Armstrong®

ARMSTRONG+COMBITHERM HIGH-TEMPERATURE INDUSTRIAL HEAT PUMPS

INDUSTRIAL HIGH-TEMPERATURE HEAT PUMPS

Experience in high-temperature heat pumps (> 80 °C / 175 °F) since 2005

HCFO-1233zd(E) working fluid is harmless to the environment (ODP = 0, GWP < 5 , TFA < 2% of potential leaks[1]) and to people (Class A1, non toxic and non flammable)

Screw compressor running below 17 barg / 250 psi, thus ensuring the reliability of the unit

Capacity from 300 kW to 2000 kW - up to 3 compressors per unit - adapted to Industrial requirements

Each compressor can run between 80% and 100% of maximum load – VFD available for partial loads down to 50%

Heat sink temperature up to 120 °C / 248 °F (heat source from 30 °C / 86 °F)

Carnot cycle efficiency > 50%

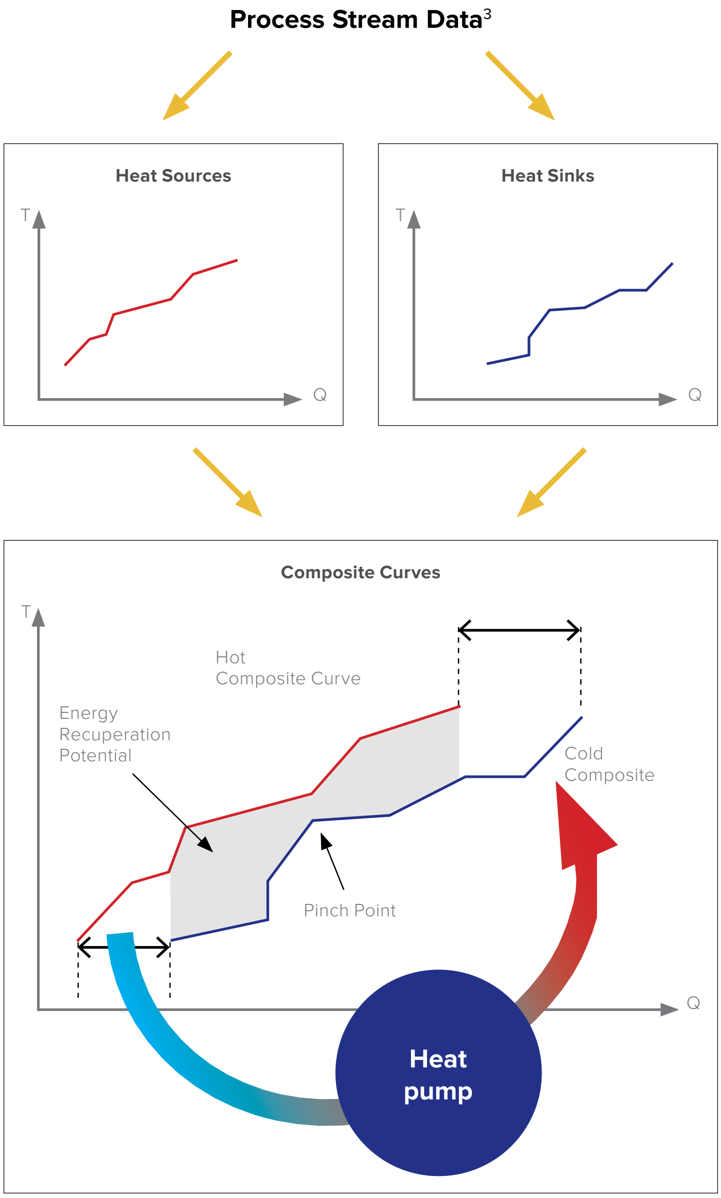
Extended warranty through preventive maintenance contract

INDUSTRIAL HIGH-TEMPERATURE HEAT PUMPS ARE AT THE HEART OF THERMAL DECARBONISATION

- allow reuse of low-temperature heat (< 50 °C / 122 °F) that is rejected by process and cooling systems and currently wasted in most industrial plants. Through the working cycle of the heat pump, hot water temperature is increased at relatively high levels – up to 120 °C / 248 °F.

