1 DEFINITIONS

DHW = domestic hot water.
AY = generic term used to designate the AY condensing boiler product range, which includes AY 35, AY 50 and AY 100.
Aerothermal appliances/units = equivalent terms, both used to designate gas-fired heat/chiller appliances intended exclusively for outdoor installation (GAHP A/GAHP-AR gas absorption heat pumps or GA ACF/HR/TK/HT/LB gas absorption chiller), which require proper heat exchange with the outdoor air to operate.
GA Appliance/Unit = equivalent terms, both used to designate the gas-fired absorption chiller GA (Gas Absorption).
GAHP appliance/unit = equivalent terms, both used to designate the GAHP gas powered absorption heat pump (Gas Absorption Heat Pump).
BMS (Building Management System) = plant or building supervisor controller not supplied by Robur.
TAC = Technical Assistance Centre authorised by Robur.
Common pump = pump supplying a set of generators.
Independent pump = pump supplying one generator only.
Primary circuit = section of the air conditioning system starting from the generators to the hydraulic separator or heat exchanger (if any).
Secondary circuit = section of the air conditioning system downstream of the hydraulic separator or heat exchanger (if any).
Parallel plumbing configuration = plumbing configuration in which the water inlet to each generator is common.
Series plumbing configuration = plumbing configuration in which all or part of the water flow entering a generator comes from another generator.
External request = generic control device (e.g. thermostat, timer or any other system) equipped with a voltage-free NO contact and used as control to start/stop the GAHP/GA unit and the AY boiler.
CCI Controller (Comfort Controller Interface) = optional Robur control device which lets you manage up to three modulating GAHP units (GAHP A, GAHP GS/WS) of the same type, for heating only.
DDC Control (Direct Digital Controller) = optional Robur control device to manage one or more Robur appliances in ON/OFF mode (GAHP heat pumps, GA chillers) or in modulating mode (AY boilers).
RB100/RB200 Devices (Robur Box) = optional interface devices complementary to DDC, which may be used to broaden its functions (heating/cooling/DHW production service demands and control of system components such as third party generators, adjustment valves, circulators, probes).
GA = generic term used to designate the GA gas absorption chillers product range, which includes ACF60-00, ACF60-00 S, ACF60-00 HR, ACF60-00 HR S, ACF60-00 HT, ACF60-00 HT S, ACF60-00 LB, ACF60-00 LB S, ACF60-00 TK, ACF60-00 TK S.
GAHP A = generic term used to designate the GAHP A gas absorption heat pump product range, which includes GAHP A HT, GAHP A HT S1, GAHP A Indoor.
GAHP-AR = generic term used to designate the GAHP-AR reversible gas absorption heat pump product range, which includes GAHP-AR, GAHP-AR S.
Third party generator = generator (usually boiler or chiller) not produced by Robur, which cannot be directly managed by the DDC and therefore requires an additional interface device (RB200).
Robur generator = generator (heat pump, boiler or chiller) produced by Robur, managed by the DDC via the CAN bus communication.
Heat generator = equipment (e.g. boiler, heat pump, etc.) for producing heat for space heating and DHW.
Base group = set of generators located on the base system.
Separable/separated group = set of generators on the separable/separated DHW system.
GUE (Gas Utilization Efficiency) = efficiency index of gas heat pumps, equal to the ratio between the thermal energy produced and the energy of the fuel used (relative to LCV, lower calorific value).
2-pipe system = system on which there is only one pair of pipes (outlet/inlet) in the primary and/or secondary circuit, therefore unable to provide simultaneous hot and cold water services.
4-pipe system = system fitted on both primary and secondary circuits with two pairs of pipes, therefore able to supply two distinct services simultaneously.
Separable DHW system = part of the primary circuit that can be hydraulically separated from the base system part and operate independently. It can assume two states, depending on the position of the three-way diverter valve:
- Water plumbing connected to the base system (**included** state): in included state this part of the system integrates the space heating service.
- Disconnected from the base system (**separate** state): in the separate state this part of the system is designated for DHW production, regardless of the service supplied by the base system.

