مؤتمر السلامة والصحة المهنية في أنظمة وعمليات الطاقة الكهربائية – فندق لاندمارك

عمان الاردن

٣–٤ ٠٥ ٢٠٢٣

تكامل أنظمة إدارة سلامة العمليات والطاقة

Integration of Process Safety and Energy Management Systems

تاريخ 04 05 2023

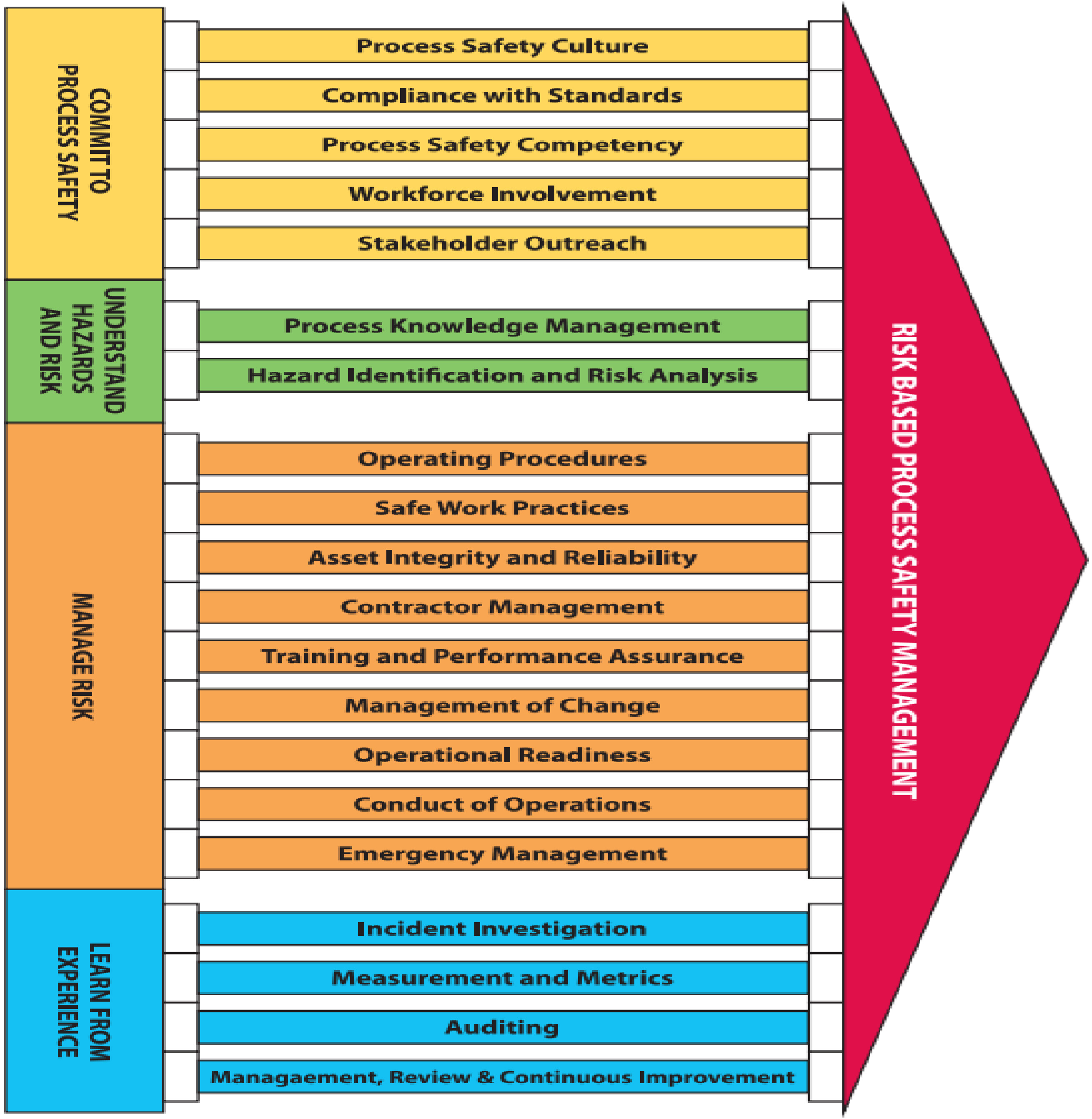
إعداد وتقديم: **المهندس يعقوب بني طه**

عضو مجلس شعبة الهندسة الكيميائية نقابة المهندسين الأردنيين

Integration of Process Safety and EnMS webinar Agenda

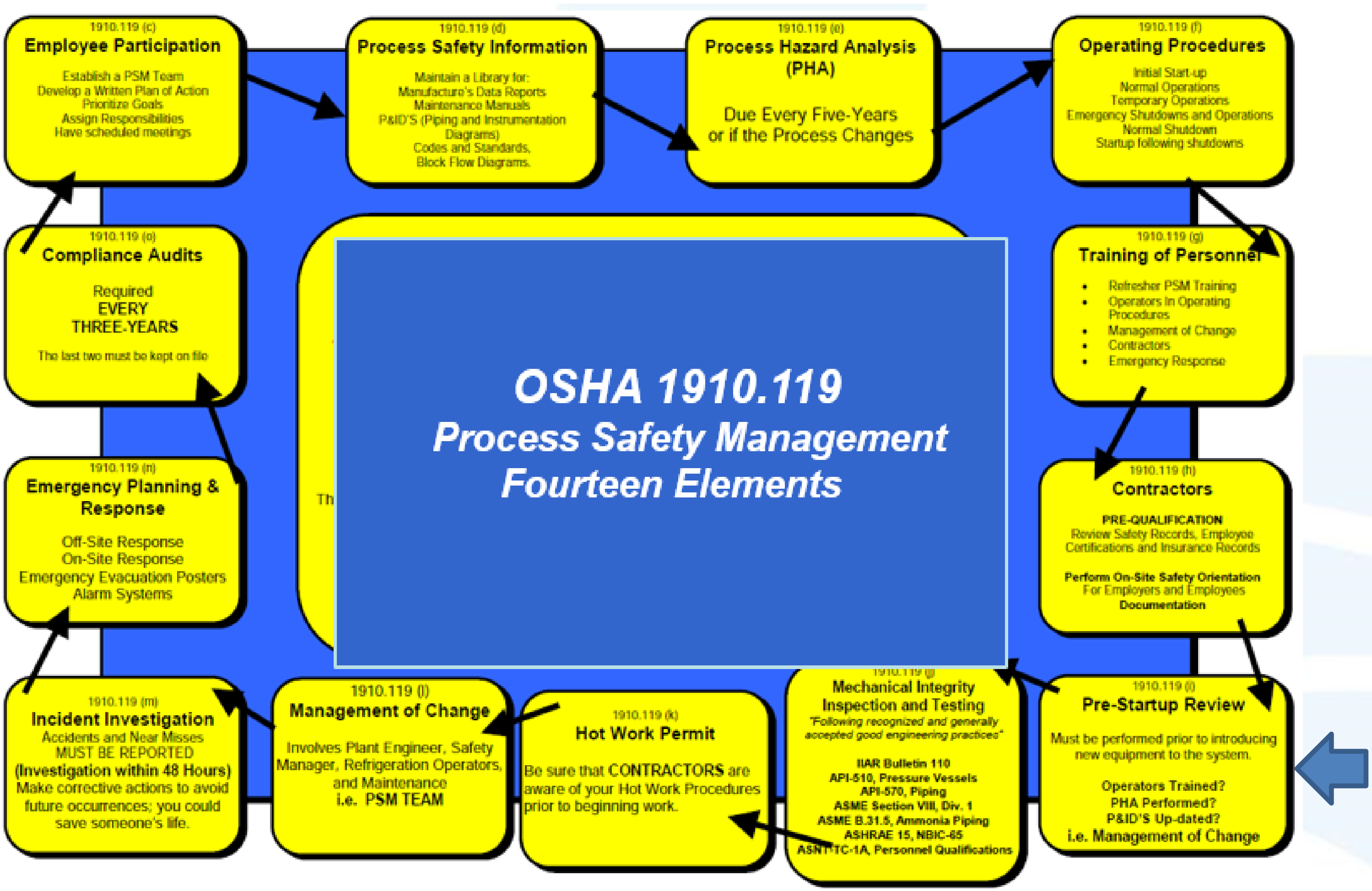
- **Introduction** of PSMS **Framework** According to **CCPS** AICHE
- Introduction to **ISO-50001** EnMS Framework
- **Common Elements** of PSMS and EnMS
- Overview of IMS Integrated Management System
- Integrating Management Systems and Metrics to **Improve Process Safety Performance.**

CCPS risk based process safety management system 20 elements / 4 Pillars



An AIChE Technology Alliance
CCPS
Center for Chemical Process Safety

OSHA PSMS 14 Elements



OSHA®

SKIJo Consulting & Training

EI Process Safety Management Framework

Guidance on meeting expectations of EI Process safety management framework

- *Element 1: Leadership, commitment and responsibility*
- *Element 2: Identification and compliance with legislation and industry standards*
- *Element 3: Employee selection, placement and competency, and health assurance*
- *Element 4: Workforce involvement*
- *Element 5: Communication with stakeholders*
- *Element 6: Hazard identification and risk assessment*
- *Element 7: Documentation, records and knowledge management*
- *Element 8: Operating manuals and procedures*
- *Element 9: Process and operational status monitoring, and handover*
- *Element 10: Management of operational interfaces*
- *Element 11: Standards and practices*
- *Element 12: Management of change and project management*
- *Element 13: Operational readiness and process start-up*
- *Element 14: Emergency preparedness*
- *Element 15: Inspection and maintenance*
- *Element 16: Management of safety critical devices*
- *Element 17: Work control, permit to work and task risk management*
- *Element 18: Contractor and supplier, selection and management*
- *Element 19: Incident reporting and investigation*
- *Element 20: Audit, assurance, management review and intervention*

Integrated PSM and Climate Change Model

Table 8. 1. (continued) Screening and selection of elements from PSM systems in the oil and gas industry adapted from Theophilus et al. (2018)

Process Safety Management (PSM) System Elements	**Energy Institute High-Level PSM Framework**	**DuPont ORM/PSM Model**	**OSHA PSM Program**	**AIChE/CCPS RBPS Standard**	**Responsible Care Process Safety Code**	**CSChE PSM Guide 4th edition**	**API RP 75/SEMS**	**API RP 750**	**COMAH Regulations**	**CIMAH Regulations**	**Safety Case**	**BP OMS**	**ExxonMobil OIMS**	**IOGP/IPIECA OMS**	**ILO PSM Framework**	**EPA RMP**	**IPSMS Model**	**Integrated PSM and Climate Change Model**
22. Training, competency and performance		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
23. Incident reporting	√			√			√	√	√	√	√			√		√	√	√
24. Benchmarking				√			√	√				√	√	√			√	√
25. Audits	√	√	√	√	√	√	√	√	√		√			√	√	√	√	√
26. Incident investigation	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√
27. Management review and intervention for continuous improvement	√			√	√	√	√	√	√	√	√	√	√	√			√	√

Subcategories of Element 16 (Management of harsh weather conditions and climate change)

