Common Hurdles, Benefits, and Costs for Fully Implementing Process Safety Worldwide – Especially in Countries without PSM Regulations

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Abstract

Process safety is implemented around the world and most of those sites do not have government regulations for compliance to push them along. The hurdles for effective (full) implementation appear to be roughly common from country to country, and site to site. This paper summarizes the lessons learned from multiple companies/sites around the world. Specifically, the paper compares hurdles to effective implementation and how company crossed these hurdles. We also update earlier papers on the costs and benefits of effective implementation of process safety. Each of these implementations is an example of process safety implementation at a non-covered process and in many of the cases mentioned, the facilities implementing process safety outside of countries with process safety regulations do so better than those in regulated countries and extend process safety to all processes (including to processes such as steel making).

Background

"Process safety management (PSM) is the application of management principles to the identification, understanding, and control of process hazards to prevent process-related incidents"[1]. PSM entails development and implementation of programs or systems to ensure that the practices and equipment used in hazardous processes are adequate and are maintained appropriately. The primary categories of programs or systems have come to be called elements of PSM. However, the basic elements of PSM have been defined by many groups in a number of ways. Figure 1 lists the elements of PSM systems from various industry and government groups. Many of the elements with different names have essentially the same meaning. For instance, "maintenance and inspection of facilities," together with some aspects of "personnel" practices, both under ACC's (formerly CMA's) Process Safety Code of Responsible Care™ are essentially the same as the single element, "mechanical integrity," under 29 CFR 1910.1190).

Figure 1. Comparison of PSM Systems

OSHA 29 CFR 1910.119 and EPA 40 CFR 68	AIChE/CCPS Risk-Based Process Safety (RBPS) standard	Responsible Care® Process Safety Code
Management System	***Commitment to Process Safety***	***Management Leadership***
Employee Participation†	Process Safety Culture *	Commitment *
Process Safety Information	Compliance with Standards	Accountability *
Process Hazard Analysis	Process Safety Competency	Performance Measurement
Operating Procedures	Workforce Involvement *	Incident Investigation
Training	Stakeholder Outreach	Information Sharing
Contractors†	***Understand Hazards and Evaluate Risk***	CAER Integration
Pre-startup Safety Review	Process Knowledge Management	***Technology***
Mechanical Integrity	Hazard identification and Risk Analysis	Design Documentation
Hot Work Permit†	***Manage Risk***	Process Hazards Information
Management of Change	Operating Procedures	Process Hazards Analysis
Incident Investigation	Training and Performance *	Management of Change
Emergency Planning and Response	Safe Work Practices	***Facilities***
Compliance Audits	Asset Integrity and Reliability	Siting
Trade Secrets	Contractor Management	Codes and Standards
	Management of Change	Safety Reviews
	Operational Readiness *	Maintenance and Inspection
	Conduct of Operations *	Multiple Safeguards *
	Emergency Management	Emergency Management
	Learn from Experience	***Personnel***
	Incident Investigation	Job Skills *
	Measurement and Metrics	Safe Work Practices
	Auditing	Initial Training *
	Management Review and Continuous Improvement	Employee Proficiency
		Fitness for Duty *
		Contractors

* Contains some of the 9 key sub-elements of a comprehensive Human Factors element

Note that the newest definition of process safety is CCPS's *Risk Based Process Safety (RBPS)*; this replaces their earlier process safety definition. In the older definition from CCPS, there was an element on Human Factors, which brought strong focus to this necessary element; in RBPS, the human factors sub-elements are now spread across 6 different elements.

Although nearly the entire industry agrees that implementing PSM is the right thing to do, interpreting and converting the PSM requirements into practices is unique to each company, and even unique to each plant site. Not only can the requirements be interpreted differently for each site based on local needs, but each site also starts from a different point when they begin to implement a system that is consistent with this regulation. These starting points, and the hurdles and advantages inherent to each, are important factors when estimating the cost of implementing each element. Many companies, especially those that are in countries with process safety regulations such as in the USA, UK, EU, Japan, and a few other countries, are choosing to interpret the process safety implementation in a minimalistic manner (e.g. just meeting the regulatory requirements). Though they may survive a regulatory audit, they are also minimizing the benefits their company will receive from implementing a more thorough process safety system. Other companies in and outside of the USA are going well beyond the minimal interpretation of the OSHA PSM requirements; therefore their cost to implement and sustain process safety will be higher than average, but these companies should (and do) have better PSM performance (fewer process safety incidents).

