PUBLISHED DOCUMENT

PD CEN/TR 14739:2004

Scheme for carrying out a risk assessment for flammable refrigerants in case of household refrigerators and freezers

ICS 71.100.45; 97.040.30

British Standards

National foreword

This Published Document is the official English language version of CEN/TR 14739:2004.

The UK participation in its preparation was entrusted to Technical Committee RHE/18, Refrigeration safety, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

Summary of pages

This document comprises a front cover, an inside front cover, the CEN/TR title page, pages 2 to 30, an inside back cover and a back cover.

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TECHNICAL REPORT

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TECHNISCHER BERICHT

CEN/TR 14739

September 2004

ICS 71.100.45; 97.040.30

English version

Scheme for carrying out a risk assessment for flammable refrigerants in case of household refrigerators and freezers

Schéma pour la réalisation d'une estimation des risques engendrés par les fluides frigorigènes inflammables dans les réfrigérateurs et congélateurs ménagers

Schema für die Durchführung einer Risikobewertung für brennbare Kältemittel bei Haushalt-Kühl- und Gefriergeräten

This Technical Report was approved by CEN on 25 November 2003. It has been drawn up by the Technical Committee CEN/TC 182.

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Ref. No. CEN/TR 14739:2004: E

Contents

Foreword

This document (CEN/TR 14739:2004) has been prepared by Technical Committee CEN/TC 182 "Refrigerating systems; safety and environmental requirements", the secretariat of which is held by DIN.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this CEN Technical Report: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

The use of CFC and HCFC is restricted by Council Regulation 2037/2000 of the European Parliament.

Both HCs and HFCs can be used as refrigerants as well as blowing agents for insulation foams. HFC 134a is commonly used as refrigerant but can also be used as a blowing agent for insulation foam.

The environmental advantages of HCs are obvious as the Global Warming Potential (GWP) is lower compared to the GWP of HFC 134a. Therefore, a majority of household appliance manufacturers are phasing out HFCs in favour of HCs.

Table 1 — Values for GWP — Global Warming Potentials

Emissions with impact on the global warming	GWP 100 years
CFC-12	8 500
141b, HCFC	630
134a, HFC	1 300
245 fa, HFC	820
Cyclopentane, Isobutane	3
CO_2	1
Others (CH_4, N_2O)	(24,5, 320)

With regard to the global warming impact see as well Annex B of EN 378-1:2000 (TEWI).

1 Scope

The document gives a scheme for carrying out a risk assessment for flammable refrigerants in case of household refrigerators and freezers with refrigerants of group A3 according to EN 378-1, taking into consideration a sealed system and a refrigerant charge of not more than 150 g. Sealed systems are refrigerating systems in which all refrigerant containing parts are made tight by welding, brazing or similar permanent connection.

NOTE For risk assessment the method with flow diagrams is selected, because these are helpful for checking the possible ignition of the whole appliances and to estimate the probability of ignition. It takes EN ISO 12100, EN 1050, EN 1127, EN 60335-2-24/A53, E DIN 7003 into consideration.

At least the probability of deflagration is the product of multiplication of the probability of defects of different components and the probability for the presence of explosive atmosphere and the probability for the ignition sources.

2 Mode of consideration

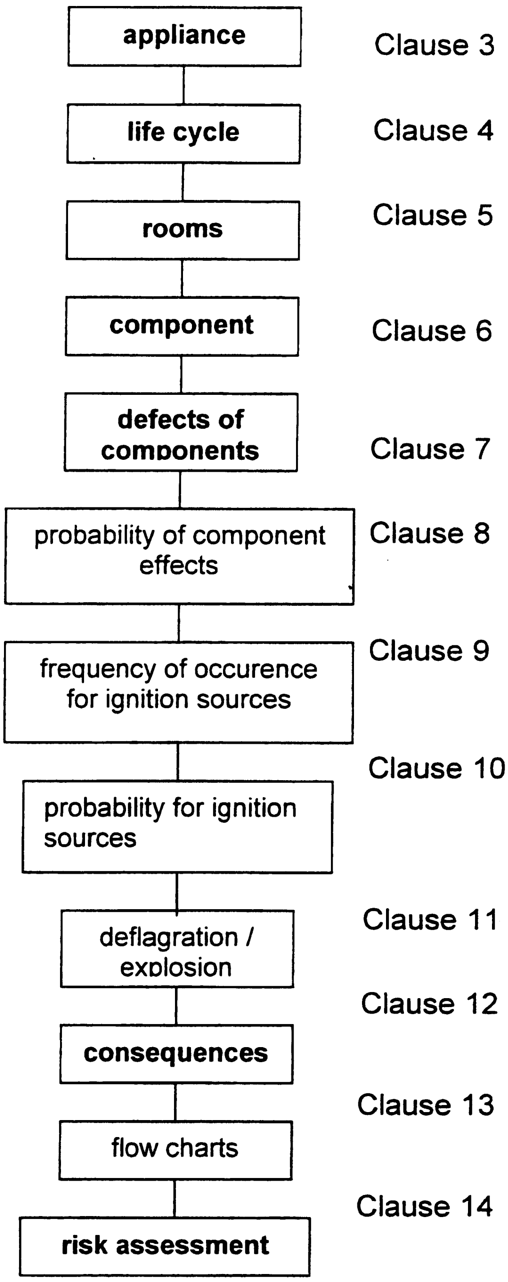


Figure 1 — Mode of consideration

Essential for the developed flow diagrams is the following mode of consideration:

First, each refrigerant containing component of a refrigerating system has to be considered for all stages of life cycle such as design, construction, production, storage, transportation, operation, maintenance, service and disposal. In principle it's necessary to sum up the risk assessment for each stage of life cycle. After considering the different stages of the life cycle it is necessary to consider the space in and around of the refrigerator and freezer where a leak may occur. At least the space is separated into four different rooms (see Figure 4). The next step of risk assessment is the estimation of possible defects of the different components. The single probability for all possible defects have to add up to the total frequency of occurrence of the hazard. The next step is the calculation of the probability for the presence of explosive atmosphere. And after that it's necessary to consider the different possible ignition sources such as vacuum cleaner, fan heater, etc.

At least the probability of deflagration is the product of multiplication of the probability of defects of different components and the probability for the presence of explosive atmosphere and the probability for the ignition sources.

3 Appliances

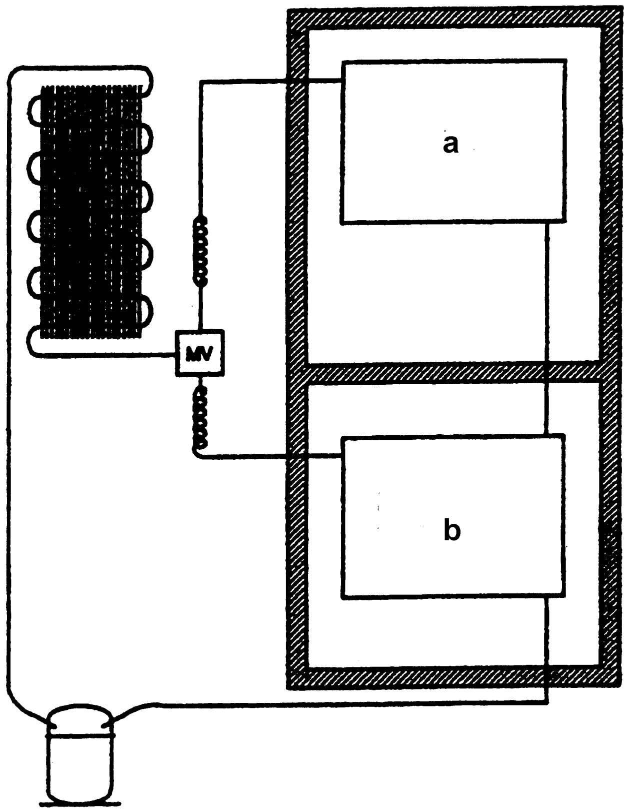
Examples of the most usual refrigerating systems:

Figure 2a: System with 1 compressor and 2 compartments

Figure 2b: System with 2 compressors and 2 compartments

Figure 2c: System with 1 compressor and 1 compartment

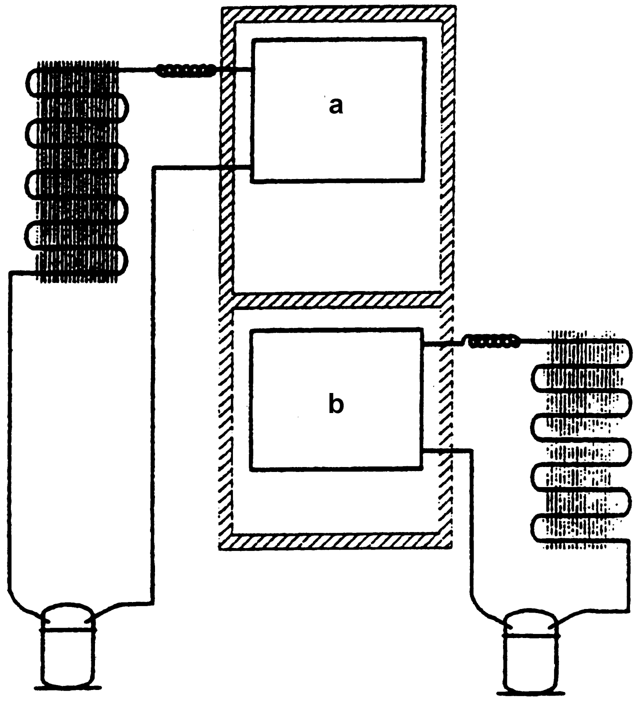
There are refrigerators, freezers and combinations of these appliances. They can be free-standing, installations in recess areas or beneath table tops.



