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Transfair Engineering Survey:

Evacuation of Cooling Circuits in the Household Refrigerator Industries Today

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Content

2. Evacuation of R134a and R600a Systems

The requirements on evacuation of cooling circuits to be charged with HFC-134a and with HC-600a are much higher as in the past using CFC-12. This concerns not only the lower pressure to be reached (CFC-12 systems <1mbar on low and high side pressure; HFC-134a < 0.4mbar), but also the removal of moisture, specially for HFC-134a, and non-condensable gas, specially for HC-600a, out of the cooling circuit and –as far as possible even out compressor oil, which is quite difficult. Therefore the whole cooling circuit assembly and evacuation process much be completely reconsidered and modified. Furthermore special precautions have to be made if HFC-134a systems will be evacuated and charged on the same lines together with HC-600a (or still CFC-12). Also a system already charged with R600a cannot be evacuated again in the same way as made with HFC-134a (or CFC-12) and needs for safety ex-proof pumps for discharge on special repair lines or special precautions. Also they cannot be recharged by the same quantity. In this chapter we will consider the specific requirement on evacuation of CFC- free system.

2.1. Evacuation Problems: Removal of Moisture and Non-Condensable Gases

Evacuation is not used only to evacuate the system underneath 0.1 mbar, but to remove moisture and non-condensable gas in the evaporator and partially even in compressor oil (low pressure side) as well as in the condenser (high pressure side):

- R134a systems require hydroscopic ester oil which reacts with humidity by building a grease easily blocking the capillary; in addition R134a and ester oil does not separate well in the circuit so that more oil are passing the circuit during operation.
- R600a systems use normal mineral oil, but because of capillary often smaller than in the past, the blockage of capillary exists as well; the R600a refrigerant charge quantity is much smaller so that small quantities of **moisture with vapour pressure of 10-20 mbar** and small quantities of non-condensable gas have strong influence on the evaporating and condensing circuit as in systems with higher charges. Modern designs even reduce the circuit volume by removing the suction accumulator, replacing it with a vertical u-bend and by this way increasing the superheat value (see Transfair engineering: Designing and prototyping of refrigerator and freezer cooling circuits, Düsseldorf 2000, p. 45, p.55).
- Especially the non condensable gas must be removed in case of R600a systems and much stronger control on the refrigerant and compressor oil cleanliness must be taken into account. Content of non-condensable gas of <1.5% as required in the EN378 standard (see Transfair engineering: Designing and prototyping of refrigerator and freezer cooling circuits, Düsseldorf 2000, p. 80) should even not be accepted from refrigerator producers for R600a; non-condensable gas values should more be in the range of 0.5%.
- Compressor manufacturers make a lot of efforts to insure a very low content of such non-condensable gases including air and of humidity, to clean better their oil and to avoid that air enter the oil, they supply R600a compressor with under-pressure to avoid solution of Nitrogen in compressor oil. Same efforts are made to keep the evaporator and condensers clean.

So an evacuation system has to solve 3 problems - in addition to the evacuation of the circuit itself:

a) **Removal of moisture** out of all circuit components on low and high pressure side, not possible on R134a compressor oil and very limited on R600a compressor oil, which needs to be controlled by compressor manufacturer),
b) **Removal of non-condensable gas** out of all circuit components including compressor oil,
c) **Evacuation and removal of moisture on the condenser** (high pressure side), if single sited evacuation is used which we do not recommend.

2.2. Single vs. Two-Side Evacuation: Single Side Evacuation Tests

The third problem is known already from the time of the use of CFC-12, but today the problem is increased because it takes much more time to remove through the capillary tube the moisture as we can show by tests and the requirement in this point are much higher as in the past when CFC-12 were used. Following tests were made by us to understand the problem and to find solutions. You can use refrigerator test equipment with pressure transducer to recheck the conditions for your models and to improve the quality control in your factory:

Single Side Evacuation Tests and Results. A range of direct cooler refrigerator models of 120-350l were evacuated by a 12m³/h pump from one side only through the compressor filling tube (low pressure side) and the low and the high pressure side pressure were measured during the evacuation time. The condenser was **not dried** by Nitrogen. The speed of evacuation was the following:

Inside of 6,5 -12 min. the low-pressure side reached the required pressure of 0.05mbar, while the high-pressure side were at the time still on the level of 50-100mbar.
Water vapour pressure is in the range of 20 mbar. That means that the moisture of condenser could not have been removed through the capillary tube by a single sided evacuation.

By further trials it could be seen that the speed of evacuation strongly depend on the content of moisture. The more it was inside the slower the low level of 0.05 mbar could be reached.

If we stop evacuation and let the system pressure equalising , after about 5-7 min. the pressures on both sides were in the range of 5 mbar on both sides. The reason for it is that the volume on the high-pressure side (condenser) is normally in the range of 5-7% in comparison to the low-pressure side (evaporator and compressor volume for direct cooler models made in subtropical version. Such a pressure level would be sufficient to remove the moisture through the capillary if system would get time for equilibration (5-7 min.) and would be re-evacuated again for few minutes. In tropical versions the high side volume can be 30-70% larger, so that the equilibration pressure would be already too high (>5mbar) for charging if the system is only evacuated from one side. Therefore in tropical countries, often even with higher humidity, single side evacuation is very critical and also very long and should not be executed.

