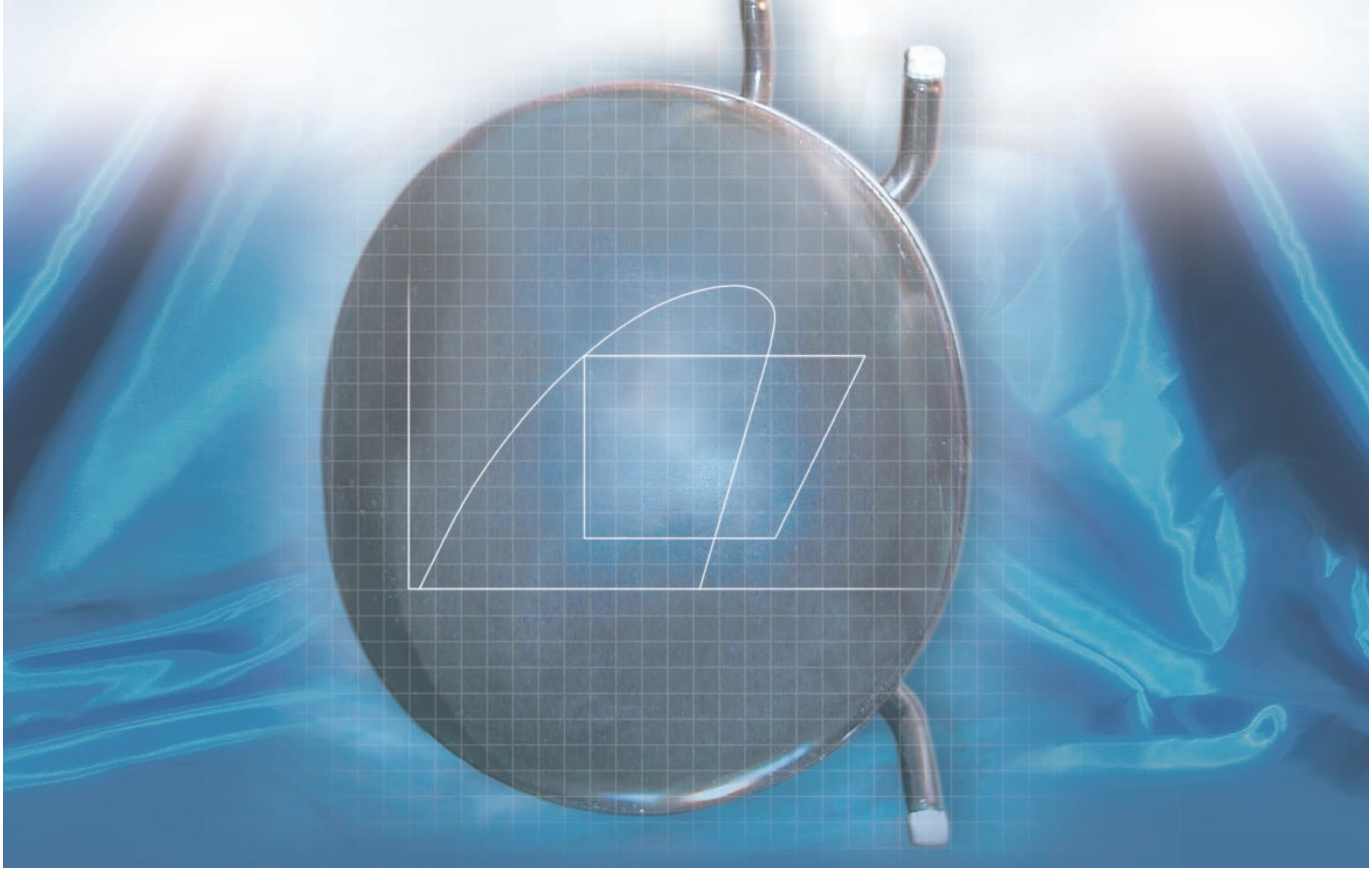
WITH MORE THAN 50 YEARS OF EXPERIENCE IN COMPRESSOR TECHNOLOGY AND HIGHLY COMMITTED EMPLOYEES, OUR FOCUS IS TO DEVELOP AND APPLY THE ADVANCED COMPRESSOR TECHNOLOGIES TO ACHIEVE STANDARD SETTING PERFORMANCE FOR LEADING PRODUCTS AND BUSINESSES AROUND THE WORLD.

APPLICATION
GUIDELINE

SECOP

PRACTICAL APPLICATION OF REFRIGERANTS R600a AND R290 IN SMALL HERMETIC SYSTEMS



1. REFRIGERANTS

Refrigerants R 600a – isobutane and R 290 – propane are possible replacements for other refrigerants which heavily impact on the environment, in small hermetic systems such as factory made household and commercial refrigerators and freezers. These refrigerants have zero ozone depletion potential ODP and a neglectible global warming potential GWP. Furthermore they are petrol gases from natural sources.
The refrigerant R 600a has been used in the past in refrigerators up to the 40'es, and has today a wide use in domestic refrigerators and freezers again, in Europe, where most refrigerators are manufactured using R 600a as refrigerant.
Isobutane R 600a is a well suited refrigerant for household application, with good energy efficiency, but with very different characteristics in several points, which implies the design is to be made or adopted.
The refrigerant R 290 has been in use in refrigeration plants in the past, and is still used in some industrial plants. In domestic heat pumps and air conditioners R 290 has been used in Germany and Sweden for some years, however, with different level of success.
Because of the availability of isobutane and propane all over the world they have been discussed widely for CFC, H-CFC and HFC replacement.
Isobutane R 600a and Propane R 290 are possible refrigerants for these applications, with good energy efficiency, but special care must be taken in regards to flammability.