Key

a Fridge
b Freezing compartment

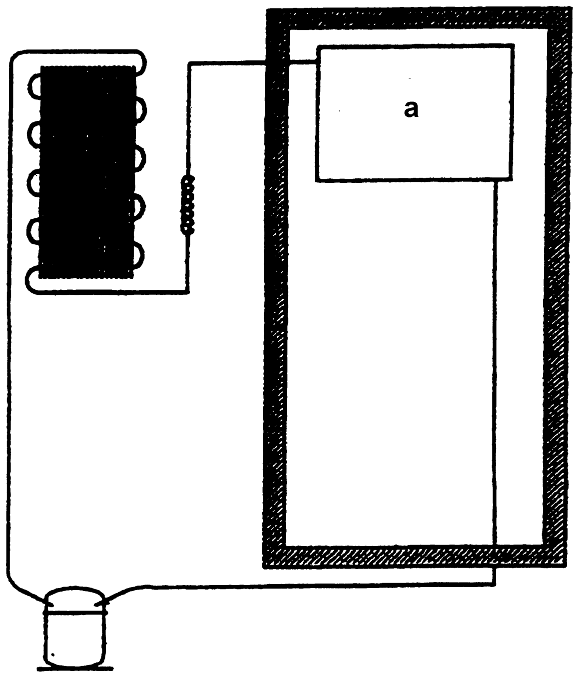
Figure 2a — System with one compressor and solenoid



Key

a Fridge
b Freezing compartment

Figure 2b — System with two compressors



Key

a Fridge/Freezing compartment

Figure 2c — System with one compressor

4 Life cycles

Important for customer and maintenance personal is transportation and storage with unpacked appliances, operation, maintenance, service and disposal (Figure 3). Responsible for design, construction, production, and to a certain degree for the transport and storage of packed appliances, is the manufacturer. The ad hoc group considered transportation and operation as the most important steps of life cycle. The typical life cycle time of a refrigerator or a freezer is 12 years[1].

Life cycles

- design
- construction
- production

- storage
- transportation

- operation
- maintenance
- service

- disposal

Figure 3 — Life cycles

Referring to operation it is necessary to consider the behaviour of refrigerators and freezers during "standstill" and "operation".

The influence factors for the appliance at standstill are the ambient temperature, charge of refrigerant, oil charge in the compressor and the inside volume of the refrigerating system. Only a quantity of refrigerant is vaporous in the system. The remaining quantity is dissolved in the oil of the compressor.

But if the appliance is in operation it's necessary to distinguish the following situations:

- compressor is running
- compressor is switched off

In general the behaviour of a leakage depends on it's location, if lying on the high or on the low pressure side.

[1] 12 years is the pragmatical value of the manufacturers.

5 Rooms

After considering the different stages of life cycles, the next step for risk assessment is to consider the different rooms. Because in case of a leak the space in and around the refrigerator is to be separated into four rooms, which are represented graphically in Figure 4. Room I consists of all inner rooms of the appliance, e.g. the fresh food storage compartment and the freezer compartment. Room II is defined as the room outside of the housing of the appliance between the back wall and the condenser of the compressor room. Room III is the room into which the appliance is built and the room for ventilation openings. And Room IV is the room in the surroundings of the appliance without rooms II and III.

In case of transport room IV includes room II and room III because an ignition source is only possible in the surroundings of the appliance (see as well Figure 4).

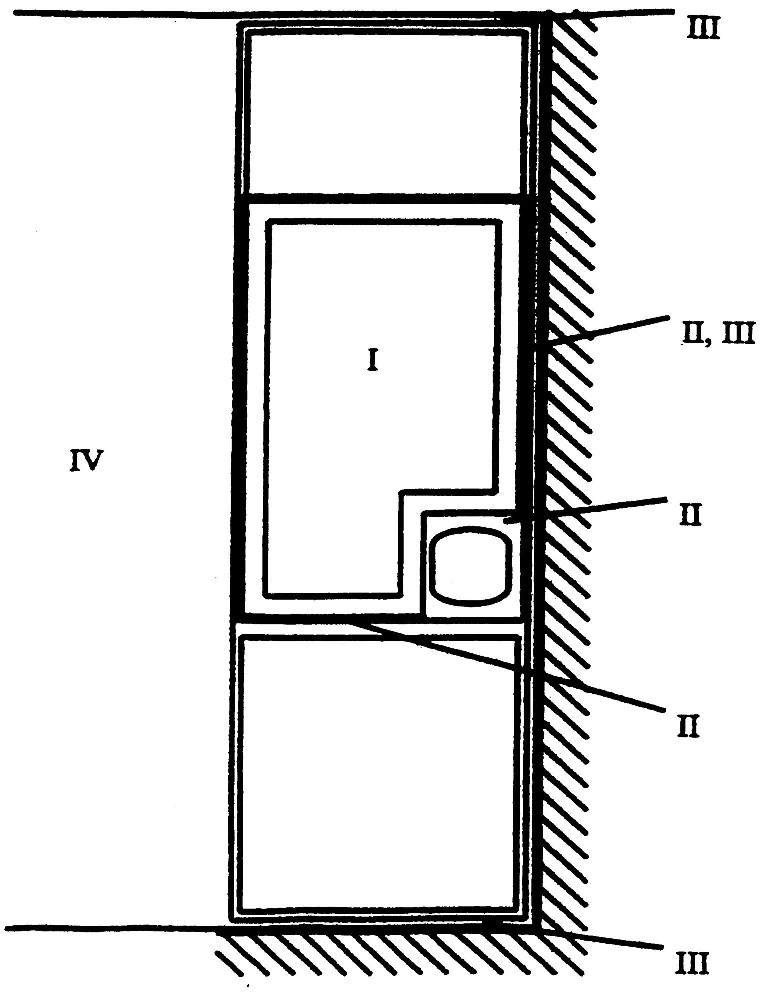


Figure 4 — Different rooms

6 Components

The refrigerating circuit of a refrigerator or freezer consists basically of the following components, which are assessed by hazard under different aspects:

— one or more compressors;

— one or more evaporators;

— one or more condensors;

— dryer, filter;

— connecting pipes;

— brazed or welded connections or equal connections;

— fan;

— defrost heater;

— solenoid;

— accumulator;

— thermostat or electronic devices;

— capillary tube.

The components shall be assessed under different aspects depending on the type and material, as well as surface protection. Thus they represent a different risk potential. Incorrect material selection or non allowable wall thickness, unsafe installation of piping or poor connections increase the risk; more details will be found under Clause 7.

7 Defects of components

After considering the life cycle stages and the rooms, it is necessary to consider the possible defects of a component.

There are defects which are influenced by the manufacturer and defects influenced by the customer or service staff. Defects of the manufacturer are for example:

— incorrect installation of pipes, susceptible to vibrations;

— non-secured parts;

— incorrect material selection, e.g. non corrosion resistant material or surface;

— bad brazed connection;

— too thin wall thicknesses;

— selection and art of component.

Defects influenced by the customer are e.g.:

— improper use - storage of explosive liquids in the appliance;

— improper defrosting;

— non-observance of the instruction manual

— incorrect installation;

— damage of evaporator/condensor by sharp objects;

— incorrect transport;

— improper disposal;

— mechanical damages.

The manufacturer shall give information about hazards due to possible incorrect use in the enclosed technical documentation for the appliance.

8 Probability of component defects

More than 35 million refrigerators and freezers with refrigerant R 600a have been produced in Europe since 1993. Not only this time, but also the time before when the refrigerators and freezers were produced with other refrigerants, give us an answer about the quality of these products. Pipe breaks during operation are unknown. That means, considering the last eight years, that the probability of a pipe break is

$$P_{\text{break operation}} \leq 1/35.000.000 = 2{,}9 \times 10^{-8}$$

In the case of transport, pipe breaks on a very small scale are known. All appliances which become defect on the grounds of bad quality of the appliance are meant.

$$P_{\text{break transportation}} = 250/\ 35.000.000 = 7{,}1 \times 10^{-6}$$

The probability of exceeding the LFL giving for the leakage cause and location of it is possible between 0 and 1. In this case the maximum probability of 1 is used.

$$P_{\text{LFL, max}} = 1$$

In principle, the single probabilities for all possible defects shall be added in order to receive the total frequency of occurrence of the hazard.

NOTE See as well TÜV-study “Brennbare Kältemittel — eine Gefahr? Ausbreitungsversuche mit einer Kühl-Gefrierkombination. Kältemittel Isobutan” (published in “Die Kälte- und Klimatechnik” in August 1999).

