Ammonia Terminals Risk Management Improvements

Through a series of corporate acquisitions, Agrium has assembled a number of anhydrous ammonia distribution terminals. Prior to Agrium's acquisition, the engineering, operating, and maintenance standards used to manage those facilities varied, and in most cases were different than those which Agrium had traditionally followed. To ensure that Agrium's standards are consistently applied going forward, Agrium embarked on a PSM based assessment project involving 10 of its ammonia terminals. The results and conclusions of this project are reviewed in this paper.

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Introduction

In contrast to manufacturing plants, terminals are often considered to be less hazardous, despite the fact that all such terminals store and handle the same product, yet often in quantities that far exceed that of the manufacturing plants. In addition, terminals have significantly less personnel involved in the operation, are unmanned a portion of the time, and generally are less automated, thus they depend on utilization of call-out systems for operator response to control process deviations.

To ensure that the storage and handling of ammonia and similar commodities met with Agrium standards, Agrium initiated a project to determine the reliability of the terminals' automated systems (regulatory controls, equipment protection and emergency shutdown systems). Agrium's intent was to ensure that the facilities met its minimum standard for emergency shutdowns and critical alarms.

Process Risk Management Improvement Project

Process Risk Management Overview

Risk management is simply a process of identifying potential hazards, determining the most likely consequences of those hazards, analyzing the probability of occurrence (frequency), and deciding what safeguards are required to reduce the probability of occurrence. The actual practice of risk management is not so simple. There are several different hazard identification and analysis tools to quantify risk and risk-reduction given the application of safeguards. To quantify the risk applicable to any potentially hazardous situation, one must have a clear understanding of the following:

- probability of the initiating event,
- most likely consequence if the event occurs,
- the acceptable frequency (tolerable frequency) of the consequence, and
- the reliability of existing and proposed safeguards.

Process Risk Management Improvement

The risk management philosophy employed at the sites when Agrium acquired them varied. Although the sites met their applicable federal, state/provincial and local regulations, they lacked a standard approach to managing process risks. Furthermore, risk tolerance was dissimilar from site to site even though a standard risk matrix was used. The objective of the risk management improvement project was to develop and standardize on a risk management process that would result in a consistent measure of risk exposure before and after safeguards are considered. In so doing, it was believed that Agrium would experience a reduction in process safety incidents.

The biggest limitation in past process risk management practices was the lack of a quantitative analysis of the risk and the safeguards required to mitigate the risk. While the sites did an excellent job at identifying the hazards, they did not have the tools to quantify the risk and adequate safeguards. In essence, the analysis of risk and safeguards tended to be subjective and diverse.

Beginning in 2007 Agrium initiated a project to improve their process risk management process. The first step was to develop a corporate risk matrix that was more appropriate for individual site process risk management. While the existing corporate risk matrix was suitable for managing the overall company risks, the fidelity was not accurate enough to deal with site-specific process risks. The results are shown in Figures 1 and 2.

The second step was to develop and standardize a risk management system that reduced subjectivity. The process hazard analysis (PHA) technique that was chosen was a guideword HAZOP, which was standardized as follows:

- standard set of guidewords,
- standard set of initiating event frequencies (sites may override if their experienced frequency is higher),
- standard set of safeguard reliabilities (sites may override if their experienced reliability is lower), and
- standard independence criteria for safeguards.

Ammonia Terminal Risk Management Improvement Project

The terminals included in the project were North American Agrium-owned terminals that handled anhydrous ammonia. The terminals are of a range of ages, had been designed and constructed to various standards, have different load-in and load-out capabilities, are often unmanned, and have dissimilar complexities of controls and safety instrumented systems. A list of Agrium's ammonia terminals is provided in Table 1. Despite the differences in the facilities, a consistent technique was required to evaluate and manage the risk exposure on equal ground.

Methodology / Approach

Through consultation with Agrium personnel with extensive experience and knowledge of such matters, the terminal group decided that the analysis would be done using a standard PHA methodology with a fixed-core PHA team. Past PHA's of the sites would not be referenced or utilized, because it was felt that relying on the recently standardized PHA methodology was the most effective quantitative means to meet the project's objectives. Although the methodology to be used had not been officially released as a standard, there was only some fine tuning required before it could be made applicable to all sites.

Initial Approach

The initial plan for this project was to develop a minimum set of critical process safety systems that would apply to all NH3 terminals. The strategy was to conduct PHA's at two modern (most recently built) facilities and use the PHA results to set the minimum standard. In other words, the existing safeguards and recommendations resulting from the PHA's would be translated into a minimum set of critical safety systems.

