Electronic Systems of Wisconsin, Inc.

ELECTRICAL TEST PROCEDURES FOR ARMATURES, STATORS AND MOTORS

Allan Naegeli
President
Electronic Systems of Wisconsin, Inc.
Racine, WI 53406

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Everyone producing electric motors, stator or armatures makes electrical tests at various locations during the production process.

The most common questions that arise about testing are: when, what, why, how and how often do I test?

To answer these questions we will first review the processes and materials used in making armatures and stators. Then we will review what can go wrong at each step of the process.

Not too long ago, the goal of the production process was simply to prevent bad units from being shipped to customers. The definition of a bad unit has grown much broader.

Today's definition includes reliability, longevity, and reducing our "in-process" rejects rates. More emphasis is on making the product better from the start so we do not depend solely on final product testing to accomplish all of the goals. Prevention of rejects and reduction on production costs are high priorities of today's testing function.

With the rapid improvements during the past twenty years in materials and the equipment used to manufacture armatures, stators, and motors, we might expect less need for testing, however, just the opposite is true, as today we are doing more testing than ever before.

Tests that were once performed only in the laboratory are now being performed on the production line. This is due to higher expectations of customers and the increasing cost of scrap.

Earlier this year, a major U.S. appliance company started to recall 300,000 units. The recall was made because four units had caused fires. Imagine the financial cost and loss of the company's reputation because of this type of recall. Just a few years ago, this type of major recall would not have been made. However, with today's high expectations, these kinds of recalls will become commonplace.

WHY DO WE NEED TO TEST?

A few tests are mandated by governmental regulations and standards. These tests are required to protect the consumer from shock hazards as well as fire and smoke damage.

Product safety certification agencies exist all around the world:

(IEC) International Electromechanical Commission
(UL) USA, Underwriter's Laboratories
(CSA) Canada, Canadian Standards Association
(BSI) England, British Standards Institute
(JIS) Japan, Japanese Standards Association
(VDE) Germany, Association of German Electrical Engineers

These agencies require a Dielectric Voltage Withstand Test on 100% of the products at the end of the production line.

The second reason testing is done is to assure that the customer gets a product that performs its specified functions and will continue to operate years later.

Another reason testing is done is to uncover any design or production flaws. These flaws can lead to early field failures, which can cost a company money months or even years later.

In order to accomplish all these criteria: safety, quality, and long life, we need to first examine how motors are made.

WHERE TO START?

We will start by reviewing the materials and various machine operations that are used in the process of building armatures and stators.

The materials that are used: wire, insulators, connectors, and commutators are tested at incoming inspection. However, due to the large quantity of these materials that are received, it is possible to inspect only a small percentage. We depend on most of the quality testing being done by the material manufacturer themselves.

It is possible to complete all the operations in building an electric motor or appliance and test it only once before shipping it. This method would be acceptable if we were living with yesterday's standards. However, today your goals include other reasons for testing as we discussed earlier, quality and life expectancy. Simply doing a test at the end of the production line will not give us the type of results we need to guarantee our testing goals.

There are several problems with waiting until the end of the production process:

1. Some tests for reliability and longevity are either difficult or impossible to accomplish with a completed motor or appliance.
2. Problems that are introduced at an early point of operation are not seen until it is to late. The result is excessive scrap or rework.
3. 100% testing at the end of a line cannot stop bad product from being shipped to a customer.

As important as final testing is, in today's market environment it cannot be expected to be your only testing operation.

Armatures and stators are the highest cause of electrical failures in a motor. Therefore, our concern is on what happens during the production of armatures and stators.

Longevity problems such as shorted turns, shorted windings, and badly fused commutators on armatures are extremely hard to detect in an assembled motor. These defects are best detected at the armature or stator component level.

SYSTEM REVIEW OF OPERATIONS IN ARMATURE AND STATOR PRODUCTION

In order to know what we are looking for and how to prevent malfunctions, we need to first examine the process and review what could go wrong. If we cannot identify the problem areas, how can we expect to correct them?

The following chart (A) will help us identify where in the production process the problems can occur. The attached photos will show examples of things that have gone wrong. Note that one test cannot detect all the possible problems that can arise.