9 Frequency of occurrence

The frequency of occurrence can be qualitatively expressed as:

Table 2 — Frequency

FREQUENCY	Specific individual item	Inventory
FREQUENT	Likely to occur frequently	Continuously experienced
PROBABLE	Will occur several times in life of an item	Will occur frequently
OCCASIONAL	Likely to occur sometime in life of an item	Will occur several times
REMOTE	Unlikely but possible to occur in life of an item	Unlikely but can reasonably be expected to occur
IMPROBABLE	So unlikely, it can be assumed occurrence may not be experienced	Unlikely to occur, but possible

Possible ignition sources in households are summarized in Table 3.

Table 3 — Frequency of occurrence for ignition sources

ignition source	number of the occurrences	time of the occurrences	whole time	frequency description
vacuum cleaner	1	10 min	24 h	probable
fire	1	10 min	24 h	probable
fan heater	1	60 min	24 h	probable
light switch	5	0,1 s	24 h	frequent
washing machine				
...				

The indicated ignition sources are exemplary.

10 Probability (for ignition sources and explosive atmosphere)

10.1 Ignition sources

The next step is to consider the possible ignition sources.

Possible ignition sources could exist at the appliance (see EN 60335-2-24/A 53) or in the surrounding. Here are to specify e.g. open fire, switches, hot surfaces, vacuum cleaner, cigarette and ventilator. The ignition durance of the ignition source is different and the time periods of each ignition could differ a lot. They will be taken into consideration in the calculation of the probability.

Table 4 — Probability of occurrence for ignition sources

kind	number of the occurrences	time of the occurrences	whole time	probability
vacuum cleaner	1	10 min	24 h	6,94E-3
fire	1	10 min	24 h	6,94E-3
fan heater	1	60 min	24 h	4,17E-2
light switch	1[a]	0,1 s	24 h	1,16E-06

[a] In case of emergency the shut off of 1 of 5 switches reach the necessary ignition energy

10.2 Explosive atmosphere

The next step in reflection concerning risk assessment is the estimation of the probability of presence of explosive atmosphere. For this it's necessary to take into consideration the pass out of the maximum amounts of refrigerant. For example: in case of a defect of a component there exists for a period of 10 min in an area of 0,1 m^3 a flammable atmosphere. Probability:

$$\text{time: } 10 \text{ min}/\ 12 \text{ a} = 1{,}6 \times 10^{-6}$$

$$\text{installation roomsize: } 0{,}1 \text{ m}^3/15 \text{ m}^3 = 6{,}6 \times 10^{-3}$$

For example a light switch connects five times a day ($5{,}797 \times 10^{-6}$). The critical period results from the time of 10 min in 12 years ($1{,}6 \times 10^{-6}$), as mentioned above, when a flammable atmosphere can occur. Therefore the probability amount to $9{,}2 \times 10^{-12}$.

Therefore the probability for a sufficient ignition energy equates to 2×10^{-1}. The probability for this ignition is $9{,}2 \times 10^{-12} \times 0{,}2 = 1{,}84 \times 10^{-12}$.

The probability of exceeding LFL, given the leakage caused, can be between 0 and 1.

The single probabilities shall be added to the total probability for all ignition sources.

NOTE Lower flammability limit in air: The minimum content of a gas or gas mixture, in air, at which the gas or gas mixture can be ignited. This limit is determined at atmospheric pressure and a temperature of 20 °C.

11 Deflagration/Explosion

The probability of deflagration respectively explosion is the result of the multiplication of the total probabilities described under 9 and 10. That means the probability of deflagration/explosion is the product of multiplication of the total probability of defects of different components and the total probability for the presence of explosive atmosphere and the total probability for the ignition sources.

Total probability

The total probability is based on the sum of the product of

$$P_{\text{tot}} = \text{sum}\ (P_{\text{failure}} \times P_{\text{LFL}}) \times \text{sum}\ (P_{\text{ignition source}})$$

P_{failure} frequency of occurrence of each failure (leakage), e.g. pipe burst

P_{LFL} probability of exceeding LFL giving the leakage cause

$P_{\text{ignition source}}$ probability of ignition source

- for example: pipe is broken during transport and ignition sources are:

  vacuum cleaner, fire, fan heater and a switch

  P_{tot} = (7,1E-6 × 1) × (6,94E-3 + 6,94E-3 + 4,17E-2 + 5,79E-6 x 0,2)

  P_{tot} = (7,1E-6) (0,00694 + 0,00694 + 0,0417 + 0,000001158)

  P_{tot} = 7,1E-6 × 5,56E-2

  P_{tot}= 3,95E-7

12 Consequences

The next step is the consideration of the consequences of an explosion. The question is, whether damages of objects or injured persons are expected or even cases of death.

In Table 5 the possible severity of a deflagration respectively explosion is shown.

Table 5 — Possible severity of a deflagration/explosion

Severity	Definition of consequences
CATASTROPHIC	Death or system loss.
MAJOR	Severe injury, severe occupational illness, or major system damage
MINOR	Minor injury, minor occupational illness, or minor system damage
NEGLIGIBLE	Less than minor injury, occupational illness, or system damage

In combination with Table 3 the following risk levels are given.

Table 6 — Risk levels

Frequency of Occurrence	Severity			
	Catastrophic	Major	Minor	Negligible
Frequent	A	A	A	C
Probable	A	A	B	C
Occasional	A	B	B	D
Remote	A	B	C	D
Improbable	B	C	C	D

NOTE See as well Swiss-Study "Ammoniak und Kohlenwasserstoffe als Kältemittel: Risikoanalyse, Produkthaftpflicht und Strafrecht" of the Bundesamt für Energie 1999.

The risk levels represent a ranking of the risk which enables an evaluation of what further actions are needed if any.

Thus:

risk level A: High risk level

risk level B:
risk level C:
risk level D: Low risk level

13 Flow Charts

13.1 General

Referring to the above mentioned explanations the different flow diagrams according to the different stages of life cycles are presented in the following (Figures 5 to 8). A further remark with regard to "40 g/10 min" Assumption: in case of an amount of refrigerant > 40 g and a leakage on the high pressure side during operation.

13.2 Explanation of the flow charts by examples

All flow charts have a similar structure. They start with general points, consider the different possibilities and go down to very specific items.

- **Example 1: life cycle — Transportation**

1. step: Which room is considered

2. step : Parts of the system with refrigerant? — No — go to the end; Yes — next step

3. step : Which part? In this case the evaporator.

4. step : Which kind of evaporator?

5. step : Which kind of defect?

Let's follow the left branch [pipe burst vibration]

6. step : defect possible? Does it lead to leakage? — No — go to the end; Yes — next step

7. step : What is the probability of occurrence of the defect?
Example: Is the defect not known, a probability of > 10E-9 is assumed?.

8. step : Lower explosive limit exceeded? — No — go to the end; Yes — next step

9. step : In room 1 is an ignition source in accordance with EN 60335 not allowed. Go to end.
You have to change the kind of evaporator.

- **Example 2: life cycle — Operation / Room 1**

1. step: Which room is considered? In this case there is no difference.

Let's follow the left branch

2. step : Parts of the system with refrigerant? — No — go to the end; Yes — next step

3. step : Which kind of evaporator?

4. step : Which kind of defect?

5. step : defect possible? Does it lead to a leakage? — No — go to the end; Yes — next step

6. step :	Leakage more then 40 g Refrigerant in 10 min?	No — go to — end Yes — next step
7. step :	Probability?	
8. step :	LFL exceeded?	No — go to end Yes — next step
9. step :	ignition source?	No — go to end Yes — next step
10. step :	go back to step 3.	

- **Example 3: life cycle — Maintenance / Service.**

1. step:	All rooms the same. The appliance is not in operation.	
2. step :	Parts of the system with refrigerant?	No — go to the end Yes — next step
3. step :	Competence of the service personal?	No — look 3 Yes — next step
4. step :	Competence of the service personal?	No — look 2 Yes — in accordance with EN 13313

For the different problem cases the probabilities are different.

5. step : **<u>Problem 0</u> — Flammability of refrigerant not identified!**
probability 1 professional trained personnel with high technical knowledge
probability 2 professional trained personnel with technical knowledge
probability 3 for non trained personnel without technical knowledge

6. step : **<u>Problem 1</u> — Opening of refrigerating system before defined removal of refrigerant!**

7. step : Problem 1 — open flame? — No — go to P 2; Yes — ignition — end

The procedure for the problem cases 2 to 4:

8. step : **<u>Problem 2</u> — Remaining of the removed refrigerant in room 4!**

9. step : **<u>Problem 3</u> — Refrigerant was not discharged totally and flows!**

10. step : **<u>Problem 4</u> — Enclosed in Refrigerant (unknown) in the refrigerating system!**

11. step :	Leakage with more then 40 g Refrigerant in 10 min?	No — go to — end Yes — next step
12. step :	Probability?	
13. step :	LFL exceeded?	No — go to end Yes — next step
14. step :	Probability?	
15. step :	ignition source?	No — go to end Yes — next step

16. step :	Probability of ignition?	No — go to end Yes — next step
17. step :	**Problem 5 — Leak detection with flame!**	
18. step :	Opening of the system with flame?	No — end Yes — ignition

14 Risk assessment

According to the Swiss study „Ammoniak ... Strafrecht“ from 1999 the following probabilities for death are accepted or not.

