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Safety with Flammable Refrigerants

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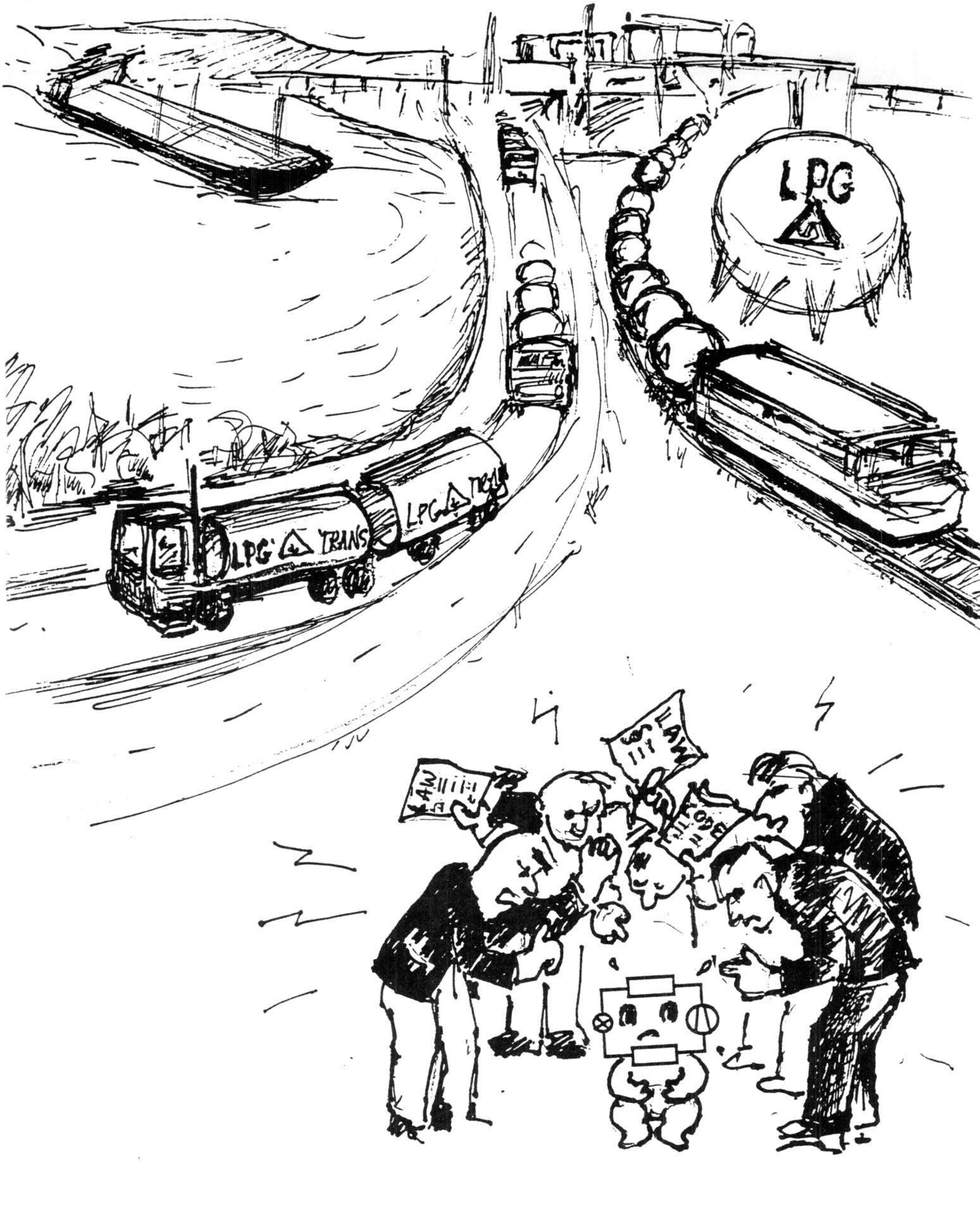

Safety with Flammable Refrigerants

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SAFETY WITH FLAMMABLE REFRIGERANTS

Summary

The discussion about the ozone depletion and greenhouse warming potential of refrigerants, has started a process of investigating other refrigerants without these problems.

Propane can advantageously replace many old refrigerants in heat pumps and refrigeration machinery. Measurements have shown that propane (R290) gives both a high output power and frequently a better efficiency [2,3]. The problem is the flammability. Until now the flammability has resulted in that regulations and public safety awareness, has made the use of propane impossible as a refrigerant.

Many interesting questions arise, among them:

- Can flammable refrigerants be used at a reasonable safety cost?

- If a safety level high enough could be achieved, would that fact be psychologically accepted?

- Why were flammable refrigerants abandoned - did they give too many safety problems?

- In which areas in the heat pump and refrigerating field can flammable refrigerants have an economic potential?

The author's opinions are that:

- flammable refrigerants should not be used for converting old units using nonflammable refrigerant.

- flammable refrigerant in new units up to say 5 kg can easily be made safe at low cost. They sould be made welded or solded, put in well ventilated cabinets and with spark free electric equipment.

- By mixing a **weakly** flammable refrigerant with small amounts of an extinguishing medium all risks of explosion and fire from the refrigerant could be avoided.

Enclosed to his report is a short computer program to illustrate the complexity of the safety problem with flammable refrigerants.

1. SAFETY REQUIREMENTS AND COSTS

1.1 How dangerous are explosive gases?

A fire or an explosion with a flammable gas requires that gas leak out, mix with air and that the mixture is then ignited.

If there is too little flammable gas, the mixture can't be ignited. The mixture is then defined as below the Lower Explosion Limit (LEL). If there is too much flammable gas there is too little oxygen available in the mixture. The mixture is then said to be above the upper explosion limit (UEL).

Ignition of the mixture happens when the temperature gets too high or when an electric spark with sufficient energy content occurs.

The values of the explosivity parameters vary between different literature sources using different measuring techniques. A rough indication of the magnitudes, picked from different sources is shown below:

Refrigerant	LEL vol %	UEL vol %	Ignition temp °C	Ignition energy J
R290 propane	2.1	9.5	466	.00025
R600a isobuthane	1.3	8.5	455	.00025
R152a	3.9	16.9		.22
R717 ammonia	15.5	27.0	651	.68

Table 1.1

One interesting question is how much ventilation air flow is needed to vent away a certain leak without reaching LEL. Let us take an example:

The molecular weight of propane is 44. Assume that the propane leakage rate is 1000 kg/year, which is a large leak. This corresponds to about 0.03 g/s or $7 * 10^{-4}$ mol/s. As each mole takes up 22.4 litres, a propane volume flow of 0.015 l/s leaks out. The volume flow of air has to be 50 times greater or 0.7 l/s in order not to reach the LEL. This corresponds to an airflow of about 2.6 m^3/h. In order not to reach 25% of LEL, an often used criterion, 10 m^3/h is needed. That seems easy to achieve.

The power of the leak above if set to fire corresponds roughly to 1.3 kW. If we assume that this leakage goes on for an hour without ignition and is then set to fire, during lets say 0.1 s, the power developed during that tenth of a second is 47 000 kW!

The two examples above show that a flammable refrigerant can be easily dealt with, but if treated wrongly, the refrigerant is potentially very dangerous.

1.1.1 General Swedish accident statistics

According to the National Board of Health and Welfare [7], 238 people were injured each year from explosions during the period 1987-1991 causing 1930 sick days. This included all explosions from firecrackers to gasoline leaks.

The National Swedish Inspectorate of Explosives and Flammables (NSIEF), should also get a report about all relevant accidents to be able to investigate them. The figure 1.1.1 showed below, concerns the period 1986-1992 [9]. The average number of accidents **reported** to NSIEF where people were injured is about 30 each year whereas the yearly number of people injured reported to [7] is 238. This means that only one accident out of eight where people **are injured** is thoroughly reported to the NSIEF.

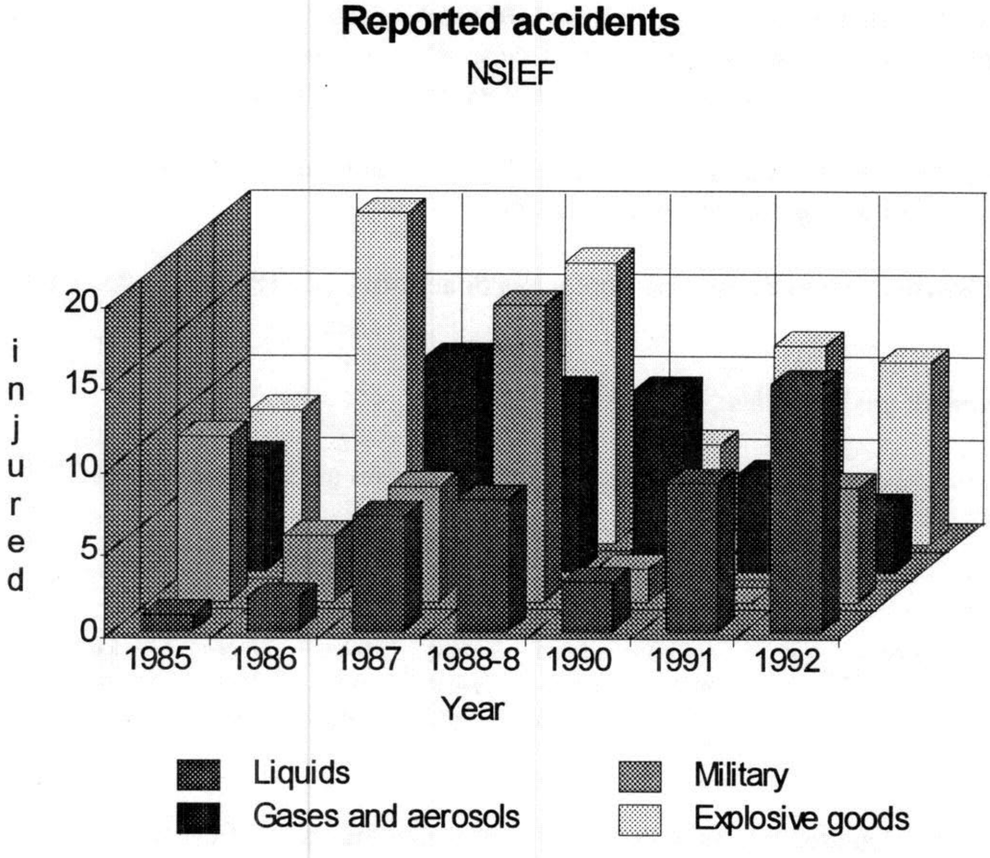

Fig 1.1.1 Number of people injured in different areas according to NSIEF

According to the Death Register [8] an average of 1.6 persons **died** in Sweden each year (1985-1991) due to all kinds of explosions.

If somebody dies in an explosion, it is much more likely that this accident is reported to NSIEF than if somebody is only slightly injured or nobody is injured at all. More explosions related deaths are reported to NSIEF than to the death register. During the period 1985-1992, 2.3 persons yearly were reported dead as an average to NSIEF [9]. The risk of death in an explosion is two orders of magnitude less than the risk of injuries.

Of the **total** number of all explosion accidents reported (both injured and killed) the number of accidents involving gases and aerosols was 19%. Of the total number of accidents reported to NSIEF where people were **injured**, 23% concerned Gases and aerosols. Of the number of people **killed**, 25% died in explosions involving gases and aerosols.

If 25% of the explosion accidents can be blamed on gases and aerosols in Sweden, then the following approximate table is valid as an interpretation of [7], [8] and [9]:

Injured people per year in Sweden due to explosions from gases or aerosols: 238 x 0.25 = **60**

Killed people per year in Sweden due to explosions from gases or aerosols: 2,3 x 0.25 = **0,6**

The fire hazard can be estimated using figures from [10]. About 30 000 fire reports came to the insurance companies in Sweden during 1992. Out of these, 48 were caused by handling of flammable liquid and 188 were caused by some kind of explosion, totally less than 1%.

If the same 25% of the fires induced by explosions and flammable liquids can be blamed on aerosols and gases the following number would be valid:

Fires per year in Sweden due to explosions from gases or aerosols: (188+48)*0,25 = **60**

1.1.2 General Swedish gas statistics

In Sweden approximately the following masses of flammable gases are handled per year according to [11]:

	1985	1986	1987	1988	1989	1990	1991	1992
Propane ton	428000	519000	660000	596000	681000	776000	811000	699000
Natural gas 1000nm3	78000	217000	292000	373000	494000	621000	663000	740000
Town gas 1000nm3	139000	116000	117000	108000	97000	96000	100227	104607

Table 1.1.2.1

That amount can be recalculated into an approximate corresponding value of energy:

	1985	1986	1987	1988	1989	1990	1991	1992
Propane Gwh	4280	5190	6600	5960	6810	7760	8110	6990
Naturalgas GWh	835	2322	3124	3991	5286	6645	7094	7918
Towngas 1000 GWh	660	551	555	513	460	456	476	497
Sum (GWh)	5774	8063	10280	10464	12556	14860	15680	15405

Table 1.1.2.2

The average value for the period 1985--1992 was 11635 GWh

1.1.3 General refrigerant statistics in Sweden

All owners of refrigeration plants totalling more than 10 kg of refrigerant have to report the refrigerant content mass indirectly to the Swedish Environmental Protection Agency each year.

Swedish EPA	1990	1991	1992	Leakage rate
Installed tons reported				1992 %
R12	920.2	1054.0	880.6	17
R22	1106.9	1287.7	1370.8	15
R502	283.3	341.2	317.3	11
R500	138.8	138.9	163.9	
R134a	0.0	0.0	4.5	
Sum	2449.2	2821.8	2737.1	

Table 1.1.3.1

The leakage rate is the number of kilos leaked divided by the number of kilos installed.

The really installed amount can be expected to be **much** higher than the reported amount. The yearly import of compounds that can be used as refrigerant are shown in the table below [14].

Imports of refrigerants						
reported to UNEP (tons	1986	1988	1989	1990	1991	1992
R11	2000	1700	1200	750	220	464
R12	2250	2350	985	735	745	541
R113	750	520	360	330	133	127
R114	70		25	35	1	1
R22			816	762	746	733
Sum	5070	4570	3386	2612	1845	1866

Table 1.1.3.2 (1987 is missing in the original)

The average value of imported refrigerants during the period 1985--92 was 3225 tons/year.

1.2 General Danish accident statistics

The Danish accident statistic is officially only printed for the period 1984--1988. Statistics for the period 1989--1992 has kindly been made available by private communication [13]. The reason for collecting the statistics is of course the need to reduce the number of accidents. Suicide is not registered as accidents. The collection is done by the police and the gas supplier. The annual number of fatal accidents is shown in figure 1.2.

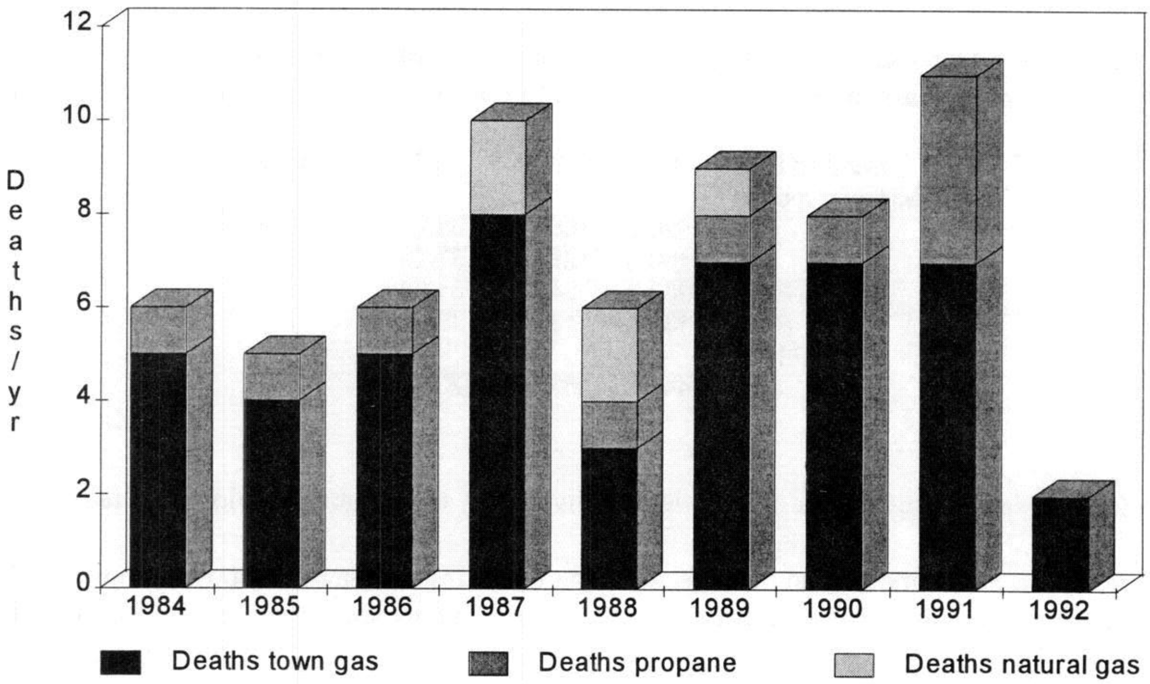

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Fig 1.2 Fatal gas accidents in Denmark

As there are about 600 000 gas installations in Denmark, the average number of fatal accidents for the period is roughly 1 per 100 000 installations and year. The average number of reported **accidents** is however 6 per 100 000 installations and year.

