INTRODUCTION :

Process safety information (PSI) is the keystone of a PSM Program as it tells us what we are dealing with from both the equipment and the process standpoint. In order to be in compliance with the OSHA PSMS regulations the process safety information should include information pertaining to the hazards of the highly hazardous chemicals used or produced by the process, information pertaining to the technology of the process and information and concerning the equipment in the process.

Information relating to the *hazards of the highly hazardous chemicals* in the process should consist of at least the following:

- Toxicity information
- Permissible exposure limit
- Physical data
- Reactivity data

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- Corrosivity data
- Thermal and chemical stability data
- Hazardous effects of inadvertent mixing of different materials that could foreseeably occur

Information relating to the *technology of the process* should include at least the following:

- A block flow diagram or simplified process flow diagram
- Process chemistry and its properties
- Maximum intended inventory
- Safety upper and lower limits for such items as temperatures, pressures, flows or compositions
- An evaluation of the consequences of deviations, including those affecting the safety and health of the employees

Information pertaining to the *equipment in the process* should include the following:

- Materials of construction
- Piping and instrument diagram (P&IDs)
- Electrical classification
- Relief system design and design basis
- Ventilation system design
- Design codes and standards employed
- Material and energy balances for processes built after May 26, 1992
- Safety system (for example, interlocks, detection or suppression systems)

The employer should document that equipment complies with Recognized and generally accepted Good Engineering Practices (RAGAGEP).

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For existing equipment designed and constructed in accordance with codes, standards or practices that are no longer in general use, the employer should determine and document that the equipment is designed, maintained, inspected, tested and operating in a safe manner.

Process safety information is used as a training tool for new hires, so the more complete, the more accurate, the more detailed the process safety information is, it is more likely to help us and in the industry. The process safety information should be completed prior to or in conjunction with a process hazard analysis. The PSI is a library of information for operators and people using the system. The process hazard analysis team needs to have that library of information in order to adequately conduct a process hazard analysis which is determining operability and safety problems associated with the system. So without PSI the process hazard analysis would be somewhat incomplete or it would have a lot of questions.

Information pertaining to the hazards of regulated material is required to be a part of the process safety information. In order to adequately assess the hazards we need to know what the hazards of the chemicals are. Information concerning the technology of the process and the information pertaining to the equipment in the regulated process are the two key things required.

Toxicity information is very straightforward which can include material safety data sheet. As long as they are in compliance with the regulations and have all the key information including permissible exposure limits, physical data, reactivity data, corrosivity data, thermal and chemical stability information as well as inadvertent mixing.

Example of material safety data sheet (MSDS):

MATERIAL SAFETY DATA SHEET

SECTION I – PRODUCT IDENTIFICATION

Product Name:	**Benefect Atomic Degreaser**
Product Use:	Grease, Fire And Soot Cleaner
WHMIS Class:	Class D – Division 2B
D.O.T. Classification:	Not Regulated
TDG Classification:	Not Regulated
Manufacturer:	Sensible Life Products
Address:	7 Innovation Drive, Flamborough, ON CA L9H 7H9
Telephone:	(905) 690-7474
Emergency Phone:	(905) 690-7474

HEALTH	1
FLAMMABILITY	0
REACTIVITY	0

SECTION II – HAZARDOUS INGREDIENTS

Ingredients	CAS#	WT%	OSHA-PEL	ACGIH-TLV	LC_{50}	LD_{50}
Sodium metasilicate	6834-92-0	1 – 5	Not available	Not available	Not available	1153 mg/kg oral, rat
Alcohols, C7-21, plant based	68991-48-0	5 – 10	Not available	Not available	Not available	~1410 mg/kg oral, rat

OSHA – MSDS prepared pursuant to the Hazard Communication Standard (CFR29 1910.1200).
SARA – Section 313 (Toxic Chemical Release Reporting) 40 CFR 372 – No ingredients above reportable quantities.
Toxic Substances Control Act (TSCA) – All the ingredients are listed or exempt from listing on the Chemical Substance Inventory.
California Proposition 65 – No ingredients listed.

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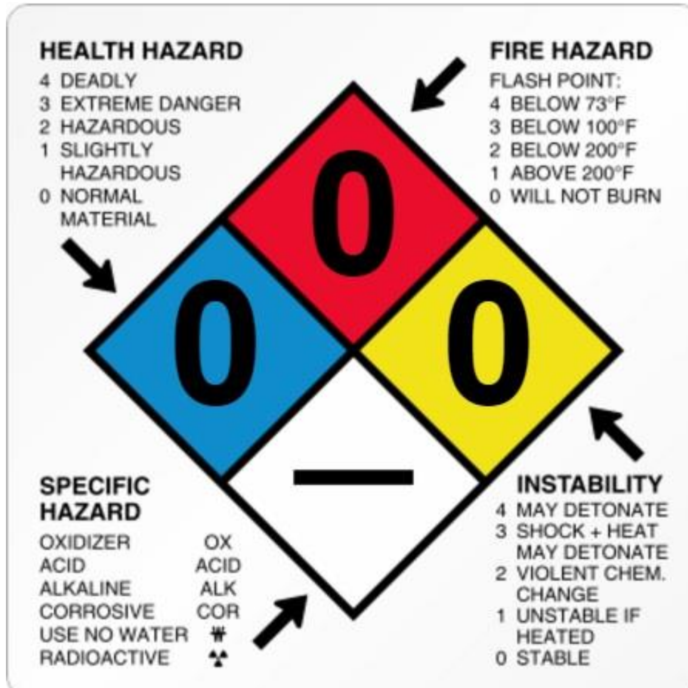
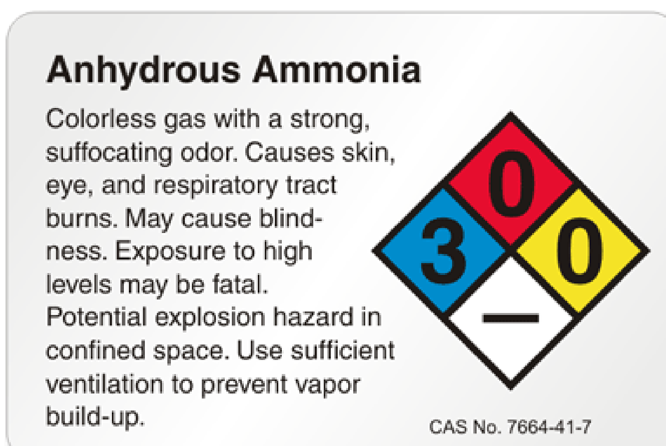
There are many changes in these material safety data sheets according to time. For example – in case of ammonia, how it is handled or classified indoors v/s outdoors, the **NFPA**(National Fire Protection Association) diamond placard used to be 3 1 0 , one in the flammability category because it was earlier considered as a non- flammable material and it still is. But the thing is that when it is handled in the ammonia filtration system, oil can migrate into the system through compressors that change the flammability levels of ammonia. So the category of the ammonia is changed in the inside of an engine room to 3 3 0, 3 on a flammability number. So we might see two different diamonds sometimes, one on the warehouse or the other outside a storage room or in engine doors.