The properties of R 600a and R 290 differ from other refrigerants commonly used in small hermetic systems, as shown in table 1. This leads to a different design of details in many cases.

Table 1: Refrigerant data comparison

Refrigerant	R 290	R 600a	R 134a	R 404A	R 22	R 12
Name	Propane	Isobutane	1,1,1,2-Tetra-flouroethane	Mixture R 125 R 143a R 134a	Chloro-difluoro-methane	Dichloro-difluoro-methane
Formula	C_3H_8	$CH\text{-}(CH_3)_3$	$CF_3\text{-}CH_2F$	44/ 52/ 4	CHF_2Cl	CF_2Cl_2
Critical temperature in °C	96.7	135	101	72.5	96.1	112
Molecular weight in kg/kmol	44.1	58.1	102	97.6	86.5	120.9
Normal boiling point in °C	-42.1	-11.6	-26.5	-45.8	-40.8	-29.8
Pressure (absolute) at -25°C in bar	2.03	0.58	1.07	2.50	2.01	1.24
Liquid density at -25 °C in kg/l	0.56	0.60	1.37	1.24	1.36	1.47
Vapour density at t_o -25/+32 °C in kg/m³	3.6	1.3	4.4	10.0	7.0	6.0
Volumetric capacity at -25/45/32 °C in kJ/m³	1164	373	725	1334	1244	727
Enthalpy of vaporisation at -25 °C in kJ/kg	406	376	216	186	223	163
Pressure (absolute) at +20 °C in bar	8.4	3.0	5.7	11.0	9.1	5.7

1.1 Pressure R 600a

The first remarkably large difference betwen R 600a and R 134a or R 12, is found in the pressure level, which is much lower, e.g. at -25 °C evaporation roughly 55 % of R 134a or 45 % of R 12. In connection with this, the normal boiling point is at 15 K resp. 18 K higher. This leads to operating pressures being much lower than previously before. Evaporators of household refrigerators will thus operate below normal atmospheric pressure.

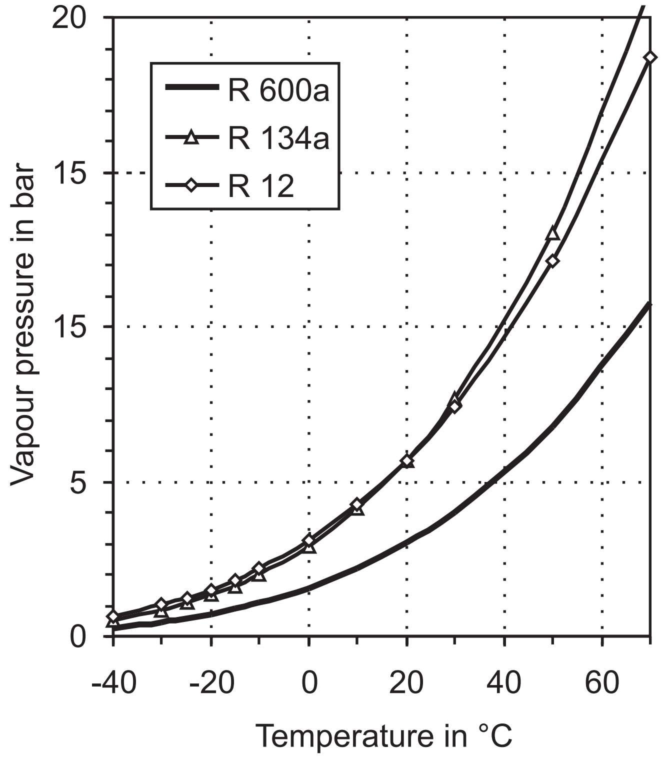


Figure 1: Vapour pressure of different refrigerants versus temperature

The low pressure level is connected to a relatively high critical temperature. This gives a good cooling capacity even at high condensing temperature.

1.2 Capacity R 600a

R 600a has roughly 50 % of R 12 or 55 % of R 134a volumetric capacity at 55 °C condensing temperature, as seen in figure 2. Because of this the necessary compressor swept volume will be up to 2 times the swept volume used for R 12.

The volumetric cooling capacity is a value calculated from suction gas density and enthalpy difference of evaporation. The compressor capacity characteristics, in terms of capacity over evaporating temperature, are close to those of the other refrigerants, as shown in figure 3.

