SRC-XS and SRC-S series compressors Capacity control (SA-03-03-E)

3. CAPACITY CONTROL **2**

3.1 SRC-S SERIES 2
3.1.1 Operating principle and oil control circuit 2
3.1.2 Step capacity control 3
3.1.3 Control sequence: step configuration 9
3.1.4 Infinity capacity control: stepless 10
3.1.5 Control sequence: stepless configuration 13
3.2 SRC-XS SERIES 14
3.2.1 L1 configuration: working principle and control circuit 14
3.2.2 L2 configuration: working principle and control circuit 16
3.2.3 Control sequence: step configuration 19
3.3 PROCEDURE FOR STARTING AND STOPPING THE COMPRESSOR 20
3.4 OPERATING LIMITS AT PART LOAD 21

3. Capacity control

The RefComp screw compressors can operate both at full load and part load. In particular for the SRC-XS compressors only the configuration 'step' L2 with 3 capacity steps (50-75-100% load) is available; while for the SRC-S compressors the user can choose among the 'step' L4 configuration with 4 capacity steps (minimum-50-75 and 100% load) and the 'stepless' LZ configuration (continuous variation of the load, either from the minimum step to 100%, or from 50 to 100%).
Hereinafter the two compressor series SRC-S and SRC-XS will be considered separately. In addition, the differences which characterized the new models SRC-S-255/285/305 with respect to the other models of the same series, will be highlighted as well.

3.1 SRC-S series

3.1.1 Operating principle and oil control circuit

For the models SRC-S-113/133/163/183/213/253/303/353/413/463/503/553/603 the cylindrical chambers that house the screw rotors are fitted with a upper longitudinal port, whose connection with the suction side is regulated by the position of the slide valve (17), see picture 3-A. For the models SRC-S 255/285/305 that port and slide valve (1) are located underneath the rotors instead, see picture 3-B.
When the slide valve completely closes the above mentioned port, the effective compression length is maximum and coincides with the entire length of the rotors; when, on the other hand, the valve moves towards the discharge and the opening expands longitudinally, the effective working length of the rotors is reduced and as a consequence a smaller quantity of gas is processed. As a result, adjusting the volume taken in by the rotors make it possible to control the mass flow processed and definitely the cooling capacity generated by the compressor.
The slide valve is controlled by a hydraulic cylinder activated by the oil pressure. Concerning the models SRC-S-113/133/163/183/213/253/303/353/413/463/503/553/603, the oil control circuit for the capacity control is characterized by three normally-closed solenoid valves: 14, 15 and 16 in the step configuration and 14, 15 e 19 in the stepless configuration, see pictures 3-A and 3-N.
On the other hand, concerning the models SRC-S-255/285/305, in both the configuration the oil circuit is characterized by the three normally-closed solenoid valves above mentioned (14 – 15 – 16) and by two different plates (4), which allow to install the step and stepless configurations, see pictures 3-B and 3-O. This means that the oil circuit can be modify just by switching the two plates (4).

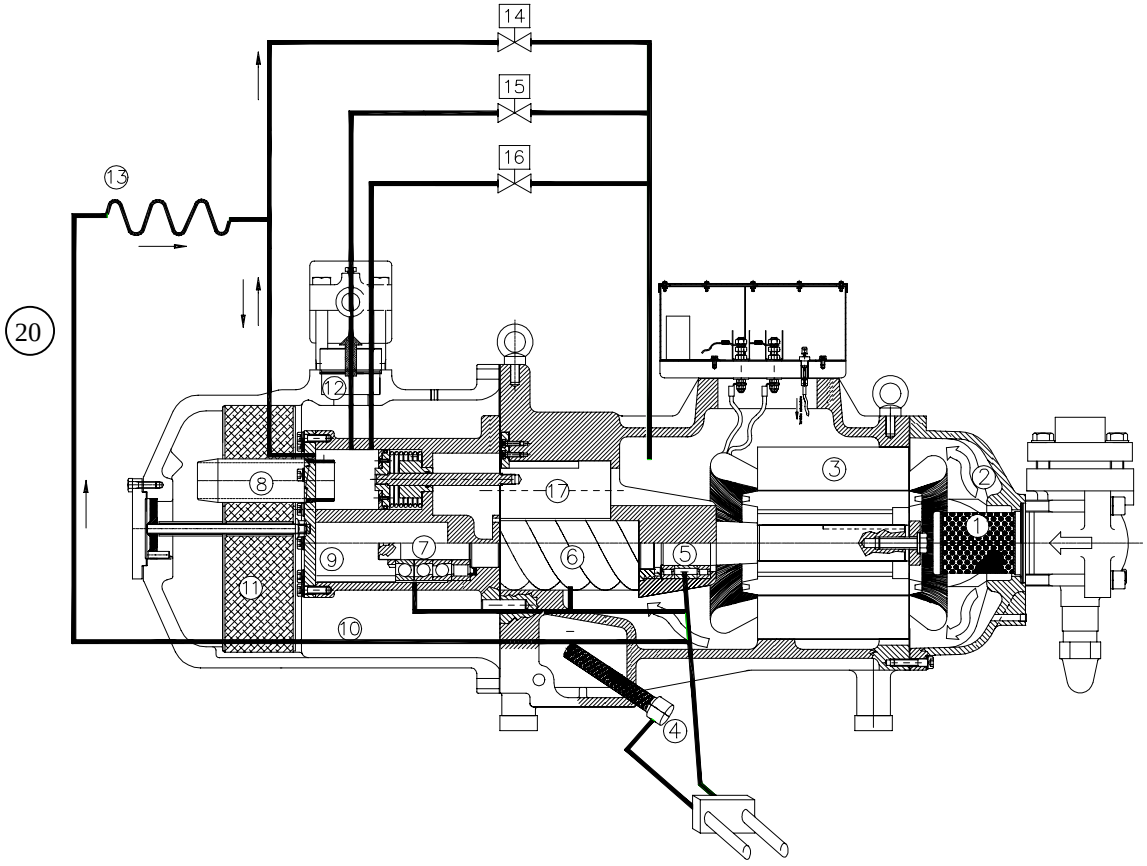
The following paragraphs describe the operating principle of the oil circuit in the step and stepless configurations and, as you can see, this principle is the same in both the SRC-S series compressor types.

3.1.2 Step capacity control

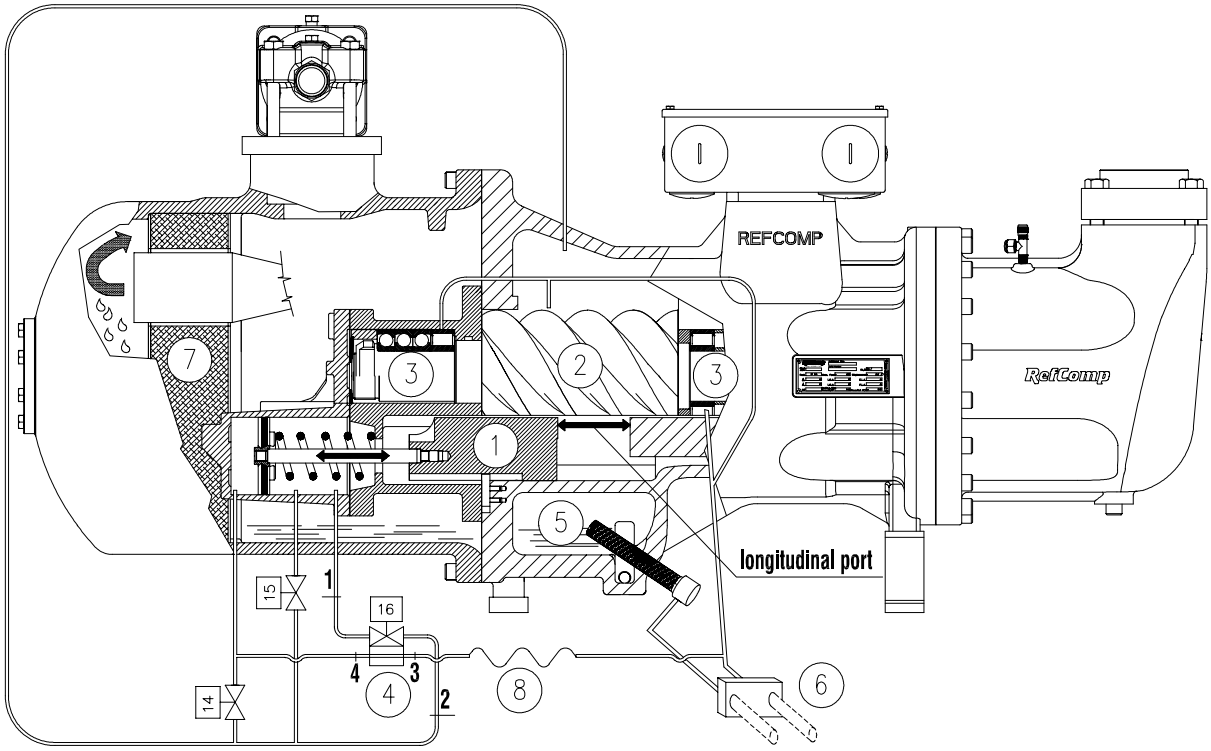
The slide valve is controlled by a hydraulic piston that can have four distinct positions, corresponding to the capacity steps: 100 - 75 - 50% - minimum step (note: the effective capacity steps may differ from the rated values, according to the normal operating conditions and from compressor to compressor).

