Electrical Motor Diagnostics Business Case Development

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Introduction

One of the key considerations to the implementation of a motor diagnostics program is to develop a business case. This development is a challenge for any maintenance or reliability technician, supervisor or manager. The purpose of this paper is to provide some information on how to determine the impact of the implementation of motor diagnostics and motor management programs within your facility.

The model used within this paper was collaboratively developed between Carol Vesier, Ph.D., President of RonaMax; Dave Humphrey, Electrician, General Motors at Allison Transmissions in Indianapolis; and, Howard W Penrose, Ph.D., General Manager of ALL-TEST Pro, A Division of BJM Corp. The model is entitled the "Motor Diagnostic Evaluator,"[1] and was developed based upon actual motor system history and successes coupled with information from the "Motor Diagnostics and Motor Health Study."[2] The programs discussed include the use of the ALL-TEST IV *PRO*™ 2000 and EMCAT motor management software. The inclusion of the ALL-TEST PRO MD (motor circuit analysis and motor current signature analysis system) has been shown to provide even more dramatic results with data to be shown in a later paper.

The Scenario

The business case for implementing excellent motor diagnostics and motor management is better for facilities with frequent motor failures**.** To be conservative, we based our business case on a world class facility where motor repairs are considered rare. In this facility the Mean Time Between Failures was 288,000 hours. This is significantly better than numbers reported by most facilities (66,000 to 120,000 hours). The following lists the details of our conservative business case.

- Mean Time Between Failure (MTBF) = 288,000 hours[3] based upon the following
  - Number of Motors: 9,600
  - Plant Operating Hours: 6,000 hours per year
  - Number of Major Repairs/Year (rewind or replaced): 150
  - Number of Minor Repairs/Year (bearings or cleaning): 50
- Of the motors receiving major or minor repair, 50 are determined as removed, not requiring repair (no problem found).
- Shop repair times for major repairs: Min = 36 hours, Max = 168 hours
- Shop repair times for minor repairs: 24 hours
- % of motors that are critical: 20%
- Time to restore equipment to service: Min = 6 hours, Max = 36 hours
- Average Cost of Major Repair or Replace: $1,500

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[1] A sample version of the Motor Diagnostic Evaluator can be downloaded at www.ronamax.com
[2] Howard W Penrose, Ph.D. and Terrence O'Hanlon, SMRP; www.motordiagnostics.com
[3] Mean Time Between Failures can be estimated by the following equation
[# of motors] x [Operating Hours]/[Total Motors Repaired]

- Average Cost of Minor Repair: $500
- $/hour Production Downtime: $25,000

The Initial Simulation

The initial simulation data was entered (Figure 1) and run. The result (Figure 2) identified an average of 6 motors repaired per week with a motor system repair and production impact of $28,433,000 average per year over ten years. Initial costs ranged from $26 to $30 Million.