1.3 Comparisons

Can accident statistics of flammables, used for the normal combustion purpose, be used for calculating the hypothetical accident frequency of flammable refrigerants? The author's opinion is that it cannot be used. What should be the **base** for such a comparison?

- The number of tons used for combustion, compared with the expected number of tons used as refrigerant?

- The contained number of tons at any specific moment?

- The used combustion energy per year?

- The contained combustible energy?

- The enclosing wall area?

- The number of installations

The results of the comparison will vary enormously depending on the base chosen for the comparison. A calculus based on the energy of combustion is shown below. The assumption is that all refrigerants would be replaced by flammable refrigerants.

Replaced refrigerants **3200 tons/year**

The weight of hydrocarbons to replace 3200 tons of conventional refrigerants is **1900 tons/year**. (They are generally lighter than the conventional refrigerants)

Energy contained in all the replacing hydrocarbons: **19 GWh**

Energy contained in all gases and aerosols for combustion: **11635 GWh/year** (see above).

Frequency of people injured due to todays use of flammable gases: **60/year**

Frequency of injured people by the replacing hydrocarbons: = 60 x 19/11635 = **0.1/year**

Frequency of killed people by to days use of flammable gases **0.6/year** (see 1.1.1)

Frequency of people killed by the replacing refrigerants = 0.6 * 19 / 11635= **0.001/year**

If on the other hand the Danish accident statistics were to be used and all refrigerators and freezers and heat pumps in Sweden were to be filled with flammable refrigerants the following calculus could be made:

Number of new hydrocarbon installations in Sweden say **5 000 000** (all refrigerators and freezers)

Frequency of accidents per 100 000 installations **6/year** (see above)

Increased number of accidents = 6 x 5000000 / 100000 = **300 / year**

Frequency of people killed per 100 000 installations in Denmark = **1/year** (see above)

Hypothetical frequency of killed persons in Sweden = 1 x 5000000 / 100000 = **50 / year**

The relation between the number of people killed using the combustion energy in the imported gases each year as a base and the number of installations as another base is 0,001/50. The span is in other words a factor **50 000**.

2. ACCEPTANCE

2.1 The historical perspective

In the ASRE Refrigerating Data Book and Catalog [15] p 51 from 1934 one can read the following:

"Inflammability, as measured by upper and lower limits, by volume of mixtures in atmospheric air is a factor. Generally speaking, fire department regulations are such that refrigerants of high inflammability are ruled out. Ethyl chloride is in this class, as are the hydrocarbons, though any of these gases **are safe enough when used in small amounts, as in the domestic refrigerator**, or in industrial work of a special nature where the flammable hazard is always present anyway, e.g. an oil field."

The same reference p 127 mentions a list of makers of "Domestic Mechanical Refrigerators". 60 different refrigerators are mentioned. Out of these 11 uses isobutane as refrigerant. In those days a filling of about 4 kg was common when using SO2 as a refrigerant (p 128). That corresponds to a filling of about **1,5 kg of isobutane.** Copeland was the only manufacturer of the isobutane filled refrigerators in the list. Large risks must have been taken then for the luxury of a domestic refrigerator taking into account that the hermetic compressor was not in the market and that shaft leaks must have been common.

2.2 Psychology

Public fear does not correspond to the actual threat against life or health. It is a matter of **culture** - in a broad sense [5]. Fear of fire induced by electricity when common electricity was introduced in the beginning of the century was common [4]. This fear was similar to the fear that can be expected from the introduction of flammable refrigerants. Many people could then not sleep at night due to the fear for electrically induced fire. Explosions especially are spectacular threatening events. If a house blows up, it is always on the front page. If it just slowly burns down instead of explodes, it is often not even reported [6].

Small risks are often overestimated whereas large risks are underestimated [12 p46]. A small risk induced by flammable refrigerants could then be expected to be overestimated. According to the same source (p 51) we are also much more susceptible to influences in the direction of overestimating a risk than underestimating it. Mass media are nourishing from tickling the sense of fear of the readers. About 30% of the content in a modern Swedish newspaper is risk related in some way [12, p50]. New technical risks are especially valuable in this context [12, p19].

However, some facts are now indicating an increased psychological acceptance of flammable refrigerants. The fear of nature damaging us has largely been replaced by a fear of us damaging the nature [1, p140]. The ozone-layer debate is but one example.

People also feel more threatened by diffuse dangers like radiation, chemical compounds that can cause cancer etc. than from more obvious dangers. Asbestos was a material specially developed to combat the obvious risk of fire. However asbestos is causing a diffuse risk for cancer and is today considered a larger threat to man than the more obvious risk of fire [5] (when renouncing the option to use asbestos). The parallel to the Freon destroying the ozone layer causing a diffuse risk for skin cancer and the obvious risk of introducing flammable refrigerants is not too far fetched.

If the risk of fire or explosion can be considered an "old well-known risk", accepting such a risk is easier [12, p53]. If it can be kept under "control" the probability of acceptance is even higher [12]. We are all driving around with a velocity of up to 30 m/s with 40-70 kg highly flammable liquid (gasoline) mainly because we **feel in control** of the situation.

2.3 Acceptance by society

Van Gerwen [20] has given some examples of what risks different societies can accept when doing a Quantitative Risk Analysis (QRA). Below I quote van Gerwen:
".

Risk is the likelihood of an adverse outcome

So risk is determined by two factors: the adverse effect (consequences) of an exposure to hazard and the frequency that these consequences occur.

In QRA for hazardous materials two criteria for risk are used.

Individual risk: the frequency of fatal injury on a certain distance from the activity as a result of accidents with the activity concerned.

Societal risk: the frequency of a minimum number of fatalities due to an accident with the activity concerned.

In the latter case, the actual presence of people in the surroundings is taken into account. In many countries, general criteria for individual and societal risk are used. An overview is given in the tables below.

Individual risks in several countries	*Individual risk criteria per year*	
	intolerable	*negligible*
Ministry VROM, the Netherlands (new activities)	10^{-6}	10^{-8}
Existing plants	10^{-5}	10^{-8}
Environmental Protection Authority (Western Australia (new plants)	10^{-5}	10^{-8}
Health & Safety Executive, UK (new housing near plants)	10^{-5}	10^{-8}
Hong Kong Government (new plants)	10^{-5}	*not used*
Department of planning New South Wales (new plants and housing)	10^{-6}	*not used*

Societal risk criteria in several countries

Authority	*FN[1] Curve slope*	*Societal risk (intercept with N = 1[2])*		*Limit on N*
		tolerable	*negligible*	
Ministry VROM, the Netherlands (new plants)	*-2*	10^{-3}	10^{-5}	*1000*
Hong Kong Government (new plants)	*-1*	10^{-3}	-	*1000*
under consideration: Health & Safety Executive, UK (existing ports)	*-1*	10^{-1}	10^{-4}	-

The intolerable risk 10^{-3} means that a certain plant can lead to 10^{-3} fatalities per year.

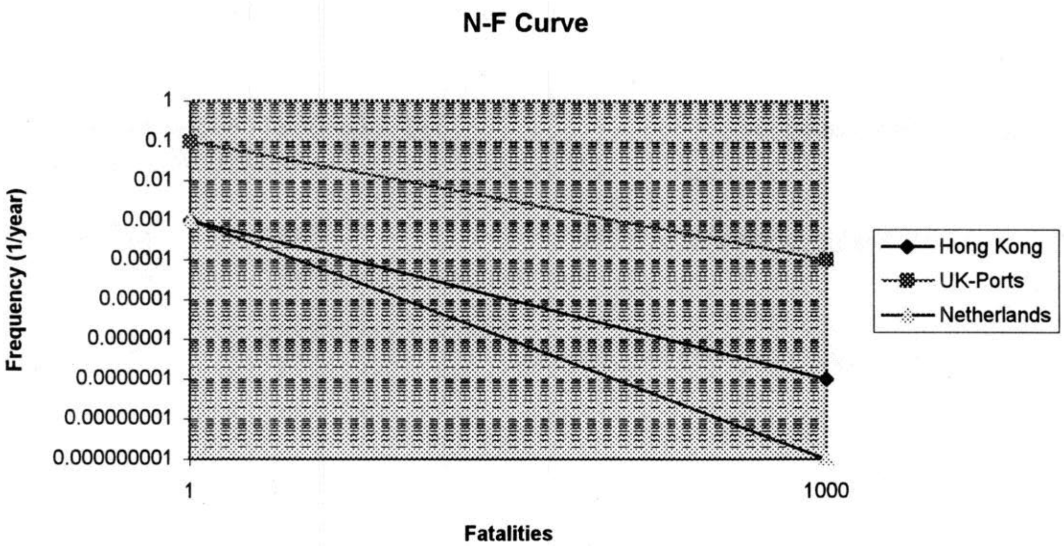

Fig 2.3 Acceptable societal risk levels in different locations

3. RULES & REGULATIONS

It is of course very difficult to describe how all different norms have evolved. This is therefore only a gleaning from the history of regulations without any wish to be complete.

[1] Frequency Number Curve Slope
[2] N=1 means one fatal accident/year

3.1 Sweden then and now

3.1.1 American standard B9-1930 [15] p 220 and forwards

This code was the first available in Sweden. The code has its roots in the tentative code from ASRE dated 1919. The present version of the code is the ANSI/ASHRAE 15-1994 (see below).

Many different refrigerants were used during the thirties. The most common household refrigerators contained Freon 12, SO2 or Isobutane. Inflammable refrigerants were quite common and the refrigeration society was used to the risk imposed by flammable refrigerants. It can be assumed that the rules are written by people used to the danger. The whole safety standard is only 5 pages long.

"310. Industrial systems using the direct method of refrigeration may be located without restriction in separate buildings or separate sections of buildings provided .... *(only relevant parts):*

.

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(b) That if a flammable gas is used the entire building for a class "A" system and the machinery room for a class "B" system is made of non-combustible material.

(c) Machinery rooms of class "A" systems using an irritant or flammable refrigerant have two exits.

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311. Commercial systems using the direct method of refrigeration are limited in locations as follows:

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*(c) If an irritant or flammable refrigerant is used and the building contains a sleeping room, systems installed between the first and top story may contain **100 lb.** or less of refrigerant. If there is no sleeping room, such systems may contain **200 lb.** or less of refrigerant.*

(d) If an irritant or flammable refrigerant is used the entire system must be confined to the space occupied by a single tenant if the building containing such a system is over three stories in height or if it contains a sleeping room.

312 A machinery room must be provided for.................. using irritant or flammable refrigerants as follows

*(a) For basement, first story and top story systems containing over **500 lb.** of refrigerant.*

*(b) For systems between the first and second stories containing more than **100 lb.** of refrigerant*

*(c) For systems between the first and top stories of a combination business and residence building containing over **50 lb.** of refrigerant.*

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352 No major electrical equipment except the motors and switchboards necessary to operate the machinery shall be permitted in a class "A" or "B" machinery room using a flammable refrigerant. All starting equipment including switches, automatic starters and the like, shall be of the oil-immersed type or totally enclosed type.

353 All class "A" or class "B" systems using a flammable or irritant refrigerant shall have an emergency switch controlling all of the electrically operated refrigerating machinery or the remote control of such a switch so located outside of the machinery room that it can be quickly reached and operated in case of necessity.

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402 Limitations as to use:

No unit system containing an irritant or flammable or harmful refrigerant shall be placed in...................................or where people are confined or helpless.

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502 Any refrigerant, the vapours of which are harmful to health and which are not readily apparent to human sense, shall have added thereto a substance to make its vapours readily detectable.

.

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507 ......

...Each evaporator must be tested to twice the pressure......"

3.1.2 The Swedish norm from 1965

The first valid Swedish code was from 1942 [38]. It was later revised 1947 and 1950. No traces of those norms have been found. They they can no longer be found at IVA (The Engineering Science Academy) who originally published the norms.

The 1965-norm was written at a time and in a society where flammable (except ammonia) refrigerants were more distant than when the norms [15] or [38] were written. The norm is about 50 pages long, i.e. 10 times longer than the norm thirty years earlier. In this norm the refrigerants are grouped according to an international system:

Refrigerant group	Code	Refrigerant
Non poisonous non explosive	1 a	CO_2
Non poisonous non explosive	1 b	CH_2Cl_2
Non poisonous non explosive	1 b	R12
Non poisonous non explosive	1 b	R22
Non poisonous non explosive	1 b	R21
Non poisonous non explosive	1 b	R11
Non poisonous non explosive	1 b	R114
Non poisonous non explosive	1 b	R13B1
Non poisonous non explosive	1 b	R13
Non poisonous non explosive	1 b	R113
Non poisonous non explosive	1 b	R502
Poisonous	2	Ammonia
Poisonous	2	Dichloroethylen
Poisonous	2	Methylchloride
Poisonous	2	SO_2
Explosive	3	Buthane
Explosive	3	Ethane
Explosive	3	Ethylen
Explosive	3	Isobuthane
Explosive	3	Propane
	4	Water

Table 3.1.2

Some highlights from the Swedish norm of 1965:

D.13.c.1 Group 2 refrigerants may be used in apartments to an amount of up to **1,2** kg or if the unit is hermetic up to **3** kg.

D.13.c.2 Group 2 refrigerants may be used up to **2** kg in a room that is not used as an apartment. If the unit is hermetic **3** kg may be used.

D.13.d Group 3 refrigerants may only be used up to **1,5** kg in apartments if a warning agent has been added to the refrigerant.

D.18.a A special machine room is always required when using more than **50** kg of refrigerant type 2 and always with refrigerant type 3 (**0** kg). An exemption is made for unit built machines where 1.5 kg of Group 3 refrigerant is allowed.

3.1.3 The Swedish norm from 1988

This norm is written 58 years later than the first from 1930 referred to under 3.1. The norm is about 200 pages or 40 times more pages than the norm from 1930. It reflects a time when very little personal knowledge about inflammable refrigerants was available. In contrast to the Swedish norm from 1965 this norm is not officially approved. It is still a (very useful and sensible) collection of existing rules.

The grouping of refrigerants complies with ISO 1662 and ANSI/ASHRAE Standard 34-78. Rooms are grouped in three categories A, B and C. A-rooms are where people might have a restricted freedom of movement and apartments. B-rooms are such where all people are free to gather. C-rooms are rooms where only qualified personnel is admitted.

7.2.2.1.1 Refrigerants of group 2 may not be used for direct air-conditioning compressor units (**0** kg). Refrigerants belonging to group 2 may only be used up to **1,5** kg and only in absorption units in room category A. Excerpts with my free translation is shown below:

7.2.2.1.2 In room category B the total filling of refrigerant group 2 in a direct system must not exceed **10** kg.

7.2.2.2. For indirect systems in a separate machine room there are no restrictions on the amount of refrigerants belonging to group 2.

7.2.3 In room categories A and B Group 3 refrigerants may not be used (**0** kg).

7.4.3 In a special machine room Group 3 refrigerants may only be used after special permission from the fire department. 1.5 kg flammable refrigerant in a unit-built machine may be used there.

7.4.5 Rooms with furnaces may not be used as machine rooms for refrigerant groups 2 or 3.

3.1.4 Comparison of the norms above

The maximum allowable amount of inflammable refrigerant in different applications and according to different standards are illustrated in table 3.1.4.

	Room category	
	A	Machine room or laboratory
American Standard B9-1930	45	no restr
The Swedish norm from 1965	1,5	no restr
The Swedish norm from 1988	0	1,5

Table 3.1.4

Comparing norms from different times and geographic regions is of course difficult. However the reflection can be made that the less used a society is to flammable refrigerants the greater the fear and the harder the rules.

3.1.5 SEK the Swedish Electric Commission

Electric installations must among others consider several standards: Swedish Standard SS4210820 Classification of Hazardous Areas, SS4210821 Electrical Installations in Explosive gas Atmospheres and SS4210822 Equipotential Bonding in Explosive Gas Atmospheres.

3.1.6 National Swedish Inspectorate of Explosives and Flammables

As mentioned in the beginning of 3.1.3 even other authorities than those writing norms are important. In Sweden the ultimate responsible authority for flammable gases and aerosols is National Swedish Inspectorate of Explosives and Flammables (NSIEF). The general view from NSIEF is that a system must be "safe enough". What that means is decided from time to time. In chapter 5 there are some examples on verdicts from NSIEF. Some important basic rules and definition exist. Some of them are shortly explained in 3.1.7. below.