The following pictures 3-A and 3-B show the internal oil circuit for the capacity control in the new models 255/285/305 and in the other of the SRC-S series respectively. As you can see from these pictures, for all the compressors the oil circuit is characterized by the three normally-closed solenoid valves 14, 15 and 16 which respectively allow to control the three capacity steps: minimum capacity, 50 and 75%.

Below is a brief description of the operation of the oil circuit in the four compressor capacity steps.



Picture 3-A: step capacity control oil circuit for the models: SRC-S-113/133/163/183/213/253/303/353/413/463/503/553/603;
14, 15, 16: capacity control solenoid valves;
17: capacity control slide valve and operation piston;
13: capillary tube (external to the compressor);

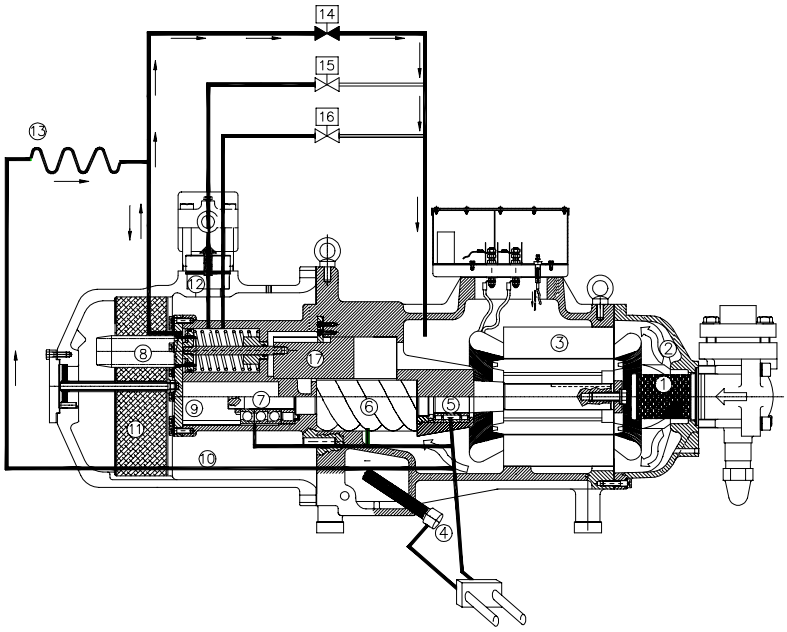


Picture 3-B: step capacity control oil circuit for the models: SRC-S-255/285/305;
14, 15, 16: capacity control solenoid valves;
1: capacity control slide valve and operation piston;
4: step-stepless switch plate;
8: capillary tube (internal to the compressor);

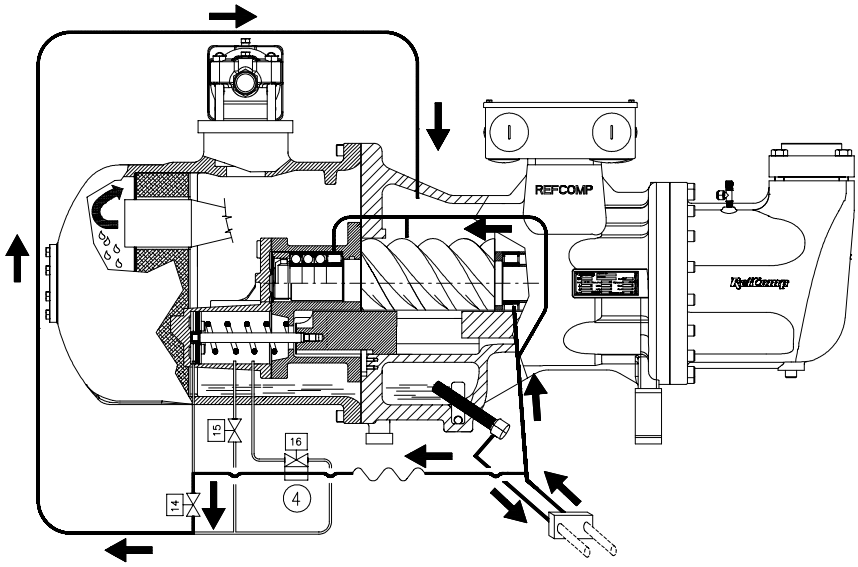
✓ **MINIMUM CAPACITY STEP (COMPRESSOR STEP FOR START UP AND STOP)**

Pictures 3-C and 3-D show how the oil runs inside the control circuit. At the minimum step the solenoid valve 14 is opened, while the valves 15 and 16 are closed. Therefore the oil, coming from the oil reservoir, flows through the opened port to the suction side, not pressurising the control cylinder. Consequently the piston is pushed to the end stroke, the longitudinal port is completely opened on the suction side and the length along which the rotors are working is the shortest.

	**Warning!** Concerning the step capacity control mode (4 steps), the minimum capacity step can be used only to start and stop the compressor; it cannot be used to give cooling power.



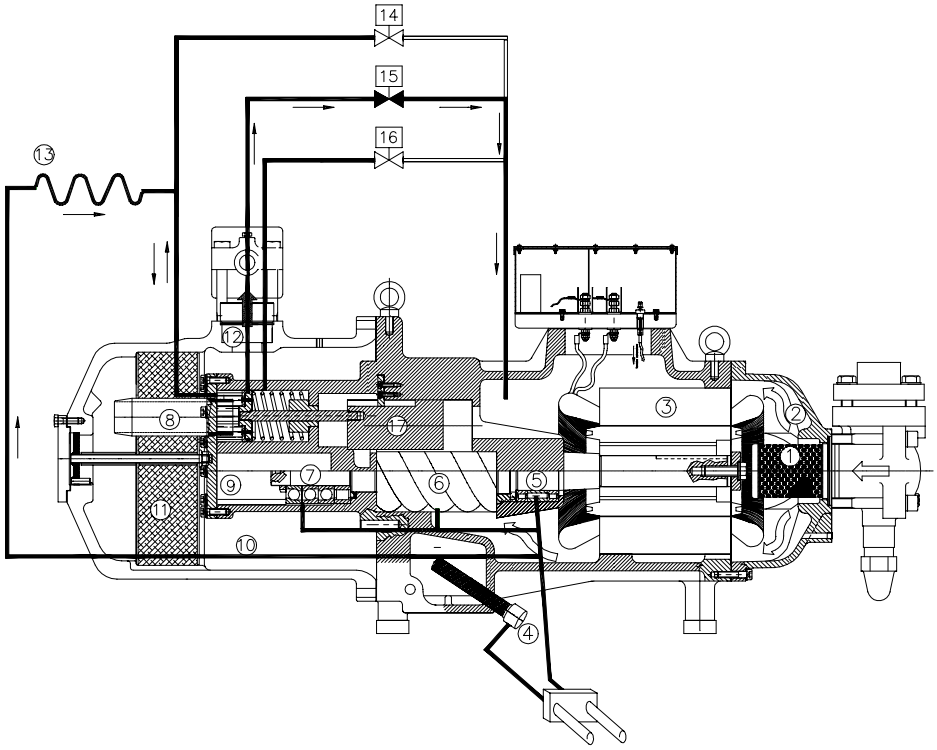
Picture 3-C: capacity control at minimum step: models 113/133/163/183/213/253/303/353/413/463/503/553/603;



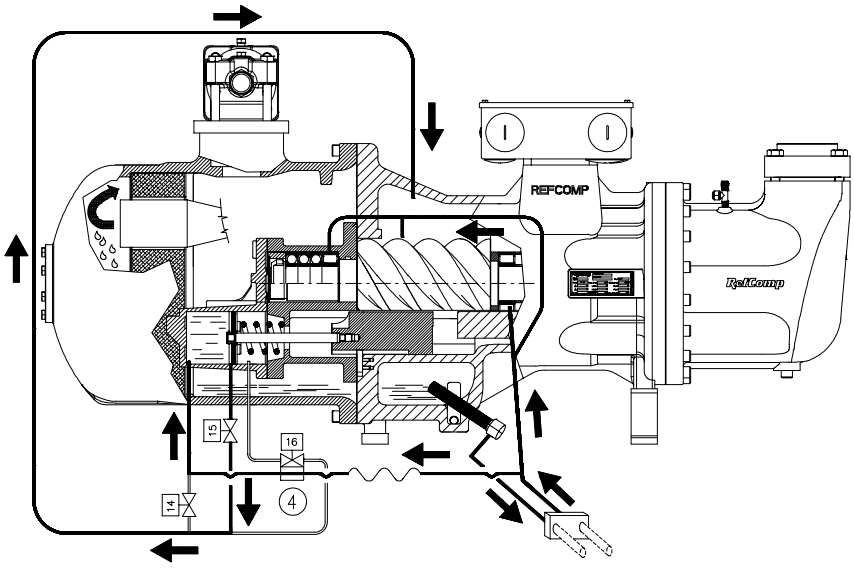
Picture 3-D: capacity control at minimum step: models 255/285/305;

✓ **50% CAPACITY**

With reference to pictures 3-E and 3-F at 50% capacity, the solenoid valve 15 is open while the valves 16 and 14 are closed; the oil enters the cylinder (through the 1st hole on the left) and drives the piston to the position corresponding to the 2nd hole, where the oil flows to the suction side. The slide valve also moves and partially closes the longitudinal opening, thus increasing the effective working length of the rotors.



