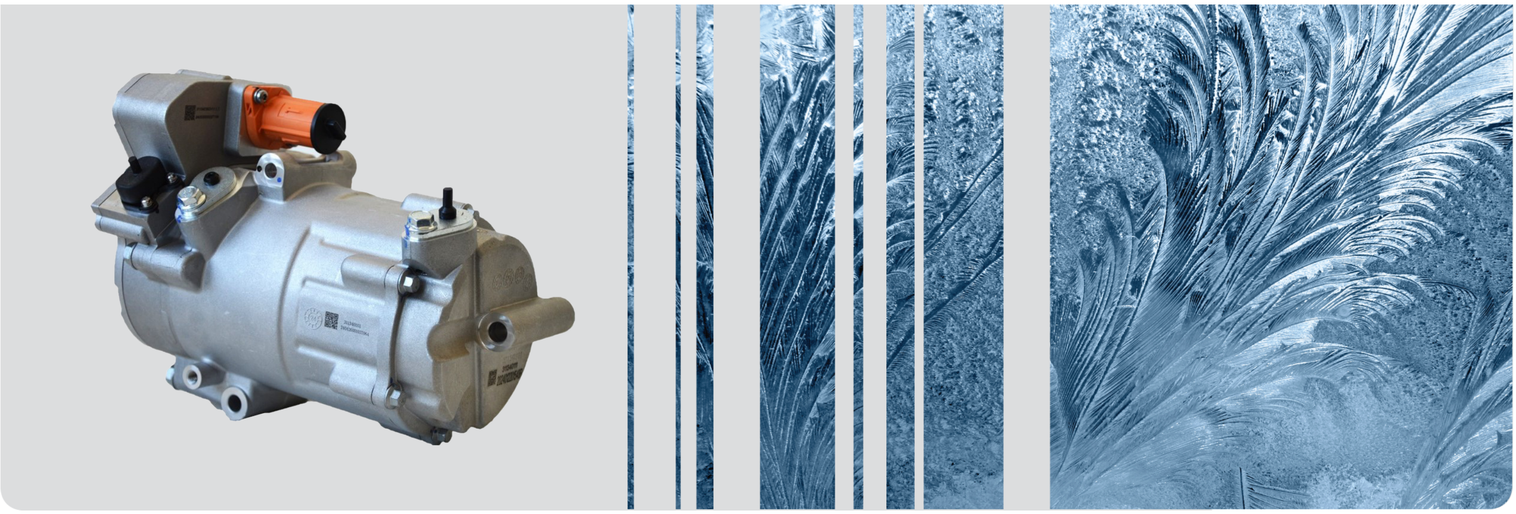
Operating- and Installation instructions

TCCI Compressor QPE34-850L0067



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1 Introduction

1.1 Scope

This document describes the information relevant to integrating the electric compressor into the usage application. This document describes only the physical (mechanical and electrical) integration details. Communication hardware specifications are included. Serial data is described in a separate document.

This manual includes important validation and process controls recommendations for potential failure modes that depend upon proper integration of the compressor into a system or vehicle. However, this is not a substitute for completing a FMEA, DVP and Control Plan specific to the vehicle or system application to address application-specific failure modes.

1.2 Notes

All pressure values in this document are given in absolute pressure, unless otherwise stated.

1.3 Change Log

Revision Date	Section Number(s)	Change(s)
2021/08/06	Initial Draft	
2021/08/18	4.4	Modified Installation Orientation Images
2022/06/29	4.5	Added pre-charge requirements
2022/10/27	4.6	Updated Electrical Specifications
2022/12/05	4.7	Updated pre-charge requirement
2022/12/07	4.7	Updated pre-charge requirement
2023/06/06	4.4, 4.6, 4.7, 4.9, 4.10, 5, 6	Revised the scope. Moved the proprietary information statement to notes. Added section 6 for customer validation items. Revised section 5 and parts of section 4.
2024/04/11	3.1	Update Signal Input Quiescent Current (WEBASTO ONLY)
2025/03/14		TCCI Rev.2024/04/11 document modified by Webasto R&D

1.4 Definitions

Signal inputs are inputs that are used for communication between the compressor and the vehicle, to provide power for communication, to indicate operating mode (run or accessory), or to indicate to wake or sleep the compressor. These inputs are low current.

Power inputs are inputs that are used for powering the motor. These are high current inputs.

Acronym	Definition
AC	Alternating Current
CAN	Controller Area Network
DC	Direct Current
HV	High Voltage
HVIL	High Voltage Interlock
LIN	Local Interconnect Network
LV	Low Voltage
RPM	Revolutions Per Minute
DVP	Design Validation Plan

2 Intended use

TCCI high-voltage products are designed to serve vehicles propelled by an electric motor in full capacity including heavy-duty trucks, buses, transport refrigeration vehicles and automotive applications. Any other use different from what is indicated in this manual is to be considered prohibited.

Contact Webasto Technical Service for further information before proceeding.

3 Function

The compressor intakes low pressure, low temperature refrigerant gas and discharges high pressure, high temperature refrigerant gas, creating flow in the refrigerant system. The compressor consists of three main parts: a compression mechanism, a motor, and a controller. The compression mechanism performs the refrigerant compression. The motor and controller are integrated into the compressor. The motor drives the compression mechanism. The controller is a sealed DC to AC inverter that controls the motor to variable speeds. The controller monitors and operates the compressor according to commands received from the vehicle. The controller provides some self-protection mechanisms to prevent damage to the compressor from certain causes. The controller also reports information used to diagnose the compressor. The compressor is designed with a target life of 25000 hours.

4 General Specifications

4.1 Specifications Summary

For information regarding the compressor displacement, performance, compatible refrigerants, voltage range, temperature range, connector information, and operating speeds and conditions, please consult the performance specification of the relevant compressor model.

The key compressor specifications are summarized in the following table.

