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Application Engineering Europe

DISCHARGE GAS TEMPERATURE PROTECTION FOR COPELAND™ HEAT PUMP COMPRESSORS

1 General remarks on protecting Copeland™ Scroll compressors

In heat pumps, malfunctions or weak design can lead to the breakdown of the compressor. Reliability testing has shown that e.g. excessive discharge gas temperature, operation outside of the envelope, lack of proper superheat control or liquid slugging can lead to compressor failure.

To ensure reliability it is strongly recommended that:

- The evaporation and the condensing pressures are controlled by means of an electronic controller to ensure that operation is within the envelope at all times.
- Superheat is controlled at all times to ensure it remains within stated maximum and minimum limits.
- Discharge gas temperature is measured and limited.

Additionally the following protections should be used:

- Low pressure switch.
- High pressure limiter according to EN 378.
- Discharge gas temperature protection.

This technical information will focus on the discharge gas temperature protection. For the other points please refer to the application guidelines.

2 Causes of excessive discharge gas temperature

Most common causes are listed below. They can all result in abnormal operation with risk of damaging the compressor.

- Reduced heat transfer in the heat exchangers, for example by:
  - fouling;
  - reduced or blocked water/brine flow in the condenser/evaporator;
  - reduced or blocked airflow on the evaporator due to, e.g., frost, snow, leaves.
- Decreasing evaporation temperature due to frost and ice formation from freezing rain or high humidity.
- Control of the compressor operating conditions by water/brine/air temperature can be inaccurate and too slow especially in transient conditions.
- Liquid slugging or excessive superheat at any conditions.
- Excessive suction gas temperature caused by operation at high ambient conditions or leakage in the 4-way valve.
- Loss of refrigerant charge.
- Time delay or incorrect setting for the high and low pressure limiter.

In summary, to avoid excessive discharge gas temperatures during normal operation, care must be taken to ensure that the compressor envelope is respected in terms of evaporating and condensing temperatures and in terms of superheat. To avoid excessive discharge gas temperatures during abnormal operation, discharge gas temperature protection is required.

3 Consequences of excessive discharge gas temperatures

Here are a few of the possible consequences:

- Since the oil circulates with the refrigerant in the system, it is subjected to high discharge gas temperatures. If the discharge gas temperature becomes too high, the so-called "cooking" effect will occur (heating of oil under exclusion of air). Carbon deposits will form at points of high temperature, for example on the valves, oil-channels, oil filters, etc., the lubricity of the oil will be reduced and a progressive wear process will occur which will prematurely damage the compressor.

- Furthermore, the stability of the refrigerant can be affected, particularly if traces of contaminant are present.
- The problems listed under the first 2 points frequently occur simultaneously, particularly since the chemical reaction time approximately doubles at every 10°C temperature rise. This directly leads to chemical reactions of the oil with the refrigerant and the compounds extracted from sealants and insulation material. As a consequence contaminants of various types, among them acids, will form inside the system.

4 Discharge gas temperature protection

Discharge gas temperature protection is the fallback for failure of the system control. It is essential that proper control of evaporating and condensing pressures and superheat is maintained and has the ability to cope with all likely conditions and high loads. Reliance on protectors will cause inadequate system performance and short cycling.

Compressors ZH12K4E to ZH45K4E, ZH06KVE to ZH18KVE, ZH04K1P to ZH19K1P and ZHI05K1P to ZHI23K1P have no internal protection. Therefore, these compressors must be equipped with external discharge gas temperature protection.

ZHW0152P and ZHW0302P, ZHV0212P and ZH0342P, ZPV0212P, ZPV0342P, ZPV0631P, ZPV0662P and ZPV0962P have no internal protection. Therefore, these compressors must be equipped with external discharge gas temperature sensor which is connected to the drive.

On compressors ZH56K4E to ZH11M4E and ZH24KVE to ZH48KVE, a thermistor is located internally in the discharge port of the fixed scroll. Excessive discharge gas temperature will cause the electronic protector module to trip. The discharge gas thermistor is wired in series with the motor thermistor chain.

