



Selected Bibliography on Electric Motor Repair



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Selected Bibliography on Electric Motor Repair

Advanced Energy Corporation, *Horsepower*. Part of the "Solutions for Industry" series, 1993.

A good pamphlet on the motor replacement decision process. There is a strong focus on the importance of efficiency and helpful information on getting a quality repair job. A number of charts and lists give rules of thumb for the decision-maker who does not have the time for an in-depth quantitative analysis.

Association of Electrical and Mechanical Trades, *Good Practice Guide—The Repair of Induction Motors—Best Practices to Maintain Energy Efficiency*, 1997.

Available through Electrical Apparatus Service Association, St. Louis, MO.

A study report describing how proper motor repair can prevent any loss of efficiency in rewinding. This guide is aimed at service centers to help them maintain efficiency levels.

Anderson, Edwin P. and Rex Miller, *Electric Motors*, 5th Edition, 1991.

A comprehensive textbook intended for electricians and industrial maintenance personnel. It gives a very thorough explanation of the principles upon which motors run and covers details of their construction, winding configurations, controls, etc. This is a good start for someone, starting from any level, to acquire a reasonably thorough knowledge of motor design, applications, and repair.

Bernow, Steve, Frank Ackerman, et al., "Direct Environmental Impacts of Demand-Side Management." *ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, ACEEE, 1992, p. 9.23-9.24.

Broadly discusses environmental impacts of DSM. Includes a good section on the comparative environmental impacts of motor rewinding vs. new motor manufacture.

Bethel, Noah, P., "Fault Zone Analysis Identifies Motor Defects in Detail." *Pulp & Paper*, Vol. 72, No. 2, February 1998, p. 87-93.

Discussion of 5 fault zones to look at during troubleshooting (power circuit, insulation, stator, rotor, rotor/stator relationship). If maintenance personnel miss any of these zones, they could miss the problem, as well as lose credibility for their fault detection skills.

Bishop, Thomas H., "Motor Repair Industry Response to the Energy Policy Act of 1992: A Status Report." *Proceedings of the 21st Electrical Electronics Insulation Conference*, 1993, p. 105-108.

Summary of actions taken primarily by EASA responding to legislation and issues pertaining to rewound motor efficiency.

Brethauer, Dale, Richard L. Doughty, and Robert J. Puckett, "The Impact of Efficiency on the Economics of New Motor Purchase, Motor Repair, and Motor Replacement." *IEEE Proceedings of the Petroleum and Chemical Industry Conference*, 1993, p. 37-50.

Provides economic analysis tools for choices involving new motor purchase, motor replacement, or repair.

- Brithinee, Wallace P., "Electric Motor Maintenance & Repair for Long-Term Efficiency." *Energy Engineering*, Vol. 95, No. 1, 1998, p. 22-30.
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- Brithinee, Wallace P., "Electric Motor Repair Industry Update." *IEEE Electrical Insulation Magazine*, July/August 1993, p. 23-24.
Summary of current issues and research pertaining to motor repair.
- "Can Rewinding Hurt Motor Efficiency." *Production Engineering*, June 1985, p. 100-102.
Summarizes EASA Core Loss Study results.
- Charette, A., and P. Angers, "Effects of Repairs on Electric Motor Efficiency." *Pulp & Paper Canada*, Vol. 98, No. 1, 1997, p. 32-34.
Analysis of the effects of motor repair on efficiency. Laboratory testing of 23 50-hp motors sent to 23 motor repair shops showed that drop in efficiency was directly related to work practices, mainly due to the stator characteristics and poor bearing lubrication.
- "A Cheap Rewind of a Motor is No Bargain." *Production Engineering*, February 1985, p. 10.
Report on study by GE of increased core losses from poor quality rewinds.
- Craig, Bill, "Positive Fault Identification Using Surge Testing." *EC&M*, September 1984, p. 40.
Describes "Surge Test" technique. This technique is used to detect errors in the rewound motor as well as diagnosing faults in failed motors.
- Dalrymple, Murray, "PM Programs Reduce Motor Failures." *EC&M*, October 1984, p. 34 & 175.
Describes testing and inspection of motor relay, circuit protectors & fuses.
- Darby, E. Steve, "Electric Motor Rewinding Should Maintain or Enhance Efficiency." *IEEE Transactions on Industry Applications*, January 1986, p. 126-132.
Good overview of techniques used in a good motor repair shop to optimize reliability and efficiency.
- Darby, E. Steve, "Rewinding Motors for Efficiency." *EC&M*, November 1987, p. 30.
Describes recommended rewind techniques for optimum efficiency (and reliability) based on rewinding experience.
- Dreisilker, Henry, "Modern Rewinding Methods Assure Better Rebuilt Motors." *EC&M*, August 1987, p. 30.
Describes efficiency benefits of mechanical winding removal at below 300°F, rather than burnout; also trickle varnishing.
- EASA, *How to Get the Most From Your Electric Motors*. Electrical Apparatus Service Association, St. Louis, MO 1997.
Guidelines on application, maintenance, cleaning, and testing of motors. Includes information on repair vs. replacement.
- EASA, *Recommended Practice for the Repair of Electrical Apparatus*, EASA AR100-1998, Electrical Apparatus Service Association, St. Louis, MO.
Formerly called a "standard," this document describes record keeping, tests, analysis and general guidelines for the repair of electrical motors and generators. It is widely considered to be the foundation for a quality electric motor repair.

