New Design Strategies

UNIFLAIR™

Variable speed compressors
on water chillers

ISAC

Innovative **S**olutions for **A**ll **C**onditions

There are various technological solutions which distinguish and characterize modern chillers, but it can be said that variable speed compressors, which are typically driven by inverter, are among the most interesting.

Set apart by the fact that they provide significant advantages, these compressors provide a high level of reliability and may be implemented in a wide range of applications and operating parameters.

Uniflair ISA* and ISC* chillers use this technology together with other technical solutions, thus optimizing the benefits which can be achieved.

These units are equipped with two scroll compressors, one of which is driven by an inverter on the same cooling circuit.

This solution, **which is only possible thanks to the exclusive patented system for optimized lubrication management of the tandem compressors,** creates several benefits.

Benefits of variable speed compressors

- Increased efficiency at partial loads thanks to the continuous regulation of the cooling capacity which can be adapted to the load, and to the installation of two compressors on the same cooling circuit
- Regulation of the cooling capacity over a wide operating range, i.e. from 10% to 100% continuously
- High precision on chilled water temperatures (±0.2°C), thanks to continuous regulation by means of inverter
- Reduction of the absorbed current, since the inverter maintains a constant cosphi of the compressors to which it is connected
- Limitation of the maximum absorbed current (LRA) since the inverter driven compressor can always be started up at low speed
- Limitation of noise emissions at partial load (for example during night time operation)
- Increased system reliability thanks to the reduction in compressor start ups and shut downs and limiting mechanical and electrical stress
- Reduction or elimination of water tanks on the hydraulic lines

Energy efficiency

One of the main advantages obtained by the use of compressors which can continuously modulate the cooling capacity, is the fact that the units can supply the precise amount of cooling capacity needed to dissipate the thermal load.
Supplying cooling at a higher level than is actually needed, something which is typical of systems featuring cooling steps and can be seen especially at partial loads, is therefore avoided.
When analyzing the different technical solutions available it is important to distinguish between “tandem” applications and those which have two distinct circuits, which is more traditional.

A further important issue regarding variable speed compressors is the correct lubrication of the compressor itself.
It can be noted that in order to ensure correct oil return in a cooling circuit with one or more compressor operating in parallel, they must be connected to an oil level equalizer, with correct sizing of the suction and discharge piping.

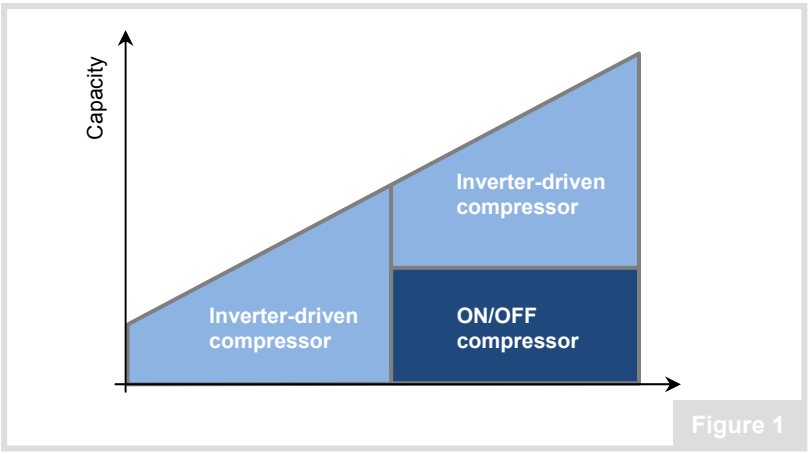

Figure 1
ISA and ISC* units are equipped with two Scroll compressors on the same cooling circuit, one fixed speed and one variable speed.*

In this way the compressors behave as if they were a single compressor, allowing for improved lubrication.
In a system which has a variable speed compressor operating in parallel with one or more fixed speed compressors, oil equalization cannot be implemented since the variable speed compressor generates differences in suction pressure leading to differing oil levels which, consequently, could flood or empty the compressor, with possible disastrous results for the compressor.
For these reasons, inverter driven compressors should not, in theory, be installed in parallel with other compressors, which would mean losing the significant benefits of “tandem” operation at partial load.

The system developed and patented by Uniflair (see the following section) ensures the correct lubrication of systems featuring variable and fixed speed compressors.
Combining a variable speed compressor with a traditional compressor on the same circuit allows optimum modulation of the cooling capacity by means of combined management of the two compressors, maximizing efficiency at partial load.