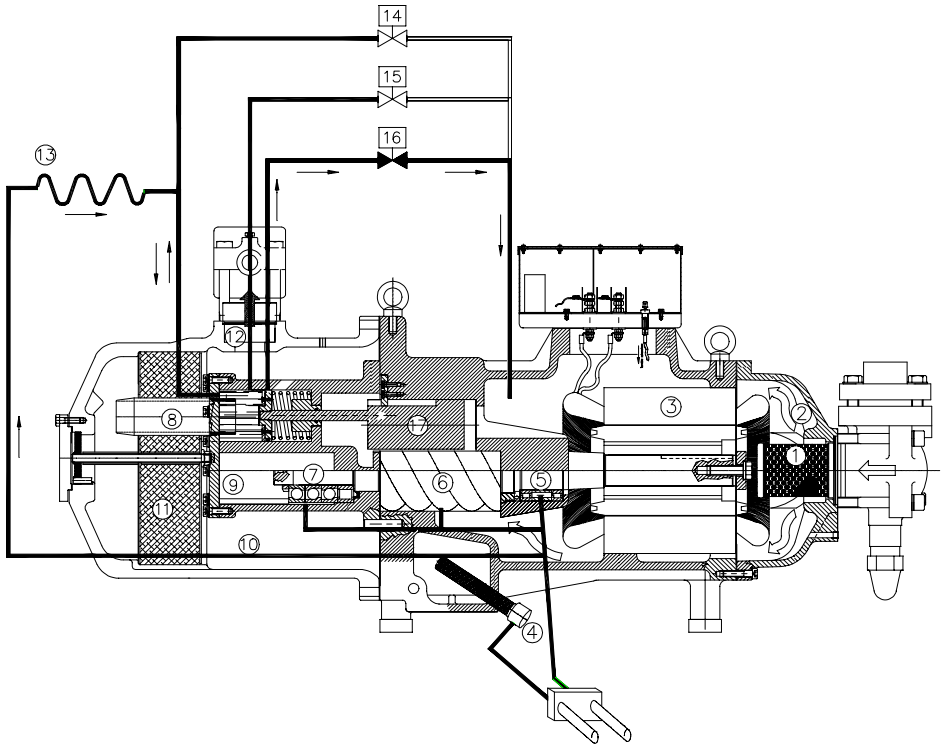
Picture 3-E: capacity control at 50% step: models 113/133/163/183/213/253/303/353/413/463/503/553/603;



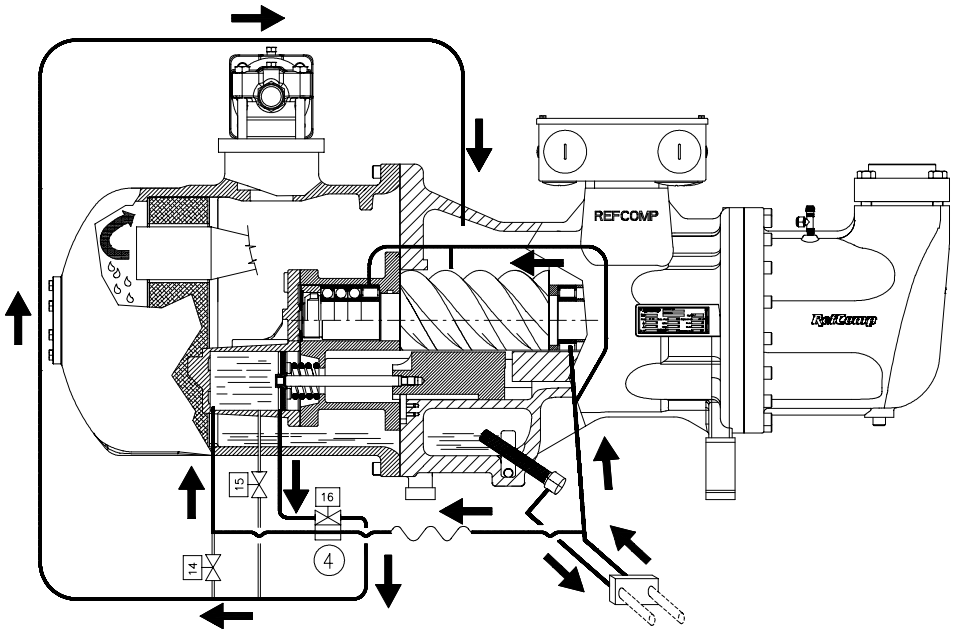
Picture 3-F: capacity control at 50% step: models 255/285/305;

✓ **75% CAPACITY**

At 75 % capacity, see pictures 3-G and 3-H, the situation is similar to the previous one, but now the solenoid valve 16 is open while the valves 15 and 14 are closed; the control piston is thus positioned corresponding to the 3rd hole, the slide valve closes the opening further and increases the working length of the rotors.



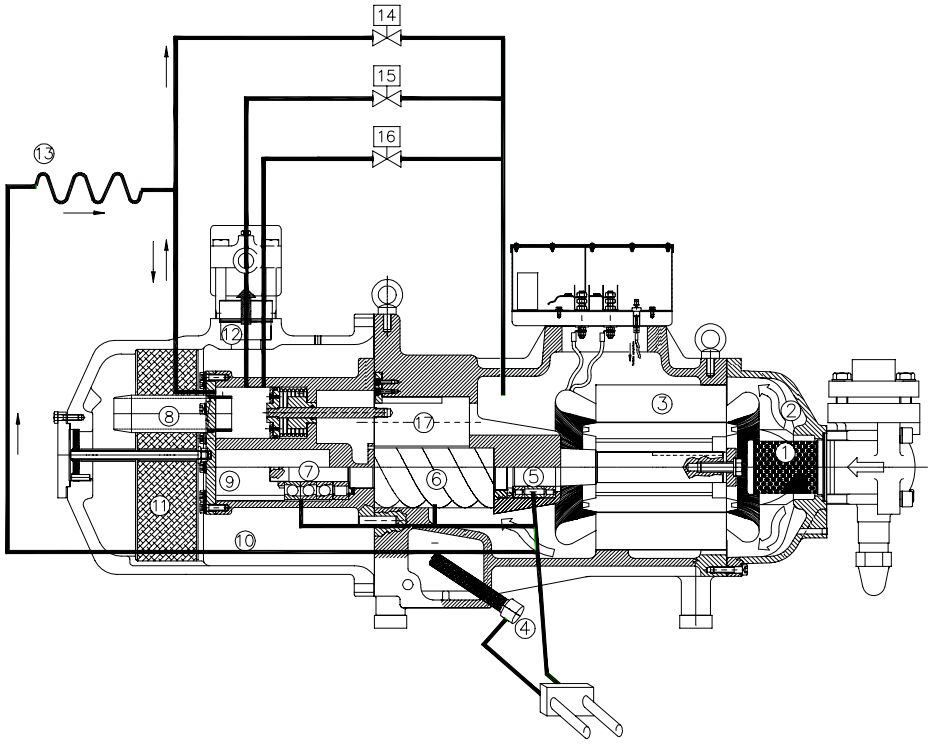
Picture 3-G: capacity control at 75% step: models 113/133/163/183/213/253/303/353/413/463/503/553/603;