Figure 1: Initial Simulation Setup

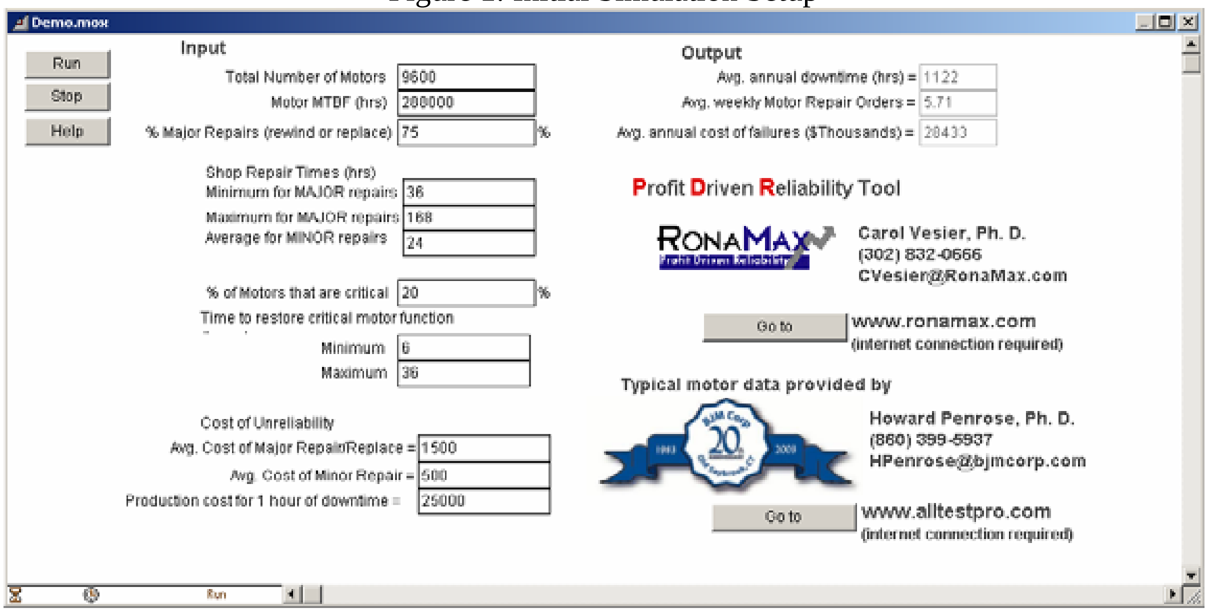
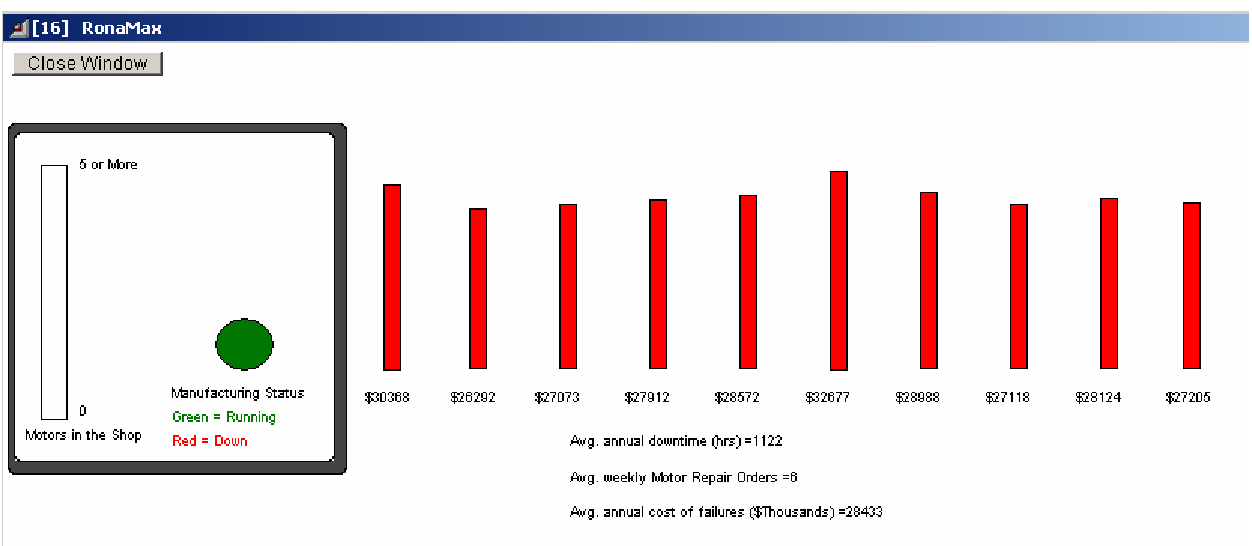


Figure 2: Initial Simulation Conclusions. In the output, the average annual downtime refers to individual lines or machines within the plant, and not the whole plant.



Application of Motor Diagnostics Impact

Excellent motor diagnostics alone will reduce major repairs and the incidence of *"No Problem Found"* (taking a good motor out of service for repair). The "Motor Diagnostics and Motor Health Study" and team experience have shown that major repairs are reduced by at least 75% and incidence of *"No Problem Found"* is virtually eliminated. Improvements at the World Class facility are smaller: major repairs are reduced by 75% and Mean Time Between Failures only increases to 384,000 hours[4] . Figures 3 and 4 show the model input and output associated with implementing excellent Motor Diagnostics at a world class facility.

