

## Safety in Refrigeration Plants and Cold Storages

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Refrigerants used in refrigerating plants become hazardous only in the event of leakage or of bursting or explosion as a result of internal over pressure. Problems resulting from mechanical failure of pressurised components or pipes, excessive temperatures, fire or explosion, corrosion, erosion and vibration are common causes of reduced component strength, work hardening and metal fatigue. Although freon refrigerants are non-flammable, ammonia is preferred to freon for reasons of economy. Ammonia leaks in refrigeration systems are common and ammonia is flammable in the range 15% to 28% by volume in air. With the advent of newer materials for construction and insulation, use of better methods of material handling and increased emphasis on energy conservation, great care is going into the planning, designing and construction of cold storages. These new systems and materials, while improving the operating efficiency, also increase the problems of fire safety in cold storages.

**Key words :** Refrigeration, cold storages, plant safety, ammonia, freon

A cold storage plant is an insulated building with its refrigerating equipment designed to receive and store fish, meat, etc., at low temperature, by the use of refrigeration. The degree of refrigeration required depends on the products being stored, the functional area of the cold storage, etc. Frozen fish and seafood are stored at  $-18^{\circ}\text{C}$ . Most of the seafood processing plants in India are using ammonia as refrigerant for reasons of economy and availability. Ammonia is preferred to freon due to the environmental hazards such as ozone layer depletion caused by the freon group of refrigerants. The possibility of leakage of ammonia is very high in the refrigeration plant. This paper deals with the safe methods of reducing ammonia leakage, fire safety and various hazards related to refrigeration /cold storages, based on guidelines provided in BIS (1967, 1968, 1974), Loader (1976), NFPA (1978) and Anon (1983).

### **Toxicity hazards**

Majority of refrigerants can burn the skin, or more importantly, eye tissue on contact at low temperatures. At high temperatures, for instance

in contact with a naked flame or surface at high temperature, CFCs produce phosgene which is lethal at a concentration of 0.02-0.05% by volume. All CFCs are dangerous after 2 h of inhalation at concentrations of 10-20% by volume. As CFCs have no smell, they are difficult to detect, and in the event of a leak, concentrations can increase up to danger levels before any one become aware of the leakage.

As leakages are difficult to detect, an additive (about 10%) can be put in the refrigerant, which colours the leakage points red and is very obvious except where the pipe is covered with insulation. This dye actually goes into solution in the oil. When the refrigerant passes through the leak the red oil carried with it indicates the location of the leakage. The dye can be used with R12 and R22 and is stable up to 370°C. However, most manufacturers of hermetic compressors forbid its use in their compressors. Another method is to introduce a solvent, which responds to ultraviolet radiation in the event of a leak. In order to reduce the emission of CFCs into the atmosphere to an acceptable level, it is necessary that only competent qualified staff install, maintain and repair CFC plants, and that regular inspection and preventative maintenance are carried out.

Ammonia is very toxic and has an unpleasant smell. Contact with food product is disastrous. The unpleasant smell, however, provides a good warning signal. A concentration as low as 5 ppm is detectable by smell. Exposure to a concentration of 1700 ppm ammonia for half an hour is lethal, at 3500 ppm very dangerous and at 5000 ppm it is lethal. The threshold limit value (TLV – maximum concentration allowable for an eight-hour-working shift) is 25 ppm. Concentrations around 200 ppm are tolerable, with irritation of the mucous membrane or irritation of the eyes. In the range 400-700 ppm it produces additional eye, nose and throat problems, which are not serious so long as exposure is less than one hour. Pure ammonia does not burn, but a mixture of ammonia and air at a concentration of 15-28% is somewhat explosive when ignited by a spark. The ignition temperature is 630°C.

### **Hazards in refrigeration plants and their prevention**

Apart from accident risks arising from such causes as unguarded belt drives or fans, the hazards of refrigerating plants include intrinsically those due to the cold produced, as well as the possibility of leakage or bursting

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of containers, accompanied by loss of a possibly toxic refrigerant. Refrigerants may be divided into three classes, depending on the health risk and/or the fire or explosion hazard involved.