2.3. Evacuation Process

Another observation was made on oil and could be made by anyone with laboratory equipment to check the quality of oil in the compressor. If the R600a and R134a compressors are only evacuated for 12 minutes and the connection to the pump will be closed, the pressure will rise from 0.05 mbar often above 10 mbar inside of 30 min. as a result of moisture and non-condensable gas inside the oil. That means also that these moisture and non-condensable gas inside the oil cannot be removed in the normal evacuation cycle of 12 or even 20 min. in the extend needed. So a lot of evacuation technology as set up are not anymore suitable for CFC-free refrigerator production with quality standards and have to be redesigned.

2.3.1. Pre-Evacuation, Stop of Evacuation and Continuation

There are only few ways to remove non-condensable gas - even not trapped by the filter dryer later in a refrigerator – during evacuation. The most use one is to **pre-evacuate and to stop evacuation for a time** to let the non-condensable gas out of the oil and than to finalise evacuation. Moisture cannot be removed out of oil by this way. Therefore 1995-1998 some companies started to let the compressor run during stop of evacuation, but because of some damage on compressor coils years later in the field they stopped it meanwhile.

So a typical evacuation process for R600a systems in Europe is the following today:

> **1-2 Min. pre-evacuation, 6-8 min. stop of evacuation and 15 min. final evacuation, and last not least a strict cleanliness control on components, refrigerant and on processing with drying of condensers and evaporators before integration.** This can be done automatically during Helium leak test. If the control is not as strict a longer evacuation time is recommended, but it does not help if compressor oil and refrigerant are source of humidity, which is from time to time the case for some compressor factories.

2.3.2. Pre-Evacuation, Compressor Run and Final Evacuation

Till 2001 some large refrigerator companies pre-evacuated the R600a system, disconnect the refrigerator from evacuation, run the compressor for few minutes and connect the system again to the pump and continue the main evacuation. During compressor run the non-condensable gas will be squeezed out of oil, and if evacuated underneath 10mbar also humidity will be squeezed out, so this proceeding seems very nice and the fastest. But Electrolux/Zanussi refrigerator factory in Sussegana and other manufacturers stopped it, because they faced some compressor problems on the market. We know meanwhile that the problem is the starting of compressors in the partially evacuated system which can cause damage on the coil. The compressor manufacturer Electrolux/Zanussi allows to run their compressors only above 100mbar, so under such conditions the pre-evacuation time is short (37-45 s), and should be regularly controlled by measurements. But at this pressure the effect of squeezing out non-condensable gas is much lower and humidity with a vapour pressure of 20 mbar will not be removed at all.

Background is the following: **Week point in compressors are the insulation strength of the painted coil wire during compressor start** always with high inductivity which can cause electrical tension spark on a microscopic liquor hairline cracks which step by step damage more and more the coil insulation so that after years the coil fails. The compressor manufacturers test the insulation strength of their compressors at atmospheric pressure in their factory. But some of them claim that the **ionization of gas in partial evacuation is much easier** because of lower resistance than under atmospheric pressure or in high vacuum (like in a neon lamp). Ionization of gas molecules is a part of the process to build up an electrical spark on the coil and to reduce resistance for sparking. Therefore some compressor manufacturers changed their application prescription or removed the guarantee on their compressors if the refrigerator manufacturers are starting the compressor to run during partial evacuation or execute insulation strength test.
But meanwhile we had in addition a fire and explosion accident at Kelon/China because of their compressor run during evacuation; the glass insulation of the electric power supply socket on compressor leaked as result of sparks during compressor run under partial evacuation and after charging R600a passes the glass insulation from inside the compressor and entered the electric terminal box and explode.

The first seconds of starting with high inductivity is the problem, **not the running of compressor during partial evacuation.** It takes a lot of time removing gas and air out of the compressor oil with low vacuum, but surely humidity with a vapour pressure of 20 mbar will not be removable by this proceeding. To start compressor and connect the evacuation pipes on low and high pressure side immediately (a compressor should nor run long with air!) is also possible without any effect on the lifetime of compressor to improve the removal of non-condensable gas out of oil and to speed up the process, but according to my information not done.

Important is to keep regularly under control the content of non-condensable gas and humidity in R600a systems and the humidity content in R134a systems , for example by measuring the pressure increase 30 min or 1h after final evacuation, to control the cleanliness of condensers and compressors and dry them during adequate stages of production so that they cannot get wet again.

As repair of soldered joints after compressor running and oil circulation is more difficult, it is strongly recommended to make a Helium leak test on the total system before the running of the system, normally before evacuation.

If the non-condensable gas was not removed from the system it can be easily identified –especially on an HC-600a system, because the compressor noise is increased.

2.3.3. Flushing with Refrigerant

Liebherr uses HC-600a in their HC-600a refrigerator production to flush and to clean the system. In this case the circuit must have a connection Hansen on both sides during evacuation. On one side few g of HC-600a is inserted and drawn from the other side to clean the system from non-condensable gas and humidity. In this case ex-proof pumps are needed. In addition rests of HC-600a will remain in the compressor oil and therefore the charging quantity must be diminished slightly (see HC-600a repair line concerning recharging quantity).

To avoid the ex-proof pumps and charging quantity problem we recommend to use for R600a systems the method of pre-evacuation, evacuation stop and continuation, but surely the Liebherr method of HC-flushing will have excellent results, if correct applied.

