Chroma Systems Solutions, Inc.

Hipot Testing of Motors and Safety Standard Compliance

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Compliance with user safety standards is of paramount importance not just to manufacturers of motors and motor subsystems, but to system designers as well.

User safety has long been a primary concern for companies that manufacture electrical, motor-driven, and transformer-type products. In addition, consumer advocates, industry spokesmen, the general public, and safety organizations such as Underwriters Laboratories (UL) continually monitor safety issues to recommend and implement changes to policy. It is important for anyone designing motors or motor subsystems into their products to understand the international safety imperatives created by the safety organizations. Since UL standards are the most widely used, this article uses them as examples.

Electrical shock and fire are the primary safety hazards addressed by manufacturers. Electrical shock potential arises when a current path is created between the exposed parts of a motor or motor-driven device and the user. Compromised insulating materials and impeded ground paths are two common causes. A fire can start when an electrical short or overload condition produces sparking, overheating, and ultimately combustion. Minimize these hazards by conducting the rigorous tests outlined in the many safety standards.

Hipot (Dielectric Withstand) Testing

All safety standards consider hipot testing of motors absolutely essential. A hipot tester (also known as dielectric withstand tester) imposes a voltage on parts of a motor that are higher than those normally encountered in service. With the motor or other device stressed in this manner, breakdowns or faults can be detected and analyzed. If the device under test (DUT) can withstand potentials higher than normal, hazards at nominal potentials would appear unlikely. Hipot tests include leakage current tests that sense and analyze current (leakage) that flows through the DUT with potential applied. The tester is configured to trip at a high current limit, low current limit, arc current limit, or a combination of the three. An excerpt from UL Safety Standard 1004 "Electric Motors" provides an example.

"An auxiliary switch shall withstand for 1 minute without breakdown the application of a 60 Hertz essentially sinusoidal potential between live parts and dead metal parts. The test potential shall be based on either the rating assigned to the switch or the rating of the motor in which it is provided, whichever is higher, and shall be:"

a) For a rating of 1/2 horsepower or less, 250 volts or less, 1000 volts: and
b) For any other rating, 1000 volts plus twice the rated voltage.1

What's That Mean?

This UL excerpt means that in order for the product to be in compliance, it must adhere to the voltage potentials specified. This is typical of all safety standards since repeatability (and thus the quality) of each test must be assured.

Safety standards also specify that a DUT be tested for specific periods of time. Most hipot testers provide a means for programming test times. On some models, ramp time is also programmable. This gives the manufacturer the ability to bring the imposed potential to the desired level at a controlled rate, avoiding product damage and safety hazards. However, it is important that the ramp-to-test feature not interfere with the full impact of the hipot test. The manufacturer should utilize this feature carefully, programming a ramp time that will not dilute the efficacy of the test.

Maximum Current Detection

Hipot testers impose a voltage on a DUT, sense current, and simultaneously compare the measured current with the user-programmable limits. In the case of maximum current detection (Figure 1), the user programs an absolute high limit at which point the tester shuts down, alerting the user audibly, visually, or at a remote point via communication over a bus. Safety standards typically specify compliance limits, so it is then a simple matter to transfer the specified limits of the standard to the programmable limit module of the tester.

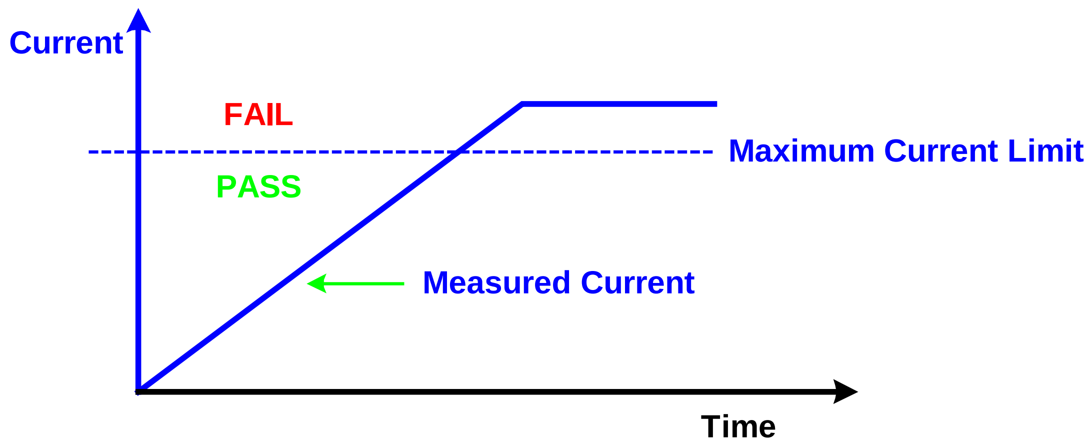

Figure 1 Maximum Current Detection

Minimum Current Detection

Although not specified in safety standards, minimum current detection capability found on instruments such as the Chroma Sentry and Guardian models, increases productivity by eliminating measurement time and effort. Minimum current detection identifies improperly connected or faulty cabling or fixturing at the start of the test.