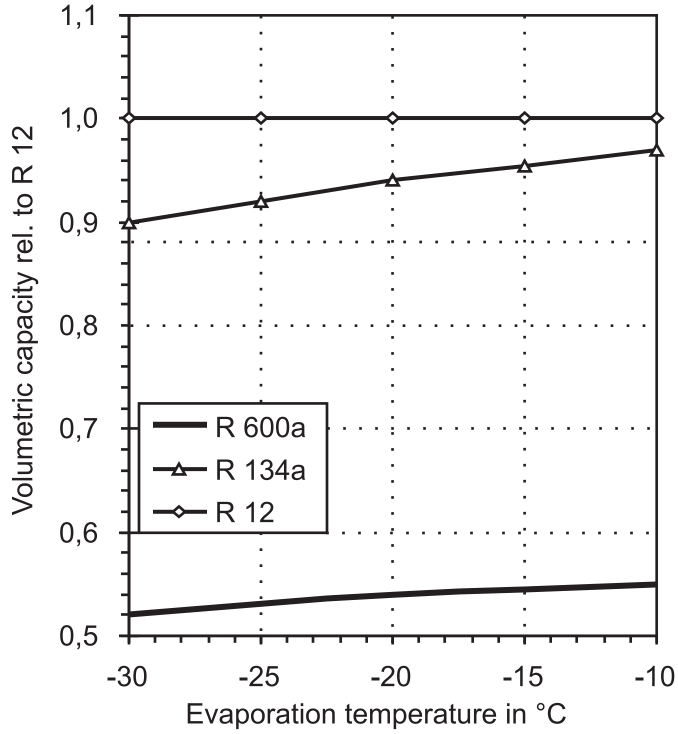


Figure 2: Volumetric capacity of R 600a and R 134a, relative to R 12, over evaporation temperature, at 55 °C condensing and 32 °C suction gas temperature

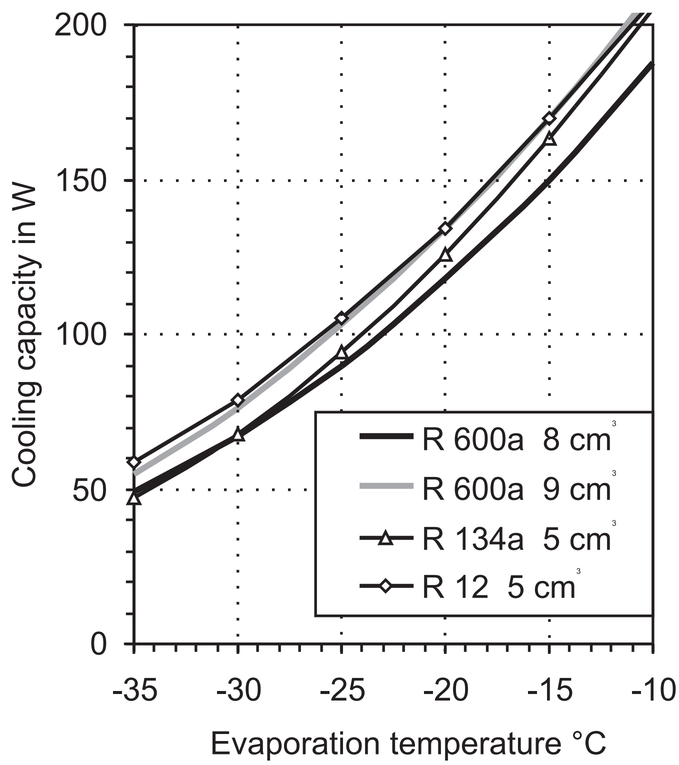


Figure 3: Cooling capacity versus evaporating temperature with different refrigerants

1.3
Pressure R290

A difference between R 290 and R 134a is in the pressure level, which is closer to R 22 and R 404A, e.g. at -25 °C evaporation the pressure is roughly 190 % of R 134a, 81 % of R 404A, 350% of R 600a or almost exactly that of R 22. In connection with this the normal boiling point is close to R 22 also. Evaporators will thus have to be designed similar as for R 22 or R 404A.

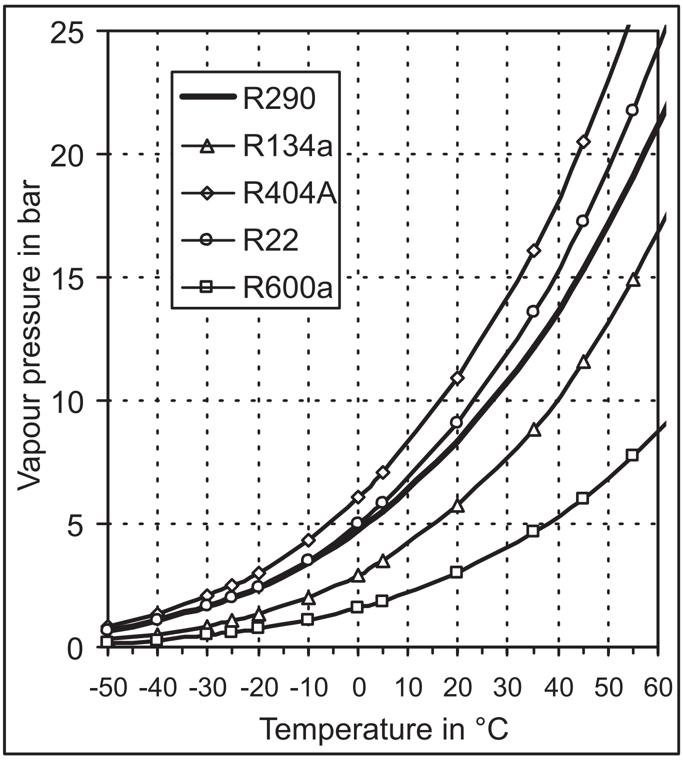


Figure 4: Vapour pressure of different refrigerants versus temperature

The pressure level and critical temperature are almost the same as R 22. However, the discharge temperature is much lower. This gives the opportunity to work at higher pressure ratios, which means lower evaporating temperatures, or at higher suction gas temperatures.

1.4
Capacity R290

R 290 has roughly 90 % of R 22 or 150 % of R 134a volumetric capacity at 45 °C condensing temperature, as seen in figure 5. Because of this the necessary compressor swept volume is close to R 22 also, and 10 % to 20 % larger than for R 404A.
The volumetric capacity is approx. 2.5 to 3 times that of R 600a. Thus the choice for either R 290 or R 600a will lead to differences in system design because of different necessary volume flows needed for the same refrigeration.

