M.TECH DISSERTATION

ON

STUDY OF P&ID, SAFEGUARDING PHILOSOPHY, DESIGN BASIS AND ITS FEATURES- RHIP LIVE PROJECT

Submitted by

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BONAFIDE CERTIFICATE

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ABSTRACT

Process Flow Scheme (PFS) is used in chemical and process engineering to indicate the general flow of plant processes and equipment. The PFS displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations. A diagram which shows the interconnection of process equipment and the instrumentation used to control the process. In the process industry, a standard set of symbols is used to prepare drawings of processes. Through this project, Process Flow Diagrams were studied in accordance with specific pre-defined standards and analyzed thoroughly so that it would make the development of Process Engineering Flow Scheme very easier. Process Engineering Flow Schemes, also known as Process & Instrumentation Diagrams were made from PFS after segregating each Process Flow Diagram into various segments on the basis of its design basis and philosophy. After implementing the safeguarding features in the PEFS, Process Safety Flow Schemes were prepared which were intended to be the desired outcome. After getting client comments on various sections, the final sample was issued for approval from the Home Office.

Keywords: Process Flow Scheme, Process Safety Flow Scheme, Plant facility

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

PFS	Process Flow Scheme
PEFS	Process Engineering Flow Scheme
PSFS	Process Safety Flow Scheme
PFD	Process Flow Diagram
RHIP	Rabab Harweel Integrated Plant
SFD	System Flow Diagram
P&ID	Piping/Process & Instrumentation Diagram
QRA	Quantitative Risk Assessment

CHAPTER 1

INTRODUCTION

1.1. Background

Process flow diagrams (PFDs) are used in chemical and process engineering. These diagrams show the flow of chemicals and the equipment involved in the process. Generally, a Process Flow Diagram shows only the major equipment and doesn't show details. PFDs are used for visitor information and new employee training.

A Process and Instrument Drawing (P&ID) includes more details than a PFD. It includes major and minor flows, control loops and instrumentation. P&ID is sometimes referred to as a Piping and Instrumentation Drawing. These diagrams are also called flow sheets. P&IDs are used by process technicians and instrument and electrical, Process, safety, and engineering personnel.

Process technology information will be a part of the process safety information package and should include employer-established criteria for maximum inventory levels for process chemicals; limits beyond which would be considered upset conditions; and a qualitative estimate of the consequences or results of deviation that could occur if operating beyond the established process limits. Employers are encouraged to use diagrams that will help users understand the process.

1.2 Scope

This project will cover Process aspects relating to equipment such as machinery, tanks, vessels and Process handling equipment together with any associated systems that are necessary to ensure safe installation, commissioning, operation, maintenance, decommissioning and removal of such equipment.

The following areas shall be considered:

- Design
- Manufacture

- Installation
- Commission
- Operation
- Maintenance
- Equipment specific

Many of the Process design requirements to achieve safe operation and maintenance of equipment are set out in industry design codes and practices.

Safety in Design (SID) is one of the three elements of Worley Parsons SEAL process (Safe and Sustainable Engineering for Asset Lifecycle), and focuses on increasing the inherent safety of designs.

1.3 Objectives

i. To study P&ID of RHIP(RABAB-HARWEEL-INTEGRATED PLANT) live project
ii. To do fire water demand calculation and Hazardous Area Classification of Mumbai Airport based project using Indian Standard available and compare the results with other available International Standards
iii. To analyze the design basis for the integration project
iv. To prepare PSFS from PEFS after implementing Safeguarding Philosophy
v. To check whether all safeguards are implemented in both FEED and detail design stage

CHAPTER 2

LITERATURE REVIEW

2.1Operations philosophy

The objectives for operations over the asset lifecycle are to:

- Demonstrate sound HSE and sustainable development management.
- Ensure acceptable risk to personnel is appropriately managed and controlled.
- Ensure the integrity and safeguarding of all wells and production facilities
- Maintain production availability in line with delivery requirements.
- Maximize production and the ultimate recovery from the fields.
- Provide and develop the competencies of the workforce.
- Use state of the art technologies to arrive at minimum manning levels
- Explain how the asset will be operated and maintained.

Key Operating Principles:

1. Achieve ALARP operations & minimize human exposure risk through plant design
2. Segregate high and low risk areas within the plant layout (Apply the guideline for toxic facility layout).
3. Reduce the probability of toxic gas release by optimizing leak paths in consideration of operability and maintainability of the facilities. Provide reliable and quality assured equipment with minimum maintenance requirements.
4. Minimize infield manning: The Central Control Room (CCR) shall be permanently manned 24 hours a day by 4 panel operators and 1 shift supervisor.
5. Key support staff will be Interior based during Start-Up and Initial Operations such as Process Support, Operations Support, etc.
6. Planned maintenance will be carried out during dayshift.
7. Breakdown maintenance during night time will be carried only by exception and will be subject to risk assessment to ensure risk is ALARP.

8. A proactive working environment based on a high level of work planning and a competent and disciplined workforce.
9. Maintenance Technicians work in all areas where their discipline is required.
10. Plant Operators – Work in specific areas, require training and competency assessment to move into other areas of the plant, e.g. Utilities, GSU, Sour Gas Injection, CCR, etc.

2. Mitigate consequences of toxic gas releases

- Provide a Leak Management System (detection, analysis, remediation, analyze/improve).
- Provide an Emergency Response Management System to ensure safe and quick evacuation of site personnel to dedicated muster locations.
- Provide, maintain and regularly drill a set of Emergency Response procedures that covers realistic emergency scenarios.

3. Assure the Process and Technical Integrity of all process facilities

- Technical Integrity established in Design and based on the PDO Technical Integrity Framework.
- Correct material selection for sour service and QA/QC attention to detail.
- Demonstrable life cycle design integrity, underpinned by early definition of safety critical elements and performance standards, and life cycle cost (Capex/Opex) evaluation.
- For all equipment the full supply chain management systems are to be established all the way down to component level.
- Provide a Competency Development, Assessment & Assurance System for all RHIP operations staff, and a full development and training plan in line with Project schedule.
- Optimize maintenance and inspection strategies to meet availability target by applying Risk and Reliability Maintenance (RRM) principles
- Compliance to Operating Envelopes will be monitored under the Operational Integrity Assurance (OIA) program.
- Develop an Alarm Management Strategy using Ensuring Safe Production (ESP)/Operations Integrity (OI).
- Implement a rigorous, robust and comprehensive Corrosion and Integrity Management System (CIMS).

- Provide Flange Management System.

4. Maximize Product delivery

- Optimize Plant Availability: o Develop a RAM model to be used for optimizing plant design and to meet plant availability target during Design and Execute Phases.
- Design for safe SIMOPS.
- Optimize maintenance and inspection strategies to meet availability target through RRM.
- Maximum efficiency/reliability of the facilities
- Considering and balancing to Project NPV.

5. Minimize OPEX

- Apply a Chemicals Management System to optimize all production and process chemical costs.
- Implement a Logistics Management System to optimize all logistics costs.
- Implement an Operations Contracting Strategy and Contract Management System to ensure optimum value from contracts.
- Optimize maintenance cost.
- Minimize infield manning.

Table: 2.1

SL.NO	TITLE OF PAPER REFERRED	YEAR	AUTHOR NAME	FINDINGS FROM LITERATURE
1.	Relationships between safety culture aspects – A work process to enable interpretation	2013	AsaEkn, Marcus Runefors, Jonas Borell	1. While the human and system aspects are vital for safety, the organizational aspect also has a fundamental influence on safety. 2. A safety culture that stresses proactive measures for maintaining safety in an organization is a vital counterforce to the possible drift into failure.
2.	Updated failure rates and risk management in process industries	2013	Paolo Pittiglio, Paolo Bragatto, CorradoDelle Site	1. Failure Rates and Risk Management in the common practice of process industries 2. “Failure Rates” in process industries: from the Seventies to the present

3.	Heat Exchanger Network Design Considering Inherent Safety	2014	Irene Chana, SharifahRafidah Wan Alwia, Mimi H. Hassimb, ZainuddinAbdManana, Jiri JaromírKlemesc	1. Integrating the ISI and the STEP graphical approach in order to obtain an inherently safer HEN design 2. Pinch Analysis (PA) is a systematic and holistic methodology for maximizing heat recovery in process systems
4.	Advanced process monitoring safeguards technologies at Pacific Northwest National Laboratory	2012	J.M. Schwantes, S.A. Bryan, C.R. Orton, Tatiana G. Levitskaia, S.H. Pratt, C.G. Fraga, J.B. Coble	1. The long term successful use of nuclear power is critically dependent upon adequate and safe processing and disposition of the spent nuclear fuel. 2. Liquid-liquid extraction is a separation technique commonly employed for the processing of the dissolved spent nuclear fuel.
5.	Development of Safety Regulation and Management System in Energy Industry of China: Comparative and Case Study Perspectives	2013	HUANG Lin-jun LIANG Dong	1. From the experience of safety legislation and management in Australia, we find that safety culture and implementation are essential to the healthy development of energy industry 2. Safety regulation and management would benefit greatly from guidance on how to form safety management system and cultivate safety culture, as well as from the further development of feasible performance measures

6.	Research on safety relief of methanol-acetic anhydride system under various process conditions	2014	DENG Jiping, SUN Xin, CHEN Wanghua, YAO Yadong, LV Jiayu	1. Safety relief is one of the most cost-effective technical measures for reducing risks of a reaction system under a runaway condition. 2. The reactor volume has minor effects on the relief area, and an increased mass of reacting substances requires an increased relief area

2.2 Safeguarding philosophy

GENERAL PRINCIPLES:

The main objectives of the shutdown system (Safeguarding system) are:

- To protect the personnel
- To avoid or minimize the pollution to environment
- To protect the Assets
- To avoid or minimize the production losses

Safeguards are systems or elements that serve as the different levels of protection against uncontrolled loss of containment. The process safeguarding system is required to reduce the risks of malfunction of plant equipment, in terms of hazards to personnel, environment and economic loss, to a level that is **A**s **L**ow **A**s **R**easonably **P**racticable (**ALARP**).

The ESD and PSD system shall be segregated from the process control and monitoring system, but shall interface with the FCS to provide shut-down and safety status information to the Operator. It shall be possible to manually initiate an ESD from the facility local control room and the central control room. Sequence control and startup will be implemented in FCS and not in IPS.

Layout and spacing of plant, equipment and location of ESD and PSD valves will play an important role in the blow down philosophy. This will be covered in QRA studies and HAZOP reviews.

The primary protection system should not consist of an alarm or procedure. Alarm signals will be provided independent of control and trip signals for alerting operator of excursion of process variable from its pre-set value for operations requirements for Integrated Alarm & Event Management. The level and potential for operator intervention will be assessed on case basis for timely and correct response to an alarm, however it shall not be considered for safeguarding action. For every trip initiating device, an alarm shall be provided.On measurements that can lead to a trip, pre-alarms shall be implemented, provided the operator has sufficient response time to take corrective action.

The shutdown system will be built hierarchically i.e. a higher level shutdown includes the actions of the lower levels. This structure improves understanding of the system and simplifies programming.

Over Pressure Protection

The process safeguarding system must ensure that suitable protection is provided against the maximum pressure that can be generated by the worst credible malfunction. There are essentially three ultimate safeguard options to protect against overpressure:

1. Fully pressure rated equipment

2. Relief valves

3. Instrumented Protective Function only (HIPPS).

Under Pressure Protection

Certain process can develop sub atmospheric pressure conditions generated by the worst credible scenario. The process safeguarding system must ensure suitable protection against minimum pressure or vacuum conditions. The ultimate safeguard for under pressure can be:-

3 Design for vacuum

4 Provision of Vacuum Relief valves

Safe Shutdown

In case of any malfunction of the plant equipment or its associated control instrumentation giving rise to a hazard for personnel or the environment, or potentially leading to consequences of economic loss (e.g. damage of main equipment or severe production loss), the safeguarding system will bring automatically the facility to a safe condition. The safeguarding system shall also prevent the start-up of system /unit/ equipment till a safe start conditions are satisfied.

The safeguarding system shall also bring the facility to a safe condition in case of:

- Confirmed detection of fire
- Confirmed Hydrocarbon gas (based on Lower Flammability Limit) / Toxic gas (based on H_2S) detection
- Instrument air failure
- Electrical supply failure
- High Level in Flare KO drum/s
- Manual Action ESD push button(Remote / Local)

In case of shutdown, the safeguarding system shall automatically carry out the following actions according to the circumstance:

- To isolate the process system units so as to limit the hazardous inventory leakage to atmosphere;
- To stop any equipment which could amplify this abnormal situation (e.g. to cut the heating source, to interrupt the electrical supply and any equipment which would be damaged if they continue running);
- To isolate the process equipment so that the depressurization can be carried out if necessary;
- To carry out automatically the depressurization, if required.
- To isolate the flow from one process unit to another in case of deviation of process conditions.

- Shutdown of the wells, if required.

Control valves

Control valves may be considered in conjunction with shutdown valves for safeguarding function. However control valves are not to be considered tight shut-off.

Non-Return Valves

NRVs are meant to restrict the reverse flow. Leak tightness of NRVs in the reverse flow direction is not always assured. Some of the places where NRV proves effective in preventing reverse flow are at departing pipelines / flow lines, well manifolds and Pumps / compressor discharge.

Locking Valves

Locking valves (in open or closed position) for safeguarding purpose can be considered. There are three different methods for locking valves:-

1. Car seal or chain lock
2. Lock integrated with valve (e.g. Castel lock)
3. Interlocking system

2.3 IMPLEMENTATION OF SHUTDOWN SYSTEMS

ESD Valve Locations:

ESD valves will be provided on the following (Ref [2]):-

1. Oil/ Gas outlets from the facility
2. Fuel Gas inlet to the facility
3. Gas inlets to the facility
4. On all hydrocarbon streams entering and leaving each “Fire Hazardous Zone”.

Failure Mode:

ESD valves shall fail safe in close position except for ESD valve on the Sulfinol-X charge pumps minimum flow recycle line which is fail safe in open position. Blow down valves shall fail safe in open position. Power / utility failure mode should move all safeguarding systems to fail safe position.

Volume (air) bottles are provided for blow down valves to ensure that these remain in the position signaled by the ESD systems until the Blow down management software requests the valves to open in the correct sequence to avoid overloading the flare.