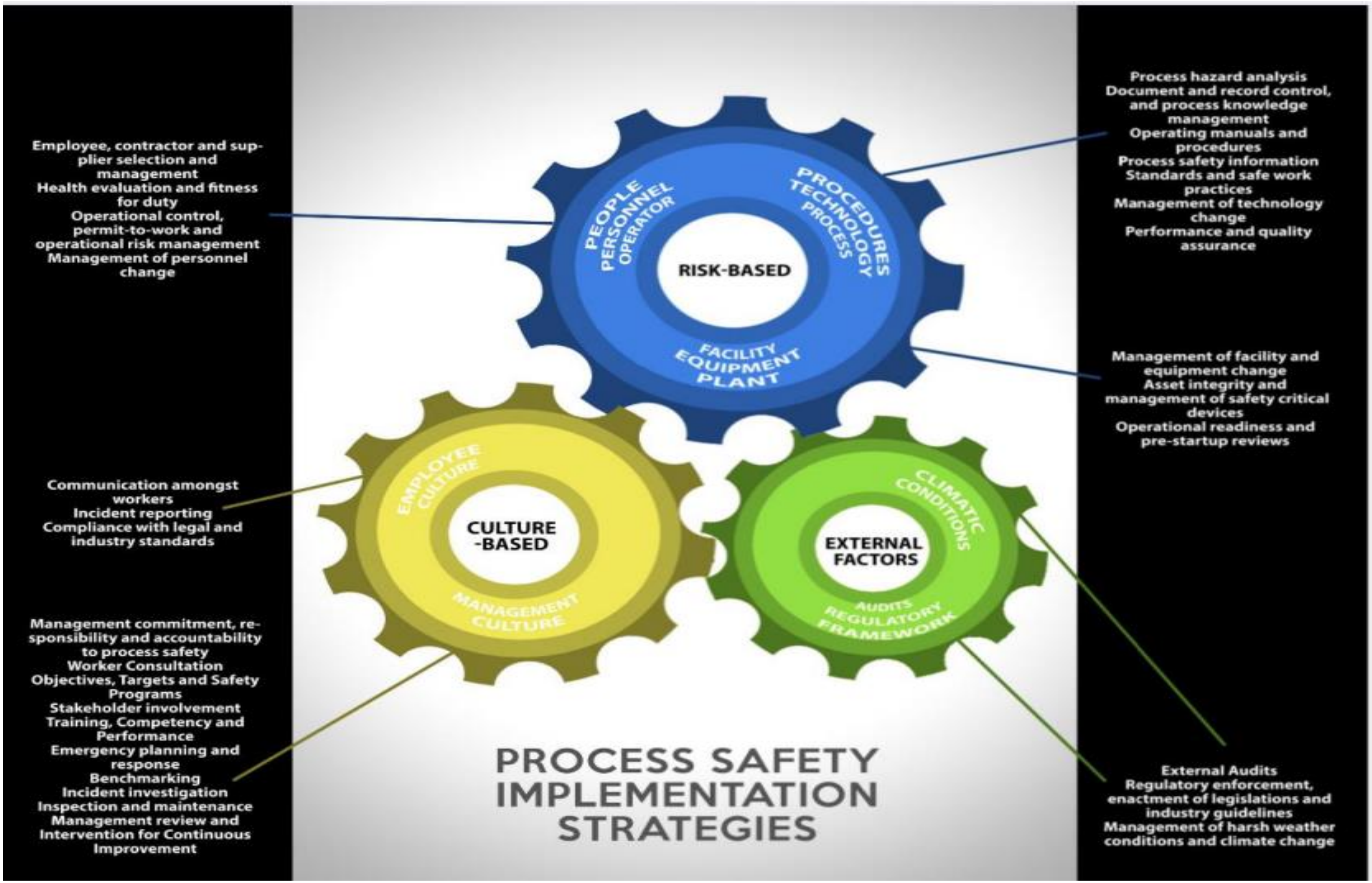
Personnel: - Training of staff on climate change adaptation strategies, staff preparedness and responses, as well as managing threats posed by harsh weather

Procedures: - Flexibility of work shift patterns, easy-to-implement process safety methods, the application of process safety to drilling operations, integration of databases for process safety improvement, consequence analysis

Facilities: - Resilience engineering and climate proofing of assets against natech events

Safety Culture: - Integration of occupational safety and process safety

Development of an Integrated Process Safety Management and Climate Change Model for the Oil and Gas Industry

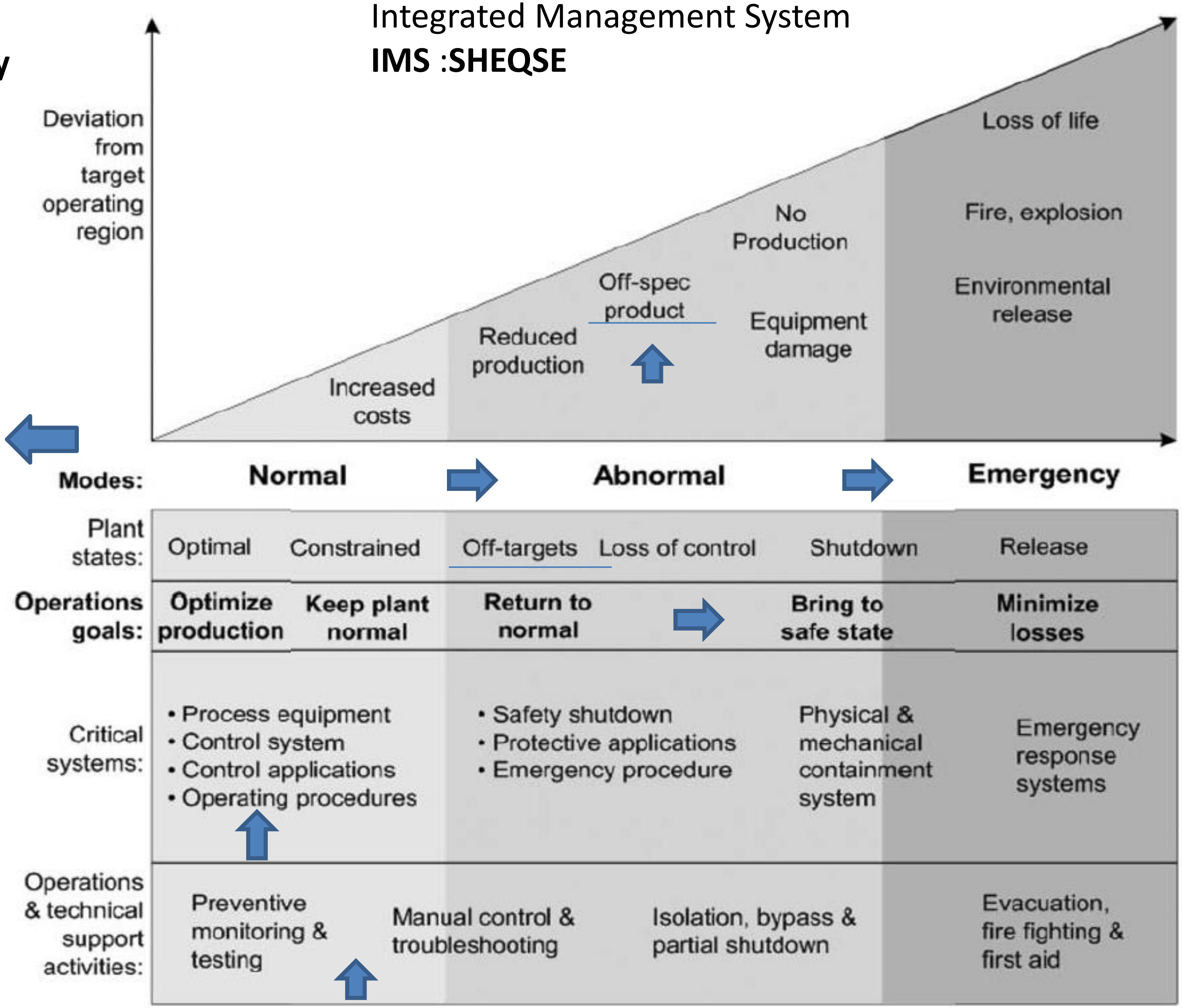


Anatomy of a loss Event

Integrated Management System

IMS :SHEQSE

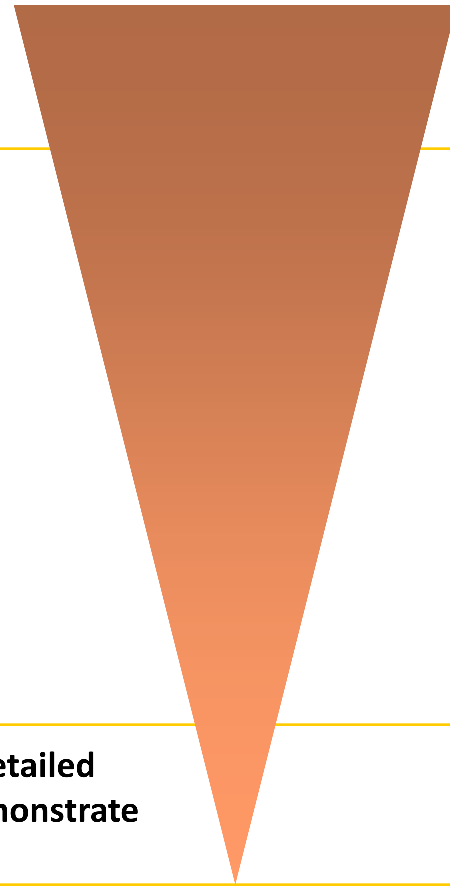
PSSR



ALARP (As Low As Reasonably Practicable):

Risk

As Low As Reasonably Practicable



UNACCEPTABLE REGION

THE ALARP REGION
(Risk is undertaken only if a benefit is desired)

Tolerable only if risk reduction is impractical or its cost is grossly disproportionate to the improvement gained

Tolerable if cost of reduction would exceed the improvement gained

BROADLY ACCEPTABLE REGION

(No need for detailed working to demonstrate risk is ALARP)

Necessary to maintain assurance that risk stays at this level

Negligible risk

=Residual risk: Remaining after **risk treatment**

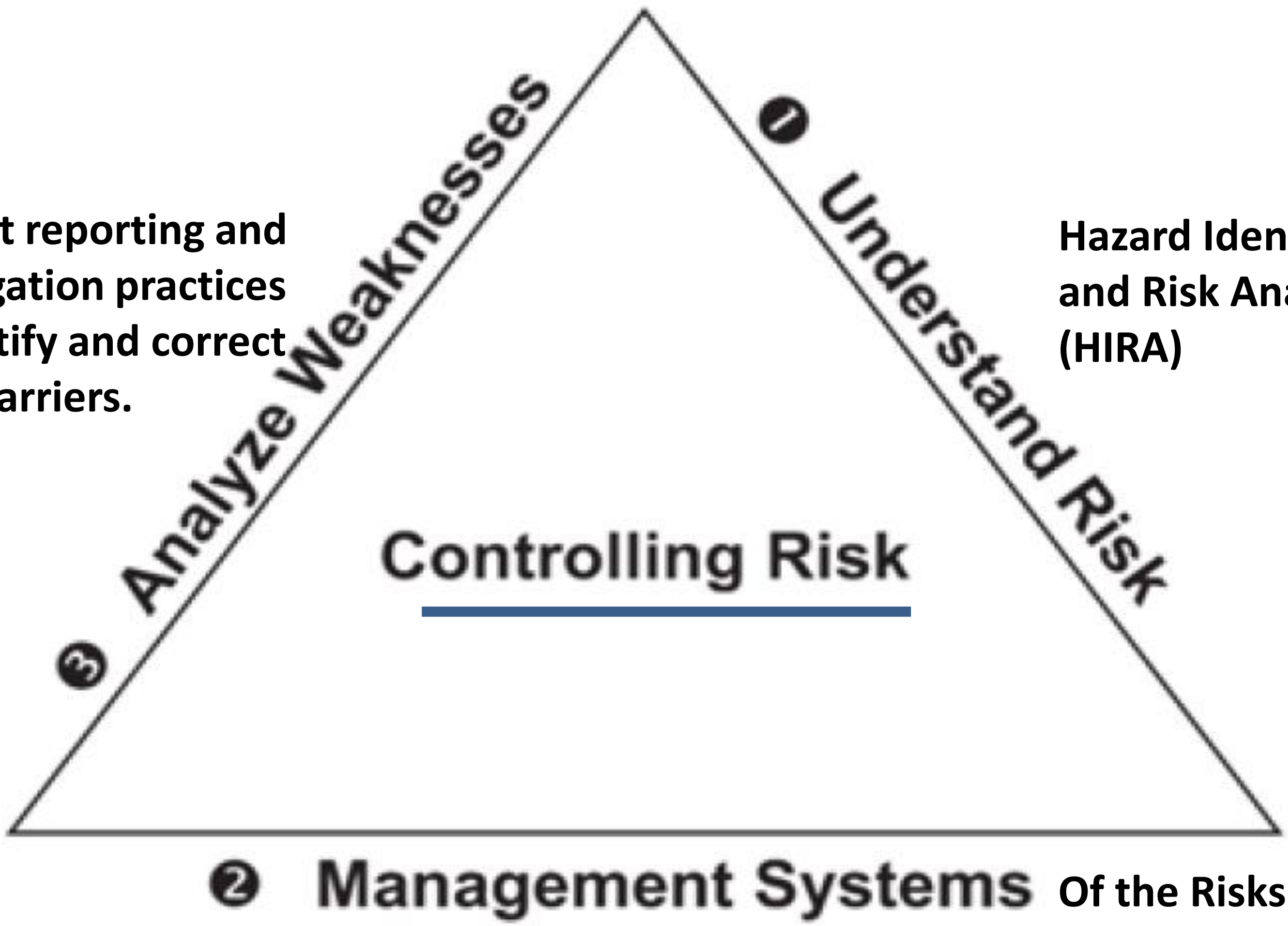
Incident Causation According to PSM Element

