Application Note CTTN #121

The Application Note is pertinent to the Mentor II/Quantum III Drive Family

DC Motor Resistance Evaluation

Testing with high voltage and low voltage instruments

Scope – Many failure modes encountered on a DC Motor controlled by a SCR-based converter such as the Mentor 2 or Quantum 3 can be diagnosed on-site with a series of resistance measurements.

This Application Note will attempt to provide a consistent, step-by-step process for resistive measurement of a DC Motor, and adequate technical information to permit insightful evaluation of these measurements by the technician. Note that the winding configurations for Practical DC motors are more involved than those found in AC Induction Motors.

Types of Resistance Measurements – Two different ranges of resistance are of interest when evaluating a DC Motor, and different instruments are used to perform these measurements.

Low voltage measurements

To confirm that the DC Motor field resistance is correct, one uses an instrument that can reliably measure resistances within the 10-ohm to 600-ohm range. This measurement is commonly performed with a 3½ digit or 4½ digit Digital Multi-meter, set to measure resistance. These instruments usually use an internal nine-volt (9.0) DC source to temporarily "excite" a test circuit that includes the instrument and the resistance to be measured.
Knowledge of the DC Motor field resistance is especially useful on the Mentor II / Quantum III drive family, as current regulation is employed on the MDA-3 and FMX5 field regulators.

High voltage measurements

To confirm that the individual windings found within DC Motor are isolated from ground as well as each other, one uses an instrument that can reliably measure a very high resistance. Additionally, these measurements should be made at "excitation potentials" that are "significant" when compared to the normal operating voltages applied throughout the DC Motor circuit. This DC Motor circuit includes the conductors from the Mentor 2 / Quantum 3 to the DC Motor, as well as the DC Motor itself.

One expects to encounter resistances above one million ohms in the course of these measurements when the DC Motor is okay, and the "*high voltage resistance meters*" employed to make these measurements are commonly referred to as "**Megohmmeters**" or "***Meggers***" (industry buzzword).
To systematically measure the insulation resistance of the DC Motor and its field connections with such an instrument is often referred to as "***Megging***" the motor.

Meg-ohmmeters differ from one another with respect to both the voltage source and the voltage level applied for the resistance measurement. Battery powered units are preferred to hand crank or line powered instruments. For the purposes of this application note, measurement at 500 Volts DC is a good all-around value for insulation resistance measurements performed on a DC Motor.

Cautions

WARNING
This Application Note provides pertinent, but not exhaustive, guidance regarding safety practices to be observed while evaluating a DC Motor. Additional guidance regarding relevant safety practices are within the scope of Industrial "**Lockout / Tag-out**" programs. The series of measurements described are not especially hazardous, ***once the panel excitation is removed***, locked-out and tagged-out. The technician must verify that that the field, armature, and motor thermal circuits that he intends to evaluate *are not excited,* ***prior to disconnecting any conductors!*** Note that breaking the circuit of an excited motor field will "throw" a surprisingly long and energetic arc at the point of disconnection. The technician should insure the area immediately to the rear, as well as around, the work area is clear of physical and electrical hazards, should rapid motion away from the drive panel be required. Also note that attempting a resistance measurement (i.e. multi-meter set for a resistance scale) on an "excited" DC Motor field circuit will **damage** or **destroy** most digital multi-meters. Initially check and confirm for the absence of voltage with the multi-meter set for AC voltage, then DC voltage, before attempting a resistance measurement. After making the resistance measurement, develop a habit to set the multi-meter used for the measurement back to the off position. Voltage and resistance measurements for evaluations of this nature can be **hazardous** when ***improperly*** or ***clumsily*** performed. These measurements should only be attempted by qualified technicians who are familiar with motors and drives of this sort, and the measuring instruments described.

