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Evaluation for the Reduction of NH_3 Contamination Risks

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Abstract

The paper offers an assessment of the use of ammonia as a refrigerant gas and the trends of increasing its generalization for the coming years, especially in the industrial sector; The thermodynamic qualities of the gas are exposed; Their chemical properties; Their preferred use in industrial refrigeration was described; The impacts and risks associated with their use; It was evaluated a possible solution that can promote the reduction of the risk of pollution to the people in case of a massive escape of NH3 in the Company "La Isabel Ecuatoriana" SA and its surroundings.

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1. Introduction

It is very likely that the first method of cooling used by man was based on natural ice and was practiced long before any thermal machine was built. There are Chinese writings before the first millennium BC, which describe religious ceremonies to fill in winter and empty in the summer basements of ice. The ancient Romans used the ice of the Apennines.

Other ancient writings describe how the Egyptians [1], Hindus, and other peoples of antiquity used procedures to produce ice artificially. Water filled with shallow porous clay or other similar material was filled with water and placed on thick straw beds during the night. If the weather conditions were favorable: cold, dry air and a night without clouds, the heat loss due to the evaporation at night, caused the formation of thin layers of ice on the surface.

These early methods of producing refrigeration constitute a striking example of human skill, which is present throughout the history of thermos technics and thermal machines to develop a useful art long before the existence of the corresponding rational and scientific basis.

In the twelfth century the Chinese used mixtures of saltpeter in order to cool water; In the sixteenth and seventeenth centuries, researchers and authors such as Boyle and Faraday (with their experiments on ammonia vaporization) make the first practical attempts to produce cold [2].

In 1607 it was discovered that a mixture of water and salt could be used to freeze the water. In the seventeenth century, refrigerant mixtures are used in scientific research. Later in the eighteenth century some scientists linked to the fields of physics and chemistry, use refrigerant mixtures in laboratories. These solutions allowed experiments at low temperatures and thus: in 1715 using a mixture of snow and ammonium nitrate, it was possible to establish the zero in a thermometer. In 1760 mercury was frozen at -40 ° C [3].

In the 19th century, many scientists studied the laws governing cold mixtures and mixtures of ice and salt, which allowed the temperature to drop to -20 ° C, were commonly used to freeze food products, and in 1904 Spanish patients Refrigerant mixtures to preserve food. These methods, however, are discontinuous and of very limited capacity, so it is not possible to speak of refrigeration until the invention of the continuous methods of two basic types: consumers of work and consumers of heat.

Mechanical cooling was obtained by various paths, but all based on the expansion of a fluid, which can be carried out without phase change (depressurizing of a gas) or more frequently, with phase change (evaporation of a liquid), which has been reheated at atmospheric pressure or lower. Although the first attempts to obtain mechanical cold were by evaporation of a volatile liquid, the first truly operative machine was air expansion. For this reason, it is called a compression refrigeration machine [4].

Up to now, ammonia remains the most widely used refrigerant in industrial refrigeration systems for processing and preserving most food and beverages. This product has been in the leadership of the advances of the technology in refrigeration, is an essential part of the processing, storage, and logistics of food distribution.

It is important to consider that ammonia is corrosive and dangerous when released into the atmosphere in large quantities, so it requires special precautions. Due to their irritating nature, people cannot remain in atmospheres containing ammonia because it is dangerous to health.

The effects of ammonia in people usually occur with irritations of the eyes, nose, and throat, this depends on the particles exposed in the environment, because when it is greater than fifteen hundred particles per million, it produces pulmonary edema with danger to life.

The risk associated with ammonia leaks from cooling circuits is still a concern. Exposed persons may present from discomfort to severe poisoning, leading in extreme cases to death.

One aspect to consider is that the consequences can not only affect plant personnel but also people residing or working in the vicinity of contamination sources. That is why we constantly establish measures aimed at reducing the risks associated with the management of this hydrocarbon.

The objective of the work is to design a pressurized water system to reduce the risk of contamination in case of an ammonia leak, in the canned refrigeration area of the company Isabel Ecuatoriana S.A.

