LOSS PREVENTION

Refrigeration on Fishing Vessels

SHIPOWNERS

SECURITY FOR SMALL & SPECIALIST VESSELS

Contents

Background

Refrigeration systems are installed and used on a large number of fishing vessels worldwide. The size of these plants varies depending on purpose and application, but can be on an almost industrial scale, particularly on vessels which freeze or process their catch on board.

Incidents involving refrigeration systems have resulted in fatalities and serious injuries to a significant number of fishing vessel crew stevedores or other shoreside staff who may be on board the vessel.

This briefing looks at some of the hazards presented by refrigeration plants with a review of previous incidents, followed by loss prevention observations and suggestions.

This loss prevention briefing has been produced in collaboration with The North of England Protecting and Indemnity Association, initiated by a shared commitment to improving fishing vessel safety and the prevention of injuries to crew and shore personnel.

Refrigerants

There are typically two types of refrigerant used in systems on fishing vessels:

1. Ammonia (R-717)
2. Fluorocarbons

Ammonia was one of the earliest refrigerants to be used and it is still a popular choice due to its wide availability, simple manufacturing process and the relatively low cost compared with many fluorocarbons.

Fluorocarbons include HCFCs and HFCs and are often referred to generically as 'Freon' refrigerants.

Ammonia

Ammonia is widely used in refrigeration systems on fishing vessels and fish factory (catcher-processor) vessels.

It is suitable for a wide temperature range (-50˚C to +10˚C) and the system can still operate when subject to air and water contamination.

Benefits of ammonia as a refrigerant include:

- Being environmentally sound and having no known effect on the ozone layer therefore not significantly contributing to global warming.
- Allows for physically smaller pipelines than those in fluorocarbon refrigerant systems due to high rates of heat transfer

However, an ammonia refrigeration plant can be quite complex. This is due to the challenges presented by the high temperatures that can be generated during compression.

Maintenance demands can be high and even in normal operation they generally require more frequent routine tasks than fluorocarbon plants. One such example is the regular draining of oil from the evaporator which, although potentially laborious and frustrating, is vitally important for the safe operation of the system and introduces the risk of gas leakage if not carried out correctly.

The choice of material is important in ammonia systems as copper based metals such as brass and bronze will be attacked by the ammonia refrigerant. This is particularly pertinent when replacing or repairing components.

There are two significant and well-known hazards associated with ammonia refrigeration systems; flammability and toxicity.

Flammability

Ammonia is explosive in air at concentrations of 16% to 27% by volume. As one litre of liquid will evaporate to 800 litres of gas when at room temperature and atmospheric pressure, the flammable range can be quickly reached in certain spaces. The vast majority of reported ammonia related incidents have not involved an explosion, but the consequences of an explosion can be significant.

Toxicity

Ammonia gas has a pungent suffocating odour and is easily recognisable, being detectable by the human nose at concentrations above 5ppm. It is lighter than air and has a tendency to collect at the top of spaces or deckheads. It is important to note that long-term exposure to ammonia will not result in an increased tolerance to it, but only weakens the person's ability to detect it.

Ammonia concentration (parts per million)	**Effect on human health**
2–55 ppm	Normal range of odour threshold
70 ppm	Stinging or burning in eyes, nose, or throat; can cause watering of eyes, sneezing, and coughing
300 ppm	Severe irritation of eyes, nose, or respiratory tract, which becomes intolerable after a few minutes; difficulty breathing; possible burning in lungs
2,000 ppm or more	Can be fatal after a few breaths

It is readily apparent from the these figures that if a person was subject to a significant leak of ammonia gas whilst within a confined area serious, if not fatal, injuries will be sustained.

Fluorocarbons

Fluorocarbon refrigerants came to prominence in the 1930s and are widely used in industrial refrigeration and air conditioning plants as well as domestic appliances. Fluorocarbons can broadly be categorised as follows:

CFCs (chlorofluorocarbons): Previously a popular refrigerant (R-11 and R-12 in particular) but was then confirmed to be a major source of harm to the ozone layer and a greenhouse gas (**GHG**). It is not permitted to use **CFCs** in new equipment, but it may still be in use in some older air conditioning and refrigeration systems.

HCFCs (hydrochlorofluorocarbons): Also an ozone-depleting substance, but is considered less damaging than **CFCs**. The production and consumption of **HCFCs** is presently being phased out and in some countries the sale of this gas was banned from 1 January 2015. The most common **HCFC** refrigerant is R-22.

