Isolation Check – Basic Procedure

The goal of performing an isolation check or insulation test (the terms are used interchangeably here) is to verify that there is no path between any high voltage source to chassis ground.
The primary way of testing this specification is to use a voltmeter that is capable of delivering voltage through a circuit that mimics the high voltage current stored and used by the vehicle.

To perform this test, set the multimeter to “insulation test” and position the leads according to the manufacturer specifications for this kind of test

Be sure to check the meter fuse be performing the insulation test with the two leads touching each other. The meter should read 0.0Ω

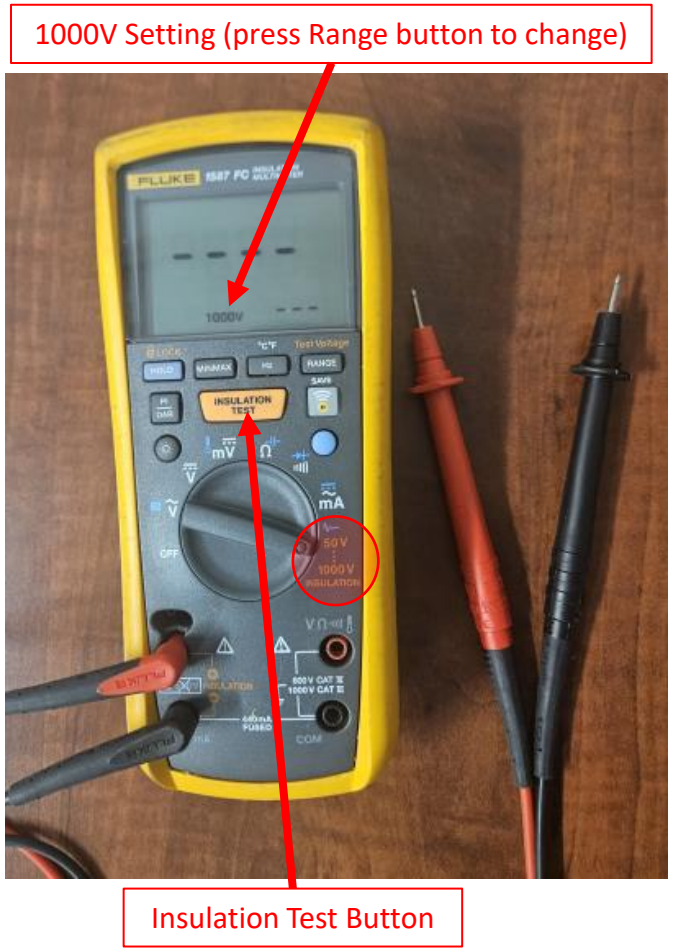
Contact the high voltage component to be tested in accordance with the recommendations in this guide with the red lead and an unpainted chassis ground with the black lead.

While wearing appropriate PPE, press the button on the meter to initiate the test

Record the test measurements and compare with the recommendations in this guide

In general, isolation (insulation) measurements should exceed 700Ω per volt. Assuming an upper limit of approximately 750Vdc, the ***absolute minimum*** measurement should be 525KΩ, but a threshold of 1MΩ has been established as the minimum operating resistance. Nominal isolation resistance is usually around *2.2**GΩ*** for most components.

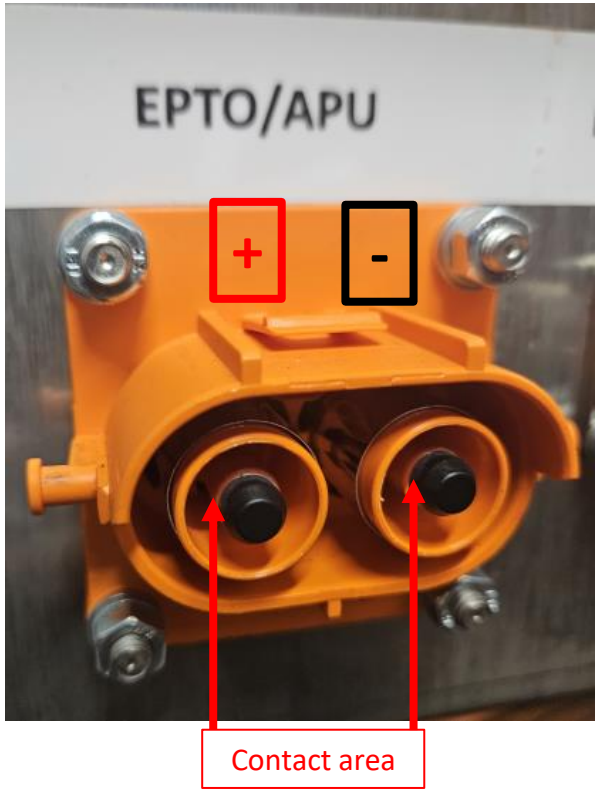
In general, it is best to disturb the components as little as possible in order to prevent masking an intermittent connection or fault that may be more difficult to locate later on



Localizing the Source of the Ground Fault

Once it has been established that an isolation fault exists on the vehicle, the next step will be to determine the source

1. Remove the EPTO/APU high voltage connector from the PDU port
2. With the black lead of the meter contacting the nearest bonding point and the red lead contacting the EPTO/APU **positive** port in the PDU, perform an isolation check with the meter set to 1000V
    1. If the meter reads greater than 1MΩ, AUX1 through AUX7 **positive** circuits can be eliminated as the source of the isolation fault
3. With the black lead of the meter contacting the nearest bonding point and the red lead contacting the EPTO/APU **negative** port in the PDU, perform an isolation check with the meter set to 1000V
    1. If the meter reads greater than 1MΩ, AUX1 through AUX7 **negative** circuits can also be eliminated as the source of the isolation fault



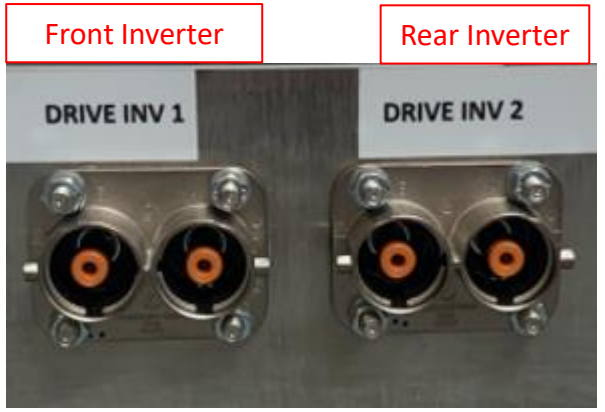
If the meter reads less than 1MΩ when conducting the above test, disconnect the AUX1 connector and repeat the test at the EPTO/AUX port