The volumetric cooling capacity is a value calculated from suction gas density and enthalpy difference of evaporation.

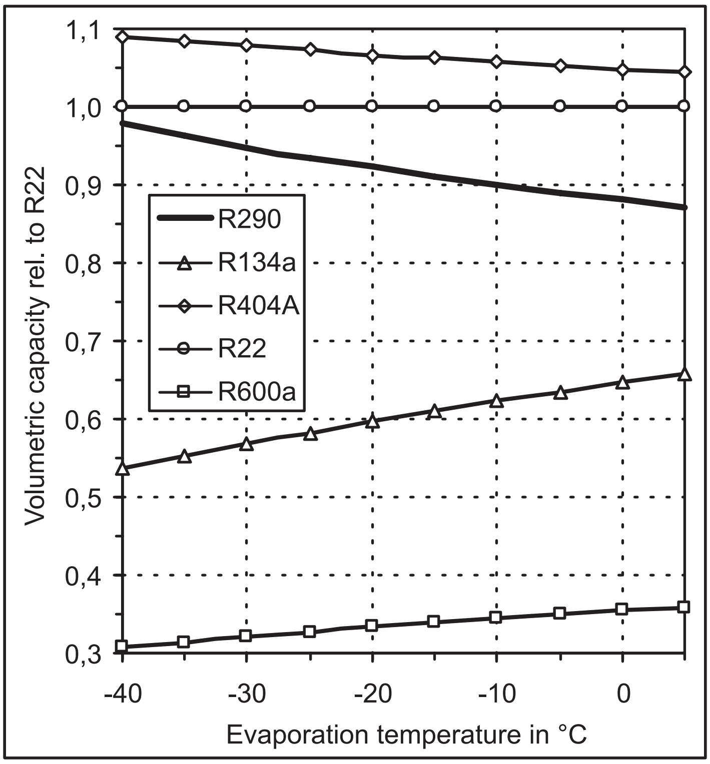


Figure 5: Volumetric capacity of R 290, R 134a, R 404A and R 600a, relative to R 22, over evaporation temperature, at 45 °C condensing and 32 °C suction gas temperature, no subcooling

1.5 Refrigerant charge

If R 600a or R 290 would be charged into an unchanged refrigeration system, charge amount counted in grams would be much lower. However, calculated in cm^3, the charge would be roughly the same liquid volume in the system. This gives charges of approx. 40-45 % of R 22, R 12, R 134a or R 404A charge in grams, according to the data from table 1, which also corresponds with empirical values.
Maximum charge according to safety regulations is 150 g for household and commercial refrigerated appliances and similar applications, which corresponds to approx. 360 g of usual refrigerants.
Additionally experience has shown a higher sensitivity of the systems to charge deviations for R 600a. Especially undercharging tends to give higher energy consumption. This means that charging accuracy must improve, in cm^3 and even more in grams. On charges of approx. 20 g, which are found on small larder refrigerators, accuracy must be within 1 g.

1.6 Purity

Specification for hydrocarbon refrigerants like R 600a and R 290 is not found in international standards. Some data is enclosed in the German standard DIN 8960 of 1998, which is an extended version of ISO 916. The purity of the refrigerant must be judged from the chemical and stability side, for compressor and system lifetime, and from the thermodynamic side regarding refrigeration system behaviour and controllability.

The specification in DIN 8960 is a general safety hydrocarbons refrigerant specification, adopted from other refrigerants criteria catalogue and covers propane, isobutane, normal butane, and others. Some points can possibly be accepted a little less narrow for specific refrigerants and impurities combinations after extensive evaluation.

For the time being no refrigerant quality according to an official standard is on the market. The specifications of possible qualities must be checked with the supplier in details.

Liquified petrol gas LPG for fuel applications or technical grade 95 % purity is not sufficient for hermetic refrigeration. Water, sulfur and reactive compounds contents must be on a lower level than guaranteed for those products. Technical grade 99.5 %, also called 2.5, is widely used.

Table 2: Specification of R 600a and R 290 according to DIN 8960 - 1998

	Specification		Unit
Refrigerant content [1]	≥	99.5	% by mass
Organic impurities [2]	≤	0.5	% by mass
1,3-Butadiene [3]	≤	5	ppm by mass
Normal Hexane	≤	50	ppm by mass
Benzene [4]	≤	1	ppm per substance
Sulfur	≤	2	ppm by mass
Temperature glide of evap.	≤	0.5	K (at 5 to 97 % destill.)
Non condensable gases	≤	1.5	% vol. of vapour phase
Water [5]	≤	25	ppm by mass
Acid content	≤	0.02	mg KOH/g Neutralization
Evaporation residue	≤	50	ppm by mass
Particles/solids		no	Visual check

1) This content is not explicitly stated in DIN 8960. Only the impurities are listed and limited. The main content is the rest up to 100 %.
   From thermodynamic calculation an isomer content of R 600 normal Butane up to 5 % in R 600a isobutane is not critical and still does not exceed the temperature glide criteria and has only very low impact on pressure, less than 0.2 K temperature at evaporation.
2) From compressor point of view a content up to approx. 1 % of butane in R 290 or 1 % of propane in R 600a is acceptable.
3) This is a maximum value for every single substance of the multiple unsaturated hydrocarbons.
4) This is a maximum value for every single aromatic compound.
5) This is a preliminary value, to be reviewed with growing experience

2. MATERIALS

Refrigerant R 600a is mainly used with mineral compressor oils, so material compatibility is almost identical to R 12 situation from oil side. Use of alkyl benzenes or polyolester oil is also possible.
Refrigerant R 290 is used with polyolester oil in compressors, so material compatibility is almost identical to R 134a or R 404A situation from oil side.
R 600a and R 290 are chemically inactive in refrigeration circuits, so no specific problems should occur there. Solubility with the oil is good.
Direct material compatibility is less problematic. On some rubbers, plastics and especially chlorinated plastics however, problems have been observed, but these materials are normally not present in small hermetic systems. Some materials, on which problems have been reported by different testers, are listed in the table 3. Critical materials testing must be performed for the specified use.

