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CFC free refrigerator technology
technologie de réfrigérateur sans CFC
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GmbH

Transfair Engineering Survey:

Refrigerator Performance Testing in the Household Refrigerator Industries Today

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Content

6. Final Refrigerator Functioning Tests

The final refrigerator functional tests have to be executed according to the refrigerator standards applied. The requirements contain at least following tests:

- safety tests according to the international valid safety standards IEC EN UL J GOST etc. 60225 part 1 and part 2-24
- refrigerator performance tests (15-35 min. short test or 70-120 min. test on all models, see next Para.), in Europe and many other areas ISO EN 1552 (2005), which replaced ISO EN 7371/8187/5155/8561 and
- long term test on samples taken from the production in climate simulated rooms to be tested for some days
- further electrical and mechanical tests
- final quality control

There exist **2 functioning or performance test line concepts today.** Both are applied on 100% of production.

- o A longer test of 70-120 min. till the first cut-off of cooling circuit by the thermostat (the class A models needs much longer time to cut off, so that it cannot applied anymore for such models) and
- o A short test of about 15-45 min. without thermostat cut-off and freezing. The class A models often need 30-35 min before the refrigerator compartment starts to cool down the first time (during normal operation with already cold freezer such systems react faster).

Both test concepts, if made in good designed computerized systems, reach same reliability and validity level in refrigerator performance testing:

- o The **longer test** allows in past to test the thermostat and cut-off with higher reliability in oposit to a short test, but today with often high performance classes like class A the time of thermostat cut-off is already so long, that the limited testing time and testing area spaces in factory does not allow to wait till the thermostat cut-off and there are few companies who test such long. By improving the performance class of models the long test has the disadvantages of the very large production space and of freezing and humidity built up before packing, which must be removed again.
- o The **short test** needs a separate thermostat control (turning of disk at the end, with a wider range), but has the strong advantage to need only 3-10 times less space (depending on models, reach performance class and used test time). The short test does not build up much freeze and humidity in the refrigerator, which facilitate packing. There are 2 short test versions:
- o
  - The **temperature pull-down of refrigerator and freezer compartment in time** and
  - The **temperature encrease on conderser side in time**.

  The measurement inside refrigerator and freezer (temperature pull-down time tables) grant more information about quality as the measurement on condenser side only, but for A-class models it often needs 30-35 min. testing time, while the **measurement on condenser side** can be made in 10-15 min. In case of condenser measurement without measuring the refrigerator compartment temperature pull down in time it is necessary to control the **refrigerant charge quantity** separately; <u>otherwise a low filled refrigerator could pass the test, which does not cool sufficiently the refrigerator compartment</u>.

Today new installed performance lines mainly use the short term test of about 15-45 min. only. Such lines are much cheaper and need less space and the refrigerators can be packed without drying. Even if someone has already invested in long computerized performance lines with all the quite expensive transmitter boxes as needed, it is quite expensive to encrease the lines and space, if he improves his models to reach high performance classes, if he encrease the capacity, and often switch to short tests.

Companies like Galileo and Agramkow can provide complete performance test lines including electrical safety tests in the older version with 70-120 min test time as well as in the newer version with short test time of about 15-45 min., but the price difference between a short and long performance test line are very big as you can see from the drawings on the next pages.

Longer performance tests today do neither provide more reliability nor validity if the both type of tests are correctly set, we therefore recommend to install only short tests, but to establish some measures and controls to insure correct functioning of thermostats and, if temperature is only controlled by conderser, to insure correct charging quantity.

6.1. Electrical Safety Tests

Safety standards. There exist special standards which regulate the electrical safety requirements of refrigerators and freezers, their control and testing. The safety standards specify which electrical safety rules the manufacturer have to respect, which electrical components acc. to which electrical standard he can use in the appliances and which kind of approval he needs. Following international valid safety standards exist for refrigerators and freezers:

- IEC EN UL J GOST etc. **Standard 60335, Part 1: Safety of household and similar electric appliances, and**
- IEC EN UL J GOST etc. **Standard 60335, Part 2-24 (1997-08): Particular requirements for refrigerators and food freezers,**

The IEC 60335-2-24 was amended to cover potential risks originated from the use of flammable refrigerants; the standard is equal to VDE 700 and DIN 57700 and to EN60335-1 and 2-24 and Test Schedule TS 95006 to IEC60335-2-24)

Such standards have to be applied in addition to the performance standards of refrigerators: ISO EN 1552 (2005), which replaced ISO EN 7371/8187/5155/8561.

The above-mentioned amendment IEC 60335-2-24 (1997-08) should be respected today in case Hydrocarbon is used as refrigerant. It based on the application of the existing electrical safety standard **IEC 79-15 Electrical apparatus for explosive gas atmospheres, Electric apparatus with type of protection N**.

Safety Tests. Each refrigerator and freezer model must pass an electric satefty test. Each refrigerator should pass an electrical safety test in the refrigerator production concerning at least following tests

- earth test 6Vac/25A (0-2.5Ohm), continuity of electric bounding circuit test
- High voltage (flash test) 0-4000Vac (0-180 s), normally at 500 or 1000Vac
- insulation test and electric strength 500Vdc (o-180 s) 3-50 MOhm

Furthermore following tests are useful to execute:

- Power and current absorbed test
- Leakage current test
- Residual Voltage test (if the refrigerator and compressor performance is improved by a capacitor).

In addition to the measurements as required from the safety standards, for quality control it is useful to test other parameters like – the current during running of compressor - as part of performance test - and test of functioning of all electrical components switches, thermostats, signal lights, light switches, light should be added.

For further details concerning safety tests on prototypes using HC-600a see **Transfair Engineering: Designing and prototyping of refrigerator and freezer cooling circuits. Düsseldorf 2000, Chapter 8, p-94ff.**

