SAFE OPERATION OF AMMONIA REFRIGERATION PLANT

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HISTORY & EVOLUTION OF INDUSTRIAL AMMONIA REFRIGERATION

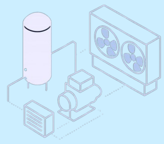
1 **1850s**
Ferdinand Carré patents the first absorption refrigeration system using ammonia and water.

2 **Early 1900s**
NH3 becomes the dominant refrigerant in industrial cold storage and food processing plants.

3 **1970s–1990s**
Global standards emerge as plant scale increases and safety regulations tighten.

4 **2000s–Present**
NH3 reaffirmed as the preferred industrial refrigerant due to zero ODP/GWP and superior efficiency.

Today, the International Institute of Ammonia Refrigeration sets the global benchmark for design, operation, and safety of NH3 systems, with guidelines adopted across food, pharmaceutical, and chemical industries worldwide.



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WHY INDUSTRIES PREFER AMMONIA (NH3)

High COP
Ammonia has one of the highest Coefficients of Performance of any refrigerant, reducing energy costs significantly.

Excellent Heat Transfer
Superior thermal properties reduce heat exchanger size and improve overall system efficiency.

Zero ODP & GWP
NH3 does not deplete the ozone layer and has zero global warming potential — fully compliant with all environmental protocols.

Long Equipment Life
Well-maintained NH3 systems routinely operate for 25–40 years, delivering outstanding return on investment.

Refrigerant Comparison

Property	NH3	CO2	R134a	R404A
ODP	0	0	0	0
GWP	0	1	1,430	3,922
COP	★★★	★★	★★	★
Toxicity	Yes	No	No	No
Cost	Low	Medium	High	High

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HEALTH HAZARDS, EXPOSURE LIMITS & FIRST AID

Exposure Limits

Standard	Limit
Threshold Limit Value	25 ppm
Short-Term Exposure Limit	35 ppm (15 min)
Immediately Dangerous to Health	300 ppm

Symptoms by Level

- **25–50 ppm:** Mild eye and nose irritation
- **50–100 ppm:** Headache, nausea, tearing
- **300 ppm:** Severe respiratory distress (IDLH)
- **>500 ppm:** Pulmonary oedema

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HEALTH HAZARDS, EXPOSURE LIMITS & FIRST AID

First Aid — By Route of Exposure

- **Eye Contact**
  Flush with large amounts of water for at least 15–20 minutes. Seek immediate medical attention. Do not rub eyes.
- **Skin Contact**
  Remove contaminated clothing. Wash skin thoroughly with water for 15 minutes. Treat for chemical burns if blistering occurs.
- **Inhalation**
  Move victim to fresh air immediately. Administer oxygen if available. Call emergency services. Do not re-enter without SCBA.

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INDUSTRIAL APPLICATIONS OF AMMONIA REFRIGERATION

Cold Storage & Food
Large-scale warehouses, blast freezers, and food processing facilities rely on NH3 for precise temperature control from –40 °C to +10 °C.

Ice Plants
Block ice, flake ice, and tube ice plants use NH3 evaporators for efficient, high-capacity ice production in fishing and food industries.

Dairy & Beverage
Milk chilling, cream separation, and beverage carbonation all require consistent, hygienic refrigeration that NH3 systems reliably provide.

Pharmaceutical & Chemical
Precise temperature-controlled environments for API storage, chemical reactors, and fermentation processes are maintained using NH3 systems.

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PLANT SAFETY PHILOSOPHY & APPLICABLE STANDARDS

Layers of Protection

1. Emergency Response
2. Safety Instrumented Systems
3. Alarms & Monitoring
4. Mechanical Integrity
5. Process Design & Safe Operation

Key Applicable Standards

OSHA PSM 29 CFR 1910.119
Process Safety Management for highly hazardous chemicals including NH3 (>10,000 lb threshold).

ASME B31.5 / API 510
Refrigeration piping systems and pressure vessel inspection codes.