A negligible amount of current safely flows through the DUT and associated cables and fixtures when they are in good working order and connected to a hipot tester. Hipot testers that have minimum current detection capability recognize the difference between this safe nominal current and a problem condition. They will alert the user if the cables or DUT are not correctly connected, or if the cables or fixture are faulty.

Programming minimum current detection is very similar to programming maximum current. The user specifies a minimum current limit that if not reached after testing begins, shuts down the tester and alerts the user (Figure 2). This saves time, increases productivity, and is invaluable to those who know (or will find out the hard way) that bad parts can pass some tests with no actual connection to the part.

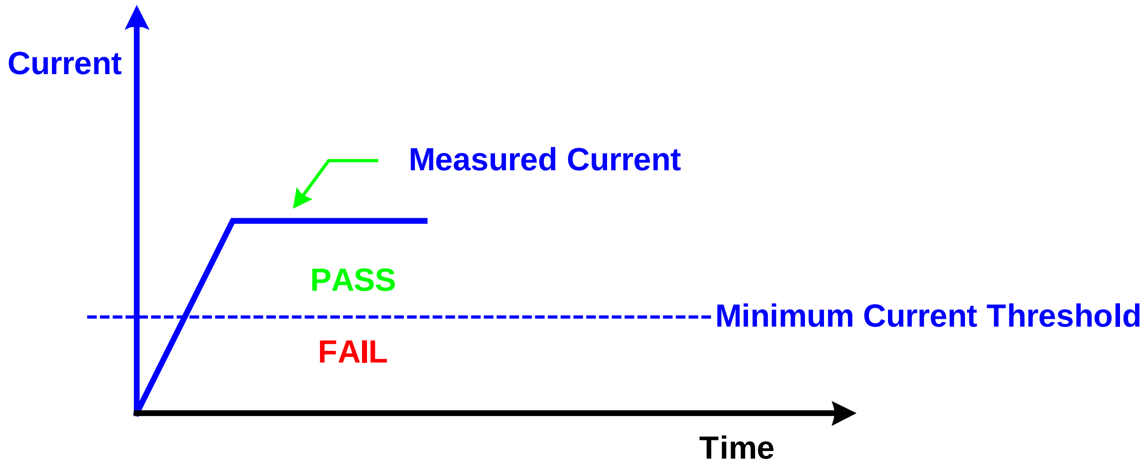

Figure 2 Minimum Current Detection

Arc Current Detection

Although arc detection is not currently directly addressed in safety standards, it is being considered for inclusion in the future because it can further minimize hazard potential. A current arc is an electrical impulse that bridges a gap separating two conductive areas. A good example is current that bridges the electrodes of an automobile spark plug when an adequate potential is applied.

Arc detection is conducted using one of two methods. The first consists of a fixed time period (typically microseconds) during which current is sensed and compared with the programmed limit (Figure 3). The second method employs a fixed current limit and a user-programmable time period. Arc detection is an "anticipatory" tool, meaning that the tester can determine at what level an electrical signal will be at some point in the future. It is based on the trend or change in current during each specified time period. This tool can rapidly remove the potential from a DUT if it is not connected correctly, which minimizes damage and safety hazards.