- i) Non-flammable refrigerants, with nil or very low toxicity.
- ii) Refrigerants with toxic and corrosive effects, or when, mixed with air, are flammable or explosive, but only within a narrow range of concentrations (lowest flammable concentration)
- iii) Refrigerants which, when mixed with air, are highly flammable and explosive (lowest flammable concentration below 3.5% by volume).

The first class includes in particular the fluorinated hydrocarbons sometimes referred to as 'safe' refrigerants. These are dangerous only to the extent that they may replace the oxygen in the air and thereby causing asphyxiation. In the presence of a naked flame or very hot surface, these may give off highly toxic gases such as hydrochloric acid gas, chlorine and phosgene. However, these substances emit a warning odour, which becomes noticeable well before a harmful concentration is reached. The present trend is towards universal use of the relatively hazard-free refrigerants in the first class, refrigerants in the second and third classes being used only in exceptional circumstances.

Of the refrigerants in the second class, only ammonia is still used to any great extent, the other substances in this class, such as methyl chloride, sulphur dioxide and ethyl chloride, are being replaced by refrigerants in the first group. Because it is economical to use, ammonia is still employed in absorption plants and medium or large-size compression plants. Owing to its high toxicity, however, the use of ammonia is forbidden in air-conditioning equipment used to promote personal comfort or for cooling public or similar premises. As ammonia has a pungent smell, small leaks are soon noticed and can usually be stopped before undesirable effects (including corrosion) arise. This smell is already apparent at atmospheric concentrations as low as 0.005% while a concentration of only 0.035% suffices to cause serious symptoms. Ammonia is flammable only at narrow range of high concentrations, outside which, there is no danger of flame propagation. Consequently precautions against explosion may be relaxed to some extent.

Table 1. Safety data sheet on ammonia

<b>Physical and chemical data</b>	
Chemical Name	: Ammonia
Synonyms	: Liquid Ammonia, Ammonia Gas, Ammonia Anhydrous
Chemical classification	: Inorganic compound
Identification	: Non-flammable gas, Class 2
Physical State	: Liquefied Compressed Gas
Appearance	: Colourless
Odour	: Strong Pungent Powder
Boiling Point	: -33.4°C
Melting/Freezing Pt.	: -77.77°C
Vapour density	: 0.6
Solubility in water, @ 30°C	: Very soluble
<b>Fire and explosion hazard data</b>	
Explosive limit	: Ammonia and air Lower : 15% Higher : 28%
Auto ignition temperature	: 651°C
Explosion sensitivity to impact	: Stable
Hazardous combustion products	: Emits toxic fumes of NH <sub>3</sub>
Hazardous polymerisation	: Does not occur
Combustible liquid	: Yes
Explosive material	: No
Corrosive material	: No
Flammable material	: No
Oxidiser	: No
<b>Reactivity data</b>	
Chemical stability	: Stable
Incompatibility with other material	: Strong oxidizers, calcium hypochlorite, mercury, silver, halogens, acetaldehyde, acrolein
Reactivity	: Reacts with silver chloride, chlorine, bromine, iodine, heavy metals and their compounds, incandescent reaction when heated with calcium.
Hazardous Reaction products	: Reacts with silver chloride, silver nitrate and silver oxide, form explosive silver nitride
<b>Health hazard data</b>	
Routes of entry	: Inhalation, skin or eyes
Effects of exposure	: 700 ppm causes eye irritation and permanent injury may result if prompt remedial measures are not taken; 5000 ppm may cause death; Contact of the liquid with skin freezes the tissues and causes the caustic burns.
Emergency treatment	: Inhalation: Remove the victim to fresh air and provide artificial respiration or oxygen, if needed. Skin and eyes: Wash the affected area with plenty of water for 15 min. Seek medical aid.

Refrigerants in the third class, such as propane, butane, ethane and ethylene, should be used only in plants, which are kept under strict supervision, as in the chemical industry. The hazards posed by refrigerants commonly relate to their pressure, temperature and chemical characteristics. Problems can result from mechanical failure of pressurized components or pipes, excessive temperatures, fire or explosion. Corrosion, erosion and vibration are common causes of reduced component strength and metal fatigue.

