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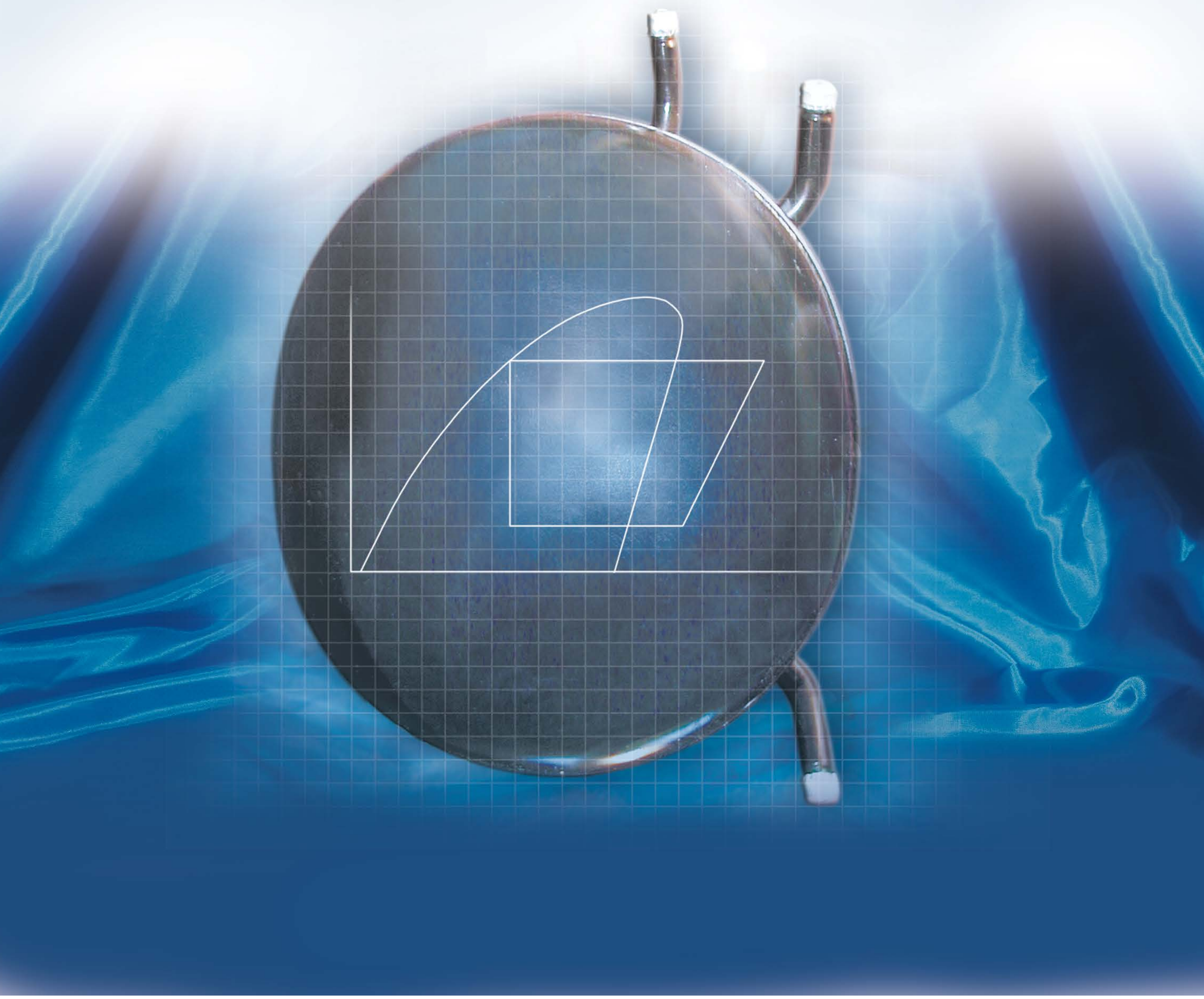
SECOP

PRACTICAL APPLICATION OF REFRIGERANTS R600a AND R290 IN SMALL HERMETIC SYSTEMS

APPLICATION GUIDELINE



1. REFRIGERANTS

Refrigerants R600a—isobutane and R290—propane are potential 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 minimal global warming potential GWP. Furthermore, they are petrol gases from natural sources.

The refrigerant R600a has been used in the past in refrigerators up to the 1940s, and has today a wide range of uses in domestic refrigerators and freezers again in Europe where most refrigerators are manufactured using R600a as refrigerant.

Isobutane R600a is a refrigerant that is well suited for household applications, with good energy efficiency yet with very different characteristics in several areas, which implies the design has to be made or adopted.

The refrigerant R290 has been in use in refrigeration plants in the past, and is still used in some industrial plants. R290 has been used in Germany and Sweden for some years in domestic heat pumps and air conditioners, however, with different level of success.

Because of the availability of isobutane and propane around the world, they have been discussed widely for CFC, H-CFC, and HFC replacement.

Isobutane R600a and Propane R290 are possible refrigerants for these applications, with good energy efficiency, but special care must be taken when it comes to flammability.

The properties of R600a and R290 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	R290	R600a	R134a	R404A	R22	R12
Name	Propane	Isobutane	1,1,1,2-Tetra-flouroethane	Mixture R125 R 143a R134a	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/m^3	3.6	1.3	4.4	10.0	7.0	6.0
Volumetric capacity at -25/45/32 °C in kJ/m^3	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 R600a

The first remarkably large difference between R600a and R134a or R12, is found in the pressure level, which is much lower, e.g. at -25 °C evaporation roughly 55 % of R134a or 45 % of R12. In connection with this, the normal boiling point is at 15 K resp. 18 K higher. This leads to operating pressure levels that are much lower than previously before. Evaporators in household refrigerators will thus operate below normal atmospheric pressure.

