Process Safety: Revisiting Evergreen Practices

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Abstract

Of all the industries, the chemical industry by its very nature of handling thousands of diverse materials, many of them hazardous, causes a high amount of risk in its operations. But the risk cannot be allowed to end in accidents as it could be devastating in many respects. However, through the experiences gathered over the years, effective management systems, latest digital technologies, well laid down procedures, a holistic top down approach, a responsive communication system and a safety culture inculcated into the very thinking and mindset of the entire workforce, the process industry can well ensure that the risks are well controlled. This paper highlights the key points related to operating procedure and process safety competency development, improved monitoring, and incident feedback, while maintaining an active and healthy safety culture.

Workplace injuries and reliability incidents are common worldwide. Although some jobs are considered safe, others carry risk. According to the United Nations, approximately 374 million non-fatal occupational accidents are reported each year, while 2.8 million workers die from work-related accidents and diseases, or about 7,500 deaths per day. These incidents in the labor force cause the global economy to lose from 10 to 15% of its GDP.

So, how can the process industry sector reduce injuries and deaths? The key to reducing occupational accidents as well as improving site safety and reliability involves implementing a fully functional Integrated Management System (IMS). A company's IMS integrates its processes and systems into one framework, allowing the company to focus on achieving a single set of goals. It covers all elements such as management's vision, industry standards, procedures, equipment monitoring and feedback, as well as national and international legal compliances.

A typical list of IMS areas to monitor includes:

- Clear and comprehensive leadership expectations, policies and procedures that align with the company values.
- Monitoring tools and digitization to stay informed of operating conditions, which serve as the foundation of the IMS.
- Full company-wide integration to ensure critical-safety information and clearly defined roles and responsibilities are communicated to all relevant

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stakeholders.

- Implementing procedures with competent operators and engineers and ensuring that a responsible workforce is engaged and held accountable for process safety improvement.
- Auditing and validating the IMS to detect issues and improve its quality and effectiveness to promote safety and a culture of continuous improvement.

Developing and maintaining the whole IMS system is a big undertaking. Even resource-rich, multi-site companies may find sustaining these tasks difficult. Therefore, the IMS team must embrace good procedure development, operating skills, and tools to improve overall safety performance and the quality of unit health monitoring. Even before the implementation of a mature IMS system, some operating sites have achieved high levels of process safety and reliability at the working level, by performing good work in these areas.

Operating Procedure Development

A procedure is generally a step-by-step guide to perform an activity. However, instructions often only explain the general requirements, or 70% of what is needed, but exclude the crucial "how," "why," and "when" information. Even with all the instrumentation available, understanding the fundamental process response and control requirements are vital components, as mistakes can happen.

A well-structured procedure management system is required to help operators determine their starting point, interim goals, the necessary resources, and the best path to achieve those goals safely.

It should include:

- Status checklists before following the procedure, similar to the checklists used by pilots before take-off.
- Sketches based on the process flow diagram (PFD) or distributed control system (DCS) screen flow-sheets, especially when different circuits are involved.
  - o Mark ups of PFDs when significant modifications have been made to the process, to ensure all systems and equipment have been thoroughly inspected.
- Comprehensive descriptions of the required actions, the estimated time, and a brief explanation of why the ordered task(s) are needed, particularly when they are unclear.
- Full descriptions of major equipment when first mentioned, rather than assigning a number.
- Status of the equipment versus its expected condition at appropriate milestones.
- Comprehensive reference list hyperlinked to back-up information, including the process plan, equipment start-up and shut-down, and more.
- Monitoring parallel activities on other linked process units, for example start-up times and steps to commission equipment on other units providing feed or utilities.
- Description of risks and mitigations involved in performing task(s).
- Cloud-based monitoring tools to provide status updates in real time such as valve closures and system depressurizations.

Operator Involvement

In practice, operators should be involved in developing the final operational procedures for their process unit, with the aid of the process engineer, vendor, or consultant as necessary. This practice enables operators to establish ownership and a thorough understanding of the process. In the final review, process engineers should also be involved in a cold eyes review.