These measurements require sufficient technical ability to:

- Discern if all panel power is truly off and properly locked out and tagged. Note that modern electrical control panels occasionally have multiple power sources within the enclosures.
- Locate the terminal strip(s) and individual conductor(s) of interest out of the dozens of wires potentially present at the terminal strip(s) found in a modern electrical control panel.
- Measure and confirm that the excitation from the Mentor 2 / Quantum 3 to the motor field windings (10 to 300 VDC nominal), motor armature windings (10 to 500 VDC nominal) and the motor thermal switch (24 VDC for M2 / 120 VAC for Q3 nominal) has been shut down.

Measurement - intro

This series of measurements are to be made with the Control Panel power off. These measurements are to include both the DC Motor and the interconnections between the Drive Control Panel and the DC Motor, but not the Mentor 2 Quantum 3 DC Drive or control panel.

Note that the conductors between a DC Motor and it's Control Panel could be routed within conduits or raceways run underground, could have nicks in the insulation, may be coated with condensation and might even be occasionally under water.

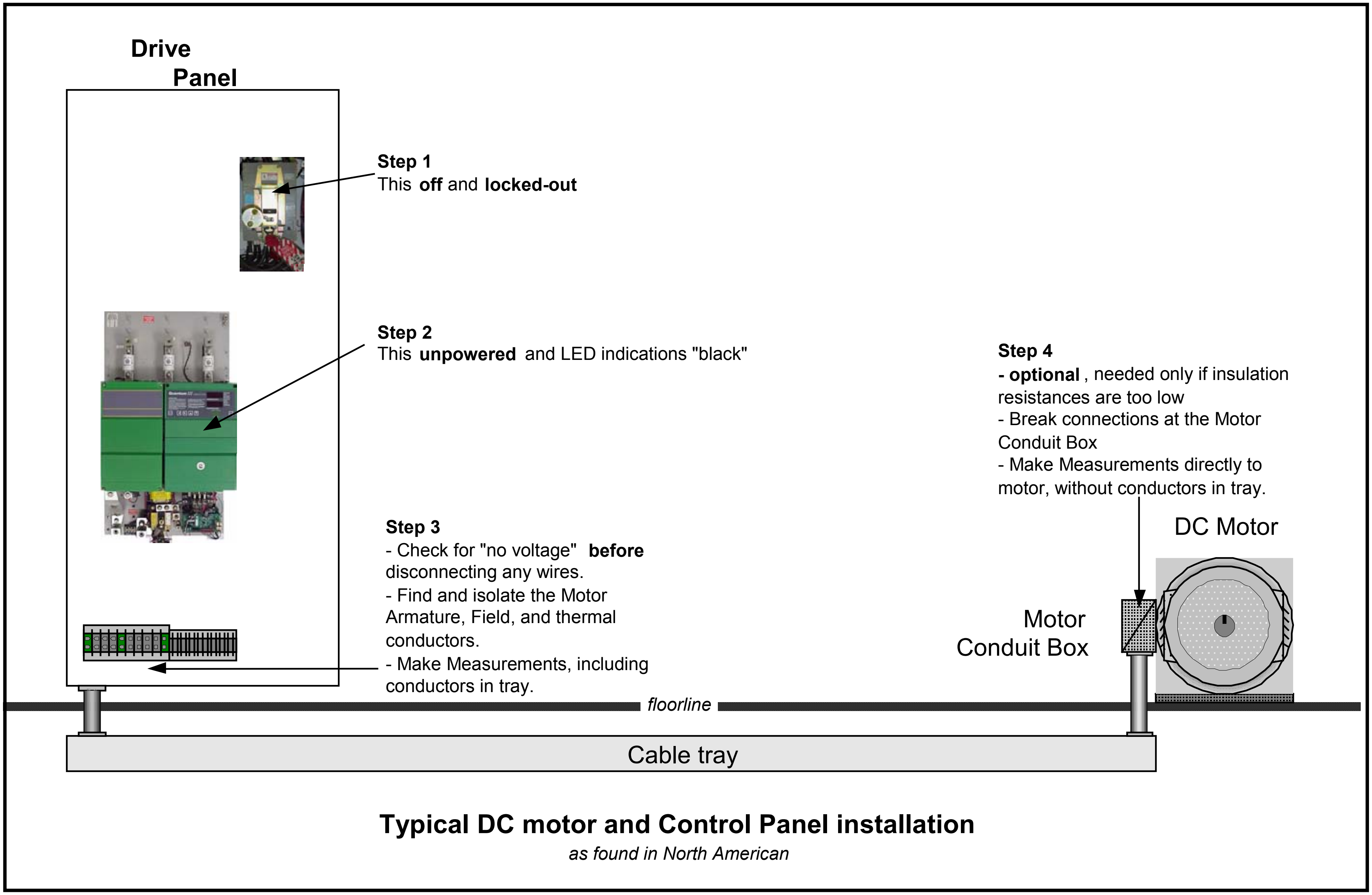

Illustration 1

Measurement – preparation (see Illustration 1 for clarification)

1. Turn off the DC Control Panel at the Enclosure Door Disconnect. Open the Panel Doors and lockout the panels disconnect with an appropriate clasp, lock and your personalized lockout tag. If additional power feeds to this panel are known to be present (such as from a Uninterruptible Power Supply), this procedure recommends that these breakers be located within the Drive Control Panel and turned off.
2. Observe that the Mentor II / Quantum III is 'dead" with all LED(s) "black" and no drive fan noise discernable.
3. Working within the control panel that houses the Mentor II or Quantum 3, at the panel terminal strip locate and confirm the absence of voltage at:
   - The two conductors for the DC Motor field (F+ and F-)
     a) Check and confirm F+ to F-
     b) Check and confirm F+ to panel ground
     c) Check and confirm F- to panel ground
   - The two conductors for the DC Motor Armature (A+ and A-)
     a) Check and confirm A+ to A-
     b) Check and confirm A+ to panel ground
     c) Check and confirm A- to panel ground