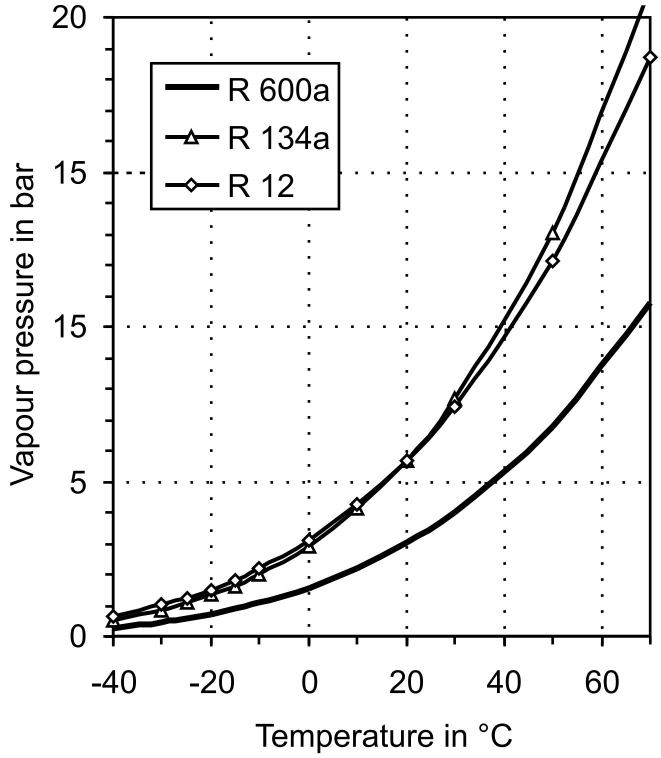


Figure 1: Vapor pressure of different refrigerants versus temperature

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

1.2 Capacity R600a

R600a has roughly 50 % of R12 or 55 % of R134a volumetric capacity at 55 °C condensing temperature, as seen in Figure 2. As a result, the necessary compressor swept volume will be up to 2 times the swept volume used for R12.

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.

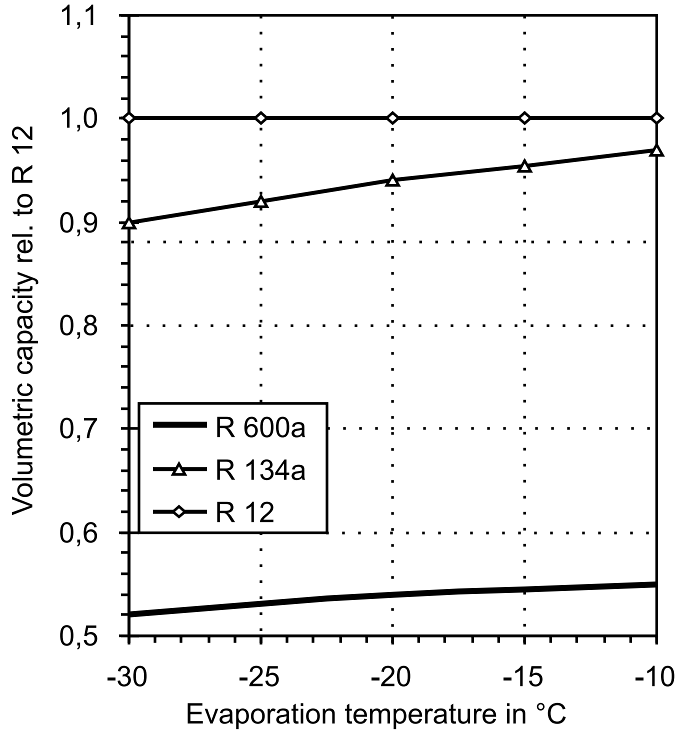


Figure 2: Volumetric capacity of R600a and R134a, relative to R12 over evaporation temperature at 55 °C condensing temperature and 32 °C suction gas temperature

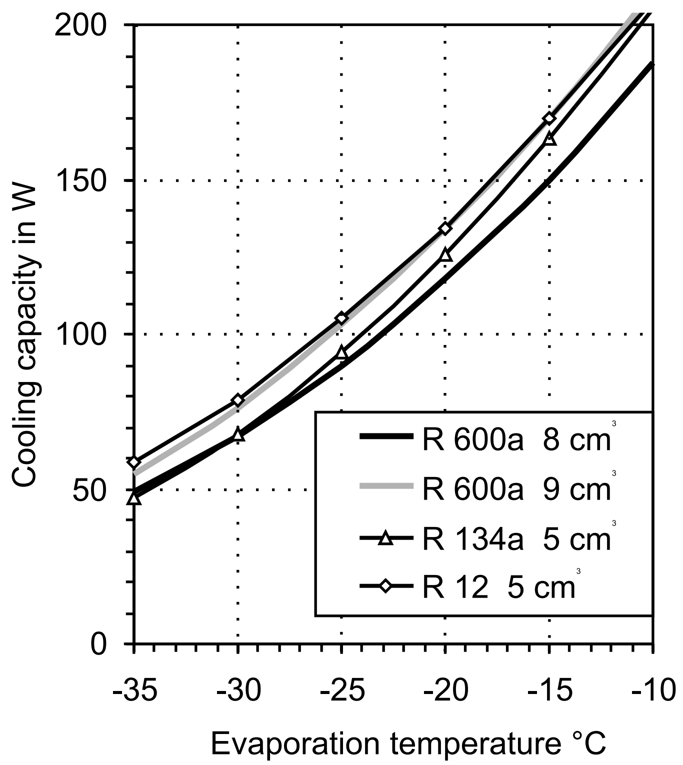


Figure 3: Cooling capacity versus evaporating temperature with different refrigerants

