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IIR WG Refrigeration Safety

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ABSTRACT

A working group under the IIR has been revived after some years of inactivity. This time, we are very optimistic about getting it up and running. We held the first meeting at the IIR Gustav Lorentzen Conference in Valencia in June 2018. Approximately 30 people from around the world participated.

The purpose of the working group is to increase the safety level for technicians and engineers who design, commission and service refrigeration systems. We all have a right to work safely, and so do the service technicians that service the chillers or air conditioning systems we have installed all over the world. Nevertheless, accidents do happen and between 40 and 60% of all accidents happen while technicians are working on the systems. This may be during installation, falling from height or while servicing the plant.
Key words: IIR working group, accidents, training and competences

1. INTRODUCTION

Over the years, we have seen some serious accidents. In an analysis, Chen (2014) presented at the IIR Gustav Lorentzen Conference in 2014, three accidents were discussed that are still a major concern to the legislators in China even now, more than five years later. The same year (April 2013), there was an explosion in Texas, USA, in which ammonia nitrate, not ammonia refrigeration, caused the death of 15 people (12 first responders and three members of the public), injured 260 people and damaged 150 buildings, some beyond repair, CBS report (2013).

The Institute of Refrigeration reports on accidents due to poor practice; Institute of Refrigeration (GDP 75). One of such accidents occurred in June 2014 at the Hotel Rochester, Bendigo, Australia, during the removal of a refrigeration system. Several factors led to the fatal accident:

1. The two people performing the job were not qualified for the task. In the report, it says that the system was known to be leaking; but why this had not been dealt with over the years is unknown. We also learn that the system, originally non-flammable, had been topped up with a flammable refrigerant (now a blend of non-flammable and flammable refrigerants) by an unqualified person, namely one of the deceased service technicians. Labelling the system would not have made a difference in this case, and when unqualified people work on a system, they cannot be assumed to know how to use the information and what the risks are.
2. Enforcement of the rules concerning all types of refrigeration systems is too weak, or not existing. Why had the leaking system not been fixed long before the fatal day? And why had the unqualified technicians not been on a training/updating course that would have qualified them for the job?
3. The owner of the system must pay much more attention to the situation and the health of the system. The owner must be taught how to be aware of the risks and what can be expected. In this case, the owner had paid for topping up the refrigerant charge many times - why had he not asked more into this?

The same report contains a summary of an accident at a brewery in Northampton, UK, in November 2016, where a subcontractor was engaged in removing a dormant compressor. The court hearing about the accident revealed that the brewery responsible person had not checked if the valves where properly closed before the unqualified technician began his work. It also turned out that the valve was already leaking. Why was this not fixed long ago on the brewery's initiative? Why had the authorities not noticed this earlier? The leaking valve was not a new issue. The brewery has since then implemented procedures to avoid repeating this accident.

In October 2018, the net media Cooling Post (2018) reported about a crew member on a trawler that had been asphyxiated by an R-22 leak. The leak occurred in the evaporator and was not the first leak on that evaporator, which had been repaired before. The picture from the report looks very similar to the picture of the evaporator

in the accident from an ice rink in Canada (Fernie Memorial Arena ice rink, also mentioned in this paper). The R-22 had travelled with the refrigerated seawater into the tanks. When three other crew members climbed down to their colleague, they quickly became dizzy and felt uncomfortable, so they abandoned the task and climbed back up. The O_2 level was measured to 6%, which is dangerously low.

Figure 1: Some of the tubes had previously been leaking and blocked.

The lesson learned from this accident is that all cargo holds should be equipped with detectors to measure both the refrigerant concentration and the oxygen level, because the oxygen can be depleted by other gases as well. You may also argue that the tanks should be ventilated when crew members enter them to avoid similar situations.

In 2018, the death of a family in Chennai, India, The Hindu (2018) was reported. The case was not fully understood, and the information from the media did not add up to a clear understanding of the cause of death. The refrigerant in the room air conditioning system was said to have leaked in the dormitory part of the flat and caused the death of the family who lived there. However, the unfortunate accident turned out to be caused by carbon monoxide from the generator set, as far as reported.