Very few countries have a process safety regulation. These include:

- USA
- UK (COMAH)
- EU (Seveso II)
- Japan
- Korea
- Peru (just issued)
- Australia
- Canada (sort of)
- Norway
- Perhaps others

But, in addition to the countries listed above, PII has helped oil, gas, petrochemical, fertilizer, chemical, and even steel companies implement process safety in the following countries:

- Saudi Arabia
- Bahrain
- Qatar
- Kuwait
- UAE
- Yemen
- Mexico
- Costa Rico
- Peru (pre-regulations)
- Argentina
- China
- Malaysia
- Thailand
- South Africa
- Nigeria
- Egypt
- Pakistan
- India
- Kazakhstan
- Azerbaijan
- Trinidad/Tobago
- Curacao

These countries do NOT have specific process safety regulations and there is essentially no government impetus to implement process safety. Yet, in many cases, the implementation in these countries is superior to implementation of process safety in the USA or other countries with regulations. As an illustration of this point, in the USA, clients often ask:

What is the minimum required to comply with the US OSHA and US EPA regulations on PSM and RMP?

Or, (especially in the case of the oil refining industry)

What are my peers doing to implement process safety?

In non-regulated countries, we of course do not ever hear the first question above, but in most cases we are instead asked:

What are best practices for process safety and how do we go about implementing those best practices?

Certainly, many clients in the USA, Canada, and UK also ask this same question about best practices, but a higher percentage of clients from outside of the regulated countries listed above want to only know and implement best practices.

The next sections recap some fundamental data on the cost and benefits of implementing process safety.

COST of Implementing Process Safety (general to all countries)

To understand the cost of PSM, we must realize that there are two main phases of implementing a PSM program: 1) installing a program, and then 2) maintaining the quality of the program. What industry is finding is that to get buy-in throughout a facility so that the PSM maintenance phase becomes feasible, you first have to make PSM a part of the facility's "culture". This does not happen overnight – it is a gradual process requiring sincere management commitment and constant nurturing. A good PSM program should provide the sound foundation for maintaining the ongoing program.

The costs of implementing process safety include:

- Costs for PHAs (process hazard analyses), LOPA (layer of protection analysis), and other risk assessment studies (if needed).
- Physical improvements to the facility to address PHA and LOPA recommendations (including appropriate relief, SIFs (safety instrumented functions) compliance with international standards, facility siting, dikes, etc.).
- Maintenance and testing for the additional physical facilities to manage process safety (relief, SIFs, dikes). Remember if you don't test your independent protection layers, you'll find out they are broken after an incident.
- Management of change studies to manage risks that may be introduced as changes are made to the facility.
- Training of operations, maintenance, technical personnel, supervision, and management in the principles of process safety and in the specific tasks for ongoing process safety management.

- Writing and maintaining procedures for operations, maintenance, and other process safety activities.

Costs of implementing a process safety system is not trivial, but the costs are more than balanced by the benefits of strong process safety systems.

Costs of implementing process safety can be significant – generally in the form of resources (people), and equipment (safety systems, gas/fire detection, automation, etc.). Also, maintenance is a critical cost component of process safety (inspections, overhauls of machinery, calibrations, etc.) that is often neglected. Again it takes management leadership and commitment to ensure there are sufficient resources to properly implement process safety and sustain good process safety performance.

Implementation Planning and Cost Estimation:

The installation phase is typically viewed as a one-time project, and includes activities such as developing concepts for each element, planning the work, training the PSM resources, writing draft programs and practices, pilot testing major programs, implementing the finished product (usually with more training), and responding to findings and recommendations of certain programs (such as recommendations from PHAs, MOC hazard reviews, and incident investigations). Most of the cost related to the development and initial implementation of a PSM program is labor (people resources), whereas the major cost related to responding to recommendations is typically capital improvements. The labor cost and out-of-pocket costs for developing and implementing a PSM element can be accounted for in one or more of the following categories:

- Meetings
- Writing documents
- Reviewing
- Revising
- Training/ orientation
- Pilot testing
- More revising
- Initial implementation

Where PSM is being implemented for the first time, it is best to begin with a gap analysis, followed by an implementation plan. Table 1 shows an excerpt from a data analysis table from a PSM Implementation Plan, where each Process Safety Gap is dissected and then a small project estimated for the closure of each gap. From such analysis, the cost to develop and initially implement PSM can be estimated and managed, like any other project. The costs to implement PSM can wary widely depending on the size of the organization. For example, the costs may be relatively small for a company with one or two small sites as opposed to a large global company with many sites in many countries.

