Copeland® | application engineering bulletin **EMERSON** Climate Technologies

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Copeland Screw Compressors
Semi-Hermetic Compact Application Manual

SCH2 & SCA2
High Temp Compressors
35 – 140 Horsepower

Contents

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Copeland application engineering bulletin — EMERSON Climate Technologies

Semi-hermetic compact screws SCH2/SCA2 series 35 to 140 HP Nominal motor power

1.General

This new series represents the result of further development to provide a simplified and favorably priced screw compressor for use in factory made systems.

Contrary to the semi-hermetic and open type, SHM/SHL and SDM/SDL compressor models for commercial and industrial installation, the compact screws are designed with an integral oil separator. The effort involved in installation is therefore comparable with that for semi-hermetic reciprocating compressors.

In addition to this, the electrical control and the monitoring of the oil circuit has been simplified. The proven basic construction and the ease of service have been retained.

The most modern screw compressor technology is now available in the middle capacity range for compact liquid chillers and air conditioning equipment.

2. Design and function

2.1 Design features

Copeland Compact Screws are of the twin rotor design with a newly-developed profile geometry (lobe ratio 5:6). The main parts of these compressors are the two rotors (male and female rotor), which are fitted into a closed housing. The rotors are precisely located at both ends in rolling contact bearings (radial and axial), which, in conjunction with the generously sized oil supply chambers, provides optimum emergency running characteristics.

Owing to the specific design, this type of compressor does not require any working valves. To protect against reverse running when the compressor is switched off (expansion operation) a check valve is incorporated in the discharge chamber (this valve does not, however, replace any check valves required by the system design). An internal pressure relief valve is utilized for over-pressure protection.

The compressor is driven by a three-phase asynchronous motor, which is built into the compressor housing. The motor rotor is located on the shaft of the male screw rotor. Cooling is achieved by cold refrigerant vapor, which mainly flows through bores in the motor rotor.

The main technical features:

Balanced product range
- 8 basic models
- Tight performance graduation

Minimal space requirements and convenient piping design
- Shortest installed length in its performance category - shut-off valves / connections within compressor dimensions
- Suction and discharge gas connections can be rotated in 90° increments
- Terminal box accessible from top, wire access from underneath

Universal applications
- R134a, R407C and R22
- R404A, R507A upon request
- With or without economizer
- Optimized R-134a version (SCA2)

New high-efficiency profile
- Further developed geometry
- High rigidity
- Patented manufacturing process for highest precision
- High tip speed to minimize blow-by

Double-walled, pressure-compensated rotor housing
- Extremely stable, therefore no expansion even at high pressure levels
- Additional sound attenuation

Proven, long-life bearings with pressure unloading
- Robust axial bearings in tandem configuration
- Bearing chamber pressure isolated by seal rings
- Pressure unloading of axial bearings

Optimized oil management
- Three-stage oil separator
- Long-life oil filter 10 µ mesh size
- Pressure relieved bearing chamber ensuring minimum refrigerant dilution in the oil and thus higher viscosity

Large volume motor for part winding or direct start - optional star delta design
- Especially high efficiency

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- Integrated PTC sensors in each winding coil
- Slot keys for maximum operating safety
- Stator is slide fit (field replaceable)

Intelligent electronics
- Thermal motor temperature control by winding PTCs
- Phase sequence control for direction of rotation
- Manual reset lock-out
- Oil temperature protection by PTC sensor

Flexible with additional cooling
- Direct liquid injection
- External oil cooler for extended application and highest efficiency

Dual capacity control
- Infinite or 4-step slide control with V_i compensation. Alternative operation modes by varying the control sequence only - no need for compressor modification
- Simple control by solenoid coils
- Automatic start unloading

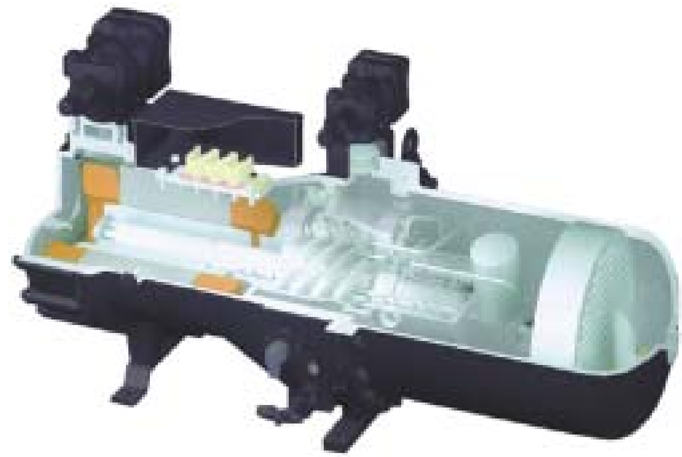
Economizer with sliding suction position
- Unique for compact screws
- Efficient economizer operation with part load as well
- Highest cooling capacity and energy efficiency at full and part load conditions

Fully equipped
- Capacity control / start unloading
- Suction and Discharge shut-off valve
- Check valve in discharge gas outlet
- Oil sight glass
- Insertion type oil heater with sleeve
- Oil fill / drain service valve
- Suction gas filter with large surface are and fine mesh
- Electronic protection system

Proven optional accessories
- Oil level switch
- Shut-off valve / adapter for economizer operation and liquid injection
- Adapter for external oil cooler

2.2 Compression process V_i-control

With screw compressors, suction, compression and discharge occur in one flow direction. With this process the suction gas is pressed into the profile hollows by the profile peaks. The volume is steadily reduced and it is thereby compressed. The compressed gas is then discharged through a discharge port whose size and geometry determine the so called "internal volume ratio



(V_i)". This value must have a defined relationship to the mass flow and the working pressure ratio, to avoid losses in efficiency due to over- and under-compression.

The internal discharge ports of the SCH2/SCA2 screw compressors are designed for a very wide application range.

In view of high efficiency and operational safety a part of the discharge channel is integrated into the control slide, which enables a V_i control at part load conditions. Due to this the internal volume ratio (V_i) virtually remains constant down to approximately 70% part load.

The economizer channel built into the control slide is another outstanding feature (figure 3). It enables a fully functional operation of the subcooler circuit independently from the compressor's load conditions. This is a design solution which is unique for screw compressors of this size. This ensures highest possible capacity and efficiency at both full and part load conditions. For details regarding economizer operation see Section 5.

2.3 Capacity control and start unloading

SCH2/SCA2 models are provided as a standard with a "Dual Capacity Control" (slide system). This allows for **infinite** or **4-step capacity control** without compressor modifications. The different operating modes can be achieved by changing the control sequences of the solenoid valves.

The special geometry of the slide means that the volume ratio V_i is adjusted to the operating conditions in part-load operation. This provides particularly high efficiency.

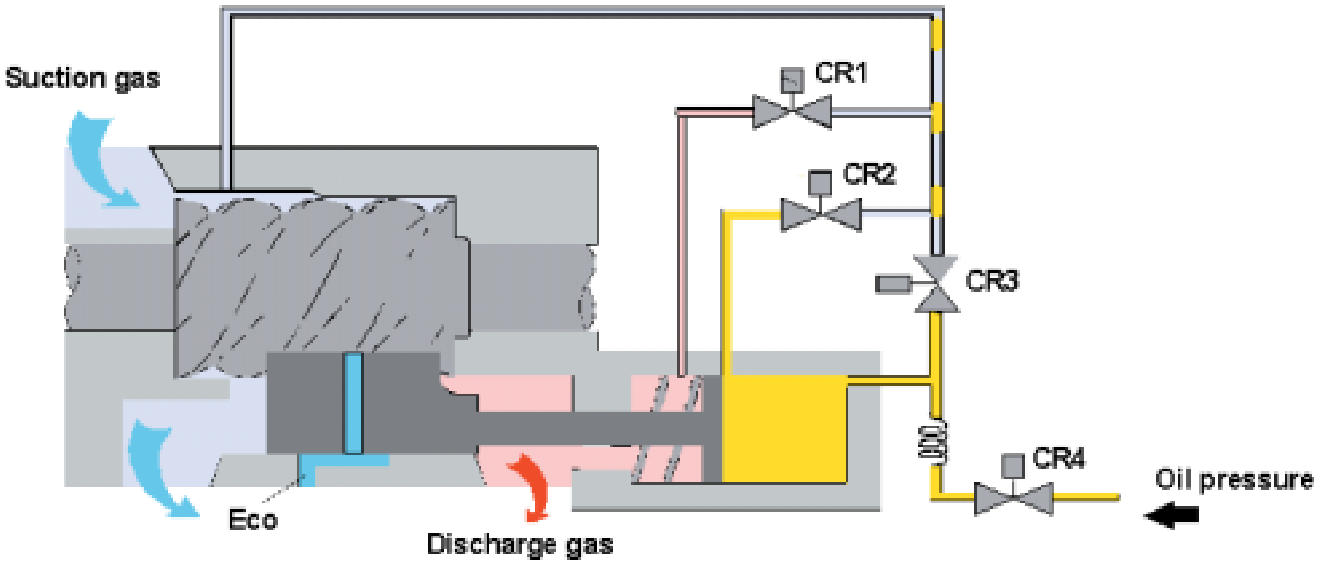


Figure 3
Oil Hydraulic Scheme

Another feature of this system is the automatic start-unloading. It reduces starting torque and acceleration times considerably. This not only puts lower stresses on motor and mechanical parts but also reduces the load on the power supply network.