1.3 Pressure R290

A difference between R290 and R134a is in the pressure level, which is closer to R22 and R404A, e.g. at -25 °C evaporation the pressure is roughly 190 % of R134a, 81 % of R404A, 350 % of R600a or almost exactly that of R22. In connection with this the normal boiling point, is close to R22 also. Evaporators will thus have to be designed similar as for R22 or R404A.

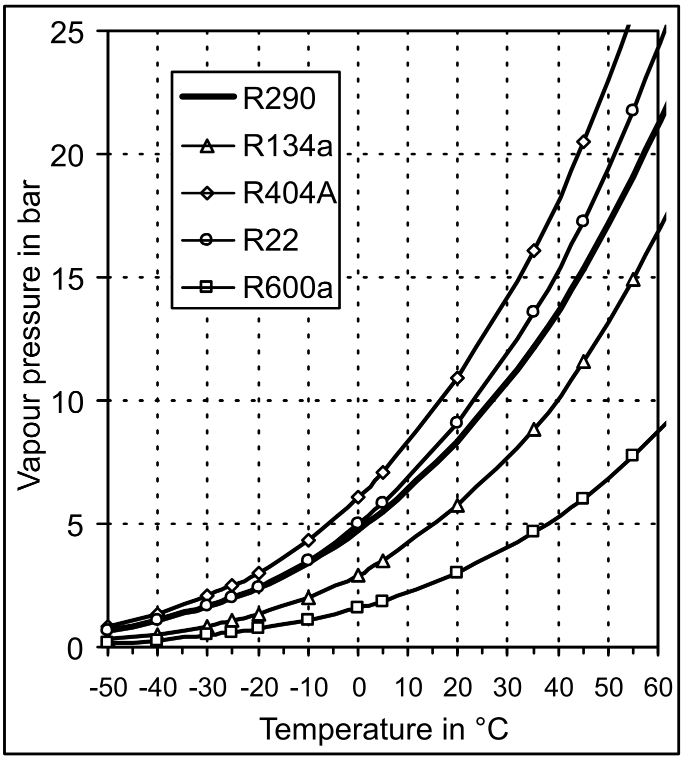


Figure 4: Vapor pressure of different refrigerants versus temperature

The pressure level and critical temperature are almost the same as R22. However, the discharge temperature is much lower. This makes it possible to work at higher pressure ratios, which means lower evaporating temperatures, or at higher suction gas temperatures.

1.4 Capacity R290

R290 has roughly 90 % of R22 or 150 % of R134a volumetric capacity at 45 °C condensing temperature, as seen in Figure 5. Because of this the necessary compressor swept volume is close to R22 also and 10 % to 20 % greater than for R404A.
The volumetric capacity is approx. 2.5 to 3 times that of R600a. Thus, the choice for either R290 or R600a 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 determined from the suction gas density and enthalpy difference of evaporation.

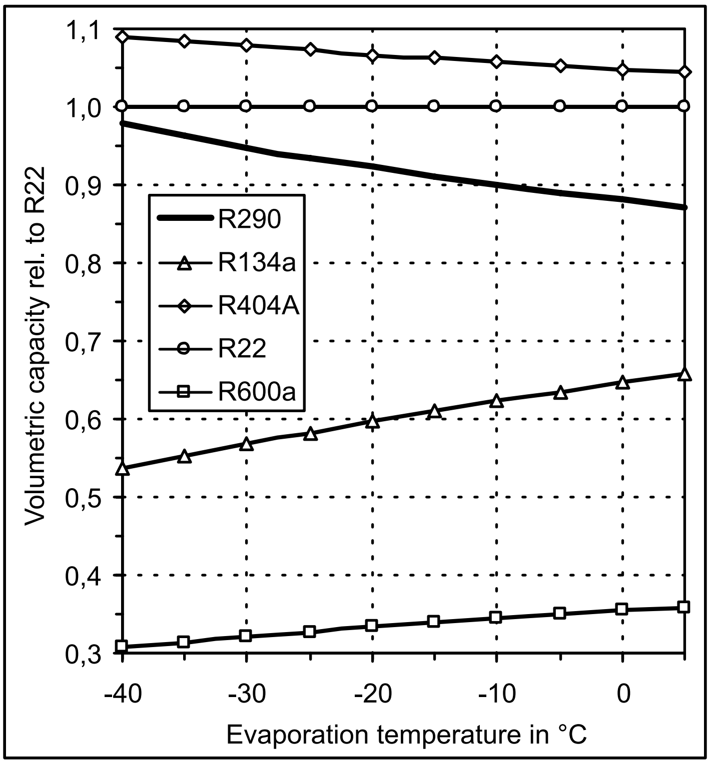


Figure 5: Volumetric capacity of R290, R134a, R404A, and R600a relative to R22, over evaporation temperature at 45 °C condensing and 32 °C suction gas temperature, no subcooling

1.5 Refrigerant charge

If R600a or R290 were to be charged into an unchanged refrigeration system, the 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 yields charges of approx. 40-45 % of R22, R12, R134a, or R404A charge in grams, according to the data from Table 1, which also corresponds with empirical values.
The 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 R600a. Undercharging, in particular, tends to result in higher energy consumption. This means that the charging accuracy must improve in cm^3 and even more in grams. The accuracy of charges of approx. 20 g, which are found on small larder refrigerators, must be within 1 g.

