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# FREON LEAKAGE

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**Abstract -** All types of Freon, including those that do not contain chlorine and are not considered Ozone-depleting substances, have negative effects to the environment because they contribute to global warming. As a result of the harmful effects Freon has upon the environment, numerous research studies of existing refrigeration systems have been carried out. Some of those studies were related to the quantity of Freon that leaks out into the atmosphere, while others were related to what causes Freon to leak. The results of a research on quantity of Freon emissions from refrigerating systems in Serbia are shown in this paper. These findings are important since they represent the starting point when defining measures aimed at reducing Freon emissions and leakage from refrigeration and air conditioning systems.

**Index terms -** Global warming, F-Gas Regulation, Freon leak, refrigeration systems.

## I. INTRODUCTION

Serbia has ratified both the Montreal and the Kyoto Protocol treaties, except that regulations of these protocols are not the same for Serbia and developed countries. Serbia has not signed the F-Gas Regulation yet and still lags behind developed countries in this respect. This paper presents the results of a research on the quantity of Freon leaked out of the refrigeration systems in supermarkets and describes what measures, in accordance to the EU legislations, are taken when installing refrigeration systems using Freon.

The amount of Freon currently released to the environment needs to be established in order to take appropriate measures for reducing Freon leakage.

Freon is widely used in refrigeration and air conditioning systems in foodservice facilities (such as petrol stations, convenience stores, grocery stores and supermarkets), cold storages for cooling and freezing food and transportation vehicles. Refrigeration systems in super- and hypermarkets contain the largest quantity of refrigerant which is proportional to their size. Moreover, refrigeration systems in these facilities use numerous branch circuits and consist of long pipelines containing large amounts of refrigerant, so pipes tend to burst more often. This can be potentially harmful to the environment and therefore more attention is being paid to refrigeration systems in super- and hypermarkets as well as to refrigerants.

Small convenience stores, mostly, do not have refrigeration system with central cooling units, yet cooling units are located in cooling display cabinets (as household refrigerators). Regarding refrigerant leakage, the aforesaid convenience stores are less dangerous than super – and hypermarkets because refrigerant is found in the cooling units of their cooling display cabinets.

Unlike EU countries, the South East European countries have far greater number of small convenience stores than supermarkets [1] . The situation in Serbia is the same, even though the trend in the world today is decreasing number of small stores and increasing number of supermarkets. The retail industry in Serbia is undergoing a transformation where key trends are showing tendency towards declining significance of small stores that will certainly not be eliminated in the future, but their number will be reduced.

It often happens that a large quantity of refrigerant leaks out into the environment due to refrigeration system failures and repair service interventions. For this reason, it is very important to take this problem into consideration when selecting refrigerants because of their negative environmental impact.

A major part of refrigeration systems in foodservice facilities utilize Freon. CFC refrigerants are also banned in Serbia and cannot be used not even for the purpose of equipment servicing, which implies that refrigeration systems using these refrigerants do not exist in Serbia. HCFCs are being phased out, but there is still great number of refrigeration systems that utilize HCFC refrigerants.

As a result of the Montreal Protocol regulations, the number of refrigeration systems with HCFCs is being gradually reduced. HFC refrigerants are mainly used in new refrigeration systems and the same thing is being also practiced in Serbia. In most countries HFCs are not banned, however, developed countries have started imposing stricter regulatory measures on the use of HFCs since they are categorised as having a high global warming potential (GWP).

Over the past three years, 2010, 2011 and 2012, the records of the quantity of Freon used during maintenance and equipment repair service at 26 supermarkets in Serbia have been kept. The data for all three years (2010, 2011 and 2012,) were collected in collaboration with company Soko Engineering. This company maintains refrigeration installations in 26 supermarkets that are the subject of research.

All supermarkets had two types of refrigeration systems. The first one is the Medium Temperature system (MT) and it serves to achieve temperature from +2 to +6ºC in cold rooms and cooling display cabinets. The other one is the Low Temperature system (LT) which serves to achieve temperature from -22 to -18 ºC in cold rooms and cooling display cabinets. Determining Freon leakage rate in both refrigeration systems has also been included in this research. The amount of refrigerant should always be the same in the refrigeration system; hence it is important that the quantity of refrigerant recharge correspond to the quantity of refrigerant that has leaked out.