Chart A
Small Motor Production Systems
Armatures & Stators

Things That Can Go Wrong	Electrical Tests For Verification
Lamination	
• Burrs in slots.	Hipot
Epoxy Coating	
• Openings in coating.	Hipot
Cell Insulator	
• Missing Insulator. • Damaged Insulator. • Short Length.	Hipot
Winding	
• Wire wound behind insulator. • Wires nicked by tooling. • Wrong number of turns. • Missed connection.	Hipot Surge Resistance
Wire Tension	
• Stretched wire.	Resistance
Wedge Insulator	
• Missing or damaged insulator.	Hipot
Fusing Connecting	
• Poor electrical connection at commutator bars or connection.	Weld Test
Testing	
• Excessive current during resistance & weld test.	Limit current to less than 1 amp
Impregnation Bonding	
• Damaged wire coating. • Bonding materials under commutator bar or connector.	Surge Weld Test
Turning Commutator	
• Copper chips in commutator bar slots.	Surge
Forming Stator	
• Wire damaged. • Wire in ID of lamination.	Surge Hipot
Lacing Stator ----------	----------
Balancing Armature	
• Metal lamination chips in wire connection areas of commutator or connections.	Surge
Handling	
• Wire Damage.	Surge
Testing	
• Marking of commutator surface. • Excessive current in resistance & weld test.	Test socket design

As chart (A) indicates, various tests are required to verify the condition of the armatures and stators.

In this section, we will review the following tests: HIPOT, SURGE, RESISTANCE, CONTACT RESISTANCE, WELD TESTING AND MILLIVOLT DROP.

Today, I want to introduce these testing concepts to you. These concepts are typically not an area of disagreement between testing equipment manufacturers. The place where the disagreements arise is when it comes to the actual circuitry details of each test.

It is important that you understand the basic concepts of these tests, because if you do not you will not be able to evaluate the claims that the testing companies make. These claims include: faster, unique, better, patented and high technology. All these claims are easy for a manufacturer to make, however, proving them is much harder. Today, however, we will only review the basic concepts.

HIPOT
(DIELECTRIC VOLTAGE WITHSTAND TEST)

This test has become universally mandated to protect consumers from electrical shock, fire or smoke damage.

The purpose of the test is to verify the quality and integrity of the insulation materials used on the armature or stator.

The test is conducted by applying to the part a voltage that is 10 times larger than the motor or appliance will ever use. Hipot testing verifies the insulating qualities between the winding of a coil and the metal surroundings of a coil as well as the metal surrounding the windings (i.e.: laminations, cases, shafts, etc.). The hipot test must be performed 100% at the final part production operation. It is also performed during the armature and stator stage. See Chart B.

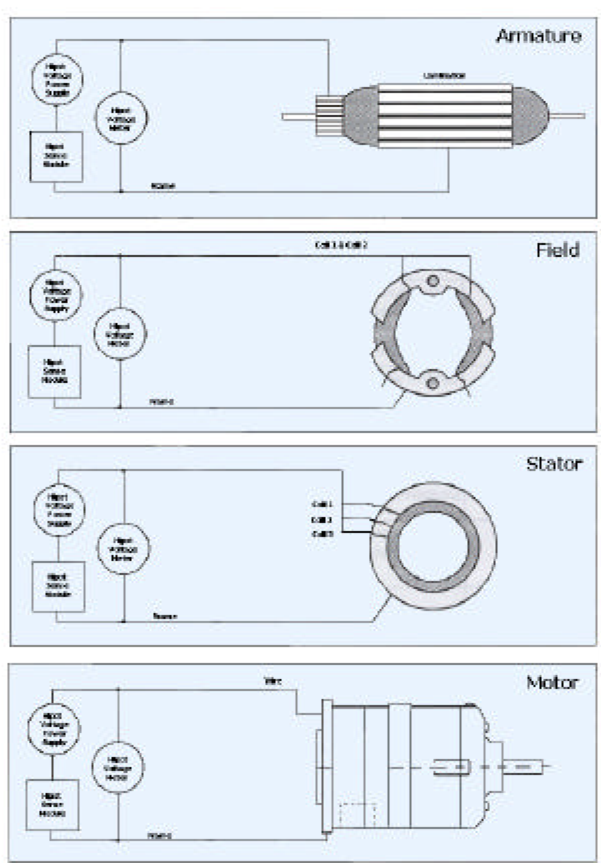


Chart B

SURGE TEST
(IMPULSE TEST)

This test is becoming a very important test to assure reliability and longevity of an electrical motor, but is not a mandated test. The value of doing a surge test is in detecting insulation weaknesses. These weaknesses can, over time, cause a motor to burn out and possibly start a fire.