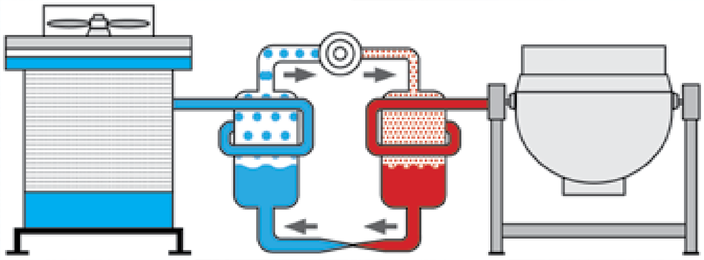
- allow wasted heat to be used in the production of hot water for high-temperature cleaning or process applications, thus replacing steam or hot water currently generated by burning fossil fuels or using electrical heaters.. The result is a significant reduction in primary energy consumption of the site in light industries, typically from 30% to 100% less[2]!

- are an economical way to generate thermal heat whenever their efficiency (COP) exceeds the "renewable electricity-to-fossil fuel" price ratio. However, for companies willing to decarbonize thermal generation, consuming fossil fuel will no longer be an option – therefore recovering their waste heat becomes a must[3]. Indeed, the impact of heat pumps (running on renewable electricity) on reducing CO_2 emissions makes it easier and more economical to tackle the thermal decarbonisation challenge compared to other renewable alternatives.



COEFFICIENT OF PERFORMANCE (COP) AND COMBINED COP (CCOP)

A heat pump uses the working cycle, which is at the heart of much of the equipment that surrounds us, such as refrigerators, building air conditioning systems, and industrial chillers. The working fluid at low pressure is able to absorb heat from a source through a heat exchanger (evaporator). Afterwards, the working fluid at gaseous state is compressed at higher pressure, thus raising its temperature. The working fluid then gives back the heat it contains to a “sink” through another heat exchanger (condenser). The loop is closed by sending the working fluid through an expansion valve, which causes a pressure drop – and partial evaporation – before returning it to the inlet of the evaporator.



The Coefficient Of Performance (COP) of a heat pump represents the ratio between the heat produced at high temperature and the electrical consumption of the compressor needed to run the working cycle. If the cooling of the heat source is also useful – for example by helping to decrease the load of a chiller – then a higher Combined Coefficient of Performance (CCOP) allows the sum of the heating and cooling power to be compared with the electrical consumption of the compressor.

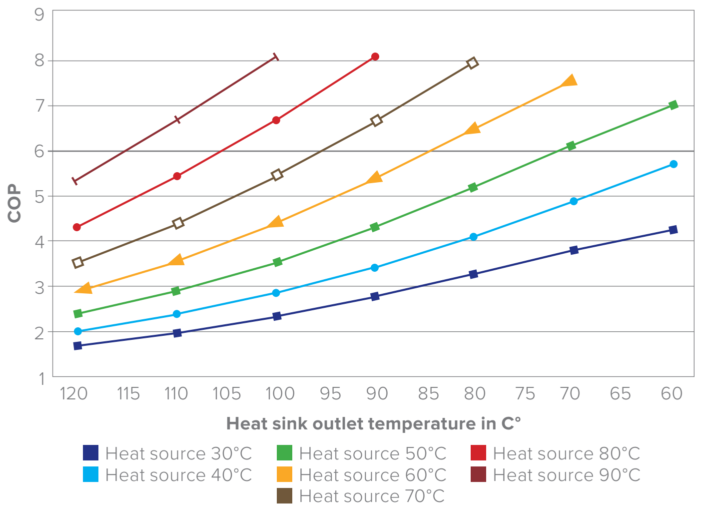
For example, a heat pump recovering 300 kW of waste heat at 30 °C / 86 °F will require 100 kW of electrical consumption to raise the heat temperature to 70 °C / 158 °F. Therefore, it will have a heating power of 400 kW, while consuming 100 kW of electrical power – thus having a COP of 4. If the 300 kW of heat extracted from the heat source are also useful – by decreasing the cooling load of the installation – then the heat pumps generates 700 kW of useful heating and cooling power, for the same electrical consumption of 100 kW. This will result in a CCOP of 7, which will greatly decrease the payback period of the unit.

OPTIMIZING COP AND CCOP

The electrical consumption of the compressor is directly related to the increase of pressure – and therefore to the increase of temperature – of the working fluid. That is why the COP of a heat pump is closely related to the heat sink and heat source temperatures – the smaller the difference, the higher the COP. Pinch studies of heat sinks and heat sources allow optimization of direct heat recovery within a plant and corelate heat sources to heat sinks most efficiently[3]. They also help quantify the opportunity to install heat pumps for recovering low-grade heat and increasing its temperature to useful levels. Pinch studies allow identification of applications for which both heating and cooling is needed, not only increasing the CCOP of the heat pump but also decreasing the load and water consumption of cooling towers (whenever these are used).