   - the two conductors for the DC Motor Thermal Switch (if present) (P1 and P2)
     1. Check and confirm P1 to P2
     2. Check and confirm P1 to panel ground
     3. Check and confirm P2 to panel ground
     4. On a Mentor II, check and confirm P1 to TB2-20 on the Mentor II MDA-2B (0v)
     5. On a Mentor II, check and confirm P2 to TB2-20 on the Mentor II MDA-2B (0v)
     6. On a Quantum III, check and confirm P1 to TB1-25 on the 9500-4025 AC Interface.
     7. On a Quantum III, check and confirm P2 to TB1-25 on the 9500-4025 AC Interface.

4. If any circuit is still energized at this point (i.e. voltage is present), **STOP,** and figure out what is going on. You have missed something. Do not continue **until you are sure** which wires are which **and** that the Motor field, Motor armature, and Motor thermal sensor circuits **are NOT Energized!**

5. Mark and disconnect the following conductors on the plant wiring side of the Control Panel Terminal Strip. See step 3 on **Illustration 1** for clarification.
   - Motor Field Positive (F+) and Motor Field Minus (F-)
   - Motor Armature Positive (A+) and Motor Armature Negative (A-)
   - Motor Thermal 1 (P1) and Motor Thermal 2 (P2)

Measurement – actual measurements

6. Using a digital multi-meter set to measure resistance, measure and record the field resistance from F+ to F-, then select off on the multi-meter. If the field voltage has been removed for several hours, this value corresponds to the "cold resistance" value of the motor field.

7. Using a battery powered 500 volt ***Megger***, measure and record the following resistance values:
   - F+ to panel earth ground
   - F- to panel earth ground
   - P1 to panel earth ground
   - P2 to panel earth ground
   - From the field circuit (F+ temporarily connected to F-) to the thermal circuit (P1 temporarily connected to P2)

8. Using a battery powered 500 volt ***Megger***, measure and record the minimum resistance value observed while rotating the DC Motor output shaft one revolution
   - From the Armature circuit (A+ temporarily connected to A-) to panel earth ground.
   - From the field circuit (F+ temporarily connected to F-) to the Armature circuit (A+ temporarily connected to A-).
   - From the thermal circuit (P1 temporarily connected to P2) to the Armature circuit (A+ temporarily connected to A-)

Evaluation and Analysis

The following table is a convenient place to record your initial measurements.