1.6 Purity

Specification for hydrocarbon refrigerants such as R600a and R290 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 evaluated according to chemicals and stability, for compressor and system lifetime, and from the thermodynamic side regarding refrigeration system behavior and controllability.

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

Currently, there is no refrigerant quality according to an official standard on the market. The specifications of possible qualities must be checked with the supplier in detail.

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 at a lower level than guaranteed for those products. Technical grade 99.5 %, also called 2.5, is widely used.

Table 2: Specification of R600a and R290 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 vapor 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 R600 normal Butane up to 5 % in R600a 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) In terms of the compressor, a content up to approx. 1 % of butane in R290 or 1 % of propane in R600a 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 R600a is mainly used with mineral compressor oils, so material compatibility is almost identical to R12 in terms of oil. The use of alkyl benzenes or polyolester oil is also possible. Refrigerant R290 is used with polyolester oil in compressors, meaning material compatibility is almost identical to R134a or R404A in terms of oil.
R600a and R290 are chemically inactive in refrigeration circuits, so no specific problems should occur. 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. Testing for critical materials 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 R290, a material with 3 Å pores is recommended, like for R134a and R404A, e.g. UOP XH 7, XH 9 or XH 11, Grace 594, CECA Siliporite H3R. Pencil driers for R134a can normally be used without changes. Burst pressure demands of IEC/EN resp. UL 60335 have to be complied with. See also Danfoss Compressors Note "Driers and Molecular Sieves Desiccants" (CN.86.A) .
If hardcore driers are to be used, please ask the manufacturer for compatibility with R600a or R290.
Danfoss type DCLE driers may be used.

3.

FLAMMABILITY AND SAFETY

The main disadvantage discussed in connection with the use of R600a and R290 is the risk in flammability. Careful handling and safety precautions are thus essential.

Table 4: Flammability of isobutane and propane

	R600a		R290	
Lower explosion limit (LEL)	1.5 %	ca. 38 g/m^3	2.1 %	ca. 39 g/m^3
Upper explosion limit (UEL)	8.5 %	ca. 203 g/m^3	9.5 %	ca. 177 g/m^3
Minimum ignition temperature	460 °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, which means steps must be taken to avoid this combination.

Figure 6: Yellow warning labels

Compressors for R600a and R290 have internal protectors and PTC starters or special relays, both preventing sparks from coming out near the compressor. As a result, no guarantees can be made for holding surrounding air below LEL in case of leaks close to the compressor.

They are equipped with a yellow label warning for flammable gas as shown in Figure 6.

3.1 Appliance

International standards have been established for safety testing of household refrigerators and similar applications. The regulations are included in the latest versions (edition 4, resp. amendments 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. Refrigerated appliances that use hydrocarbons as refrigerants have received approval in Europe according to the procedures of these standards since 1994. 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 requirements.

- All electrical elements that switch during normal operation are considered possible ignition sources. This includes thermostats, door contacts for lighting, on/off switches inclduing other switches, such as 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/m³ for a standard kitchen, the ignition risk is very low, even if refrigerant distribution in case of leakage is initially uneven for some time.

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

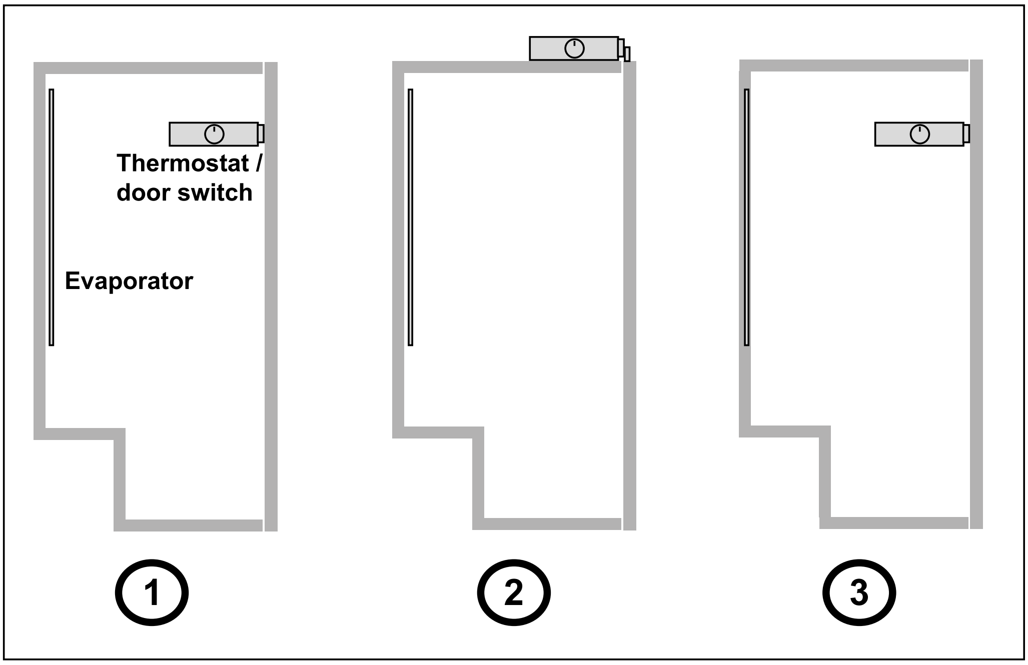


Figure 7: Appliance designs variants

Three main options are shown in figure 7

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 offers 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 current situation.

