IMPLEMENTATION OF THE HAZARDS AND EFFECTS MANAGEMENT PROCESS (HEMP) at Shell Chemical Facilities

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Abstract

The Hazards and Effects Management Process (HEMP) has been developed to identify the HSE hazards at a manufacturing facility and assess management of the hazard. The HEMP process is an analysis technique that reviews the identified hazards and uses a Risk Assessment Matrix to rank the risks based on consequence and likelihood. The hazards and identified risk rankings of high, medium or low are documented in the “Hazard Register”. The hazards identified as a “high risk” ranking are reviewed using the “bowtie” technique. The bowtie technique combines a fault tree analysis with an event tree analysis into a pictorial representation. The “top event” is identified at the center of the bowtie, “threats” that could lead to the top event are identified on the left hand side, and the “consequences” from the top event are identified on the right hand side. The control measures that prevent the top event from occurring are reviewed for each threat and placed on the line from the threat to the top event, while recovery measures are identified for each consequence and are placed on the line from top event to consequence. The result is a pictorial representation that resembles a bowtie. Tasks and activities are identified for each of the measures with responsibility for maintaining those tasks and activities assigned. As a result the site has a identified list of tasks and activities that identifies the measures in place for the site to manage the identified “high risks.”
Background

The Shell Hazard and Effect Management Process (HEMP) is used as an element in the Health Safety and Environment Management System (HSE-MS) to address risk assessment. The HEMP methodology identifies various hazards at the facility and assesses management of the identified hazards. The HEMP process requires key or critical tasks and/or activities to be identified with the individual who is accountable for maintaining the controls. This paper shares some of Shell Chemical LP’s experiences with implementation of the HEMP since 2002.

HEMP Process

The HEMP process is broken into structured parts that allows for a rigorous review of the potential hazards associated with operating the particular petrochemical facility. The process starts with “Identify” – Are people, the environment or assets exposed to potential hazard? Once this question is answered then the “Assess” stage is completed – What are the causes and consequences? How likely is Loss of Control? What is the risk? The next step is “Control” – Is it feasible and can the causes be eliminated? What controls are needed? Then the questions focuses on “Recovery” – Can the causes be eliminated or the potential effects mitigated? What recovery measures are needed? Are the recovery capabilities suitable and sufficient? Then identification of the “Critical Tasks and Activities” takes place – What are the critical tasks and activities needed to maintain control and recovery measures? Who is responsible? “Gap Analysis” is then completed to assess whether the systems are in place and the personnel are aware that they are responsible for particular parts of the systems. See Figure 1.

To complete the above steps the review work is broken into three parts:

1. Hazard Register
2. Bowtie Analysis
3. Gap Analysis

Once these parts are completed, the work is combined into an “HSE Case” that is used as reference documentation for future work at the site or facility. This documentation is maintained via the management of change process, incident investigation, and other ongoing processes on an evergreen basis. A complete revalidation of the HSE Case is done on a five year interval.

Hazard Register

The Hazard Register is used to document the hazards identified, the consequences related to the hazard, the risks associated with the hazard, and what actions are used to control the risk. Hazard identification consists of reviewing all of the activities on site and determining the hazards associated with the activity. Typically, hazards are chemicals or physical phenomena such as heat, impact or height, such as high-pressure gas, LPG, and hot surfaces. Once a hazard has been identified, the “top event” that leads to the consequence is discussed. For example, a top event might be identified as “loss of containment” for a process fluid or “loss of control” for physical events. Consequences of the hazard are documented in the hazard register, and then each consequence is risk ranked using an internal risk assessment matrix. Risks are ranked in
four categories: People (injury or illness); Assets (damage to or loss of assets, property, consequential business loss); Environment (affect on the environment or the community); and Reputation (of the company). A sample list of the hazards categories that may be reviewed can be found in Table 1. See Table 2 for a sample hazard register from a hypothetical olefins unit.