Typically, heat pumps cannot recover more than 50 % of the theoretical value of the Carnot cycle. ARMSTRONG + COMBITHERM industrial high-temperature heat pumps can reach Carnot efficiency above 50% by optimizing the sizing of the compressors; and by integrating an internal heat recovery.

COP of compact screw compressor and HCFO-1233zd(E) for different heat source inlet temperature (spread 5K)



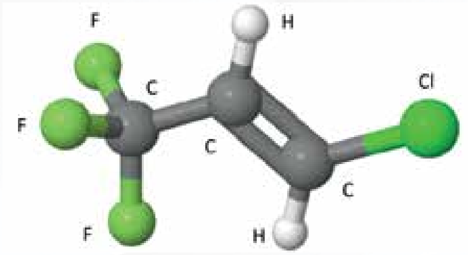
HEAT PUMPS AND HOT WATER STORAGE HELP SOLVE THE RENEWABLE INTERMITTENCE ISSUE

Heat pumps can be programmed to run during certain periods of the day when the cost of electricity is lowest, especially due to the intermittence of renewables. By adapting load management to the mix of the grid, heat pump systems (including storage on heat source and heat sink sides) help flatten the demand for renewables. Operating when electricity costs are lowest improves the payback of the unit.

ARMSTRONG+COMBITHERM industrial high-temperature heat pumps can be integrated into plant operations systems through the PLC delivered with the unit. They are also IoT-ready, with the possibility of communicating critical energy and operational data to cloud-based dashboards.

HCFO-1233ZD(E) IS THE WORKING FLUID OF CHOICE FOR INDUSTRIAL HIGH-TEMPERATURE HEAT PUMPS

Selecting the right working fluid is a critical decision when designing a heat pump. Indeed, the working fluid should not only be harmless to the environment and to people, it should also have the thermodynamic characteristics required to produce heat above 80 °C / 176 °F reliably and economically by running the refrigeration loop at relatively low pressure.



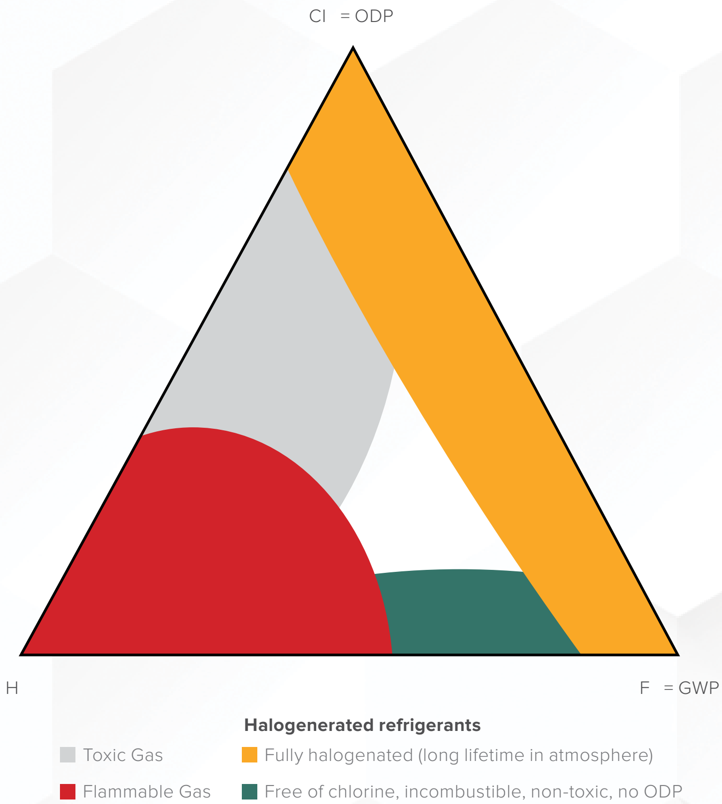
Armstrong International and Combitherm have conducted comprehensive technical and economical reviews of all the working fluids available for high-temperature industrial heat pump applications[4]. Our conclusion is that only HCFO-1233zd(E) delivers the level of safety, reliability and cost necessary for high-temperature heat pumps to be scaled-up sufficiently to have a significant impact on the decarbonisation of light industries.

HARMLESS TO THE ENVIRONMENT AND PEOPLE

The characteristics of HCFO-1233zd(E) – which belongs to the HCFO category – make it the working fluid of choice for industrial high-temperature heat pumps. Its Ozone Depletion Potential (ODP) is 0, and it has a Global Warming Potential (GWP) below 5[1] – substantially lower than the GWP > 1000 of most HFC working fluids used previously[5].