* Probability for death $< 1 \times 10^{-6}$/a
  → The risk is acceptable.
* Frequency of death $> 1 \times 10^{-6}$/a and $< 1 \times 10^{-4}$/a
  → The risk is acceptable if there is a sufficient benefit for society.
* Probability for death $> 1 \times 10^{-4}$/a
  → The risk is not acceptable.

For injured persons the probability could be 10 times higher.

If you consider other countries, for example, you get other individual risks:

— **USA: 20 fires caused by refrigerators**

accepted $P_{\text{fire}} = (20 \times 10^{-8}) = 2 \times 10^{-7}$

— **Environmental Protection Authority Western Australia (new plants)**

$P_{\text{intolerable}} = 10^{-5} / P_{\text{negligible}} = 10^{-8}$

— **UK: Health & Safety Executive (new housings near plants)**

$P_{\text{intolerable}} = 10^{-5} / P_{\text{negligible}} = 10^{-6}$

— **Dutch Ministry VROM (Housing, Spatial Planning and the Environment)**

<u>Individual risk criterias per year:</u>

	Intolerable	Negligible
new activities	10^{-6}	10^{-8}
existing plants	10^{-5}	10^{-8}

Societal risk criteria per year:

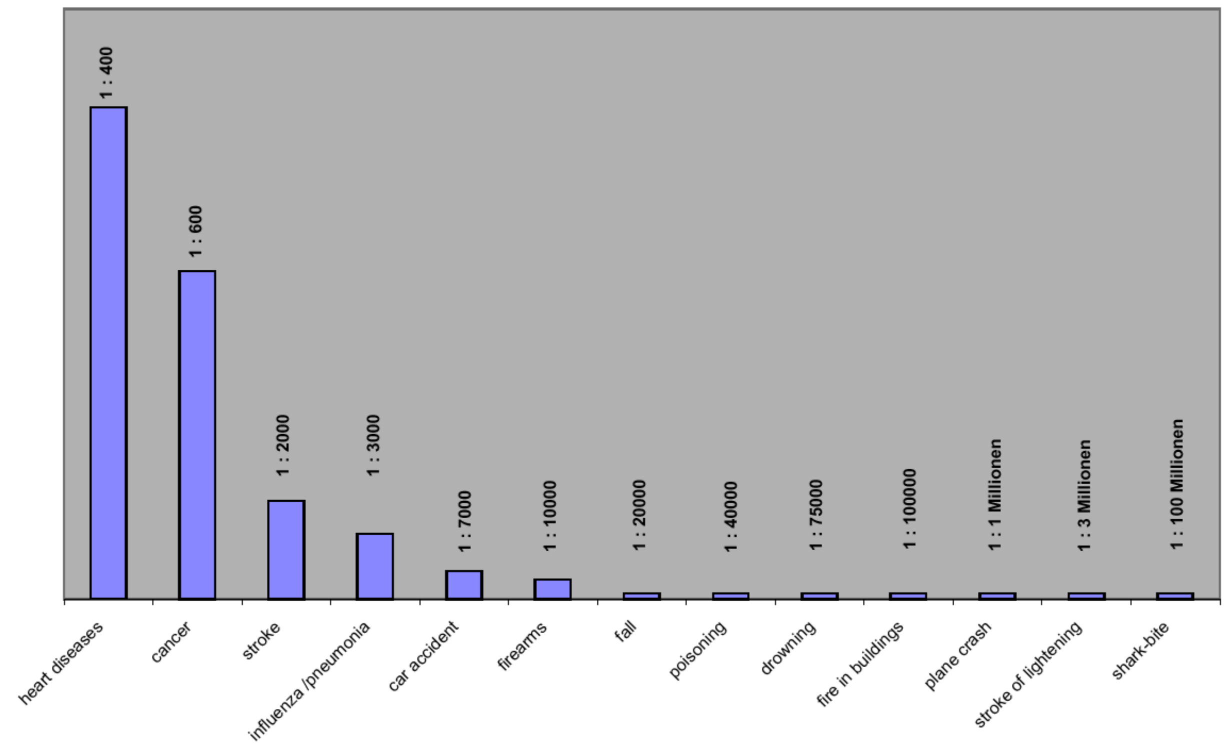
	Intolerable	Negligible	Limit on N(umber of casualties)
new plants	10^{-3}	10^{-5}	1 000

For comparison in Table 7 and 8 probabilities for different death causes are mentioned.

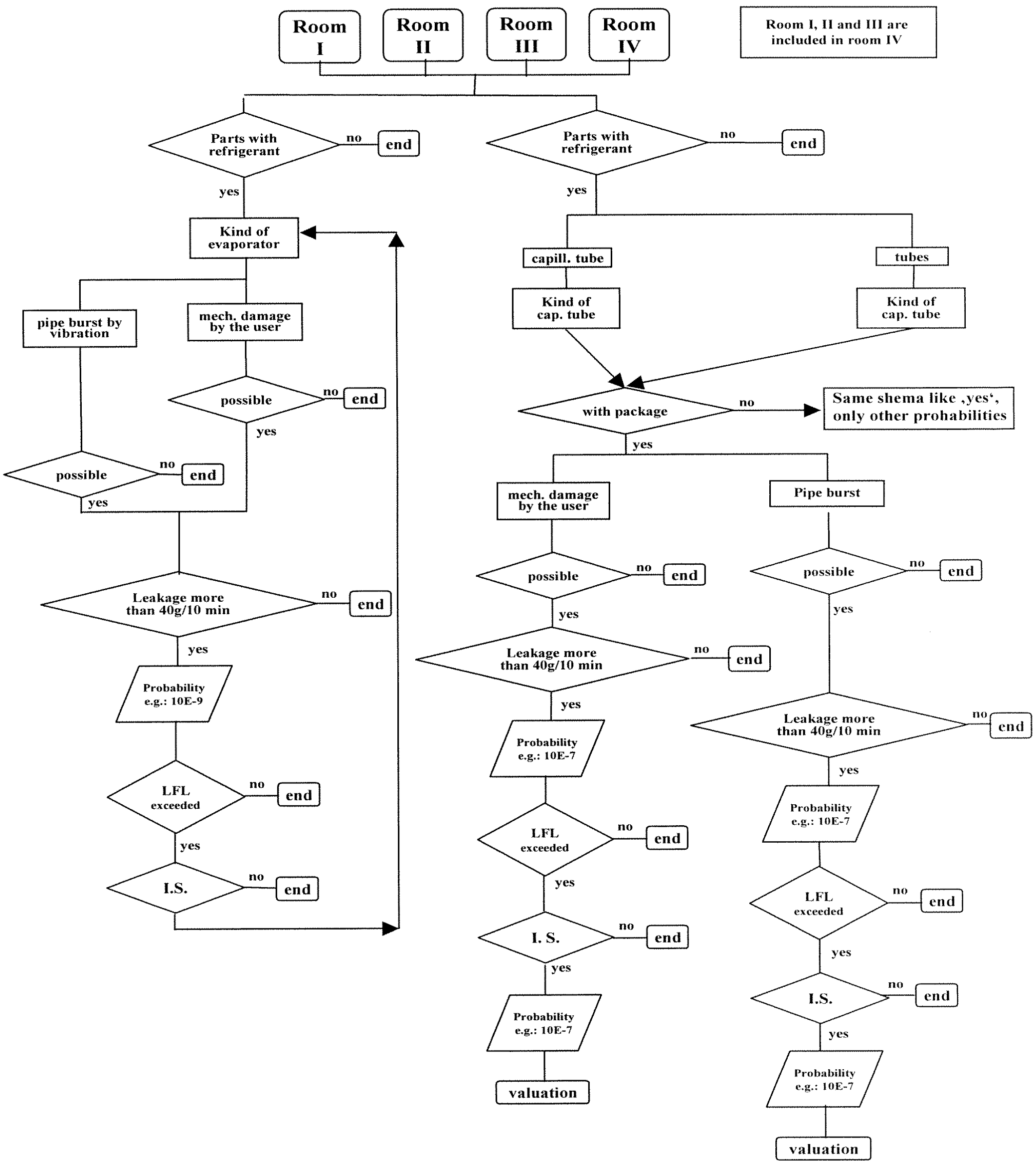
Table 7 — Risk estimate for the critical examination of technical safety

Death as risk per head and year:	
per year	
10^{-2}	natural death between 45 – 55 years
3×10^{-3}	natural death between 35 – 44 years
$5\ \ 10^{-4}$	natural death between 5 – 15 years
$2,7 \times 10^{-4}$	8000 dead by traffic accidents in Germany
10^{4}	accidental death during work
5×10^{-5}	drowning
3×10^{-5}	murderous assault (Germany)
3×10^{-6}	natural catastrophes (USA)
3×10^{-6}	death by current impulse (Germany)
7×10^{-7}	lightning-stroke (Germany)
4×10^{-7}	bee's sting
10^{-7}	death caused by crashed plane

Table 8 — Probability of death of a person within one year



(US-risk expert Fred Kilbourne, Focus 43/2001)