- Source :*Process Safety Progress Vol.26 No. 4*

PSM Element No.	*PSM Element*	*% of Incidents*
6	Process and equipment integrity	23.8
2	Process knowledge and documentation	21.2
4	Process-risk management	16.8
7	Human factors	8.9
5	Management of change	7.3
3	Capital project review and design procedures	6.5

Universal Concept for Controlling Risk

Incident reporting and investigation practices to identify and correct weak barriers.



Hazard Identification and Risk Analysis (HIRA)

Of the Risks

HLS of ISO 50001:2018

- 0 Introduction
- 1 Scope
- 2 Normative references
- 3 Terms and definitions

PLAN

4 Context of the organization
- 4.1 Understanding the organization and its context
- 4.2 Understanding the needs and expectations of interested parties
- 4.3 Determining the scope of the energy management system
- 4.4 Energy management system

5 Leadership
- 5.1 Leadership and commitment
- 5.2 Energy policy
- 5.3 Organizational roles, responsibilities and authorities

6 Planning
- 6.1 Actions to address risks and opportunities
- 6.2 Objectives, energy targets and planning to achieve them
- 6.3 Energy review
- 6.4 Energy performance indicators
- 6.5 Energy baseline
- 6.6 Planning for collection of energy data

DO

7 Support
- 7.1 Resources
- 7.2 Competence
- 7.3 Awareness
- 7.4 Communication
- 7.5 Documented information
  - 7.5.1 General
  - 7.5.2 Creating and updating
  - 7.5.3 Control of documented information

8 Operation
- 8.1 Operational planning and control
- 8.2 Design
- 8.3 Procurement

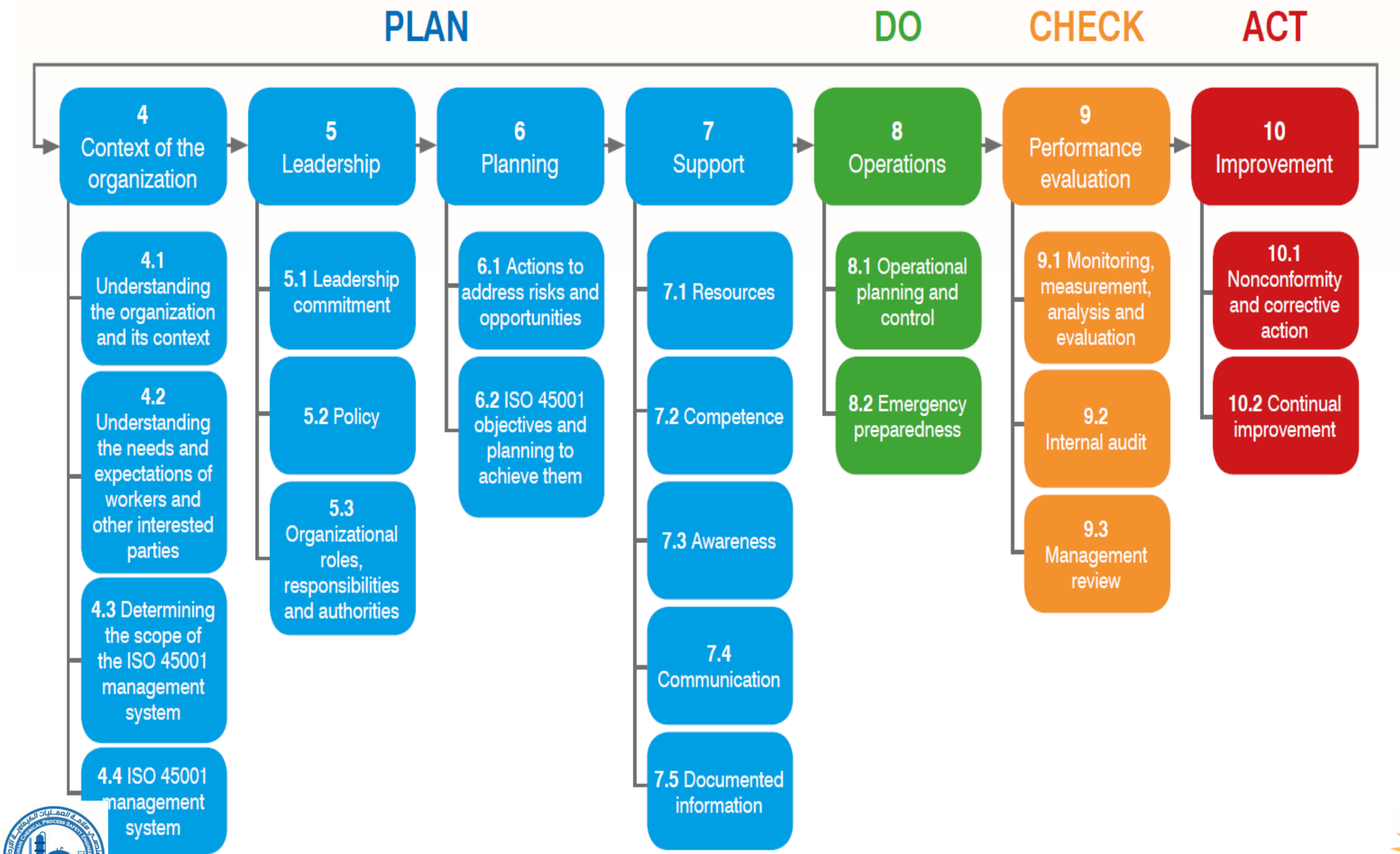
CHECK

9 Performance evaluation
- 9.1 Monitoring, measurement, analysis and evaluation of energy performance and the EnMS
  - 9.1.1 General
  - 9.1.2 Evaluation of compliance with legal and other requirements
- 9.2 Internal audit
- 9.3 Management review

ACT

10 Improvement
- 10.1 Nonconformity and corrective action
- 10.2 Continual improvement

HLS of ISO-45001 :2018



Key Aspects of the Risk Management Process ISO-31000

Establish the Strategic, Organizational and Management **Context** of ...

Identify ... (What can happen and how)

Analyze ... (Possibility x Consequence)

Evaluate ... (Priority List)

Control. Planning and implementing measures to eliminate, reduce, mitigate, or take contingency actions on...

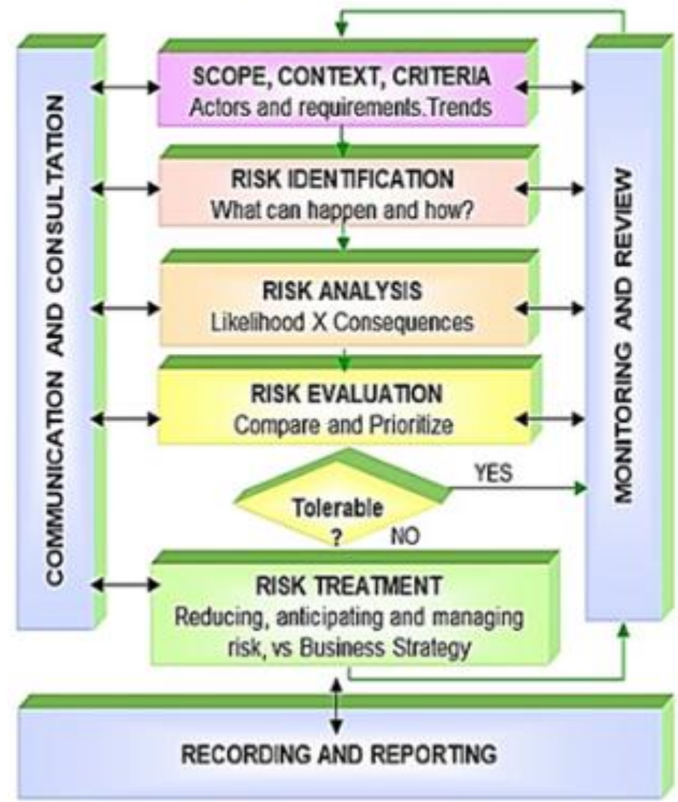
Monitoring of the control system and the state of ...

Recording and Reporting. Communication and Consult. Interaction with the parties to have full information about ...

(Identification + Analysis + Evaluation = **Risk Assessment**)

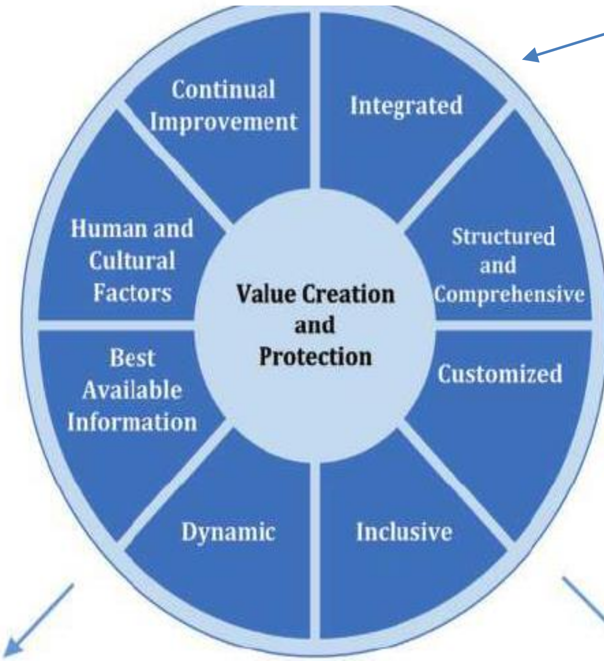
THE RISKS

"Effect of uncertainty on objectives. Risk is usually expressed in terms of **risk sources, potential events,** their **consequences,** and their **likelihood**" *(ISO 31000:2018).*



Risk management is an integral part of all organizational activities.