Parameter	Value	Note
Displacement	34 cc/rev	
Compression Mechanism	Scroll	
Refrigerants	R134a and R1234yf	
Lubricating Oil	TCCI PAG (polyalkylene glycol)	Specially formulated for high isolation resistance. Compatible with R134a and R1234yf. Do not use oil that is not approved by TCCI for this compressor.
Minimum Speed	1000 RPM	
Maximum Speed	8500 RPM	Maximum speed is limited by the current limit. As discharge and/or suction pressure increase, speed may need to reduce to stay within the current limit.
Cooling Capacity	8.5 kW / 29,000 BTU/h	See performance curve for further details.
Power Input Voltage Range for Full Performance	500 – 850 V DC	Voltage range for normal operation of the compressor. This is the voltage as detected by the compressor. Voltage drop will occur in lead wires at high current.
Power Input Voltage Range for Reduced Performance	450 – 499 V DC	Reduced maximum current, which results in reduced max operating pressures.
Power Input Maximum Overvoltage Long Term	930 V DC	No failure from 60 minutes exposure to this voltage.
Power Input Maximum Overvoltage Short Term	1100 V DC	No failure from 5 minutes exposure to this voltage.
Power Input Max Current	15 A DC Continuous 20 A DC	These are steady state currents. Transient currents will vary due to controls overshoot. Sensor accuracy also adds tolerance.
Power Input Max Power	6500 W	
Signal Inputs Voltage Range (besides CAN or LIN pins)	9 – 32 V DC	Compatible with 12 and 24 V systems with same part number.
Signal Input Current Consumption	300 mA	
Signal Input Quiescent Current	3.6 mA	
Communication	Controls Specification for TCCI Electric Compressors	See communication section and Control Specification document for details (refer to the "SI CONTROLS SPECIFIC TCCI QPE34-850L0067" Manual).
Motor Operating Temperature Range	0 to 95 degC	Based on internal electronics temperature sensor reading.
Communication Temperature Range	-40 to 105 degC	Based on internal electronics temperature sensor reading.
Storage Temperature Range	-40 to 85 degC	There must be no voltage applied to signal nor power inputs if temperature is outside of their respective ranges.
Mass	6.5 kg	Approximate
Isolation Resistance (HV to LV & Ground)	Nominal: ≥ 200 MOhm @ 1000 V DC Worst Case: ≥ 2.5 MOhm @ 1000 V DC	As tested with TCCI oil and worst-case condition with liquid refrigerant surrounding motor.
X Capacitance	21.5 µF	Nominal value
Maximum Pre-Charge Rate	100 V/ms	Pre-charge circuit to be provided by the HV system.
Recommended Fuse	30 A Slow blow fuse	

4.2 Performance

Below is the compressor performance data at the rated operating condition:

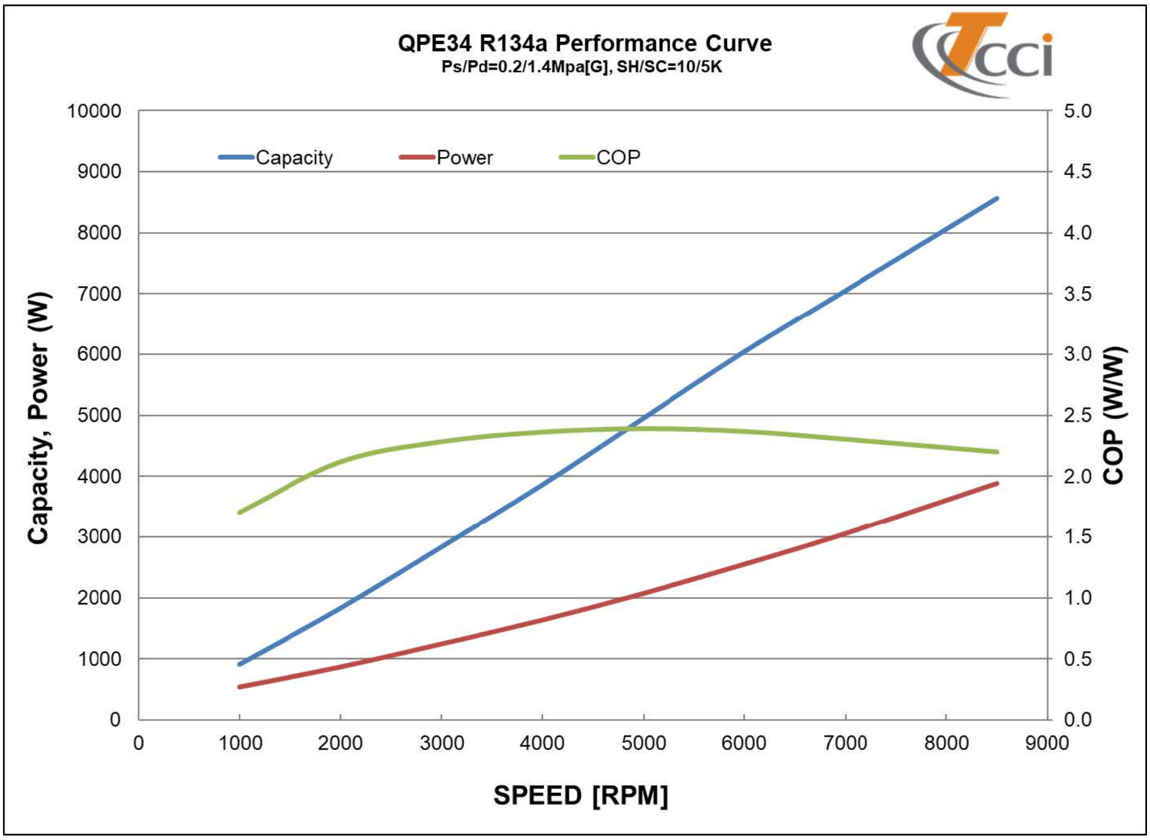

Fig. 1 QPE34 R134a Performance Curve

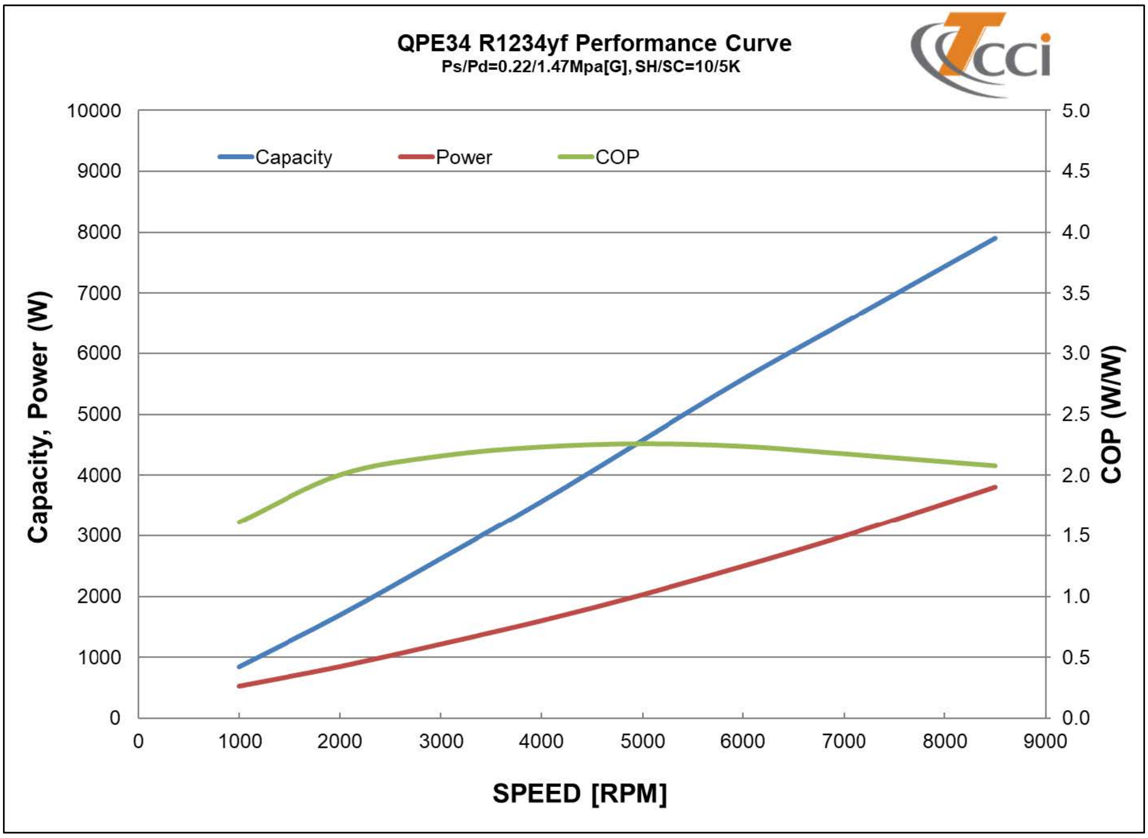

Fig. 2 QPE34 R1234yf Performance Curve

4.3 Environmental Capabilities

The compressor is semi-hermetically sealed against the environment. The electronics generate internal heat and are cooled by the flow of refrigerant through the compressor.

The following specifications are met when the compressor is mated to the matching refrigerant plumbing and sealed electrical connectors and TCCI approved oil is used.

Topic	Standard	Tests
Electrical Loads	ISO 16750 Part 2	If specified as 12 V nominal: Electrical Code C, (9-16 V). If specified as 24 V nominal: Electrical Code F (16-32 V).
Mechanical Vibration / Mechanical Shock	ISO 16750 Part 3	Code N (details below) ● Random Vibration with Thermal Cycling: Test VII — Commercial vehicle, sprung masses. ● Mechanical Shock: Test for devices on rigid points on the body and on the frame. ● Free Fall.
Operating Temperature	ISO 16750 Part 4	Communication: Code I (-40 degC to 95 degC ambient). Operation: Code Z (0 degC to 85 degC ambient).
Climatic Loads	ISO 16750 Part 4	Code D (details below) ● Low Temperature ● High Temperature ● Temperature Steps ● Temperature Cycling ● Rapid Change of Temperautre ● Ice Water Shock ● Salt Spray ● Humid Heat Cycling ● Damp Heat ● Dust Test
Ingress Protection	IEC 60529 (ISO 20653)	Protection against dust: IP6KX Protection against water: IPX9K (high pressure cleaning) and IPX7 (temporary immersion)
EMC	ECE R10 E Mark	Inquire for other EMC tests

4.4 Mounting Requirements

The compressor should be attached to the system with suitable fasteners. The recommended fastener grade is 8.8. Fastener tightening torque should be suitable to the fastener used. At least three fasteners should be used to attach the compressor to the system/vehicle. Fasteners should be corrosion resistant and suitable for use in the application.

It is recommended to mount the compressor on the vehicle in a location where it will not be subjected to nearby high heat sources, such as an exhaust system.

It is recommended that the compressor be mounted to a bracket or device that has elastomers isolating vibration transfer from the compressor to the chassis. This is a consideration for noise and vibration transmission to the end user. (See additional recommendations in chapter 4.9, "Noise and Vibration from the Compressor" on page 10). However, use of vibration dampers may interrupt the path form the compressor housing to the chassis ground. For high voltage safety, it is necessary to maintain two independent circuits connecting the compressor housing to chassis ground. When vibration isolators are used, a ground strap is typically needed to be attached to the compressor. When vibration isolators are used the design of the system should ensure that the compressor will remain attached to the system in event of a vibration isolator failure.

The compressor contains an internal oil separator in the discharge port. The oil separator relies on gravity to operate. The compressor also has internal oil passages that rely on gravity to function. Therefore, the mounting orientation of the compressor is restricted to maintain internal oil flow and proper durability. The compressor must be mounted according to the diagram below. If an application requires different orientation, then a different housing may be required.

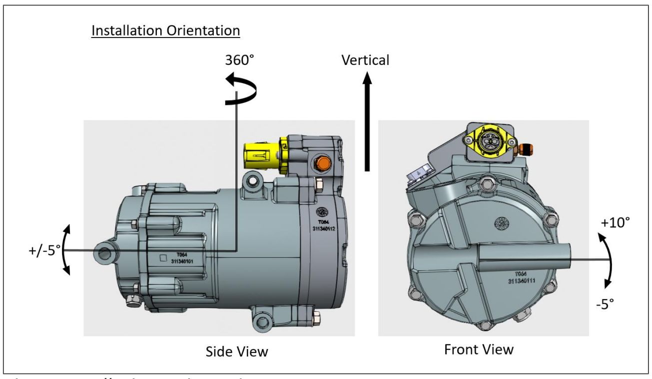

Fig. 3 Installation Orientation

Relevant part numbers: QPE34-850C0029, QPE34-850C0031, QPE34-850L0032, QPE34-850C0041, QPE34-850L0037.

Note: The above indicates nominal orientation. Consult with TCCI for other needs.

4.5 Mechanical Interfaces

For mounting and plumbing interfaces, see the figure below:

