Main Components of Heat Pump/Reversible cooling System

Heating/Cooling application has four main components:

- Compressor
  Compressor keeps the right differential pressure between evaporator and condenser to maintain the proper phase change to interact with the external load.
- Expansion valve
  Expansion valve takes the refrigerant from the condenser pressure to evaporator pressure, which causes change of state from liquid to vapor state.
- Condenser
  Condenser is a heat exchanging device in which refrigerant condenses by heat transfer. The superheated vapor coming from the compressor to liquid with some degree of subcooling to prevent vapor entering the expansion valve.
- Evaporator
  Evaporator is a device where the mixture coming from the expansion device vaporizes. The exiting vapor can be either saturated (wet evaporator) or superheated (dry evaporator). In the former case, a proper device (separator) is needed to prevent liquid from entering the compressor. In the latter case, the vapor leaving the evaporator has a superheat with a few degrees for the same purpose.

<u>Heating and cooling application usage</u>

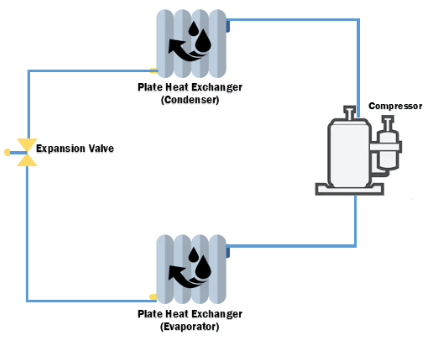


Figure: BTW (Brine to Water system)

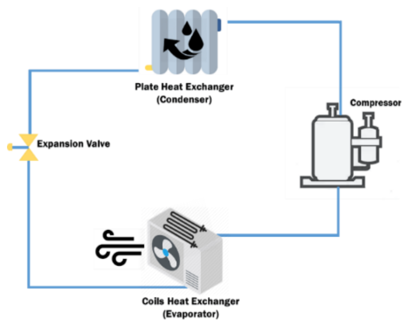


Figure: ATW domestic hot water/Pool heating (Air to Water system)

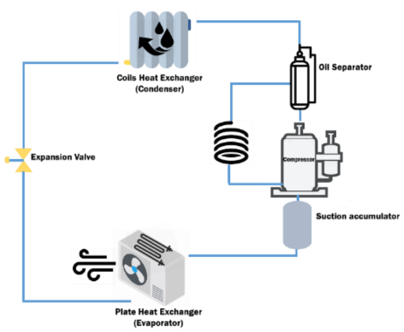


Figure: ATW (Air to Water system) split

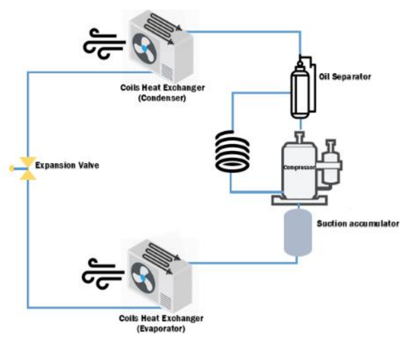


Figure: ATA (Air to Air system) split

SCI Compressor Outline

We have two types of compressor that are Rotary and Scroll in fixed speed and variable speed technology. Customer needs to take care of compressor limitation based on compressor type that affects reliability of compressor.

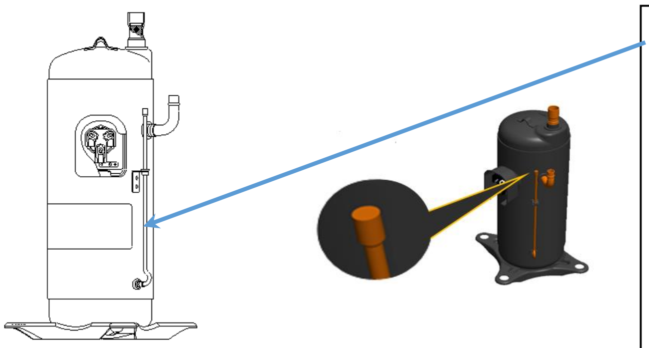
<u>Scroll compressor structure</u>

High-pressure shell type

For SCI scroll compressor, the pressure in a shell is high (discharge) pressure as we call high-pressure shell type compressor. The system design must be executed differently from low-pressure shell type compressor which the pressure in a shell is low (suction) pressure.

Because of high pressure in the compressor shell, the temperature inside the compressor shell is also high. For SCI motor, heat resistant cable (125°C (257°F) or more) is applied for the lead wires. Please do not overcharge the refrigerant for the purpose of reducing shell temperature.

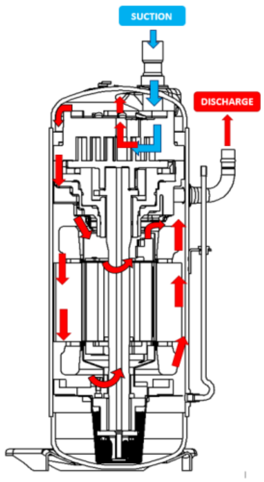
Also, the suction gas is sucked directly into the compression chamber. Compressor itself has some ability to compress some small portion of liquid refrigerant. Thus, Discharge Superheat value need to be considered.



This pipe is oil equalization mechanism for plural compressors connection. There are increasing capacity by adding on compressor and oil level balance from higher oil volume compressor to other compressors by oil balance pipe. This pipe is not for oil return from oil separator. This pipe must be closed when there is a compressor in the system.

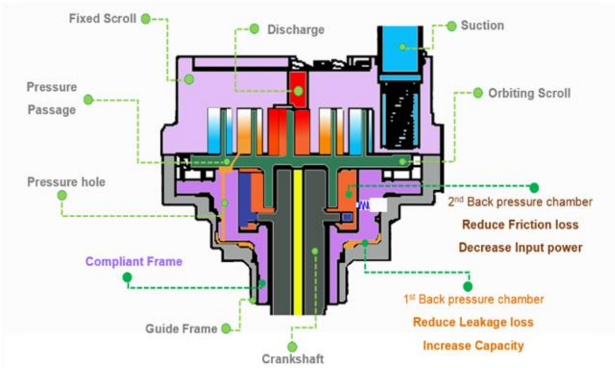
Suction gas from suction pipe enters the compression chamber. The gas is compressed in the compression chamber and discharged toward upper shell. Then, the gas is introduced downward and flows around the motor. After leaving the motor, the gas is discharged from discharge pipe. In this process, oil is separated from discharged gas and falls into the oil sump at the bottom of the shell.

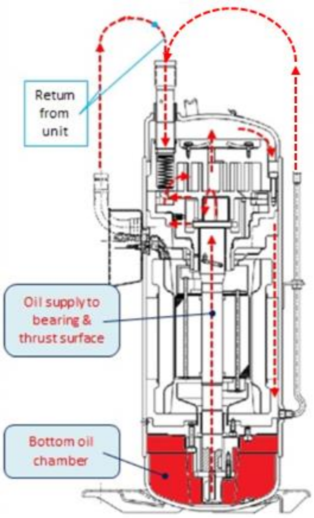
While in another type of compressor technology such as low-pressure shell compressor, suction pipe enters the compressor shell directly. This could be an issue if liquid refrigerant from low suction superheat mixed with compressor oil.



FCM (Frame Compliance Mechanism)

SCI scroll compressor has an excellent mechanism called FCM (Frame Compliance Mechanism) which is a Mitsubishi's Patent. FCM scroll compressor has two back-pressure chambers which provide high performance by reducing leakage loss and thrust bearing loss.





The oil is supplied from bottom oil chamber through oil supply port inside the shaft to lubricate bearing and thrust surface by difference pressure between discharge pressure and suction pressure.

Compressor can operate in low speed for long time as far as difference pressure has been control.

To ensure that oil can supply to the sliding parts of compressor, discharge pressure should be higher than suction pressure for 0.35 MPa. But this does not apply to short-term loads of a transitional nature. For transitional period at starting, suction and discharge pressure have to be kept following.

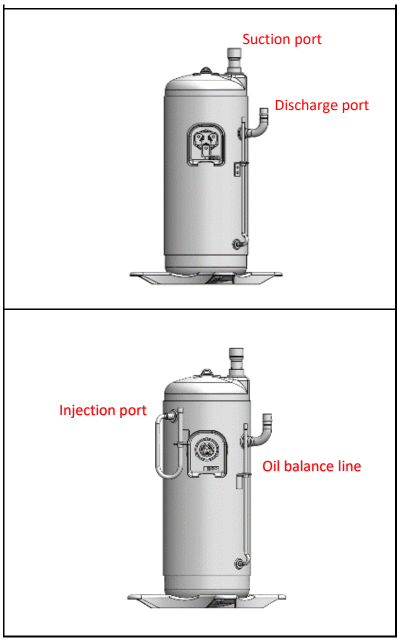
Pd - Ps > 0.05 MPa within 20 seconds after starting.

Pd - Ps > 0.35 MPa within 3 minutes after starting.

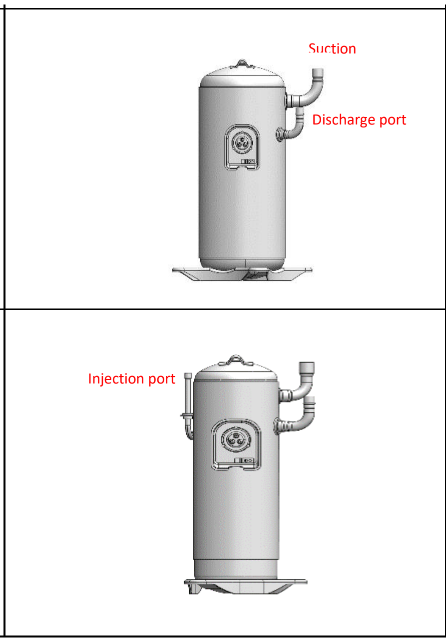
Where Pd is discharge pressure and Ps is suction pressure

Also, amount of oil in bottom oil chamber has to be 300 cc for minimum (A Series) and 450 cc for minimum (B Series) at all of compressor operating period.