Surge testing tests the insulation between adjacent or overlapping turns of wire. It differs from the hipot test in that it tests a different insulation of the motor. This is an insulation quality that a hipot test cannot detect.

Surge testing is only used on armatures and stators before they are assembled into a complete motor. Armatures and stators should be surge tested at least once during the production process.

The surge test is accomplished by applying a voltage that is five times larger than would normally be applied to it.

As we review what can go wrong, it becomes apparent why surge testing has increased in importance in the last ten years.

Because a few shorted turns represents so small a percentage of total turns in a winding, resistance and inductance testing is not effective. (Note: inductance testing will only find shorted turns if they are shorted under low voltage conditions, such as dead shorts.)

Previous tests for shorted windings (inductance and growler testing) used low voltages. The insulation properties were never stressed. These tests also lacked the sensitivity for detecting a few shorted turns.

Before we get into a discussion on surge testing, we must first clear up some terminology: shorted turns, shorted windings and the equivalent 1 shorted turn circuit. See Chart C.

Since a few shorted turns have little effect on total resistance, this defect will not be detected in the final motor performance testing.

So why do we worry about shorted turns? Shorted turns absorb energy, which converts into heat. After a period of extended use, this heat can deteriorate more insulation in adjacent turns. More heat is produced, until the winding shorts out. This will destroy the winding and possibly create a fire.

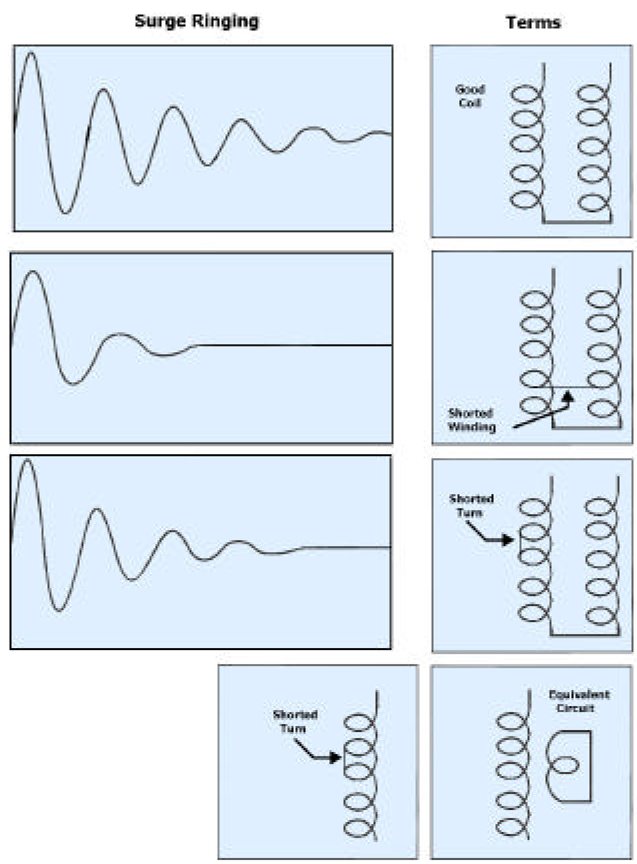


Chart C

The original shorted turns condition can be caused by poor insulation on the copper wire or by thermal stress, mechanical movement or chemical aging.

The basic surge test consists of charging a capacitor to a high voltage (1000-3000 volts) and discharging it through a winding you want to verify. See Chart D.