Significant design features are the robust dimensioning as well as the precise guidance of the slide elements and the control piston. Capacity control is achieved by means of solenoid valves that are flanged on to the compressor. A "dual set point controller" or any similar component is suitable as a control module.

2.4 Hydraulic control

Figure 3 shows the design principle of the hydraulic scheme. By moving the slide the suction gas flow is controlled.

If the slide is moved totally to the suction slide (in the figure 3 to the left), the working space between the profiles is filled with suction gas. The more the slide is moved to the discharge slide, the smaller the resulting profile volume becomes. Less refrigerant is taken in. The mass flow is lower, and the cooling capacity decreases.

The slide is controlled by a hydraulic piston. If the valve CR4 is opened, the oil pressure in the pressure chamber increases. The slide is moved to the suction side. The cooling capacity increases.

If the valve CR1, CR2 or CR3 is opened, the pressure on the hydraulic piston decreases. By means of the discharge gas the slide is pressed to the discharge side. The cooling capacity is reduced.

2.5 Starting the compressor

During the shut - down of the compressor the solenoid valve CR3 is open. The pressure in the hydraulic cylinder is then released. The spring (fig. 3) pushes the slide to the discharge side end position.

When starting the compressor, it is unloaded. Valve CR4 is energized on demand thus moving the slide towards the suction side. The refrigerating capacity increases to the set load condition by energizing the valves CR1, CR2 or CR3.

2.6 Infinite capacity control

Infinite capacity control is recommended for systems where high control accuracy is required. For control principle see charts A, B, and C.

If the actual value is within the set control range H, the cooling demand of the plant remains unchanged. Then

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there is no need to move the slide. No solenoid valve is energized.

The control input can be the air or water temperature at the evaporator or the suction pressure.

Chart A
Control Sequence – Infinite Capacity Control
Minimum Capacity ❍

CR	1	2	3	4
Start/Stop	❍	❍	●	❍
Cap ⇑	❍	❍	❍	●
Cap ⇓	❍	❍	●	❍
Cap ⇔	❍	❍	❍	❍
Cap. 100%	❍	❍	❍	●
Cap. Min.W	❍	❍	●	❍

Chart B
Control Sequence – Infinite Capacity Control
Minimum Capacity 50%

Cap ⇑	❍	❍	●	
4 Cap.	❍	●	❍	❍
Min.50%				

Increased cooling demand

If the actual value exceeds the upper set point, the cooling demand has increased (operating point A in fig. 4). The solenoid valve CR4 is opened for short intervals till the actual value is within the set control range again (operating point B). Now the compressor operates with increased cooling capacity.

Chart C
Control Sequence – 4-Step Capacity Control

CR	1	2	3	4
Start/Stop	❍	❍	●	❍
Cap 25%	❍	❍	●	⍓
Cap 50%	❍	●	❍	⍓
Cap 75%	●	❍	❍	⍓
Cap. 100%	❍	❍	❍	❍

❍ **Solenoid Coil De-Energized**
● **Solenoid Coil Energized**
⍓ **Solenoid Coil Pulsing (10 secs. on / 10 secs. off)**

Decreased cooling demand

A decreased cooling demand falls below the lower set point (operating point C). The solenoid valve CR3 now opens for short intervals till the actual value is within the set control range again (operating point D). The compressor operates with decreased cooling capacity.

With the solenoid valves CR3 / CR4, capacity can be controlled between 100% and nominally 25%. Alternatively valves CR2 / CR4 can be energized; in this case control will be limited between 100% and nominally 50%.

The limitation to a minimum of approximately 50% cooling capacity is recommended for the following application conditions (control with valves CR2 / CR4):

- In case of operation at high-compression ratios / condensing temperatures, the main concern is high discharge temperature.
- For systems with multiple compressors either used in split or singlecircuits. Under these conditions capacity control between 100 and 50%, in combination with individual compressor on/off cycling, guarantees highest possible efficiency – without significant restrictions in the application range. Due to the usually lowered condensing temperature at part load conditions, the lead compressor can even be operated very effectively down to nominal 25% of cooling capacity (with valves CR3 / CR4)

2.7 4-step capacity control

This type of capacity control is particularly suited to systems with high inertia – in connection with indirect cooling, for example. Liquid chillers are typical applications. Chart C shows the control of the solenoid valves or the individual capacity steps.

The cycle time of the intermitting valve, CR4, should be adjusted to about 10 seconds before commissioning. Even shorter intervals may be necessary, particularly with systems with high pressure differences. Therefore, in this case adjustable time relays should be used. For this type of operation a restriction of minimum refrigeration capacity to approximately 50% is also recommended, as with the systems described in Section 2.6. Control is then effected with the CR4 valve (intermittent) and with CR1 (75%) and CR2 (50%).

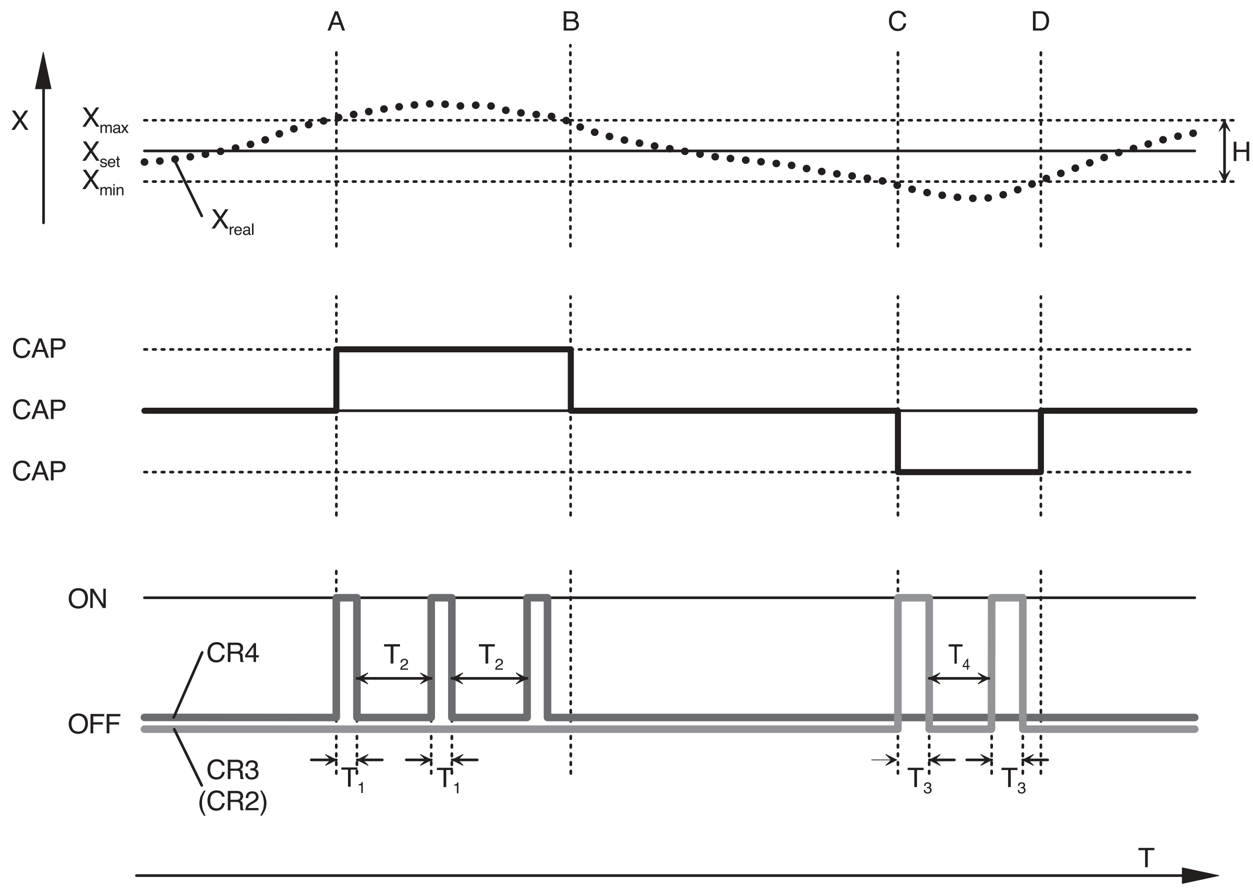

Figure 4
Infinite capcity control scheme

2.8 Oil circulation

The lubrication circuit is designed as is typical for screw compressors. This type of design, however, has a vessel directly flanged-on to the compressor housing at the high-pressure side. It contains the oil reservoir. The vessel simultaneously serves as an oil separator.

The oil circulation results from the pressure difference to the oil injection point, where the pressure level is slightly above suction pressure. The oil flows through a generously sized filter element to the throttle point and subsequently to the bearing chambers and the profile spaces of the rotors. The oil is then transported together with the refrigerant vapor in the direction of compression. In addition to lubrication it also provides a dynamic seal between the rotors and between the housing and the rotors. The oil then flows together with the compressed vapor into the reservoir vessel. Here oil and vapor are separated in a highly efficient process. The oil collects in the lower part of the separator vessel and flows back into the compressor either direct or via an external oil cooler. Depending on the operating conditions the circulating oil must be cooled with liquid injection or an external oil cooler (see Section 4.4 and 4.5)

Monitor the oil circuit

- For short circuits **without** refrigerant injection for additional cooling and for small system volumes and refrigerant charges: indirect monitoring by means of oil temperature protection (standard)

> ***CAUTION!***
> ***Lack of oil leads to a dramatic temperature increase.***

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- For circuits **with** refrigerant injection for additional cooling and / or for greater system volumes: Direct monitoring by means of an oil level monitor in the oil separator(optional accessory) is recommended.