Step	measurement description	value	units
6	Field Resistance **( ) cold ? ( ) hot ? ( ) in-between ?**		ohms
7	F+ to panel earth ground		megohms
	F- to panel earth ground		megohms
	P1 to panel earth ground		megohms
	P2 to panel earth ground		megohms
	F+ and F- (in parallel) to P1 and P2 (in parallel)		megohms
8	A+ and A- (in parallel) to panel earth ground		megohms
	F+ and F- (in parallel) to A+ and A- (in parallel)		megohms
	A+ and A- (in parallel) to P1 and P2 (in parallel)		megohms

1. **The field resistance recorded in step 6 should measure within a 40% range from what is calculated from ohm's law and the Motor Nameplate.**

   A DC Motor's field current is specified at a rated voltage (nominally 300 VDC or 200 VDC or 150 VDC in North America) and rated temperature change (100 degrees Centigrade rise over ambient). Practical DC motors use copper wire for winding the field windings, and the resistivity of copper is a simple physical constant that can predict the resistance change over this temperature rise.

   Room temperature is approximately 25 degrees Centigrade, and the resistance of any given coil of copper wire ranges from a relative value of 1.0 (unity) at this temperature, to a value that is 1.4 times greater at a temperature of 125 degrees Centigrade.

   For example, a 300 VDC field rated at 1.8 amps should measure approximately 168 ***ohms*** "hot" (300 ***vdc***/1.8 ***amps***). The expected "cold" resistance should be about 120 ***ohms*** (168 ***ohms*** /1.4).

   For this example and with a properly set up Mentor 2 / Quantum 3 field regulator (MDA-3 or FMX-5), the expected terminal voltage measured across F+ and F- would be 214 ***vdc*** when first powered on (300 ***vdc*** /1.4). The terminal voltage would slowly rise to approach the rated 300 ***vdc*** as the motor comes up to temperature.

   Note that an external motor blower is often so effective at cooling, that a DC Motor so equipped and controlled by a Mentor 2 / Quantum 3 will not reach rated temperature (and field voltage) unless heavily loaded.

2. **All insulation resistances measured in steps 7 and 8 should range well above 500 kilo-ohms**.

   If any of the measurements are below 500 kilo-ohms, break out the connections at the Motor Conduit Box and repeat the measurements directly at the DC Motor (without the conductors from the control panel). If the insulation resistance values still remain below 500 kilo-ohms, the next step is to pull the covers off the DC Motor and blow out (clean) the carbon dust out of the Motor. Low insulation resistance values after these steps suggest problems with the DC Motor that will require expert assistance to resolve (usually found at a motor repair facility).

3. **If all measurements in step 7 and step 8 are above 10 meg-ohms, all is well with the motor.** Put everything back together. You have succeeded in measuring and recording everything that resistance evaluation can tell you about this motor.

4. **Resistance values greater than 500 kilo-ohms but less than 10 meg-ohms indicate some degradation in motor insulation integrity.** Repeating these measurements periodically can permit the technician to plot DC Motor insulation degradation over time, and these trends have some predictive value in projecting eventual motor failure. Page 7 can serve as a guide for such records.

Reference

The following illustration diagrams the simplified electrical details of a practical 4 pole DC Motor. The coils for the various windings are shown "true" to the locations of the iron "field poles" that they are wound on. This diagram can be helpful in visualizing proper isolated from one circuit to another circuit and / or earth ground, and can be useful when evidence of insufficient insulation resistance is encountered.