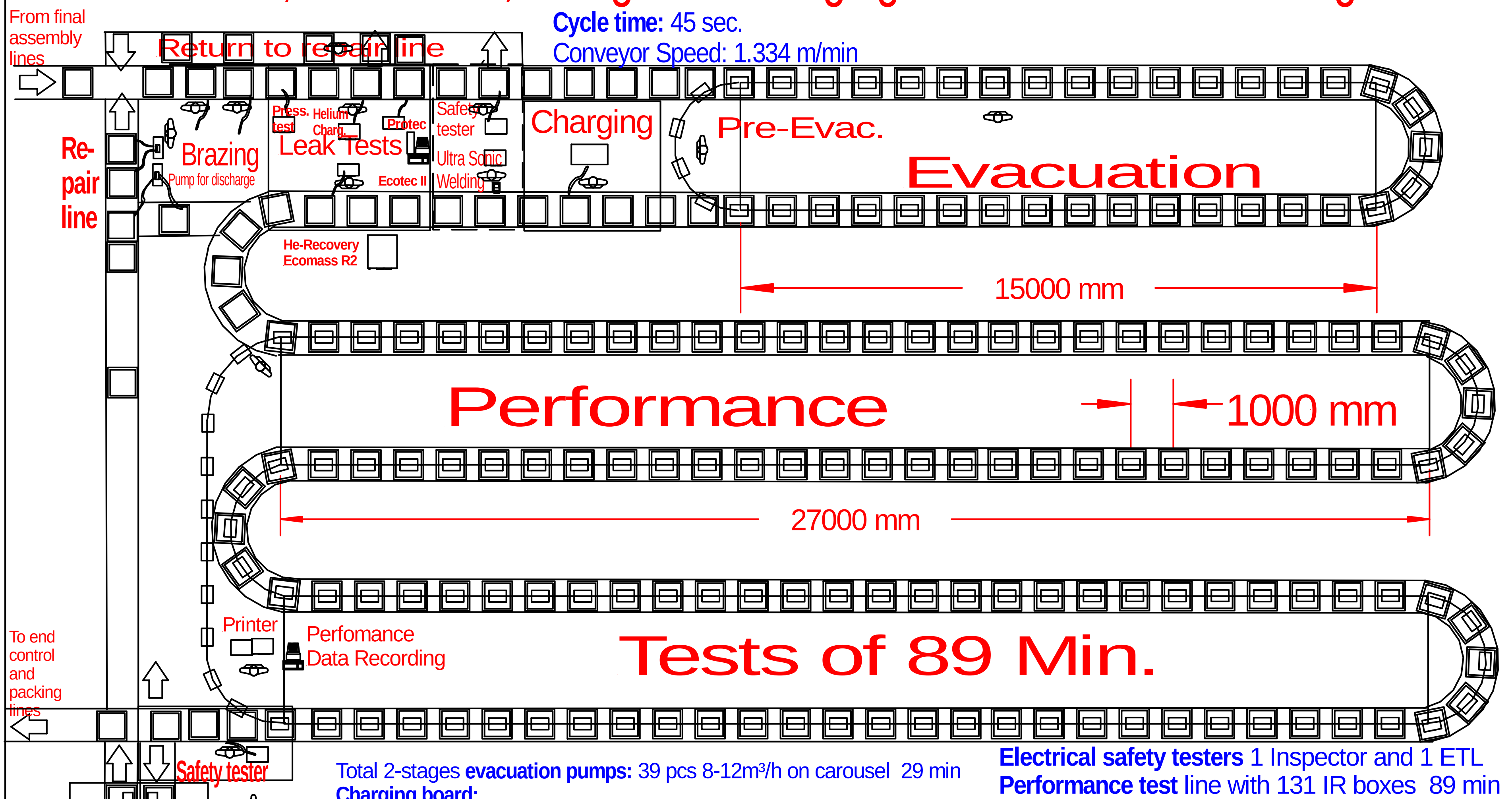
For its integration of the performance test into a refrigerator quality system see **Transfair Engineering: Refrigerator quality System.**

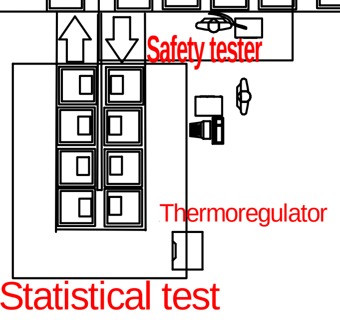
On the next 4 pages are Layouts **for Leak detection, evacuation, refrigerant charging and performance Test lines.**

The first layout is the one with long evacuation cycles, not optimized with pre-evacuation, evacuation stop and final evacuation and long performance test of 89 Min, still used by some refrigerator manufacturers today, but it is not recommended by me, as it needs to much space, while the next 2 layouts optimize the evacuation by using pre-evacuation, evacuation stop and final evacuation and reduces the performance test times dramatically.

Leak Detection, Evacuation, Refrigerant Charging and Performance Testing Lines:

Cycle time: 45 sec.
Conveyor Speed: 1.334 m/min





Total 2-stages **evacuation pumps:** 39 pcs 8-12m³/h on carousel 29 min
Charging board:
For R600a(and R134a): 1 Frigus H11 or H22 with Alarm system Ceberus with 2-3 sensors, Ventilation control, 2 HC-Closing valves, 4 Safety valves/refrigerant, 1 Ventilation system, 4 side walls
For R134a: Algor
Leak detection in press. test room:1 Nitrogen or dry air Charger Astra C, 1 He-charger+tester Astra A/TS and 1 Protec (He) after brazing, 1 He-recovery Ecomass, 1 Absorption fiter dryer,1 Ecotec II after circuit closing made by **Ultrasonic Welding:** 1 Stada RSA 3000.

Electrical safety testers 1 Inspector and 1 ETL
Performance test line with 131 IR boxes 89 min
Main and backup station,
Perform. Long statistical tests, 8 test places,
Repair lines with HC-Discharge ex-proof pumps.

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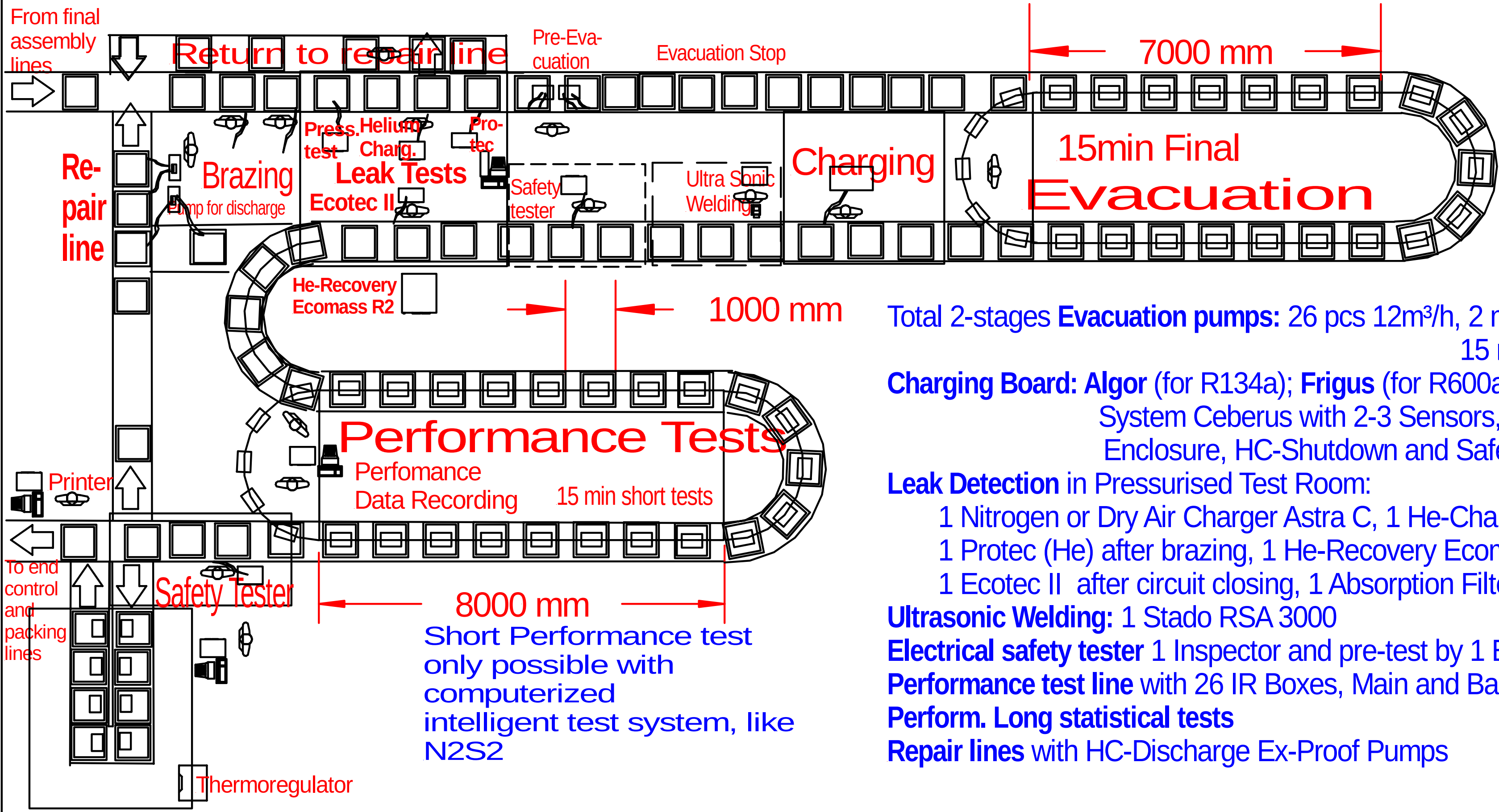
LAYOUT R600a/R134a CHARGING, LEAK DETECTION AND PERFORMANCE	15.2.2000 Drawing No. 20002.120.00

Leak Detection, Short Evacuation, Refrigerant Charging and Short Performance Testing Lines:



Short Evacuation of 2 min. pre-evacuation, 6-8 min Stop and 15 min. final evacuation under strict quality control of components and during production.