Separate DHW system = part of the primary circuit for the exclusive production of DHW, hydraulically disconnected permanently from the base system.
DHW system = system intended for DHW production.
Base system = part of the primary circuit comprising all generators, excluding those that can be hydraulically separated from it by means of a suitable three-way valve.
Heat system = system intended for the production of hot water for heating and/or DHW.
Cold system = system intended for production of cold water for cooling.
Integration = coordinated control of different types of generators with the aim of maximizing overall system efficiency.
Power integration = integration mode in which all generators produce power at the same temperature.
Temperature integration = integration mode in which different types of generators can produce power at different temperatures.
"Integration and progressive replacement" operating mode = possible operating mode for a series plumbing configuration in which the delivery temperature request is not compatible in some operating conditions with the operating temperatures of some generators (in particular the GAHP).
“Integration and replacement” operating mode = operating mode in which the temperature setpoint under certain operating conditions may not be compatible with the operating temperatures of some generators (in particular the GAHPs).
“Integration” operating mode = operating mode in which the temperature setpoint in all operating conditions is compatible with the operating temperatures of all generators.
Heat module = for a Robur generator, this is the logic control unit that manages hot water production functions.
Cold module = for a Robur generator, this is the logic control unit that manages cold water production functions.
First start-up = appliance commissioning operation which may only and exclusively be carried out by a TAC.
Service request = it is the signal that turns on a specific service. Some service requests may be relayed to the Robur control

system in different modes (directly to the DDC or through RB100/RB200).
Service = for Robur control systems, this is the term used to identify a specific functionality of the resources managed by the controllers (heating service, DHW service, cooling service, valve service, pump service, probe service...).
Base DHW service = DHW service obtained with the base system.
Separable/separate DHW service = DHW service obtained with the separable/separate DHW system.
Hybrid system = system consisting of Robur heat pumps and boilers (Robur or third party units).
Mixed system = system consisting of Robur units and third party units.

2 ADVANTAGES OF GAS ABSORPTION TECHNOLOGY

- Very high winter energy efficiency.
- High savings on management costs (up to 40%).
- Very high reliability due to almost no moving parts.
- Avoids an increase in installed electrical power.
- Can be combined with third-party boilers or chillers.
- Stable and efficient operation even at very low outdoor temperatures (aerothermal versions).
- No performance degradation over time.
- Uninterrupted power output during defrosting (aerothermal versions).
- Thermodynamic circuit free of any scheduled maintenance (maintenance is comparable to that required for a condensing boiler).
- Service continuity thanks to modular control.
- In geothermal application for space heating, it halves the need for geothermal probes.
- No use of refrigerants that are toxic, harmful for the environment or the ozone layer.
- Sealed circuit requiring no refrigerant top-up.
- No water consumption in cooling mode (no evaporative cooling tower).
- Increase in the building's energy rating.
- Performance data certified by independent third parties at their laboratories.
- The absorption cycle can be powered using various energy carriers such as natural gas, biomethane or hydrogen.
- Possibility of access to incentive mechanisms for heat pumps and high-efficiency heating appliances.
- Possible sealed circuit warranty extension (labour and spare parts).
- Remote monitoring and optimisation via IoT (Internet of Things) devices for collecting data and sending them to the cloud and web portal for data display and settings change.

3 GAS ABSORPTION CYCLE

In the conventional refrigeration cycle (with vapour compression) the process by which the gaseous refrigerant goes from low pressure/low temperature at evaporator outlet to high pressure/high temperature conditions at the condenser inlet is performed by a mechanical compressor (usually driven by an electric motor).
The main difference with the gas absorption cycle is that this same process is performed by means of thermal compression in three main steps:

1. The high-pressure solution is heated by the energy carrier to the point where the refrigerant is released in the gaseous phase at high temperature.
2. Through a spontaneous refrigerant/absorbent reaction, the gaseous refrigerant is absorbed in a low-pressure liquid phase.
3. The pressure of the liquid solution is raised by a pump and the solution is fed back into the generator to repeat the cycle.