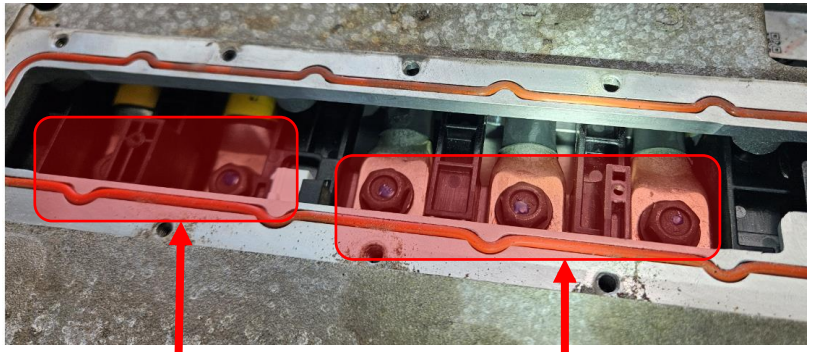
1. Continue disconnecting each of the AUX1-AUX7 connectors one at a time, repeating the test each time another connector is removed until the isolation value is greater than 1MΩ
    1. Once the meter reads greater than 1MΩ, the last connector that was removed is the likely circuit causing the isolation fault – diagnose that circuit using this guide until a component is determined to be the cause

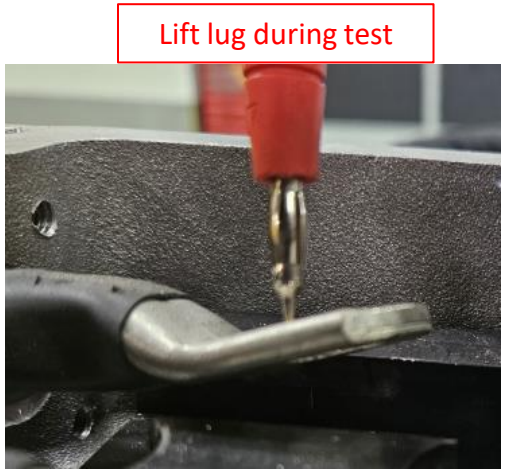
- ***Intermittent isolation faults can be caused by stray pieces of shielding and improper cable assembly techniques. For intermittent isolation faults, wiggling the connectors and cables during the isolation test is recommended if the source is not located in the course of these static inspection procedures.***

Isolation Check – Drive Inverter

1. Disconnect high voltage cable from the “Drive Inv X” port of the PDU corresponding to the inverter being tested
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, the cable can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the two cables from the five inverter terminal lugs and repeat the test on each the cables individually.
        1. Perform the insulation test on the cable by contacting the metallic lug of the cable with the red lead while holding the lug away from the inverter terminal block. Ensure the black lead of the multimeter is contacting an unpainted part of the chassis
        2. Perform the insulation test with the multimeter
        3. If either cable insulation measurement is below 1MΩ, replace that cable
4. Perform the insulation test on the inverter itself by contacting the five inner terminals of the high voltage terminal block one at a time with the red probe and an unpainted section of the chassis with the black probe
5. If any inverter terminal measures below 1MΩ, replace the inverter