The team of individuals used to complete the hazard identification process may include process specialists, HSE Specialists, industrial hygienists, hardware discipline specialists, and operational specialists. The team then reviews the hazards, and all the hazards identified as “high risks” are collated for further evaluation using the bowtie methodology. In general the bowtie is used to demonstrate the controls for identified “high risks”. In some instances additional risk assessment techniques may be used to assess the risk management.

**Bowtie Analysis**

The bowtie analysis is a risk assessment tool that is designed to generate the following three outcomes:

1. A framework for each hazard that identifies incident scenarios and the associated threats that lead to one or more consequences. The framework associates control measures to the threat and consequence lines and relates these to the critical tasks and activities. In some cases, the bowtie analysis might combine multiple threats with multiple consequences into numerous theoretical incident scenarios and hundreds of control measures, critical tasks and activities. A bowtie analysis is different from other risk assessment or review tools that do not generate such a framework.
2. An action list of the status of controls and/or critical tasks and activities in the actual project, site or production unit.
3. A link between the management system of the site or production unit to the necessary controls and/or critical tasks and activities.

The bowtie starts with the hazard that has been identified in the hazard identification and assesses the potential threats that could lead to the top event. Here a threat is a possible cause that will potentially release the hazard and result in an incident. Examples of threats related to a hydrocarbon hazard are high temperature, corrosion, runaway reactions, metal fatigue, overpressure, freezing, and opening of equipment. The top event is the way in which the hazard can be released to do harm. Examples of “top events” are loss of containment, loss of control, oxygen deficiency, and uncontrolled release of energy.

“Control measures” are used to reduce the probability of either the hazard’s potential for harm and/or its consequence. These control measures are designed to prevent the threat from becoming an event or prevent a particular event from reaching a particular consequence. Examples of controls are materials of construction, protective devices, segregation, procedures, inspection, and training. The controls are represented on the main line of the bowtie between the threat and the top event (see Figure 2).

Pursuant to the HEMP, the consequence is the final result of the hazard being released but not being controlled. Examples of consequences are fire, explosion, injury or illness, and vegetation.
or fish kills. Controls on the main line from the top event to the consequence are called recovery measures. These reduce the risk that the release leads to the consequence or mitigates the consequence. Examples of these include dikes, gas detectors, emergency responders, and fire suppression. These can reduce the likelihood that the top event will develop into further consequences and/or provide life saving capabilities should the event develop further. Figure 2 shows the complete bowtie. The resulting bowtie is a combination of a fault tree analysis with an event tree analysis into a pictorial representation.

Each of the controls, whether on the threat side or consequence side of the bowtie, requires a critical task or activity to be defined to maintain the effectiveness of the barrier. At least one critical task or activity is required for each control, but there may be more, and they may be cross-functional. Engineering, operations, and maintenance may all have activities to support a single control on a given threat line. The task or activity is documented to identify the party (e.g. department head, inspector, operator, etc.) who is accountable for the activity. The critical tasks and activities identified during the bowtie analysis are then linked to the HSE-MS of the unit and/or site.

**Gap Analysis**

Once the bowtie analysis is complete and the critical tasks, activities and risk reduction controls are identified for the production unit, facility or site. The next step is confirmation that the risk reduction controls are in place and implemented. The next step is for the production unit, facility or site to complete a gap analysis. The gap analysis helps to determine if each of the identified required controls are in place and if the individuals responsible for maintaining the controls are aware of their respective responsibilities. These gaps are then documented, and remedial action plans are developed if necessary. Implementation is tracked via the HSE-MS management review process.