Procedure Writing

Developing and writing the procedures goes in tandem with training. Procedures are often developed and/or updated only 1-2 weeks before utilization. This minimal time frame prevents operators from assimilating to the procedures and identifying problems. For instance, a missing drain or vent can hamper a procedure, making it ineffective and even hazardous. To minimize the risk of oversight, critical process steps, such as mitigations from a Hazard and Operability Study (HAZOP), should be clearly identified within the procedure. This may include steps to mitigate situations such as over-pressure, vapor blow through, or pumps operating in no-flow conditions.

Some procedures are imperfect and may cause accidents. A key source of learning is to keep procedures current in the context of managing risk and include incidents and procedure feedback.

Root Cause Failure Analysis (RCFA).

In theory, RCFAs may seem like the appropriate tool to find the root cause of a problem. However, poor root cause analysis may stop at the first identified contributor or determine the physical cause of an incident, such as a human and/or systemic issue, but fail to identify the underlying cause(s). Regardless of the incident, other causes are often overlooked and a mitigation strategy is only developed for that one issue. An effective RCFA should always try to explore how human error and systemic failings contribute to causing incidents. These causes can then be addressed through the IMS, via procedures and training, to prevent this incident from repeating.

When finding and developing sound solutions to the real root cause(s), gaps often exist between the mechanical practices and processes. The key to an effective RCFA is ensuring that the RCFA team consists of discerning professionals with the ability to propose unconventional, multi-functional solutions.

which conceals the underlying cause.

Additionally, cooling water leaked from crude overheads exchangers. This caused the water treatment chemicals to plate out in the reactor. A sound foulant analysis was key to finding the root causes. Now, the conclusions were closer to identifying multiple root causes, though actions like filtering may have been a faster mitigation.

Finally, frequent plant shutdowns and thermal cycling also contributed to the pressure drop trend. Foulant and scale spalled off the upstream equipment into the reactor. This finding suggested that better restart procedures were required.

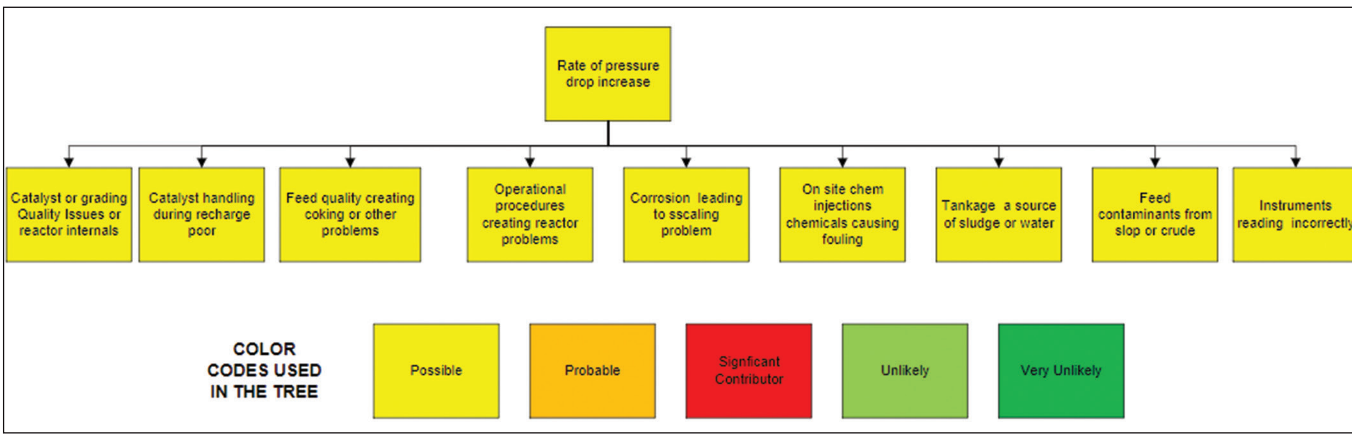

Figure 1. Nine potential contributors to the problem

Case Study 1

A refining operation on a diesel hydro-treating unit was in mid-cycle when a significant reactor pressure drop occurred. In this case, the root cause of the problem was not the one originally defined. In a reactor system, a pressure drop may signal several issues such as feed, catalyst loading, corrosion, and more. While an obvious mitigation solution involved filtering the feed or adding a filtration layer to the top of the reactor, these were not the root causes of the problem. Figure 1 shows the other eight potential contributors to the incident that needed to be checked, too.