EASA, *Can Energy Efficient Motors Be Rewound Satisfactorily?* EASA Tech Note 26, Electrical Apparatus Service Association, St. Louis, MO.

Reprint of an article by Professor David Walters in the February/March 1998 EASA Currents newsletter. Provides test evidence that proper rewinding can maintain original efficiency.

“Electric motor tester diagnoses problems, prevents downtime.” *Oil & Gas Journal*, Vol. 96, No. 8, February 23, 1998, p. 69-70.

Results from a new motor circuit evaluator (MCE) tester used to troubleshoot problems and provide diagnostic results and data trends on electric motors.

Electrical Apparatus

This journal of electromechanical and electronic applications and maintenance offers extensive reporting on electric motor repair in every issue.

Falkner, Hugh, “Drive for more efficient motors.” *Metallurgia*, Vol. 64, April 1997 supplement, p. S4-S5.

Discusses recent changes in the energy-efficient motor market, and repair/replace options.

Farlow, Jeff, “Predictive Maintenance Enhances Motor Longevity.” *Energy User News*, Vol. 23, No. 2 February 1998, p. 12 and 14.

Discusses the reasons for motor failure as well as techniques/tools for diagnosing a motor’s condition and predicting and preventing failures.

Gupta, B.K., and D.K. Sharma, “Degradation of Turn Insulation in Motor Coils Under Repetitive Surges.” *IEEE Transactions on Industry Applications*, June 1990, p. 320-326.

Test the hypothesis that electrical surges (such as produced by utility switch gear) ages winding insulation. Tests indicate minimal effect. Very technical.

Idhammar, Christer, “Basic Motor Cleaning, Inspection Can Help Reveal Possible Problems.” *Pulp & Paper*, February 1994, p. 68.

IEEE Standards Board, *IEEE Recommended Practice for the Repair and Rewinding of Motors for the Petroleum and Chemical Industry*, May 1990, IEEE STD 1068-1990, p. 23.

Specific step-by-step technical instructions for repairing motors, as recommended for the petroleum and chemical industries.

Jenkins, J.E. Sr., “How to Perform Electrical Maintenance on Induction Motors.” *EASA Currents*, July 1990, p. 3.

Guidelines on in-situ maintenance and testing of induction motors.

Lahaie, S., *Evaluation of Electric Motor Repair Procedures*. Canadian Electricity Association, Montreal, Quebec (Canada), CEA 9205 U 984, December 1996.

A study of repair procedures on low voltage induction motors in the 1 to 500 horsepower range. Includes a practical guidebook on quality motor repair procedures, testing verification, and equipment requirements that minimize degradation of efficiency.

Lawrie, R. J., “How Modern Service Firms Keep Your Motors Running Better and Longer.” *EC&M*, July 1992, p. 39-48.

Description of standard and innovative motor repair and testing procedures, featuring several progressive shops throughout the U.S.

Lawrie, R. J., “Modern Motor Test Techniques.” *EC&M*, July 1992, p. 33-38.

Description of important motor testing techniques for troubleshooting and verification of proper repair.

LeFevre, Rick, "Predictive Maintenance Surge Testing." *Plant Engineering*, June 1987, p. 108-107.