2.4. Evacuation Cycles

Further consequences out of such evacuation tests are the following:

a) **Two-side evacuation** is more reliable to remove moisture on the high-pressure side (condenser) and should be favoured, especially under high humid environment. It allows a 5-7 min. shorter evacuation cycle in comparison to a single sited evacuation. But the a.m. pre-evacuation. plus the stop of evacuation should be executed in both cases first. Afterwards the two-side evacuation have to be executed in the range of 12-15 min. if all components were kept under strict control concerning moisture, or in the range of 15-20 min. if the transport ways and/or storage are long, the work are executed under humidity or the moisture control on components are not fully possible.

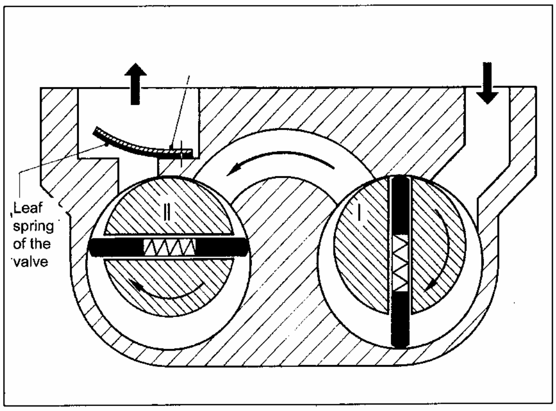
b) If a **single side evacuation** have to be executed - anyhow only possible in a low humidity area with short transport and storage and good quality control on humidity of components –and not suitable for tropical area condenser sizes, the evacuation should be done in 3 phases: 3-5 min. pre-evacuation (<5 mbar), disconnection of pump 6-8 min. to remove moisture and non-condensable gas out of oil and continuation of evacuation for further 15-22 minutes. Some shorten the first interruption and make a second interruption of evacuation.

Single sided evacuation can only be done if the condenser were dried with dry air (<-45°C dew point) or Nitrogen immediately before their mounting on the refrigerator and closing of the circuit.

Under very strict material control and cleaning procedures inside the factory some European companies make the evacuation inside of 12-15 min., that means about 7-8 min final evacuation, but it is really not recommended to do the same under an environment with longer material transport, longer storage, less quality control on raw materials and processing. **To be always on the safe side evacuation time of 20-25 min from both sides respective 25-30 min from one side including the interruption period are recommended evacuation times.**

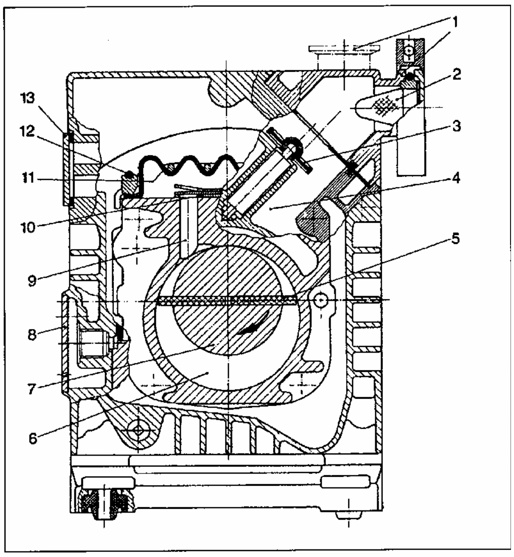
2.5. Vacuum Pumps

2.5.1. 2-stages rotary vane pump



To get high quality evacuation with the a.m. shorter cycle times following vacuum pumps should be selected: **2 stages rotary pump of 8-18m³/h and with final performance of 0.01 Pa (= 0.0001 mbar, partial pressure without gas ballast) measure on the pump without being connected to the cooling circuit. Final total pressure of pump connected to a system should be in the range of <0.005 mbar with gas ballast and <0.002 mbar without gas ballast.** It is a prejudice that larger vacuum pumps >8 m³/h pump speed up the evacuation or removal of moisture or non-condensable gas. Their speed is the same for the small volume of a circuit in a household refrigerator as it is only depending from the diameter of tubes. Therefore what is the sense to increase pumping capacity? More relevant is for the cycle time the cleanliness of the system. Even a 10 years old good quality pump maintained regularly should be able to reach 0,01-0.02 mbar (without being connected to a refrigerator circuit).

Leybold Vacuum Pump (Trivac B):



1. Intake port
2. Dirt trap
3. Anti-suckback valve
4. Intake duct
5. Vane
6. Pumping chamber
7. Rotor
8. Orifice, connection for inert gas ballast
9. Exhaust duct
10. Exhaust valve
11. Demister
12. Spring
13. Orifice; connection for oil filter

Characteristic of all pump are

- Pumping speed – we need 8-18m³/h in our application.
- Compression ration: 1st stage: 1:3 + 2nd stage: 1:4 = totally **1:7**,
- Base pressure, caused by oil sealing or else, the total base pressure is the gas pressure, gas ballast in oil and the oil vapour pressure and
- Final total pressure – we need <0.005 mbar with gas ballast and <0.002 mbar without gas ballast.

Daily Gas Ballast Removal, Vacuum Check and Oil Level Control. The used pumps have to be maintained daily to keep the quality level by

- running in the first 20-30 min in the morning with opened oil venting screw plug to remove gas ballast and moisture out of pump oil,
- oil level check,

- performance check with Pirani pressure instrument: If the performance value exceeds 0.05 mbar after complete exchange of sealing, it is time to replace them on such a production line and to use them for repairs.

Oil Change. Every half up to one year the oil, ballast filter and perhaps even sealing should be replaced according to the recommendation of the manufacturer of pumps.

