AC Induction Motor Specifications
An Update on Currently Available Procedures and Options

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Abstract – This paper will discuss the use of motor specifications and the resulting challenges presented to the motor manufacturer. Many motor specifications were written years ago and call for materials and processes that have been replaced or improved. The paper will identify “traditional” items that often appear on older specifications. Newer materials or devices that can provide better service or protection may represent a more standard part for the motor manufacturer. The goal is to add usable value and shorter delivery time to the customer while eliminating non-standard practices or special parts.

Index Terms – Electric motors, AC induction motors, IEEE 841, Specification sheets

I. INTRODUCTION

This paper will attempt to provide data for use in writing specifications for AC induction motors. Special attention will be given to motors used in the pulp and paper industries. Many modern materials and components are available which add to the reliability and life of electric motors. Also, newer designs are available which provide significant energy savings over the life of the machine.

II. BEARING SYSTEM

The number one failure mode for electric motors is its bearing system. Failure modes include improper
lubrication, either too much or too little grease or using greases that are not compatible with each other. Contamination is another leading cause for bearing failures. The problem of bearing fluting from conduction of electrical current has been a continuing problem that is more prevalent when applied with pulse-width modulated (PWM) adjustable speed drives.

When developing bearing specifications for electric motors, care must be exercised in specifying actual operating conditions so motor manufacturers can select the best bearing system. For most motors, it makes a difference whether the load is direct coupled or belted.

Special high strength shaft steel may be required for heavy overhung loads. Applications that place high axial thrust loads on motor shafts require a different bearing system. Mounting orientation of the motor should be specified, as this needs to be considered on large motors.

Vertical pump motors often have a unique bearing system to handle severe axial loads. Some specs allow a bottom thrust bearing and others only allow a top-mounted system. Shaft thrust in both directions should be noted for these applications. Many of these motors are oil-bath lubricated. Also specify if an anti-reverse ratchet is required.

For a properly designed and applied bearing system, lubrication is the most important element. Greases have been developed especially for electric motors. Most motor manufacturers have in-depth experience in lubricants that work well in most applications and environments. It may not be wise to specify grease that is readily available in a given location over one that is recommended by the motor manufacturer. It is also dangerous to mix greases that are incompatible. Many manufacturers supply polyurea-based greases as required by IEEE 841-2001. Lithium-based greases are not compatible with polyurea-based greases. The manufacturers’ re-lubrication intervals should be utilized as a guideline.

Large sleeve bearing motors have their own set of requirements depending on the design of the motor and its speed. Lubrication is often by oil ring with a motor mounted sump. If external flood lubrication is used, the oil supply of the motor needs to be considered on coast-down. Some users have specific sleeve bearing requirements such as a removable and replaceable labyrinth seal on the inboard and outboard side of the bearing that can serve as a provision for the shaft to ride on during rundown after a bearing failure (rather than riding on end bracket material).

Contamination of bearing systems by liquids and solids can be prevented by the use of slingers, labyrinth and contact seals. Simple, flat “rubber” slingers are being replaced by newer designs that incorporate a Forsheda-style seal. This type of slinger has a lip that seals against the motor end bracket when at rest. Centrifugal force raises the lip when the motor comes up to speed, resulting in a non-contact slinger. These newer devices are rapidly replacing older slingers.

Bearing isolators are often used on motors where additional protection is needed from dust, liquids and slurries. As these isolators rotate, they expel liquids and keep them from entering the bearing cavities. A labyrinth device normally affords optimal protection whether the motor is stationary or running. Most motor manufacturers install labyrinth seals on the output shaft of IEEE 841 compliant motors, while several install them on the fan end as well.

Contact seals provide a solid barrier to prevent anything from entering the bearing system. These have a lip that is in continuous contact with the rotating shaft. The lip can be damaged if allowed to run without lubrication. Abrasive contaminants can also cause the lip to fail prematurely. Lip failure leads to contaminants entering the motor and bearing failure. There are some newer designed contact seals available that minimize these problems.