ISO 5149 / ISO 817
International standards for mechanical refrigerating systems and refrigerant classification.

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TRAINING OBJECTIVES

By the end of this programme, everyone will have the knowledge and confidence to run the plant safely, respond correctly under pressure, and protect both people and equipment.

1. **Operate Safely**
Run all plant systems within design limits and approved procedures.

2. **Pre-Startup Checks**
Complete pre-startup inspections before every start to confirm plant readiness.

3. **Monitor Parameters**
Track critical operating parameters every hour and detect deviations early.

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TRAINING OBJECTIVES

4. **Identify Hazards**
Recognise unsafe conditions and potential hazards before they escalate.

5. **Respond to Alarms**
Follow the correct sequence of actions for alarms and automatic trips.

6. **Execute Emergency Procedures**
Implement emergency shutdown and ammonia leak response without hesitation.

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SAFETY PHILOSOPHY: EVERY ONE MUST FOLLOW

Safety is not a department — it is an attitude. These six commitments form the foundation of safe operation at every ammonia refrigeration plant.

Safety First
Production never takes priority over personnel safety.

Stop Unsafe Work
Any operator has the authority and duty to stop work they believe is unsafe.

Report Near Misses
Every near miss reported is an accident prevented in the future.

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SAFETY PHILOSOPHY: EVERY ONE MUST FOLLOW

No Shortcuts
Every step in every procedure exists for a reason — skip none.

Follow SOPs
Standard Operating Procedures are not suggestions — they are requirements.

Use PPE
Personal Protective Equipment must be worn at all times in hazardous areas.

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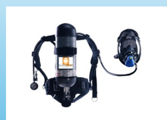
SAFETY EQUIPMENT'S SHOULD BE AVAILABLE – PERSONAL PROTECTION EQUIPMENT'S (PPE)



Gas Mask with oxygen cylinder

Gas Mask with canister

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Eye Goggles

Ammonia Suit

Eye Shower and wash

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PRE-STARTUP SAFETY CHECKLIST

This checklist must be completed and signed off before any start-up attempt. A missed item before start-up is far easier to address than an incident during operation.

Mechanical & Process Readiness

- All work permits closed and returned
- Maintenance work fully completed
- All guards installed and secure
- Oil level confirmed normal
- Cooling water available and flowing
- Plant confirmed ammonia leak-free
- All valves in correct positions

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PRE-STARTUP SAFETY CHECKLIST

Electrical, Safety & Site Readiness

- Electrical systems healthy — no faults showing
- Emergency exits clear and unobstructed
- Gas detectors powered and functional
- PLC/HMI showing no active alarms
- PPE worn by all personnel in the area
- SCBA sets charged and accessible
- Shift supervisor informed and authorised start

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SAFE COMPRESSOR START-UP SEQUENCE

Follow this sequence every time, without exception. Skipping steps — even under time pressure — risks compressor damage, ammonia release, or personal injury.

1 **Check Oil Level**
Confirm oil level is within normal range on the sight glass.

2 **Start Oil Pump**
Pre-lube bearings and confirm oil pressure builds to minimum before proceeding.

3 **Open Required Valves**
Open suction, discharge, and cooling valves as per the valve list.

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SAFE COMPRESSOR START-UP SEQUENCE

4 **Start Compressor**
Engage start command only after all pre-conditions are satisfied.

5 **Monitor All Parameters**
Observe oil pressure, suction pressure, discharge pressure, motor current, and vibration simultaneously during the first five minutes.

6 **Record Readings**
Log all start-up values in the shift log immediately after stable operation is confirme

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SAFE PLANT OPERATION: WHAT OPERATORS MUST MONITOR

Continuous monitoring is the core duty of every shift operator. Detecting a deviation early — before an alarm activates — is the mark of an experienced, safety-conscious operator.