Cost from Prior Paper:

But, where does a company get the cost factors for such implementation? The answer is from the experience of others. One source of overall cost data is from the paper on PSM Cost & Benefits from 1994.[2] This paper provides the overall cost of implementing process safety are a site, the data is scalable, and in some cases, the data is provided for the cost of individual process safety activities.

Table 1. Excerpt from a Detail Implementation Plan Analysis Table

Element 8: Mechanical Integrity (j) Responsibility: Joe Doe Support: Maintenance Manager
Consultant/Contractors

Main Activity: Develop and implement a program, procedures, and training for ensuring mechanical integrity Revision Date: March 31, 2004

Task	Staff-hours (E-Engineer/management, H-Hourly/nonexempt, C-Clerical)									Expenses & Capital
	Code	Meet	Write	Review	Revise	Pilot	Train	Implement	Total	
1. MI Program: Develop overall MI program	E	32	160	40	20				252	
	H	32	40	40	20				132	$10,000
	C		40		10				50	
2. MI Program: Improve and implement the proposed quality assurance program	E	16	80	40	20				156	
	H	16	80	40	20				156	
	C		24		10				34	
3a. MI Procedures: Write standard maintenance procedures (SMPs) for repair and preventive maintenance of mechanical equipment (if not provided by vendor information)	E	24	40	40			64		168	See Op. Pro. element for course costs
	H	24	400	40	24		64		552	
	C		40		8				48	
3b. MI Procedures: Collect and input vendor supplied procedures for repair and preventive maintenance of mechanical equipment into the MI procedures	E		80						80	
	H								0	$2,000
	C		300						300	
3c. MI Procedures: Improve and implement the proposed inspection, testing, and calibration procedures	E	80	400	72	40				592	
	H	240	200	48	40				528	
	C	40	80						120	
4. MI Training: Determine how to ascertain and document that each employee has received and understood the training. (Some labor included in Task 3 above, and some in the Operating Procedures element)	E								0	
	H								0	
	C								0	
5. MI Training: Train personnel on MI issues and standard maintenance practices	E		80				480	480	1040	
	H						7200		7200	$200,000
	C		20				80		100	
Total Resources for This Element	E	152	840	192	80	0	544	480	2288	
	H	312	720	168	104	0	7264	0	8568	$212,000
	C	40	504	0	28	0	80	0	652	

In the 1994 paper, 84 facilities, representing a total of 25 companies, completed surveys. Dow Chemicals and Olin Chemicals responded with helpful comments and data, but were unable to complete a survey, since their programs are so mature and they did not gather data on major elements of PSM during each program's evolution. Both companies also shared some interesting insights and data on PSM benefits. The facilities that completed surveys together employ about 31,000 workers, which represent about 1 % of the workers which OSHA claims are protected by the PSM regulation.[2] The size of the survey sample and breakdown of respondents by industry segment are shown in Tables 2 and 3, respectively.

Table 2 Sample Size for 1994 PSM Cost/Benefit Survey[2]

- 25 Companies
- 84 Locations
- 25,000 Direct Hire Employees
- 6,000 Contract Employees
- 20,000 P&IDs
- 850 PHAs

Table 3 Industry Represented in 1994 PSM Cost/Benefit Survey[2]

Industry	Number of Sites
Gas Plant/Oil field	46
Oil Refinery	5
Petrochemical/Plastic	3
Pulp/Paper	13
Chemical	16
Iron & Steel	1
ALL	84