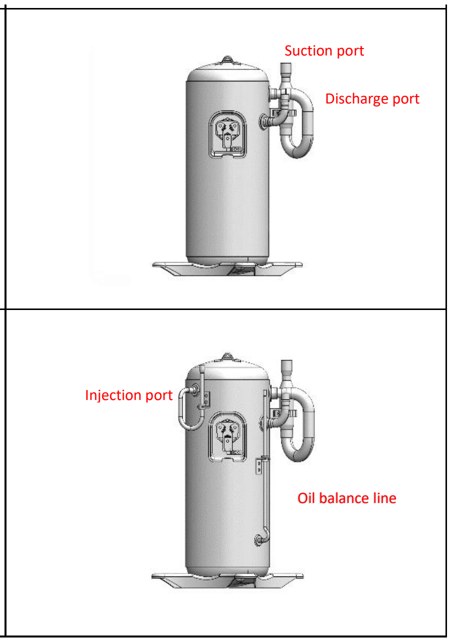
Scroll compressor outline



Commercial Model



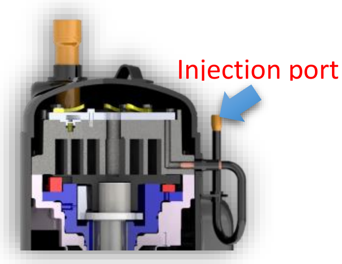
Residential Model
without strainer



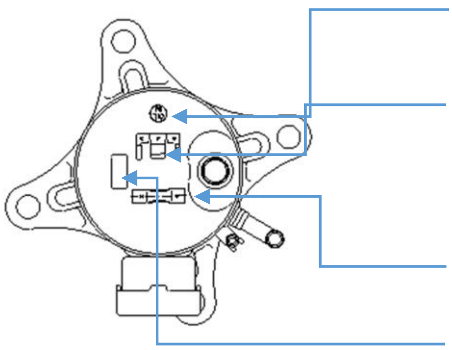
Commercial/Residential model
with strainer

Vapor injection scroll type

The vapor injected-scroll compressor enables operating at very low evaporating temperature and also increases capacity and efficiency.



Top compressor detail



"Oil in" stamp indicates that oil has already been filled in this compressor.

Thermo holder is used for measuring top shell temperature (discharge temperature)

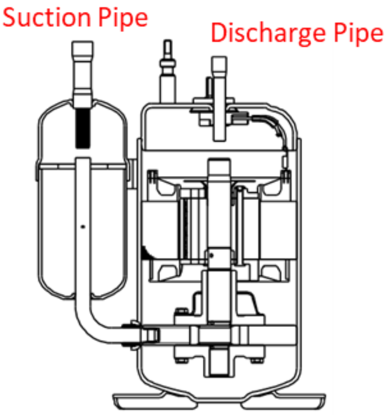
Lifting eye is used for compressor move by using holder.

2D Barcode for compressor information checking.

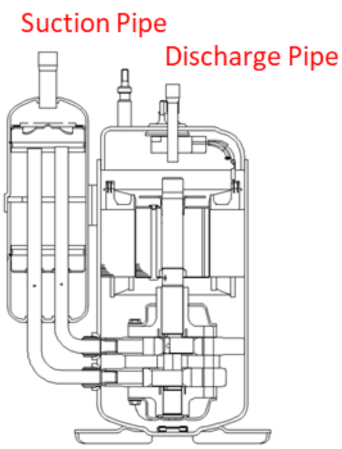
<u>Rotary compressor structure</u>

Rotary compressor is the hermetic compressor type that use rotary-type positive-displacement with high-pressure shell type mechanism. For SCI rotary compressor, there is high reliability from the oil supply stirrer and pressure difference, which supply the oil to all mechanical moving parts of the compressor.

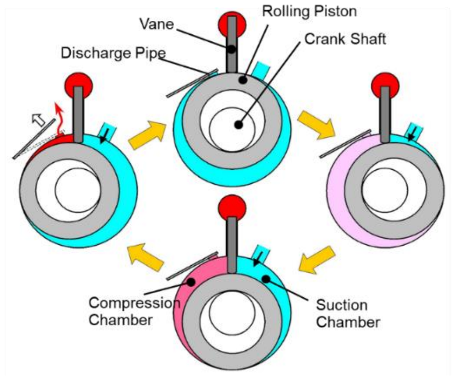
Single Rotary



Twin Rotary



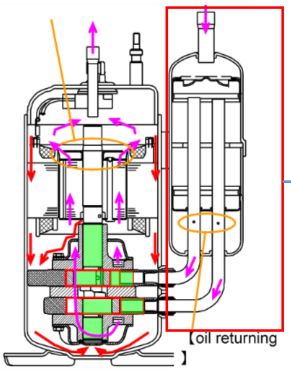
The rotary compression process



The refrigerant gas, which is flowing in the chamber for the first round, will be compressed and discharged for the next round.

Suction and compression process can operate at the same time in the suction and compression chamber which is separated by vane.

Suction Muffler

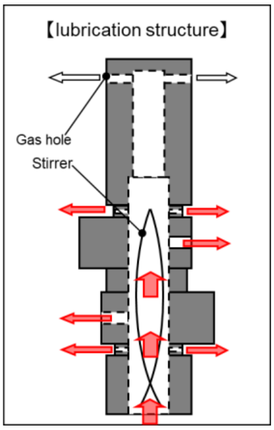


The rotary compressor has a suction muffler for noise reduction. Inside of suction muffler, there is a oil returning hole that causes the high reliability for oil return.

Oil returning hole in suction muffler has also the role as an accumulator of the compressor which prevent the flush back of liquid refrigerant into the compression chamber.

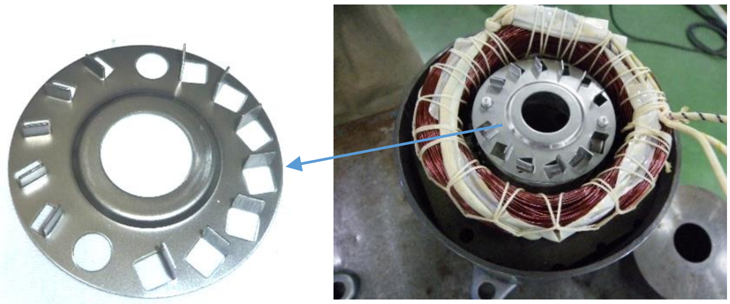
A suction strainer is installed in the suction muffler to prevent contaminants and other particles entering the compressor.

Lubrication Seal



For oil supply in the rotary compressor, SCI Rotary compressor has an "Oil stirrer" to pump the oil from the bottom shell and supply to all moving parts, this function will be worked together with pressure difference.

Internal oil separator disc



Oil separator disc will help separate the oil from the refrigerant.

SCI compressor installation guide

1. Remove rubber plugs on discharge pipe and confirm with the gas purging noise.

2. Soldering method: Soldering should be completed within 10 minutes after rubber plugs are removed.

- Vapor flux should be used and nitrogen gas should be passed through the piping for non-oxidation soldering. Prevent flux, dirt, foreign matter, and moisture from entering the refrigeration circuit at all times.

- The recommended clearance and the minimum insertion depth for soldering parts are shown in the table below;

Outer pipe diameter [A] mm (in)	Minimum insertion depth [B] mm (in)	Clearance [C-A] mm (in)
5(0.20) to less than 8(0.31)	6 (0.24)	0.05~0.35 (0.0020~0.0138)
8(0.31) to less than 12(0.47)	7 (0.28)	
12(0.47) to less than 16(0.63)	8 (0.31)	0.05~0.45 (0.0020~0.0177)
16(0.63) to less than 25(0.98	10 (0.39)	
25(0.98) to less than 35(1.38)	12 (0.47)	0.05~0.55 (0.0020~0.0217)
35(1.38) to less than 45(1.77)	14 (0.55)	

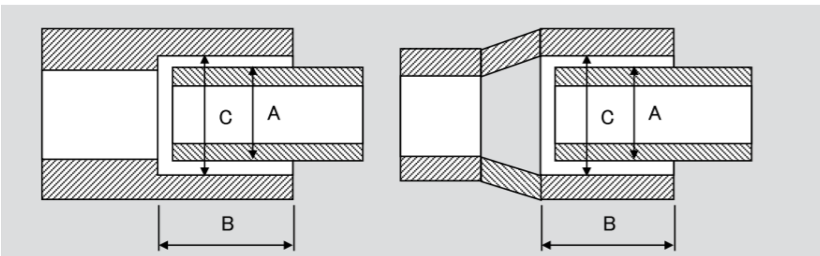


Figure: Minimum insertion depth and clearance for soldering joints

3. Execute evacuation for the piping immediately after soldering and leakage check. From evacuation, the pressure is desirable at 133 Pa [abs] (0.019 psi) or lower.

4. Charge the refrigerant after evacuation. For mixed refrigerant, such as R410A or R407C, charge of liquid refrigerant is required. Liquid refrigeration charge should be executed from the high-pressure side of the unit (condenser outlet), otherwise the refrigerant oil may be diluted and bearings or sliding parts will be damaged.

5. Installation of lead wires, electrical parts, and reversed operation

- Execute the correct circuit connections according to the wiring diagram in the respective specification.

Expansion devices selection

Expansion equipment is a metering device that feeds refrigerant into the evaporator. Lowering pressure of refrigerant from the condenser pressure to that of the evaporator, the evaporator keeps suitable transformation temperatures for heat sources.

The expansion valves are general classified as:

Constant pressure expansion valve also improperly called automatic expansion valve. This valve keeps the pressure inside the evaporator constant, no matter what the load inside the evaporator is. This valve does not allow the control of flow of refrigerant, thus this type of valve is not used when this control is needed.

- Thermal (thermostatic) expansion valve controls the amount of refrigerant flow by controlling superheating at evaporator outlet. Thermal expansion valve is often generically referred to "metering devices". This valve employed with variable thermal load.