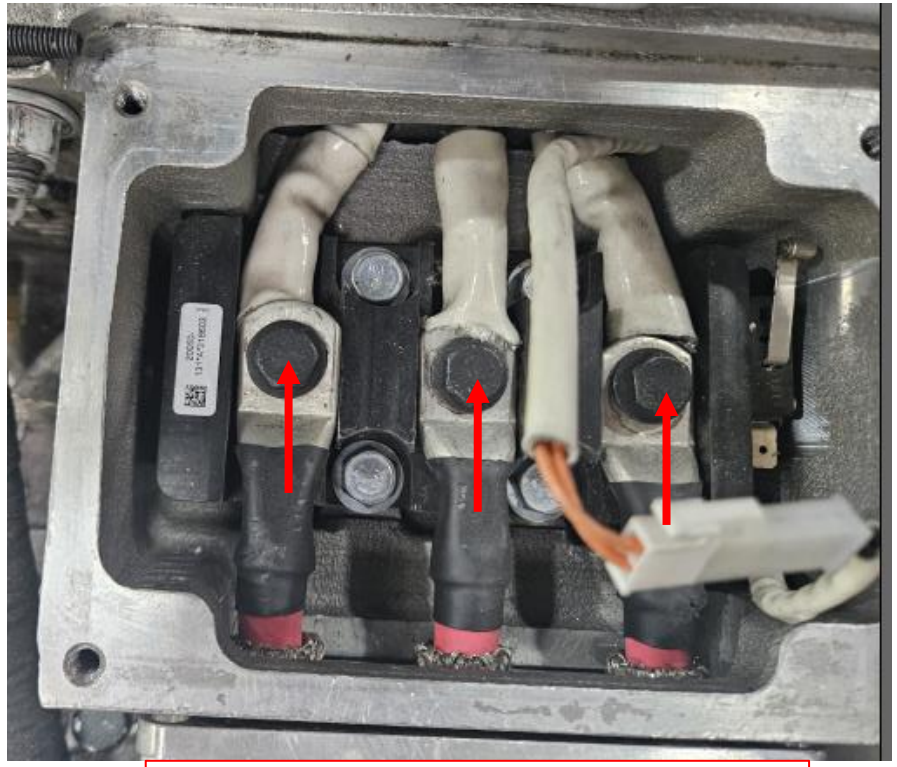




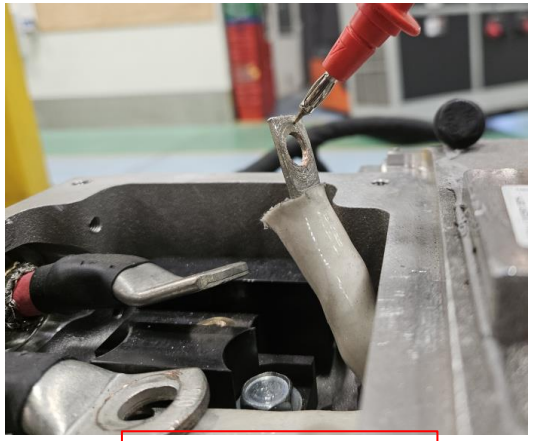


Isolation Check – Propulsion Motor

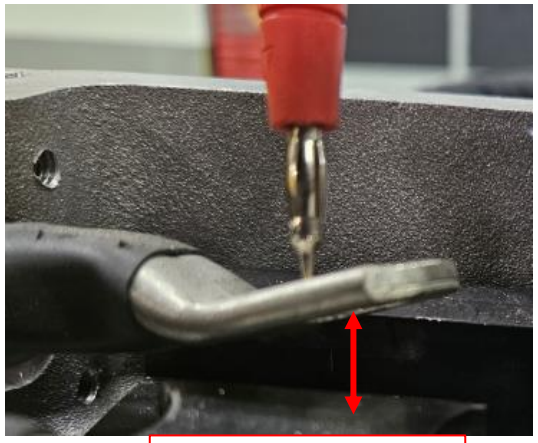
1. Remove propulsion motor electrical box cover to expose high voltage lugs
2. Before disturbing any cables or lugs, perform the insulation test, contacting the tops of the three bolts with all cables still in their original positions
    1. If all three bolts measure above 1MΩ, the issue is not in the motor or in the phase cables
    2. If any of the three bolts measure less than 1MΩ, remove the three bolts securing the phase cable lugs to the motor terminal block
3. Lift the high voltage phase cable lug away from the terminal block and contact the phase cable lugs with the red probe of the multimeter
    1. Conduct the insulation test
    2. If a measurement below 1MΩ, remove the opposite side of the phase cable from its inverter and repeat the test on the cable alone
        1. Replace the phase cable if insulation resistance is less than 1MΩ
4. Repeat this test on each of the three terminals on the propulsion motor block
    1. Replace the propulsion motor if any phase winding measures below 1MΩ



Motor winding lug bolts – place probes in location indicated by arrows



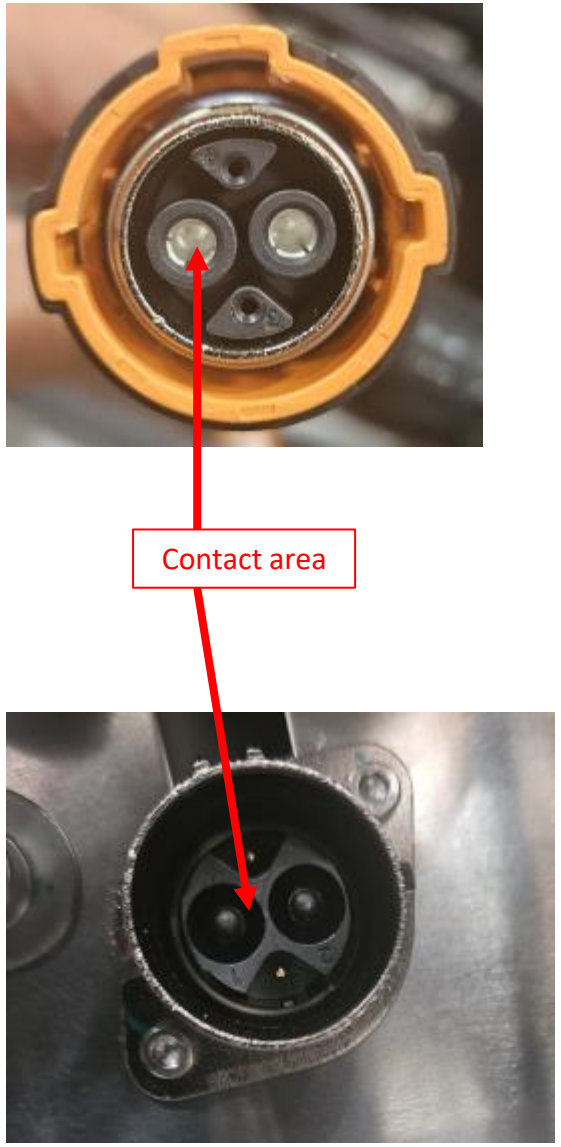
Motor winding lug



Lift lug during test

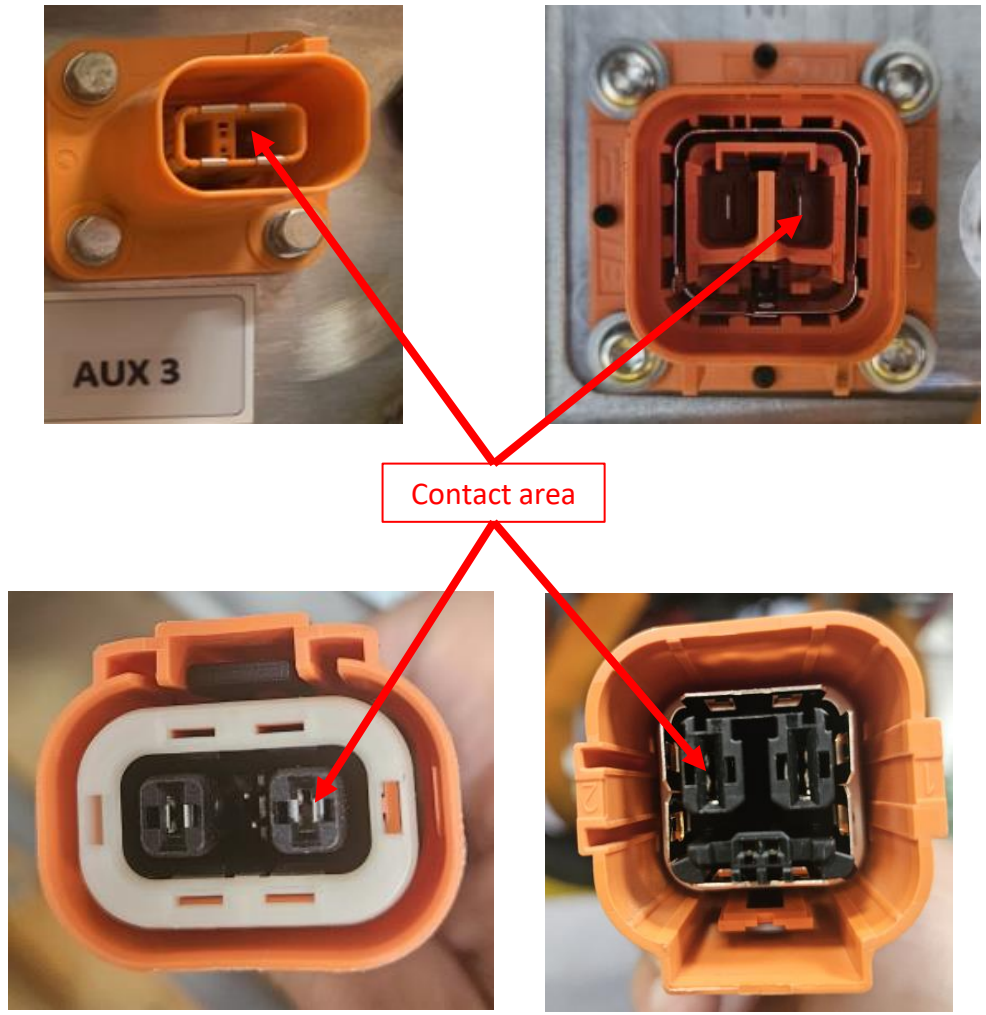
Isolation Check - Chiller

1. Disconnect high voltage cable (110821) from the AUX 7 port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, both the cable and the chiller can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the chiller as well and repeat the test on both the cable and the chiller converter individually.
        1. Perform the insulation test on the cable by again contacting the inner metallic terminal with the red lead while the black lead is contacting an unpainted part of the chassis
        2. Perform the insulation test on the chiller itself by contacting the inner terminals of the high voltage connector of the compressor
4. If either the cable or the chiller measure below 1MΩ, replace the component