3 Lubricants

Apart from the lubrication it is also the task of the oil to provide dynamic sealing of the rotors. Special demands result from this with regard to viscosity, solubility and foaming characteristics. Copeland approved oils may therefore be used only.

Important instructions

- Observe the application limits of the compressors.
- The lower limit value of the discharge gas temperature (140°F) is a reference value only. It must be ensured by sufficient suction super-heat that the discharge gas temperature is at least 54°F (R134a, R404A / R507A mi. 36°F) above the condensing temperature.
- Ester oils Solest170 (for HFC refrigerants) and CP4214-320 (for R22) are very hygroscopic. Special care is therefore required when dehydrating the system and when handling open oil containers.
- A corrected design may be necessary for direct-expansion evaporators with finned tubes on the refrigerant side (consultation with manufacturer).

The above information corresponds to the present status of our knowledge and is intended as a guide for general applications. This information does not have the purpose of confirming certain oil characteristics or their suitability for a particular case.

4 Integration into the refrigeration circuit

Compact screw compressors are well suited for integration in factory-assembled plants (liquid chillers and air conditioning units). Their use in extended systems is also possible, for example, with remotely installed condenser.

Systems with multiple compressors should preferably be designed with individual circuits. Parallel compound is possible, but requires a special oil equalizing system by means of oil level control.

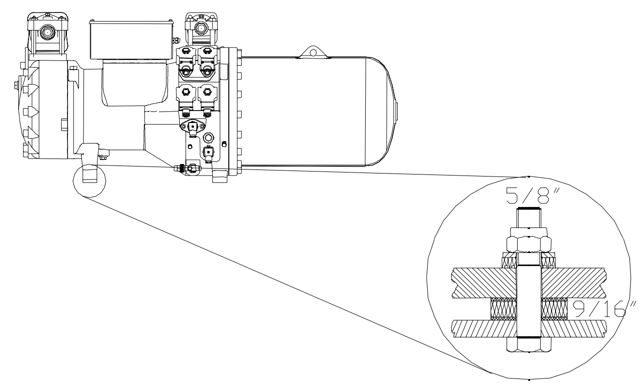

Figure 5
Mounting and installation

4.1 Mounting the compressor

With stationary systems the compressor has to be installed horizontally.

In case of marine application, mounting in direction of the longitudinal axis of the boat may be required. Detailed layout recommendation can be provided upon request.

Anti-vibration mountings

Rigid mounting of the compressor is possible. The use of anti-vibration mountings especially matched to the compressors is recommended, however, to reduce the transmission of body radiated noise.

With direct mounting on water cooled condensers:

> ***CAUTION!***
> ***Do not mount the compressor directly on the condenser. Do not use the condenser structural mmember! Damage of the condenser is possible (fatigue fractures). Use anti-vibration mountings!***

The installation of the anti-vibration mountings is shown in figure 5. The bolts should only be tightened until slight deformation of the upper rubber disc is just visible.

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4.2 System layout

The compressor is installed in the refrigerating circuit similar to semi-hermetic reciprocating compressors.

Plant design and pipe layout

The pipelines and the system layout must be arranged so that the compressor cannot be flooded with oil or liquid refrigerant during shutdown.

Suitable measures are (also as a simple protection against liquid slugging during start)
- either to raise the suction line after the evaporator (goose neck)
- or to install the compressor above the evaporator.

Additional safety is provided by a solenoid valve installed directly before the expansion valve. In addition the discharge line should first be angled downwards after the shut-off valve.

Due to the low level of vibration and discharge gas pulsation the suction and discharge lines can be made without the use of flexible elements or mufflers. However, pipelines must be sufficiently flexible and supported to not exert any strain on the compressor. The most favorable pipe runs are designed parallel to the compressor axis and the discharge line first leading downwards. The distance to the axis should be as short as possible and the parallel pipe section should be at least half the compressor's length. Finally, long radius elbows should be used.

Due to gas pulsations there can be vibrations especially in discharge and economizer lines. Therefore critical pipe lengths (+/- 15%) with their natural frequencies being in resonance with the compressor pulsations must be avoided.

Among other things the operating conditions and the refrigerant (sonic speed) as well as the compressor's pulsation frequency must be considered in the calculation.

The base frequency of the compressor is approx. 250Hz (50Hz network) or 300 Hz (60 Hz network). Frequencies of higher orders (500 / 1000 Hz or 600 / 1200 Hz) should also reviewed at in the final layout.

Oil heater

An oil heater is provided to prevent too high a concentration of refrigerant in the oil during shutdown. It is mounted in a heater sleeve and can be replaced if necessary without accessing the refrigerating circuit. For electrical connection see section 6.4.

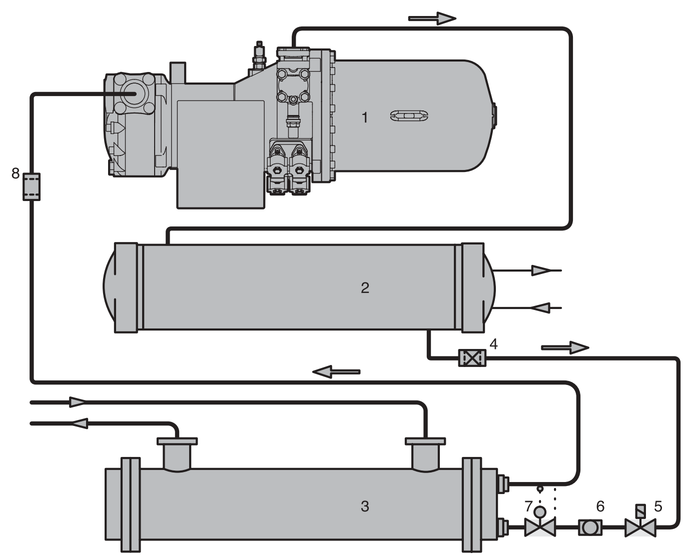

Figure 6
Typical system design

Additional insulation of the oil separator

Operation at low ambient temperatures or at high temperatures on the discharge side during standstill (such as heat pumps) requires additional insulation of the oil separator.

Filter drier

Generously sized filter driers of suitable quality should be used to ensure a high degree of dehydration and to maintain the chemical stability of the system.

Suction side cleaning filter

The use of a suction side filter (filter mesh 25 m) will protect the compressor from damage due to dirt from the system and is strongly recommended for site built systems.

Expansion valve and evaporator

Expansion valve and evaporator have to be adjusted using utmost care. This is especially important for those systems that cover a large control range, e.g. 100% to 25%. In each case, sufficient suction gas superheat and stable operating conditions must be assured in full load as well as part load modes. Depending on the evaporator's design and performance range several circuits may be necessary each with separate expansion and solenoid valves.

3.3 Guidelines for special system variations

Pump down circuit

If the evaporator and / or the suction line can become warmer than the compressor during shutdown, a "pump down" cycle must be incorporated in addition to the oil heater.

Additional check valve in the discharge line and automatic sequence control

For systems with multi-circuit condensers and / or evaporators, an increased danger exists when individual circuits are shut off. During this period liquid refrigerant can migrate into the evaporator (no temperature and pressure equalization possible). In these cases an additional check valve must be installed in the discharge line. In addition the compressors should be operated with an automatic sequence control.

The same is also valid for individual systems without temperature and pressure equalization during longer shutdown. In extreme cases a suction accumulator or "pump down" cycle can also become necessary.

Additional oil level control

The above guidelines also apply to systems with long pipelines (suchas a remote evaporator and / or condenser). In addition the compressor must be equipped with an oil level switch (accessory). For electrical connection see Section 6.4.

Systems with reverse cycling and hot gas defrost

These system layouts require individually system design review to protect the compressor against liquid slugging and increased oil carry-over. A suction accumulator is recommended to protect against liquid slugging. To effectively avoid increased oil carry-over (such as due to a rapid decrease of pressure in the oil separator), the oil temperature must remain at least 54° F above the condensing temperature during charge over. In addition, it may be necessary to install a pressure regulator immediately after the oil separator to limit pressure drop. Under certain conditions it is also possible to turn off the compressor shortly before the change over procedure and to restart after pressure equalization. It must however be assured that the compressor is operating with the required minimum pressure differential no longer than 30 seconds (see application ranges Section 9).

3.4 Additional cooling by means of direct liquid injection

Additional cooling is required in areas of high condensing and / or low evaporating temperatures. A relatively simple method is direct liquid inject at the economizer connection.

The following criteria must be followed to ensure reliable operation and to avoid excessive dilution of the oil.

Liquid inject valve

Specially designed expansion valves are only suitable for liquid injection. They must control the discharge temperature to setting of 190°F (e.g. Danfoss TEAT20, also series 935-101-B, Sporian Y1037).

