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Optimising Barrier Management

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Summary

This paper is an abstract of the thesis study report issued for the postgraduate Masters in Management of Safety, Health and Environment, titled as Optimising Barrier Management. The thesis study is initiated due to findings of the Health and Safety Executive’s Key Programme 3 – Asset Integrity Programme. This concluded that the Oil and gas industry is not fully aware of the potential impact of degraded barriers as well as the concept of barriers in managing major hazard risks. Venture considers better control of barriers a means to improve control of major accident hazards. The thesis study has looked closer at barrier management and focussed on the following research question:

“How can Venture Production Nederland BV improve the management of barriers devised to prevent major accident hazards?”

The problem solving cycle from Hale’s model was used to position the study. The benefit of this model is that it provided a structured approach in the assessment.

From the assessment the following conclusions could be drawn:
1. The brainstorm sessions have concluded in 11 bow-ties, which depict the major hazards for Venture’s organisation. It has resulted in 847 independent and multifunctional barriers.
2. Within Venture, barriers are managed through audit, monitoring and review processes; however, no consideration is given to barriers being multifunctional and/or critical.
3. Barriers currently used in the branches are not all independent.
4. The consequence of failure of a critical barrier is a higher probability of a major accident event occurring. The PTW system was selected for further evaluation as it was the most deployed barrier. The aspect of a failing Permit to Work system its consequences and the statistical consequences in the chain of causation concluded that an IRPA (Individual Risk Per Annum) could increase momentary with a factor 144. The increase due to a failure of a PTW system is a momentary peak causing higher risk levels.
5. Failure probabilities may increase over time in relation to the current maintenance strategy.
6. It can be concluded that the management of barriers needs to be improved. The current situation is not as safe as we believe it to be, bearing in mind the aspect of aging installations. It can be concluded that this thesis has provided another way of thinking in barrier management.

From the conclusions, recommendations for improvement in management of barriers can be made, namely:
1. All critical barriers are to be evaluated according to the action plan as depicted in figure 3 on page 12, in order to define the adequacy of the critical barriers. It is recommended to do this evaluation for all Venture assets not only Venture Production Nederland BV assets.
2. The 11 bow-ties are living documents and subject to change. It is recommended to review the bow-ties after any major modification or at least bi-annually.
3. Adopt an audit, monitoring and review processes for barriers, specifically critical barriers.
4. Develop a Leading Key Performance Indicator on the performance of critical barriers for the Management Team to monitor the performance on a monthly basis.
5. Evaluate true independency of barriers in the bow-ties.
6. It is recommended to do further analysis on human error probabilities i.e. failure of a PTW system in QRA calculations.

Further Research
1. Further research is required in order to evaluate Venture’s maintenance strategy from a static- to a dynamic perspective i.e. to cater for the factor age.
2. Venture should do further research in evaluating their QRA methods. Currently no consideration is given to degradability over time.
Additionally a recommendation can be made for the Oil and Gas Industry:
1. As this is an industry wide issue, it is recommended to start a NOGEPA workgroup on barrier management populated by Safety Professionals from the Oil and Gas Industry.

Introduction

In November 2007 the United Kingdom Health and Safety Executive issued the findings of their Key Programme 3 – Asset Integrity Programme [1]. Some conclusions are:
1. The state of plant was often not understood because of the complexity of categorising and recording equipment, which was overdue for maintenance or found to be defective.
2. Significant improvement in maintenance systems could be achieved by improved training and a clear statement of performance standards in testing and maintenance routines.
3. There is a poor understanding across the industry of potential impact of degraded, non-safety critical plant (barriers) and utility systems on safety-critical elements (barriers) in the event of a major accident.
4. The role of asset integrity and the concept of barriers in major hazard risk control is not well understood.
5. Companies need better key indicators of performance available at the most senior management levels to inform decision making and to focus resources.

