transfair

CFC free refrigerator technology / technologie de réfrigérateur sans CFC / FCKW freie Kühlschranktechnologie

GmbH

Transfair Engineering Survey:

R600a and R134a Refrigerant Charging in the Household Refrigerator Industries Today

Walter Dirk Adler

Düsseldorf 11/2006

Transfair GmbH
Mörsenbroicher Weg 179
D-40470 Düsseldorf /Germany
Email: Transfair_GmbH@t-online.de
Internet: www.transfair.info

Content

3. R600a and R134a Charging Lines

There are many manufacturers of industrial refrigerant charging boards in the world: Agramkow, Galileo TP, PCU, Servequip, Frigofrance, Toyo Oil Machinery, Robinair, but only 2 which have the accuracy (<1g) as needed today for smaller household refrigerators with capillary tube: Galileo TP, Italy and Agramkow, Denmark. Therefore we concentrate on these 2 only. Furthermore their exist mainly in China copies of the Agramkow charging machine.

3.1. Charging Board Accuracy in Household Refrigerator Production

Accuracy. Household refrigerators with capillary as throttle device needs high charging accuracy. Modern, recently developed high efficiency designs have no suction accumulator anymore, but using a vertical u bend tube to avoid that liquid gas can enter the suction line and destroy the compressor. In addition to optimise the cooling circuit, to reach optimal superheat values in general the filling of gas is on the low border of the filling area tolerable by a system to allow running. Therefore – beside of lower acceptable leak rates (=/<1g/a) – a higher charging accuracy is recommended in the range of 1g for HFC-134a and 0,5 g for HC-600a. This can normally be reached by slower charging speed. If we take into consideration

- the higher requirements in evacuation,
- consequently normally the longer time of pressure rise test,
- slower charging speed to increase charging accuracy, specially for small refrigerator models, like in Europe, China, India and many developing countries,

the cycle times for gas charging will increase slightly to 20-30 s for the fastest models working with this accuracy requirement.

Eventually foreseen oil charging on the same position as sometimes used should be stopped if smaller models with low charges and high accuracy have to be produced.

The HFC-134a and the HC-600a charging boards have different requirements.

Galileo Frigus N11 (0.5 g accuracy <100g)

3.2. HFC-134a Charging Boards

Charging boards used for HFC-134a must be free of mineral oil, so the evacuation pump must use either ester oil or mineral oil with very low volatility. Existing R12 charging boards can be re-used also for R134a by cleaning it from normal mineral oil, if the parameters of R134a exist in the program (for the re-use of pumps see last chapter). For a survey of boards see chapter 3.5. HFC-134a has a high global warming effect (1300 times higher than CO_2), is therefore under international control and should be avoided.

3.3. R600a Charging Boards

R600a is flammable and explosive. Therefore R600a charging boards are specially designed for ex-zones, have special safety devices in the board itself, in the R600a pipeline, around the charging place, like exhaust ventilation, fire protection and alarm and gas sensor systems (see chapter 3.7). Such lines can be made and can run very safe, if correct done, but the problem is that many factories neglect the technical and legally needed safety devices and precautions in their R600a installations, so that persons are already killed and factories were blown up; all installations, which I visited in China using Hydrocarbons in the production are unsafe, illegal and sooner or later will blow up, kill further people and will put others in prison. This is not necessary, but some people start to learn only, when they have enough time to think about it in prison. Therefore we will go in some details in a separate chapter 3.7.

Because of higher volumetric capacity of R600a the charging quantity in g is very low in comparison to R12 or R134a systems (20-50g). Therefore a much higher accuracy in the charging quantity is needed – in combination with new refrigerator designs without accumulator and higher super heat - a charging board with accuracy of 0,5g, for small models is recommended. Such high accurate charging boards are not anymore delivered in a special version to fill oil in addition to refrigerant as used in car air conditioners.

3.4. Dosing Systems: Flow meter or Volume Measurement by a Potentiometer

Production charging boards are dosing the charge amount with 2 different methods: either with

- **a mass flow meter** or with
- **a volume measurement**. by a potentiometer

Agramkow uses mass flow meters while Galileo have volumetric cylinders with piston connected to a potentiometer to measure stroke of the rod. Both reach the required accuracy of +/-1g for small R134a charges underneath 200g respective +/- 0,5 g for small HC-600a charges. The Galileo Frigus H reaches the highest accuracy today, which is important in high efficient systems with low refrigerant charges and higher superheat. The mass flow is not mechanical while the moving piston with sealing is mechanical. Nevertheless the experience shows that the sensitive mass flow meter does not have longer lifetime and higher reliability as the mechanical dosing cylinder. In opposite, the last can be repaired by replacing cheap sealing, while the mass flow meter in total has to be replaced, which is expensive. Both need regular calibration by filling an evacuated vessel and weighting it to keep accuracy.