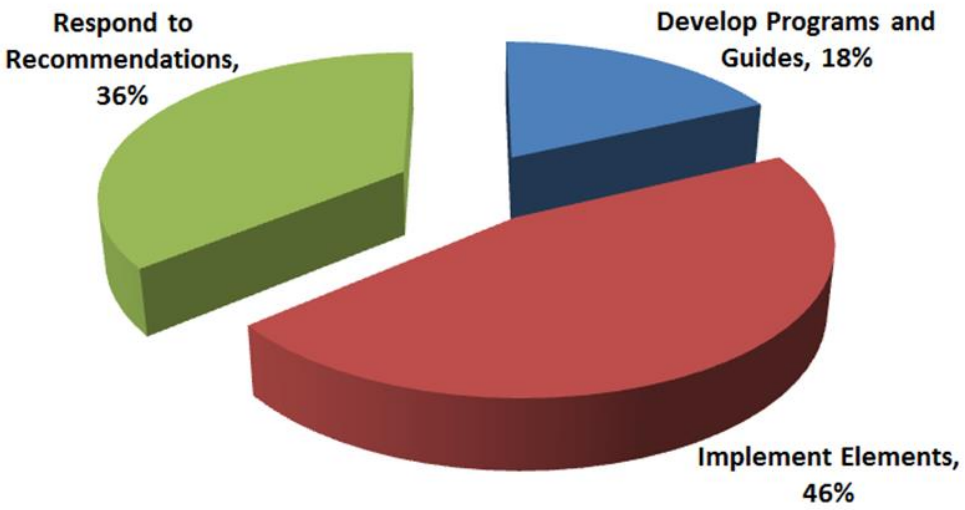

Figure 2. Breakdown of Cost for Initial Implementation of Process Safety from 1994 Cost/Benefit Survey[2]

Figure 2 illustrates the distribution of the cost of compliance based on an average of all survey data, versus the three primary cost categories:

- ***Developing PSM Programs***. The cost, primarily in equivalent labor costs, to bring the PSM program (and individual element programs) from the concept stage through the final design (such as developing an MOC or MI written program that your facility personnel are confident will work). This category also includes the cost of training personnel to be proficient in various PSM activities, such as leading PHAs, leading incident investigations, leading compliance audits, writing procedures, and leading employee training.

- ***Implementing PSM Programs.*** The cost (again primarily in equivalent labor costs) to do implementation tasks, such as writing operating and maintenance procedures, updating PSI, doing initial training of operators and maintenance personnel, and performing/documenting PHAs.

- ***Responding to Recommendations.*** The cost, primarily capital costs and expenses, to implement improvements to address recommendations from PHAs, MOC hazard reviews, incident investigations, and MI deficiency reports.

The total cost for years 1-10 for the 84 facilities surveyed was $484 million beginning at an average compliance of 40 %, or $592 million if extrapolated proportionally back to 0% compliance. As the prior paper warns, the averaged factors presented in that paper are not appropriate for estimating the cost of PSM at an individual facility. However, large, multi-facility companies will be able to use these averaged factors with more confidence and the factors can be used to estimate the cost for the industry as a whole. ***The average cost per facility to reach full compliance was estimated at $5.8 million (over a period of 10 years, beginning at 40% compliance) which is based on the average facility responding to this***

survey. For a continuous process plant, it was recommended that the scaling factor of $22,000 per P&ID be used (rather than the factor per employee) - more reliable results are produced)) to estimate the cost of reaching PSM compliance, starting a 40% compliance. So, if there are 100 P&IDs worth of equipment at the site, PSM implementation might take 4-5 years and might cost 2.2 million (in 1994 dollars), or about 3 to 4 million today, since the inflation adjustment between 1994 and 2016 is a multiplier of 1.6.[2]

The 1994 survey[2] also collected cost data for completing individual PSM activities. For example, the average cost to update a D-sized P&ID was $1,800. For comparison, an informal survey of over 500 attendees of a 3-day course on PSM indicated that the average cost is (1) $1,500 to field validate and then update an existing D-sized P&ID and (2) between $2,500 to $3,500 to create (or substantially revise) a P&ID, in 1994 dollars (multiply by 1.6 to get to 2016 dollars). [2]

A detailed analysis of the survey data (which is only summarized in this paper) indicates that the combined cost of (1) training personnel to lead PHAs (or contracting leaders), (2) performing and documenting PHAs, and (3) responding to PHA recommendations accounts for about 50% of the cost of PSM. Therefore, it is in every facility's best interest to maximize the benefit (value) of each PHA. Using the right PHA techniques, providing skilled (efficient) leaders and scribes, and allocating the highest qualified personnel to participate as subject-matter experts during the PHA meetings are fundamental ways to optimize the PHA efforts. Also, expanding the scope of the meetings to uncover more operability improvements can result in significant benefits that have proven to far outweigh (often by a factor of 10 or more) the incremental cost of longer PHA meetings to uncover and discuss operability problems. (There are many fine papers on how to perform high quality PHAs [3, 4, 5, 6, 7].)

Most respondents indicated verbally that MI and MOC were the most difficult elements for facilities' employees to develop and implement, since so much indoctrination and "culture" change were necessary.

