Analysis and Discussion of Deepwater Horizon Accident and Barrier Strategies

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Accident Summary

Nov-09						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	**9**	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Dec-09						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Jan-10						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	**14**	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Feb-10						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	**6**
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

Mar-10						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
7	**8**	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Apr-10						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1	**2**	3
4	~~5~~	~~6~~	~~7~~	8	**9**	~~10~~
~~11~~	~~12~~	~~13~~	~~14~~	**15**	**16**	~~17~~
18	**19**	**20**	21	22	23	24
25	26	27	28	29	30	

Comparison to other similar accidents

Similar Blowout Accidents

Macondo 2010

Initiating event- High pressures in the wellbore
Accident Progression- Well abandonment- kick in well- hydrocarbon leak- two explosions
Fatalities- 11 of 126 (9%)

Usumacinta 2007

Initiating event- Bad weather
Accident Progression- Storm- hydrocarbon leak
Fatalities- 22 of 81 (27%)

Enchova 1984

Initiating event- Unknown
Accident Progression- Drilling- Gas leak
Fatalities- 42 of 249 (17%)

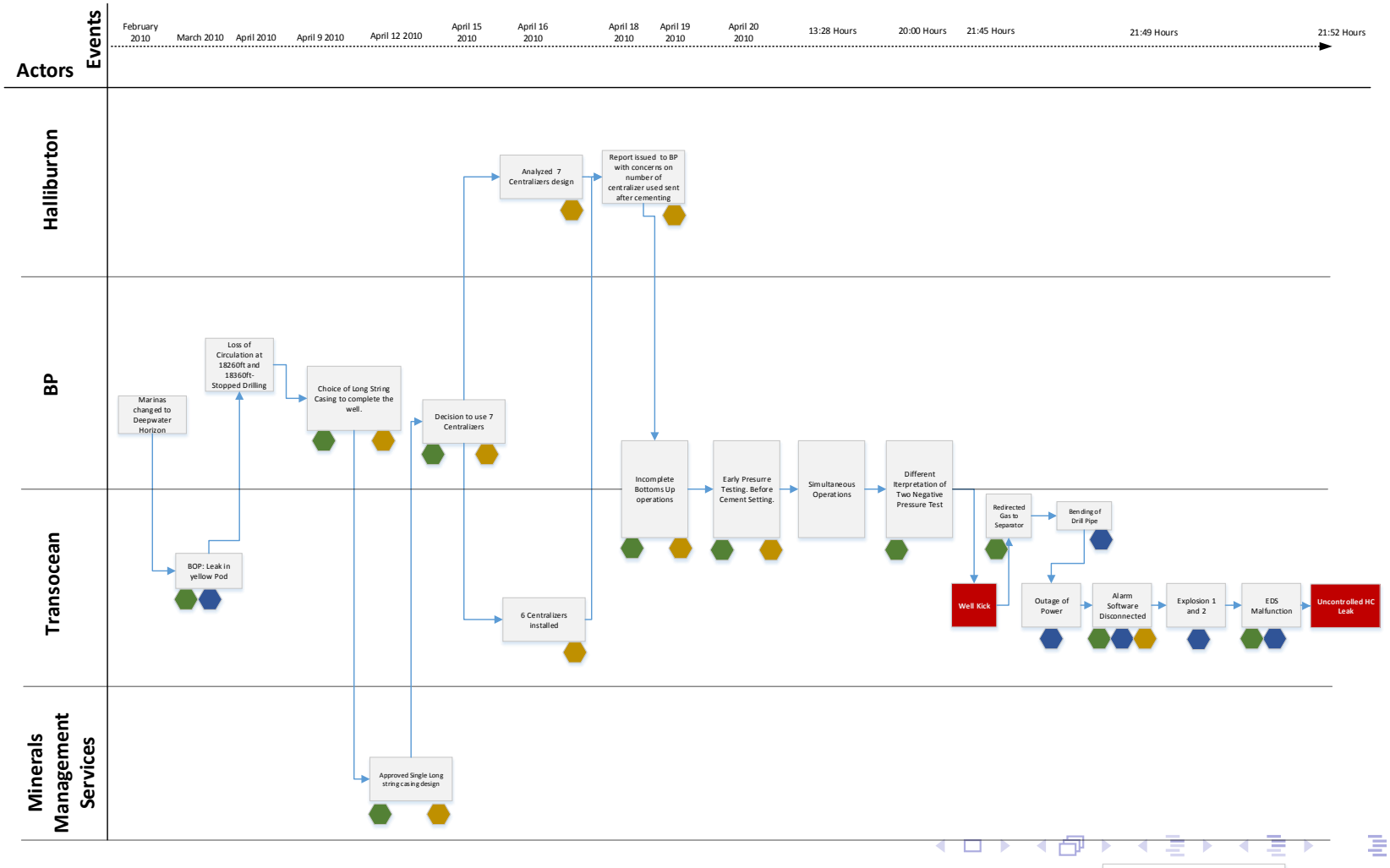
The evacuation process in Deepwater Horizon, did not result in fatalities [Vinnem, 2014].