Figure 2 illustrates an overview of the reactor loading process where each potential contributor benefits from a more complex analysis.

As shown in Figure 3, looking at feed contamination there are several possible root causes and mitigations, with the major contributors highlighted in red. As a result of corrosion in the crude unit, hydroprocessing units often experience increased pressure drop and may lack complex filtration systems. Feed filtering can camouflage the symptoms of upstream corrosion,

Case Study 2

Operators lacked an understanding of WHY a step in the procedure was safety-critical. Despite the sequence of actions being part of an agreed mitigation from the units' HAZOP study, they discovered a convenient workaround to the procedure.

The required steps involved placing a second pressure-regulating valve (PRV) into service while switching a level control valve to prevent over-pressure in the downstream vessel due to a failed valve. The valves in the field were key-locked sequentially. Because the distance between the key-locked valves and the control room with the keys appeared excessive, the operators learned to defeat the key-locks to complete the task.

Subsequently, the procedures were modified to highlight the mitigated steps from HAZOP studies. Additionally, the operators were re-trained.

Process Safety Competency Development

All processes carry some risk; hence Hazard Identification is required to enable competent people

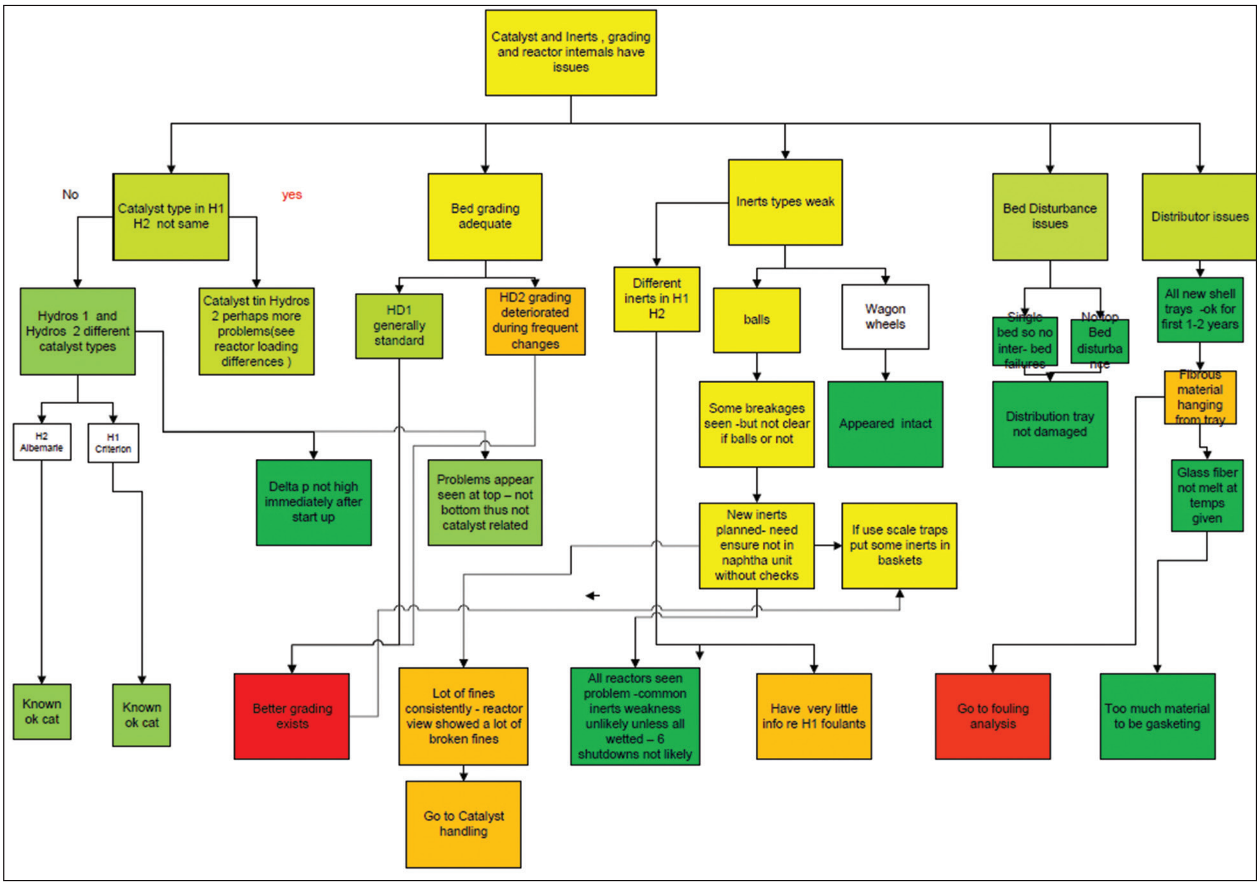

Figure 2. Catalyst bed impacts on the pressure drop incident

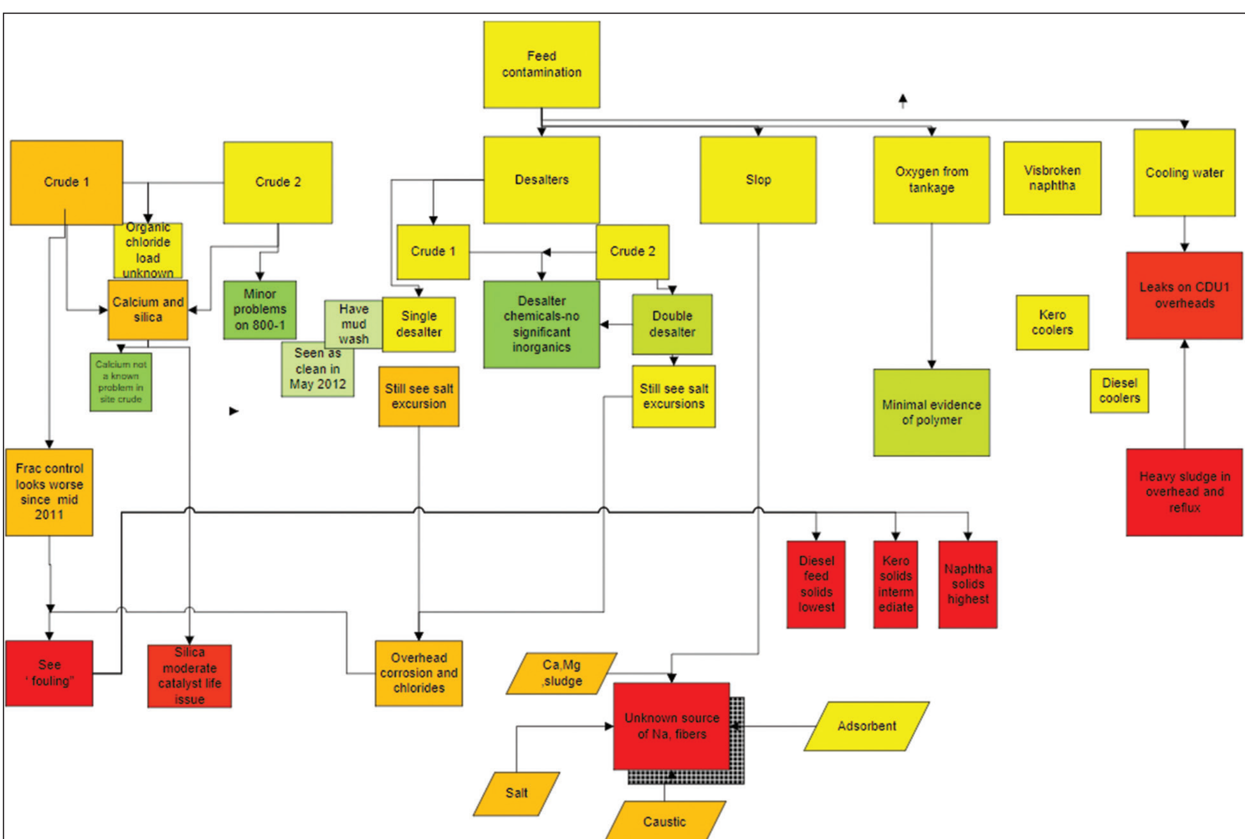

Figure 3. Feed quality impact on the fouling problem

familiar with the process to identify and manage the risks. In addition, the training and assessment cycle of a Competence Program should be embedded into the plants' operating procedures.

