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Safety Barriers Integrity Management System

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Since the beginning of 2010 Petrobras has been searching for a tool that could help it to manage the risk of all E&P (Exploration & Production) production installations. At the end of 2010 it has been decided to use the Bow-tie diagram tool to identify all the qualitative risk and manage it. At the beginning of 2012 Petrobras were challenged to elaborate the Bow-tie Diagrams for all offshore installation that totalize 125 production platforms.
In order to be successful on this challenge it was decided to standardize the Bow-tie modelling for all events and hazards from all Risk Analysis of those platforms. As a result it was developed a proprietary Bow-tie diagram tool. The safe barriers of this tool are based on the conception of LOPA (Layers Of Protection Analysis) tool, which are comprise of nine layers of protection. For Petrobras, the first five layers are set to prevent the event and the last four are set to mitigate the consequences.
Besides the Bow-tie diagram, it was developed a systematic system to monitor the integrity of those layers. This approach is based on a computerized system that collects real time data from operational systems to give an idea of the safety functions of the platform. The integrity is monitored based on a series of questions of management elements of the unit analysed, about the instrument or equipment related to each layer.
The system has been developed as a pilot for one single platform. The results of this pilot have been analysed in order to tune the operational limits to achieve the best performance in safety and operational. The idea is to answer those questions automatically to give an updated information to the OIM (Offshore Installation Manager) as soon as the status changes. This will help him to make the best decision in order to maintain a high safety level of the platform.
In the future, Petrobras intends to extend this approach to all onshore E&P (Exploration & Production) installation.

1. Introduction

Safety is an issue that is directly related to operations due to the risk involved. With the increasing of complexity on today installations is becoming almost impossible to manage all risk related to the design and the operation. All operators companies are seeking for a tool that can help to take the right decision within a minimum time. The tool that will be described on this work is a tentative solution adopted by Petrobras that can perform this job.
This methodology is being implemented in one Petrobras' Offshore Unit as a pilot in order to evaluate the reliability of this system in helping the operators regarding the integrity of the safety barriers.

2. Methodology

The methodology used to define the barriers and the relation among them was based on the Bow-tie Model and LOPA (Layers Of Protection Analysis).

2.1 Bow-tie Model

The Bow-tie model (Figure 1) was developed by Shell to meet the requirements for risk assessment while integrating the understanding of how accidents happen derived from the Swiss Cheese Model.

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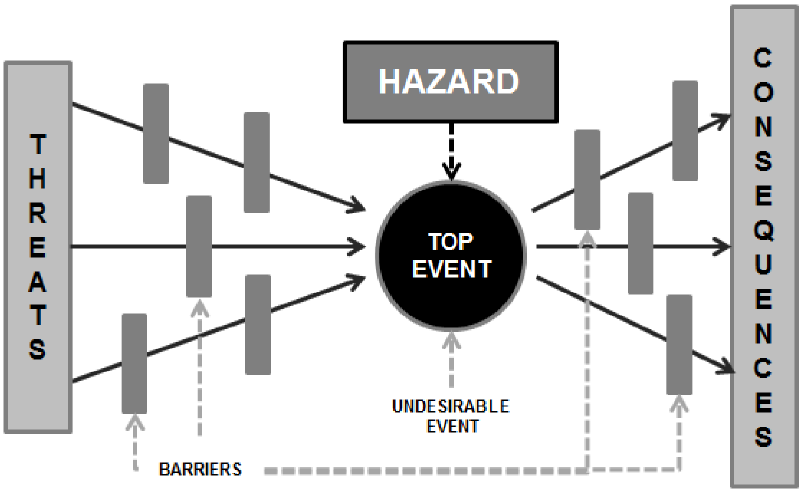


Figure 1 - Bow-tie Diagram

The Bow-tie technique does not offer a new or different way of analyzing risk. The diagrams that it creates greatly assist in the communication of the hazards analysis process - particularly to non-specialists. Also, the technique identifies the barriers that normally prevent an accident from occurring and their integrity statuses allow the operator to understand the risks at that moment.

The Bow-tie also combines the concepts of fault tree (the left hand side) and an event tree (the right hand side) used in quantitative risk assessment.

The left hand side of the Bow-tie represents the threads or circumstances, either in isolation or in combination that can lead to undesirable event with potential to harm people, environment, assets or company's reputation and protection barriers. The right hand side represents the various scenarios that might develop from the undesired event leading to harm and damage as a consequence.