HFCs (hydrofluorocarbons): are not thought to harm the ozone layer but are greenhouse gases. Common refrigerants in use are R-410A, R-407C and R-134a.

The level of toxicity is dependent on the type of refrigerant but it should also be recognised that these refrigerants can displace oxygen in confined areas and cause asphyxiation.

The safety characteristics of a fluorocarbon are denoted by its safety classification; the capital letter corresponds to toxicity and the digit to flammability (e.g. A2).

Toxicity

Class A - toxicity has not been identified at concentrations less than or equal to 400 ppm and Class B for which there is evidence of toxicity at concentrations below 400 ppm.

Flammability

Class 1 (low flammability) up to Class 3 (high flammability).

Fluorocarbons are heavier than air and are generally odourless which means detecting leaks is very difficult without the aid of specially designed sensing equipment, as opposed to ammonia leakage where it is almost immediately noticeable by smell.

However, the leaking of fluorocarbons from a refrigeration plant has sometimes been described as having a "sweet ethereal odour".

Real Cases: Findings and Observations

A number of refrigeration-related incidents as reported to the major marine insurers of fishing vessels, namely North P&I, Shipowners' P&I and Sunderland Marine were considered with a view to understanding the circumstances of events leading to the incident and to identify the causative and contributory factors. A case study has been included at the end of this section.

The findings highlighted a number of significant and often repeated factors:

- A lack of appreciation of the hazards presented by both fluorocarbon and ammonia gas refrigerants; particularly so with the latter where there can be an element of complacency as it is sometimes perceived as being a 'safe' refrigerant.
- Poor material condition of the refrigeration plant and its components, resulting in the plant being more susceptible to leaks.
- Poor standards of operation and maintenance of the plant with crew members found to be lacking in familiarity.
- Failure to identify high risk tasks relating to the plant operation and maintenance; subsequently failing to identify and implement suitable control measures.
- Insufficient or inadequate levels of formal training in refrigeration engineering and plant specific operation.
- Defective, missing or a failure to install suitable placed gas leakage detection alarms.
- In the event of a leakage incident, the re-entry and rescue operations were carried out without using breathing apparatus or without following a safe procedure.
- A failure in emergency response management with inadequate emergency and evacuation procedures and a lack of crew familiarity in what to do in such an event.
- Ineffective crew drills on leakage response and safety equipment not being thoroughly tested.
- The positioning of unprotected refrigeration plant and equipment near to busy working areas with insufficient warning signage and little guarding against impact protection.

The review also highlighted a need to promote the use of strategically and appropriately placed emergency escape breathing devices (EEBDs).

Case Study

This unfortunate incident occurred on a fishing vessel whilst unloading a catch from the vessel's holds.

A shore side crane, operated by a stevedore, was being used to discharge fish. During a load, heavy contact was made with one of the vessel's refrigeration pipes causing it to rupture at the weld and leak ammonia gas into the hold. Three stevedores assisting with the operation managed to leave the hold when the ammonia started to leak. However, the stevedore who was closest to the pipe when ruptured suffered severe ammonia burns to his eyes and lungs. His injuries were so severe that it resulted in instant hospitalisation, with the prognosis of ongoing medical care for the rest of his life.

It is industry practice to isolate a hold's refrigeration system by draining back the ammonia into the reserve storage before unloading commences. This is to ensure that no leakage of ammonia gas occurs if there is a breach in the system.

The subsequent investigation into the incident found that the vessel's refrigeration system, which utilised ammonia, had not been fully isolated and therefore ammonia gases had not been vacuumed from the system when unloading had commenced. Only after the leak had occurred were the valves fully closed, completely isolating the system and preventing further ammonia entering the hold.

Observations:

- It is imperative to check that the vessel's refrigeration system is fully isolated and vacuumed prior to any operations being carried out in the hold. Failure to do so potentially exposes anyone in the vicinity to the risk of severe injury or death if the system is damaged and a leak occurs.
- In this incident it was the chief engineer's responsibility to isolate the system but the subsequent investigation discovered that he had been late to begin the isolation process. This resulted in the gas not being fully vacuumed from the system. In addition, the isolation valves had not been properly closed when unloading had begun due to a lack of time.