The picture ahead describes the NFPA card and what each number signifies.



The NFPA card for anhydrous ammonia is shown below.



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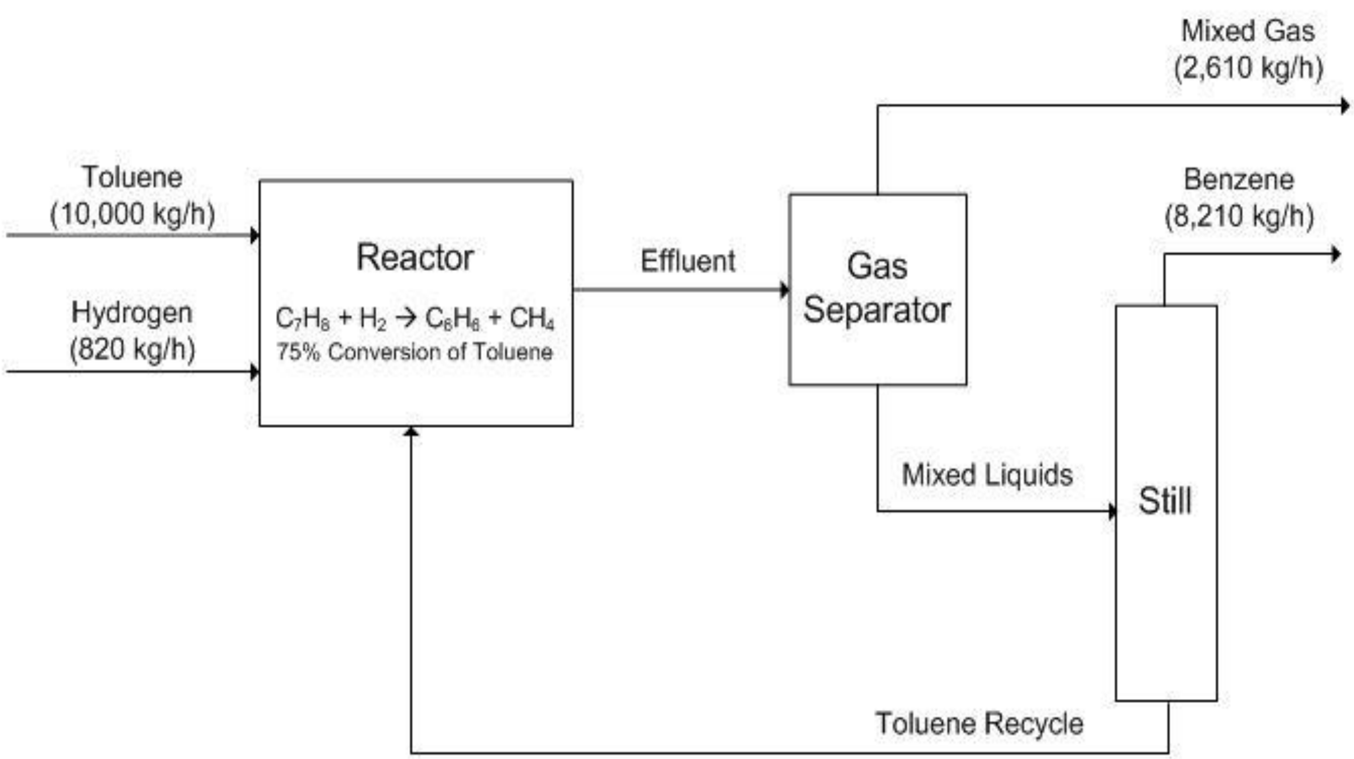
Block Diagrams:

Block diagrams are the simple demonstration of any chemical process. These help us to figure out the start and end of the process and which elements or equipment have been used in that process. Basically these can be categorized into two forms, one is single stage and the other one is multiple stage block diagram. It consists of pumps, evaporators, condensers, vessels and all the equipment basically used in the process.

Below is an example of single stage simple block diagram of a particular process:



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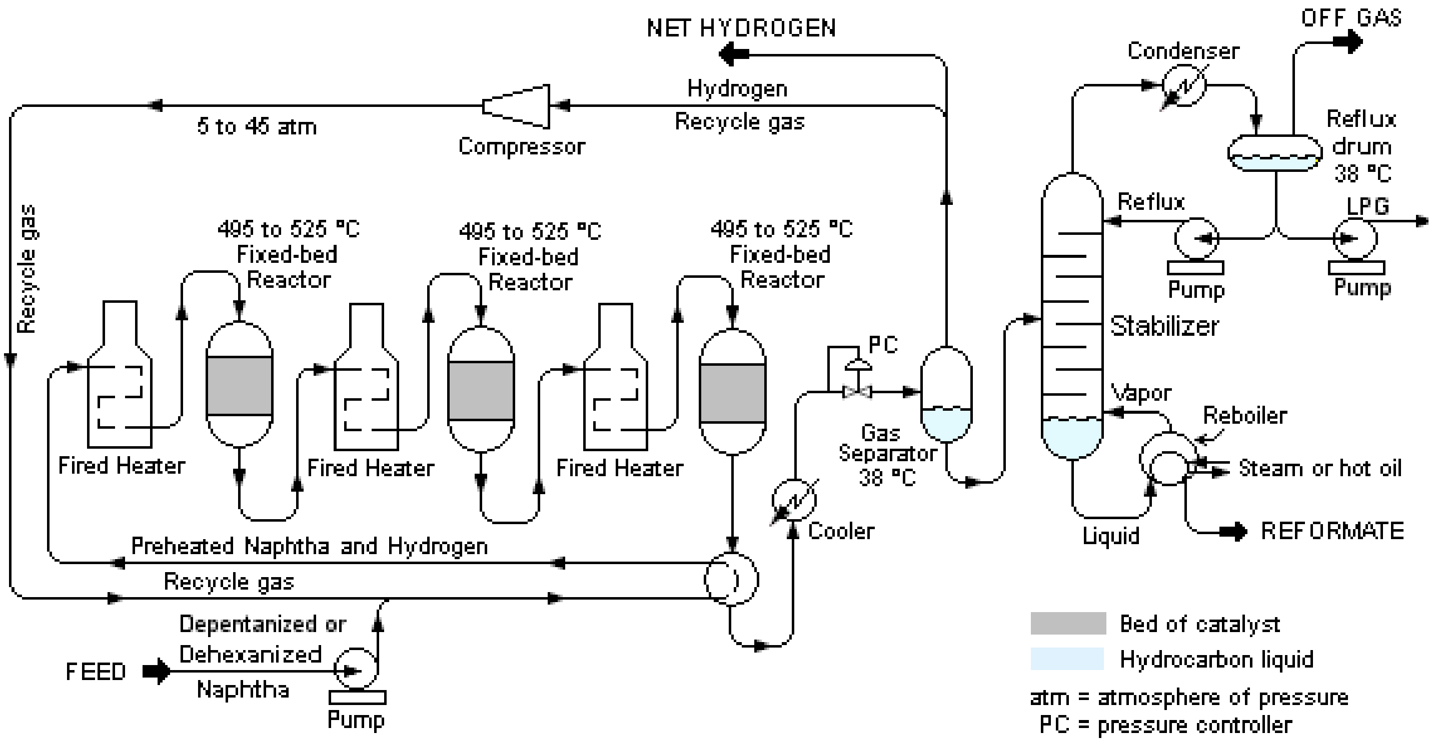
Example of a multi stage block diagram:



The above diagram is of multi stage process which consists of many vessels, equipments, recycle streams as we can see clearly in the picture.

Process Chemistry:

It is the information that we need to look at, it is general and specific. Something that tells us about the general idea, for example in a refrigeration system that it is a closed loop system is a general information and if we go into more detail such as the pressure of the liquid circulating in the pipes and types of valves present, the it is termed as specific information. It may include number of evaporators or number of condensers, and also the type of condenser or evaporators

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used. It goes through all the temperatures, pressures, valves, flows and all other things in detail.

Maximum Intended Inventory:

The meaning of maximum intended inventory is exactly what the words imply – *the maximum chemical inventory that a facility intends to utilize (having onsite) at any time*. For a transient process in which a chemical is consumed, this corresponds to the capacity of the storage vessels within the process. For a closed-loop system (ammonia refrigeration), the maximum intended inventory is the **actual** inventory required to operate. Many vessels within a refrigeration system are designed to operate partially filled with liquid or completely full of vapor (e.g. oil separators) during normal operation. The maximum intended inventory is not the inventory of ammonia that could be contained if all vessels, pipe, and equipment were filled to 100% capacity with liquid as this scenario would never be "intended". It can be time consuming to calculate the inventory contained within a refrigeration system. To give an idea of what is involved in calculating the inventory (mass) within a horizontal pressure vessel. Equations have been included necessary to perform the analysis below. Thanks to spreadsheets and software, the calculations can be performed with more ease than otherwise would be the case if forced to do the work long-hand.

Mass of Liquid:

$M_L = V_L \cdot \rho$

M_L = Mass of liquid (lb.)

V_L = Volume of liquid (ft^3)

ρ = Density of the liquid ammonia (lb/ft^3)

Mass of Vapor

$M_V = V_V / v_V$

M_V = Mass of vapor (lb)

V_V = Volume of vapor (ft^3)

v_V = Specific volume of ammonia vapor (ft^3/lb)

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Total Mass

$M_T = M_L + M_V$

M_T = Total mass (lb)

M_L = Mass of liquid (lb)

M_V = Mass of vapor (lb)

Total Volume of a Vessel

$V_T = 2V_h + V_s$

V_T = Total volume (ft^3)

V_h = Volume of the head (ft^3)

V_s = Volume of the shell (ft^3)

Shell Volume

$V_s = \pi D^2/4 \bullet (L-2\bullet HD/12)$

V_s = Volume of the shell (ft^3)

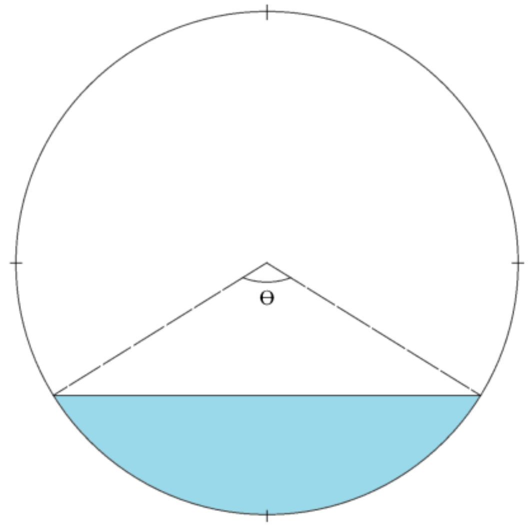
D = Inside diameter of the vessel (ft)

L = Length of the vessel (ft)

HD = Head depth (in)

Horizontal Vessel Liquid Volume

$\Theta = 2\cos^{-1}(1-2x/D)$



θ = Theta

x = height of liquid minus the wall thickness of the vessel (in)

D = Inside diameter of the vessel (in)

$A = D^2/8 \bullet (\theta - \sin\theta)$

A = Cross sectional area of the liquid (in^2)

D = Inside diameter of the vessel (in)