Both systems need permanent compensations of temperature and pressure fluctuation during operation to enable the accuracy. The Agramkow charging board needs in addition an accumulator (6 l) for building up enough pressure for the measurement while the dosing cylinder with piston itself produces the pressure needed to remain liquid for measurement. In the past there was a difference under which temperatures the charging board can operate. But meanwhile nearly all new machines from both companies can operate in temperatures of 15-45°C, the Galileo machine even up to 50°C.

Agramkow Proforce

3.5. Charging Board comparison table

We divide the Galileo and Agramkow models in 3 groups according to the required refrigerator capacity per year. We mention also the cycle time, though more relevant for this classification is the total workload and reliability for our opinion:

Charging Board comparison table (10/2003):

CAPACITY /shift/year:	Cycle times/ refrigerator:	HFC-134a Charging boards		HC-600a Charging boards	
		Galileo	**Agramkow**	**Galileo**	**Agramkow**
85000 -175000 refrige-rators	**15-45 s**	**Algor** with Feed-ing pump RP2 **Accuracy:** +/- 0.5g (<300g); <0.4% (>300g) [1)]	**Proforce** with feeding pump **Accuracy:** +/- 0.5g (40-100g) +/-0.5% >100g [1)]	**Frigus N** with - feeding pump RP2 - Cerberus Alarm board - Ventilation system **Accuracy:** +/-0,5g <100g; +/-0,25% >100g [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure.	**Proforce** with - feeding pump R600a - Safe5+ Alarm board - Ventilation **system** **Accuracy:** +/-0.5g <100g ; +/- 0.25% >100g [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure. Installation must be kept perfect to avoid explosion.
50000-100000	**35-60 s**	**Habilis** with feeding pump TP2000 **Accuracy:** +/-1g (<200g); <0.5% (>200g) [1)]	**EMAC 25** with external feeding pump RSS40 **Accuracy:** +/- 1g (<100g); <1% (>100g) [1)]	**Habilis** with - feeding pump RP2, - Cerberus Alarm board - Ventilation **Accuracy:** +/-1g (<200g); <0.5% (>200g) [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure.	**HC.1** with - feeding pump - Safe5+ Alarm board - Ventilation **Accuracy:** +/-0.5g 20-50g; +/- 1% >50g [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure. Installation must be kept perfect to avoid explosion.
30000-60000	**45-60 s**	**Habilis** without feeding pump **Accuracy:** +/-1g (<200g); <0.5% (>200g) [1)]	**EMAC 10** without external feeding pump **Accuracy:** +/- 1g (<100g); <1% (>100g) [1)]	**Habilis** with - feeding pump RP2, - Cerberus Alarm board - Ventilation **Accuracy:** +/-1g (<200g) <0.5% (>200g) [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure.	**HC.1** with - feeding pump - Safe5+ Alarm board - Ventilation **Accuracy:** +/-0.5g 20-50g; +/- 1% >50g [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure. Installation must be kept perfect to avoid explosion.
<30000 refr.	**>/= 60 s**	**PQ Charge** **Accuracy:** +/-1g (<200g); <0.5% (>200g) [1)]	**Black Sara** **Accuracy:** +/- 3g (<100g); <3% (>100g) [1)]	a.m. **Habilis** with - feeding pump RP2, - Cerberus Alarm board - Ventilation **Accuracy:** +/-1g (<200g) <0.5% (>200g) [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure.	A.m. **HC.1** or if only larger models to be charged: HCS 1 [2)] with feeding pump, Safe5+ Alarm board, Ventilation **Accuracy:** +/-2g (<100g); <2% (>100g) [1)] **Safety:** Low R600a quantity can be released, therefore low risk. High tolerance against equipment and human failure. Installation must be kept perfect to avoid explosion.

[1)] The accuracy depends on the charged quantity (the more charging the more accuracy can be reach, and on the charging speed, slow charging allow better accuracy.

[2)] In household applications the Agramkow HCS board (using volumetric dosing) is with 3g often not accurate enough, but could be used for larger refrigerator models, for larger commercial models and for medium and larger size air conditioners. Because of section valves it is much safer as the other Agramkow R600a charging boards.