2. Research Method

As a research methodology, a combination of qualitative and quantitative methods has been used, since an analysis of the problem of study is carried out from the localized bibliography, while quantitative methods such as mathematical analysis are used to solve problems and calculations Complexes associated with the danger of contamination and the design of a technical device that allows reducing the risk of contamination caused by a possible massive escape of the NH3 gas.

Practical procedures were used through the use of pressure, temperature and water flow measurement equipment. Interviews with people in the refrigeration area that is responsible for the proper use of the equipment, as well as other workers who carry out their work in places close to the possible source of contamination.

3. Results and Analysis

3.1 NH_3 technical qualities

Ammonia is a common compound that exists naturally in the environment, which breaks down into hydrogen and nitrogen molecules. It can be found in water, soil, air and is a source of essential nitrogen for plants and animals. In fact, ammonia is one of the most abundant gases in the environment [5].

NH3 consists of one nitrogen atom and three hydrogen atoms, being a key element in the nitrogen cycle and under normal conditions is essential for many biological processes (forofrio.com, 2015). It has a heat transfer coefficient higher than R-22, due to its thermodynamic and transport properties [6].

The boiling point at standard atmospheric pressure is -33 ° C. The pressures on the evaporator and the condenser at the standard ton conditions of -15 ° C and 30 ° C are 2.37 bar and 11.67 bars, respectively. They are moderate pressures and therefore lightweight material can be used in the construction of the refrigeration equipment. However, the adiabatic temperature at the discharge is relatively high, 98.89 ° C for the standard tonne conditions, so it is appropriate to have water cooling in both the head and the compressor cylinders [7].

NH3 belongs to the group of so-called natural refrigerants together with carbon dioxide, water, air and hydrocarbons (ethane, ethylene, propane, propylene, butane, and isobutane). Natural refrigerants stand out because they are efficient and have low maintenance costs. In addition, they are cheap and available in large quantities [8]. Table 1 shows a summary of the thermodynamic properties of NH_3.

Table 1. Thermodynamic properties (-8 ° C) of NH3

PROPIEDAD	NH_3
Calor específico (KJ/Kg °C)	4.65
Conductividad térmica (W/m °C)	0.55
Viscosidad (cP)	0.20

In Table 2 shows a summary of the heat transfer coefficient (W / m2 ° C) for ammonia.

Table 2. Coefficient of heat transfer (W/m^{2}° C)

Terms	(W/m^{2}°C)
Condensing on the outside of the tubes	3500-7000
Condensen incide the tubes	2500-6000
Evaporating on the outside of the tubes (Circulation with pump)	600-6000
Evaporating inside the tubes (Circulation with pump)	1000-6000

3.2 Use of ammonia in refrigeration

Currently, 90 % of industrial refrigeration systems for food use ammonia refrigerant. The NH3 has been a leader in the advancement of refrigeration technology; even NASA has recognized its advantages as a refrigerant, selecting it for use in a space station [8].

Ammonia was the first refrigerant used in refrigeration plants by means of mechanical compression in 1876 by Carl von Linde. Since then, it has been used in large refrigeration plants such as dairies, breweries and other places with great demands for cooling [5].

With the entry into force of the Montreal Protocol in the 1980s, chlorofluorocarbons (CFCs) and hydrochloric fluorocarbons (HCFCs) are banned because their composition has a destructive effect on the ozone layer. From this moment the ammonia regains the functionality that had had in previous years.

Ammonia as a refrigerant offers four clear economic advantages over other commonly used [7]:

a. It is compatible with the environment. It does not destroy the ozone layer and does not contribute to the global warming of the land, so the costs associated with reducing environmental impacts are negligible.
b. It has higher thermodynamic properties, so ammonia refrigeration systems consume less electrical energy.
c. The nauseating odor characteristic of ammonia is its highest quality of safety, allowing leaks to be detected easily and quickly, causing personnel to leave the area before dangerous gas accumulation.
d. The cost of NH3 is much lower than any synthetic refrigerant, generally costs between 10% and 20% less and has no cut-off date on which it can be produced or used, unlike other synthetic refrigerants, whose use or production is limited to a certain amount of years.