Exposure to refrigerants can cause personal injury as a result of:

- i) Toxic effects from refrigerant vapour or from decomposition products resulting from contact with flames or hot surface;
- ii) Suffocation resulting from refrigerants escaping into inadequately ventilated spaces;
- iii) Narcotic and cardiac sensation effects;
- iv) Fire resulting from or intensified by burning of escaping refrigerants (or lubricant);
- v) Freezing of tissue by contact with refrigerant liquid or clothing saturated by refrigerant liquid;
- vi) Solvent action of liquid refrigerant on the skin;
- vii) Corrosive attack on sensitive tissues such as the eyes;
- viii) Shock, resulting from sudden or unexpected noise or sight; and
- ix) Impact, resulting from component or pipe work failures.

The maximum charge of refrigerant is restricted according to the room volume, occupation and maximum allowable concentration. There is no restriction if a purpose built plant room is used. Here, the limiting factor will be the capacity of the ventilation system, which must be designed to permit safe evacuation from the room in the event of a major release.

### **Pressure resistance**

Refrigerants used in refrigerating plants become hazardous only in the event of leakage, or of bursting or explosion as a result of internal overpressure. Such plants must therefore be designed so that every part will easily withstand the highest permissible working pressure of the installation. The relationship between the pressure and temperature of refrigerants is

governed by well-known physical laws and the plant specifications are laid down accordingly. National regulations usually specify either the temperatures or the pressures, a distinction being made between the high-pressure and low-pressure sections of the plant. Higher temperatures should be chosen if, for example, unprotected parts are exposed to sun, or when the temperature of cooling water or cooling air is higher than normal or when dust containing refrigerant must be thawed out by heating or washed with hot water. However, all containers must be built and tested to withstand an excess pressure of at least one atmosphere.

Pressure in refrigerating plants is caused by external heat (especially when the plant is not working) as well as by the action of the compressor. If the temperature specified for the permissible working pressure is observed, it is likely that any increase in pressure will be caused only by the compressor, assuming that there are no unusual heating effects to be taken into account. Hence it will suffice, when the maximum permissible working pressure is reached, to cut out the compressor by means of some pressure-limiting device, or to install a safety valve to relieve any excess pressure produced. In smaller installations, there is no need for extra safety devices affording protection against overpressure, provided the final pressure in the compressor does not exceed the maximum permissible working pressure in the plant.

Components, which may become completely filled with liquid refrigerant, on the other hand, must be individually protected against excess pressure. These include containers, such as receivers and separators, which can be closed off on all sides in normal operation and in which liquid pressure is liable to build up. The same applies to pipes and pipe sections which can be entirely isolated and can convey refrigerant in a fully liquefied state; as well as to circulating pumps for liquid refrigerant and refrigeration lines. Components in which the maximum permissible working pressure may be exceeded because of exposure to heat, such as evaporators which are operated in flooded condition and can be shut off, must also be equipped with individual safety devices. Refrigerants, which may be released by safety devices, must be channelled off in such a way that they do not represent any hazard to persons.

### **Maintenance**

The escape of refrigerant is a possibility always to be reckoned with in maintenance and repair work. Hence appropriate protective equipment,

such as gloves, canister gas masks (especially for ammonia) and gas light clothing should be provided for maintenance workers. Splashes of refrigerant can injure the skin, due to the intense cold; while ammonia can produce corrosive burns in the eyes, mouth and respiratory tract. When repair work is in progress, access should be permitted to the repairmen only. When a unit must be opened, it is exceedingly important to ensure that no liquid refrigerant is present in the section of the plant. The removal of oil from ammonia-refrigerated plants must be effected only under supervision to avoid the accidental escape of ammonia.

### **Hazards and precautions**

Should some refrigerant escape from a unit, it must be eliminated from the premises. To this end, means of ventilation, calculated on the basis of the total refrigerant capacity  $C$  (in kg) of the plant must be provided. In the case of heavy gases, ventilation must be provided at floor level and in the case of light gases, at ceiling level. Since ammonia dissolves very readily in water, sprinklers can easily dissolve atmospheric ammonia. Even in large premises, a water mist curtain can be used to seal off any area, which is of risk following an escape of ammonia or whenever there is a likelihood of such an escape. Should ammonia suddenly escape the premises affected must be vacated in all haste. Hence it is important to ensure that escape routes are kept open and can be readily found; safety drills should be instituted with an eye to such an emergency.