IMS : SHEQS



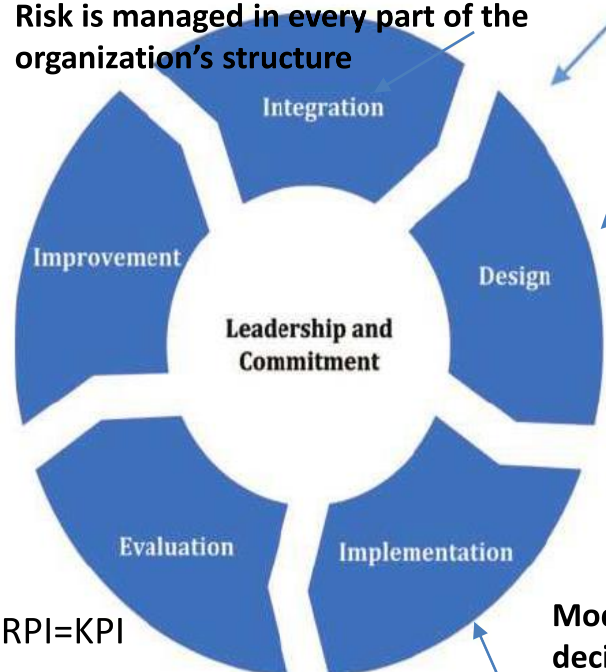
Principles

ISO 31000:2018 Principles ,Framework and Process of Risk Assessment

Leadership and commitment **:**
Issuing a <u>statement or policy</u> that establishes a risk management approach, <u>p</u>lan or course of action;

Ensure that risks are adequately considered when setting the organization's objectives;

Risk is managed in every part of the organization's structure



Framework

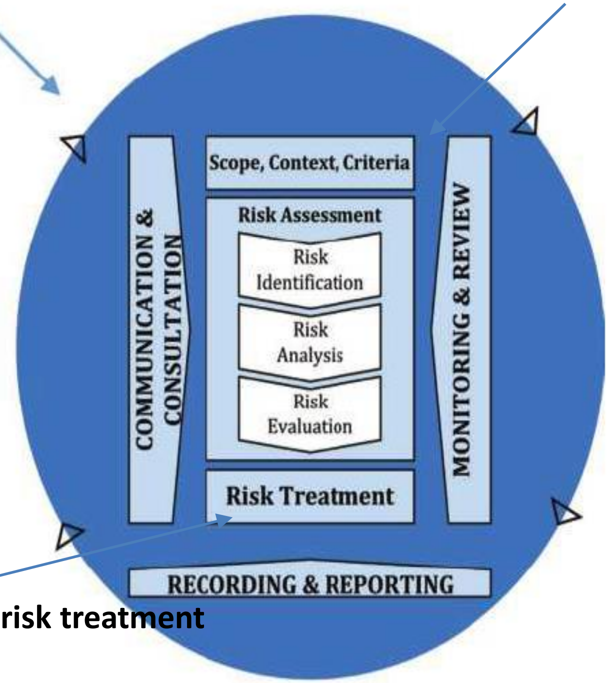
RPI=KPI

Understanding the organization and its (internal ,External) context (issues)

SWOT /PESTELE Analysis's

Modifying the applicable decision-making processes where necessary;

Significance of tolerable risk



Selection of risk treatment options

Process

Relationship between Energy Performance and EnMS

EnMS context

- Continually improve energy management system
- Continually improve energy performance
- Achieve intended outcome(s)

Energy management system (3.2.2)

Set of interrelated or interacting elements of an organization such as:

- policy
- objectives
- energy targets
- energy baselines
- energy performance indicators
- internal audits
- addressing non-conformities
- procurement processes
- design

Promotes, supports and sustains

Energy performance improvement (3.4.6)

Improvement in measurable results of:

- energy efficiency, or
- energy consumption related to energy use, compared to the energy baseline

Achievement of other intended outcomes such as:

- reduced cost of energy
- meet overall climate change goals
- improved reliability
- increased use of renewables

Continual improvement of the EnMS in terms of:

- suitability
- adequacy
- effectiveness
- alignment with strategic direction

MERITT

- MERITT (**M**aximizing **E**HS **R**eturns by **I**ntegrating **T**ools and **T**alents) for **enhancing process development** through more ***effective integration* of environmental, <u>Energy</u> , health, and safety evaluations.** MERITT has been based on the **benchmarked best practices of industry leaders** in this field and draws upon **critical components of pollution prevention, inherent safety, green chemistry, and related paradigms through selective adoption and adaptation of their existing tools, skills, and knowledge resources**

MERITT (**M**aximizing **E**HS **R**eturns by **I**ntegrating **T**ools and **T**alents)

- Experienced process/project **professionals** feel that there is **commonly *a 15–35% life-cycle cost reduction* available when EHS issues are addressed in a concurrent and timely manner.** ***Improvements of 50% or more in project costs*** have been attained in some cases.

The Need for Integration

- **Increasing and overlapping regulatory demands**

—Documentary and record-keeping requirements

—**Formal** and demonstrable **programs**

—**Improved performance** (particularly in areas such as **emissions standards**)

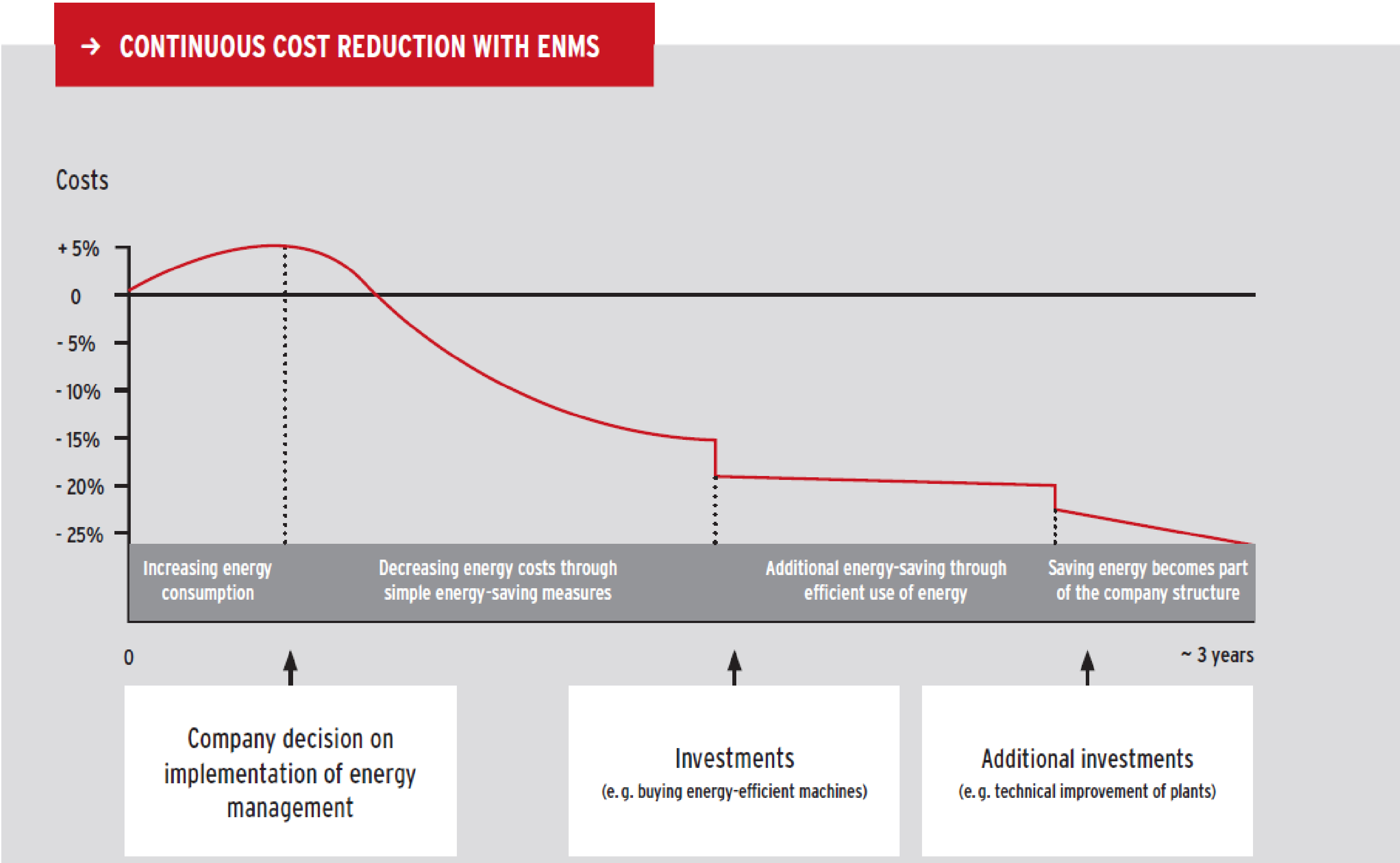
- **Pressure to reduce cost of operation** and at the same time improve performance

—To maintain and **improve competitive position**

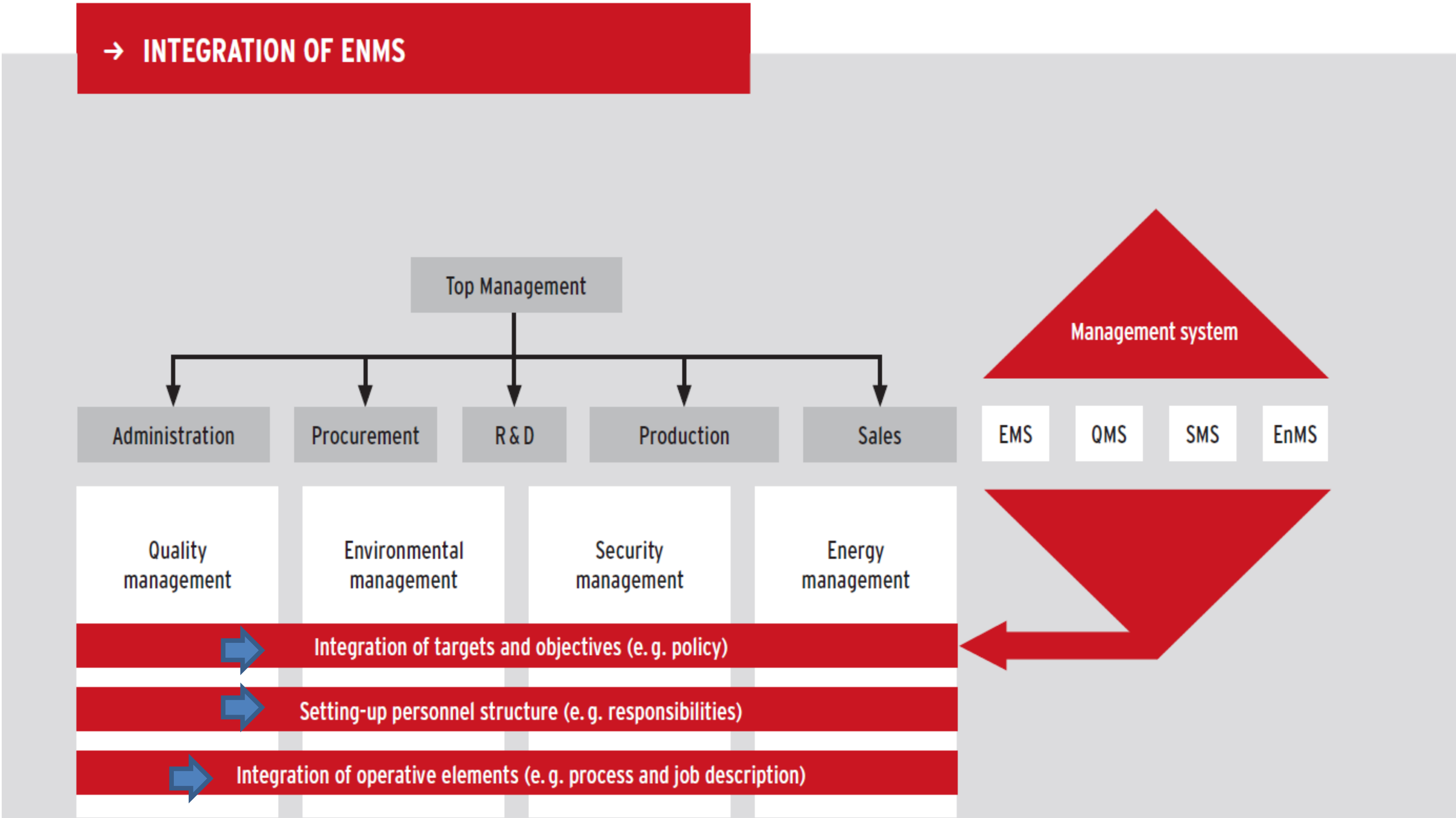
—To avoid **costs of poor performance**

- Pressure to **continuously improve ESH performance** and Well-designed management systems