3.1.7 Some definitions and codes from NSIEF

All valid general codes in Sweden can be found in [29]. A very short excerpt of the ideas behind the codes - when relevantly for the usage of flammable refrigerants can be found below:

In [25] buildings are classified as either A-, B- or C-buildings. The classification is as below:

A-building - where people live or dwell and should have no reason to expect flammables.
B-building - where people can expect flammables.
C-buildings - where people can't normally be expected.
Cistern-room - a special room for flammables

Table 3.1.7.1

Which types of permissions that are required, when storing certain masses of flammables at different locations are specified in [25] (table 3.1). In our case refrigerant can be treated as flammable gas. The table has got two columns. The first column is for "unconnected" containers and the second is for connected "containers". Connected containers are according to the definition such an apparatus that is "continuously connected to a central heating or similar system". The code-maker was clearly not aware of the possibility of heat pumps or air-conditioning systems with flammable refrigerants. The code-makers presumption is therefore that the gas is led to a furnace of some kind. If a refrigeration machine can be considered as a sealed "unconnected" container, the following volumes of the refrigeration system could be allowed **without any permission** (my translation):

1. Storage room, basement, garage in a residential building or in a building where people generally dwell	
a Without fire sealed walls	*30 litres of gas*
b With fire sealed walls	*60 litres of gas*
c With fire sealed walls in industrial area	*100 litres of gas*
2. Shed, magazine or garage where people normally don't dwell and within a safe distance from a building where people dwell	
a Neither fireproof or fire sealed walls	*100 litres of gas*
b Fireproof or fire sealed walls	*600 litres of gas*
3. Outdoors	
a Closer than 12 m to a building	*100 litres of gas*
b Further away than 12 m from a building	*300 litres of gas*
4. Shops	
a Handling opened packages and demonstr.	*100 litres of gas*
b Handling only sealed packages	*200 litres of gas*
5. Workshops and industrial buildings	
a Without fire sealed walls people normally present	*200 litres of gas*
b With fire sealed walls people norm. not present	*400 litres of gas*
c Whole building fire sealed only workshop	*600 litres of gas*

Table 3.1.7.2

The "Gas" volume may also include condensed liquid. It can be argued weather a refrigeration plant should be considered as a "gas container". So the table above might not be applicable at all. If the refrigeration machine is assumed to be "connected", only the values under point 5 will be allowed without any permission. If permission is granted from the local fire authorities, the volumes under 5 can be increased to 400, 600 and 1000 litres.

Reference [26] below deals with some basic definitions. The first point is the definition of where the code is valid (my translation):

"This code is valid for rooms, spaces or areas, where an explosive gas mixture can result when storing, handling, selling or transporting or transporting in a pipe flammable substance under such circumstances that a considerable risk of fire or explosion can be assumed to exist.

> *Note. The validity area cannot be tied to any specific amount of flammable substance as the circumstances vary from case to case taking into account what has been said above."*

A refrigeration device using flammable refrigerant is certainly storing some flammable and transporting it in pipes - but is the risk considerable? Again this code is not specifically made for refrigeration applications. Let us however assume that the code is valid. Reference [26] states then the following definitions (my translation):

"Explosive gas mixture	*flammable mixture of gas, steam or mist with air.* *Note: As flammable in this context is a mixture with a concentration higher than 25% of the LEL as defined by SS 421 08 20 (see Reference. [30] at the end of this work)*
Classification	*establishing risk zones and their extensions. See also part 3 the first part.*[3]
Risk area	*a room, space or area within which an explosive gas mixture can exist under such circumstances that special demands must be set on among other things electrical material (compare part 1 validity area*[4] *)*
. . .	
Zone 0	*risk area in which an explosive gas mixture is present always or under long time periods.*
Zone 1	*risk area in which an explosive gas mixture can be expected temporarily under normal running conditions.*
Zone 2	*risk area in which an explosive gas mixture cannot be expected under normal running conditions, and if it occurs only seldom and during short periods of time.................."*

Table 3.1.7.3

When dealing with refrigeration machines and heat pumps the most common zone specification to be concerned about is zone 2. According to [30] page 26 "Systematical Classification" three key questions must be answered before one can judge whether an area is "Zone 2" or "Not subjected to explosion hazard". The questions are (my translation):

- *"Can an explosive gas mixture with air arise under such conditions that special demands must be posed on (among other things) electrical apparatuses and installations?"*

- *"Can precautions be taken that inhibits the formation of an explosive gas mixture with air or diminishes the releases concerning frequency, duration and/or released amount?"*

- *"Judge (After answering the question above) the probable presence of an explosive mixture with air "*

Weather the acceptable probability for an accident is 10^{-4}, 10^{-6} or 10^{-8} per year is not clearly stated. That is really the core question.

[3] Deals with classification of areas irrelevant to this study.
[4] The room area where the statements are valid. (See above).

3.2 An international outlook

Only parts of respective standards are quoted below. No guarantee at all is given by the author that the interpretation is completely correct. The statements below may not be used as a reference when building or installing refrigeration equipment.

3.2.1 ANSI/ASHRAE 15

ASHRAE 15 [41] is the most established safety code in the world. It has been the template for many other standards in the world since 1919. The latest edition is from 1994.

The following conclusions can be drawn from that standard:

The standard acknowledges that also escaping lubricant can result in or intensify a fire[5].

One can draw the conclusion that a special machinery room is required only if the amount of propane is higher than 8 g/m^3 room space or the amount of isobutane is higher than 8.2 g/m^3 (see footnote[6]). This corresponds to about 20% of LEL[7]. For a small room of 10m^2 and a height of 2.5m the standard would allow for 200 g of propane.

It can be however be concluded that type A3 refrigerants like propane and isobutane are prohibited, except for laboratories in commercial occupancies[8]. The mass of refrigerant used there must be less than 3 kg. When reading further one can see that systems meeting the demands[9] can use 3 kg of any refrigerant.

The authority that has jurisdiction can allow exceptions from the requirements of the code[10]. Thus the Swedish code from 1988 is in good accordance with ASHRAE 15 [41]except that the Swedish code only allows for 1.5 kg in laboratories.

3.2.2 German proposed standard DIN 7003 [42]

The suggested norm is from November 1994. This standard is much more allowable for flammable refrigerants than ANSI/ASHRAE 15 [41]. It must be clearly stated that these rules are not yet taken.

If the mass of flammable refrigerant is **less than 0.15 kg** and all joints are welded or brazed in a hermetic unit, there is no restriction on where the refrigeration equipment may be placed. If all the joints are not welded or brazed, the hermetic unit must either be placed above ground level or, if placed under ground, have natural ventilation using a ventilation area of at least 100 cm^2.

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[5] at page 1
[6] from page 1 low right and table 1
[7] note e under table 1
[8] from table 2 and point 9 on page 9
[9] paragraph 7.4.1
[10] 7.4.1 it is mainly referring to 2.5

If the mass of flammable refrigerant is **higher than 0.15 kg** one of the following measures must be taken:

- The room volume must be so large that 50% of LEL cannot be reached.

- The room must be supplied with natural ventilation. If it is less than 1 kg of refrigerant, 300 cm^2 ventilation area is sufficient otherwise the area A (in m^2) must be greater than 0,14*(mass of refrigerant in kg)$^{1/2}$.

- The machinery must be supplied with a ventilated housing according to DIN EN 378-8 5.5.3 [43].

- A mechanical ventilation with a ventilation flow in litres per second of at least 14 * (mass of refrigerant in kg)$^{2/3}$ running continuously or an approved gas sensor starting the ventilation and set at 25% of LEL.

- If the mass of refrigerant is less than 5 kg, a low pressure pressostat (DBFK, DIN 32733) can be used as an alternative to the gas sensor. This pressostat must cut the current to the unit, start the ventilation and give an alarm signal.

If the mass of refrigerant is greater than 0.15 kg, electric equipment must be designed according to Zone 2 requirements, within a volume extending 1 m from equipment filled with flammable refrigerant.

3.2.3 IEC 335-2-40 [44] and IEC 335-2-24 [45]

The IEC (International Electrotechnical Commission) has given out a special standard for heat pumps, air conditioners and dehumidifiers. The Standard is under revision and a special group will write an addendum for the requirements on appliances using flammable refrigerants. Sweden is the convenor for this group. Bernt Engström is chairman and the author is a member of the group. We have not presented anything so far.

An earlier group IEC 335-2-24 [45] has suggested a standard for household appliances for refrigerators etc. This group was headed by Italy. The draft is now under examination of subcommittee 61C.

3.2.4 Electrical Apparatus for Explosive Gas Atmospheres IEC 79-10 [46]

The most important parts of this standard are the zone definition criterions (my translation):

"2.4 Zones

Hazardous areas are classified in zones based upon the frequency of the appearance and the duration of an explosive gas atmosphere as follows:

2.4.1 Zone 0

An area in which an explosive gas atmosphere is present or continuously present for long periods

2.4.2 Zone 1

*An area in which an explosive gas atmosphere is likely to occur in normal operation**

2.4.3 Zone 2

An area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist for a short period only.*

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**2.7 Normal operation*

The situation when the plant equipment is operating within its design parameters.

Minor releases of flammable material may be part of normal operation. For example, releases from seals, which rely on wetting by the fluid, being pumped are considered minor releases.

Failures (such as the break down of pump seals, flange gaskets or spillage's caused by accidents) which involve repair and shut down are not considered a part of normal operation."

With this definition most normal refrigeration equipment like pressostats, thermostats and circuit breakers would be placed inside Zone 2. Compare the Swedish equivalent text in table 3.1.7.3.

If the equipment is considered to be in zone 2 the following demands would be applied (according to for example SS4210821 (Swedish Standard corresponding)):

- Protection class lowest according to IP54 (IEC 34 part 5)
- No sparks (Pressostats, thermostats electric outlets and fuses must then be made explosion proof.)
- Surface temperature below 200°C
- All cables at least 1 mm^2 area

3.3 Future American Standards?

The American ASHRAE standards and UL-testing have since long time ago set also the international standards in this area. Taking part of the present discussion in USA can therefore be interesting.

Underwriters Laboratories has undertaken discussions with industry on the risks involved by using flammable refrigerants [24]. It has been a very good and open discussion, which can be recommended for reading. Outlines of items discussed in the paper are referred below

Leaks

:

- Should thin walled copper tubing and aluminium tubes be allowed?
- Should service valves be vented only to the outdoor air?
- Should joints of quick connect type, flare or compression types be allowed or not?
- Should it be required to pump refrigerant to the outdoor parts during a standby?
- What type of vibration test should the equipment undergo?
- Should detectors set to 25% of LEL be required and where should they be located?
- How should the coils be guarded?

Ignition

- Where should arc-generating electric parts be placed and how should they be protected?
- What is the highest surface temperature that can be allowed?
- How should the wiring be protected?

Build up of Flammable Concentrations

- Should 3 kg be the maximum filling?
- How should dead spots with still standing refrigerant be avoided?
- How should the condenser fan be controlled?

Installation and disposal

- How should the service personnel be brought to attention that it is flammable refrigerant?
- How should the equipment be marked?

External fire

- How should the pressure relief device be constructed and where should the outgoing pipe end?

These questions have not found their answers yet, and it is my opinion that the break through for the usage of flammable refrigarants will not come in the US due to the hard liability laws there.

4. SAFETY ESTIMATION

The event tree and fault tree techniques are described by Pershagen [16] and many other researchers discussing nuclear safety. A statistic mathematic background in concentrated form can be found in [34]. There also exist many mathematical computer tools that can be helpful when trying to solve often complicated trees [35], [36] and [37]. The methods were usually developed for nuclear reactor safety purposes. They can also be used for technical systems other than nuclear reactors. The main obstacle is though that only limited or no failure statistic can be found for components used in other areas than the nuclear or aviation area. Of course only anticipated faults can be analyzed. Summing up many "incredible" (not anticipated) events, which each has a very low probability, can occasionally add up to a significant number.

Other methods such as index methods try to make a simplified formula of empirical knowledge of hazards. The Goetzler study [17] is an example where the fault tree technique has been used and the Berghmans study [18] is an example on a study using the Index technique.

4.1 Very short about event and fault trees

Event trees are constructed from cause to effect. In our case we would start with a pipe break at a certain point. Then we would look at all the different locations into which the gas can leak. Finally we would look for all possible ignition sources at those locations that could ignite the gas.

Fault trees start the other way around and go from effect to cause. Figure 4.1.1 is an example from [17]. We presume that an undesirable top event has taken place (an explosion in our case) and then we go backward asking ourselves which events (failures) can have caused this top event. Figure 4.1.2 is an example from [17]. It gives a very compact picture of how a fault tree can be drawn. The author recommends the whole reference [17].

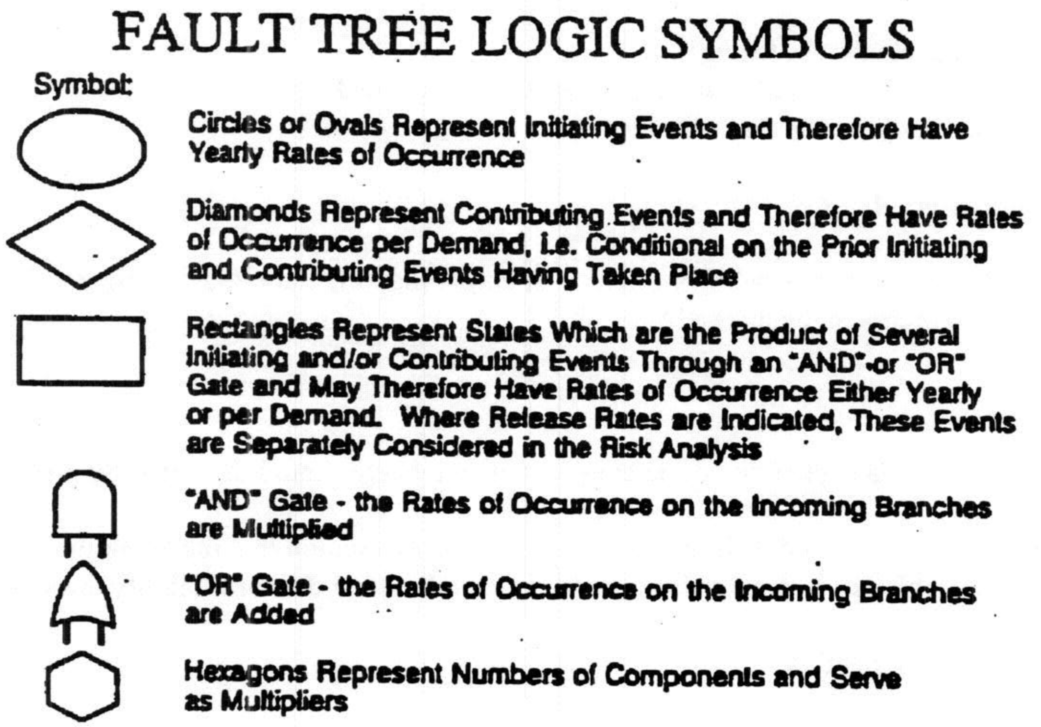

Fig 4.1.1 Symbols

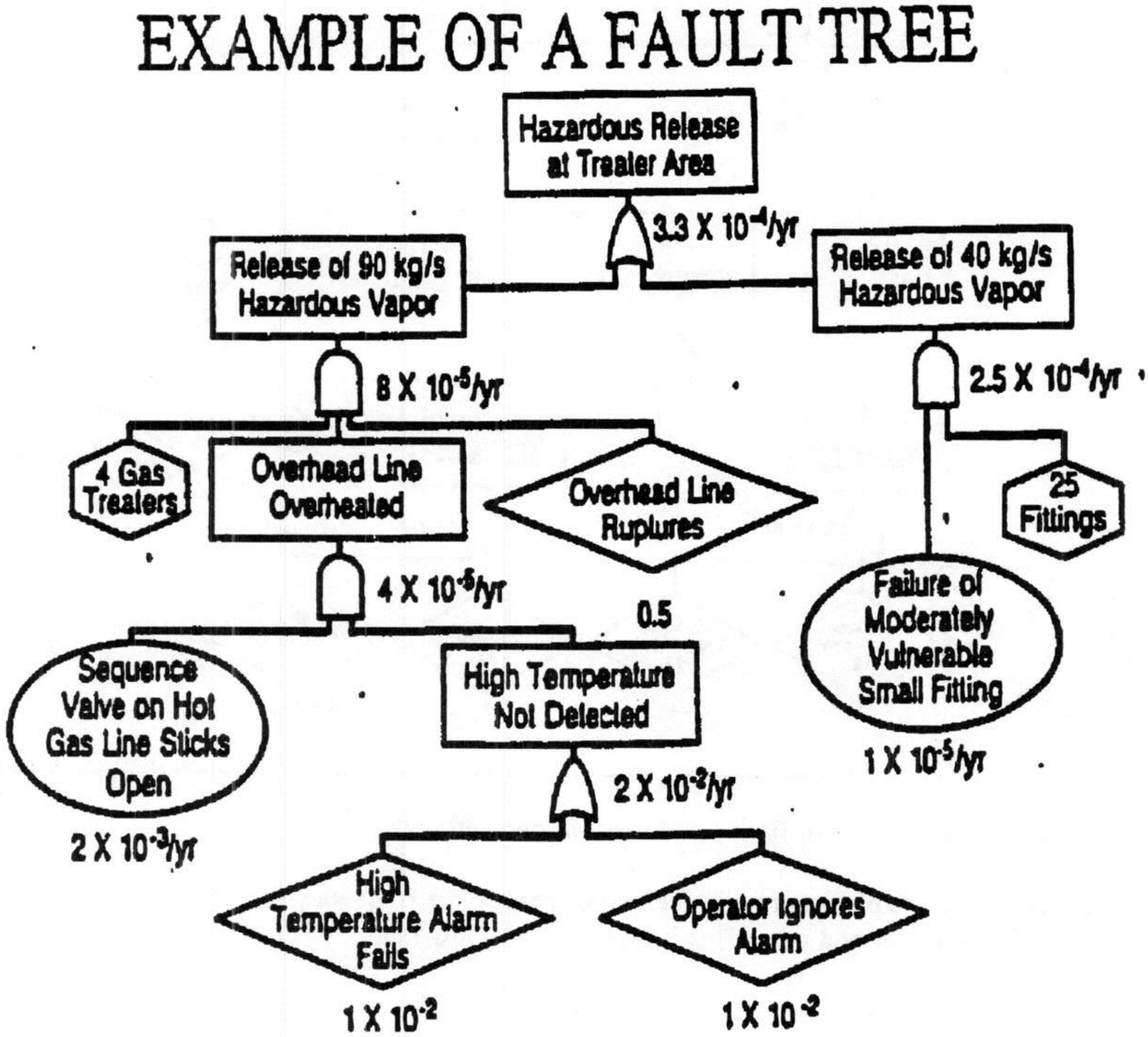

Fig 4.1.2 Fault tree example from [17]

4.2 Studies by Goetzler [17]

Goetzler [17] has made a rigorous study about R152a used in kitchen refrigerators. He concludes that the number of kitchen fires would increase with 0.04%, if all refrigerators were filled with R152a.