Frostbite prevention is based on the principle of modern hygiene and on the wearing of waterproof clothing and footwear which are not too tightly fitting and which provide protection against the cold whilst still allowing circulation of air around the body.

Risks from machinery can be prevented by secure machinery guards. Mechanical handling equipment, especially conveyors, is widely employed and particular attention should be paid to in running nips on such equipment.

Falls may occur on wet and slippery floors, and suitable floor surfaces, maintenance, good housekeeping, and non-slip footwear will help in prevention. Curbs round machines will prevent water flowing on to the floor but good drainage should be provided to remove rapidly any spillage that does occur.

Electrical hazards are high and should be countered by efficient earthing. Inspection lamps and portable electric equipment should be of the low-voltage type. Electrical systems and fittings in cold compartments should be of the fireproof type, which must be inspected regularly and maintained well.

Access to the plant room should be strictly limited using a key control system. These should open outwards from the plant room and be self-closing if they open into other parts of the building. They must be adequate in number to ensure freedom for persons to escape in an emergency. There should be no openings, which permit escaping refrigerant to enter other parts of the building. Staff should be instructed not to wedge plant room doors open; dangerous vapour concentrations will quickly build up in corridor spaces between fire doors outside plant rooms, or in other adjacent spaces.

No one should enter platforms after a major refrigerant leak has occurred until the ventilation system has had adequate time to clear the refrigerant from the room. Only suitable trained persons should be allowed to deem that it is safe to enter if a refrigerant alarm has been triggered. Reasonable working space with adequate illumination is essential for inspection, maintenance and replacement of components. This must include provision for ladders, platforms and clear areas as required.

Sound absorption materials used must meet the fire regulations. Sound and vibration result in problems in other parts of the building as pipes and ducts act as transmitters; this needs to be controlled with silencers and vibration isolators. The best procedure is to identify the sources and extent of noise vibration and to treat them separately, for example by machine enclosures, zoning the plant room, vibration mountings etc.

Every refrigeration system must be designed so that pressure due to fire conditions can be safely relieved. Devices used to relieve pressure include pressure relief valves, bursting discs, which rupture at a pre-determined pressure and fusible plugs, which have elements which are sensitive to temperature only. Such devices should comply with appropriate standards.

Appropriate fire-extinguishing equipment must be available. Chemical reactions can occur between certain extinguishing fluid and certain refrigerants. Equipment must be chosen carefully after consultation with the

refrigerant supplier and should be in accordance with guidance from the local fire authorities. The plant room will have been designed so that the requirements of the fire certification process for buildings are satisfied. The local fire brigade should be contacted if changes have been made.

### **Hazards in cold storage rooms**

The very low temperatures prevailing in cold storage and especially deep-freeze rooms may be dangerous if a person working in them is immobilized by an accident, becomes drowsy, or is inadvertently locked in. The hazards range from frostbite and other cold-induced injury, which may occur at temperatures of 0°C or below, to death from body temperature loss following prolonged exposure to cold. Accordingly, any person entering such rooms should wear protective clothing appropriate to the temperatures prevailing there. Protective clothing consists of a padded jacket with hood, gloves, warm trousers and boots. Such clothing must not prevent the evaporation of moisture from the body, nor must such moisture freeze inside the clothing. Protective clothing should be light and flexible so as not to hamper the worker.

Care should also be taken to ensure that any person working in a cold-storage room can always get out. This can be done by fitting doors, which can be opened from the inside as well as from the outside. Should the doors be electrically or pneumatically operated, manual opening should be provided, for use in case of power failures. If the doors cannot be designed to open from the inside, then at least an escape hatch, which can be opened from inside, must be provided. All emergency exits must be checked at regular intervals; they must be ready for use and easily accessible at all times.

