Application of Danfoss hermetic compressors
There are no general standards on how to indicate the size of hermetic compressors. Previously, compressor sizes were indicated in hp, but this unit of measurement did not provide a clear definition of the refrigeration characteristics. Therefore, since the 1960s, Danfoss has used and continuously extended the following system. The compressor is marked in accordance with the current standard, as shown in the table below. The abbreviations are explained in the subsequent sections.

### Identification/marking of the compressor

- **Identification/marking of the compressor**
- **Motor systems**
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#### Example:

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TLE S4 F K
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The first letter (P, T, N, F or S) indicates compressor series whereas the second indicates motor protection placing. Nominal displacement is indicated by a number, which – for practical reasons – has been approximated to the actual displacement. Between the indicators for compressor series and displacement the identification marking for the optimization of the compressor is given. Here, the letters E (energy-optimized), S (semidirect suction) or Y (high energy optimization) appear, with E and S sometimes appearing together. If there are no such extra markings, the compressor in question is a standard compressor.
Danfoss compressors are equipped with single phase AC motors (with the exception of the BD compressor for 12 V and 24 V d.c., and the TLV compressor which is driven by a 230 V d.c. motor with dedicated electronics). The AC motors are available with the following motor systems:

- **RSIR (Resistant Start Induction Run):** Induction motor with resistant start
- **RSCR (Resistant Start Capacitor Run):** Induction motor with resistant start and run capacitor
- **CSIR (Capacitor Start Induction Run):** Induction motor with start capacitor
- **CSR (Capacitor Start Run):** Induction motor with run and start capacitor

Compressors featuring RSIR or RSCR motor systems have a low starting torque (LST) and are used in refrigerators with capillary tubes where pressure equalization takes place prior to each start-up.

RSIR systems incorporate a PTC or a relay and bifilar winding (current relay) as starting equipment. The increased application of PTCs resulted in a considerable reduction in the number of the various starting devices. But, in all circumstances, the PTC must be at standstill for approx. 5 minutes in order to cool down before it can restart.

The RSCR system, which consists of a PTC and a run capacitor, is primarily used in energy-optimized compressors.

Compressors with CSIR and CSR motor systems have a high starting torque (HST) and can be used in refrigerators with capillary tubes as well as in systems incorporating expansion valve operation (without pressure equalization). The CSIR system is formed by using the start relay and start capacitor specified for the individual compressor type. A voltage relay, a start capacitor and a run capacitor are required in connection with CSR systems.

With the exception of the smallest compressors, the TL, FR, NL and SC compressors equipped with an RSIR motor system intended for refrigerant R134a can be converted to the CSIR motor system by replacing the externally mounted electrical equipment. Compressors of the TF, FF and NF type incorporate a bifilar winding, a relay and an external motor protector on the compressor. Here it is thus not possible to switch between RSIR and CSIR. Compressor types from the TL, FR, NL and SC series are equipped with a protector incorporated in the motor.

The letter following the marking for nominal displacement indicates which refrigerant must be used as well as the field of application of the compressor. LBP (Low Back Pressure) indicates the range of low evaporating temperatures, MBP (Medium Back Pressure) the range of medium evaporating temperatures, and HBP (High Back Pressure) the range of high evaporating temperatures. The extra “T” indicates a compressor intended for the tropics.

The final letter in the compressor marking provides information on starting torque. If, as standard, the compressor is intended for LST and HST, this place is left empty.

“K” also indicates low starting torque (Capillary tube, LST = Low Starting Torque) and “X” high starting torque (Expansion valve, HST = High Starting Torque).
G compressors can thus be characterized as R134a HBP compressors, which means that they are suitable for operation under conditions where they are exposed to high evaporating temperatures, e.g. in air dehumidifiers, liquid coolers and various commercial refrigeration appliances. G compressors can be used in high, middle and low evaporating temperature ranges, and they can therefore be considered as universal. A motor dimensioned in this manner is also an advantage in the case of an unstable power supply. G compressors are consequently an excellent supplement to the F design. The G models are the correct LBP/MBP system for countries with unstable power supply, weak mains and extreme undervoltage in proportion to line voltage. The G models from the TL and FR series are highly suitable for R134a LBP operation in household refrigerators and freezers in countries with nominal voltages of 220 V 60 Hz and 230 V 60 Hz.