In-depth description of "Surge Testing," with specific testing program recommendations.

Litman, Todd, *Efficient Electric Motor Systems Handbook*, Fairmont Press, 1995.

Discusses the typical kinds of problems that lead to motor inefficiency or failure. Also discusses how to determine when it makes economic sense to upgrade to an energy-efficient motor, and whether an adjustable speed drive or other advanced control system will give you the results you seek. It covers all aspects of motor systems including motor repairs, and predictive & preventive maintenance. Nine useful appendices are included, such as a procedure for motor repair shop evaluation, model electric motor repair specifications, and forms and checklists for tracking a motor through a quality repair.

Maassen, Erik, "Maintenance Tips for Electric Motor Bearings." *Maintenance Technology*, November 1992, p. 26-59.

Discussion of motor bearing maintenance for optimizing reliability.

McCoy, Gilbert and Johnny Douglass, *Energy-Efficient Electric Motor Selection Handbook, Revision 4*. U.S. Department of Energy/Bonneville Power Administration, DOE/GO-10096-290, August 1996.

Summary of considerations for selecting energy-efficient motors for specific applications.

McCoy, Gilbert and Johnny Douglass, *Energy Management for Motor Driven Systems*, U.S. Department of Energy, DOE/MC-10021, June 1997.

Comprehensive guidebook on motor systems management. It covers systems management from the electrical distribution system to the driven load.

Montgomery, David, "Testing Rewinds to Avoid Motor Efficiency Degradation." *Energy Engineering*, Vol. 86, No. 3, 1989, p. 24-40.

Overview of impacts of rewinds on motor efficiency.

Montgomery, David, "The Motor Rewind Issue—A New Look." *IEEE Transactions on Industry Applications*, September 1984, p. 1330-1335.

Good overview of impacts of rewinds on motor efficiency. Also disputes that motors lose efficiency merely because of aging.

Motor Challenge Sourcebook, U.S. Department of Energy, DOE/GO-10096-254, 1996

A master list of activities and resources in the industrial motor systems market. It covers product manufacturers, references and standards, government associations, trade associations, and much more.

"Motor Repair." *Drivepower Technology Atlas*, Chapter 10, E-Source, Inc., Boulder, CO, 1997.

A very comprehensive reference that promotes a strong emphasis on energy efficiency. Chapter 10 covers all aspects of the motor repair and rewind process. Emphasis is placed upon efficiency and performance. Alternative methods are reviewed in terms of their convenience, environmental effects, and impact on motor efficiency. Studies on efficiency of rewound motors are reviewed and summarized.

"Motor Winding Analyzer Detects Problems Early." *Power Engineering*, December 1991, p. 45.

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- Moudy, W. Howard, Jerry S. Honeycutt, Roland P. Krebs, Jr., and Norm Holladay, "Considerations Regarding Coil and Insulation Systems for Medium and High Voltage Motor Rewinds." *Proceedings of the 57th American Power Conference*, Chicago, IL, Vol. 2, 1995, p. 1251-1256.
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- Nailen, Richard L., "Explosion-proof Motors Need Careful Repairs." *EC&M*, April 1986, p. 30 & 36.
Discusses specific repair requirements for explosion proof motors.
- Nailen, Richard L., *Managing Motors*. Barks Publications, Inc., January 1991.
This book provides very thorough coverage of electric motor design, efficiency, application, maintenance, and repair.
- Nailen, Richard L., "Taking Another Look at Insulation Resistance." *Electrical Apparatus*, Vol. 50, No. 5, May 1997, p. 28-33.
A comprehensive and critical look at motor insulation testing. The various popular tests are compared in terms of what they can find and the stress they impose on the motor. Temperature effects and the behavior of different insulation materials are discussed.
- Nailen, Richard L., "Understanding surge comparison testing." *Electrical Apparatus*, Vol. 48, No. 12, December 1995, p. 27-31.
What surge comparison testing is, and what it isn't. This testing for variations is used mainly to diagnose insulation condition, but it will also reveal improper winding connections unrelated to dielectric integrity.
- Nailen, Richard L., "A User's View of Motor Repair Standards and Specifications." *IEEE Transactions on Industry Applications*, November 1988, p. 1131-1137.
Author describes his program to establish motor repair standards.
- Nailen, Richard L., "What's Wrong with That Motor?" *Electrical Apparatus*, Vol. 49, No. 5, May 1996, pp. 39 & 45.
A good general approach to troubleshooting, this makes use of a medical analogy to discuss diagnosis of motor systems problems. The reader is encouraged to think creatively and with appropriate skepticism toward hearsay information.
- NEMA Standards Publication No. MG 1-1998, Motors and Generators*, National Electrical Manufacturers Association, Rosslyn, VA
This major standard of the National Electrical Manufacturers Association covers the design and performance standards of electric motors. It is a must for any serious motor systems manager.
- Nicholas, Jack, "Evaluating Motor Circuits." *Maintenance Technology*, November 1992, p. 30-34.
Advice for evaluating motor circuits to maximize reliability.
- Penrose, Howard W., "Anatomy of an energy efficient electric motor rewind." *IEEE Electrical Insulation Magazine*, Vol. 13, No. 1, January-February 1997, p. 14-19.
Analysis of methods and procedures for rewinding electric induction motors. Emphasis on efficient and reliable motor repairs that comply with CSA 390 standards.