However in some cases the pressurization action needs to be automated. In such cases, a small ESD valve (in combination with orifice) can be considered in parallel to the main ESD valve for the purpose of pressurization of the downstream system. This type of arrangements is very common in compressor suction system ESD/ PSD valve or at separator inlet ESD / PSD valve.

CHAPTER 3
METHODOLOGY

3.1 Safety in Design

3.1.1 Design Activities and Deliverables

Whereas Process engineers/designers need to be constantly aware of the safety impacts of their design activities, there are a number of project activities and deliverables which generate safety related outcomes. Engineers/designers must be fully acquainted with these activities and deliverables and shall ensure any safety related outcomes are incorporated into the designs they are preparing.

Design Activities and Deliverables include:

Project Basis of Design

A key deliverable for each project is the Basis of Design which establishes the key requirements for a facility's design and is the prime document that identifies specific aspects that relate to safety. The Basis of Design generally includes the following data:

- Applicable industry codes and standards
- Process parameters for the required range of normal and extraordinary (fault, commissioning, shutdown etc.) operating conditions
- Control and shutdown system philosophy (level of automation)
- Site conditions and seasonal variations
- Level of system availability
- Isolation for maintenance philosophy
- Provision of alternative power supplies
- Provision for future growth

- European Union regulations and CE marking for equipment supplied to European countries

3.2 Hazardous Area Classification

As part of the electrical disciplines responsibility, details of hazardous substances (flammable, explosive, toxic etc.) and the plant areas where they are used, stored and can leak from machinery are identified and incorporated on to specific project deliverables such as Hazardous Area Reports. Hazardous Area Plans detail and classify those Hazardous Areas of a facility and define the design requirements for equipment in those areas according to the relevant project standards.

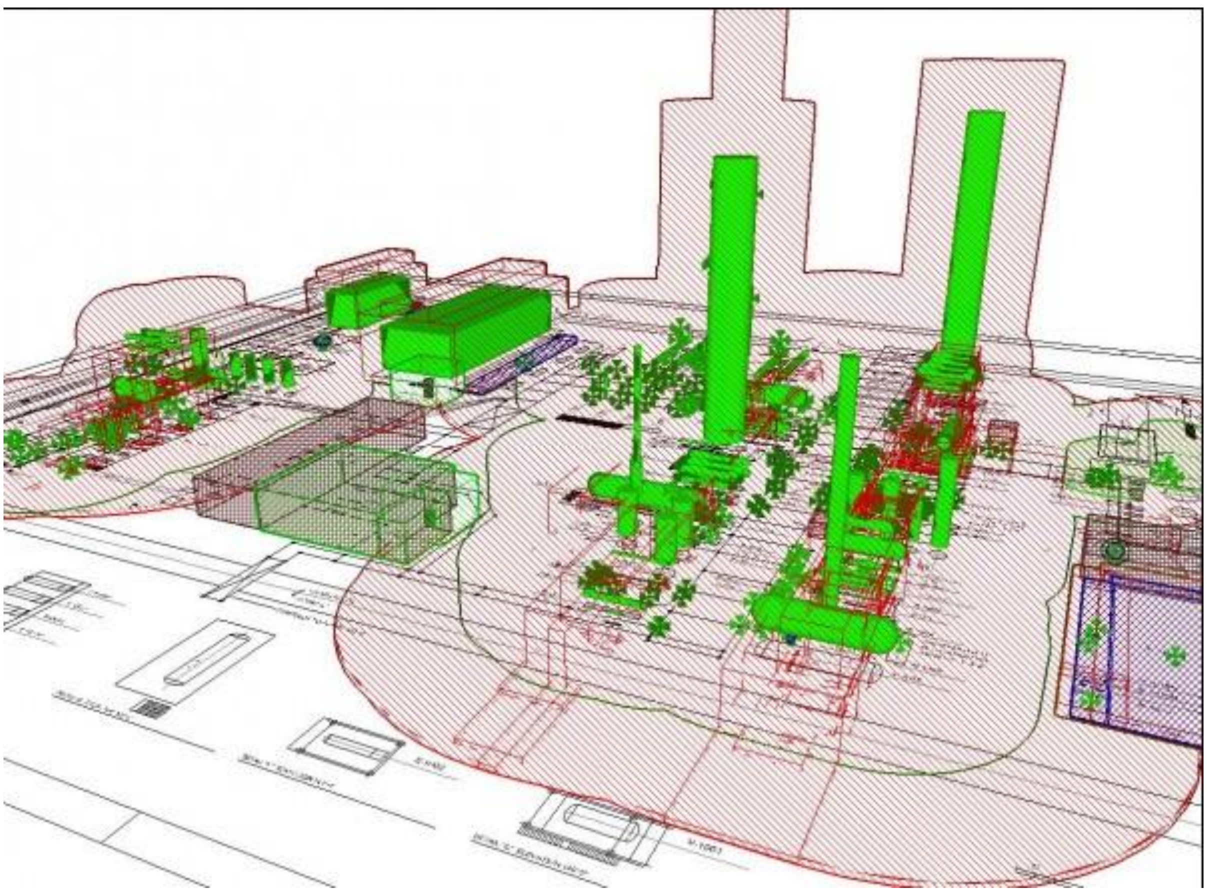

Fig: 3.1 – Hazardous Area Classification

3.3 Qualitative Risk Assessment

Critical components shall be reviewed for potential causes of failure and the means of prevention identified. Requirements for manufacturer's quality systems, inspection and Non Destructive Testing (NDT) requirements and instruction manuals shall be identified. Venting, draining, purging and installing instrumentation shall be recommended where applicable.

RISK OUTCOME

- Low
- Moderate
- Significant
- High

Likelihood	Consequence				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Possible 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Fig: 3.2 – Quantitative Risk Assessment

A Qualitative Risk Assessment is used to evaluate the level of risk associated with the hazards identified in the HAZID and compare it against predetermined standards, target risk levels or other criteria. The risk assessment documents those hazards that require protection via an additional safety function. Risk assessments classify the frequency and severity of the risks to determine the need to implement the Safety Instrumented System (SIS) and what level of performance will be required of the SIS.

3.3.1 Design Reviews

Different design reviews are carried out to address issues relating to layout, constructability, operability and maintainability of facility design.

Design reviews shall be implemented as early as possible into the project life cycle so that maximum benefit can be obtained from the design review process.

3.3.2 HAZOP

HAZOP (Hazard and Operability Study) reviews are attended by representatives of each engineering discipline and generally by customer operations and maintenance representatives. A formal guideword process is typically used to identify and record potential facility issues.

3.4 Process Hazards

Good Safety in Design is concerned with the principles of ergonomic design, (human factors) and provides for the eliminating or protection of personnel from potential hazards. Generally hazards attributable to Process equipment may be categorized as:

- Drawing in points
- shearing points
- pinch Points;
- impact and crushing areas;
- cutting areas;
- entanglement areas;
- stabbing points;
- abrasion areas;
- flying particles & objects;
- chemical emissions;
- noise emissions;
- dust emissions and containment;
- fire, explosion & blast areas:
- high surface temperatures:
- seismic regions:
- protrusions that could cause injury; and
- Accessibility for maintenance.

3.5 Assessing Risks

Once the potentially dangerous areas of a machine are identified, the risk (likelihood of injury or illness) associated with those areas should be assessed by considering:

- Whether any person (workers and visitors) would be exposed to those areas during installation, commissioning, erection, operation, inspection, maintenance, repair, service and cleaning of the machine.
- What existing measures are in place, to protect the health and safety of people who may be exposed?
- How adequate the existing measures are for protecting the health and safety of people who may be exposed.

In considering the issue of exposure, you need to consider:

- Are any parts of the body likely to come into contact with the machine?
- Are there any non-Process hazards present that may cause injury or illness?

If the answer to both questions is no, then there is no risk and no additional risk control measures are required. If the answer to either of the questions is yes, consideration should be given to the adequacy of existing control measures for protecting the health and safety of people who may be exposed.

3.6 Controlling Risks

If there is a likelihood of injury or illness associated with certain areas of the machine when all existing control measures are considered, the risk must be eliminated or reduced so far as is practicable by adopting the hierarchy of controls. Provision of appropriate guarding for danger areas of a machine is a form of engineering control designed to:

- Prevent access to the danger areas of the machine; or
- Contain flying particles generated from the materials which the machine processes; or
- Contain work piece ejection or disintegration of machine parts

Guarding a machine's danger areas is one of several options available to you for controlling risks. Other options, descending in order of effectiveness are as follows:

- Eliminate the process all together and therefore the need for the machine.
- Replacing the machine with another with a safer design.
- Isolate the machine from people.
- Develop safety procedures, requirements and signage for the installation, commissioning, erection, operation, inspection, maintenance, repair, service and cleaning of the machine and make sure the relevant people are familiar with these measures.

3.7 Protective Measures

Protective measures include:

- Understanding of full design envelope including any cyclic operations
- Understanding of environmental conditions and possible process stream contaminants
- Importance of material specifications (testing, positive material identification)
- Equipment guards
- Fire protection
- Insulation
- Understanding when personnel protection is required
- Corrosion prevention/protection
- Lockout (electrical and Process) and tag-out
- Shutdown systems and signage

3.8 Fire water demand calculation methodology

3.8.1 Fire water demand for single largest fire

(For locations with aggregate storage capacity upto 30000KL)

Consider various areas under fire and calculate fire water demand for each area based on design basis as indicated below, however, actual tank dimensions available in the terminal shall be considered.

A. Fire water flow rate for floating roof tank protection

Total storage capacity in one dyke area = 20,000 m3.

No. of tanks = 2.

Capacity of each tank = 10,000 m3.

Diameter of each tank = 30 m.

Height of each tank = 14.4 m.

a) Cooling water flow rate

(i) Cooling water required for tank on fire

Cooling water rate = 3 lpm/m2 of tank area for tank on fire.

Cooling water required = π x 30 m x 14.4 m x 3 lpm/m2.

= 4073.1 lpm.

= (4073.1 x 60)/1000 m^3/hr = 244 m^3/hr.

Assuming that second tank is also located within the same tank dyke at a distance more than 30 m from the tanks shell. Therefore, in such case cooling required is at the rate of 1 lpm/m2 of tank shell area.

(ii) Cooling water required for tank falling beyond (R+30) from center of tank on fire

Cooling water rate = 1 lpm/m2 of tank area.

Cooling water required = π x 30 m x 14.4 m x 1lpm/m2.

= 1357.7 lpm.

= (1357.7 x 60)/1000 m^3/hr

= 81 m3/ hr

Total Water required for cooling of tanks (item i + ii) = 244+81 = 325 m3/ hr

b) Foam water flow rate

Water flow required for applying foam on a largest tank burning surface area (rim seal area)

For floating roof tank of 30 M diameter,

Diameter of the tank (D1) = 30M

Distance of foam dam from shell = 0.8M

Diameter of roof up to foam dam (D2) = 30 - (2X0.8) = 28.4

Rim seal area = (π /4) x (302-28.42)

= (π /4) x 93.44

= 73.4 m2

Foam solution rate @ 12 lpm/ m2 = 880.8 lpm

Foam water required (For 3% foam concentrate) = 0.97 x 880.8 lpm

= 854.4 lpm.

= (854.4 x 60)/1000 m^3/hr

= 51 m^3/hr.

Total water flow rate (item a + item b) for floating roof tank protection:

(i) Tank cooling = 325 m^3/hr.

(ii) Foam solution application = 51 m^3/hr.

Total (item i + ii) = 376 m^3/hr.

B. Fire water flow rate for cone roof tank protection

Total storage capacity in one dyke area = 10,000 m^3.

No. of tanks = 2

Capacity of each tank = 5000 m^3.

Diameter of each tank = 24 m.

Height of each tank = 12 m.

a) Cooling water flow rate

(i) Cooling water required for tank on fire

Cooling water rate = 3 lpm/m2 of tank area for tank on fire.

Cooling water required = π x 24 m x 12 m x 3 lpm/m2.

= 2715.4 lpm.

= (2715.4 x 60)/1000 m^3/hr

= 163 m3/ hr

Assuming the other tank is also located within the same tank dyke at a distance less than 30 m from the tanks shell. Therefore, in such case cooling required is at the rate of 3 lpm/m2 of tank shell area.

(ii) Cooling water required for tank falling within (R+30) from centre of tank on fire

Cooling water rate = 3 lpm/m2 of tank area.

Cooling water required = π x 24 m x 12 m x 3 lpm/m2

= 2715.4 lpm.

= (2715.4 x 60)/1000 m^3/hr

= 163 m3/ hr

Total cooling water required = 163 + 163 = 326 m3/hr.

(Item i + ii)

b) Foam water flow rate

Foam solution application rate = 5 lpm/m^2 of liquid surface area.

Foam solution required = (π/4) x (24 m)^2 x 5 lpm/m2.

= 2262.9 lpm.

Foam water required (For 3% foam concentrate) = 0.97 x 2262.9 lpm = 2195 lpm.

= (2195 x 60)/1000 m^3/hr

= 132 m^3/hr.

Total water flow rate (item a + b) for cone roof tank protection:

(a) Tank cooling = 326 m^3/hr.

(b) Foam solution application = 132 m^3/hr.

Total = 458 m^3/hr.

C. Fire water flow rate for cooling pol tank wagon loading gantry

Total No. of loading points = Conventional or BTPN.

Width of tank wagon gantry = 12 m.

(Cooling two spur)

Cooling water flow rate

Divide total area of gantry into equal segments such that each segment measuring

15 m X 12 m and consider 3 segments operating at a time.

Water rate required = 3 x 15 m x 12 m x 10.2 lpm/m2.

= 5508 lpm

= 330 m3/hr

D. Fire water calculation for full surface fire on largest floating roof tank (roof sinking case)

Total storage capacity in one dyke area = 20000 m3

No. of tanks = 2

Capacity of each tank = 10,000 m3

Diameter of each tank = 30 m

Height of each tank = 14.4 m

a) Cooling water requirement:

Cooling water rate @ 3 lpm/ m2of tank shell area for tank-on-fire

Cooling water required = π x 30 x 14.4 x 3

= 4073.1 lpm

= 244 m3/hr

Assuming that second tank is located within the tank dyke at a distance more than 30M from the tank shell.