Conclusions three and four, the potential impact of degraded barriers in the event of a major accident and the fact that the concept of barriers in major hazard risk control is not well understood, are key in initiating the requirement for the assessment. In combination with this it can be questioned what the consequences may be if several barriers are simultaneously degrading over time. Historical catastrophic events have shown that their underlying causes are simultaneous failures of several barriers in time.

Venture considers better control of barriers a means to improve control of major accident hazards. This study will therefore look closer at barrier management and will focus on the following research- and sub-questions:

"How can Venture Production Nederland BV improve the management of barriers devised to prevent major accident hazards?"

And the following sub-questions:
1. What are the barriers in place for Venture’s Production operations?
2. How are these barriers currently managed?
3. Which barriers are the most critical and how many times are these critical barriers deployed?
4. What is the consequence of failure of a critical barrier?

Methodology

The problem solving cycle from Hale’s model [2] (figure 1) is used to position the study. The benefit of this model is that it provides a structured approach in the assessment. It distinct the current situation, the desired situation and the structured approach to get to the desired situation.

Figure 1 Problem solving cycle
Actual and desired situation

Actual Situation
The actual situation can be described by the following three main aspects:
1. Singular Barrier Management Philosophy
2. Degradability of barriers and its increase in failure probabilities
3. Possibility of simultaneous major accident hazards occurring

Desired Situation
The desired situation is to know our critical barriers and what they are required to do, set good performance standards to those critical barriers that we consider to be active and available in multiple major accident hazards scenario’s.

Adopt a maintenance strategy that assures multifunctional barriers to be available when required, that they will operate with the required reliability and they are able, as necessary, to survive incidents against which they are designed to protect. The maintenance strategy should take account of the factor age and should therefore be more dynamic than the current static situation.

This maintenance strategy should acknowledge degradability of systems versus failure probabilities, i.e. review and optimise maintenance interventions.

The desired situation is as follows:
1. Robust system to overlook independent and multifunctional barriers
2. Have a system in place to define, audit, monitor and review critical barriers
3. Have leading Key Performance Indicator on the performance of critical barriers
4. Promote the use of independent barriers
5. Define that barriers can control its required functionalities, even double tasks
6. Withstand simultaneous failures
7. Insights, knowledge of the issues
8. Being able to cope with multiple scenarios

Problem analysis and priority allocation
The bow-tie methodology has been selected to make an inventorisation of all Venture’s barriers in major accident hazards management. It has been selected as it provides readily understandable visualisation of the relationships between the causes, the barriers preventing the event and the barriers in place to limit the consequences.

Priority allocation – interdependency analysis
After the bow-tie sessions were held an inventorisation was made on how many times barriers appear in the different bow-ties, a so called interdependency analysis.

The analysis consists of cross referencing all bow-ties and their barriers and summarising how many times the barriers are deployed. The total number of barriers in the 11 bow-ties is 847. An overview of the 11 bow-ties is given in table 1.

<table>
<thead>
<tr>
<th>Bow-tie development Venture Production Nederland B.V. GMA Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbon Gas In Field Subsea Pipelines – Loss of Containment</td>
</tr>
<tr>
<td>Hydrocarbon Gas Topsides Satellites - Loss of Containment</td>
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<td>Hydrocarbon Gas Topsides ST-1 - Loss of Containment</td>
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<td>Hydrocarbon Gas Topsides J6A - Loss of Containment</td>
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<tr>
<td>Hydrocarbon Gas Export Pipeline – Loss of Containment</td>
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<tr>
<td>Hydrocarbons in Formation Wellhead platforms – Loss of containment</td>
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<tr>
<td>Fire Hazards Non Process Fires</td>
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<tr>
<td>Overhead Equipment Dropped Objects</td>
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<tr>
<td>Helicopter Transport Impact – Ditching</td>
</tr>
<tr>
<td>Boat Collision Vessel Impact</td>
</tr>
<tr>
<td>Evacuation, Escape and Rescue</td>
</tr>
</tbody>
</table>
**Solution generation, choice of solution and implementation**

It can be concluded from the interdependency analysis that there are multiple barriers, which are multifunctional. At this moment within Venture there is no consideration of barriers being multifunctional and therefore no selection of barriers being more critical than others. No consideration is given to this aspect in the audit, monitoring and review processes.