BENEFITS of Implementing Process Safety (general to all countries)

For a moral and ethical company, it is not appropriate to tolerate higher risk in countries that do not have process safety regulations. It is not appropriate (and it is not good public relations) to "export" risk from a developed country to an emerging-market country. The value statement for many corporations emphasizes the importance of protecting the community, the employees, and the environment from adverse impacts from the company's operations. Implementing process safety worldwide, even in countries where it is not required by regulation, ensures compliance with the stated values of the corporation.

- Implementing process safety actually (documented; proven) improves the economic performance of the facilities. Improving the understanding of the chemistry, engineering, and reliability of the process can pay dividends in improved performance, improved quality, and reduced downtime. Lost production and repairs due to a process safety incident can be very expensive. Modifications made after an incident are typically 2 to 4 times as expensive as the same modifications made in normal times (the additional cost is attributed to overtime, urgent procurement, and overkill in corrective actions in the aftermath of a serious incident).

- Improving the knowledge and skills of employees to implement process safety can also improve the knowledge and skills to produce quality product with fewer upsets, thereby improving the economic performance of the facility
- The company can use the improved reliability of the facility that has implemented process safety as a selling point to their customers.
- We have observed that organizations that implement strong management of change programs to support process safety make fewer changes, but the changes are better engineered, better executed, better operated, and better maintained. The changes are less likely to be removed after startup and operation because potential issues were detected and addressed before the change was made.
- The same system that produces product also produces fires, explosions, injuries, and off grade product. Improving the system by implementing process safety also improves the performance of the system for on-time delivery and quality product.
- Process Safety and Process Reliability and Operational Excellence are all related and intertwined. And to a lesser extent, so is Occupational Safety. Having good process safety processes (proactive MI, good procedures, good control of human factors, excellent near miss reporting and incident investigation, thorough PHAs, etc.), will improve process reliability, profitability, and occupational safety, by having fewer incidents and less production downtime.
- A company's reputation and license to operate can be adversely affected by process safety incidents. So by implementing a good process safety system, these type of incidents can be reduced/eliminated thus improving: 1) company's bottom line (profit), and 2) improving how a company is perceived by various host governments which will help to get new agreements and licenses to operate. In most places safety performance (including process safety) plays a role in which company will be selected to build/operate a new facility.

Benefits from Prior Paper:

Very few respondents provided benefit data, since the cost avoided due to implementing PSM is so difficult to isolate from other ongoing safety and quality improvement efforts. Obviously, better data on the benefits of individual PSM activities are needed. Many companies have stated that an effective PHA program, especially when expanded to include hazard evaluations during the early phases of new projects, will produce benefits far beyond the cost of performing and responding to the PHAs. In the preamble to 29 CFR 1910.119, OSHA quoted one plant manager concerning PSM benefits:

> "Our small organization was quietly infused with a rebirth of innovative thinking. Process technology that was more than 35 years old was routinely being questioned .... This quickly led to the same questioning being applied to process improvement .... Ultimately, I believe that this thoroughness and training approach will result in cost savings to a small plant site on the order of 4 to 7 percent of an operating budget". [2]

Overall, the majority of companies responding said they feel PSM should be implemented, though most objected to some of the paperwork requirements (especially process safety information). Companies with more than 5 years of PSM experience unanimously echoed the comment in one survey response:

"It is indefensible not to implement PSM, and it's worth it."

But, the prior paper also concludes that due to the "fear of citations resulting from insufficient documentation on what we've done," the paperwork and associated labor to over-document PSM activities could outweigh many of the benefits that would otherwise be realized in the absence of regulatory pressure.

Table 4. PSM Compliance Benefits: Avoided Incidents (2016 dollars)

Type of Incident Avoided	***EPA USD Value per Incident[8]***
• Impact to Facility/Operations	
o Business/Production Interruption	13,000
o Equipment Damage	Not available (but more than 20,000,000 per significant PSE)
• Environmental Harm	
o Soil Contamination	$310,000
o Vegetation Damage	$80,000
o Groundwater Contamination	2,200,000
• Personal Injury (per person)	
o Injury/First Aid/Outpatient	28,000
o Hospitalization (excess over injury alone)	19,000
o Death (and Litigation)	18,000,000 (versus 10,000,000 for fatality on construction jobs)
• Other Expenses	
o Litigation per Environmental Action	90,000
o Evacuation and Sheltering in Place (per incident; effect on public only)	120,000

Note: Source is EPA's regulatory impact analysis related to RMP regulation (1993); corrected for inflation to 2016[8]

Table 5. PSM Compliance Benefits: Non-Incident related

- Quality and Productivity Improvements due to less process upsets and increased efficiency
- Lower Insurance Rates (or less increases in the rates in the future)
- Lower Workers' Compensation for Lost Time

Note: Some companies, such as Olin Chemicals, have reported that improvements in productivity and quality that were identified during their PHAs more than offset the total cost of the PSM implementation. Others, such as Eli Lilly and ALCOA have reported that just improvements in Near Miss reporting have paid for all of PSM implementation.