In order to identify the best solution, it is necessary to compare:

- a system equipped with variable and fixed speed compressors on two different cooling circuits
- a system equipped with variable and fixed speed compressors on the same cooling circuit

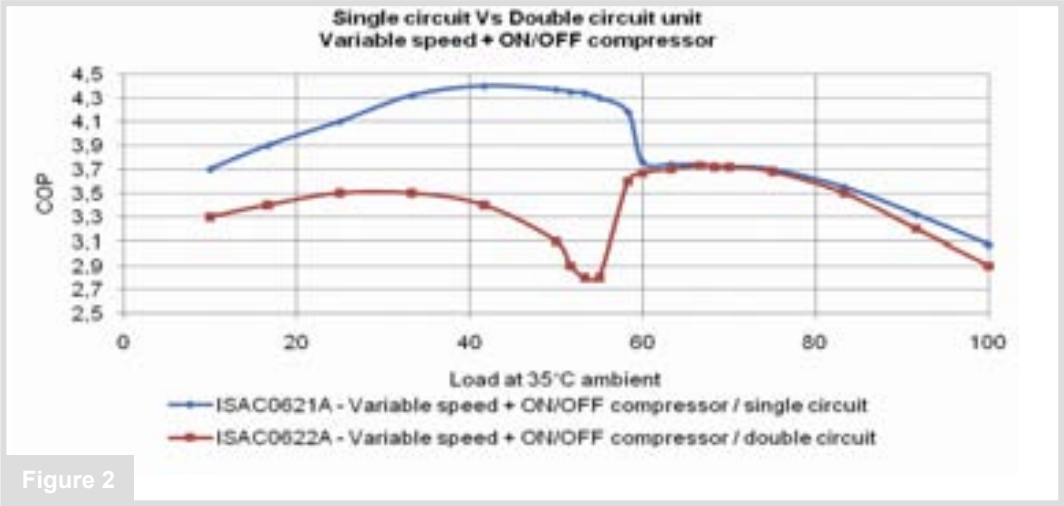

Figure 2

Figure 2
Comparison between units equipped with variable and fixed speed compressors on two different cooling circuits and units equipped with variable and fixed speed compressors on the same cooling circuit

From the analysis carried out, as shown in figure 2, it can be seen that in order to maximize efficiency in all load conditions, the solution using an inverter must be used in combination with a tandem concept.

"Tandem" system

By using multi compressors connected in parallel on the same cooling circuit it is possible to increase energy efficiency at partial loads compared to multi-circuit units.

The heat exchangers are sized for the full capacity of the unit, so when the chiller is operating at partial loads, the heat drops in the exchangers reduce (due to an increase in the evaporating temperature and a decrease in the condensing temperature), providing improved efficiency compared to full load operation.

ISA*/ISC* models, which have one fixed speed and one variable speed compressor connected in parallel on the same cooling circuit, extend this concept, optimizing therefore efficiency in all load conditions.