Then, cooling water requirement @ 1 lpm/ m2of tank shell area = π x 30 x14.4 x 1

= 1357.7 lpm

= 81 m3/hr.

Total cooling water = (244 + 81) m3/hr

= 325 m3/hr

b) Water requirement in foam application

Foam Application Rate@ 8.1 lpm/m²

Foam Solution Requirement = (π x 30m x 30m) / 4 x 8.1 lpm/m²

= 5727.9 lpm

= 344 m3/hr

Water required for the foam solution = 0.97 x 344 m3/hr

= 334 m3/hr …… refer Note below

Total water required for roof sink case:

Tank cooling 325 m3/hr

Foam application 334 m3/hr (Plus requirement for foam losses as per Note below)

Total 659 m3/hr

Total water requirement = 659 m3/hr (Plus requirement for foam losses as per Note below)

Note: Potential foam losses from wind and other sources to be added to this value as per design requirements. These losses are not considered in this typical calculation sheet.

E. Total design fire water flow rate for single fire contegency

The total fire water flow requirement will be highest of one of the fire water requirement calculated in 2.1 (376 m^3/hr) & 2.2 (458 m^3/hr), 2.3 (330 m^3/hr) and 2.4 (659 m^3/hr) above

i.e. 659 m3/hr plus supplementary water (36 x 4 = 144 m^3/hr) = 803 m^3/hr.

WATER STORAGE REQUIREMENT

Case 1: When make-up water is not available:

Let us assume two main pumps of capacity 410 m^3/hr each and one stand-by pump of equal capacity and equal head are provided.

Water requirement is 410 x 2 = 820 m^3/hr

Design flow rate (Fire water pump discharge) = 820 m^3/hr

Fire water storage required (4 hrs) = 820 x 4

= 3280 m3

Case-2: When 50% or more make up water is available

Fire water storage requirement (3 hrs) = 820 x 3

= 2460 m3

3.8.2 Fire water demand for two major fires simultaneously

(For locations with aggregate storage capacity > 30000KL)

The only differences from Single Fire Contingency are:

Storage capacity >30000 KL

Diameter of tank

TOTAL DESIGN FIRE WATER FLOW RATE FOR TWO SIMULTANEOUS FIRE SCENARIO

The total fire water flow requirement will be sum of the two largest fire water requirement calculated in A) (504 m³/hr) & B) (1341 m³/hr), C) (330 m³/hr) above i.e. (1341+504) =

1845 m3/hr plus supplementary water (36 x 4 = 144 m³/hr) = 1989 m³/hr.

OR water requirement alone as calculated in D) i.e. 1028 m3/hr plus supplementary water (36 x 4 = 144 m3/hr) = 1172 m3/hr

Hence water requirement for double contingency locations shall be 1989 m3/hr

WATER STORAGE REQUIREMENT

Case 1: When make water is not available:

Let us assume three main pumps of capacity 750 m³/hr each and two stand-by pump of equal capacity and equal head are provided.

Water requirement is 750 x 3 = 2250 m³/hr

Design flow rate (Fire water pump discharge) = 2250 m³/hr

Fire water storage required (4 hrs) = 2250 x 4 = 9000 m3

Case-2: When 50% or more make up water is available (consider single largest fire plus supplementary firing)

Fire water storage requirement (3 hrs) = (1341+144) x 3 = 1485 x 3

= 4455 m3

= 5000 m3 (Say)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Considerations Overview

4.1.1 Desirable Equipment Characteristics

The desirable characteristics of Process equipment include reliability, simplicity in design, convenience (accessibility) and low total installed cost. These characteristics should be inherent to all stages of the equipment life-cycle, including; maintenance; component replacement, commissioning, testing and normal operation and should be able to be performed without excessive noise or vibration using a minimum number of operating personnel.

Equipment layout and design should allow for the best possible ergonomics and efficiency for operation and maintenance tasks.

Automation of production should be considered to enable the most complete solution to problems associated with maintaining steady operation, easy maintenance and a minimum of operating personnel.

4.1.2 Customer Preferred Equipment

Relevant customer / equipment supplier alliances and their pre-determined technical agreements are to be clarified, as this will have a bearing on the equipment available for selection.

Proven equipment suppliers for specific equipment and their safety aspects including material choices and limits of pressure, temperature, flow, speed and power shall be reviewed and confirmed prior to purchase.

4.1.3 Reliability

Reliability and availability for service is an extremely important factor in equipment safety as it minimizes interaction by operation personnel having to overcome operational difficulties and perform work-around to compensate for poor machine performance, and also minimizes interaction by maintenance personnel to perform repairs and modifications.

Equipment Criticality Rating Procedure (EPP-0029) shall be followed to establish the criticality rating of the equipment. This will be used to determine:

- The amount of required non-destructive examinations and testing to be performed on the equipment and
- The level of required inspection during the equipment fabrication process.

For equipment with shorter mean times between failures than the planned time between shutdowns and/or where downtime on continuously operating plant cannot be tolerated, it is customary to install a standby unit.

Complex equipment, which is generally with no redundant capacity, shall have high reliability and will normally require instrumentation and electronic and Process controls.

4.2 General Material Properties and Selection Criteria

Proper material selection for equipment is one of the first important tasks encountered by the engineer. Among the many parameters that must be considered are structural strength specifications, heat resistance, corrosion resistance, physical properties, fabrication characteristics, composition and structure of material, and cost.

The properties that materials must have for a particular application depend largely on the environment in which they are to be used in. Material selection begins from determination of equipment, operating conditions, temperature, pressure, and various components in the process.

It would be unusual that a material would have properties that fulfill all requirements. For example;

- Good heat conductivity is a desirable property for the fabrication of heat exchanger surfaces, but not for insulation purposes.
- A corrosion resistant material may be insufficient for heat resistance or Process strength.
- Strong materials may be too brittle.

- Materials that have good Process and chemical properties may be too expensive.

Because any material may be characterized by some desirable and non-desirable properties with respect to a specific application, the selection of materials is reduced to a reasonable compromise. In so doing one should strive to select materials so that properties correspond to the basic demands determined by the function and operating conditions of the equipment, while tolerating some of the undesirable properties if necessary.

The basic concern with materials intended for fabricating chemical apparatuses is mostly corrosion resistance because this determines the durability of equipment. Often, corrosion data are reported as a weight loss per unit of surface area per unit of time.

Materials must have high chemical resistance as well as durability. For example, if the material dissolves in the product, the product quality may deteriorate, or materials may act as catalysts promoting side reactions and thus decreasing the yield of the primary product. Usually there are several materials suitable for use under the process conditions. In such cases the material is selected by additional considerations.

4.2.1 Material Selection

The evaluation and selection of materials are fundamental considerations in engineering design. If done properly, and in a systematic manner, considerable time and cost can be saved in design work and design errors can be avoided.

The design of any apparatus must be unified and result in a safe functional system. Materials used for each apparatus should form a well-coordinated and integrated entity, which should not only meet the requirements of the apparatus' functional utility, but also those of safety and product purity.

The following is a list of general guidelines that can assist in material selection:

- Select materials based on their functional suitability to the service environment. Materials selected shall be new, free of defects, suitable for the application, capable of maintaining their function safely, for the expected life of the equipment, and at reasonable cost.

- When designing equipment with several materials, consider all materials as an integrated entity. More highly resistant materials should be selected for the critical components, and for cases in which relatively high fabrication costs are anticipated, often a compromise must be made between mechanically advantageous properties and corrosion resistance.
- Thorough assessment of the service environment and a review of options for corrosion control must be made. In severe, humid environments it is sometimes more economical to use a relatively cheap structural material and apply additional protection, rather than use costly corrosion-resistant ones. In relatively dry environments many materials can often be used without special protection, even when pollutants are present.
- The use of fully corrosion-resistant materials is not always the best choice. One must optimize the relation between capital investment and cost of subsequent maintenance over the entire estimated life of the equipment.
- Consideration should be given to special treatments that can improve corrosion resistance (e.g., special welding methods, blast peening, stress relieving, metalizing, sealing of welds). Also, consideration should be given to fabrication methods that minimize corrosion.
- Tempered grades of alloys selected should be free of susceptibility to corrosion and should meet strength and fabrication requirements. Often a weaker alloy grade is more suitable than one that cannot be reliably heat treated and whose resistance to a particular corrosion is low.
- If, after fabrication, heat treatment is not possible materials and fabrication methods must have optimum corrosion resistance in their as-fabricated form. Materials that are susceptible to stress corrosion cracking should not be employed in environments conducive to failure. Stress relieving alone does not always provide a reliable solution.
- Materials with short life expectancies should not be combined with those of long life in non-repairable assemblies.
- For equipment in which heat transfer is important, materials prone to scaling or fouling should not be used.

- For service environments in which erosion is anticipated, the wall thickness of the components should be increased, this thickness allowance should be sufficient to ensure that various types of corrosion or erosion do not reduce the components wall thickness below that required for Process stability of the operation. Where additional thickness allowance cannot be provided, a proportionally more resistant material should be selected.
- Non-metallic materials should have the following desirable characteristics: low moisture absorption, resistance to microorganisms, stability through temperature range, resistance to flame and arc, freedom from outgassing, resistance to weathering, and compatibility with other materials.
- Fragile or brittle materials whose design does not provide any special protection should not be employed under corrosion-prone conditions.

4.2.2 Material Suitability

When a suitable material is determined, an examination of design limitations and economic factors must be made before optimum material selection is accomplished. Design limitations or restrictions for materials might include:

- size and thickness
- strength
- velocity
- temperature
- composition of constituents
- bimetallic attachment
- geometric form
- static and cyclic loading
- surface configuration and texture
- special protection methods and techniques

- maintainability
- compatibility with adjacent materials
- susceptibility to brittle fracture, corrosion, erosion and frictional wear
- machinability
- weld ability
- Materials of proprietary components shall be specified or requested to be detailed by the machinery vendor.

Economic factors that should be examined may be divided into three categories: availability cost of different forms, and size limitations and tolerances. More specifically, these include:

Availability;

- In required quantities (single, multiple, limited, unlimited)
- In different forms (bar, casting such as sand, centrifugal, die, permanent mold, etc., extrusion, forging, impact extrusion, pressing, sintered, powder pressing)
- In metalized and pre-treatment forms (galvanized, plastic coated, plated, prefabrication treated)
- In coated or clad forms
- Uniformity of material
- Freedom from defects
- Delivery time

Cost in different forms;

- Bar, shape, plate, sheet
- Casting (sand, centrifugal, die, permanent mold, etc.)
- Extrusion
- Forging

- Impact extrusion
- Pressing
- Sintered

Size limitations and tolerances in different forms;

- Powder pressing
- Gauge
- Length
- Weight
- Width

4.3 Process Failure

Process failure generally leads to hazards associated with a loss of containment, flying objects, damaged equipment and components requiring replacement. Deterioration of a materials properties and strength can have the same outcome.

The primary areas to be addressed to avoid this may be categorized as follows:

4.3.1 Pressurization Rating

Piping system components subject to pressurization shall be manufactured to appropriate standards published by recognized standards organizations. These standards shall be applicable to cast and weldable grade metallic materials, and be suitable for the full range of service design conditions (e.g. product medium, pressure, temperature, corrosion resistance etc.)

Components and piping systems should be pressure tested hydraulically (water) in accordance with the relevant piping standard it has been constructed to. Pneumatic testing should be avoided unless there is a compelling reason to use this method, and extensive review and risk assessment complete and approval from the relevant local authority given.

4.3.2 Temperature Rating

Materials and components should be rated to withstand the full range of expected temperatures, including extremes due to start-up, upset conditions, weather conditions etc. to prevent failure.

Allowance should be made for expansion and contraction in the design and arrangement of equipment, particularly piping and larger equipment subject to large temperature ranges during operation such as furnaces, combustion engines etc.

4.3.3 Corrosion

Often complex apparatus and systems, process piping arrangements and even support structures utilize different metals, alloys or other materials. These are often employed in corrosive or conductive environments, and in practice the contact of dissimilar materials cannot be avoided totally. It is important that the designer minimize the damaging effects of corrosion by optimizing the compatibility of materials either by selection or arrangement in the overall design.

Compatible materials are those that will not cause an uneconomic breakdown within the system when they are utilized together in a particular medium in appropriate relative sizes and compositions. In addition to material influences on each other by virtue of inherent or induced differences of electric potentiality, adverse chemical reactions can occur as a result of changes in materials caused by environmental variations. All these possibilities must be examined thoroughly by the designer.

The following general considerations should be followed in designing all types of process equipment:

- Dissimilar metals should be in contact (either directly or by means of a conductive path such as water, condensation, etc.) only when the functional design so dictates.
- Scales of Galvanic Potentials are useful indicators of galvanic corrosion; however, information is needed on the amount of current flowing between dissimilar metals.
- To ensure compatibility, detailed engineering descriptions of all materials and their metallurgical properties are needed. General information (e.g., mild steel) does not provide sufficient data to establish compatibility in conductive or corrosive media.

- Galvanic corrosion of dissimilar metals can be minimized by controlling humidity near such bimetallic connections. In general, continuously dry bimetallic joints do not corrode.
- Avoid mating together surfaces of dissimilar metals by separating them completely from each other. Note that dielectric separation can be provided in several manners, e.g., insulating gaskets (synthetic rubber, PTFE, etc.), spreadable sealants, coatings.
- The formation of crevices between dissimilar metals should be avoided. Corrosion at such connections is generally more severe than galvanic corrosion alone. Also, crevices between metals and certain types of plastics or elastomers may induce accelerated rates of combined crevice and chemical attack. Testing is recommended prior to establishing final design specifications.
- Noble metals should be specified for major structural units or components, particularly if the design requires that these are smaller than adjoining units. There is an unfavorable area effect of small anode and large cathode. Corrosion of a relatively small anodic area can be much more severe than the corrosion of bimetallic components, which have the same area submerged in a conductive medium. Hence, less noble (anodic) components should be made larger or thicker to allow for corrosion. In addition, provision should be made for easy replacement of the less noble components.
- Brazing or welding alloys should be more noble (i.e., cathodic) than at least one of the joined metals. Also, these alloys should be compatible with the parent metals being joined.
- Fasteners made of dissimilar metal should be insulated completely from both metals of the joint or at least the one that is least compatible with the metal of the fastener.
- Clad metals are candidates for galvanic corrosion along exposed edges.
- Proper system and sequences of welding attachment of bimetallic pads for structures and equipment should be specified to avoid distortion and input stresses.
- In aluminum castings, integral corrosion-resistant steel inserts may be used.
- Sources of mercury (e.g., mercury thermometers) should be avoided in the vicinity of aluminum and copper alloy equipment.