The valve bulb must be mounted on the discharge line:

- Clean the tubes surface carefully to bright metal. Distance from discharge shut-off valve approx. 8 to 10 inches.
- Apply heat transfer paste to the contact surface.
- Fix the bulb firmly with adequate pipe clips. Mind heat expansion!
- Insulate the bulb and the section of discharge line

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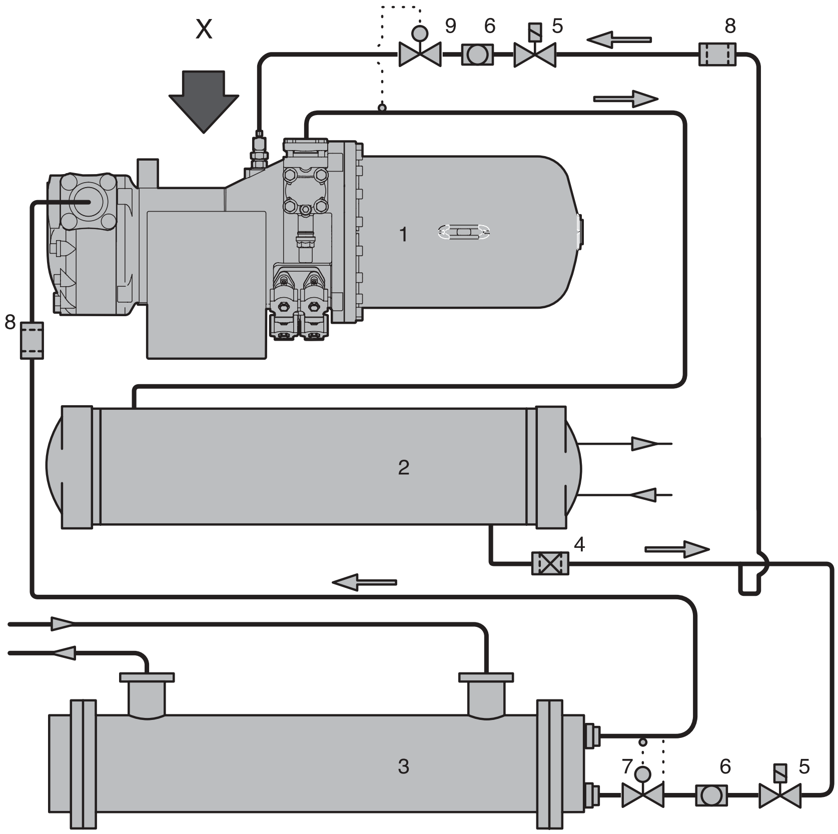

enlargement of area X

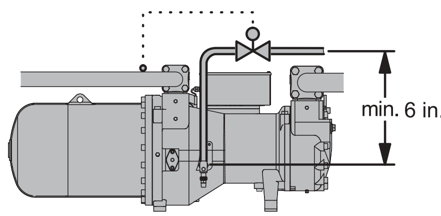

Figure 7
Liquid injection valve (system design)

Pipe runs

To ensure a bubble free liquid supply to the liquid injection valve, the connection must be made on the bottom of a horizontal section of the liquid line.

Installation of the liquid inject valve at the compressor

- Min. 6 to 8 in. above liquid injection connection

> ***CAUTION!***
> ***Vibration fractures possible! install liquid injection and solenoid valves with adequate supports!***
> ***Check for vibration during operation!***

Calculating the cooling capacity of the liquid injection valve

- With the selection software
- Consider the most extreme conditions to be expected during actual operation:
  - min. evaporating temperature
  - max. suction gas superheat and condensing temperature

Further conditions for valve selection

- Pressure at the injection point:
  - R134a approximately 30 to 45 psig above suction pressure R407C, R22 approx. 40 to 50 psig above suction pressure
  - Never size the valve too large danger of refrigerant flooding!

Additional components in the liquid line

- Solenoid valve (energized parallel to compressor contactor)
- Filter dryer (if required)
- Liquid sight glass

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3.5 Additional cooling by means of external oil cooler

The application of an external oil cooler (air, water or refrigerant cooled) instead of refrigerant inject provides additional extension of the application envelopes and even better efficiency.

When calculating an oil cooler, worst case operating conditions must be used:
- Min. evaporating temperature
- Max. suction gas superheat
- Max. condensing temperature
- Operation mode (capacity control, ECO)

Oil cooler capacity can be calculated by using the selection software.

Recommendations for external oil coolers

- Connections for external oil coolers are located on the back side of the compressor below the discharge shut-off valve (oval or rectangular flange). The flange is replaced by a tube adaptor (option):

- Install oil cooler as close as possible to the compressor.

- Piping design must avoid gas pockets and any drainage of oil into the compressor during shutdowns (installation of the oil cooler preferably at compressor level or below).

- Due to the additional oil volume (cooler, piping) a solenoid valve may be necessary in the oil line. This is to avoid oil migration into the compressor during shutdowns. The solenoid valve must be installed close to the compressor's oil inlet connection and its electric control should be parallel to the contactor's normally open contact. Recommended additional components:

  - Sight glass to check oil flow,
  - Manual shut-off ball valves in both feed and return lines for ease of service,
  - Oil filter (max. 25 µ mesh size)

  With an additional oil volume (cooler and piping) of 10% of the compressor's standard oil charge and assured cleanliness of components and pipes the above mentioned measures can be omitted.

- Oil coolers must be controlled by thermostats (see table for temperature settings).

- For rapid heating of the oil circuit and minimizing the pressure drop with cold oil an oil by-pass (or even heating the cooler during shut down) is required under the following conditions:
  - the oil temperature in the cooler drops below 60°F during shut down,
  - the oil volume of cooler plus oil piping exceeds the compressor's oil charge,
  - The oil cooler is an integral part of the condenser coil

- The by-pass valve should have a temperature responsive modulating control function. The use of a solenoid valve for intermittent control would require highly sensitive control thermostat and a minimal switching differential (effective temperature variation < 18°F).

- The oil side pressure drop during normal operation should not exceed 7 psig.

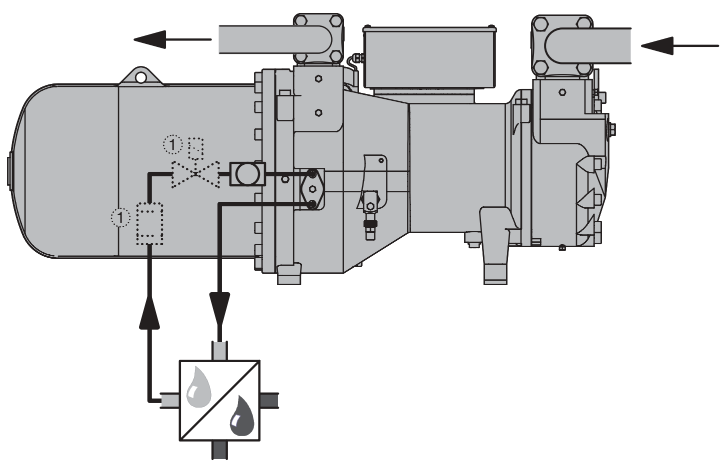


Figure 8
External oil cooler connecccoption

Water cooled oil cooler

Temperature control by thermostatic water regulator (for set point see table, required sensor temperature should be equal to or greater than 250°F).

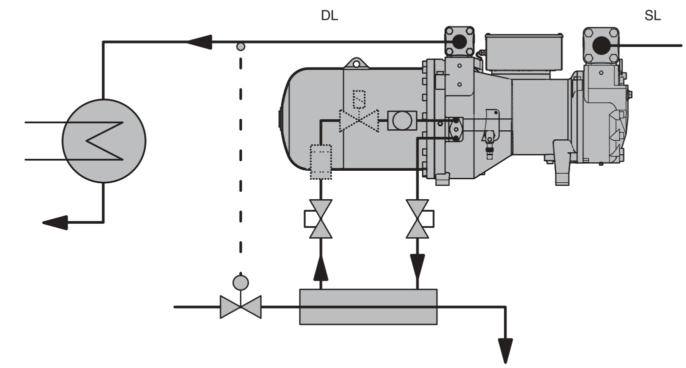


Figure 9
Water-cooled oil cooler

Air cooled oil cooler

Temperature control by thermostatic switching on and off or stepless speed control of the cooler fan (see table for set point, required sensor temperature should be equal to or greater than 250°F).

If the oil coolers is integrated into the condenser the by-pass valve controls the temperature (see table for set point; admissible operating and / or sensor temperature should be equal to or greater than 250°F).