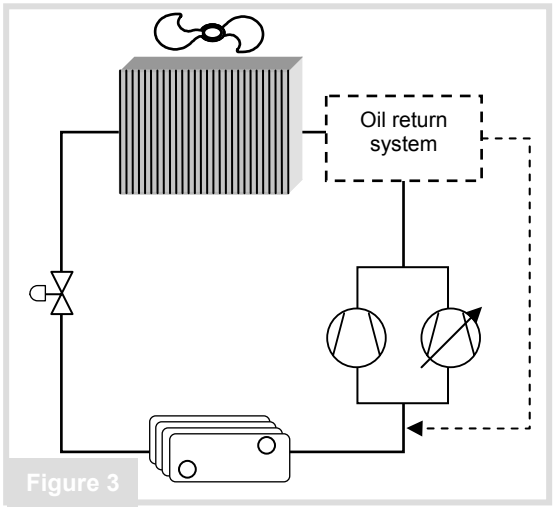

Figure 3

Figure 3
Cooling diagram "in principle" per unità ISA/ISC**

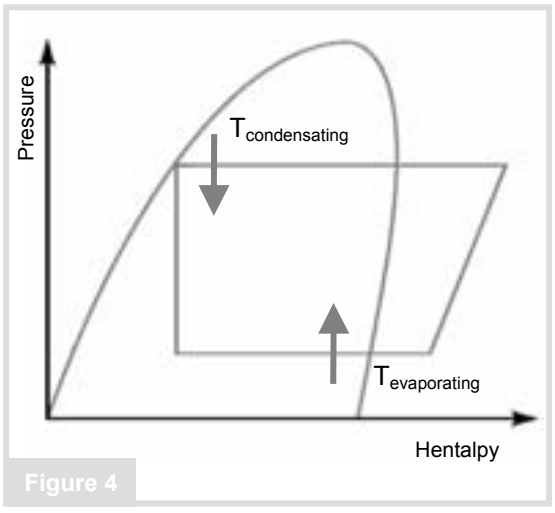

Figure 4

Figure 4
Graph showing "tandem" compressor operation

Figures 5 and 6 EER variation to changes in cooling load, comparing units equipped with two ON/OFF Scroll compressors on the same cooling circuit with ISAC units. Data refer to: discharge water temperature: 7°C, external temperature: 35°C (Fig.5) and 25°C (Fig.6).

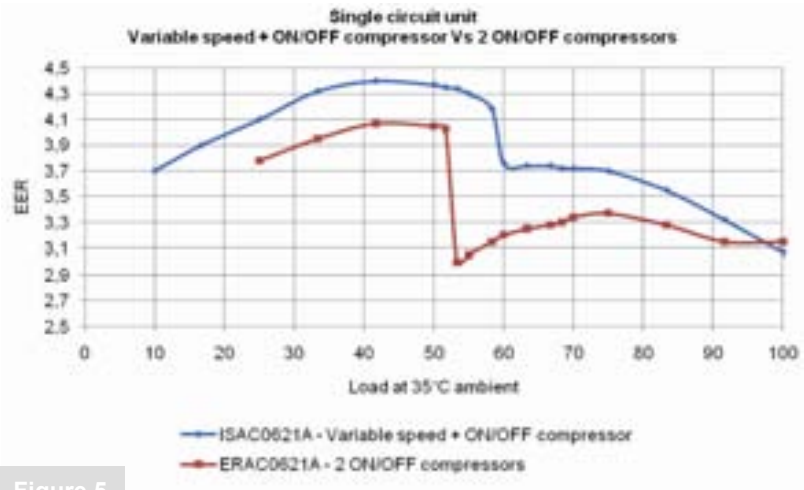

Figure 5

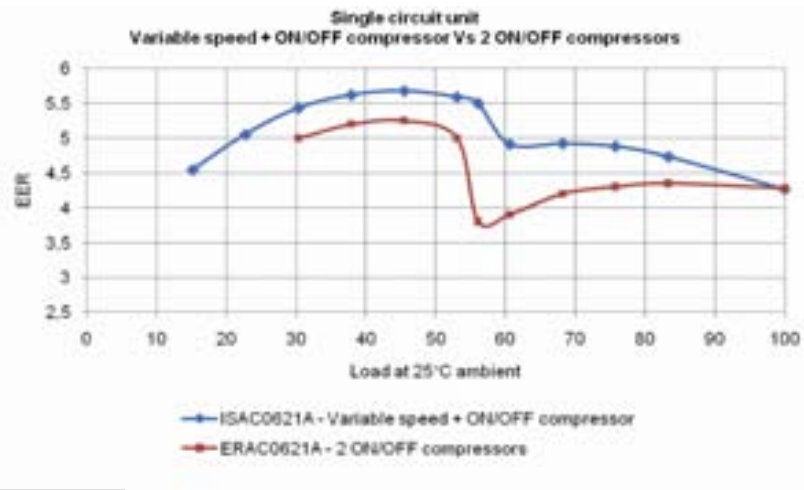

Figure 6

Figures 5 and 6 show the comparison between units with a traditional tandem concept and those driven by inverter.

The graphs show the changes in energy efficiency (EER) due to variations in the load, when comparing units equipped with two ON/OFF Scroll compressors on the same circuit with ISAC units (chillers with a fixed speed compressor and a variable speed compressor on the same circuit).

Both at high external temperatures (35°C) and milder ones (25°C) it can be noted that variable speed compressors combined in tandem with another compressor results in optimized efficiency at all load conditions.

This result can also be clearly seen when the **ESEER** and **IPLV** values are compared for ISAC units and ERAC units, a similar Uniflair series of units featuring two traditional scroll compressors on the same cooling circuit.