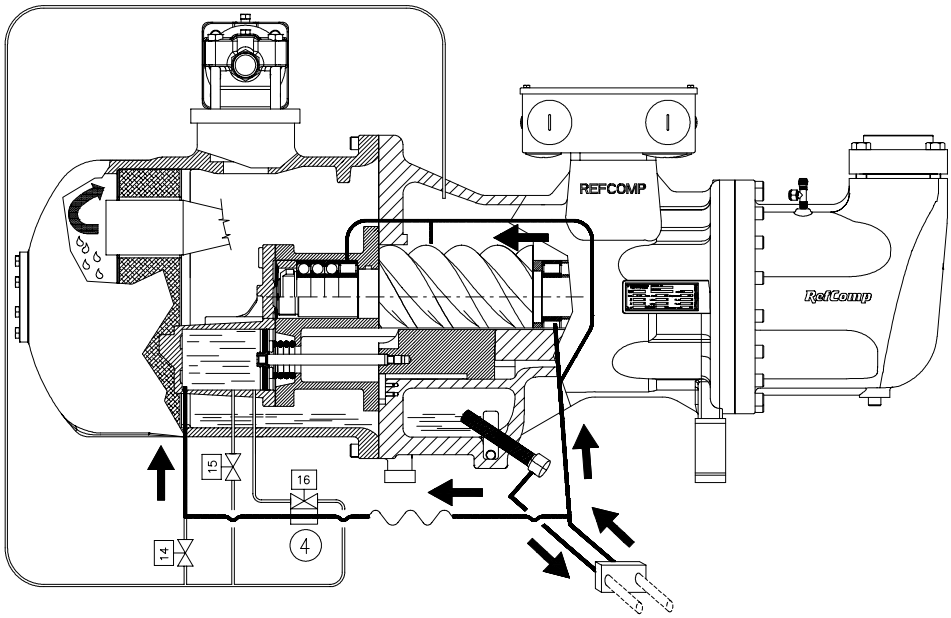
Picture 3-H: capacity control at 75% step: models 255/285/305;

✓ **100% CAPACITY**

At 100% capacity, see pictures 3-I and 3-L, all the solenoid valves are closed; the oil can no longer leave the cylinder and pushes the piston to the limit on the right side and the slide valve completely closes the longitudinal opening, meaning that the compression occurs along the entire length of the rotors.



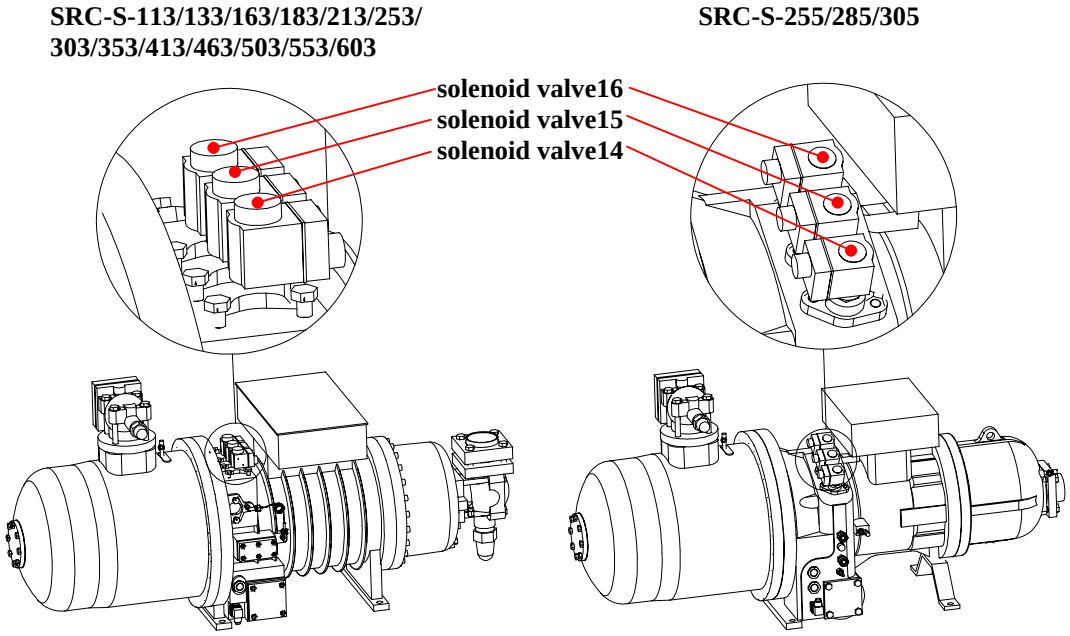
Picture 3-I: capacity control at 100% step: models 113/133/163/183/213/253/303/353/413/463/503/553/603;



Picture 3-L: capacity control at 100% step: models 255/285/305;

3.1.3 Control sequence: step configuration

The oil flow is controlled by the three solenoid valves, normally-closed, positioned on top of the compressor casing, see picture 3-M. For all the compressors series SRC-S these valves are energized according to the logic shown in Table A.



Picture 3-M: solenoid valve position on the compressors;

	Solenoid valves		
Load (capacity steps)	**16**	**15**	**14**
100%	Off	Off	Off
75%	On	Off	Off
50%	Off	On	Off
Minimum step (start up and stop)	Off	Off	On

"Off"= solenoid not energized; **"On"**= solenoid energized;

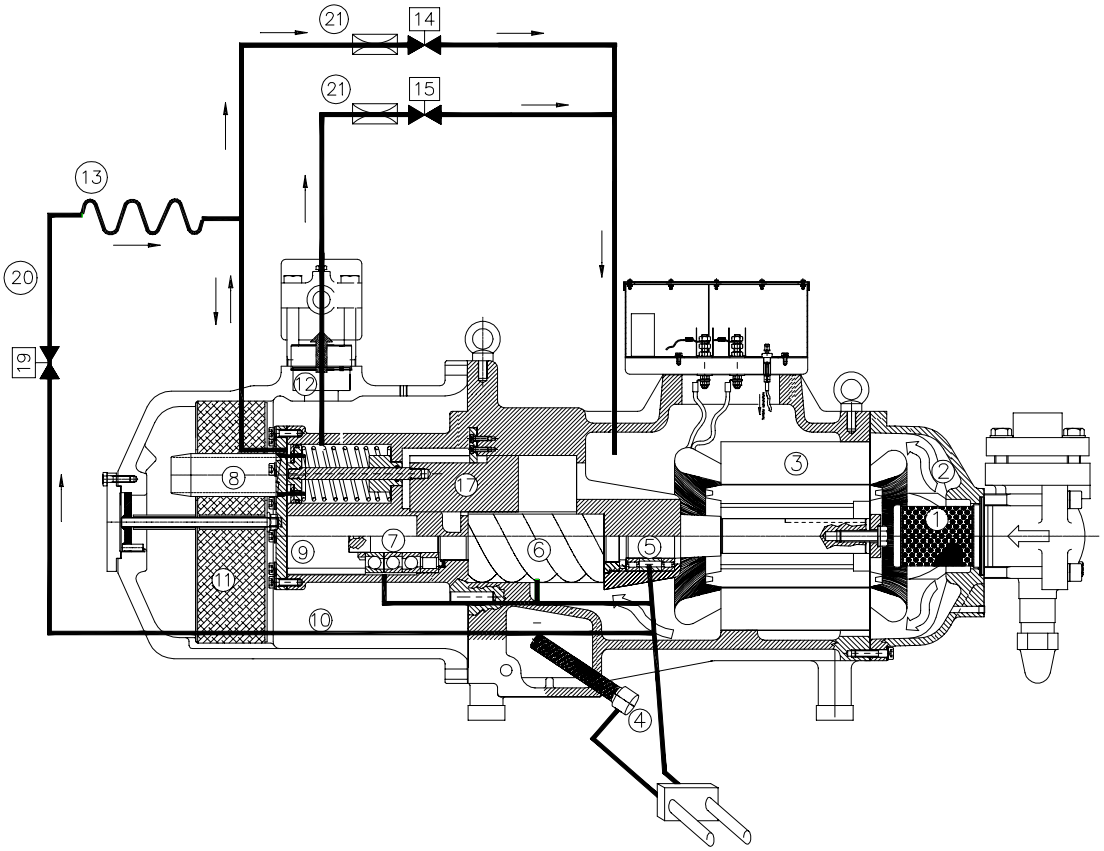
Table A: operating logic of the solenoid valves for step capacity control;