Good armatures and stators exhibit the same ringing patterns when surge voltage is applied. A winding with shorted turns has
less ringing. Detecting variations in ringing patterns can be done in many ways. Usually

Surge Tests

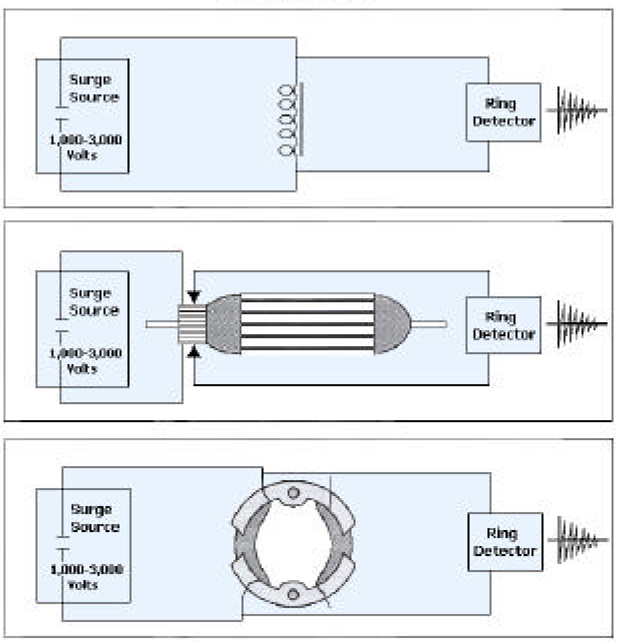


Chart D

using a tester, either with a test master or Masterless, by observing the waveforms generated on a CRT display for an operator to review, or by circuitry that automatically determines good or bad parts. Today, the techniques to accomplish this test vary, but it is important that the tester can detect a 1 shorted turn. Many testers, even computer and digital testers, may not be capable of detecting them.

RESISTANCE TEST

This test is valuable for verifying armature and stator specifications. If the resistance is not corrected at this stage, the current and wattage test limits will not be acceptable in the final motor performance test.

As previously shown on our systems chart (See Chart A) many things can cause resistance problems. The majority of problems come from the winding process.

In order to make reliable resistance readings (in ohms) the test circuitry must use the Kelvin Principle. Without the Kelvin Principle, and a constant current source, low resistance levels cannot be adequately measured.

KELVIN PRINCIPLE

This principle is based on using a constant DC current source and a 4-wire connection to the part being tested.

In order to accurately measure low resistance levels and maintain repeatability, variations in wire length (which create resistance changes) and the contact resistance between the part and the connecting post must be eliminated. The Kelvin Principle accomplishes this.

The constant current (100mA) flows through the two wires into the part being tested. The voltage drop across the part is measured through the other two wires.

The current source (regardless of lead wire or connecting post resistances) delivers a constant 100 mA through the post.

Since the voltage meter is very high in resistance it does not draw current from the current source. The voltmeter measures the voltage. The voltage across the part and the constant current through the part is then converted to ohms by applying Ohm's Law:

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current (100 mA)}}$$

See Chart E.

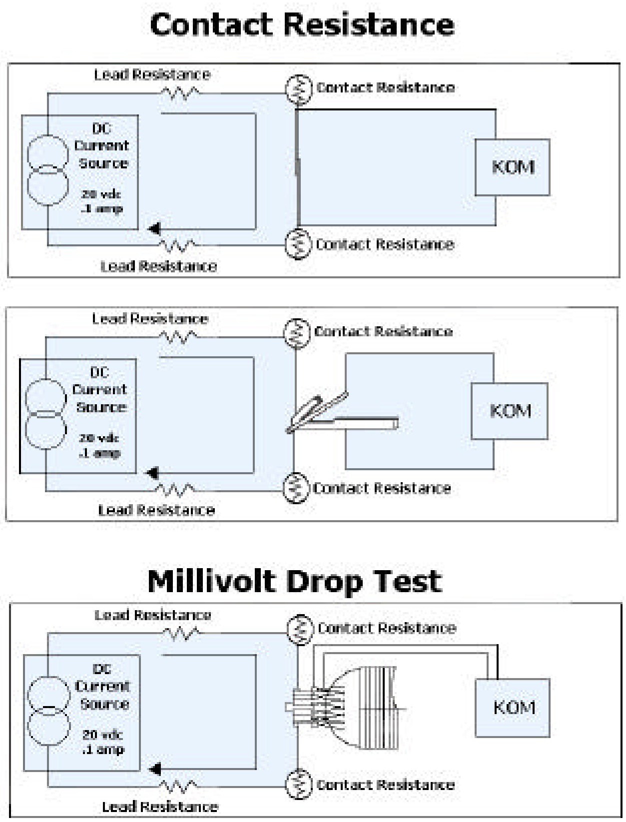


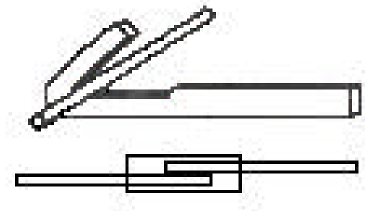
Chart E

CONTACT RESISTANCE

Wires can be connected together or to the terminals by many methods:

1. Twisting
2. Soldering
3. Bonding
4. Fusing
5. Welding
6. Pressing

Regardless of the method used, the question is how good of a connection is made mechanically and electrically.



(Illustration of wire and tang with wire)

Measuring the contact resistance at the bonding point is an excellent method to verify that a good electrical connection is made. The lower the measured resistance is in Ohms, the better the electrical bond is. See Chart F.

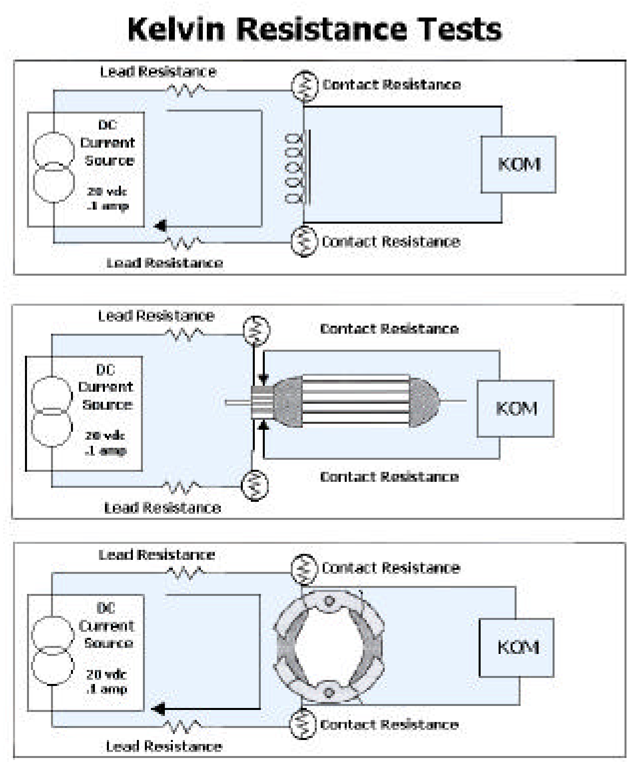


Chart F

MILLIVOLT DROP TEST

The millivolt drop test is generally associated with testing for weld quality on the armature. It is the best test for verifying armature weld quality.

The millivolt drop test is the ultimate electrical test for detecting bad welds. Unfortunately, it is difficult to make on armatures with large diameter wire and nearly impossible to make on armatures with small wires.

The difficulty is breaking through the insulation on the wire as it exits the tang or commutator bar contact. The one testing contact, usually a sharp knife edged probe, from the KOM (Kelvin Ohm Meter) can cut through small wires and destroy the armature. Contact with the knife-edge probe needs to be made on each bar. Since this is such a difficult test to perform, it is only practical as a laboratory test.

Various test methods have been developed over the last twenty years that come close to making this test. These tests make it possible to test 100% of the armatures. However, none of these tests are as accurate or repeatable as the Millivolt Drop Test.

ESW's weld test, which uses techniques that have been developed over the past 20 years, comes very close to the Millivolt Drop Test. The repeatability and speed of the test using a stationary armature test fixture assures that a reliable test has been performed.

SUMMARY

We have only been able to touch on the surface of electrical testing for armatures, stators and motors. As you might imagine, each of the areas that we went over could easily be expanded into papers of their own. However, the goal here is just to introduce you to the problems, terminology and testing concepts.

Testing is an important part of today's manufacturing process. Through the use of electrical testing of armatures, stators and motors, you can greatly reduce the risk of scrap and product recall for your company.

We have reviewed the problem areas in making armatures, stators and motors. In addition we have specified the testing that is necessary to verify the quality requirements and touched upon the basic concepts of each test. You will need to determine what level of sophistication and speed is needed for your factory. In addition, the ease of equipment set-up and use will be additional features your company needs to decide.