The a.m. charging boards are quality wise and from the features comparable with slight differences. The Galileo Frigus and Algor board have quite sophisticated self diagnose software and controls on all process relevant parameters to keep the quality control on a high level. It is a complete computerised diagnose and maintenance work to be made. The Galileo board even identifies smallest leaks from inside the machine to inform the operator 1-2 weeks in advance that maintenance has to be made. But a big difference concerns the safety of the R600a charging boards. In case of any failure the Agramkow machine can cause much bigger explosions (see chapter 3.7.), because much high quantities of R600a can be released.

The price of the comparable systems became in the last 2 years nearer and nearer to each other, the price of boards are today practically the same. But in the accessories (feeding pumps, alarm boards for HC-600a) Agramkow are more expensive, so their system price is still exceeding the system price of Galileo by 10-15%, but not anymore 20-30% as in the past. Agramkow uses Leybold vacuum pumps on their board today, while Galileo TP uses their pump of their sister company Galileo Vacuum.

3.6. Charging Work Cycle

The standard work cycle of such charging boards are:
a) Connection of filling gun to compressor filling tube with Hansen, start of filling cycle
b) In case of HC-charging board: Pre-vacuum to check tightness of system and test if system is already filled with refrigerant
c) Evacuation to preset vacuum value
d) Pressure rise test
e) Charging
f) Filler release (for larger charging boards: automatically or manually)
In cycle time underneath 20 s the raw leak test made by c) evacuation and d) pressure rise test are often removed for speed reasons.

3.7. Safety Requirement on HC-R600a Charging Systems

Already some severe accidents has happened and factories were blown up and people were killed because of some bad charging board designs, wrong safety installations around the charging boards, low maintenance responsibility and bad safety management.

Safety approvals. All Galileo R600a charging boards and mayor Agramkow boards have safety approvals from German TÜV-Süddeutschland, Ulm, the most experience safety auditor in the use of Hydrocarbon in the refrigerator industries in the world, but often the installation of a single R600a line is made by different companies and not interlinked as required. Some make the R600a storage, feeding station and pipelines, other the exhaust ventilation and enclosures and even other the alarm boards with gas sensors are supplied from other sources, so that relevant installation requirement of the safety approval of the charging machine, as fixed by TÜV to use the R600a charging board safely are lost between different responsibilities and neglected; such machine approvals are not valid for installation neglecting the installation conditions. It is recommended, that not only the charging board, the safety board, the feeding system is safety approved, but also the final installation again controlled and safety approved, which is often not the case. At least the supplier of charging board should control the complete installation including the equipment from other suppliers, needed to run the R600a charging board safely (this is legally required in Europe using the CE correctly, but often not practiced) and should not allow to switch on the supplied R600a charging board, if the installation with all required safety devices are wrong and unsafe.

HC-boards separate the electric board with standard electric equipment from the compartment, which contains Hydrocarbon by walls with sealed cable clamps; the HC-compartment is exhaust ventilated and sometimes the electrical board over-pressurised EX-p); the exhaust ventilation and, if needed, the overpressure ventilation, are controlled by pressure switches. In addition a gas sensor in controlling leaks in the HC-compartment. Solenoid valves, pressure transducer, temperature transducers (PT100) and flow meter (Agramkow) or potentiometer (Galileo) in the hazardous zone (ventilated HC-compartment) respective ex-zone 0 (HC-tubes) or ex-zone 1 (potential leak areas) are made intrinsically safe by Ex i barriers (galvanic separation) and Hydrocarbon in the filler is removed after each shot by a pump or by Nitrogen flushing. By this way the charging bard are made safe.

Alarm system and exhaust ventilation. To operate such a R600a line an alarm system must be installed with gas sensors in the charging board, underneath the filling point of refrigerators and in the charging area enclosure to switch off the power supply to the machine in case of gas concentration of 30% of LEL value. Furthermore the charging board itself and the charging area must be efficiently exhaust ventilated, in case of failure of ventilation the power supply to the hazard zone with charging machine must also stop. All safety devices must be regularly controlled and any maintenance intervention must be recorded and the functioning rechecked. In case of failure (no ventilation, Butane above >30% of LEL, broken sensors, no power) the charging board and all electrics inside the charging area must be automatically switched off in a fail-safe manner and the R600a pipeline before the flexible pipe and at the entry point to the building automatically closed by shutdown valves.
The charging board and all metals in the charging area are earthed and the ground is not static loading (conductivity resistance < 10^8 Ohm). Any plastics, hoses etc. must not be charged with static electricity (</=10^6 electric surface resistance).

But there are relevant safety differences between Galileo and Agramkow, which were relevant for Transfair not to integrate any HC-600a charging board from Agramkow anymore, especially not in countries with lower level of work responsibility and safety management.