Persons working alone in cold-storage rooms should be checked upon, as a safety precaution, at least once an hour. This can be done by detailing another worker as watchman, or the worker concerned can be called at regular intervals. When work is finished, before the doors of the cold storage rooms are shut, a responsible person should make a final check to ensure that nobody is left inside.

Workers must be warned against the slipping hazard on entering cold-storage rooms with damp soles. Respiratory protective equipment, protective clothing, arrangements for warning signals and quick exits are essential. Adequate measures should be taken for explosion prevention and fire fighting.

### **Safe methods for reducing ammonia leakage**

#### *Compressor*

Install the compressors in the machine room with adequate ventilation

Give importance in testing the suction side valve and discharge valve of the compressor.

Pressure control switches or electric solenoid valve is to be provided in the HP/LP line and tested periodically for safe and smooth operation of the compressor.

Do not allow liquid ammonia to enter the compressor otherwise it can be get crashed.

Check the tightness of packing of stuffing boxes of compressors otherwise it may draw air and can cause explosion and also check the oil seal of the compressor periodically.

#### *Condenser*

- i Condenser descaling and painting by using anticorrosive paints must be done intermittently.
- ii. In the case of water cooled condenser a platform with suitable ladder must be provided up to the level of the header valves for closing the valves smoothly at the time of leakage through condenser pipes
- iii In the case of shell and tube condenser, safety devices like pressure gauge, pressure relief valve (safety valve), drain cock and stop valves are required and the pressure releasing exist of the PRV or SV must be connected with flexible pipe and other end must be immersed in water as in the case of receiver tanks.

#### *Oil Separator*

- i Oil separator must be provided before condenser and evaporator for separating the oil.
- ii While separating the oil by opening the drain valve at the bottom of the receiver, connect a flexible pipe and immerse the other end in water as a safety measure against ammonia leakage and also operate the drain valves in short intervals.
- iii Use double valve safety system.

*Receiver*

- i Safety valve of the receiver or pressure releasing exist of the pressure relief valve must be connected with a flexible pipe and other end of the pipe must be immersed in the water to avoid exposure to ammonia vapour at the time of opening of the safety valve or relief valve.
- ii Due importance should be given in testing the safety devices like pressure gauge, pressure relief valve or safety valve, level gauge, drain cock and stop valve of the receiver
- iii Toughened glass made up of polycarbonate material can be insisted for level gauge glass, which can withstand shock and impact. Level gauge guard is required for minimising the accidental breakage of glasses
- iv. Air purging can be allowed only after connecting a flexible pipe with the air release valve and immersing the other end in water for avoiding leakage at the time of air purging.
- v. Always keep the valve connections for ammonia charging on the pressure side of the receiver. While charging ammonia in receiver, as a safety measure, provide tank containing water near the receiver for immersing the cylinder head against the cylinder gland leakages which are uncontrollable.

*Freezers*

- i. Keep the freezer in a separate area away from the work area to avoid exposure to ammonia at the time of leakage.
- ii. Rubber hoses in freezers have the property of binding or sticking each other due to freezing of moisture or water particle present over the outside surface of the hoses. Hence, before raising or lowering the loaded freezing plates for unloading the frozen food, the bonded rubber hoses must be washed with hot water for separating them otherwise leakage can be occurred due to the rupture of the bonded part of the rubber hoses.
- iii. Use of Teflon coated stainless steel flexible tubes are safer than flexible rubber hoses, which can with stand low temperature and high pressure and having no binding property. It can be used for longer periods.
- iv. Give importance for testing the safety valve or pressure relief valve of the accumulator and float valve of the freezer or evaporator.

- v. Pressure control cut out provided in the HP/LP line to be tested and alive by proper electric connections.
- vi. Freezer pressure gauge and warning alarm can be fitted in the machine room for the attention of operators.
- vii. Solenoid valve can be provided in the liquid line near to the freezer for smooth and safe operation.
- viii. Defrosting can be done by stopping the compressor for short interval, opening the door of the freezer, place trays of warm water inside the freezer or wash with hot water, opening the valve of the hot vapour line passing through the freezer