Table 3: Material compatibility

Material	Compatible
Butylic rubber	No
Natural rubber	No
Polyethylene	Depends on conditions
PP	No
PVC	No
PVDF	No
EPDM	No
CSM	No

2.1 Driers

For domestic and commercial refrigerators the common desiccant is a molecular sieve, a zeolithe. For R 290 a material with 3 Å pores is recommended, like for R 134a and R 404A, e.g. UOP XH 7, XH 9 or XH 11, Grace 594, CECA Siliporite H3R. Pencil driers for R 134a can be used without changes normally. Burst pressure demands of IEC/EN resp. UL 60335 have to be complied with. See also note CN.86.A .
If hardcore driers are to be used, please ask the manufacturer for compatibility to R 600a or R 290. Danfoss type DCLE driers can be used.

3. FLAMMABILITY AND SAFETY

The main disadvantage discussed in connection with the use of R 600a and R 290 is the risk in flammability. Therefore careful handling and safety precautions are essential.

Table 4: Flammability of isobutane and propane

	R 600a		R 290	
Lower explosion limit (LEL)	1.8 %	ca. 38 g/m^3	1.7 %	ca. 37 g/m^3
Upper explosion limit (UEL)	8.5 %	ca. 203 g/m^3	9.5 %	ca. 177 g/m^3
Minimum ignition temperature	494 °C		470 °C	

Due to a wide concentration range of flammability, safety precautions are necessary, on the appliance itself and in the manufacturing factory. The risk assessments behind these two situations are quite different. The main common starting point is that accidents must have two essential preconditions. One is the flammable mixture of gas and air and the other is the ignition source of a certain energy level or temperature. These two must be present together for combustions, so steps to avoid this combination must be taken.

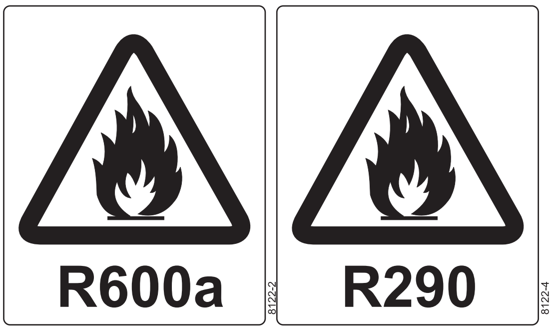


Figure 6: Yellow warning labels

compressors for R 600a and R 290 have internal protectors and PTC starters or special relays, both preventing sparks from coming out near the compressor, as it can not be guaranteed to hold surrounding air below LEL in case of leaks close to the compressor.

They are equipped with a yellow label warning for flammable gas, like shown in figure 6.

3.1 Appliance

For safety testing of household refrigerators and similar applications international standards have been established. The rules are included in the latest versions (edition 4, resp. amendmends to edition 3) of

- IEC / EN 60335-2-24 for household refrigerators and freezers
- IEC / EN 60335-2-89 for commercial refrigerated appliances
- IEC / EN 60335-2-34 for motor compressors

and for North America

- UL 60335-2-24 and UL 250 for household refrigerators and freezers
- UL 471 Amendment SB for commercial refrigerated appliances
- UL 60335-2-34 for motor compressors

which are the normal electrical safety standards. Approvals for refrigerated appliances using hydrocarbons as refrigerants are according to the procedures of these standards since 1994, in Europe. The methodology is based on the following short description. Other applications must take different national standards and legislation into account, e.g. EN 378, DIN 7003, BS 4344, SN 253 130, which can have different demands.

- All electrical elements switching during normal operation are considered possible ignition sources. This includes thermostat, door contacts for lighting, on/off and other switches, like superfrost, compressor relays, external klixon and other overload or safety switches, defrost timers and so on.
- All refrigerant containing parts are considered possible refrigerant sources through leaks. This includes evaporators, condensers, door heaters, tubings and the compressor.
- Maximum refrigerant charge is set to be 150 g for most of these standards, please see the specific standard for reference. By keeping the charge to max. 20 % of lower explosion level LEL, which is approx. 8 g/m^3, for a standard kitchen, ignition risk is very low, even if refrigerant distribution in case of leakage is uneven for some time first.

The main target of the safety precautions is to separate rooms with refrigerant containing parts from rooms with switching elements.