Short Performance test only possible with computerized intelligent test system, like N2S2

Total 2-stages **Evacuation pumps:** 26 pcs 12m³/h, 2 min Pre-Evac. and 15 min. Final on Carousel

Charging Board: Algor (for R134a); **Frigus** (for R600a) with Alarm System Ceberus with 2-3 Sensors, Ventilation System in Enclosure, HC-Shutdown and Safety Valves,

Leak Detection in Pressurised Test Room:

1 Nitrogen or Dry Air Charger Astra C, 1 He-Charger+Tester Astra A/TS,
1 Protec (He) after brazing, 1 He-Recovery Ecomass R2 and
1 Ecotec II after circuit closing, 1 Absorption Filter

Ultrasonic Welding: 1 Stado RSA 3000

Electrical safety tester 1 Inspector and pre-test by 1 ETL

Performance test line with 26 IR Boxes, Main and Backup Station

Perform. Long statistical tests

Repair lines with HC-Discharge Ex-Proof Pumps

Cycle time: 45 sec.
Conveyor Speed: 1.334 m/min

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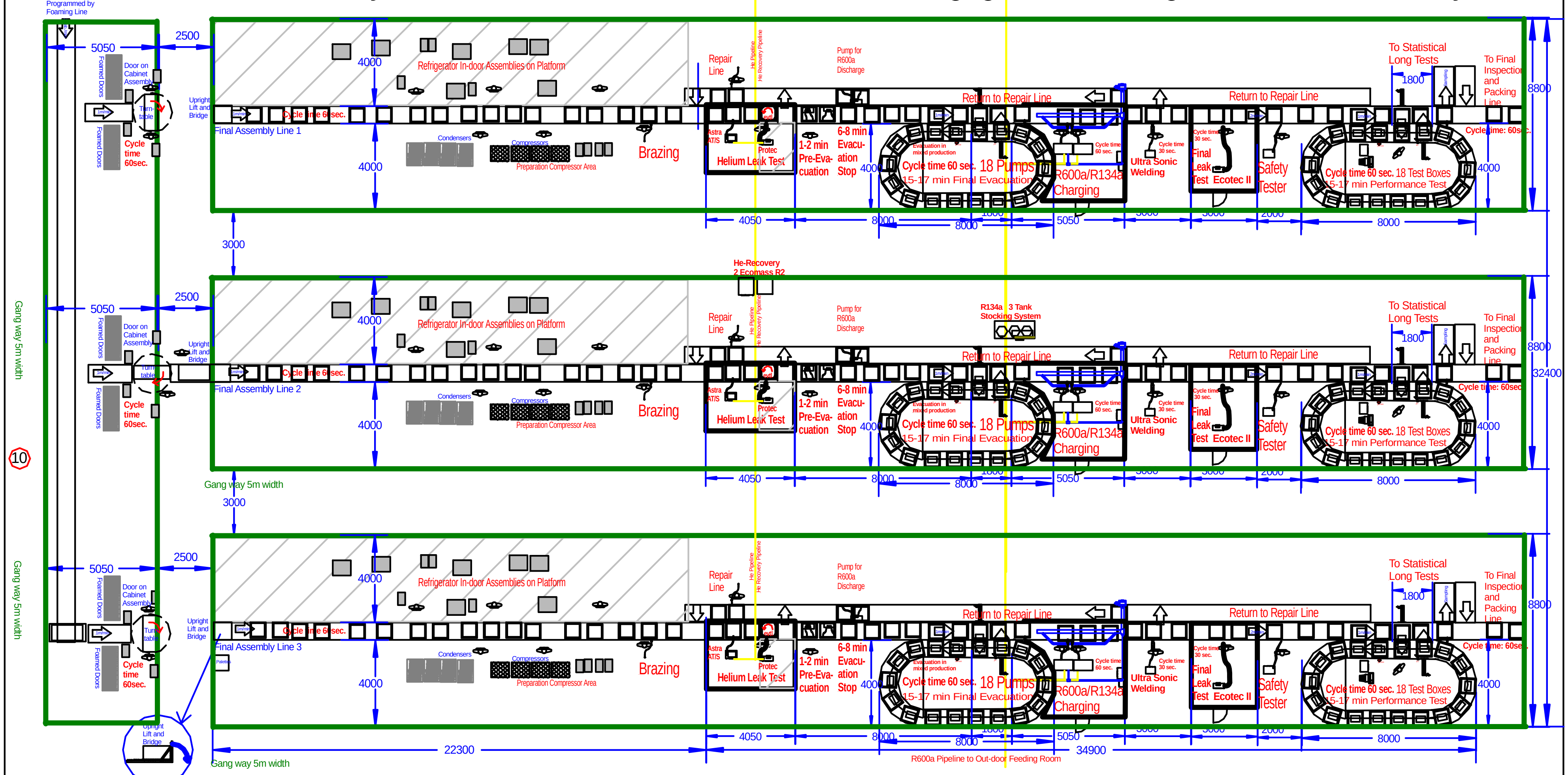
LAYOUT R600a/R134a CHARGING, LEAK DETECTION AND PERFORMANCE	15.2.2000 Drawing No. 20002.121.50

3 Final Assembly, Helium Leak Detection Lines, Evacuation, R600a Charging and Final Testing Lines, each with 60 sec. Cycle Time



3 Final Assembly, Helium Leak Detection Lines, Evacuation, R600a Charging and Final Testing Lines, each with 60 sec., totally with 20 sec. Cycle Time and total Output of 1152 refrigerators in 8h shift at 80% efficiency. Following Equipment are needed in this area (without assembly):

Evacuation: **Each line**: **2** Pre-evac. pumps (1-2 min.), Evacuation Stop (6-8 min.) and 18 Final Evac. Pumps (15-17 min.) on Carousel and **1 Burst Free Pumps** for R600a Refrigerator Repair; **Totally: 60** 2-Stages Pumps, 12m³/h with Suction oil Separator and **3** Burst Free Pumps.

Refrigerant Charging: **Each line: 1 Frigus H11 or H22 for R600a** (and one in reserve) with **1 Cerberus** Alarm Systems with 2-3 Gas Sensors, 2 HC-Closing valves, 3 Safety valves per refrigerant, **1 Ventilation System** inside Side Walls) and/or **1 for R134a Algor Boards; Totally at least 3 Charging Boards** and 1 in Reserve and **1-2 Autotank 3** Feeding Systems plus 1 HC Closing valves and 2 safety valves.