2.5.2. Comparison Table of Standard 2-Stages Rotary Vane Pumps

Features	Leybold Trivac B	Galileo Vacsound	Edwards RV	Alcatel Pascal SD
Product range (Pneurop)	7 sizes: 1,6-65m³/h	7 sizes: 5-80m³/h	4 sizes (SV): 3,3-12m³/h	7 sizes: 4,8-100m³/h
Model for our application Pumping speed (50Hz)	**Trivac D16B 16,5m³/h**	**Vacsound D18ECO 17,4m³/h**	**RV12 12m³/h**	**Pascal SD2021 15,5m³/h**
Forced lubrication by built in oil pump	Provided for all sizes	Provided for all sizes	Provided for all sizes	Not in size needed, only for large model≥33m³/h
Easy assembly of pump	Yes	Simplest assembly	More difficult	More difficult
Vane design	2-stages/no spring	2-stages/multi spring	2-stages/multi spring	2-stages/multi spring
Intake exhaust	Vertical or horizontal	vertical	vertical	Vertical or horizontal
Anti-suck-back valve	Built-in, no pressure rise, no contamination, full shut off of vacuum line, failure safe	Built-in, no pressure rise, no contamination, full shut off of vacuum line, failure safe	Built-in, oil vapour contamination of vacuum line occurs at any pump stop. No failure safe	Built-in, oil vapour contamination of vacuum line occurs at any pump stop. No failure safe
Manual gas ballast	Provided	Provided	Provided	Provided
Built-in oil filter	Located in Exhaust channel	Metallic strainer on oil pump intake,	Strainer on small-med. Filter on large	none
Exhaust filter	Available	Available	Available	Available
Final total pressure without gas ballast after 10 years of use (2 shifts/day)	>85% of pumps with 0,01-0,03mbar	>85% of pumps with 0,01-0,03mbar	>70% of pumps with 0,01-0,03mbar	>70% of pumps with 0,01-0,03mbar
Sales prices for naked pump (in line quantities)	~ € 2400	~ € 2000	~ € 1800	~ € 1850

The final total pressure of pumps connected to a system should be <0.005 mbar with gas ballast and 0.002 mbar without gas ballast.

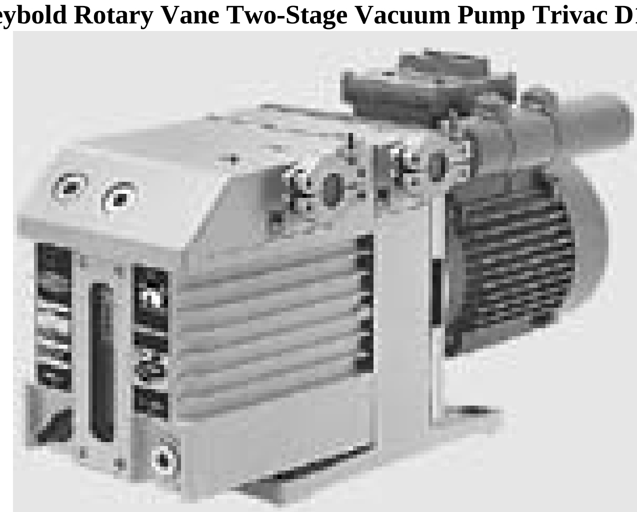
Relevant for the quality of the pump is that it can run 10-20 years in 1-2 shifts per day without any problems. Only oil has to be refilled and 1-2 times per year replaced as well as the oil mist filter. After 2-4 years of use also sealing could need to be replaced, but nothing more. Under the reliability aspects following models can be recommended by us:

- **Leybold Trivac Version B model D16B,** but not the other versions not as good or for other application or
- **Galileo Vacsound D18ECO,**

always with 2 DN25 PVC hoses (2m) and Hansen, DN25 cross, oil mist and exhaust filter are recommended.

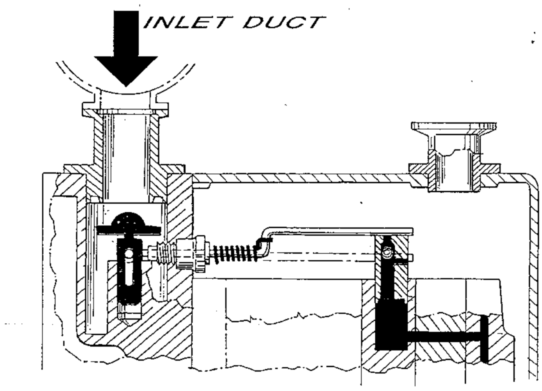
Galileo Rotary Vane Two-Stage Vacuum Pump D18

Leybold Rotary Vane Two-Stage Vacuum Pump Trivac D16B

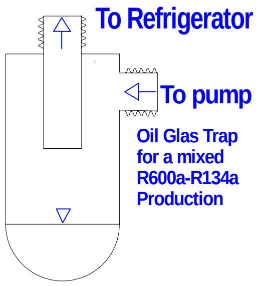


In addition at least 1 **Pirani gauge** with Pirani head (and always 1 spare head on stock) is needed to make the regular control and maintenance on the pumps.

Evacuation pumps - especially in countries with power failure - should have an **anti-Suck Back Valve:**



Anti-Suck Back Device is the best as no oil can move from pump to already evacuated refrigerator. Some pumps have anti-suck back valves, either mechanical or as solenoid valve, to avoid that in case of power failure oil from the pump can be sucked into the cooling system already evacuated. The Galileo and Leybold pumps have such an anti-suck device. Also a venting solenoid valve, which will vent the vacuum pump in case of power failure, will help to avoid that any oil from the pumps can enter into the refrigerator circuit. Such an anti-suck device is absolutely needed, not only in a country with power failure, also in cases the pumps on the line was stopped for other reasons.