Goetzler uses the fault tree technique. A fault tree showing the risk of an explosion **inside** a R152a refrigerator for an average case is shown in the picture below:

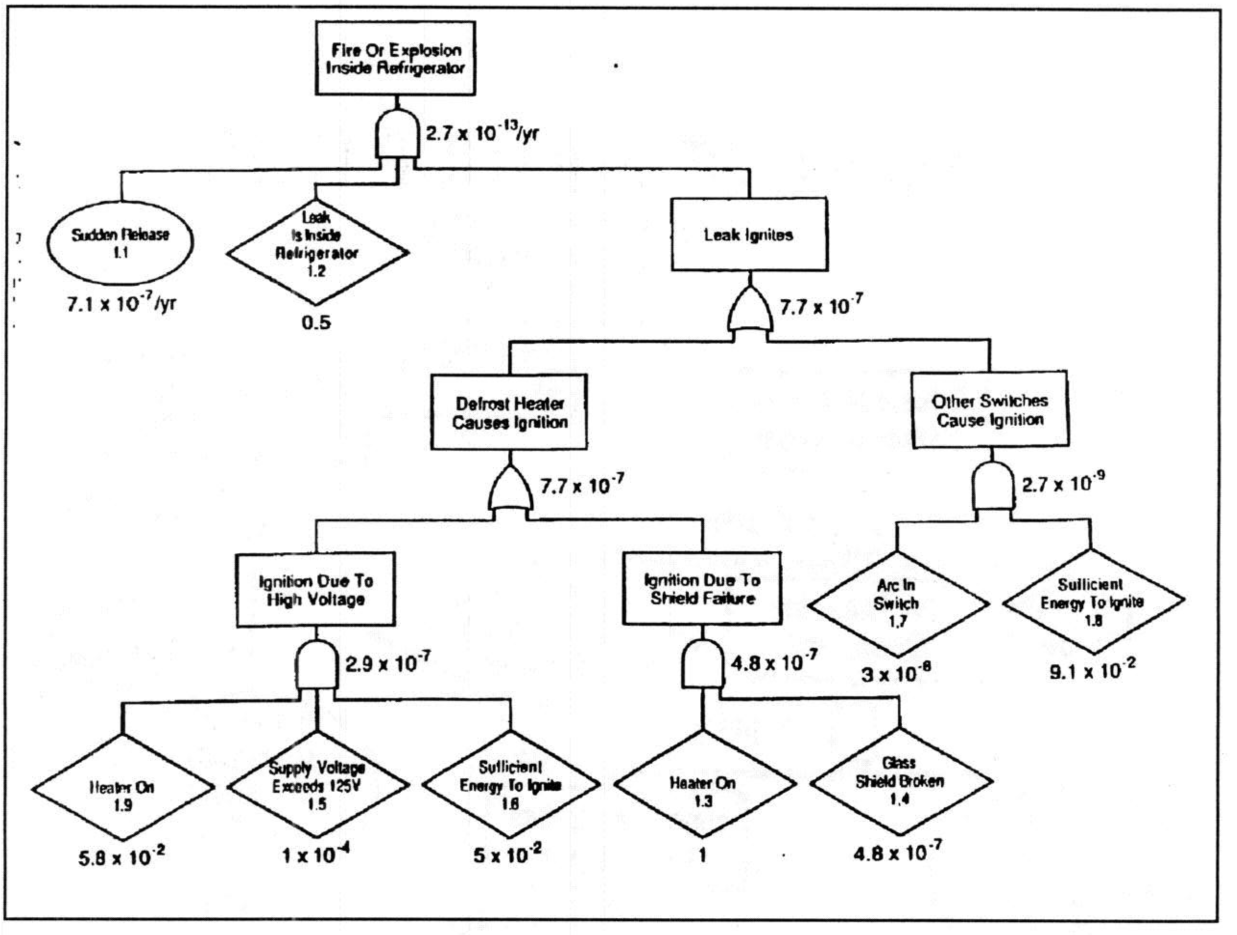

Figure 4.2 The frequencies for fire or explosion inside a refrigerator

The top event is an **explosion inside the refrigerator**. The frequency for that is $2.7 * 10^{-13}$ /refrigerator and year. This is clearly a very low risk.

To create the explosion:

1. Refrigerant has to leak out suddenly which has a frequency of once every $7.1*10^{-7}$ /year refrigerator

2. The leak has to be inside the refrigerator. The probability of the leak being inside being 0.5

3. There has to be an ignition source, which, has a probability of $7.7*10^{-7}$

Multiplying the three figures above gives us $2.7 * 10^{-13}$ for the average frequency of explosions.

Goetzler [17] also has a worst case scenario in which the proportion of "fast leaks" to the total number of leaks is 1%. By also changing other parameters, he winds up with a total risk that is about 26 times greater than when using his average case assumptions.

Goetzler [17] also has analyzed the risk of a **kitchen fire**. In the average case:

1. Refrigerant has to leak out suddenly either inside or outside which has the probability of once every $7.1*10^{-7}$ /year refrigerator.

2. The leak has to ignite which has a probability of $2.8*10^{-2}$ considering a typical American kitchen.

The average probability for a kitchen fire is thus $7.1*10^{-7} * 2.8*10^{-2} = 1.99*10^{-8}$ / year and refrigerator. Using the worst case scenario, this figure is increased about 25 times or to $5.03*10^{-7}$ / year refrigerator. The fault tree is larger in this case and is therefore not shown here.

The analysis of Goetzler [17] puts the probability figures in relation to the number of fires occurring from other sources in the US. Putting the risk of additional kitchen fires in a context is thus possible. From the Goetzler [17] data we get the following:

Number of households in the US (=number of kitchens?)	88000000
Total number of fires in households 1983-87	430000
Corresponding number of deaths	4148
Kitchen fires 1983-1987	144400
Corresponding number of deaths	635
Fires starting from fixed, stationary, local refrigeration units yearly	2140
Corresponding number of deaths	13
Refrigerator fires/year due to mechanical, design or installation faults (NFPA[11])	1500
Estimating the same figure as above (Industry)	150

Using the data from fault tree statistics the increased number of kitchen fires and explosions would vary between 2 and 45 (worst case) if R152a was used as refrigerant in all refrigerators.

Goetzler [17] also discusses the disposal of refrigerators filled with flammable refrigerant and the risks of explosions or fire when the units are for instance shredded. These problems would be smaller in for instance Sweden where now most refrigerators are collected as a separate type of waste.

Goetzler has in the appendix A of his report also given a model of how to calculate the peak pressure in a kitchen with closed windows during an explosion.

Many interesting conclusions can be drawn from the Goetzler study for example:

[11] National Fire Protection Agency

If the number of persons killed are divided by the number by the number of household fires, the death probability/fire is about 1%.

Let us assume the same number of killed persons per fire as for other refrigerator induced fires. Then the number of deaths would vary between 0.012 and 0.25 per year if all refrigerators in the US were filled with R152a.

In Germany isobutane is the chosen refrigerant instead of R152a. As can be seen from table 1 the ignition energy required for R152a is much lower than for isobutane and the lower explosion limit are much higher. Taken together this means that R152a is maybe an order of magnitude safer than isobutane. Seeing the development in Germany in the future will be very interesting.

4.3 Study by Berghmans [18]

Berghmans [18] studied with much wider scope than Goetzler [17] above. Berghmans covers both accidents with toxic (ammonia) refrigerants and explosive refrigerants. One problem with the report was that it was not open for general public studies from the beginning. Only those countries that participated in the study could get access to it. It is now released.

Berghmans [18] starts with a survey of known risk data for ammonia installations:

Country	Death frequency per year and installation
Japan	$100*10^{-6}$
Holland FACTS	$170*10^{-6}$
Norway	$80*10^{-6}$

Table 4.3.1

Ammonia plants are mostly big refrigeration installations and cannot be compared with refrigerators.

In chapter three Berghmans discusses 15 contemporary refrigeration standards. He also tries to get some structure into it by asking 10 key questions and interpret the different standards with respect to the answers. Berghmans work was done, using the valid standards of 1993.

A key question is how many kg of a certain refrigerant that are allowed in certain room types. When dealing with explosive refrigerants, saying where it is allowed is simpler than where it is forbidden. No standard allowed for instance explosive refrigerants in homes or public areas. The standards were thus in a consensus with one another.

Another key question, if alarms are needed when using flammable refrigerants, gave another picture of the consensus. There is a big difference between different norms from "No detectors required" to "Detector and alarm required set at 25% of LEL". Berghmans findings are shown below:

"BSI[12]	*:alarm and emergency ventilation shall be activated if the concentrations exceeds 30% of the LEL.*
NBN[13], *ISO*[14]	*:alarm shall be activated if the concentration exceeds 25% of the LEL.*
NEN[15], *SN*[16], *NF*[17]	*:no detectors required*
ASHRAE[18]	*:alarm shall be activated if the TLV-value is exceeded*
SK[19]	*:alarm and emergency ventilation shall be activated if the concentation exceeds a certain value related to the LEL-value (see SK)*
NK[20]	*:alarm shall be activated if the LEL-value is exceeded*
JN[21]	*:a description identical to that of group 2 is made"*

Berghmans [18] in Part 2 of his report has a very thorough treatment of the consequences of an accident. The following types of fires are treated:

- Jet flame
- Pool fire
- Fire Ball
- Flash fire

and the following types of explosions:

- Mechanical explosions
  - Compressed gas
  - Boiling liquid
- Chemical explosions
  - Unconfined Vapour Cloud Explosion
  - Explosion in a confined space

One conclusion is that the excess pressure, resulting from a confined explosion, is much higher than if the explosion is unconfined (often a factor 2.5 - 5).

In a later chapter he also gives formulas for the consequences, i.e. over pressure and heat (radiation) from the events above.

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12 Great Britain
13 Belgium
14 International
15 Holland
16 Switzerland
17 France
18 USA
19 Sweden
20 Norway
21 Japan

There exist several types of risk-indexes. Berghmans uses the DOW Fire and Explosion Index [19]. The core of this method is roughly to multiply indexes for *type of fluid * general process hazard * special process hazard*. By doing that after certain given rules one winds up with a fire and explosion index for the risk. One could say that the risk calculated in this way replaces the fault or event tree analysis to a certain extent. For an insurance company for instance using a fault tree diagram when deciding the insurance cost is often too difficult.

Berghmans has given an example of how to use the index technique for an ethylene refrigeration compressor. The index is calculated as the product of a "material factor" * "a general process hazard factor" * "a special hazard factor". Example:

The material factor depending on type of fluid is	24 (from a table of substances)
The General process hazard factor is	1.5 (1 is base + 0.5 for drainage and spill control)
The Special process hazard factor is	4.36 (1.00 is base + 0.20 for toxic material + 0.68 for relief pressure + 0.88 for quantity of flammables + 1.50 for leakage - joints and packing+ 0.10 for use of fired heaters

The fire and explosion index then is 24 * 1.5 *4.36 = 157. The interpretation of the obtained index can be done with a table. For the DOW method the following table applies according to Berghmans.

F&EI	Degree of Hazard
1 - 60	light
61 - 96	moderate
97 - 127	intermediate
128 - 158	heavy
>159	severe

Based on his study Berghmans has also developed a special computer program. Judging from the written examples, it deals mainly with the consequences of fires and explosions.

4.3 Goetzler and Berghmans findings with respect to damage and injuries

Radiation kW/ m2	Goetzler	Bergmahns
1.5		Pain limit
1.6	no discomfort	
4.0	second degree burns	
4.5		first degree burns
5.0		Glass damage
9.5	second degreee burns 20 s	
10.0		damage on electrical cables
12.5	wood ignites if source av., plastic melts	wood ignites if source av.
25.0	ignition of wood	ignition of wood
37.5	damage to process equipment	

Table 4.3.1

Over pressure bar	Goetzler	Berghmans
.01	Shattering of glass windows	Breaking of window panes
.02		Temporary deafness
.03		Killing by glass possible
.04		Injuries from glass negligible
.05		Damaging of roofs of houses
.07		Partial damaging of houses
.10	Damaging brick walls	Wood, metal siding damage
.14		Walls fall apart
.20	Block walls shattered, steel frame distorted	
.30	Rupture of eardrum, concrete wall failure	Rupture of eardrum,housedest.
.50	Failure of brick wall 8-12" thick	
1.00	Lung damage	Lung damage
2.00		Directly killing pressure wave
2.50	1% fatality	
3.50	50% fatality	
5.00	99% fatality	

Table 4.3.2

Berghmans gives a good list of references for the quoted damages. It is natural that the consequences between Goetzler and Bergmahns partly are inconsistent due to underlying differences in assumptions.

5. NSIEFS RULING ON REAL INSTALLATIONS

To evaluate the practical possibilities to use flammable refrigerants in some real applications have been made. Initially the following set of applications was planned:

New residential heat pump 1,5 - 10 kW.
Converted[22] residential heat pump 1,5-10 kW.

New refrigeration plant 2-10 kW
Converted[22] refrigeration plant 5-10 kW

New larger refrigeration or heat pump plant 1 MW
Converted[22] refrigeration or heat pump plant 1 MW

For various reasons it stood clear that the initial study objects were not the best choice. The NSIEF is overloaded with applications and therefore the response time is long. Studying the response to other applications was therefore better. As both questions and answers are long, and in Swedish, they have been put in an appendix [appendix 1]. The highlights of the answers are however translated below.

5.1 New household refrigerator/freezer

In a paper about household refrigerators SEMKO (The Swedish electrical safetyorganizationon) wrote to NSIEF about the proposed EN 60 335-2-24 standard for refrigerators and freezers containing isobutane (my translation). SEMKO got the following answer 1993-12-29:

."............*we repeat our demand points for approval:*

1. *Flammable refrigerant should be noted clearly in text on the cupboard.*

2. *The marking shall be clear and of a non-destructible type close to gas containing parts inside and outside the cabinet.*

3. *The suggested pressure testing must be completed with a corresponding leak testing.*

4. *In the description of the testing the word "isobutane" should be replaced with "flammable refrigerant (for example isobutane)"*

5. *Risk areas may not contain electrical components*[23]

[22] With converted means, that a unit previously filled with for instance CFC or HCFC, would be filled with a flammable refrigerant after retrofitting following the safety demands.

6. The refrigeration system must be supplied with a device protecting it from overheat.

7. The mechanical strength of the tubing must be high enough to withstand "defrosting" with different tools.

8. The mass of refrigerant should not exceed 70 grams."

The author's opinion is that the demand 5 is unclear as "risk areas" are not well defined. Goetzler [17] for instance at page 24 quotes UL-experiments. Releases of 8 oz (0.227 kg) R152a could be ignited up to 6 ft (1.83 m) from the refrigerator at floor level. In another test where R152a was released through a 1/4" OD-pipe, the mixture could not be ignited two feet (0.61 m) from the point of release.

The demand 7 is only relevant if the refrigerant carrying parts are accessible for defrosting.

5.2 New small air to air residential heat pump [46]

To explore the realism of propane as a working fluid in a small domestic heat pump for a possible market introduction, a specific construction drawing of an air to air heat pump containing 300 g of propane was supplied. We then asked for permission to use it. The heat pump had an indoor and an outdoor heat coil and was intended for ordinary domestic use.

We got the permission to use propane in the heat-pump under the following conditions:
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The indoor heat exchanger must be protected so that an unintentional puncture is made very difficult.

All indoor equipment as compressor, flexible piping, dryers, and filling valves must be placed in a gas tight box ventilated to the outdoor air by two openings (in the upper and the lower part of the box)

The installation description must state that the heat pump may be installed in ordinary domestic rooms only if the volume of these rooms is so large that 25% of the lower explosion limit cannot be reached even if the whole refrigerant filling should leak out there. This means that the room volume must be greater than 25 m^3.

The heat pump must be marked so that it can be seen that it contains propane.

If the above terms are fulfilled the NSIEF considers that the risk is not to be taken into account which means that the installation can be made without classification plans for the room."

Without classification plan, means that a room can be considered safe from explosion and fire hazards, i.e., outside zone two. The author's opinion is here that the demands can be handled in practice. A prototype was built and tested, but the manufacturer has not yet committed himself for an introduction on the market.