Figure 3: MCA Application Simulation Setup

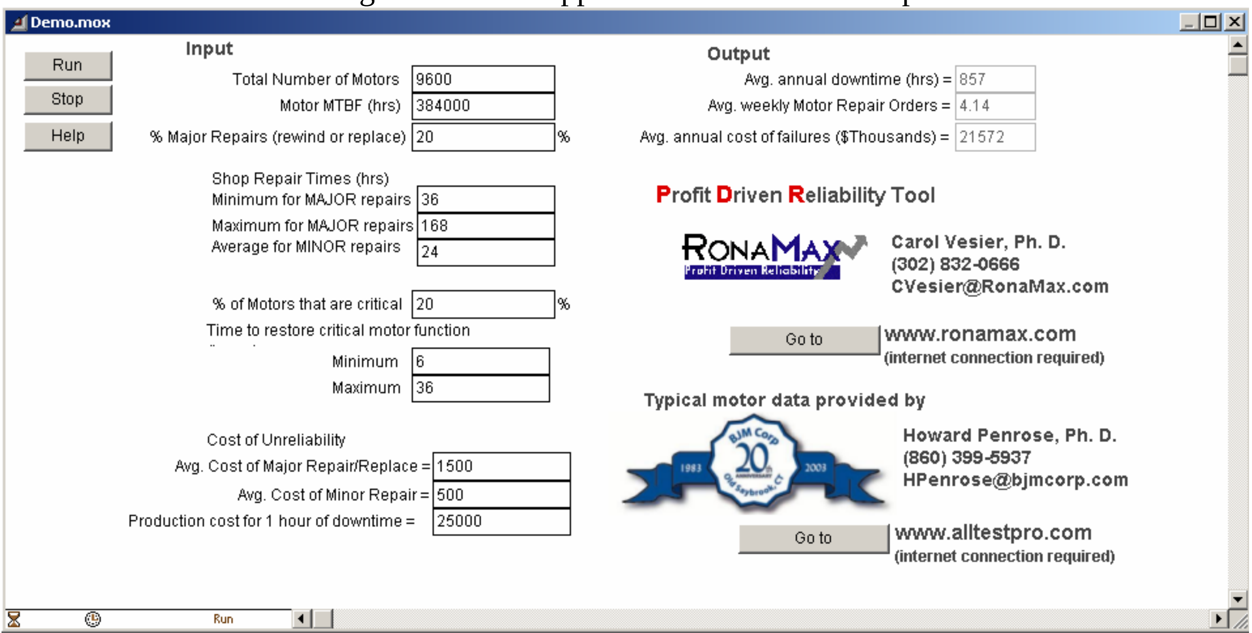
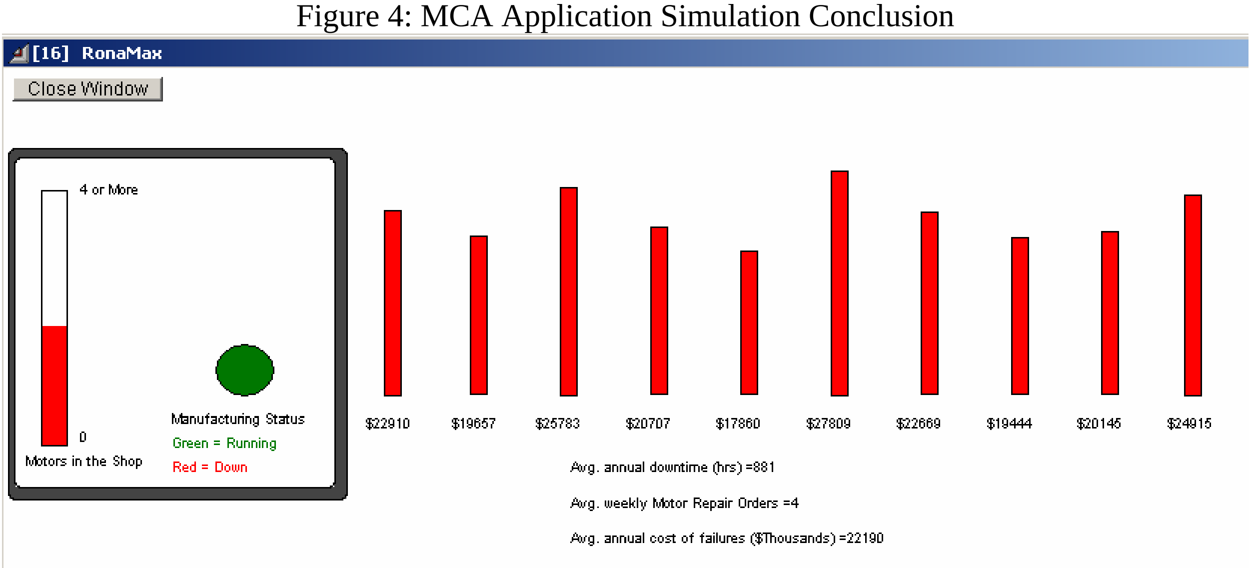


Figure 4: MCA Application Simulation Conclusion



[4] MTBF increases to 384,000 hours when the annual incidents of *"No Problem Found"* is reduced from 50 to 5.

As you can see, the average number of motors in for repair drops to an average of 4 per week, a two motor per week reduction, with the motor related costs dropping to $22,190,000 average per year over ten years (From $17.9 to $27.8 Million). This represents a reduction of 22% from the original repair and production related costs. Average annual downtime is improved to 881 average hours per year. Consider, as well, that quoted from one industry, every dollar saved by maintenance represents $7 that sales would have to make up, this represents an equivalent of $43,701,000 that sales would have had to perform.

Final Model – Full Implementation of Motor Management Program

Implementing excellent motor diagnostics represents only a small part of the Motor Management Opportunity. As time moves forward, a complete motor management program can be implemented. The motor management program would consist of a view of the system from incoming power to driven equipment. It would include:

- Partnering with vendors
- Application of motor diagnostics
- Repair specifications
- Infrared, Ultrasonics, Vibration
- Alignment, Greasing and Training programs
- Monitoring of critical equipment
- And, Other motor management measures

A complete motor management system based on excellent diagnostics will further reduce both major and minor repairs. Using typical improvements, MTBF would double (288,000 hours to 576,000 hours) and % major repairs would drop (50% to 10%). Figures 5 and 6 show the model input and output associated with implementing excellent a complete motor management program at a world class facility.

