing Operations
Two Risk Allies: Process Integrity and Industrial Safety (HSE)

The BIG Accidents are Process Integrity* Related:
- Multiple fatalities or permanent total disabilities
- Extensive damage to the installation
- Severe impact to the environment

Industrial Safety (HSE)
- Focus on Individuals (personal safety)

The two risk allies require COMPLEMENTARY approaches for Analyzing and Assessing Risk

*Also known as Operational Risk in the IADC Deepwater Well Control Guidelines 2nd Ed., 2015
Different ways of Understanding and Using the term “Barriers”

Process Integrity

“Barriers” are Physical Objects

Casing, Cement, Fluid Column, BOPs, Valves, Pipelines, ...

Are “Barriers” – Physical Barriers

Equipment, procedures, people, training ...

Are important BECAUSE they support the Physical Barriers.

Industrial Safety

“Barriers” are often described metaphorically

People, Procedures, Training, Meetings, ...

Are considered to be “Barriers”

Physical and Metaphorical Barriers are often treated the same -- but in reality, they are not the same. .
Where Does Operational Risk Come From?

Proposal:
Operational accidents occur when a required physical barrier is breeched, non-functioning, or is absent

(A barrier focus model is widely used in nuclear, maritime, aerospace, and other industries)

Operational Risk/Safety is about **Barrier Assurance**
One Way To Characterize Operational Risk:
“What can go Wrong”

Many, many paths can go wrong:
- a broken washer …
- not enough lubrication …
- improper equipment use …
- procedures too difficult …
- training missed a topic …
- distraction …
- overseers not overseeing…
  - …
  - …
  - …
  - …
Characterize Operational Risk by Success: “What MUST go RIGHT”

There is a manageable number of steps that must go right

Design for Success

Economics favor this approach
Barrier Assurance: Success Path + Effective Response

- **Knowing** what/where the tested barriers are
- **Knowing** what is needed to make the barriers work
  - Success Paths e.g. Design, Construction (installation, testing), Operation, Maintenance, support systems needed (hydraulic power)
  - How success paths relate to each other
  - FMECA supports success paths
- **Knowing** when there is a barrier problem
- **Knowing** when/how to respond to barrier problems
  - Capability to respond must be “designed in”
Success Paths: A Drilling Example

- Identify the Physical Barriers
- Create a Success Path for each barrier
TIW Valve (FOSV) Success Path

- Design (to support fluid containment)
  - Rated and tested to withstand anticipated well pressures

- Operation (to support use of the TIW Valve)
  - Valve operational and accessible on the Rig Floor
  - Valve in open state
  - Correct threads for current operation
  - Operating wrench present
  - Drill pipe at working height
  - Lift device available
  - Trained personnel available

If any of these are missing, you don’t have a barrier!

The well must NOT be flowing or spewing in a way that keeps available personnel from being able to install the TIW Valve
Success Path: TIW Valve (FOSV)

- Identify key support systems e.g. hydraulic power
- Identify backup barriers if this fails
- Use FMECA if desired

Diagram supports risk quantification

### FOSV Critical Safety Function

**Alternate Success Path(s)**

1. **Identify key support systems**: e.g. hydraulic power
2. **Identify backup barriers if this fails**
3. **Use FMECA if desired**
4. **Diagram supports risk quantification**

### Critical Support Systems

- Electrical power needed to operate crane/lifting device (if required)

### Limitations

- This is a manual operation, and may be far more difficult during bad weather and unfavorable working conditions. Flowing wellbore fluids may limit workers ability to install the FOSV.

#### Diagram:

**Physical Barrier: Full Opening Safety Valve (FOSV)**

- Sunburst diagram illustrating the various steps and conditions required for success.
- Key symbols and notation for logical operations (AND, OR, etc.).

**Success Path:**

- TIW Valve (FOSV)

**Applicability**

- Drilling, Completions & Workovers

**Critical Safety Function**

- Keep Fluids Contained Inside of Drill Pipe or Tubular

**Success Path(s):**

- Design Supports Fluid Containment
- Confirm FOSV is Rated for MASP*
- Operation Supports Fluid Containment

**Limitations:**

- This is a manual operation, and may be far more difficult during bad weather and unfavorable working conditions. Flowing wellbore fluids may limit workers ability to install the FOSV.
The Coiled Tubing String Barrier Component