“CL / DL” compressors
Examples: TL4CL, SC10CL, FR6DL, SC15DL

CL/DL compressors are designed for refrigeration systems operating with R404A or R507. Compressors with the final designation letters CL are suitable for application in commercial refrigeration and freezing units or similar units with low evaporating temperatures (LBP). Compressors with the designation DL at the end are developed for high evaporating temperatures (HBP). They are used in refrigeration units such as liquid coolers, vending machines, heat pumps, commercial refrigerated display counters, air dehumidifiers and similar appliances. The compressors are cooled by fans (minimum 3.0 m/s air flow).

“K” compressors
Examples: FR15K, NL10K, TLS4K

The designation for all compressors using R600a (isobutane) includes the letter K at the end. These compressors are designed for low evaporating temperatures (LBP), i.e. for application in refrigerators, chest freezers and similar apparatus. Just like F compressors, K compressors are equipped with a motor developed for use in countries having a stable mains supply. Some of the smaller TLS-K, TLES-K, TLY-K and PLE-K compressors have also been approved for the medium evaporating temperatures (MBP).

R600a (C₄H₁₀) is a flammable refrigerant and has been classified A3 in accordance with ANSI/ASHRAE 34. Consequently certain safety instructions should be observed. A specific test procedure (TS95006) was accepted as a supplement to the European standard EN 60335-2-24 (similar to IEC335-2-24) for household refrigeration appliances. This standard describes the test requirements when using hydrocarbons in appliances. Danfoss compressors with isobutane (R600a) are only allowed for use in units designed for R600a in accordance with TS95006 or subsequent regulations. This means that the compressors cannot be used in units not developed and approved for R600a from the beginning.

Applications

In the following some examples of the fields of application for F, FT, G and K compressors are given.

“F“ compressors
Examples: TL4F, NL7F, SC15F

The letter F indicates that the compressors are intended for operation with R134a refrigerant at low evaporating temperatures (LBP). Typical fields of application are refrigerators, chest freezers, refrigerated display counters and similar appliances. This indicates that the field of application is LBP (MBP) and that the evaporating temperature range is approx. -35°C to approx. -10°C. In order to ensure trouble-free compressor operation, extreme voltage fluctuations (in excess of +/- 10%) in proportion to nominal voltage must not occur. F compressors in sizes intended for household refrigeration appliances are also available in designs featuring low energy consumption (E, ES, Y). However, this means that the motors cannot start with certainty on a line voltage of less than 90% of nominal voltage. Consequently, F compressors are the solution preferred in industrialized countries with a stable voltage supply of 220-240 V 50 Hz (115 V 60 Hz) and with a special interest in low energy consumption. 240 V 50 Hz enhances motor torque in proportion to 220 V 50 Hz and as a result, F compressors are capable of withstanding higher loads when connected to a 240 V mains supply rather than 220 V. On the other hand, 220 V F compressors are not suitable for operation on a 60 Hz mains supply such as 220 V 60 Hz and 230 V 60 Hz. F compressors intended for a nominal voltage of 115 V 60 Hz can normally also be operated at 110 V 50 Hz and 100 V 50 Hz, because a change from 60 Hz to 50 Hz enhances motor torque.

“FT“ compressors
Examples: TLS3FT, NL7FT

FT compressors are particularly suitable for countries with an unstable power supply, i.e. extreme undervoltages. These are F compressors specially developed for the tropics and are particularly suitable for use in regions with more critical operating conditions (e.g. high ambient temperatures, large voltage fluctuations in the mains supply). As is the case with the F type, FT compressors are dimensioned for fields of application involving low evaporating temperatures (LBP).