Figure 5: Simulation Setup for Motor Management Program

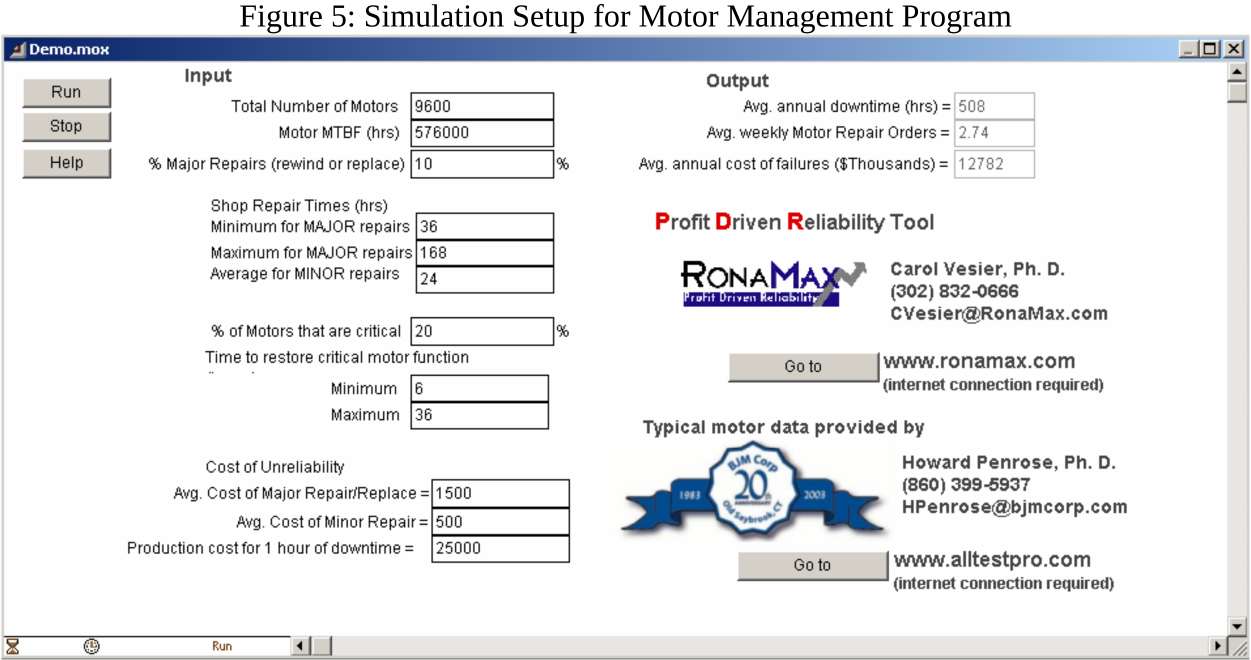
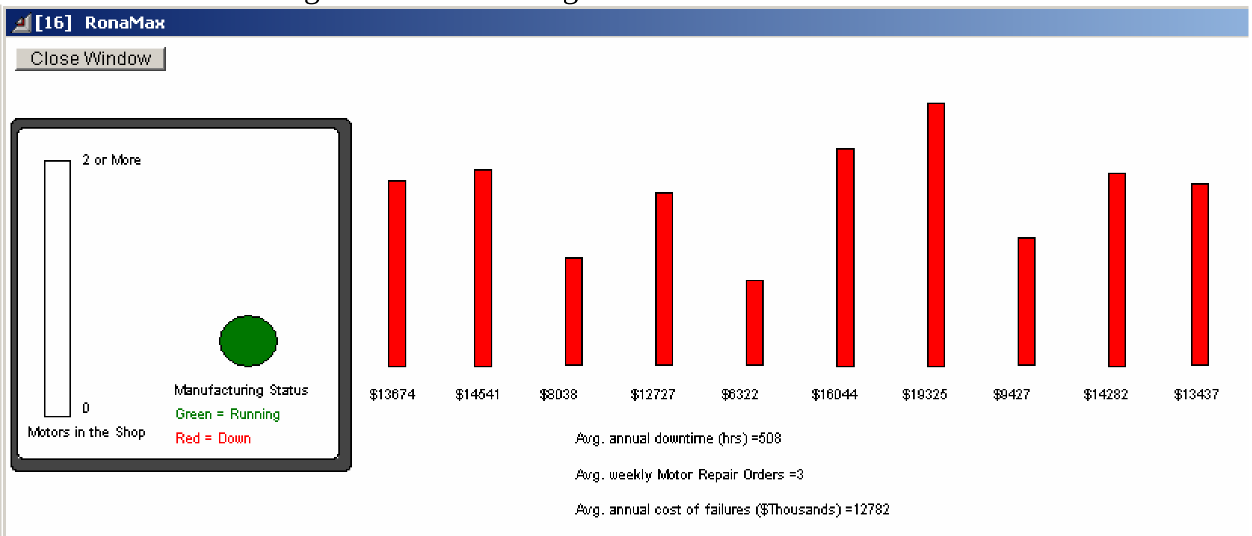


Figure 6: Motor Management Simulation Conclusions



The complete motor management program brings the total cost of motor failure down to an average of $12,782,000 (between $6.3 to $19.3 Million). This cost is 45% of the initial average annual production and repair losses. The average annual downtime improves to 508 hours. You can think of this cost avoidance as an average annual maintenance income of $15,651,000 (or 'sales equivalent' of $109,557,000) with an average of less than three motors in repair per week.