- Penrose, Howard W., "Electric motor repair for low voltage induction motors in PWM inverter duty environments." *Proceedings of the 1997 23rd IEEE Electrical/Electronics Insulation Conference and Electrical Manufacturing & Coil Winding Conference*, Rosemont, IL, 1997, p 841-848.
Presents a recommended repair specification meant to reduce the chance of inverter duty failure with VFD-driven motors.
- Penrose, Howard W., and Barry Bauer, "Time savings and energy efficiency through alternate electric motor rewind methods." *Proceedings of the 1995 22nd IEEE Combined Electrical/Electronics Insulation Conference and Electrical Manufacturing & Coil Winding Conference and Exhibition*, Rosemont, IL, 1995, p. 457-460.
Introduces techniques for reducing turn-around time including mechanical stripping, automated winding, and trickle varnish impregnation.
- "Preventative Maintenance of Motors and Controls." *EC&M*, February 1986, p. 24-28.
Outlines recommended motor and motor control maintenance program.
- "Proper Burnout Methods Maintain Efficiency of Rebuilt Motors." *EC&M*, March 1985, p. 71.
Report on study by EASA on impact of stator winding burnout temperature on motor efficiency.
- Protopapas, C. A., S. D. Kaminaris, and A. V. Machias, "An Expert System for Fault Repairing and Maintenance of Electric Machines." *IEEE Transactions on Energy Conversion*, March 1990, p. 79-83.
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- Ramsey, Milton H., and J. Kirk Armintor, "Recommended Practice for Repair of Electrical Motors." *IEEE Transactions on Industry Applications*, January-February 1993, p. 52-59.
History and summary of IEEE Standard 1068, pertaining to motor repair for the petroleum and chemical industries.
- Reason, John, "Cut the Cost of Cleaning Electric Machines." *Electrical World*, April 1989, p. 74.
Describes predictive testing for large (power plant) motors.
- Reason, John, "How and When to Grease Motors." *Power*, May 1984, p. 154.
Recommendations for motor regreasing.
- Rewound Motor Efficiency: Technology Profile*. Ontario Hydro, November 1991, p. 3.
Fact sheet discussing efficiency of rewound motors, and arguing for replacement of failed motors whenever possible.
- Rosenberg, Robert, and August Hand, *Electric Motor Repair*, 3rd edition. Holt, Reinhart and Winston, 1987.
First published in 1904, this is considered by some to be the "bible" on electric motor repair. Detailed text and illustrations covering single phase, polyphase, and DC motors and generators, and motor controls.
- Rospond, Kathryn M., "Motor Repairs, Rewinds Exempt from Energy Policy Act." *Consulting-Specifying Engineer*, Vol. 18, No. 6, December 1995, p. 12.
Report noting that motor labeling and efficiency requirements established by EPACT will affect only general-purpose motors built after October 24, 1997.

Schueler, Vince, "Opportunities for Improving the Energy Efficiency of Repaired and Rewound Motors." *ACEEE Summer Study on Energy Efficiency in Industry*, Vol. 2, 1995, p. 509-519.

Summarizes results of a project to assess motor repair practice in the U.S. and to identify opportunities for, and barriers to, improving energy efficiency and quality of repairs. Study included a detailed survey of 65 motor repair shops.