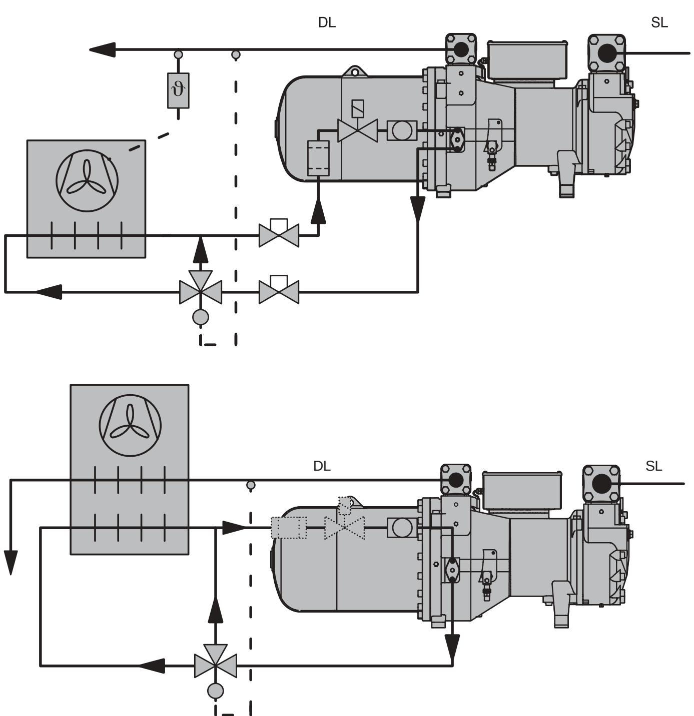
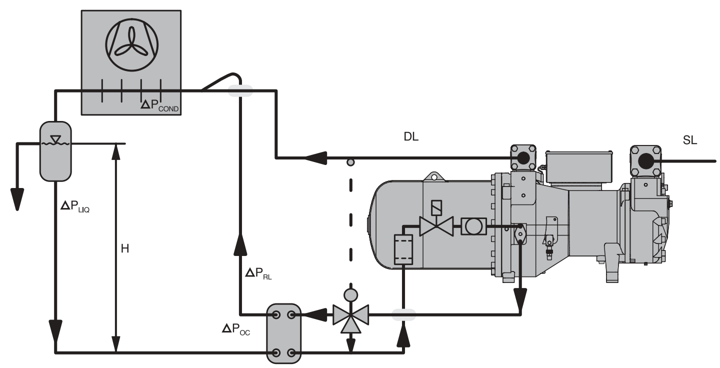


Figure 10
Air cooled oil coolers

Thermosyphon oil cooling (cooling by refrigerant)

Temperature control either by thermostatic regulation valve for refrigerant feed or by-pass valve (see table for set point; admissible operating and sensor temperature should be equal to or greater than 250°F).

As an example figure 11 shows a layout with a primary receiver after the condenser. An alternative layout of the thermosyphon circuit as well as refrigerant circulation by means of a pump or an ejection is also possible (information upon request).



$H(\Delta P) > \Delta P_{COND} + \Delta P_{LIQ} + \Delta P_{OC} + \Delta P_{RL}$

Figure 11
Thermosyphon oil cooling

4 Economizer operation

1.1 General

SCH2/SCA2 screw compressors are designed for economizer operation "ECO". With this operation mode both cooling capacity and efficiency are improved by means of a sub-cooling circuit or 2-stage refrigerant expansion. There are capacity and efficiency advantages in ECO operation over the conventional application, particularly at high condensing temperatures.

A unique feature of the compact screws is the economizer channel integrated into the control slide (fig.12). This enables to operate the sub-cooling circuit regardless of the compressor load condition. Screw compressors with a fixed ECO suction position have this frequently located in the suction area of the rotors during part load and then has no effect.

5.2 Operation principle

With screw compressors the compression process occurs only in one flow direction (see Section 2.2). This fact enables to locate an additional suction port at the rotor housing. The position is selected so that the suction process has already been completed and a slight pressure increase has taken place. Via this connection an additional mass flow can be taken in, which has only a minimal effect on the flow from the suction side.

The pressure level at the ECO suction point is similar to the intermediate pressure with 2-stage compressors. This means that an additional sub-cooling circuit or intermediate pressure receiver for 2-stage expansion can be integrated into the system. This design achieves a significantly higher cooling capacity through additional liquid sub-cooling. At the same time, there is a relatively low increase in the compressor's power input, as the total working process becomes more efficient – due to the higher suction pressure, among other things.

5.3 Economizer operation with sub-cooling circuit

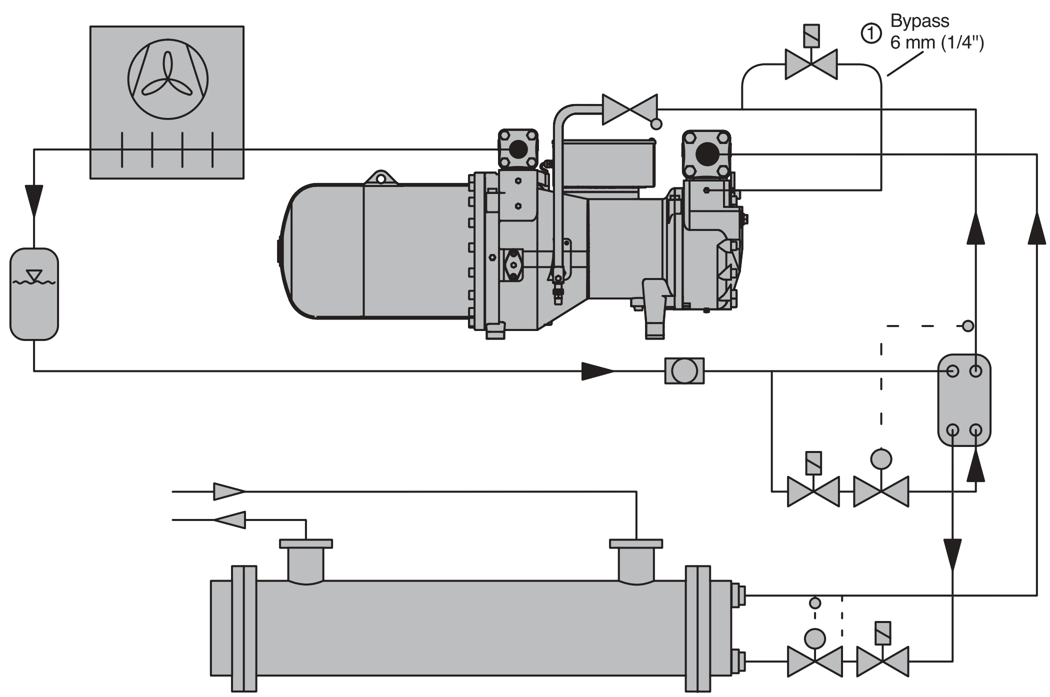
With this operation mode a heat exchanger is utilized as a liquid sub-cooler. A part of the refrigerant mass flow from the condenser enters the sub-cooler via an expansion device, and evaporates upon absorbing heat from the counter-flowing liquid refrigerant (sub-cooling). The superheated vapor is taken in at the compressor's ECO connection, mixed with the mass flow from the evaporator and compressed to a high pressure.

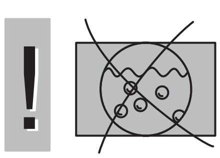
With this type of operation the sub-cooled liquid is under condensing pressure. Therefore the piping to the evaporator does not require any special features – apart from insulation.The system can be applied universally.

5.4 ECO operation with intermediate pressure receiver

This layout version for 2-stage refrigerant pressure relief is particularly advantageous in connection with flooded evaporators and is therefore primarily used in plants with large cooling capacity.

Figure 12
System with sub-cooling circuit





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5.5 Layout and selection recommendations

Pipe layout

- Design the sub-cooler so that during shutdown, neither liquid refrigerant nor oil can enter the compressor.
- Until operating conditions are established during temporary operation without economizer and when switching off the compressor, the compressor can discharge a certain amount of oil through the ECO connection. Oil transfer into the sub-cooler must therefore be prevented by a pipe bending vertically upwards with a check valve (see fig.13).

  In order to avoid instability of the check valve when the ECO circuit is switched off, a by-pass-line with a solenoid valve towards the suction side must also be included (1/4”). The solenoid valve is only open when the ECO is not operating. This way it creates sufficient closing pressure for the check valve.
- See Section 6 for electric control. Other layout versions are also possible, but must be checked for their suitability and operating safety in individual tests.
- The ECO connection leads directly into the profile area. For this reason a high degree of cleanliness must be maintained for sub-cooler and pipes.
- Dimension of the ECO suction line:
  In view of the usually short pipe lengths, the following pipe diameters can be used:
  SCH2 5000 to 9000 1 ¼” – 12 Rotolock
  SCA2 3500 to 7000
  SCH2 11H0 to 14H0 1 ½” – 12 Rotolock
  SCA2 9000 to 11H0

Min 6 – 8” rise

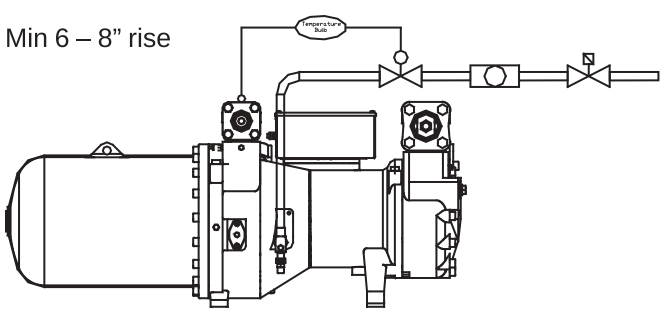


Figure 13
Liquid injection connections

- Pipe vibrations:
  Due to the pulsations emitting from the profile area of the compressor, critical pipe lengths must be avoided. See also Section 4.2.

5.6 Additional components

Refrigerant sub-cooler

Frost proof shell and tube, coaxial or plate heat exchangers are suitable as sub-coolers. In the design phase the relatively high temperature gradient on the liquid side must be taken into consideration.

For capacity determination see output date in the compressor software:
- Sub-cooler capacity
- ECO mass flow
- Saturated ECO temperature and
- Liquid temperature.