5.3 A new small residential heat pump using exhaust air

The heat pump is to take heat from the exhaust air from the house and to use the produced heat for hot water production. The heat pump contains about 500g propane or isobutane. The demands for the equipment from SNIEF can be seen from a letter dated 1995-01-25 Dnr 41/408/94 (my translation):

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Your question 1 and 2: Can it be accepted that leaking gas enters the ventilation system? Can it be accepted that the heat pump is connected to an arbitrary ventilation system?

Answer to question 1 and 2.
The ventilation system refers to both air that is taken from the rooms to the heat pump and air that is blown from the heat pump to the outdoor air. Neither of these systems may contain electric components. Apart from that the ventilation ducts must be earthed.

The low- and high pressure pressostat must have a metallic membrane separating the refrigerant from electric circuit breaking functions. This membrane must be at least 0.2 mm thick and be made of corrosion resistant material (according to CENELEC TC 31 suggestion Oct. 1992).

Both the fan and the differential pressure gauges and the pressostats must be of a type which does not generate sparks or have a surface temperature exceeding 200°C. They must be made according to a good industrial quality and with a protection class of at least IP54 in the area T1-T3 according to SS 421 08 21 p 17.

Your question 3: Can it be accepted that leaking gas can collect in the hot tap water tank?

Answer to question 3.
Leaking gas may not collect in the hot tap water tank, i.e. the hot tap water and the propane system must be separated with an intermediate circuit or a double wall ventilated construction. Leaks tend to lower the refrigerant pressure which shall result in that the low pressure pressostat stops the compressor but not the fans. Both the fan in the room where the heat pump is installed (which must have a capacity of 10 l/s) and the fan blowing the air from the heat pump and out (which must have a capacity of 20 l/s) must be kept running.

SNIEF states further:
- The deliverer of equipment must show that both the compressor as well as all other parts of the heat pump are designed for flammable gas for example must vibration damping be installed so that dangerous tension corrosion on the pipes does not occur.

- That all other service than routine service shall be done by certified personnel i.e. certified according to the "Refrigerant Rules" completed with additional demands for flammable gas for instance knowledge about the product and the service instruction about gas systems with flammable gases.

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5.4 A new medium sized refrigeration plant 3-5 kW [19]

Right in the centre of Stockholm under some government buildings three propane filled units are installed. Two of the units are indirectly coupled and serve nine refrigerated rooms, five refrigeration gondolas and the machine room itself. The brine is ethanol (29%) and water. One of the units serves a freezing room and is directly coupled. The condensers are cooled by lake water.

SNIEF has not written anything about this unit but Lars Synnerholm from SNIEF has given advice during the build up period. He is quoted in [19] (my translation):

"In principle we pose the same demands on a propane refrigeration plant as on any other plant where propane is burnt. We have for example demanded that the plant should be leakage free. This means that all joints have undergone a special control.

It is also important that the risk of ignition is minimised. From places where propane can leak out all ignition sources, for example in the form of electric equipment, has been removed or is protected according to the rules....... "

Klas Rosberg who is the man responsible for the construction says in [19]:

"............the risk of leakage is minimised by only allowing brazed joints. Pressostats and capillary tubes have been replaced by pressure transducers. Electrically the machine room is made safe according to "IP54""

The author visited the plant and observed the following with respect to safety:

Ventilation

The floor in the far end of the room is ventilated by a "protected" fan. The circulation ratio is 1 time/hour. The outgoing air goes through a duct hanging in the garage roof outside and out. The inlet of air is in the opposite side of the room. The air source is the garage outside.

Safety valves

The safety valves are all vented to the outside. The pipe from the safety valve exits about three m above street level.

Sight glass

Standard type sight glasses were used before the expansion valves

Signs and marking

A big sign warning for flammables, was outside the door.
A no smoking sign was inside the room.
On each machine, there was a big sign with the following text:
"Flammable refrigerant
Before work evacuate and flood with nitrogen.
When brazing use nitrogen as protection gas"

Electrically

The central electric control cupboard is of IP54 type used in for instance ammonia plants. Some meters extending through the wall in the cupboard are not of the IP54-type. They have been covered by a rubber tightened glass frame. Inside the cupboard itself the equipment is not of the IP54-type.

The connection box on the Prestcold compressors has been separately tightened to correspond to IP54.

Heat exchangers

Brazed type of plate heat exchangers

Other flammables

A tank with 29% ethanol brine can catch fire if not kept cold. The machine room is therefore kept cold.

Meters and warning devices for propane in room air

Presently non, (as approved) but might be installed later

The Stockholm local fire authorities have also approved the installation.

5.5 A large heat pump 1 MW

In Östra Främby outside Falun in Sweden a large heat pump is delivering about 1 MW heat. The heat source used is cleaned sewage water. The heat pump was built 1982 and uses R12. It would be retrofitted with one ton of propane. To ensure that the best application possible was made to SNIEF a special consultant, Nils Lindgren from Hydrosafe, was contacted (he has earlier made many applications to SNIEF). Lindgren made a description of the plant and suggested a classification plan following a normal standard for this type of job.

During the lifetime of the plant, 13 years, three major releases of R12 had happened. One release was from a bursting level sight glass, another was from a packing in a differential oil pressure meter and the third was a copper tube break.

The answer from SNIEF is as follows (my translation):

"First an excerpt from LBE §6 (a law)

6§ Buildings and other plants where flammable or other explosive goods are handled and appliances for handling these shall be constructed so that they are safe from fire and explosion and situated at such a distance from the surrounding that is needed considering the handling. This applies also to the areas containing such buildings, plants and appliances.

The government or the authority appointed by the government may decide that the buildings, plants and appliances shall comply with special demands. The government or the authority appointed by the government may decide that such buildings, plants and appliances may not be *used, held for sale or be sold if they are not by technical control inspection or other investigation found safe.*

That a unit, like the one in Östra Främby, has had three major releases of Freon, which means about one ton in twelve years implies that the plant does not comply with basic demands of gas tightness. To process flammable gas the plant must first undergo an increase in technical safety.

This means among other things the following:

1. Vibration damping

2. No copper tubes as these can undergo vibration hardening during vibrations. *(This demand has been corrected (by the author) from tensile corrosion to vibration hardening)*

3. Double safety valves between isolation valves.

4. Bolts on valves close to process pressure vessels must be built in.

5. Tight and pressure tested equipment, no dripping shaft seals. To days demand for a typical refrigeration plant is a maximum leakage of about 3 grams/year.

6. Compressor and process equipment should be so well ventilated that they in principle are placed outdoors with a protective roof. (Compare refineries where all process equipment is placed outdoors.) Low temperature sensitive process equipment is insulated and if needed heated with electric resistance cable.

7. All joints welded - only flanges when absolutely required.

8. Housing and weather protection by non flammable material

9. The district heating network circuit must be separated from the refrigerant circuit with a special intermediate circuit if propane is used as refrigerant.

10. All packings must be made "blow out safe".

11. Screw compressors for flammable gases are used at refineries only when documented good experience and advantages compared with other compressor types are available (at the Shell refinery)."

With the demands posed above it is the author's opinion that it is impossible, or at least not economically feasible, to either:

- convert **old** plants to propane independently of size
- build a new **large** heat pump or refrigeration machines using flammable refrigerant.

The demand 1 vibration damping is unclear. The demand 2 not to use copper piping is hard to meet in the refrigeration area. Demand 4, 7 and 10 are difficult to meet in an existing plant. Demand 6 is difficult to meet in a heat pump, whereas refrigeration equipment very well can be

The demand 1 vibration damping is unclear. The demand 2 not to use copper piping is hard to meet in the refrigeration area. Demand 4, 7 and 10 are difficult to meet in an existing plant. Demand 6 is difficult to meet in a heat pump, whereas refrigeration equipment very well can be placed outdoors. The demand 9 is devastating for the performance. The demand 11 means that only compressors earlier used with propane can be used.

6. LEAKS AND IGNITION PROBABILITIES

One requirement for a flammable refrigerant accident, is a leak of refrigerant. The statistic knowledge about why leaks in refrigeration equipment occur, how much that leaks out and at which rate is low or nonexisting. The frequency of leaks seems also poorly documented. To get at least rudimentary knowledge the author has conducted some "unscientific" research based on about 1000 service reports from a service company.

6.1 Survey of service reports

Getting hold of service reports is not so simple. It requires a trustful relationship with a service organisation. In my case, I was allowed to go through about five years of service reports from a small service company, under the promise that the name of that firm should not be revealed. The service reports were from the period 1988-1993. A total of 374 leaks was registered. They had the following spectrum:

Leaks from small and medium heat - pumps

Cause	Number of leaks	Leaked kg	Average kg
Capillary tube	15	77	5,1
Compressor	17	104	6,2
Condenser	33	124	3,8
Connection	5	11	2,1
Copper tube	4	29	7,3
Distributor	2	6	3,2
Drying filter	5	18	3,6
Evaporator	1	28	28,0
Expansion valves	21	60	2,8
Ground-source-evap.	2	5	2,3
Hose	6	26	4,4
Magnetic valve	5	18	3,6
Melt plug	10	44	4,4
Not given	7	87	12,4
Pressostat	10	31	3,1
Pressure pipe	2	9	4,4
Pressure transducer	1	6	6,0
Safety valve	4	18	4,4
Schrader	54	138	2,6
Service	8	38	4,8
Service valve	20	65	3,3
Sight glass	25	63	2,5
Stop valve	2	14	7,0
Strange	1	1	1,0
Switch valve	1	5	5,0
Tank	7	14	2,0
Unknown	104	236	2,3
Valve general	2	62	31,0

Many leak types have by far too few events to be statistically significant. One can also argue that, as mostly heat pumps have been serviced, the material is not valid for typical refrigeration plants. Small service valves (like schrader valves) compressors and condensers might be a big problem common to both heat pumps and refrigeration plants. For about 30% of the leaks, finding any leak at all, was not possible for the service technicians. This shows that those leaks must be very small.

Jonasson [40] made an extensive investigation about leak sources in 1988. A comparison with his findings, where the author's statistic material has been reorganised to fit the Jonasson study is shown below.

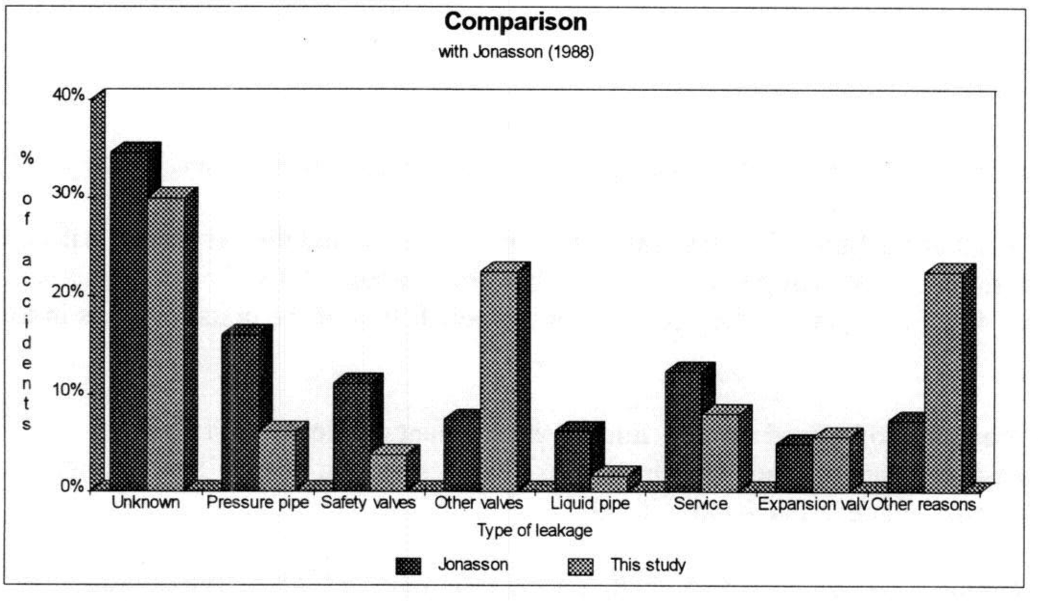

Figure 6.1.1 Comparison of leakage sources

As can be seen when reorganising the results in this way quite another picture emerges. This focuses the attention on the need to formulate a standardised way in which the leak (failure) data should be collected. The knowledge about the manufacturer of leaking equipment is for example lost now. In the air plane industry and nuclear industry all leakages would be registered after certain rules including the manufacturer.

How much that has leaked out at each leak before the leak was tightened can be seen from the figure below.

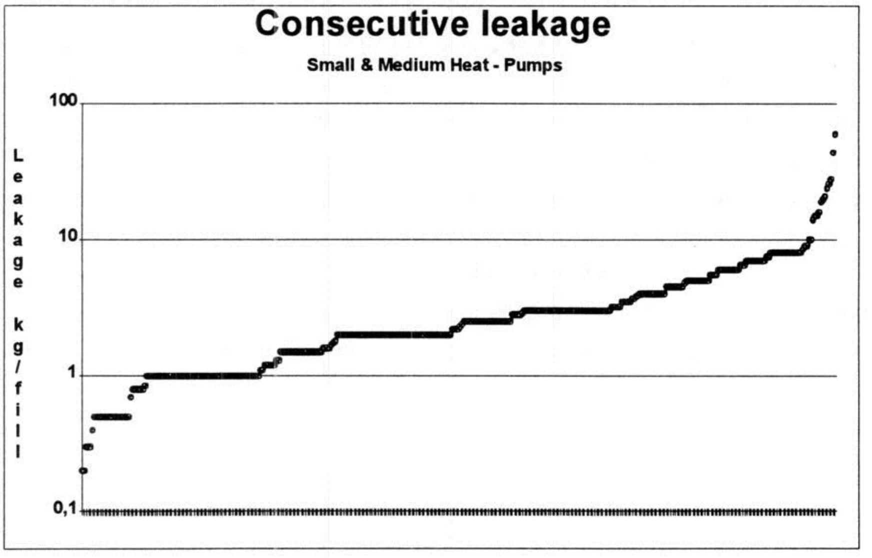

Fig 6.1.2 (On the X-axis in the figure is each of the 374 leaks ordered after their magnitude.)

This picture is rather credible. The very small leaks are not found and the very large leaks are few. The maximum size of heat pumps served by this firm is about 200 kW of heat so it is natural that 30-40 kg is the largest leak found. The average filling of the units served is in the order 3 kg.

If these data are going to be used for determining the frequency of leaks the following (unscientific) estimate can be made after having read the description of each leak (though sometimes unreadable due to bad handwriting).

The leaked amount of refrigerant was 1340 kg during four years. This means assuming that about 20% of the refrigerant leaked out each year the 1340 kg represents a total filling of 1675 kg. In the Jonasson study [40] 33-35% of the content leaked out each year. This study is, for the average timepoint of the leak, made later and the trend has been to make the units more leak proof.

Again assuming that the average filling of the units was 3 kg, which seems reasonable when reading the service reports, the number of installations containing the 1675 kg would be 558.

The number of leaks were 374 in four years or 94 leaks per year in the 558 installations. This corresponds to a leakage frequency of 0.16 leaks/year and installation. The average leaked amount per installation and year was then 0.6 kg. The impression after reading the reports was that eight leakages of the 374 were large enough to even consider the possibility of an explosion if the filling had been propane. Only one was so large that a large risk for fire or explosion clearly could arise.

Leaked amount	1340	kg/4years
Content in all plants	1675	kg
Average amount/plant (estimate)	3	kg/plant
Number of plants	558	
Number of leaks	374	1/4 year
Leakages/plant and year	0.167463	1/year
Leaked amount/plant and year	0.600	kg/year
Medium leakages/plant and year	0.003582	1/year
Large leakages/plant and year	0.000448	1/year

Table 6.1.2

Goetzler [17] assumes the frequency of catastrophic leaks to be $1.8*10^{-5}$ for refrigerators where the total filling amount is about 50 times smaller than in our case. There is no severe contradiction between Goetzler and this study with all its shortcomings.

6.2 Interviewing servicemen

Other companies were also contacted but they denied me access to the service reports often with the motivation that I probably could not get anything out of them. One of the companies however kindly let me write questions to their service personnel. Also here the presumption was that the name of the company should not be revealed. The interview was then made with 6 service technicians working mainly with larger and medium sized heat pumps. They are all highly skilled craftspeople. Summing up their direct answers with the only dubious assumption that the average fillmength is of the magnitude 3 kg yields the following result:

Totally filled refrigerant (13 years)	35100	kg
Estimated number of leakages (assumed 3 kg)	11700	
Number of kg lost in big leaks	2077	kg
Percentage of refrigerant lost at big leaks	6%	
Total number of big leaks	18	
(Definition: "Could explode if propane")		
Number of big leaks to total leaks	0,00154	

Table 6.2.1

A big leak was defined for the service technicians as a leak where the risk for fire or explosion would be obvious if it had been a flammable refrigerant.

Another interview has been made with five service technicians working in a large company mainly servicing refrigeration and air-conditioning equipment. All these were also very skilled craftspeople. They were among other things asked what they thought about the leak rates. The results are summarised in table 6.2.3.

Part of the amount leaked distributed after the leakage size (in kg/year).