The advantages of this thermo-physical process compared to conventional mechanical compression are essentially as follows:

1. Raising the pressure of a liquid requires far less energy (electricity) than compressing a gas
2. The absorption reaction is strongly exothermic and the released heat may be usefully exploited
3. The energy vector supplying energy to the process is primary energy (natural gas/LPG, but also biomethane) or hydrogen.

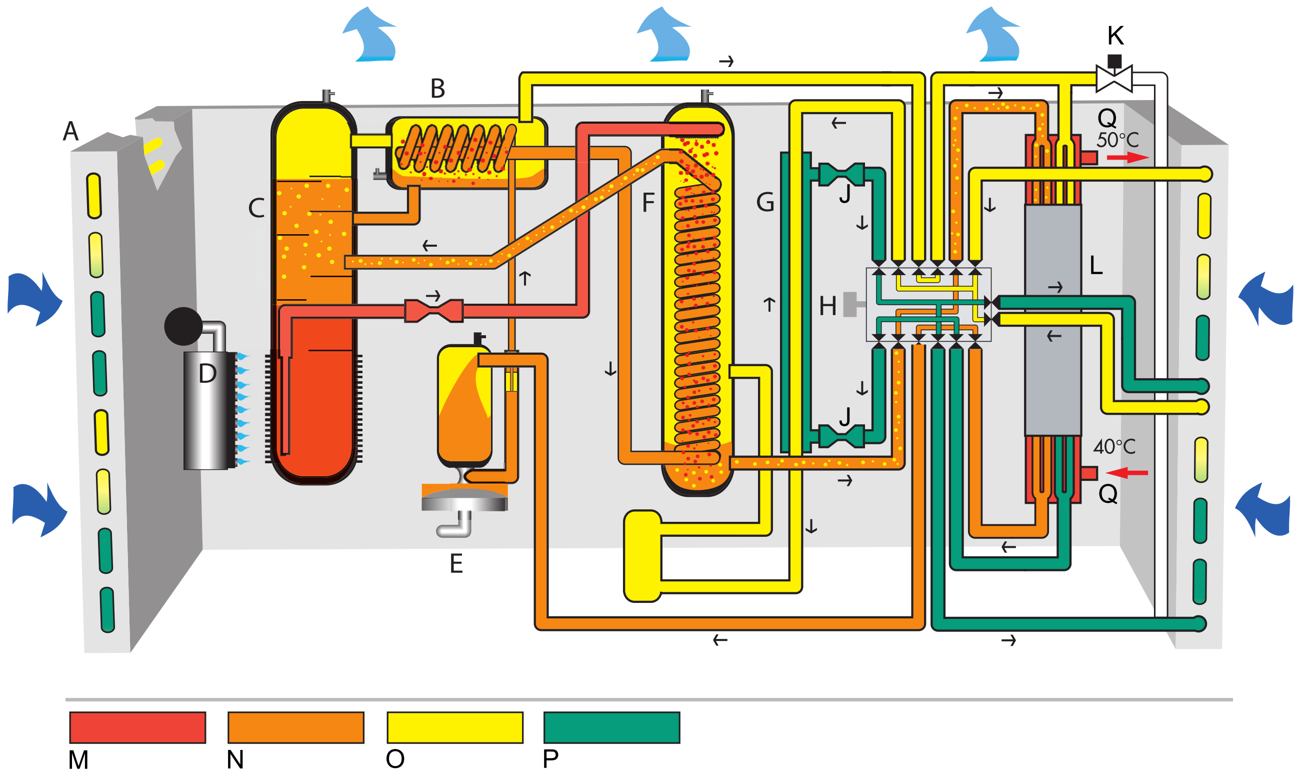
In the gas absorption cycle the refrigerant is ammonia and the absorbent is water.