In order to structurally approach the evaluation it is intended to work through one example and propose from that a structured action plan for improvements in barrier management.

A priority allocation has been done through the interdependency analysis, the barrier “PTW / TRA” will be used in this evaluation. In order to complete the evaluation we need to set some boundaries in which we approach this. These boundaries are:
1. If a barrier fails in one place it is assumed to fail everywhere
2. Multifunctional barriers are not as effective as independent barriers
3. Were one or more multifunctional barriers are used in a Threat – Event – Consequence branch, remedial actions need to be taken
4. Were a multifunctional barrier is supported with only one independent barrier in a Threat – Event – Consequence branch, remedial actions need to be considered
5. Remedial actions can be in threefold;
   a. Define additional independent barriers
   b. Define adequate performance standards for existing barriers
   c. Maintain a strict programme for monitoring the condition of the barrier according to the performance standard.

The evaluation will be done according to the following action plan:
1. Generate a multifunctional barrier task list
2. Select a barrier for evaluation (in this example the barrier “PTW / TRA”)
3. Define the criticality of the selected barrier by analysing what other barriers are in the specific branch of the bow-tie.
4. Define the adequacy of the Threat – Event – Consequence branch in which the multifunctional barrier is located by using the boundary set.
5. If the branch is found to be adequate, no improvement actions are required
6. If the branch is found not to be adequate, define remedial actions
7. Focus in on the aspect of a failing Permit to Work system its consequences and the statistical consequences in the chain of causation of were the PTW system is used in the bow-ties.

**Results**

The results are based on an evaluation of the PTW/TRA barrier. The evaluation is as discribed in the action plan page 6 and a statistical dependency of Permit-to-Work in the chain of causation, i.e. what is the increase in risk if the PTW/TRA barrier fails.

The interdependency analysis has shown that the PTW/TRA barriers used in the branches are not all independent and therefore the branches need to be reviewed if they require additional parallel or serie branches. This should be done for all branches in all of the bow-ties. The interdependency analysis has shown that in 8 different bow-ties 18 “PTW / TRA” barriers are used. 6 of the 18 are in the consequence side, of these 6 none are defined as adequate as per items 3 and 4 of the boundary set as described in chapter 4. Interestingly enough they are related to the Escalation Factor, Temporary Equipment on the barrier Control of Ignition Sources. Looking at the Baker report [3] the first explosion was caused by ignition of the vapour cloud by a diesel pick-up truck that was parked about 8 meters from the blow-down drum. For these 6 branches additional barriers need to be defined. The remaining 12 PTW/TRA barriers of the 18 are in the prevention side, 3 of which are found to be adequate in relation to other independent barriers available in the branch, 9 are found to be inadequate as per items 3 and 4 of the boundary set as described on page 6. For these 9 branches additional barriers or performance standards need to be (re-)defined.

The statistical dependency of Permit-to-Work in the chain of causation is based on catering for a factor of human error in risk determination. The failure probability of a PTW system is assumed to be according to B. Kirwin [8] generic guideline data, i.e. a momentary increase in risk due to human error.
The current Quantitative Risk Assessment (QRA) approach for the offshore installations within Venture has no consideration for Human Error i.e. it does not cater for e.g. a failing Permit to Work System. All QRA work is done on the failure of platform hardware like flanges, shutdown valves etc.

Due to human error a momentary increase of risk is probable at a certain moment in time. The failure probability profile for a Permit to Work System could be increased when human error occurs as is given in figure 2 by the red line. The blue line showing a normal degradation of a Permit to Work system over time, when not reviewed or audited for example.