One could infer that Transocean had better evacuation procedures than PEMEX (Usumacinta) or Petrobras (Enchova).

Texas City Refinery

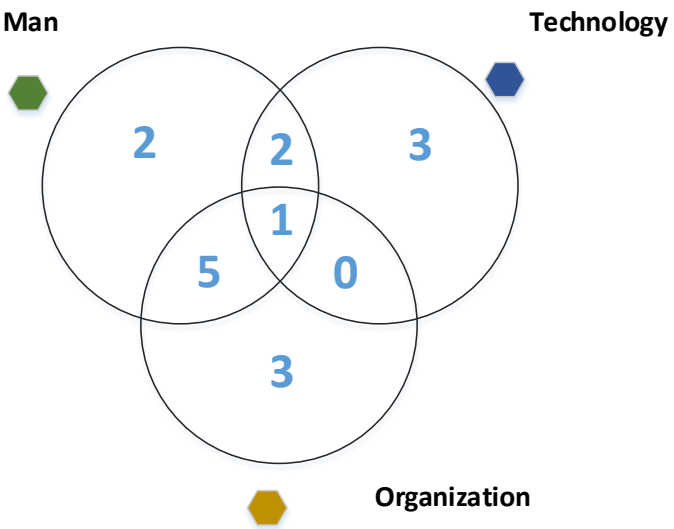
Initiating event- Overfilling of splitter tower.
Accident Progression- Maintenance faults- malfunction of level transmitters- explosion
Fatalities- 15 people
Injured- 170 people