What is Competence? Competence is the ability to perform a task well. This accompanies technical expertise, experience, industry and cross-functional knowledge, and being able to manage unplanned situations under pressure. Competence is also required to develop and apply solid procedures and RCFA practices.

Competent persons must be cognisant of the "safely" aspect of the procedure while performing a task. Operating teams require several competent persons on-board in case they need to respond to and mitigate an emergency.

The following are ways to develop and build competency:

- Touring other site(s), for a multi-site company, to showcase proven practices.
- Training from experienced peers within the wider global industry or hiring external consultants.
- Evaluating knowledge by asking simple to complex questions as well as employing scenario-based testing, for example what can happen when depressurizing LPG systems.
- Using simulators to hone skills during emergency situations.
- Participating in complex situational development exercises to test whether individuals, and particularly groups, can collectively create and apply solutions. A good analogy is the activity in a plane cockpit where pilots operate instrumentation under stress, which determines whether passengers live or die. Training in competitive teams is also often useful.

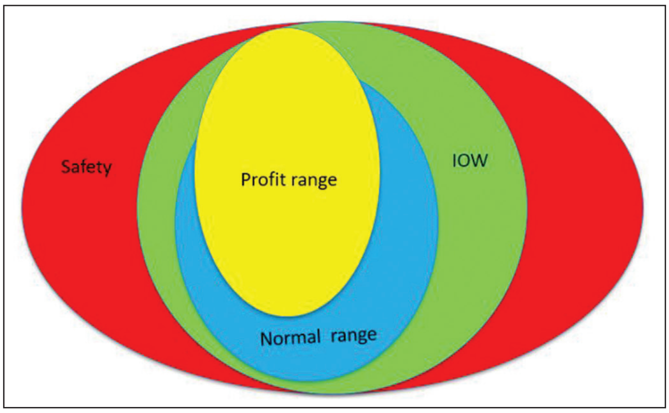

Figure 4. Operations overlap to meet economic and process safety targets while skirting unplanned outages

The most experienced and competent professionals will have started up multiple process units including grass roots facilities. Their vast knowledge includes understanding the equipment, equipment hold up, and heat-up times. Often, veteran operators conduct this training to transfer their knowledge across multiple sites. Some consultant groups also specialize in providing this expertise.

Process Safety, Reliability Monitoring, and Digital Enhancements

An additional pillar of support involves implementing reliable monitoring tools and systems to improve operational and technical support.

Operators or engineers have always needed good processes, training, and effective procedures. Process Monitoring has advanced from simply maintaining material balance and monitoring flows, pressures, temperatures, and process stream properties in real time to balancing process safety, quality, profitability, and environmentally-friendly operations. Figure 4 shows how these different operating targets overlap.

Monitoring includes:

- Safe Operating Windows.
- Integrity Operating Windows (IOW) to measure equipment corrosion and remaining useful life between maintenance changes and more.
- Process and mechanical key performance indicators (KPIs) such as catalyst deactivation rates or thermal cycling severity and frequency. These metrics flag warnings for corrective action.

A digital twin dashboard (see Figure 5) offers a full monitoring package for daily control and long-term reliability issues such as corrosion or catalyst deactivation. These systems include:

- Digital twin models to allow comparison of expected and measured performance of all equipment.
- Digital tools to monitor equipment, detect warnings, and schedule as well as record tasks.

Parallel modeling (also known as digital twins) of the whole process or system can help engineers identify deviations to improve reliability and process safety before an incident occurs.

