The LNG industry enjoys a commendable track record in reliability and safety. There is however no reason to be complacent, as we can learn from various major hazard accidents across the energy industry which regrettfully resulted in fatalities, asset damage and environmental impact. LNG operations may be similarly vulnerable to major incidents if hazards are not properly managed. In 2009, Shell launched a new Health, Safety, Security, Environment and Social Performance (HSSE&SP) Control Framework. This framework addresses process safety management (PSM) explicitly and has a clear line of sight between: Risk assessment; Designing and constructing; Operations, maintenance and inspection; and Leadership and culture. The article will provide:

- Implementation challenges of process safety management
- Insight in findings from the assurance group and how these appear to apply pan
- LNG operating assets
- Examples of results related to e.g. reliability, incident rate and culture changes.

The standard has redefined the way we work. It is generic and believed to cover PSM aspects which may be useful to other LNG operators. PSM is not only a social or legal obligation for LNG operators, it also makes business sense. Good process safety performance requires good reliability, which also translates into more production and less operating costs. It is a key enabler to 'sustaining future growth'. Last but not least, PSM is a journey towards 'Our assets are safe and we know it'. This journey never ends; it is our way of working. Sustaining the effort remains our key challenge.

1. INTRODUCTION

The LNG industry enjoys a commendable track record in reliability and safety. There is however no reason to be complacent, as we can learn from various major hazard accidents across the energy industry (e.g. Piper Alpha, Texas City, Macondo), which regrettfully resulted in fatalities, asset damage and had environmental impact. LNG operations may be similarly vulnerable to major incidents if hazards are not properly managed.

Root causes for major accidents are often complex in nature. They are related to a series of interlinked failures in mechanical, human judgment, engineering design, operational implementation and team interfaces.

To avoid such incidents, we must translate learning into effective barriers, aimed at reducing risk to acceptable levels. This article will share some insights on how this is done in Shell.
2. WHAT MAKES THE LNG INDUSTRY DIFFERENT?

In principle the LNG industry is not different from the typical oil or chemical business except a few areas that characterizes LNG:

- Key hazards in a LNG plant are typically high pressure feed gas, LNG, LPG and condensate. These hazards contain high risks if not managed properly.
- LNG Production plants represent significant capital value (billions of dollars)
- LNG import or export facilities are often in remote geographical areas
- LNG plants have long term supply contracts with customers. A major incident can lead to significant loss of production and reputation damage.
- Key equipment (e.g. main cryogenic heat exchanger, loading jetty, rotating equipment) is sensitive, often not spared and can be vulnerable to failure (long outage).
- Some facilities are already operational for 30 years or more, older facilities could bring integrity challenges (e.g. corrosion under insulation, slug catchers)

These characteristics should be addressed when managing process safety in LNG effectively.

3. THE PROCESS SAFETY FRAMEWORK

In 2009, Shell launched a new Health, Safety, Security, Environment (HSSE) Control Framework. This framework contains a single, consistent and structured standard that defines the requirements on Process Safety Management (PSM).
LNG assets are often joint ventures (JV) where Shell as a partner uses its influence to convince the JV partners to adopt the Shell PSM approach. In practice JV partners share the same goal (making it safe) and adopt the Shell standard (or materially equivalent system) although the way to implement (methodology, systems) can be different.

The Process Safety Management manual defines “What” needs to be done (22 requirements). “How” this is done (implementation) is defined by the LNG venture.
4. BARRIER THINKING

A key feature in the PSM manual is the ‘line of sight’ between the hazard, the top event (e.g. loss of containment) and the consequence. By thoroughly managing this “line of sight” hazards can be managed to a risk “as low as reasonable practical” (ALARP). The method used for this is HEMP (Hazard & Effect Management Process) which uses bow ties for high risk hazards, see figure below. The risk reduction is achieved by defining barriers that are typically preventive in nature (left hand side e.g. relief valve) but, if controls fail, can also be a recovery measure (right hand side barrier e.g. fire fighting).

To support a consistent approach towards risk management across various LNG assets a number of model bow ties have been developed by Shell. These model bow ties serve as a ‘typical’ example that a specific LNG plant can use to localize and make site specific bow ties.

Table 2 – Typical LNG model bow ties

<table>
<thead>
<tr>
<th>#</th>
<th>Bow-Tie</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB01</td>
<td>Feed Gas Acid Gas removal unit</td>
<td>Typical LNG Plant Feed Gas Acid Gas removal section</td>
</tr>
<tr>
<td>MB02</td>
<td>Feed Gas Drying and Mercury removal</td>
<td>Typical LNG Plant Feed Gas Drying and Mercury removal section</td>
</tr>
<tr>
<td>MB03</td>
<td>NG/LNG Liquefaction NG Precooling</td>
<td>Typical LNG Plant Liquefaction NG Precooling section</td>
</tr>
<tr>
<td>MB04</td>
<td>C3 Cooling Loop</td>
<td>Typical LNG Plant C3 Cooling Loop</td>
</tr>
<tr>
<td>MB05</td>
<td>Mixed Refrigerant Cooling Loop</td>
<td>Typical LNG Plant Mixed Refrigerant Cooling Loop</td>
</tr>
<tr>
<td>MB06</td>
<td>Jetty operations</td>
<td>Typical Terminal Jetty for receiving LNG from a marine vessel</td>
</tr>
<tr>
<td>MB07</td>
<td>Fractionation and Condensate</td>
<td>Typical LNG Plant section</td>
</tr>
<tr>
<td></td>
<td>Stabilization</td>
<td></td>
</tr>
<tr>
<td>MB08</td>
<td>Gas Turbines</td>
<td>Example of gas turbine in use a LNG plant</td>
</tr>
<tr>
<td>MB09</td>
<td>Centrifugal Compressors</td>
<td>Applicable to centrifugal compressors</td>
</tr>
<tr>
<td>MB10</td>
<td>Reciprocating Compressors</td>
<td>Applicable to reciprocating compressors</td>
</tr>
<tr>
<td>MB11</td>
<td>Cold Storage</td>
<td>Cold Atmospheric storage of liquid LNG</td>
</tr>
<tr>
<td>MB12</td>
<td>Inlet Pipelines</td>
<td>Off plot feed gas pipeline(s) to a LNG Plant</td>
</tr>
</tbody>
</table>
5. OPERATIONALISING THE BARRIERS (BOW TIES)