Bearing life is often included in motor specifications. As an example, bearing design life is described in the IEEE 841-2001 specification as a minimum of 26,280 hours. Some users specify requirements as 130,000 hours direct-connected and 70,000 hours belted service per ANSI/AFBMA 9-1990 based on NEMA belting application limits of NEMA MG 1-1998, section 14.42. All of these bearing life figures are based on L-10 life that means 10% of the bearings will have failed by this time. It should be noted that calculated bearing life is based on the fatigue life of bearing components and assumes they always have “PERFECT” lubrication and never exceed normal operating temperatures. Actual bearing life depends as much on proper application and maintenance as design criteria.

When motor specifications are written, more complete details of application data and environmental issues will be most useful to the motor manufacturer. Knowing pulley and belt data, special thrust requirements, or the existence of severely contaminated environments provides essential data allowing the motor designer to help specify the best motor for the job.
III. CORROSION AND MOISTURE PROTECTION

After bearings, motor corrosion is the second most frequent cause of premature motor failure. Pulp and paper production contains many highly corrosive liquids and gases. The user should specify cast iron motor housings and TEFC (Totally-Enclosed Fan-Cooled) motors (IP54 - IP55) if possible. Open (IP23) motors should not be specified where corrosion or moisture is a problem.

Most severe-duty motors used in the pulp and paper industry are built with cast iron housings, endplates, fan covers and conduit boxes. These are standard construction features for motors complying with IEEE 841, tested to ASTM B117-97. Motors are painted inside and out with a corrosion resistant primer and finish paint. Rotors are also provided with a corrosion resistant coating. Any exposed or unprotected aluminum motor parts should be avoided if possible.

Joints between the housing and endplate must have a rust-preventative and conduit boxes supplied with gaskets. Many motors utilize lead separators as part of the gasket system between the conduit box and motor frame. The motor’s varnish system is often upgraded by either a double dip process or VPI (vacuum pressure impregnation). Epoxy-based varnish is more resistant to black liquor than polyester-based varnishes.

Ideally, motors that comply with the IEEE 841 standard will provide additional protection without the specifier writing a custom motor specification. Perhaps the only upgrade to IEEE 841 would be to specify a motor with Premium Efficiency resulting in lower operating costs.

Hardware on most motors is plated for rust prevention. If desired, stainless hardware can be provided for extra corrosion resistance.

Despite the care taken in sealing, moisture can form inside the motor from condensation. In the worst of cases, the moisture may contain chlorine or other highly corrosive liquids. Breather drains at the lowest point in the motor allow the condensation to exit the motor. It is common to use drains made of stainless steel or composite materials rather than brass. These may be molded into a “T” configuration for two points of exit. Some specifications call for brass breather drains. Newer designs using stainless steel or composite material are standard with many motor manufacturers and still offer exceptional corrosion protection.

In applications where there is a severe problem with condensation, space heaters should be used to keep the motor from cooling down and drawing in outside air that can condense. Space heaters are often used to help prevent condensation inside of the motor by elevating the temperature of the motor above ambient.

When using a vector drive with feedback, if the motor is in a very wet area, a pulse generator should be specified rather than an optical encoder. Black liquor may enter the encoder and obstruct the disc. Magnetic pulse generators are more rugged and can provide the same type of output signal as an encoder while maintaining relatively high pulse counts.

IV. MOTOR CONDITION MONITORING

Great strides in motor monitoring and predictive maintenance have been made in the last few years. While many newer integrated condition-monitoring technologies have been presented in previous IEEE papers, there are still some basic devices that may allow status monitoring of the motor.

A simple winding thermostat or thermistor can alert the operator to an overheating motor allowing a controlled shutdown before failure. RTDs make a quantitative measurement of the temperature and a single device can be used as an alert and a shutdown indicator.

Temperature monitoring devices installed to monitor bearing temperatures are also often used. Remembering that bearing failures cause the majority of motor failures, many maintenance departments utilize thermal image scanning to look for abnormally hot spots on in-plant inspections.

Vibration monitors on the motor bearing system can be used to indicate an impending failure before it happens. Many suppliers have added new products that can easily make readings utilizing portable equipment. A simple low-cost probe can be mounted to the motor in the bearing area and a portable device can be connected that will record the bearing status for immediate or later evaluation.