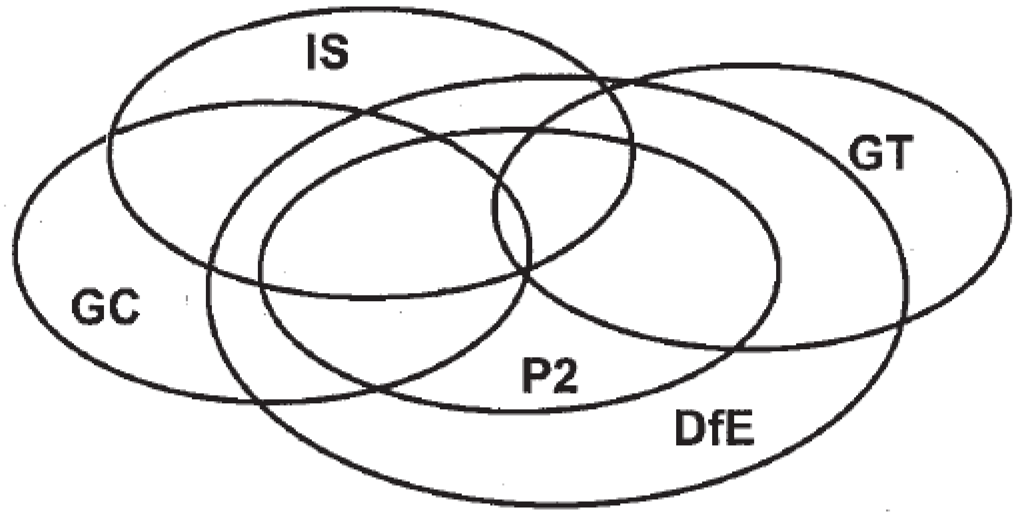
Cost Reduction with EnMs



Integration of EnMS with Other MS



The Overlapping EEHS Paradigms.



IS : Inherent Safety
GC: Green Chemistry
GT: Green Technology
P2: Pollution Prevention
DfE: Design for the Environment

integrating the concepts endorsed by P2, DfE, IS, GC, and GT within a **programmatic effort** that l*inks information, decision making, and validated results* throughout the **development process.**

Paradigm comparison matrix.

Strategy/ Tenet (Based on IS)	Example Concepts	IS	P2	GC	GT	DfE
Substitution	Reaction chemistry, Feedstocks, Catalysts, Solvents, Fuel selection	Primary	Strongly related	Primary	Some aspects	Primary
Minimization	Process Intensification, **Recycle,** Inventory reduction, **Energy efficiency,** Plant location	Strongly related	Primary	Some aspects	Strongly related	Primary
Simplification	Number of unit operations, DCS configuration, Raw material quality, Equipment design	Primary	Primary	Some aspects	Strongly related	Primary
Moderation (1) [Basic Process]	Conversion conditions, Storage conditions, Dilution, Equipment overdesign	Primary	Some aspects	Some aspects	Some aspects	Strongly related
Moderation (2) [Overall Plant]	**Offsite reuse,** Advanced waste treatment, Plant location, Beneficial co-disposal	Strongly related	Primary	Little	Some aspects	Strongly related

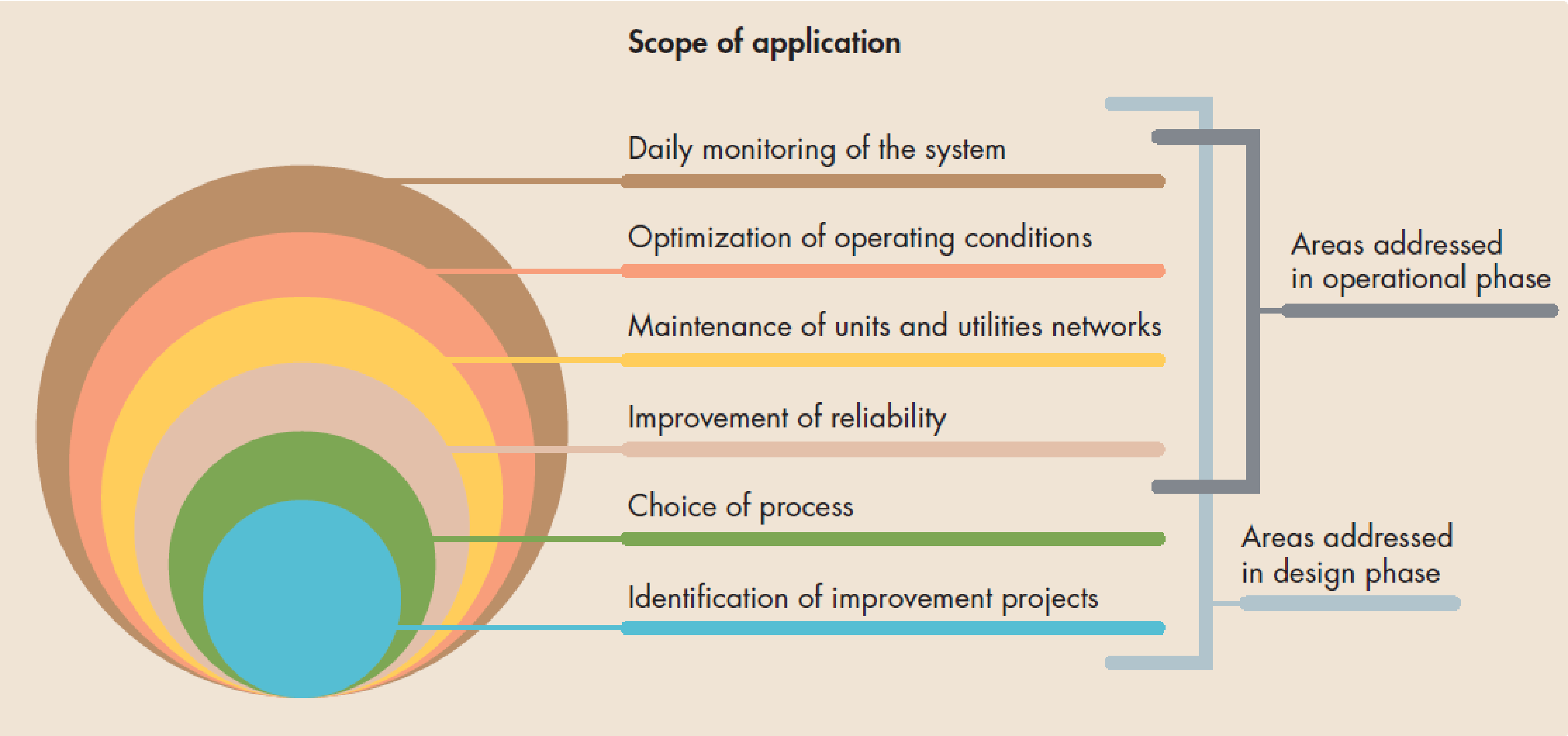
Key: ■ Primary tenet/concepts; ■ Strongly related tenet/concepts; ■ Some aspects addressed; ☐ Little relationship.

IS : Inherent Safety **GC**: Green Chemistry **GT**: Green Technology **P2**: Pollution Prevention **DfE**: Design for the Environment

Life Cycle Stages

Phase	Project/Life-Cycle Stage	
Research and Development	0	Discovery
	1	**Concept Initiation**
	2	**Process Chemistry**
	3a 3b	**Process Development or Definition (replication)**
Project Implementation	4	**Basic Process Engineering**
	5	Detailed Engineering/Design
	6	Construction & Commissioning
Production	7	**Operations (includes upgrades)**
Postproduction	8	Shutdown, Decommissioning, Disassembly

Areas of energy focus at different stages of a project

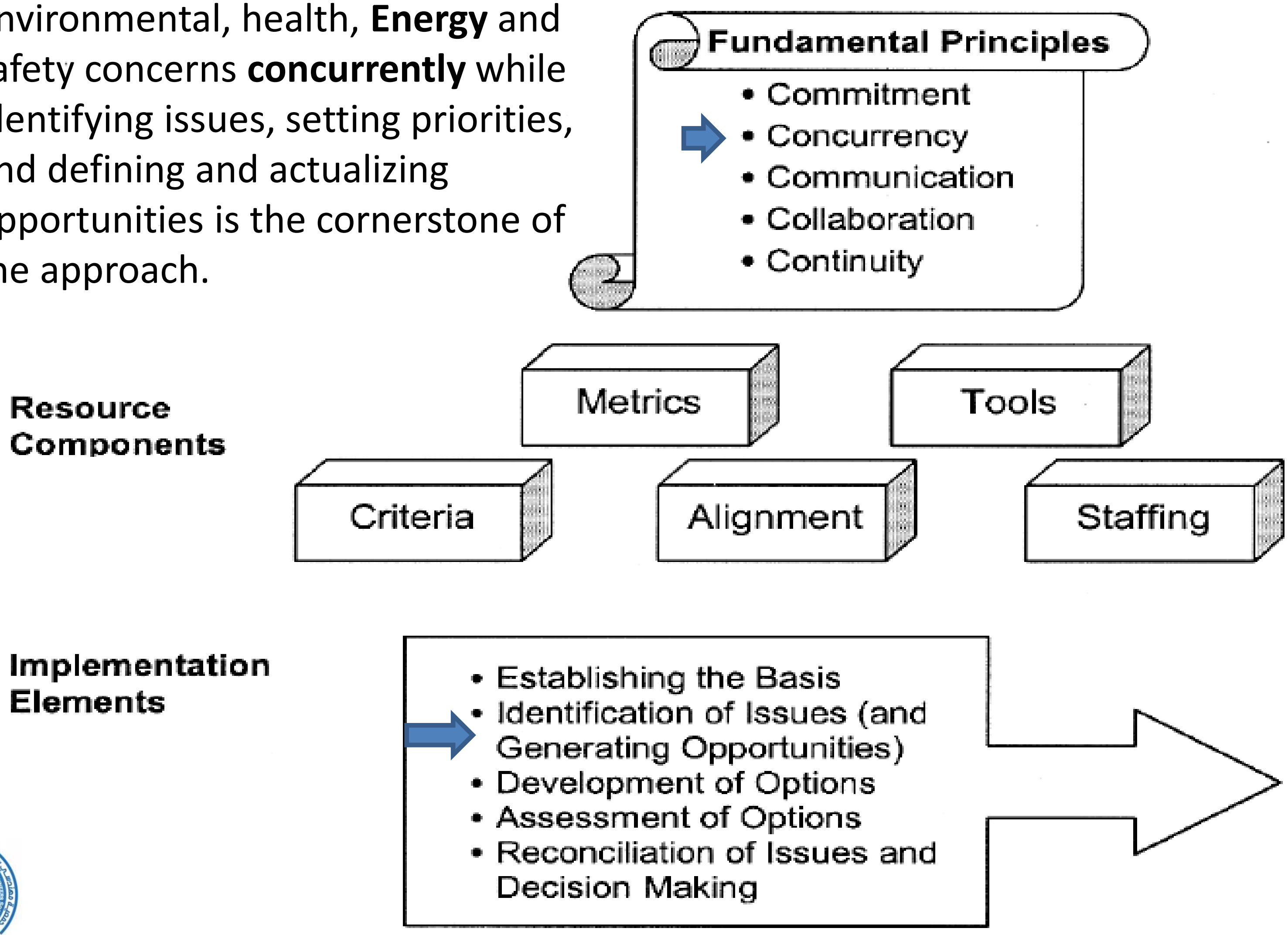


Representative EEHS Opportunities

Process Aspect	Opportunities
Materials/Resources	Alternate reagents
	Alternate solvents
	Alternate catalysts
	Alternate raw materials
	Waste/byproduct reuse
	Recover/recycle solvents
	Raw materials modification
	Recycle raw materials
Conditions	Alternate catalyst system
	Reaction heat sink (Moderation)
	Moderate conditions (P, T, pH)
	Adjust concentrations (Moderation)
	Transform waste (Alternative waste treatment)
Equipment/Containment	Combine steps (Minimization/Simplification)
	Fewer reaction steps
	Total containment design
	Reduce equipment size (Intensification)
	Improve constructability
	Continuous versus batch operation

MERITT Framework

***Concurrency*—Thinking** about environmental, health, **Energy** and safety concerns **concurrently** while identifying issues, setting priorities, and defining and actualizing opportunities is the cornerstone of the approach.