The identification of barriers is much a design matter (HEMP). To make the barriers effective requires translation into operational, maintenance and inspection activities. For example:

- Barriers need to be setup in the maintenance computer system.
- Each barrier needs a performance test to demonstrate its proper working.
- The performance test has to be scheduled periodically.
- Overdue tests need approval by a technical authority.
- Tests can only be done by staff assessed as competent (certified). All test results are approved and, in case of failure, corrective action is initiated.
- Technical changes to barriers are tightly managed by a change process (MOC).
- Condition of barriers is recorded and monitored.
- Staff that operate, maintain and inspect barriers are competent.
- Operators need to know the limits of a barrier and what to do in case of exceedance (slow down, stabilize, shut down).
- Staff are trained on barrier thinking.

Barrier management touches on all aspects of an asset organization and it takes significant time, effort, resources, commitment, and…leadership to set this up properly.

6. MAKING PROCESS SAFETY MANAGEMENT SUSTAIN

To create strong Process Safety Management in an asset is a journey. The journey starts very often with having a reactive culture where structure and compliance to PSM are largely absent. Notable efforts are required to introduce the PSM standard and get assets to meet the minimum requirements (“calculative” level in Figure 4). This effort is typically very significant, e.g. 3 man years for simple facilities to 100 man years for complex facilities. This journey then needs to continue with sustaining and improving further the PSM performance towards proactive and generative levels (“this is the way we do business here”).

A very essential element in this change journey is to achieve sustainability of the PSM performance step change. Experience from other journeys show that performance can drop when not ensuring proper attention. Causes can be related to change of leadership, change of direction/new priority settings in company, poor ownership of PSM processes, lack of training, lack of review, …all potentially setting the asset back on the PSM journey.

To prevent this set back a very explicit sustainability program is run at LNG asset level to make sure that PSM is effectively embedded in leadership, people, process, structures and culture. This sustainability program is focused on developing a ‘chronic unease’ mindset where leaders at all levels have created a culture where they are made aware of weak signals, and make effective and timely challenges and interventions on risk assessments and decision making. In such context leaders are expected to, e.g.:

- **Know the main hazards** in an operation.
- **Engage with those doing the work** – “what could go wrong, and what controls are in place to prevent it?”
- **Welcome bad news** – “what do you not want to tell me” - and react appropriately.
- **Watch traffic light reporting** – challenge the greens and support the reds.
- **Be on the lookout for weak signals** that people are concerned with the current situation. Tune into the rhetorical question, the quizzical look from faces, the vague statement(s), or unsure answers.
Figure 4 - Implementing a Process safety management system is a journey

7. IS PROCESS SAFETY MANAGEMENT GOOD BUSINESS?

PSM is not only a social or legal obligation for LNG operators, it also makes business sense. Good process safety performance requires good reliability which also translates into more production and less operating costs.

Figure 5 – Shell CEO Peter Voser commenting on safety

“Safety is not only our number one priority and value, it is a fundamental reflection of our performance…”

Below are examples of some typical improvements for a LNG asset before and after implementing PSM, see figures. These examples are mostly based on “hardware” improvements. More important are even the improvements made on the soft side e.g. culture and behaviors. Examples of behavioral changes are:
• Operators feel empowered to shut down a unit when they believe it is unsafe or in doubt.
• Shift handover is more structured and cover important PSM items (overrides, bypass, safety critical equipment out of operation, etc.).
• PSM is an essential part of leadership communications (e.g. town hall session).
• There is a reinforced compliance culture for e.g. overrides, reporting leaks, closing of permits
• There are dedicated process safety walk rounds.
• There is focus towards preventive rather than corrective work.

Below examples show performance improvements made while implementing PSM.

Figure 6 – Example of reduction of alarms per console per hour for a LNG asset

Figure 7 – Reduction of LNG trips per train over time
Figure 8 – Comparison of performance data for a typical LNG import asset before and after implementing Process Safety requirements.

Figure 9 – Reduction of maintenance activities to be done over time

8. CONCLUSION

Incidents have happened and unless we change the way we work will continue to happen. For LNG assets it is the PSM standard that has redefined the way we work. It is generic and believed to cover all PSM aspects useful to other LNG operators. The implementation of PSM is a journey towards our vision “Our assets are safe and we know it”. This journey never ends: sustaining the step change in performance remains a key challenge.
Lastly, PSM is not only a social or legal obligation, it has become the way we work and helps to continuously improve the LNG business. A safer plant is also a plant that is more reliable, produces more and runs typically with less costs.

9. ACKNOWLEDGEMENT

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