Leak Detection: **Each line: 1 Helium charging Board Astra A/TS and 1 Leak Detection Protec** in a Pressurized Test Rooms and 1 Ecotec II in a Pressurised Test Room, **For Evaporator Tests: 2 Astra A/TS** and **2 Protecs** in Press. Room and eventually a Vacuum Helium Leak detector Astra V. Furthermore 1 Absorption Filter Dryer, 2 Helium Recovery units **Ecomass R2**, totally 5 Astra A7TS, 5 Protec, 3 Ecotecs (incl. 1 in reserve), 2 Ecomass R2, 1 Absorption Filter and evtl. 1 Astra V.

Closing of Filling Tube: Each line has 1 **Ultrasonic Welding Machines:** Stado **RSA 3000** and **1** in reserve

Electrical Safety Tests: Each line has 1 Galileo Inspector and 1 in reserve, all with Power Kit and Interfaces.

Performance Tests: Each line has Performance Test Line each with 18 IR Boxes, 1 Transmitter Box and On-line Computer Station, 1 Off-line Computer Station for Evaluation and Leaning, all with interface and LAN connection, N²S² Neural Network Softwares; Furthermore about 10 Test Boxes and Test Places in thermoregualed room for Long Statistical Tests, with 1 Computer, Interface and LAN connection.

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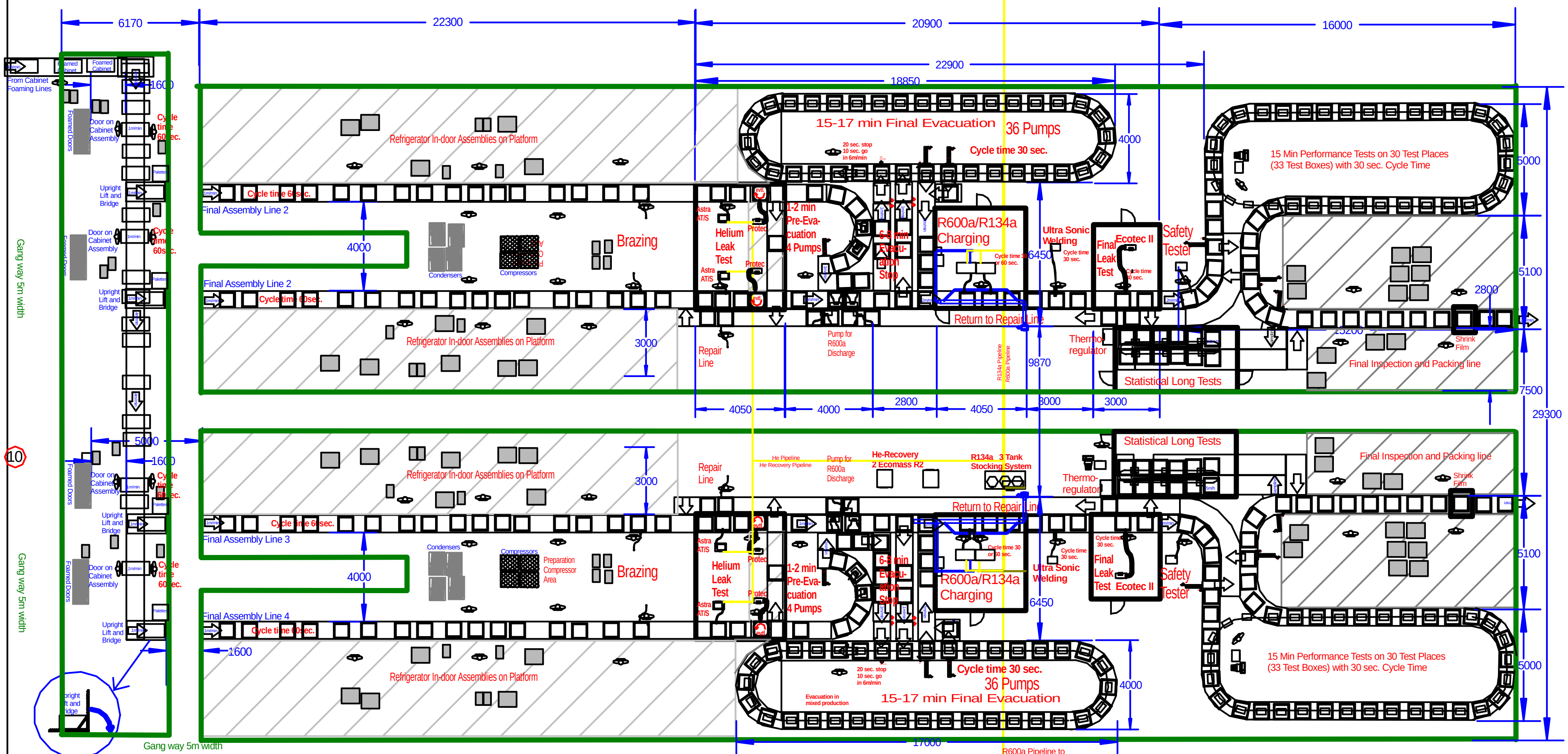
Project: Proposal of LAYOUT of Evacuation, R600a/R134a CHARGING, LEAK DETECTION LINES	15.2.2002 Drawing No. 20001.300.53



4 Final Assembly and Helium Leak Detection Lines, each with 60 sec. Cycle Time and 2 Evacuation, R600a Charging and Final Testing Lines, each with 30 sec. Cycle Time

Evacuation: **2 Evacuation Lines:** each with 4 Pre-evac. pumps (1-2 min.), Evacuation Stop (6-8 min.) and 36 Final Evac. Pumps (15-17 min.) on Carousel totally 80 2-Stages Pumps, 12m³/h with Suction oil Separator to produce every 15 sec. 1 Refrigerator.
On Repair Lines: 2-4 Burst Free Evacuation Pumps to evacuate slightly the refrigerators already charged with R600a.

Refrigerant Charging: **2 Frigus H11 or H22 for R600a** (and one in reserve) with 2 **Cerberus** Alarm Systems, each with 3 Gas Sensors, 5 HC-Closing valves, 12 Safety valves (7 per refrigerant), 2 Ventilation System inside Side Walls) and/or **2 for R134a Algor Boards** and **1-2 Autotank 3** Feeding Systems.

Leak Detection: **6 Helium Leak Detection Lines** in 3 Pressurized Test Rooms. each with **2 Astra A/TS** and **2 Protec**(1 Test room for 2 Evaporator Test Lines, 4 on the final assebly lines after brazing, evtl. 1-2 Vacuum Helium leak Detector Astra V, furthermore 1 absorption filter dryer, 2 Helium Recovery units Ecomass R2 and in 2 pressurized rooms **2 Mass Spectrometric Leak detectors Ecotec II** after closing of circuit and **1** Ecotec 2 as reserve.

Closing of Filling Tube: 2 Ultrasonic Welding Machines: Stado **RSA 3000** and **1** in reserve

Electrical Safety Tests: 2 Galileo Inspector and 1 in reserve, all with Power Kit and Interfaces at the Performance Lines

Performance Tests: 2 Performance Test Lines each with 33 IR Boxes, 1 Transmitter Box and On-line Station, 1 Off-line Station for Evaluation and Leaning, N²S² Neural Network Softwares; 2 Long Statistical Tests each with Test Boxes, and 1 Computer with Interface, all computers in a LAN.

transfair gmbh - CFC free refrigerator technology	
Project: Proposal of LAYOUT of Evacuation, R600a/R134a CHARGING, LEAK DETECTION LINES	15.2.2002 Drawing No. 20001.300.51

6.2. Performance Test Lines

To ensure the companies own established **quality standards** and to meet the requirements of valid refrigerator standards final performance tests have to be executed. In these tests the efficiency of the cooling circuit has to be controlled and bad models eliminated for repairs to avoid guaranty cases and to build up and to maintain a good reputation on the market.