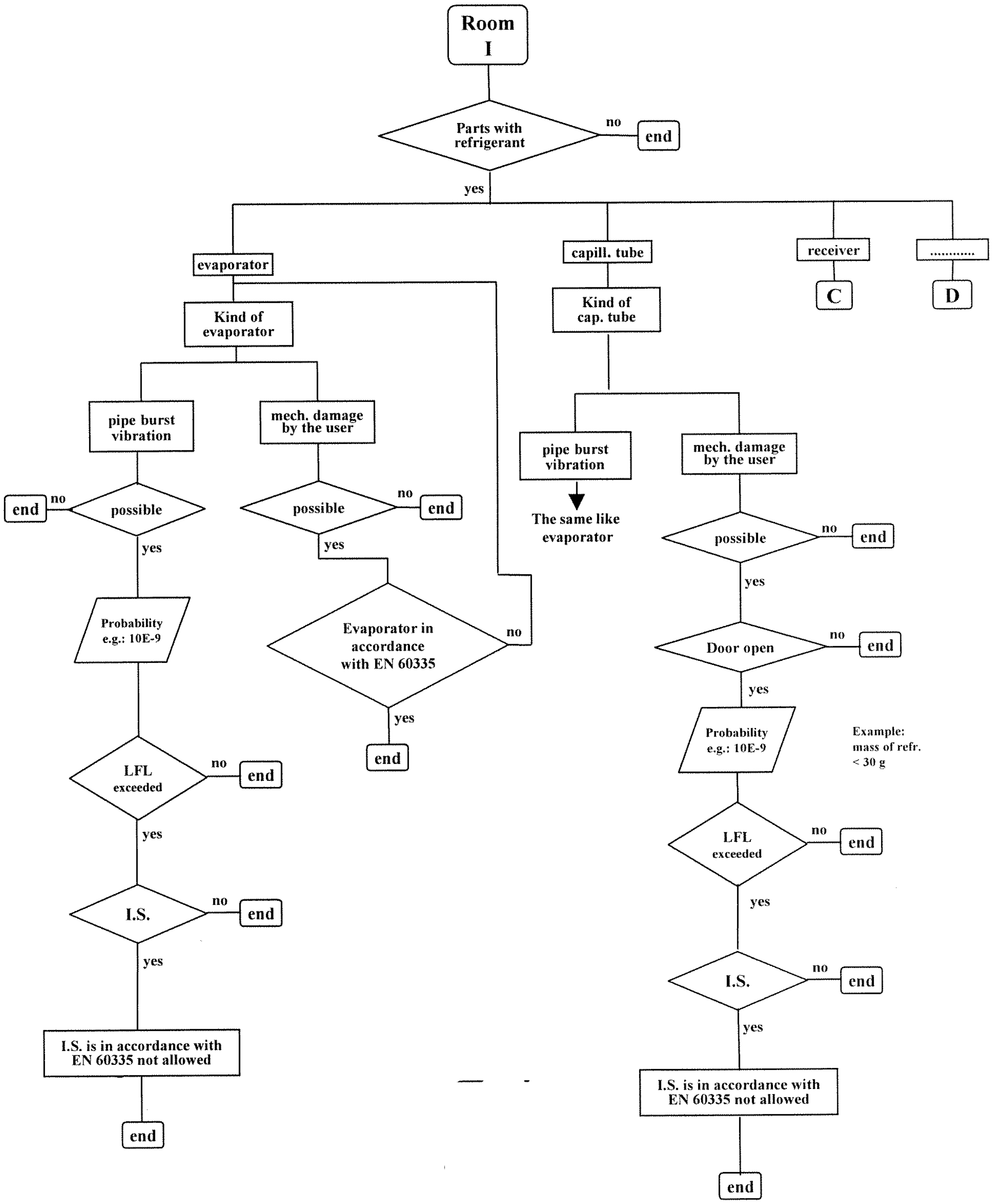
Explanations

LFL lower flammable limit

EN 60335 EN 60335-2-24/A 53

I.S. Ignition source

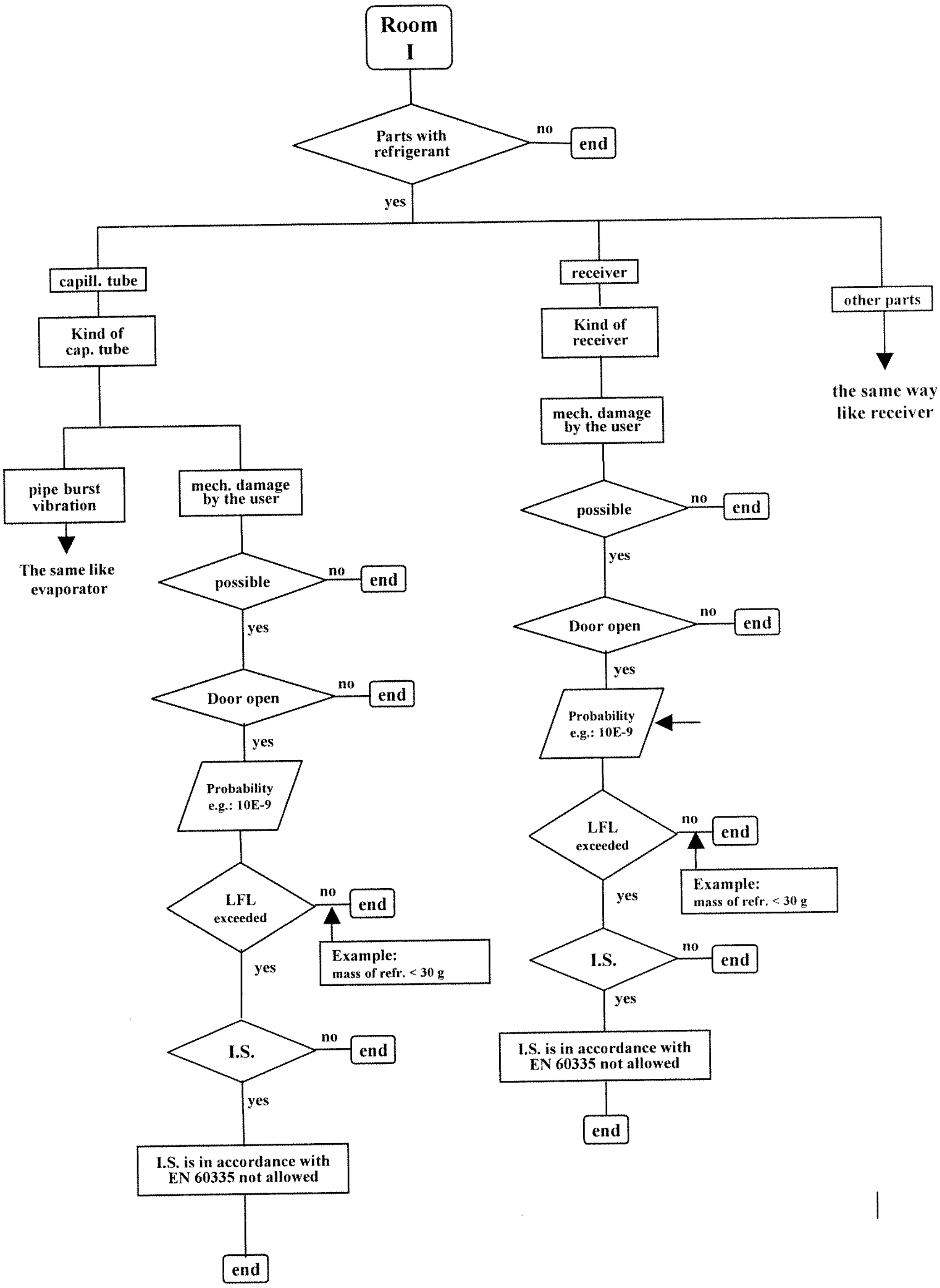
Figure 5 — Risk assessment — Transportation