Both the base KPIs and equipment IOWs can be built into the unit monitoring and included in the unit field operating tablets to enable operators and engineers to maximize awareness and reduce the chance of process safety incidents. Figures 6 and 7 show how critical limits can be developed. Figure 8 shows how a

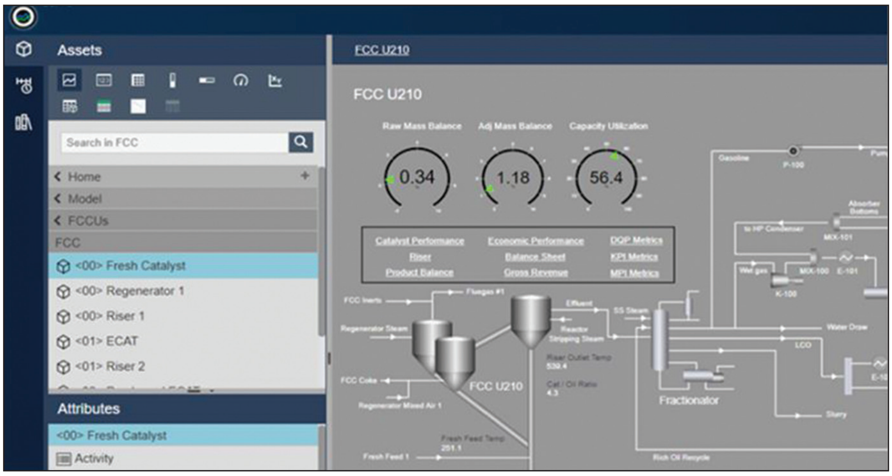

Figure 5. Digital Twin Dashboard

flowsheet can be used to give information to set KPI/IOW target.

Additional design and administrative barriers that require effective monitoring include:

- Safety Critical Equipment
- Fire and Gas Protection Systems
- Emergency Shutdown Systems
- Alarm Management Displays.
- Permit to Work Forms
- Management of Change Processes (MOCs)
- Equipment Inspections
- Actions outstanding from RCAs, etc...
- Equipment Life Monitoring

The IMS plays a crucial role in ensuring that all of these processes and digital tools are effective, through integration of different departments, business processes, tasks, and data.

An example of this is IOW monitoring. The monitoring of IOW may be carried out by a process engineer, however in the event of an excursion, it is critical that this is communicated to the engineering or inspection department, to assess the risk of the excursion versus the risk-based inspection (RBI) analysis for a given piece of equipment.

These activities require employees to have a positive and dynamic mental attitude to Process Safety. This environment is created by a healthy safety culture. Some tips to provide this are summarized below:

Safety Culture Tips

A healthy safety culture goes beyond a list of rules and regulations. Employees must be engaged, keep safety and reliability top of mind, and adopt a posi-

	Targets								Intermediate Intervention		Intervention Over Time		No Intervention Required		Action Required	Plant Data	
Section Area	Catalitica III					Design	Standard Deviation	Actual Average	Critical		Standard		Informational			Dates	
Parameter Description	Tag Identification	Unit of Measure	Minimum Value	Target Value	Maximum Value				Min	Max	Min	Max	Min	Max		22/03/2022	23/03/2022
Unit Feed and Product Flows																	
Feed																	
Diesel Feed	D_FY001.PV	Tonnes/hr	70	max	140											109,8	109,7
Cracked Feed	D_FY002.PV	Tonnes/hr	0	1,5	3											1,5	2,1
Total Diesel Feed	D_FY003.PV	Tonnes/hr	70	MAX	140											105,3	105,3
Make Up Gas	D_FY13_AMPV	Tonnes/hr	0,5	>1	1,5											0,7	0,7
Total Feed In		Tonnes/hr														112,0	112,5
Products																	
HP Purge Gas	D_FY16_AMPV	Tonnes/hr	0	MIN	0,1											0,1	0,1
LP Stripper Offgas	D_FI25.PV	Tonnes/hr	0,3	MIN	1,5											0,5	0,5
Wild Naphtha	D_FY027.PV	Tonnes/hr	0,5	MIN	4											0,4	0,4
Diese Product	D_FY033.PV	Tonnes/hr	70	MAX	140											111,7	118,9
Diesel Product	D_FY029.PV	Tonnes/hr	70	MAX	140											0,0	0,0
Total Products Out		Tonnes/hr														112,8	119,9
Deviation between Calculated Feed and Measured Feed		wt%														6%	7%
% mass balance error (out-in)		wt%														7%	14%
% Converstion (Gas+Gasoline)		wt%														1%	1%
%Yield (Treated Diesel/Feed)		wt%														106%	113%
Preheat and Furnace																	
Feed Temperature	D_TI4.PV	°C	40	MAX	90											71	72
Furnace Feed Pressure	D_PI23	Kg/m2(g)	40	MAX	48											45,8	45,8
Feed Percent CV Open	D_FCV3.CV	% open	15	70	85												
Furnace Preheat Temparature	D_TI2I.PV	°C	250	MAX	300											250	250
E-01 Feed Inlet Temperature	D-TI4	°C	50	MAX	80											71	72
Carbon Steel limit vs. D E1 D out SS						252											
E-01 Effluent Outlet Temperture	D_TI15.PV	°C	70	MIN	100											100	100
E-01 Cold end approach temperature delta T (Fouling indicator)	(D_TI15-D_TI4)	°C	30	MIN	50											29	28

