Process Safety Management

Benefits of PSM
Flexible
Comprehensive
Adaptive
Creative

Designed to be the root elements of the Industrial process safety effort.
Process Hazards Analysis (PHA)

**Systematic evaluation** of the process hazards

What could **go wrong** (how often and how badly)

Evaluation of the **administrative and engineering** systems - process safety

**Group effort** - process operator involvement
Operating Procedures (OP)

- Instructions on how to operate the process
- All phases of operation
- Written
- Operator involvement is critical
- Reviewed annually
  - Ensure they reflect current and actual operating practice
- Includes safe work practices
  - Lockout, confined space entry, hot works permit, etc.
Compliance Audits

Plan-Act and DO…document

- Audit of compliance with the standard
- Every three years - Prepare a report of findings

How do I assess yearly program effectiveness?

- Who should do the audits?
- What should be audited?
- How is an audit conducted?
- What happens if the auditors find problems?

Execute, evaluate and correct as a routine and the audit will be a breeze!

Audit, Near Miss, Accident, Emergency Event
Commonly Observed RMP Deficiencies

- Deficient annual Inspections
- Mechanical Integrity (MI) deficiencies and 5-year MI audits
  - PRVs
  - Corrosion
- Inadequate ventilation
- Improper relief system design
- Inadequate component labeling
- Deficient SOPs

The same mistakes are repeated…

When the deficiencies are managed (prevented and mitigated), higher levels of safety and sustainability will occur.
IIAR, EPA, and OSHA formed Alliances to define the essentials to safe industrial refrigeration operations.

IIAR created industry standards and bulletins.

David Rule – President, IIAR
Eric M. Smith, P.E. – Vice President and Technical Director, IIAR
Gary Smith – President, ASTI
Scott Melton – ASTI Chief of Operations and Training
Inspection: What do you Ask?

- Location of SOPs, accessible?
- Emergency Action or Response SOP
- Are there any knocking or hammering noises?
- Relief valve replacement record
- Who has access to safety settings? Operating settings?
- Agency Reporting Records
- Do workers generally feel safe?
Common Citation Issues

- The “Palmer Letter” – use of trained personnel when isolating equipment
- The “torque” problem – use of torque wrenches only needed if a specialized procedure is required
- Emergency Eyewash/Safety Shower – needed when opening or potentially opening the system – not for inspection or other maintenance
- Evaporators and Surge Vessels – ice makers, water chillers etc. in non-machinery rooms – these are evaporators and require surge drums
Accidents Can Happen

IIAR Standards ● For the Safe and Efficient Use of Natural Refrigerants

QUESTION #7:
MOST COMMON CAUSES OF AMMONIA RELEASE

![Bar chart showing the most common causes of ammonia release](chart.png)
Accidents Can Happen

THE MOST OFTEN CAUSES OF RELEASE, RELATING TO QUESTION #7, CAN BE CATEGORIZED IN FOLLOWING:

- HUMAN ERROR
- MECHANICAL FAILURE
- OTHER (NATURAL DISASTER, FIRE, AMMONIA THEFT ect.)

- HUMAN ERROR: 60%
- MECHANICAL FAILURE: 37%
- OTHER: 3%

IIAR Standards • For the Safe and Efficient Use of Natural Refrigerants
Personnel Training
Emergency Responder Training
Regulatory Enforcement Training
“Engineered Solutions” are certainly a part of the solution
Standards Development
Higher pressure rated vessels - 250 psig
Smaller Ammonia charges (direct expansion, electric defrost, penthouse location for process evaporators)
Over pressure relief to lower pressure side (EPCS)
Physical Protection
Adherence to Standard Operating Procedures
Limit Access to Trained People
Secondary coolants in process and storage areas CO2, Glycol, Brine
The Refrigeration Cycle
Managing heat – removing it from where it’s not wanted to where it doesn’t matter (e.g. outside)
Five Key Refrigeration System Components

Evaporator

Compressor

Expansion Valve

Condenser

Receiver

Gas

Liquid

Block Diagram
IIAR Bulletin 114: Color Code

Liquid/Vapor Phase Change (room heat absorbed into the ammonia)
Phase and Pressure Changes

Low /High Side Transition Point:
Compressor receives low pressure vapor and delivers high pressure “hot” gas to the condenser.
Evaporator receives liquid and meters it into the Evaporator

Liquid/Vap or Phase Change (room heat absorbed into the ammonia)

Cold (Heat Absorbed)
How does this machinery room SCORE?

Natural ventilation!