$L_{normal} = (L - 2 \bullet HD/12) + 2 \bullet (4\bullet V_h/(\pi(D/12)^2))$

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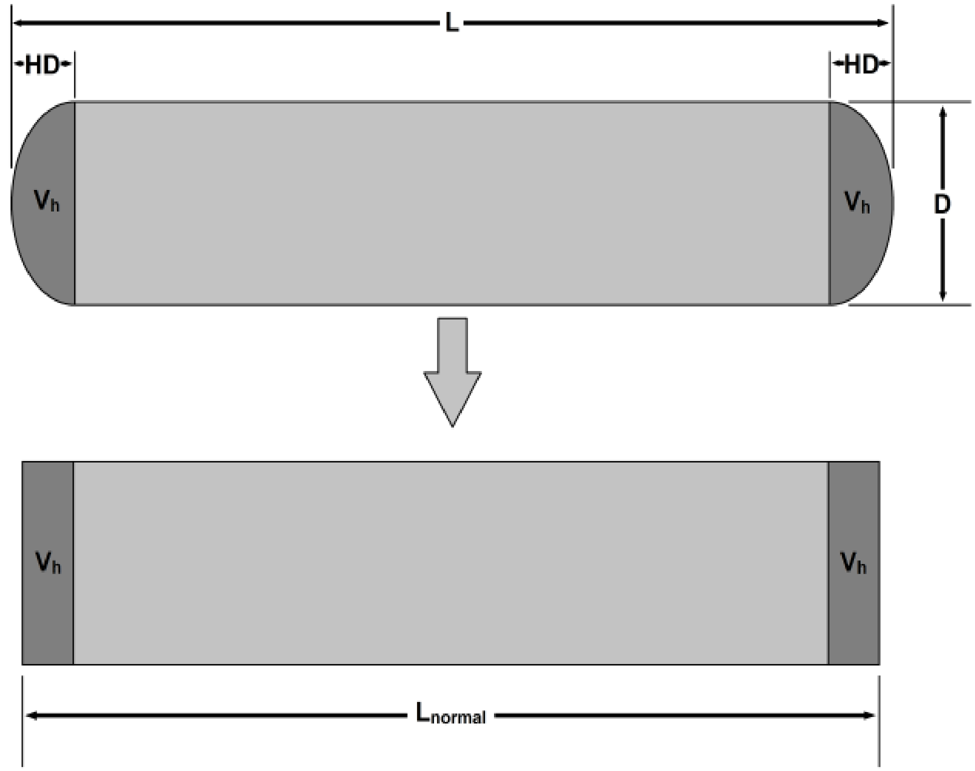

L_{normal} = Normalized length of the vessel if it were a simple cylinder (ft)

L = Length of the vessel (ft)

H_D = Head depth (in)

V_h = Volume of the head (ft^3)

D = Inside diameter of the vessel (in)

$V_L = A/144 \cdot L_{normal}$

V_L = Volume of liquid (ft^3)

A = Cross sectional area of the liquid (in^2)

L_{normal} = Normalized length of the vessel if it were a simple cylinder (ft)

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SAFE UPPER AND LOWER LIMITS

Safe upper and lower limits are intended to relate to the equipment itself. For example, a process circuit will have multiple pieces of equipment within the circuit with varying design maximum pressure ratings. Whereas each piece of equipment will have different pressure rating, the safe upper limit for the circuit should be something that is less than the maximum working pressure of the lowest rated equipment or component in the circuit. For example, if “Vessel A” has a maximum rating of 250 psi, its safe upper limit is something less than 250 psi. Likewise If “Vessel B” has a maximum rating of 275 psi, its safe upper limit is something less than 275 psi. However, if “Vessel A” and “Vessel B” are in fluid communication with each other and are part of a common circuit, the effective safe upper limit of equipment with that circuit may be controlled by the vessel/component with the lowest rating. Sources of safe operating limits may be manufactures designs, or codes or specifications.

Often operators will confuse the concept of operability limits with safe upper and lower limits. An operator of the circuit discussed above may never intend to operate above 175 psi and establish a safe operating limit of 180 psi. That operator may reason, since his equipment is rated well above his operations limit, it is extra safe. Although the logic is sound, the operator’s action does not match OSHA’s and EPA’s intent. Safe upper and lower limits are a component of *process safety information.*

Regulatory references to upper and lower limits:

• Process safety information

Information concerning the technology of the process shall include safe upper and lower limits for such items as temperatures, pressures, flows or compositions.

• Operating procedures

Develop and implement written operating procedures that provide clear instructions for safely conducting activities involved in each covered process consistent with the process safety information and must address operating limits.

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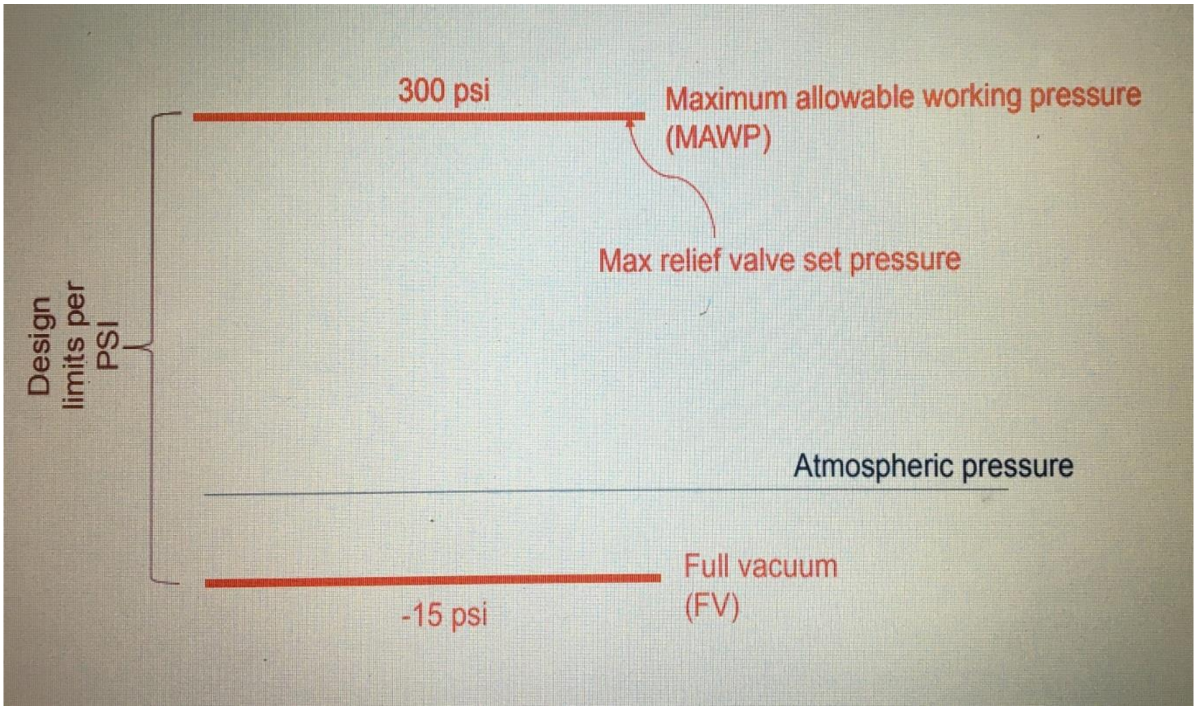
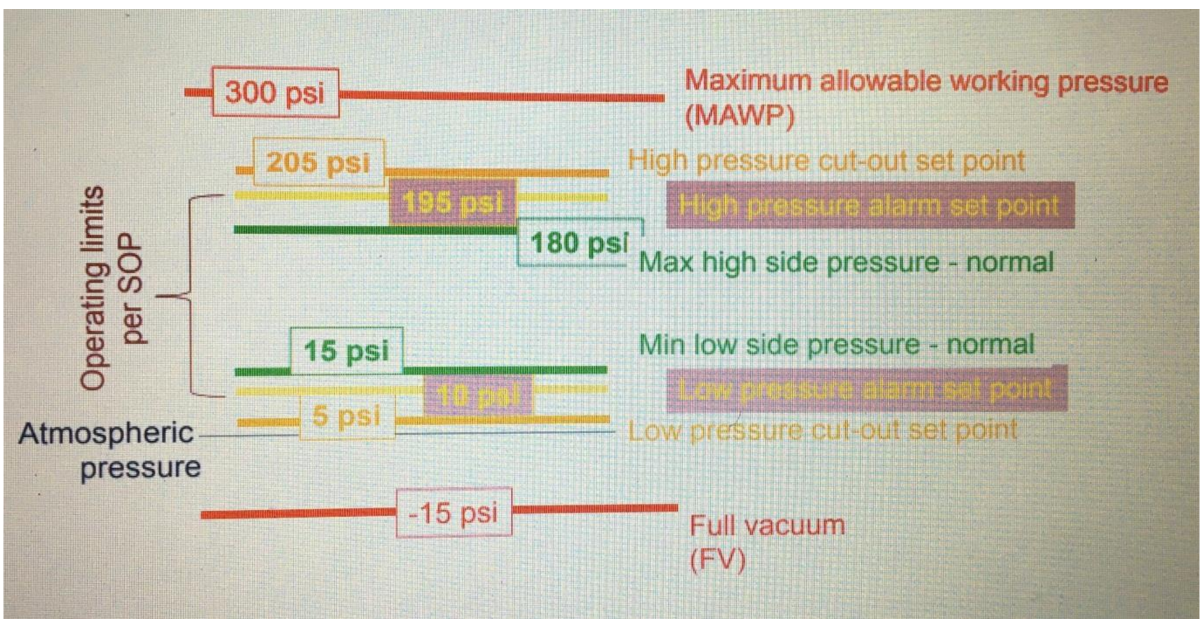
Example – pressure (design limits):