Furthermore, it is nonflammable and nontoxic, thus belonging to the safest A1 Class. HCFO-1233zd(E) has a very short atmospheric lifetime of 36 days (global average, local values depending on climate conditions[1]) and 0% experimental probability to yield TFA (< 2% theoretical probability[1]).

These characteristics explain why HCFO-R1233zd(E) is increasingly used as a replacement for HFCs in other applications, such as insulation foam sprayed at construction sites, and car air conditioning systems.

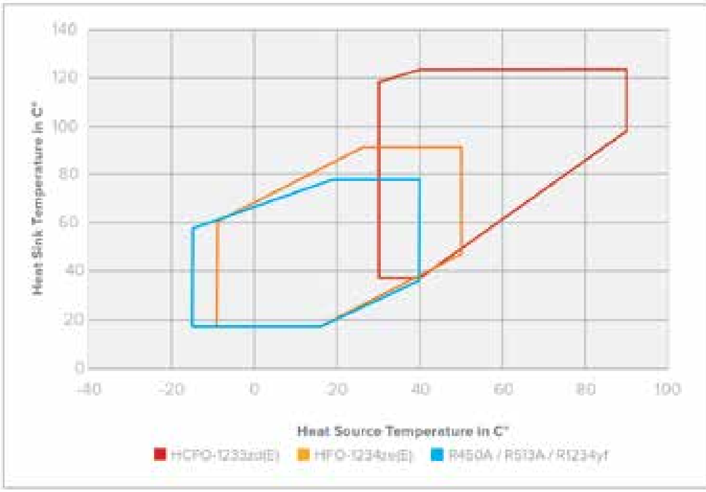


HEAT SOURCES FROM 30 °C (86 °F) AND HEAT SINKS UP TO 120 °C (248 °F)

The boiling point of HCFO-1233zd(E) is 18 °C / 65°F, which allows 1 barg pressure at the evaporator, while recovering waste heat from sources at 30 °C / 86 °F or above. The critical temperature of this working fluid is 166 °C / 331 °F, which means that the pressure at the condenser is less than 17 barg / 250 psi, while delivering heat sink temperatures up to 120 °C / 248 °F. At this temperature level, hot water can be evaporated to generate low-pressure steam for applications that require it.

In case the heat source temperature cannot reach 30 °C / 86 °F, it is possible to implement a primary loop using a different working fluid – HFO-1234ze(E) (belonging to Class A2L, low flammability) or even water. HFO-1234ze(E) allows the heat sink temperature to reach up to 90 °C / 194 °F), thus facilitating the design of a cascading system.

Application fields for screw compressor



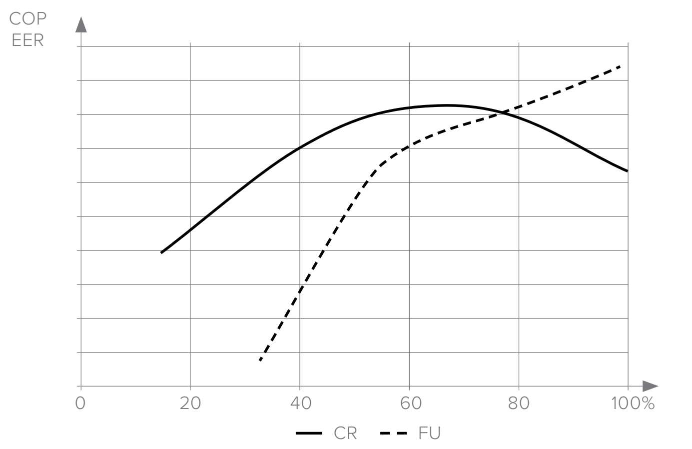
FLEXIBLE OPERATION TO ADAPT TO LOAD VARIATIONS AND ELECTRICITY COST

Heat pumps operate most efficiently at 100% compressor capacity, which requires hot water storage at the heat sink side. However, slider controls integrated into screw compressors allow operations down to 80% of the maximum load, with a limited negative impact on the COP.

In order to avoid further degradation of the COP for loads between 50% and 80%, a Variable Frequency Drive (VFD) is recommended.

Designing the unit with multiple compressors also achieves this flexibility – sometimes without the need for a VFD – while limiting the negative impact on the COP.

Variation and Electricity Cost



INCREASED RELIABILITY FOR LOWER MAINTENANCE AND DOWNTIME

ARMSTRONG+COMBITHERM industrial high-temperature heat pumps are the result of our experience in high-temperature heat pumps (above 80 °C / 176° F) since 2005. The screw compressor technology was proven using other working fluids, before adapting it in 2020 to HCFO-1233zd(E) and applications up to 120 °C / 248 °F. The specific volume of this working fluid allows it to run the compressor at relatively low pressure levels (less than 17 bar / 250 psi) – well below its design pressure of 28 bar / 400 psi.