Suction Condensate Separator or Glass Trap. A suction condensate separator or glass traps cannot really replace anti-suck devices, because it has the disadvantage that in case of power failure all pump oil levels have to be checked before continuing the evacuation process.. Suction separators are needed in repair of already run refrigerators (see 2.9.), because in such cases oil will be in the circuit. Also in evacuation lines used to evacuate R134a and R600a with different oils such condensate separators on suction line is needed to avoid oil mixing. This suction device is not identical with the ballast exhaust filter.

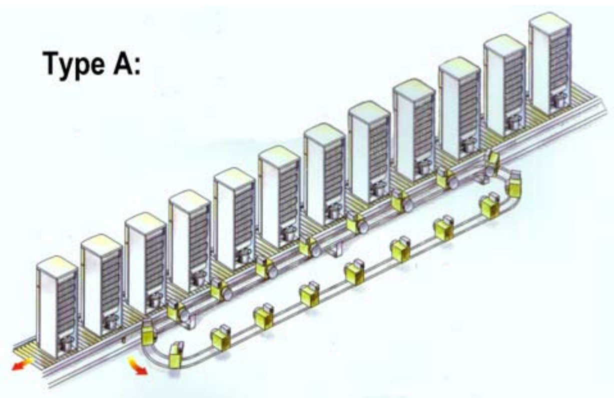
Further a set of spare parts are **needed, consisting of pump oil, gasket set, oil mist filter, exhaust filter.**

In full automatic lines with process control a solenoid valve to open automatically gas ballast 30 min. before starting of production with 30 min timer is useful. In countries with cheap labour this can and has to be done daily by a worker starting 1h before the regular shift to make the 30 min gas ballast phase manually.

2.6. Carousels

If cycle times of <1min. are required a one loop carousel for pre-evacuation, evacuation stop or compressor run and final evacuation is recommended as it is the most economic way with the least space required. The evacuation time of each refrigerator is between 15 min. and 30 min. A short evacuation of 15 min. can only be recommended if the refrigerator is evacuated from 2 sides (not only from compressor filling hole), if - in case of R600a systems the evacuation is interrupted after about 1-2 minutes of pre-evacuation for about 6-8 minutes to remove non-condensable gas - and if in case of R134a and R600a all circuit component including refrigerant are kept under very strict control, that no moisture and in case of R600a non-condensable gas can enter them. Only few companies can realize this condition without taking quality risks.

There exist at least **3 types of carousels, including or excluding pre-evacuation and evacuation stop**:



Type A is the less economic way, which needs nearly doubles as much pumps as the Type B and C. If the pre-evacuation (about 1-2 min.) and the evacuation interruption of 6-8 min. is done before the carousel about 30% less pumps are needed.

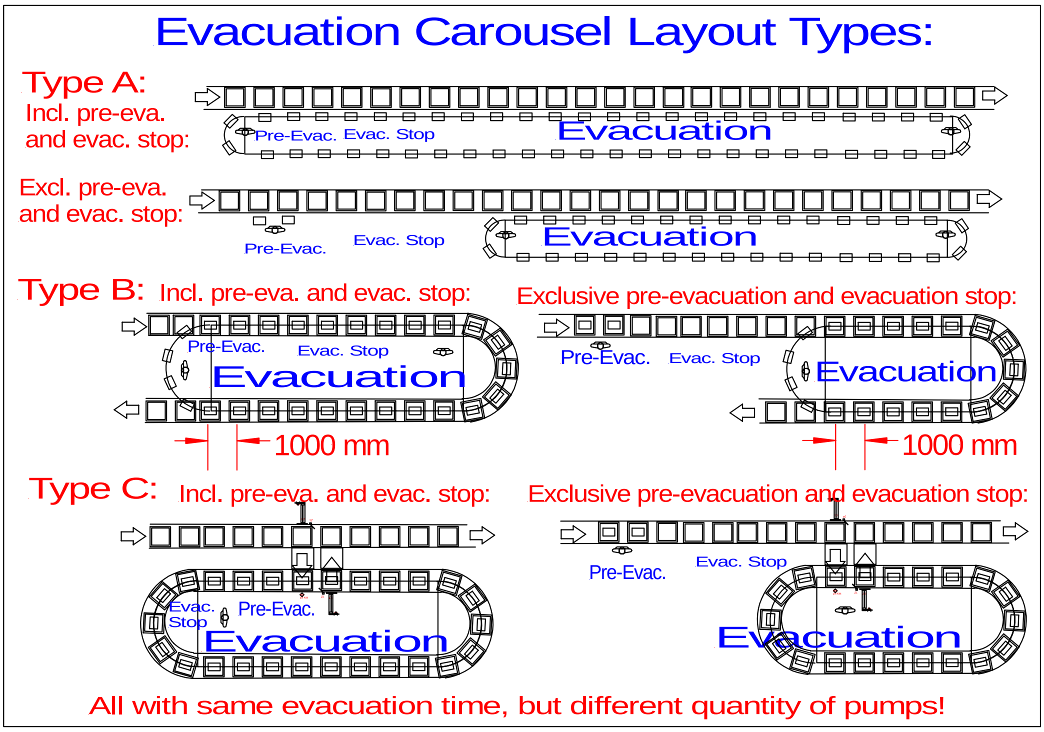
Quantity of pumps n=2*((evac. time t [s]/Cycle time ct [s])+3)*1.1 with time t including or excluding the evacuation stop. The factor 1.1. is to get +10% reserve pumps.