Motor current is often monitored by means of current transformers. Records from current monitoring have been used as a means to analyze mysterious motor bearing failures such as when roller bearings have been run at idle for extended periods.

Readings in all these categories, taken at time of installation, can provide valuable base-line data for long-term trending.
V. STARTING METHODS / ADJUSTABLE SPEED DRIVES

When times were simpler, motors had a starter and started across the line. Larger motors might be started with part winding start or wye-delta. Today we have solid state starters that can ramp up the motor voltage, providing a peak pulse to get the load moving, then folding the voltage back to increase the power factor if there is a light load. Sometimes a bypass is used with these solid-state starters.

It is very common to use a variable frequency drive in a mill or add one to an existing motor. On some new motors designed specifically for use with inverter drives, the motor design may not allow the motor to be started across the line because the design was optimized for adjustable frequency use. If the motor needs to run directly from the line or with a bypass as well as a drive, this should be specified when ordering.

Most low voltage motors (<600-volt) are suitable for operation from an adjustable speed drive for typical variable torque applications such as pumps and fans. In fact many premium efficiency and severe duty motors come standard with an insulation system utilizing magnet wire that is specifically designed to withstand the voltage spikes from PWM drives. These motors stand up to the spikes as defined by NEMA MG 1-1998, Part 32.4.4.2. However, the best guarantee of successful motor application with an ASD is consultation with the motor manufacturer.

The majority of ASD applications are for pumps and fans, presenting the motor with a variable torque load that reduces as the speed is lowered. If constant torque loads are present, most 4 and 6 pole premium efficiency motors are capable of at least a 10:1 CTSR (constant torque speed range). If used over a wider speed range, TEBC (totally enclosed blower-cooled) models can provide full torque to zero speed when used with a vector drive. The motor manufacturer’s performance data should be evaluated to see the motor’s speed/torque operating envelope.

If the motor is operated from an adjustable speed drive, eliminating bearing currents should be considered, especially on larger motors or those that are important to the process. Conductive grease, isolated bearings and other methods don’t work as well as shaft grounding brushes. Common mode voltages, reflected voltages, filters and line reactors should be discussed with the drive supplier. Special attention should be made of installing the drive, using correct power cables and grounding practices.

VI. SPECIAL SERVICE CONDITIONS

When special service conditions are requested on a specification sheet, confusion is often very common. Manufacturer’s trade names may mean little to others.

Generic names like “Arctic Duty” may have different meanings to each potential bidder. For example, one Arctic Duty user may specify minus 40°C where standard cast iron may be acceptable and another user may specify minus 55°C, which may require nodular or ductile iron for the castings.

Certain industry specifications, such as API 541, are designed for specific – size motors. In the case of API 541, revision 3 is meant for motors 250 HP and above. The spec is under revision to become above 500 HP (so it doesn’t conflict with IEEE 841, 1- 500 HP). Requests to quote on 75 HP API 541 motors have been received with an insistent customer that couldn’t be swayed to accept an IEEE 841 motor. IEEE 841 could be built as a larger HP motor, although the specification doesn’t make provision for sleeve bearings. Often, a user may specify “IEEE 841 features” (for example) on motors that are not covered by the specification.

Until recently, even what may be considered a “premium efficient” motor was not clearly defined. NEMA recently has proposed minimum standards for this as NEMA Premium® that includes low and medium voltage ratings. CEMEP in Europe defines premium efficiency with their eff1 ratings, as does NRC in Canada and Australia/New Zealand with AS/NZS 1359.5:2000. The CEE (Consortium for Energy Efficiency) is setting efficiency guidelines to be used by utilities that may be offering rebates for upgrades. EPAct took effect in 1997 for minimum efficiency in the U.S. and many other countries are setting their own standards. Other papers are being presented on worldwide efficiency standards.