**HEMP Results**

The time it takes to complete the HEMP work at a facility varies depending on the size of the site. The first sessions consists of the hazard identification phase for the site. The group completing the hazard identification may consist of process personnel, HSE specialists, public relations staff, pressure equipment specialists, and industrial hygienists, as well as the facilitator. The process units are broken into smaller process blocks with similar chemical and physical properties. An overview of what happens in the process block is given so the whole group understands the basis for the area. Then the top event and consequences are discussed for the process block. Each consequence is then risk ranked per the risk assessment matrix, and the risk is documented in the hazard register. Those items with high risks are identified and clearly marked. Table 2 shows a hazard registry from a sample olefins plant with the risk assessment completed for People, Assets, Environment and Reputation.

The analysis for the sample olefins plant unit results in bowties being developed, several of which are very similar due to the nature of the equipment. For example, the propylene and ethylene refrigeration systems are very similar in their design, with the exception of materials of construction and temperature of operation. Therefore, one bowtie could be developed for the ethylene refrigeration system and then modified to address the propylene refrigeration system.
The bowtie analysis brainstorms the threats that could lead to the loss of containment. The controls that are in place for the prevention or reduction of the threat that leads to the top event are then documented.

As an example, internal corrosion is a threat to loss of containment of a process gas compressor. Controls that could mitigate this are:

- Design - Corrosion allowance, metallurgy, including the need to stress relief those systems in caustic service.
- Mechanical Integrity – Inspection of the pressure equipment and piping.
- Procedures – Decontamination of the lines in caustic service when down for maintenance.

Figure 3 provides a sample Process Gas Compressor Bowtie – Corrosion Threat Line. This process is completed for all the threats identified for the loss of containment scenario. A threat is identified the controls are discussed and documented, then on to the next threat. A single bowtie can have as few as one threat to as many as thirty or more threats identified.

The next step is to consider a hypothetical scenario that assumes the top event occurs and then review the controls for the recovery or mitigation of the consequence. For example, in a Process Gas Compressor case, one of the consequences could be a Vapor Cloud Explosion (VCE). The controls that mitigate or minimize the risk of a VCE from occurring might be as follows:

- Design – Control of ignition sources (electrical area classification, unit spacing, grounding requirements, etc.).
- Design – Fixed fire water system, deluge, gas detection, etc.
- Permit to Work – Control of ignition sources (vehicle entry, low energy/hot work, etc).
- Initiate Emergency Response – Call the plant emergency number.
- Emergency Preparedness and Response – Drills, pre-plans, staging, people, equipment, etc.

See Figure 4 for a sample Process Gas Compressor Bowtie – Vapor Cloud Explosion Consequence Line

For each of the identified controls, the critical tasks and/or activities associated with the control are determined, and the responsible individual is assigned to the task. In this manner, a list of critical tasks is developed for each individual at the site from the operations/crafts specialists to the plant manager. These tasks are then collected and used to identify the tasks for each job role and to make the responsible individual aware of the tasks. For example, on the corrosion threat line the procedure for decontamination of caustic lines was identified as a control. The critical tasks for this control might be as follows:

- Operations Specialist – Follow the procedure for decontaminating all lines in caustic service to determine that the temperature of the piping does not exceed design requirements.
- Maintenance Foreman – Make craftsmen aware of the lines to be worked on that may have caustic contamination and require stress relief after repair work.
This list of critical tasks and activities is now a tool for the site to use to help manage HEMP identified HSE risks, and assist in identifying training and development plans for the site. It also becomes a tool in the management of organizational change. It also provides an auditing tool. In many instances, most tasks and activities that are identified by this process are not new, and the site is already completing most of the tasks. The power of this tool is to put all this into a framework that can be used to document the identified HSE hazards and controls that are in place and implemented.