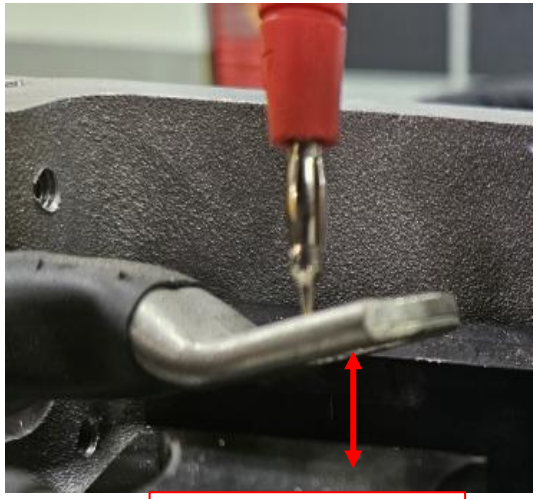
Isolation Check – DCDC Converter

1. Disconnect high voltage cable (107159) from the AUX 3 port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, both the cable and the DCDC Converter can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the DCDC Converter as well and repeat the test on both the cable and the DCDC converter individually.
        1. Perform the insulation test on the cable by again contacting the inner metallic terminal with the red lead while the black lead is contacting an unpainted part of the chassis
        2. Perform the insulation test on the DCDC Converter itself by contacting the inner terminals of the high voltage connector of the compressor
4. If either the cable or the DCDC Converter measure below 1MΩ, replace the component



Isolation Check – ePTO (Part 1)

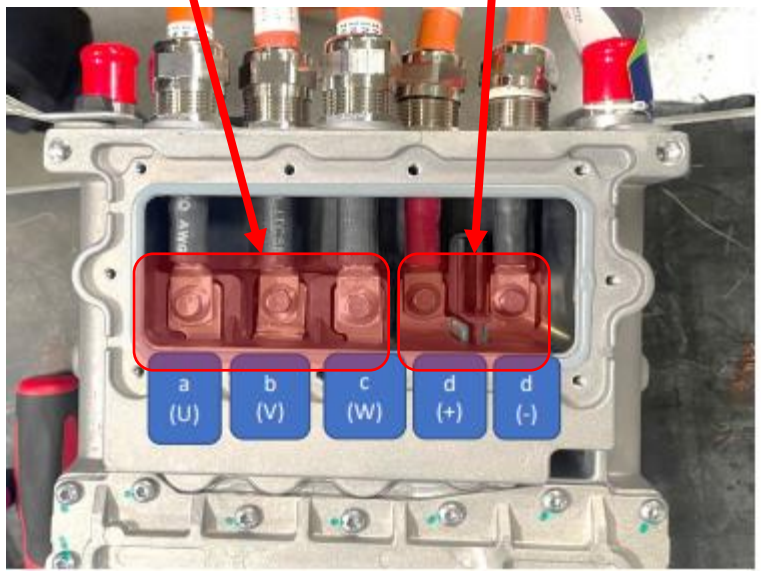
1. Disconnect high voltage cable (110429) from the EPTO/APU port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, the cable can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, remove the two DC Link cable lug bolts from the ePTO inverter and repeat the test on the cable alone while lifting the lugs away from the inverter terminal block
        1. Replace the cable if the measurement is below 1MΩ
4. Remove high voltage phase cable lugs from the ePTO inverter
5. Perform the insulation test on the ePTO inverter phase cables by contacting the three lugs one at a time with the red lead while the black lead is contacting an unpainted part of the chassis
        1. If any of the three phase cable lugs measure below 1MΩ, replace that cable
6. Perform the insulation test on the five inverter terminals with the five cables removed by contacting the metal terminals on the inverter terminal block
    1. If any of the five terminals measure less that 1MΩ, replace the inverter



Lift lug during test

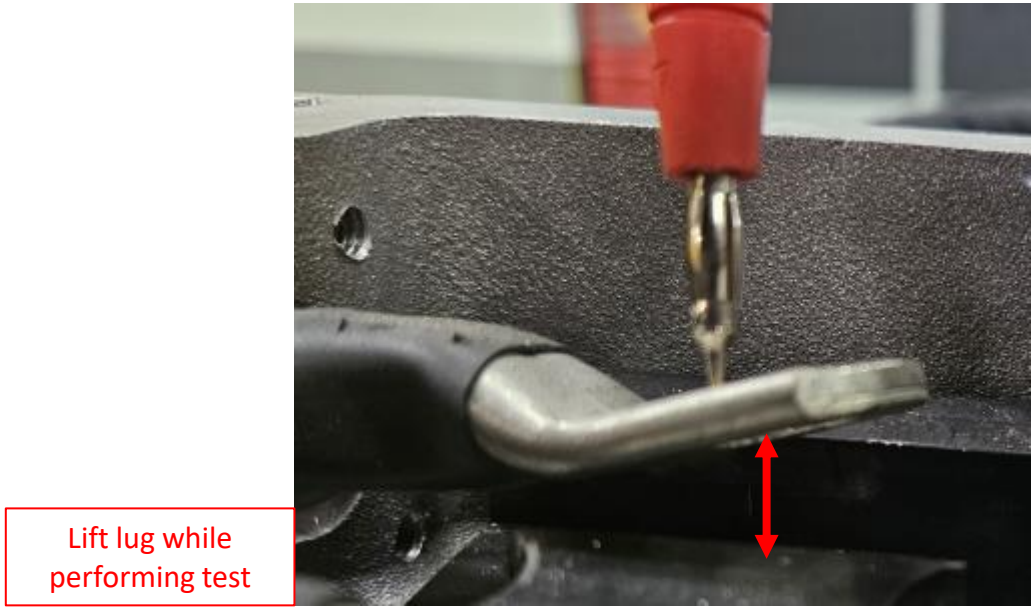
Motor Phase Cables

DC Link Cables



Isolation Check – ePTO (continued)