Duty cycles sometimes cause confusion. If we think of a 30-minute duty cycle, to some people this may be 30 minutes on, 30 off. By NEMA definition, 30-minute duty cycle means that the motor will take 30 minutes of operation to go from ambient to its maximum operating temperature. The motor shouldn’t be operated again until it cools down to ambient – depending on the motor size, this make take hours. 30-minute duty cycle in the crane industry is a totally different meaning according to CMAA (Crane Manufacturers Association of America) Specification 70, which defines a certain number of lift cycles within a 30-minute period. IEC defines duty cycles by S1, S2, S3 etc, each defining a full-load time versus no-load operating time.
Some applications require a motor to start a load with a high inertia or have frequent starts. NEMA specifies starting conditions and load inertias in MG 1-1998, Part 12.55 and 20.11 in tables 12-6 and 20-1. If load inertias or number of starts exceed these figures, the motor must provide sufficient torque to accelerate the load. An adjustable speed drive may also be utilized to help accelerate the load over a longer time period while limiting motor inrush current. It may be more economical to reduce the reflected load inertia through gearing or belting.

The best guarantee of a successful motor installation may be a complete description of load characteristics and duty cycle, to allow the motor manufacturer to recommend the best motor for the application.

Most motors used in a pulp and paper plant are of a size that would comply with NEMA MG 1 standards or the IEC equivalents. Within these specs, dimensions and performance requirements are clearly defined. Higher horsepower motors above NEMA size do not have industry specifications that are clearly defined. Motors located in hazardous locations have requirements defined by ANSI/NFPA 70 or IEC/CENELEC. Hazardous-duty motors listed by UL or CSA can be supplied for North America.

VII. APPLICATION INFORMATION

When motors are being specified, often the actual application is not noted. Knowing where and how the motor is used may assist the bidder in making recommendations that may provide for longer life and reduced operating costs. Certain applications may result in the bidder noting that necessary items have been omitted from the bid request or that the motor may be over-designed for the application. Application engineers from the bidder may have first-hand experience in that particular application and knowledge of what may be the best solution.

The larger the motor is, the more important it is to know more about the application. The mechanical construction of the motor, and related equipment, are important to its critical speed, shaft and bearing loading. The motors starting intervals and load inertia also need to be supplied, particularly in above-NEMA ratings.

VIII. TESTING

Standard production testing varies from manufacturer to manufacturer, but typically include no-load speed and current, noise and vibration and a high-potential test. Larger motors will have more complete standard tests, up to full-load testing in some cases.

By specifying motors complying with IEEE 841, many additional standard tests and documents are supplied with each motor at time of shipment. Per IEEE 841-2001, 9.2, these include:

- Measurement of winding resistance
- No-load readings of current, power, and nominal speed at rated voltage and frequency
- Mechanical vibration check in accordance with IEEE 841-2001, 6.9, using either elastic or rigid mount
- High-potential test in accordance with Paragraph 12.3 of NEMA MG 1-1998, Part 12

Many optional tests may be specified, either unwitnessed or witnessed. As a manufacturer, some of these tests may have usable value where others may not. These tests include:

- Full IEEE 112 Test
  - Production test per NEMA MG 1-1998 Part 12.56
  - Measure winding resistance
  - No load measurement of current and speed
  - Locked Rotor Current
  - Winding Hi-Pot in accordance with MG 1-3.1 & 12
  - Measure efficiency at 100%, 75%, 50% and 25% of full load.
  - Measure power factor at 100%, 75%, 50% and 25% of full load.
  - Temperature rise test.
  - Measure locked rotor current.
  - Measure breakdown and starting torques.
- Sound pressure tests – Test procedure per IEEE 85. Even though IEEE 85 isn’t a current standard, it is still commonly specified.
- Speed-torque and Speed-current Curves – Provide curves of motor speed-torque and speed-current at specified input voltage and frequency.
- Bearing temperature test – Determines the stabilized bearing temperature at no load. Minimum test duration time must be specified.
• A temperature rise test over the operating speed range and torque load using a drive. Operate motor to Class F rise to establish operating envelope for the motor.
• Polarization index test per IEEE 43 Standard.

Sometimes a water immersion test is requested, usually when the motor is to have a sealed insulation system. This test is performed per MG 1-1998 Part 20.18. Some manufacturers feel water immersion tests are destructive and refuse to do it on a production motor stator that will be used in the application. They build a “like stator” and perform the test on it. New test equipment is available for testing a completed stator winding by partial discharge testing giving similar results without submerging the winding. These partial discharge tests are extremely sensitive and can show variances in the quality of the insulation system resulting from manufacturing faults, mechanical damage or aging.

