

Latest Repair Technologies

The two common elements in most of the latest electrical apparatus service center repair technologies are computers and data acquisition, often used in combination. Here we will consider how some of these recent additions may impact on a typical commercial or industrial use motor as it goes through the repair process in a technologically advanced electrical apparatus service center.

Such a service firm will monitor the repair process, from initial telephone call or written order, by way of a computerized order tracking system. A typical system will indicate the nameplate data of the machine to be repaired, customer correspondence records, and special repair instructions. Data on labor and materials that go into the repair process are likewise acquired by computer, often through bar-coding. Parts are labeled with bar codes and their usage is recorded by scanning the code with a light pen or similar device. Labor may also be entered by way of bar codes for the specific tasks being performed, e.g., "Make coils for new winding". Repair technicians may carry their own personal identification bar code cards with which to log "on" and "off" of repair jobs. The added benefit of this computer controlled data acquisition system for the repair firm, and the customer, is accurate billing for work done and materials used.

When a motor arrives at the service center it is tested with not only instruments such as the traditional and still reliable megohmmeter, but also devices such as a surge comparison tester. This surge tester will apply a high voltage stress between the winding elements, such as coil to coil and turn to turn. Megohmmeters and conventional high potential testers only test the winding insulation strength to ground, i.e., the machine frame. The data from the surge test can be downloaded into a computer data base for future comparison, and printed out to the repair record file for hard copy documentation purposes.

Following dismantling of the motor, the stator core should be core loss tested to ascertain the relative core quality. Comparisons of core tests before and after winding removal verify that core quality has not been compromised and that core losses have not increased. Core tests cannot be reliably compared between different manufacturers' core testers, or even the same make under different conditions. Therefore, a computer database is essential for acquiring and then establishing acceptance criteria for such critical elements as "hot spot" temperature and watts per pound of core loss under equivalent test conditions. The test results in Figure 1 are for the same stator core. The "fail" assessment applies to the core as tested before winding removal. Testing of the same core after winding removal and core repair indicated an improvement in core quality to an acceptable "pass" level.

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PASS	FAIL
 LONGO INDUSTRIES Wharton, NJ	 LONGO INDUSTRIES Wharton, NJ
Customer Data Customer: BOMA Horsepower: 150 Work Order: 14330 Voltage: 460 Manufacturer: Marathon Rated Amps: 170 Ser. Number: 09-02192-10-1 RPM: 1780 Date: 12/21/98 Frame: 445T	Customer Data Customer: BOMA Horsepower: 150 Work Order: 14330 Voltage: 460 Manufacturer: Marathon Rated Amps: 170 Ser. Number: 09-02192-10-1 RPM: 1780 Date: 12/20/98 Frame: 445T
Stator Data Diameter: 12.125 Vent Width: 0 Back Iron: 1.50 Number of Vents: 0 Slot Depth: 2.00 Length of Core: 10.625	Stator Data Diameter: 12.125 Vent Width: 0 Back Iron: 1.50 Number of Vents: 0 Slot Depth: 2.00 Length of Core: 10.625
Test Data Pyrolyzed: Yes Power Factor: 0.31 Voltage: 3.633 Kilolines/Sq.In.: 90.0 Kilowatts: 0.522 Watts/Pound: 2.25 Amperage: 458 A.T./Inch: 8.27	Test Data Pyrolyzed: No Power Factor: 0.36 Voltage: 3.628 Kilolines/Sq.In.: 89.9 Kilowatts: 0.657 Watts/Pound: 2.84 Amperage: 504 A.T./Inch: 9.11
Hot Spot Data Duration of Hot Spot Check 15 Minutes. Unit Ran at a Level of 458 Amps.	Hot Spot Data Duration of Hot Spot Check 15 Minutes. Unit Ran at a Level of 504 Amps.
Temperatures: (Celsius) Ambient 17 Core Average 19 Hot Spot 21 Temp Rise 4	Temperatures: (Celsius) Ambient 21 Core Average 29 Hot Spot 34 Temp Rise 13
Judgements Temperature rise is acceptable Watts per pound are acceptable. The unit has passed core tests.	Judgements Temperature rise is marginal. Watts per pound are marginal. Core repair is recommended.
TESTED BY: D.A. ENGINEER: R.C.	TESTED BY: P.R. ENGINEER: R.C.
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Figure 1: Actual core loss test results from a 150 horsepower motor. The “FAIL” assessment on the right was for the core as-received. The core was repaired to achieve the “PASS” acceptance level shown on the left.

Infrared scanning for hot spots can be used to test both stator windings and squirrel cage rotors. The primary application for infrared testing of stator windings is to inspect for physical looseness or high electrical resistance in connections. The test is performed by passing high current through the stator windings, usually at or above the machine’s rating, and observing temperature rise through a camera associated with the infrared scanning device. This test is invaluable in detecting, and exactly locating, connection faults that if left uncorrected could lead to premature winding failure. Infrared scanning may be used to test for loose or high resistance connections on any electrical circuit, not only stator windings.

