

SCOPE

- I * 1.1 This practice covers design and inspection of medium voltage a-c motors, low voltage a-c motors in sizes over 200 hp (150 kW) and all synchronous motors. When specified, this practice may be used for low voltage a-c motors in sizes 200 hp (150 kW) and below.
- I 1.2 **An asterisk (*)** indicates that a decision or approval by the Purchaser is required or that additional information is to be furnished by the Purchaser.

SUMMARY OF ADDITIONAL REQUIREMENTS

- I 2.1 **IP 2-1-1, Plant Noise Design Criteria** shall be used with this practice.
- I * 2.2 **Table 1** lists the practices and publications which shall be used with this practice as specified by the Purchaser.

TABLE 1

PRACTICES	
IP 3-3-12	Oil Mist Lubrication Systems
IP 10-12-1	Vibration, Axial-Position, and Bearing Temperature Monitoring Systems for Compressors and Drivers
IP 20-1-1	Inspection of Equipment and Materials
PUBLICATIONS	
IEC	
34	Rotating Electrical Machines
72	Dimensions and Output Series for Rotating Electrical Machines
85	Recommendations for the Classification of Materials for the Insulation of Electrical Machinery and Apparatus in Relation to their Thermal Stability in Service

- I ↗ 2.3 **Table 2** lists the standards which shall be used for a-c motors for use in the USA:

TABLE 2

STANDARDS	
ANSI / ABMA Standards	
9	Load Rating and Fatigue Life for Ball Bearings
11	Load Rating and Fatigue Life for Roller Bearings
AGMA Standard	
460	Gear Motors Using Spur, Helical, Herringbone and Spiral Bevel Gears
ANSI Standard	
C50	General Requirements for Synchronous Machines
API Standards	
541	Form Wound Squirrel Cage Induction Motors - 250 Horsepower and Larger (see Note)
546	Form-Wound Brushless Synchronous Motors
IEEE / ANSI Standards	
43	Testing Insulation Resistance of Rotating Machinery
112	Test Procedures for Polyphase Induction Motors and Generators
115	Test Procedures for Synchronous Machines
522	Testing Turn-to-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines
ANSI / NEMA Standard	
MG1	Motors and Generators
NEMA Standard	
MG2	Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators

* **Note:** When specified, usually for large critical unspared motors.

IP 16-9-2		A-C Motors: Medium Voltage and Low Voltage Over 200 HP (150 kW) (This practice is appropriate for attachment to Inquiry or Purchase Document)	
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- I *2.4 **For other conditions of purchase and use** the applicable standards of manufacture and test will be specified by the Purchaser.