Step Diagram



MTO Analysis

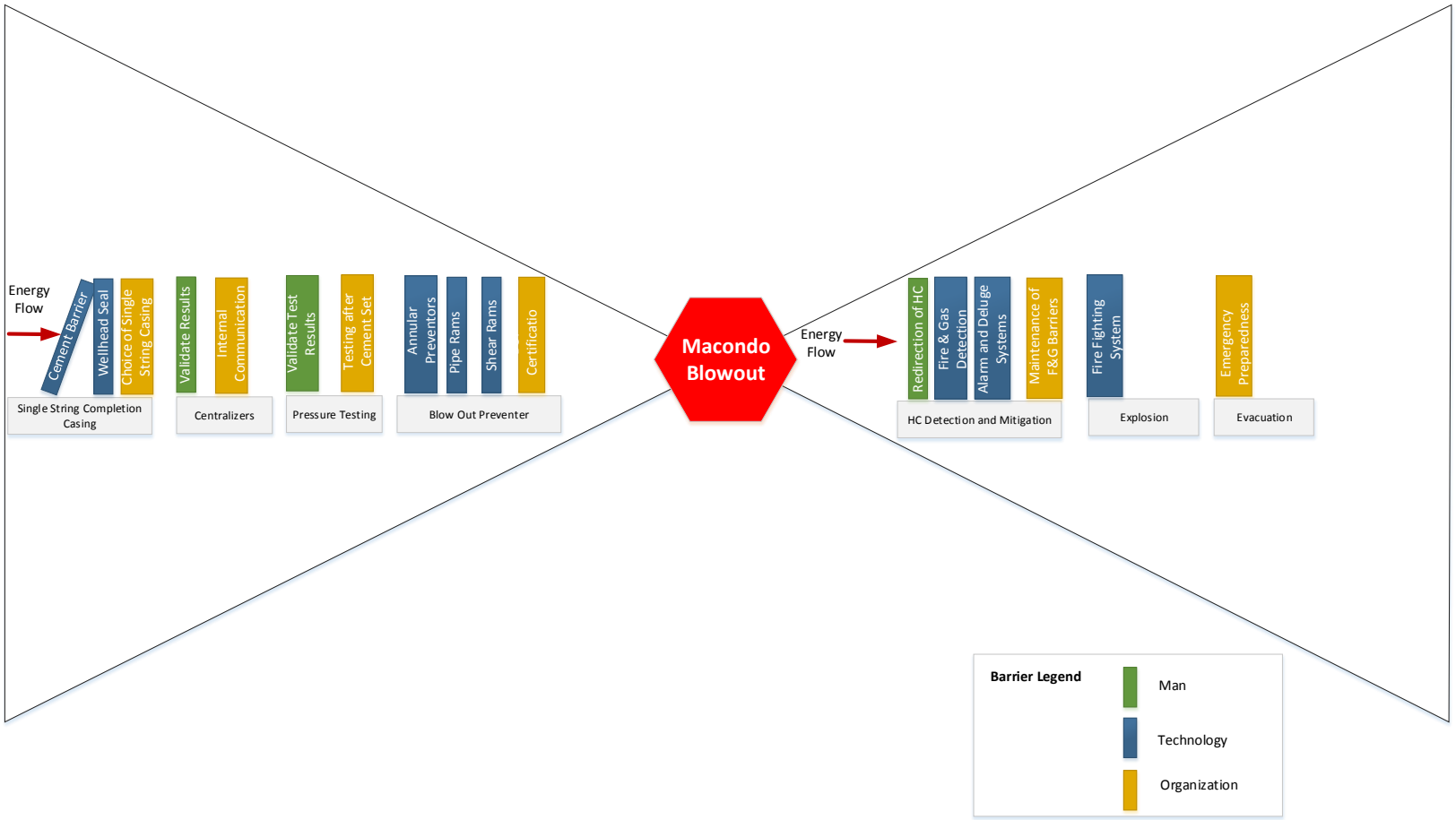
Failed MTO Barriers



Failures in the intersection of man and organizational barriers are higher in number than other categories.

The combination of man and organization resulted in six failed barriers

Bow-Tie Diagram



PSA Barrier Mangement Process

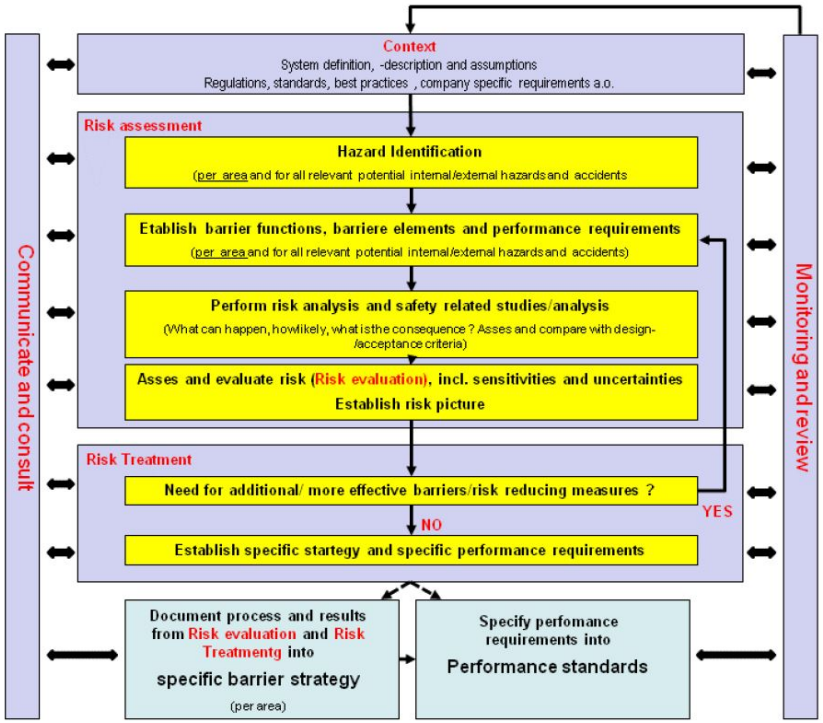


Figure: [PSA, 2013]