*General safety measures*

- i. Annual shut down maintenance should be properly carried out.
- ii. Refrigeration plant equipment like compressors, all pressure vessels etc. must be tested periodically.
- iii. No pressure vessel or plant which has been previously used or has remained isolated or idle for a period exceeding 2 months or which has undergone alterations or repairs shall be taken into use in a plant unless it has been thoroughly examined externally and internally if practicable and hydrostatically tested at a pressure which shall be 1.5 times the maximum permissible working pressure.
- iv. All the valves in the plant especially float valve (pressure reducing valve), drain valve, safety valves or pressure relieving valves and cock, glands packing etc. must be tested periodically.
- v. Personal protective equipments like breathing apparatus (S.C.B.A.) or canister type mask must be provided to the operators to attend emergency situations like ammonia leakage without risk to life.
- vi. Do not store ammonia cylinder for more than six months and keep the same in a cool place away from direct vicinity of sunrays.
- vii. Ammonia leak in the system can be detected by:
  - a) Litmus paper test (yellow paper changes to red)
  - b) Halide torch test (colour of the rays changes)
  - c) Sulphur candle test (thick fumes develop)
- viii. Don't use chlorine water test because while reacting ammonia with chlorine (halogen) explosive mixture can be formed.

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- ix. Make available water points at various locations for spraying water at the source of leak. Don't direct water at the source of leak or at venting because the leaking point cannot be traced out as a result of the fog formed due to the release of heat when ammonia dissolved in water. Instead of that, sprinkle or spray water near and over the leaked portion so that leaked ammonia dissolves in water and thereby spreading of ammonia gas in the atmosphere and formation of ammonia – air explosive mixture can be avoided.
- x. Damaged or deteriorated liquid lines should be removed immediately and proper support must be given to the pipelines at various locations.
- xi. All ammonia-carrying parts like pipes, valves, tanks, plates, flanges etc. of the ammonia refrigeration plants must be made out of cast iron, wrought iron or carbon steel.
- xii. Emergency alarm must be provided in the cold storages and it should be maintained in working condition always.
- xiii. Machine operating logbook is to be maintained by the operators.
- xiv. Periodic service chart showing details of replacement or overhauling of valves, gauges, cocks, pipelines, freezer tubes etc. are to be maintained.
- xv. One senior operator assisted by a junior operator is necessary for each shift and they must have a minimum qualification of I.T.I. in Refrigeration & Air Conditioning.
- xvi. Proper information, instruction and training must be given to the operators and workers about the operation of plant and safety measures to be taken by them at the time of emergency situations like ammonia leak etc.

### **Fire safety in cold storages**

Products stored, packaging materials used, insulating and some building materials can contribute fuel to a fire. Building elements can lose their structural property during fire. At the same time, necessarily closed atmosphere of a cold storage make fire fighting difficult. Generally, cold storage fires have been associated with electrical faults, hot work and ammonia leaks. Due to their typical construction features such as air conditioning and concealed utility ducts, fires in cold storages may remain

undetected before they have grown large. It is important, therefore, that architects, builders, owners and users of cold storages evaluate the fire risk and loss potential in such occupancies.

In the past, cold storages were modified general warehouses. However, with the advent of new materials for construction and insulation, use of better methods of materials handling and increased emphasis on energy conservation, great care is going into the planning, designing and construction of cold storages. These new systems and materials, while improving the operating efficiency, also increase the problems of fire safety in cold storages. Cold storage buildings in India are generally constructed with RCC columns and beams and brick walls.

The Indian standards Institution (ISI) in its Code of Practice for Fire Safety in Warehouses (BIS, 1967) recommends a maximum floor space area for a warehouse compartment and also the maximum height of a warehouse building. While the same recommendation applies for cold storages as well, in neither case are any guidelines stipulated for the number of storeys with the building.

### *Insulation*

The internal insulation used in cold storages depends on the materials available at a particular time. At one time cork was used extensively as insulation but it was replaced by the more economical fibreglass when this material became available. Fibreglass, however, has air gaps within its matrix, and moisture condensation leads to deterioration of insulation quality. With the introduction of polystyrene (trade name 'thermocole') fibreglass was largely phased out as insulation in cold storages. Expanded polystyrene, besides having good insulating properties, has no vapour space within it. In India now EPS (expanded polystyrene) is gradually replaced by RPUF (rigid polyurethane foam). Besides its excellent insulating properties, RPUF can be foamed on site and is also available in prefabricated panels.