DEFINITIONS

- I 3.1 **A weather-protected (Type II) machine** is defined as an open machine with its ventilating passages at both intake and discharge so arranged that high-velocity air and air-borne particles blown into the machine by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electric parts of the machine itself. The normal path of the ventilating air which enters the electric parts of the machine shall be so arranged by baffling or separate housings as to provide at least three abrupt changes in direction, none of which shall be less than 90 degrees. In addition, an area of low velocity not exceeding 600 fpm (3 m/s) shall be provided in the intake air path to minimize the possibility of moisture or dirt being carried into the electric parts of the machine. Its ventilation openings shall be so constructed as to prevent the passage of a cylindrical rod 3/4 in. (20 mm) in diameter.
- I 3.2 **A totally-enclosed machine** is defined as a machine so enclosed as to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed air-tight.
- I 3.3 **A totally-enclosed non-ventilated machine** is defined as a totally-enclosed machine which is not equipped for cooling by means external to the enclosing parts.
- I 3.4 **A totally-enclosed fan-cooled machine** is defined as a totally-enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.
- I 3.5 **A totally-enclosed fan-cooled guarded machine** is defined as a totally-enclosed fan-cooled machine in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grilles, expanded metal, etc., to prevent accidental contact with the fan. Such openings shall not permit the passage of a cylindrical rod 3/4 in. (20 mm) in diameter, and a 1/2 in. (12 mm) diameter probe when penetrated 4 in. (100 mm) shall not contact the blades, spokes, or other irregular surfaces of the fan.
- I 3.6 **An explosion-proof machine** is defined as a totally-enclosed machine whose structure is designed and constructed to withstand an explosion of a specified gas or vapor which may occur within it, and to prevent the ignition of the specified gas or vapor surrounding the machine by sparks, flashes, or explosions of the specified gas or vapor which may occur within the machine casing.
- I 3.7 **A totally-enclosed pipe-ventilated machine** is defined as a totally-enclosed machine except for openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of the ventilating air. This air may be circulated by means integral with the machine or by means external to and not a part of the machine. In the latter case, these machines shall be known as separately- or forced-ventilated machines.
- I 3.8 **A totally-enclosed water-air-cooled machine** is defined as a totally-enclosed machine which is cooled by circulating air which, in turn, is cooled by circulating water. It is provided with a water-cooled heat exchanger for cooling the ventilating air and a fan or fans, integral with the rotor shaft or separate, for circulating the ventilating air.
- I 3.9 **A totally-enclosed air-to-air-cooled machine** is defined as a totally-enclosed machine which is cooled by circulating the internal air through a heat exchanger which, in turn, is cooled by circulating external air.
- I 3.10 **A watertight enclosure** is one into which there shall be no leakage after 5 minutes under test with a water hose from a distance of 10 ft (3 m) in any direction.
- I 3.11 **"Measurement of"** means measuring the actual quantity, at design voltage, load, and the like, as applicable.
- I 3.12 **"Determination of"** means a calculated determination of the quantity at rated conditions, based on tests of that or other quantities at other than design conditions (usually reduced voltage).
- I 3.13 **Motor continuous overload capability / service factor** is defined as a multiplier which, when applied to the rated horsepower, indicates horsepower loading which may be carried continuously without exceeding, by more than 10°C at continuous overload / service factor loading, rated temperature rise per **ANSI / NEMA MG1** or **IEC 34-1**, if rated voltage and frequency are maintained.

When the motor is operated at any service factor greater than 1.0, it may have efficiency, power factor and speed different from those at rated horsepower, but the locked rotor torque and current and breakdown torque will remain unchanged.

DOCUMENTATION

- I ♦ *4.1 **Table 5** provides a **Specification Sheet for Purchaser's Requirements and Manufacturer's Data**. **Motor data**, including the following, shall be furnished by vendor with all proposals. All the same data shall be furnished with final drawings and data corrected to apply to the actual motor furnished. Guaranteed or published values are acceptable for motors that do not require certified test reports.
- Rated horsepower (kW).
 - Rated full-load speed.
 - Rated voltage.
 - Full load current at rated voltage.
 - Efficiency at 1/2, 3/4, and full load and by what method determined.
 - Power factor at 1/2, 3/4 and full load.
 - Rated temperature rise.
 - Continuous overload capability / service factor (may be omitted if standards of manufacture do not provide for continuous overload capability / service factor).
 - Locked rotor current at rated voltage.
 - Allowable time at locked rotor with rated voltage applied for the following conditions:
 - Motor starting cold (at design maximum ambient temperature).
 - Motor starting hot (motor having attained allowable full load temperature rise at design maximum ambient temperature).

Note: In Subpars. 1 and 2 above, design maximum ambient temperature is 40°C unless otherwise specified.
 - Bearing type and lubrication system type.
 - For horizontal sleeve bearing motors, calculated value of the maximum axial force to constrain the motor rotor at either limit of its end float with motor operating at rated voltage.