The expect return on investment is generally accepted as 100 to 1, if the site implements best practices.

Anecdotal Benefits Observed by Various Companies (outside and within the USA)

- Olin Chemicals found in the 1980s that the "reliability and operability improvements" that resulted from PHAs that were balanced between safety and operability paid for all of process safety. So the rest of the benefits were free!
- PII has found that doing excellent PHAs of all modes of operation has nearly a 1000 to 1 payback due to avoided cost of major accidents that occur during startup, shutdown, and online maintenance.
- AMOCO Oil found in the early 1990s that doing multiple PHAs (3 to 4) during a project, versus just one PHA/HAZOP at design freeze, saved enough in startup cost to pay for all project PHAs several times over.
- An undisclosed multi-national company (head-quartered in the USA) found that when the board of directors cut the budget of process safety in 2008 and 2009 due to the "economic" crisis, that the number of Significant Process Safety Events spiked, resulting in an increase of more than $30 million in actual losses and leading to the occurrence of two events that nearly cost more than $1 billion each, but luck (not good practices) saved the day in both cases. And yet the cost savings of the cuts was only about $2 million.

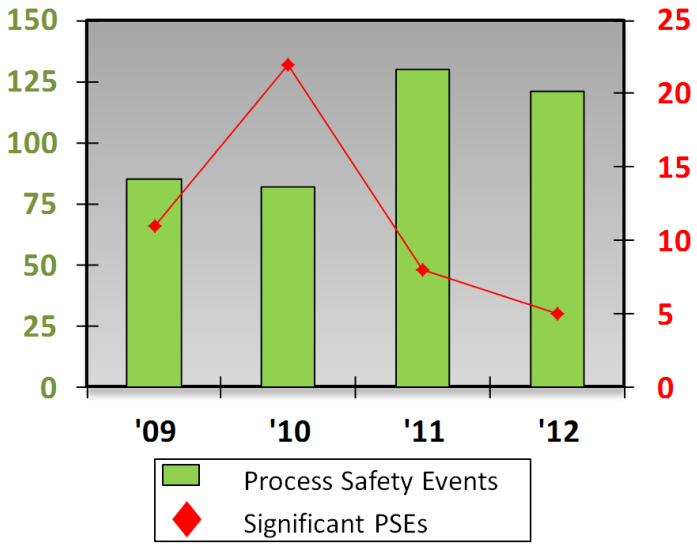

Figure 3. Significant PSE Trend

- The total implementation cost estimate for Excellent PSM in all 25,000 regulated facilities in the USA is about $100 billion initial implementation and $10 billion annual cost thereafter. This is about $4 to 5 million per site initially and $0.5 million per site thereafter. Just ONE significant process safety event averages more than $20 million but could be higher than the replacement cost of the facility (about $100 million replacement cost, on average), especially when legal liability is added.

The rest of this paper discusses the Hurdles and Advantages of implementing process safety, especially in sites that are not in countries with PSM regulations. This data is summarized from PSM implementation in more than 20 countries without PSM regulations, working with more than 50 companies.

HURDLES to Implementing Process Safety in Countries that Do NOT have a PSM Regulation

There are many hurdles to implementing process safety in countries that do not have regulations. Chief among these is the lack of in-country resources to help with the implementation since fewer companies may be implementing PSM in that country. One limitation is the lack of motivation because there is not regulation for a government to enforce; but on the other hand, we have seen that in many cases the quality of the implementation of process safety is better outside of regulated countries because once a company decides to implement process safety, the company is more inclined to follow best practices (best industry standards) rather than settling for minimal compliance. This may be in part because in the USA, some may confuse compliance with OSHA PSM as sufficient to prevent accidents. This is not necessarily true. So, some disadvantages become advantages.

Below are some of the hurdles we have found, in order of importance.