Leak rate	Man 1	Man 2	Man 3	Man 4	Man 5	Average
0-1	30%	20%	20%	10%	1%	16%
1-10	48%	59%	30%	75%	30%	49%
10-100	20%	20%	25%	15%	50%	26%
100-1000	2%	1%	25%		15%	9%
1000-10000					4%	1%

Table 6.2.3

Of course all investigations like this are only to be taken as intelligent guesses. The guess is however that 1% of the mass leaked out comes at a high rate (more than 1000 kg/year). A leak rate of 1000 kg/year (= 0.03 g/s) when set to fire is equivalent to a power of 1.3 kW and is clearly a big leak from that point of view. Propane mixed in air has a LEL of 39 g/(m^3 of air). If refrigeration machinery is placed in a vented box or room, the airflow through the box or room must be at least 2.93 m3/hr in order not to reach LEL in the outgoing air. For an ordinary room this is no problem but for a sound insulated box it could be quite a challenge to get so much air through without sound getting out.

6.3 Authors opinion about leaks

Most leakages are small. **The number of big leakages that could cause a fire or explosion is probably in the magnitude 0.1% of the total number of leaks.**

The frequency of big leaks is probably in the magnitude 0.05 - 0.01% / (unit * year) for a small refrigeration unit or heat pump.

The mass of refrigerant that leaks out during big leaks to the total mass leaked out by all plants is however for medium sized systems probably in the magnitude 1% - 10%.

Goetzler [17] confirms this for refrigerators as he has found that in the average case 0.1% of the leaks that occurred after delivery to the individual homes were "fast leaks" (page 27). Goetzler [17] in the average case estimates the frequency of big leaks to 0.013%/(refrigerator and year) during the first year in the home (page 27).

6.4 Ignition probability

There are two basic principles to avoid ignition once the flammable refrigerant has leaked out. The first is to remove all sources of ignition, which often means that all electric equipment must be made "Explosion proof". It also means that no hot areas are allowed near the unit. The other method is to ventilate the area so much that the lower explosion limit is never reached.

Goetzler [17] has made an estimate about the possibility that a flammable refrigerant mixture would ignite inside alternatively outside a typical refrigerator in a kitchen using R152a as refrigerant. The probability of ignition is $7.7*10^{-7}$ inside the cupboard and $2.8*10^{-2}$ outside. (This reflects the fact that when you are aware of a risk, already when designing a product like a refrigerator, you can diminish risks to a very low level. When the kitchen as a whole was built however, no thought was given to the possibility of a flammable refrigerant entering the kitchen.

probable event of ignition is that flammable gas collects inside the cupboard and is ignited by the range or oven when opening the cupboard (probability $2.17*10^{-2}$).

6.5 The effect of ventilation

Several different scenarios of how a leak can develop exist. The two most commons are:

1: A leak releases the total content of refrigerant momentarily.

2: A leak starts with a constant rate and after a certain time the machine is emptied.

The room model is also often considered in one of three ways:

A: A mixture of refrigerant and air is always assumed evenly distributed in the whole room.

B: The refrigerant is assumed to leak out into an air stream passing through the room to the outlet.

C: The distribution of the refrigerant is assumed to be uneven in the volume.

In room model B the average concentration of the room will depend on whether the release of refrigerant is close to the inlet of air or close to the outlet of air or in the middle of the room. In model C there are at least three different possibilities. The first model assumes that gas collects somewhere in a pocket from where it cannot escape easily. The second model assumes that as the gas is heavier than air it will creep along the floor (see for instance Eggen [21]). UL has also looked into the distribution problem with heavy gas [24]. The third model assumes that as the gas is lighter than air (i.e. NH_3) it will then rise to the ceiling and collect there.

If the gas is assumed to distribute evenly in the room, there is a great problem with ignition sources. If the room is not large enough, the whole room must be made explosion proof. If on the other hand the installation is made so that one can always be sure about the refrigerant/air direction during the leakage only the part downstream of the leakage theoretically has to be made explosion proof.

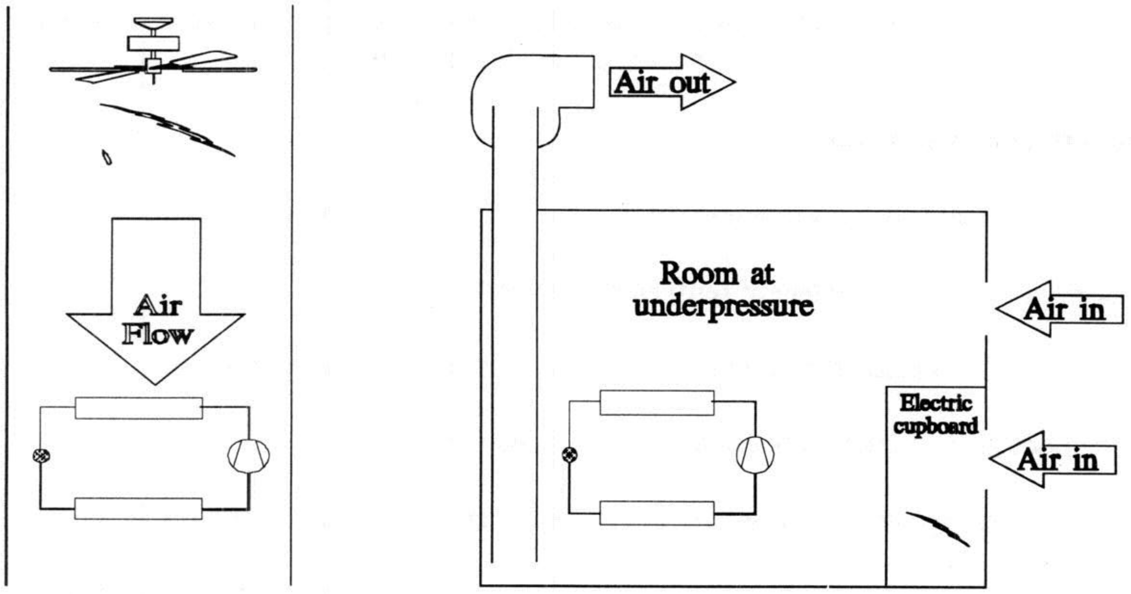

Fig 6.5 Ventilation principles
The air flow should be led from electric equipment towards the outlet. If all electric enclosures are held at a relative over pressure compared with the room where gas can leak out the risk of fire or explosion is diminished.

If the air is intentionally led in with over pressure (compared with the room) to electric control centrals, motors and instruments where a spark could emerge it can be defined as an "Exp" protection type according to SS4210821 point 4.2.7.

6.6 Reducing flammability by mixing

It is possible to reduce flammability by mixing the refrigerant with a non flammable compound [22]. If for instance a flammable is mixed with a certain percentage of R227ea (heptapluoro-propane) a non flammable mixture will be achieved

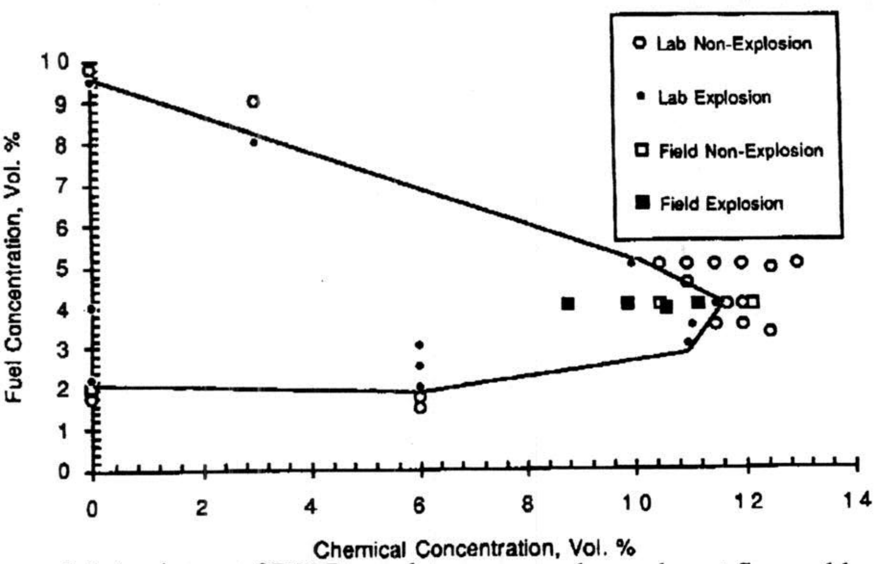

Figure 6.6 A mixture of R227ea and propane can be made not-flammable

If the gas concentration of propane in the room air is 4% after the leakage, the concentration of R227ea thus has to be 11.4% to avoid flammability. An example: 1 m3 of air contains normally 1.2 kg air at 20°C. The molecular weight of air is 29. One m^3 of air therefore contains 0.0414 kmols. If 4% + 11.4% of the volume is taken up by other gases, the volume taken by air is 0.846 m3 corresponding to .035 kmols.

If 4% of propane had leaked in the perceived m3 of air the number of kmol must be 4% of 0.0414 kmols, which correspond to 0.072 kg of propane with the molecular mass 44. In order to inertiate the propane-air mixture, 11.4% of 0.0414 kmol of R227ea is needed. As the molecular weight of R227ea is 170 the mass of R227ea needed would be 0.802 kg. The weight ratio of R227ea/propane is .802/.072 = 11.1! Obviously propane is difficult to inertiate. (This was earlier misunderstood by the author.)

Other flammable refrigerants are easier to inertiate, for instance R152a or R32 that are far less flammable, could be inertiated. R227ea might be a good candidate but other bromine compounds might be more interesting.

6.7 Author's opinion about ignition and ventilation

The possibility to say anything general about ignition probabilities in "normal" refrigeration plants is limited. However with even a very small effort making the installation safer, compared with ignition probabilities in a normal kitchen, is simple. According to Goetzler [17] the probability of ignition in a kitchen is in the magnitude 3%, once the refrigerant has leaked out.

By just carefully considering the flow direction of ventilation air, bringing down the risk of ignition one or possibly two orders of magnitude, should be possible.

7. CONCLUSIONS AND SUGGESTIONS

It is not advisable to convert existing units using non flammable - to flammable refrigerants. Even for large plants the cost to make the plants safe seems discouragingly high. For smaller plants the situation will be even worse. All persons that should do the conversion in the field are not likely to have enough knowledge and resources available.

If new units using flammable refrigerant are made, with todays standard of tightness, and placed in todays type of home or small business environment the fault tree will typically look as below in the authors opinion:

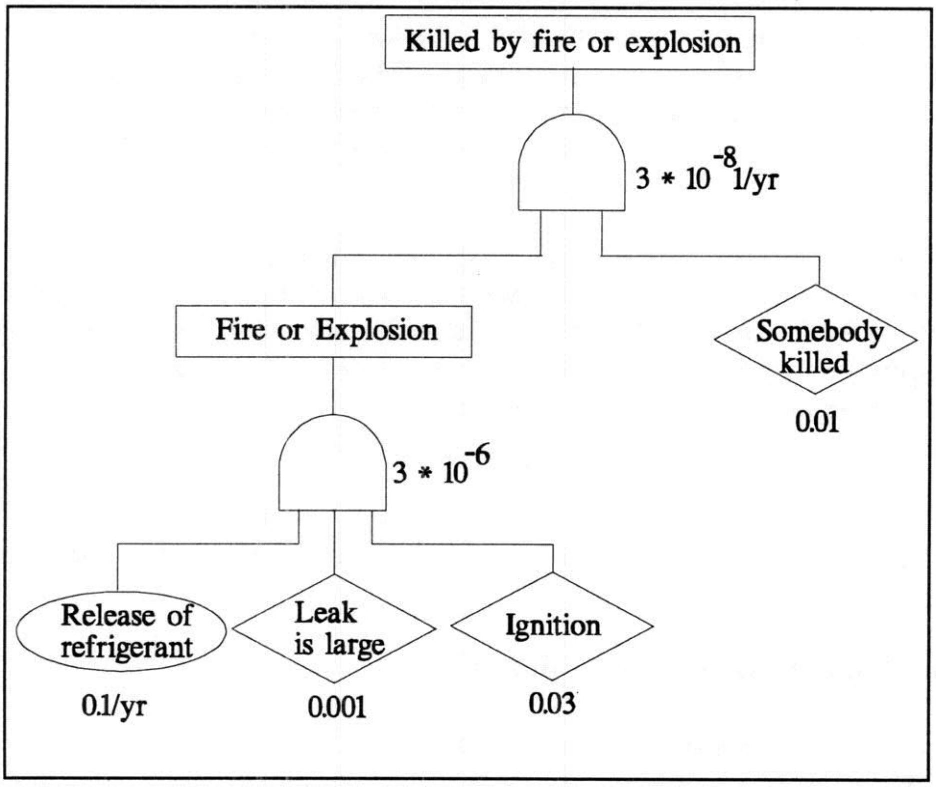

Fig 7 A typical fault tree for a new small refrigeration machine or heat pump

According to Goetzler [17], who was studying specially made refrigerators filled with R152a in kitchen environment, the risk of fire or explosion was between $2*10^{-8}$/year and $5*10^{-7}$/year (worst case). Berghmans [18 on page 13] estimates a death risk of considerably less than 10^{-7} - 10^{-8} /year when using flammable refrigerant. He compares then with data for the risk of using natural gas in households.

Ventilating in the right way like introducing ventilation overpressure around electric equipment and fitting sensors for explosive gas could reduce the risks further - maybe two more orders of magnitude at low costs. Placing the flammable refrigerant outdoor, will also decrease the risk several orders of magnitude. Thus the risk level from small units (up to say 5 kg) could be made acceptable to society even today.

By mixing a flammable refrigerant with an extinguishing medium all risks of explosion and fire hazards from the refrigerant could be avoided at a low cost. However it is probably much more feasible to succeed with weakly flammable substances like R152a and R32 than with propane or isobutane.

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ISSN-1041-2336

42 Kälteanlagen und Wärmepumpen mit brennbaren Kältemittel der Gruppe L3 nach DIN EN 378-3
(Refrigeration Plants and Heat Pumps with Flammable Refrigerants of the group L3 according to DIN EN 378-3)
DIN 7003 (Suggestion)
Beuth Verlag Gmbh, 10772

43 Kälteanlagen und Wärmepumpen; Sicherheitstechnische und umweltrelevante Anforderungen; Teil 8 Aufstellung; Deutsche Fassung prEN 378-8 : 1993
(Refrigeration Plants and Heat Pumps; Safety and environmentally relevant demands; Part 8; Installation; German version of prEN 378-8 : 1993)

44 International Electrotechnical Commission
Safety of household and similar electrical appliances;
Part 2: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers.
©IEC 335-2-40

45 International Electrotechnical Commission
Safety of household and similar electrical appliances;
Household and similar electrical appliances.
©IEC 335-2-24

46 International Electrotechnical Commission
Electrical apparatus for explosive gas atmospheres
Part 10: Classification of hazardous areas
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47 Eric Granryd, Nicklas Tengblad and Jan-Erik Nowacki
Propane as a refrigerant in a small heat pump.
Safety considerations and performance comparisons.
New Applications of Natural Working Fluids in Refrigeration and Air Conditioning
Hannover, Germany 10 - 13 May 1994
IIR Commission B2
ISSN 0151-1637, ISBN 2 903 633 68 1

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APPENDIX 1
QUESTIONS AND ANSWERS FROM NSIEF

Appendix 1:1

SPRÄNGÄMNESINSPEKTIONEN
National Swedish Inspectorate of
Explosives and Flammables
E-enheten
Tomas Grut,MH

1993-11-04 Dnr 41/556/93

Exp 4/11-93/.41t

SEMKO AB
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Brandfarligt köldmedium

Er förfrågan huruvida hinder för SEMKO att certifiera kylskåp föreligger om dessa är fyllda med propan/butan.

Svaret på frågan är att Ni måste ta hänsyn till lagen och förordningen om brandfarliga och explosiva varor (SFS 1988:868 resp 1988:1145) med tillhörande föreskrifter. Lagen 6 § säger att anläggningar och anordningar i vilken hanteras brandfarliga varor skall vara så utformade att dessa anordningar är betryggande från brand och explosionssynpunkt.

Det innebär att ändring fordras i nuvarande kylskåpsstandarden då den inte tar hänsyn till att brandfarligt köldmedium finns.

Detta kan ske så att de mekaniskt konstrueras så att läckage ej kan uppkomma inuti skåp eller att tändkällor placeras utanför riskzon för explosiv gasblandning. Att konstruera apparat så att explosionsfarliga utrymmen kan uppkomma och därigenom behöva använda egensäkra kretsar eller annan explosionsskyddad utrustning anser vi vara olyckligt för konsument/varuprodukter då dessa utrustningar lätt vid utbyte kan ersättas med standard komponenter.

Svaret på Er fråga om speciell varningsmärkning krävs är:

Märkning på skåpet skall vara tydlig och varaktig vid gasförande delar såväl i som utanför skåpet. Märkningen utgörs av varningstriangel enligt SS 3611 Skylt 10 "Varning för extremt brandfarlig vara".

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För närvarande pågår arbete med utarbetande av standard för kylskåp med brandfarligt köldmedium. Först när denna standard föreligger kan SEMKO utföra certifiering.