- Electronic Expansion Valve matching with compressor (EEV)

EEV uses an electronic controller to calculate the superheat based on the temperature and pressure input. A program for the controller can be set to follow several different protocols which will adjust opening and closing of the EEV based on inputs of the controller.

EEV uses a pressure sensor located on the suction line and pressure will be converted to the signal, which is used for the value determination. The temperature is read by using a PT1000 sensor or similar one which uses the concept of changing resistance based on the temperature of a probe.

The main point for matching EEV with SCI compressor;

1. EEV must optimized for maximum and minimum heat pump/reversible cooling capacity.
2. The stable of EEV step control should be stable to avoid system-overshooting situation.

Thermostatic Expansion Valves matching with compressor (TXV)

TXV uses a sensing bulb to collect the temperature of the suction line leaving the evaporator which should be higher than the saturation temperature of the refrigerant. The bulb contains a mixture of components that will evaporate based on the temperature of the bulb. If the suction line becomes warmer in regard to the saturation temperature, this signifies that more refrigerant is needed in the evaporator to manage the heat load. The pressure in the bulb increases and since the bulb is connected directly to the power element, the increase in pressure is also applied to the diaphragm located in the power element. The diaphragm bends downward and pushes on a stem which will open the valve.

Liquid Receiver

A tank placed at condenser outlet and upstream the expansion valve to store high-pressure liquid leaving the condenser. It is sized to contain the whole refrigerant charge during the off-duty periods. Purpose of the tank is to collect fluid when load fluctuation occurs. A scheme of the receiver is illustrated in below figure. Receiver is a cylindrical steel tank with a pipe introducing the refrigerant coming from the condenser and an internal dip tube. However, this type of device is not used when a capillary tube is used instead of an expansion valve, as no flow modulation is possible.

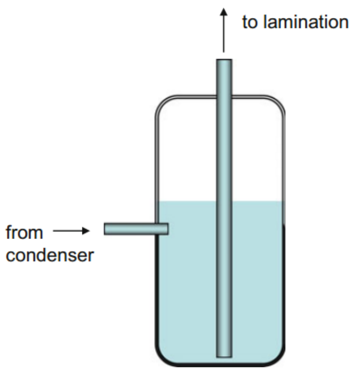


Figure: Liquid receiver

Accumulator

This equipment used for preventing the liquid flush back to the compressor. In case of DSH can control above compressor limit especially in light load operation with lowest compressor speed, an accumulator is unnecessary to install.

The size of a suction accumulator is recommended about 80% of refrigerant charged amount to enable stacking most of liquid refrigerant and leave only the vapor entering the compression chamber.

The size of oil return hold (orifice) must cover viscosity of oil when the system operates at the lowest temperature condition. The size of oil return hole to handle lowest PVE oil viscosity should be bigger than 0.8 mm.

Figure: Cross section of accumulator

The ability of the accumulator should be perform without adding excessive pressure drop to the system more than 5%. Application heating/cooling capacity is necessary for accumulator manufacturer. This heating/cooling capacity can calculate by maximum load operation.

Accumulators should have a Heat Element added on low temperature applications (-18 C and below) to help boil off liquid refrigerant and raise the oil temperature to help facilitate oil flow.

Evaporator and Condenser

For heating mode, evaporator and condenser are heat exchanger device when heat extracted by evaporator (outdoor) and released by condenser (indoor). Heat pump can be switched to the cooling mode by changing direction of refrigerant flow that will make evaporator as heat sink and condenser as heat source. Besides the air, heat sink can also be water of a hydraulic system or sanitary water while heat source can be water or ground. With regard to the type of heat sources, heat pumps can synthetically classified as;

- Air/Air heat pump when heat source and heat sink are air.
- Air/Water heat pump when heat source is air and heat sink is water.
- Water/Water heat pumps when heat source and heat sink is water.

The air-cooled heat exchanger mainly consists of a finned tube bundle with rectangular box headers on both ends of the tubes. Cooling air is provided by one or more fan. If refrigerant exchanges heat with water, plate and frame heat exchangers are used. Corrugated metal plates are applied in the heat exchanger to transfer heat between the fluids.

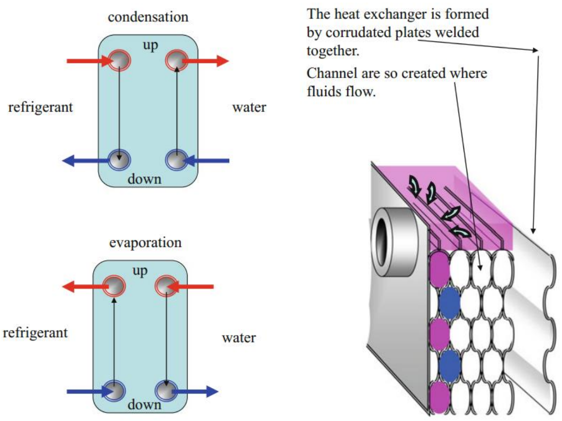


Figure: Shows the schematic of the braze plate heat exchanger

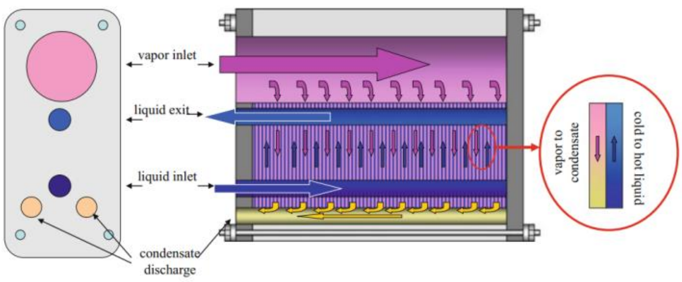


Figure: Shows the schematic of plate heat exchanger

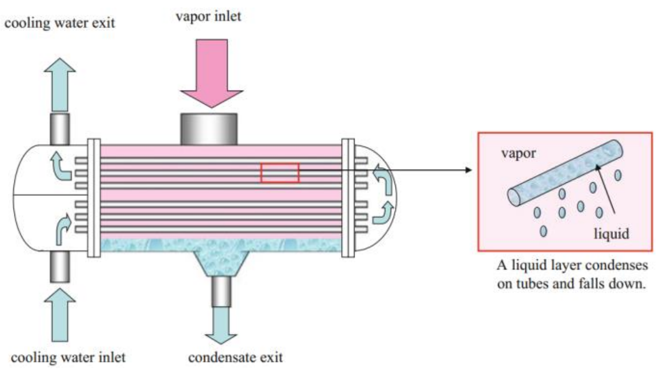


Figure: Show the schematic of shell and tube heat exchanger

Economizer and Vapor Injections

The vapor injected-scroll compressor can help increase the heating capacity and heating COP value with smaller size of the compressor for low ambient application.

Injection Schematic

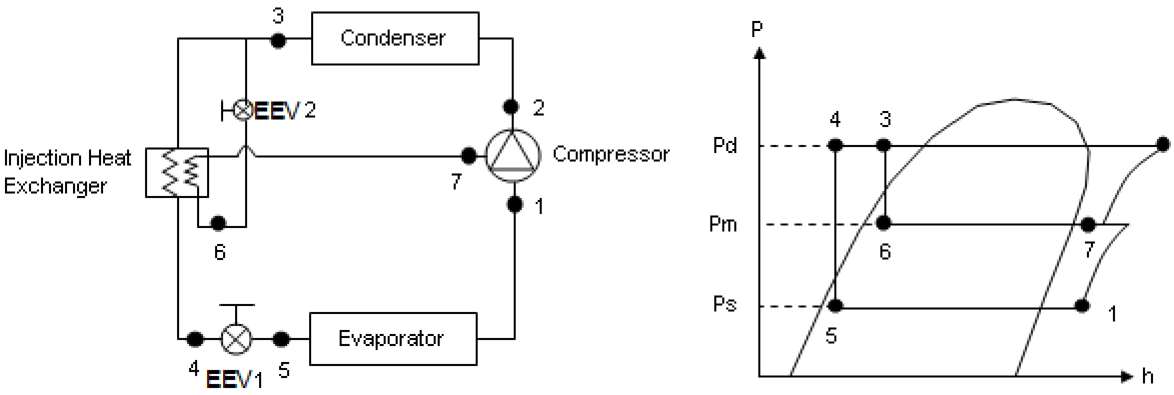


Figure: Schematic of internal heat exchanger vapor-injection cycle

State 1: Suction Pressure

State 2: Discharge Pressure

State 3: Subcooled refrigerant leaving the condenser.

State 4: Subcooled refrigerant leaving the injection heat exchanger of main circuit.

State 5: Refrigerant from the injection heat exchanger is expanded by EEV1.

State 6: Refrigerant from the condenser is expanded by EEV2.

State 7: Saturated vapor inject to compressor.

The Injection system has two additional parts, which are injection heat exchanger and electronic expansion valve (EEV2)

Injection Heat Exchanger is used for providing additional subcooling to increase heating capacity of the system.

Electronic Expansion Valve (EEV2) is used for controlling the amount of evaporated refrigerant that flows to the compressor. In spite of more input power desire, the heating capacity is increased.

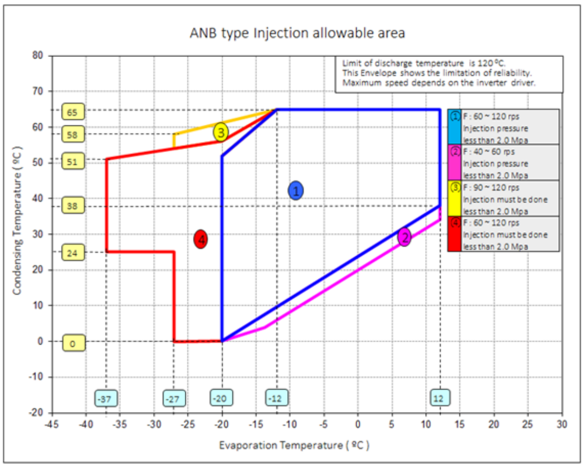


Figure: Example of Operating Envelop of ANB Type with Injection

Remark: Different compressor model may have different operating envelop. Please check operating envelop of desired model of compressor.