Pressures

- Suction Pressure
- Discharge Pressure
- Condenser Pressure
- Oil Pressure

Electrical & Mechanical

- Motor Current (Amps)
- Compressor Vibration
- Unusual Noise

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SAFE PLANT OPERATION: WHAT OPERATORS MUST MONITOR

Temperatures
- Oil Temperature
- Discharge Gas Temperature
- Evaporator Temperature
- Cooling Water Temperature

Safety Systems
- Ammonia Leak Detector Reading
- Receiver Liquid Level
- Active PLC Alarms

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SAFE COMPRESSOR & OIL SYSTEM OPERATION

Always Monitor
- Oil pressure above minimum operating value at all times
- Discharge temperature — stable and within normal range
- Motor current — stable, no sudden spikes
- No abnormal vibration or unusual mechanical noise
- No oil leakage from seals, flanges, or fittings

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SAFE COMPRESSOR & OIL SYSTEM OPERATION

Daily Oil System Checks
- Oil level on sight glass
- Oil filter differential pressure (DP)
- Oil cooler performance
- Oil temperature within specification

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SAFE COMPRESSOR & OIL SYSTEM OPERATION

❌ **Never Do This**
- Start compressor with suction valve closed
- Run compressor with low or uncertain oil level
- Bypass, defeat, or ignore trip functions
- Continue running with abnormal vibration
- Ignore a rising oil filter DP — change the filter

Poor oil management causes bearing failure, rotor damage, and compressor seizure — all costly and avoidable.

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CONDENSER, RECEIVER & PUMP SAFE OPERATION

These three systems are critical links in the refrigeration cycle. Each requires specific monitoring disciplines to prevent high-pressure events, liquid carryover, and pump damage.

Condenser
- Confirm cooling water flow or fan operation before every shift
- Monitor condensing pressure — rising pressure signals fouling or water loss
- Check approach temperature to detect scaling or non-condensables
- Respond to high-pressure alarms immediately
- Follow the routine cleaning schedule without delay

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CONDENSER, RECEIVER & PUMP SAFE OPERATION

Receiver
- Check liquid level — never allow overfilling
- Monitor receiver pressure against normal operating range
- Inspect safety valve and level indicator visually each shift
- Check for abnormal frost patterns that indicate a leak
- Report any leakage from fittings or connections immediately

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CONDENSER, RECEIVER & PUMP SAFE OPERATION

Pumps

- Confirm correct rotation direction after any maintenance
- Check mechanical seal for leakage during every round
- Monitor bearing temperature — elevated temp signals inadequate lubrication
- Listen for unusual noise or vibration
- **Never run pumps dry** — cavitation causes rapid seal and bearing damage

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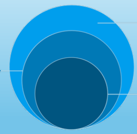
PLANT SAFETY LAYERS: DEFENCE IN DEPTH

No single safety device protects the plant. Safety is achieved through multiple independent layers — each one acting as a backstop if the layer above it fails. Operators are the first and most important layer.



When an operator is alert and follows procedures, downstream safety systems rarely need to activate. Bypassing or ignoring any layer eliminates that protection for everyone on site.

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ALARM RESPONSE & SHIFT MONITORING

Every Hour — Record These Values

- Suction & discharge pressure
- Condensing pressure
- Oil pressure & temperature
- Motor current (Amps)
- Receiver liquid level
- Ambient temperature
- Leak detector status (ppm reading)

Trend analysis across shifts reveals developing faults before alarms activate. A rising oil temperature over three consecutive readings is a warning — not just a number.

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ALARM RESPONSE & SHIFT MONITORING

Alarm Response Protocol

Identify the alarm
Read the HMI alarm description carefully — do not guess.

Verify the instrument
Confirm the reading is genuine, not a sensor fault.

Inspect the equipment
Go to site — look, listen, and smell for abnormalities.

Take corrective action
Follow the relevant SOP. Do not improvise.

Inform supervisor & log event
Every alarm must be recorded with the time, cause, and action taken.

⊗Never acknowledge and ignore an alarm. Every alarm is a symptom of a real condition.

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SAFETY – ELECTRICAL

- Almost 90% of fire accidents are mainly due to electrical abnormalities
- Standard codes to be followed while selecting electrical equipment's
- Electrical PPE should be available such as Rubber mats, Gloves, Testers, safety shoes etc.