1) First reason is that the **Agramkow board does not have an internal leak control like the Galileo machine** beside of a gas sensor. During each operation the Galileo machine pressurize the dosing cylinder with valves, the pipeline to the filler

and the filling gun, even a very, very small leak, safety wise not relevant, inside the Galileo board up to the filler, the Galileo board can identify using the potentiometer movement, and inform the operator to inform the maintenance to change the sealing inside the next 2 weeks, but in case the small leak is growing and the requested maintenance are not executed and would in future become a safety risk, Galileo board stops the charging operation till the machine is really maintained and leak free. While the Agramkow machine and all its Chinese copies, depends on the correct working of gas sensor, partially not even installed or not correctly maintained in some installations I have seen. There are often no clear instructions how to operate, to maintain and to control the installations, so that accidents with killed persons will happen.

But the main safety differences between a Galileo and the Agramkow board is the high difference of HC-600a quantity, which can be released in worse case and therefore the high risk level difference, which request much higher safety demand and precautions for an Agramkow machine:

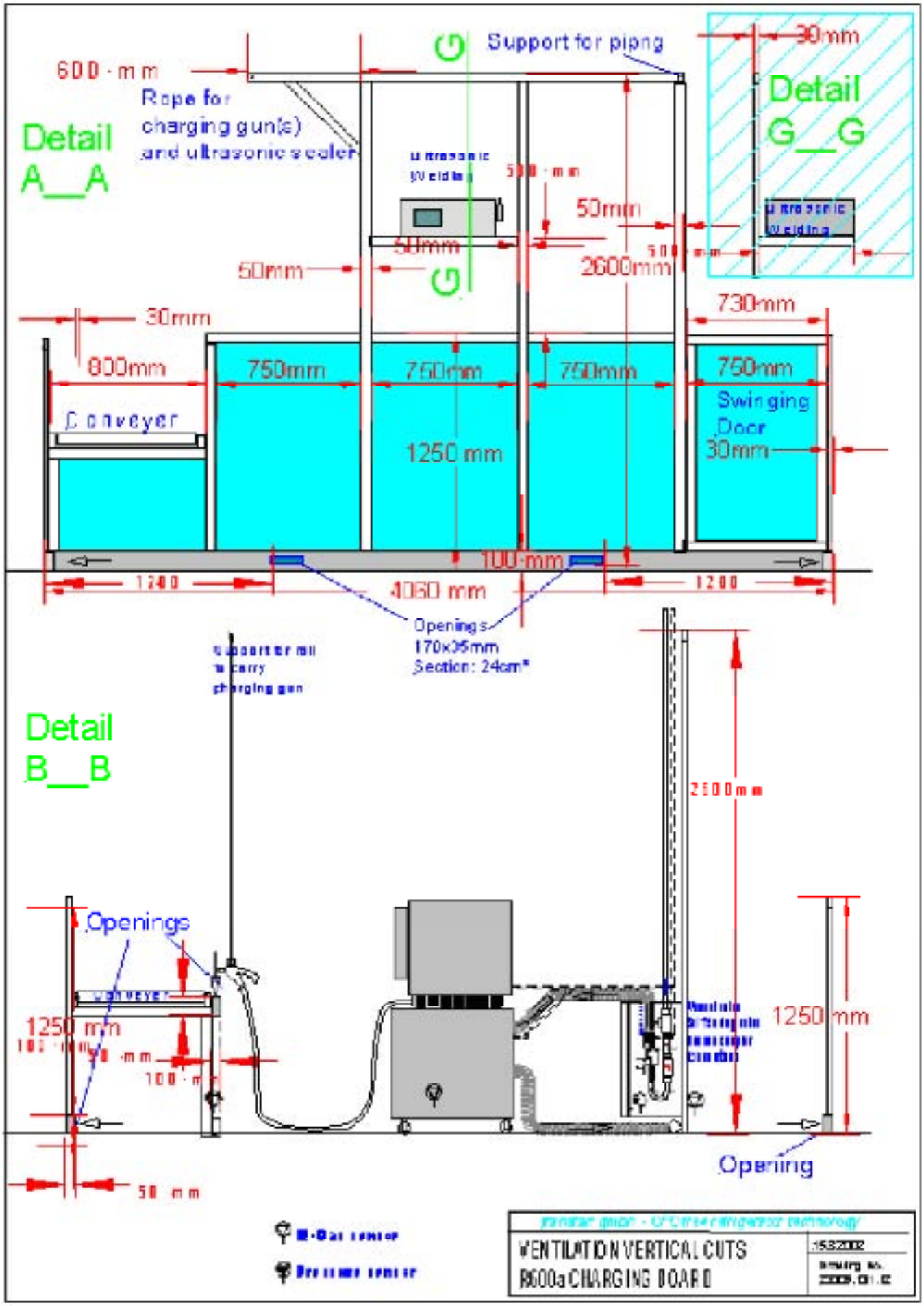
2) **Already over night and in time the charging lines are not operated the Agramkow board has more that 3 kg liquid Isobutane** inside the charging board because of its booster of 6 liters, which built up an explosive atmosphere of 113 m³ (on 1.3 vol. % LEL according to actual valid international standard IEC 61799 (=EN 61799) or 92 m³ (on 1.6 vol. % LEL according to the valid US standards) and which already is **sufficient to cover an area of 361m² of 0.3m height with explosive gas** – this is already the case in time the machine is not working! To prevent any explosion overnight and during off-days the machine must be positioned always in a closed cabin and the gas sensors must always function and the exhaust ventilation must always have power. Any alarm at night must be taken very serious from the guards. A power supply failure in time of a leak could cause an explosion. So the power back up generators is essential and must always function well, must be regular maintained, that means their starting batteries must be always charged. The safety depends on the well functioning of these safety devices (gas sensor system, ventilation system and power back up system) and correct working of operation and maintenance staff including guards over night. While a Galileo machine during stand-by over night and on off-days is already passively safe. Even if the gas sensor system is not working, even if the ventilator does not get power the maximum release of Isobutane from a Galileo charging board is 120-300g, depending which version and configuration, which can build up an explosive atmosphere of 4.6 up to 11.5 m³ which cannot spread outside the protected charging area enclosed by small side walls of 1-1,2m. This is a very big risk difference.