Hazard Identification

SL. No.	Generic Hazard	Hazard
1	Mechanical hazards	High/unstable pressure in the well Stability Degradation of equipment
2	Dangerous materials	Flammable
3	Thermal hazards	Flame Explosion Personnel exposed to high temperature and heat radiation
4	Organizational hazards	Safety culture Less than adequate maintenance Less than adequate competence Crowd control

[Rausand, 2011]

Preliminary Hazard Analysis

Terminologies

Generic Hazard

Mechanical, dangerous, thermal and organizational.

Identifier

Identify and arrange different probable causes.

Hazard

Specific hazard in relation to generic hazard.

Accidental Event

Describe what, when, where things can go wrong.

Probable Causes

Causes triggering the accidental event.

Probability

Evaluating likelihood of occurrence of an accident event.

Severity

Evaluating consequences if an accident event occurs.

Initial Risk Level

Factor of probability, severity and lack of preventive measures.

Residual Risk Level

Factor of probability, severity and introduction of preventive measures.

Risk Picture

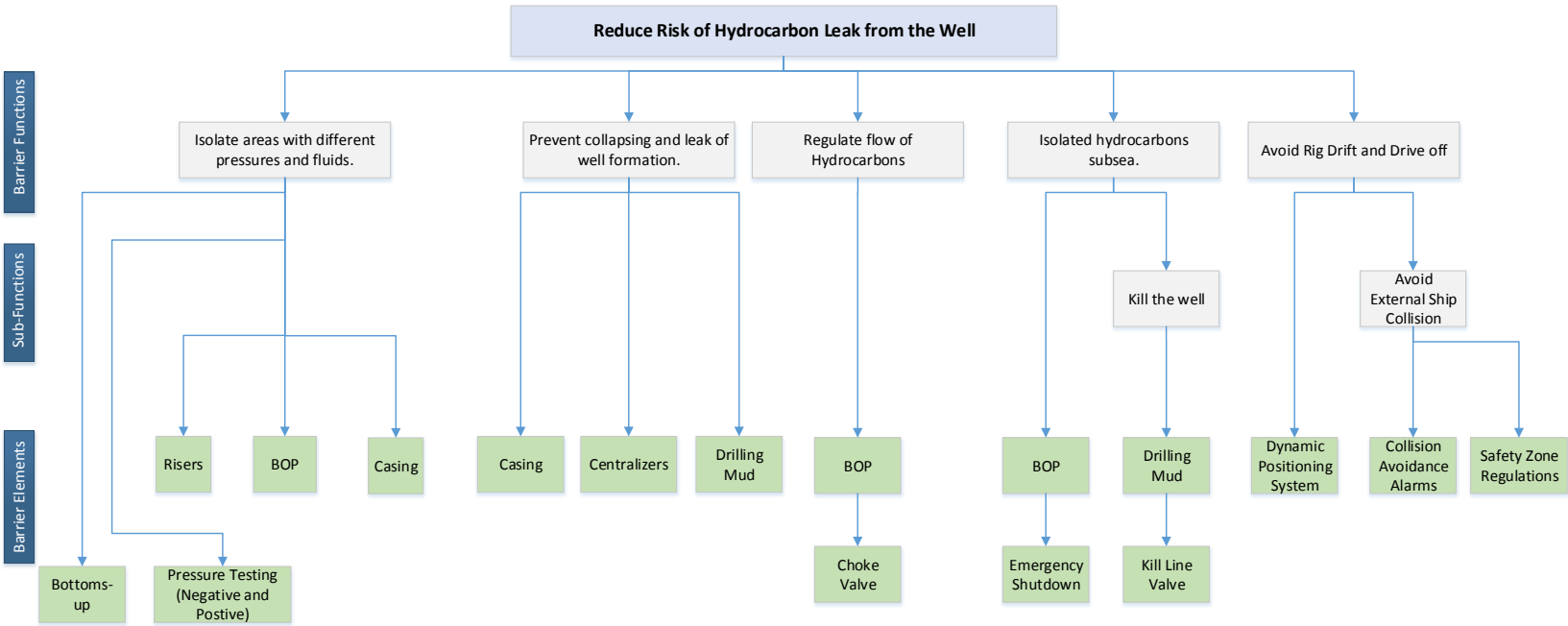
Initial Risk Picture

Frequency/ Consequence	1-Very Unlikely	2-Remote	3-Occasional	4-Probable	5-Frequent
4-Catastrophic			3b, 5e, 5g	1a, 2a, 3a, 5b	
3-Critical		1d	1b, 5f	1c, 5d	4b, 4c, 4e, 5a
2-Major				3c, 5c	4a, 4d
1-Minor					