Energy indexes

Energy indexes define the behaviour of a chiller in particular situations. There are energy indexes which refer to nominal conditions and seasonal energy indexes, which are more reliable and which enable the average energy consumption over a year to be calculated.

The principle indexes are C.O.P. and E.E.R, while from the other the I.P.L.V. (Integrated Partial Load Value) and l'E.S.E.E.R. (European Seasonal Energy Efficiency Ratio) stand out.
The criteria used to establish these indexes allow the annual behaviour of a chiller to be analysed using a single figure in the considered operating conditions.
These parameters are essentially the average found by the E.E.R. at different loads (100%, 75%, 50% and 25%) and differ from each other regarding the weight given and the conditions in which the different E.E.R. are calculated.

Formula for calculating ESEER and IPLV

$$\underbrace{PE_{100\%} \cdot EER_{100\%} + PE_{75\%} \cdot EER_{75\%} + PE_{50\%} \cdot EER_{50\%} + PE_{25\%} \cdot EER_{25\%}}_{IPLV - ESEER}$$

Where:
P.E. is the "weight" given to each operating condition
E.E.R. represents the energy efficiency at different load conditions

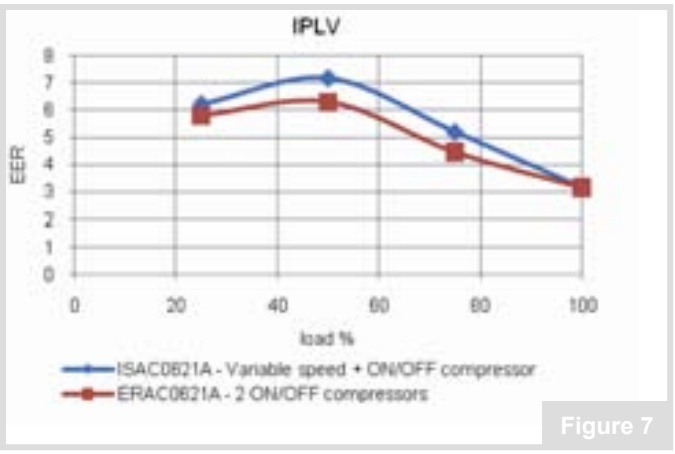

Figure 7 Comparison of IPLV values between traditional and ISAC units

Figure 7

By analysing solutions equipped with variable speed compressors and considering the various energy indexes for ISAC and ERAC units, it is clear that the main advantage is at load conditions of between 30% and l'80% when the unit is equipped with fixed speed compressor operates by switching itself on and off.

These load conditions are among the most frequently found which leads to a considerable reduction in annual energy consumption.

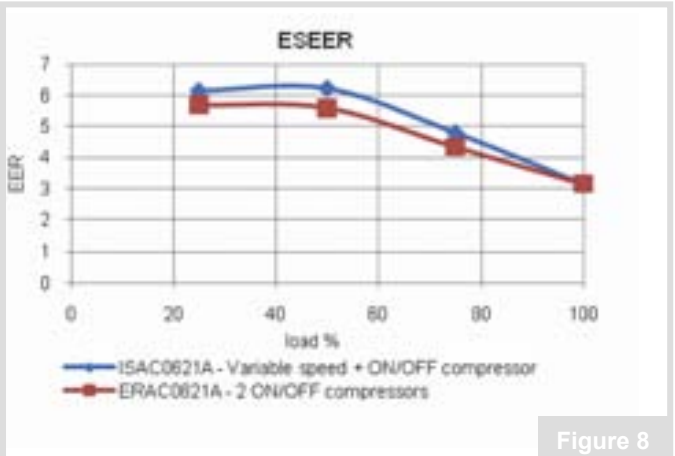

Figure 8 Comparison of ESEER values between traditional units and ISAC

Figure 8

Table 1

Model	0621A	0921A	1221A
Nominal cooling capacity [kW]	59	87	115
E.S.E.E.R.			
ISAC	5.66	5.71	5.72
ERAC	5.16	5.26	5.38
Delta	**+10%**	**+9%**	**+8%**

Table 1
Comparison of ESEER values for traditional units and ISAC

Precision on the chilled water regulation

Units equipped with more than one fixed speed compressor maintain the load conditions by switching the compressors on and off.
This method leads to dips in the temperature supplied by the chillers, which are usually balanced and attenuated by the collection tank (see figure 9).

The compressor which is used on ISA*/ICC* units makes it possible, when combining a variable speed compressor with a fixed speed one, continuous modulation of the load from 10 to 100%.