**Conclusions**

♦ The Hazards and Effects Management Process or HEMP is a way to build a framework for the management of identified hazards at the site.
♦ HEMP provides a systematic consistent method of risk assessment.
♦ The bowtie analysis provides a framework for documenting that controls are in place to manage identified “high risks”.
♦ HEMP allows the facility to compile an action list of the status of controls and/or critical tasks and activities in the actual project, site or production unit.
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<th>No.</th>
<th>HAZARD DESCRIPTION</th>
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<td>H-14.03</td>
<td>Diesel fuel</td>
<td>H-15.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-15</td>
<td>Electricity</td>
<td>H-15.68</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Sample of Hazards for Hazard Identification
<table>
<thead>
<tr>
<th>Hazard #</th>
<th>Stream</th>
<th>Top Event</th>
<th>Consequence</th>
<th>Risk Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-01.01</td>
<td>Fuel gas to furnace:</td>
<td>• Loss of containment</td>
<td>• Unignited release in open area (up to max 160 ppm H₂S in gas during start up)</td>
<td>P L L L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Explosive mixture in firebox</td>
<td></td>
<td>M M M M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Jet fire</td>
<td></td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vapour cloud explosion (VCE, furnace re-ignition)</td>
<td></td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Explosion on relight</td>
<td></td>
<td>L M M M</td>
</tr>
<tr>
<td>H-01.02</td>
<td>Process Gas:</td>
<td>Loss of containment</td>
<td>• Fire or explosion</td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Pump seal fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Flange fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• VapourCloud Explosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Spills/Release (unignited release)</td>
<td>M L L</td>
</tr>
<tr>
<td>H-01.03</td>
<td>Green oil overhead to guard dryers</td>
<td>Loss of containment</td>
<td>• Fire or explosion</td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Flange fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• VapourCloud Explosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Spills/Release (unignited release)</td>
<td>* M L L</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Uncontrolled energy release</td>
<td>H M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Rupture, violent failure of equipment, mechanical damage, missile, pipe-work</td>
<td></td>
</tr>
<tr>
<td>H-01.04</td>
<td>Dilution steam system</td>
<td>Loss of containment</td>
<td>• Spills/Releases</td>
<td>* M L L</td>
</tr>
<tr>
<td>H-01.05</td>
<td>Ethylene refrigeration compressor cooling system</td>
<td>Loss of containment</td>
<td>• Fire or explosion</td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Vapour Cloud Explosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Spills/Releases (unignited release)</td>
<td>* H H M</td>
</tr>
<tr>
<td>H-01.06</td>
<td>Ethylene to pipeline – product</td>
<td>Loss of containment</td>
<td>• Fire and Explosion</td>
<td>H H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Pipeline explosion (detonation)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exposure to Hazardous Decomposition in Pipeline</td>
<td>• Spill release (unignited release)</td>
<td>* H H H</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Release to flare</td>
<td>- H H</td>
</tr>
<tr>
<td>H-01.07</td>
<td>Vents and drop outs to flare</td>
<td>Loss of Containment</td>
<td>• Liquid fire at the flare tip and ground.</td>
<td>H H M M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Explosion in Flare line.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Unignited vapour cloud, liquid release</td>
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<tr>
<td></td>
<td></td>
<td>Smokey flare</td>
<td>Compliance incident (full unit relief to flare)</td>
<td>* M M M</td>
</tr>
</tbody>
</table>

P – People,  A – Assets,  E – Environment,  R - Reputation
H – High,  M – Medium,  L – Low
What are the causes and consequences? How likely is loss of control? What is the risk?

Are people, environment or assets exposed to potential harm?

Can the causes be eliminated? What controls are needed? How effective are the controls?

Can the potential consequences or effects be mitigated? What recovery measures are needed? Are recovery capabilities suitable and sufficient?

What are the critical activities and tasks needed to maintain control and recovery measures? Who does it?

Is it being done?

Figure 1 – Hazards and Effects Management Process

The bow-tie

Objective: reduce likelihood

Objective: mitigate consequences

Figure 2 – The bowtie
Control of threats

Figure 3 – A Sample Process Gas Compressor Bowtie excerpt – Corrosion threat line

Recovery Measures

Figure 4 – A Sample Process Gas Compressor Bowtie – Vapour Cloud Explosion Consequence Line