Today there exist 4 different kind of tests

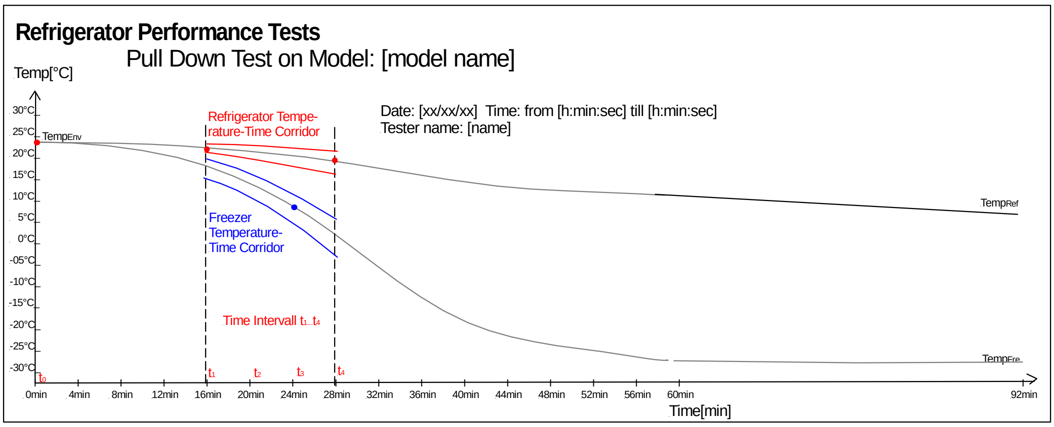
- a long term test of 1-3 hours
- a short term test of 10-45 min
- a full test of statistically taken samples of the production over 3-12 h
- refrigerator laboratory tests in a thermo-regulated room for 12-72h

6.2.1. Long-Term Performance Tests (1-3h)

20-30 years all refrigerator manufacturers made long performance test of 1-2h till the first cut-off of thermostat, some even till the first cut-in, but meanwhile nearly all producers in developed countries and bigger producers in developing counties uses shorter test for production space reasons. It is a prejudice that the longer such a test is the better quality control is reached. This is not at all the case if only the final temperatures are controlled. Even bad models, which need to be repaired, can reach after longer time the required final temperatures. Computerized short performance test systems are meanwhile so sensitive and so sophisticated that they reach higher reliability and validity as long test without such features. Another reason for short test was that energy saving models with low power compressors needs quite long time to reach cut-off and more than 24h till the first cut-in of thermostat. Quality wise unacceptable are long test, which only measure the final reached temperatures, like often done in developing countries. Such methods are not contributing much to the quality control, because if you wait long enough you nearly get any bad refrigerator without load to the low temperatures required, as long the compressor can run, refrigerant was charged, the leaks are not too big and the capillary is not blocked. By this way mistakes in mounting of evaporators or wrong condensers cannot be eliminated under environmental test temperature conditions without load inside the refrigerator. In winter time even a 30% smaller condenser, a smaller compressor or a refrigerator with 15% less or more refrigerant would pass such tests, but the consumer getting such a bad refrigerator would come latest next summer to his dealer and ask for replacement under guarantee.

6.2.2. Short-Term Performance Tests (10-45 min)

Today nearly all household refrigerator manufacturers in Europe, North America, Japan, Korea, and the ones in other areas competing in these markets use short tests by taking temperatures in the time interval of 14-35 min., in shortest time tests mainly on the condenser (pull up curve) and tests of 16-35 min mainly in the freezer compartment and refrigerator compartment as Pull down test. Companies which measure in the refrigerator compartment often had to encrease the test time after developing high performing A-class models, which are slow in first pull-down of refrigerator (30min.) or to switch to measure only freezer or only on condenser side. But in this case they have to control the refrigerant charge quantity to avoid that a low charged refrigerator could pass tests. The measured data should be inside a temperature time corridor, this corridor is shifting upon environmental temperature, the test is executed. Few use this method, but add on top of it other more sophisticated test procedures to it (Galileo), see chapter 6.3.



See a typical pull down curve sample of a 2 door fridge-freezer combination for N-climate class (up to 32°C) and energy class A with one common cooling system for both compartments and without any load inside, measured already under relatively high environmental temperature of 24° for factories making mainly refrigerators for such climate. Already such a

curves show that testing time longer than 40 min. does not make sense for the freezer, while for a class A model the refrigerator compartment still needs time to pull down. If the test would have been done under 20°C environmental temperature instead of 24°C, the pull down near to final temperatures would be faster, so that a testing time longer than 35-40 min. would already be wasting of time, as long as the freezer is empty. Refrigerators for subtropical climate or even tropical climate need stronger compressors and therefore also their pulldown measured in 24°C environment would be also faster as the above curve.
But small accumulator often can speed up refrigerator pulldown and widen enviromental temperature and load conditions – even today without energy consumption encrease.

Measuring on the condenser side the temperature-time curve starts immediately upon compressor run near the entry point of condenser, so that already after few minutes the complete condenser is already near to 55°C so that good and bad models could be discriminated. Therefore some refrigerator manufactures even test by this way there refrigerators only for 5 minutes. But such 3-5 minutes tests have some limits. The condenser warms up even if the refrigerant charge are not sufficient to finally cool down the refrigerator compartment in the speed as needed. So such test can only be done if the refrigerant charge quantity is under strict control.

Measurement Table of Pull Down Test $Temp_{env}$: 23°C (Sample)

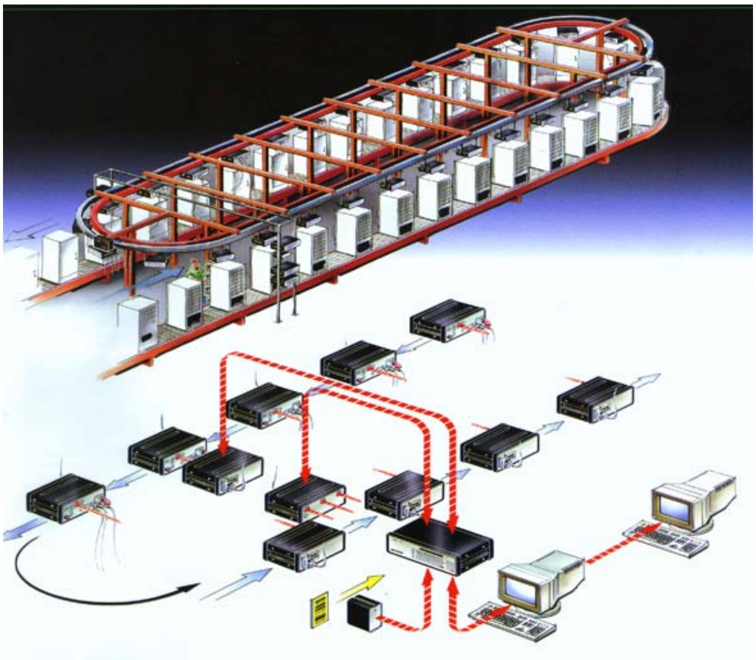
Time [min]	**t_1**	**t_2**	**t_3**	**t_4**
	16	20	24	28
$Temp_{ref}$ [°C]	22,5	22,3	22,1	21,9
$DTemp_{ref}$		-0,2	-0,2	-0,2
$Temp_{fre}$ [°C]	19,0	15,1	9,2	2,8
$DTemp_{fre}$		-3,9	-5,9	-6,4
$f'(Temp_{ref})=f(Temp_{ref})/d(Time)=DTemp_{ref}\ /DTime$		-0,05	-0,05	-0,05
$f'(Temp_{fre})=f(Temp_{fre})/d(Time)=DTemp_{fre}\ /DTime$		-0,975	-1,48	-1,6