From the global point of view, the trend observed in the sector is that it is increasingly oriented towards the use of NH_3. Synthetic refrigerants will still continue to play a significant role in the refrigeration and air conditioning sector, but always in systems with small loads and using new substances that have a low global warming potential (GWP). In the immediate future, the choice of refrigerants is influenced by their efficiency, safety, environmental impact, a life time in the atmosphere and chemical properties.

3.3 Impacts and risks associated with the use of ammonia as a refrigerant

At the end of the 1990s, with the problem of global warming and climate change, the Kyoto protocol came into force, mainly to reduce greenhouse gas emissions. Fluorinated gases were among the main causes of global warming [9].

Environmental concern is forcing scientists and refrigeration technicians to seriously look at natural refrigerants like air, water, ammonia, carbon dioxide and others as a long-term alternative, which would be seen as a "No Regrets Solution".

The total equivalent warm-up impact (TEWI) is defined as the sum of these direct and indirect contributions. The TEWI value of ammonia [5], is very low because it does not contribute to global warming by itself. Due to their favorable thermodynamic characteristics, ammonia refrigeration systems use less energy than other common refrigerants. As a result, there is an indirect benefit to global warming due to lower CO_2 emissions from power plants.

But the inadequate use of ammonia as a refrigerant in industrial facilities may represent a group of potential risks of toxic pollution to humans. It is often heard that ammonia is dangerous. It is a toxic and flammable refrigerant in high concentrations, being necessary to consider that the technicians possess sufficient qualification and that the installation counts on systems of detection of leakages and a correct ventilation, as well as the use of an absorption system or other technology of reduction of Risk that works in case of escape of this gas.

A safe installation of ammonia requires the commencement of an engineering design that includes all the necessary safety measures and to continue with a proper installation maintenance that minimizes the risk of leakage. With this care, a refrigeration system will be safer than any other, with the added advantages of using an environmentally friendly, long-lasting and energy-efficient refrigerant. To meet this requirement incorporates robust materials and security systems in the main areas of the system. For example; Safety valves in the containers and pipes, ammonia detectors in the engine room and enclosed spaces, overpressure valves in pumps, among other safety devices [9].

In the company of Conservas Isabel Ecuatoriana S.A ammonia is used as refrigerant gas in the industrial process. This entity maintains a social commitment and of sustainability, with the purpose of satisfying the needs and expectations of the consumer, placing at its disposal high-quality products.

Accidental releases of ammonia can be caused by several situations, including difficulties in the plant leading to high-pressure conditions and removal of the exhaust valves; Leakage of rotary shaft seals and valve stems; Failures in refrigerant piping due to loss of mechanical integrity due to corrosion; Physical damage of system components by equipment collisions; Hydraulic shock; And faults in hoses occurring during ammonia supply [11].

In refrigeration systems, NH_3 is liquefied under pressure. The liquid ammonia released into the atmosphere would be converted into an aerosol producing a mixture of liquid and vapor with a temperature of -33 ° C. The released gas quickly absorbs moisture in the air and forms a cloud of white dense, visible ammonia hydroxide. This thick mixture tends to travel at ground level rather than rising, increasing the exposure potential of workers and people in general.

Exposure to ammonia can affect you in different ways. It is corrosive, affecting the eyes, skin and respiratory tract. It's most common route of entry is respiratory if high concentrations are inhaled it can lead to pulmonary edema, which does not become apparent until after a few hours and may be aggravated by physical exertion. It can also cause frostbite.

Ammonia can be harmful if inhaled in high concentrations. The Permissible Exposure Level of the Occupational Safety and Health Administration (OSHA) is 50 parts per million (ppm), 8 hours of weighted average times. The effects of ammonia inhalation vary from irritation to severe respiratory injury, with possible fatalities if there is a higher concentration [10].