Layout parameters

- Intermediate temperature
  - corresponds to the evaporating temperature in the sub-cooler
  - for layout design, take 18°F suction gas superheat into consideration
- Liquid temperature (inlet)
  As a nominal selection basis, liquid sub-cooling of 4°F is assumed

  example:
  t_c = 90°F liquid temperature (inlet) = 86ºF.
- Liquid temperature (outlet) The software pre-set date are based on 18°F above saturated ECO temperature

  Example:
  t_m = +68ºF liquid temperature (outlet) = 86ºF

  Input of individual data is possible. Keep in mind, however, that in practice a stable operating mode is very difficult to achieve with differences between liquid temperature (outlet) and saturated ECO temperature of less than 18°F.

Thermostatic expansion valves

- Valve layout for liquid sub-cooler:
  - Basis is the sub-cooling capacity
  - Evaporating temperature corresponds to the ECO intermediate temperature.
  - Valves with a superheat adjustment of about 10 K should be used in order to avoid unstable operation when switching on the sub-cooling circuit and in connection with load fluctuations.
  - If the sub-cooling circuit is also operated under part-load conditions, this must be given due consideration when designing the valves.

- Valve layout for evaporator:
  Due to the high degree of liquid sub-cooling suction mass flow is much lower than with systems with similar capacity and no sub-cooler (see software data). This requires a modified layout. In this context the lower vapor content after expansion must also be taken into consideration. For further hints on the layout of expansion valves and evaporators see Section 4.2.

5.7 Control

Between that start and the stabilization of operating conditions, the solenoid valve of the sub-cooling circuit is switched on time delayed or depending on suction pressure. For further hints and a schematic layout diagram see Section 6.4.

6 Electrical connection

6.1 Motor design

The compressors are supplied as standard with part winding motors of connection (Part Winding "PW"). Start delta motors are available as special design.

Part winding motors

Starting methods (connections according to figures 14 and 15):
- Part winding start to reduce the starting current
- Direct on line start (DOL)

Start delta motors

Starting methods (connections according to figures 16 and 17).

The start current value in star mode (1/3 of the direct on line value) is generally stated according to standard locked rotor conditions. In reality, however, approx. 50% are obtained during the start. Moreover, when switching from start to delta mode there is a current peak as high as the direct start value. This is caused by the voltage interruption during switch-over of the contactors, which results in a speed drop due to the compressor's small rotating masses.

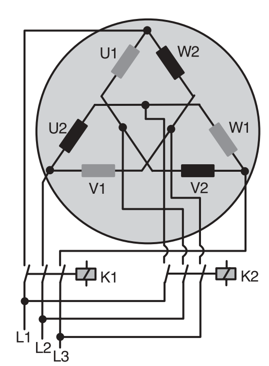
A


Figure 14

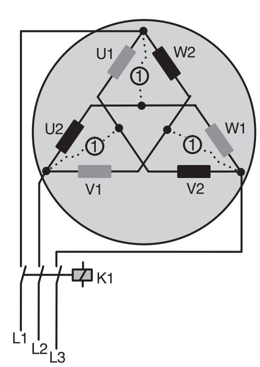
B


Figure 15

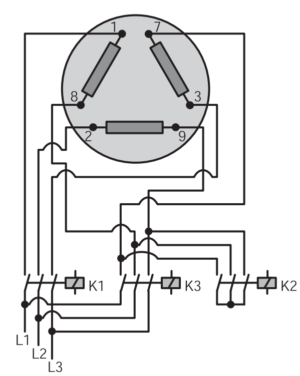
A


Figure 16

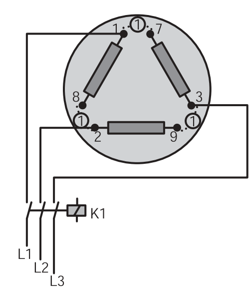
B


Figure 17

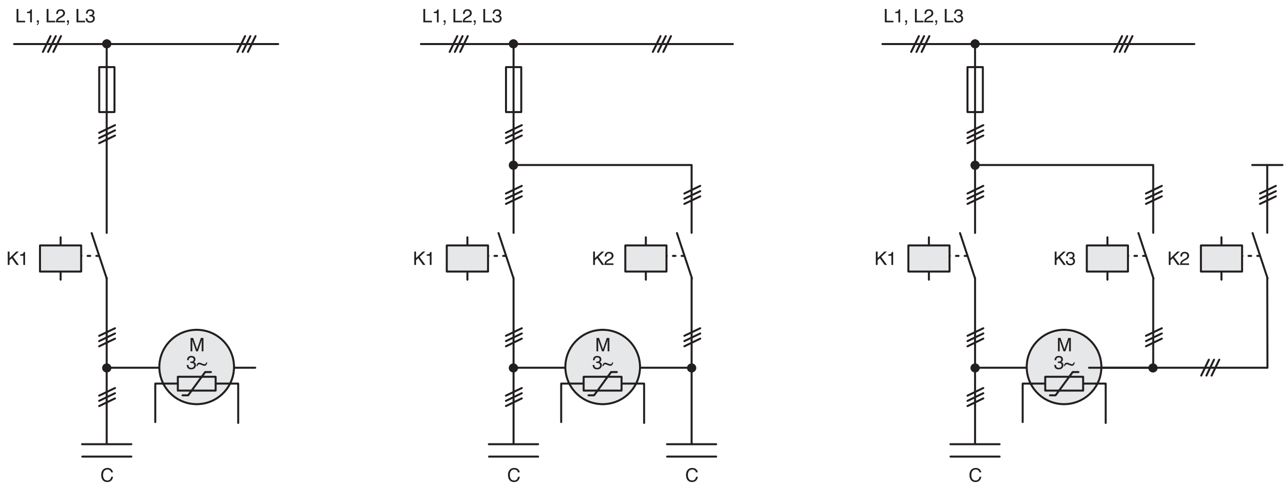


Figure 18
Power factor correction on individual compressors

6.2 Selection of electrical components

Cables, contractors and fuses

CAUTION
Nominal power is not the same as maximum motor power! When selecting cables, contactors and fuses: Maximum operating current / maximum motor power must be considered. See chapter 8. Contactor selection: according to operational category AC 3.

Part winding motors

The following current values appear in the part windings:

PW1	PW2
50%	50%

Both of the contactors should be selected for at least 60% of the maximum operating current.

Star delta motors

Calculate mains and delta contactor each to at least 60%, start contactor to 33% of the maximum operating current.

Power factor correction

For the reduction of the reactive current when using inductive loads (motors, transformers), power factor correction systems (capacitors) are increasingly being used. However, apart from the undisputed power supply advantages, experience shows that the layout and execution of such systems is not a simple matter, as insulation damage on motors and increased contact arcing on contactors can occur.

With a view to a safe operating mode, the correction system should be designed to effectively prevent "over-correction" in all operating conditions and the uncontrolled discharge of the capacitors when starting and shutting down the motors.

General design criteria

- Maximum power factor (P.F. 0.95 - taking into consideration all load conditions.)

Individual correction (Fig. 21)

- With capacitors that are directly fitted to the motor (without the possibility of switching off with contactors), the capacitor capacity must never be greater than 90% of the zero-load reactive capacity of the motor (less than 25% of max. motor power). With higher capacities there is the danger of self-exiting when shutting off, resulting in damage to the motor.

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- For part winding start a separate capacitor should be used for each half of the winding (50% each). Only one capacitor is used for start delta motors (parallel to contactor K1).

- In the case of extreme load fluctuations (large capacity range) combined with high demands on a low reactive capacity, capacitors that can be switched on and off with contactors (in combination with a discharge throttle) may be necessary. Design is similar to central correction.

Central correction (Fig. 22)

- When the designing, connected loads and the operating times of all inductive loads (including fluorescent lamps if they do not have their own correction) must be taken into consideration.

- The number of capacitor stages must be selected so that the smallest unit does not have a larger capacity than the lowest inductive load (with P.F. 0.95). Extreme part load conditions are particularly critical, such as can occur during the night, at weekends or while being put into operation. If loads are too low the entire correction device should be disconnected from the power supply.

- With central correction (as well as with individual correction with contactor control) discharge throttle must always be provided. Reconnection to the power supply may only occur after complete discharge and a subsequent time delay.

The layout of correction systems for motors with direct starting is similar.