7. Using a multimeter set to “Insulation Test” at 1000V, contact each of the three lugs on the inverter side of the HV phase cables (110426, 110427 and 110428) with the red lead and chassis ground with the black lead one at a time
8. Press the measurement button and perform the test.
    1. If the each of the measurements are above 1MΩ, the cables and motor can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the ePTO motor and repeat the test on the cable individually
        1. Remove the cable lug bolt from the motor electrical junction box and lift the cable lug away from the motor terminal block while performing the insulation test
        2. Replace the cable if the measurement is below 1MΩ
9. Perform the insulation test on the ePTO motor by contacting the inner metallic terminals with the red lead while the black lead is contacting an unpainted part of the chassis
        1. Perform the insulation test on the motor windings by contacting the inner terminals of the motor winding lugs
            1. If the motor winding lugs measure below 1MΩ, replace the motor

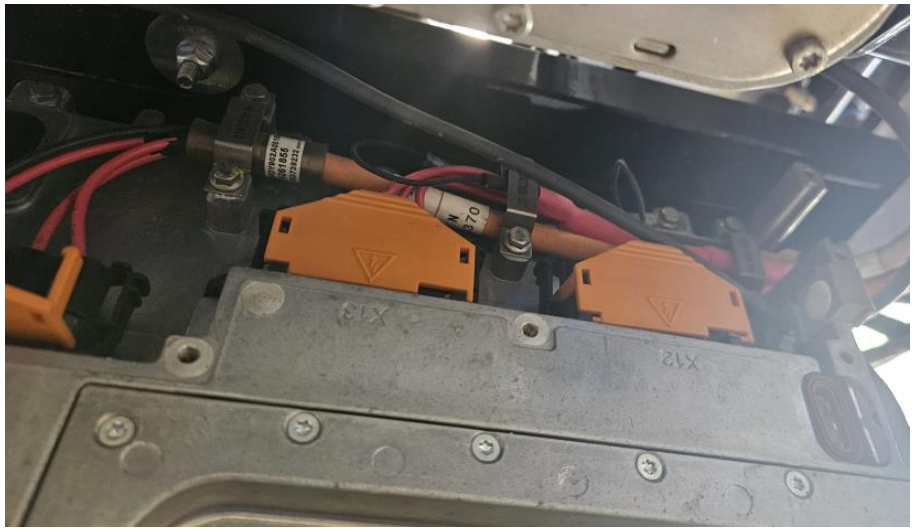


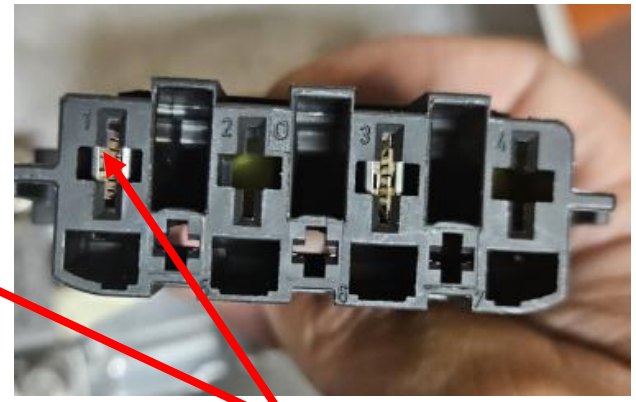
Isolation Check – Air Conditioning Compressor

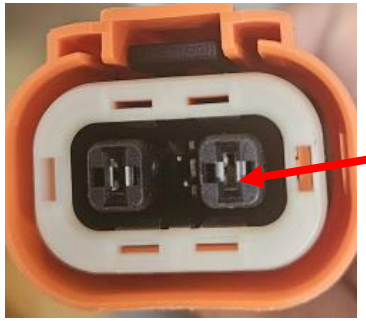
1. Disconnect high voltage cable (107154) from the AUX 1 port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, both the cable and the compressor can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the compressor as well and repeat the test on the cable individually.
        1. Perform the insulation test on the cable by again contacting the inner metallic terminal with the red lead while the black lead is contacting an unpainted part of the chassis
        2. Replace the cable if the measurement is below 1MΩ
4. Perform the insulation test on the compressor itself by contacting the inner terminals of the high voltage connector of the compressor
5. If the compressor measure below 1MΩ, replace the compressor

Isolation Check – Accessory Inverter

1. Disconnect high voltage cable from the Aux 6 port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, that cable can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the high voltage cable from the power steering motor and the air brake compressor at those components and repeat the test on the same Aux 6 cable.
        1. If the insulation measurement is still below 1MΩ, access the accessory inverter electrical access panel and remove it
            1. Disconnect the three high voltage cables from the accessory inverter and re-test the three cables individually
            2. Replace any cable with an insulation measurement below 1MΩ
    3. Perform the insulation test on the inverter itself by contacting each of the inner terminals of the accessory inverter connectors one at a time with the red probe and an unpainted section of the chassis with the black probe
4. If any inverter terminal measures below 1MΩ, replace the accessory inverter