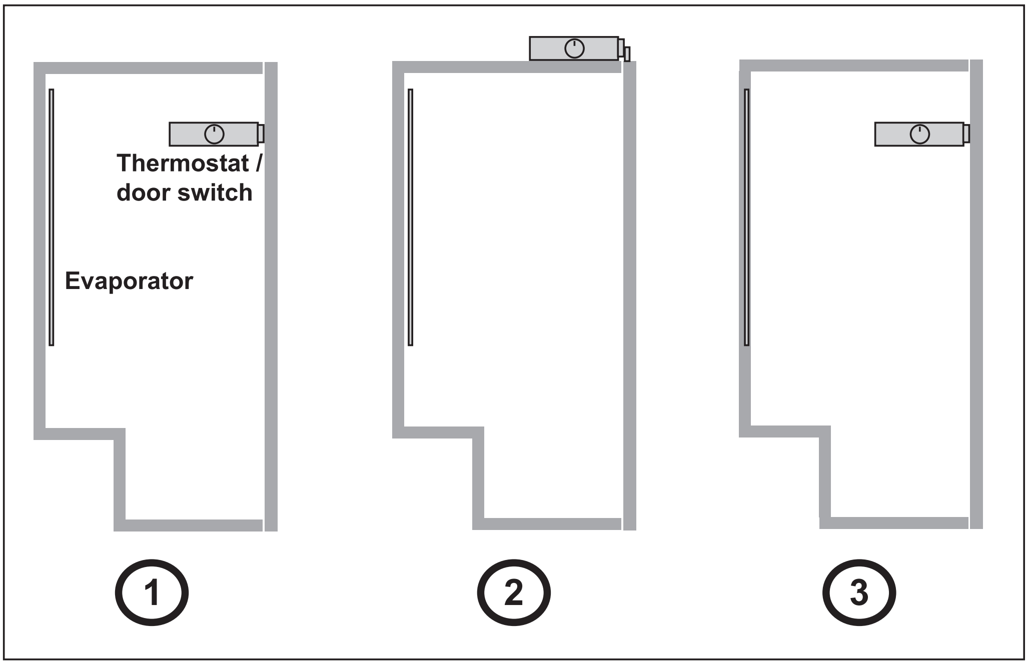


Figure 7: Appliance designs variants

In figure 7 three principal possibilities are shown

Option 1 has the evaporator and thermostat/door switch located in the storage volume both. This is critical for flammable refrigerants and should not be used.
Option 2 has the evaporator inside and the thermostat/door switch outside on top. This normally gives a safe solution.
Option 3 has thermostat/door switch inside, but the evaporator foamed in place behind the inner liner. This is a possible solution used in many cases.
The chosen option must be designed and proven in leakage tests according to IEC / EN 60335 resp. UL demands.

On many refrigerator or freezer designs this separation is already the existing situation.
- Large free standing bottle coolers and freezers often have all electrical switches in the top panel
- Some refrigerators have the evaporators hidden behind the liner, in the foam not in the cabinet space, where thermostats and so on are allowed in this case.

A critical situation is whenever it is not possible to avoid evaporator and thermostat or switches being in the cabinet (Option 1). In this case two possibilities are left.
- Thermostats and switches must be changed to sealed versions preventing gas from penetrating them and thus reaching the switching contacts. Danfoss offers electromechanical thermostats with sealed switches (077B with enclosed break device EBD) and electronic thermostats (ETC) suitable for this application.
- Fans inside the refrigerated compartment must be safe and sparkfree even if blocked.
- Electrical connectors and lamp holders must be in accordance with certain specifications.

Every R 600a and R 290 appliance type must be tested and approved according to the IEC / EN procedures, by an independent institute, even if the above criteria mentioned is included in the design. Please see the standard for details. Instructions for use should contain some informations and warnings for careful handling, like not to defrost freezer compartments with knives, and for installing in a room with at least 1 m^3 of space per 8 g of charge, the latter to be seen on the type label.
Systems using relays or other electrical components near the compressor must meet the specifications. These are include:
- Fans at the condenser or compressor must be sparkfree even when blocked or overloaded. Either they must be designed to not need a thermal switch, or this switch must meet IEC 60079-15.
- Relays must meet IEC 60079-15 or placed where a leakage can not produce a flammable mixture with air, e.g. in a sealed box or at high altitude.

3.2 Factory

The refrigerant containing system and the safety system design is to be approved and controlled regularly by local authorities normally. Below the design principles for installations in Germany are given. In many details this is based on regulations for liquified gas installations. Specialities are found around the charging stations, where gas connectors are to be handled frequently and a charging of the appliances occurs.

The basic principles for safety are:
- Forced ventilation to avoid local accumulation of gas.
- Standard electrical equipment except for the ventilation fans and safety systems.
- Gas sensors continuously monitor possible leakage areas like around charging stations, with alarm and doubling of ventilation at 15 % to 20 % of LEL and with disconnection of all non explosion proof electrics in the monitored area at 30 % to 35 % of LEL, leaving the fans running at full speed.
- Leakage tests on appliances before charging to avoid charging of leaking systems.
- Charging stations designed for flammable refrigerants and connected to the safety systems.

Safety system design can be supported by suppliers of charging stations and gas sensing equipment in many cases.

For handling of R 600a or R 290 in small containers, the rules are less strict in some countries.

4. REFRIGERATION SYSTEM DESIGN

In many cases of transition from non flammable to flammable refrigerants the appliance cabinet must be modified for safety reasons as listed in section 3.1. Changes can also be necessary for other reasons.

Refrigerant containing system parts according to IEC / EN 60335 must withstand a specified pressure without leaking. High pressure side must withstand saturation overpressure of 70 °C times 3.5, low pressure side must withstand saturation overpressure of 20 °C times 5. This gives the following values:

	R 600 a	R 290 a	
Low Pressure side	25	38	bar overpressure
High Pressure side	35	90	bar overpressure

National standards and UL standards might have different specifications, depending on the application.