## II. Research Elaborations

### *1.1. Research results in 2010.*

Table 1 shows research results for 26 supermarkets in Serbia regarding Freon leakage rate in 2010.

**Table 1:**Freon leakage rate for supermarkets – 2010

| Supermarket | First installation of refrigeration system | The amount of refrigerant in the installation (kg) | Refill freon in the system (kg) | Leakage (%) |
|---|---|---|---|---|
| 1 | 2007 | 330 | 66 | 20,0 |
| 2 | 2004 | 157 | 0 | 0,0 |
| 3 | 2004 | 140 | 66 | 47,1 |
| 4 | 2007 | 157 | 0 | 0,0 |
| 5 | 2007 | 151 | 77 | 51,0 |
| 6 | 2007 | 136 | 66 | 48,5 |
| 7 | 2008 | 137 | 33 | 24,1 |
| 8 | 2008 | 108 | 0 | 0,0 |
| 9 | 2008 | 370 | 66 | 17,8 |
| 10 | 2006 | 602 | 231 | 38,4 |
| 11 | 2008 | 153 | 55 | 35,9 |
| 12 | 2009 | 95 | 11 | 11,6 |
| 13 | 2009 | 186 | 44 | 23,7 |
| 14 | 2004 | 123 | 33 | 26,8 |
| 15 | 2004 | 102 | 0 | 0,0 |
| 16 | 2006 | 234 | 55 | 23,5 |
| 17 | 2006 | 125 | 0 | 0,0 |

| | | | | |
|---|---|---|---|---|
| 18 | 2004 | 125 | 25 | 20,0 |
| 19 | 2007 | 146 | 33 | 22,6 |
| 20 | 2006 | 159 | 0 | 0,0 |
| 21 | 2006 | 146 | 55 | 37,7 |
| 22 | 2004 | 154 | 63 | 40,9 |
| 23 | 2004 | 126 | 55 | 43,7 |
| 24 | 2007 | 82 | 33 | 40,2 |
| 25 | 2008 | 85 | 0 | 0 |
| 26 | 2008 | 70 | 3 | 4,3 |
| Average freon leakage rate in 26 supermarkets - 2010 [%] | | | | 22,2 |

*1.2. Research results in 2011.*

Table 2 shows research results for 26 supermarkets in Serbia regarding Freon leakage rate in 2011.

**Table 2**: Freon leakage rate for supermarkets – 2011

| Supermarket | First installation of refrigeration system | The amount of refrigerant in the installation (kg) | Refill freon in the system (kg) | Leakage (%) |
|---|---|---|---|---|
| 1 | 2007 | 330 | 117,6 | 35,6 |
| 2 | 2004 | 157 | 11 | 7,0 |
| 3 | 2004 | 140 | 0 | 0,0 |
| 4 | 2007 | 157 | 66 | 42,0 |
| 5 | 2007 | 151 | 20 | 13,2 |
| 6 | 2007 | 136 | 10 | 7,4 |
| 7 | 2008 | 137 | 55 | 40,1 |
| 8 | 2008 | 108 | 22 | 20,4 |
| 9 | 2008 | 370 | 45 | 12,2 |
| 10 | 2006 | 602 | 164 | 27,2 |
| 11 | 2008 | 153 | 33 | 21,6 |
| 12 | 2009 | 95 | 33 | 34,7 |
| 13 | 2009 | 186 | 110 | 59,1 |
| 14 | 2004 | 123 | 35 | 28,5 |
| 15 | 2004 | 102 | 5 | 4,9 |
| 16 | 2006 | 234 | 77 | 32,9 |
| 17 | 2006 | 125 | 0 | 0,0 |
| 18 | 2004 | 125 | 66 | 52,8 |
| 19 | 2007 | 146 | 60 | 41,1 |
| 20 | 2006 | 159 | 11 | 6,9 |
| 21 | 2006 | 146 | 91 | 62,3 |
| 22 | 2004 | 154 | 73 | 47,4 |
| 23 | 2004 | 126 | 6 | 4,8 |
| 24 | 2007 | 82 | 0 | 0,0 |
| 25 | 2008 | 85 | 0 | 0 |
| 26 | 2008 | 70 | 5 | 3,5 |
| Average freon leakage rate in 26 supermarkets - 2011 [%] | | | | 23,3 |

*1.3. Research results in 2012.*

Table 3 shows research results for 26 supermarkets in Serbia regarding Freon leakage rate in 2012.