This standard would then be applied to one of the oldest (perceived as most outdated) terminals, and a PHA would be performed to verify if all risks were adequately mitigated. Based on this third and final PHA, and after some fine-tuning, this standard would then be rolled out to all the terminals for full implementation within a year. As the facilities' PHA revalidations came due, new PHA's would be conducted to complete the cycle.

Actual Project Execution

As was realized after completion of the first two PHA's, each site is unique and it would not be possible to address the root cause of all ammonia release scenarios with a single standard set of safety systems. The differences in design, instrumentation, and legacy systems were too great. The team decided that a PHA would have to be completed at each site, using the knowledge gained from the first two PHA's, to develop customized improvements within their specific instrumentation and safety systems. Other factors that contributed to this decision included the facility's proximity to a community, and the ability for timely alarm response to callout situations.

The following is a summary of the actual project execution:

- PHA's were conducted at each terminal.
- Each site's P&ID's were checked, validated and updated, in preparation for the PHA.
- The scope of the PHA's was limited to ammonia release scenarios only (business loss and disruption risks associated with equipment damage and operation issues were not considered).
- All 10 PHA's would be conducted consecutively over a minimum range of time
- A set group of team members would be utilized at each PHA (see project resources below).
- Follow-up Layer of Protection Analyses (LOPA) would be completed within two months of receipt of the final PHA report.

Approximately $1,000K was budgeted for completion of PHA's and LOPA's. This cost included P&ID updates, employee travel expenses and consultant contract services.

Project Resources

Since the objective of this project was to establish a standard of risk management across all the ammonia terminals, and the "one standard fits all" approach was not appropriate, a unique strategy to obtain consistency was required. The plan involved utilizing a core PHA team at each terminal. The core PHA team consisted of the following:

- Leader / Scribe (Consultant)
- Sr. Technical Specialist
- Terminals Manager
- Terminals Engineering Manager

The site specific team members were as follows:

Terminal Operations Supervisor
Instrumentation/Controls Technician
Offsite Engineer

Contract electricians and P&ID drafters were added to the analysis team as needed.

To further ensure consistency of the PHA's, each site was functionally partitioned as close as possible, using the following six nodes:

1. Load-in to Storage
2. Storage to load-out
3. 1st Stage Vapor Compression
4. Interstage and Flash
5. 2nd Stage Vapor Compression and Condensing
6. Load-out vapor return

Due to internal resource constraints, third party consultants and contractors were used for the P&ID verification and updates, PHA and LOPA facilitation, report documentation, and some engineering development activities.

Results

Key Findings

Looks can be deceiving – the terminals with relay logic and controls had less overall risk than terminals who had programmable logic controllers (PLC) or distributed control systems (DCS), owing to the fact that safety instrumented function design wasn't uniformly incorporated into critical safety shutdowns in the earlier control systems.

P&ID's deviated in quality and accuracy, and required a greater than anticipated effort for updating and verifying. During the update process, a shutdown matrix was developed as a quick-reference guide, which listed trip and alarm instrumentation with their associated field action (e.g., high-high level switch closes feed flow valve and activates indication/annunciation in the control room).

Equipment identification (alpha-numeric tagging) and drawing/documentation conventions across all the sites were not the same. Standardization of equipment tagging and P&ID convention would simplify ongoing revalidations. However, this task would have to be planned and completed over a subsequent period of time.

Inconsistent methodologies and rigor had been applied to past PHA's.

Terminal personnel gained an expanded understanding of existing risk and risk management practices by actively participating in the assessments.

The first three LOPA's required revalidation, because it was later recognized that not all existing safeguards for given scenarios where listed during the PHA. Rather, only "enough" safeguards were recorded to mitigate the perceived risk level at the time. Also, LOPA participation was extended to include key operational and instrumentation participants.

Engineering support at the terminals had been previously focused on capital project management, and was not routinely available for support with PSM activities.

Scheduling the PHA's and LOPA's for all participants, around existing job accountabilities, commitments, and business seasons was a great challenge. Consequently, analyses were completed over a 15 month period.

Owing to the unanticipated level of work required to update P&ID's, and the requirement to revalidate three LOPA's, the actual overall assessment cost was higher than planned.

Uniform set of analysis assumptions and predetermined criterion on how consequence severities are rated must be established.

Operating concerns stemming from group discussion, however unrelated to an identified risk or not required to mitigate risk, where recorded as "parking lot" issues, to be considered for future implementation at management discretion.

- Excess flow valves were not given credit as a safeguard in most scenarios, since excess flow valves close with exceptionally high flow, which is not attainable given a small-scale leak/loss of containment.
- Differences between Canadian and US regulatory PPE requirements caused variance with normalizing analysis.