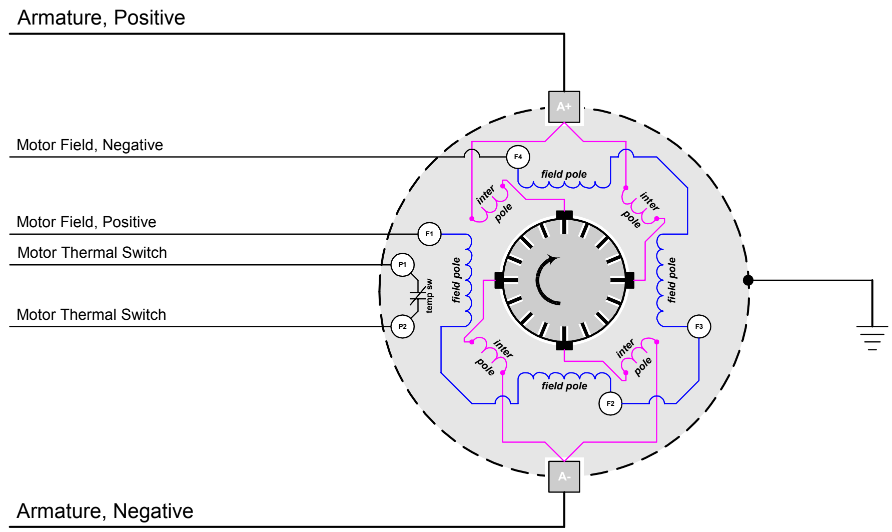

Illustration 2

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Motor Insulation Resistance Record

Date:

Step	measurement description	value	units
6	Field Resistance **( ) cold ? ( ) hot ? ( ) in-between ?**		ohms
7	F+ to panel earth ground		megohms
	F- to panel earth ground		megohms
	P1 to panel earth ground		megohms
	P2 to panel earth ground		megohms
	F+ and F- (in parallel) to P1 and P2 (in parallel)		megohms
8	A+ and A- (in parallel) to panel earth ground		megohms
	F+ and F- (in parallel) to A+ and A- (in parallel)		megohms
	A+ and A- (in parallel) to P1 and P2 (in parallel)		megohms

Date:

Step	measurement description	value	units
6	Field Resistance **( ) cold ? ( ) hot ? ( ) in-between ?**		ohms
7	F+ to panel earth ground		megohms
	F- to panel earth ground		megohms
	P1 to panel earth ground		megohms
	P2 to panel earth ground		megohms
	F+ and F- (in parallel) to P1 and P2 (in parallel)		megohms
8	A+ and A- (in parallel) to panel earth ground		megohms
	F+ and F- (in parallel) to A+ and A- (in parallel)		megohms
	A+ and A- (in parallel) to P1 and P2 (in parallel)		megohms

Date:

Step	measurement description	value	units
6	Field Resistance **( ) cold ? ( ) hot ? ( ) in-between ?**		ohms
7	F+ to panel earth ground		megohms
	F- to panel earth ground		megohms
	P1 to panel earth ground		megohms
	P2 to panel earth ground		megohms
	F+ and F- (in parallel) to P1 and P2 (in parallel)		megohms
8	A+ and A- (in parallel) to panel earth ground		megohms
	F+ and F- (in parallel) to A+ and A- (in parallel)		megohms
	A+ and A- (in parallel) to P1 and P2 (in parallel)		megohms

Date:

Step	measurement description	value	units
6	Field Resistance **( ) cold ? ( ) hot ? ( ) in-between ?**		ohms
7	F+ to panel earth ground		megohms
	F- to panel earth ground		megohms
	P1 to panel earth ground		megohms
	P2 to panel earth ground		megohms
	F+ and F- (in parallel) to P1 and P2 (in parallel)		megohms
8	A+ and A- (in parallel) to panel earth ground		megohms
	F+ and F- (in parallel) to A+ and A- (in parallel)		megohms
	A+ and A- (in parallel) to P1 and P2 (in parallel)		megohms