Vapor injected-scroll compressor has bigger operating envelop than the standard compressor which can make CT at 51°C and ET at -37°C as a result. This advantage is suitable for heating application which makes hot temperature in very low ambient temperature.

Injection Heat Exchanger (Economizer)

Heat exchanger capacity

Heat exchanger capacity can be calculated by equation below. There are 3 variables which are Pm (pressure at state 7), the injection flow which located in compressor performance data and the last one is enthalpy between state 6 and state 7.

Heat Exchanger Capacity (kW) = Injection Flow * (Enthalpy7 – Enthalpy6)

An estimation of injection heat exchanger capacity should be 20-40% of heating capacity at minimum operating ambient temperature.

Flow direction

The best flow direction for subcooling is counter flow. From injection schematic, the refrigerant from state 3 to state 4 counter flows with the other one from state 6 to state 7.

Design condition

The best design condition for customer depends on the minimum ambient temperature of unit operation that the COP improvement of injection system gives the highest value.

For example (from temperature data below), if the minimum ambient temperature for unit operating in Sweden is -20 ˚ C, the injection heat exchanger should be designed by using this ambient temperature which will give the best efficiency of the injection system. From graph, the best time to start operating injection system is at ambient temperature below 7˚C.

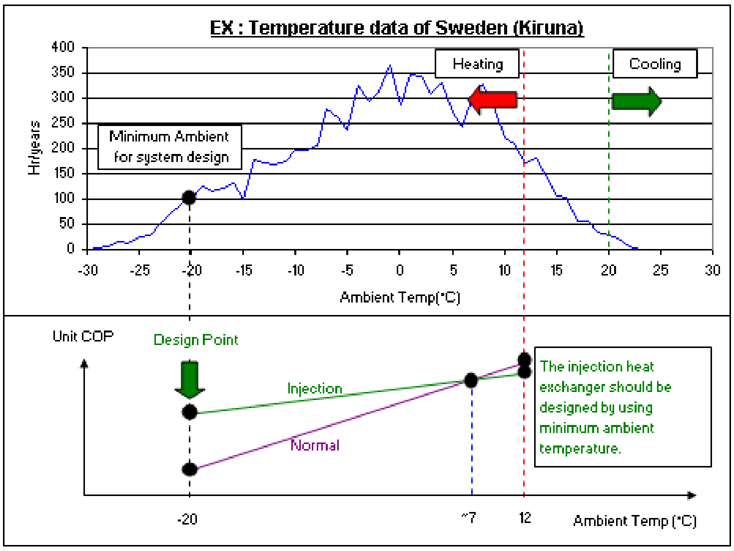


Figure: Example of injection heat exchanger value selection

Injection Expansion Valve Control and Main Expansion Valve Control

Starting period

EEV1 should be controlled by suction superheat until discharge superheat (DSH) value over than discharge superheat setting point value. Then, EEV1 will be controlled by discharge superheat value.

EEV2 should be closed until discharge superheat value over than 10K.

Working period

To get the highest COP value of the system,

EEV1 should keep discharge superheat value to follow discharge superheat control guideline for improvement.

EEV2 should keep injection superheat value between 1 and 5 K

A control system operation should be followed the compressor envelop.

Stopping period

EEV2 should be closed to stop the injection before the compressor stops.

The Four Way Reversing Valve

Four way-reversing valves used for reversing the cycle of one-to-one heat pump systems. Such valves may be used for heating mode and cooling mode requirement. Besides, four way reversing valves are used for providing an effective defrosting method.

Furthermore, four ways valves matching should be considered the heating capacity and refrigerant type. Therefore, the customer should choose the compatible four ways valve with the systems.

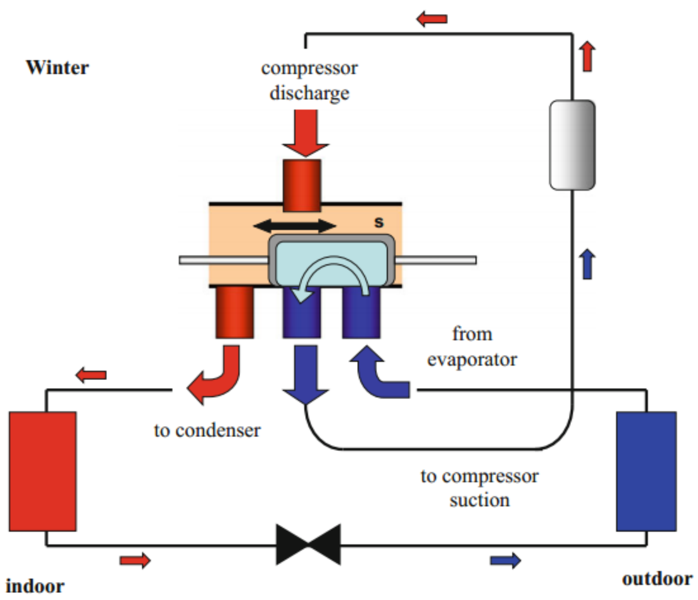


Figure: Showing the schematic of four ways valves in heating mode

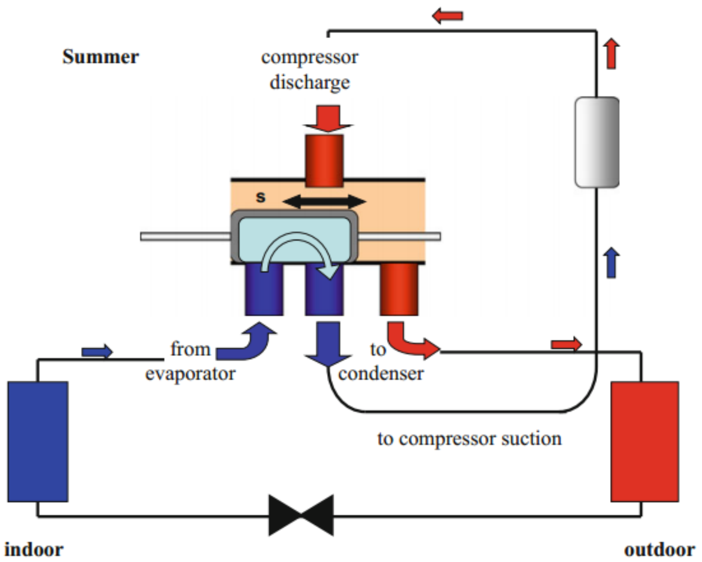
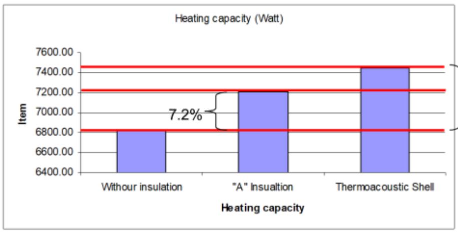


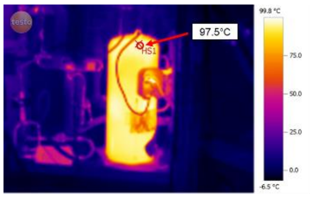
Figure: Showing the schematic of four ways valves in cooling mode

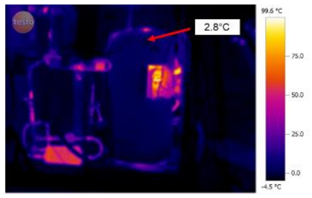
The refrigerant flow is controlled by the four way valves that are activated by an electric coil. If the coil is fed, the winter mode is active. If the coil is not fed, the summer mode will takes place. This alternative process is done for seasonal operation change and defrosting.

Thermo-acoustic shell

Heat loss is one of the issues which affects to the system efficiency. In extreme cold climate zone, the capacity may be reduced when compressor is placed in outdoor. The compressor insulation jacket can help prevent this kind of issue. The customer can select suitable jacket or ask SCI to support about this equipment. In case of SCI jacket called Thermo-acoustic shell, SCI has improved the jacket to solve the heat loss issue. The result of improvement is shown in the figures.







*Condition : Comp ANB52

: Ambient : -15C

: “A” insulation -> Felt+Rubber

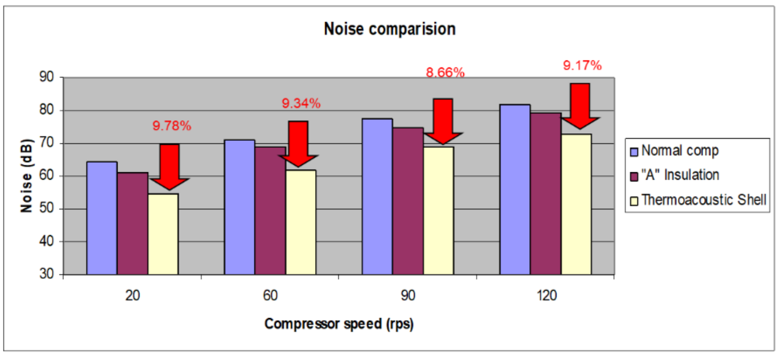
Without insulation

Thermoacoustic Shell

Ambient 0°C

Figure: Heat absorption by Thermo-acoustic shell

Thermo-acoustic shell is not only improves capacity but also noise reduction. The noise reduction can be expected by 9dB from normal.



*Condition : Comp ANB52 ,ARI condition

: “A” Insulation ->Felt+Rubber

Figure: Noise absorption by Thermo-acoustic shell

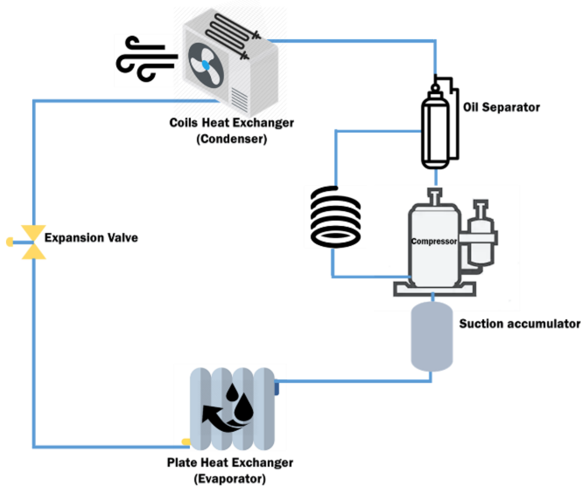
SCI Oil separator

Oil Management is preventive and corrective process to handle the oil in the refrigeration system. Especially, the oil management maintains oil amount inside the compressor to prevent compressor breakdown from lack of oil lubrication.