Explanations

LFL	lower flammable limit
EN 60335	EN 60335-2-24/A 53
I.S.	Ignition source

Figure 6 a — Risk assessment — Operation
Room I : Example with not all steps

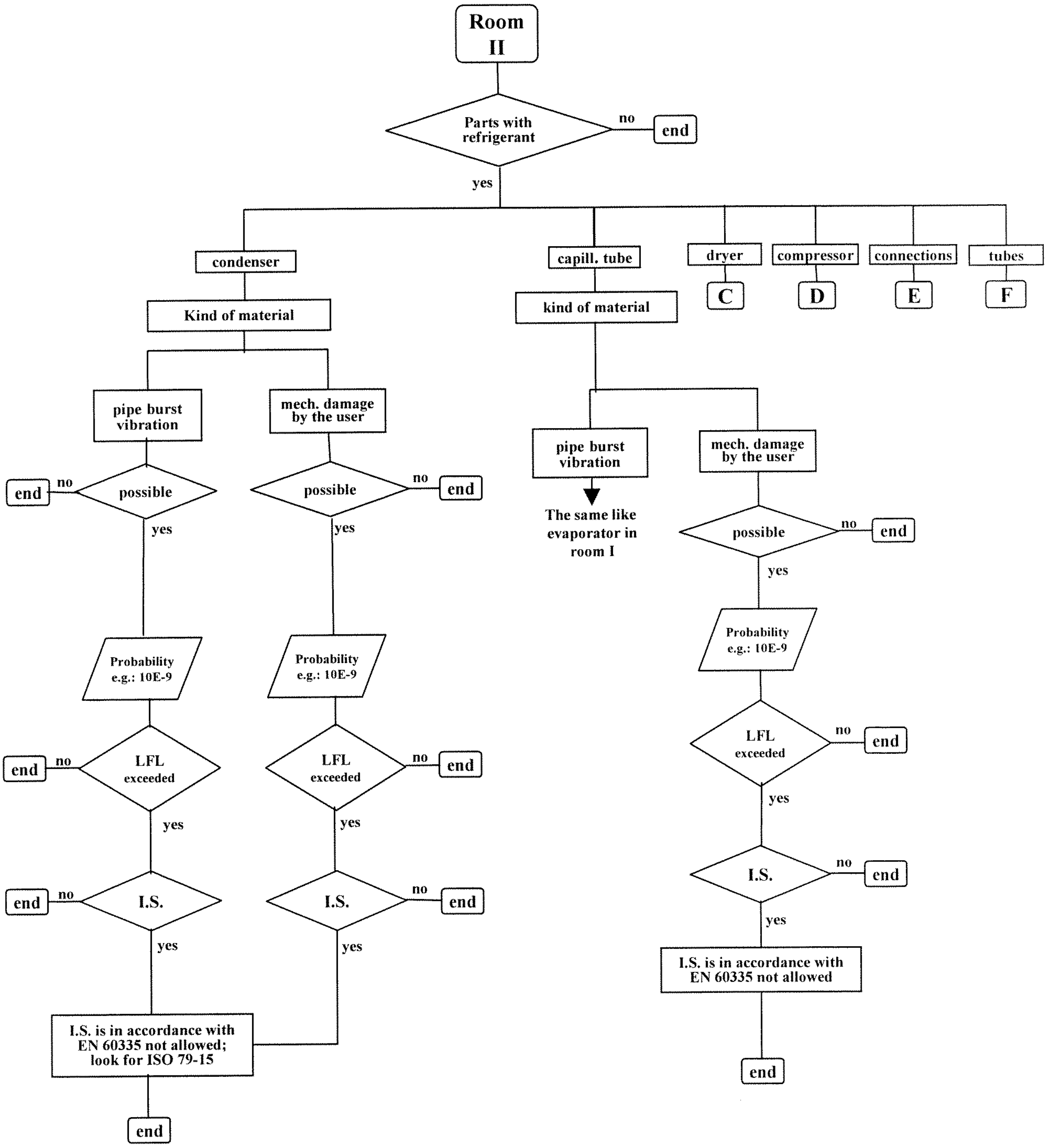


Explanations

LFL	lower flammable limit
EN 60335	EN 60335-2-24/A 53
I.S.	Ignition source

Figure 6 b — Risk assessment — Operation

Room I : Example with not all steps



Explanations

LFL	lower flammable limit
EN 60335	EN 60335-2-24/A 53
I.S.	Ignition source

Figure 6 c — Risk assessment — Operation