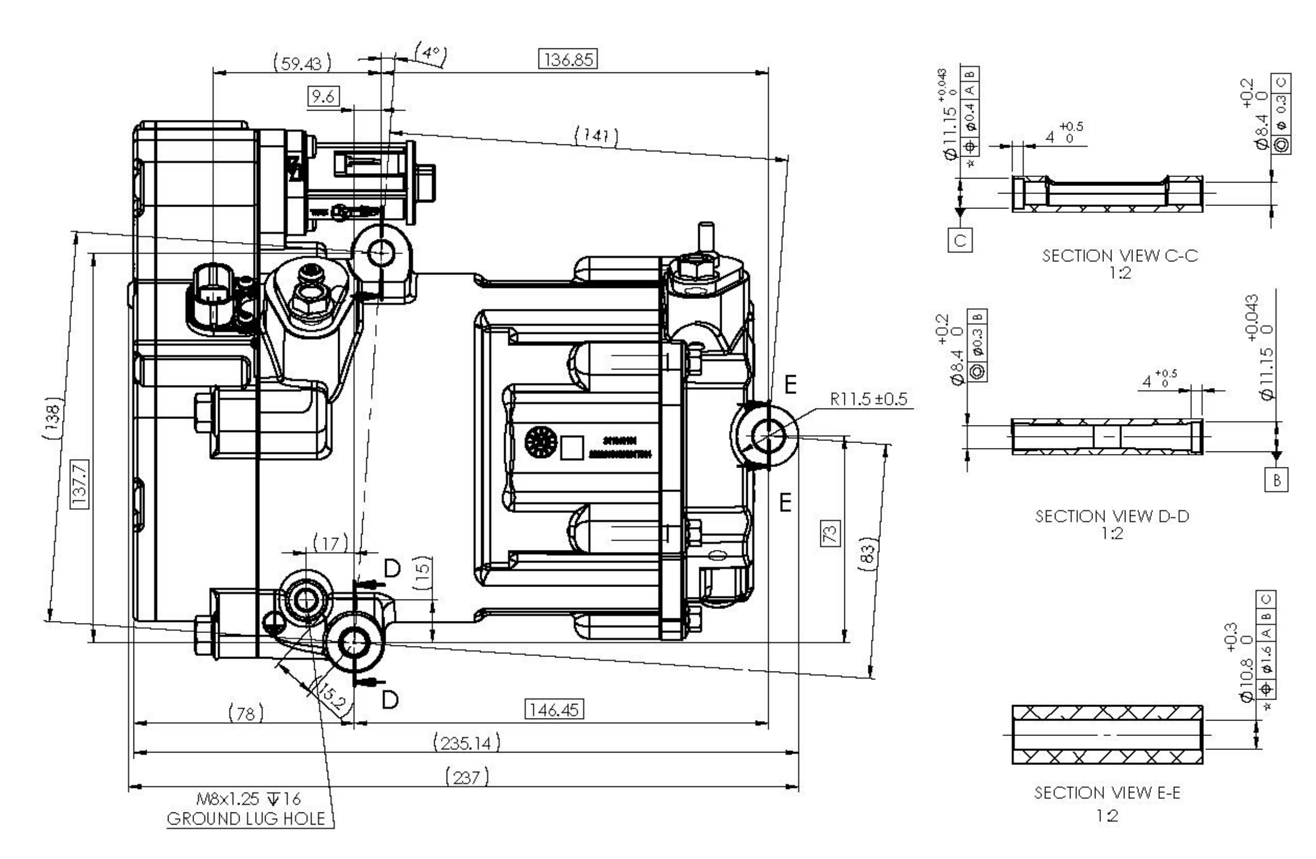

Fig. 4 Mounting and plumbing interfaces

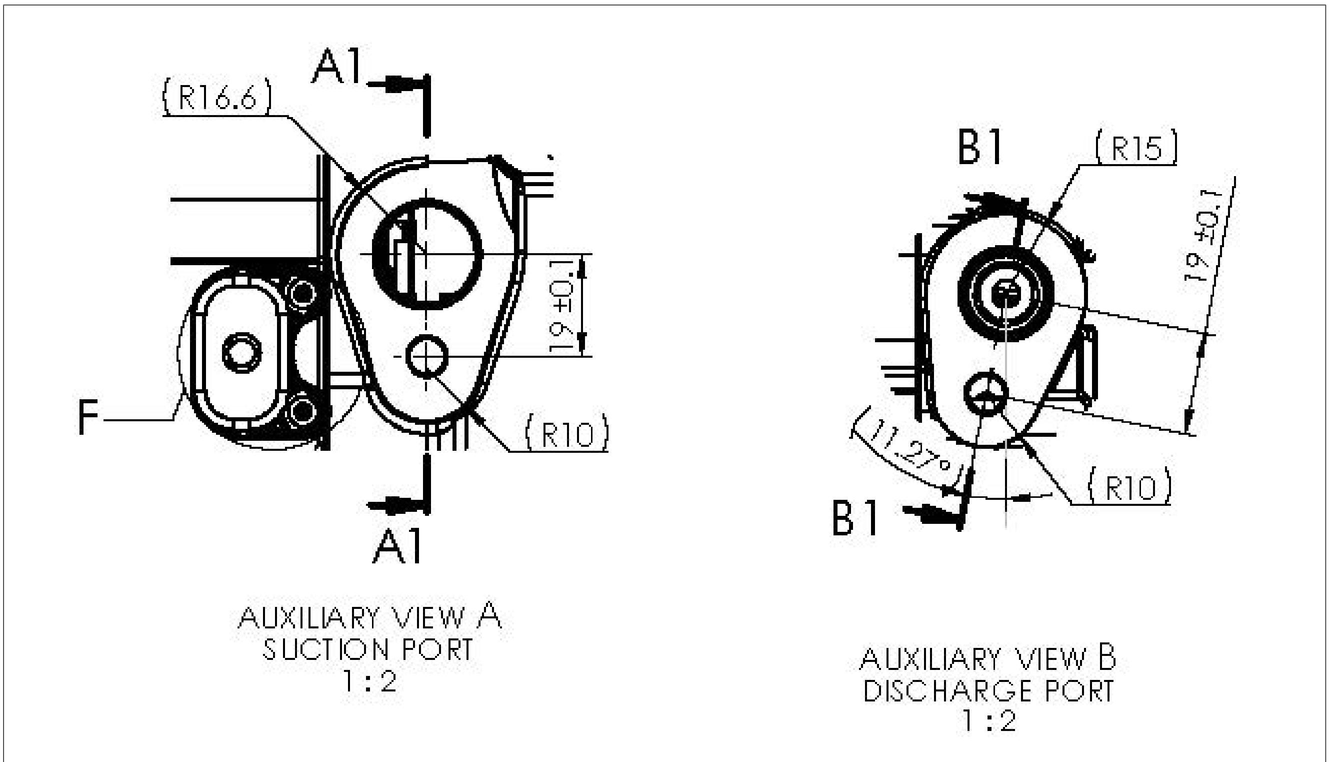

Fig. 5 Auxiliary View

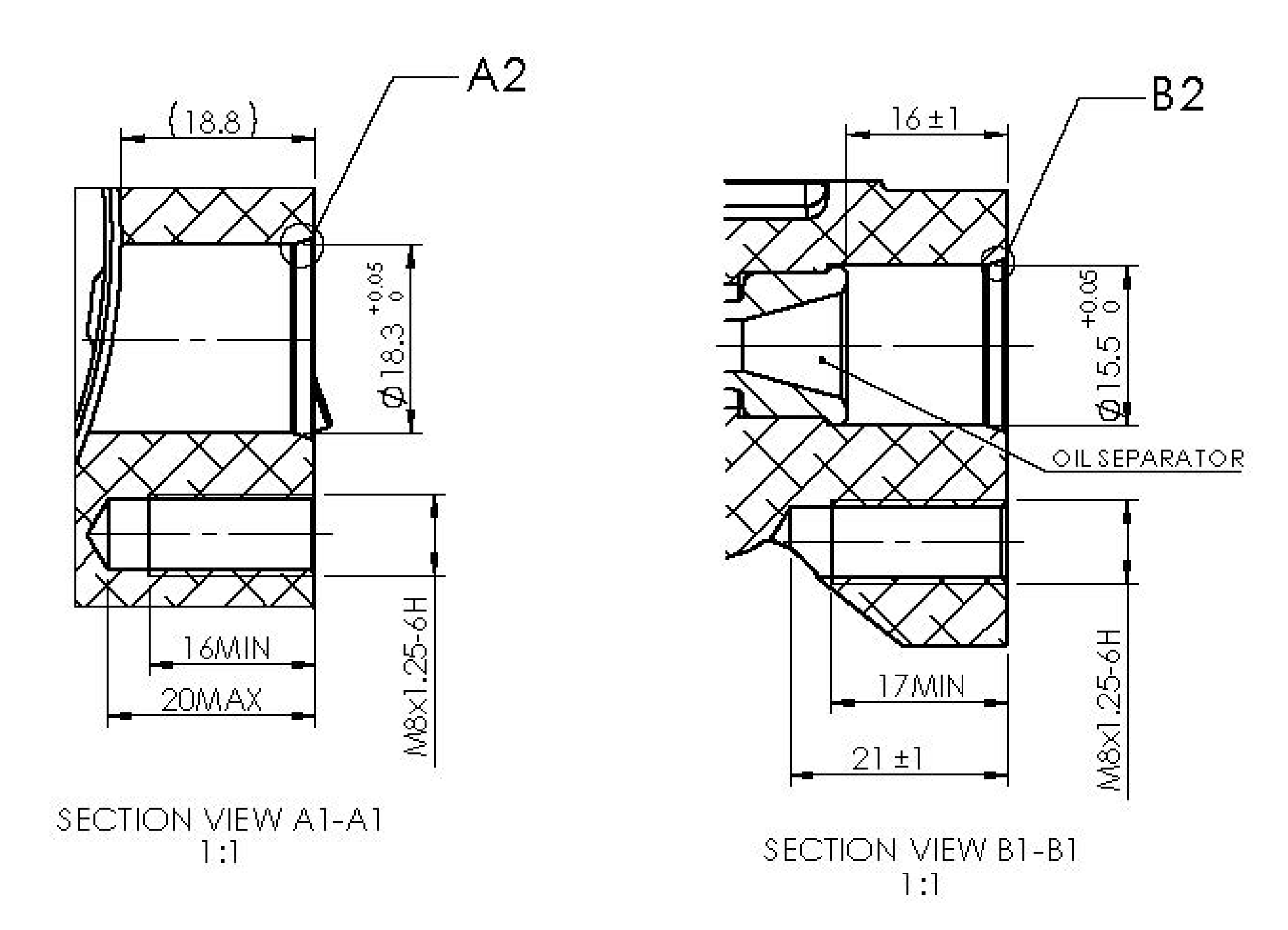

Fig. 6 Section View

The system integrator should perform 100% online checks for leakage of the refrigerant system. This should consist of the following steps:

- Add pressurized dry air to the assembled system through the service ports for a set amount of time. Confirm a minimum pressure is reached.
- Close off the air inlet and monitor the system pressure for decay. Confirm pressure loss does not exceed a maximum value.
- Vacuum the system through the service ports for a set amount of time. Confirm a minimum vacuum level is reached.
- Close off the vacuum inlet and monitor the system pressure for increase. Confirm vacuum loss does not exceed a maximum value.
- Only charge refrigerant to the system if the above checks are passed.
- Confirm system operates and performs normally.

TCCI cannot make recommendations for the specific values to be used for the leakage check because they are highly dependent on the system design, equipment and time periods used.

4.6 Electrical Interfaces

The compressor contains an integrated inverter to convert DC input to 3 phase AC output for the brushless motor.

The compressor must be grounded to the vehicle ground. See chapter 5.7, "Protective Earth (Grounding to Chassis)" on page 11.

For EMC, see chapter 4.10, "Electromagnetic Compatibility" on page 10.

A properly sized fuse (or other sufficient current interruption device) shall be used on the positive voltage supply line for the low voltage and high voltage power inputs. The fuses should be sized such that they do not open the circuit in case of continuous operation at the compressor maximum current and handle inrush current. The fuse should be sized to ensure the electrical harnesses are protected in case of short circuit. See chapter 5.5, "High Voltage Short Circuit Protection" on page 11.