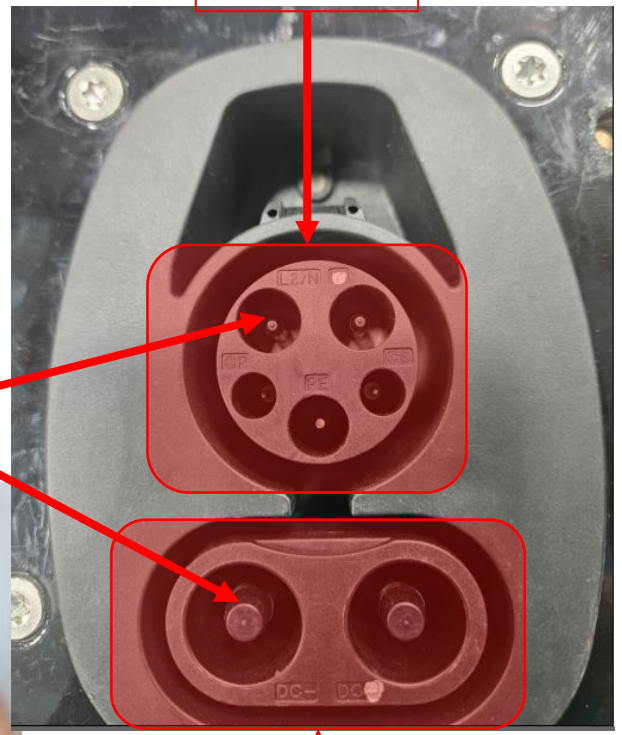




Contact area

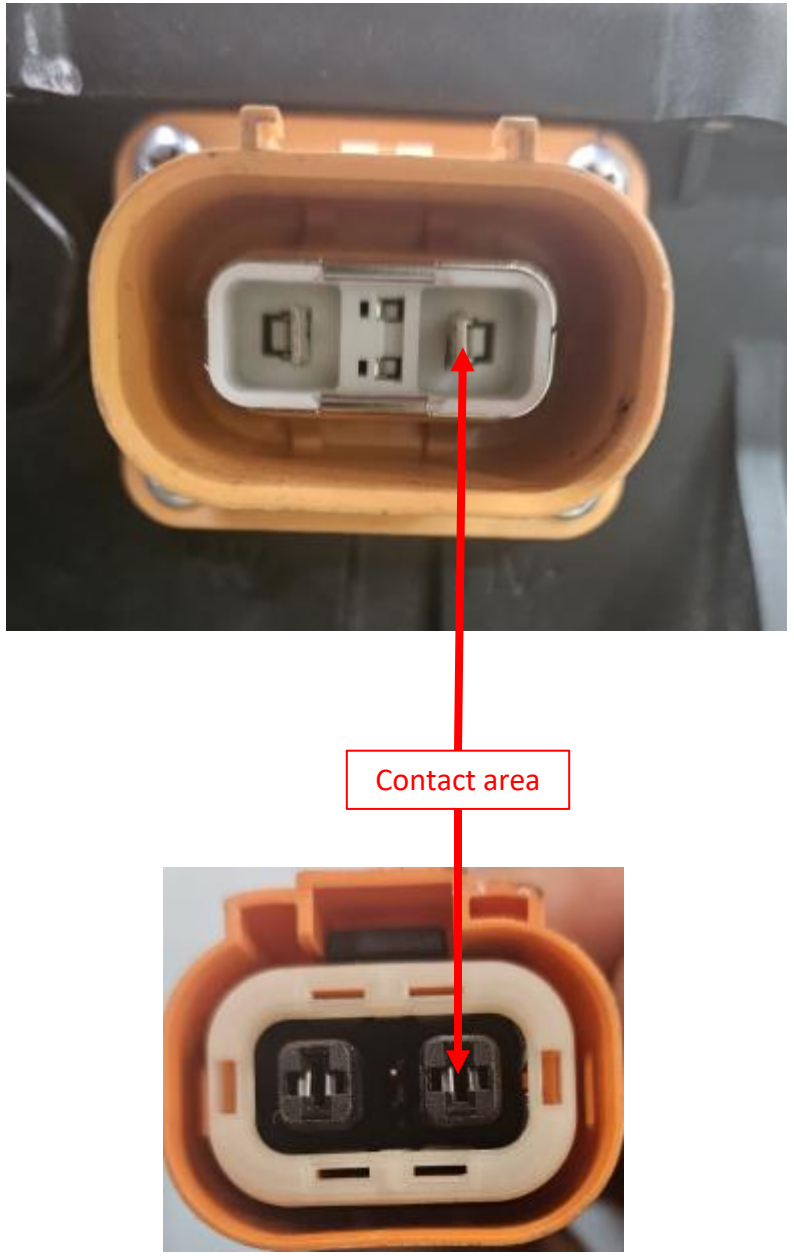
Isolation Check – Charge Port

1. Remove the protective cover on the charge port and identify both the DC and the AC charging ports
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test on each of the charge port connection points ***except*** **for the AC terminals “PE”, “CP” and “CS”**
    1. If the measurement is above 1MΩ for each of the four positions, the cable can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the PDU (DC Charge – and DC Charge +) and from the onboard charger and repeat the test
        1. Perform the insulation test on the cable by again contacting the inner metallic terminals with the red lead while the black lead is contacting an unpainted part of the chassis
        2. Perform the insulation test on each leg individually by contacting the inner terminals of the high voltage posts
        3. If any of the high voltage cables ***except*** **for the AC terminals “PE”, “CP” and “CS”** measure below 1MΩ, replace the charge cable



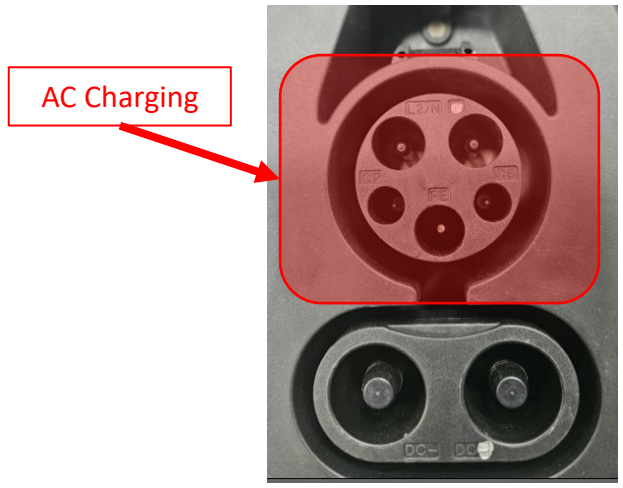
Isolation Check – Cabin Heater

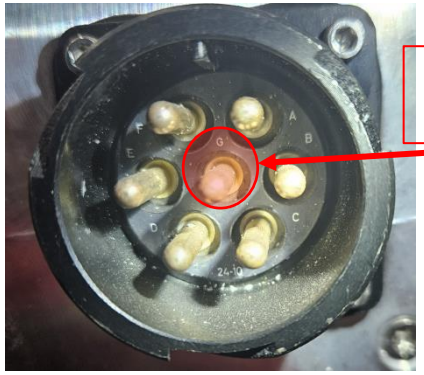
1. Disconnect high voltage cable (107155) from the AUX 5 port of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor on the harness side of the HV cable with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is above 1MΩ, both the cable and the cabin heater can be eliminated as the source of the ground fault
    2. If the measurement is below 1MΩ, disconnect the cable from the cabin heater as well and repeat the test on both the cable and the cabin heater individually.
        1. Perform the insulation test on the cable by again contacting the inner metallic terminal with the red lead while the black lead is contacting an unpainted part of the chassis
        2. Perform the insulation test on the cabin heater itself by contacting the inner terminals of the high voltage connector of the compressor
4. If either the cable or the cabin heater measure below 1MΩ, replace the component