Room II : Example with not all steps

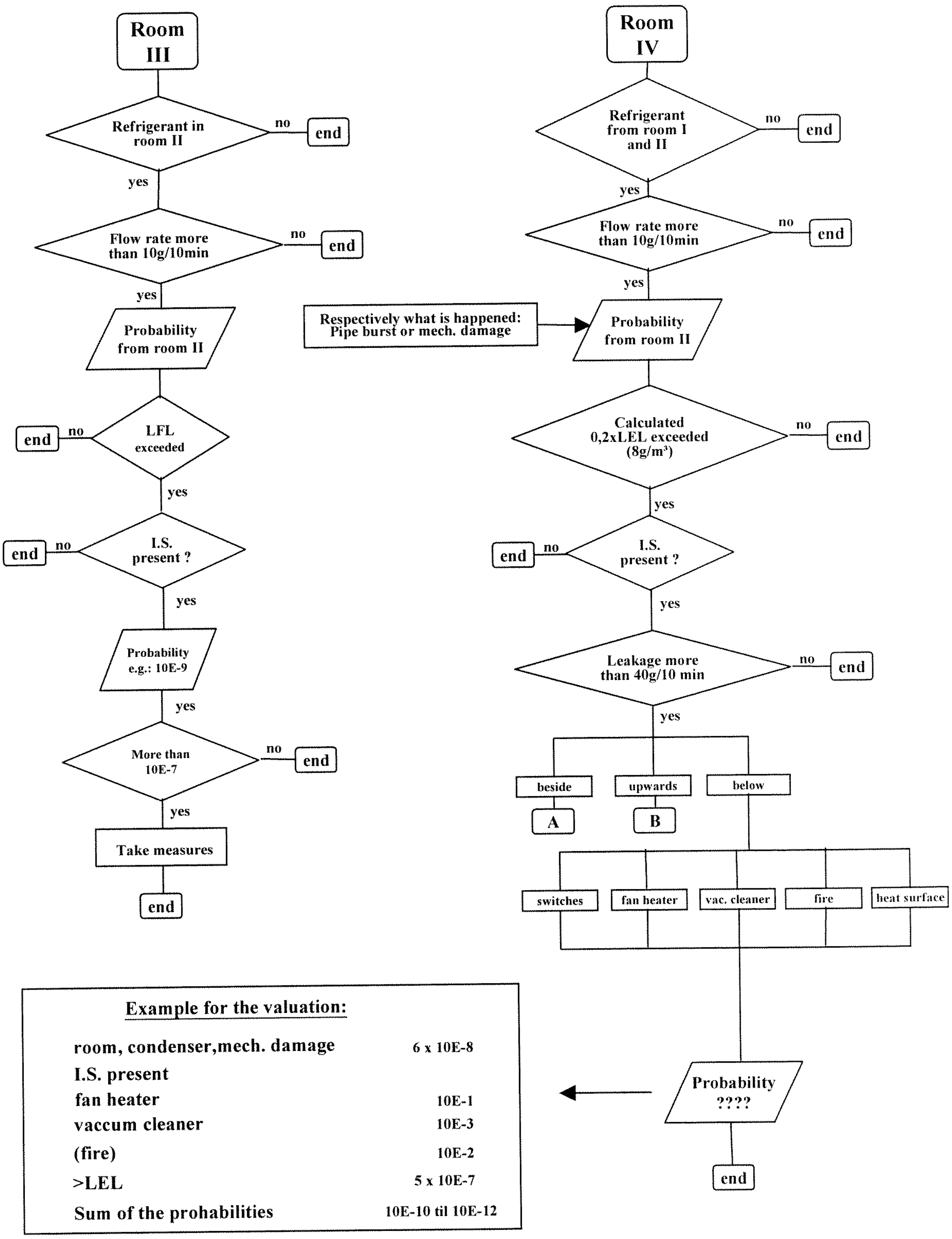


Figure 6 d — Risk assessment — Operation

Room III and IV : Example with not all steps

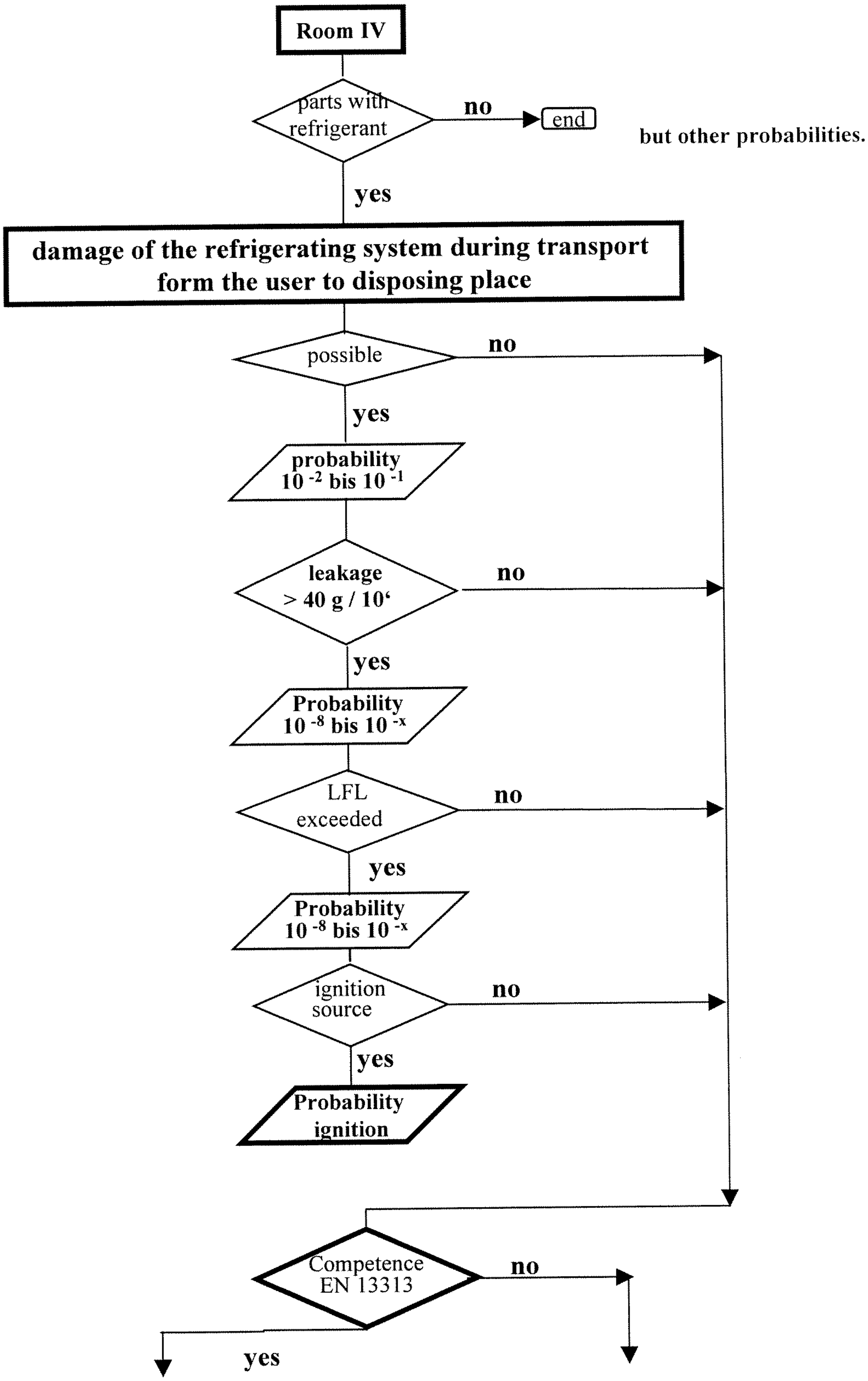


Figure 7 a — Disposal

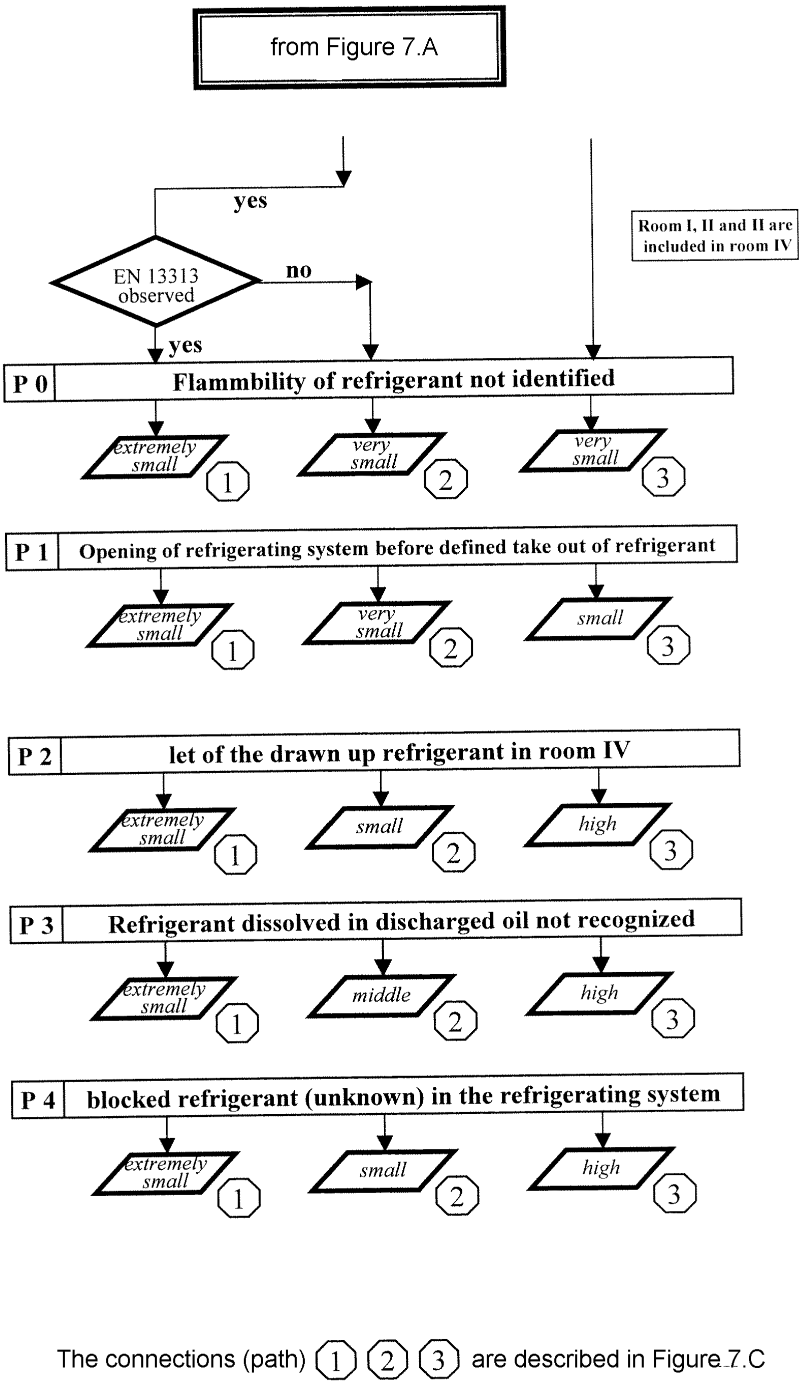
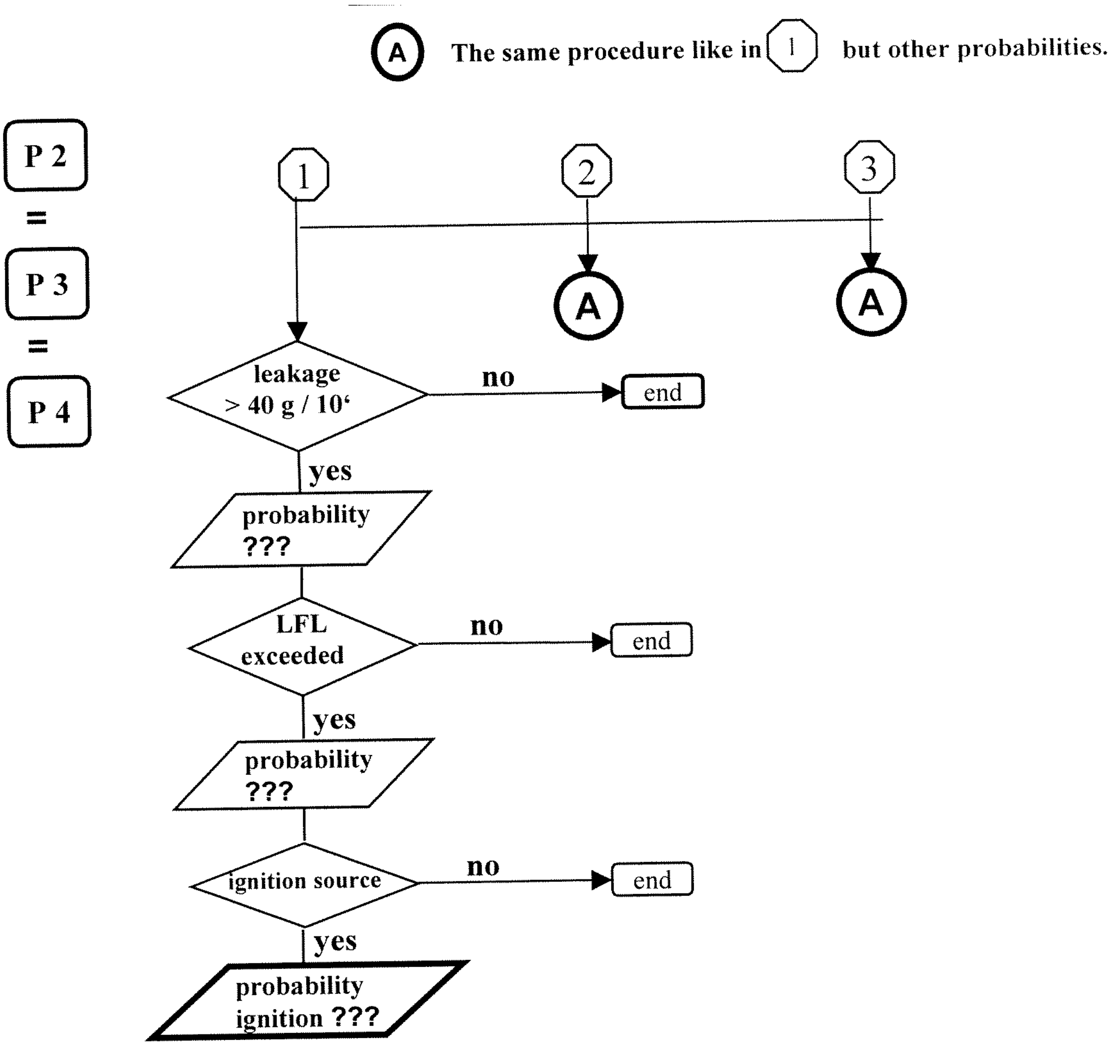


Figure 7 b — Disposal



Declaration of probability :

extremely small	$< 10^{-4}$
very small	$> 10^{-4}$
small	$> 10^{-3}$
middle	$> 10^{-2}$
high	$> 10^{-1}$
very high	$> 5 \times 10^{-1}$