- Avoid coupling carbon or graphite components with other metals in conductive environments.
- Designs that establish large temperature gradients in equipment resulting in adverse polarization of metals should be avoided.
- If dielectric separation of fasteners in non-compatible joints cannot be implemented readily, fasteners should be coated with a zinc chromate primer and exposed ends encapsulated.
- Use sealing (encapsulating or enveloping type with shrinkable plastic) on bimetallic joints if geometrical arrangements prohibit access to such joints for replacement.
- Secondary components should also be considered for corrosion susceptibility, including seals, gaskets, inserts, seats etc.
- Common corrosion problems arise from processes handling sour service (H2S) and/or CO2. Materials are susceptible to increased corrosion and require specific attention. For materials in H2S service the main reference document is BS EN ISO 15156. Materials requirements prescribed by this document should be specified for all sour services.
- Although there is currently no corresponding NACE standard for CO2 corrosion there are reference publications for guidance. CO2 corrosion results from CO2 dissolved in water to form carbonic acid (H2CO3) in sufficient quantities to promote general and/or pitting corrosion of carbon steel. Increasing the level of chromium in steels to a minimum of 12% offers a major improvement in resistance.

In addition to these, there are geometric considerations that can minimize corrosion problems if accounted for in design. The following are general guidelines pertaining to geometry in a design aimed at minimizing corrosion. The overall design approach involves the selection of the optimum geometry for a piece of equipment that is less likely to undergo certain types of corrosion, either directly or indirectly. Such shapes, forms, combinations of forms and their method of attachment, along with their fabrication technique and treatment, should not aggravate corrosion.

- For structures and equipment, the utility should be located where it cannot be affected by natural and climatic conditions. This includes corrosive pollution that may be airborne, prevalent winds, and surface water currents from near or remote sources.
- Non-drainable traps that accumulate liquids and absorbent solid wastes should be avoided. Structures should be designed to be self-draining.
- Provisions should be made for the removal of moisture or other corrosive media from critical areas.
- Laps and crevices should be avoided if possible. If they cannot, then effective seals should be used (particularly in areas of heat transfer) between metal and a porous material or where aqueous environments contain inorganic chemicals or dissolved oxygen.
- Laps should be faced downward on exposed surfaces.
- Asymmetrical shapes of unequal thickness should be avoided for galvanizing. Extremes in weight and cross sections of design members also should be avoided.
- Where corrosion is anticipated the wall thickness of the components should be increased, this thickness allowance should be sufficient to ensure that various types of corrosion or erosion do not reduce the wall thickness below that required for Process stability of the component. Where additional thickness allowance cannot be provided, a proportionally more resistant material should be selected.

4.3.4 Fabricated Components

Fabricated components generally consist of smaller pieces cut from standard sections of material; plate, pipe, beams, angles etc., and joined together to form larger specifically shaped pieces. The safety of these fabricated components is dependent on the correct design of the components and also the correct selection and execution of the joining process; welding, gluing, bolting etc.

Drawings should show all necessary details and dimensions to enable individual components to be produced and also overall dimensions, including checking and reference dimensions, to enable the final fabricated item to be assembled. Details and references for specific joining methods shall be nominated on the drawings. Where a specific sequence of steps for work-shop assembly and/or field erecting must be followed to achieve the desired outcome, this should be noted on drawings or instruction manuals also.

Ensure fabricated pressure containing components, including vessels, piping systems, etc. are purchased from fabricators with the proper forms and stamps required by the local authorities. If the construction contractor is involved with the final assembly or installation of these components, they must confirm they understand the final approval process required by the local authorities before the equipment can be put into service.

4.3.5 Fatigue

Fatigue failures occur over time, long after the initial construction and commissioning personnel have completed their tasks and moved on. Machine components should be designed to withstand fatigue for the expected loading of the machine over its expected lifespan.

Use Finite Element Analysis to determine high stress areas that are prone to fracture.
Design or maximum recommended loadings and life-cycle limits should be noted in equipment documentation. Periodic inspection schedules should be recommended and specific areas for inspection noted to ensure fatigue faults are detected before failure.

4.3.6 Friction

Friction creates heat, wear and increased loading, all of which can cause failure in machinery. Anti-friction bearings, bushings, material selection, lubrication and sealing all act to control or reduce friction.

4.3.7 Erosion

Process erosion is caused either by incorrect design, such as pump impeller erosion caused by cavitation, or by incompatible material selection such as wear in conveyor chutes.

Where erosion by material flowing or impacting within a process stream cannot be avoided then sacrificial wear plates may be used so that the parent structure remains intact and worn items are replaced as required.

4.3.8 Process Loading

Vessels, equipment, housings, support structures and platforms shall be designed for all known load conditions; this includes cyclic process conditions, seismic and wind loads as well as loads from other external forces such as piping loads or auxiliary equipment.

4.3.9 Thermal Expansion

Equipment operating in high temperature shall account for thermal expansion. Thermal stresses can cause Process failure in constrain components. Bolted connections shall have slotted hole and spring support or hanger shall be considered for pipe supports.

Following studies were done and incorporated in RHIP live project.