Owe Fredholm

Tomas Grut

SEMKO

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C:a 20 g småskåp
c:a 50 g stora skåp
föreslå < 70 g =
skåp volym 50 >5 < 300

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41/556/93

Brandfarligt köldmedium, Isobutan (R600)

Då gällande standard för kylskåp SS-EN 60 335-2-24 ej innefattar användandet av brandfarligt köldmedium, har det från tillverkare uppstått ett behov av en SEMKO provningsanvisning i avvaktan på att kompletterande krav och provmetoder har utvecklats och fastställts inom IEC och CENELEC.

Med anledning av detta föreslår SEMKO att nedansstående tilläggskrav införs till SS-EN 60 335-2-24 för kylskåp innehållande Isobutan (R600).

Dessa krav är baserade dels på ett förslag inom IEC TC 61 om uppdatering av IEC Publ. 335-2-24 i syfte att täcka kylar och frysar innehållande brandfarligt köldmedium, och dels på underhandskontakter med Sprängämnesinspektionen.

Föreslagna krav är sända på remiss även till Elsäkerhetsverket och AB Electrolux.

2. Termer och definitioner

Tillägg.

2.2.112

Risk utrymme (Dead area): Utrymme begränsat med sidor och botten med begränsad ventilation där läckande Isobutan (R600) kan samlas. Utrymme skall för att betraktas som risk utrymme innehålla gasförande delar eller ha sådana öppningar att läckande gas kan tränga in i utrymmet

S 100

Ⓢ – märkt, kontrollerad säkerhet — Ⓢ – marked, certified safety

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7. Märkning

Tillägg.

7.1

Apparat där Isobutan (R600) används som köldmedium , skall vara försedd med varnings symbol enligt SS 3611, skylt 10. Symbolen skall vara tydlig och varaktig, och placerad vid gasförande delar såväl i som utanför skåpet.
Dessutom skall skåpet vara märkt så att det framgår att Isobutan (R600) används som köldmedium.

7.6

Tillägg.

Varningssymbol enligt SS 3611, skylt 10

se bilaga.

7.12

Tillägg.

För apparater där Isobutan (R600) ingår, skall bruksanvisningen innehålla varningssymbol enligt SS 3611, skylt 10 samt en varningstext om att speciell försiktighet skall iakttagas vid hantering, installation, sevice,rengöring och skrotning för att undvika skador på kylsystemet och därmed minska risken för läckage med påföljande explosion eller brand.

0,2 l ?
Täthetsprov

[illegible] ? att Tryckvakt.

Konstruktionsfrågor

22. Utförande

Tillägg.

22.103

Risk utrymme får ej innehålla elektriska komponenter.

Vi emotser Erat svar på förslaget, **senast 93-11-30**.

Med vänlig hälsning

SEMKO AB

B. Zetterström

Björn Zetterström

Bilagt

SS-EN 60 335-2-24
Varningssymbol.

LGM

SPRÄNGÄMNESINSPEKTIONEN
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1993-12-29 Dnr 41/556/93

Exp 931230/TG

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Brandfarligt köldmedium,isobutan(R600)

De av Er föreslagna tilläggskraven till SS-EN 60 335-2-24 för kylskåp och frysar innehållande brandfarligt köldmedium (t.ex.-isobutan) som grund för en provningsanvisning i avvaktan på att kompletterande krav och provmetoder har fastställts inom IEC och CENELEC synes sakna minst tre av våra föreslagna 7 punkter, varför vi här repeterar samtliga.

1.Brandfarligt köldmedium bör utmärkas i klartext på skåpet.

2.Märkning på skåpet skall vara tydlig och varaktig vid gasförande delar,såväl i som utanför skåpet.

3.Den provning som är beskriven är endast en tryckprovning och skall kompletteras med en täthetsprovning.Läcksökning av icke provtryckt rörledning faller under ASS kunggörelse AFS 1985:14, vilket även tryckprovning gör.

4.I provningsanvisningen bör samtliga specifika köldmedier utgå och ersättas med -"brandfarligt köldmedium (t.ex.isobutan)".

5.Riskutrymme får ej innehålla elektriska komponenter

6.Köldsystemet skall vara utrustat med överhettningsskydd.

7.Mekanisk styrka på kylrör eller motsvarande skall inte bara ta hänsyn till inre övertryck utan även yttre påverkan t.ex. påfrestningar vid hårdhänt avfrostning (m.h.a. mekaniska hjälpmedel)varför dessa bör förläggas skyddat.

Av ovannämnda punkter har Ni i era tilläggskrav inte ännu tagit hänsyn till punkterna 3,6 och 7.

Vi vill vidare införa en begränsning på skåpens storlek så att volymer större än 70 gram köldmedium inte omfattas av dessa provisoriska provningsanvisningar.Detta torde klara skåpvolymer upp till 300 liter.

Bertil Öhlin Tomas Grut

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Beteckning/Reference
BOE/

Er beteckning/Your reference
Tomas Grut

Sprängämnesinspektionen
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94 -..

| 41 | 556 / 93 |

Provisoriska provningsbestämmelser för kyl- och frys-apparater innehållande Isobutan som köldmedel, SEMKO MEMO 704

SEMKO har, efter Elsäkerhetsverkets och Sprängämnes-inspektionens hörande, utarbetat provisoriska provningsbestämmelser för kyl- och frys-apparater innehållande Isobutan som köldmedel, SEMKO MEMO 704.

Bestämmelserna avses tillämpas av SEMKO vid provning och certifiering av kyl- och frys-apparater inne-hållande Isobutan tills dess harmoniserad standard föreligger.

För Er information översänder vi ett exemplar av SEMKO MEMO 704.

För ytterligare information kan nämnas att kopia av SEMKO MEMO 704 har översänts till CENELEC/TC 61 och till medlemmarna i CENELEC CCA-Agreement.

Med vänlig hälsning

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CENELEC/TC 61(SE)
January 1994

EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION (CENELEC)

TECHNICAL COMMITTEE 61: SAFETY OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES

Information by the Swedish National Committee on a SEMKO document issued in accordance with CENELEC Memorandum No. 7.

For your information we are enclosing document

M E M O R A N D U M 7

S E M K O M E M O No. 704 (Issue 1)

Refrigerators and freezers for household use containing Isobutane (R600a) as refrigerant

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M E M O R A N D U M 7

S E M K O M E M O No. 704 (Issue 1)

Refrigerators and freezers for household use containing Isobutane (R600a) as refrigerant

This test schedule has been prepared by SEMKO in accordance with the requirements of CENELEC Memorandum No. 7. The SEMKO safety mark will be granted to refrigerators and freezers for household use containing Isobutane (R600a) as refrigerant which meet the safety requirements of EN 60 335-2-24:1989 and the requirements detailed in this schedule.

Preface

This schedule specifies requirements and test methods for electrical refrigerators and freezers for household use which contain Isobutane (R600a) as the refrigerant and for which international standards are missing.

This schedule shall be used in conjunction with EN 60 335-2-24:1989.

The clauses in this schedule supplement or modify the corresponding clauses in EN 60 335-2-24:1989. Where a particular subclause of EN 60 335-2-24 is not mentioned in this schedule, that subclause applies without modifications.

2. Definitions

2.2.112 Addition

Hazard area: Area limited by the sides and the bottom and having limited ventilation so that leaking refrigerant can be colleced and having either parts containing gas or is provided with such openings that gas can enter the area.

7. Marking

7.1 Addition

Refrigerators and freezers containing Isobutane (R600a) as refrigerant shall be marked with a warning symbol according to SS 3611, symbol No.10. The symbol shall be clearly legible and durable, and shall be placed close to parts containing gas on the inside as well as on the outside of the refrigerator or freezer.
Furthermore, the refrigerator or freezer shall be so marked that it is clear that Isobutane is used as refrigerant.

7.6 Addition

Warning symbol according to SS 3611, symbol No.10

Nr 10
"Fara för brand -
Brandfarliga varor eller
annat mycket lättantändligt material."

No.10

Danger of fire -

Flammable goods or other
very flammable material

7.12 Addition

The instructions for use for refrigerators and freezers having Isobutane (R600a) as refrigerant shall contain the warning symbol No.10 according to SS 3611 and shall include the substance of the following cautionary information:

Care must be taken at transportation, installation, service and cleaning, in order to avoid damages to the refrigerant system so that the risk of leakage, fire or explosion is decreased.
Care must also be taken with regard to these risks when the refrigerator or freezer is scraped.

21. Mechanical strength

21.101 Addition

Gas conduits shall be so constructed and so fixed that they withstand the mechanical stresses that are likely to be expected in normal use.

Gas conduits placed in the food compartment of the refrigerator or freezer are subjected to the tests of a, b och d.

Gas conduits so placed on the outside or in an uncovered recess of a refrigerator or freezer that they, in normal use, are not subjected to mechanical stresses, are subjected to the tests of c and d.

The complete gas conduit system is subjected to the test of e.

Other gas conduits are subjected to the tests of a, b och d.

a)

Gas conduits are tested by applying the end of a test pin with a diameter of 2,5 mm ± 0,1 mm and a length of 100 mm ± 2 mm with a force of 30 N ± 0,5 N on every part of the gas conduits that is likely to be weak.

b)

Gas conduits are tested with a pull force of 30 N ± 0,5 N for 30 s on each part of the gas conduits that is likely to be weak.

c)

Gas conduits are tested with a pull force of 15 N ± 0,5 N for 30 s on each part of the gas conduits that is likely to be weak.

During the tests of a - c no leakage is allowed and the gas conduits must not loosen or in any other way get displaced from its original position.

d)

Gas conduits are subjected to one blow with an impact energy of 0,5 J ± 0,05 J, applied to every point of the gas conduits that is likely to be weak by means of the spring-operated impact-test apparatus described in 21.1. The blow is applied to an intermediate piece of steel with a weight of 50 g ± 0,5 g and a diameter of 10 mm ± 0,1 mm. The end of the intermediate piece facing the gas conduits is formed to a tip with an angel of 90 ± 1 and the tip rounded of with a radius of 0,3 mm ± 0,05 mm.

e)

Gas conduit systems are tested for 5 min. with a pressure equal to two times the normal working pressure assigned by the manufacturer.

During the tests of d - e no leakage is allowed.

22. Construction

22.103 Addition

Electrical components are not allowed in hazard areas.

Compliance is checked by inspection.

Note:

This memorandum will remain valid until a harmonized standard has been endorsed.

Appendix 1:2

Nowab

92-07-03

Sprängämnesinspektionen
Att Tomas Grut
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PROPAN I LITEN VÄRMEPUMP

Ert ärende nr 47/560-92

Undertecknad är ombud för en grupp av intressenter bestående av:

KTH-Kylteknik
Energihuset
Mälarkyl
och
Nowab (mitt företag)

Refererande till vårt möte den 5/6 anhåller vi om godkännande att ur få använda propan eller gasol i värmepumpar av det slag som vi diskuterade med följande modifikationer och begränsningar.

Värmepumparna får inte installeras i bostadsrum som är så små att 25% av LEL överskrids om hela köldmediemängden skulle läcka ut där.

Såväl kompressor som lyror och torkpatron skall placeras i en tät låda ventilerad mot utomhusluften via två öppningar nedtill och upptill. Om expansionsventilen placeras inomhus skall också den ligga i lådan.

Inomhusvärmeväxlaren, som får vara i kontakt med inomhusluften, skyddas på ett sådant sätt att oavsiktlig punktering av denna försvåras avsevärt.

Värmepumpen märks så att alla - speciellt servicepersonal inser att värmepumpen är fylld med propan eller gasol.

Bifogat finns också de principritningar som överlämnades vid vårt möte på KTH, men korrigerade med tanke på ovanstående punkter.

Med vänlig hälsning

Jan-Erik Nowacki

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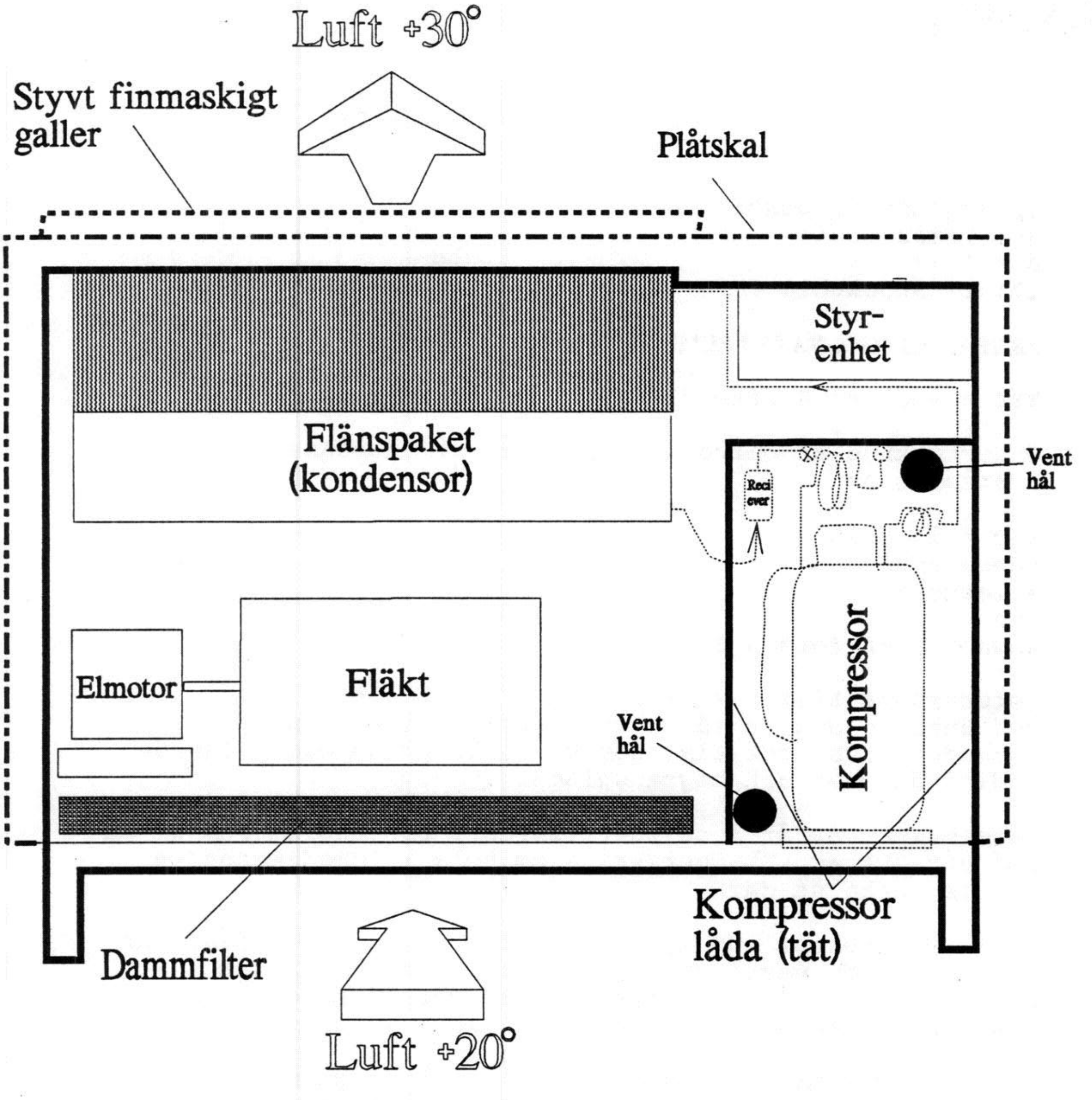

Luft +30°
Styvt finmaskigt galler
Plåtskal
Styr-enhet
Flänspaket (kondensor)
Reci ever
Vent hål
Kompressor
Elmotor
Fläkt
Vent hål
Kompressor låda (tät)
Dammfilter
Luft +20°

Inomhusdel

SPRÄNGÄMNESINSPEKTIONEN
National Swedish Inspectorate of
Explosives and Flammables
E-enheten
Tomas Grut, MH

1992-12-03

Dnr 47/560/92

Nowab
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Propan i liten värmepump

Den av Er redovisade värmepumpen innehållande 300 g propan, innehållande en inomhusdel och en utomhusdel får Sprängämnesinspektionen (SÄI) meddela följande.

Utomhusdelen - en förångare till värmepumpen samt expansionsventil anses betryggande vid utomhusplacering.

Inomhusdelen består av 2 enheter

a) kondensorn (värmeväxlaren som skyddas så att oavsiktlig punktering av denna försvåras avsevärt

b) övrig inomhusplanerad utrustning som kompressor, lyror, torkpatroner eventuell påfyllningsventil (schröder-ventil) m.m. skall placeras i gastät låda ventilerad mot utomhusluften via två öppningar (nedtill och upptill).

Av installationsföreskrift skall framgå att värmepumpen får installeras i bostadsrum endast om volymen i dessa är så stor att 25 % av undre explosionsgränsen ej uppnås om hela köldmediemängden skulle läcka ut där. Detta innebär att rumsvolymen skall vara större än 25 m^3.

Värmepumpen märks så att det framgår att den är fylld med propan.

Om ovanstående villkor är uppfyllda anser SÄI att risken är icke beaktansvärd varför installation kan ske utan klassningsplan på utrymmet.