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AMMONIA LEAK DETECTION SYSTEM

There are two leaks in NH3 system. Vapor Leaks & Liquid Leaks.

Vapor leaks can occur in high-side components (piping, valves, compressors, flanges, etc.) and low-side components operating above atmospheric pressure.

Liquid ammonia leaks are from the mainly low-side components such as NH3 pumps.

Ammonia detectors are recommended for personnel and property protection.

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OPERATOR'S GOLDEN RULES

These ten rules govern every decision an operator makes on shift. They are non-negotiable — no exception, no excuse, no override.

1 **Safety before production**
2 **Never bypass interlocks**
3 **Verify before starting**
4 **Respond immediately to alarms**
5 **Record all abnormalities**

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OPERATOR'S GOLDEN RULES

6 **Stop work if unsafe**
7 **Report all leaks — even small ones**
8 **Follow SOPs at all times**
9 **Use PPE at all times in hazardous areas**
10 **Ask if unsure — never assume**

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INTRODUCTION TO HAZOP

What Is HAZOP?

Hazard and Operability Study (HAZOP) is a **systematic and structured risk assessment technique** used to identify potential hazards, operational problems, and deviations from the intended design before and during plant operation.

It helps ensure that the plant operates **safely, efficiently, and reliably** by identifying risks and implementing appropriate safeguards.

What HAZOP Does

- Identifies credible hazards in every part of the process
- Identifies operability problems that cause downtime or unsafe conditions
- Evaluates whether existing safeguards are adequate
- Generates specific, trackable recommendations for improvement

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INTRODUCTION TO HAZOP

Why It Matters

- Prevents ammonia releases and accidents before they occur
- Improves plant reliability and reduces unplanned downtime
- Enhances emergency preparedness across the team
- Meets regulatory and corporate process safety requirements
- Captures and preserves operating experience from the plant floor

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THE HAZOP PROCESS & TEAM

Who Participates?

→ **HAZOP Leader**
Facilitates the study — independent and trained in HAZOP methodology.

→ **Process & Operations Engineers**
Provide technical and practical plant knowledge.

→ **Maintenance, Instrumentation & Electrical**
Assess equipment reliability and control system safeguards.

→ **HSE Representative**
Ensures regulatory compliance and risk assessment rigour.

→ **Operations Representative**
The operator's voice — critical for realistic cause-and-consequence analysis.

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THE HAZOP PROCESS & TEAM

Required Documents

- PFD — Process Flow Diagram
- P&ID — Piping & Instrumentation Diagram
- Equipment Datasheets
- Cause & Effect Diagram
- Control Philosophy
- Alarm & Trip List
- Operating Procedures
- Emergency Procedures

ⓘ Without current, accurate P&IDs, a HAZOP cannot be completed reliably. Always verify documents are as-built before the study begins.

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HAZOP METHODOLOGY: GUIDE WORDS & PARAMETERS

The HAZOP team works node by node through the plant, applying standard guide words to each process parameter to generate deviations — then asking "what causes this?" and "what happens as a result?"

Parameters Reviewed

Pressure	Temperature
Flow	Level
Composition	Phase
Speed	Power

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HAZOP METHODOLOGY: GUIDE WORDS & PARAMETERS

Guide Words & Examples

Guide Word	Meaning	Example Deviation
No	None of the intent	No Flow
More	Quantitative increase	High Pressure
Less	Quantitative decrease	Low Flow
Reverse	Opposite direction	Reverse Flow
As Well As	Additional component	Contamination
Other Than	Complete substitution	Wrong Material
Part Of	Partial intent achieved	Partial Flow

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HAZOP CASE STUDIES: COMPRESSOR, CONDENSER & RECEIVER

These worked examples show how the HAZOP process turns a simple deviation into a structured action. Operators should recognise every one of these scenarios from their own experience on the plant floor.