Return on Investment

The return on investment for the above scenarios works out to be immediate. For each of the models, using the commercial list pricing for ALL-TEST Pro motor diagnostics equipment:

- Application of diagnostics system only: 1.75 days, less than 5 business days including training and manpower costs
- Application of Motor Management Program: less than half day, less than 7 business days including training and manpower costs for all equipment and practices used

Business Case at a Glance

Not everyone is world class. They may also have more or less motors. We can use the Motor Diagnostic Evaluator to quickly evaluate how the business case changes for realistic scenarios. For this, we will use the following fixed information (Constants):

- Time for major repair (hours): 36 min, 168 max
- Time for minor repair (hours): 24
- % of motors are critical: 20%
- Time to restore operation (hours): 6 min, 24 max
- Major repair cost: $1,500 repair or replace average
- Minor repair cost: $500
- Cost per hour downtime: $10,000

The variables are as follow:

- Number of motors: 100; 500; 1,000; 5,000; 10,000; and, 15,000

- MTBF: 60,000 and 120,000
- Change in Major Repair: 80% to 20%

Figure 7: Analysis Simulation Setup Example

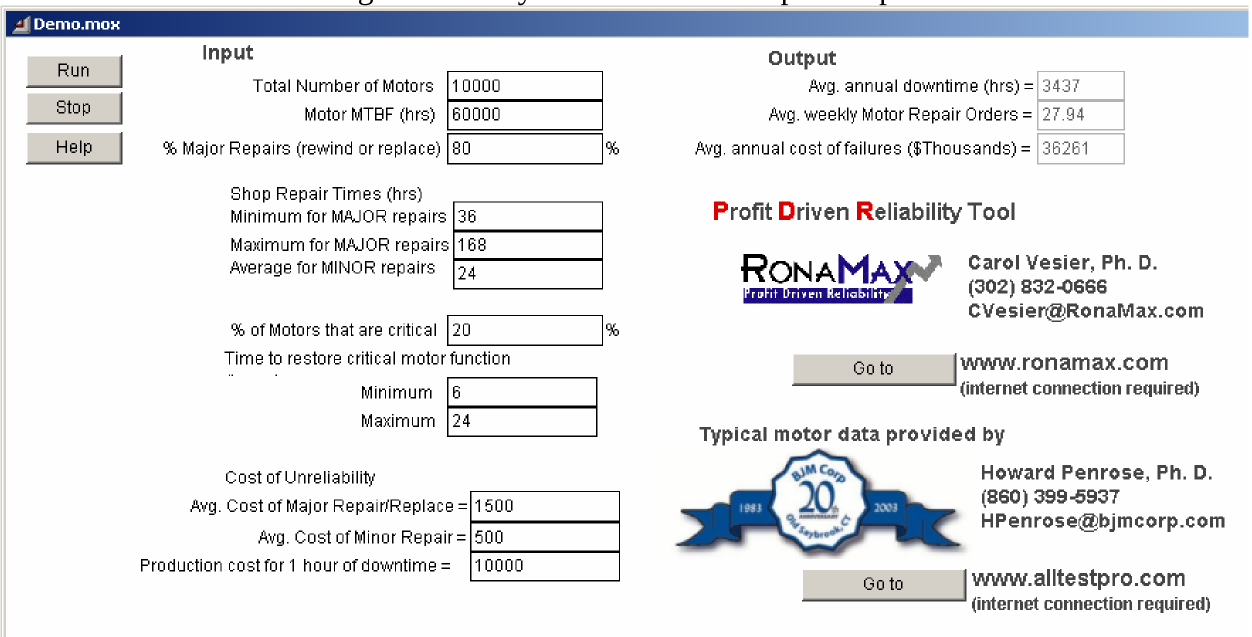
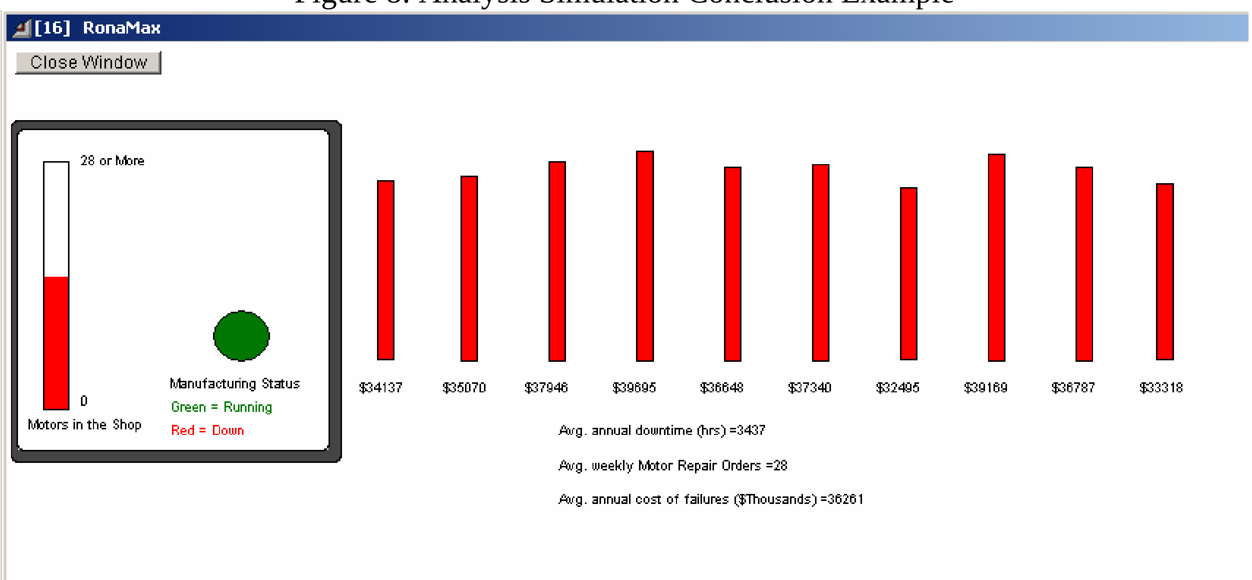