When there is much oil stack in the unit system, the capacity performance may affected because the oil will stack in the heat exchanger instead of refrigerant that reduce the efficiency of heat transfer. For this reason, SCI would like to recommend using an oil separator.

Oil separator device options provided by SCI

Option A : Capillary tube



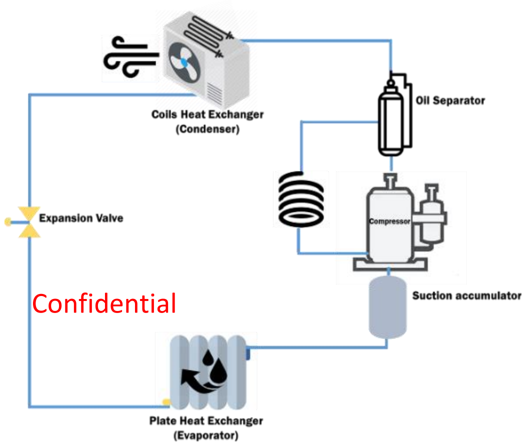
a.) This solution is easy and inexpensive for oil management.

b.) The size of capillary tube and orifice depends on applications and running conditions.

Table. Initial capillary tube and orifice size

Model	Initial recommend size	
	Capillary tube ID (inch) x Length (mm)	Orifice [inch]
MUTO-A2053N	0.044"x1300 mm	0.032
MUTO-A4053N	0.055"x1200 mm	0.032

Option B: Electronics expansion valve



a.) An EEV valve increases seasonal performance system when the EEV valve works at varies speed of compressor (Port size of initial EEV is 1.4 mm.)

***The size of port and step valve must be complied with the customer's actual unit ***

b.) When an oil level sensor detect oil problem, the EEV valve will activate and refill oil to compressor.

c.) During the compressor running state, EEV valve should not close 100%

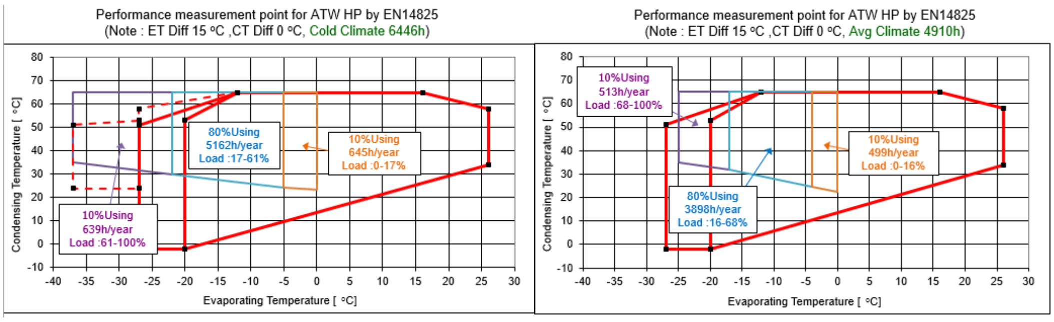
d.) Before the compressor starting process, balancing pressure can be done by using the EEV valve as an extra function.

Testing and Evaluation Item

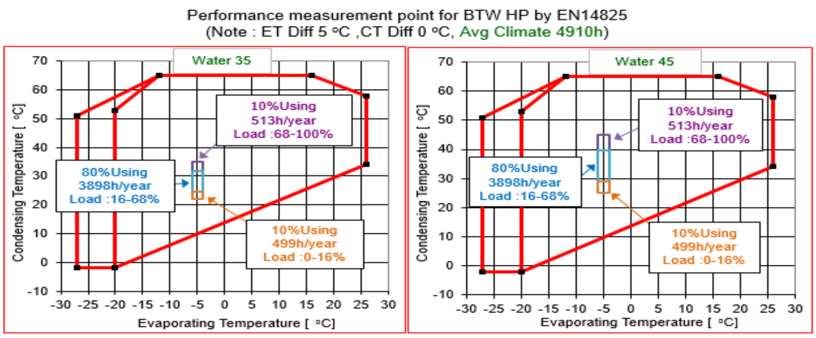
Heat pump application operating condition

Operational envelop is very important for compressor selection. The compressor model and refrigerant selection should be covered application requirement. The following example is operational application based on EN14825 European standard comparing with R410A scroll compressor without injection envelop. Customer should consider operational condition and follow standard condition in each country.

ATW heat pump



BTW heat pump



Another refrigeration please refer to compressor envelop following by compressor specification.

SCOP/HSPF for heating application

Calculation of SCOP/HSPF in general

SCOP/HSPF (Seasonal Coefficient of Performance) describes the heat pump's average annual efficiency. SCOP/HSPF expresses how efficient in the specific heat pump will be from given heating demand profile.

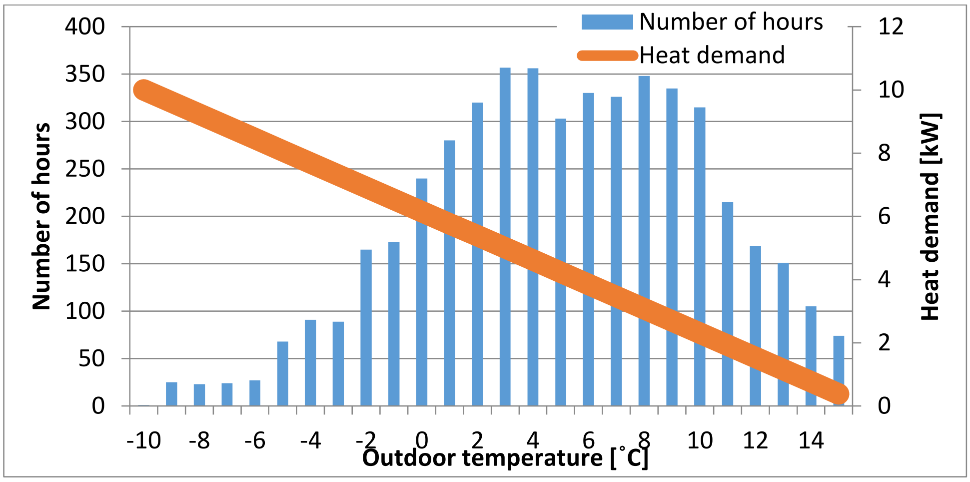


Figure: Shows example profile ambient temperature Bangkok Thailand

Compressor selection should match with demand profile following by standard mentioned. SCI compressor characteristic showing best efficiency for motor design will be around 60-70 rps operation speed. (Depending on model, please contact SCI for assistance.)

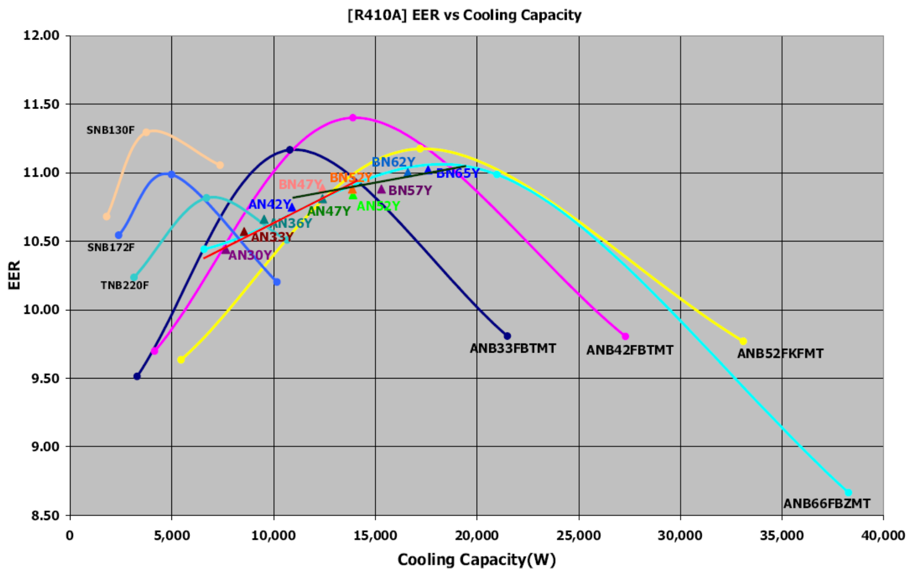


Figure: Shows example profile for compressor EER characteristic

Compressor oil level selection

The amount of oil in SCI compressor will provided to suit the application usage. Customer has to verify the oil test as following.

For all running conditions of the system, the amount of oil in the compressor should be higher than the minimum limit of the compressor in each series.

Example

For A series scroll compressor, the minimum oil level in the compressor is 300 cc.

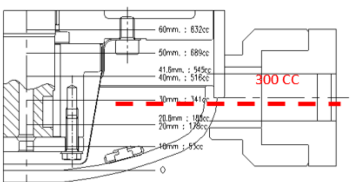
For B series scroll compressor, the minimum oil level in the compressor is 450 cc.

For S series Twin rotary compressor, the minimum oil level in the compressor is 180 cc.

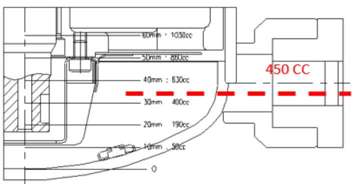
For T series Twin rotary compressor, the minimum oil level in the compressor is 320 cc.

For Q series Twin rotary compressor, the minimum oil level in the compressor is 350 cc.