Therefore the control system, by monitoring the inlet and outlet water temperatures and adjusting the cooling capacity supplied, enables the chilled / hot water temperature to be maintained with a precision of ±0.2°C even for a set point set in conditions of rapid changes to the thermal load.

ISA*/ISC* units are therefore particularly suitable for situations which require high levels of stability or which feature significant changes in load.

Table 2

Model	0621A	0921A	1221A
Nominal cooling capacity [kW]	59	87	115
load 10%-100% of the nominal value			
ERAC	±1°C		
ISAC	±0,2 °C		
load < 10% of the nominal value			
ERAC	±1,6°C		
ISAC	±0,7°C		

Table 2
Comparison of the pressure guaranteed by units with two fixed speed Scroll compressors and units with two Scroll compressors, one of which is fixed speed and the other is variable speed

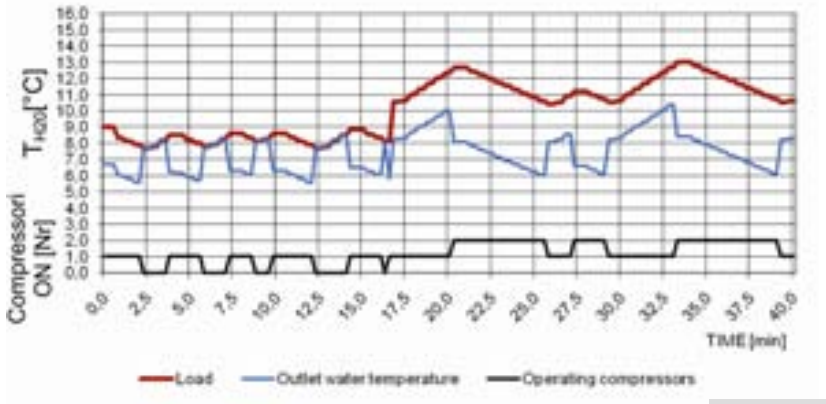

Figure 9

Figure 9
Oscillation in outlet chilled water temperature for a unit equipped with two fixed speed Scroll compressors (ERAC)

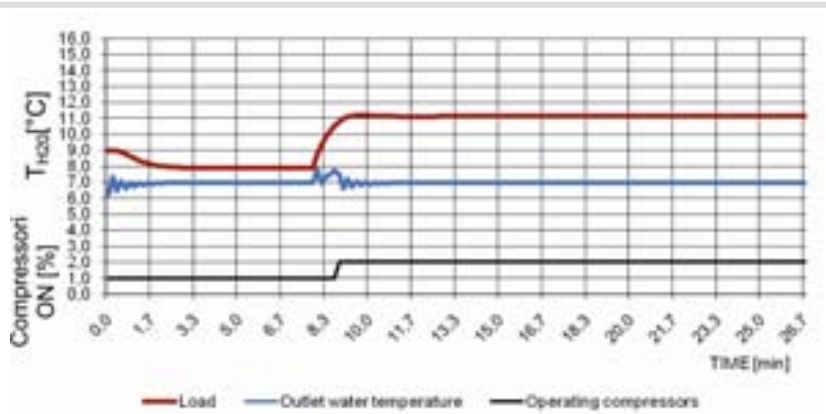

Figure 10

Figure 10
Oscillation in outlet chilled water temperature for a unit equipped with two Scroll compressors, one of which is fixed speed while the other is variable speed (ISAC)

Reliability of the compressors and variable speed systems

The use of variable speed compressors increases the level of system reliability.
In fact, the maximum absorbed currents (LRA) are lower thanks to the possibility of started the inverter driven compressors at low speed and reducing the number of compressor start ups and shut downs which are a source of mechanical and electrical stress.

The fundamental issue which must however be addressed is the correct lubrication of the compressors. In order to achieve this, special techniques have been designed and developed for both the compressor and the circuit.

Lubrication of the compressor

This compressor, which has been carefully designed and developed to operate at different speeds, allows the cooling capacity to be modulated depending on the requirement, managing, by means of its particular construction layout, correct lubrication at different load conditions.

The main issue is, in fact, that modifying the rotation speed and subsequently the refrigerant mass, changes the quantity of oil which passes through the compressor, affecting correct lubrication, and consequently reliability.

The compressor which is installed in ISA* and ISC* units is therefore supplied with an internal by-pass line which is connected to a solenoid valve which controls the addition of oil to the compressor.