Generalized Guideline for Critical Safeguards

Several broad trends are apparent from the assessments. The following is a summary of these generalized safeguard trends:

- Ammonia detection covering key facility locations, configured to alarm and/or activate shutdowns at pre-determined setpoints
- Loading hose/arm break-away couplings
- Sufficient basic process control
- Independent safety instrumented function shutdown systems
- Emergency quick-activating shutoff /isolation valves triggered automatically or manually
- Compressor vibration monitoring
- Compressor building air quality control (adequate ventilation and space heating)
- Flare and vent header design criteria
- Safety eye-wash/shower design for very low ambient temperatures
- Spring-loaded manual valves for bleeds
- Routing of PSV exhausts to safe locations
- PSV placement and design criteria
- Critical External Temperature of piping and equipment
- Mechanical Integrity (MI) inspection program (corrosion under insulation, check valves, critical devices, vessels)
- General SOP revisions
- Car Seal Open/Car Seal Closed logging
- Under tank heating w/zone control & alarms
- Guard posts to protect equipment against mobile equipment impact
- Site security to protect against unauthorized entry
- Installation of redundant instrumentation for extra reliability

Conclusions

The key to consistent process risk management across a variety of sites is to adopt a standard methodology. While most companies have a standard risk matrix, the methodology and analysis techniques are often left up to the individual site or the individual PHA leader. The standard methodology should be sufficiently detailed to ensure that the risk is consistently measured, and the required safeguards are consistently analyzed.

Instrumentation projects that are undertaken to improve reliability and maintainability must be carried out with an understanding of the required independence between the various control and protection systems. This understanding can only be obtained through a properly conducted process hazard analysis that results in the functional specification of the various systems. If not, modern computer based instrumentation systems can adversely increase risk while improving the facility reliability.

Corporate standards with respect to risk mitigation systems can only be generalized when dealing with existing facilities, especially if the existing facilities have different legacies. It is more important and more effective to have clear and concise risk tolerance criteria and to have a standard methodology to identify and measure specific mitigated risks at individual sites. Only with quantitative or semi-quantitative analysis can a large corporation meet its overall risk objectives.

		Frequency				
		Frequent	Occasional	Unusual	Rare	Remote
		Several times per year	Up to once per year	Up to once per 10 years	Up to once per 100 years	Only 1 to 2 incidents world-wide
Consequence	A	**X**	**X**	**H**	**MH**	**M**
	B	**X**	**X**	**H**	**M**	**L**
	C	**X**	**X**	**M**	**L**	**N**
	D	**M**	**L**	**L**	**N**	**N**
	E	**L**	**N**	**N**	**N**	**N**

Figure 1 – Original Agrium Risk Matrix (before improvement)

		UNMITIGATED FREQUENCY				
		5	4	3	2	1
		Frequent $\geq 10^{-1}$ per year (greater than 1 in 10 years)	Probable $\leq 10^{-1}$ per year (up to 1 in 10 years)	Remote $\leq 10^{-2}$ per year (up to 1 in 100 years)	Improbable $\leq 10^{-3}$ per year (up to 1 in 1000 years)	Highly Improbable $\leq 10^{-4}$ per year (up to 1 in 10,000 years)
Consequence	A	**X**	**X**	**H**	**MH**	**M**
	B	**X**	**H**	**MH**	**M**	**L**
	C	**H**	**MH**	**M**	**L**	**N**
	D	**MH**	**M**	**L**	**N**	**N**
	E	**M**	**L**	**N**	**N**	**N**

Figure 2 – Improved Agrium Risk Matrix (quantified risk and risk tolerance by orders of magnitude)

Table 1: Agrium Ammonia Distribution Terminal Information

Location	Year Built	Owner		Type Storage		In Load	Out Load	Self Load
		Original	At Acquisition	Atmospheric	Pressurized			
Bloom, MB	1981	Esso	Viridian	Y	Y	Rail	Truck	N
Roma, AB	1994	Esso	Viridian	N	Y	Rail	Truck	N
Watson, SK	1982	Sherrit	Viridian	Y	Y	Rail Truck	Truck	Y
Early, IA	1968 1998	Hill Chem, Cominco	Cominco	Y	Y	Pipeline	Pipeline Truck	Y
Garner, IA	1969	Hill Chemical	Cominco	N	Y	Pipeline	Truck	Y
Hoag, NE	1965 2005	Cominco	Cominco	Y	Y	Pipeline Rail	Truck	Y
Leal, ND	1987 1995	Cominco	Cominco	Y	Y	Rail Truck	Truck	Y
Marseilles, IL	1963	Chem & Ind Corp, IL N2 Corp	Royster Clark	Y	N	Barge	Truck	N
Meredosia, IL	1966	Mobil Oil	Royster Clark	Y	N	Barge	Truck	N
Niota, IL	1967	Apple River Chem Co.	Royster Clark	Y	N	Barge	Truck	N