The industrial high-temperature heat pumps design has been optimized to facilitate commissioning, testing and maintenance of the main components.

Our confidence in the reliability of ARMSTRONG+COMBITHERM heat pumps is proven by the extended warranty given when preventive maintenance contracts are applied.

NO EXTRA SAFETY REQUIREMENTS DECREASES OVERALL CAPEX INVESTMENT

Our choice of HCFO-1233zd(E) not only improves the reliability of ARMSTRONG+COMBITHERM industrial high-temperature heat pumps, it eliminates requirements for additional safety systems to protect users from the toxicity and flammability of other working fluids. This significantly decreases overall Capex investment and operational costs, making waste heat recovery achievable.

NO TIME TO WASTE

The recovery of low-grade waste heat will be one of the most significant contributors to energy efficiency, thus facilitating the thermal decarbonisation challenge the world is facing. ARMSTRONG+COMBITHERM industrial high-temperature heat pumps are the solution for significantly decreasing the primary energy consumption of plants. Thermal decarbonisation is achievable – safely, reliably, and economically.

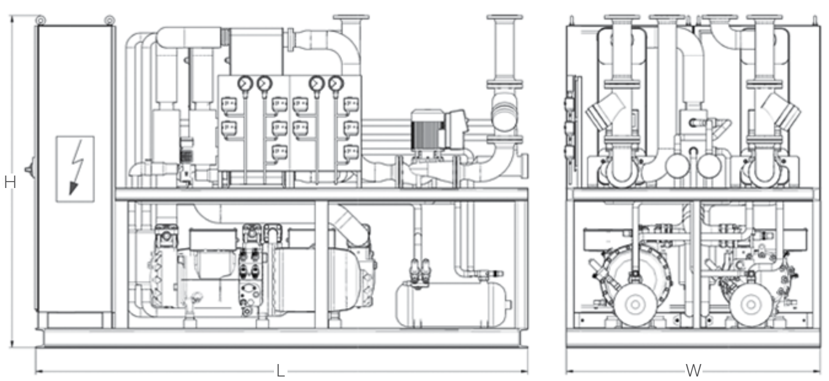
DIMENSIONS AND HEATING CAPACITIES IN KW

HWW series with screw compressor, working fluid HCFO-1233zd(E)

Heat Pump Type	Power[1]	Length mm	Width mm	Height mm	Weight kg
HWW 7553	127	3100	1200	2100	1900
HWW 7563	147	3200	1200	2100	1900
HWW 7573	167	3200	1200	2100	2000
HWW 7583	191	3200	1200	2100	2200
HWW 8553	204	3300	1200	2100	2500
HWW 8563	232	3300	1200	2100	2600
HWW 8573	265	3400	1200	2100	2800
HWW 8593	346	4000	2000	2100	3600
HWW 9553	346	4000	2000	2200	4000
HWW 9563	397	4000	2000	2200	4200
HWW 9573	452	4100	2000	2200	4500
HWW 9583	520	4100	2000	2200	4800

Heat Pump Type	Power[1]	Length mm	Width mm	Height mm	Weight kg
HWW 2/7553	255	3100	1600	2100	3000
HWW 2/7563	293	3200	1600	2100	3200
HWW 2/7573	333	4200	2000	2100	4000
HWW 2/7583	381	4200	2000	2100	4200
HWW 2/8553	407	4200	2000	2100	4800
HWW 2/8563	464	4300	2000	2100	5100
HWW 2/8573	530	4500	2000	2100	5300
HWW 2/8593	691	4900	2000	2100	6300
HWW 2/9553	691	4900	2000	2200	7200
HWW 2/9563	795	4900	2000	2200	7400
HWW 2/9573	905	4900	2000	2200	7800
HWW 2/9583	1040	4900	2000	2200	8500

[1] Heat Source Hot Water 60 °C / 140 °F, Heat Sink Hot Water 98 °C / 208°F



NOTES

Sources:

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4. George Kosmadakis, *Estimating the potential of industrial (high-temperature) heat pumps for exploiting waste heat in EU industries* (HTTPS://DOI.ORG/10.1016/J.APPLTHERMALENG.2019.04.082)

5. Guido Francesco Frate, Lorenzo Ferrari, Umberto Desideri, *Analysis of suitability ranges of high temperature heat pump working fluids* (HTTPS://DOI.ORG/10.1016/J.APPLTHERMALENG.2019.01.034)

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