**Table 3.** Freon leakage rate for supermarkets – 2012.

| Supermarket | First installation of refrigeration system | The amount of refrigerant in the installation (kg) | Refill freon in the system (kg) | Leakage (%) |
|---|---|---|---|---|
| 1 | 2007 | 330 | 56 | 17,0 |
| 2 | 2004 | 157 | 20 | 12,7 |
| 3 | 2004 | 140 | 10 | 7,1 |
| 4 | 2007 | 157 | 32 | 20,4 |
| 5 | 2007 | 151 | 10 | 6,6 |
| 6 | 2007 | 136 | 11 | 8,1 |
| 7 | 2008 | 137 | 11 | 8,0 |
| 8 | 2008 | 108 | 0 | 0,0 |
| 9 | 2008 | 370 | 44 | 11,9 |
| 10 | 2006 | 602 | 66 | 11,0 |
| 11 | 2008 | 153 | 22 | 14,4 |
| 12 | 2009 | 95 | 56 | 58,9 |
| 13 | 2009 | 186 | 11 | 5,9 |
| 14 | 2004 | 123 | 26 | 21,1 |
| 15 | 2004 | 102 | 18 | 17,6 |
| 16 | 2006 | 234 | 30 | 12,8 |
| 17 | 2006 | 125 | 11 | 8,8 |
| 18 | 2004 | 125 | 12 | 9,6 |
| 19 | 2007 | 146 | 16 | 11,0 |
| 20 | 2006 | 159 | 36 | 22,6 |
| 21 | 2006 | 146 | 6 | 4,1 |
| 22 | 2004 | 154 | 56 | 36,4 |
| 23 | 2004 | 126 | 16 | 12,7 |
| 24 | 2007 | 82 | 38 | 46,3 |
| 25 | 2008 | 85 | 40 | 47,1 |
| 26 | 2008 | 70 | 0 | 0,0 |
| Average freon leakage rate in 26 supermarkets - 2012 [%] | | | | 16,6 |

## III. RESULTS OF FINDING

*1.4. Comment and comparison with research results obtained in other countries*

The research conducted in 2010 showed that annual Freon leakage rate was 22.2% out of the total operating charge. The excessive Freon loss in the event of a catastrophic leak was taken into account as well. Regardless of all the precautionary measures, catastrophic leaks occur and they have been taken into account in this research because it is the only way to get a real insight into the amount of Freon that leaks out into the environment.

The average Freon leakage rate at 26 supermarkets in 2011 was 23.3% out of the total operating charge. Refrigeration systems of these 26 supermarkets were relatively new which started operating between 2004 and 2009, so the leakage rate is lower than the one in older refrigeration systems. Old and worn components, joints and devices within refrigeration systems can cause increased Freon leakage.

In the first half of 2012 all filters with flared joints were replaced with filters with welded joints. All valves (solenoid, stop valves...) were also replaced with valves with welded joint. That resulted in Freon leakage reduction, therefore the average Freon leakage rate in 2012 at 26 supermarkets was 16.6%. Replacing flared joints with welded joints led to significant reduction of Freon leakage compared with the years 2010 and 2011.

Refrigerant leakage is typical for all refrigeration systems and depends on the complexity of the system, working conditions, maintenance methods and many other factors. In recent years research studies on Freon leakage has been carried out mostly all over Europe and in the United States.

A study conducted in Germany reported annual Freon leakage rate for supermarket central refrigeration systems of between 5% and 10% [2]. In 2006, another research conducted at 21 supermarkets in the United States indicated refrigerant leakage rate of around 8% [2]. Freon leakage in refrigeration systems that are 1 to 4 years old is below this level.

In Sweden, between 1996 and 2003 a research carried out at 450 supermarkets indicated Freon leakage rate of around 12% [3]. According to the EIA (Environmental Investigation Agency), UK supermarkets are reported an 11% annualised refrigerant charge loss. Furthermore, the agency reported leakage rates in other countries of between 5% and 22%.