Includes CT Design and Inspection

Includes tracking of service life and operations to assess fitness for purpose

In Effect we are *designing* the barrier for success
A CT Example

- Identify the Physical Barriers and Their Components
- Know the Success Paths for Each Barrier
<table>
<thead>
<tr>
<th>CT Barrier</th>
<th>Barrier (component)/Operational Equipment</th>
<th>Main Function</th>
<th>Support Equipment</th>
<th>Success Path Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT Barrier 1 Components</td>
<td>Pipe Ram</td>
<td>Closes on Demand onto CT OD and Isolates Annulus Pressure</td>
<td>Hydraulic power, ram lock(s)</td>
<td>Figure 26, Figure 32</td>
</tr>
<tr>
<td></td>
<td>Downhole Flow Check Device</td>
<td>Seals and Holds Annulus Pressure from CT ID Pressure</td>
<td>N/A - passive barrier component (PBC)</td>
<td>Figure 28</td>
</tr>
<tr>
<td></td>
<td>Coiled Tubing String</td>
<td>Isolates CT ID Pressure/Flow Path from Annulus Pressure/Flow Path</td>
<td>Injector, Support Systems</td>
<td>Figure 27</td>
</tr>
<tr>
<td>CT Barrier 2 Components</td>
<td>Blind Ram</td>
<td>Closes on Demand to Seal Across ID Bore of Stack and Contain Wellbore Pressure</td>
<td>Hydraulic power, ram lock(s)</td>
<td>Figure 29, Figure 32</td>
</tr>
<tr>
<td></td>
<td>Shear Ram</td>
<td>Closes on Demand to Shear the Tubing and Provides Means for Blind Ram to Properly Close and Seal Wellbore</td>
<td>Hydraulic power</td>
<td>Figure 30, Figure 32</td>
</tr>
</tbody>
</table>
Coiled Tubing String 
Isolates CT I.D. 
Pressure from 
Annulus Pressure

AND

Coiled Tubing String 
Set 
Up and Validated to 
Withstand External and 
Internal Pressure

AND

Coiled Tubing String 
Operated and 
Monitored to Ensure 
Continued Coiled Tubing 
Body Integrity

AND

Inspect O.D. Surface of 
Coiled Tubing String 
Body

AND

Monitor and Record 
Bend Cycles and 
Internal Pressure

AND

Monitor and Record 
String Repairs and 
Maintenence

AND

Monitor and Record 
Service History

AND

Utilize Bend Cycle 
Fatigue History to 
Anticipate Crack 
Initiation

Coiled Tubing String 
Designed and 
Configured to Isolate CT 
I.D. Pressure from 
Annulus Pressure

Coiled Tubing String 
Rated to Withstand 
Internal and External 
Pressures for the 
Prescribed Job

One can Design the 
System to minimize risk …

Opposite of a fault tree

Includes tracking of 
service life and 
operations to assess 
fitness for purpose
Consider the CT Shear Blind Ram Barrier
Shear-Blind Ram Closes on Demand to Shear the CT* and Seal Across ID Bore of Stack to Contain Wellbore Pressure

- Hydraulic Power
  - OR
    - Pump Feed Supports Simultaneous Barriers
    - Accumulator Supports Simultaneous Barriers

- Shear-Blind Ram Designed and Configured to Shear Coiled Tubing and Contain Pressure
  - AND
    - Shear-Blind Ram Designed to Shear O.D. Size, Wall Thickness, and Grade of Pipe
    - Shear-Blind Ram Rated for MASP
    - Shear-Blind Ram Assembly Rated for Required Closing Speed
    - Shear-Blind Ram Assembly Rated to Shear and Seal at MASP

- Shear-Blind Ram Set Up and Validated to Contain Pressure
  - AND
    - Functionality Testing Demonstrates Shear-Blind Ram Closes on Demand
    - Pressure Testing Demonstrates Shear-Blind Ram Contains Pressure

- Shear-Blind Ram Operated and Monitored to Maintain Efficacy

- Shear-Blind Ram Valves in Open Position
  - OR
    - Ensure Accumulator Isolation Valve is Holding Pressure
    - Monitor Closing System Pressure Gauges (and Opening System Pressure Gauges if Available)
    - Ensure That all Relevant Components are Functioning as Expected

*Including all Spoolable Components inside the Tubing Installed for the Service Application
## Barrier Focused FMECA

### Example Consequence and Risk Ranking

<table>
<thead>
<tr>
<th>Consequence Ranking</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System degraded but operational, no direct impact on barrier</td>
</tr>
<tr>
<td>2</td>
<td>System disabled, but alternative system available, no direct impact on barrier</td>
</tr>
<tr>
<td>3</td>
<td>System disabled/degraded with barrier degraded but operational</td>
</tr>
<tr>
<td>4</td>
<td>Barrier disabled, but alternative barrier remains</td>
</tr>
<tr>
<td>5</td>
<td>Barrier(s) disabled, no barriers remaining</td>
</tr>
</tbody>
</table>

### Risk Ranking

<table>
<thead>
<tr>
<th>Consequence Ranking</th>
<th>Occurrence Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
<td>2</td>
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<td>3</td>
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<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Risk Ranking**

- **Low**
- **Medium**
- **High**
A Common CT Power Pack & Console

A single point of failure
A Common CT Console & Controls

A single point of failure
The hydraulic power pack and certain connector hoses are single points of failure.

If these power pack hoses are damaged or ruptured, **ALL** ram functionality will be lost.

One solution is to use a dedicated accumulator:
- Independent hydraulic power system connected to XSBR
- Independent controls (hoses and flow path)

Additionally, the XSBR creates an overall improvement since it provides a fall-back barrier for all the other CT barriers.
The failure rate of critical hoses is not well agreed upon

Reliable occurrence data is needed to properly conduct the FMECA process (or to calculate risk)

- It is imperative that a reliable tracking system be implemented to effectively track key failure rates

Building redundant systems to replace single point failures dramatically enhances safety

- Two barriers between personnel and pressure
Summary

Operational Risk is about *Barrier Assurance*

The Success Path approach:
- Is used to “design in” operational safety
- Communicates Risk in an easy-to-understand way
- Is an effective tool for **building consensus** on Risk
- Enables operational risks to be **compared**
- Supports **quantification** of operational risk

End Result is a *Demonstrably Safer* CT System