- It is vital that all crew are fully informed of the associated dangers of ammonia, the operating criteria of the on board system and the emergency contingency plans in case of refrigerant leaks.
- Crew must ensure that correct procedures are followed to prepare the vessel for carrying out cargo operations and that positive reporting is recorded.
- All appropriate safety equipment, such as breathing apparatus, must be located nearby prior to commencing operations and the on board crew trained on its use.

Financial Cost: US$ 1,110,639

Loss Prevention

Know the Hazards

Uncontrolled leakage of refrigerants can lead to severe harm to health due to their toxic or asphyxiating nature as well as potentially generating an explosive atmosphere. Crew members operating and maintaining the refrigeration plant must understand the nature and characteristics of the refrigerant in use and appreciate the hazards it presents.

Ammonia receivers with colour coded pipework and protective grating around exposed parts

Safe System Operation

Formal safety management systems are often considered to only apply to merchant vessels but some basic principles can well apply to all vessels regardless of type and size.

Take the time to fully consider the operational requirements of the plant and assess each task for the associated risks. When the risks have been identified, control measures and working instructions can be developed accordingly to lower the potential of a hazardous incident occurring.

If the method of operation or the provided instructions are unworkable, do not look to bypass the stated procedure – bring it to the attention of a senior officer or supervisor and allow the modification or improvement to be properly considered and safely carried out.

It should always be considered that efforts to create a safe working environment are far more effective if the crew understand the risks and the need for the control or procedural requirements. Therefore crew training and education are key.

As with any industrial refrigeration plant, it is important to monitor the operating data to ensure it is running within the design parameters. Recording this data will allow trends to be noted, such as any deterioration in performance, as well as providing good evidence to prove the system was in good working order in the unfortunate event of an incident.

Maintenance

The pipework carrying the refrigerant to and from the holds and freezers can pass through a number of spaces and not always be readily visible. Pipes may be obscured by other system pipework or they may run under floor plates and walkways. This leads to difficulties in identifying sections of piping and fittings that are affected by or are vulnerable to corrosion. If undetected, this corrosion can result in wastage and ultimately the failure of the pipes or the associated fittings.

To ensure the condition of the pipes and fittings do not deteriorate to an unacceptable level, the system should be clearly marked to make it easily identifiable and a maintenance regime should be put in place to check and record the condition at suitable intervals. Obscured sections should be given special attention.

A good standard of line identification and valve marking, such as colour-coding and/or labelling, will also help in making sure sections of the system are properly isolated during maintenance periods and furthermore will greatly assist when having to isolate a leaking section in an emergency. The ready availability or prominent posting of a system layout diagram will also be beneficial.

Perishable components which require periodical renewal, such as braided hoses, should be scheduled for replacement as per the manufacturer's guidance and their condition given attention during inspections.

System and component planned maintenance should be carried out in accordance with manufacturer's instruction and be suitably documented. There should be an adequate quantity of essential spares on board to allow the engineers to carry out the maintenance as well as any emergency repairs.

It may be appropriate, and in some cases mandatory, to include system and component pressure testing at prescribed intervals as part of the planned maintenance program. Such testing will aid in verifying the system integrity.

Records should be maintained for the use and purchase of ammonia, which will readily alert the crew to any increase in consumption and therefore provides an early indication of leakage.

System safety devices, such as emergency trips and remote shut downs should be tested periodically and documented accordingly. This also applies to any fixed fire fighting or drenching installation protecting the plant.

Before carrying out any repairs or maintenance to the refrigeration plant, it is important to ensure it is disabled and placed in a safe condition. A program, such as a lockout-tagout system should be in place and followed whenever maintenance is carried out or for any other reasons where a section or component requires isolation. Additionally, a '*permit to work*' system may be appropriate for certain tasks or types of work.

If shore-based technicians, have been appointed to carry out repairs or maintenance to the refrigeration system, it is still the crew's responsibility to ensure the system is isolated, secured and presented to the contractors in a safe condition.

The technicians should be briefed before commencing any work on emergency responses and the locations of the relevant safety equipment. Contractors' work should be suitably monitored and appropriate checks made before re-commissioning the system.

The above makes numerous references to recording and documentation. In the event of a refrigerant-related incident it is possible that a claimant will allege that the system was in poor condition that rendered the vessel unseaworthy. In order to effectively defend against these allegations, documents showing that hazards had been identified, risks assessed, safe operating procedures were in place, and the system was properly maintained prove to be vital items of evidence and their importance cannot be understated.