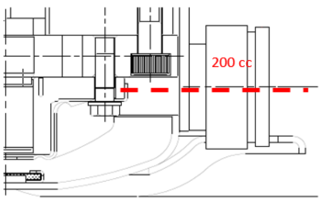
The minimum amount of oil can check by using a sight glass compressor can provide from SCI upon request. If the amount of oil is lower than the minimum level during testing, oil separator is recommended to install.



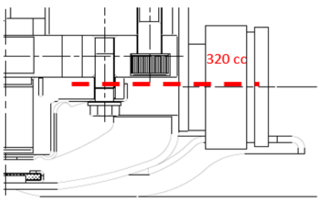
Scroll A-Series



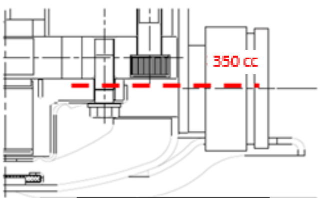
Scroll B-Series



Rotary S-Series



Rotary T-Series



Rotary Q-Series

Oil testing recommendation

Oil is the most important for the compressor reliability since the compressor cannot operate without oil. Oil can stack in heat exchanger, piping and other components in the system. In case of developing a new system or changing a system design, the oil level in the compressor must be confirmed every time.

The oil level in compressor can check by using the sight glass compressor. The sight glass compressor can be used only for laboratory test (Short-term running). In term of safety, the sight glass compressor is not be recommended for mass production because the compressor is special made for short-term running only and may leak at the sight glass.

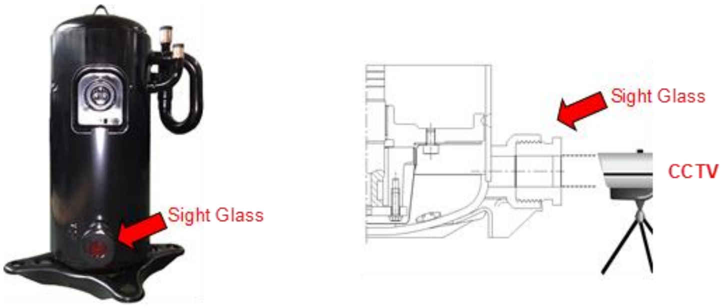


Figure: Compressor with Sight Glass

For safety reason, a video camera was recommend to use for observing the oil level in the compressor. Please do not see directly through the sight glass with eyes.

Recommended testing condition

Transient condition

Starting condition

For testing system at very low ambient temperature, the compressor should left until the temperature of a compressor shell is equal to the ambient temperature at least 12 hours before starting. For fixed speed compressor, the compressor should be started and run until oil level reaches the stable state. For inverter compressor, the compressor should be started and speeded up to the minimum and maximum speed until oil level is stable. However, oil level in the compressor should be higher than the minimum level all the time.

Discharge superheat should be higher than compressor specification limit within 3 minutes after starting the compressor. (Please see compressor specification limit in general specification of each model)

In case of testing system at very low ambient temperature and having crankcase heater, please examine that the crankcase heater is activated before starting the compressor.

Defrost running

Defrost mode of the system should be tested at the minimum defrost duration and the maximum defrost duration at least 3 cycles for each condition (1 cycle = test normal operation for 3 minutes and switch to defrost mode for the minimum defrost duration or the maximum defrost duration and back to normal operation again) or more cycle until oil level in the compressor is stable. Oil level in the compressor should be higher than the minimum level all the time.

During defrosting, the compressor can operate at low compression zone. Please be careful out of compressor envelop operation. This can allow 3 min for transient condition, which is out of envelop period.

Switching mode with liquid back operation. This condition must observe the DSH value. It must higher than 10K (20K for T-series) within 3 min.

Running condition

System without hot gas bypass

The system should test at the lowest refrigerant flow condition or at the lowest evaporating temperature, the highest condensing temperature, and the highest discharge temperature. For inverter compressor, the system should test at the minimum and the maximum speed.

The system should test at the maximum oil circulation rate condition or at the highest evaporating temperature, the highest condensing temperature, and the lowest discharge temperature. For inverter compressor, the system should be tested at the minimum and the maximum speed.

The system should be run until oil level in the compressor is stable at least 4 hours. Oil level in the compressor should be higher than the minimum level all the time.

System with hot gas bypass

The system should test at the lowest load or no load condition with the maximum bypass opening and the lowest speed of compressor in case compressor is inverter compressor. The system should be run until oil level in the compressor is stable. Oil level in the compressor should be higher than the minimum level all the time.

Recommend for system combination

Piping length

Between indoor unit and outdoor unit, the system can be tested with the longest total piping, the maximum height in vertical direction, and the biggest piping diameter.

Refrigerant charge amount

The system should be tested with the minimum and the maximum refrigerant charge amount.

Compressor running speed

The system should be tested with the minimum and the maximum running speed.

Recommendation for oil separator

Oil separator should be used in;

1. Multi Indoor unit

2. Long piping application (Evaporator and condenser are split type and piping length is more than 5 meter.)

System control

Starting function and speed changing requirement

Inverter compressor should start at 50-60 rps and kept running at that speed until the pressure difference reaches the compressor specification and DSH is greater than compressor limit (10 K for scroll compressor or 20 K for rotary compressor). This process is required to warm up the system and protect oil leaving the compressor.

Compressor stopping control method

Before stopping the compressor, normally inverter compressor should be reduced the speed to the minimum level. In case of emergency, power supply can be cut off directly. There is not any effect to the compressor reliability.

Acceleration and deceleration limit for inverter compressor

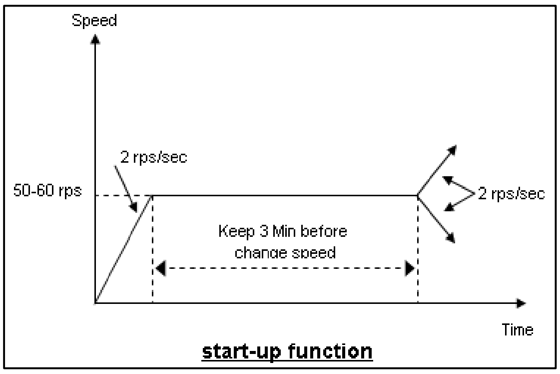
Case 1 for normal control: Acceleration and deceleration should not be faster than 2 rps/sec.

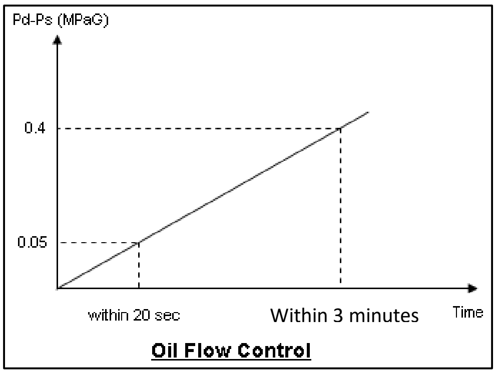
Case 2 for protection mode: Acceleration and Deceleration should not be faster than

7 rps/sec for scroll compressor and 5 rps/sec for twin rotary compressor.

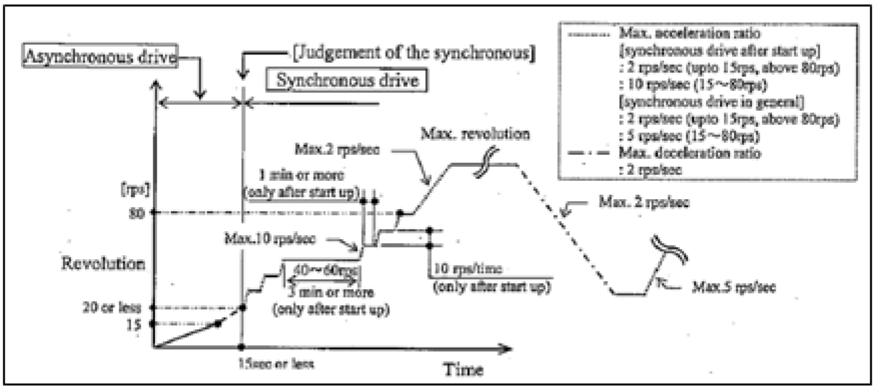
In case of emergency, compressor can stop suddenly.

Scroll compressor pattern





Twin rotary compressor pattern



Inverter compressor speed limit for defrost.

The changing of heating mode to cooling mode or cooling mode to heating mode is not necessary to stop compressor but speed of compressor should be lower than 40 rps during switching four-way valve.