- Large free-standing bottle coolers and freezers often have all electrical switches in the top panel
- Some refrigerators feature evaporators hidden behind the liner, in the foam not in the cabinet space, where thermostats and such 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 options remain.

- 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 R600a and R290 appliance type must be tested and approved according to the IEC / EN procedures, by an independent institute, even if the criteria mentioned above is included in the design. Please see the standard for details. Instructions for use should contain some information and warnings for careful handling, such as not to defrost freezer compartments with knives or install the unit in a room with at least 1 m^3 of space per 8 g of charge, the latter being visible on the type label.
Systems using relays or other electrical components near the compressor must meet the specifications. These include:

- Fans at the condenser or compressor must be spark-free 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 cannot 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 must be approved and controlled regularly by local authorities normally. The design specifications for installations in Germany are provided below. In many details, this is based on regulations for liquified gas installations. Special cases are found around the charging stations, where gas connectors are handled frequently and appliances are charged.

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 such as around charging stations with an alarm and doubling the 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 R600a or R290 in small containers, the regulations 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 x 3.5, low pressure side must withstand saturation overpressure of 20 °C x 5. This yields the following values:

	R600a	R290a	
Low pressure side	25	38	Bar overpressure
High pressure side	35	90	Bar overpressure

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

4.1 Heat exchangers

The refrigeration system's efficiency will normally require changing the evaporator or condenser size, which means the outer surface can be left the same as with R134a, R22, or R404A.
The inside design of the evaporator may need to be modified since the refrigerant volume flow is different, according to the compressor swept volume. With R290 it is close to R22 or R404A.
When comparing R600a to R12 or R134a, the refrigerant volume flow increases by 50 % to 100 % according to the larger compressor swept volume. This leads to an increased drop in pressure 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 R600a 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.
Aluminum rollbond evaporators are normally not used for R290 because of the high demands on burst pressure.
Special care must be taken when designing the accumulator in the system. When using R22, R12, R404A, or R134a the refrigerant is heavier than the oil used, while with R600a and R290 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.
Tips on evaporator design can be found in Danfoss Compressors Note "Evaporators for Refrigerators" (CN.82.A).

4.2
Capillary

For R600a, experience and theoretical modelings show the need for a flow rate almost similar to R12 again. When changing a refrigeration system with capillary from R12 to R134a, very often the capillary flow rate, expressed in liters of nitrogen per minute at specific conditions, is reduced by elongating the capillary or by using a smaller inner diameter.

For R290, experience shows the need for a capillary flow rate almost similar to R404A. At least this is a good starting point for optimization.

As with R134a and R404A, the suction line heat exchanger for R600a and R290 is very important for system energy efficiency of R290, which it was not for R22, 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 R290 is caused by a high vapor 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 to prevent 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.

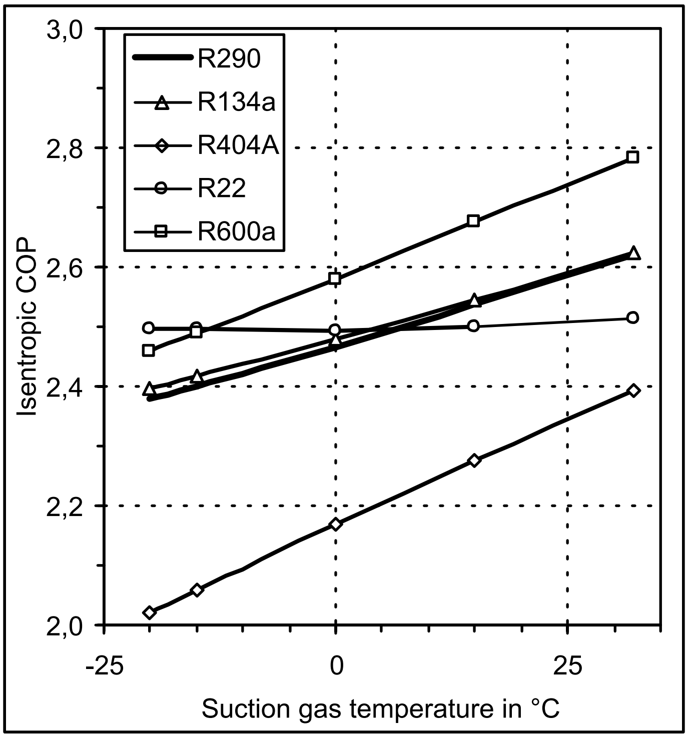


Figure 8: Theoretical COP increase of different refrigerants versus suction temperature with adiabatic compression, internal heat exchange, at -25 °C evaporation, 45 °C condensation, no subcooling before internal heat exchanger

At high superheat, with good internal heat exchange, the theoretical COP of R290, R600a and R134a is higher than for R22. At very low superheat the COP of R290, R600a and R134a is lower than for R22. The R290 behavior is similar to R134a, with respect to internal heat exchange.

4.3 Evacuation

For R290 generally the same rules for evacuation and processing are valid as for R22, R134a or R404A systems. The maximum allowable content of non condensable gases is 1 %.