3.1.4 Infinity capacity control: stepless

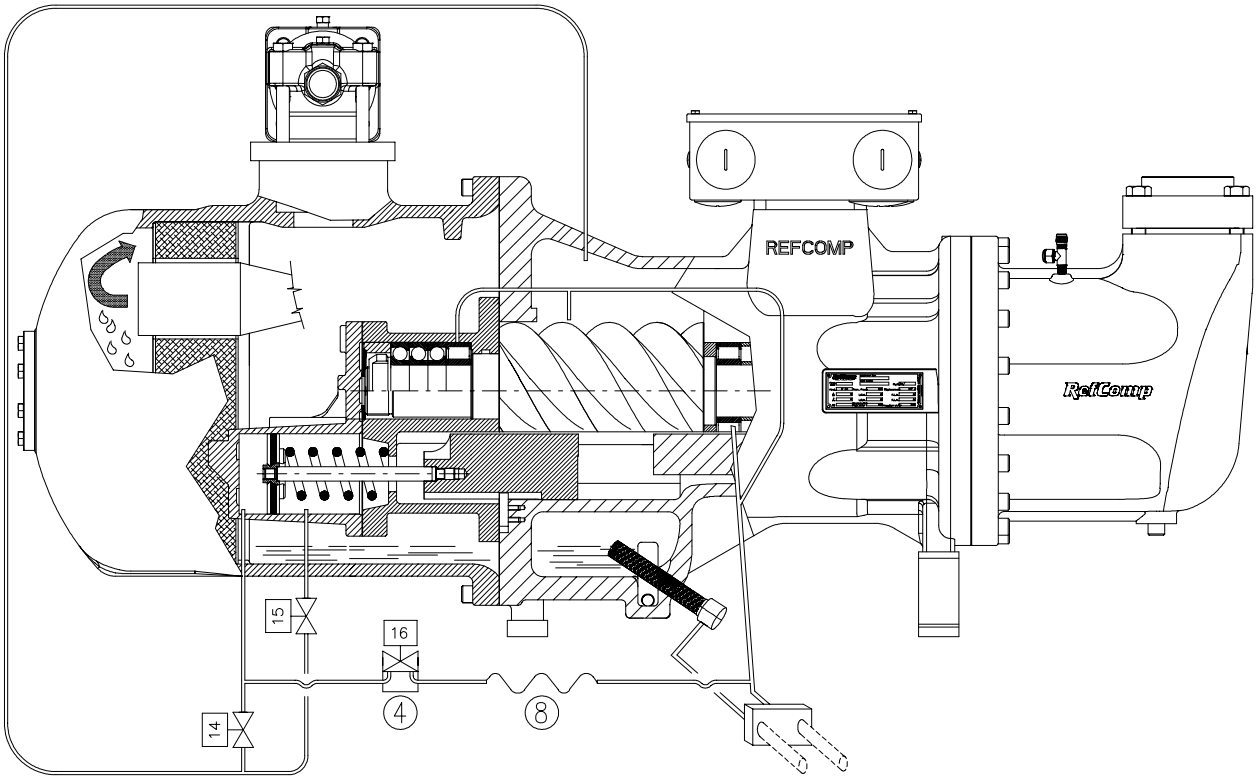
Infinite capacity control is recommended whenever the cooling capacity of the system has to be controlled with a high degree of precision, while it is not very useful in systems featuring high inertia, where step capacity control is more suitable.
With reference to picture 3-N, to perform the stepless configuration in the models 113/133/163/183/213/253/303/353/ 413/463/503/553/603 you have to move the solenoid valve located in position (16) to the position (19) on the circuit (20). With this switch the valve, which in the step configuration controlled the 75% capacity step, now controls the oil flow towards the slide valve control cylinder. The other two solenoid valves do not change their position.
In the models 255/285/305 with this configuration, see picture 3-O, the plate (4) is configured so that the solenoid valve (16) controls the oil flow entering the hydraulic cylinder that operates the slide valve (section of the circuit marked by numbers 3 and 4 in Figure 3-B). The 75% step control function is disabled, and for this reason the section of circuit marked by numbers 1 and 2 in picture 3-A will not be shown in picture 3-O below.
The cooling capacity is therefore controlled by using the normally-closed solenoid valves (14), (15) e (19) in the models 113/133/163/183/213/253/303/353/413/463/503/553/603 and the valves (14), (15) e (16) in the other three models 255/285/305. The valves have the following logic:

- ✓ (16), (19): fill the hydraulic cylinder for increasing the cooling capacity required by the users;
- ✓ (14), (15): empty the hydraulic cylinder, until the minimum step or 50%, to decrease the cooling capacity required by the users.

This brings about <u>continuous control</u> of the flow processed by the compressor, from the minimum value to the maximum value. For details on how to convert the configuration from the step to stepless for all the compressors SRC-S, see chapter SA-15 "*Capacity control conversion*".

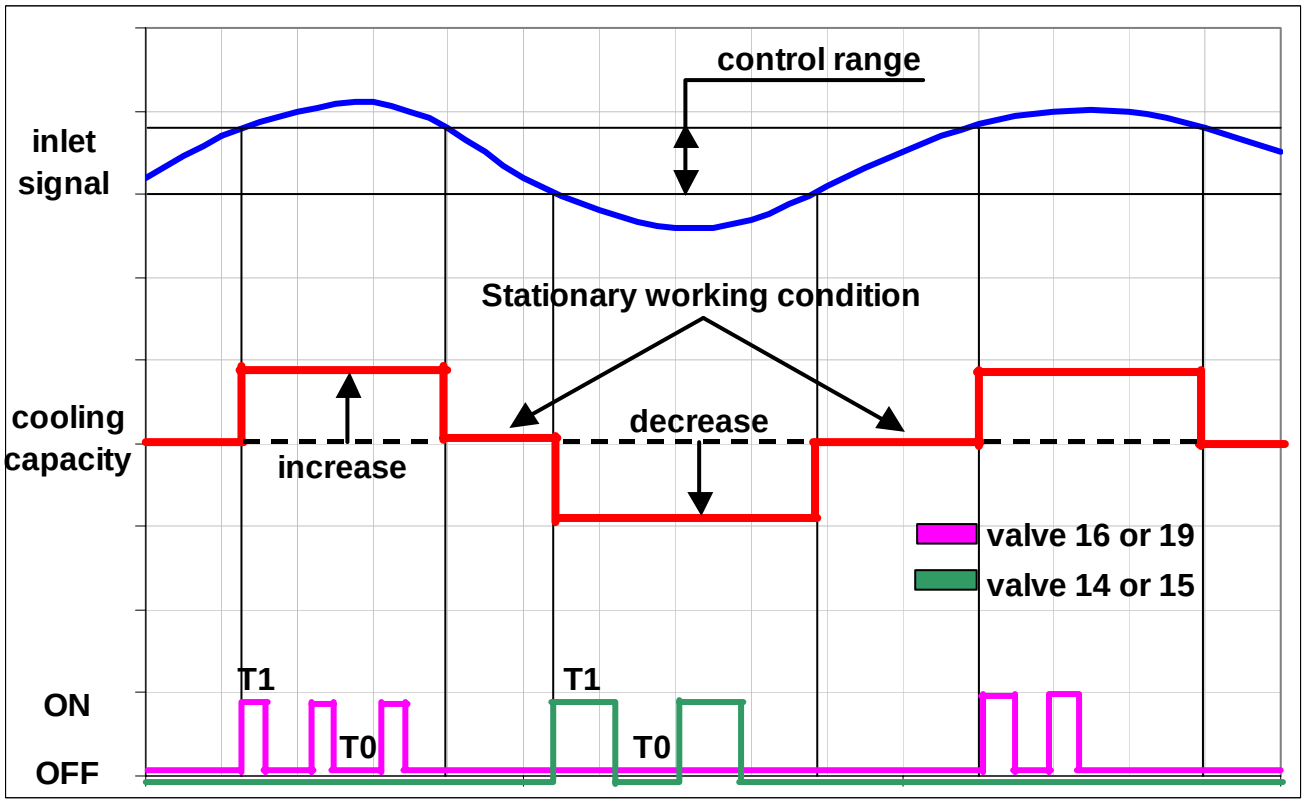


Picture 3-N: infinite capacity control oil circuit (step less configuration): models SRC-S-113/133/163/183/213/253/303/353/413/463/503/553/603;



Picture 3-O: infinite capacity control oil circuit (step less configuration): models SRC-S-255/285/305;

Only for the models 113/133/163/183/213/253/303/353/413/463/503/553/603 the oil channels must be throttled to achieve slower motion and more accurate positioning of the control piston. With reference to the picture 3-N, the load channel (20) can be throttled by installing a modified capillary tube (13). The unload channel (14) or (15) can be throttled by installing an orifice (21) upstream the solenoid valve. Both items are supplied on request as they belong to the conversion kit from the configuration step to the stepless one, and have to be assembled by the user (see chapter SA-15: "*Capacity Control Conversion*").



Picture 3-P: infinite capacity control logic;

With reference to picture 3-P, the capacity delivered by the compressor is controlled by using a control device that, in response to a variation in the load required by the users, opens the solenoid valves (14), (15) and (16) described above. In particular, these valves are energized by pulse signals and, as regards the control device input signal, the chosen parameter should be sensitive to the variation in the load required by the users. For instance the suction pressure or the air/water temperature can be used.
Picture 3-H shows the series of impulses that energize the valves (14), (15) and (16)/(19) and used to adapt the delivered mass to the required cooling capacity. You can note that when the value of the input variable does not move outside of the range of control (differential), the system does not react and the compressor operates in stationary conditions.
The solenoid valves should be energized by brief impulses (T1= 0.5-1 sec). Usually, the energizing period of solenoid valve (16) can be shorter than the energizing period of solenoid valves (14 or 15). The series of impulses continues until the value of the control variable returns within the range of control (differential).
The time interval between two impulses (T0) must be set to optimize the control, according to the inertia of the system.

⚠	**Refcomp at any rate suggests:** ✓ not to operate with a capacity below 50% for longer than around 5 minutes, so as to avoid excessive overheating of the electrical motor; ✓ not to switch rapidly from full load conditions to minimum load, but rather to remain for a minimum time of 3 minutes at 50%. Otherwise liquid may enter the compressor causing damage; ✓ to check and if necessary adjust the timers on the control device when a continuous variation in the compressor capacity is not related to appreciable variations in the load required by the users.