“G“ compressors
Examples: TL4G, FR7.5G, 5G, SC12G

The letter G signifies that the motor is of higher nominal power than the F compressor and consequently a G compressor can be used at higher evaporating temperatures than the F compressor.
The motor designation relates to the output at a load corresponding to half the breakdown torque. The concept “breakdown torque” expresses the highest load the motor is capable of handling without stopping. When testing a compressor in practice, motor breakdown torque should be sufficiently high to enable the motor to handle extreme conditions.

The load the compressor is capable of withstanding is illustrated by means of “breakdown curves” and the operating conditions the compressor is capable of withstanding are thus made clear. These curves are determined by maintaining a constant suction pressure (evaporating temperature) and subsequently allowing the compressor to work at an increasing back pressure on a constant voltage. If the load becomes too high, the number of revolutions will fall while current consumption increases markedly and finally the compressor will stop.

The figure illustrates the load limits for compressors TL-„F” and TL-„G” on various undervoltages and the same motor temperature. In addition, the limit for TL-„G” at 60 Hz has been included in the diagram. The diagram also shows a typical example of the load fluctuations to which a compressor is subjected from start-up to stationary operation in a refrigerant circuit with capillary tube throttling. The pressure sequence, determined by the start condition and system composition, is called “system characteristics”. In this example the start condition is determined by the occurrence of pressure and temperature equalization in the refrigeration system at 43°C.

For a compressor to be able to handle the shown load sequence, it is a precondition that the breakdown curve at a specific voltage does not intersect the system curve.

It can be seen from the figure that the sequence of the breakdown curve for a TL-„G” at 60 Hz is more or less the same as the curve for a TL-„F” at 50 Hz. In the example shown consideration should be given to the inclusion of a G compressor if refrigeration appliances designed for 230 V 50 Hz are to be connected to a 220 V or 230 V 60 Hz mains supply. Furthermore, improved undervoltage properties are obtained at the same frequency by the stronger motor of a G compressor, than is the case with a corresponding F compressor. This is the reason why G types are an excellent solution in fields with heavier undervoltage, while the F type is used in household refrigeration and freezing appliances intended for countries with a more stable power supply.

Higher motor torque will be required for operation at high evaporating temperatures (HBP) than for operation at low evaporating temperatures (LBP). G compressors are suitable for this field and can thus be characterized as R134a universal compressors.

Energy-optimized compressors are characterized by a minimum in mechanical and electrical losses but high volumetric efficiency. With a view to achieving high motor efficiency, well-defined application conditions, limited undervoltage and a proper system curve should be taken into consideration when dimensioning the compressor. Here, the careful dimensioning of system components (condenser surface, condenser volume and capillary tubes) is necessary.

Seen from this point of view, F compressors are a better solution in terms of energy consumption than the G types, and are intended for household refrigeration appliances. In all cases the precondition for trouble-free operation is a stable supply voltage (min. 90% of line voltage) and suitable system dimensioning.
LST / HST start characteristics

Breakdown torque limits the load possibilities during operation and start-up. Sufficient starting torque is, however, also required in order to start the motor.

The figure illustrates the torque curves for an LST and an HST motor. LST and HST are abbreviations for Low Starting Torque and High Starting Torque respectively. On the ordinate torque is indicated and on the abscissa the motor speed. As can be seen, low starting torque is characteristic of LST motors and high starting torque is characteristic of HST motors. Compressor motors featuring high starting torque are always equipped with a start capacitor. Single-phase compressor motors are started by engaging an auxiliary circuit consisting of a start winding and a starting device. The starting device may consist of a current relay (or voltage relay) or a semiconductor, a so-called PTC (Positive Temperature Coefficient).