Methods of installing central refrigeration systems in Serbia and in other countries around the world are not so different with respect to installed components and implemented regulations and measures, especially in large supermarket chains. Serbia does not have manufacturing companies of refrigeration system components (such as compressors, air cooled condensers, evaporators, oil separators, receivers, valves, etc.), so all these components are being imported mainly from Italy, Germany and some from France. Although the same principles, installation methods and the same quality of installed components are being respected, there are other factors as well affecting the quality of refrigeration systems and thereby Freon leakage.

The aforesaid factors, comparing with other countries, are caused by inadequate education of contractors, service technicians and service and maintenance engineers. Installing the Freon leak detector in the supermarket machine room, retail space and storage rooms where cooling chambers are located can considerably contribute to Freon leakage reduction. Nowadays in most European countries installation of the Freon leak detector is mandatory and stipulated by the F-Gas Regulation. The number of detectors to be installed is based on the size of a machine room. Freon leak detector is simple device, very inexpensive in comparison to the price of supermarket refrigeration system and long-term cost-effective for an investor himself because it will prevent Freon loss.

Freon price increase in the world and in Serbia will compel both installers and investors to take appropriate measures in order to reduce Freon emissions. Refrigeration systems usually have 1 year limited warranty, so the interest of installation companies is to have as less Freon leakage as possible within that period, in order to avoid greater costs by charging the refrigeration system with additional amounts of Freon. After the limited warranty expires the costs are defrayed by the investor, i.e. the purchaser. Until 2007 Freon prices were low, so speaking from this point of view, the problem of Freon emissions and leakage was not even considered.

In order to reduce Freon emissions many research aimed at detecting the most common causes of refrigerant leakage has been conducted. For that purpose the Forshungsrat Kältetechnik investigated the causes of Freon leakage at 62 commercial refrigeration systems in Germany which were installed between 1990 and 1999 [4] . The results showed that out of these 62 refrigeration systems, 19 were with central cooling units, 43 were decentralised systems, and refrigerant charge was of between 0, 7 and 360 kg. It was determined that 83% of the total refrigerant loss was through joints. Empirical data obtained in Serbia is very similar to this research conducted in Germany.

Figure 1 shows research results of the most common refrigerant leak points at 62 commercial refrigeration systems in Germany.