![Figure 2: Degradation of a Permit to Work System over time](image-url)

In relation to offshore safety cases in which individual risk profiles per working groups are calculated based on hardware failures, it can be concluded that these risk figures may momentary increase when human error occurs, e.g. when a PTW system fails.

Based on a failure of a PTW system the IRPA (Individual Risk Per Annum) could increase momentary with a factor 144. Please note this is a very conservative approach as the IRPA risk is an average calculated risk per year. On the other hand in times of stress this factor could be much higher, see Kirwin [8]. The increase due to a failure of a PTW system is a momentary peak causing higher risk levels.

**Conclusions**

Reflecting back on the research question and the sub-questions, the thesis has concluded the following:

**What are the barriers in place for Venture’s Production operations?**
The brainstorm sessions have concluded in 11 bow-ties, which depict the major hazards for Venture’s organisation. It has resulted in 847 independent and multifunctional barriers.

**How are these barriers currently managed?**
Within Venture these barriers are currently managed through the existing audit, monitoring and review processes as described within the existing Integrated Management System [6]. There is no consideration of barriers being multifunctional and therefore no selection criteria for critical barriers. No consideration is given to this aspect in the audit, monitoring and review processes. This can be considered as a malfunction in the Safety Management Process. Besides that from the evaluation in chapter 4 it can be concluded that barriers currently used in the branches are not independent.

**Which barriers are critical and how many times are these critical barriers deployed in the bow-ties?**
The interdependency analysis has concluded which barriers are critical and how many times they are deployed. Currently the most critical barrier is the Permit to Work System, it has been deployed 18 times in the 11 bow-ties. The evaluation (Appendix IV) has shown there are short term remedial actions to be taken.

**What is the consequence of failure of a critical barrier?**
The consequence of failure of a critical barrier is a higher probability of a major accident event occurring. Based on a failure of a PTW system the IRPA could increase momentary with a factor 144. Failure probabilities may increase over time in relation to the current maintenance strategy.
It can be concluded that degradation of barriers may lead to an increase in failure probabilities. Having a Structured Driven Safety culture existing within an organisation will not favour this situation.

“How can Venture Production Nederland BV improve the management of barriers devised to prevent major accident hazards?”

It can be concluded that the management of barriers needs to be improved. The current situation is not as safe as we believe it to be. The aging aspect of the installations is not in our favour. It can be concluded that this thesis has provided another way of thinking in barrier management, leaving us with unanswered questions.

**Recommendations**

Reflecting back on the research question and the sub-questions, the thesis study report recommended the following:

“How can Venture Production Nederland BV improve the management of barriers devised to prevent major accident hazards?”

It is recommended that all critical barriers are evaluated according to the action plan as depicted in Figure 3. This structured approach will define the adequacy of the critical barriers. It is recommended to do this evaluation for all Venture assets not only Venture Production Nederland BV assets.

**Figure 3 Action Plan**

1. Initiate the control barrier review at least bi-annually or after each major modification.

2. Develop the list of multifunctional barriers from the bow-ties.

3. Execute the criticality rating of all the control barriers deployed in the bow-ties. Develop the list of critical control barriers.

4. Define whether the critical control barriers are adequately managed. (Are their sufficient independent barriers deployed in the selected branch?)

5. If it is found acceptable, no further improvement actions are required.

6. Define additional, preferably independent control barriers.

7. If no other control barriers can be deployed, define a performance standard as per the defined criteria in section 2.1.2.

*Barriers in place for Venture’s Production operations*

The 11 bow-ties are living documents and subject to change. It is recommended to review the bow-ties after any major modification or at least bi-annually.
Management of Barriers
It is recommended to adopt an audit, monitoring and review processes for barriers, specifically critical barriers.

Critical Barriers
It is recommended to develop a Leading Key Performance Indicator on the performance of critical barriers for the Management Team to monitor the performance on a monthly basis.

Independent Barriers in branches
A review needs to be made if barriers deployed in branches are truly independent.