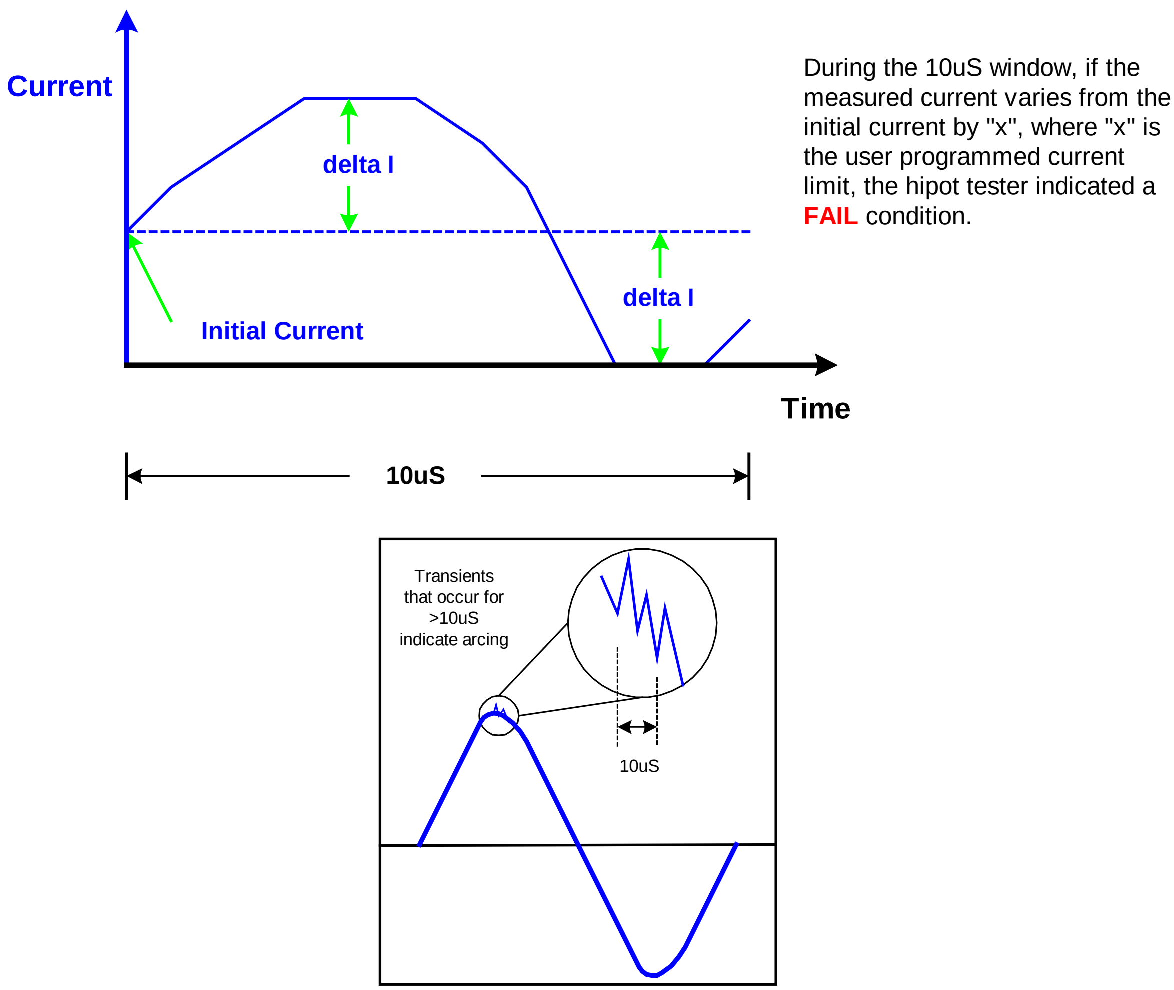

Figure 3 Arc Detection

Insulation Resistance Tests

Insulation resistance tests are commonly performed to satisfy specific motor safety requirements as they relate to electrical insulation and insulating systems, and bushing and winding tests. Insulation resistance tests consist of high-resistance measurements at relatively high potentials, accompanied by pass/fail detection. The resistance range for an insulation test typically ranges from 1MΩ to the PΩ and TΩ regions. Voltage potentials vary from 100V to 1000V DC. The instruments can be programmed to provide simple pass/fail annunciation. An excerpt from the UL 1004 Safety Standard for Electric Motors:

"Material used to support live parts shall be acceptable with respect to resistance to flame propagation, resistance to arc tracking, resistance to ignition from electrical sources, resistance to moisture absorption, dielectric strength, and mechanical strength"[2]

Although an insulation resistance test will not satisfy all requirements listed in the above directive, it will satisfy many of them. Keep in mind that to gain compliance with a safety standard, other electrical and mechanical instruments, in addition to hipot testers, are required.