For R600a the evacuation process must be improved remarkably. At -25 °C evaporation temperature R600a has a pressure of 0.58 bar, while R12 has 1.24 bar and R134a 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 costs.

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 R600a at low cooling capacity, compared to R134a, 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 the compressor noise is reduced, the flow noise appears to be the loudest since it is not covered by the compressor noise any longer, and produces an unexpected noise, a hiss. Additionally, the higher volume flow can result in higher gas pulsations and thus 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 R134a or R404A. 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 R600a and R290, but in principle, the same limits are useful.

5.
SERVICING AND REPAIR

Hydrocarbons (HC) progressively replace synthetic refrigerants due to their environmental sustainability and efficiency from the market, although their flammability requires additional safety measures. For example, brazing is only allowed in combination with the use of nitrogen as a protective gas. Therefore the connections between two tubes are established with pressure fitted connections.

Hydrocarbons are the environmentally friendly alternative to CFCs, HCFCs and HFCs. They save the ozone layer and have a much lower Global Warming Potential (GWP) of 3 in comparison to the GWP-value of R404A which is at 3900.

As a pioneer of environmentally friendly refrigeration, Secop promotes the conversion of refrigerants actively and already used environmentally friendly hydrocarbons (HC) such as R290 (propane) and R600a (isobutane) as refrigerants since the 1990s. They play a key role in the reduction of harmful greenhouse gases. A normal supermarket, for example, emits 5-10 % of its used refrigerant into the atmosphere due to leakages. HCs as a replacement are able to reduce the greenhouse gas emissions by many tons per year.

Image 1: DELTA R600a compressor, source: VULKAN Lokring

5.1 Efficiency

To use them doesn't only mean an improvement in environmental protection but also improved efficiency. The physical properties of HC-based systems – a lower liquefaction point, advantages in thermodynamics as well as a higher coefficient of performance (COP) – create a very energy efficient operation.

The energy savings due to the use of HC-systems have already been proven in many studies. Hydrocarbons as a replacement for CFCs and other detrimental refrigerants have been tried and tested. An additional advantage of HCs is its cost-effective availability as a by-product of the production and processing of oil and gas.
The relevance of Hydrocarbons as refrigerants is shown most clearly in the segment of household refrigeration. For the first time isobutane was used as an alternative to the harmful R134a in refrigerators in the 1990s. In commercial grade cooling machines, the same development took place.

With commercial refrigeration systems meanwhile, the development is similar. Refrigerants such as R404A and R134a are getting expendable. In supermarkets as well as at many other locations, R290 (propane) is used as a substitute for the ozone-depleting refrigerants.

HC-systems are operating with the same cooling circuit as such with synthetic refrigerants. Therefore propane is compatible with applications and systems, which were designed for the refrigerant R22. It is a direct replacement, which is superior with regard to performance.

5.2 Safety requirements

The biggest challenge in the handling of a system with R600a or R290 is the flammability of the used gases. Refer to **Table 4** on page 9 for the flammability limits.

In most States there are laws, regulations and standards in place to avoid explosions and increase the safety level when it comes to hydrocarbons. As an example, the German regulation of industrial safety as well as the European ATEX-regulation 94/9/EG, were replaced by the new 2014/94/EU-regulation on April 4, 2016.

Secop compressors for flammable refrigerants are provided with a special warning-sign. According to the aforementioned safety-regulation, the maximal filling capacity is 150 g per system, which equates to approximately 8 g/m³ in a 20 m³ kitchen and thereby around 25 % of the lower flammability limit. These precautions minimize the risk of an ignition in case of a leakage. Under favorable conditions however, the overstepping of these numbers is officially allowed.
All manufacturers of HC-systems have to follow these safety regulations. The customer service, as well as the repair of R600a and R290 applications, should only be accomplished by highly trained and experienced personnel. This implies also knowledge about tools, transportation of compressors and refrigerants as well as laws, regulations, and standards.
National safety regulations demand leakage simulations and strictly require the isolation of electrical components close to the flow of refrigerants.

5.3 Braze free compressor replacement

The disposal of R290 and R600a does not include the filling of a recycling cartridge. Due to the low GWP, the flammable refrigerants are directed away from the workplace into the open through a tube. During the process, external ignition sources must be avoided.

Furthermore, those refrigeration systems must be opened with a pipe cutter. The brazing on HC-cooling circuits is only allowed if the existing refrigerant has been disposed according to regulations and if the high and low-pressure circuits are subsequently flushed separately with nitrogen. Even if the compressor is not to be replaced, the brazing is only allowed under flowing nitrogen as a protective gas. On all other occasions, the brazing close to flammable refrigerants is strictly forbidden.

Image 2: With a Lokring® connection, the hermetic connection between two different materials can be established, source: VULKAN Lokring

During the work at a system, the connections have to be established with pressure fitted connections. With a braze free connection, this can be established for aluminum, copper or steel pipes. The connection consists of two rings and a connection piece to receive the two pipes, which is to be connected. Because of the conical internal contour of the rings and the special external contour of the connection piece, the radius of the connection piece will be reduced to the diameter of the pipes to generate a hermetic metal to metal compound.

Prior to assembly, the pipe ends have to be cleaned thoroughly with fine steel wool or abrasive sheets in a rotating motion. Thereby scratches will be avoided along the pipes, which could lead to reduced sealing.

To ensure a sealed connection, the pipe ends are treated with Lokprep®. This evens out any irregularities at the pipe's surface and quickly hardens. After the insertion of the pipe end into the connection pieces, the pipes should be rotated by 360°, to guarantee the even spread of the sealant. Afterwards, the two rings are compressed to the stop in the middle with a special pair of pliers for manual assembly.