General resistance to Process safety:

- It is much more difficult to get interest started in process safety in countries that
  - do not have regulations that require implementation of a process safety system (like OSHA PSM or UK HSE process safety regulations), and
  - where human life may not seen as being as important/valuable as in developed countries (e.g., some third world countries, but not limited to just third world countries).
- Since it is not required by the government, our competitors are not doing it, and we cannot implement process safety and remain competitive. Further, our customers will not pay for process safety.
- Due to lack of regulations, most companies do not seem to participate in industry organizations (such as CCPS or API). Nor do they monitor the development of standards and recommended practices. So unless the technical firm responsible for the design or some good partner is still actively involved, this key PSM knowledge source is untapped.
- PSM is generally still a "Safety" responsibility, not part of the operational discipline of the facility.

- Process Safety is harder to understand and explain than personnel safety, especially in countries without process safety specific regulations. Most people understand personnel safety (slips, trips, falls, personnel injuries), but much fewer people understand process safety (preventing loss of containment, fires, explosions, etc.). The benefits of a good process safety system/program may not be easy to calculate on a cost benefit basis, and benefits are generally longer term (preventing large process safety incidents).
- Isolated, but still strong pockets of Senior Management insisting that "it hasn't happened yet". Or, "the company XYZ responsible for technology has not told us this is could be a problem."
- The knowledge, skills, and training of our workforce are not at a sufficient level to implement process safety. There is limited supply of appropriately-skilled personnel in the country to conduct studies, write procedures, and train personnel. There is a lower percentage of folks in the population of technical staff in such countries with process safety expertise, so the companies wanting to implement PSM according to best practices must start by importing labor (at first these being consultants) with this expertise.
- Many of the personnel who built, started-up, operated and maintained the facility since inception are at retirement age, and persons with sufficient experience are not available in-house to backfill these positions.
- Related to the two points above, there is no pool of qualified staff to facilitate a succession plan. So even if new hire persons are technically proficient, knowledge of the specific facility has just retired and walked out the door. Life experiences while working at the facility have not been intentionally captured through incident investigations, near misses, knowledge transfer, etc. Frequently technical and operating manuals are out of date.
- The point immediately above is exacerbated by a struggle to convince the technical personnel that their skills/experience is lacking in process safety issues.
- For companies that have started implementing PSM, they are implementing largely in silos within each element. Linking elements together to fulfill interlocking horizontal implementation is quite weak. One recurring weakness is these companies lack of near miss reporting and investigation with subsequent RCAs, making it difficult for management to see the importance of horizontal PSM integration/function.
- Establishing nomenclature, vocabulary, and definitions to insure complete communication (with outsiders and within organization) is even a problem, since process safety is not as widespread.

Hurdles related to Specific Process Safety Elements

- PHAs are out of date and have been conducted without using "best practices," particularly for the non-continuous modes of operations. This results in the remaining PSM program implementation being severely flawed/lacking. This is especially true for the PHAs (HAZOPs) conducted during the initial projects. In nearly all cases outside of the USA and UK, there was only one PHA/HAZOP conducted at the project design freeze, and changes since the design freeze were never incorporated into the Project PHA (rendering the original PHA/HAZOP essentially useless).

- All of the project PHAs are missing analysis of non-routine modes of operation, and many sites do not realize how important it is to perform a detailed analysis of these modes of operation.[3, 7]

ADVANTAGES to Implementing Process Safety in Countries that Do NOT have a PSM Regulation

In many ways, there are significant advantages in driving process safety forward in countries without regulations. The key is company leadership and site leadership. Below is list of the some of these advantages.