Note: This data is required to permit Purchaser to check capacity of driven equipment thrust bearing. Data shall be furnished immediately after order placement.
 - L₁₀ rating life per **ANSI / ABMA Std. 9 and 11** for vertical motor anti-friction bearings (other than in-line pump motors) and the thrust load on which rating life is based.
 - Locked rotor power factor.
 - Locked rotor torque at rated voltage.
 - Motor weight (lb) [kg] and, rotor weight and inertia (Wk², lb-ft²) [GD², kg-m²]
 - Motor type - (horizontal/vertical).
 - Enclosure type - (WP, TEFC, EX-P, etc.).
 - Rotation, viewed from coupling end - (cw/ccw).
 - Rotor endfloat - mils (mm).
 - Thrust bearing mounting - (face-to-face, back-to-back, tandem).
 - Vertical motors - maximum allowable thrust up / down.
 - For unspared critical motors, and motors larger than 1500 hp (1100 kW):
 - Complete coil makeup and dimensional data.
 - Rotor bar material and dimensional data.
- I *4.2 **Test reports** (5 certified copies) shall be submitted to the Purchaser for each motor for which inspection is specified. Reports for low voltage motors shall be supplied only when specified.
- I *4.3 **Outline drawings** (5 certified copies) showing principal dimensions, mounting and shaft dimensions shall be submitted to the Purchaser for each motor. Drawings shall also show motor manufacturer's or bearing manufacturer's identification.

- I * 4.4 **Motor and driven equipment data** referenced by **Sections 7 and 11** of this practice shall be submitted to Purchaser at the time motor proposal is submitted. Typical data for identical or similar proven motor designs may be submitted at proposal time. If this is the case, however, it must be clearly stated in the bid proposal, and data for the specific design required shall be furnished as soon as it is available.
- I ♦ * 4.5 **At time of bid**, motor and/or driven equipment vendor must provide the following for antifriction bearings:
 - a. Motor bearing housing drawings showing details of lubrication system proposed.
 - b. True axial loading on motor bearings at rated motor load.
 - c. Maximum allowable axial loading on bearings consistent with the specified L_{10} rated life.
- I * 4.6 **Drawings and Performance Data Marking** - The following information is required on all copies of drawings and performance data:
 - a. Requisition, purchase order and specification numbers.
 - b. Manufacturer's serial number.
 - c. Driven equipment identification number.

GENERAL REQUIREMENTS

INSULATION, CONDUCTORS AND LEADS

- I * 5.1 Unless otherwise specified, **insulation shall be Class F with Class B temperature rise**. Special applications requiring alternative insulation systems will be specified. Motors rated 4000 volts and above shall have anti-corona protection on the slot portions of the coils.
- R 5.2 **Copper conductors** shall be used for **stator windings** and **terminal leads** and for **field windings** (if any).
- R * 5.3 **The following additional requirements apply** to all motors rated **2300 volts** and above:
 - a. Stator coils shall be form wound.
 - b. Unless otherwise specified, the stator insulation shall consist of a epoxy resin vacuum pressure impregnated (VPI) system. On any motor physically too large for the VPI tank, magnetic slot wedges shall not be used.
 - c. Weather protected motors and others as specified, shall have a "sealed" insulation system capable of withstanding an immersion test in accordance with **NEMA MG1**.
 - ♦ d. For motors rated 4000 volts and greater, the vendor shall submit for Owner's approval a stator insulation design which will withstand the following surge tests without the use of external surge protective devices. Surge tests, if specified, shall be made in accordance with **IEEE 522** at the following rise times and peak surge levels.

RISE TIME (m sec)	SURGE LEVEL (p.u.)
0.1 to 0.2	3.5
1.2	5.0

The vendor shall provide the following information including coil cross section dimensions, on the proposed stator winding insulation design:

- 1. Strand insulation material.
- 2. Turn insulation material.
- 3. Ground well insulation.
- 4. Slot anti corona, and stress grading protection.
- R 5.4 **Motor leads** shall be insulated with heat-resistant, thermosetting insulation.

BEARINGS AND LUBRICATION

- R,M 5.5 **Grease lubricated anti-friction bearings** shall be furnished on the following motors:
 - a. Motor speed >1800 rpm; nameplate rating ≤ 600 hp (450 kW).
 - b. Motor speed ≤ 1800 rpm; nameplate rating ≤ 1000 hp (750 kW).