Ground Bond

Ground bond tests are arguably the most important tests found in safety standards. They ensure that accessible parts of a device that can become energized can safely conduct the energy to ground and safely away from the user. This is the reason that products are checked for continuity during final testing. No manufacturer would want a customer to find the ground continuity deficiencies of its product. The safety standard excerpts below are good examples of ground continuity requirements. From UL 1004 Safety Standard, "Electric Motors" Fifth Edition, pg.27, section 21A:

"For a motor provided with an attached grounding-type power-supply cord, electrical continuity shall be provided between all exposed dead-metal parts and the point of connection of the grounding conductor of the power-supply cord of a motor. "

From UL 982 "Motor Operated Household Food Preparing Machines" Fourth Edition, pg. 30, section 19.2:

"If a grounding means is provided on an appliance, whether required or not, all exposed dead metal parts and all dead metal parts which are exposed to contact during any servicing operation and which are likely to become energized shall be connected to the grounding means. Servicing, here mentioned means 'user servicing', not repairs made by a qualified service person. The following are considered to constitute means for grounding:"

a. In an appliance intended to be permanently connected by a metal-enclosed wiring system

b. In an appliance intended to be permanently connected by a non-metal-enclosed wiring system.

c. In a cord-connected appliance

The safety standards are straightforward with regard to continuity, and usually no more than a tenth of an ohm is permitted to impede a signal to ground. The basic continuity test is a low-resistance measurement, but since high current potentials are required to simulate real-world conditions, a simple milliohmmeter cannot accurately perform the test.

More Ground Bond

To differentiate between ground bond and ground continuity, look at the current used in the test. Both tests verify that all conductive parts of a product that are exposed to user contact are connected to power line ground. The ground bond test verifies the integrity of that ground connection with a high current (20-30A) AC signal. This bond test is a better simulation of how the product will perform under an actual fault condition.

For ground bond tests, a test instrument is set up to impose and direct an electrical current from exposed metal to the ground plane. The tester imposes the current and simultaneously monitors the resistance between these two points. The typical current and resistance ranges required for ground bond testers are 1A to 30A and 1mΩ to 0.5Ω, respectively. Of course, a resistance present in the path of the test signal indicates a problem and should be corrected before product is shipped to the end user.

The Value of Sequence Testing

During safety compliance testing, it is often useful to run a series of tests automatically in sequence (e.g. insulation resistance test, hipot test, and insulation resistance test). In this example, the first insulation resistance test provides a base-line resistance measurement. The hipot test then stresses the DUT, and the final insulation resistance test determines the effect of the hipot test on the insulation resistance of the DUT. If the results of the second insulation test match the first, the integrity of the insulation has not been compromised. If the insulation resistance of the second test is much lower than the first, the DUT's insulation resistance has been diminished.

Sequence testing is an invaluable tool for detecting latent product failures. Such failures are somewhat common and offer some evidence of their existence. However, unless the proper test equipment and methods are employed, these latent defects will be discovered by the customer and not during the manufacturer's final test. It's easy to see why an instrument that offers sequence testing is attractive in detecting failures before the customer is exposed to them.

Latent defects in a motor, for example, which will not likely result in an actual breakdown until the customer receives the unit, can only be uncovered by performing a sequence of tests. A hipot test, which is the best indicator of future motor failure, is first performed. Next, an insulation resistance test is conducted, which is the most common way to determine existing defects (including those that can be caused by the hipot test itself). Many hipot testers (mostly of the digital variety such as the Chroma line) can conduct sequence testing and test parameter storage. This provides not only the ability to program and run a sequence of tests, but to store the tests in groups for later recall as well.

Summary

The standards governing the design of products using electric motors and motor subsystems clearly define the electrical requirements that must be met. The standards are usually not difficult to satisfy, but must be well understood in order to do so. Attention to the detail of the standards, along with strict quality control, will ensure that the consumer is not the one who ultimately determines the safety of the product.

A Guide to the Safety Organizations

Underwriters Laboratories, Inc., founded in 1894, examines and tests devices, systems, and materials to determine their relation to hazards to life and property. They define and publish standards and specifications affecting such hazards.

The major international safety organizations make their standards available to anyone, most at a cost. To locate national and international testing laboratories and safety organizations check the world-wide-web for the latest information. A few are listed below:

Underwriters Laboratories, Inc. (UL)
333 Pfingsten Road
Northbrook, Illinois 60062-2096
(708) 272-8800
http://www.ul.com

American National Standards Institute (ANSI)
1 West 42nd street
New York, New York 10036
(212) 642-4900
http://www.ansi.org

International Standards Association (ISO)
1 Rue de Varembe, Case postale 56 CH-1211
Geneve 20 Switzerland
+ 41 22 749 01 11
http://www.iso.ch

Occupational Health & Safety Act (OSHA)
JFK Federal Building, Room E340
Boston, Massachusetts 02203
(617) 565-9860
http://www.osha.gov