Residual Risk Picture

Frequency/ Consequence	1-Very Unlikely	2-Remote	3-Occasional	4-Probable	5-Frequent
4-Catastrophic					
3-Critical		1d, 2a, 3a, 3b, 5b			
2-Major		1b, 5d, 5g	1a, 3c, 4a, 4c, 4d, 4e, 5a, 5e, 5f	1c	
1-Minor			5c	4b	

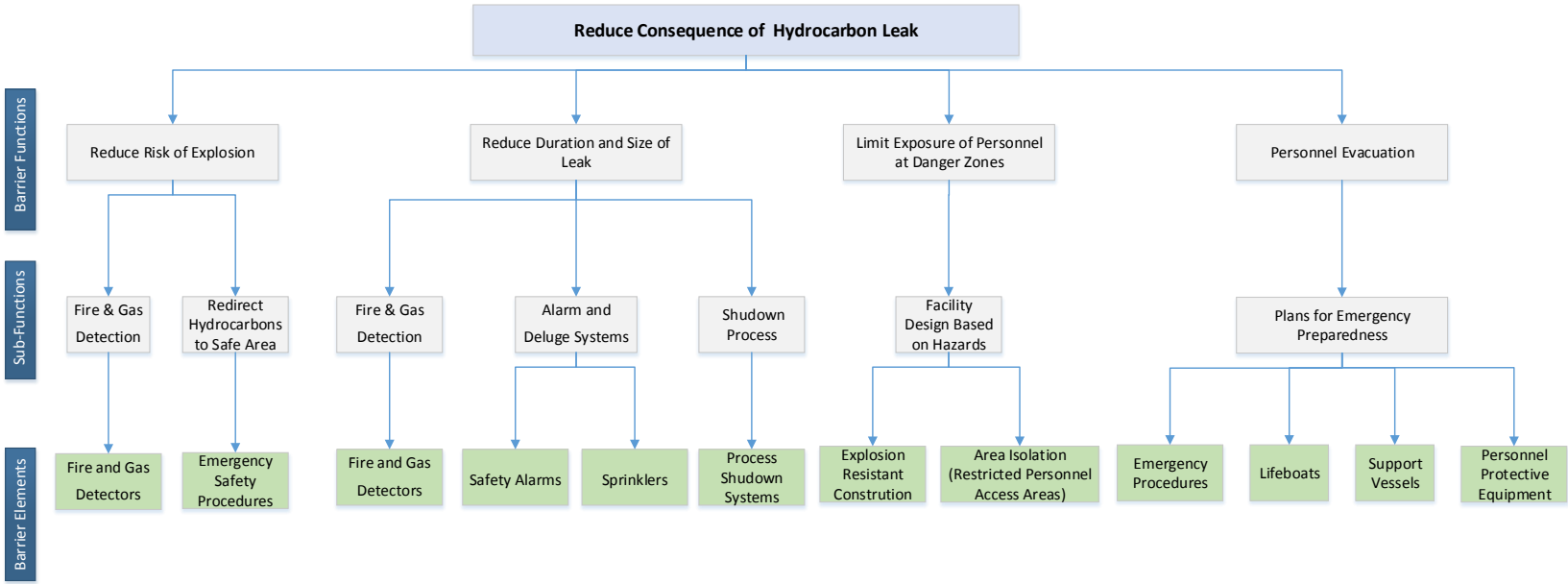
Barriers according to PSA Memo- Part 1



Organization and Man barriers are included in each barrier element because the selection of the above phyiscal barriers depends on the individual/organization perceptions in form of analysis and design.