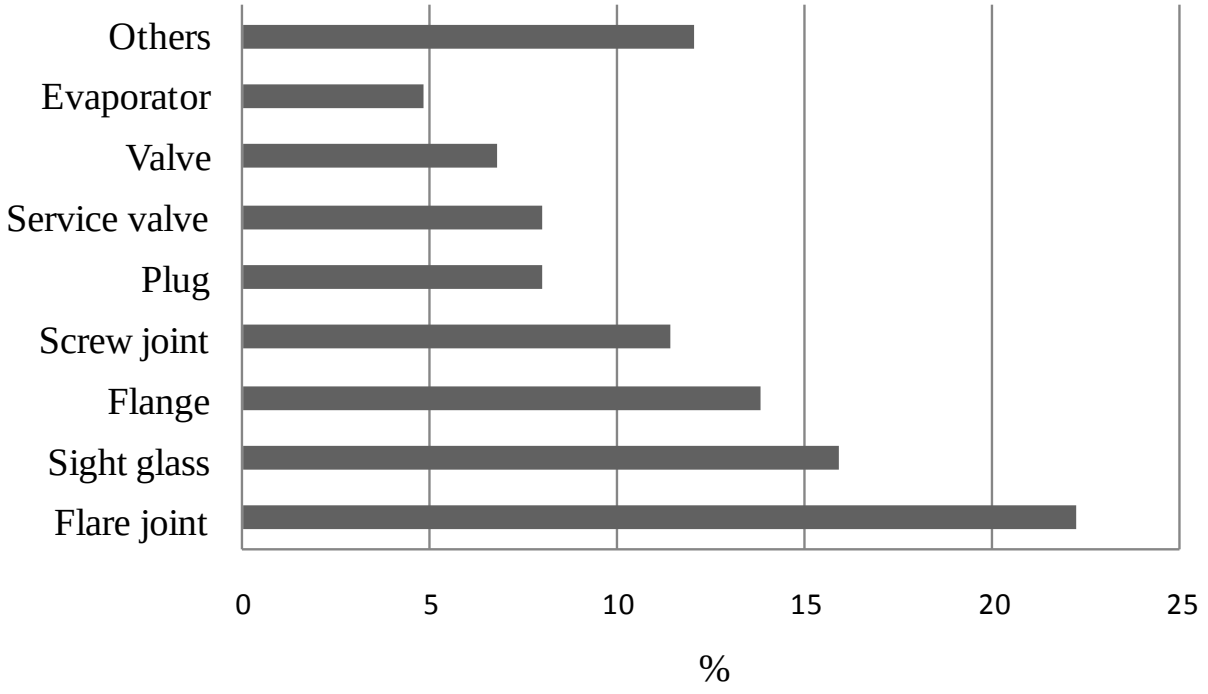


**Fig. 1**. Refrigerant leak points (according to the number of leaks, not the quantity) at 62 commercial refrigeration systems in Germany [4]

Since the great portion of leaks occurred at flared joints, the number of flared joints at refrigeration systems with central cooling units was considerably reduced, and special attention was given to the points where pipe bursting occurs due to vibrations. A lot of effort has been put into improving the quality of welded joints where Freon leak most often occurs (afore-mentioned research refers to the number of leaks, and not to the amount of Freon that leaks out). The same measures are applied in Serbia as well when installing refrigeration systems.

Figure 2 shows the most common causes that lead to refrigerant leakage, according to the research presented at the International Congress of Refrigeration in China. 86% of refrigerant leaks are caused by mechanical wear-and-tear on the system and vibration, as shown in the graph. The major portion of refrigerant leaks within mechanical wear-and-tear is related to flared joints. These findings are important because they indicate that considerable leak reduction can be accomplished by improving the design of cooling units, piping installation methods that would reduce vibrations and the quality of components and joints.

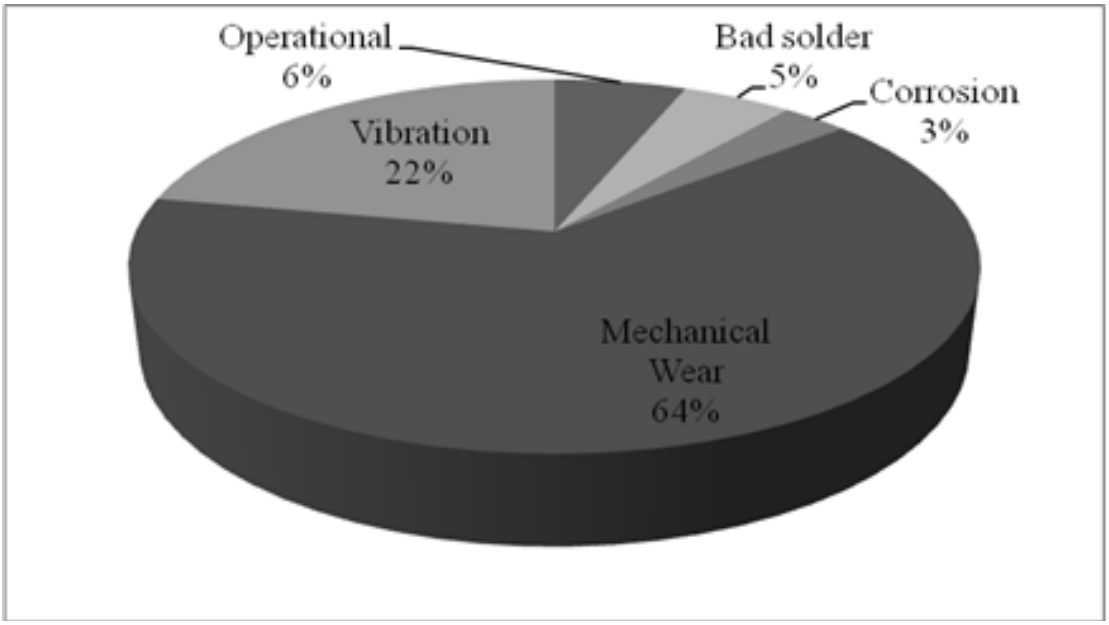


**Fig. 2**. Most common causes of refrigerant leakage from the system [5]

*1.5. Measures implemented in Serbia to reduce Freon leakage*

Leakage reduction can be achieved by improving the quality of components, joints and installation methods. The use of anti-vibration rubber feet or spring mounts under refrigeration compressors reduces vibration which causes 22% of Freon leaks. Figure 3 shows the anti-vibration rubber feet and spring mounts that are installed under the refrigeration compressors.