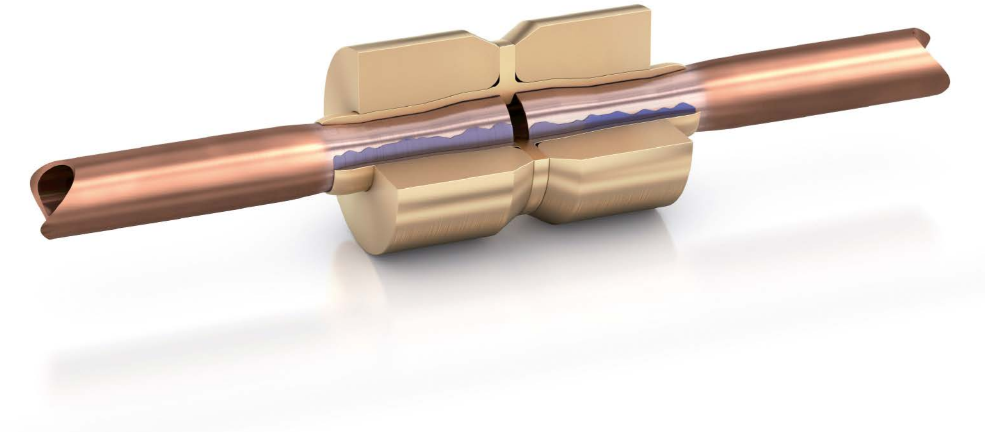
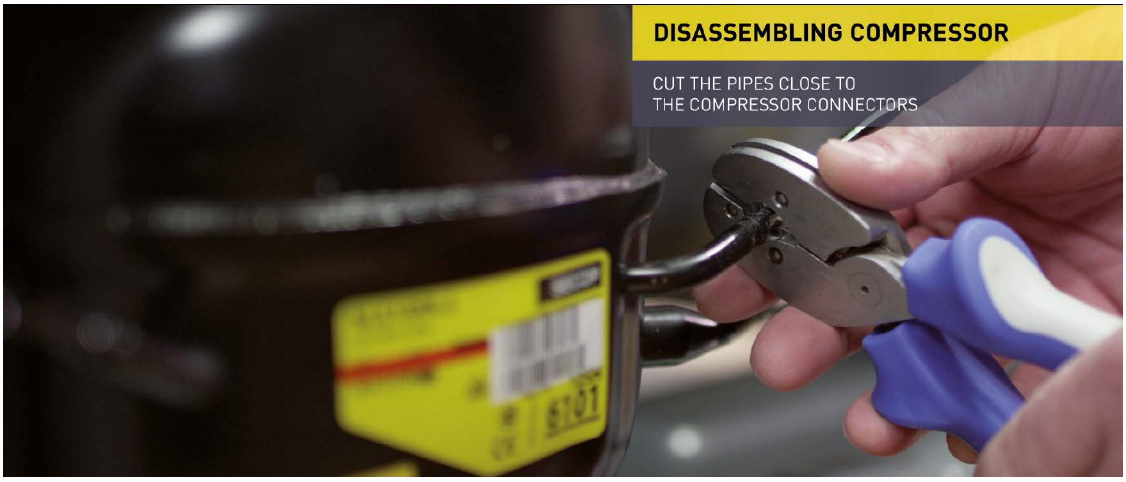


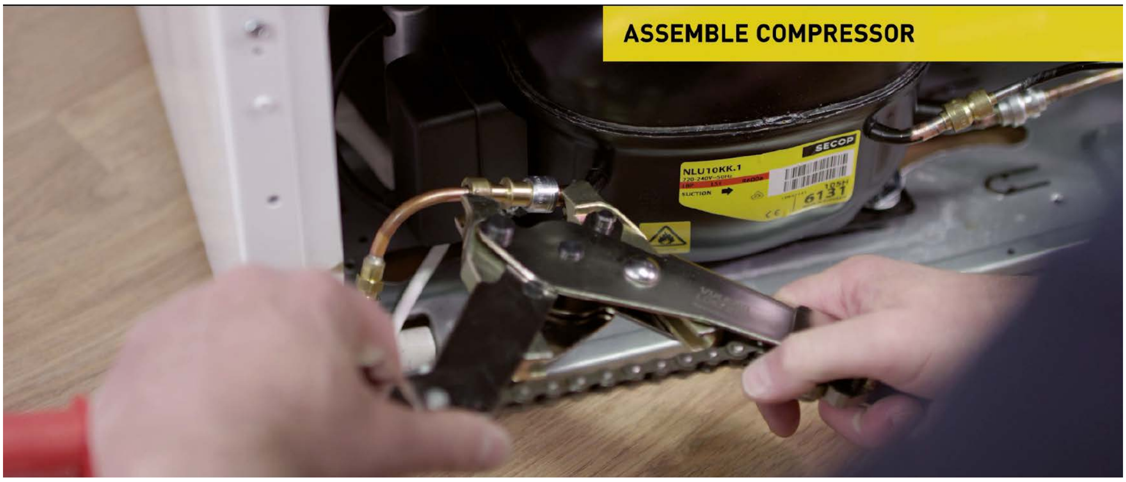
Image 3: Cross-section of a Lokring®-connection, source: VULKAN Lokring