- Management focus on safety through campaigns. (Top to bottom and bottom to top)
- Accountability of the company towards safety incidents through industry and national regulations
- Establishing single point of contacts and analysing it through Social Network Analysis tools
- Continuous improvement of safety drive in the company and expansion of each project's Risk Analysis Assessment to keep up with changes made to the original plan during the execution phase - continuous reassessment of the risk picture.
- Periodically re-optimize maintenance costs
- Investment in continuous training of personnel in best available safety practices
- Investment in mentoring programmes
- Hiring competent personnel
- Sharing lessons learnt to other companies
- Timely certificaiton and maintenance of safety critical systems

Barriers according to PSA Memo- Part 2



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Barrier Performance Requirement- Functional Level

Barrier	**Performance Standard** (Functionality, Integrity, Vulnerability)	**Performance Standard**
Isolate areas with different pressures and fluids	Functionality	Established pressure limits in various zones
Prevent collapsing and leak of well formation	Functionality	Loss of drilling mud should not exceed the given limit
Regulate flow of Hydrocarbons	Integrity	Minimum failure rate of BOP through quantitative analysis. Example- SIL analysis
Isolated hydrocarbons subsea	Integrity	Minimum failure rate of BOP through quantitative analysis. Example- SIL analysis
Avoid Rig Drift and Drive off	Functionality	Limits and accuracy dynamic positioning system envelopes

Barrier Performance Requirement- Element Level

Barrier	**Performance Standard** (Functionality, Integrity, Vulnerability)	**Performance Standard**
Fire and Gas Detectors	Integrity	Determine acceptable failure rate of detectors through quantitative analysis. Example- SIL analysis
Emergency Safety Procedures	Functionality	Be aligned with the risk picture
Safety Alarms	Integrity	Determine acceptable failure rate of detectors through quantitative analysis. Example- SIL analysis
Sprinklers	Integrity	Determine acceptable failure rate of FF equipment through quantitative analysis. Example- SIL analysis
Process Shutdown Systems	Integrity	Determine acceptable failure rate of Process Shutdown System through quantitative analysis. Example- SIL analysis
Lifeboats	Functionality	Have sufficient capacity to include all personnel onboard the rig
Support Vessels	Functionality	Response to an emergency call within a given time limit
Restricted Personnel Access Areas	Functionality	Normally manned working stations should be sheltered or out of reach from potential explosions caused by HC release
Personnel Protective Equipment	Vulnerability	Guarantees impact and thermal protection to a stipulated level

Barrier Performance Requirement- Organizational Level

Barrier	**Performance Standard (Functionality, Integrity, Vulnerability)**	**Performance Standard**
Management focus on safety through campaigns	Functionality	Commit management time to safety activities. Safety walk. Walk-Observe-Feedback.
Accountability of the company towards safety incidents through industry and national regulations	Functionality	Social corporate responsibility drive
Establishing single point of contacts and analyzing it through Social Network Analysis tools	Functionality	Make contact information of single points of contact public and know
Continuous improvement of safety drive in the company and expansion of each projects Risk Analysis Assessment to keep up with changes made to the original plan during the execution phase - continuous reassessment of the risk picture.	Functionality	Risk Analysis Assessments should be reviewed at fixed intervals during planning phase and whenever a major modification to plan occurs during project execution
Periodically re-optimize maintenance costs	Functionality	At predetermined given time intervals, aiming to cut a given percentage of labor

Barrier Performance Requirement- Organizational Level

Barrier	**Performance Standard (Functionality, Integrity, Vulnerability)**	**Performance Standard**
Investment in continuous training of personnel in best available safety practices	Functionality	Annual evaluation of relevant technical knowledge
Investment in mentoring programmes	Functionality	Ensure mentoring program for new employees
Hiring competent personnel	Functionality	Assessment of technical knowledge and personality
Sharing lessons learnt to other companies	Functionality	Target number of published industry white papers
Timely certification and maintenance of safety critical systems	Integrity	Traceability of equipment and process certificates

Conclusion

1. Complex systems = complex accident propagation
2. Risk analysis must be performed and updated
3. Barrier management is paramount
4. Organizational and human barriers are constantly in demand during accident progression
5. Systems safety should not be neglected in favor of traditional HSE indicators

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