Further Research
It is recommended that Venture does further research in order to evaluate its maintenance strategy from a static- to a dynamic perspective i.e. to cater for the factor age.

Furthermore Venture should do further research in evaluating their QRA methods. Currently no consideration is given to degradability over time. This is a lack of knowledge within Venture and possibly other industry operators. As pointed out by Prof.dr. B.J.M. Ale other industries do take account of this, a lead for further research would be available literature regarding process safety assessments in nuclear power stations written by Ioannis A. Papazoglou and associates.

Recommendations for the Oil and Gas Industry
As this is an industry wide issue it is recommended to start a NOGEPA workgroup on barrier management in which Safety Professionals throughout the Oil and Gas Industry can fine-tune this action plan and look closer at some of the discussion items.

Discussion
Venture Production Nederland BV, a fully owned subsidiary of Venture Production Plc. is a leading new generation oil and gas company focused on recapturing the potential of stranded reserves. Venture acquire, operate, and revitalise 'stranded' assets - oil and gas fields with proven but untapped potential.

In just eight years, Venture has increased production from only 200 barrels of oil (equivalent) per day in 1999 to 59000 barrels of oil (equivalent) per day in 2008. Revenues have grown from £1m in 1999 to £360m in 2006. Venture has established herself as a trusted partner in the United Kingdom’s and the Dutch North Sea and is poised for continued future growth.

For this thesis project all bow-ties of Venture Production Nederland BV have been used. No other bow-ties have been used. Within Venture globally there is more bow-tie information available.

Within the given timeframe to run this thesis project no scientific research documentation on dependency, interdependency and multifunctionality of barriers is found or known to exist. I have performed extensive research on internet in the given time frame to find relevant literature on dependency, interdependency and multifunctionality of barriers and have not succeeded. There seems to be a lot of literature on interdependencies (Ali Mosleh, c.s.) however nothing that really fits with my problem. This only more emphasis the fact that this problem requires more attention as the solutions is not within reach.

This thesis has shown there is a lot to think about. The fact that there is no consideration of barriers being dependent, interdependent or multifunctional demonstrates a malfunction in the Safety Management process. Some questions arise from this thesis that needs to be looked at and not be ignored:
1. How do we manage double deployment of barriers?
2. How do we manage mutual independence of barriers?
3. Are all of the bow-tie branches truly in series or are there other parallel branches?
4. How does barrier management fit-in the current safety management process?
5. Does Venture actually adapt its platform maintenance management regimes to cater for “old age” problems?
It is known that the Oil and Gas industry demonstrates its case for safety to operate an installation by writing Operational Safety Cases [4] for each installation. One major aspect in this is performing Quantitative Risk Assessments (QRA). A QRA is carried out based on a number of assumptions, for example failure probabilities. Failure probabilities are based on historical data and as they are utilised at the moment within the Oil and Gas Industry they are per definition out of date. They present an “average” failure rate, however there is no consideration to take account for degradability over time. As discussed this is however unknowingly an Oil and Gas industry problem. As pointed out by Prof.dr. B.J.M. Ale other industries do take account of this, for example the nuclear power industry.

Knowing this, the fact that barriers degrade over time and that these barriers are used in multiple scenarios we can ask the following questions:

1. How valid are our QRA’s, what are our true risk figures?
2. Can we truly demonstrate ALARP knowing what this thesis has concluded?
3. Is the Operational Safety Case the best way to demonstrate management of major hazards?

From the NOGEPA safety behaviour a survey [5] it can be concluded that human error increases the more a Structured Driven Safety culture exists. What could the consequences be of a combination of the above, i.e. increased failure probabilities of barriers combined with a Structured Driven Safety culture.

References

1. Key Programme 3 Asset Integrity – A report by the Offshore Division of HSE’s Hazardous Installations Directorate, Health and Safety Executive, November 2007.


3. ST-1 Operations Safety Case, Document Number HSE-05-0006 Rev.06, 18/04/07, Venture Production Nederland BV.