Refrigerator laboratory tests in a thermo-regulated room for 12-72h. But before any model can be tested in a short performance test under environmental temperatures without load a **statistical relevant group of new models have to be tested with load in a thermo-regulated room under the temperatures of the climate class**, for which the models are made. The testing time must exceed the time till the first cut-in of thermostat (normally today 24-36h in N-climate classes, shorter in ST and T-Climate classes). Best is to test 50-100 refrigerators of a new developed model in a longer test with full cut-off and cut-in cycle, not possible in 2 hours, but by good models in 24-36h hours by measuring the temperature time and current data in intervals and to define by this longer tests which of the models can pass and which should be repaired. From models which perform well and the ones which perform bad the temperature time data like the above mentioned have to be taken in a under different environmental temperatures, which could exist in the factory during the years. By knowing which models were good and which ones failed the temperature time corridor, which discriminates best between good and bad refrigerators, should be selected. Some models could be tested already after 14 min. other are better to be tested after 18 min. During further production the data of the full-scale test samples can be taken to adjust these expectation corridors. If these data are collected in shorter intervals and samples of long test are executed and the data expectations strong controlled which is for my opinion only possible with a computerised system, than short term test can be executed, which will reduce strongly the space.

There are different approaches to evaluate the measured data. It could be described as differential quotient:

$dTemp_{fre}\ /dtime \approx \Delta Temp_{fre} / \Delta Time$ or $dTemp_{ref}\ /dtime \approx \Delta Temp_{ref} / \Delta Time$ or $dTemp_{cond}\ /dtime \approx \Delta Temp_{cond} / \Delta Time$

Today more intelligent is a test data evaluation using the temperature time data of freezer, the temperature time data of refrigerator or the temperature time data of condenser and the compressor Power [W] or current [A]. lasts measured in true RMS, are inserted into a multi layer table, out of which a Vector is calculated and compared with the quality set point Vector amount. If the refrigerator data vector amount passes this set point vector amount the refrigerator is good, if not it failed.



As first sample we like to introduce an **Agramkow solution:**

Computerised Performance Test Systems (CPT). According to our information Agramkow was the first manufacturer of test equipment in the refrigerator production with these data recording boxes which store the temperature and current data in programmable intervals from up to 3 channels during the performance test run on a carousel and pass it over by infrared to a transmitter/receiver communication box connected with a computer. Such installations from Agramkow and from Galileo are the most in use in the world. A second computer is used as backup. Even a bar code reader to identify the model is integrated. By this way a complete record of all manufactured refrigerators were possible. Instead of IR transmitters radio transmitters will replace in future the communication.

A further step (**Galileo PLIS**) was to integrate the charging board data (charged amount, pressure test), the leak test data, the electrical safety test data as well as the measurement data of taken samples for a full tests according to the valid refrigerator standards.

This quality documentation was useful for internal and external quality (ISO9000ff.) and production improvements.

6.2.3. Full Test of Statistically Taken Samples (3-12 h)

In addition to this short term tests samples according to established standards have to be taken out of the running production and longer tested.

This is not only part of the refrigerator and freezer standards, but a must to control reliability and validity of short tests. The data stes are stored per refrigerator serial no. The short test and long test data sets are correlated to each other to check how reliable and valid short test differ between good and bad performing refrigerators.

Furthermore from time to time tests in a thermo-regulated room of a period of 12-72h are needed to check cut-off and cut-on of modern refrigerators and freezers with Tylose packages with low energy consumption. Also these tests are part of standards today. And the test results allow to check reliability and validity of test already executed in 15-45min and in 3-12h.

See also: Transfair Engineering: Designing and Prototyping of refrigerator and freezer circuits, Düsseldorf 200, chapter 10: Final tests, p. 110ff and the valid refrigerator and freezer standards.

The next presented system is from **Galileo. They supply systems similar to the one of Agramkow and this new generation test system with a self-learning software of a neural network.** This new system uses the traditional temperature time corridor with a weight of 50% of test data, but add further test instruments.

6.3. Galileo TP Process Equipment Final Test Equipment

In short such a system, representing 50% of test data evaluation**, consider the refrigerator like a black box,** not really knowing what happens in each model and why. But by **manipulating some relevant factors**, like compressor run and stop, **and by measuring at the same time relevant factors** like temperature changes during such compressor runs and stop, **each system behave slightly different,** and even one model can have different pattern of data of good working models and other different patterns of bad working models, **but important in the test is that even smaller deviations in the data set** and its vector **could be identified**, **so that such deviating refrigerators could taken from the test line and retested in a longer test, to check if they are still good or have to be repaired.** The deviation data set of the still good ones will be integrated into the data set of good ones so that next time a similar refrigerator would pass (self-learning). **By this way the quality control can keep much better under control the manufacturing and supplied components as** it is possible with the temperature-time corridors alone. But this sophisticated test instrument requires quite good educated quality controllers with high understanding about what he and the test system is doing, which is not always the case.

The present documentation is a technical description of a system to test functional parameters of refrigerators, which have the characteristics to comply with specific norms to guarantee safety and quality standards. All our equipment are designed and manufactured in accordance with the European Norms with special reference to:

· CEI EN 61010-1: safety standard for electric device for measurement, control and laboratory tests.

Thanks to its modularity characteristics, the system we are proposing is suitable to automatic tests for laboratory purposes: it is possible to carry out single tests and also to configure a sequence of tests thus allowing performing a complete test program automatically.

6.3.1. Plant Configuration

In view of the above considerations the plant will have two lines each provided with the following systems:

- **Safety tester,**
- **Functional test system,**
- **Label printing station,**
- **Statistical long term test,**
- **Laboratory test system**

A small, not final safety test is strongly recommended if the refrigerator will be powered in the fore vacuum carousel, see Chapter 2.3.2. to test at least the following to protect workers: Earth wire efficiency test, Insulation resistance test and Voltage test (Dielectric strength)

The **functional test system** on dynamic carousel will test the functional parameters of refrigerators, often called also performance test.

The Final **safety tester** will test the compliance of equipment with the electrical safety standards.

For 2 reasons it is recommended to print at the end of the functioning test line a test report: First to identify refrigerators which needs to be reworked, second such a **label printing station** on a PC will manage and print a test report polling the data from all the test equipment to supply each refrigerator with its test results which can be done in this station before the refrigerator is packed.

Regulations require taking out by statistical means of running production **some models to be tested in a longer period**, preferable on complete cycle. This can be done separately near the production or combined with the laboratory. The **laboratory test system** will have the purpose of testing the prototypes in order to verify the design parameters.

All the units will be interconnected by means a serial line.