Example – pressure (operating limits):



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The questions that need to be addressed are:

Do you have established upper and lower limits for:

• Pressures

• Temperatures

• Concentrations

Such as water in ammonia, water in refrigeration oil, secondary fluids, water treatment chemicals

• Refrigerant flows

• Refrigerant liquid levels

CONSEQUENCIES OF DEVIATION:

Safe upper and lower limits for such items as temperatures, pressures, flows or compositions; and an evaluation of the consequences of deviations, including those affecting the safety and health of employees, it is worth pointing out that the information that is developed to satisfy this requirement will be used again in the development of Operating Procedures.

Since it is required that operating procedures address operating limits including **consequence of deviation**, steps required to correct deviation, and steps required to avoid deviation.

Here is an example of how one might document safe upper and lower limits and consequence of deviation for an ammonia refrigeration high pressure receiver:

Type of Vessel - High Pressure Receiver

Normal Operating Pressure (PSIG) – 120 PSIG – 200 PSIG

Consequence of Exceeding Normal Operating Pressure - 1. Compressors will shut down on high pressure cutout; 2. Pressure relief valves may lift.

Consequence of Deviating Below Normal Operating Pressure -
1. Difficulty feeding high pressure liquid to each zone of refrigeration;
2. Difficulty cooling the oil on liquid injection oil cooled screw compressors

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Steps to Avoid Deviating From Normal Operating Pressure –

1. Operator monitors system pressures daily;
2. System safety devices will shut down equipment before the pressure reaches an unsafe level;
3. Annual mechanical integrity inspection verifies that equipment is in good working condition and that safety devices are properly functioning;
4. System safety devices will alert operator in the event of a high pressure cutout alarm

Steps Required to Correct Deviating From Normal Operating Pressure -

1. Check accuracy of gauges;
2. Check set point on computer or PLC to make sure that it is set correctly;
3. Turn on/off condensers and compressors to resolve the problem.

Max. Operating Pressure (PSIG):
225 PSIG (90% of Relief Valve Setting).

Consequence of Exceeding Max. Operating Pressure :

1. Compressors will shut down on high pressure cutout;
2. Pressure relief valves may lift;
3. Vessel may rupture

Steps to Avoid Exceeding Max. Operating Pressure :

1. Operator monitors system pressures daily;
2. System safety devices will shut down equipment before the pressure reaches an unsafe level;
3. Annual mechanical integrity inspection verifies that equipment is in good working condition and that safety devices are properly functioning;
4. System safety devices will alert operator in the event of a high pressure cutout alarm.

Steps Required correcting Exceeding Max. Operating Pressure :

1. Check accuracy of gauges;
2. Check set point on computer or PLC to make sure that it is set correctly;
3. Turn on/off condensers and compressors to resolve the problem;

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4. Replace relief valve if it has lifted;

5. Turn zone off if problem can be determined;

6. Perform an incident investigation.

Normal Operating Temperature (°F):
70°F – 100°F

Consequence of Exceeding Normal Operating Temperature :
None (consequence is related to the pressure, not the temperature).

Consequence of Deviating Below Normal Operating Temperature:
None (consequence is related to the pressure, not the temperature).

Steps to Avoid Deviating From Normal Operating Temperature :

1. Operator monitors system daily.

Steps Required to Correct Deviating From Normal Operating Temperature:

1. Check accuracy of gauges;
2. 2. Check set point on computer or PLC to make sure that it is set correctly;
3. 3. Turn on/off condensers and compressors to resolve the problem.

Max. Operating Temperature (°F) :
108°F (corresponding to 225 PSIG).

Steps Required Correcting Deviating From Max. Operating Temperature:

1. Check accuracy of gauges;

2. Check set point on computer or PLC to make sure that it is set correctly;

3. Turn on/off condensers and compressors to resolve the problem;

4. Replace relief valve if it has lifted;

5. Turn zone off if problem can be determined;

6. Perform an incident investigation

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PROCESS EQUIPMENT INFORMATION

Process equipment is used in several applications like water treatment, steam power generation, pipelines, salt water disposal etc., where chemical or mechanical methods are applied.

Some examples of process equipment popularly used in the industries are pumps, valves, vessels, filters, coolers, heat exchangers, pulsation dampeners and piping. Each of this equipment is very important because of their indispensable usage in the working of a process.