The 1-2 pre-evacuation pumps can be separate as stationary on the line and an line area in which the evacuation is interrupted (6-8 Minutes) to reduce needs of pumps to be installed. By this way about 30% of pumps can be saved.

In some carousels of type A the pumps are not on one chain, but are driven on the back loop faster, to reduce needed quantity of pumps for a given capacity.

Type A can have horizontal or vertical loop of pumps.

The carousel **types B and C** need only half of pumps are needed for type A, if pumps are moved by a fixed chain; nearly all pumps are connected. Therefore type B and C are more economic, especially if no pumps are installed in the area in which the evacuation is interrupted for about 6-8 min. They can have pumps on ground or above the refrigerators in high:



By this way following quantities are needed:

Type B: Quantity of pumps n=(evac. time t [s]/Cycle time ct [s])+4)*1.1

Type C: Quantity of pumps n=(evac. time t [s]/Cycle time ct [s])+2)*1.1

with time t including or excluding the evacuation stop. The factor 1.1. is to get +10% reserve pumps.

The needed total evacuation and evacuation interruption time of a refrigerator is in the ranges of minimum 19 min and maximum 26 minutes, depending on the a.m. points. For cycle times of 30, 45 and 60 s following quantities of pumps for Type B and C are needed:

Cycle Time [s]	Con-veyor [m/min]	Disconnec-ted pumps Type C-B	Pumps during pre-evacuation and evacuation		If any, pumps during evac. interruption		**Total pumps without pumps during evac. interruption**		**Total pumps with pumps during evac. interruption**	
			14min	18min	5min	8min	14min	18min	19min	26min
							C - B	C - B	C - B	C - B
60	1	1 3	14	18	5	8	15-17	19-21	20-22	27-29
45	1.3	1 3	21	27	8	12	22-24	28-30	30-32	40-42
30	2	2 3-4	28	36	10	16	30-32	38-40	40-42	54-56

To the totals according to selected evacuation time, type of carousel B or C including or excluding pumps in time of evacuation interruptions 10% have to be added as reserves on stock.

For lines with cycle times of 2 min or more stationary pre-evacuation pump with 2 hoses can be used as this pre-evacuation of 3-5min. can be done from one side only through the compressor filling tube.

2.7. Vacuum Pump Oils

Lubricating oils for rotary vane vacuum pumps use in the refrigerator industry to evacuate refrigerator cooling circuits must fulfil following conditions according to Leybold and Galileo:

1. Low vapour pressure at high pump temperatures (<1x10^{-5} mbar at 25°C up to <3X10^{-3} at 100°C),
2. Minimal water content and water uptake,

3. Flat viscosity characteristics (SAE30, 90mm²/s at 40°C up to 10mm²/s at 100°C),
4. Excellent lubricating properties,
5. Resistance against cracking upon mechanical stress, thermal and chemically against used media.

Galileo and Leybold vacuum pumps having anti-suck devices to prevent mixing of compressor and vacuum pump oil, so the criteria, that the compressor and vacuum oil should be compatible and mixable, are not relevant.

Following vacuum pump oils are used:

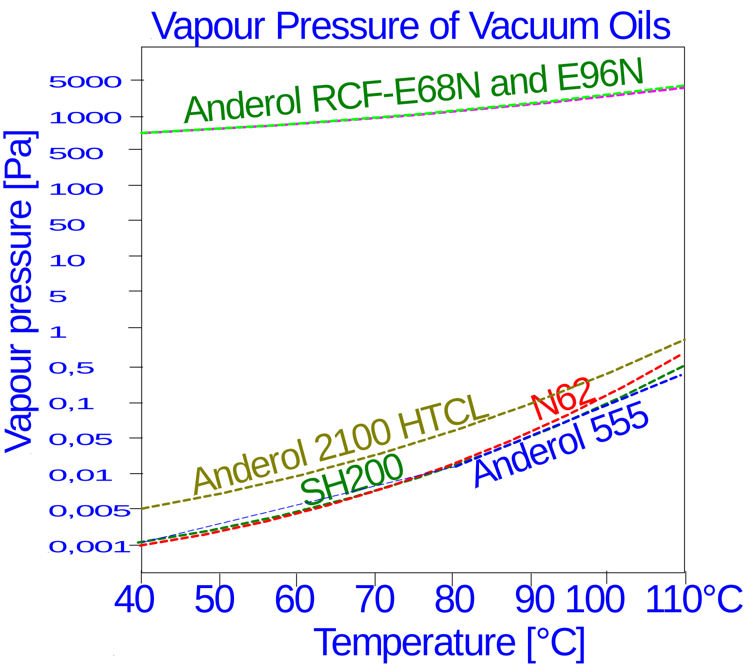
Mineral Oils. Mineral oils are products distilled and refined from crude oil. These are mixture of compounds, depending of treatment, grouped according to paraffin-base, naphthenic or aromatic, with flash point >250°C. To reach low ultimate pressures, mineral oils are selected on the basis of a core fraction. There exists special treated mineral oil which fulfil all above conditions for vacuum pumps like a.m. low vapour pressure, minimal water content and uptake, flat viscosity, excellent lubricant, resistant against mechanical stress thermal and chemical.