6.3.2. Safety Tester

Galileo PQ Electric

The internationally valid IEC EN UL J GOST etc. Standard 60335-1 and 60335-2-24, in connection also with IEC EN 60204-1 require a group of safety test on refrigerators. Following safety tests are required for each model of household refrigerators and freezers. A refrigerator manufacturer has to proof that his production keeps this safety standards at least by sampling, but it is industrial standard to execute on each single refrigerator following tests, at least the first 4 test

- Earth Wire Efficiency Test
- Insulation Resistance Test
- Voltage Test (Dielectric Strength)
- Power Test and Absorbed Currents
- Leakage Current Test
- Residual Voltage Test

Important is that these tests are automatically executed and the results stored in case of any claims. But the electrical behaviour of different models vary in some parameters, the safety test system must be programmable to execute all these tests one after the other in different automatic cycle phases with different programmable test parameters, depending of the model features to be tested, so that the system display at the end if a specific refrigerator or freezer model passes or fails the test. The programmable Parameters for each test type should be the following to enable a good safety and electrical functioning test:

- Earth wire efficiency test: Test current, minimum and maximum impedance value or voltage value set point and test time,
- Insulation resistance test to be executed with 500Vdc or 1000Vdc: minimum resistive value set point and test time,
- Dielectric Strength: maximum current value set point,
- Power and absorbed current test: Test Voltage, maximum and minimum active power set point, minimum cos φ set value, test time and waiting time at beginning of absorbed power measurement,
- Short circuit test: Maximum resistance set value;
- Leakage current test: Test voltage, maximum leakage current value and test time,
- Residual voltage test: Test voltage, maximum residual voltage value set point, nominal electrical voltage functioning time, waiting time after automatic power supply interruption to the unit under test.

The system should have an RS232 to pass over the test reports to a PC and it should be able to be connected to a bar code reader.

The Galileo safety tester **Inspector** with the options Power kit performs all the a.m. requirements and it is exactly made according to the EN safety standard regulations for refrigerators and freezers while other safety testers often are not made for this standard and do not fulfil in all points the regulation.

The net cycle time of the test is approx. 30 seconds including plugging and unplugging of refrigerator. The unit performs the a.m. tests. The same Galileo safety tester Inspector can be extended by options to be used with further electrical safety tests as end of line safety tester.

It is recommended to add to the system the Galileo calibration check box and the serial ports to connect computer, bar code reader and printer. The system is complete with pliers for the connection to the electrical equipment under test during the protection bonding circuit test. The net cycle time of the test is approx. 30 s.

6.3.3. Functional Test System by Neural Network Software

Galileo KAM Test Box

The system has been designed to operate on dynamic carousels and to secure a correct running in case of micro interruptions of electrical supply line due to operational defects of electrical contacts. The data transmission is in the range of ± 40 cm referring to the receiver axis. Furthermore the system has been realised taking into considerations the following goals:

· Fast installation and start-up
· Hard operation
· Impossible maintenance
· Very high investment costs

COMPOSITION. The system consists of 2 PC stations with 2 different software packages:

- 1 PC is working off-line and it is used for evaluation of test data with the N²S² Offline software to built up the test parameters and values to be checked in the functional test and the
- Other PC with the N²S² online software is online with infrared receiver (a.m. KAM box switched as receiver) and a number of acquisition boxes (same a.m. KAM box switched as transmitter) to perform the actual check of the products by collecting the data from each tested refrigerator and to identify if the refrigerator passes or fails.

Both computers are interlinked.
The quantity of test box in the carousel depends from the production rate and the functional test time.

Galileo's N²S²- Neural Network Software System

Galileo TP has developed N^2S^2 (Neural Network Software System) for the functional testing of refrigeration units and installed several lines in leading refrigerator factories. This software product was developed by Galileo to meet following market demands:

a. Considerably reducing the functional testing times of refrigeration units.

b. Improving the ability to detect possible malfunctioning of the products.

c. Achieving a diagnosis system independent from the operator's subjective evaluations.

d. Creating a completely automatic system integrated with the company information system.

e. Immediate answer concerning the functioning or malfunctioning of the product.

Self-Leaning Phase on PC with N^2S^2 Offline Software. If new models are introduced the first quantities are used to teach the system to differ between good and bad refrigerators of this model (self-leaning phase). The first 30-50 units which are perfectly working according to a long term test are tested also in short term on this neural network system. In the first stage all temperature and current data are collected. The resulting graphs allow selecting which signals are relevant and which ones can be neglected, so that a **leaning set** of input and output signals can be selected according to experience which ones are relevant for the functioning of this model. By this selection the testing time as needed will be reduced. 50 units used in the learning phase built up a set of about 1000 numeric values to test new units inside of about 15 Minutes. The offline package individuates for each refrigerator model the characteristic temperature and current signals necessary to define its functioning and refrigeration efficiency. Now this learning set per model can be passed over to the online system to test new units of this model.

N^2S^2 Online Test Software. By correlating test input and output signals matrices of short tests with long tests ones the system "learnt" to differ between refrigerators correctly working and the ones anomalously working. The result is given in a form GOOD or NOT GOOD as well as in details like temperature and current curves and data records. If the data base is increased it even can re-lean to improve discrimination. From time to time the system has to re-lean, because even small changes in components (for example change of a bend of condenser) can have effects on the data set values and it has to be checked by long laboratory tests if such modifications are under performance aspect acceptable for the model or not. If yes this new results have be inserted in the leaning set.

Such a system is not static. The producer decides where he put his benchmark on quality per model and version to differ between the ones which pass and which fail, so that he can try to reach higher benchmarks after a while.

Together with the software N^2S^2 consisting of the above described 2 packages Galileo provide in their software further features to control relevant data concerning the products and the production, for example technical features of the models, serial number, date, time of production etc. and the testing data details collected into a history data base file. By this way not only each single model can be re-controlled in case of claims, but also time periods can be compared and result per models can be evaluated to improve design or production and to identify weak points.

The experience on this new testing way is meanwhile long enough and it can be recommended as efficient and very sensitive system to control refrigeration performance and quality and to detect any deviation which can have effects on the cooling circuit performance.

The hardware is as following: The acquisition devices called KAM boxes can be installed on the test carousel just next the electrical supply line of refrigerator to test. At the end of the test cycle the acquisition device transmits the test data to a fixed infrared receiver (same KAM box as the transmitter, switched to receiver). The following functional parameters can be monitored and then transmitted.

· 3 Temperature values
· Compressor condition (ON/OFF) and its current absorption
· Digital signal for test conclusion from the switch

The accuracy of temperature reading is ± 1 °C.

The current sensor that is connected to the electrical supply line of the refrigerator detects the compressor condition.

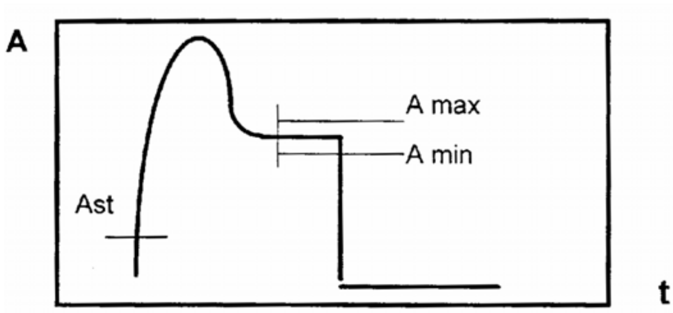
It is possible to monitor the temperature either at fixed intervals or at the compressor start/stop. In the last case the PC taking into consideration the room temperature carries out the comparison between the detected and the nominal values automatically.
The operator can define the comparison parameters and the relevant algorithms.

In both cases it is possible to print test reports with the diagram of the three measured temperatures.