For connector interfaces and pinouts, see the figure below:

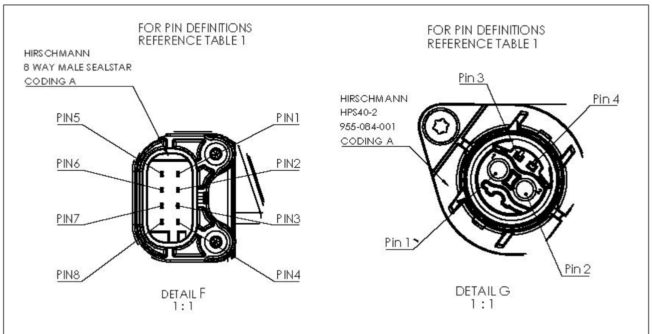

Fig. 7 Connector interfaces

Connector Details			
Compressor Connector	**PIN**	**Definition**	**Mating Connector**
Signal (See Detail F)	1	DC(+) 9 V – 32 V	Hirschmann Housing 8 Way 1.2 Sealstar 805-031-541, Coding A Select MLK 1.2 Terminals and Wire Seals from Kostal DWG 1030489 4-1
	2	LIN	
	3	GND	
	4	Reserved	
	5	Reserved	
	6	HVIL	
	7	HVIL	
	8	Reserved	
Power (See Detail G)	1	DC(+)	Hirschmann Subassembly 807-655-501, Coding A Configure Remaining Assembly per Hirschmann DWG 807-655-…00 TCCI Wire Assembly, P/N 311340341, May instead be used (6 mm^2, 5 m Wire, Coding A)
	2	DC(-)	
	3	HVIL Shunt	
	4	HVIL Shunt	

Table 1: Connector Interfaces

The connectors are rated for IP6K9K dust and water protection. It is necessary to ensure the wire harnesses are made according to the electrical connector supplier's specifications to ensure that the IP6K9K performance is achieved. This may require the use of plugs for unused terminal positions, wire seals, terminal position locks, connector position locks, and a connector back side shell or boot. To prevent water migration through the wire harness, all connectors on the harness should be dust and water resistant. The connectors have connector position assurance (CPA) locks. The system integrator should perform 100% online checks that CPA locks are in the mated position during system assembly.

Wire harnesses should be capable of handling maximum current at maximum temperature. Wire harnesses should be suitable for the usage environment. Terminal plating should be selected to avoid oxidation due to fretting from vibration.