Synthetic Oils. Synthetic oils are produced by a chemical reaction. They differ widely in their chemical structure, composition physical and chemical properties. Synthetic oils are only used in those cases where special properties of the oil are required which can not be fulfilled by mineral oils. Following group of synthetic oils are used in vacuum pumps:

Polyalphaolefin (PAO) Oils. Polyalphaolefin oils are synthetic hydrocarbons which are paraffin like, but have a uniform structure. Thermal and chemical resistance is better compared to mineral oils. Elastomer compatibility and resistance against hydrolysis are comparable to mineral oils.

Ester oils. Ester oils are organic compounds with high thermal resistance to cracking compared to mineral oils. The chemical resistance depend on the type of ester oil. The ones used in our application to be compatible with R134a compressor oil, are hydroscopic and not and completely resistance against hydrolysis and have a higher vapour pressure. Therefore household refrigerator manufacturers – even the one who make R134a refrigerators avoid it today to reach higher cooling circuit qualities.

Perfluorinated polyether (PFPE). PFPE are used to pump chemically aggressive media like oxygen (O_2), fluorine F_2 and uranium hexafluoride UF_6, not in our application.



The manufacturer of Anderol Polyesteroil RCF-E68N and RCF-E96N meanwhile learnt that such oils are not very good for vacuum pumps used for the evacuation of refrigerator cooling circuits: they have too high vapour pressure for the evacuation of a household refrigerator so that the final pressure after evacuation is not very good. Meanwhile they replaced it by the new Polyester oils 2100 HTCL and the Diester oil Anderol 2100 HTCL, which both would be under this aspect of low vapour pressure now acceptable. But in general ester oils are hydroscopic and can accumulate and increase humidity inside the cooling circuit. Therefore it is not useful to use such oils in pumps for R600a refrigerators.

In past it was recommended to use ester oils in pumps to evacuate R134a refrigerators. But today even this is not anymore recommended because good pumps, like the ones from Galileo and from Leybold, do not allow any mixing of oils of compressor and of pump and good treated mineral oils and synthetic mineral oils, like Leybold N62 and Galileo SH200, have such a low vapour pressure that even mineral oil vapour cannot mix with the ester oil of R134a compressor. Therefore such special mineral oils are recommended in this application not only for R600a refrigerators, also for R134a refrigerators.

2.8. Converting Pumps from Evacuation of HFC-134a to HC-600a Systems

The compressor oil of HC-600a refrigerant is again mineral oil, and not anymore expensive and hydroscopic ester oil, as used for HFC-134a compressors. Therefore after phasing out the use of HFC-134a the pump oil of all pumps should be recharged to cheaper and easier to handle mineral oil, if the mineral oil with low volatility was not anyhow used which does not need any cleaning now. If ester oil was used in the pumps the same cleaning procedure as described in last chapter, can be used to remove ester oil and replace it with refined or better synthetic mineral oil of low volatility. **For R600a system evacuation we recommend to use the synthetic mineral oil with low volatility.**

2.9. Special Conditions for using of R600a and R134a (or R134a and R12) in the same Evacuation or Charging Lines

In this chapter we like to mention some special conditions which concerns the working with the 2 refrigerants using 2 different types of oil in compressors: Mineral oil (R600a, R12) or ester oil (R134a systems). In this case special precautions have to be made to avoid that the 2 oils will mix, which easily can happen in case of power failure during manufacturing and sucking back of oil from the already evacuated refrigerator circuit, if there is no anti-sucking device installed inside the pump.

Oil Problem and Separation of Mineral from Ester Oil in Evacuation and Charging Lines. R134a compressor systems cannot work with standard mineral oil as used for R600a, R600a blends and R12 systems. R134a compressors need ester oil, which is hydroscopic. Mixing of this 2 different oils must be absolutely avoided! Therefore any oil mixing must be prevented during evacuation, by anti-sucking devices built into pump (a must) and a condensate separator (only recommended) or by a complete separation of evacuation, charging and repair lines of such systems using different oils and refrigerants to avoid mixing of charging and of mineral and ester oil.

Mixed Production Lines. In cases such separation cannot be made in the production and the same evacuation and charging line have to be used for compressors charged with mineral oil and others charged with ester oil, special precautions has to be added **to avoid charging of wrong refrigerant into the cooling system** (R134a or R600a marking on the backside) and mixing of different oils from compressor and vacuum pump under normal operation and under power failure. In cause of power failure the already evacuated refrigerator cooling system will suck back oil from the pump is there is no anti-suck back valve built inside the vacuum pump. In such evacuation lines with HFC-134a systems mixed with HC-600a (or CFC12) either the pumps should be filled with ester oil or with the less expensive synthetic mineral oil with low volatility (like SH200 or N62) and for safety a condensate separator should be added, which is a must, if repaired refrigerators which had run already have to be evacuated again.

The evacuation time for R134a systems is normally prolonged to remove in the last stage any residuals, gasses or moisture from the system. Also the removal of gas ballast (20-30 min. each morning) out of the pump is much more important for R134a as in the past when R12 was charged, especially if the pump is filled with hydroscopic ester oil.

The **repair of R134a and R600a (or R600a) on the same pumps** is restricted by following conditions – in addition to the a.m. conditions for mixed evacuation lines:

- **A system already charged with** R600a must be evacuated with **burst free evacuation pump** or in the first stage with venture pumps, and not with standard pumps.
- **Refrigerators already running** during evacuation as needed in case of R600a or during performance tests **should be repaired on separate pumps,** the R600a (or R12) ones on pumps with mineral oil and the R134a one on pumps filled with ester oil **or on pumps with oil separator on suction** - beside of the already mentioned anti-suck back valve.