- I 5.6 **For all motors, the following lubrication systems are acceptable:**
- a. Non-forced-feed oil lubrication for anti-friction and sleeve bearings.
 - b. Forced-feed oil lubrication.
 - * c. Pure mist for antifriction bearings, when specified by the Purchaser.
- R,M 5.7 **Motors with regreasable bearings** shall meet the following:
- a. Be capable of being regreased in service.
 - b. Be capable of operating for at least 8000 hours without requiring addition of grease or a complete change of grease.
 - * c. Be equipped with external relief or drain plugs. Alternative arrangements for expelling or collecting used grease may be proposed for the Owner's Engineer approval.
 - d. Seals shall be provided to prevent loss of lubricant.
 - * e. If grease fittings are to be furnished, the type will be specified. Otherwise motors are to be furnished with pipe plugs in the tapped holes normally provided for such fittings.
- R 5.8 **For motors with non-forced-feed oil lubrication** or oil mist lubrication of the wet sump or "purge mist" type, the bearing housings shall have oil reservoirs of sufficient depth to serve as settling chambers. Bearing housings for ball and roller bearings shall each be fitted with an adjustable constant level, pressure balanced, sight feed oiler. Bearing housings for sleeve bearings shall be fitted with a sight gage mounted on the housing and marked with the proper oil level. **The oil system shall meet the following requirements:**
- a. Oiler bottles, when used, shall be of plastic or Pyrex glass. Plastic bottles shall be of a plastic inhibited against sunlight attack and normal running oil level shall be visible in the bottle.
 - b. The oil system shall have sufficient surge capacity to absorb, without overflowing, all oil from the bearing when the motor is stopped.
 - c. Bearing housings shall be provided with fill and drain openings accessible from outside the motor enclosure, necessary slingers, equalizers, vents, or other devices to prevent loss of lubricant.
 - d. The proper oil level for bearings shall be shown by marks inscribed and identified on the motor enclosure. If the oil level with motor running is different from the level with motor stopped, both levels shall be indicated.
 - e. Pipe nipples connected to housings (such as those to oilers) shall be steel pipe Schedule 80 or heavier.
- I * 5.9 **For motors requiring forced-feed lubrication**, oil shall be supplied from the driven equipment lubrication system if a suitable system is available. In this case:
- a. The motor vendor shall specify his oil flow, pressure, and quality requirements and the heat rejection rate.
 - b. All oil piping to supply the motor bearings will be furnished by the driven equipment vendor. Piping shall meet the same specifications as for the driven equipment piping.
 - c. If bearings are insulated, the motor vendor shall furnish insulating fittings in the oil supply connections to prevent the oil supply lines from bypassing the bearing insulation.
- M 5.10 **All horizontal sleeve bearing motors**, and all motors with axially unrestrained roller bearings, shall have a location bearing or other thrust provision to enable the motor to be tested and run-in uncoupled, with the shaft approximately horizontal. In addition, horizontal motors with sleeve bearings shall have split capsule type bearings with split bearing brackets to permit bearing replacement without removing the bottom bearing bracket.
- R 5.11 **Anti-friction bearings** for all direct connected horizontal motors shall have an L₁₀ rated life per **ANSI / ABMA Std. 9 and 11** of at least 100,000 hours, and 50,000 hours for normally loaded belt-connected motors. The following additional requirements also apply:
- a. Anti-friction bearings shall be retained on the shaft and fitted into housings in accordance with **ABMA** standards; however, locking of ball thrust bearings to the shaft shall be restricted to a tongue-type lock washer, for example, Series W.
 - b. Anti-friction bearings, except for the angular contact type, shall have loose internal clearance fit equivalent to ABMA Fit No. 3 unless vendor can demonstrate satisfactory operating experience with an alternate bearing clearance. Bearings shall be single row, Conrad type without filling slots and shall be single shielded. Non-metallic (plastic, phenolic) cages are not acceptable.
- R 5.12 **Bearings shall be supported by bearing brackets which are an integral part of the motor end cover or by separate bearing pedestals.** Designs having **bearing brackets** which extend out from the motor end covers in a cantilever arrangement are not acceptable. The following additional requirements also apply:

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- a. Bearing loads shall be based on rated or maximum speed (if a two speed or variable speed motor) and shall include a minimum radial component of 1/2 the rotor weight.
- b. Bearing housings, when integral with the motor end covers, shall be designed with sufficient wall thickness to permit sleeving without requiring redrilling and tapping of the end cap bolt holes. This arrangement will permit reusing motor end covers by repairing damage to the bearing housing bore.
- S c. Motors specified for operation in a Division 1 electrical area classification shall have bearing housing shaft openings sleeved with nonferrous material to prevent sparking in the event of shaft rubbing.
- d. Motors shall have shaft seals provided to prevent moisture or dirt from entering the bearing housing along the shaft and to prevent oil mist leaks to atmosphere.

ENDFLOAT AND MAGNETIC CENTER FOR HORIZONTAL MOTORS WITH AXIALLY MOVABLE SHAFTS

- R 5.13 **Motors shall have a total end play** of at least 1/2 in. (12 mm). The running center of the rotor shall not shift from either side of the geometric center of the rotor's total endplay by more than 3/32 in. (2 mm).
- I 5.14 **An indicator**, to indicate allowable limits of rotor movement after coupling installation and alignment, shall be furnished equivalent to the following:
 - a. It shall be made of stainless steel and shall be rigidly mounted in a permanent manner.
 - b. The method of indication shall be durable such as a notch at least 1/32 in. (1 mm) deep and of width equal to the coupling endfloat. The notch shall be adjacent to a shaft shoulder and shall mark the allowable excursion of the shoulder.
 - c. It shall be positioned so that the marked limits of allowable rotor movement shall be at least 1/8 in. (3 mm) from each end of rotor endplay limits.
 - d. It shall be observable without removing motor covers or coupling guards.
 - e. Single bearing motors shall have magnetic center marked on stator referenced from both ends of the shaft.

COUPLING INSTALLATION

- R * 5.15 **Motor half couplings**, if specified to be mounted by the motor vendor, shall be mounted on motor shafts with either a taper or cylindrical fit and keyed. Cylindrical fits shall be shrink fits equivalent to ANSI / ASME B4.1 Class FN1.
The coupling and coupling-to-shaft juncture shall be capable of withstanding momentary high torque overloads equal to or exceeding four times motor nameplate rating to provide for peak torque resulting from out of phase switching. The suitability of this rating shall be confirmed by the Purchaser after final electrical system characteristics are defined.

VIBRATION

- R 5.16 **For all motors, vibration** in any direction, as measured on the bearing housing under the following conditions, shall not exceed the limits given in [Table 3](#):
 - a. The motor running uncoupled at no load, at normal voltage and frequency, and for multi speed motors test shall be made at each rated speed.
 - b. The shaft axis in normal position, with the motor properly shimmed and securely bolted to a relatively massive foundation or test floor stand.
 - c. A half key in the shaft keyway.
- R 5.17 **For motors having provisions for vibration monitoring systems, vibration** shall also be measured on the **shaft** adjacent to each bearing housing or through the bearing or coupling housing. Vibration as measured per the conditions of **Par. 5.16, Subpars. a, b, and c.** shall not exceed the limits given in [Table 3](#), observing the following:
 - * a. Measurement shall preferably be made with a non-contacting proximity probe. Measurement with a shaft contacting probe may be proposed for the Owner's Engineer approval.
 - b. If vendor can demonstrate that "electrical run-out" due to shaft material anomalies is present in measurements made with proximity probes, this may be added to the allowable vibration level up to a maximum of 0.25 mils (0.006 mm), provided a hand-held shaft contacting probe gives results not exceeding the allowable limit.