In fact, in order to minimise the **OCR - Oil circulation rate** (Ratio between the oil quantity and the refrigerant mass) the compressor separates the refrigerant from the oil at high speeds: an internal by-pass line is activated whenever the compressor is operating at high speed.

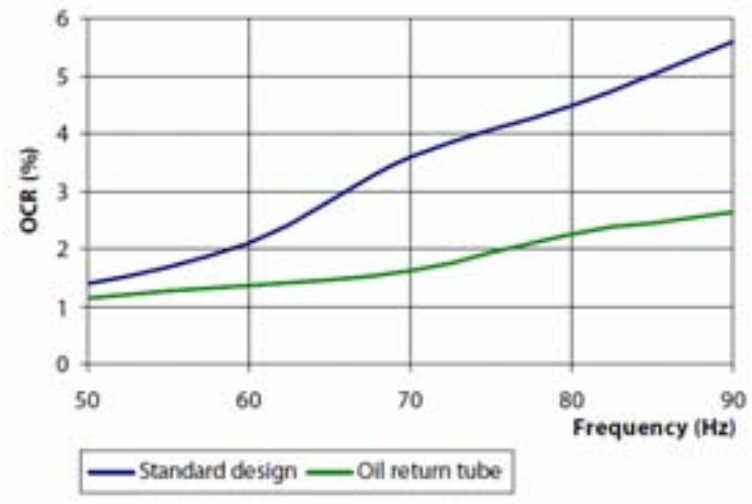

Figure 11

Figure 11
Ratio between the oil quantity and the refrigerant mass (OCR) for traditional variable speed compressors or those equipped with oil by-pass system

Lubrication of variable speed Scroll compressors in multi-compressor circuits (Uniflair patent)

Ensuring correct oil return in a refrigerant circuit with one of more compressors operating in parallel at a fixed speed is a rather delicate and critical question which has traditionally been resolved by allowing the compressors to communicate with the oil equalizer and with suitable sizing of the suction and discharge tanks.

In this way, the compressors operate almost as if they were one single compressor and the oil level is more or less the same for all of the compressors. allowing for optimum lubrication.
In a system which has a compressor with variable speed working alongside one or more compressors operating with a fixed speed, the equalization system does not function since the compressor with variable speed generates different suction pressures, therefore creating different oil levels which could flood or empty the compressor.

The system which has been patented by Uniflair to ensure correct oil levels and return in a cooling circuit with one or more Scroll compressors operating in parallel, is based on a specific circuit which, by means of a highly efficient oil separator and several solenoid valves controlled by a system of sensors placed in the compressor itself and the unit management control.

The sensors monitor the correct oil level and, by means of the control system and the solenoid valves, maintain the oil level in all operating conditions, ensuring correct lubrication of the compressors in all operating conditions.

The separator limits oil discharge along with refrigerant gas along the cooling circuit as well as integrating the lubricant reserve. In this way the compressors are supplied according to their requirements and the amount of oil in circulation with subsequent advantages regarding the efficiency of the exchangers.

The control system manages the timing and compressor shut down alarms in the event of a low oil level.

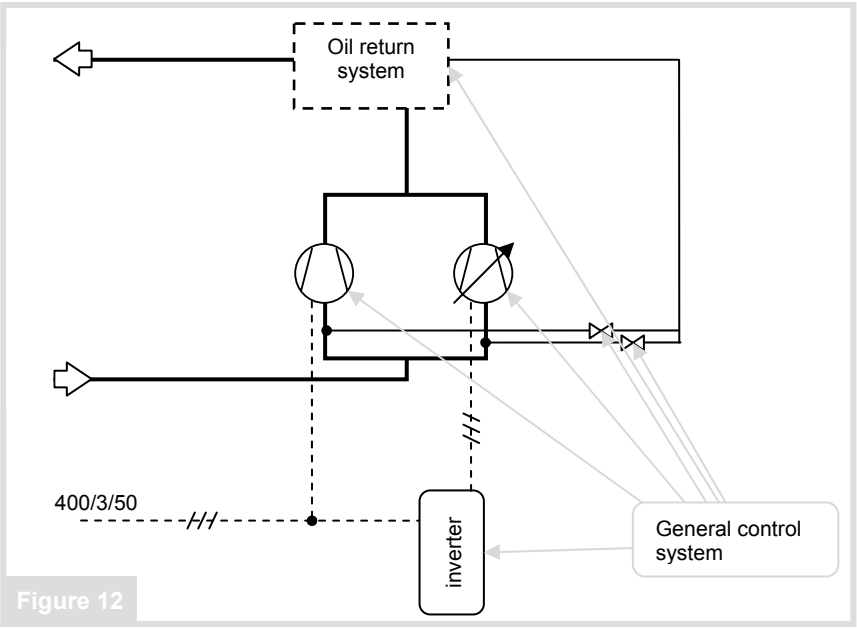

Figure 12
General diagram of Uniflair patent for lubrication of multiple compressors operating in parallel