Strategy/Tenet	Concepts	Inherent Safety	Pollution Prevention	Green Chemistry	Green Technology	Design for Environment	Application to Stages: Concept Initiation	Process Chemistry	Process Development	Basic Process Engineering	Detailed Engineering Design	Application to Retrofits/ Upgrades
Substitution	Synthesis Route - Reaction Chemistry	✔	✔	✔		✔	●	●	◐			
	Feedstocks & Reagents	✔	✔	✔		✔	◐	●	◐	○		●
	Catalysts	✔	✔	✔	✔	✔	◐	●	◐	○		●
	Solvents	✔	✔	✔	✓	✔	◐	●	◐	◐	○	●
Minimization	Process Intensification	✔	✔	✓	✔	✔		○	●	◐	○	
	Inventory Reduction	✔	✓			✔			○	●	◐	●
	Recycle		✔		✓	✔			◐	●	○	●
	Focused Analytical Techniques	✓	✓	✔		✔			◐	●	○	
	Plant Location ("Co-Location")	✔	✔			✔			●	◐		
Simplification	System Design (Multi-step vs. Integrated)	✔	✔		✓	✔	○	◐	●	◐		●
	DCS Configuration	✔	✔		✔	✔			◐	●	◐	
	Pre-purified Raw Materials		✔	✓		✔		○	◐	●	○	●
	Individual Equipment Design	✔	✓		✓	✓			●	◐	○	
Moderation (1)	Conversion Conditions (pH, T, P)	✔		✔	✔	✓	◐	●	●	○		●
	Storage Conditions (T, Form, State)	✔	✓			✓			●	◐	○	●
	Dilution (Heat Sink, Reaction Kinetics)	✔							●	◐		
	Equipment Overdesign (Pressure)	✔				✓			○	●	◐	
Moderation (2)	Offsite Reuse		✔			✔			◐	●		◐
	Advanced Waste Treatment		✔			✔			○	●	○	◐
	Benefical Co-Disposal		✔							◐	○	
	Equipment/Process Cleaning Design	✓	✔		✓	✔			◐	●	◐	
	Plant Cleanup Practices (Dry vs. Wet)		✔		✓	✔				●	◐	◐
	Plant Location (Climate)	✔	✔			✔			●	○		
	Monitoring Systems	✔							○	●	◐	
	Secondary Containment	✔							○	●	◐	
	Backup/Redundant Systems	✔								●	◐	
Energy Efficiency	Waste Heat Recovery (Cascading)		✔		✓	✔			○	●	◐	◐
	Fuel Mix	✓	✔			✔			○	●	◐	
	Heat Transfer Equipment Efficiency		✔		✔	✔			○	◐	●	●

✔ Basic Concept
✓ Related Concept

● High Potential
◐ Moderate Potential
○ Low Potential

Value Creation Opportunities Matrix

Alignment of EEHS Disciplines to project stage

Stage	Green Chemistry	Pollution Prevention	Inherent Safety	Green Technology
Concept Initiation	Eliminate, Substitute, Low Persistence, or Bioaccumulation	Eliminate	Substitute	Eliminate, Substitute, Energy Use
Process Chemistry	*Process:* Eliminate, Renewable, Order of Steps, Minimize/Simplify *Chemistry:* Atom Economical, Selectivity, Reduced Toxicity, Mass Efficient	Reduce/ Recycle	Minimize/ Simplify	*Reactors, Mixers:* Minimize, Scale, Simplify, Eliminate (steps, unit operations, etc.), Energy Use *Separations:* Substitute, Eliminate
Process Development	Attenuate/Moderate	Re-use	Attenuate/ Moderate	Attenuate, Order of Unit Operations, Combination of Steps
Basic Process Engineering	Low Waste or Nonproduct	Treat, Contain	Intensify	Intensify
Detailed Engineering		Reliability/ Redundancy	Mechanical Integrity	Reliability, Redundancy
Production		Dispose, Process Redesign	Mitigate, Process Redesign	Process Redesign

Inherent SHEE Tool Framework

HAZARD/PROBLEM IDENTIFIER/PRIORITIZER

- uses existing company datasheets/hazard studies
- hazard/problem record to track hazards
- hazard/problem ranking/prioritizer

↓

OPTION GENERATOR

- sets structure for analysis
- sets objectives
- guide word/brainstorm methods
  - —prompt deviations
  - —question functionality
  - —prompt different means to achieve same function

↓

INITIAL SCREENING

- compares options against key success factors
- rapid screening to find best options
- warns of possible conflicts between S, H, and E

↓

DECISION AIDS

- used where no clear best option identified
- ranking index for inherent S, H, and E
- multiattribute analysis to aid decision making
- defines "musts" and "wants" criteria/constraints
- includes provision for cost, feasibility, and other decision criteria
- provides stand-alone decision support tool or can feed in to existing company decision support tools

Frist Cut Screening Ideas Examples

Recycle Vent Stream and Add Additional O_2 as Needed	
Cost	\$200,000 investment, \$500,000/yr operating cost
Benefit	Reduced end-of-pipe investment of \$700,000 Reduced operating cost of \$70,000/yr
Waste Minimization	Reduced gas flow to be treated
Energy Conservation	Reduced electricity requirements
Probability of Success	90%
Recycle Benzene from the Steam Stripper Overhead Stream	
Cost	\$100,000 investment, \$10,000/yr operating cost
Benefit	Reduced operating cost of \$90,000/yr
Waste Minimization	Reduced gas rate to thermal oxidizer
Energy Conservation	No change
Probability of Success	90%
Use Steam Stripper Bottoms as the Source of Water for the Water Scrubber	
Cost	\$300,000 investment, \$10,000/yr operating cost
Benefit	Water conservation and reduced treatment cost
Waste Minimization	Reduced wastewater treatment load (35 gpm to 1 gpm)
Energy Conservation	No change
Probability of Success	90%

Frist Cut Screening Ideas Examples

Use Fluidized-Bed Reactor (reduces air volume)	
Cost	$500,000 investment, $500,000/yr operating cost
Benefit	Reduced end-of-pipe investment of $800,000 Reduced operating cost of $40,000/yr
Waste Minimization	Reduced gas flow to be treated
Energy Conservation	Reduced electricity requirements
Probability of Success	80%

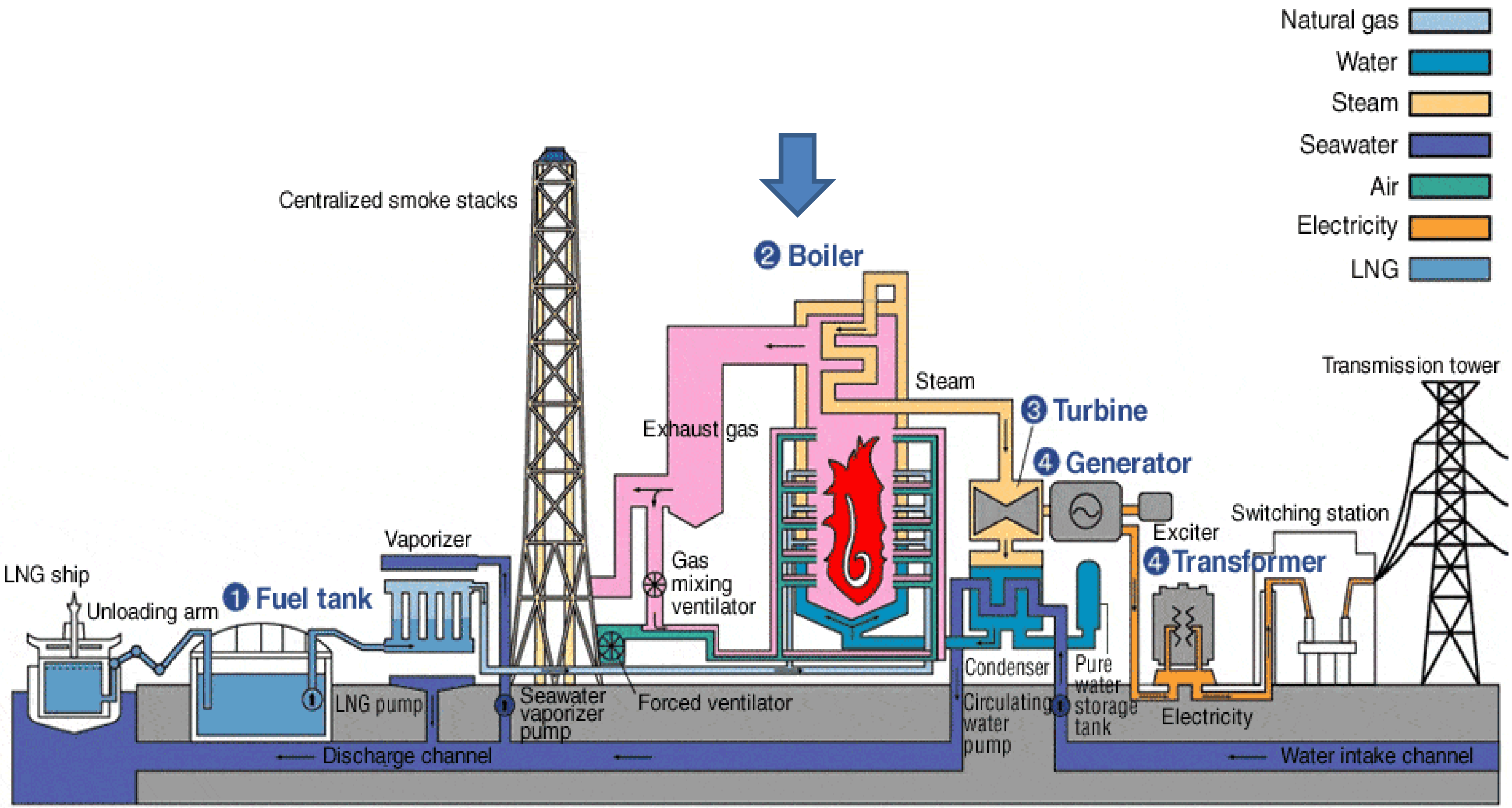
Use New Catalyst with Better Selectivity/Conversion	
Cost	Unknown
Benefit	Unknown
Waste Minimization	Reduces waste generation by 50% for a 5% increase in yield
Energy Conservation	None
Probability of Success	50%

Change Air-to-Feed Ratio to Reactor to Reduce COS Generation	
Cost	Unknown
Benefit	Unknown
Waste Minimization	None
Energy Conservation	None
Probability of Success	50%