**Fig. 3**. Anti-vibration rubber feet and spring mounts for refrigeration compressors

Besides compressor, the matching anti-vibration feet are also installed under the central cooling unit for levelling and vibration control. Figure 4 shows the anti-vibration rubber feet used for cooling units.

**Fig. 4**. Anti-vibration rubber feet for cooling units

To avoid vibration, the anti-vibration flexible hoses should be installed in the suction and discharge lines of the refrigeration compressor. At cooling units these anti-vibration hoses are mounted in all incoming and outgoing pipes. Figure 5 shows the anti-vibration flexible hose for refrigeration systems.

**Fig. 5**. Anti-vibration flexible hose for refrigeration systems

Reduction of refrigerant charge can result in reduced refrigerant leakage. Arranging the refrigeration equipment in only one section of the super-or hypermarket and installing the machine room closer to the cooling display cabinets and cooling rooms can contribute to refrigerant charge reduction. Technical solutions such as this should be carried out during architectural design process phase when good cooperation between architectural and mechanical engineers has to be established. Mechanical engineers, whose role is to give guidance or instructions and to oversee the mechanical equipment installation, ought to take into account that the short-length pipeline would result in reduced amount of refrigerant in the system.

Apart from afore-mentioned, reduction of the quantity of Freon in the refrigeration system can be accomplished by various technical solutions. One of them is to use water-cooled instead of air-cooled condensers in order to reduce the amount of refrigerant charge. In this manner the system would not have external units (air-cooled condensers) but water-cooled condensers placed in the machine room next to the cooling units. Accordingly, the length of the pipeline between cooling unit and condenser is shorter, which leads to reduced amount of refrigerant in the system [6].

Another efficient method to reduce the refrigerant charge is to use certain type of heat exchangers. If the air-cooled condensers in the system are needed due to deficiency of clean water, then the optimum choice would be to use micro channel condensers. The volume of these condensers is a few times less than the volume of standard air-cooled condensers of the same capacity which are made of copper tubes with aluminium fins. The use of water-cooled or air-cooled micro channel condensers enables easier compliance with the F-Gas Regulation and contributes to a real reduction in refrigerant leakage [6].

It should be mentioned as well that according to the F-Gas Regulation the frequency of leak testing depends on the amount of Freon in the system, thereby leak checking needs to be done more frequently at systems containing larger amount of Freon.

Apart from the Montreal and Kyoto Protocol requirements, additional measures to reduce greenhouse gas emissions are being applied in developed European countries. Denmark, Netherlands, Norway, Austria and Sweden have introduced regulations that prohibit the use of HFC refrigerants, which do not deplete the Ozone layer but have a high global warming potential (GWP). The tax on refrigerants has not being yet introduced in Serbia and the only regulations put into effect are the Montreal and Kyoto Protocols.

Even though Serbia has not still signed the F-Gas Regulation, we should be working towards system upgrades and better training of mechanical engineers, service and maintenance engineers and service companies because the opportunities to reduce refrigerant emissions are most likely to be associated with improvements to service and maintenance regimes and procedures.

## IV. Conclusion

In comparison with other developed countries, Freon leakage rate in Serbia is significantly higher.

Freon leak reduction can be accomplished in many ways. One way is replacement of flared with welded joints and the use of flexible hose and anti-vibration feet under compressors. Decisive factor providing reduced amount of refrigerant charge in the system is the choice of the machine room location and position of cooling devices in order to shorten the length of the pipeline.

In existing systems Freon leakage can be reduced by installing the leak detector, keeping records of service interventions and providing training of engineers.

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