Air-cooled modulating water chillers, heat pumps and free-cooling chillers with axial fans

Models		0621A	0921A	1221A
ISAC – cooling only				
Cooling capacity (1)	kW	59	87	115
Absorbed power (1)(2)	kW	18.7	26.6	35.9
E.S.E.E.R.		5.66	5.71	5.72
I.P.L.V.		6.19	6.27	6.22
ISAH – heat pumps				
Heating capacity (3)	kW	66	97	128
Absorbed power (3)(2)	kW	18.1	26.2	35.9
ISAF – free-cooling				
Cooling capacity (4)	kW	62.4	92.2	122.2
Absorbed power (1)(2)	kW	20.0	28.5	38.3
Noise pressure level (5)	dB(A)	43.5	44.3	54.7
Dimensions and weights				
Height	mm	1560	1560	1874
Length	mm	1190	1190	1192
Width	mm	2008	2798	3075
Weight ISAC (basic version) (6)	Kg	652	810	1047
Weight ISAH (basic version) (6)	Kg	682	840	1092
Weight ISAF (basic version) (6)	Kg	751	935	1212

(1) Data refer to nominal conditions: water temperature 12/7°C; ambient temperature 35 °C; glycol 0%; modulating compressor at 90 rps; refrigerant R410A
(2) Data refer to total absorbed power (compressors and fans)
(3) Data refer to nominal conditions: water temperature 40/45°C, external temperature 7°C dry bulb, 6°C wet bulb; modulating compressor at 90rps; refrigerant R410A
(4) Data refer to nominal conditions: water temperature 15/10°C; ambient temperature 35 °C; glycol 20%; modulating compressor at 90 rps; refrigerant R410A
(5) Data measured in free field at 10 mt. from the unit operating at nominal conditions, coil side, directional factor Q=2
(6) Data refer to empty unit without onboard pump

Air-cooled modulating water chillers, heat pumps and free-cooling chillers with backward curved blade fans

Models		0621A	0921A	1221A
ISCC – cooling only				
Cooling capacity (1)	kW	59.7	88.1	117.0
Absorbed power (1)(2)	kW	21.4	30.8	41.4
E.S.E.E.R.		3.98	4.42	4.35
I.P.L.V.		5.63	5.70	5.66
ISCH – heat pumps				
Heating capacity (3)	kW	67.4	98.7	131.0
Absorbed power (3)(2)	kW	21.5	31.2	42.5
ISCF – free-cooling				
Cooling capacity (4)	kW	64.7	95.3	126.8
Absorbed power (1)(2)	kW	22.0	31.5	42.4
Noise pressure level (5)	dB(A)	65.3	66.8	71.2
Dimensions and weights				
Height	mm	1560	1560	1874
Length	mm	1190	1190	1192
Width	mm	2008	2798	3075
Weight ISCC (basic version) (6)	Kg	818	1179	1277
Weight ISCH (basic version) (6)	Kg	848	1209	1322
Weight ISCF (basic version) (6)	Kg	917	1304	1442

(1) Data refer to nominal conditions: water temperature 12/7°C; ambient temperature 35 °C; glycol 0%; modulating compressor at 90 rps; refrigerant R410A; 50Pa
(2) Data refer to total absorbed power (compressors and fans)
(3) Data refer to nominal conditions: water temperature 40/45°C, external temperature 7°C dry bulb, 6°C wet bulb; modulating compressor at 90rps; refrigerant R410A; 50Pa
(4) Data refer to nominal conditions: water temperature 15/10°C; ambient temperature 35 °C; glycol 20%; modulating compressor at 90 rps; refrigerant R410A; 50Pa
(5) Data measured in free field at 1 mt.of the unit operating at nominal conditions, coil side, directional factor Q=2
(6) Data refer to empty unit without onboard pump

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