Development Bias Comparison between General process and MERITT

Element	Basis
	Objectives
General Process	Production capacity Product efficacy Plant availability/reliability Investment cost
MERITT	Produce zero manufacturing waste Develop molecules that are not persistent, toxic, and bioaccumulative Nonhazardous manufacturing process (i.e., low toxicity, explosivity, and reactivity)
	Criteria
General Process	Product quality Operational efficacy Process economics High controllability
MERITT	Limit water use Limit hazardous byproducts Limit toxic solvent use
	Requirements/Constraints
General Process	Corporate design standards Plant commercialization date Utilities availability/cost
MERITT	Environmental regulations OSHA regulations Community acceptance

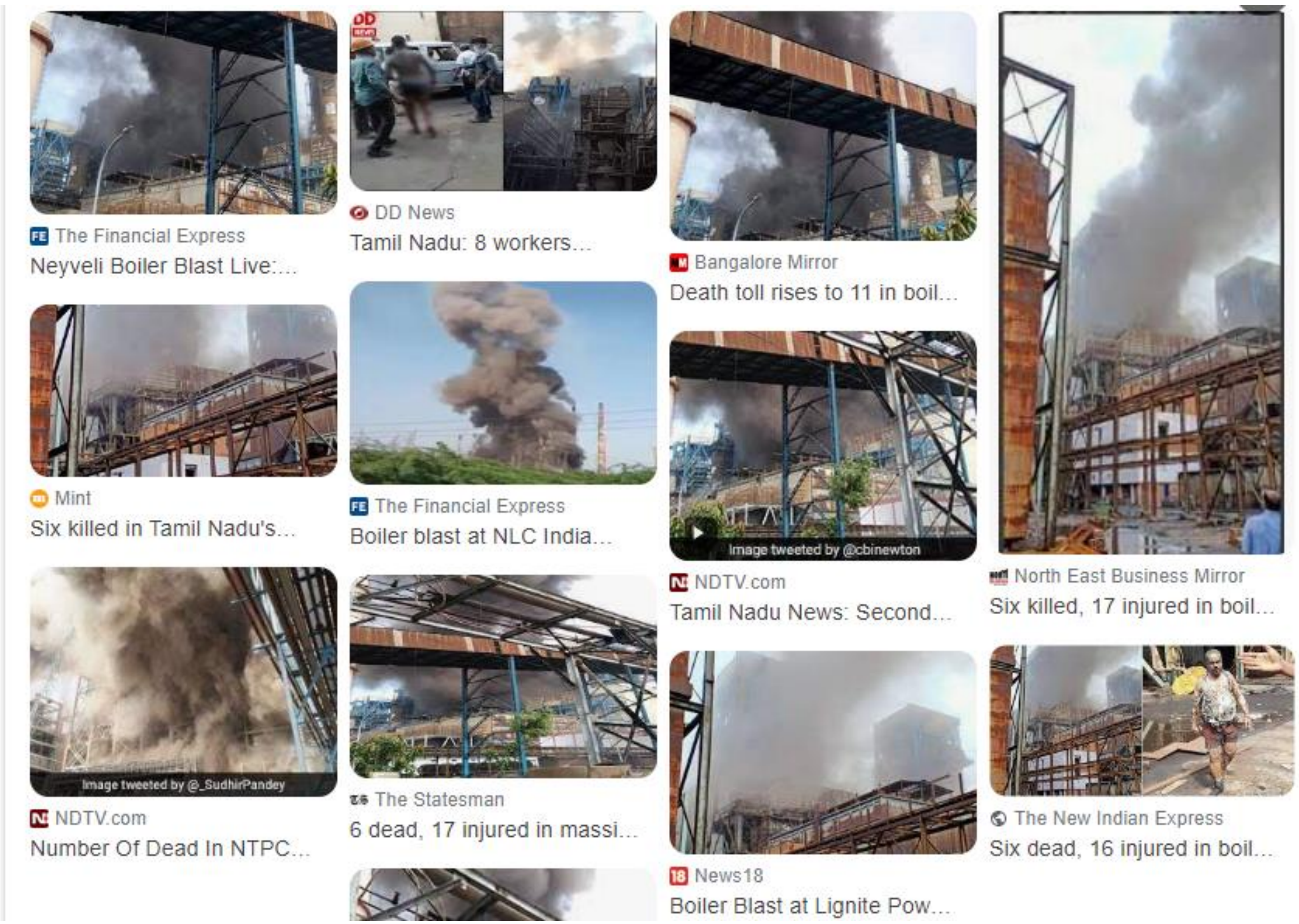
Power Steam Generating Unit



Boiler Explosion –Noodle Making factory

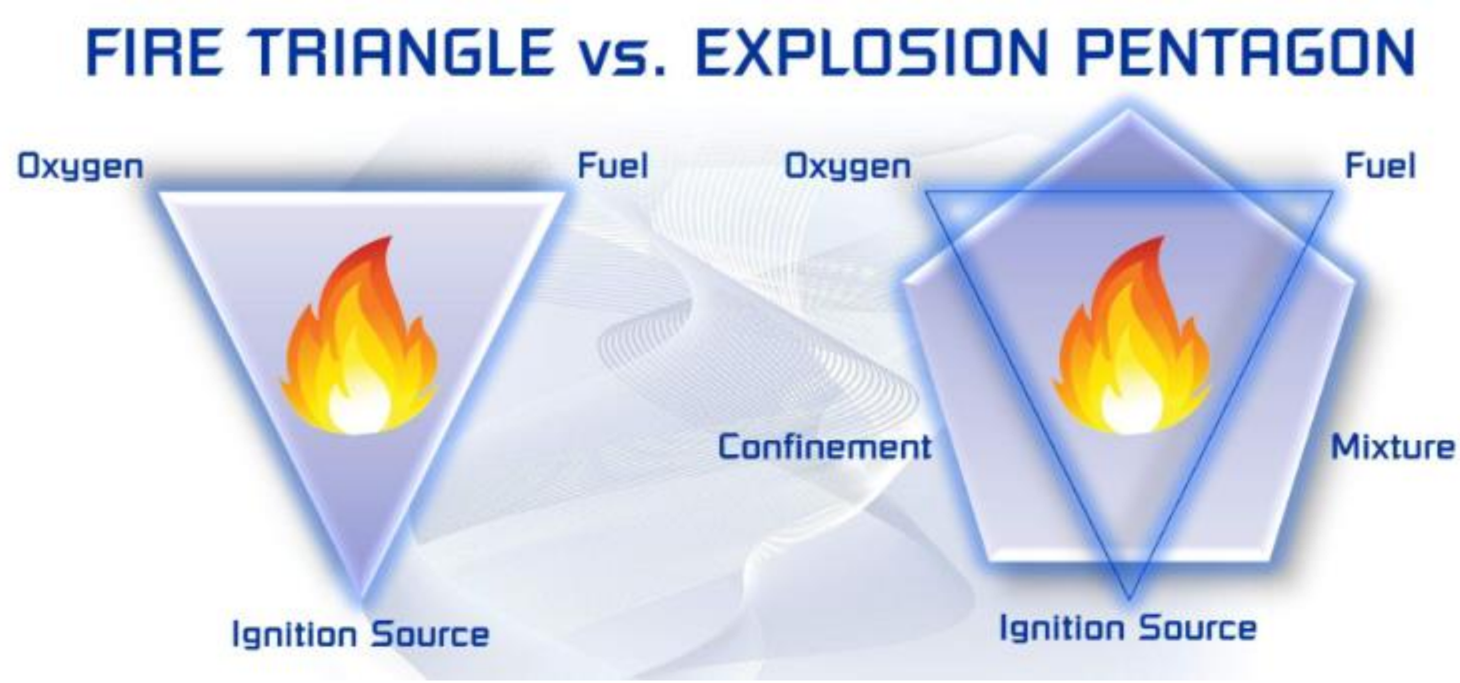
ps://english.jagran.com/india/bihar-explosion-muzaffarpur-noodle-making-factory-st-death-toll-casualties-live-news-updates-10036917

Boiler Explosions Accidents



Explosion Pentagon

Explosion A sudden, rapid release of energy that produces potentially damaging pressures-Blast



Boiler Process Safety Codes and Standards

- **ILO** Ordinance on Safety of Boilers and Pressure Vessels
- NFPA -85 :**Boiler and Combustion Systems Hazards Code**
- NFPA-69 : **Standard on Explosion Prevention Systems**
- ASME(B&PVC) : **Boiler and Pressure Vessel Code**
- API RP 538 : **Industrial Fired Boilers** for General Refinery and Petrochemical Service

دليل إجراءات تفتيش العمل ــوزارة العمل

د/5

اتخاذ الإجراءات اللازمة للوقاية من المخاطر الناجمة عن البويلرات في المنشأة وعلى النحو التالي:

التسلسل	الإجراء
.1	التأكد من منظومة الاطفاء في غرفة المرجل.
.2	التأكـد مـن وجـود صـمام أمـان اوتوماتيـكي لغلـق الوقـود في حالـة الحريـق أو ارتفـاع درجـة الحـرارة.
.3	التأكـد مـن وجـود فحـص دوري لصامـات الأمـان relief valve/ safety valve كل سـتة اشـهر.
.4	التأكد من تشغيل منظومة معالجة المياه قبل التشغيل.
.5	التأكـد مـن صلاحيـة اجهـزة القيـاس لجميـع خطـوط وحـدة توليـد البخـار.
.6	التأكـد مـن عـدم وجـود خطـوط بخـار راجعـة الى خـزان ميـاه التزويـد بشـكل مبـاشر.
.7	التأكد من عدم وجود أي تسريب للوقود.
.8	التأكـد مـن وجـود كتيـب تسـجيل قـراءة وحـدة توليـد البخـار اليومـي والتأكـد مـن تسـجيل جميـع القـراءات.
.9	التأكـد مـن وجـود موظـف فنـي يتابـع أعـمال وحـدة توليـد البخـار.
.10	التأكـد مـن وجـود سـجل صيانـة دوريـة لوحـدة توليـد البخـار.
.11	توفـير لوحـة ارشـادية في التعليـمات اعـلاه بشـكل واضـح ومناسـب بطريقـة يفهمهـا العامـل المعنـي.
.12	وضع البويلر خارج منطقة الانتاج

CSB Investigation Report

Cause :

The CSB determined that the cause of the explosion was **deficiencies** in Loy-Lange's **operations, policies, and process safety practices** that failed to **prevent or mitigate chronic corrosion** in its **Semi-Closed Receiver** and Kickham **Boiler** and Engineering's performance of an inadequate repair to the SCR in 2012 that left damaged material in place