3.1 DETAILED DESCRIPTION

For a detailed description of the thermodynamic cycle of a GAHP heat pump, please refer to Figure 3.1 *p. 3*, which shows the cooling circuit of a GAHP-AR (reversible gas absorption heat pump for alternate production of hot or chilled water) in heating mode.
The multi gas burner (D) is used to heat the absorbent-refrigerant solution causing separation of the two components by evaporation of the refrigerant in the distillation column (C).
In the gas absorption cycle the refrigerant is ammonia and the absorbent is water.
The burner-distillation column assembly (C+D) is called a generator and in absorption heat pumps replaces the compressor typical of electrical heat pumps.
The refrigerant vapour leaving the generator, passing through the rectifier (B), separates from any residual water and enters the shell and tube heat exchanger (L), which, if the appliance is operating in heating mode, takes on the role of the heat pump condenser.
In this part of the cycle, the heat exchanger acts as the refrigerant condenser, which transfers the latent condensation heat to the water of the heating system.
This change of state of the refrigerant, therefore, represents the first useful effect of the thermodynamic cycle.
The refrigerant on outlet of the condensation section passes through a first lamination section (J), a tube-in-tube heat exchanger (G) and a second lamination section (J) where, through successive decreases in pressure and temperature, it is progressively brought to the ideal conditions for changing state again to the gaseous phase.
In the finned coil (A) the refrigerant evaporates by taking heat from the outdoor air.
In this part of the circuit, the heat pump imports into the cycle a portion of aerothermal renewable energy.
The refrigerant used by GAHP heat pumps, ammonia, can evaporate down to -33 °C at ambient pressure.
This thermodynamic characteristic of the refrigerant allows renewable energy to be taken from the air even when its temperature goes down to deep negative values, thus dispensing with the need to have backup boilers.

The ammonia evaporated in the finned coil (A), after overheating in the tube in tube heat exchanger (G), enters the pre-absorber (F) where it meets the atomized absorbent (water) thus giving rise to the actual absorption reaction.
Absorption is an exothermic chemical reaction whereby the emitted thermal energy needs to be removed.
In the pre-absorber (F) this energy is partially used to preheat the water-ammonia solution that is about to go back into the generator.
To complete the absorption reaction, the solution is sent back to the shell and tube heat exchanger (L).
At this stage of the cycle, the heat exchanger allows a considerable amount of thermal energy to be transferred to the heat transfer fluid of the heating system, which constitutes the second useful effect of the thermodynamic cycle.
The water-ammonia solution coming out of the heat exchanger (L) is conveyed by the solution pump (E) back to the generator, passing through the pre-absorber (F) and the rectifier (B) again, where it is preheated, recovering heat from the cycle itself.
In the generator, therefore, the thermodynamic cycle just described restarts.
The inversion valve of the heat pump cycle (H), only provided for GAHP-AR units, consists of a mechanical component through which the refrigerant flow is diverted into the circuit.
This operation makes it possible to seasonally reverse the operating mode and produce hot water in the heating season and chilled water in the cooling season.
The defrosting valve (K), provided only for GAHP A and GAHP-AR aerothermal heat pumps, allows rapid defrosting of the finned coil, if required, without the need to reverse the refrigeration cycle or switch on electrical auxiliary heaters.
This is because, as shown in Figure 3.1 *p. 3* below, only one of the two energy inputs to the heat exchanger (L) is diverted to the finned coil, namely hot ammonia vapour.
This makes possible a quick ice removal while assuring 50% power to the heating circuit, without markedly altering the appliance's efficiency.

Figure 3.1 *GAHP-AR absorption cycle (heating mode)*



A	Finned coil	G	Tube in tube heat exchanger	N	Ammonia-rich solution
B	Rectifier	H	Cycle inversion valve	O	Ammonia in vapour state
C	Distillation column	J	Lamination valve	P	Ammonia in liquid state
D	Burner	K	Defrosting valve	Q	Heating system water
E	Solution pump	L	Shell and tube heat exchanger		
F	Pre-absorber	M	Ammonia-poor solution		