IX. MOTOR MANUFACTURERS

Many quote requests list manufacturing companies no longer in business, inactive in business after a merger, acquisition (under that name) or using motors not manufactured by that company. The buyer may think he is getting a motor made by his old supplier when that is not the case. Visits to qualify bidders are suggested to audit manufacturing and quality processes. A statement of motor and component manufacturing and/or assembly location may help make these issues clearer for the user.

X. CONCLUSIONS

Motor specifications sent for bid should be reviewed by the user or specifier for current manufacturing processes, components, accessories and relevance to the actual application for the motor. Most motor manufacturers are willing to assist the writer with specification development. Visits to the manufacturers plant site to view the manufacturing, testing and quality process will result in more knowledge and confidence in what is actually being specified. Providing detailed application data with the quote request helps to ensure motors that are better suited for the intended application. By updating old specs, upgraded motors may be specified using standard components, resulting in increased life, lower operating costs, shorter deliveries and reduced costs.

XI. REFERENCES

[1] NEMA MG 1, 2001 “Motors and Generators”
[5] CMAA Std 70, “Specifications for Top Running Bridge & Gantry Type Multiple Girder Electric Overhead Traveling Cranes No. 70”

XII. APPENDIX

Appendix A, a worksheet for AC Induction Motors follows.
APPENDIX A
AC INDUCTION MOTOR DATA SHEET

Plant: __________________________ Contact: __________________________

Industry: __________________________________________________________

Type of equipment: ________________________________________________

Application: _______________________________________________________

SITE DATA

Location: City __________________ State ______________________________

Elevation    ❑ less than 3300 ft / 1000 m  Other – Specify _____________

Ambient temperature Min _______ oC  Max _______ oC

Humidity    Min _______ %  Max _______%

Motor location ❑ Indoor    ❑ Outdoor    ❑ Heated    ❑ Unheated

❑ Roof over motor    ❑ No roof over motor

Special conditions: __________________________________________________

MOTOR PERFORMANCE REQUIREMENTS:

HP __________________________ kW __________________________

Poles: _______________________ RPM __________________________

Speed ______________________ ❑ Fixed speed    ❑ Adjustable speed

❑ Variable torque    ❑ Constant torque

Min Speed _______ Max speed _______

Volts ___________________ 3-phase    ❑ 60Hz    ❑ 50Hz

NEMA Design: ❑ Design B (IEC N)    ❑ Design C (IEC H)    ❑ Design D

Efficiency level ❑ Premium    ❑ High Efficiency (EPAct)

Rotor design: ❑ Standard    ❑ Fabricated copper bar

Service Factor: ❑ 1.0    ❑ 1.15

Insulation Class: ❑ F    ❑ H

Temperature rise: ❑ Class B (80°C) at F.L.
❑ Class F at F.L.
❑ Class B (80°C) at F.L.; Class F at S.F.

Torque (Full Load) ___________ Torque (Pull-up % Flt) ___________

Torque (Breakdown % Flt) _______ Torque (Locked Rotor % Flt) ___________
### Enclosure:
- TEFC
- TEBC
- ODP
- WPI
- WPII
- No filter
  - Galvanized steel filter
  - Aluminum mesh filter
  - Stainless mesh
  - Differential pressure switch

- Explosion Proof - Class ______ Group ______ Zone ______
- Division 2 – Temperature code ______

### Mounting:
- NEMA
- IEC
- Horizontal
- Vertical
- F1
- F2
- Top
- Other __________
- C-face
- D-flange
- P-base - specify flange diameter _________________

### Shaft:
- Drive end shaft
  - Diameter ______
  - Length ______
  - Key ______________
- Opposite drive end shaft
  - Diameter ______
  - Length ______
  - Key ______________

Special shaft machining – specify or supply drawing ________________

### Shaft Material:
- Standard (not specified)
- 1045
- 4140
- Other – type __________
- Stainless – type __________

### Special Standards:
- NEMA MG 1
- IEEE 841
- API 541 – data sheets attached
- CSA approval
- IEC
- Other ________________