CSB
U.S. Chemical Safety and Hazard Investigation Board

Pressure Vessel Explosion at Loy-Lange Box Company

St. Louis, MO | *Incident Date: April 3, 2017* | No. 2017-04-I-MO

Investigation Report

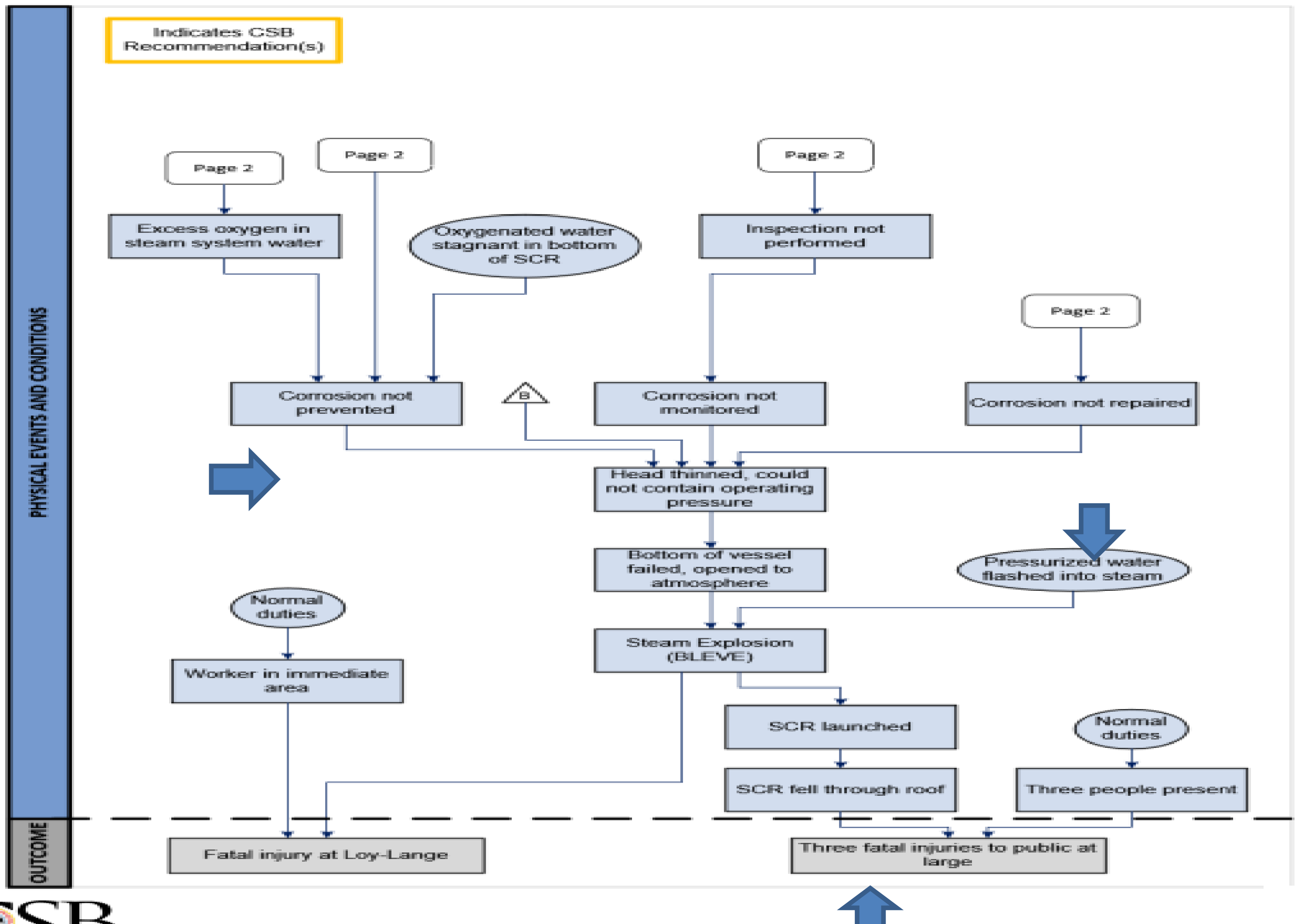
Published: July 29, 2022

KEY ISSUES:

- Pressure Vessel Corrosion
- Pressure Vessel Inspection and Regulation
- Pressure Vessel Repair
- Process Safety Management Systems

CSB –Causal Analysis

Appendix A—Causal Analysis (AcciMap)



Process Safety Beacon-Boiler Safety

CCPS
An AIChE Industry Technology Alliance

Process Safety Beacon

http://www.aiche.org/ccps/safetybeacon.htm

Messages for Manufacturing Personnel

Sponsored by NOVA Chemicals

January 2004

Avoid Improper Fuel to Air Mixtures

Photograph of the heater and adjacent column

Here's What Happened:

On June 11, 2003, an explosion destroyed the natural gas furnace at the NOVA Chemicals Bayport plant. Before the explosion, an operator noticed flame stability problems with the low NOx burners and began to manually adjust the airflow. During the few minutes that adjustments were being made to manage the burners, a loud puff was heard followed by a major explosion in the furnace. Damage included total destruction of the furnace and adjacent column. Fortunately, no one was injured, however the consequences could have been much worse.

What You Can Do !

To prevent a similar explosion at your plant:

- Ensure that a thorough hazard review and management of change is conducted
- Ensure that adequate performance testing is conducted
- Ensure that the burners and flow lines are cleaned and devoid of debris before startup
- Log and record any operating issues that occurred during your shift
- Communicate any issues during shift-to-shift meetings
- Ensure that the operating procedures, safe operating limits and control parameters for all new equipment are accurate and well understood. You may have only minutes to act to prevent an explosion.

How Did This Happen?

It appears that the explosion was caused by clogging in the nozzles on the new Ultra Low NOx burners resulting in an unstable flame. However, there were several other contributing factors that reinforce the importance of establishing effective design, construction and operating management of change processes when introducing new technology.

PSID Members check: "Furnace" in Free Search

Learning from this incident is being presented here with the permission of NOVA Chemicals. If you have questions or comments, please call Daniel Wiff, NOVA Chemicals Process Safety Advisor @ 412-490-4649.
A more detailed report on this incident is available by request to ccps_beacon@aiche.org.

Flame Instability is Dangerous.
Ensure that you understand the consequences of Change.

This edition is also available in German, French and Spanish. Contact CCPS at ccps_beacon@aiche.org for information.

SKIJo Consulting & Training

NFPA-69 –Ventilation Calculation –Purging Methods

Annex E Purging Methods

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

E.1 General. Any of several methods might be used to ensure the formation and maintenance of a noncombustible atmosphere in an enclosure to be protected. These include "batch" methods for one-time or occasional use, as in purging equipment during shutdown, and "continuous" methods intended to ensure safe conditions during normal operations. The following is an outline of various purging methods.

E.2 Purging Methods.

E.2.1 Batch Purging. This method includes siphon, vacuum, pressure, and venting to atmosphere.

E.2.2 Continuous Purging. This method includes fixed-rate application and variable-rate or demand application.

E.2.3 Siphon Purging. In this method, equipment might be purged by filling with liquid and introducing purge gas into the vapor space to replace the liquid as it is drained from the enclosure. The volume of purge gas required is equal to the volume of the vessel, and the rate of application can be made to correspond to the rate of draining.

E.2.4 Vacuum Purging. In this method, equipment that normally operates at reduced pressure, or in which it is practical to develop reduced pressure, might be purged during shutdown by breaking the vacuum with purge gas. If the initial pressure is not low enough to ensure the desired low oxidant concentration, it might be necessary to re-evacuate and repeat the process. The amount of purge gas required is determined by the number of applications required to develop the desired oxidant concentration. Where two or more containers or tanks are joined by a manifold and should be purged as a group, the vapor content of each container or tank should be checked to determine that complete purging has been accomplished.

E.2.5 Pressure Purging. In this method, enclosures might be purged by increasing the pressure within the enclosure by introducing purge gas under pressure and, after the gas has diffused, venting the enclosure to the atmosphere. More than one pressure cycle might be necessary to reduce the oxidant content to the desired percentage. Where two or more containers or tanks are joined by a manifold and should be purged as a group, the vapor content of each container or tank should be checked to determine that the desired purging has been accomplished.

If the system is complex, involving side branches through which circulation cannot be established, the sweep-through purging method might be impractical, and pressure or vacuum purging might be more appropriate.

The relationship between the number of volumes of purge gas circulated and the reduction in concentration of the critical component in original tank contents, assuming complete mixing, is shown on the graph in Figure E.2.6.

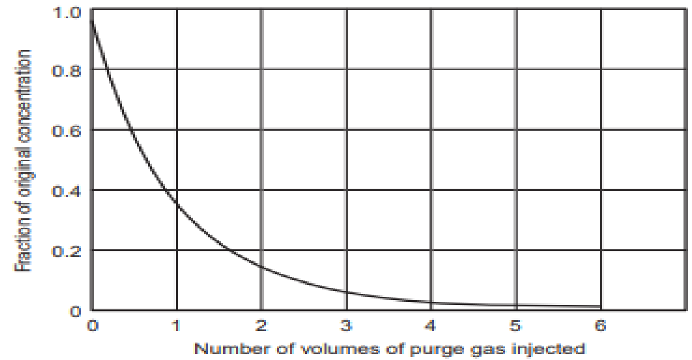


FIGURE E.2.6 Dilution Ratio — Purging at Atmospheric Pressure (Complete Mixing Assumed).

The following points should be noted:

(1) The total quantity required might be less than that for a series of steps of pressure purging.
(2) Four to five volumes of purge gas are sufficient to almost completely displace the original mixture, assuming complete mixing.

E.2.7 Fixed-Rate Purging. This method involves the continuous introduction of purge gas into the enclosure at a constant rate, which should be sufficient to supply the peak requirement in order that complete protection is provided, and a corresponding release of purge gas and whatever gas, mist, or dust has been picked up in the equipment.

The following information regarding the fixed-rate purg-

Metering Control Systems with O2 Trim-NFPA Requirement

Excess air is required to ensure **complete mixing** and optimum heat-release characteristics, however, it contributes to significant heat loss. **<u>Excess air is also essential from a safety standpoint.</u>**

Without it, the amount of O2 at the burner might drop below the theoretical stoichiometric level during load changes, possibly leading to a boiler explosion. By keeping excess air at the minimum level required for stable firing, effluent heat losses may be minimized.

For boilers that are now currently operating at high excess-air levels, the potential efficiency gain by reducing excess air is significant. *The idea behind low-excess-air combustion control is to maximize boiler efficiency by operating at the theoretical point where both combustible*

Combustion Process Hazards Protection

Accumulation of Combustibles :(*Loss of Flame or Substoichiometric Combustion)*

Potential hazardous events include:

a. **Afterburning** in the furnace which may result in the **overheating and failure of tubes and/or tube supports systems;**

b. An **explosion** which may result in the *partial or total destruction of the boiler*, and which may be hazardous to personnel in the operating area

Process Hazards Considerations

At startup conditions, the **accumulation of combustibles within the boiler should not be permitted to exceed 25% of the lower explosion limit (LEL) before corrective action is initiated**.

The LEL may be calculated at laboratory conditions using **Le Chatelier's formula and LEL data for pure components as listed in NFPA 325**, Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids

Boiler Explosion Purging Requirement

Potential advantage - This option reduces the number of times a boiler is shutdown in response to substoichiometric combustion. Some facilities have operating experience to indicate that explosions are more likely to occur during light off, due to inadequate purge or delayed ignition, than during substoichiometric combustion. For those facilities, reducing the number of restarts may be an important consideration.

INDUSTRIAL FIRED BOILERS FOR GENERAL REFINERY AND PETROCHEMICAL SERVICE

API RECOMMENDED PRACTICE 538

7.4.4.2 Low Combustion Air Flow

7.4.4.2.1 Process hazard

Combustion air flow below that needed for stable flame operation may lead to the accumulation of carbon monoxide or hydrocarbon within the boiler. See 7.4.4.1 for a description of the hazardous events that may occur.

7.4.4.2.2 Considerations

Maximum Continuous Rate

This section is intended to apply to boilers equipped with forced draft fans.

a. For multi-burner boilers, the NFPA 85 committee set a minimum purge limit of 25% MCR airflow to resolve insufficient purge-based explosions in the 1960's. With improvements in airflow measurement technology, the prescriptive requirement to maintain 25% MCR airflow presents a problem for the refining and petrochemical industry with requirements run an N+1 boiler on standby. As a result, many refineries run the pilot in standby mode and elevate the airflow to 25% MCR airflow prior to lighting the main burner.

النتائج والتوصيات

- توسيع اطار نظام إدارة الطاقة من الاطار الحالي والارتباط المباشر مع نظام إدارة البيئة ليتم شمله ضمن **نظام الإدارة المتكاملة (إدارة الجودة والسلامة الشاملة والبيئة والطاقة)**
- تلبية تجهيزات **نظام إدارة الحارق** (Boiler Burner Management) للبويلرات لمتطلبات الوكالة الامريكية للوقاية من الحرائق (NFPA-68/69/85) وخصوصا فيما يتعلق بمتطلبات (Purging –Ventilation)ومتطلبات (Excess Air)
- توفير تعليمات وأنظمة وطنية تتعلق بسلامة البويلرات وأسس الفحص والتفتيش ذات العلاقة