Figure 7 c — Disposal

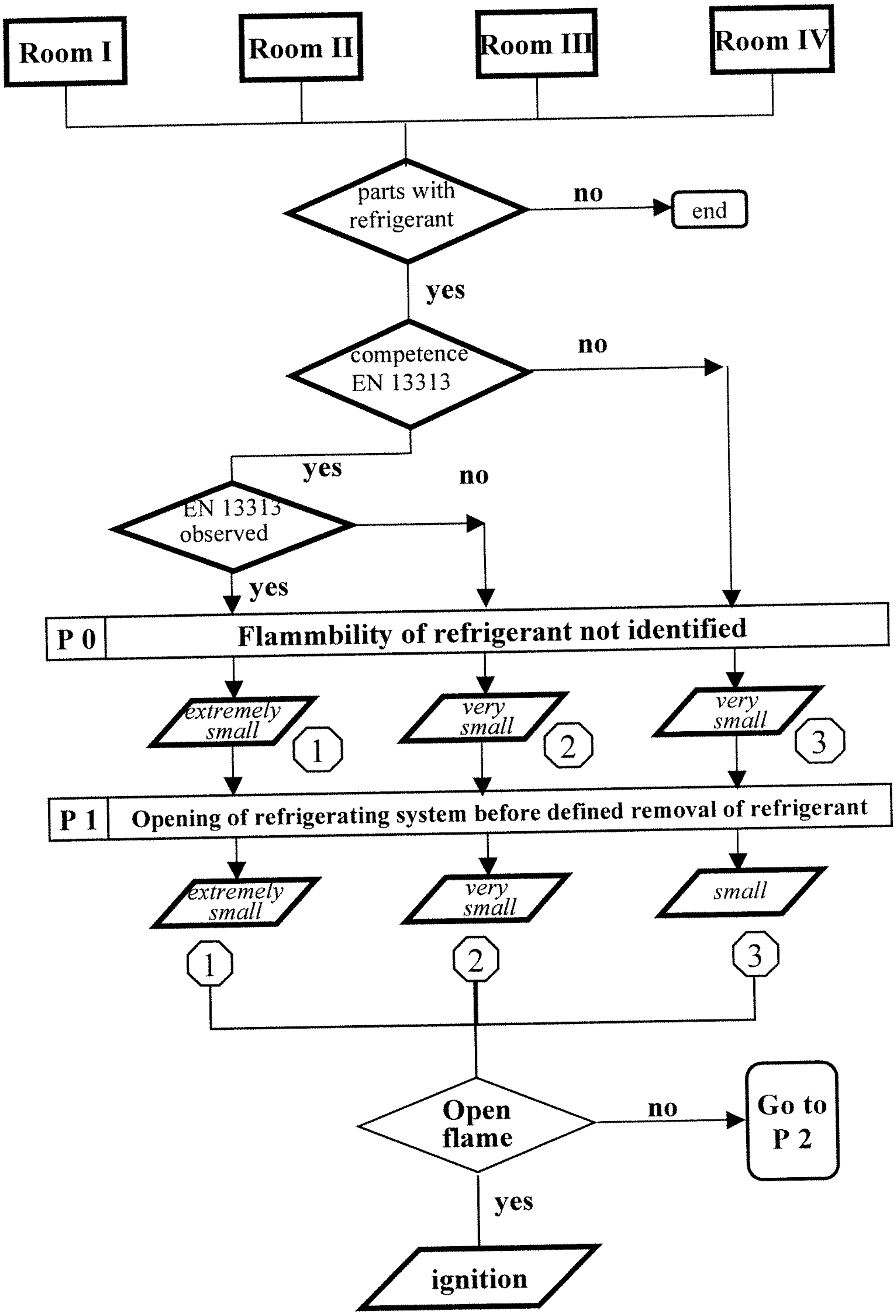


Figure 8 a — Maintenance service

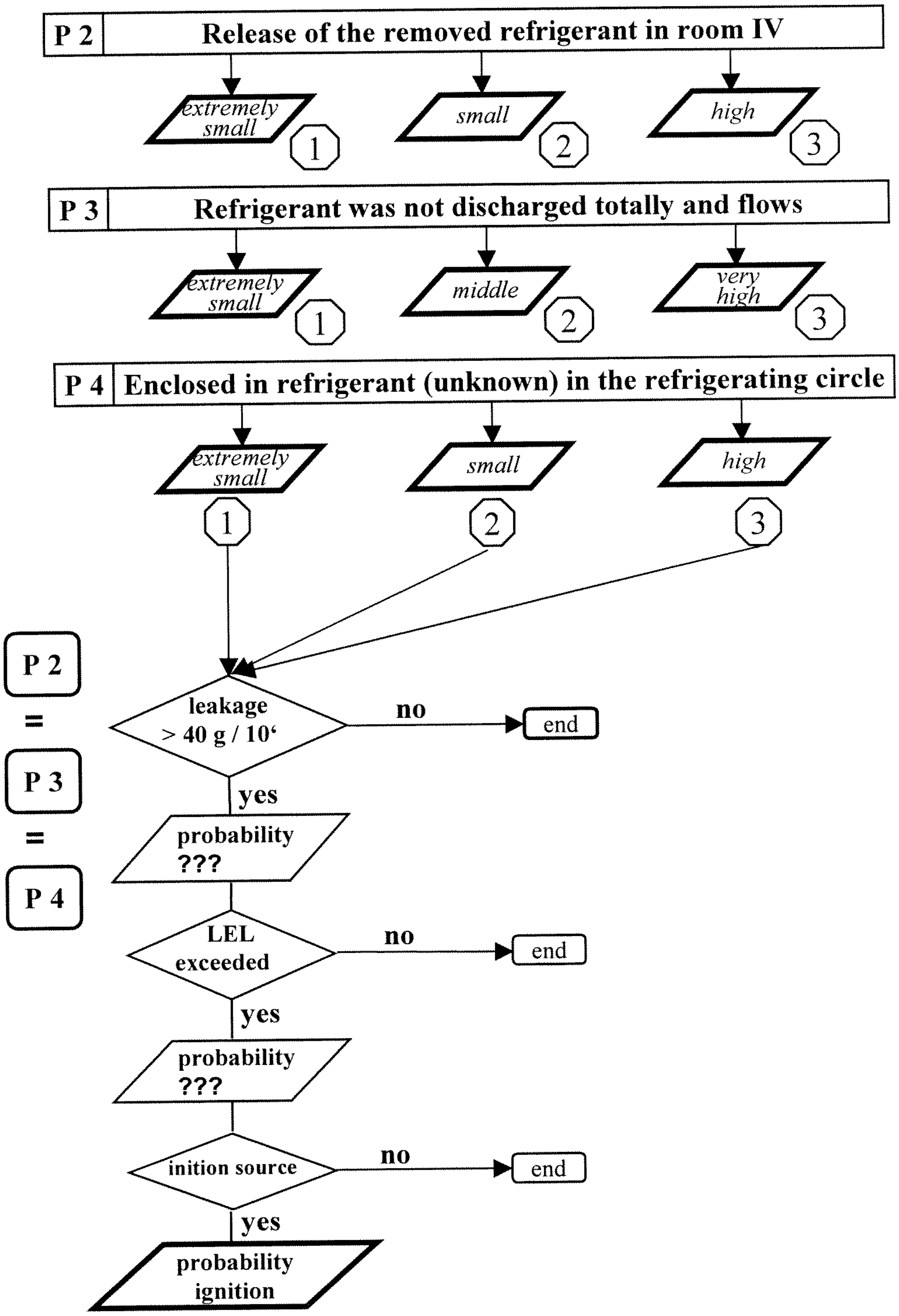
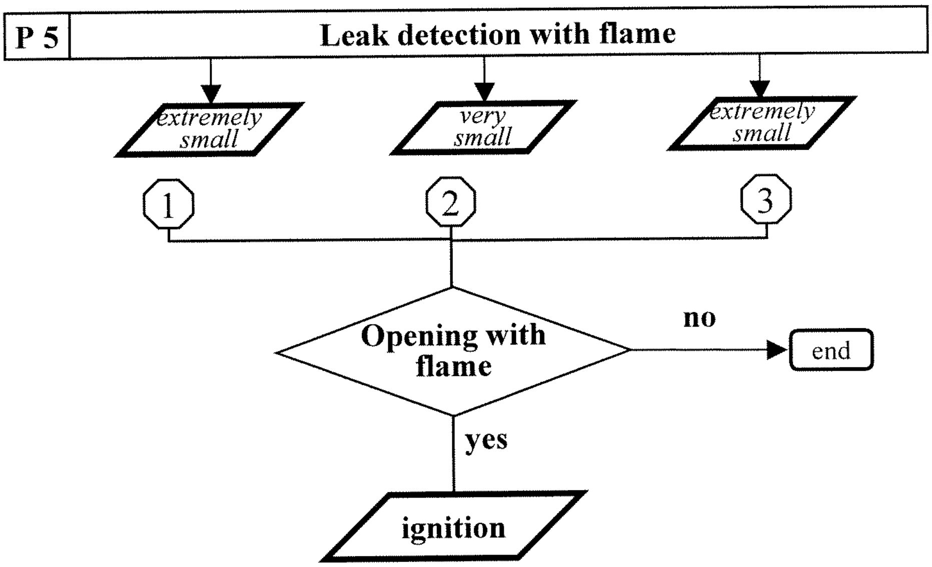


Figure 8 b — Maintenance service



Declaration of probability :

extremely small	$< 10^{-4}$
very small	$> 10^{-4}$
small	$> 10^{-3}$
middle	$> 10^{-2}$
high	$> 10^{-1}$
very high	$> 5 \times 10^{-1}$

Figure 8 c — Maintenance service

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