3.1.5 Control sequence: stepless configuration

INFINITY CONTROL 100-50%				INFINITY CONTROL 100-minimun step			
	Solenoid valve				Solenoid valve		
Capacity variation	**14**	**15**	**16/19**	**Capacity variation**	**14**	**15**	**16/19**
Load	OFF	OFF	**ON**	**Load**	OFF	OFF	**ON**
Stationary work	OFF	OFF	OFF	**Stationary work**	OFF	OFF	OFF
Unload down to 50%	OFF	**ON**	OFF	**Unload down to minimum capacity**	**ON**	OFF	OFF
(START/STOP)	**ON**	OFF	OFF	**(START/STOP)**	**ON**	OFF	OFF

OFF = solenoid not energized; **ON** = solenoid energized;

Table B: operating logic of the solenoid valves for infinite capacity control in all the SRC-S series compressors;



Warning!

The working at partial load condition is allowed according to the application limits reported in the chapter SA-10: "*Application limit*".

Particularly, the compressor can work at the minimum capacity step only during the start up phase, the stop phase (see paragraph 3.3) and in any case for short period of time (see previous page).

At any rate the part load operation requires specific actions to prevent:

- ✓ The insufficient return of oil due to the reduced speed of the gas;
- ✓ Higher temperatures on the discharge side, caused by the compression lower efficiency and by the lower refrigerant mass flow;
- ✓ An overheating of the electrical motor that might occur whenever the tension value is out of the given range.

Thorough and extensive testing is recommended.

3.2 SRC-XS series

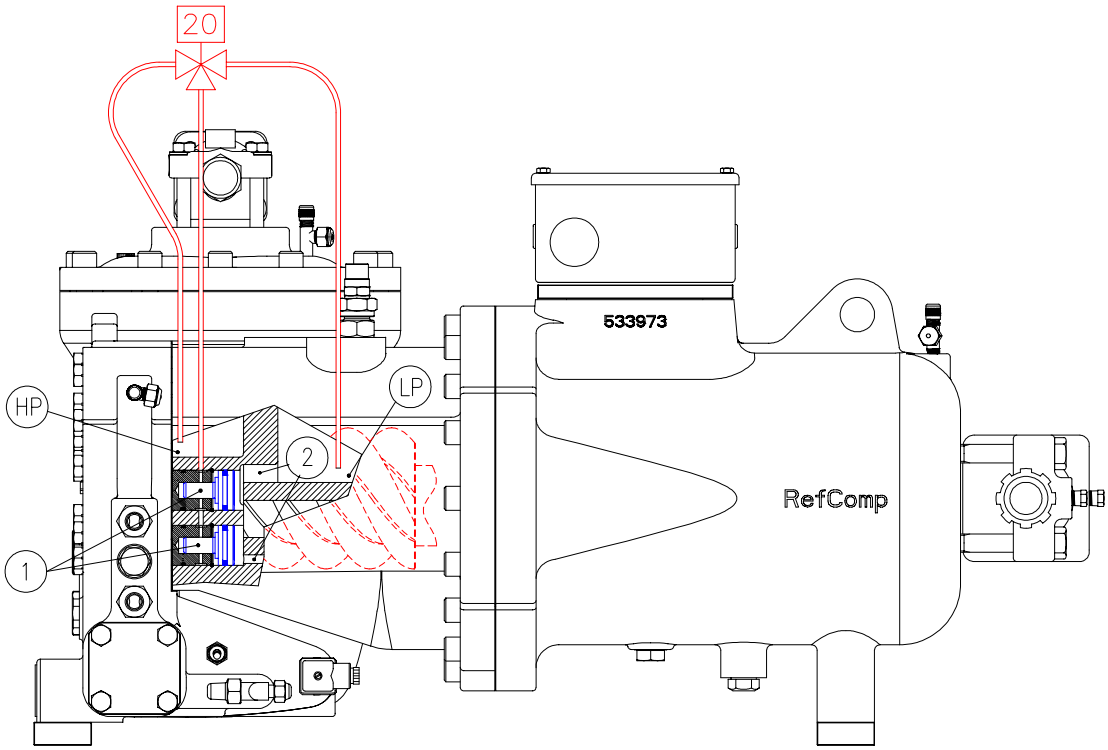
For the SRC-XS series the capacity control is now obtained by the new configuration L2, while in the past L1 was the capacity control system. The difference between these two configurations is basically the number of the capacity steps. As a matter of fact for:

- ✓ L1 configuration: one only solenoid valve and two capacity steps (50-100%);
- ✓ L2 configuration: two solenoid valves and three capacity steps (50-75-100%);

Hereinafter are described the working principle of the two different configurations.

3.2.1 L1 configuration: working principle and control circuit

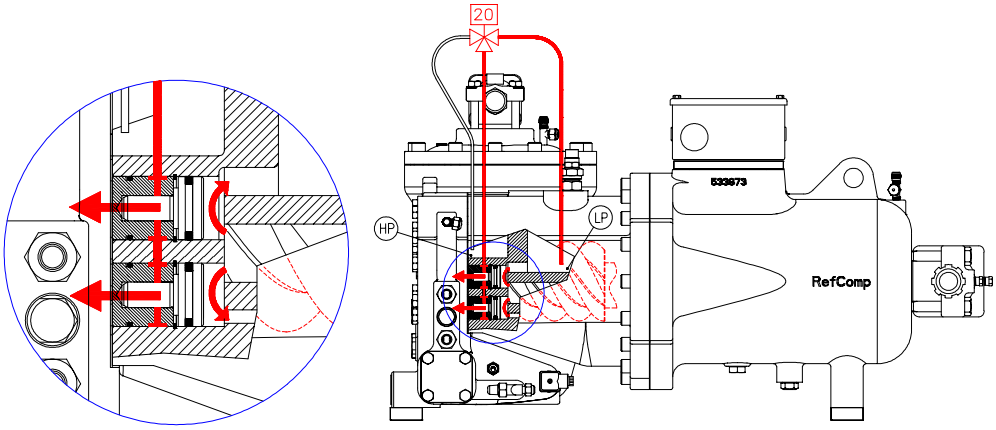
With reference to picture 3-Q, the capacity is controlled by the pistons (1) which, exploiting the high or low pressure through just one solenoid valve (the number 20), open or close the internal passageways (2). These passageways bypass part of the fluid compressed by the rotors (50%) directly to the suction side. Consequently only 50% of the mass flow reaches the discharge side. Bypassing part of the mass flow processed by the compressor thus controls the cooling capacity.
Hereinafter the 50% and 100% load capacity steps are considered.



Picture 3-Q: working principle for the capacity control on SRC-XS series compressors: L1 configuration;
20: solenoid valve for controlling the 50 and 100% capacity steps;
1: pistons activated by the refrigerant-oil mixture to bypass the mass flow to the suction side;
2: passageways to bypass the refrigerant to the suction side;
HP: high pressure (discharge side);
LP: low pressure (suction side);

✓ **50% CAPACITY**

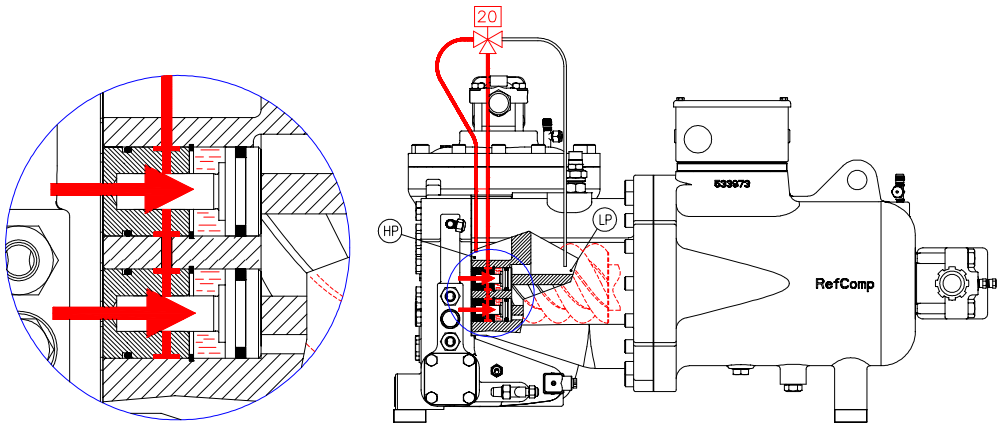
With reference to picture 3-R, the solenoid valve (20) is energised, making the cylindrical chambers, that house the pistons, communicate into the low pressure suction side. Due to the higher pressure in the compression chambers (intermediate pressure between suction and discharge) the pistons move and open the passageways that bypass 50% of the flow to the suction side (the red arrows in the picture show the movement). This ensures operation at part load.