4.1 Heat exchangers

The refrigeration system efficiency will normally not cause a need for changing the evaporator or condenser size, which means the outer surface can be left the same as with R 134a, R 22 or R 404A.
The inside design of the evaporator possibly needs some modification, because the refrigerant volume flow is different, according to the compressor swept volume. With R 290 it is close to R 22 or R 404A.
With R 600a compared to R 12 or R 134a the refrigerant volume flow increases by 50 % to 100 % according to the larger compressor swept volume. This leads to increased pressure drop in the refrigerant channels or tubes, if the cross flow section stays the same.
To keep the refrigerant flow speed within the recommended range of 3 to 5 m/s it may be necessary to make the cross flow sections wider. In rollbond evaporators for R 600a this can be done by either increasing the channel system height, e.g. from 1.6 mm to 2 mm, or by designing parallel channels instead of single ones. A parallel channel design however must be developed carefully to avoid liquid accumulations.
Aluminium rollbond evaporators are normally not used for R 290 because of the high demands on burst pressure.
Special care must be taken when designing the accumulator in the system. When using R 22, R 12, R 404A or R 134a the refrigerant is heavier than the oil used, while with R 600a and R 290 the refrigerant is less heavy, as can be seen in the data table 1. This can lead to oil accumulation if the accumulator is too large, especially too high, and has a flow path which does not guarantee emptying sufficiently during startup phase of the system.
Evaporator design hints can be found in note CN.82.A

For R 600a experience and theoretical modellings show the need for a flow rate almost similar to R 12 again. When changing a refrigeration system with capillary from R 12 to R 134a, very often the capillary flow rate, expressed in litres of nitrogene per minute at specific conditions, is reduced by elongating the capillary, or by taking a smaller inner diameter.

For R 290 experience shows the need for a capillary flow rate almost similar to R 404A. At least this is a good starting point for optimization.

As with R 134a and R 404A for R 600a and R 290 the suction line heat exchanger is very important for system energy efficiency of R 290, which it was not for R 22, see figure 8. The figure shows increase of COP with superheat from few K up to +32 °C return gas temperature, where a range from +20 °C to approx. +32 °C is usual for small hermetic systems. This large increase in COP for R 290 is caused by a high vapour heat capacity. In combination with the need for keeping the refrigerant charge close to the maximum possible in the system, thus giving no superheat at evaporator outlet, the suction line heat exchanger must be very efficient for preventing air humidity condensation on the suction tube. In many cases an elongation of the suction line and capillary gives efficiency improvements. The capillary itself must be in good heat exchanging contact with the suction line for as long a part of total length as possible.

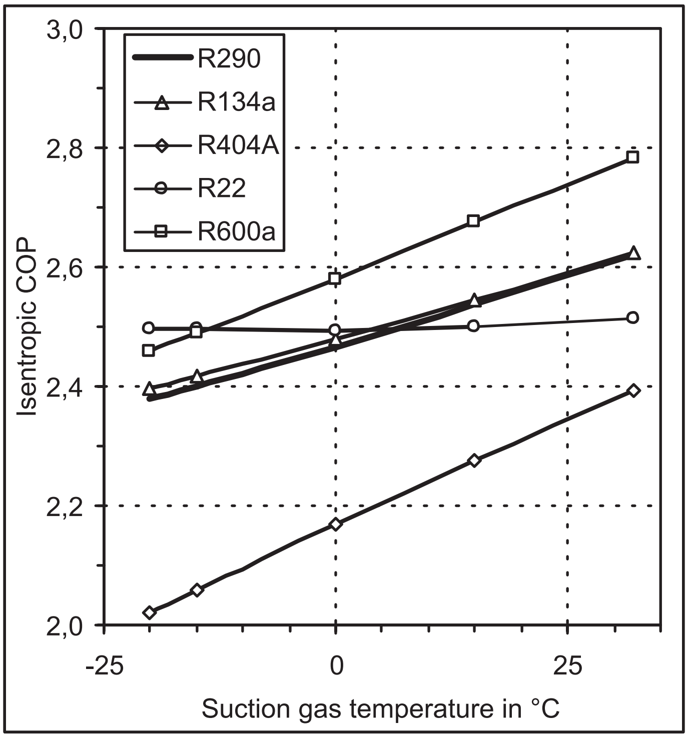


Figure 8: Theoretical COP increase of different refrigerants versus suction temperature with adiabatic compression, internal heat exchange, at -25 °C evaporation, 45 °C condensation, no subcooling before internal heat exchanger

At high superheat, with good internal heat exchange, the theoretical COP of R 290, R 600a and R 134a is higher than for R 22. At very low superheat the COP of R 290, R 600a and R 134a is lower than for R 22. The R 290 behaviour is similar to R 134a, with respect to internal heat exchange.

4.3 Evacuation

For R 290 generally the same rules for evacuation and processing are valid as for R 22, R 134a or R 404A systems. The maximum allowable content of non condensable gases is 1 %.

For R 600a the evacuation process must be improved remarkably. At -25 °C evaporation temperature R 600a has a pressure of 0.58 bar, while R 12 has 1.24 bar and R 134a has 1.07 bar, which means only 47 % or 54 %, or roughly half, of previously handled pressure values are present.
This means that non condensable gas contents in a refrigeration system will have double the negative effect than with the other two refrigerants, or, taken from that, necessary maximum level for non condensable gases residue must be halved. Due to a main part of non condensable gases coming from the compressor oil, which takes some time to extract and shows to be an effect not linear with time, minimum necessary evacuation times will be more than double.
Working with single side evacuation on the process tube of the compressor only, necessary evacuation times will raise, depending on the appliance design. Changing to two side evacuation, on process tube and a second connection at the drier, reduces necessary time again, but increases cost.