Erik Nilsson

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Appendix 1:3

SPRÄNGÄMNESINSPEKTIONEN
National Swedish Inspectorate of
Explosives and Flammables

1995-01-25 Dnr 41/408/94

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Brandfarligt köldmedium i frånluftsvärmepumpar.

Refererande till Ert brev 1994-04-13 införs nedanstående komplettering till tidigare tilläggskrav grundat på motsvarande för kylar och frysar innehållande högst 500 g brandfarligt köldmedium (propan eller isobutan) till SS-EN 60335-2-40 för frånluftvärmepumpar för en-och tvåfamiljshus.

Er fråga 1 och 2: Kan det accepteras att läckande gas kommer in i ventilationssystemet? och Kan det accepteras att värmepumpen ansluts till valfritt ventilationssystem ?

Svar på fråga 1 och 2.
Ventilationssystemet i frågorna syftar på såväl frånluft (från rum till värmepump) som avluft (från värmepump till det fria). Ingen av dessa ventilationssystem får innehålla elkomponenter dessutom skall ventilationsrören vara jordade.
Låg- och högtryckspressostaten skall ha metallmembran som avskiljer köldmediet från elektrisk brytfunktion. Detta membran skall vara minst 0,2 mm och utgöras av korrosionsbeständig metall (enl CENELEC TC 31 förslag okober 1992).

Fläkten liksom differenstryckvakterna och pressostaten skall vara av sådan typ som i sin funktion icke ger upphov till gnistor eller till yttemperatur överstigande 200^0 C,och av god industriell kvalitet och med kappslingsklass lägst IP 54 i område T1 - T3 enl SS 421 08 21 sid 17.

Er fråga 3: kan det accepteras att läckande gas kan ansamlas i vattenvärmardelens vattenbehållare?

Svar på fråga 3.

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Läckande gas får ej ansamlas i vattenvärmardelens vattenbehållare,dvs tappvattnet och propansystemet skall avskiljas med separat mellankrets eller en dubbelväggig ventilerad konstruktion.Bägge felen sänker köldmedietrycket som dessutom resulterar i att lågtrycksvakten stoppar kompressorn dock ej fläktarna i såväl uppställningsrummet som skall ha en kapacitet på minst 10 l/s som fläkten i ventalitionsaggregatet för avluft med en kapacitet med minst 20 l/s.

Vidare anser SÄI
- att utrustningsleverantören får visa att kompressorn såväl som övriga aggregatdelar är designade för aktuell brandfarlig gas tex vibrationsdämpningar så att farlig spänningskorrosion på rörsystemet ej åstadkommes.

-att all annan service än rutinservice skall utföras av behörig personal dvs behörighet enl köldmedie-kunggörelsen kompletterat med tilläggskrav för brandfarlig gas tex produktkunskap och serviceinstruktion om gassystem med brandfarliga gaser.

Detta provisoriska regelförslag gäller i avvaktan antingen på ett nationellt eller ett internationellt regelverk för brandfarliga köldmedier i värmepumpar med tillhörande provningsbestämmelser blivit fastställt.

Vi ber ER översända komplett provningsanvisning för ovanämnda frånluftvärmepump som resultat av våra krav,om ni utarbetar en sådan.

Bengt Einerth

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1995-04-24

95-04-26
41 408/94

1321A Provning av alternativt köldmedium propan i frånluftsvärmepumpar.

Provningen utfördes på typerna 570 och 480A enligt SEMKO-provningsanvisningen "Särskilda fordringar på elektriska frånluftsvärmepumpar där Isobutan eller Propan används som köldmedium".

Protokoll delges över resultatet från ovannämnda provning.

7. Märkning

Varningsskyltar enligt SS 3611, placeras i kompressorutrymme och under övre filterluckan samt i nedre rörkopplingsutrymmet för typer som har köldmediumrör i detta utrymme.

På märkskylt anges köldmedium R 290. Varningsmärkning bifogas för placering invid elcentralen.

7.12 Anvisning

Anvisningen kompletteras med uppgift om att värmepumpen innehåller brandfarligt köldmedium, instruktion om skrotning och ingrepp i köldmediekretsen. Anvisningen upplyser också om att luftkanalerna skall skyddsjordas.

21. Mekanisk hållfasthet

a) Gasförande ledningar, kopparrör, har provats med 30 N kraft mot en stålpinne med diametern 2,5 mm och längden 100 mm placerad mot rören utan anmärkning.

b) Gasförande ledningar har utsatts för en dragkraft av 30 N under 30 sekunder utan anmärkning.

d) Gasförande ledningar har utsatts för slagprov med slagenergi av 0,5 J. Slaget anbringades mot en ståldyna med vikten 50 g och som hade en diameter av 10 mm. Dynans ände som anbringades mot gasledningen var spetsig med en

Ⓢ SEMKO
An Inchcape
Testing Services Company

Handläggare
Ingvar Sätterström
Telefon direkt
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vinkel av 90° med spetsen avrundad med radien 0,3 mm. Provet kunde utföras utan anmärkning.

e) Gasförande ledningssystemet provades under 5 min. med övertrycket 42 bar (2x21 bar) utan anmärkning.

22. Utförande

Gasförande ledningar i vattenvärmardelen ligger i en rörhylsa med rillor som tillförsäkrar värmeöverledningen mellan gasförande rör och rörhylsan.
Ev. läckande köldmedium kan rinna ut utan tryckförhöjning.
Fabr. Outokumpu copper typ 92.

Lågtrycksvakt som stoppar kompressorn men ej fläktar vid läckage finns.

Fläktkapaciteten är över 20 l/s och kan ventilera ut uppställningsrummet med kapaciteten över 10 l/s.

Kompressorn är monterad med vibrationsdämpare och rördragningen är utförd så att risken för spänningskorrosion är minimerad.

24. Komponenter

Elektriska komponenter är placerade i utrymmen som ej klassas som riskområde. Gasförande rörledningar är skarvade med hårdlödning och klämkoppling fabr. Vulkan Lokring typ Lokring.

Låg- och högtryckspressostater av fabr. Texas Instruments typ 20PS269-1 (2 st. membran med tjocklek på vardera 0,1016 mm) respektive typ 20PS270-1 (4 st. membran med tjocklek på vardera 0,127 mm).

Sammanfattningsvis kan konstateras att värmepumparna uthärdar tilläggskraven för värmepumpar med köldmedium propan.

Med vänlig hälsning

SEMKO AB

Björn Zetterström

Kopia
Sprängämnesinspektionen
Tomas Grut, Box 1413, 171 27 SOLNA

INS/AKL Elekt-st - 451

/6

Appendix 1:4

Hydrosafe ab
FÖR SÄKER GASHANTERING

Datum 940421
Vår ref Nils Lindgren
Er ref.

Mottagare
SPRÄNGÄMNESINSPEKTIONEN
Box 1413
171 27 SOLNA

FÖRHANDSUTLÅTANDE ANGÅENDE KLASSNING AV VÄRMEPUMPANLÄGGNING

För att utröna möjligheterna att ersätta befintligt freon med propan 95 som köldmedia i värmepumpanläggningen vid Falu Kommuns reningsverk har följande förslag utarbetats för klassning av explosionsfarliga områden.

Avsikten är att se om klassningen kan accepteras av SÄI innan ytterligare arbeten görs.

TÄNKT UTFÖRANDE:

Befintlig freon ersätts med ca 1 ton propan 95. Gasolen skall tjänstgöra som köldmedia och kommer att finnas både som vätskefas och gasfas i systemet. Trycket kan uppgå till 25 bar i vissa delar av systemet. Som tryckhöjande enhet finns en skruvkompressor.
Eftersom propanet är en brandfarlig gas erfordras klassning av anläggningen för att ha erforderlig säkerhet på bl.a elutrustningen.
Elutrustningen är omfattande i maskinhallen varför kostnaderna att helt flytta bort den är orimliga.
Av den anledningen är tanken att kapsla in gasförande utrustning i ett plåthölje med undertrycksventilation och behålla elutrustningen utanför kapslingen.
Klassning skulle då utföras med zon 1 inom kapslingen och oklassat utanför densamma.

Ventilationen dimensioneras till ett tänkt läckage i den största flänsen, DN 250, där det förutses lossna en bit mellan 2 flänsbultar. Sprickan skulle då bli:

A = 5 mm x 104 mm = 520 mm^2 = 0,000520 m^2.

Utsläppt massflöde beräknas enl: 0,6 A $\sqrt{2 \Diamond \Delta p}$ = 0,05 kg/sek = 180 kg/tim (90 Nm^3/tim)

A = aria = 0,000520
$\Diamond$ = Densitet propanvätska = 510 kg/m^3
Δp= 25 bar(e)

För att späda denna gasolmängd med luft till 25% av UB åtgår 18 000 Nm^3 luft/timme.

Adress
Box 6023
781 06 BORLÄNGE
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Telefon **0243-386 20**
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Hydrosafe ab
FÖR SÄKER GASHANTERING

Förångarrummet klassas zon 2 i sin helhet. En mellanvägg uppsätts vid entrén för att frånskilja vattenpumpgrop.

Innan ytterligare arbeten vidtas i detta ärende önskas en kommentar från SÄI i ärendet.

Vid ett positivt svar kommer vi med ytterligare tekniskt underlag för diskussion för en slutlig lösning. Flera anläggningar kan senare komma i fråga.

Eftersom detta är en ny användning av gasol på en befintlig anläggning, vill vi givetvis inte åsidosätta säkerheten på något sätt, utan syftet är att se om det överhuvudtaget finns någon ekonomisk acceptabel säker lösning.

För ytterligare information kan undertecknad kontaktas.

Med vänlig hälsning
Hydrosafe ab

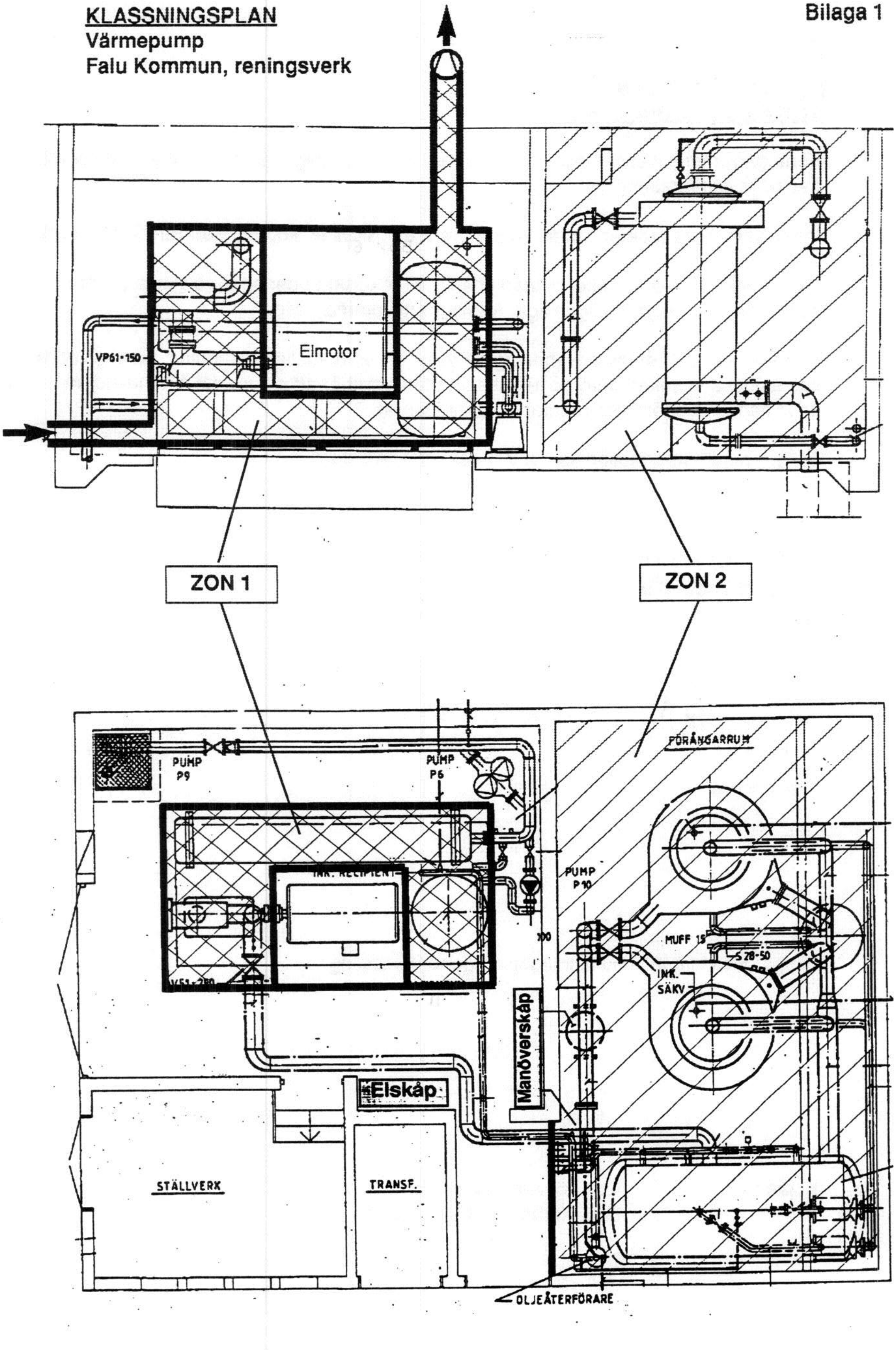
Nils Lindgren

Bilaga: Skiss på tänkt klassningsplan genom kapsling.

Kopia till: Nowab, Jan-Erik Nowacki, Lidingö
Falu Kommun, Bengt Montan

KLASSNINGSPLAN
Värmepump
Falu Kommun, reningsverk

Bilaga 1



SPRÄNGÄMNESINSPEKTIONEN
National Swedish Inspectorate of
Explosives and Flammables
E-enheten
Tomas Grut,TG

1994-12-13 D Nr 41/431/94

Hydrosafe AB
Nils Lindgren
Box 6023
781 06 Borlänge

Besiktning av värmepumpanläggning Östra Främby angående möjlig konvertering från Freon 12 till propan / isobutan den 5 december 1994.

Närvarande: Bengt Montan , Falun kommun reningsverk
Jan Erik Nowacki, NOWAB
Nils Lindgren Hydrosafe AB
Tomas Grut , Sprängämnesinspektionen

Först ett utdrag ur LBE 6:e paragrafen:

" 6 § Byggnader och andra anläggningar där brandfarliga eller explosiva varor hanteras samt anordningar för hantering av sådana varor skall vara inrättade så att de är betryggande från brand och explosionssynpunkt och förlagda på sådant avstånd ifrån omgivningen som behövs med hänsyn till hanteringen.Detta gäller också områden med sådana byggnader,anläggningar och anordningar.
Regeringen eller den myndighet som regeringen bestämmer får meddela föreskrifter om att byggnaderna,anläggningarna, anordningarna och områdena skall omfattas av särskilda krav.Regeringen eller den myndighet som regeringen bestämmer får meddela föreskrifter om att sådana byggnader,anläggningar och anordningar inte får användas,saluhållas eller säljas om de inte efter kontroll genom teknisk provning,besiktning eller annan undersökning har befunnits vara betryggande från skyddssynpunkt."

Att en anläggning ,som den i Östra Främby, har haft tre haverier med totalt Freon utsläpp,vilket innebär c:a 1 ton,på tolv år talar för att anläggningen ej uppfyller grundläggande gastekniska krav. För att få processa brandfarlig gas i dessa mängder,om det nu skall få förekomma, måste anläggningen först få en säkerhetsteknisk höjning .
Det innebär bl.a. följande:

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1. Vibrationsdämpningar
2. Inga kopparrör då dessa lätt kan få spänningskorrosion i samband med vibrationer.
3. Dubbla säkerhetsventiler efter avstängningsventil.
4. Bultar på ventiler nära processkärl skall vara inbyggda.
5. Tät och trycktestade anläggningsdelar,ej droppande axeltätningar.Dagens täthetskrav för köldmedieanläggningar talar om max läckage på 3 gram/år
6. Kompressor och processutrustning bör vara så välventilerade att de i princip placeras utomhus med eventuellt väderskydd i form av tak (jämför med raffinaderi där all process utrustning är utomhus).Köldkänsliga anläggningsdelar får värmeisoleras kompletterat med värmekabel.
7. Helsvetsade rörsystem och endast av montageskäl dito med flänsförband.
8. Hus - väderskydd ,utföres av ej brännbart material.
9. Fjärrvärmesystemet och dagens freonsystem måste om propan användes avskiljas med separat mellankrets för att omöjliggöra läckage till fjärrvärmesystemet.
10. Utblåsningssäkra packningar i hela systemet.
11. Skruvkompressorer för brandfarliga gaser används vid raffinaderier endast när dokumenterad god erfarenhet samt fördelar gentemot andra kompressortyper föreligger. Vid Shell raffenaderi skall dessutom de vara i överensstämmelse med API std 619 och därutöver vara sanktionerade av teknisk koncernstab för att få användas. Ett motsvarande krav ställer vi dvs:
    -Utrustningsleverantören får visa att kompressor såväl som övriga aggregatdelar är designade för propan.
12. Skyddsavstånd till allmän väg skall bygga på gjord riskutredning som får grunda sig på ett dimensionerande skadefall vilket vi kommit överens om.

Bengt Einerth

Tomas Grut