Ammonia Machinery Room
Refrigeration Machinery Rooms

- Authorized Personnel Only
- Swing To Egress And 2-exits >1,000 sqft
- Make-up Air
- Refrigerant Vapor Alarm
- Seal Penetrations, e.g. pipeline penetrations
- Ordinary Ventilation And Emergency Exhaust
- Openings sealed (rated?)
- 1-hour Construction Per ASHRAE (Waived if fire-sprinklered)

Emergency Shutdown:
- Adequate ventilation
- Construction
- Access/Exit
- Virtual equipment protected
- Control of sources of ignition
Inspection: What do you Look For?

- Electrical Hazards (exposed wiring, panels removed)
- Piping system openings – plugged or capped
- Nameplates (or duplicates) legible on vessels
- Equipment and piping supports in good condition
Compressors receive low pressure vapor from the evaporator (even below 0 psi) to aid in the ammonia cooling effect.

Compressed hot gas travels to the condensers to be condensed to a liquid.
Inspection: What do you Look For?

- Generally neat Machinery Rooms
- Suction piping sloped, account for roof pitch
- No sags in piping
Compressor - Increases system pressure and “pushes” refrigerant through the circuit

- **Challenges**
  - Seal leaks
  - Pressure cut-outs
  - Solenoid and relief valves
  - Service and maintenance
  - Slugging and Hydraulic Shock (condensation in the check valve)

**Compressor Package**
Low side (suction) to High Pressure Hot Gas

**Diagram Details**
- Low side (suction)
- High side (hot gas)
- High side (receiver)
- Liquid returned from the Condenser
- King Valve (HP Liquid)
- HP Liquid control to downstream
Refrigeration Machinery Rooms

• Codes specify two levels of machinery room protection for refrigeration equipment
  • Basic machinery room
  • Special machinery room

• Except for small installations, such as listed, factory assembled units, ammonia refrigeration systems will require a special machinery room
Compressor

- Are compressors enclosed in an engine room?
  Ventilation adequate?
- Are PRV’s piped out of the engine room?
  Where to?
- Preventive Maintenance Program?
- Valves Labeled? Detailed SOP’s?
- Moving parts are guarded
- Unobstructed access for both normal and emergency tasks
Common Citation Issues

- Rooms that AREN’T machinery rooms
- Ice on Valve Stations and bare pipes
Common Citation Issues

- NDT for systems not showing problems
- Interior Inspection of Vessels – not needed, poses hazard
- Vibration analysis on Reciprocating Compressors
- Relief header routing
- Ventilation capacity – new vs. old
Compressor Concerns:
Maintain safety cut-outs and system readiness so all process control opportunities work!

Seal leaks are common

What types of emergency releases would require shutdown of the compressor?
Gas Emergency Shutdown

Emergency Shutdown Operations – Compressor shutdown is NOT always the first move
Engage SIMPLE - Refer to 30-Minute Plan

Concerns:
When the compressors are adding pressure to the release point…shut them down.
If compressors can be used to move liquid from the leak site, or reduce system pressure at the release site, leave them on.
Inspection: What do you Look For?

- Emergency Shut-off and Ventilation Switches
- Eyewash/Safety showers – do these work?
- Self-closing valves on oil pots
- King Valves (if used) or other valves used in emergencies – labeled, accessible.
Survive a maintenance accident!

- Respirators and full skin coverage – used during maintenance and emergency action plan “critical tasks”
Lower Temperature/Pressure

• Like any liquefied compressed gas, the release of ammonia gas cools the remaining liquid and lowers the system pressure.
• When the system pressure drops to the boiling point, the vapor pressure will try to reach 0 psig (IF we avoid adding new heat).
• Dramatically reducing the evaporation rate allows the liquid to essentially sit in a much safer state.

Pressure Management
Objective:
Vent the vapor pressure and/or reduce heat absorption to lower liquid temperature and the vaporization rate.
High Pressure - Release Prevention Steps

Concerns:
How might the compressor mitigate a refrigerant release?
Do we ALWAYS shut them down during a high side release?
Emergency Pressure Control System

- Automatic Emergency Pressure Control Systems are now required in lieu of emergency control boxes.
- Automatic hi-low crossover valve
- Redundant overpressure cutouts
- Ammonia diffusers still exist but they are not required by national standards
System will sit at -28 °F and 0 psi

Initial fill

After 2-hours plus manually draining 2 cups
Pressure Relief Valve Systems

Preferred Methods:

- Atmosphere

Alternates:

- Flaring System
  - Needs fuel source, testing
- Diffusion Tank
  - Filled with water, problematic

Other Notes:

- New Standard Method for Atmospheric Discharge
  - “Vertically Upward”
- Relief Valve Replacement
  - Every 5 years

Note: replacement every five years is the general rule but there are two other options in IIAR Bulletin 110, 6.6.3

Pressure Relieve Valve (PRV):

- Dual PRV’s
- Calibrated or replaced every five years
- Design to relieve at the upper end of the design envelope.
Pressure Relief Valves (PRV’s)
So what do you think?