At the IEA Heat Pump Conference 2017 in Rotterdam, the Netherlands, Tomohiro Higashi et.al. (2016) presented a paper on the risks associated with the pump down of air conditioning systems. This was a continuation of work presented in Dang (2015). A number of accidents have been reported on the internet. Like the case in India, it is not always clear exactly what the technician was doing. However, pictures from different sites show compressors exploding from forces within the compressor. The paper by Wang Zhang (2015) shows that R-32 and oil blend has a maximum explosion pressure of 1.02 MPa, and the maximum rate

of pressure rise of R-32 is 74.76 MPa/s when the air concentration is 20%. For comparison is used R-290 (propane), which has a maximum explosion pressure of 0.875 MPa and a maximum explosion pressure rise of 60.38 MPa/s with an air concentration of 4%. The reason for this is partly the amount of refrigerant present when the mixture of air and refrigerant explodes. The lubricant plays another role, which is not fully understood in this paper.

On 17 October 2017, there was an ammonia release at the Fernie Memorial Arena in British Columbia, Canada, Technical Safety BC (2018). The release resulted in three fatalities and evacuation of 95 residents from 55 homes.

Technical Safety BC investigated the accident (Link)[i]. The results of the investigation were released at a press conference on 25 July 2018 and contained clear recommendations for contractors as well as owners and management of arenas and refrigeration systems in general.

The problems started with a relatively small leak, but the leak was not dealt with over the years, and, in the end, the secondary brine loop gave in for the pressure, and the accident happened.

A key learning point was that the system owner(s) need to be educated to understand how to receive bad news and deal with it. However, this is a two-sided issue because the contracting company may be afraid of losing the project because they have to deliver bad news, which may upset the customer. In this case, the contractor did not object to the order of starting the system despite the fact that they knew something was wrong. They tried to meet the customer's demand of getting the ice rink ready in time for the season.

The investigation process also included a survey of other ice rinks, and it turned out that seven other ice rinks had the same problem as the one in Fernie. Two of the systems were closed down immediately to fix the problem, but the other five were still running during the press conference without any plans of action.

The ventilation in the machine room probably worked when the system was first started. But over the years, a section was removed, and the exhaust was no longer sent over the roof but could enter parts of the building resulting in a concentration of up to approximately 300 ppm in the entrance area.

Figure 2: The heat exchanger had previously been reported to be leaking, and some of the tubes were blocked.

2. ANALYSIS AND RECOMMENDATIONS

As can be seen from accidents in the field, the cause of accidents is very often lack of knowledge or qualifications. ISO has recently approved the new standard pr-EN/ISO 22712 (previously EN 13313). In ISO 5149 and EN 378:2016 part 1, it says: "§3.2.2 separate refrigeration machinery room: machinery room

intended to contain only components of the refrigeration system, accessible only to competent personnel for the purposes of inspection, maintenance and repair." and "§3.8.1 Competence: ability to perform satisfactorily and safely the activities related to a given task. NOTE 1 to entry: Levels of competence are defined in EN 13313". Therefore, there can be no doubt now that only competent persons are allowed to perform work in a refrigeration machine room.

It has already been established that the number of accidents happening with any type of refrigerant often comes down to the competence level of the involved technician. We also know that if an employer does not ask to see the certificates or proof of proper training, there is a significant risk that a new employee does not have the required qualifications and may make expensive or, in worst case, fatal mistakes.

One of the lessons learned from the Fernie Memorial Arena accident is very clear: The owner and the daily user, who in many cases are not the same person, must be prepared to receive bad news about the refrigeration plant and to take the necessary action when they get the message. It is not acceptable if the owner simply asks for a quick short-term repair to keep the plant running and then does nothing further. It is not acceptable either that the owner can ask another company to do the job without informing them of the state of the system and the associated risk they will be assuming if they perform the job.

It may also be an issue that the contractor fears losing the job if he informs the owner about problems. This is a very common dilemma among technicians and contractors. Some think it is better to just fix the problem and hope for the best, instead of informing the owner. During the investigation of the Fernie Memorial Arena accident, other similar plants in the state were inspected. Five plants had the same problem with the evaporator leaking into the brine. Two of the sites decided to shut down when they found out, and three kept on going. Is that acceptable?

Too many installations are carried out without ensuring proper surveillance of safety. Detectors to monitor the concentration in case of a refrigerant leak in the machine room should be installed everywhere when there is a risk that a valve or flange may leak during operation. The problem is that even if you wear a personal detector when entering the machine room, it may be too late when the machine room door closes behind you before the alarm is triggered.