Pumps:

Pumps are widely used in various industries to essentially serve the purpose of moving different types of fluids such as water, chemicals, petroleum, wastewater, oil, slurry or gas. Two main types of pumps are ***Centrifugal Pumps and Positive Displacement Pumps***. They can be further classified on the basis of other features and use or applications such as multi-stage and single-stage, multi-stage – horizontal, multi-stage – vertical, direct acting - air & steam pumps, Triplex pumps, Duplex pumps, Quintuplex Pumps, metering

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pumps, double acting pumps, single acting pumps, piston pumps, gear pumps, lobe pumps, rotary pumps, vane pumps, progressive cavity pumps, peristaltic pumps etc. These are used in industries such as oil & gas, agriculture, mining, municipal, manufacturing etc.

They are also used in various applications such as boiler feed water, pipeline, descaling, water supply, saltwater injection, water transfer, slurry, sump pump, sludge transfer, acid pumping, chemical fluid transfer etc.

Pumps are very important pieces of equipment used in industries and understanding the right pump for your application requires a thorough knowledge of each pump’s characteristics to suit the requirements of your process. For example, the best types of pumps for high viscous fluids are positive displacement pumps. Similarly, an in-depth knowledge of pump parts would be very helpful in choosing a pump that would be more reliable, efficient and durable.

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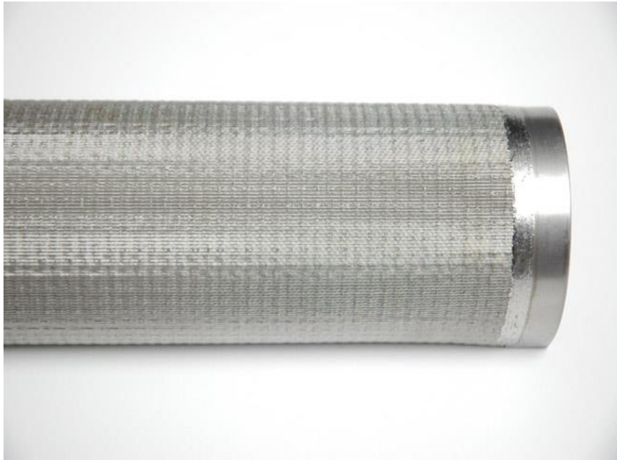
Filters :

Industries use *filters* for removing unwanted substances from the main product during any process or application. Different kind of filters are available in the market as per requirement of the process such as air filter, hydraulic filter, panel filter, bag filters, screen filters, sand filter or gas filter. They perform the primary function of filtering or removing dust, purifying oil and fuel, removing debris, and removing contaminants from a gas stream etc.



Filters are commonly used in *oil and gas* industrial applications. They are available as part of the whole pump package and make the disposal process easier, efficient and safe. One such example is salt water disposal, which is critical as gas and oil are harvested from porous rocks from which these fuels are extracted. Saltwater is a by-product and it needs to be separated and further processed for proper disposal. Use of conventional method for filtering is unable to facilitate cost-effective and efficient saltwater management, disposal and reuse. Therefore, filters are used to remove toxic oils and hydrocarbons from the product, enabling safer discharge into the environment.

Picture of hydraulic filters:

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Valves:

A valve is a device which regulates, directs or controls the flow of fluids or gases, liquids, liquefied solids or slurries. Valves are used in various applications such as industrial, engineering, manufacturing, scientific etc.

Different types of valves are shown in the given figure:

Valves are available for high temperature and extreme pressure applications in a wide variety of designs including *globe valve*, *gate valves*, *ball valves*, knife valves, V-ball valves, *butterfly valves* and *more*. Valves can come with simple hand levers or sophisticated air, hydraulic or electric power actuators that can be connected to a PLC.

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Vessels and Tanks:

A vessel is a container that can generally handle pressure. A tank generally refers to a container that simply holds fluid at low or no pressure.

The following points should be considered when specifying a tank or a vessel.

- Function to be performed/Application to be used in
- Location where it has to be stored
- Nature of fluid used
- Temperature level and pressure level
- Volume or capacity required
- Codes and regulations required
- Secondary containment requirements.

Open vessels are often used as surge tanks between operations, whereas closed vessels can facilitate operations that use toxic fluids/gas or dangerous chemicals.

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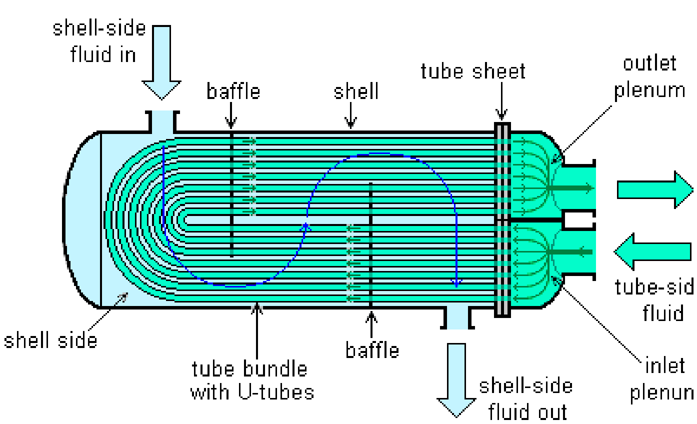
Heat Exchangers:

A heat exchanger is most widely used in process equipment for transferring heat between fluids or from a solid to a fluid or vice versa. They are mostly used in chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. Double pipe heat exchangers are the most commonly used in industrial applications since they are simple, low cost and require low maintenance.

However, more efficient heat exchangers like shell and tube or plate are being used today. One must carefully choose the type and size of a heat exchanger to suit the process, depending on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamic properties.

U-tube heat exchanger



Air coolers are another type of heat exchanger that transfers heat between a fluid and the ambient air. The most commonly seen form of this type of cooler is the radiator on a car or a truck, where a fan pulls air across pipes with hot glycol in them to cool the engine. Air coolers can be used for small lubrication oil cooling, or can become very large.