3) If the Agramkow R600a charging board is working the charging gun is connected without any closed valve till the storage with bottle of 45kg, a drum of 450kg Isobutane or a bigger tank, able to blow up a complete factory hall in case of a leak and if one of the safety systems do not work properly. The reason is the following: The Agramkow machines make the dosing by flow meters, which can only measure the dosing quantity under flow of refrigerant, that means the filler during filling is connected by the pipeline till the HC-600a feeding and storage with all interceptive valves open. Even between filing operations during stand-by the Agramkow board is connected with large kg's of burnable and explosive gases, so that in case of a leak huge explosive gas amounts can be released, while Galileo works with dosing cylinder with closed valves on both side of cylinder, so that the risk of release is already minimized by Galileo to 120 up to 300g, depending of the machine and configuration. This is not only a theoretical risk consideration; on 12.11.2001 at 6.03h an Agramkow charging board in the Electrolux factory in Sussegana/Italy, line 3, had a big leak inside the charging board (a pressure transducer broke), so that inside of max. 2 minutes so much HC-600a was released that in 12m distance to the exhausted charging board cabin with open door the explosion started and injured 9 persons, 3 women heavily burned, 1 died, and the lines 3 till 6 inside the factory building burned down. For us it is not so important if Electrolux as user of the line, Agramkow or other companies involved in the installation failed and who will go now in prison; mistakes can always happen, safety devices can fail as well as operators or maintenance men, but the system should be made that it does not have such severe consequences..

4) Gas sensors are good for small leaks, but react too slow (about 20-30s) to prevent accidents caused by bigger leaks, like burst of hoses, break of sensors or joints; therefore Galileo developed around the flexible pipes, filter group, Hansen couplers and the dosing system a detection system which react on such larger leaks in less time as a second to close the machine and pipeline automatically.

We don't like to depend too much on well functioning of all items; we know that operators and maintenance men under strong time pressure can fail. The design of machines and safety devices, the installation and repairs, the safety management concept must be made that human and equipment mistakes do not lead to such catastrophes, as we have already seen and carefully studied several times.