Picture 3-R: 50% capacity control: L1 configuration;
LP: low pressure;

✓ **100% CAPACITY**

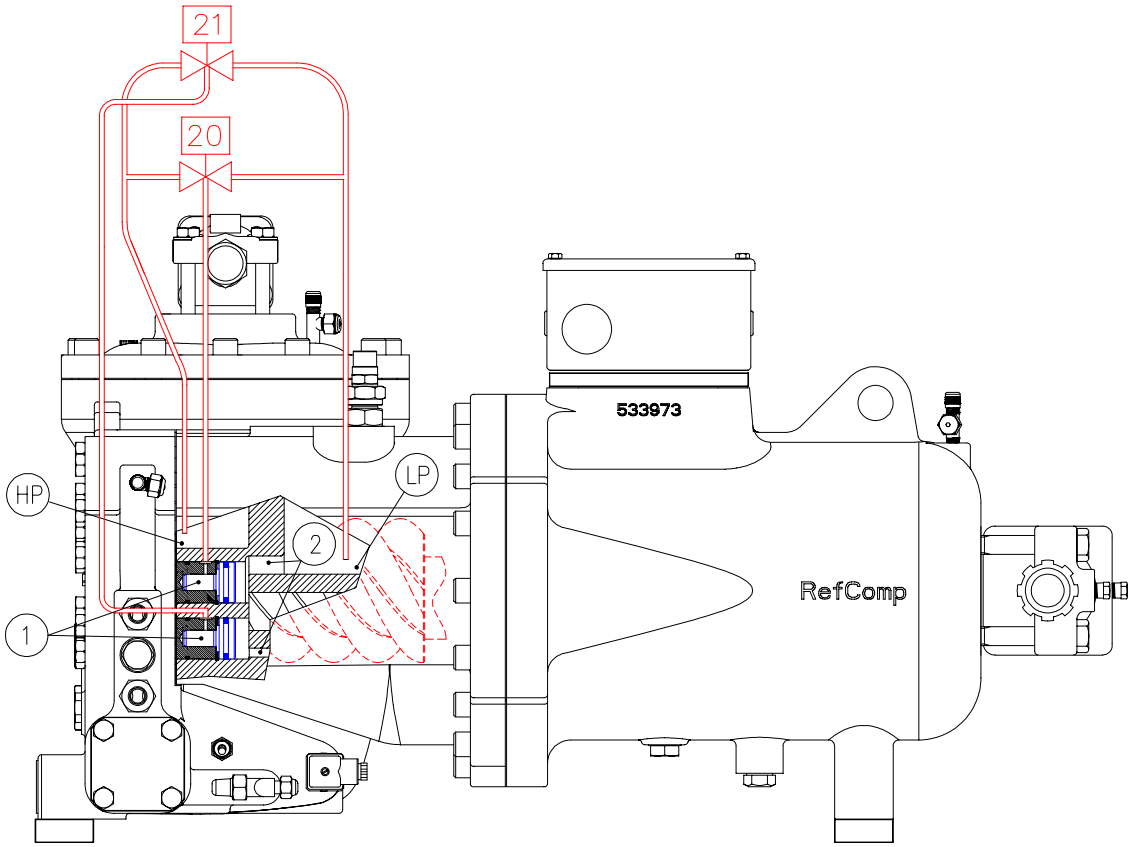
In this case and with reference to picture 3-S, the solenoid valve (20) is not energised and as a consequence the cylindrical chambers communicate into the high pressure discharge side. Due to the higher pressure here than the intermediate pressure in the compression chamber, the pistons move (the red arrows show the movement) closing the passageways that bypass the fluid. The entire flow of refrigerant processed by the compressor thus reaches the discharge, meaning operation at 100% load.



Picture 3-S: 100% capacity control: L1 configuration;
HP: high pressure;

3.2.2 L2 configuration: working principle and control circuit

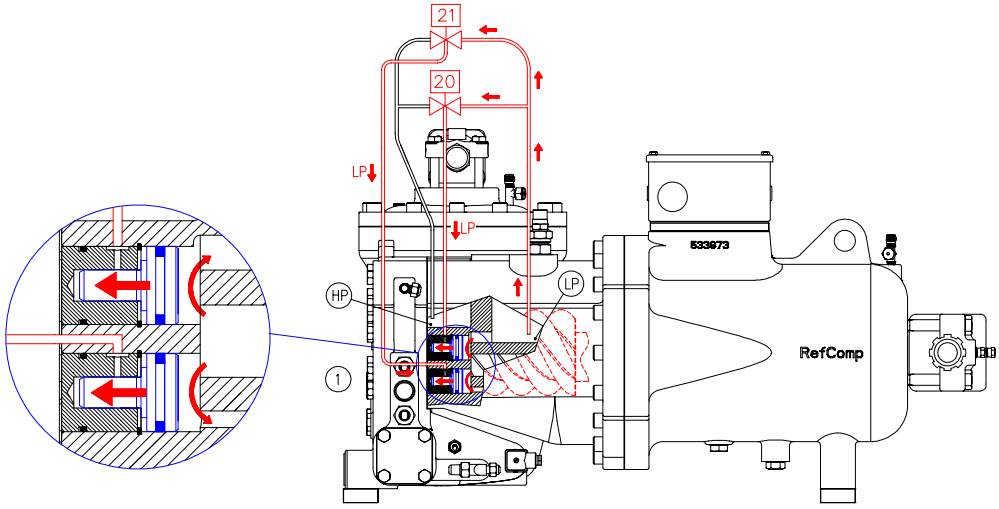
With reference to picture 3-T, the working principle is that already described in the previous paragraph. But now there are two solenoid valves instead of one. They are marked by the numbers 20 and 21, and each of them controls a single piston (1). So now the two pistons are independent and each one allows the by-pass of the 25% of the refrigerant mass flow. Via the solenoid valves is then possible to assure either the 75% or the 50% of the cooling capacity.
Hereinafter are described the three possible capacity steps: 50%, 75% and 100%.



Picture 3-T: working principle for the capacity control on SRC-XS series compressors: L2 configuration;
20, 21: solenoid valves for controlling the 50, 75 and 100% capacity steps;
1: pistons activated by the refrigerant-oil mixture to bypass the mass flow to the suction side;
2: passageways to bypass the refrigerant to the suction side;
HP: high pressure discharge;
LP: low pressure suction;

✓ **50% CAPACITY**

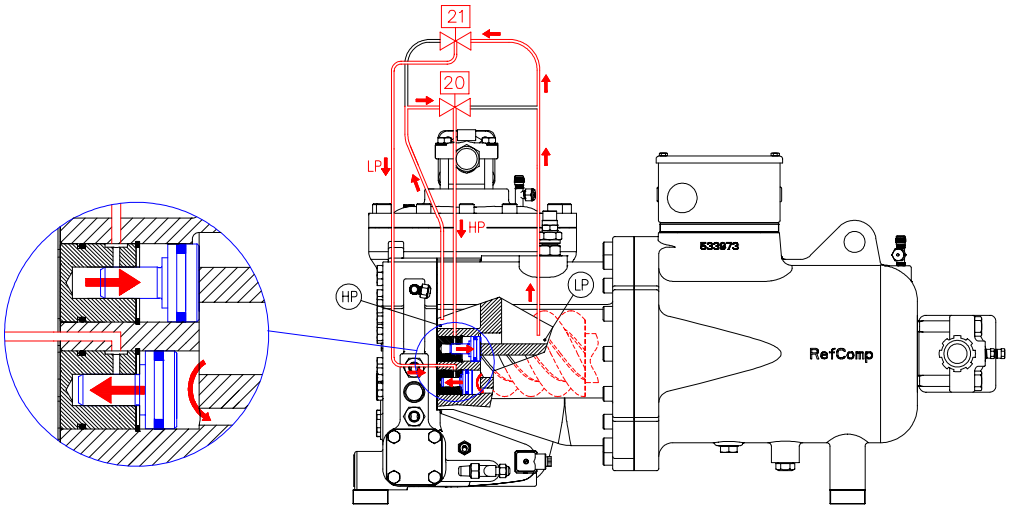
With reference to picture 3-U, both the solenoid valves (20) and (21) are energised, making the cylindrical chambers that house the pistons communicate into the low pressure suction side. The pistons, then, due to the higher pressure in the compression chamber (intermediate pressure between suction and discharge) move (the red arrows show the movement), opening both the passageways that bypass 50% of the flow to the suction side. This ensures operation at 50% part load.