Although pure ammonia vapors are not flammable in concentrations below 16%, fire and explosion hazards may exist in concentrations between 16 and 25%. However, mixtures involving ammonia contaminated with lubricating oil from the system may have a higher explosive range. A study to determine the influence of the oil on the flammability limits of ammonia concluded that the oil reduced the lower flammability limit to 8%, depending on oil type and concentration [10].

It has been observed that accident risks in recent years have been one of the main concerns of the industry, so it has been necessary to carry out various studies and evaluations to find solutions to reduce risk by contamination with ammonia.

3.4 Design of a device for the reduction of NH3 contamination risks

One of the chemical properties of ammonia is related to its behavior in the presence of water, as the NH_3 dissolves in the presence of H_2O. For this reason, the design of a system capable of neutralizing the pollutant potential of ammonia in the event of a massive escape of ammonia can be an effective measure to reduce the risk of contamination of people working in the company, as well as those who work and reside in the surroundings.

The system consists of installing in the ammonia area of the industry an automatic pressure water injection device, where twenty critical points have been identified that present NH3 escape hazard. The system is activated by the signal of the installed sensors for the detection of ammonia exhaust. The total volume of water pumped by the system to neutralize ammonia was calculated; the flow rate of the system was also determined by defining the total flow and the time to neutralize the ammonia which, according to analyses, was neutralized in 6 minutes, a time necessary to avoid environmental catastrophes.

Figure 1 shows the technical diagram of the automatic pressure water sprayer system to neutralize the pollutant effect against a possible NH3 leak in the "La Isabel Ecuatoriana S.A" refrigeration plant.

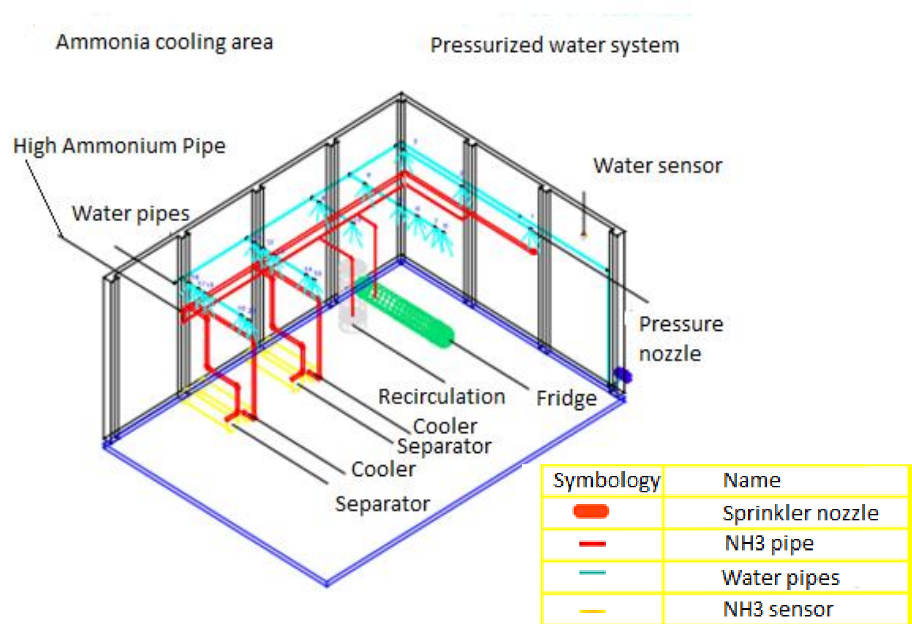

Figure 7. Technical drawing of automatic pressure water sprayer system

So far in the company, there is no device or system to neutralize the pollutant effect of ammonia in the event of gas leakage, so the proposed solution may be an advantage in reducing the risk of NH_3 contamination.

4. Conclusion

The use of the pressurized water reactor in the ammonia area of the company "La Isabel Ecuatoriana" SA, consisting of 20 jets with hollow-cone spray nozzles, installed on points that offer a greater risk of gas leakage, Allows to reduce the risk of contamination by ammonia to the workers of the entity and the surrounding population, with an estimated time for the escape neutralization of 6 minutes.

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