Figure 8: Analysis Simulation Conclusion Example



The results of the scenarios are summarized in the following three graphs. Figure 9 shows just the value of shifting repair types from major to minor (i.e. the total number of repairs does not change). While impressive, you have only accounted for a small portion of the business case. Figure 10 shows the total financial opportunity is in the 7 figure range ($10,000,000 to $60,000,000). This is because you haven't accounted for the *production impact*. In reality, the number of motors repaired will be reduced by eliminating when motors are accidentally repaired or replaced due to older evaluation methods (i.e.: resistance and insulation to ground only). This will increase MTBF and reduce production downtime. Figure 11 shows the total business case assuming MTBF is increased from 60,000 to 120,000 hours

Figure 9: Reduced costs associated with only reducing major repairs from 80% to 20% in a typical facility..

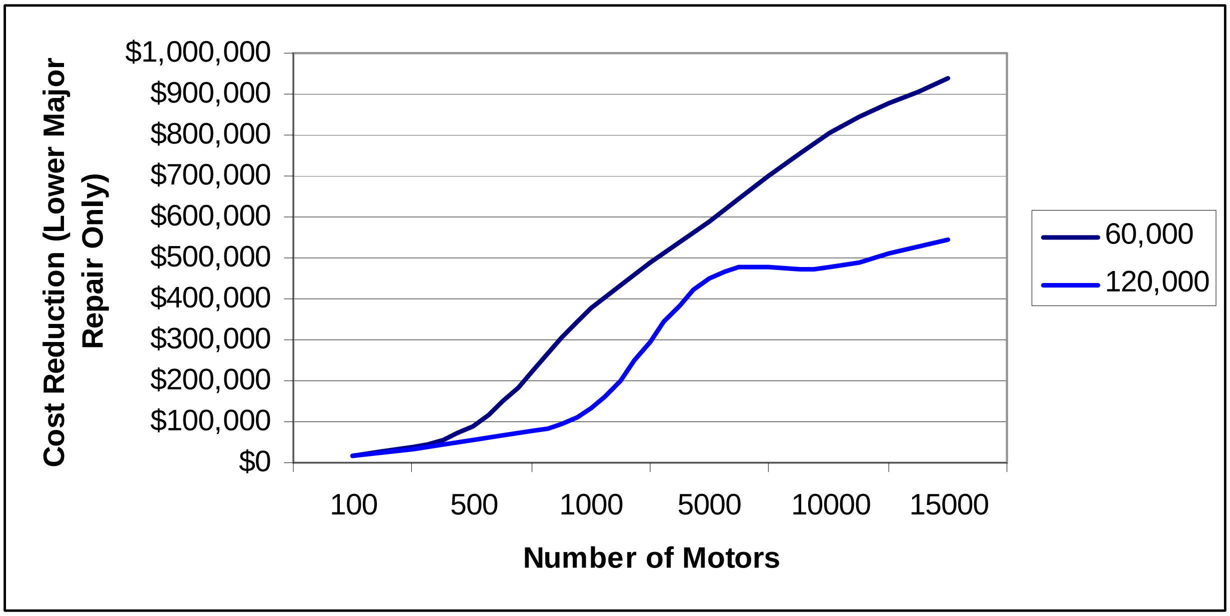


Figure 10: Total business opportunity for a motor management system. Business opportunity is the total cost (production plus repair) of motor unreliability.