For serial data communication, see the serial data (CAN or LIN) Controls Specification for TCCI Electric Compressors. System integrator should validate serial data communication details before building first prototypes. Details to verify include data protocol, baud rate, addressing, message format, termination resistance and pinout.

The compressor does not incorporate a low voltage nor high voltage pre-charging circuit.

4.7 Lubricating Oil

The electric compressor must be used with an oil that meets the following criteria:

- Isolation Resistance: The motor in the compressor is exposed to refrigerant and oil. Therefore, isolation resistance of the oil must be high enough to prevent the possibility of excess electrical conduction. This is a safety requirement.
- Lubrication: The compression mechanisms and other friction surfaces must be properly lubricated to prevent damage or premature wear.
- Material Compatibility: The oil must not react with the refrigerant, metals and elastomers of the refrigerant system.

Many oils on the market do not meet all the above criteria. Even oils of the same type (for example, PAG 46) are not equivalent in isolation resistance and material compatibility. It is critical that only oils that are approved by TCCI are used in the refrigerant system with the electric compressor. This includes service oil and oil in other components of the same refrigerant system.

POE and PAG oils are not compatible in any amount. Small amounts of contamination can form acids that can lead to short circuit failure of the compressor motor and other system components.

The compressor is pre-filled with the type and quantity of oil listed below:

- PS-R1 PAG 120 +20/-0 cc

It is not feasible to cleanse the compressor of oil without disassembly. Oil quantity may be reduced or increased by pouring oil at the suction port.

Refrigerant charge and oil charge determination testing shall be done to establish proper lubrication. Oil trapping testing shall be done to ensure proper lubrication of the compressor at all operating conditions. Of particular concern are low refrigerant and oil flow rate conditions, such as low compressor speed combined with low heat load. Oil circulation rate and oil trapping shall meet TCCI criteria. Testing may be done by TCCI, with cost, timing and availability considerations.

4.8 Refrigerant Related Capabilities

The following validation is performed by TCCI:

Test	Description	Note
Variable Speed Cycling	Cycle on, accelerate to max speed, cycle off, repeat 35,000 cycles.	Stresses capacitors, transistors, shaft, crank pin.
Slow Speed Ramping	Speed sweep at high load to confirm no resonance-related fatigue.	Stresses shaft and bearings.
High Speed, High Current	Continuous operation at max load conditions.	Stresses all mechanical and electrical parts.
Low Speed, High Inverter Temp	High load at low speed with hot suction gas.	Thermal stress for electronics and mechanical.
High Pressure Ratio	High discharge pressure at low suction pressure.	Stresses scroll, crank pin, bearings.
Liquid Slugging	Liquid in compressor during operation.	Stresses discharge reed and scroll, confirms control algorithm.
Accelerated Life Test	Expose a compressor sample to various stresses to simulate a full life of operation.	Stresses entire compressor.

Table 2: Validation criteria

Validation criteria: No failures. Pre- to post-test comparison: performance degradation ≤ 10%, power consumption increase ≤ 5%, COP decrease ≤ 5%.

4.9 Noise and Vibration from the Compressor

As mentioned in chapter 4.4, "Mounting Requirements" on page 6, the compressor should be mounted in a way that vibrations are isolated from transferring to the chassis and other components that may transfer vibrations to the end user. Additionally, vibration should not be allowed to transfer to non-stiff surfaces that may act like a speaker and transform vibrations into airborne noise. Large flat surfaces are a particular concern.

Vibration and pressure pulsations from the compressor will transfer to the other refrigerant system components, which then can lead to noise and vibration being transferred to the user. Thus, it is important to also isolate the other refrigerant system components. It is recommended to isolate every heat exchanger as well as the refrigerant plumbing attachments to chassis. It is recommended that the plumbing that attaches to the compressor have rubber portions of sufficient length, softness and low tension to allow it to handle relative movement of parts and dampen pulsations and vibrations.

4.10 Electromagnetic Compatibility

Electromagnetic compatibility (EMC) performance is highly dependent on the system integration. Regardless of compressor component EMC test results, significant EMC issues can be created by improper system integration.

Some EMC requirements only apply at the system level and must be tested at the system level.

The high voltage connector has a 360-degree ground shield that should be connected to the high voltage cable shield and connected to chassis ground at both ends. The compressor HV connector shield is connected to the compressor housing, which in turn shall be connected to ground by the system integrator. The system integrator shall ground the non-compressor HV connector shield. This creates a fully shielded HV harness, which is important for favourable EMC performance.

The HV harness shall not be oriented in a similar direction as the harnesses of EMC-sensitive components such as radios and data busses.

4.11 Sensors

The compressor integrates voltage, current and temperature sensors. The voltage and current sensors are on the motor power circuits, not the signal circuits. Compressor sensor readings are communicated to the system. Compressor temperature sensing is a measure of the internal temperature of the compressor electrical housing and is subject to internal heat generation. It is used for protection of the internal power electronics and should not be used by the system for any other purpose. The reading of the sensor may not be accurate at temperatures below 0 degC.

It is necessary to have sensors to detect low side refrigerant pressure (compressor in or suction) and high side refrigerant pressure (compressor out or discharge). Refrigerant pressures cannot be detected by the compressor and need to be kept within the compressor durable operating limits by the system controls. Additionally high side pressure needs to be regulated by the system to prevent over pressurization of the refrigerant system high side. It is possible to use pressure switches (on/off or three level) but it is highly recommended to use pressure measuring devices.

It is highly recommended to have discharge refrigerant temperature sensing. This enables detection of mechanical overheat of the compressor which may result from otherwise hard to detect causes such as low charge and expansion device dysregulation. It is considered essential for heat pump operation. Combined discharge pressure and temperature sensors are available in the market.

Evaporator freeze protection shall be implemented by the system. This can be done by air side temperature (thermistor or fin probe) or by refrigerant low side temperature or pressure sensing. Each has pros and cons. However, it is necessary to prevent evaporator freezing to maintain cooling performance and so that the compressor does not get continuously flooded with unevaporated (liquid) refrigerant.

5 High Voltage Specifications

This section defines the specifications of the high voltage (greater than or equal to 60 V DC) circuit.

5.1 High Voltage Safety

The system integrator and vehicle manufacturer are responsible for ensuring vehicle integrity and safety in the application. The system integrator and vehicle manufacturer shall ensure the vehicle, with the compressor integrated into it, complies with relevant regulations and industry safety standards. Only production approved compressor assemblies shall be used outside of development work.

5.2 High Voltage Pre-Charge Requirements

The high voltage compressor requires an external pre-charge resistance to protect the internal high voltage capacitors. The compressor X capacitance and minimum pre-charge voltage ramp rate are specified in the specifications summary table.