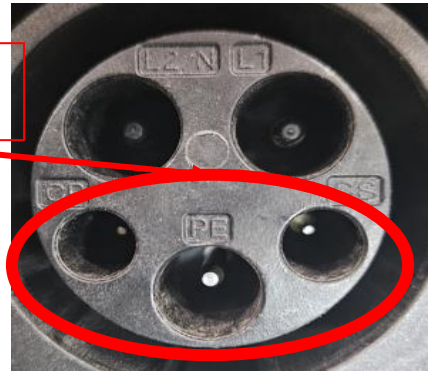
Isolation Check – Onboard Charger

1. Disconnect the two high voltage cables in the AUX 4 (and AUX 2 for the 22kW models) high voltage ports of the PDU
2. Using a multimeter set to “Insulation Test” at 1000V, contact the two inner conductors on the harness side of each cable, one at a time, with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test on the two cables with two terminals each
    1. If the measurement is below 1MΩ, disconnect the cable(s) from the onboard charger(s) and repeat the test
        1. If any terminal of the cable(s) measure less than 1MΩ, replace the cable
    2. If the measurement is above 1MΩ the cables can be eliminated as the source of the isolation fault
4. Remove the cover of the charge port and identify the AC charging contacts
    1. Perform an insulation test on the two inner conductors on the charge port marked “L1” and “L2/N”, one at a time, using the red lead with the black lead on chassis ground
    2. If the measurement is below 1MΩ, disconnect the high voltage AC charging cable from the circular port of the onboard charger and repeat the test
        1. If the cable measurement is above 1MΩ, the cable is not the source of the isolation fault
        2. If either post measures less than 1MΩ, replace the charge cable
5. Perform the insulation test on the charger itself by contacting the six inner metallic terminals of the high voltage connector, one at a time, with the red lead while the black lead is contacting an unpainted part of the chassis – do not test terminal “G” as it is a ground connection
        1. If any of the charger contacts measure below 1MΩ, replace the charger

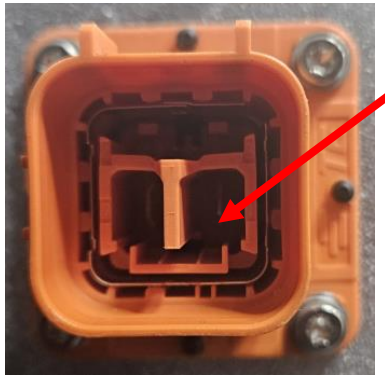


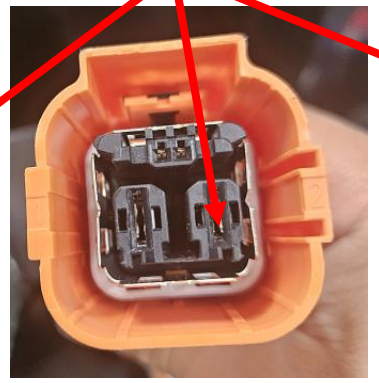


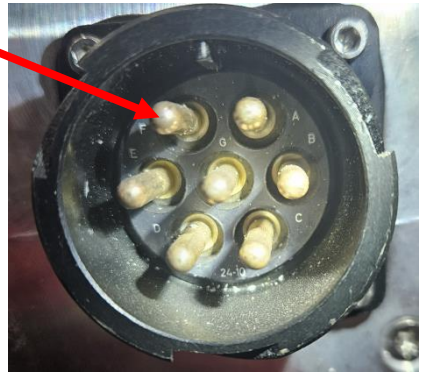
DO NOT TEST THESE TERMINALS!