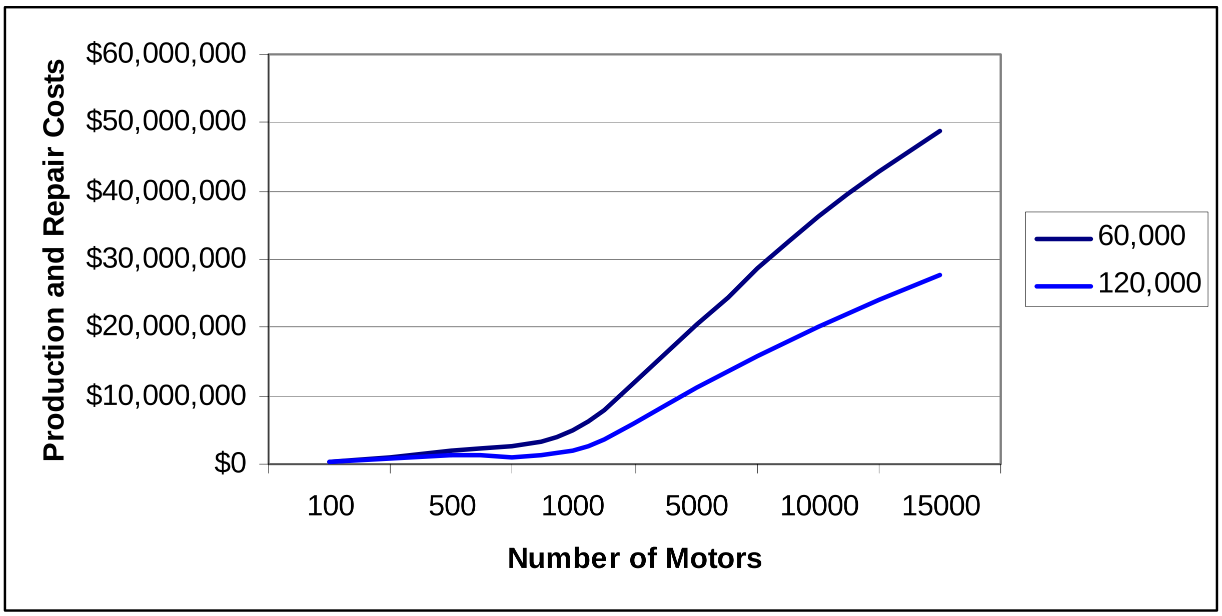
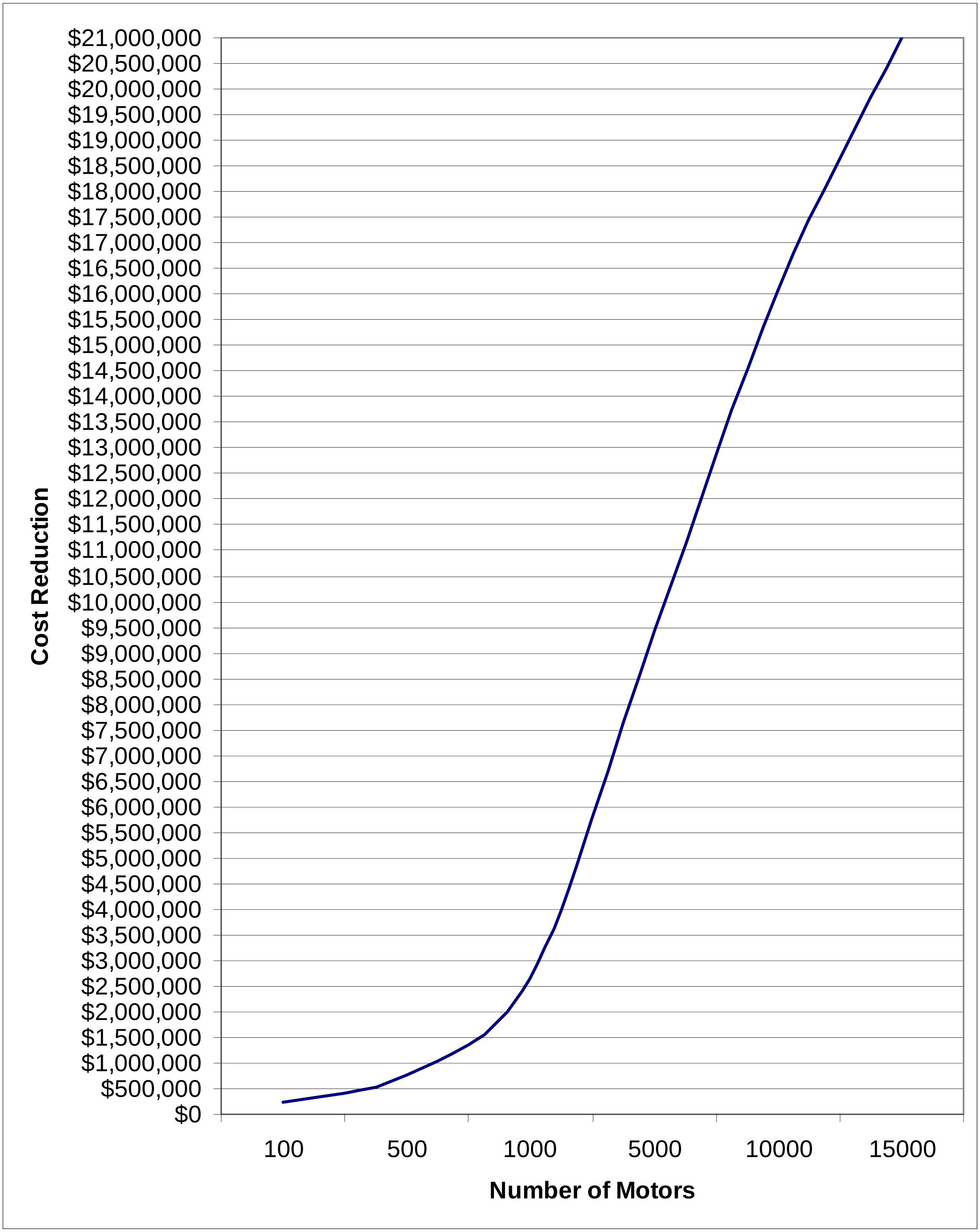