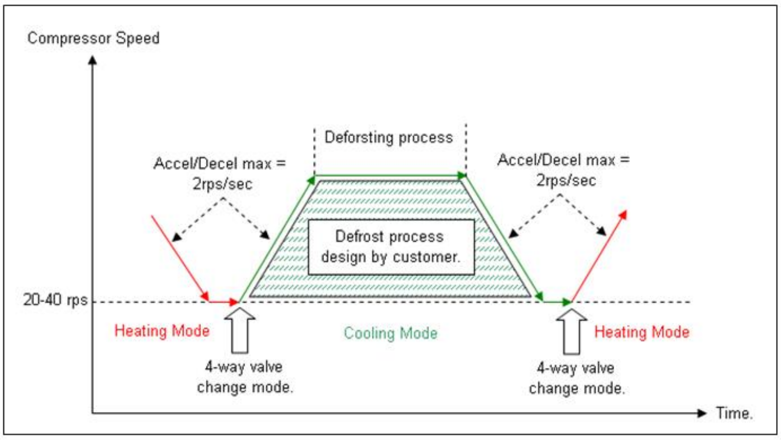


Figure: Compressor speed limit for defrost

Design caution and protection

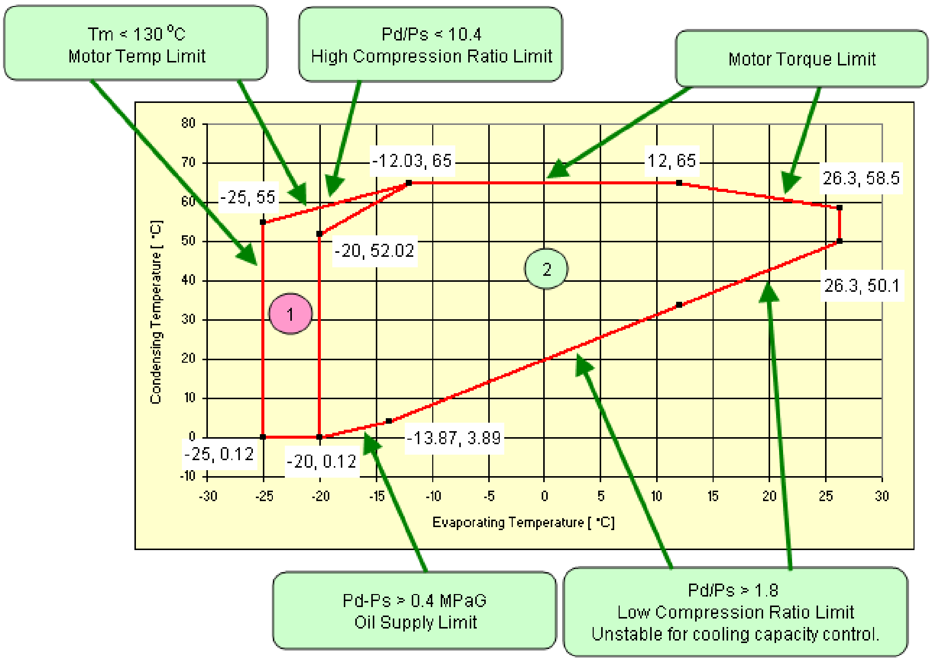
Controller design for compressor protection

There is no self-protection in inverter compressor. The protection should be set on driver and controller.

Compressor operating limit.

The compressor has to be run under operating area (compressor envelop in specification sheet).

Example operating area for R410A scroll compressor



Area	Speed Limit (rps) min	Speed Limit (rps) max	Discharge Temp Limit (°C)
1	20	120	110
2	20	120	120

For oil supply limit of R410A, the pressure difference (Pd-Ps) should be over than 0.4 MPaG or specified in SCI recommendation to avoid problem of lubrication.

For another refrigerant, please refer to compressor specification.

Compressor discharge temperature limit.

SCI scroll and rotary compressor are high pressure shell type. Since compressor motor is designed to cool down by discharge gas, the temperature of discharge gas has to be controlled not to exceed the limit which is mentioned in the compressor envelop.

Recommendation for discharge temperature measuring position:

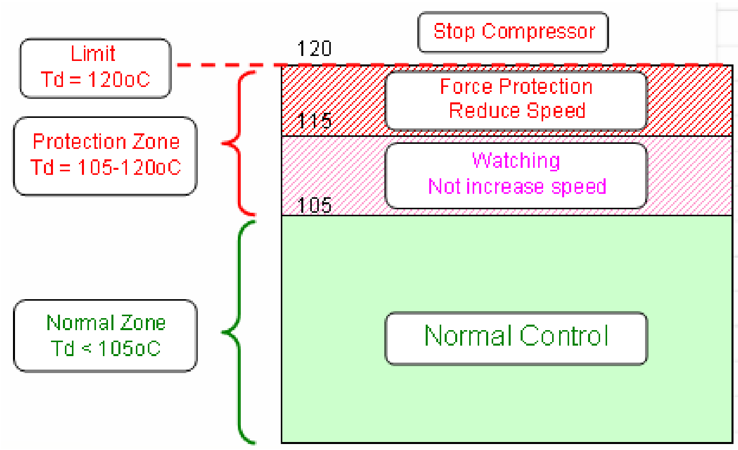
1. at the top shell of scroll compressor.

2. at discharge pipe of scroll and twin rotary (within 15 cm from compressor shell)

Recommendation for discharge temperature protection control:

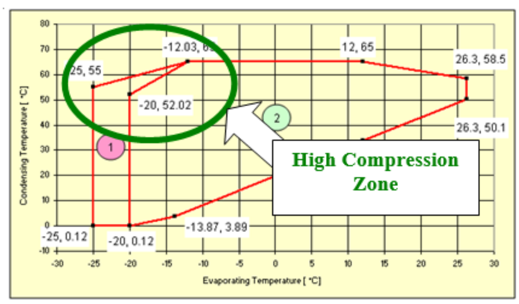
The compressor should not be stopped too often. The controller should be set to protect the compressor from over stopping of the compressor. The limit of compressor stopping frequency is mentioned in general specification.

<u>Example:</u> Separating zone of control; Normal zone and protection zone.



The concept of control can also be applied to the other compressor limits that can improve system control quality.

Recommendation for discharge temperature control in high compression zone.



<u>Td Control for High compression zone</u>
In general system, superheat control is at suction side. The control value is between 5-10K. But it may have problem of discharge temperature over than compressor limit (115oC & 120oC) by this control method. Then it seems that compressor can not operate in this zone.
<u>Recommendation for solving the problem</u>
Discharge superheat [DSH] control for this area is recommended. The control value of DSH is between 20-30 K. Suction superheat by this control will be close to zero K or a little wet refrigerant. By this method, expansion valve will open more and discharge temperature will reduce to be lower than the limit. Furthermore, this method can improve system efficiency.
Note: DSH control method has no reliability problem from liquid back if DSH is more than following limit. Scroll compressor DSH limit is > 10 K, and Twin rotary compressor DSH limit is > 20 K.

Liquid back protection

The compressor cannot operate in liquid back condition. The compressor should be protected by;

1. Suction superheat control

Suction superheat should be more than 0 K. (SSH = Ts – Tssat)

Note: Ts = Suction temperature.

Tssat = Saturated temperature from suction pressure.

2. Discharge superheat control

Discharge superheat should be more than 10 K for scroll compressor and 20 K for twin rotary compressor. (DSH = Td-Tdsat)

Note: Td = Discharge temperature.

Tdsat = Saturated temperature from discharge pressure.

3. Controlling the percentage of refrigerant mixed with the oil in the compressor

The percentage of oil concentration by weight should be controlled to exceed 50%. The percentage can be measured in 2 ways.

- Direct measurement

The percentage can be measured by taking mixed refrigerant and oil from the compressor and measuring weight of refrigerant and oil.

- Calculation from oil property chart

The percentage of oil concentration can be calculated from oil property chart by measuring oil pressure (discharge pressure) and oil temperature at the bottom shell of the compressor. Oil property chart is provided by SCI.

System piping design

Piping design recommendation

Piping design is very important for compressor application development. Especially for inverter technology, there are several operational speeds which concern resonance phenomenon. There are 2 factors of piping properties that should be considered.

Natural frequency

The shape and length of piping must be properly designed when the vibration of the pipe must not exceed 0.8 mm. at all frequency ranges of the compressor (15-130 rps for inverter model or 40-70 Hz for fixed speed model) with ±10% of voltage of the compressor operation. There is no need to adhere to the above conditions if there are other methods that can be used to check the pipe resonance.

Piping stress

The piping must be designed to prevent damage during transportation, starting, and stopping the compressor.

Limitation of piping stress

At starting and stopping: < 3.5 kg/mm^2

During operation: < 1.8 kg/mm^2

Simulation process can help save the time of development. As the picture below, this example piping design is a simulation which is designed to avoid the resonance and the piping stress matter.

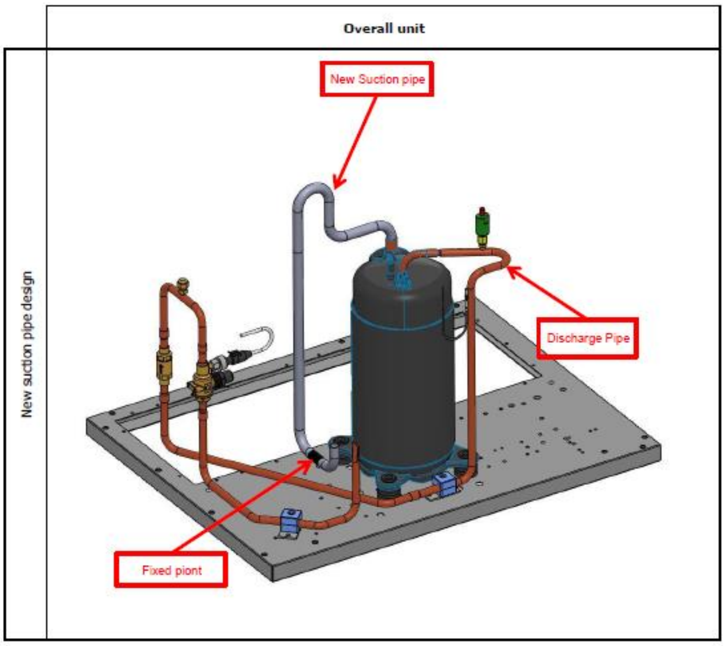
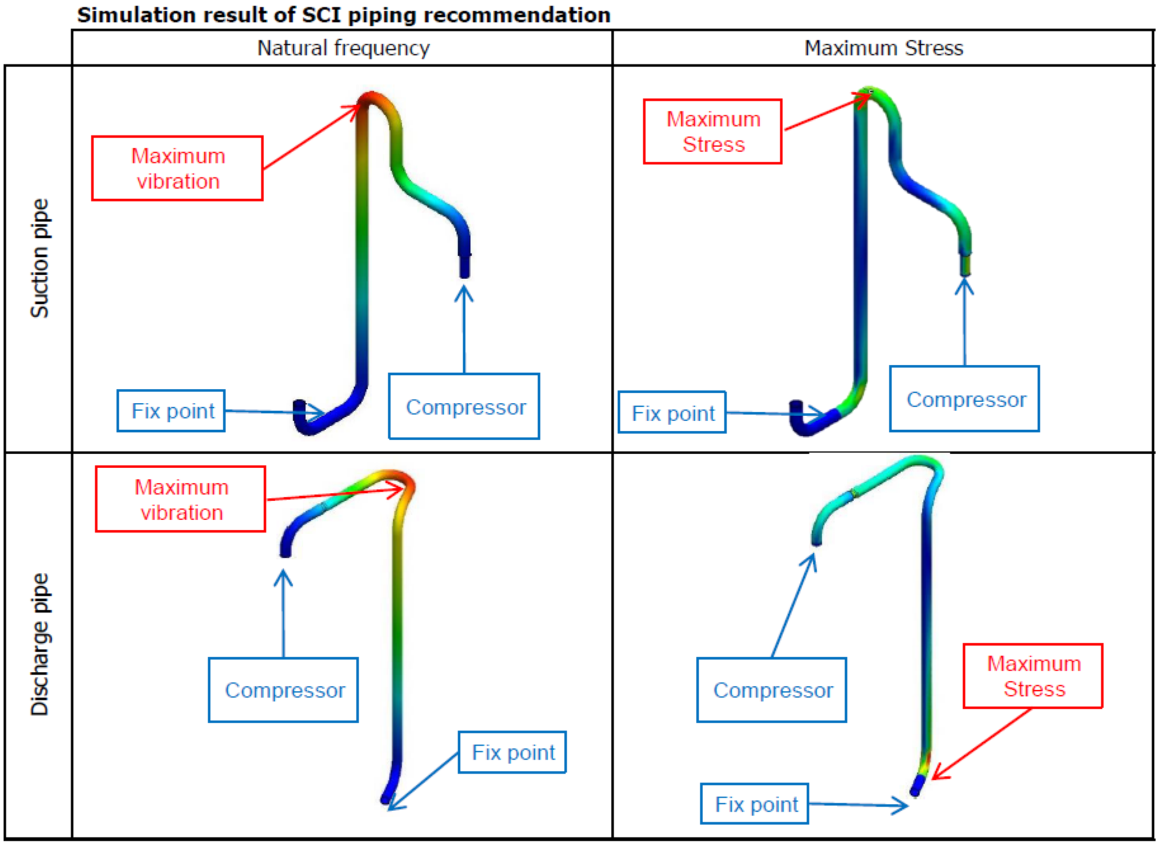