Plant Design and Retrofitted Systems

The refrigeration plant as fitted on board a fishing vessel may have been installed at the newbuilding stage, or it may have been added at a later date as part of a re-fitting or modernising project.

A system installed at the vessel's newbuild stage has the distinct advantage of being designed with dedicated spaces in mind, allowing for equipment and refrigerant storage to be positioned in suitable and secure locations on board the vessel.

In the cases of replacement systems or where retro fitted systems have been installed, where no system existed before, there are particular challenges when deciding where to locate plant components on board the vessel. Space is at a premium both under deck and on deck, and compromises may need to be made when installing, particularly with the large capacity receivers required for ammonia systems.

Particularly vulnerable are receivers, piping and components positioned on the open working decks of fishing vessels that tend to be near hold accesses. These are busy working areas, especially during fishing and cargo discharge operations, with heavy items on the move in a fast-paced environment.

There have been a number of major incidents leading to fatal injuries on fishing vessels involving retrofitted ammonia refrigeration systems. Commonly found factors include the exposed locations of the refrigeration equipment/pipework and the lack of impact protection, as well as failure to exercise care when handling the catch or discharging cargo.

If the installation of such equipment in these locations is unavoidable, then it is very important to assess the risks accordingly, paying particular attention to:

- Protection: barriers must be fitted to guard equipment and pipework to protect equipment, components and pipes from impact damage.
- Signage: ensure appropriate warnings are conspicuously posted.
- Fishing and/or Cargo Operations: consider how the routine working operations could affect the safety of the plant and how the positioning of the plant could affect safe working.

Example of well protected refrigeration equipment/pipework

Care must be taken to prevent unauthorised and improper modifications to the refrigeration system. A system with initial design flaws can lead to those who operate and maintain it to work around these flaws (taking short cuts) or take it upon themselves to modify the system to make it workable.

Crews must be aware of the dangers associated with modifying refrigeration systems and understand the consequences if the alteration is inappropriate or poorly executed.

A well designed system will include, but is by no means limited to, the following considerations:

- Easy and effective section and component isolation.
- Appropriately positioned operating switches for the emergency ventilation and fixed fire fighting arrangements. The switches should be identifiable with emergency signage.
- Fixed gas leakage detectors at suitable locations, ensuring the alarms are set at an appropriate level.

With specific regard to ammonia systems:

- Consider replacing single pressure relief valves (PRVs) with dual relief valves to allow easy maintenance of a device without losing safety protection. Installation of a dual relief valve would consist of one three-way shut-off valve and two pressure safety release valves.
- Ability to drain the system contents back to the storage receivers when the plant is shut down for cargo operations or maintenance.
- Safe arrangements for the drainage of oil from the system, with self-closing valves.

Emergency Response Management

It is of high importance to have emergency response procedures in place in the event of a leak. The on board emergency response plan should include procedures that are clear, precise and unambiguous, and be available in the languages spoken on board the vessel. It must be understood by all and incorporate actions required by stevedores if appropriate.

The exact nature of the response procedures will be vessel specific; however they should identify the following activities and scenarios as a minimum:

- Emergency shutdown and isolation of the plant (and sections of the plant).
- Confinement and ventilation of an affected space.
- Mustering and evacuation of personnel (crew and shore based workers).
- Re-entry into the affected space; including checking the atmosphere.
- How to rescue personnel in an affected space.

Exercise the crew in periodical drills relating to the leakage of refrigerant. To achieve the maximum benefit, drills must be made as realistic as possible and try to engage everybody on board.

Crew members must know all of the possible escape routes from their working area to allow a safe exit in the event of a major leak which may block their usual route.

Ensure crew familiarity in the use of self-contained breathing apparatus (SCBA). It is vital that they know how to use it before needing it in a life threatening emergency situation.

In addition to any mandatory requirements on carrying SCBA units that may apply, consideration should be given to the use of emergency escape breathing devices (EEBDs) – the quick and easy deployment of which will allow a crew member to escape safely from an affected area. Crew would be trained in their use and the devices conspicuously placed (with prominent signage). As with SCBA units they should be periodically checked to ensure they remain fully charged and in full working order. It should be stressed that EEBDs are for use in the event of an escape and not suitable as a breathing apparatus for re-entry into an affected space.

EEBD in Situ

A further consideration is to review and investigate not only the circumstances of actual incidents, but also any near misses involving the refrigeration plant. Identifying the causes and addressing any found challenges could prevent a serious incident in the future.

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