Image of shell and tube heat exchanger:

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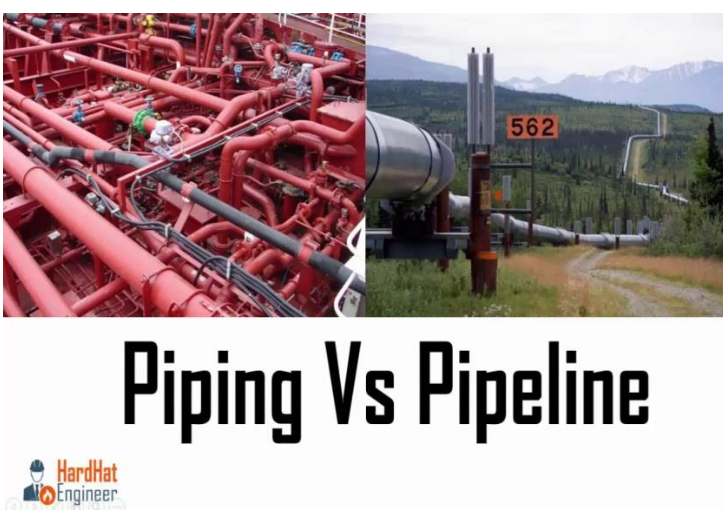
Piping:

Piping is a comprehensive system of pipes used through which fluid or gas is flowing fluid/gas from one place to another. It is also essential process equipment used in all kinds of machines to tie together all other types of process equipment. It is usually made of metal or plastic and is in the shape of a tube. However, for special applications where pipes are exposed to frequent corrosion, high pressurized operations, or high temperature, non-metallic materials such as fiberglass, plastic, glass, copper, iron, stainless steel or aluminum are more suitable for use. Pipes which can withstand very high temperature are typically defined as heat pipes and they normally operate between **400 and 1,100°C.**



Elbows, tees, flanges, couplings, unions etc. are few of the pipe fittings mostly used.

Because the pressure in piping presents a serious safety hazard, much care and consideration must be taken to design a safe and workable system.

In the case of metal piping that is welded together, the fabricator generally must be certified for the specific type of pipe he is manufacturing, such as B-31.3, B-31.9 etc. A wide variety of NDE (non-destructive examination) tests are available to ensure the piping is safe and fit for use. These NDE tests include XRAY, Hydrotesting, Mag-particle, Ultrasonic, and more.

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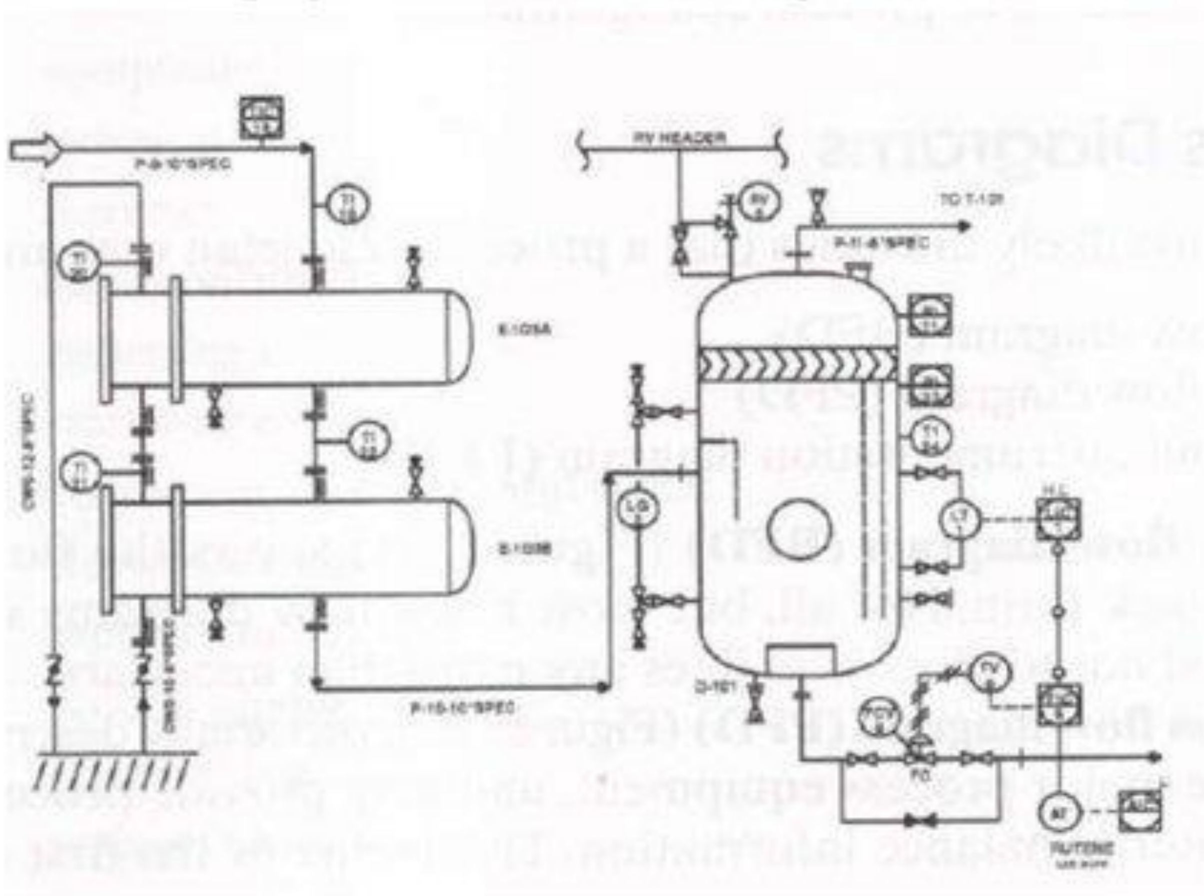
Piping and instrumentation diagram (PID)



Choosing the right type of equipment needed in the process is very important for the successful operation and maintains the efficiency of the process along with the safety of a plant. It helps in good quality of output and also aids the operators with hassle- free and smooth operation.

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Relief System Design and Design Basis:

Relief System Design and Design Basis is one of the most commonly inspected components of Process Safety Information.

Relief System Design and Design Basis documentation will include at least the following information:

- Basis of the relief system design (code/standard used)
- Name of each piece of equipment required to be protected by relief valves
- Specifications for each piece of equipment required to be protected by relief valves (e.g. length and diameter of pressure vessels)
- Manufacturer / model of each relief valve
- Set pressure (psig) of each relief valve
- Capacity (scfm or lb/min) of each relief valve
- Analysis proving that the set pressure and capacity are adequate
- Diameter and length of discharge termination piping
- Analysis proving that the discharge termination piping does not adversely affect relief valve performance

In general, relief system analysis is performed using spreadsheets. For those desiring, a more robust analysis, the Industrial Refrigeration Consortium's Safety Relief Vent Tool allows a user to model their relief system and then to test the system for compliance with respect to various relief valve lifting scenarios.