LST compressors

LST compressors can only be used in refrigeration systems where evaporating pressure and condensing pressure are equalized prior to each start-up. A precondition here is expansion through a capillary tube. A characteristic feature of the Danfoss LST electrical system is that it incorporates a 103N...PTC as an auxiliary component, and a built-in motor protector. The PTC is a semiconductor with a positive temperature coefficient, which means that it allows high current flow when cold. Once the PTC has been heated by current flow, its resistance increases to the point where current flow becomes just high enough to keep the PTC warm.
HST compressors

When starting a compressor at a pressure difference, the motor requires a high starting torque and HST starting equipment is thus required. Refrigeration systems with expansion valve must always be equipped with HST compressors as the compressor is always started at a pressure difference.

Some refrigerators featuring capillary tube operation also have short standstill times that complete pressure equalization between the high pressure and suction sides prior to the next start-up can hardly be expected. A compressor with HST start characteristics should also be used in such refrigerators.

Since HST starting equipment always incorporates a start capacitor, the cut-in current of the HST compressor is lower than that of the corresponding LST compressor. From time to time this relationship is utilized in connection with weak mains supply so that the voltage drop in the starting phase can be reduced. The HST starting system can also be used for a refrigeration circuit where pressure equalization takes place and where it has been planned to include LST starting equipment.

All FR compressors, a large part of the TL and NL, as well as many SC types incorporate motors which can be equipped with an LST or HST starting device at the customer’s request. This gives advantages with respect to stocks and customer service (in comparison with the conventional concepts which prescribe incorporating LST or HST motors in the compressors).

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All SC compressors not equipped with LST / HST universal motors are only available with HST starting equipment. The electrical diagram for the HST motor system CSIR is shown below:

In the working cycle displayed in the above figure, resistance is indicated in ohms (Ω) on the ordinate and temperature in degrees Celsius (°C) on the abscissa. The curve shows the connection between resistance and temperature during heating (start-up) and cooling (disconnected). It is characteristic of the PTC that it only allows a limited cut-in time in the start winding. If start-up fails, the start winding cannot become overloaded. A current relay, on the other hand, is capable of performing repeated cut-in and cut-out at very short time intervals, which could lead to overloading relay contacts and start winding. In all cases, the PTC requires time to cool prior to restarting. In order to illustrate the PTC operating principle, the figure also displays a current/time diagram. The longer the PTC starter is allowed to cool, the better it is prepared for the subsequent start-up, which means the start winding also works longer.

Preconditions for using the PTC system:
- Standstill times permitting pressure equalization to take place in the refrigeration system must be ensured by the thermostat.
- Depending on compressor size, standstill time should be longer than 3 to 5 minutes (e.g. TL minimum 3 minutes, SC minimum 5 minutes)

The PTC system offers a number of advantages:
- Improved start winding protection
- PTC functioning independent of over and undervoltages
- No radio and television interference
- No wear
- Identical PTC starter for many different compressor sizes

In the diagram below the E wiring diagram for the LST motor system RSIR is shown with relay as well as with PTC.

The motor is normally protected by the internal motor protection. The already mentioned TF, NF and FF types incorporate an external motor protector.

Many compressors can be converted from LST to HST operation by merely replacing the starting device.

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Many compressors can be converted from LST to HST operation by merely replacing the starting device.
Refrigerants R134a, R404A or R507 used today need improved oils. They are only used in connection with polyolester oils of a special quality.

Because of these new oil types and the application of the above mentioned refrigerants there is – in practice – no longer any danger of valve coking.

Restrictions on condensing and motor temperatures are now set to protect the motor and thus increase its life.

For the application of Danfoss compressors in household and commercial refrigeration using the available refrigerants, we recommend the following rules to be observed.

**Coil temperature**

Coil temperature must not exceed 125°C during continuous operation.

For limited periods of time, e.g. during compressor start-up or in the case of short load peaks, the temperature should not exceed 135°C.

For commercial refrigeration with R134a the same limits as for household refrigeration apply. However, fan cooling of the compressor is recommended.