Compressor — Low Suction Pressure
Causes: Low refrigerant charge · Blocked suction filter · Closed suction valve
Consequences: Compressor trip · Loss of cooling · Equipment damage
Safeguards: Low-pressure alarm · Automatic trip · Routine inspection

Receiver — High Liquid Level
Causes: Expansion valve failure · Pump failure · Operator error on liquid management
Consequences: Liquid carryover to compressor · Compressor damage · Relief valve operation
Safeguards: Level transmitter · High-level alarm · High-high automatic trip

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HAZOP CASE STUDIES: COMPRESSOR, CONDENSER & RECEIVER

Condenser — High Condensing Pressure
Causes: Cooling water failure · Dirty condenser tubes · Fan failure · Non-condensable gases
Consequences: High-pressure trip · Relief valve lifting · Production loss
Recommendations: Regular cleaning · Fan PM schedule · Air purging procedure

Evaporator — Low Temperature
Causes: Incorrect control setpoint · Low product load · Expansion valve malfunction
Consequences: Product freezing · Coil icing · Reduced system efficiency
Recommendations: Verify control settings · Inspect valves · Monitor temperatures every hour

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RISK ASSESSMENT, SAFEGUARDS & ACTION TRACKING

Existing Plant Safeguards

- **Pressure Relief Valves**
  Last line of defence against overpressure — must be inspected and tested on schedule.
- **Gas Detectors & ESD**
  Continuous monitoring triggers automatic plant shutdown on confirmed ammonia release.
- **PLC Interlocks & Trips**
  High-pressure, low-oil-pressure, and temperature trips protect equipment automatically.
- **Preventive Maintenance & Training**
  The most cost-effective safeguards — scheduled maintenance prevents unplanned failures.

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RISK ASSESSMENT, SAFEGUARDS & ACTION TRACKING

HAZOP Recommendation Tracking

Every HAZOP recommendation must be tracked to closure. No recommendation should be left open without a documented status update.

Field	Required
Recommendation type	Engineering / Procedural / Training
Action owner	Named individual responsible
Due date	Agreed completion date
Status	Open / In Progress / Closed
Verification	Signed off by HAZOP leader

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CASE STUDY: AMMONIA LEAK FROM COMPRESSOR SHAFT SEAL

This is a real-world scenario. Work through it as a team — your experience and instincts as an operator are the most valuable input in this discussion.

Initial Indication
Operator notices sharp ammonia odour during routi rounds

Root Cause
Mechanical shaft seal has deteriorated due to wear and age. Seal was not included in the last PM

Immediate Actions
Alarm raised · Personnel evacuated from the area · SCBA donned · Isolation valve closed · Emergency team notified ·

Lessons Learned
Shaft seal inspection added to PM schedule. Gas detector sensitivity threshold reviewed. Operator nose-detection credited as first warning. SOPs

Discussion prompt: Have you ever detected a problem before an alarm activated? What did you do — and what would you do differently today?

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KEY TAKEAWAYS & NEXT STEPS

Safe operation of an ammonia refrigeration plant is not complicated — but it requires discipline, vigilance, and respect for the hazards involved. Every operator who completes this training carries a responsibility to apply these principles every shift, every day.

Operate by the Rules
Follow SOPs, complete checklists, record readings, and never by

Monitor Continuously
Hourly readings and trend analysis are how experienced operators catch faults before they become emergencies.

Respond — Don't React
Know your alarm response and emergency procedures so well that you act calmly and correctly under pressure.

Contribute to HAZOP
Your operational experience is invaluable. Report near misses, participate in HAZOP reviews, and verify that actions are closed out.

Apply Today
Report Near-Miss
Join Safety Review

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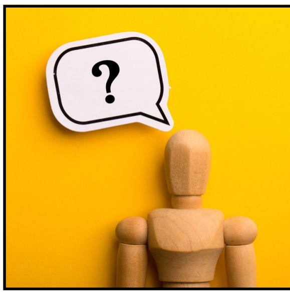

Thank You

Questions & Discussion

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