Symbols and description

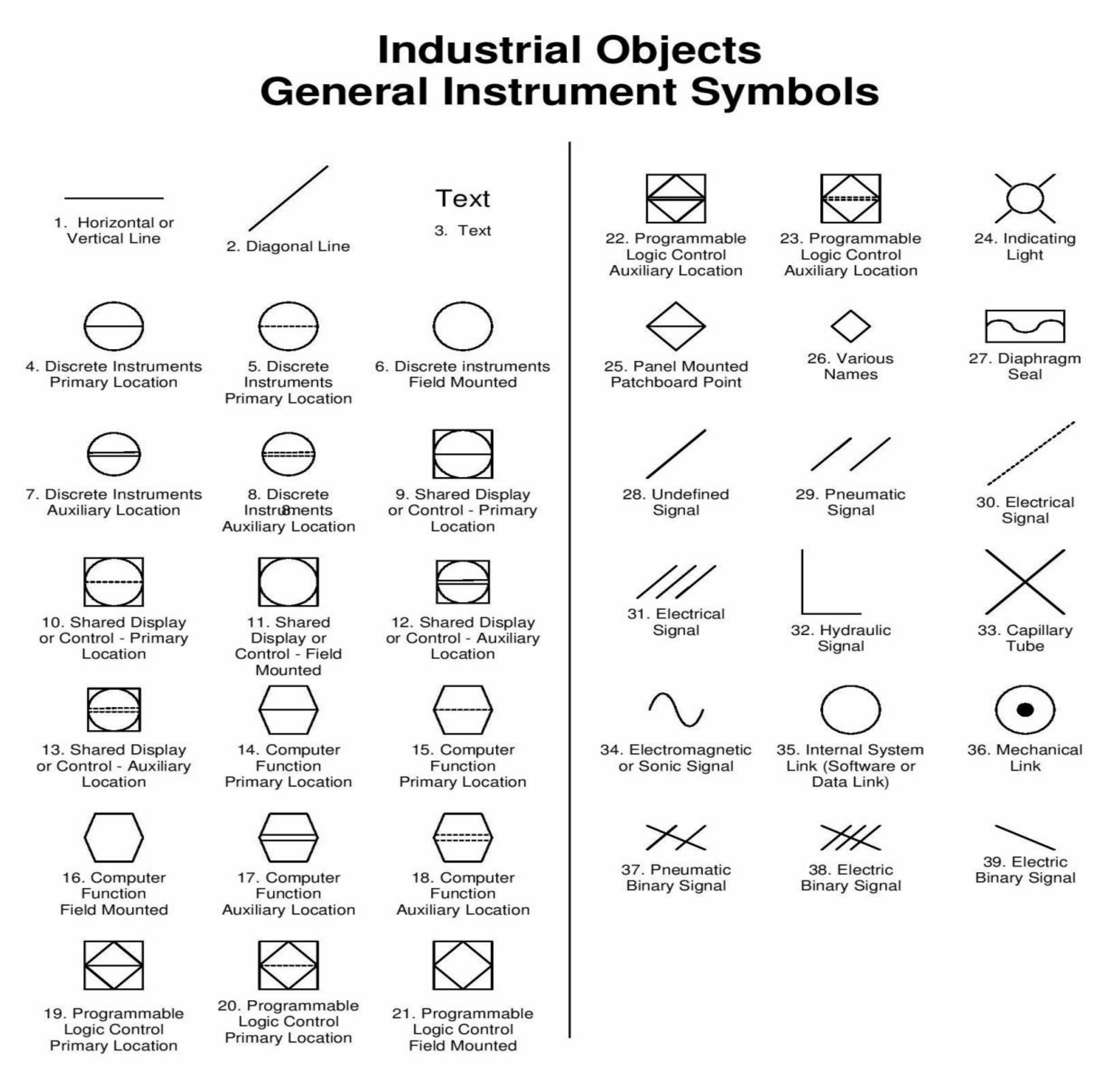

Fig: 4.1 – General Instrument Symbols

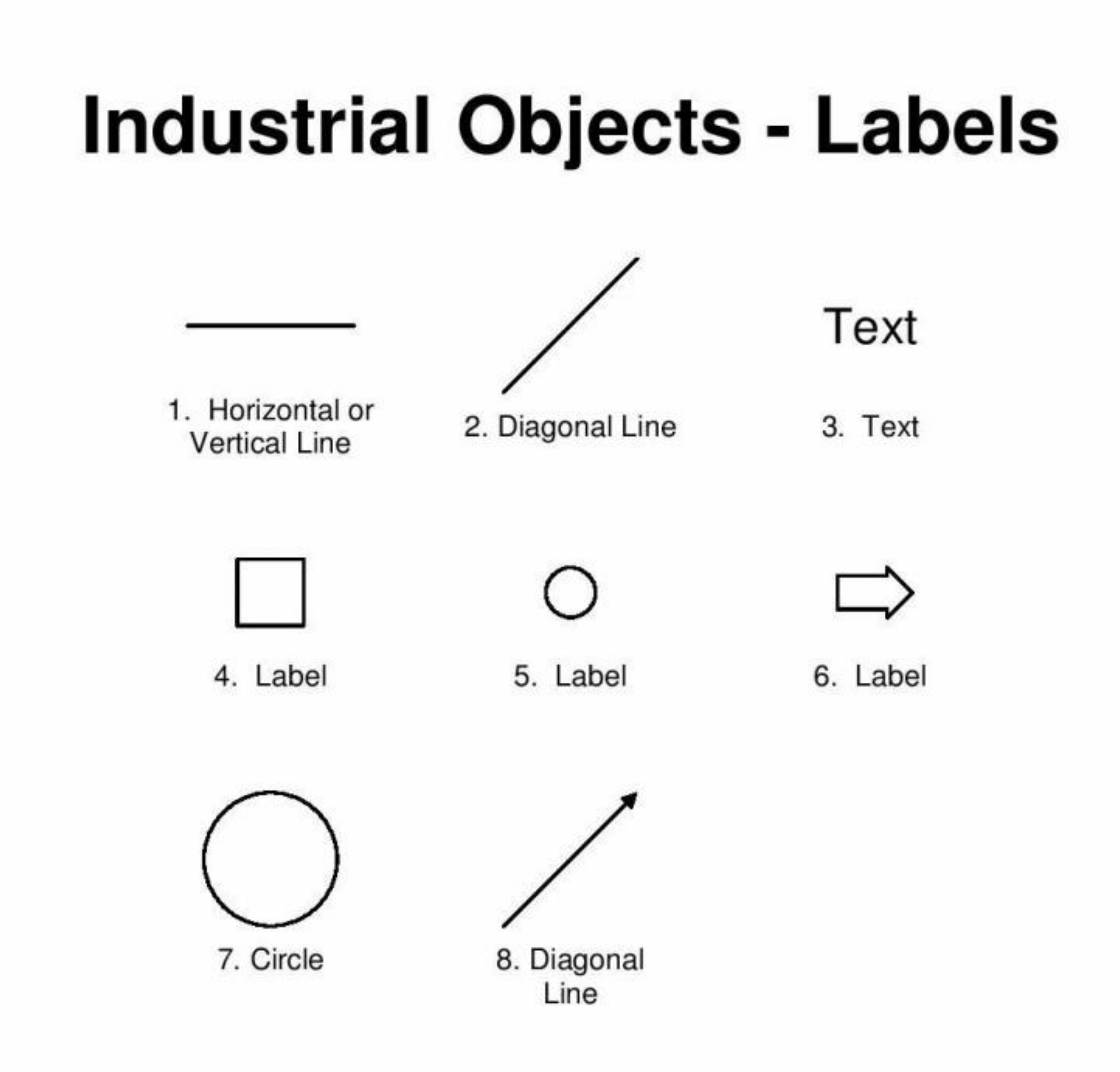

Fig: 4.2 – Industrial Objects - Labels

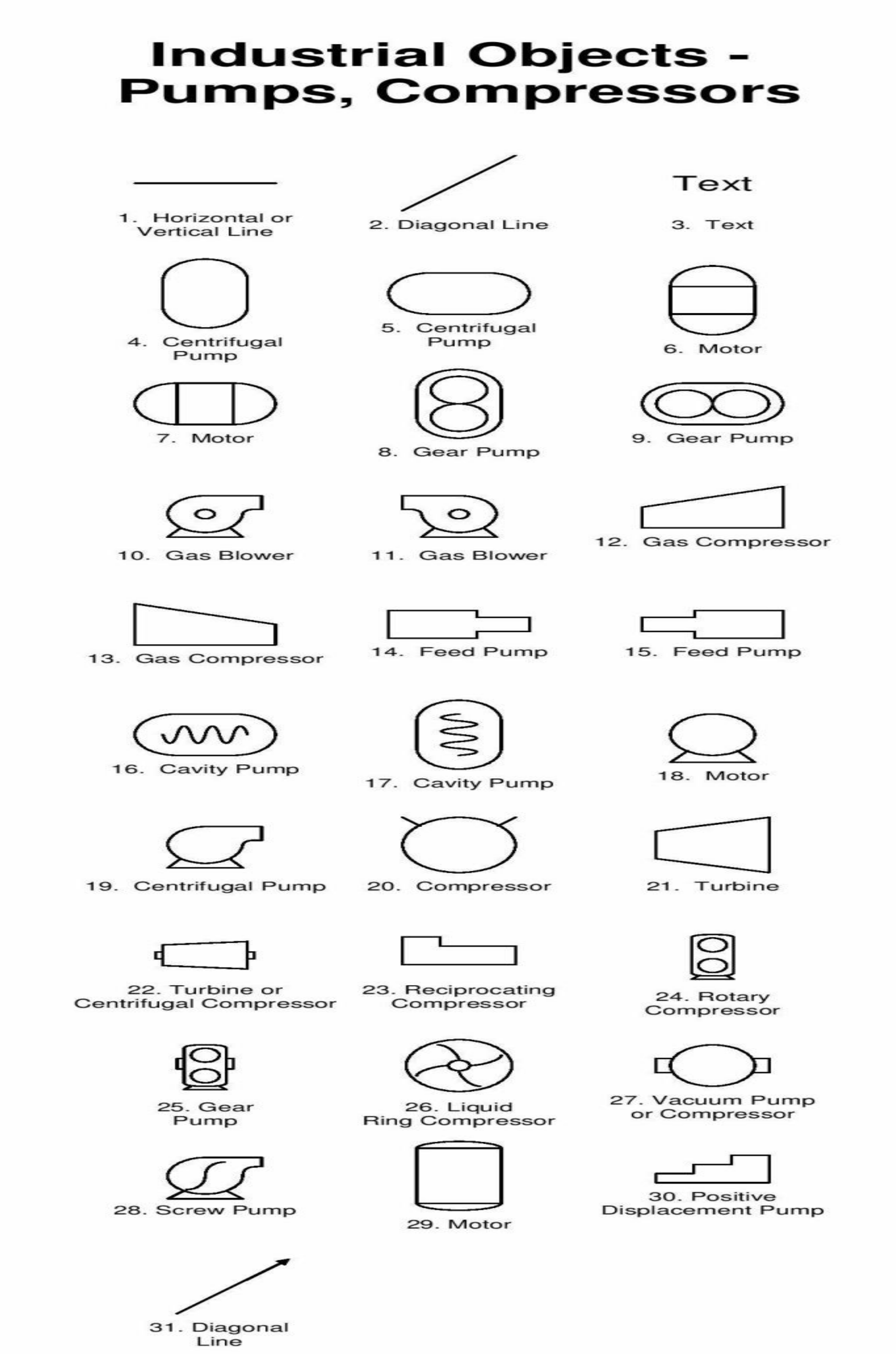

Fig: 4.3 – Pumps & Compressors

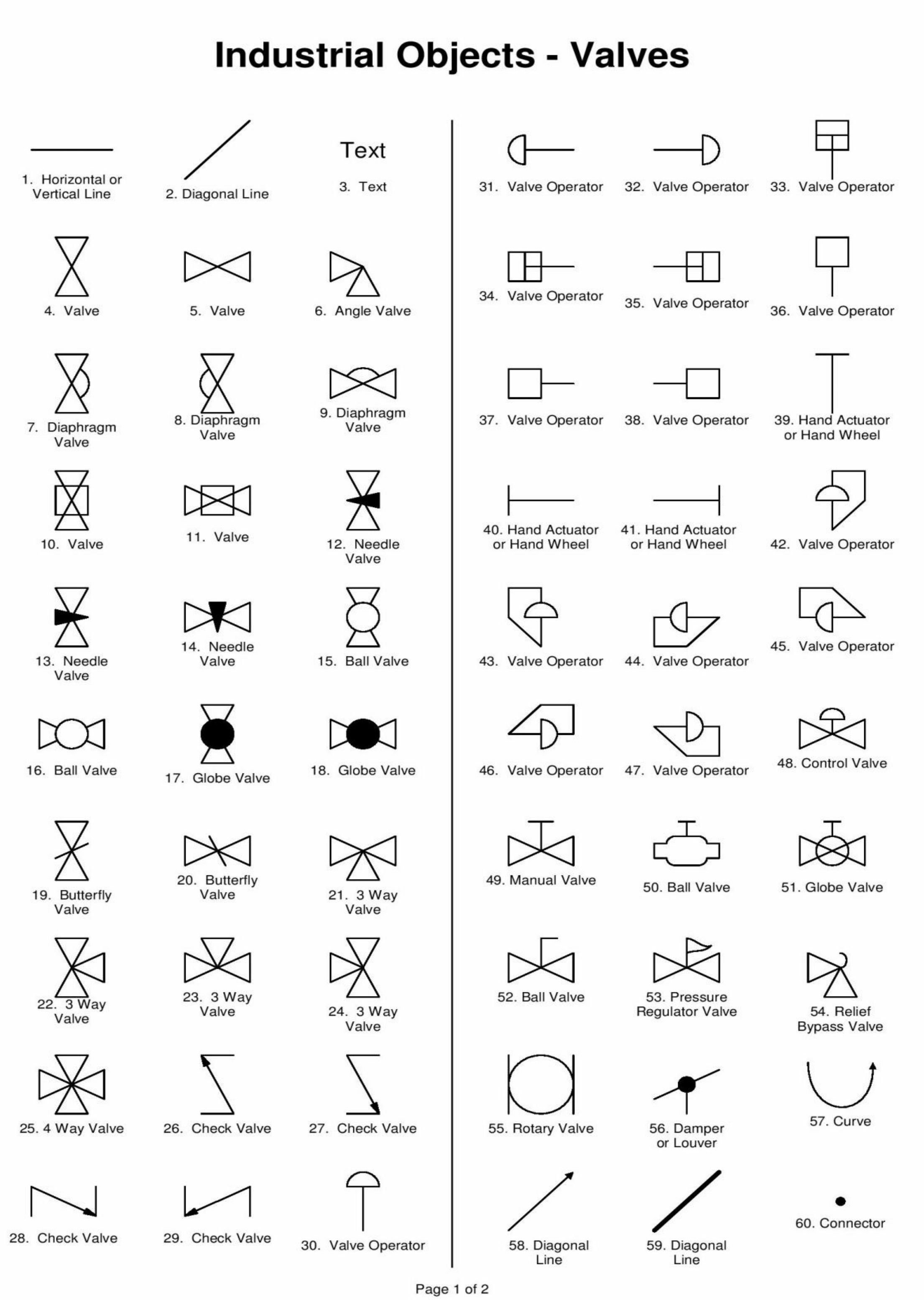

Fig: 4.4 – Valve Types

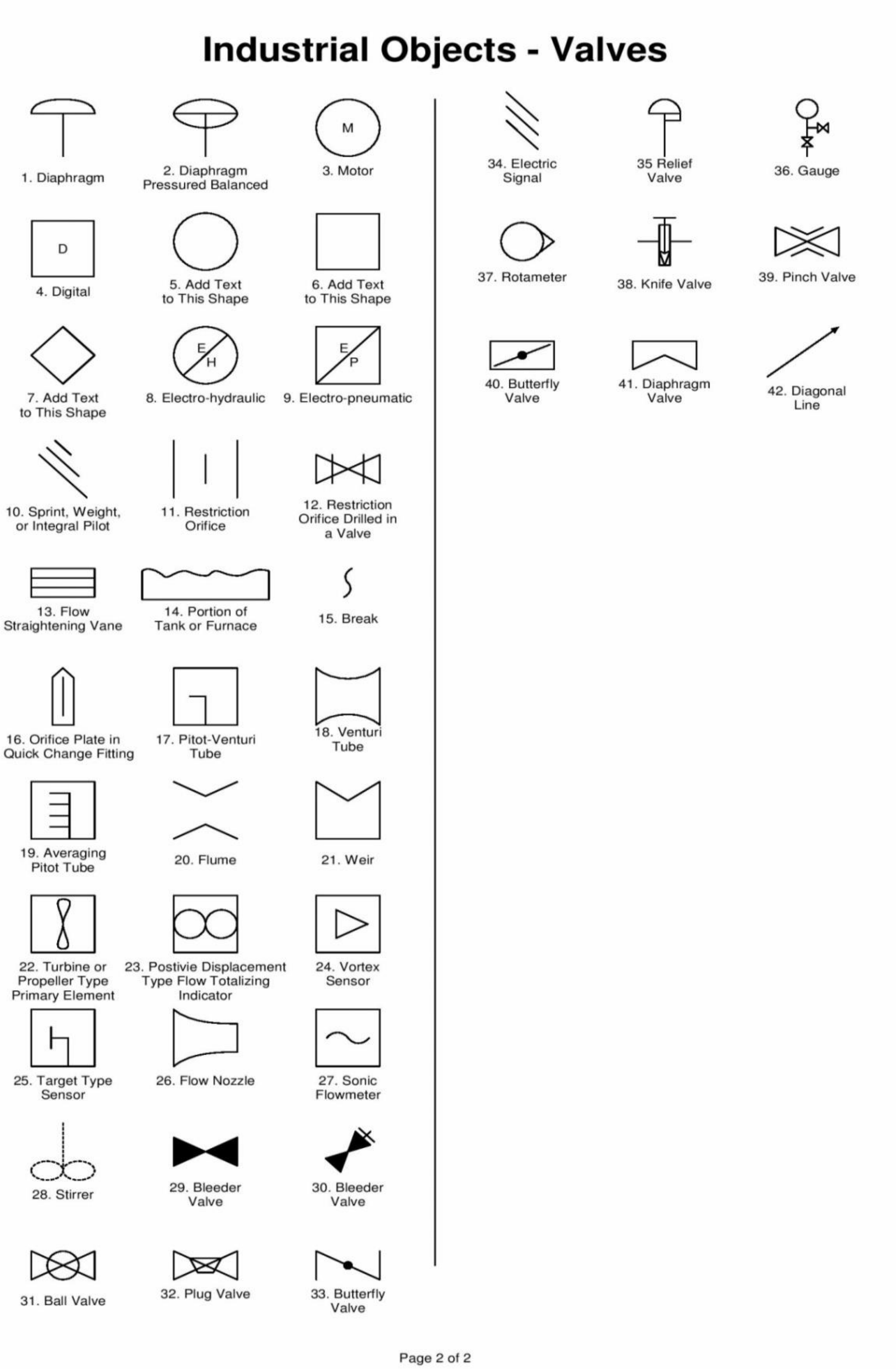

Fig: 4.5 – More Valves

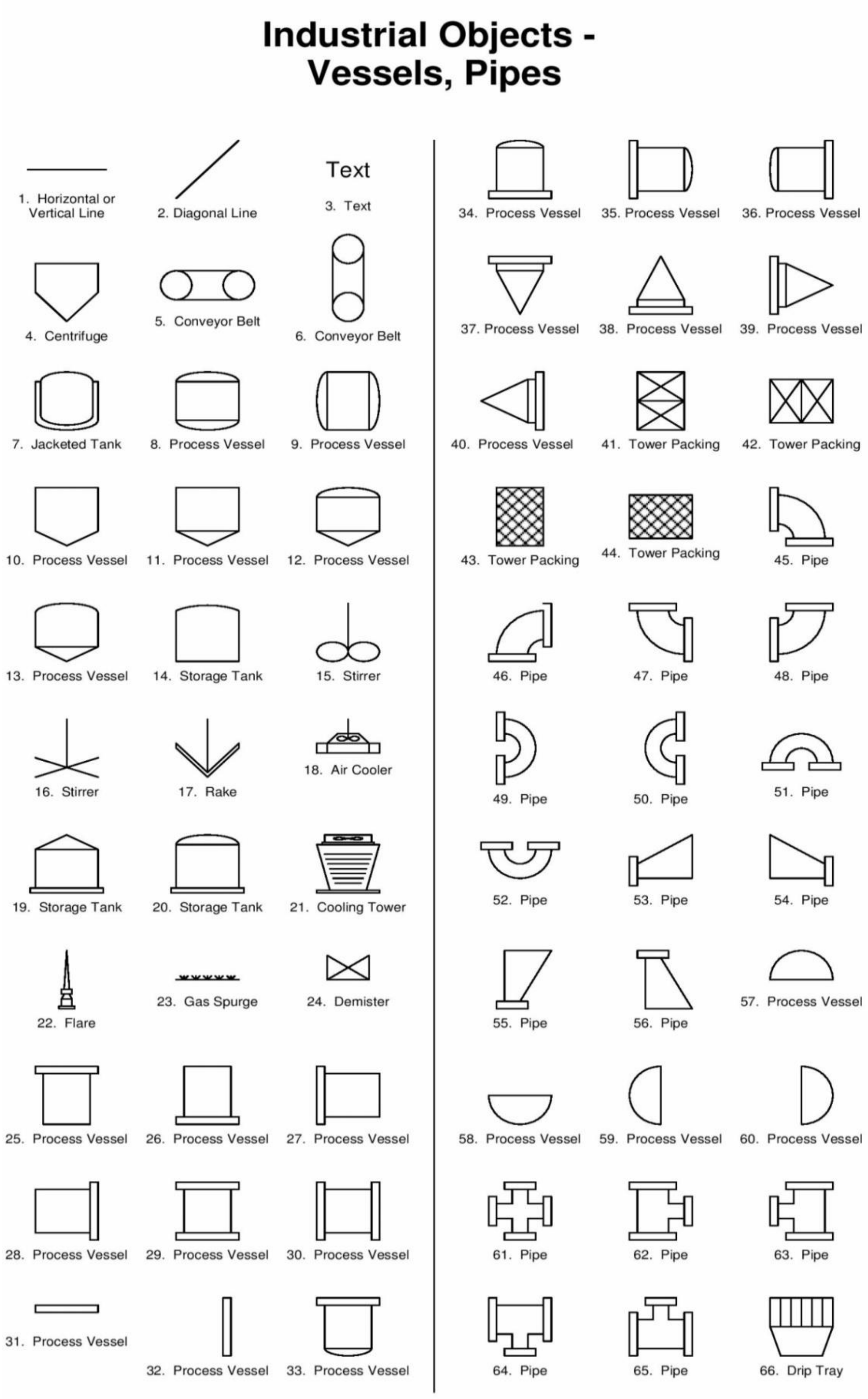

Fig: 4.6 – Vessels & Pipes

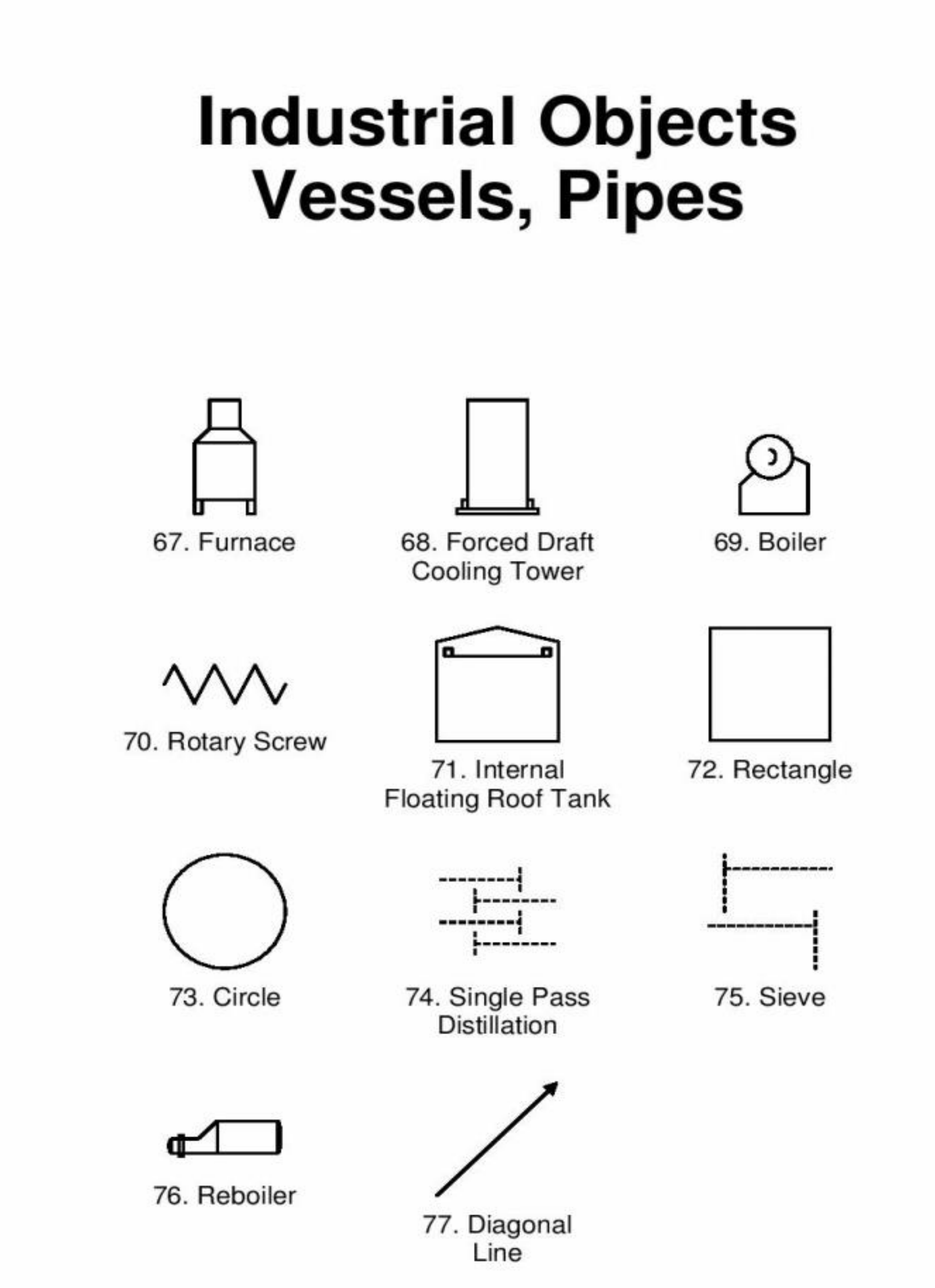

Fig: 4.7 – Other vessels & pipes

4.4 Process Flow Scheme (PFS)

A Process Flow Scheme (PFS) or Process Flow Diagram - PFD - (or System Flow Diagram - SFD) shows the **relationships** between the major components in the system. PFS also tabulate process design values for the components in different operating modes, typical minimum, normal and maximum. A PFS does not show minor components, piping systems, piping ratings and designations.

A PFS should include:

- Process Piping
- Major equipment symbols, names and identification numbers
- Control, valves and valves that affect operation of the system
- Interconnection with other systems
- Major bypass and recirculation lines
- System ratings and operational values as minimum, normal and maximum flow, temperature and pressure
- Composition of fluids

This figure depicts a small and simplified PFS or PFD:

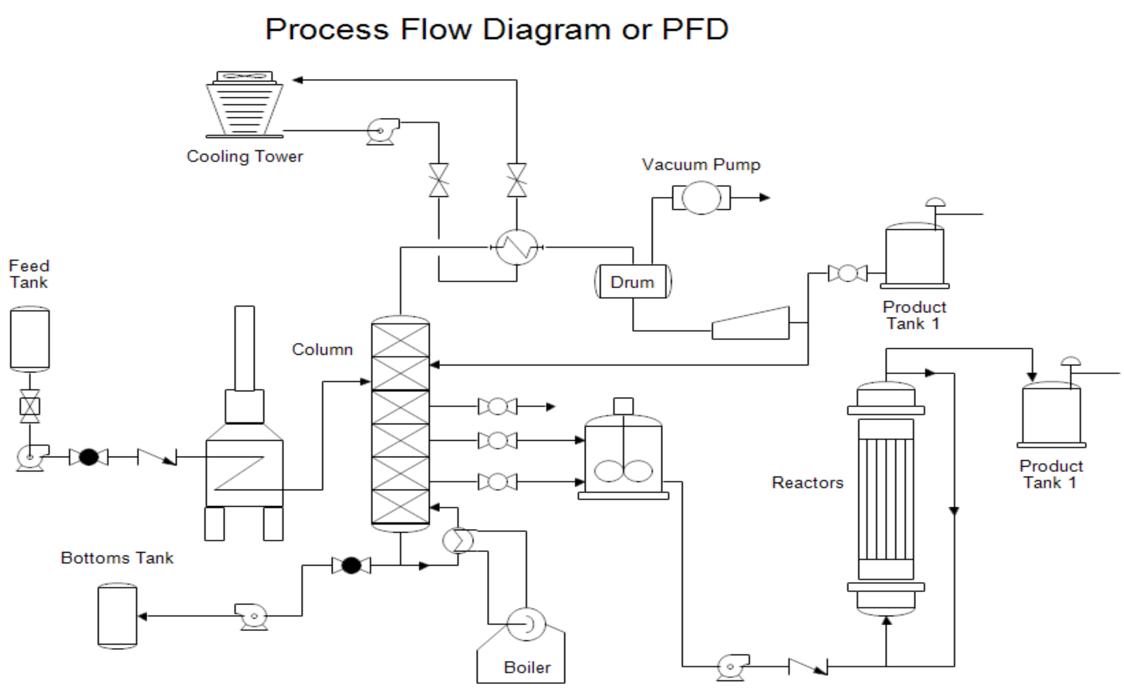

Fig: 4.8 – PFS

System Flow Diagrams should not include:

- pipe class
- pipe line numbers
- minor bypass lines
- isolation and shutoff valves
- maintenance vents and drains
- relief and safety valve
- code class information
- seismic class information

4.4.1 Advantages of Process Flow Scheme

The process flow chart providing a visual representation of industrial process equipment is interconnected by a system of pipelines. It has the following six benefits.

- Gives everyone a clear understanding of the process.
- Shows the plant design basis indicating feedstock, product and main streams flow rates and operating conditions.
- Help to identify the scope of the process.
- Facilitate teamwork and communication.
- Shows graphically the arrangement of major equipment, process lines and main control loops.
- Improves utilities which are used continuously in the process.

4.5 Process Engineering Flow Scheme (PEFS)

Process Engineering Flow Scheme (PEFS) or Piping (or Process) and Instrumentation Diagram (P&ID) is also known as the mechanical flow diagram and piping and instrumentation diagram. A P&ID is a complex representation of the various units found in a plant. It is used by people in a variety of crafts. The primary users of the document after plant startup are process technicians and instrument and electrical, mechanical, safety, and engineering personnel. **P&IDs** provide information needed by engineers to begin planning for the construction of the plant. P&ID shows how industrial process equipment is interconnected by a system of pipelines.

P&ID schematics also show the instruments and valves that monitor and control the flow of materials through the pipelines.

This figure depicts a small and simplified PEFS or P&ID:

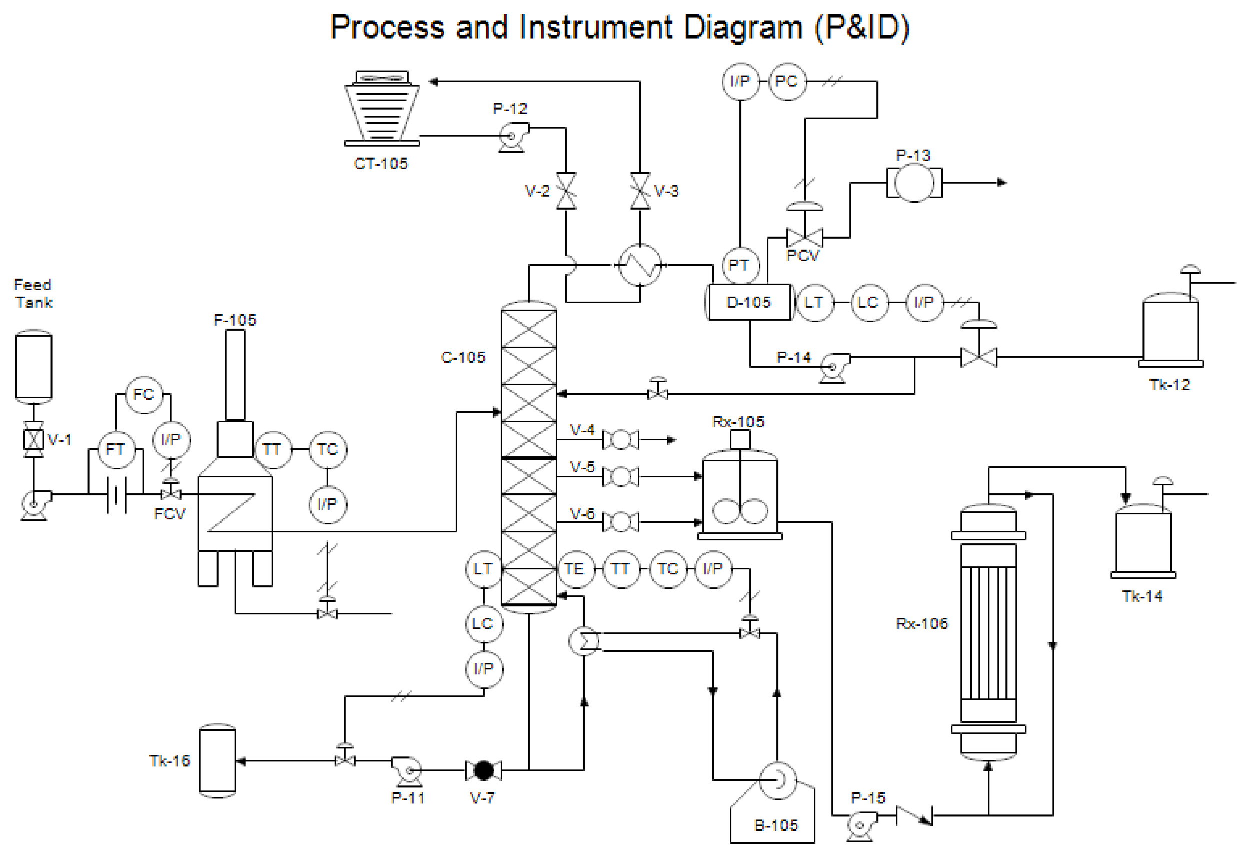

Fig: 4.9 – PEFS

