The RoHS Pack 22 report: Consequences of Öko-Institut's recommendations regarding RoHS Exemption 7(a) and 7(c)-I for PTCs in compressors for heating, refrigeration and air conditioners

Exemption 7(c)-I "*Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound*"

https://rohs.exemptions.oeko.info/exemption-consultations/2020-consultation-2/aiii-ex-7c-i

Exemption 7(a) "*Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)*"

https://rohs.exemptions.oeko.info/exemption-consultations/2020-consultation-2/aiii-ex-7a

PTCs are used as temperature sensors for motor protection in compressors for refrigeration, heating, and air conditioning. These are wired with an electronic module so that compressor power will be quickly removed if the motor overheats. This is required for product safety and longevity.

These motors have an unusually high energy density (watt per Kg of mass) and are refrigerant gas cooled. High load conditions, liquid refrigerant, low voltage, loss of a power phase, or locked mechanicals can each cause a rapid temperature rise and quickly damage or ruin a motor.

Hence, thermal protection in all three phases is necessary. In many cases it is necessary to imbed thermal sensors in both ends of the motor winding in each phase to sense all the potential hot spots.

Motor protection is also needed to ensure pressure vessel integrity. Because refrigerants can be toxic, flammable, or have a significant global warming potential, compressors must be hermetically sealed. Wires for power and protection circuits, coming from the inside of the compressor outward, use feedthroughs. These are metal and glass terminals that keep the pressurized refrigerant inside while allowing electrical signals to pass through. A motor short circuit can cause feedthrough breakage and refrigerant venting. This must be prevented (F-gas regulation).

PTCs with leads have a highly nonlinear resistance vs. temperature characteristic. They are the only thermal sensor which can be daisy chained (run in a series circuit) allowing the use of only two metal pins in the feedthrough to bring up to nine temperature readings to the outside of a compressor. This is significantly important because sensors with a more flat or linear characteristic make it impossible to differentiate if an increase in the sum of all resistances is because all sensors are slightly warmer or because one of them is intolerably hot.

Additional PTCs are often added to this daisy chained circuit to monitor other parts of the compressor to prevent conditions that could cause compressor damage. With this, a refrigeration system problem does not lead to a compressor failure. The protection circuit can be a whole compressor protection circuit.

The steepness of the PTC response characteristic is also crucial for fast protection response in locked rotor circumstances. High motor energy results in fast temperature rise if the motor is unable to rotate. This could be for a mechanical issue or for loss of a phase due to a blown fuse. Shut down must take place within a few seconds. PTCs can respond quickly enough where a more linear sensor would be too slow resulting in motor winding and insulation burn. In the case of an open fuse, an otherwise good compressor would be ruined.

With this PTC circuit and fast response time, motor and compressor damage can also be prevented during compressor start-up, when refrigerant flow is beginning, increasing, and not fully established. Very high torque under this heavy load can quickly increase winding temperatures.

Currently, high lead content lead-tin solder is used to bond the PTC ceramic to connecting wires. This solder has a melting temperature of 296°C which ensures safe and durable operation at all points of normal operation up to 180°C while enduring abnormal temperature spikes to 225°C and more. If PTCs are soldered with lead-free material, the melting temperature is significantly reduced. A typical melting point is around 220°C.

Because compressors have high vibration amplitudes, long cycle fatigue durability of the solder joint must be considered. Normal operating temperature must be 80°C below the melting temperature. Above this temperature the solder starts to become soft and weak; the mechanical strength is reduced significantly. This would impact the durability and system life-time expectancy very negatively. Durability over decades means preventing compressor replacement and keeping refrigeration circuits closed. This is the most environmentally friendly condition. Any replacement will increase the potential for leakage of F-gases. An objective of the EU is to reduce these.

Lead-free solder would also reduce the maximum operating PTC temperature to 140°C. This would constrain heating, refrigeration, and air conditioning applications with constricted condensing temperatures.

In addition, compressors are required to survive 2000 cycles of locked rotor testing (UL and EN 12693 requirements). For short duration, winding and PTC temperatures can exceed the lead-free solder melt temperature. Weaker solder joints would not survive these stringent conditions that were established for high reliability, durability, and safety.

The heating, refrigeration, and air conditioning industry is facing the challenges of regulation improvements that will drive-up temperatures further. New refrigerants with low global warming potential in compliance with the EU F-gas regulation result in higher than historical temperatures, both in the motor winding and the discharge gas. Due to this, PTC trip

temperatures of up to 180°C are necessary, especially in compressors with high vibration levels. This is technically only possible with lead in the solder.

These compressors are used in many applications: In the production of vaccines, in the medical supply chain, and in the whole food and beverage cooling chain (farming, food processing, supermarkets, logistics for food, restaurants, etc.). They are also widely used in industrial process cooling (cooling of cooling lubricants, injection molding machines, etc.), in air conditioning systems, in cooling systems for data centers and in many more applications.

Especially important are the emerging heating applications using heat pumps. These address decarbonization objectives for residential heating, domestic hot water heating, as well as high temperature industrial process applications.

In the field, there is a successful basis of many million compressors equipped with PTCs. This technology has been proven over approximately four decades with compressor lifetimes of easily 10 to 20 years.

Because of this special situation with heating, refrigeration and air conditioning compressors, Exemptions 7(a) and 7(c)-I of the RoHS Directive are extremely important as applied to PTCs. No other thermal sensor can be used as a substitute in this special application. Only PTCs with lead in ceramics have the necessary steepness in their characteristic to be daisy chained. Only PTCs with lead in the solder can withstand the high vibration levels and temperature demands of heat pump, refrigeration and air-conditioning compressors.

In addition, the Exemption under 7(c)-I would technically only work if 7(a) would be allowed also. These are interconnected and the timelines must be aligned accordingly.

After scrutinizing the RoHS Pack 22 report and in particular Öko-Institut's recommendations for Exemption 7(a) and 7(c)-I, it is our conclusion that PTCs used in compressors for heat pump, refrigeration, and air conditioning are <u>not</u> covered by the proposed new exemptions.

If the recommendations were to be approved by the European Commission, this would have severe consequences for the heating, refrigeration, and air conditioning industry. We therefore strongly recommend rejecting Öko-Institut's proposal and prolonging Exemption 7(a) and 7(c)-I with the current wording.

We would appreciate the opportunity to elaborate on our viewpoints in a virtual or physical meeting.