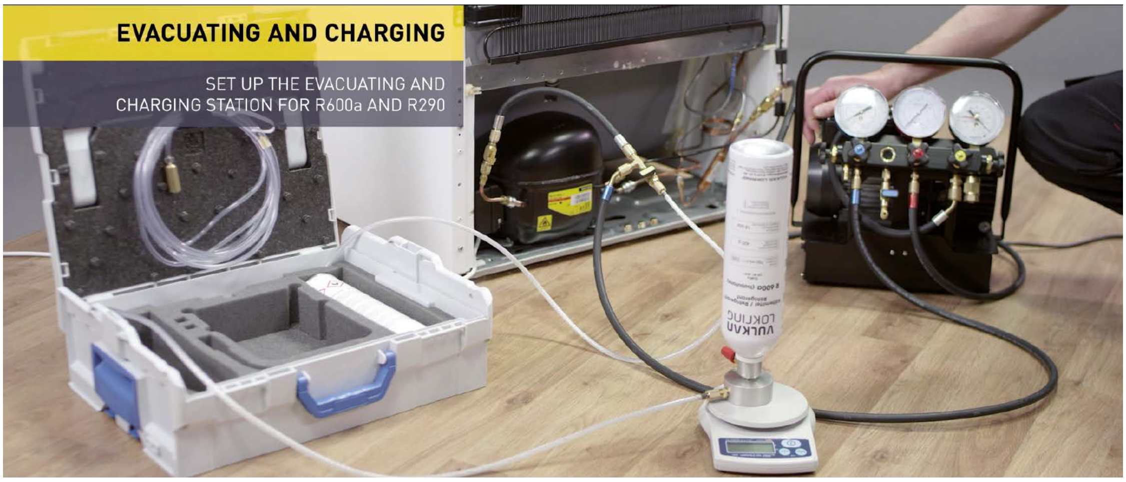
Image 4: With the pliers for manual assembly, a hermetic connection will be established due to pressure, source: VULKAN Lokring

Depending on the material and the environmental temperature, the Lokprep® hardens in three to four minutes, so that all necessary connections can be established alongside the replacement of the compressor and filter dryer as well as the filling process. Due to maximal precision in the manufacturing process, the connection can be established with minimal effort. It guarantees an absolutely clean, inseparable and purely mechanical pipe connection with high durability regarding the hermetical seal.

Servicing and repair for R600a and R290 systems is possible for skilled and well trained service technicians. Please see our Guidelines "Service on Household Refrigerators & Freezers", "Mounting Instructions for Hermetic AC Compressors" and "Repair of Hermetic Refrigeration Systems" for details. Our video "Compressor Service for Isobutane (R600a) and Propane (R290) – Step by Step" can also be used as a reference.







Images 5-7: Screenshots from educational film "Compressor Service for R600a/R290 - Step by Step"

Local laws and regulations must also be taken into account. Very careful handling is required due to the flammability of the gas, which is a potential danger during work on the refrigeration system. 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 R600a and R290 in terms of evacuation quality and refrigerant charge accuracy. An electronic scale is recommended to control refrigerant charge to within the needed accuracy.

Converting a R22, R12, R502, or R134a system to R600a or R290 is not recommended by Secop, since these systems are not approved for flammable refrigerant use, so electrical safety is not proven in accordance with the relevant standards.

6. REFERENCES

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CN.82.A	"Evaporators for Refrigerators", Danfoss Compressors
DES.G.620.A	"Repair of Hermetic Refrigeration Systems", Secop
DES.G.620.B	"Mounting Instructions for Hermetic AC Compressors", Secop
DES.G.620.C	"Service on Household Refrigerators & Freezers", Secop
DES.K.490.A	"Hermetic Compressors for AC Voltage", Secop
VIDEO	"Compressor Service for Isobutane (R600a) and Propane (R290) – Step by Step" → https://www.secop.com/solutions/compressor-qa-tools/compressor-service/ → https://www.youtube.com/SecopGroup
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UL 471	"Commercial Refrigerators and Freezers", 2006, Supplement SB, 2008
UL 250	"Household Refrigerators and Freezers", 2000

OUR IDENTITY

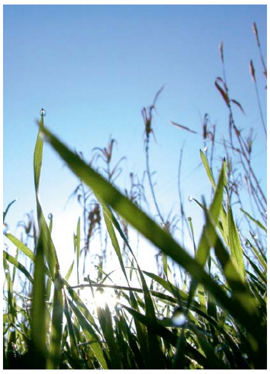
At Secop we are committed to our industry and are genuinely passionate about the difference we are able to make for our customers. We understand their business and objectives and the challenges of today's world of refrigeration and cooling systems.

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.

A NEWCOMER WITH 60 YEARS OF EXPERIENCE

Formerly known as Danfoss Compressors, Secop is one of the founding fathers of modern compressor technology with an experience that goes back to the beginning of the 1950s.

For more than 25 years, Secop has been setting the standard in compressor technology by developing highly efficient variable-speed compressors and by compressors working with hydrocarbons.



OUR JOURNEY SO FAR

1956 Production facility and headquarters in Flensburg, Germany founded.

1958 Start of production for PW compressors.

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

1972 Introduction of FR compressors.

1977 Introduction TL and BD compressors.

1990 Introduction of NL compressors.

1992 Introduction of 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 of 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 DC compressor. Introduction of DLX and NLU compressors.

2013 Introduction of the XV compressor - opening a new chapter in refrigeration history. Secop acquires ACC Fürstenfeld, Austria.

2015 New generation of energy-efficient propane compressors. New variable-speed platforms for household and light commercial applications.

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