4.5.1 Advantages of PEFS

The process flow chart provides a visual representation of industrial process equipment interconnected by a system of pipelines. It has the following six advantages.

- Gives everyone a clear understanding of the instrument process
- Represents the sequence of all relevant operations occurring during a process and includes information considered desirable for analysis
- Help to identify the scope of the process
- Presenting events which occur to the materials
- Incorporates specifications, standards and details that go into the design

- Facilitate teamwork and communication
- Shows graphically the arrangement of major equipment, process lines and main control loops
- Improves utilities which are used continuously in the process
- Digs into all the gory details about materials of construction

4.6 Process Safety Flow Scheme (PSFS)

The major objective of process safety management (PSM) of highly hazardous chemicals is to prevent unwanted releases of hazardous chemicals especially into locations that could expose employees and others to serious hazards. An effective process safety management program requires a systematic approach to evaluating the whole chemical process. Using this approach, the process design, process technology, process changes, operational and maintenance activities and procedures, non-routine activities and procedures, emergency preparedness plans and procedures, training programs, and other elements that affect the process are all considered in the evaluation.

Process Safety Flow Scheme is the diagram obtained after incorporating the safeguarding philosophy features in PEFS and ensuring that safety is imparted to the maximum possible level.

4.7 Commissioning

4.7.1 Inspection and Testing Requirements

Comprehensive inspection during manufacture and performance testing provide a level of verification that equipment meets the specified requirements and can often highlight deviations or faults that could result in compromising safety. Inspection and testing requirements should be included in the scope of work and specification documents attached to the requisition.

Equipment specific inspection and non-destructive examination requirements must be developed in conjunction with Inspectors in the Quality department.

All tests are to be fully documented and evaluated in accordance with a recognized and specified test procedure.

4.7.2 Equipment Start-up

Initial equipment start-up and commissioning and testing should include the following points;

- Carried out competent persons who have been provided sufficient information, training and instruction of the equipment and its operation.
- Conducted in accordance with specifications for any proprietary equipment issued by the manufacturers or suppliers
- Stresses should not be imposed on the plant and machinery that exceed design specifications
- Inspected before starting to ensure it has been erected or installed in accordance with design specification.
- Any damage caused during commissioning is to be repaired prior to continuing.
- All isolation procedures should be adhered to.
- The person in control of the worksite shall be informed of any hazards that may result from commissioning.