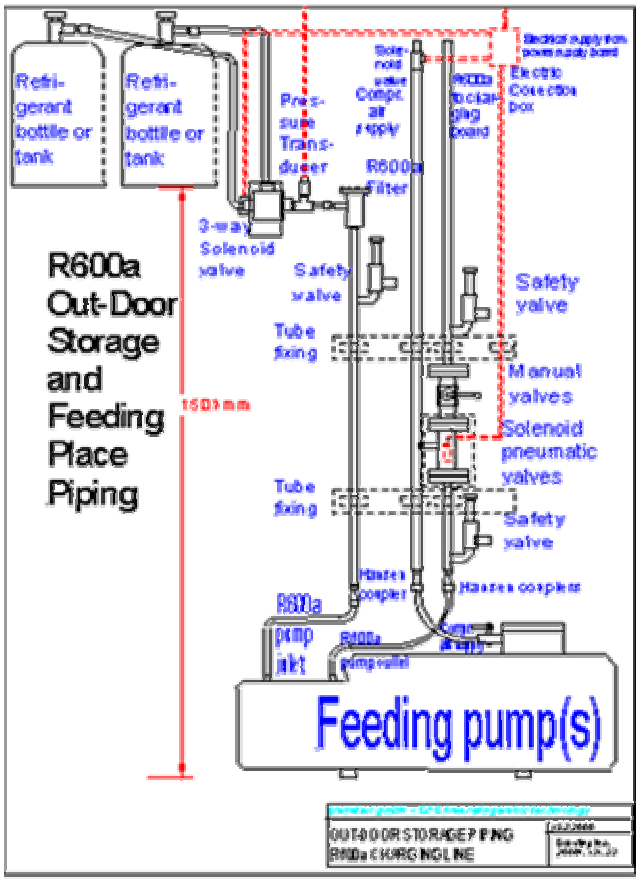
According to the most experienced safety auditor in the world for refrigerator manufacturing lines using Hydrocarbons, TÜV Ulm, Transfair R600a charging lines are very safe and we have developed a concept to keep it safe. And it is not a question of costs, only more intelligence is applied. We use Galileo Frigus and Habilis.



Such side walls not allowed for Agramkow R600a charging boards, which needs completely closed cabins.

3.8. Out-Door Refrigerant Feeding Place

For the HC-600a an out-door feeding place is a must. The charging boards are connected with the a pipeline to the outdoor feeding place either with exchangeable bottles and drums or connected to an underground refrigerant tanks in case of a large scale production. Last is technically the best solution. To avoid production interruptions by an empty bottle or drum an automatic switch over system is used to switch from an empty refrigerant bottle or drum to a full bottle or drum. Such systems can be supplied from Agramkow (RSS…) and by Galileo (Autotank 3). Alternatively a manual switch over system piloted from the charging place using a 3-ways solenoid valve or 2 single solenoid valves and a pressure transducer (for R600a both in Ex-version) or an automatic pressure switch with bottle change over alarm can be used for switch over.



R600a quality problems. Since 2004 all R600a refrigerator manufacturers using bottles or drums face regular quality problems with non-condensable gases. The gas phase contain some percentages of non-condensable gases which at the end of filling causes refrigerator cooling quality problems. Also in underground tanks the non-condensable gases are accumulation more and more in gas phase which must be regularly release. To solve the quality problem on bottles or drums the some hundred grams of bottles of gas phase or 1-3kg of drums out of gas phase outlet must be released savely into a gas release pipe or the bottles or drums should not be emptied till the gas phase, which causes even more material losses.

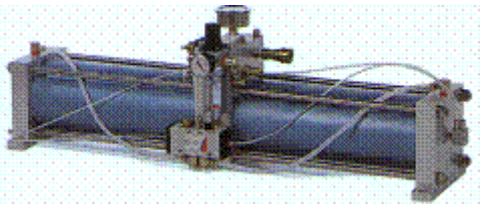
R600a feeding room outside of factory building, for example on outside factory wall near charging area with concrete roof and concrete ground can be made in the sizes needed: a **small storage room** of about 2x1x3m (l*w*h) to position refrigerant feeding pump(s) on ground and some bottles on a platform on 1500 mm height to ensure proper feeding to pump in liquid and to avoid gas bubbles or a **larger storage room** of about 3x2,5x3m **(l*w*h)** to install inside automatic switch over system like **Galileo Autotank 3.** If larger tanks are used they should to be placed separately from the feeding room (at least 3m away) and from the factory building (at least 10m, often 15 m, depending from the stored gas quantities and the national rules) for safety reasons (see next chapter).

Preferable is if the Hydrocarbon bottles have a liquid outlet pipe in the normal upright positions and have not to be connected upside down for safety reasons. For bottles in the upright position the minimum height difference between the lowest level of the bottle and the pump inlet should be 1000 mm.

R600a at -12°C get under-pressure. The RP2 pump can suck a little bit, but underneath a certain temperature value the bottles have to be heated to continue production (see underneath Bottle heaters).

We recommend installing light and switches inside Ex-zone must be in Ex-version, but often they can be placed outside hazard area, for example light in 5 m height in front of door behind side wall plastic window near roof and light switches 5m away of outdoor feeding room, all outside the ex zone, to use only IP65 or IP54 protection. Smoking, open fire, electrical maintenance work or welding in this area in presence of the gas cylinders, tubes, feeding pump or other installations containing hazardous gas have to be prohibited (No Open Fire, No Smoking, Explosive Atmosphere, Flammable Material in ISO **labels** like symbol B 3.2 according to ISO 3864 and others according to local rules).