On compressors ZHW08K1P and ZHW16K1P, a temperature sensor is located internally in the discharge port of the fixed scroll. Excessive discharge gas temperature will cause the drive to trip the compressor. The discharge gas temperature can be accessed through the Modbus.

On compressors ZHI27K1P to ZHI46K1P, a NTC temperature sensor is preassembled in an insert in the compressor top cap. This sensor must be connected to the system controller and has to be used to limit the discharge gas temperature. Please see the resistance characteristics in **Table 2**.

5 Temperature sensor versus thermostat for external discharge gas temperature protection

For external Protection it is recommended to use a temperature sensor e.g., NTC or PT100. This sensor has to be connected and monitored by the system controller or the drive according to table 1, which trip the compressor when exceeding the discharge gas temperature limits. The tripping set point should be chosen with allowances for the maximum tolerances of the setup temperature sensor and should be verified by system testing.

For example for the ZH18KVE a maximum discharge gas temperature of 130°C must be respected (see **Table 1**). The tripping set point has to be chosen to respect the tolerances on the sensor and even more important to respect the temperature differences between discharge gas temperature and sensor due to heat transfer. These are different for each individual system configuration. There is no general tolerance value. The differences have to be verified by lab testing through the whole envelope. If the lab test shows that the extreme difference can be up to, e.g., 10K then the tripping set point has to be set to a maximum of 120°C.

For thermostats the open and close temperatures are determined by dipping the complete housing into a temporized bath, so that the complete surface of the thermostat is at the same temperature. Here in this application for ZH compressors the contact surface and the rest of the surface are at different temperatures. Please be aware that this means, that the thermostat will open in this application at a discharge gas temperature different from the set point of the thermostat of 120°C ± 4.4K. Emerson has verified by thorough testing that with assembly according to paragraph 6 the thermostat will give compressor protection even with unfavourable tolerance combinations. Please be aware, that it is possible that the thermostat will trip just inside the compressor envelope.

Brine-to-water heat pumps do typically not run close to the limit line of the compressor application envelope so for this application a thermostat is a good option.

6 Assembly of external discharge gas temperature protection

For compressors with external discharge gas temperature protection (see **Figure 1**) the temperature sensor or the thermostat has to be installed with a distance along the - straight or bended - pipe of 120mm from the compressor shell. To reduce the impact of ambient temperature the discharge pipe including the sensor or thermostat has to be insulated (see **Figure 1**). To improve heat transfer to the sensor or to the thermostat use thermal compound that is approved for minimum temperatures according to **Table3.** Protect the sensor or the thermostat from being moved or removed from its position by transport, vibration or any other incident.

The sensor has to be installed in a copper sleeve, to improve response time and to reduce setoff. The cooper sleeve has to be brazed on the surface of the discharge pipe (see **Figure 1**). Use thermal compound to improve the heat transfer from the sleeve to the sensor.