It is recommended that refrigeration organisations all over the world implement training schemes to qualify refrigeration engineers and service technicians according to ISO 22712. If both the system designers and the technicians who work with the systems are competent, this will reduce the number of accidents and save lives. At the same time, it will increase the quality of the performed work and benefit the energy efficiency of the systems in general, due to a better understanding of processes and what it takes to achieve high energy efficiency.

3. COLLECTION OF INFORMATION

Typically, we find information about accidents in the press. However, when trying to dig further into the facts, it is often in vain. In some countries, for instance the UK and the US, information is available after an investigation has taking place and if the case has been in court. In other countries, for instance Denmark, no information is available, not even if there have been fatalities.

There are also reports about accidents, for instance in India; but it is difficult to get any insights from local staff, and the results of the investigations are not published so the industry can learn from them. This is a problem in a country with many accidents and a poorly developed training system.

If we broaden the understanding of safety to cover a wider aspect and include other situations, we may consider the accident triangle, also known as Heinrich's triangle or Bird's triangle, which is a theory of industrial accident prevention.

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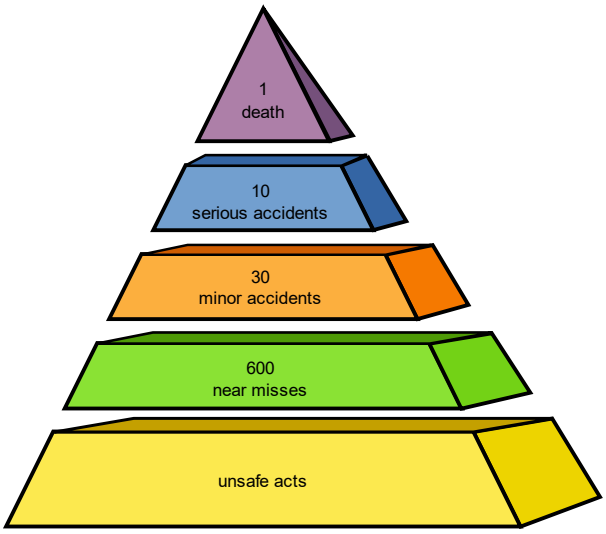

Figure 3 Bird's enhanced safety triangle
https://en.wikipedia.org/wiki/Accident_trianglehttps://commons.wikimedia.or

If we use this theory, accidents are only the tip of the iceberg – or the tip of the pyramid. The Heinrich triangle has been criticised for being too simple, and we therefore use the Bird version here. There are several versions of the pyramid with different numbers at the levels, but the message is the same. It can be difficult to get information about minor accidents, near misses and unsafe acts, because they are rarely reported. The numbers are dark numbers, which we can only guess about. However, this has to be part of the everyday considerations and training of employees, sub-contractors and suppliers.

In some countries, e.g. Australia, all accidents must be reported. It is valuable to report even minor accidents as they may develop later. Both doctors and hospitals normally report serious accidents to the authorities. However, it varies a lot how the data is used and disseminated. Statistics can be difficult to use, because the accidents are put into different groups, and refrigeration systems or similar are rarely included.

A paper (Pachai, 2014) presented at the Gustav Lorentzen conference in Hanzhou, China, mentions that 60% of accidents and incidents reported and the same time 50% of these systems are of age. Age of the system is of significant importance the paper says. Valves and other components change as the manufacturer gains more experience and as the requirements change. This also has the consequence that sealing materials can change over time for a specific valve. If the service technician is not aware of these changes and uses the wrong materials, there can be a potential leaking component sitting in the system.

In many countries the certification of the individual certificate holder is only valid for a limited time e.g. 5 years, after which it can be renewed if the certificate holder can demonstrate that he has active participated in product updates and other training modules. It is also important that the company regularly checks if the individuals are always have acquired the necessary competence to do whatever he/she is asked to do on a daily basis. If that is not the case it is the company's responsibility that the individual gets the competences required to safely do the job.