Feeding pump for R134a for smaller scale production: Galileo TP2000

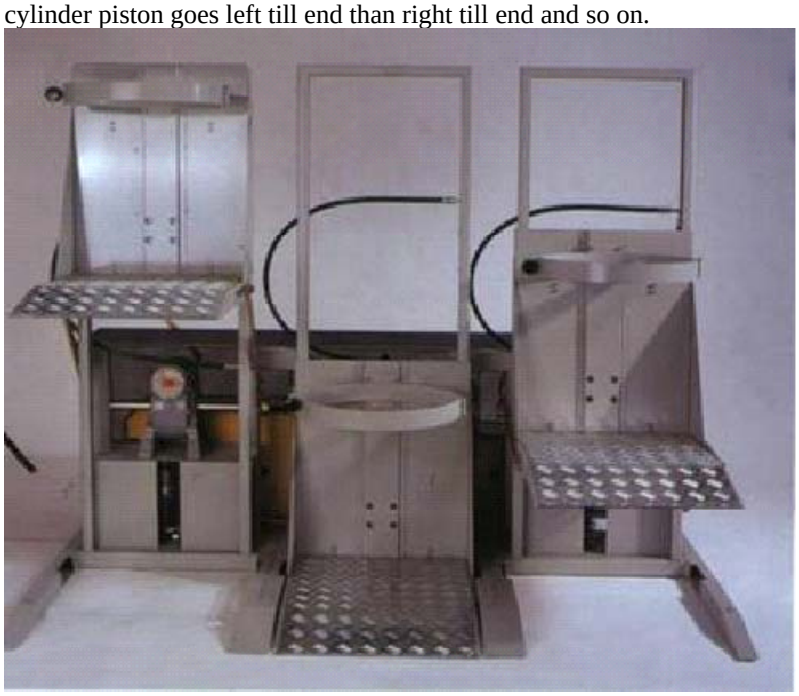


The feeding pumps can work outdoor. In case outdoor temperature can be less than –6°C only dry air as produced by filter dryers should be used.

Feeding pump for R600a and for R134a for medium

and large scale production: Galileo RP2

The feeding pump has a large pneumatic and a smaller refrigerant cylinder and the 2 pistons are interconnected by one bar. The cylinder piston goes left till end than right till end and so on.



Galileo Autotank 3 Automatic Switch-Over System:

If the R600a supplier guarantee low non-condensable gas inside gas phase (<500ppm) or if some hundred grams are released form gas phase under save conditions, a good solution for refrigerant feeding is an automatic switch over system if one bottle is empty to avoid production interruption, and an alarm to exchange inside the next hours (depending of scale of production and sizes of bottles in use) the empty bottle. The Autotank 3 uses a pressure transducer to count the right-left cylinder piston direction exchange of the built-in RP2 pumps. If either

- Inside a programmed time interval (normally 60s) a programmed quantity of direction changes (normally 2) are exceeded, or
- The minimum interval time between a single exchange to the next exchange is less as a programmed time (normally 10 s),

The bottle is identified to be empty when the piston in pump changes more frequent or faster the direction as result of vapour in the pump instead of liquid refrigerant. The Autotank 3 system has 3 bottle lifts (see picture), to lift the heavy bottles to a 1000mm height to ensure liquid entry of refrigerant into the pump. But it can be as well used for large drums, to be as well positioned in such height. The Autotank 3 is suitable for flammable and explosive R600a.

Grounding. All steel construction in the storage hazard area has to be connected to earth.

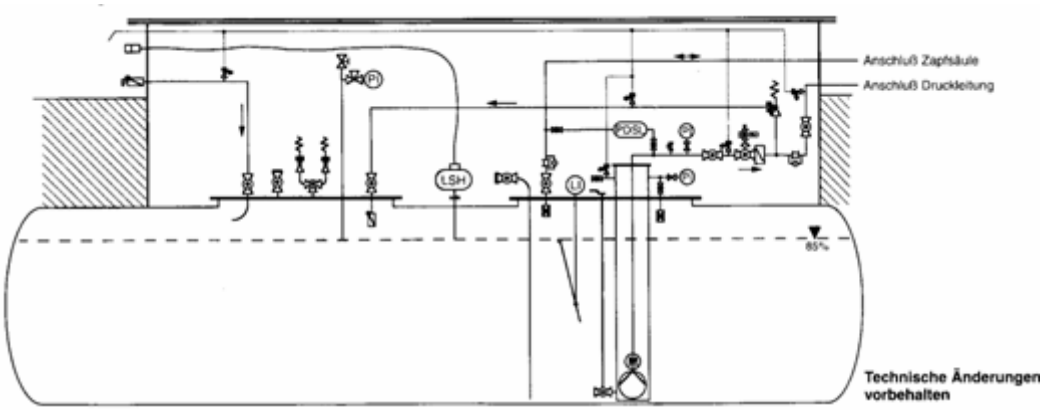
Fire extinguishers. At least 2 fire extinguishers must be available in the area.