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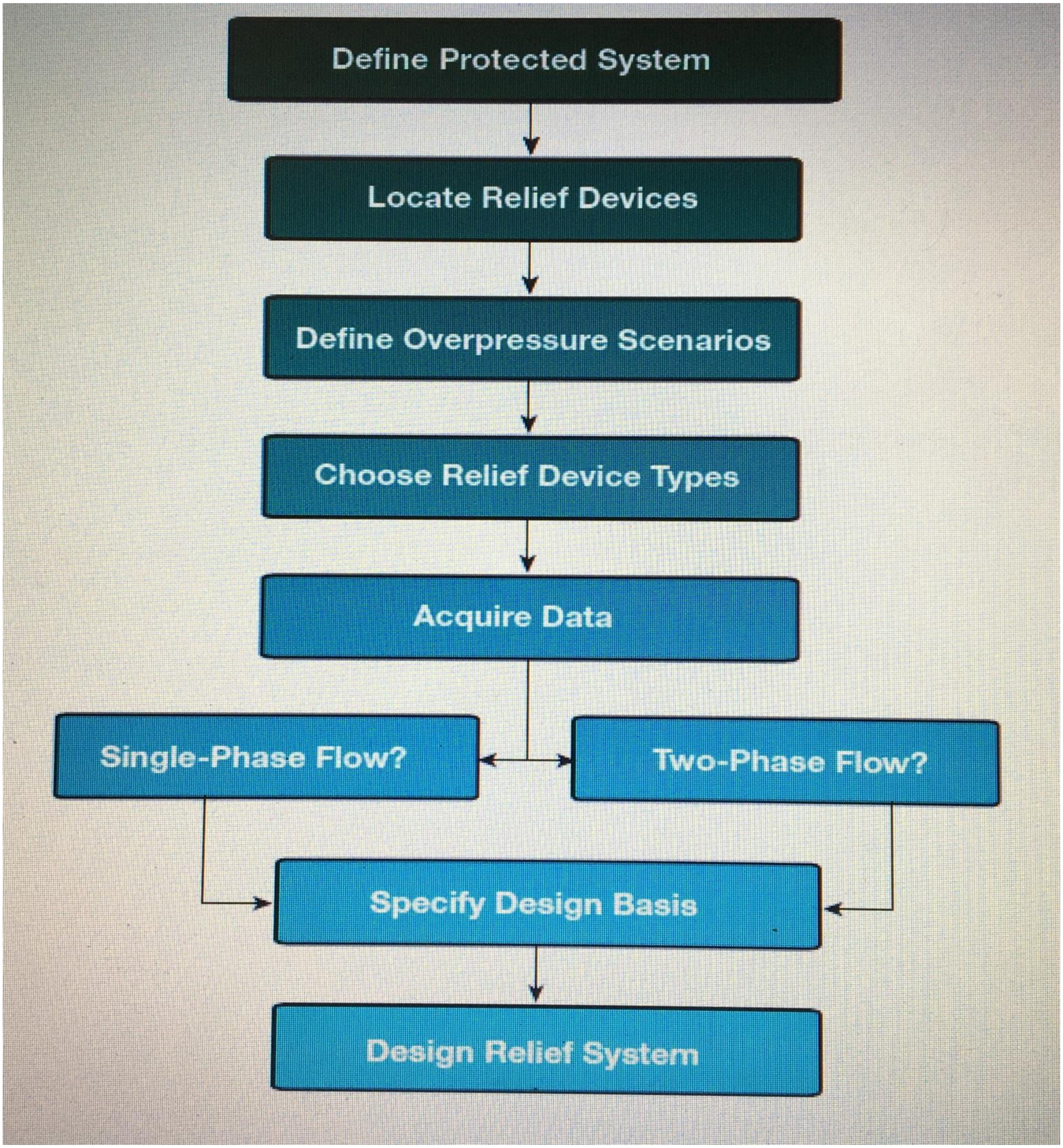
The steps involved in the relief – device sizing procedure are shown in this flowchart:



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Material and Energy Balances:

Material Balance -

A material balance is an assessment of the material (mass) input into a process compared to the material output. This is particularly important for processes that involve reactions in which one or more of the chemicals are consumed. In this type of process, a material balance must summarize the names and quantities of the chemicals that are entering the process compared to the names and quantities of the chemicals/products produced by (or leaving) the process.

Certain processes exist for the purpose of storing a hazardous chemical and then distributing that chemical as required. For example, a fertilizer distribution business having large anhydrous ammonia storage tank which is filled by a vendor for storage onsite. The business uses the large storage vessel to fill smaller shipping and/or application containers. In this example, the material balance would clearly document the rate at which ammonia is added to and removed from the process storage tank.

Other processes use hazardous chemicals in a closed loop system where the chemical is not added to or removed from the process. Ammonia refrigeration is an example of this type of process. Here, the system material balance becomes trivial since the overall quantity of ammonia in the process is not changing over time. Material balances can be performed on select components (e.g. compressors, condensers, evaporators, vessels, etc.), but this type of analysis is limited to the assumptions made and represent a hypothetical flow of ammonia through the process at a given load pattern.

Energy Balance –

Whereas a material balance compares the material input to output for a given process, an energy balance summarizes all energy input vs. energy output for a given process. In an ammonia refrigeration system, this is accomplished by examining the sources of ammonia energy input and output:

Energy Input

- **Compressor** – Heat of Compression
- **Evaporator** – Refrigeration Load

Energy Output

- **Condenser** – Heat of Rejection

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If the energy input from the evaporators and compressors exceeds the energy output of the condensers, the result will be poor system performance, high discharge pressure, or both.

Typically, both material and energy balances are analyzed and documented by an engineer familiar with the chemical process. Spreadsheets are often employed to assist with calculations associated with the analysis.

While discussing the major accidents that have occurred in the past in oil and gas industries or any of the major incidents, one question consistently comes to mind that what went wrong. In response to this question it can be clearly said that their occurrences are directly or indirectly connected to the issues concerning PSM systems.

The development of new techniques and technologies designed to improve Operational safety has evolved to meet the challenges of ever changing safety landscape of the companies and we TheSafetyMaster™ are continually growing and helping the world conquer these challenges over time.

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How can we help?

TSM TheSafetyMaster Pvt Ltd, is a young organization with a dedicated team of young, innovative, research driven & experienced safety professionals, who want to create value for their customers by providing ingenious Audit, Risk Assessment, Consulting and training services in the field of Safety. We can carry out Process Safety Management, Hazardous Area Classification, PHA, HAZOP study for batch or continuous chemical processes You can send your enquiry to info@thesafeymaster.com or visit www.thesafetymaster.com

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