Figure: Example of piping design guideline



Note: 3D file of piping design for each compressor model can be shared upon request.

Figure: Example of piping simulation result

Checking and design guide

- All sensors should be located after fixed point as the weight of equipment will cause piping to be broken.
- Allowing the suction and discharge piping to be flexible can prevent over stress on piping.
- Bands can be used to prevent piping resonance.
- The pipe should have clearance to prevent excessive adjacent of parts. The clearance between parts (piping, wall, compressor, fan, etc.) should be over 15 mm.

Safety procedure for R290 and flammable refrigerant

R290 and flammable refrigerant safety procedure recommendation

As natural refrigerant is being used more widely in heat pump application market. R290 is one of the popular refrigerant in heat pump application. Nevertheless, R290 is A3 flammable refrigerant so safety features should be considered for development state and field installation.

Prevention against air entering the compressor

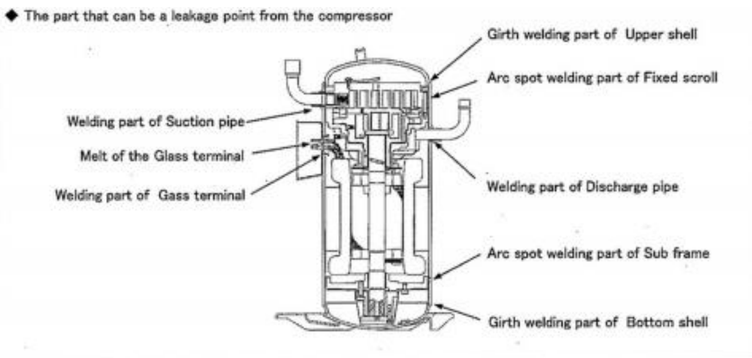
To prevent the compressor piping from breaking, the piping must not exceed the stress limit.

SCI has a piping guideline and piping work recommendation. Please contact SCI for this assistance.

The stress of high pressure piping should be checked by appropriate method of measurement to prevent the piping from breaking such as using strain gauge for measuring stress or acceleration for vibration.

System should be designed to protect refrigerant from reaching flammable density when there is a leak of refrigerant. For refrigerant leak part,

Design system that refrigerant will not reach its flammable density when refrigerant leak. The part that can be a leakage point is shown in the picture below.



Moreover, all welding points in the system should be considered.

Protection against low pressure

Heat pump operation should be stopped by controller or low pressure switch in case low pressure side becomes negative pressure.

Protection against low gas volume

When refrigerant gas in the system is significantly less than half of the total charged amount, the system should be stopped by protection measure. If the measurement is difficult, low pressure protection should be double. The low pressure switch must be operated according to envelop limitation.

Protection against high pressure

The system should be stopped before discharge pressure reaches 1.25 times of the highest pressure limit indicated in the compressor envelop. (Please refer to compressor envelop in the specification sheet.

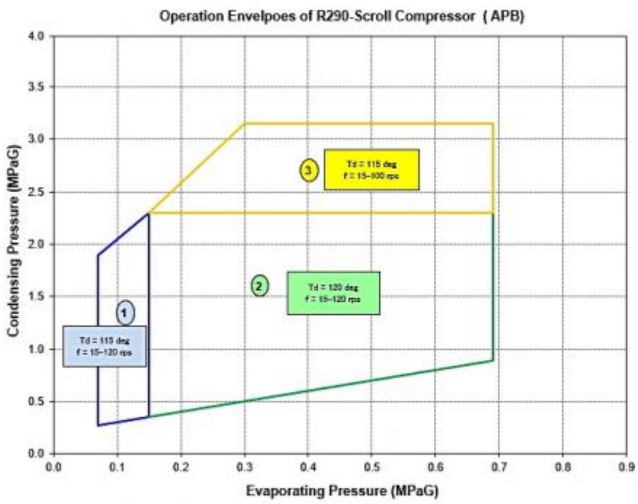


Figure: Example for R290 (APB) operating envelop

Protection against the abnormal operation of compressor

The system should be stopped when overcurrent of compressor input occurs more than 1 minute. In addition, high pressure protection should be double of the highest pressure limit indicated in the compressor envelop.

Protection against overcurrent on fixed speed compressor

Mitsubishi Electric and SCI quality control avoids damage of motor winding which cause overcurrent or contaminants inside the compressor which causes a short circuit.

Protection of overcurrent on the system

A fuse (3 Phase) or a circuit breaker should be equipped on the main system to protect overcurrent. Thermal relay is recommended to prevent the system from malfunction.

High pressure shell compressor benefits

Discharge superheat control

For heat pump efficiency improvement, customers can take advantage of the high pressure shell compressor by using discharge superheat (DSH) control. DSH as shown in the P-h diagram of figure 1 can be calculated from T_{sat} of P_d and T_d.

High pressure shell compressor stores heat inside the compressor. The stored heat can be transferred to condensing unit by an increase of refrigerant flow that maximizes compressor efficiency. Refrigerant flow increase can be controlled by DSH control concept.

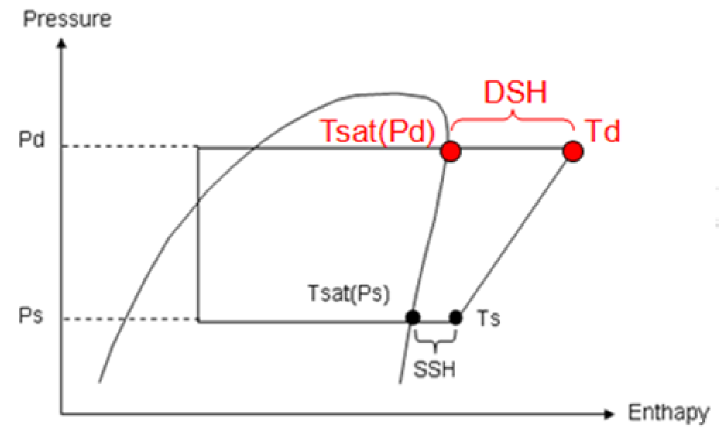
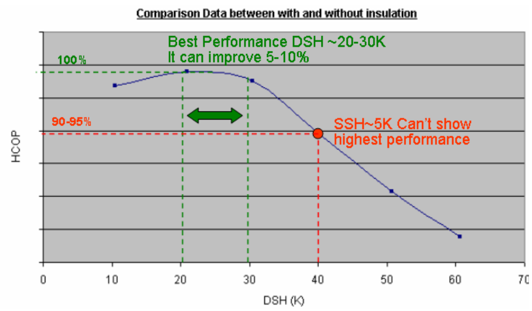


Figure: P-h diagram showing discharge superheat

From SCI experiments, DSH control can increase heat pump efficiency about 5-10% as shown in figure3. Moreover, the improvement of heat pump efficiency depends on running condition, refrigerant charge, and heat exchanger size. the optimum DSH value is related to the compression ratio (Pd/Ps) with linear relation as shown in figure below. To apply DSH control, the relation can be programmed in the controller for electronic expansion valve control.



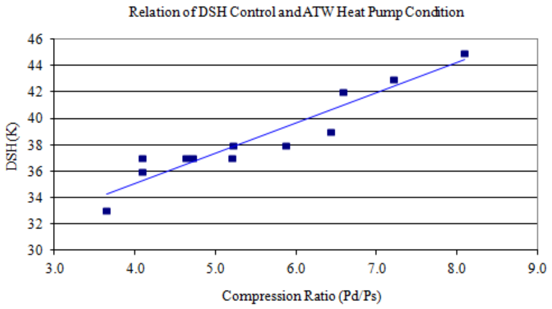


Figure: Relation between DSH value and compression ratio/HCOP

SCI high pressure shell compressor can be used under liquid back condition, without impacts to the compressor reliability. SCI's compressor limit is:

- For scroll/twin rotary compressor: DSH > 10K
- For rotary compressor T series: DSH > 20K

DSH control cannot be used with low pressure shell compressor as oil is mixed with liquid refrigerant that will reduce lubrication and affect compressor reliability.