Contact area

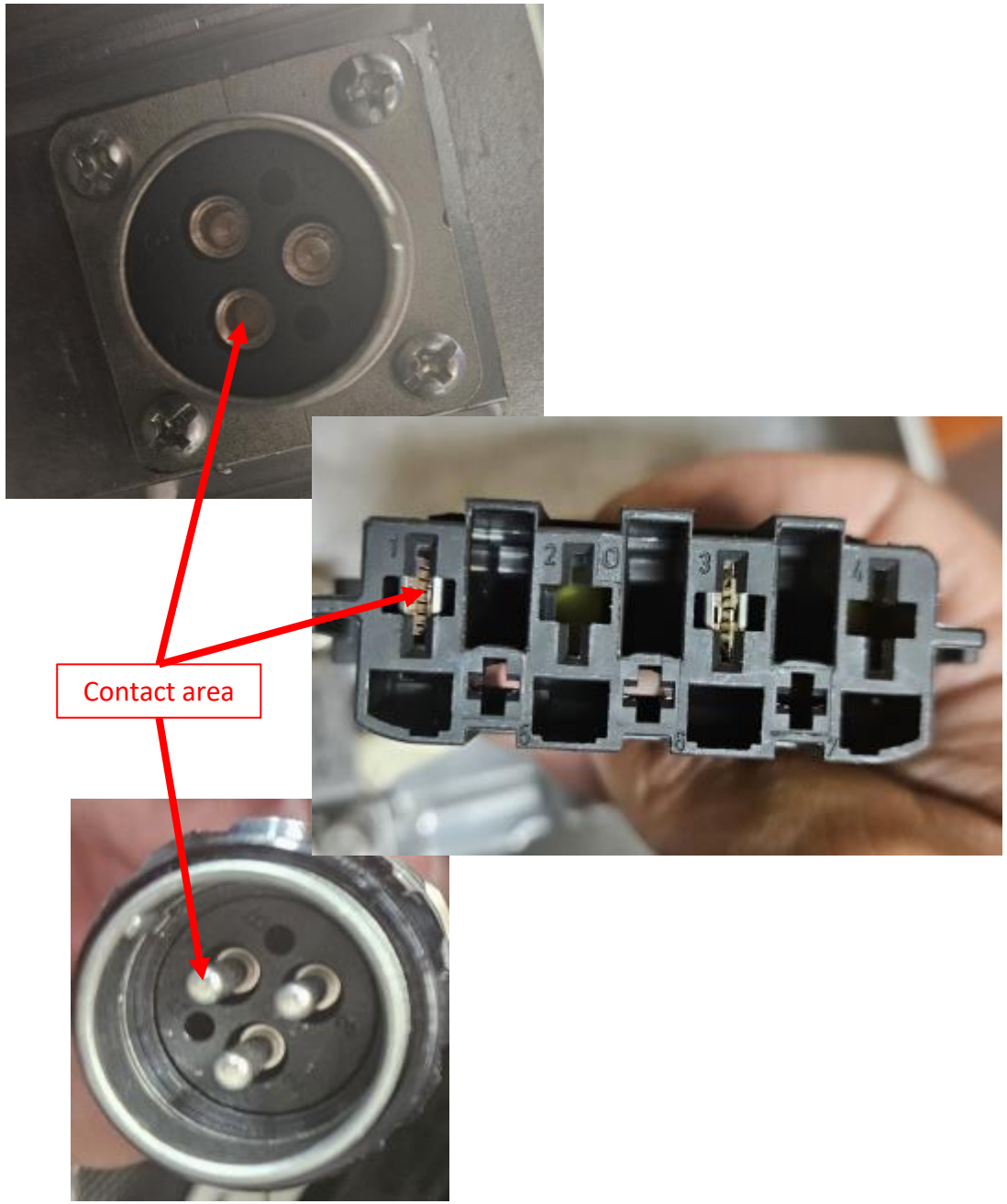






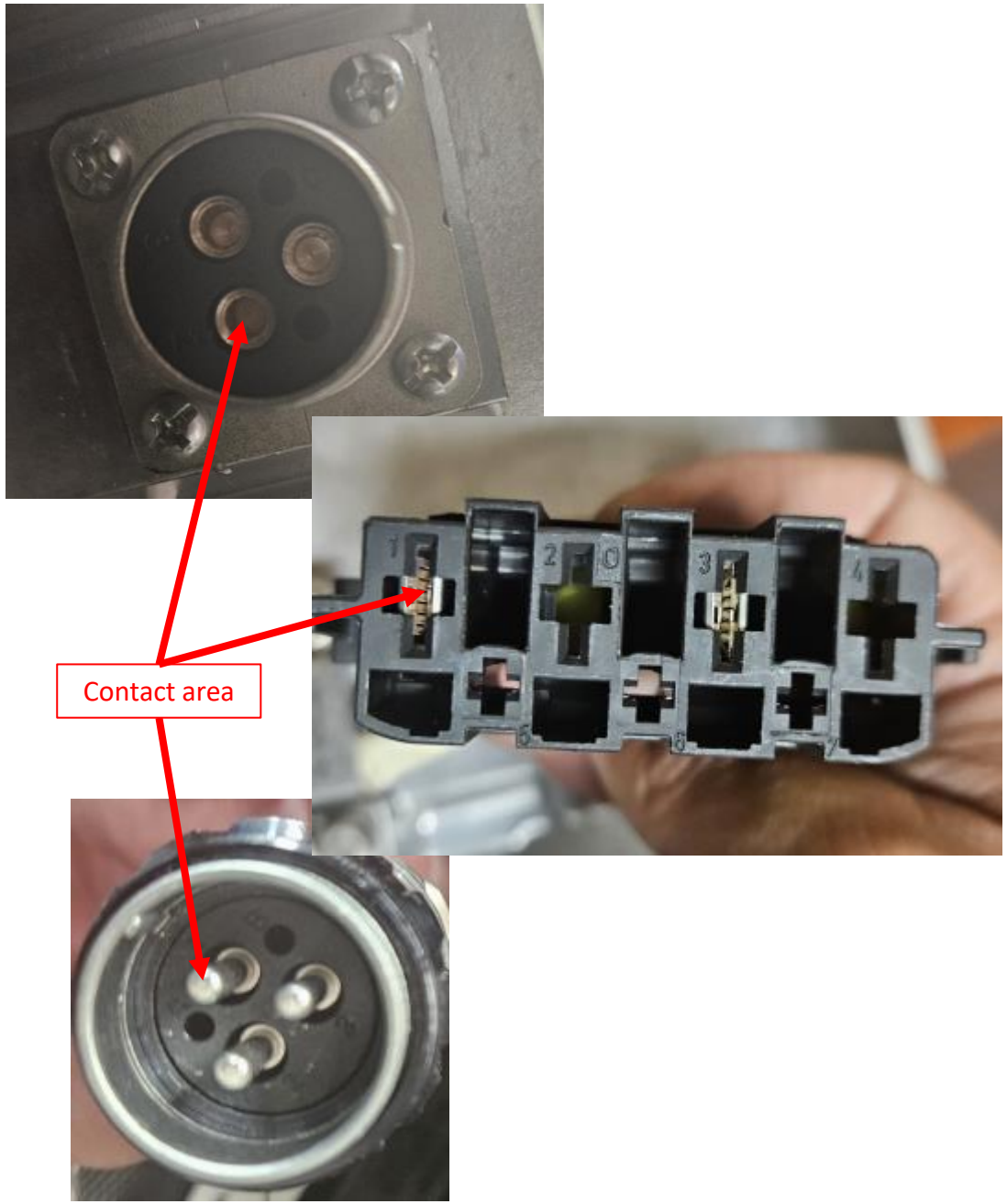
Isolation Check – Power Steering Motor

1. Disconnect high voltage cable from the high voltage port of the power steering motor
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor inside the power steering motor high voltage connector with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is below 1MΩ, replace the power steering motor
    2. If the measurement is above 1MΩ, the power steering motor can be eliminated as the source of the ground fault
4. Perform the insulation test on the cable by contacting the inner metallic terminals of the cable one at a time with the red lead while the black lead is contacting an unpainted part of the chassis
5. If any post of the cable measures below 1MΩ, disconnect the other end of the high voltage cable at the accessory inverter and repeat the test on the cable alone
    1. If the measurement is below 1MΩ, replace the high voltage cable
    2. If the measurement is above 1MΩ, the cable can be eliminated as the source of the ground fault
6. If both the cable and the power steering motor insulation measurements are above 1MΩ, test the accessory inverter for loss of isolation



Isolation Check – Air Brake Compressor

1. Disconnect high voltage cable from the high voltage port of the air brake compressor motor
2. Using a multimeter set to “Insulation Test” at 1000V, contact the inner conductor inside the air brake compressor motor high voltage connector with the red lead and chassis ground with the black lead
3. Press the measurement button and perform the test.
    1. If the measurement is below 1MΩ, replace the air brake compressor motor
    2. If the measurement is above 1MΩ, the air brake compressor motor can be eliminated as the source of the ground fault
4. Perform the insulation test on the cable by contacting the inner metallic terminals of the cable one at a time with the red lead while the black lead is contacting an unpainted part of the chassis
5. If any post of the cable measures below 1MΩ, disconnect the other end of the high voltage cable at the accessory inverter and repeat the test on the cable alone
    1. If the measurement is below 1MΩ, replace the high voltage cable
    2. If the measurement is above 1MΩ, the cable can be eliminated as the source of the ground fault
6. If both the cable and the air brake compressor motor insulation measurements are above 1MΩ, test the accessory inverter for loss of isolation



Isolation Check – Other Sources

- If the source of the isolation fault is not detected using these procedures, it is also a possibility that the high voltage battery system is the source.
  - Refer to OEM inspection procedures for pinpoint analysis
- Some locations that could cause an isolation fault include:
  - Damaged or defective high voltage cables between individual battery packs
  - Improperly installed high voltage battery cables
  - Internal insulation breakdowns of the battery modules
  - Defective high voltage battery fuses
  - Improperly installed high voltage fuse covers