4.8 Operational Considerations

4.8.1 Equipment Layout

Safe layout of plant and equipment is addressed in the Safety in Design Discipline Manual (Plant Layout). This manual covers all aspects of plant layout and location of equipment and associated service and infrastructure.

4.8.2 Ergonomics

The ergonomic layout and operation must be considered at the design stage to enable personnel to safely, efficiently and productively operate machinery for it intended purpose.

Ergonomic factors to include are;

- Posture and movement

- Physical effort required for operations
- Noise and temperature
- Lighting
- Design, clarity and layout of controls & instrument displays to promote intuitive use.

When designing for ergonomics the variation of human dimensions, height, reach etc., should be taken into account. Data on body dimensions (Anthropometric Data) is available from various sources, including AS4024:1704 Safety of Machinery- Anthropometric Data.

4.8.3 Identification and Labeling

Machinery should have adequate and sensible identification of all controls and isolation points to enable it to be safely and efficiently operated without error or confusion.

Where a customer has a pre-existing identification system this should be followed when identifying new equipment. Where a system does not exist a logical identification sequence must be developed. Grouping of like items or functions, e.g. pneumatic, hydraulic, start, stop etc. should be considered.

Signage for warnings and hazards, moving equipment, automatic start-up, noise etc. must also be specified for installation at strategic locations.

Items that are subject to regular safety and/or statutory inspections should be labeled. These items would include; monorails, pressure vessels, emergency stops etc.

4.8.4 Lighting

Adequate and correct lighting is an important requirement for a safe and healthy work environment to eliminate shadow and prevent eyestrain.

Lighting type and intensity is dependent on building size, type of tasks being carried out, arrangement of equipment and other factors. Each application will require a specific assessment to determine the style, quantity and placement of lights to adequately illuminate the area. A lighting luminance of 400lx or better is recommended for machine operation.

Design manuals such as the IESNA Light Handbook, by the Illuminating Engineering Society of North America, define lighting requirements and design methods.

4.8.5 Machine Guards

Machine guarding is mandatory wherever personnel could sustain an injury should they inadvertently make contact with a component. This could take the form of contact with:

- Moving parts associated with rotating equipment such as shafts, pulleys, gears, couplings, rollers and flywheels;
- Moving parts associated with reciprocating equipment such as pistons and connecting rods;
- Moving parts associated with feeders, conveyor belts, chain & belt drives and mixing equipment;
- Hot and cold surfaces such as turbine bodies, engine exhausts and equipment & piping that is either heated or cooled by the fluids it is engaged in processing.
  Note: Temperature alone is not the only factor that determines whether a surface is hazardous and can cause 'cold' burns in the event of contact. Equipment and piping should always be evaluated to determine whether external surfaces and conditions are such that any inadvertent contact with the surface will result in damage to the skin tissue.
- Flying debris or particles arising from processes such as grinding and milling.

Design Requirements for Machine Guards

A guard may be defined as a physical barrier designed to prevent access to dangerous aspects of plant and equipment. Machine guards should be designed to meet this requirement yet still allow personnel to safely access plant and equipment when carrying out routine inspection and maintenance activities. This standard details the SID requirements for Machine guarding in the form of devices for the close shielding of dangerous parts located on plant and equipment. It does not deal with guards in the form of remote barriers that prevent access to plant and equipment.

Machine guards should:

- Be designed and manufactured to a recognized standard such as AS 4024, API RP 11ER or ISO 14120, and Canadian CSA Standards.
- Be fully enclosing such that it is not reasonably possible for a person to come in contact with the plant and equipment hazards;
- Be configured such that it makes by-passing or disabling, whether deliberately or by accident, as difficult as is reasonably possible;
- Be securely fastened and robust enough to support impact load from falling personnel such that any deflection will not cause the guard to come into contact with moving parts. For this propose the guard and fasteners shall be capable of withstanding a static point load of 900N (200 lbs) in any direction.
- Contain hazards resulting from failure of any moving part, flying debris, dust or liquid splashes;
- Feature removable, sliding, or hinged sections to avoid removal of guard during routine inspection, adjustment and lubrication;
- Be well fitting and easy to handle so as to encourage refitting after work has been completed. Difficult to use guards tend not to be refitted, particularly at times of operational or maintenance difficulties when the access frequency is high. Consider if the weight of the guard can be moved by one or two people. If more required, then look at a component design where no single component weighs more than 60 lbs.
- Be free from sharp edges and be designed such that it does not present a risk in itself by creating bumping or tripping hazards;
- Does not interfere with the operation of equipment or machinery nor prevent or hinder the removal of machine parts during maintenance.
- Where fully enclosed guarding is not required, particularly hot/cold surfaces requiring protection from inadvertent contact, guarding shall protect a minimum of 2100mm (7 ft) vertically above or 800mm (3 ft.) within reach of any work area, platform, walkway or access point.

- Interlock switches or electronic light curtain style devices may be used to stop machinery if guarding is opened or removed, or if personnel enter a danger zone while it is operating
- Exposed shafts at the back of coupling hubs should be fully enclosing and preferably with removable, sliding, or hinged sections for viewing.
- Drive chain guards should be fully enclosing and provide features to enable lubrication and viewing without guard removal.
- V-belt drive guards should be fully enclosing and provide features to enable adjustment and viewing without guard removable. Drives belts located in potentially explosive environments, shall be certified as 'static dissipative' or 'anti-static' and labeling provided to ensure correct replacements are used.
- Openings in stuffing box extensions and discharge heads necessary to service seals on pumps are to be fitted with open mesh type coverings that permit visibility of the seal and are easily removed to enable ease of maintenance.
- Reciprocating parts and similar should be guarded through their full range of movements.

Materials for Machine Guards

- Guard materials shall preferably be metallic and of the expanded mesh form where visibility of moving parts is required.
- Where guards are likely to be exposed to corrosive elements they shall be manufactured from corrosion-resistant materials or have applied an appropriate surface coating protection system;
- Guards located in potentially explosive environments and used for protection of moving parts shall be manufactured from 'non-sparking' materials.

  Note: As corroded carbon steel in contact with aluminum presents a sparking risk, the use of aluminum materials for protection of moving parts, (e.g. steel couplings), should be avoided.
- Nonmetallic guards used in 'outdoor' locations shall only be manufactured from plastic materials that are certified as being UV (ultra-violet light) stabilized.

- Open materials for guarding shall be corrosion resistant woven wire, expanded metal, or perforated plate.
- Insulation and cladding is the preferred means of protection from hot and cold surfaces.
- Where heat retention by insulation is undesirable, guarding may be located between 350mm (12 in) and 500mm (20 in) away from the surfaces likely to cause harm, provided the guarding not exceed 60°C (140°F) and minimum temperature not less than ambient temperature during normal site weather conditions.
- For metal clad insulation where there are dissimilar metals that could lead to galvanic action, an electrical contact path between each dissimilar metal is required.
- Materials for insulation shall be certified to be low toxicity and shall be non-flammable.

4.8.6 Flying Objects

Flying objects may be defined as components that are ejected from equipment after Process failure of moving parts such as couplings, drive chains and belts or when stationary parts such as pressure retaining cases and bolting fracture. Because such failures usually occur with some force and in random directions, it is not always possible to provide adequate protective guarding to contain the hazard that a flying object represents.

Where such risks exit and protective guards are not practical, equipment must be designed or selected with aspects and features that mitigate the risk of catastrophic Process failure. In this respect the following SID considerations shall be met:

- To ensure design integrity, custom–built machinery, (i.e. machines made to order usually from raw materials), shall be designed and manufactured to recognized industry design codes such as API, ANSI AS/NZS and ISO who publish standards where mandatory requirements for design life, design margins for pressure retaining components & drive components and material Non-Destructive testing are included.
- The integrity of pressure containing components is detailed on Section 4.5.1
- Equipment should be arranged so that trajectories of flying objects are directed away from, or so that larger pieces of machinery form a natural barrier for; operating consoles,

walkways and other areas where personnel are expected to access while equipment is in operation.

4.8.7 Vibration

- To avoid vibrations associated with resonance, lateral and torsional analyses shall be carried out to ensure rotating machines and their drive trains do not have critical frequencies that occur within the expected operating speed range. As a rule, equipment operating speed ranges shall be designed to be either below the 1^{st} naturally occurring frequency or between the 1^{st} and 2^{nd} order frequencies. Depending on the application a safety margin between critical frequencies and operating speeds shall be established. Separation margins shall not be less than 10% away from any naturally occurring (critical) frequency.
- To minimize machine vibration, rotating elements and drive couplings shall be dynamically balanced according to ISO 1940 balance quality standards and to a residual un-balance grade appropriate for the equipment type, the machine's characteristics and operating speeds.
- For the type of equipment in question, appropriate levels of field vibration shall be established based on relevant industry standards, as published by recognized organizations such as API, HI, AGMA or ISO. To establish that maximum vibration limits are not exceeded, verification testing shall be carried out preferably during factory assurance testing, or if not impractical, during field commissioning.
- Natural frequencies of individual machine items such as blading and impeller vanes shall be calculated and proven to be not subject to damaging excitation frequencies.
- Where vibration is an inherent part of a machines operation, e.g. vibrating feeders, shaker screen, then substantial foundations or support structures may be required to absorb mounting vibrations and prevent damage to adjacent equipment. Isolating of control cubicles or platforms by rubber mounting may be necessary for operator comfort and well-being.

- Where fasteners may be susceptible to loosening, self-locking style fasteners such as; nyloc nuts, spring or star washers, or thread locking adhesives should be used.
- Fatigue failure occurs due to the sustained cyclic loads. The loads may be within the capacity of the component but the repeated cycles can cause cracks to develop and enlarge to failure.
- Excessive deformation can occur when a vibration frequency resonates with the natural frequency of a machine or components, and the resultant deflection reaches amplitude beyond the capacity of the member.
- Vibration monitoring and analysis techniques are an advisable practice to ensure vibration is detected and rectified before machine damage results.

Drive Considerations

To ensure design integrity Process drive elements for high energy machines shall be designed and manufactured to recognized industry design standards such as API, AGMA , CEMA NEMA IEEE and ISO who publish standards where requirements for design life and design margins for components are included.

Protrusions and Sharp Edges (moving or stationary)

Machine guards wherever possible should be in place to protect people from injury. Where this is not possible due to equipment configuration or operation other methods may be required, including;

- Automating processes so personnel can be eliminated from the area.
- Arranging equipment and platforms so that personnel cannot contact the protrusions

Where protrusions and sharp edges within a machine are a hazard only during cleaning or maintenance tasks temporary guarding, sheathing or other forms or protection should be provided. Any temporary protection should be highly visible and be included in any isolation/de-isolation procedures and should ideally inhibit access until it is installed and start-up until it is removed by, for example, forming an access barrier in its stored position and a locking device when in place.

Lubricant Hazards

To avoid toxicity hazards arising from coming into contact with lubricants equipment requiring periodic lubrication attention (draining, refilling and top-up) should be designed with lubrication requirements in mind.

Fill points should of a design and location for ease of filling appropriate for the volumes required. Small volumes, up to 20 liters (5 gal), may be hand filled via drum and funnel, but larger volumes will require use of pump and hose connected to a bulk supply. There should be sufficient clearance for forklift, crane or other means to position the bulk supply within a practical distance for hose and pump capability. Where a pump, or other pressurized feed, is to be used then fill points should be positively connected either by quick-release or screw type fittings. Hoses should be fitted with shut-off valves or nozzles to prevent spillage whilst transporting and positioning the hose.

Drainage should similarly be suitable for volumes required. Collection containers, suitable to collect total volume, must be able to be fitted under the drain point or drain extension piping.

Bunding or spill trays to collect spillage that may occur due to lubrication system failure should be considered for larger volumes, or where multiple hoses, fittings or remote pumps are utilized. This is especially important in locations where spillage may enter drains or pose other environmental hazards.

Hazards associated with the ergonomics of accessing awkwardly located grease points, and also the risk of equipment failure with overlooked greasing, can be overcome with centralized greasing manifolds and/or automated greasing systems. Manifolds should be grouped according to like greasing requirements, e.g. grease type, frequency, quantity, and be labeled with the area, or specific component, of the machine that they service.

Non-flammable lubricants should be selected where possible in applications where it presents a fire hazard.

Food grade lubricants should be specified for all food service applications.

Blocking of Safety Devices by Product

To prevent equipment failure due to over-loading, over-pressurizing, and blockages various devices are employed.

These devices can include;

- relief valves
- bursting discs
- pressure sensors and transmitters
- high level sensors
- overflow pipes
- Electric motor overload trip (material handling)
- Holdback for conveyor to stop them rolling back
- Brakes to ensure conveyors stop in the required time for emergency stop
- vents
- float switches
- shear pins
- Break-away couplings etc.
- over speed trip devices
- frequency synchronization devices

All of these devices will only protect personnel and equipment if they are able to operate as intended. Factors such as type, location, product buildup and shielding, bypassing, failure to reset or deliberate interference can all render these safety devices in-operable.

Any safety device such as these should be tested, either in situ or by removal and workshop tested, on a regular basis to ensure correct operation.

When safety devices do operate, either as intended or by false tripping, machinery should be prevented from re-starting until the reason for operation has been ascertained and rectified, and the safety device has been reset or replaced as necessary.

Discharge from safety valves, and other similar gas and liquid relieving safety devices, should be routed safely away from personnel and other equipment. Consideration should be given to chemical, temperature, noise and environmental factors to ensure no hazards is created by discharging product.

Noise

Noise from specific pieces of equipment, as well as collective back ground noise, must be kept to approve levels for the health and safety of personnel in the local vicinity and also in neighboring areas.

Noise levels are set by standards, company guidelines and also local governing regulations. Allowable noise levels vary for intermittent and continuous exposure.

Noise produced by machinery may interfere with concentration and can cause operator stress. Noise can lead to mistakes and can prevent a verbal warning being communicated.