- Facilities tend to be newer; 5 to 30 years old or younger. Therefore MI is not quite as challenging (yet) and the design standards used are typically better than at older facilities and the materials of construction are usually better as well (if good vendors and EPCs were chosen). This is significant advantage compared to the USA in particular, where most of the facilities tend to be older.
- Companies that decide to implement process safety in such countries are far more receptive to "best practices" rather than a goal of "compliance" since there are no regulations to comply with. This is a very strong positive for implementation efforts since such companies are more focused on the business case for each facet of process safety, rather than considering a minimalistic approach for the sake of compliance. On the other-hand, this relatively stronger drive to be the best in process safety may reflect (1) the influence of joint venture partners who have high standards, (2) the desire to be best due to strong leadership in the company, or (3) the legal environment (less regulation → less lawsuits → less fear of doing what is best). Regardless of the reasons, it is certainly refreshing to work with clients who ask: "What are best practices for this element?"
- Global Companies operating outside of USA many times have a "core value" of process safety throughout their worldwide operations, and work to ensure that everyone in their organization (worldwide) understands the importance of process safety, and resources are provided to properly implement and sustain process safety systems and processes. In some instances, the affiliates outside of the regulated countries become the Best in process safety within such companies.
    - KEMYA, a petrochemical company in Saudi Arabia, is a JV of SABIC and EXXONMOBIL. They implemented process safety in a strong way before startup about 30 years ago and due to local leadership, they have never taken their eye off the ball. They have the best process safety performance of any facility in Saudi Arabia and we rank them in the top 5% of the world in quality of their process safety implementation (and this is echoed in their very low rate of process safety accidents).
    - HADEED, a large steel plant in Saudi Arabia and another affiliate of SABIC, implements process safety nearly as well as (perhaps even just as well) as KEMYA, just mentioned. HADEED implements process safety in every portion of the steel plant, not just the units with highly hazardous chemicals. This is not even done in many facilities in the USA.
- Operational skills (Operations and Maintenance) seem to be strong and enthusiastic in such countries, likely because the companies implementing process safety tend to be larger, more

profitable companies, or because they bring in labor from other countries. But, as mentioned earlier, major PSM competency gaps exist.

OTHER DRIVERS for Implementing Process Safety in Countries that Do NOT have a PSM Regulation

Besides the drivers mentioned above under "Advantages," there are several drivers for implementation of PSM outside of countries with PSM regulations:

- Companies with strong ties to or are affiliates of a company with strong process safety standards and culture, exhibit stronger desire to implement process safety correctly.
- Responsible Care™: Many international companies have made commitments at the executive level to fully and voluntarily comply with *Responsible Care™* and this has driven compliance with the associated *Process Safety Code* shown in Figure 1.
- AIChE: The American Institute of Chemical Engineers has more than 50,000 members world-wide and there are many local chapters or sections of AIChE around the world. These sections work with the CCPS (of AIChE) to push for global implementation of best practices in process safety, with particular focus on the process safety model of RBPS.
- Economics: Implementing process safety correctly improves the competitiveness of a company primarily by improvements to operating efficiencies and reductions in downtime (or reduction of other losses)
- Companies with strong ties to a government or to a central agency (such as with strong enforcement by insurance companies) exhibit a stronger desire to implement process safety correctly. This is very evident in China.

Conclusions

Implementing process safety in facilities that are not regulated is no different than in regulated facilities, but there are some unique hurdles and advantages. Some of the best examples of process safety implementation can in fact be found in sites outside of countries with PSM regulations or in sites that are not covered by regulations. The keys to effective implementation are the same in all instances: effective and tangible leadership, active employee participation, solid technical competencies in process safety activities, keen attention to optimizing all controls of human factors, and thorough risk assessments.

The cost of implementing process safety is likely in the range of $9 million USD per average facility and will normally take 4-5 years to reach minimal (but full) compliance and 5-10 years to reach excellence. The benefits of PSM implementation likely outweigh the cost by a factor of about 100.

Acronyms Used

AIChE– American Institute of Chemical Engineers
ACC – American Chemical Council (formerly CMA)

API – American Petroleum Institute
CCPS – Center for Chemical Process Safety (a division of AIChE)
CFR – Code of Federal Registry (USA)
CMA – Chemical Manufacturer 's Association, now American Chemical Council (ACC)
COMAH – Control of Major Accidents Hazards
EPA – US Environmental Protection Agency
EU – European Union
HAZOP – Hazard and Operability Analysis
HSE – UK Health Safety Executive
IPL - Independent Protection Layer
JSA – Job Safety Analysis
JV – Joint Venture
LOPA – Layer of Protection Analysis
MI – Mechanical Integrity
MOC – Management of Change
NUREG – Nuclear Regulation, US Nuclear Regulatory Commission
OSHA – Occupational Safety and Health Administration, US Department of Labor
PHA – Process Hazard Analysis
PII – Process Improvement Institute, Inc.
P&ID – Piping & Instrumentation Diagram
PSE – Process Safety Event
PSI – Process Safety Information
PSM – Process Safety Management
RBPS – Risk Based Process Safety
RCA – Root Cause Analysis
SOP – Standard Operating Procedure
UAE – United Arab Emirates
UK – United Kingdom of Great Britain
USA – United States of America

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