> ***CAUTION!***
> ***It is essential to observe the general design and layout instruction of the correction system manufacturer.***

Frequency inverter

Operation with a frequency inverter is possible. However, layout and operating conditions must be individually approved by Copeland**.**

3.3 Compressor protection system

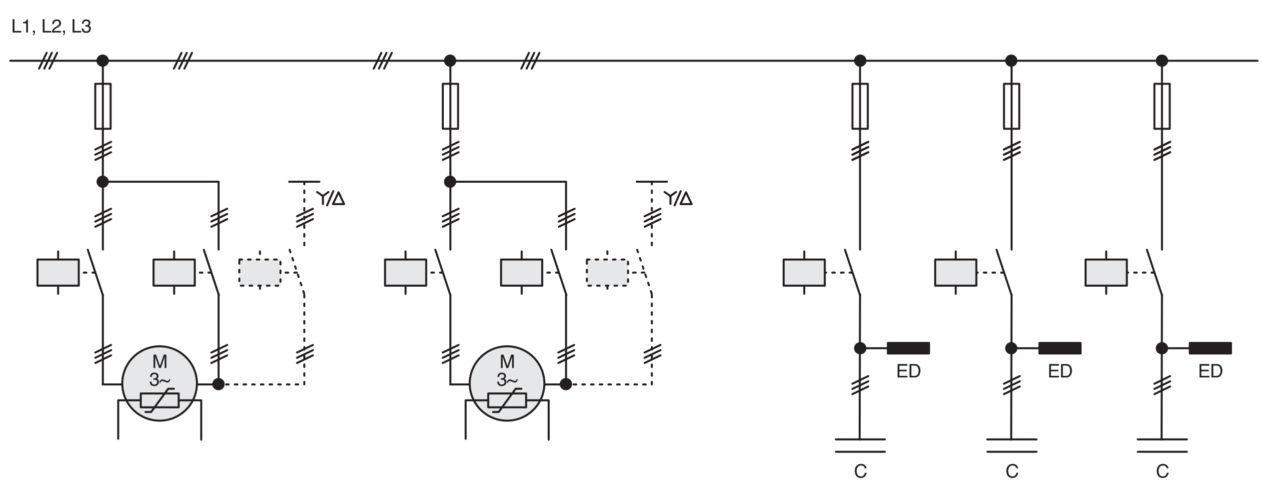
The SCH2/SCA2 compressors are fitted with the protection device INT69VSY-II.

Monitoring functions

- Winding temperature (PTC sensors in motor winding)
  - Interruption of the control current with excess temperature
  - Manual reset (after winding has cooled) by interruption of supply voltage L/N for at least 2 seconds

- Oil temperature (sensor with PTC resistance in oil sump)
  - Function as above (winding temperature)

Figure 20
Power factor correction on central power system



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- Direction of rotation/phase sequence (direct measurement at compressor terminals)
  - Immediate interruption of control current and lock-out with wrong direction of rotation / phase sequence (indication via signal contact 12)
  - Reset (after correction of fault) by interruption of the supply voltage L/N for at least 2 seconds.

The protection device is built into the terminal box. The wiring to the motor and oil temperature PTC sensors and also to be motor terminals is factory mounted. The electrical connections to the device should be made according to figure 21 or 22 and the schematic wiring diagrams.

In principle the device could be also built into the control panel. In the case it is essential to adhere to the following recommendations:

Special attention must be given when fitting the INT69VSY-II in the control panel:

- The connecting cables to the motor terminals must be wired in the sequence described (L1 to terminal "1" etc.) Check with a direction of rotation indicator!

- Danger of induction!
  Only use shielded cables or a twisted pair to connect to the PTC motor sensors and oil temperature PTC sensors.

- Additional fuses (4 A) must be incorporated in the connecting cables between "L1/L2/L3" of the protection device and the motor terminals "1/2/3".

- The terminals T1-T2 on the compressor and 1-2 on protection device must not come into contact with supply or control voltage.

CAUTION
If the rotation direction is wrong: Danger of severe compressor damage!

6.4 Schematic wiring diagrams

The following schematic wiring diagrams show examples of application for **part winding and star delta start each with infinite and 4-step capacity control.** In addition optional control schemes for liquid injection, economizer operation and oil level controls are included.

CAUTION
Make sure that the rotation monitoring is functioning! Terminal D1 of the INT69VSY-II must be connected according to the wiring diagram. Remove the jumper L/D1 at this time.

The following requirements must be ensured by the control logic:

- Minimum time of standstill: 1 minute. Valid during maintenance also!
  Returning time of the control slide - CR3 (Y3) energized
- Maximum cycling rate 6 to 8 starts per hour!
- Minimum running time desired 5 minutes!
- Switch-over time part winding 0.5 seconds start delta 1 second

Instruction for start delay timer with economizer operation

The switching-on device F7 must ensure that the refrigerant flow to the liquid sub-cooler is not switched on until operating conditions have sufficiently stabilized. This is achieved by using the solenoid valve Y6.

With frequent starting from high suction pressure, a pressure switch should be sued. The set point should be sufficiently above the nominal evaporating temperature in order to prevent the economizer solenoid valve Y6 from short cycling.

For systems with relatively constant pull down cycles (such as liquid chillers), an alternative is to use a time relay. The delay time must then be checked individually for each individual systems.

Legend

B2 Control Unit
F1 Main fuse
F2 Compressor fuse
F3 Control circuit fuse
F4 Control circuit fuse
F5 High pressure cut out
F6 Low pressure cut out
F7 Start delay timer "Economizer"
F8 Oil level switch (option)
F13 Thermal overload "motor" PW1

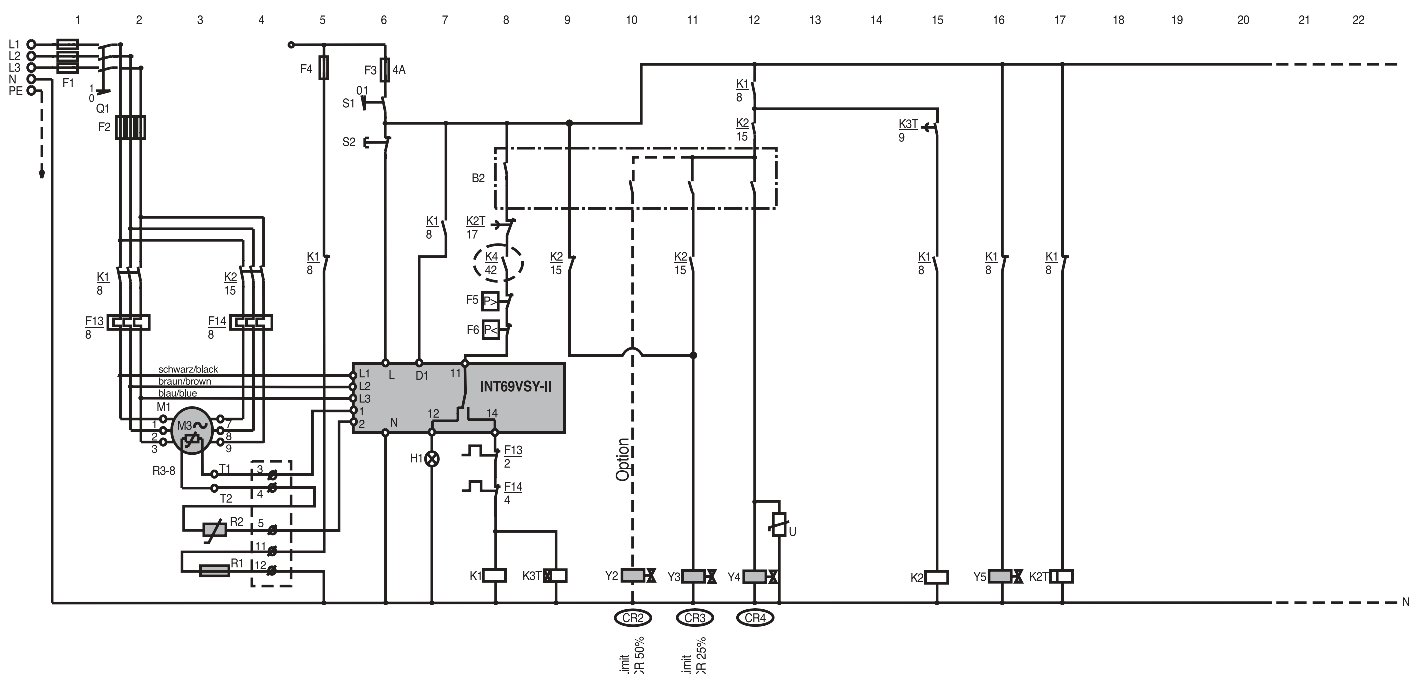
F14 Thermal overload “motor” PW2
H1 Signal lamp “motor fault” (over temp / phase failure)
H4 Signal lamp “oil level fault”
K1 Contactor “first PW” (for PW) “Mains contactor” (Y/)
K2 Contactor “second PW” (PW) “Start contactor” (Y)
K3 “Delta contactor” (Y))
K4 Auxiliary contactor (option)
K2T Time relay “pause time”
K3T Time relay “part winding: or “star delta”
K4T Time relay “oil level switch”
K5T Fixed pulse relay “CR4” flashing function on / off 10 seconds
M1 Compressor
Q1 Main switch
R1 Oil heater *
R2 Oil temperature sensor (PTC) *
R3-8 Motor PTC sensor *
S1 On-off switch
S2 Fault reset “motor & discharge temperature” and/or “direction of rotation”
S4 Fault reset “oil level”
U Screening unit (if required, such as from Murr Elektronik)
Y1 SV “capacity control” *
Y2 SV “capacity control” *
Y3 SV “capacity control” *
Y4 SV “capacity control” *
Y5 SV “liquid line”
Y6 SV “refrigerant injection” alternatively “econimizer”
Y7 SV “economizer by-pass” INT69VSY-II Control device for motor protection and dis charge gas superheat protection *
SV Solenoid valve