Equipment emits noise depending on its design, style and construction and if an alternate type of machine cannot be utilized for a particular task then other means must be considered to limit noise. These include;

- Enclosures or sound dampening panels
- Alternate materials of construction for certain components
- Isolation mountings
- Remote operation to remove personnel from the area.
- Consider the layout of equipment and generate a noise contour profile
- Ensure signage is included to identify high noise areas

Product Build Up

Product build up inside machinery, chutes, pipes and other areas is a hazard to machinery operation resulting in damage and reduced throughput. It is also a safety hazard to personnel required to clean out build up as this is generally required to be carried out manually, in difficult locations with poor ergonomics and with risks of material dislodging causing injury.

Layout of equipment, materials of construction and/or linings and selection of correct upstream and downstream equipment can all ensure build ups are avoided. Provision of hatches, purging systems, permanent and temporary platforms and handrails, and positive means of isolating upstream product can all ensure cleaning of buildup can be carried out safely if it does occur.

Where waste material is generated as part of the production process, a means of collection and accumulation, such as bins, skips, tanks or bunkers should be provided to allow emptying to be done at a convenient time.

Don't place tank overflows near isolation valves.

4.8.8 Chemical Hazards

Chemicals in industry present many hazards to personnel and the environment.Emissions can be of various forms; noise, particulate, radiation etc. for which limits or allowable levels will be stipulated by local authorities and the sites' own operating licenses. Sources of emissions can include;

- Radioactivity
- Fire and explosion
- Combustion
- Pressure relief
- Blow down
- Dust
- Disposal systems

Flora, Fauna, Vermin Attack

Materials for instrumentation and control equipment should be impervious to damage from naturally occurring flora and fauna where they are installed (i.e. fungi, marine organisms, rats, mice, rabbits, birds, etc.). Openings that may present an opportunity for entry should be protected with mesh or similarly blocked.

Lightning/Surge Protection

Field equipment is susceptible to weather conditions. To protect against propagating damage to control systems it is recommended to locally earth (ground) casings, base plates and support structures to protect against lightning strike.

Maintenance Considerations

Equipment Openings

Openings in equipment casing for access and assembly shall be fitted with appropriate covers or guarding where there is a danger of touching moving or hot/cold components.

Where solid covers need to be removed during operation for inspection they should instead be fitted with mesh inserts for safety. Depending on the weight of the cover a safe method of opening should be included with special attention to pinch points.

Man way flanges shall have a hinge or davit for ease of removal.

Size of equipment openings shall be adequate for safe entry and exit. Consideration shall be made to account for personnel protective equipment such as respirators and face mask

Permanently open cut-outs of equipment should be designed so as not to accumulate dust or debris which could potentially pose a fire, health or safety hazard.

Isolation

To enable equipment to be safely maintained energy sources must be able to be controlled, isolated or removed so as to prevent accidental start-up and to prevent un-controlled movement of machines or components.

Drive units can be isolated by electrical switches and de-contactors, fuel supply cut-off and by providing valve. These methods should also ensure no damage occurs to the drive and/or driven units.

Stored energy sources; such as gravity take-ups, spring tensioners, pressure accumulators, product trapped mid-process, must all be dissipated, disconnected or controlled by Process locking or propping. Process or physical locking mechanisms must be designed so that they can be put in place without endangering personnel, either by requiring them to place all or part of their body under suspended loads or by entering an area or machine whilst it is only partially isolated. Aids such as extension handles and actuated locking pins may be necessary.

Isolation points and devices must have a means of positive locking to prevent inadvertent re-energizing, ideally by keyed padlock, and also a means of verifying that energy source is isolated or eliminated, e.g. bleed valves, manual start buttons, pressure gauges or visual checks.

Isolation points shall also be adequately identified by name or numbering to prevent incorrect or incomplete isolation and to enable isolation procedures to be developed. Isolation points should ideally be located adjacent to the machine to assist intuitive identification. Where isolators are mounted remotely both isolator and machine shall be labeled with identical description and numbering to avoid confusion.

Equipment and Component Handling

The design and layout of all machinery should consider that all equipment must, at some time, be handled by operations and maintenance personnel.

To safely ensure this can be achieved, the following should be considered;

- When possible, similar equipment and piping should be grouped together to simplify maintenance.
- Piping and cable tray arrangements shall be routed to facilitate maintenance tasks, and should also provide sufficient space for use of lifting equipment such as bridge cranes, monorail hoists and temporary rigging equipment.

- Adequate access shall be provided for routine maintenance tasks, e.g. changing of filters. Personnel shall not be required to stand on nearby pipes, cable trays, handrails or any other elevated surface not specifically designed to be used as a standing surface.
- Movement routes and lay-down areas for large equipment and components should be designated.
- Adequate tool clearance shall be allowed for all mounting bolts, flange bolts and similar. The swing path of tools shall be considered to avoid finger pinch points and orientation of fasteners to avoid tool slip off.
- Lift points (lugs, pad eyes, eye bolts etc.) shall be attached to, or mounting point incorporated into, larger items to facilitate removal by overhead lifting gear.
- Piping spools, preferably with a change in direction to facilitate removal, shall be used to allow for equipment items to be removed without the unnecessary removal or temporary supporting of nearby equipment and piping.
- Cabling and instrument supply line piping should be installed with sufficient flexibility to accommodate normal maintenance and equipment movement.
- The weight of parts and components should be assessed to determine if they can be handled manually, by one or multiple personnel. The physical location and ergonomics of the personnel must be factored into the maximum weight they are able to safely lift.
- The carry distance to a lay-down area should also be considered. Trolleys, tracks, monorail etc. can assist in minimizing carry distances.
- The method of lifting components should be considered, and permanent lifting equipment or structures installed where practical. Lifting equipment may include; davits, jibs, cranes, monorails etc.
- Handles of correct size and location should be provided if the shape or weight distribution of a component do not permit easy manual lifting.

4.8.9 Access to Equipment

Equipment requiring routine operator inspection, testing and maintenance should be accessible without the need for temporary ladders, scaffolding or lifting devices which are additional risks to personnel. To facilitate this equipment must be arranged to enable access or adequate access points incorporated into the equipment design.

Further points to consider are;

- Field equipment shall be located in such a manner as not to obstruct operational and maintenance access to other plant, e.g. cable supports shall be kept above head height and at a minimum above ground level in all other areas.
- All field equipment (instruments, valves, drives etc.) should be well labeled, with sufficient lighting to read labels both night and day.
- Piping should be labeled with contents, and where possible flow direction.
- Where instruments, electrical cabinets, valves and other equipment are mounted along walkways which have handrails, the equipment shall be mounted above the handrails and not intrude on or impede normal traffic on walk / passage ways.
- Consideration shall be given to the body position of the worker while performing the particular task as well as the equipment required to perform the task.
- Structural members of the skid, platform, or individual piece of equipment shall not prevent access to, or removal of, items or prevent removal of any panels, covers or guarding required to be removed to service or replace components.
- Items that are difficult to remove shall be so mounted that they will not prevent convenient access to other items.
- Items which can be easily damaged shall be located so as not to be damaged during removal of other items.
- Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

The placement of components relative to other components and equipment should be considered also;

- Items which are most critical to system operation and which may require immediate access and maintenance shall be readily accessible.
- When immediate access is not a factor, items requiring the most frequent access shall be the most accessible.
- Items such as pumps, compressors and turbines, relief valves and exchangers shall, when practical, be located on the outside periphery of a skid for ease of access.
- Adequate space for removal and replacement activities shall be provided around items such as pump and compressor seals, couplings, bearings and stuffing boxes and exchangers. The required access space shall be provided by the supplier and indicated on the supplier's general arrangement drawings.

4.8.10 Working at Heights

Where the layout of equipment requires personnel to work in an area that is unprotected from lower areas by hand railing or guarding, or where there is a potential to fall through an elevated area (e.g. roof areas, tank lids etc.) these areas should be considered as working at heights areas and appropriate precautions taken. Generally this work should be limited to construction or occasional maintenance tasks. For routine tasks, either operational or maintenance, permanent barriers and access should be provided.

Wherever possible the need to work at heights should be reduced or eliminated by providing a safe work area by installing permanent barriers (handrails, guarding) and/or platforms or by the use of temporary scaffolding or Elevating Work Platforms (EWP).

Local regulations may vary and should be consulted, but generally an elevated area greater than 1.8 meters (6 ft) not protected by a barrier will require the use of safety harnesses and restraints. Where there is no risk of falling through the work surface (concrete or steel plate roof, or concrete floor inside building with a pit) then a 2 meter exclusion area, if it is able to established, may suffice instead of fall protection.

Working at heights shall be controlled by either permit or procedure to ensure proper consideration is given to;

- Risk assessment
- Appropriately trained personnel
- Anchor point integrity
- Harness and restraint styles
- Take-up distances for inertia reels, shock absorbers, static line deflections
- Rescue plans

When components are removed for maintenance, or removed to gain access to maintain other components, this may inadvertently create openings that are no longer protected from heights. Consideration should be given to this relative equipment placement at the design stage to avoid this or to enable permanent or temporary barriers to be provided for these situations.

4.8.11 Working Space (Confined space)

Access shall be such that all activities necessary to operate or maintain equipment and systems safely can be completed by personnel wearing the appropriate personal protective equipment, including chemical suits and/or self-contained breathing apparatus (SCBA), and carrying or using all necessary tools and/or test equipment.

Documentation

To ensure equipment is constructed in accordance with the design calculations and decisions, drawings and specifications must be complete, accurate and legible.

Manufacturer's data book is required to provide a complete record of the equipment, material, fabrication, testing, authorities' approval, etc. performed on the equipment.

Operations and Maintenance Manuals should cover all aspects, features and requirements of the equipment. Spare and replacement part descriptions should contain enough detail to ensure replacement items of the correct size, rating and quality are used whenever these items are replaced. Commissioning data and setup information should be included to ensure the original operating characteristics is recorded and any future variances can be evaluated and rectified, so as to ensure the machinery does not operate outside its design capacity and limits.

Testing requirements and methods, or references to appropriate statutory codes or standards, for tasks such a load testing lifting equipment and pressure testing piping, should be marked on drawings to ensure it is correctly performed during construction and also for any subsequent repairs or replacement during the life of the equipment.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary

5.1.1 Fire Water Demand Calculation

In case foam pourers are provided on tanks having diameter up to 18 m, minimum 2 nos. foam pourers shall be provided. The estimation of number of foam discharge outlet is based on pourer capacity of 1000 lpm at a pressure of 7 kg/cm^2 (g), upstream of eductor. This can be suitably adjusted for different pourer capacity in accordance with (Table 5.1).

Table: 5.1

Tank diameter (In M)	Foam Pourer (Min. Nos.)
Above 18 **&** up to 20	2
Above 20 **&** up to 25	3
Above 25 **&** up to 30	4
Above 30 **&** up to 35	5
Above 35 **&** up to 40	6
Above 40 **&** up to 45	8
Above 45 **&** up to 50	10

5.1.1.1 Floating Cum Fixed Roof Tank Protection

Protection facilities shall be provided as required for fixed roof tank.

5.1.1.2 Protection For Dyke Area/Spill Fire

Portable monitors/foam hose streams shall be considered for fighting fires in dyked area and spills.

5.1.1.3 Foam Application Rate

The minimum delivery rate for primary protection based on the assumption that all the foam reaches the area being protected shall be as indicated below :-

For cone roof tanks containing liquid hydrocarbons, the foam solution delivery rate shall be at least 5 lpm/m2 of liquid surface area of the tank to be protected.

For floating roof tanks containing liquid hydrocarbons foam solution delivery rate shall be at least 12 lpm/m2 of seal area with foam dam height of 600 mm of the tank to be protected.

In determining total solution flow requirements, potential foam losses from wind and other factors shall be considered.

5.1.2 Duration Of Foam Discharge

The equipment shall be capable of providing primary protection at the specified delivery rates for the following minimum duration.

i) Tanks containing Class 'A' & 'B' - 65 minutes
ii) Where the system's primary purpose is for spill fire protection -30 minutes.

5.1.3 Water For Foam Making

Water quantity required for making foam solution depends on the percent concentration of foam compound. Foams in normal use have a 3% to 6% proportioning ratio. However, foam supplier data shall be used for determining water requirement.

5.2 Conclusion

Comparison that shows the differences between a PFS and PEFS is in Table: 5.4

Table: 5.2

Description	PFD	P&ID
Used for Construction?	No	Yes
Shows all process and service piping?	No	Yes
Indicates presence of all controls?	No	Yes
Shows all motors?	No	Yes

Shows thermal insulation?	No	Yes
Shows major equipment?	Yes	Yes
Shows flow quantities?	Yes	No
Shows stream compositions?	Yes	No

This is the most revealing distinction. The P&ID on a job site is probably one of the most used documents. Everyone working on piping has one in pocket, and it is constantly spread out during discussions. PFDs, on the other hand, are never seen on a job site. They are available, in the files, but not used.

The PFD is a drawing needed early in the project. Indeed, the PFD is the most important drawing while the mass balance is being prepared. Later, the PFD guides the preparation of the P&ID. Finally the P&ID supplants the PFD, totally eclipsing it.

Both PFDs and P&IDs can be characterized as

- Communication tools
- Records
- Aids to thought processes

And PSFS is the desired outcome for any project after implementing safeguard features in the PEFS.

Hazardous area classification

The basic elements for establishing the hazardous zone types are:

- Identification of the sources of release
- Determination of the grade of release
- Determination of the release rate, velocity, etc
- Determination of the type of area (openness)
- Degree and availability of ventilation
- Use of an appropriate code or calculations to determine the extent of zone

- Extent of zone: *Distance in any direction from the source of release to the point where the gas/air mixture has been diluted by air to a value below the LEL.*

It's not easy to compare the two different systems for classifying hazardous locations. They are both good systems and were developed independently of each other.

Each has its own approach to area classification and each has its own advocates and approval organizations. Neither system has been proven to be safer than the other. Generally, cost comparisons of the two are inconclusive. Currently the IEC system has wide use throughout most of the world (except in the U.S.) in the chemical and petrochemical industries.

With oil activity in scores of different countries, the IEC standardized approach suits these industries well.

The Class/Division method is the dominant method used in the U.S. and is meant to serve all hazardous areas from oil to sewage treatment to paint spray locations to everyday gas stations.

The Class/Division method is very straightforward, leaves little doubt as to a classification and which electrical material can or cannot be used.

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