5.3 High Voltage Interlock Circuit (HVIL)

The compressor implements a passive high voltage interlock (HVIL) circuit. There are HVIL pins in the low voltage connector that are connected to the HVIL pins in the high voltage connector. The mating HV connector contains a jumper for the HVIL pins, forming a complete circuit between the HVIL pins in the LV connector when the HV connector is mated. The compressor does not monitor the HVIL circuit, therefore it cannot act based on the status of the HVIL circuit. The compressor will operate normally regardless of HVIL status. It is up to the vehicle to monitor the HVIL circuit and take appropriate action as needed.

If the HV system does not utilize an HVIL, it should have alternate means of detecting an open circuit in the HV system and de-energizing the circuit.

5.4 High Voltage Isolation Monitoring

The vehicle manufacturer shall monitor isolation resistance between high voltage circuits and low voltage circuits (including chassis ground). If isolation resistance is detected below a safe threshold, the high voltage system shall be de-energized by the vehicle.

5.5 High Voltage Short Circuit Protection

The system integrator or vehicle manufacturer shall provide a current limiting device for short circuit protection of the high voltage supply circuit on the positive input. The fuse should be sized such that it does not open the circuit in case of continuous operation at the maximum compressor current and handle in-rush current. The fuse should be sized to ensure the electrical harnesses are protected in case of short circuits.

5.6 High Voltage Discharge

The compressor will stop the motor when commanded to do so. When high voltage input is disconnected, the compressor HV circuit will passively discharge per the specification's summary table. Unless otherwise stated, the compressor does not actively discharge the HV circuits. The system integrator or vehicle manufacturer shall provide an active high voltage discharge feature if active discharge of the high voltage bus is required. If communication between the compressor and master ECU is lost; the compressor will stop operation of the motor in case the HV bus needs to be discharged by the system.

5.7 Protective Earth (Grounding to Chassis)

It is necessary to maintain system safety in the event of high voltage short to low voltage or non- electrical parts. Thus, the system integrator shall ensure that the compressor is grounded to the chassis with two independent ground paths, each with a resistance of less than 0.1 Ohm. If vibration dampers (rubber isolators) are used, the system design shall ensure these do not interrupt the ground paths.

6 System Integration Validation and Process Controls Recommendations

This section describes recommendations for system and vehicle integration validation and process controls related to potential failure modes. These failure modes are based on common usages and are not comprehensive for any specific application. **System and vehicle integration safety is the responsibility of the system or vehicle integrator.** The recommendations in this section are for the purposes of consideration by the integrator. Specific test procedures and criteria are the responsibility of the integrator as are any required hazard prevention actions. The system integrator should complete a DFMEA, PFMEA, DVP and Control Plan with the participation of TCCI as relevant.

6.1 System CAD Packaging and GD&T Studies

The system integrator should perform 3D and 2D CAD and GD&T studies of the compressor and the surrounding parts. Some of the items to verify are proper mating of attached parts, clearances to nearby non-attached parts (including in dynamic conditions) and considerations for servicing and assembling the system.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Mounting Surface; Compressor to Rubber Isolator; Compressor to Refrigerant Plumbing.	Excessive loss of refrigerant (potential regulation violation).	Mounting surfaces do not mate, leaving a gap, which causes housing deformation and breakage when fasteners are tightened, creating a leak. Refrigerant sealing surfaces are not properly mated, creating a leak.	Ensure part mating surfaces properly mate; ensure fasteners align; ensure fasteners are of correct size and torque; ensure clearance to nearby parts. Implement process controls for 100% refrigerant system leak check prior to charging.
Compressor to Mounting Surface; Compressor to Rubber Isolator; Compressor to Nearby Parts.	Excessive noise or vibration transfer.	Compressor or refrigerant system components are not properly vibration isolated from other parts.	Ensure all refrigerant system components are vibration isolated from nearby parts Avoid large surface area, low stiffness surfaces near the compressor.
Compressor to Ground Strap; Compressor to Electrical Connectors.	Loss of HV safety (potential safety hazard). Loss of many functions, including cooling performance and communication Failure to comply with ECE R100 and FMVSS 305.	Electrical connectors do not mate. Wire harness interferes with nearby parts. Wire harness failure due to excessive strain.	Ensure correct connectors are specified; ensure correct pinout of connectors; ensure wire harness routing avoids interference; ensure wire harness chafing protection; ensure wire harness strain relief. Implement process controls for 100% check for connection of ground strap, electrical connectors CPA Implement redundant HV ground path.

6.2 System Trial (Prototype) and Builds

The system integrator should determine (either through FEA or hammer test) the stiffness (first order resonant frequency) of the mounting surface for the compressor and the surrounding parts. Generally, it is recommended that the first order resonant frequency be greater than or equal to 365 Hz to prevent it from being excited by the compressor vibration energy.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to System/Vehicle.	Excessive loss of refrigerant (potential regulation violation).	Defective refrigerant system components Damage to seals during assembly. Improper fastening of refrigerant system joints.	Perform 100% leak check on the assembled refrigerant system before refrigerant charging (including positive pressure decay check and vacuum decay check).

6.3 Mounting Surface Stiffness Study

The system integrator should determine (either through FEA or hammer test) the stiffness (first order resonant frequency) of the mounting surface for the compressor and the surrounding parts. Generally, it is recommended that the first order resonant frequency be greater than or equal to 365 Hz to prevent it from being excited by the compressor vibration energy.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Mounting Surface; Compressor to Nearby Parts.	Excessive noise or vibration transfer.	Compressor mounting surface or nearby parts are not sufficiently stiff.	Ensure compressor mounting surface and nearby parts are sufficiently stiff.

6.4 Refrigerant Plumbing Interface Validation

The system integrator should specify the refrigerant plumbing to compressor interface such that it meets the requirements of the application. The sealing interface should be robust against damage during assembly and service. It should meet the refrigerant leakage requirements throughout the system life for all system operating conditions. The materials used should be compatible with the refrigerant, compressor oil, fluorescent dye and any other fluids in the system. Refrigerant leakage prevention depends on the compressor portion of the joint, the plumbing portion of the joint, the seal, and the fastener, as well as the design, manufacturing and assembly of them. As such, the system integrator must validate the integrated system leakage, even if the design is an existing one from TCCI.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Refrigerant Plumbing.	Excessive loss of refrigerant (potential regulation violation).	Insufficient design of the refrigerant sealing interface. Ineffective process controls for refrigerant sealing interface assembly Ineffective process controls for refrigerant system leak check prior to refrigerant charging.	Refrigerant plumbing interface design shall be specified by or confirmed by system integrator. Validate for robustness to vibration, corrosion, thermal cycling, and other environmental factors. Validate for material and fluid compatibility Implement system/vehicle assembly process controls for plumbing joint assembly Implement system/vehicle assembly process controls for 100% refrigerant system leak check prior to charging (including positive pressure decay check and vacuum decay check).