The main concept behind this methodology is that barriers that interpose the threads can stop progression to lead to harm and damage. There are diagrams related to each `top event' and its 'consequences'. Those top events are related to different hazards.

Each barrier relies on one or more activities carried out by the company, such as design, engineering or operations, to ensure its presence and effectiveness. Barriers can be hard, such as designs that do not allow certain problems or make failure less likely, or soft, such as procedures and individual competence.

Benefits:

- Clear communication and improved understanding:
  Bow-ties keep sight of the big picture and can capture the sequence of events as well as previous incidents;
- Greater ownership:
  When people feel involved they tend to 'buy-in' the process;
- Efficiency gains:
  The method is less labour intensive than many other traditional techniques, it identifies where resources should be focused for risk reduction;
- Practical approach:
  Focusing on risk management by people on a day-to-day basis, rather than analytical studies by a technical risk specialist;
- Logical structured approach:
  Considering all aspects of the management of risk, from initial cause to final consequence in a sequential manner, this logical approach often identifies gaps and issues that are missed by other techniques;
- Auditable trail:
  The diagrams and critical task lists help internal or regulators' auditing since they can focus on what people are actually doing rather than the condition of physical systems.

Limitations:

The Bow-tie model is not applicable to quantify your level of risk and to identify individual safeguards. There are others techniques that are more suitable for these purposes.

2.2 Layers Of Protection Analysis (LOPA)

Layers Of Protection Analysis (LOPA) is a powerful analytical tool for assessing the adequacy of protection layers used to mitigate process risk. LOPA builds upon well-known process hazards analysis techniques, applying semi-quantitative measures to the evaluation of the frequency of potential incidents and the probability of failure of the protection layers. It is a simple tool and identifies the safeguards to be considered for risk assessment and risk reduction.

The LOPA was originally developed in the context of defining Safety Integrity Levels (SILs) for electronic/programmable safety related systems.

LOPA is based on the assessment of single event – consequence scenarios. A scenario consists of an initiating event and its consequence. Multiple initiating events can lead to the same consequence; all these initiating events must be used to develop scenarios for a subsequent assessment. A typical LOPA scenario chain is indicated as figure 2 for understanding:

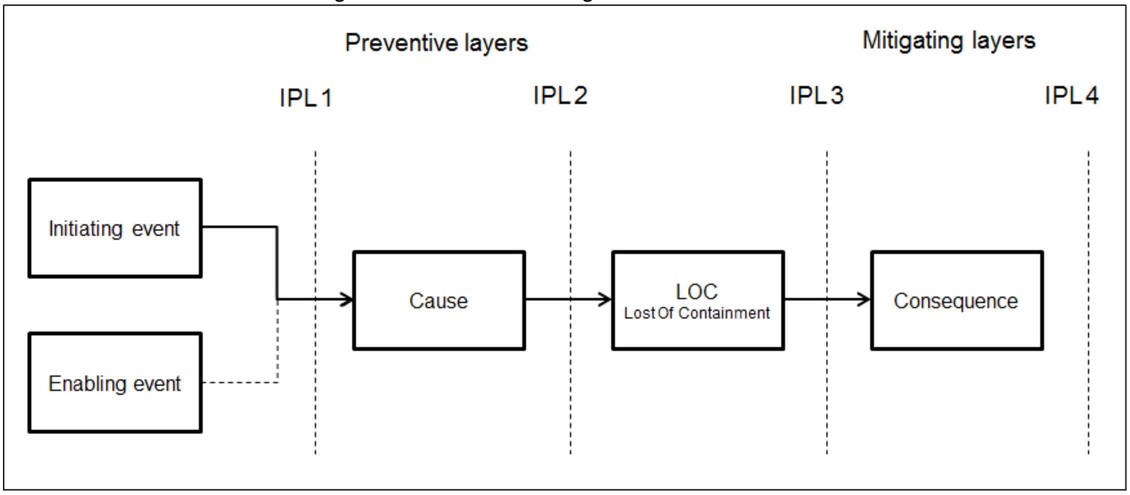


Figure 2 - LOPA scenario

The methodology helps to identify safeguard that meet the Independent Protection Layer (IPL) criteria. IPL are often depicted as an onion skin (Figure 3), each layer is independent in terms of operation and the failure of one layer does not affect the next. They are designed to prevent the hazardous event or mitigate its consequence.