Heating of the R600a bottles. Bottle heaters can be supplied for cold environments. The problem of an out-door feeding place is that R600a at -10°C has only 1 bar, at –12°C the pressure is O bar and the suction of the RP2 pump is limited, so that at lower temperatures (<-15 or -20°C), no refrigerant can be sucked out of the bottles, if the bottles are not heated. Therefore in countries with colder winter the out-door solution needs heating of the refrigerant bottle. Self regulating electrical heater band (PTC) and special EX-terminals and plugs all approved for the Ex-zone can be used as these heaters cannot pass the temperatures for which they are designed for. The bands are wrapped around the bottles on these cold days. To avoid heating in warm environment a thermostat switch for switching on < -5°C should be added as well as a residual current device (30mA). To stop heating overnight and to heat up the tanks already 1-2h before the morning shift started, a 24h timer is useful to insert into the circuit.

3.9. R600a Storage

To reduce explosion and fire risk the R600a storage should be separated from the R600a feeding place.

Stationary LPG-Gas Tank. For large scale production an above or underground LPG Gas Tank is useful, if trucks with gas tanks for charging of



this stationary tank are available in the country. If the environment can be colder than -10°C the tank should be underground, covered by 600mm earth (in very could areas by 1000mm earth to insure that it can not freeze. With such tanks we face less non-condensable gas problems. The regular release of accumulated non-condesable gas out gas phase can solve the problem. Normally such tanks have big walls for 10-15 bar, a liquid outlet, an inlet with one way valve, a safety valve, pressure gauge and Ex-proof pressure transducer and level control with alarm for refilling demand. They are normally refilled before being empty, so one tank is sufficient. Between the stationary tank and feeding place a safety approved shut-down valve to be closed in time of no work and in case of alarm and a safety approved safety valve are needed.

Large exchangeable tanks. There exist also larger tanks for R600a supplied from the R00a supplier, like 960l drums and exchanged when they are empty. In this case at least 2 tanks are needed to switch-over from a complete empty one to the full one with switch-over equipment as mentioned in last chapter. Such tanks should have a liquid outlet. 2 solid stands are needed for above pumps to deposit such tanks safely in a height of about 1m by crane or forklift . At least 2 of such tanks should be connected to an automatic switch-over system (see last chapter). The problem is that gas phase contain more non-condensable gas as acceptable, mainly Nitrogen out of cleanings of production lines (in very cold environment of <-18°C, in which drum is under vacuum even air can come in), which should be removed if In cold areas with temperature less than -12°C it is necessary to heat the tanks. Several solutions for heating are possible:

a) Electrical PTC self regulating heaters for Ex-zones approved by an Authorized Body integrated in a bottom support in a shape of a half cylinder with 40-50 mm insulation and insulation mats of 30-40 mm with a grounded metal grid inserted on top and on the 2 other small sides. To avoid heating in warm environment a thermostat switch for switching on < -5°C should be added as well as a residual current device (30mA). To stop heating overnight and to heat up the tanks already 2-4h before the morning shift started, a 24h timer is useful to insert into the circuit.
b) Heating water tubes a bottom half cylinder support in insulation and insulation mats on top and the 2 other sides.
c) Room or container heater either electrical in EX-proof version or by water heaters.

Bottle storage. A bottle storage can be made in open air with roof and fence around or in a natural ventilated room with large openings on ground. Important is that the bottles are protected by chains not to fall down.

Hazard zone. A minimum of 5 m around the R600a in open air storage a hazard zone has to be enclosed by fences and marked with the labels: No Open Fire, No Smoking, Explosive Atmosphere, Flammable Material in ISO **labels** like symbol B 3.2 according to ISO 3864 and others according to local rules. A minimum of 3 m around and R600a storage room with brig or concrete walls and roof is considered as hazard zone and has to be marked with the labels: No Open Fire, No Smoking, Explosive Atmosphere, Flammable Material in ISO **labels** like symbol B 3.2 according to ISO 3864 and others according to local rules.

Grounding. All steel construction in the storage hazard area as well as the pipelines has to be connected to earth.

Lightening arrestors. The hazard area and the pipeline have to be protected against lightening by arrestors in heights and sized according to IEC and local rules.

Fire extinguishers. At least 2 fire extinguishers must be available in the area.