An even more important use of infrared testing in the service center is the testing of squirrel cage rotors for cage defects. The rotor core is magnetized by using a core loss tester to pass very high levels of current (typically thousands of amperes) through the rotor shaft to induce current in the rotor cage. The infrared scanner is then utilized to observe the rotor bars and end rings, which together make up the cage winding, for hot spots. The camera, normally attached to a video recorder, documents the test results. A Polaroid photo is often used to provide “snapshots” of any defects detected. Hot spots in a die cast rotor are usually due to voids in the casting, whereas fabricated rotor defects are usually associated with cracked bars or poor quality brazed joints.

An important part of the winding removal process is accurate data taking, wherein key design elements such as the number of turns and wire size of the coils, and physical dimensions of the core are recorded. The winding design is then analyzed by a computer program that evaluates the electrical and magnetic parameters using the as-found data. If values are found to be outside industry accepted norms, a call to the original manufacturer or contact with a motor designer is usually made. The benefit of this rigorous computer analysis for the customer, and the repair service facility, is that previous mistakes are not duplicated. Further, the machine is accurately restored to its original electrical design parameters.

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Following the design verification, coils for the new winding to be inserted are wound on a computer-controlled winding machine. The computer stores all the key winding parameters such as turns, wire size, and exact coil shape. By precisely "layering" the turns, less winding space is required in the slots, and the voltage between adjacent wires can be better controlled. The significant effects of these two features are less chance of physical damage during insertion and, consequently, a more reliable winding. The built-in repeatability of computer programming further assures that each winding circuit will be equal and, therefore, the winding will be magnetically balanced.

If the winding power source is a variable frequency drive (inverter), it is advisable to increase the turn-to-turn, and winding-to-ground, dielectric strength. Doing this requires additional insulation throughout the winding. Making use of the computerized winding machine to create the new coils provides the capability to produce stator coils that can fit in the same physical space as the original. This is achieved without reducing the copper volume which would reduce efficiency, yet increasing the wire and ground insulation thickness (strength).

Winding redesign for new requirements can be achieved by making use of commercial design programs produced by engineers with extensive motor manufacturing design experience. Although such rigorous programs should only be used by experienced engineers, the resulting calculated redesign machine parameters have a high level of confidence and accuracy. Thus the customer (end user) and the service center both achieve satisfactory and reliable results from an optimized design, rather than a "guess" or conservatively underrated machine. The use of such programs can preclude the need for dynamometer testing to verify acceptable performance.

On the mechanical side, computerized dynamic balancing machines are found in many medium and larger repair service centers. The computer determines the exact (to within one mechanical degree) location and amount of balance correction weight required. Hard copy printouts are standard for these machines, and the ability to store the data for future reference is an added feature. Having the dynamic balancing data stored will allow for future balancing of the same rotating element to be accomplished in one run following the initial setup.

When the repaired motor reaches the final test area it can be operated from a stepless variable voltage supply, with the ability to precisely balance line to line voltages. The inputs to the motor, its physical parameters, and power output, if desired, can be measured and recorded by a data acquisition system linked to a computer. Electrical inputs to be measured and recorded would typically consist of line voltages and currents, and power. Physical characteristics that are measured and recorded most often are speed, vibration at each bearing, and the temperatures of the windings and bearings. The data acquisition system can record these not only at start up, but also at any number of points, usually equal time periods during the test run. If output data is desired, normally by dynamometer test, this would add the torque parameter to those already mentioned. There are sophisticated data acquisition systems linked to computer programs for performance testing that go beyond just measuring characteristics at specific load points. By making use of mathematical models, termed algorithms, they are capable of using data taken without load to calculate the motor starting speed-torque curve. As such systems evolve they hold the potential to preclude the need for dynamometer testing to determine the efficiency and torque characteristics of motors.

In addition to measuring the performance characteristics of the motor on final run test, vibration can be recorded using a Fast Fourier Transform (FFT) analyzer. This instrument records and can download the vibration data to a computer for either record keeping or further analysis, or both. The FFT typically provides a vibration spectrum, which is a plot of vibration amplitude versus frequency. Such a spectrum can be used to identify the sources of operating deficiencies such as mechanical looseness, or uneven air gaps. The analytical capabilities of such instruments extend beyond the mechanical into the field of diagnosing electrical faults. A significant example of this is the use of rotor "side band" frequencies to identify rotor cage faults under load.

Although motors are not normally load tested during routine repairs, an advanced technology service firm may have a regenerative dynamometer. Conventional dynamometers "absorb" the motor load and convert it to heat energy that is normally wasted. Compounding the waste is the fact that the utility will have a demand charge based on the kilowatt consumption associated with the load test.

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For example, a 250 horsepower motor may require about 200 kilowatts at full load. If the demand charge is \$10 per kilowatt, the test will cost about \$2000! By utilizing a regenerative type dynamometer, only the losses must be supplied by the line. The electronic controls regenerate, i.e., "pump back" the bulk of the load test energy onto the incoming lines. For the case just mentioned, if the regenerative system was 90% efficient, the utility demand charge would be reduced by \$1800, a substantial saving. Dynamometer testing has the advantage of simulating load conditions, making it possible to test for vibration, electrical parameters, and temperatures. As mentioned above, the rotor cage can also be tested for load related defects using an FFT analyzer.

A modern electrical apparatus service center is one that will have some, but almost certainly not all, of the latest repair technologies mentioned here. The nature and demands of the facility's customer base will have the most significant effect on which advanced technologies the service firm will offer its customers to provide the greatest value possible at a reasonable cost.