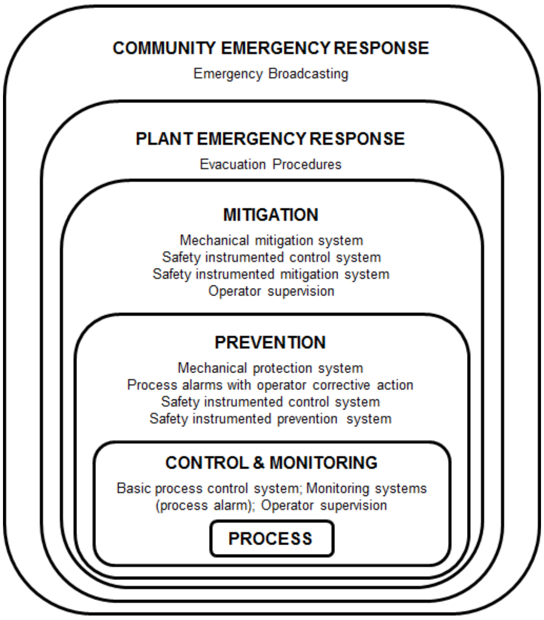


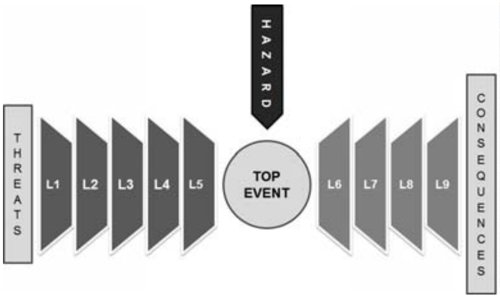
Figure 3 - IPL Diagram

3. Description of the System

3.1 Methodology used

The tool is based on Bow-tie diagrams, but these diagrams were standardized since that it had to be applied to all facilities. The diagrams were standardized using the traditional Bow-tie plus the LOPA concept. Firstly the hazards were standardized, the top events, then the threats and the barriers, this last one based on LOPA concept. Once the diagrams were standardized it was defined typical diagrams for each installation family considering the similarity among them.

The Bow-tie typical diagram follows the figure 4 in which the barriers can be applied or not according to the threats and top events. In the same figure it can be seen the relation between Petrobras barriers and LOPA layers.



Layer	Description	LOPA Description
L1	Process Design	Process
L2	Basic Process Control	Control & Monitoring
L3	Process Alarm & Operator Supervision	
L4	Safety Instrumented Control System	Prevention
L5	Mechanical Protection System	
L6	Mechanical and Safety Mitigation System	Mitigation
L7	Process Plant Emergency Response	Plant Process Response
L8	Installation Emergency Response	
L9	Evacuation Procedures	

Figure 4 – Standardized Bow-tie by Petrobras

3.2 The System

The system was developed to run on Petrobras Intranet collecting data from different systems. It collects data of maintenance and inspection status from our CMMS (SAP PM Module), information of process variables by PI (Plant information) application and other information from our operation administration of platforms system called APLAT.

The data collected are related to the barriers and they are grouped in seven groups. Four related to the threats and three related to the consequences. The threats and consequences grouping are shown in table 1. The barriers were grouped due to similarity among the typical threats and consequences.

Table 1: Threats and Consequences Grouping

THREATS	CONSEQUENCES
Structural Integrity (corrosion, erosion and fatigue)	Fire or Explosion
Process Variable	Environmental impact
Personal Factor (inappropriate qualification and task execution)	Company´s reputation
Simultaneous Operation	

The system interface presents the risk scenarios in two main screens as seen in figure 5.