6.5 Refrigerant System Integration Validation

The system integrator is responsible for integrating the various refrigerant system components. The materials used should be compatible with the refrigerant, compressor oil, fluorescent dye and any other fluids in the system. It is considered by TCCI to be necessary to have sensors to detect low side refrigerant pressure (compressor in or suction) and high side refrigerant pressure (compressor out or discharge). Refrigerant pressures cannot be detected by the compressor and need to be kept within the compressor durable operating limits by the system controls. Additionally high side pressure needs to be regulated by the system to prevent over pressurization of the refrigerant system high side.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Refrigerant Pressure Sensors.	Compressor seizure Excessive loss of refrigerant (potential regulation violation).	Missing, failed or improperly reading high pressure sensor Missing, failed or improperly reading low pressure sensor. Operation of compressor at pressures that exceed the durable operating limits Discharge pressure exceeding high pressure relief valve opening pressure, leading to loss of refrigerant and oil.	Operating refrigerant pressure limits validation High side refrigerant pressure cut-out test. Low side refrigerant pressure cut-out test.
Compressor to Refrigerant System.	Inadequate cooling or heating performance Compressor seizure. Loss of cooling or heating performance.	Inadequate capacity of system components Excessive pressure drops in refrigerant system. Lack of lubrication due to inadequate oil circulation.	Refrigerant charge determination. Oil charge determination Validate for robustness to vibration, corrosion, thermal cycling, and other environmental factors. Validate for material and fluid compatibility Implement system/vehicle assembly process controls for plumbing joint assembly Oil trapping test.

6.6 System Communication and Controls Tests

The system integrator should verify that all communication and controls features interact correctly between the compressor and system. Of particular concern are serial data functions (sleep and wake, communication) as well as safety and protection functions. The compressor does not have information about the refrigerant system operating conditions such as refrigerant pressure and temperatures. It is up to the system controls to keep the compressor from operating outside of its durable operating limits.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Serial Data Bus.	Loss of many functions, including cooling performance and communication.	Incorrect baud rate, incorrect termination resistance, incorrect pinout, incorrect addressing.	Serial communication validation with full system data bus. Verify CAN or LIN database file.
Compressor to System Controls.	Loss of many functions, including cooling performance Compressor seizure.	Missing protection functions. Missing safety functions Software bugs.	System controls validation including operating refrigerant pressure limits, evaporator temperature control, oil trap cycling strategy.

6.7 System Environmental Tests

The system integrator should verify the system is robust to the usage environments and stresses. Environmental and usage tests include corrosion, vibration, thermal stress, and chemical resistance. Of particular concern are the following failure modes during or after the tests.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to Ground Strap; Compressor to Electrical Connectors.	Loss of HV safety (potential safety hazard). Loss of many functions, including cooling performance and communication Failure to comply with ECE R100 and FMVSS 305.	Electrical connectors do not mate. Wire harness interferes with nearby parts. Wire harness failure due to excessive strain.	Ensure use of electrical connector wire seals as needed. Ensure unused electrical connector wire holes have plugs as needed. Ensure use of electrical connector rubber boots as needed. Ensure wire harness is made per electrical connector and terminal supplier's recommendations. Ensure mating parts do not have galvanic corrosion issues. ECE R100 and FMVSS 305 compliance testing Electrical system safety validation.
Compressor to Low Voltage Electrical System.	Loss of many functions, including cooling performance and communication. Loss of communication of modules on the data bus.	Many	Continuous monitoring of data bus for faults and communication failures Electrical system safety validation.
Compressor to Refrigerant Plumbing.	Excessive loss of refrigerant (potential regulation violation).	Insufficient design of the refrigerant sealing interface. Ineffective process controls for refrigerant sealing interface assembly. Ineffective process controls for refrigerant system leak check prior to refrigerant charging.	Refrigerant plumbing interface design shall be specified by or confirmed by system integrator. Validate for robustness to vibration, corrosion, thermal. Refrigerant plumbing interface design shall be specified by or confirmed by system integrator. Validate for robustness to vibration, corrosion, thermal.

6.8 System Electrical Tests

The system integrator should verify the system is robust to the electrical stresses including under voltage, over voltage, over current, short to ground, short to battery, jump start, uncontrolled voltage generation, current ripple, voltage ripple and resonance. Testing for failure modes and regulatory compliance are also required, including crash testing. Of particular concern are the following failure modes during or after the tests.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to High Voltage Electrical System.	Loss of HV safety (potential safety hazard). Loss of many functions, including cooling performance and communication Failure to comply with ECE R100 and FMVSS 305. Loss of communication of modules on the data bus.	Many	Continuous monitoring of HV system isolation resistance Continuous monitoring of HV system for open circuit Continuous monitoring of HV system for short circuit. ECE R100 and FMVSS 305 compliance testing Electrical system safety validation.
Compressor to Chassis Ground (Protective Earth).	Loss of HV safety (potential safety hazard). Loss of many functions, including cooling performance and communication Failure to comply with ECE R100 and FMVSS 305.	Many, especially interruption of ground path due to use of vibration isolators, insufficient current capability of ground path, excessive resistance in ground path.	Continuous monitoring of HV system isolation resistance Continuous monitoring of HV system for open circuit Continuous monitoring of HV system for short circuit. ECE R100 and FMVSS 305 compliance testing Electrical system safety validation.
Compressor to Low Voltage Electrical System.	Loss of many functions, including cooling performance and communication Loss of communication of modules on the data bus.	Many	Continuous monitoring of data bus for faults and communication failures Electrical system safety validation.

6.9 System Electromagnetic Compatibility Tests

The system integrator should verify the system meets requirements for electromagnetic compatibility (EMC), including radiated emissions, conducted emissions, radiated immunity, conducted immunity and related tests. There are many EMC requirements that apply to the system and may be affected by interaction of multiple devices. Compliance with some regulations is the responsibility of the system or vehicle integrator which must perform testing at the system or vehicle level. Of particular concern are the following failure modes during or after the tests.

Interface(s)	Potential Failure Mode(s)	Failure Cause(s)	Recommended Validation or Process Controls
Compressor to High Voltage Electrical System.	Loss of HV safety (potential safety hazard). Loss of many functions, including cooling performance and communication Failure to comply with ECE R100 and FMVSS 305. Loss of communication of other modules on the data bus.	Many	Continuous monitoring of HV system isolation resistance Continuous monitoring of HV system for open circuit Continuous monitoring of HV system for short circuit. ECE R100 and FMVSS 305 compliance testing Electrical system safety validation.
Compressor to Low Voltage Electrical System.	Loss of many functions, including cooling performance and communication. Loss of communication of other modules on the data bus.	Many	Continuous monitoring of data bus for faults and communication failures Electrical system safety validation.

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PERFORMANCE AND DURABILITY COUNT

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