Figure 6. Base KPI bracketing

		Safety / IOW	IOW	Economics
KPI/ IOW Variable Response Development	Variable Level	Safety / Environmental Fast Response	Reliability /Equipment intervention	Economic /Energy / Carbon Footprint Intervention
Failure Occurs Fast	VeryHigh	x		
Failure May Occur With Sustained Operations	High	x	x	
Safe, Stable & Reliable	Operating Range		x	x
Failure May Occur With Sustained Operations	Low Level		x	
Failure Occurs Fast	Very low	x	x	

Figure 7. Critical limit set-up

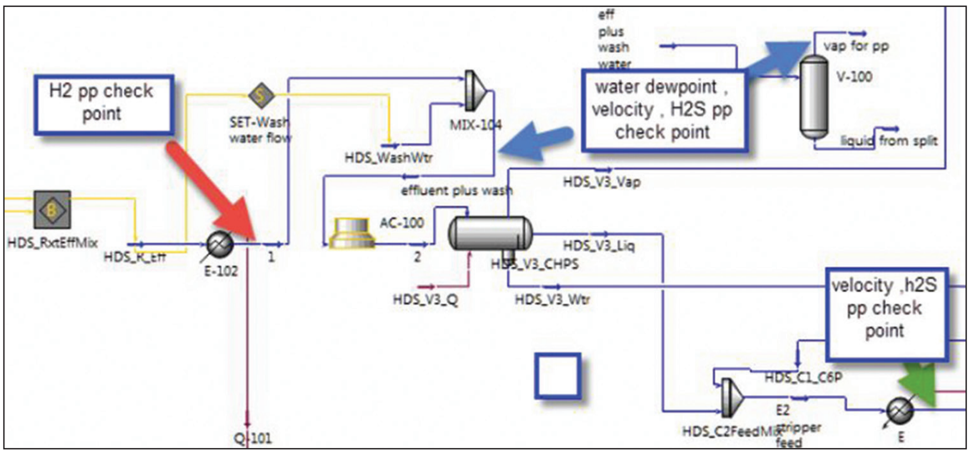

Figure 8. Use of flowsheet to generate information for KPI/ IOW targets

tive mindset. While Safety is a large topic, many static training methods can be employed, including:

- Safety training, including tests and minimum pass rates
- Safety videos
- Safety statistics
- Safety signage
- Visual communication of incidents and resolutions
- Safety moments before meetings and presentations
- Safety activities which improve the employee's safety skills and awareness using:
- External training courses such as first aid, behavioral safety, and advanced driving for building awareness of surroundings
- Safety competitions such as speed in deploying fire-fighting equipment
- Process safety improvement incentives

A positive, open safety culture requires top-down leadership and bottom-up reverberation. Employees must be confident that they can perform their jobs in a safe environment and improve their skills to facilitate the company's safety goals.

Conclusion

In the last decade, process safety has been recognized as a critical issue in operating complex, industrial processes. As the cases presented in this article illustrate, it is often challenging for operators and process engineers to identify potential safety threats and defend against them. With a fully functional IMS, companies can more easily detect potential safety threats and eliminate them before they materialize into a real problem. The goal is to not only ensure that processes are safe when in operation but also to build and maintain a robust safety culture throughout the company.

This article discussed several basic process safety and reliability activities that can be simply developed and implemented. These evergreen activities will prevail regardless of the proposed management process. Most can be applied at the operational level, where it counts.