Picture 3-U: 50% capacity control: L2 configuration;
LP: low pressure;

✓ **75% CAPACITY**

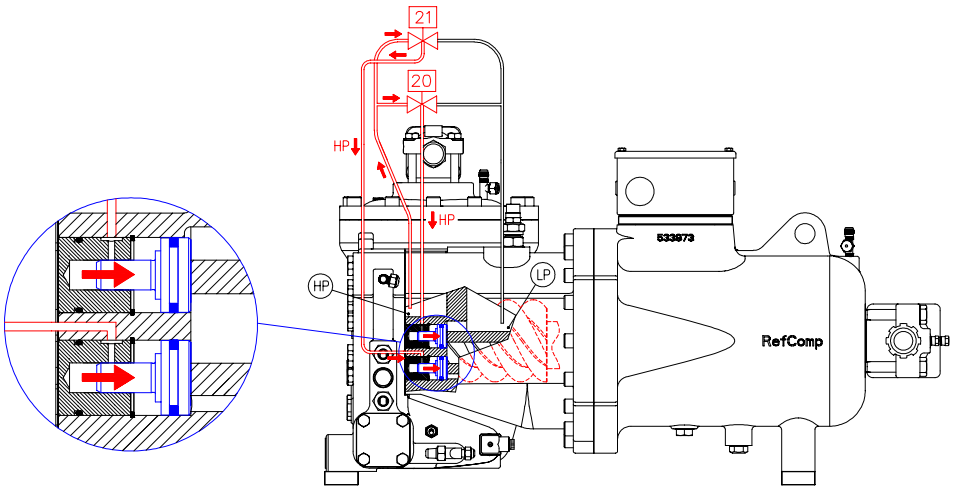
By looking at picture 3-V, the solenoid valve (21) remains energised so that the related lower piston opens the passageway for the by-pass of the 25% of the flow to the suction side. The solenoid valve (20) instead is de-energised and its related upper piston closes the other by-pass passageway (the red arrows show the movement of the pistons). That way only one piston assures the mass flow by-pass and consequently the discharge mass flow is 75% of the total one.



Picture 3-V: 75% capacity control: L2 configuration;
LP: low pressure;
HP: high pressure;

✓ **100% CAPACITY**

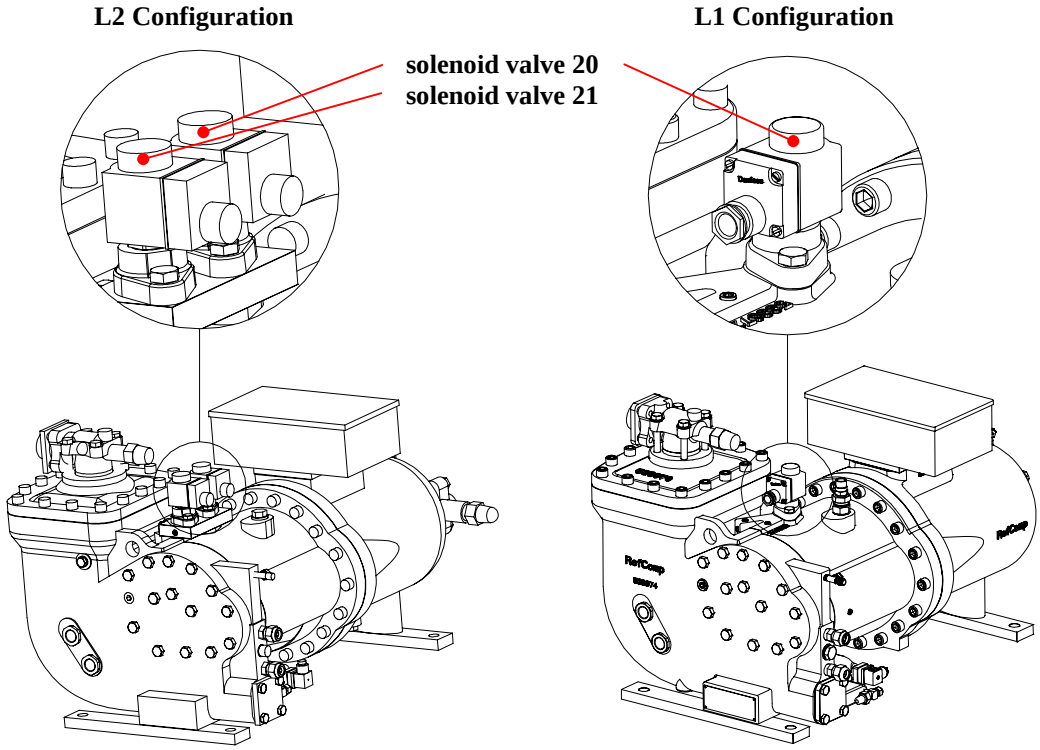
With reference to picture 3-X, both the solenoid valves (20) and (21) are not energised and as a consequence the cylindrical chambers communicate into the high pressure discharge side. Due to the higher pressure here than the intermediate pressure in the compression chamber, the pistons move (the red arrows show the movement) closing both the passageways that bypass the fluid. The entire flow of refrigerant processed by the compressor thus reaches the discharge, meaning operation at 100% load.



Picture 3-X: 100% capacity control: L2 configuration;
HP: high pressure;

3.2.3 Control sequence: step configuration

The capacity control is achieved by the solenoid valves (20) and (21) which are located on the top of the compressor casing, see picture 3-Y. In Table C is shown how to energise the solenoid valves.



Picture 3-Y: position of the solenoid valves (20) and (21) for capacity control in the series SRC-XS compressors;

Capacity	L1	L2	
	Solenoid valve	Solenoid valves	
	20	20	21
100%	OFF	OFF	OFF
75%	-	OFF	ON
50%	ON	ON	ON

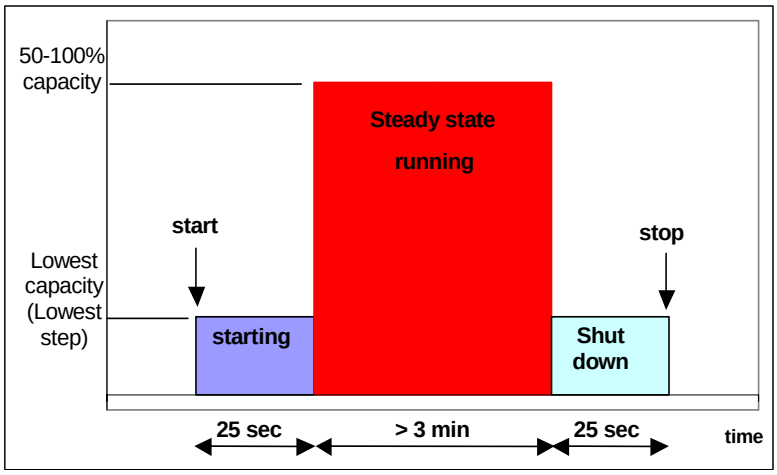
OFF = solenoid not energised; **ON** = solenoid energised;

Table C: operating logic of the solenoid valves for step capacity control;

3.3 Procedure for starting and stopping the compressor

To limit the peak current when starting, the electric motors are started in the part-winding configuration, or alternatively with the windings connected in the star configuration (see chapter EA-05: '*Electrical devices'*). This, however, means also a drop in the starting torque, and as a result the resisting torque needs to be reduced in order to start the compressor without excessively overloading the electric motor. For this purpose, Refcomp recommends to start the compressors at the minimum capacity step, see Figure 3-Z.
Concerning the SRC-S series compressors, distinction needs to be made between the step and the stepless configuration.
In the configuration with 4 steps the slide valve automatically returns to the position of minimum capacity after the compressor stops. In fact due to the pressure difference the oil can flow out of the cylinder to the crankcase through the pipe marked by number 20, see picture 3-A or through the pipe marked by numbers 3 and 4 for the compressors 255/285/305, see picture 3-B. Therefore the compressor can start again at the minimum capacity.
In the infinite configuration, on the other hand, this pipe is closed by the solenoid valve (19), see picture 3-N,which is normally closed (or by the solenoid valve (16) in the models 255/285/305, see picture 3-O). Consequently, unless the solenoid valve (14) is energized before stopping, the oil cannot flow out of the cylinder and as a result the compressor is not discharged.
For this reason, so as to stop and re-start the compressor at the minimum capacity step the valve (14) must be energized for around 25 seconds before switching off the compressor, see picture 3-Z. Moreover the valve (14) should be kept energized during the compressor standstill periods.
The starting and stopping procedure indicated in picture 3-Z has to be followed for all the screw compressors, both in the step and in the stepless version, as this avoids noisy stopping due to the temporary reverse rotation with high mass flow.

	**Warning!** If having to shutdown in an emergency, the compressor will stop at the current capacity step. In the stepless configuration then, before restarting the unit, make sure that the compressor is at the minimum capacity step.



Picture 3-Z: starting and stopping the compressor;

Concerning the SRC-XS series compressors, which are not fitted with the capacity control slide valve and do not need to empty any hydraulic cylinder, it is just necessary to start them with both the solenoid valves 20 and 21 energized for 25 sec.

3.4 Operating limits at part load

Operation at part load increases the discharge temperature (it is recommended not to exceed 110° C) and has a slightly lower efficiency than at full load.

In particular, the discharge temperature increases if:

- The condensing pressure increases;
- The evaporation pressure decreases;
- The temperature of the suction gas (superheat) increases.

To define the operating limits at part load, see chapter SA-10: "*Application range*".