TEMPERATURE READING AT FIXED INTERVALS. In this case the acquisition devices are programmed to read temperatures at fixed time intervals; it is possible to set the following parameters:
· Max. and min. values of each quantity according to the model,
· Code Number reading by optical pen,
· Storing of data read by acquisition devices,
· Visualisation of temperature curves and automatic selection of parameters out of specified range,
· Print of test report with temperature diagrams,
· Data storing,
· Recall and visualization of historical data,
· Statistic evaluations.

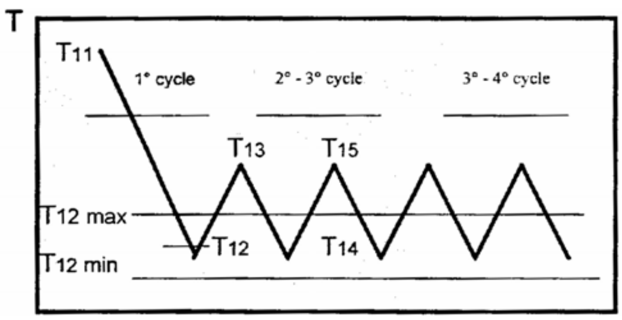
TEMPERATURE READING AT THE COMPRESSOR START/STOP. In this case the acquisition devices are programmed to read the temperature values at compressor start and stop only with particular reference to:
· Cycle start and parameters reading when the current value rises above a specific value,
· Parameters reading at each compressor start/stop,
· Cycle stop by digital input and start data transmission (4/5 times),
· Data reset and stand-by for a new cycle.

SOFTWARE FUNCTIONS.
· Set of limits and evaluation algorithms according to models,
· Model and Number acquisition by bar ode reading or through key board,
· Storing of data read by acquisition devices,
· Visualization of temperature curves and automatic selection of parameters out of specific range,
· Print of test reports with temperature diagrams,
· Data storing,
· Recall and visualization of historical data.

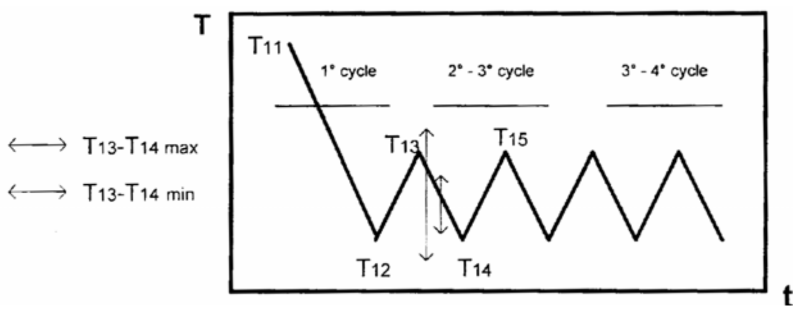


LIMITS AND EVALUATION ALGORITHMS. The software allows the user to set the evaluation parameters as described herein. As regards the current absorption it is possible to set a range of acceptable values according to the refrigerator model as shown by the diagram here below.

For each temperature curve it is possible to set min and max values according to different cycles and model.



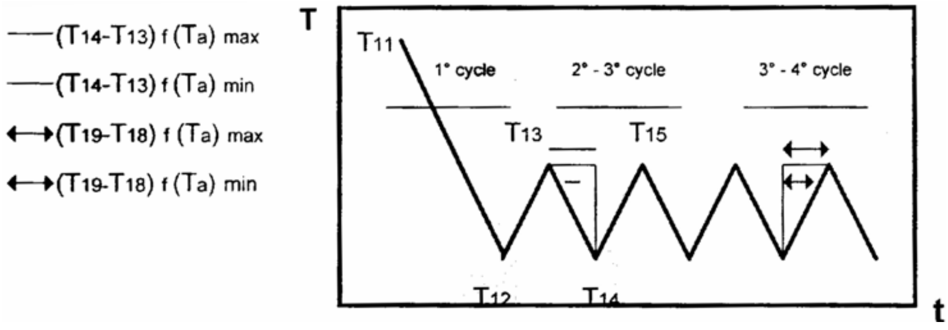
For each temperature curve it is possible to set 3 differences between the min and max values according to cycle number and model.



For each temperature value it is possible to set min and max values related to room temperature and time between two subsequent readings and according to the model. This function can be linear or set by user.

ACQUISITION DEVICE. The acquisition device is provided with infrared transmitter for data transmission at the end of the test cycle. The data communication is achieved by means of an infrared receiver at the end of the test carousel.
The following parameters can be monitored:

- · Up to 4 temperature values,
- · Compressor Current absorption,
- · Digital input of test start,
- · Digital input of test stop.



The input of test start is automatic when reading a current absorption for 10 s mimum whilst a switch gives the stop signal.
The temperature parameters are monitored by NTC probes with ± 1 °C precision.

The refrigerator is connected to one (or more upon request) supply plug providing the device; a current sensor positioned on the supply line will monitor the compressor absorption.

Technical Data. The acquisition device will consist of a metallic box fitted with:

- · 4 Temperature probes (range -50°C = +100°C ± 1 °C),
- · 1 Current sensor (range 0 Aca - 10 Acs ± 3%),
- · 2 Digital inputs for START/STOP,
- · 1 Switch for cycle stop,
- · 1 Supply plug 230 V 50 Hz,
- · 1 Supply plug 110 V 60 Hz,
- · 2 Safety switch,
- · 1 RS232 or equivalent for Infrared photocell,
- · 1 Infrared photocell.

DATA ACQUISITION. The parameters reading will be carried out as follows:

a) READING AT COMPRESSOR START/STOP. The cycle start will be given through a digital input by reading a current absorption for 5 s at least. The parameters are read at compressor start/stop and are stored together with the intervention of the cycle stop switch, which also enables the data transmission through photocell.

Max. number of readings: 200
Max. cycle time: 4 h 16 m

The parameters are stored as follows:

- · Current value 1 BYTE
- · Temperature 1° value 1 BYTE
- · Temperature 2° value 1 BYTE
- · Temperature 3° value 1 BYTE
- · Temperature 4° value 1 BYTE
- · Time in minutes from start 1 BYTE

b) READING AT FIXED INTERVALS. The cycle start will be given through a digital input by reading a current adsorption for 5 s at least. The parameters are read at fixed intervals (min 60 s). The acquisition ands with the intervention of the data transmission through photocell.

Max. number of readings: 200

The parameters are stored as follows:

- · Current value 1 BYTE
- · Temperature 1° value 1 BYTE
- · Temperature 2° value 1 BYTE
- · Temperature 3° value 1 BYTE

· Temperature 4° value 1 BYTE
· Time in minutes from start 1 BYTE

6.4. Refrigerator Laboratory and Statistical Long-Term Tests

Samples of the production have to be taken according to the applied standard in a thermo-regulated room and long term performance test have to be made. This can be done near the production line or in the laboratory.

For the test laboratory equipment see **Transfair Engineering: Refrigerator Test Room, Düsseldorf 2000.**

For the tests to be executed see **Transfair Engineering: Designing and Prototyping of refrigerator and freezer cooling circuits, Düsseldorf 2000, Chapter 10. Final tests, p. 110 and valid refrigerator standards.**

Refrigerator performance is the core part of the refrigerator quality control system and the performance data must be stored per refrigerator serial No. and evaluated. Also the electrical tester machine data has to be read out automatically upon each single refrigerator (bar code or RFID serial no.) and stored into a databank. This is foreseen in the Galileo PCIS Systems and in general part of the separate Transfair Engineering: Quality Control booklet.