**Condensing temperature**

When using R600a or R134a condensing temperature during continuous operation must not exceed 60°C. During limited load peaks the temperature must not exceed 70°C.

In commercial refrigeration using R404A and R507 the condensing temperature limit is 48°C during continuous operation and 58°C in the case of load peaks.

All CL and DL compressors are fan-cooled.

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**Precondition for long operating life**

In order to achieve trouble-free operation and long operating life for a hermetic compressor, the following preconditions should be observed:

1. Sufficient starting torque of the compressor motor to allow the motor to start at the pressure conditions in the refrigeration system.
2. Sufficient breakdown torque to allow the motor to handle the load conditions at start-up and during operation.
3. When the refrigeration system is in operation, the temperature in the compressor should not rise to levels which could damage its components. Consequently, condensing and compression temperatures should be kept as low as possible.
4. Precise dimensioning of the refrigeration system in question and careful evaluation of the operating conditions of the compressor at expected maximum loads.
5. Sufficient cleanliness and low residual humidity in the circuit.

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**Motor overload**

Compressor start-up is influenced by the starting and/or breakdown torque of the motor. If starting and/or breakdown torque is insufficient, the compressor either cannot start or the start will be hampered and delayed because the motor protector is activated. Repeated start attempts subject the motor to overload, which sooner or later will result in failure. Faults of this kind can mostly be avoided by using the correct compressor/motor combination. Danfoss offers the best solution for nearly all applications. It is a question of selecting the correct compressor for difficult fields of application.

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**Thermal overload**

Operating conditions resulting in thermal decomposition of the materials used in the compressor must be avoided to ensure long compressor life. The materials relevant in this relation are motor insulation, refrigerant and oil. The motor insulation consists of the insulating enamel for the copper wires, the slot liner of the stator iron, bandages and feeder cables.

As early as 1960, Danfoss introduced fully synthetic insulation materials on all its compressors and the enamel for the wire insulation and the insulating system itself has improved continuously ever since. The result is constantly improved protection against motor overload.

Like all other CFC gases, R12 and R502 were found to be harmful to the environment and were consequently prohibited. These refrigerants were used together with mineral oils. A so-called Spauschus reaction between oil and refrigerant could consequently occur at high temperatures, which in the end led to valve coking, especially at high residual humidity.

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In accordance with the Montreal Protocol the use of CFC refrigerants (chloro-fluoro-carbons) has been discontinued. This also includes refrigerants such as R12 and R502. Within the foreseeable future HCFC refrigerants (partly halogenated chloro-fluoro-carbons) cannot be used in Europe any longer. In order to observe the time limits for abandoning HCFC refrigerants, various refrigerants were developed to replace the old ones.

All new refrigeration units must operate with the remaining refrigerants, i.e. PFC (perfluor-carbons), HFC (hydrofluoro-carbons), hydrocarbons or inorganic refrigerants.

In the case of HFC refrigerant R134a a long-term replacement for the ozone-depleting R12 has been found. R134a has approximately the same thermodynamic properties as R12, which simplifies the conversion of installations. Danfoss can offer a wide range of compressors designed for R134a refrigeration units.
In Germany, the flammable hydrocarbon refrigerants (such as R600a isobutane) have found widespread use in household appliances. Only time will show whether the propagation of hydrocarbons will continue. In the USA, a similar development cannot be expected.

Until recently, the CFC refrigerant R502 was used in commercial refrigeration. There are some HFC-mixtures which will – in the long run – replace R502. Among these mixtures are R404A and R507. Instead of the HCFC refrigerant R22, R404A and R507 can also be used in commercial applications. CL and DL compressors are designed for use in refrigeration systems working with R404A and R507.

Information on Danfoss compressors

Information on Danfoss’ compressors and condensing units can be found in the extensive specialist literature and technical data sheets.

In addition a program is available on CD-ROM for assisting our customers in quickly selecting compressors to suit their conditions. Additional information on Danfoss can be found on the Internet: www.danfoss.com/compressors.