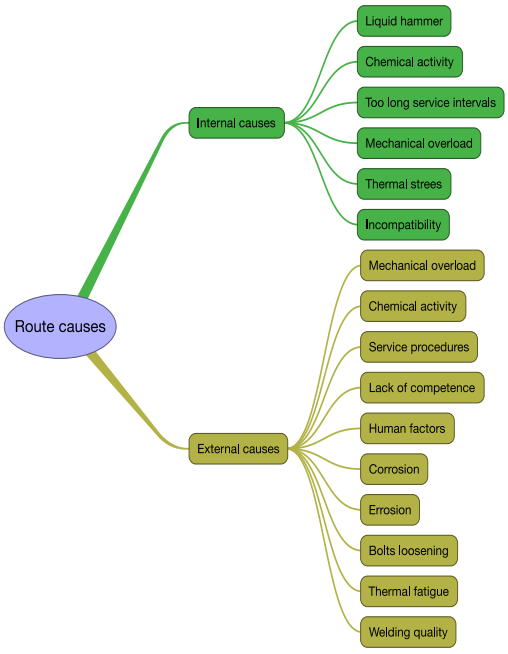

Figure 4 Route causes can be found both internally and externally

The paper (Pachai, 2014) shows, see figure 4, that accidents can be caused by external and internal changes. This is an important point to bear in mind especially when you are looking for a root cause to the accident that you are investigating. Especially thermal stresses are seen to cause problems, and a good example is heat exchangers in cascade system where a leak of a CO_2 system in a NH_3 system can cause major problems if not dealt with quickly. Other well-known problems is copper plating in on hot surfaces in systems where the refrigerant can form acids attacking copper surface in the system and deposit the copper ions on the bearing surface. Of newer occurring phenomena is heat problems with some types of O-rings which are not compatible with the high temperatures seen in high temperature heat pumps.

The expected wider use of industrial and commercial heat pumps, as a result of the political decision to reduce or ban the use of fossil fuels, for producing hot water or steam over 120°C raises new sets of challenges to the current certification system for HVACR&HP service technician. There are a set of regulations and requirements to be met for individual working on these kinds of systems. You for the same reason often see that owners considering heat pumps, will specify temperatures to be no higher than 115°C for the same reason. Customers currently working with processes and tools using steam produced at 8bar and 160°C are not going to accept heat pumps which would require a change in the production or the process resulting changes to their final product. The heat pumps are therefore expected to be delivering the same temperature and pressure steam which will require an up-skill of the HVACR technicians or alternatively an up-skill of the boiler technician as boilers will disappear over time if the changes demanded by the regulators are to be met.

For the compressor manufacturer the new temperature regimes raise new challenges. Stability of refrigerants is one set of problems but what is more of a challenge is the lubricants. The lubricants used until now have comfortably been able to withstand the temperatures which have been limited to about 160°C. The lubricants/oil used in the modern compressors start to produce soot at about 180°C and coke in the discharge valves at about 200°C. This is a challenge which worries the compressor manufacturer and the producer of the lubricant/oil. On the other hand, you should avoid cooling the lubricant/oil too much in the heat pump compressor in order to avoid condensation of refrigerant/working fluid in the crankcase resulting in breakdown of the bearings.

Many compressor manufacturers have traditionally had a little reservation against additives in the lubricant which could probably have given the lubricants a little more heat resistance. Here is a challenge for the partners in the industry to work with the coming years.

4. CONCLUSION

There is still a lot to learn within the refrigeration industry, also when it comes to safety. Especially now, where new refrigerant families are being introduced in the market, there is a need for better understanding of what it takes to work safely with the so-called A2L class of refrigerants. Many accidents have happened over the past years, and the majority of technicians do not fully understand the dynamics.

In the future it is expected that bans on boilers and furnaces will require a wider used of heat pumps but also heat pumps working at temperatures higher than the industry has previously used. Systems working with temperatures up to about 160 and 180°C are already being developed but also systems achieving temperatures as high as 250°C are foreseen to enter the market. This will require up-skill of many technicians especially if the technicians are work on heat pumps producing temperature over 120°C.

All parties have to change their mind-set if we are to achieve a safer industry for coming generations. The owners have to understand the importance of using competent technicians, not only for their own safety but also to get the energy-efficient system they are paying for. Employers must allow technicians the necessary time to obtain the qualifications required to perform a good job to the benefit of the customers – and of course, happy customers will be returning customers. The authorities must play their part too and ensure that the rules are followed, and the maintenance level is acceptable. This also requires qualified inspectors.

Always remember: Safety is a lifestyle.

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