2.10. Vacuum meters

Vacuum pumps have to be controlled by a vacuum meter, some even install on each pump a vacuum meter with programmable low and high vacuum switches. Pirani sensors are mainly used in this pressure level of 10^{-3} Pa up to 10kPa. Good instruments are

- Galileo VG300, 1 channel, with 2 programmable switches and with Balzer/Leybold Pirani sensor TPR250, or
- Leybold Center TWO (2 channels, programmable switch) or Combivac 2T and Leybold TTR91 Pirani sensor.

2.11.Vacuum tight quick couplers and tube adapters

Transfair recommended to use quick adapter and Hansen coupler to connect refrigerator filling tube and hoses of pumps, helium charging board and refrigerant filler, which consists of following parts:

Quick Adapter from Vulkan Lockring QAA-04 (6mm), QA-05 (8mm) with R1/4” connection to fit with **male coupling** QCM-04 (for R600a) or QCM-04H.NBR (for R134a); inserts QAI-04 (6mm) or QAI-05 (8mm) and gaskets QAG-04 (6mm) or QAG-05 (8mm). This are cheapest on the market.

Quick Adapter from Refco 14550 with ¼” NPT with 2 pcs. **Inserts** 14520 in 6mm or 14530 in 8mm and 1 **Gasket** 14502 in 6mm or 14503 in 8mm to fit to

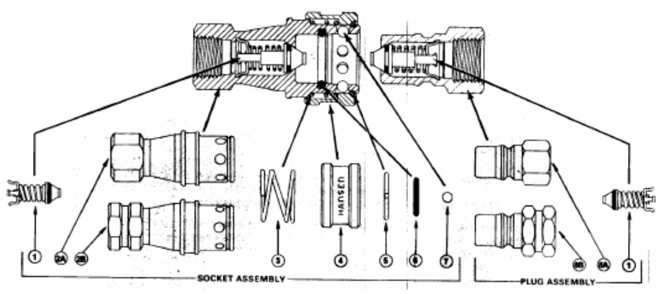
Original Hansen plug 2-K-16 with Buna N sealing good for Isobutane, but bad for R134a) ,
For R134a the version **2-K-16-118** is best with Neoprene sealing).

Original Hansen socket 2-H-16 with Buna N sealing good for Isobutane, but bad for R134a.
For R134a the version **2-K-16-118** is best containing Neoprene sealing).

Hose specific male adapter, for example ¼”NPT- SAE ½” (called U1-8B) or else, depending on hose connector.

Such couplers are made according to **ISO7241-1 Series B.** But they can have American ¼”NPT or European ¼” female threat. Relevant is the sealing material: For R600a NBR (Buna N, Perbunan), H-NBR, FKM (FPM,Viton), but for R134a all sealings are not good, but Cloroprene (CR, Neoprene) or FFKM are used. Also Rectus has such couplers: male 72 SB IW13 MPX or female 72KB IW13 MPX both with Perbunan and G1/4”. The Hansen coupling copies from Faster and other are not always as as reliable as originals! Sealing sets should be available and regularly exchanged to avoid leaks.

Following parts must often to be replaced during refrigerator production to insure quality production:



About once per 2 weeks up to once per month in 2 shifts production:

- **Adapter Gaskets** in quick adapter
- **Hansen O-ring set** consisting of **914-3** Buna N and **2H09** Teflon o-ring in Hansen socket
- **Hansen O-ring set** consisting of 914-3-118 Neoprene and 2H09 Teflon o-ring for R134a in the Hansen socket

About once per month:

- **Hansen socket or plug valve** VA-2HKA with Buna N sealing for Isobutane in the Hansen plug or socket.
- **Hansen socket or plug valve** VA-2HKA-118 with Neoprene sealing for R134a in the Hansen plug or socket.

2.12.Pressure Unit Conversion Table

Internationally agreed today is the use of Pa instead of bar, Micron, Torr or Psi; practically bar in Europe and psi in USA is still more used.

PRESSURE UNIT CONVERSION TABLE

	Bar	**mbar**	**Pa**=1N/m²	**atm**	**Torr**=mmHg	**Micron**=mTorr	**psi**
Bar	1	10^3	10^5	0,9869	750	$0{,}750*10^6$	14,773
mbar	10^{-3}	1	10^2	$0{,}9869*10^3$	0,75	$0{,}750*10^3$	$1{,}4773*10^{-2}$
Pa=1N/m²	10^{-5}	10^{-2}	1	$0{,}9869*10^{-5}$	$0{,}750*10^{-2}$	$0{,}750*10^1$	$1{,}4773*10^{-4}$
Atm	1.01325	$1{,}01325*10^3$	101325	1	760	$0{,}760*10^6$	14,696
Torr=1mmHg	$1{,}3332*10^{-3}$	1,3332	133,32	$1{,}32*10^{-3}$	1	10^3	$1{,}9336*10^{-2}$
Micron=mTorr	$1{,}3332*10^{-6}$	$1{,}3332*10^{-3}$	0,13332	$1{,}32*10^{-6}$	10^{-3}	1	$1{,}9336*10^{-5}$
psi	$6{,}7691*10^{-2}$	67,691	$6{,}7691*10^3$	$6{,}8046*10^{-2}$	51,715	51715	1