A level too high of non condensable gases increases energy consumption because of higher condensing temperature and a portion of the transported gas being inactive. It can additionally increase flow noise. On two temperature one compressor systems it can give problems with the cyclic defrosting of the refrigerator cabinet, where risk for ice block forming is increased.

4.4 Noise

While the compressors tend to be less noisy with R 600a at low cooling capacity, compared to R 134a, partly because of the lower working pressure levels, some other noise problems can occur on appliances.
The larger required displacement can cause higher vibration and thus create noise in the appliance. The increased volume flow can give higher flow noise in evaporators, especially at the injection point. But even if this noise in many cases is not increased, it can be a problem. If compressor noise is reduced, the flow noise appears to be the loudest part, not covered by the compressor noise any longer, and it is an unexpected noise, a hiss. Additionally the higher volume flow can result in higher gas pulsations and by that increase flow noise or even create vibrations on appliance parts.
Increased suction line heat exchanger length can reduce flow noise too, because it equalizes the flow and thus stabilizes injection.

4.5 Cleanliness of components

The specifications for cleanliness are generally comparable to R 134a or R 404A. The only official standard on cleanliness of components for refrigeration use is the DIN 8964, which also is used in several countries outside Germany. It specifies maximum contents of soluble, insoluble and other residues. The methods for determining soluble and insoluble contents are to be modified for the actual refrigerant R 600a and R 290, but in principle the same limits are useful.

5. SERVICE/ REFERENCES

Servicing and repair of R 600a and R 290 systems is possible for skilled and well trained service technicians. Please see note CN.73.C for details. Local laws and regulations must be taken into account also. Very careful handling is required due to the flammability of the gas, which is a potential danger during work on the refrigeration system. A good ventilation of the room is necessary and the discharge of the vacuum pump must be lead to open air. The equipment of the service technician must meet the requirements of R 600a and R 290 in terms of evacuation quality and refrigerant charge accuracy. An electronic scale is recommended to control refrigerant charge to within the needed accuracy.
Conversion of a R 22, R 12, R 502 or R 134a system to R 600a or R 290 is not recommended by Secop, because these systems are not approved for flammable refrigerant use, so electrical safety is not proven in accordance with the relevant standards.

5.1 References

CN.86.A "Driers and Molecular Sieves Desiccants", Danfoss Compressors
CN.82.A "Evaporators for Refrigerators", Danfoss Compressors
CN.73.C "Service on Household Refrigerators and Freezers with New Refrigerants", Danfoss Compressors

DIN 8960 "Kältemittel-Anforderungen und Kurzzeichen", 1998
DIN 8964 "Kreislaufteile für Kälteanlagen", Beuth Verlag GmbH, Berlin

IEC 60335-2-24 "Household and similar electrical appliances - Safety Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers", 2002, A1:2005 (EN:2003)
IEC 60335-2-89 "Household and similar electrical appliances - Safety Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporate or remote refrigerant condensing unit or compressor ", 2002 (EN:2002)
IEC 60335-1 "Household and similar electrical appliances - Safety Part 1: Genral requirements ", 2001 (EN:2002)
IEC 60079 "Electrical apparatus for explosive gas atmospheres", 2004 (EN:2004)

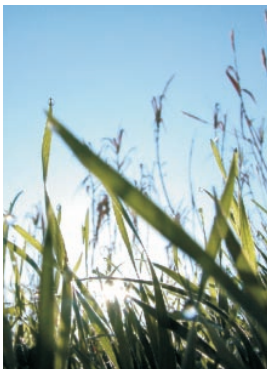
UL 60335-2-24 "Standard for Household and Similar Electrical Appliances, Part 2: Particular Requirements for Refrigerating Appliances, Ice -Cream Appliances and Ice-Makers", 2006
UL 60335-1 "Safety of Household and Similar Appliances, Part 1: General Requirements", 2006
UL 471 "Commercial Refrigerators and Freezers", 2006, Supplement SB, 2008
UL 250 "Household Refrigerators and Freezers", 2000

OUR IDENTITY

At Secop we are committed to our industry and are genuinely passionate about the difference we are able to make for our customers. We understand their business and objectives and the challenges of today's world of refrigeration and cooling systems.

We work in a straightforward way, being open, direct and honest because we want to make things clear and easy.

Our people are committed to increasing value for our customers and constantly strive for better performance, knowing that our own progression and success is dependent on theirs.



OUR JOURNEY SO FAR

1956
Production facility and headquarters in Flensburg, Germany founded

1958
Start up production of PW compressors.

1970
Introduction of SC compressors.
The birth of a standard setting platform in the light commercial market.

1972
Introduction FR compressors.

1977
Introduction TL and BD compressors.

1990
Introduction NL compressors.

1992
Introduction PL compressors.

1993
Start of production with natural refrigerant R600a (Isobutane)

Production facility in Crnomelj, Slovenia founded.

1999
Start of production with natural refrigerant R290 (Propane).

2002
Production facility in Zlate Moravce, Slovakia founded.

2005
Introduction GS compressors.

2008
Production facility in Wuqing, China founded.

2010
Introduction SLV-CNK.2 and SLV-CLK.2 variable speed compressors.
Introduction BD1.4F Micro compressor.

Secop GmbH · Mads-Clausen-Str. 7 · 24939 Flensburg · Germany · Tel: +49 461 4941 0 · Fax: +49 461 4941 44715 · **www.secop.com**

Produced by Secop | May 2011

DES.A.610.A1.02