Schueler, Vince, Paul Leistner, and Johnny Douglass, (Washington State Energy Office), *Industrial Motor Repair in the United States: Current Practice and Opportunities for Improving Customer Productivity and Energy Efficiency*. Prepared for Bonneville Power Administration, Portland, OR (DOE/BP-2749, 1995) and Electric Power Research Institute, Palo Alto, CA (EPRI-TR-105731, 1996).

From a national survey of motor repair shops this report characterizes the motor repair industry in the U.S., summarizes current motor repair and testing practice, identifies barriers to energy-efficient motor repair practice, and recommends strategies for overcoming these barriers.

Schueler, Vince, and Johnny Douglass, (Washington State Energy Office), *Quality Electric Motor Repair: A Guidebook for Electric Utilities*. Prepared for Bonneville Power Administration, Portland, OR (DOE/BP-2747, 1995) and Electric Power Research Institute, Palo Alto, CA (TR-105730, 1996).

Information and tools that utilities can use to raise the quality of electric motor repair practices in their service territories. Also an excellent guide for the motor end user.

Schump, David E., "Motor Insulation Predictive Maintenance Testing." *Plant Engineering*, January 1991, p. 47-49.

Description of insulation tests: insulation resistance test, dielectric adsorption test, DC high-potential test, power factor test, and surge comparison test.

Steel Products Manual. American Iron and Steel Institute, January 1983.

Electrical steels: description of core plate lamination insulation used in motors and transformers.

Strugar, Don, and Ray Weiss, "Why Electric Motors Fail." *Plant Engineering*, July 1994, p. 65-66.

Good description of the ambient conditions and power system problems that often shorten the life of motors.

Ula, Sadrul, Larry Birnbaum, and Don Jordan, *Energy Efficient Drivepower: An Overview & 3 Literature Reference Lists*. U.S. Department of Energy, Western Area Power Administration and Bonneville Power Administration, p. 41.

Summary of motor system efficiency, with a short section on rewinds, and three large bibliographies.

"Understanding Insulation Resistance Testing." *EC&M*, July 1984, p. 46-50.

Describes three tests used to identify problems in motor insulation resistance.

Vaughen's Complete Price Guide for Motor Repairs & New Motors, Vaughen's Price Publishing Co. Inc., 1998.

Annually updated cost estimator for electric motor repair and rewind. Costs of repair are broken down by many variables pertaining to the motor construction, geographical location, size, etc. Each year the guide is updated based upon a survey of the market.

"Vibration Monitoring Prolongs Electric Motor Life." *Maintenance Technology*, November 1992, p. 51-54.

Description of successful use of vibration monitoring on electric motors to anticipate problems for correction before failure.

Washington State Energy Office, *Electric Motor Model Repair Specifications*, DOE/BP-2748 and EPRI-TR-105729, prepared for Bonneville Power Administration, Portland, OR (1994) and Electric Power Research Institute, Palo Alto, CA (1996).
Minimum requirements for the repair and overhaul of polyphase AC squirrel cage induction motors. The specifications cover all power ranges, voltages, and speeds of squirrel cage motors.

Yung, Chuck, "Why end play must be checked in ball bearing motors." *Electrical Apparatus*, v. 51, n. 3, March 1998, p. 37-38.

Since most service shops test-run repaired motors for a relatively brief time, under no-load conditions, it is important that technicians understand a few basics about end play. The end play must be checked to ensure that the bearings are not pre-loaded when the motor reaches operating temperature.

Zeller, Edward, "Motor Efficiency is Not Hurt by Careful Rewinds." *Power*, October 1984, p. 142-143.

Summary of EASA study of motor rewind efficiency and burnout temperature.

Zeller, Markus, "Rewound High-Efficiency Motor Performance." *Guides to Energy Management*, BC Hydro, August 1992.

This is a landmark study, forming the basis for assumptions about efficiency degradation following rewinding. Ten 20 horsepower motors were failed and rewound in separate shops in a study sponsored by BC Hydro. Each motor's efficiency was tested per CSA C390 (the Canadian equivalent to IEEE 112B) before and after failure and rewinding. The before and after efficiencies were recorded and the motors were autopsied to explain changes in efficiency.

**Bibliography compiled by Washington State University
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