Figure 11: Total cost reduction based on increasing MTBF from 60,000 to 120,000 hours and reducing major repairs from 80% to 20%.



These figures can be used to evaluate the baseline cost savings to justify investing in motor reliability. Using Figure 11, a plant has 100 motors with a production downtime cost of $10,000 per hour. The application of a motor diagnostics program results in an annual average cost savings of $250,000. **This results in a simple ROI of 1.5 months.** If a plant has 2500 motors, the application of the motor diagnostics program will result in an average cost savings of $6,000,000 per year. **This results in a simple ROI of less than 2 business days.**

Conclusion

Most maintenance professionals **drastically** underestimate the value of an investment because they may not realize the production impact of unreliability. The inclusion of the production impact of the application will identify a significant business impact that will have real and immediate results that typically greater than the repair savings. The application of a simulation to model the business model for applying motor diagnostics and a motor management plan will allow the maintenance or reliability technician, supervisor or manager to quickly provide real numbers to management. The Motor Diagnostics model developed by RonaMax, based upon the application of ALL-TEST Pro motor diagnostics equipment, provides an outstanding example of how this model can be applied.

Bio Howard W Penrose, Ph.D. (Email Dr. Penrose or Go to www.alltestpro.com)

Dr. Penrose joined ALL-TEST Pro in 1999 following fifteen years in the electrical equipment repair, field service and research and development fields. Starting as an electric motor repair journeyman in the US Navy, Dr. Penrose lead and developed motor system maintenance and management programs within industry for service companies, the US Department of Energy, utilities, states, and many others. Dr. Penrose taught engineering at the University of Illinois at Chicago as an Adjunct Professor of Electrical, Mechanical and Industrial Engineering as well as serving as a Senior Research Engineer at the UIC Energy Resources Center performing energy, reliability, waste stream and production industrial surveys. Dr Penrose has repaired, troubleshot, designed, installed or researched a great many technologies that have been, or will be, introduced into industry. He has coordinated US DOE and Utility projects including the industry-funded modifications to the US Department of Energy's MotorMaster Plus software in 2000 and the development of the Pacific Gas and Electric Motor System Performance Analysis Tool (PAT) project. Dr. Penrose is the Vice-Chair of the Connecticut Section IEEE (institute of electrical and electronics engineers), a past-Chair of the Chicago Section IEEE, Past Chair of the Chicago Section Chapters of the Dielectric and Electrical Insulation Society and Power Electronics Society of IEEE, is a member of the Vibration Institute, Electrical Manufacturing and Coil Winding Association, the International Maintenance Institute, NETA and MENSA. He has numerous articles, books and professional papers published in a number of industrial topics and is a US Department of Energy MotorMaster Certified Professional, as well as a trained vibration analyst, infrared analyst and motor circuit analyst.

Bio Carol Vesier, Ph.D. (Email Dr. Vesier or Go to www.RonaMax.com)

Dr Vesier has a unique background that spans both the business and technical worlds. On the business side, she was a financial analyst for A.G. Edwards and Sons. Her accomplishments include:

- Receiving her Ph.D. in Chemical Engineering from Georgia Institute of Technology for her research in computational methods
- Developing simulation tools needed to minimize the profitability impact of unreliability, and
- Developing the Asset Management Analyst position at Rohm and Haas

As the Asset Management Analyst, Dr Vesier assisted the businesses in defining the profitability impact of unreliability and unpredictability. In this role, Dr Vesier defined the probable outcome of capital deployment, process improvement, maintenance, and supply chain strategies. This knowledge was key in achieving a 2% gain in RONA (Return on Net Assets). For Rohm and Haas at this time, a 2% RONA gain was equivalent to a 4.5% gain in ROE (Return on Equity) and a $0.50 gain in EPS (Earnings per Share).

Upon leaving Rohm and Haas, Dr Vesier created Profit Driven Reliability® based on the work processes and tools that she had developed. Using Profit Driven Reliability®, she has assisted her clients in improving their profitability in a variety of industries including chemical, durable goods, aerospace, petroleum, food, and semi-conductor.