Both polystyrene and polyurethane have relatively high ignition temperatures (488°C and 416°C respectively), but once ignited, burn rapidly giving out copious toxic fumes of combustion. Although normally a solid, polyurethane melts and burns as a liquid. Even flame retardant grades of these materials can be ignited by high-energy sources and burn readily once a fire is established.

For applying insulation on walls and ceilings, bitumen is used as vapour seal on the inner surface of the compartment elements and also between layers of insulation. The last layer of insulation is covered with a wire mesh over which layer of cement plaster is applied. The use of any open flame while fixing or removing insulation must be avoided as a fire safety measure. The top layer of cement plaster should be maintained well so that the insulation itself is not exposed. Providing a kerb on the floor along all walls and stacking goods with a gap from the wall will protect insulation on the walls against damage.

Packaging materials for products like cartons, polyethylene sheets, polystyrene have varying degrees of combustibility. Their configuration in packaging and stacking can enhance the fire hazard.

Stacks and racks in cold storages must be laid out not only for ease of handling in normal conditions but also for easy accessibility during fire fighting and salvage operations. Cold storage compartments usually have a low visibility, and aisles between stacks or racks are kept narrow for maximum utilisation of space. Aisles inside the compartments must be wide enough for emergency personnel to work in, and in no case should products spill into the marked passageways.

Ammonia leaks in refrigeration systems are common and ammonia burns in the range 15 to 28% by volume in air. The refrigeration plant room should, therefore, be well ventilated. Filled ammonia cylinders should be kept in separate stores. The plant room itself should be of fire resistant construction, and pipe work and duct penetrations should be sealed.

The cold and humid circumstances of a cold compartment can be detrimental for metallic equipment and their condition should, therefore, be monitored. Cables insulated and/or sheathed with general purpose PVC should not be installed where the temperature is consistently below 0°C, even if certain sections of a cold store are to operate at temperatures above this. Frequent variation in temperatures may increase the risk of cable failure. Neoprene cables/mineral insulated metal sheathed cables/silicon insulated cables are preferred to PVC cables for cold storage application.

#### *Personnel safety*

The main door of a cold room should have the facility of opening from both inside and outside. Additionally, there should be provision for

a manual alarm (which can be heard at a manned point outside) to be used if the door is jammed. One or more insulated emergency exit doors, which can be opened from inside are also recommended. Such doors should be fitted with heater strips to prevent its freezing and the doors can be fitted with an alarm to indicate their use. The access to emergency doors must always be kept clear of any obstruction. Emergency lighting is recommended for cold rooms and all emergency gear should preferably be self-illuminating.

Personnel handling ammonia leaks in cold rooms should use canister gas masks for gas concentrations up to 2% (volume in air). Self-contained breathing apparatus (SCBA) are suitable for higher concentrations. Personnel safety wear must be always easily accessible and should be inspected at regular intervals.

#### *Fire protection*

Due to conditions existing in cold rooms, portable equipment such as extinguishers can rarely be used indoors. Therefore some form of fixed fire protection system is recommended. Automatic sprinklers are generally considered to be the best protection despite the low temperatures in cold store compartments.

Relief venting of cold rooms is recommended to vent out any explosion that may occur indoors due to leakage of ammonia or due to any other reason. Where carbon dioxide flooding systems are installed, the relief venting provision should be designed to vent out any carbon dioxide overpressure as well. In the absence of an automatic extinguishing system, installing a fire detection system should be considered. Detectors selected must be suitable for use in cold temperatures and misty conditions which are normal in cold rooms. Regular fire patrols are a way of initiating early emergency action. Security personnel will be aided in such efforts if glass covered peepholes are provided on cold store outer walls. Choosing a suitable fire protecting system should be done after consulting experts. System must be well maintained and closely monitored. Personnel need to be thoroughly trained in the operation and maintenance of these systems.

The authors wish to express their sincere thanks to Dr K. Devadasan, Director, Central Institute of Fisheries Technology, Cochin for granting permission to publish this paper.

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