### Bearings
- Anti-friction:
  - Ball
  - Roller
- Coupled
- Belted (data sheet attached)
- Sleeve – Renk insert-type (horizontal - coupled only)

### Thrust:
- Horizontal:
  - Towards motor ______ lbs or ______ kg
  - Away from motor ______ lbs or ______ kg

### Vertical:
- Down Continuous ______ lbs or ______ kg
  - Maximum ______ lbs or ______ kg
- Up Continuous ______ lbs or ______ kg
  - Maximum ______ lbs or ______ kg

### Lubrication:
- Self lubricated
- Oil Mist
- Force lubricated
  - Special grease or oil ________________

Bearing protection:
- None
- Forsheda” type
- Inpro/Seal” VBX
- Contact seal

Bearing electrical protection:
- Shaft grounding brush
- Electrically isolated bearings
### Bearing temperature monitoring:
- **RTDs** - Qty. 2 – 1 per bearing
  - 100 ohm platinum
  - 10 ohm copper
  - 120 ohm nickel
- **Thermistor** - Brand ______________________

### Bearing vibration monitoring:
- Robertshaw 365 Vibraswitch™
  - Both ends
- Bentley-Nevada
  - 2 probes each bearing
  - 1 probe each bearing
  - 2 probes one bearing
  - 1 probe one bearing
- Provisions for 2 probes/bearing

### Vibration level
- < 0.15 in/sec
- < 0.10 in/sec
- ____ in/sec velocity

### Sound level
Max sound pressure level _____ dBA at _____ ft or _____ m, NL.

### Motor Starting / Drive
- Full voltage
- Reduced voltage
- Electronic soft start
- Loaded
- Unloaded

### Load WK_ at Shaft:
- < NEMA MG 1-2001-20.11
- Specify reflected load inertia ______________________

### Number of starts:
- NEMA MG 1-2001 -20.12.1
- Additional _____ Cold _____ Hot

### Drive Requirements
- Inverter
- Vector
- Vector – open loop
- Brand / model ______________________

### Feedback:
- PPR _____ Voltage ______
- Optical Encoder
- Magnetic pulse generator – # of pickups ______
- Specific brand / model ______________________

### Special Options and Accessories
#### Winding Temp. Device:
- Thermostats – normally closed
- RTDs - Qty. 6 – 2 per phase
  - 100 ohm platinum
  - 10 ohm copper
  - 120 ohm nickel
- Thermistor - Brand ______________________
- Separate conduit box (required for medium voltage)

#### Space Heaters:
- 120 volt
- 230 volt
- Separate conduit box (required for medium voltage)

#### Surge Protection:
- Lightning arrestors
- Surge capacitors
- Differential current transformers
- 3 Current balanced current transformers
- 1 Current balanced transformer
Special items:  
- Deferred warranty / long term storage provision  
- Export crating

Special Testing

- Standard Production Test  
  - Unwitnessed  
  - Witnessed

Each motor will be tested per NEMA MG 1-12 or MG1-20.47 as required.
Tests include:
1. Measure winding resistance.
2. Measure no load current, power and speed at rated voltage and frequency.
3. Insulation resistance.
4. High potential test per NEMA MG 1-20.48.
5. Mechanical balance and vibration.

- Complete IEEE 112  
  - Unwitnessed  
  - Witnessed

1. Routine tests above.
2. Measure efficiency at 100%, 75%, 50% and 25% of full load.
3. Measure power factor at 100%, 75%, 50% and 25% of full load.
4. Temperature rise test.
5. Measure locked rotor current.
6. Measure breakdown and starting torques.

- Sound test  
  (per IEEE 85)  
  - Unwitnessed  
  - Witnessed

- Speed torque test  
  - Unwitnessed  
  - Witnessed

  Provide curves of motor speed-torque and speed-current at specified input voltage and frequency

- Bearing temperature  
  - Unwitnessed  
  - Witnessed

  Determines the stabilized bearing temperature at no load. Specify minimum test duration time on order.

- Motor/Drive Operating Envelope  
  - Unwitnessed  
  - Witnessed

  Temperature rise test using drive. Operate motor to Class F rise to establish operating envelope for the motor.

- Other ____________________  
  - Unwitnessed  
  - Witnessed

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