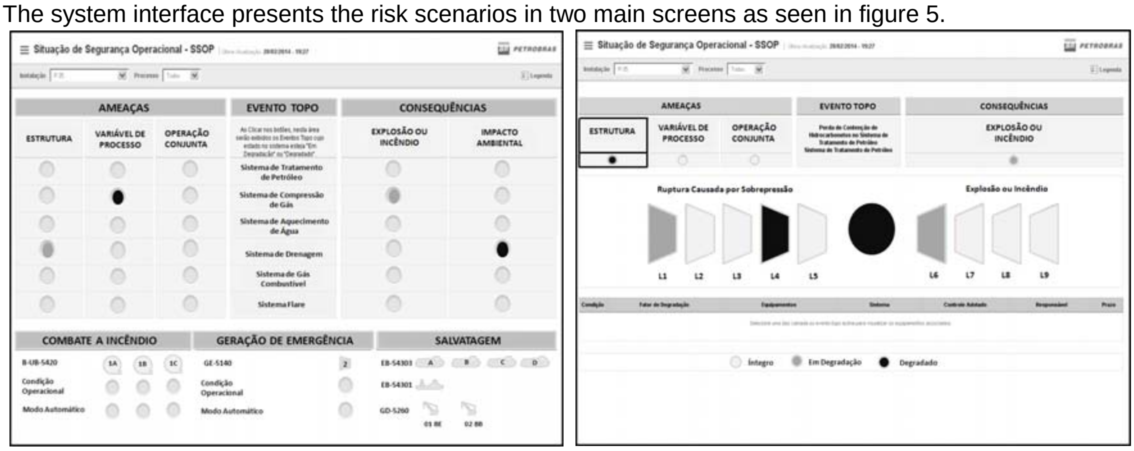


Figure 5 - System screen

- The first one shows an overview of the process integrity, indicating the existing threats and consequences. At the bottom there is the base life support equipment status such as firefighting pumps, emergency generator and rescue systems.
- The second interface provides a diagram specifying each threat, its consequences and degradation status for a particular operational system related to a top event.

3.3 The Rules

The barriers are monitored by a specific group of degradation factors (table 2).
The groups of degradation factors have an algorithm that determines the final degradation state of each protective barrier. If there is a condition on process plant that is discrepant to the interface, the operator, responsible for the diagnostic, can override the algorithm logic in a upward direction only (GREEN to YELLOW or YELLOW to RED).
Each of the nine barriers has a direct relation to information gathered from the different systems in order to define its colour. If the system is healthy, the colour will be GREEN, YELLOW colour means that degradation starts and if the colour is RED the system is degraded. The data used for assessing integrity of each protective layer is updated in two ways: high and medium rates of data change in real time from pre-existing systems and low rates of data change manually, daily or by event such as recommendation from audits.

Table 2: Barriers and Control of Degradation

THREATS Preventive Layers	Controls of Degradation Factors	Mitigating Layers	CONSEQUENCES Controls of Degradation Factors
L1 Process Design	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance	L6 Mechanical and Safety Mitigation System	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Inhibited Control
L2 Basic Process Control	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Operation Mode	L7 Process Plant Emergency Response	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Inhibited Control
L3 Process Alarm & Operator Supervision	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Training Tools	L8 Installation Emergency Response	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Training Tools Inhibited Control
L4 Safety Instrumented Control System	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Training Tools Inhibited Control	L9 Evacuation Procedures	Diagnostics Responsible Management Of Change Maintenance and Inspection Plans Legal Compliance Training Tools
L5 Mechanical Protection System	Diagnostics Responsible Maintenance and Inspection Plans Legal Compliance		

4. Conclusions

The system is being implemented in one offshore installation. Before the implementation there were problems on developing interfaces to collect data and training the operators in using the system.

The system is able to help the operator since it can simplify the combination of events that happens during daily operation. As an evaluation of the overall system performance it has to have some upgrade in order to be more user friendly to the operator and the causes of degradation to be clearly understood. It will be implemented in the next version a hierarchic relation among the barriers to help decision support to prioritize the actions to be done to correct or mitigate the problem in order to keep the installation operating within an acceptable risk range.

References

Hudson, Patrick T.W., Guchelaar, Henk-Jan, Risk assessment in clinical pharmacy, Pharm World Sci, Kluwer Academic Publishers, 2003; 25(3): 98–103.

J. Ramesh Babu, Layer of Protection Analysis – An effective tool in PHA

N. Khakzad, Faisal Khan, Paul Amyotte, Dynamic safety analysis of process systems by mapping bow-tie into Bayesian network, 2013, Process Safety and Environmental Protection 91 (2013) 46-53.

Steve Lewis, Kris Smith, Lessons Learned from Real World Application of the Bow-tie Method, 2010, 6th Global Congress on Process Safety, San Antonio, Texas, USA.

E. Okstad, S. Hauge, R.K. Tinmannsvik, Monitoring the risk picture by using QRA and barrier based indicators, 2013, NTNU IO Center

Bert Knegtering, Hans Pasman, The safety barometer. How safe is may plant today? Is instantaneously measuring safety level utopia or realizable?, 2013, Journal of Loss Prevention in the Process Industries 26 (2013) 821-829.

William Bill l. Mostia Jr., Got a risk reduction strategy?, 2009, Journal of Loss Prevention in the Process Industries 22 (2009) 778-782.

Alan Blacklaw, Al Ward, Kevin Cassidy, The Cumulative Risk Assessment Barrier Model, 2011, SPE Offshore Europe Oil and Gas Conference and Exhibition, Aberdeen, UK.