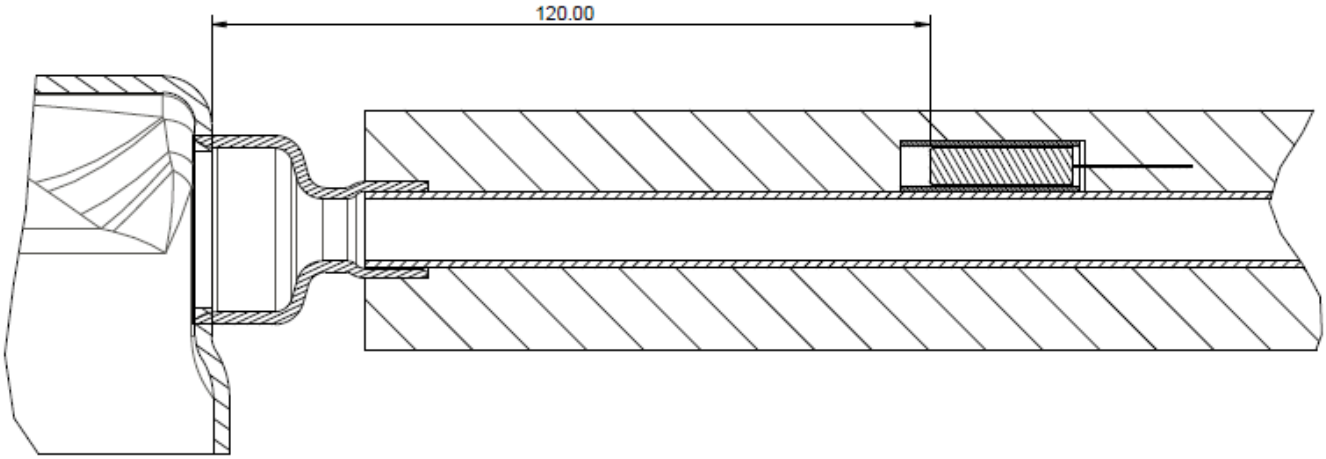

Figure 1: Sketch of discharge gas temperature protection for compressors with external sensor, with a distance along the - straight or bended - pipe of 120mm from the compressor shell

The Emerson Climate Technologies discharge gas thermostat 8854416 is designed for discharge pipes with an outer diameter of about 12.8 mm. To improve heat transfer, apply some thermal compound between pipe and contact surface of the thermostat. For the electrical wiring of the thermostat please refer to the application guidelines.

Thermostat Ident Number	Voltage	Current	Open	Close
8854416	120/240 V AC	10/5 A	120°C ± 4,4K	95°C ± 6,1K

Table 1: Technical data of Thermostat 8854416 for ZH compressors

Temperature °C	Resistance kΩ	Temperature °C	Resistance kΩ	Temperature °C	Resistance kΩ
-40	2889.60	40	45.81	120	3.35
-30	1522.20	50	30.99	130	2.58
-20	834.72	60	21.40	140	2.02
-10	475.74	70	15.07	150	1.59
0	280.82	80	10.79	160	1.25
10	171.17	90	7.87	170	1.01
20	107.44	100	5.85	180	0.83
25	86.00	110	4.45	190	0.68
30	69.28	120	3.35		

Table 2: Temperature resistance characteristic of NTC temperature sensor for ZHI27K1P to ZHI40K1P

Verify by system testing, that the discharge gas temperatures according to **Table 3** are not exceeded and that there is no nuisance tripping with normal operation of the system.

Compressors	Refrigerant	Max discharge gas temperature in °C at sensor location	Protection	Tripping set point
ZH12K4E to ZH45K4E	R407C/R134a	140°C	External temperature sensor or thermostat required	System testing required to define set point
ZH56K4E to ZH11M4E	R407C/R134a	140°C	Internal sensor + motor protection module	Fixed set point in motor protection module, no access
ZH06KVE to ZH18KVE	R407C	130°C	External temperature sensor or thermostat required	System testing required to define set point
ZH24KVE to ZH48KVE	R407C	140°C	Internal sensor + motor protection module	Fixed set point in motor protection module, no access
ZH04K1P to ZH19K1P	R410A	140°C	External temperature sensor or thermostat required	System testing required to define set point
ZHI05K1P to ZHI23K1P	R410A	135°C	External temperature sensor or thermostat required	System testing required to define set point
ZHI27K1P to ZHI40K1P	R410A	135°C	Preassembled sensor in top cap + system controller required	135°C **(Table3)**
ZHW08K1P & ZHW16K1P	R410A	140°C	Internal sensor connected to the drive	System testing required to verify correct tripping
ZHW0152P & ZHW302P	R410A	125°C	External sensor connected to the drive	System testing required to verify correct tripping
ZHV021 2P & ZHV034 2P	R410A	125°C	External sensor connected to the drive	System testing required to verify correct tripping
ZPV0212P & ZPV0342P	R410A	121°C	External sensor connected to the drive	System testing required to verify correct tripping
ZPV0631P & ZPV096 2P	R410A	135°C	external sensor connected to the drive	System testing required to verify correct tripping

Table 2: Maximum discharge gas temperatures for ZH and ZPV-compressors