Pictures:
Capacity to prevent back-flow (header size)?
Control valve to switch PRVs?
Location/size of discharge header?
Corrosion and serviceability?
Water diffusion tanks, pros/cons:
Do you really want your last line of defense before a release from the system to be located 30 feet under water?
- Corrosion of RVs
- Ice Plugs
- Difficult to Maintain
- Hazardous Material Leftover
- But effective and should be considered for some installations
Condensers to HP Receiver

Condensers

Receive high pressure vapor from the compressor at 85° to 115° F, equates to 150 to 250 psi.

Hot gas condenses to HP-liquid as the water spray suddenly cools the hot gas.
Condenser Emergency Shutdown

Hot gas will be vented to the atmosphere; quickly moves to cooler air.

High pressure liquid leak; powerful aerosol that will evaporate and cool.
Condenser Supports
Condenser
Cools the high pressure hot gas causing \(\text{NH}_3\) condensation to liquid

- Usually on roof...fall protection(?)
- Confined Space?
- Do PRV’s vent near condensers?
- Portable-eyewash/shower?
HP Receiver to Expansion Valve

Receivers
Receive high pressure liquid from the condenser.
HP-liquid release will cause an aerosol that can quickly increase in concentration to threaten as a LFL (Lower Flammable Limit concentration).
King Valve should be readily accessible and identified with a prominent sign (IIAR-109, 4.10.3) Must be able to reach in an Emergency.
There are several different components that may be connected between the King Valve and evaporator. The additional components are added to improve performance, safety mitigations, to increase system capacity.

- Ammonia accumulator vessel
- Flash cooling vessel
- Ammonia pump
- Oil pots
- Recirculator vessel
- Surge drums
- SOP’s
- Labeling
- Preventive Maintenance Program?
- Pumps are protected from hydrostatic overpressure with a relief device.
- All exposed rotating parts of the pump are guarded.
- Liquid refrigerant pumps are equipped with low liquid level pump cut-out or differential pressure sensor.
High & Low Side Emergency Shutdown

A release conditions occurring within the system can be improved with the use of the compressor – high side problems will reduce in pressure when suction pressures are low (5 psig)

Low side problems can be controlled with the compressor by pumping-down a leaking evaporator and storing the liquid in the HP Receiver or other safe storage vessel within the system.
Evaporator

➢ Are there ammonia detectors in the room(?) What are they set at?
➢ Valves and lines labeled?
➢ Level gauges protected from impact?
➢ Valves Accessible(?)

Emergency Shutdown: Pump down and address the risks of automated hot defrost
Evaporators and Expansion Valves

1989 Loma Prieta Earthquake
7.1 magnitude

Several evaporators not braced for the horizontal movement failed. We contained the NH3 in the cold room for several days with no downwind threat.

The picture shows a fire sprinkler pipeline that smashed against the evaporator unit.

Stored product fell off the racks but no refrigeration system fails occur.
Valves

Automatic or Manual
If Manual can they be reached?
Must be part of MI program
Valve tags for critical shutdown valves
Inadequately developed/implemented

- Equipment not compliant with RAGAGEP
- Mechanical integrity procedures
- P&IDs
- Operating procedures
- PHA findings not resolved
- Emergency response and planning
- External Corrosion
- Inadequate Piping Support
- Ice Buildup on Pipes
- MI Program for Piping
- Labeling on Pipes
This insulation damage calls for vessel inspection and needs to be repaired or replaced.
Mechanical Integrity:

Preventative maintenance program:

- Detect and control corrosion,
- Deteriorated vapor barriers, ice buildup, and pipe hammering,
- Inspect integrity of equipment/pipe supports.
- Piping system openings (except relief header) plugged or capped, or valve is locked.
Can This Valve be Turned?
Sagging Ammonia Pipe
Inspection: What do you Look For?

- Iced or excessively moldy insulation
- Excessive Ice accumulation on/near evaporators
Evaporator?
Pipe Supported by Another Pipe
Corrosion control???