** Parts are included with compressor*

Capacity control

Y1	CR1,	Y2	CR2
Y3	CR3,	Y4	CR4

Figure 21
Part winding start wiring diagram



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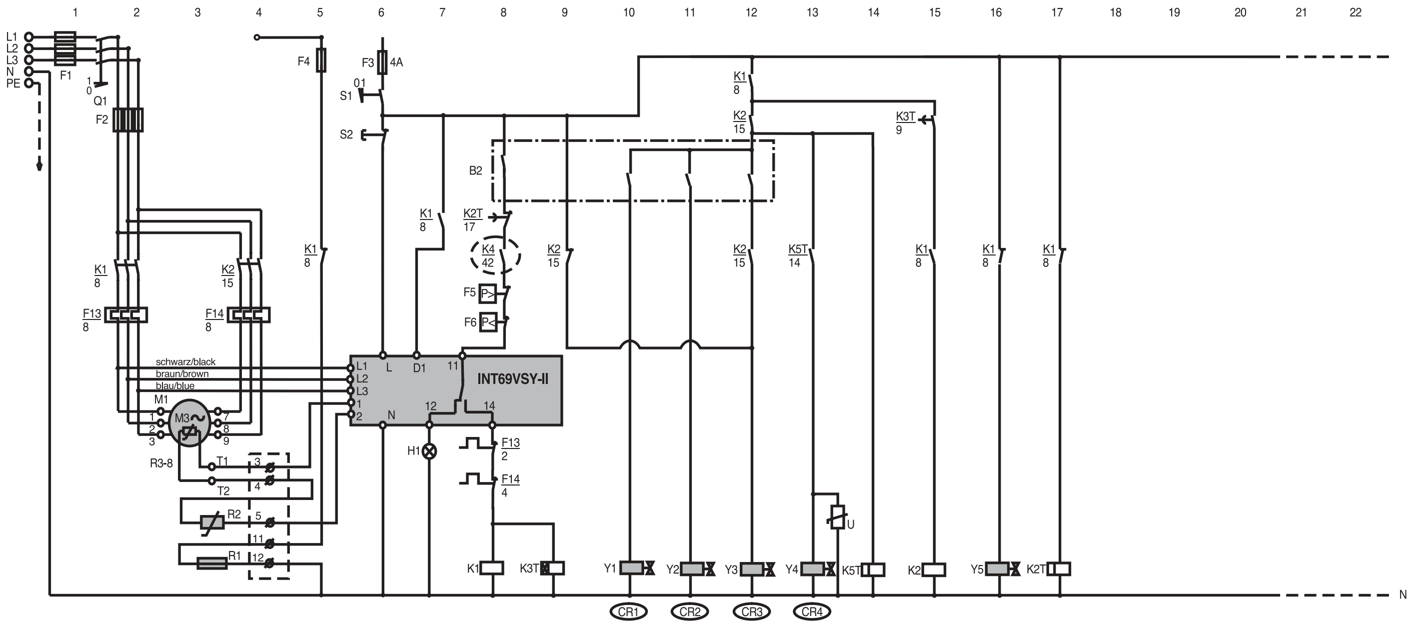

Figure 22
Part winding start with 4-step capacity control

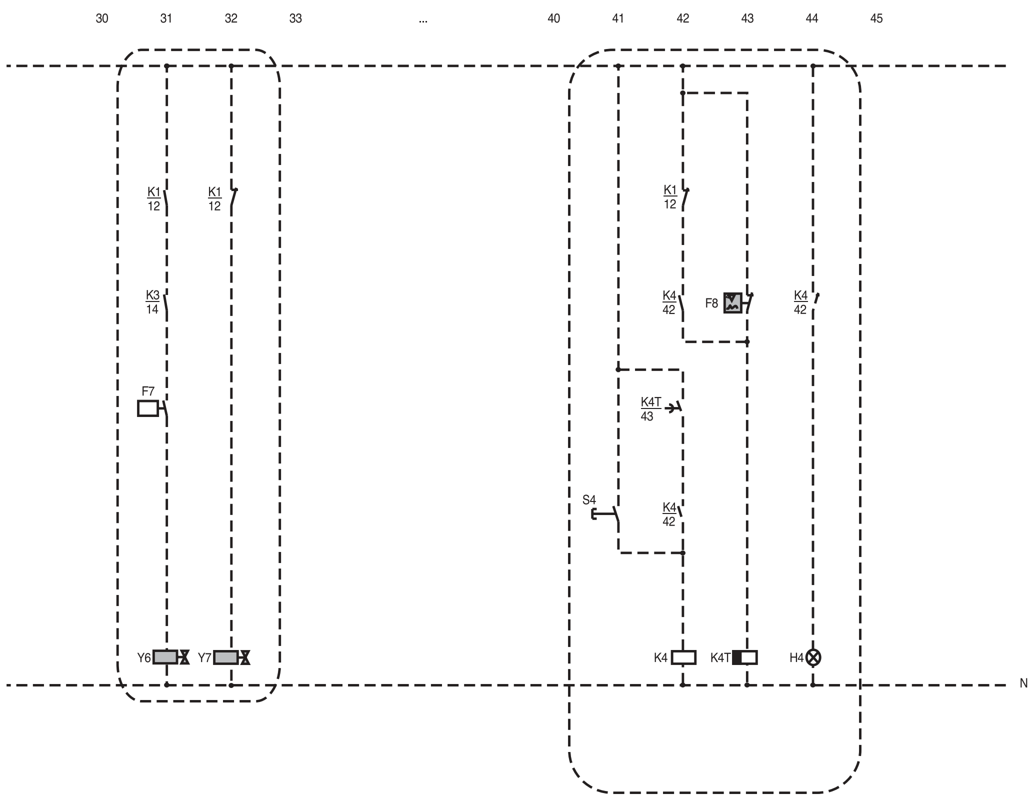

Figure 23
Part winding start options

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Data for accessories and oil charge

- Oil heater: 115/230 VAC
  SCH2 5000 to 9000 200W
  SCA2 3500 to 7000
  SCH2 11H0 to 14H0 300W
  SCA2 9000 to 11H0
- Capacity control:
  24/115/230 VAC 50/60 Hz
- Oil charge:
  Solest170 for R134a, R407C, R404A and R507A
  CP4214-320 for R 22

Oil heater

Ensures the lubricity of the oil even during long stand-still periods. It prevents increased refrigerant dilution into the oil and therefore reduction of viscosity.

The oil heater must be used during the shutdown for
- outdoor installation of the compressor (insulate the oil separator additionally if necessary)
- long off cycles
- high refrigerant charge
- danger of refrigerant condensation into the compressor

10 Performance data

For detailed compressor selection with the option of individual data input our selection software is available as CD-ROM or can be downloaded from our internet web site. The resulting output data include all important performance parameters for compressors and additional components, application ranges, technical data and dimensional drawings. Moreover, specific data sheets can be generated which may either be printed out or transferred into other software programs, such as Excel, for further use.

Basic parameters

Evaporating and condensing temperatures correspond to “dew point” conditions (saturated vapor). With zeotropic blends like R407C this leads to a change in the basic parameters (pressure levels, liquid temperatures) compared with data according to “intermediate temperatures” used so far. As a consequence this results in a lower numerical value for cooling capacity and efficiency (COP).

Liquid sub-cooling

With standard conditions **no** liquid sub-cooling is considered. Therefore the rated cooling capacity and efficiency (COP) show lower values in comparison to data based on 9 or 15°F of sub-cooling.

Economizer operation

Data for economizer operation system inherently include liquid sub-cooling. The liquid temperature is defined as 18°F above saturated temperature (dew point with R407C) at economizer inlet ($t_{cu} = t_{ms} + 18°F$).

10.1 Compressor selection by software

- Select the menu CSH Compact Screws.
- Type the desired Cooling Capacity.
- Select desired operating conditions:
  -Refrigerant and for R407C
  -Reference temperature
  -Evaporating temperature
  -Condensing temperature
  -Without or with economizer
  -Liquid Sub-cooling
  -Suction Gas superheat or suction gas temp.
  -Useful superheat
  -Power supply
- Hit Calculate.
  In the window Output Data the selected compressors with performance data are shown (fig. 24).
- Data output:
  At this stage an input of individual text (Head line) is possible.
  - Print: Print-out at standard printer, with application limits (application ranges)
  - Export: Output as ASCII file

10.2 Finding compressor performance data using the software

- Select the menu CSH Compact Screws.
- Select Compressor Type.

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- Select the desired operating conditions:
    - Refrigerant and for R407C reference temperature
    - Evaporating temperature
    - Without or with economizer
    - UCT. gas superheat or suction gas temperature
    - Useful superheat
    - Capacity regulator
    - Power supply

- Hit Calculate.
  In the window Output Data the selected compressor with performance data is shown.

- Data output:
  at this stage an input of individual text (Head line) is possible.
    - Print: Print out at standard printer, with application limits (application ranges)
    - Export: Output as ASCII file

Operating point in application limits diagram
- Hit Limits.
  Standard application limits diagram with operating point (blue cross) is shown in the window.
  Further window: application limits diagram for ECO.

Technical data of a compressor
- Hit T. Data.
  Window Data appears, in which the technical data are listed.
  Further windows:
  Dimensions (dimensional drawing and Notes (notes and legend)

- Export all data with Print (Print-out at standard printer, or Export (as ASCII file).

Export performance tables
- Hit Tables.
  The blank Performance Table is shown in the window.

- Check the default values (white fields) and change where necessary.
  The Input Values can only be changed in the window Single Point Calculation.

- Hit Calculate.
  The Performance Table is shown in the window.

- Export the data with Print (print-out at standard printer, Export (as ASCII file) or Copy into the clipboard).