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# Technical Note

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**author:** David E. Weems

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## INTRODUCTION

Conventional electrical motors are constructed with copper windings around an iron core that is mounted in a cast iron frame. In recent years the cost of casting iron has caused the manufacturers of electrical motors to fabricate motor frames and end shields out of aluminum. After contacting several manufacturers of electrical motors it was determined that motors with aluminum frames and end shields are commercially available with drip-proof or totally enclosed fan-cooled frames and rated capacities up to 25 hp. The Civil Engineering Laboratory (CEL) has conducted tests to determine the suitability of using such motors at Naval Shore Facilities.

## BACKGROUND

In recent years, aluminum has been used as an alternate material for the fabrication of motor frames and end shields. The choice of aluminum was based on several factors. Iron is harder to obtain and is more expensive to cast than aluminum. In addition, the number of iron foundries currently operating has been reduced because of their inability to meet antipollution requirements without costly modifications.

The cost and availability of copper have caused many manufacturers to use aluminum as the conductor material in electrical equipment. The switch from copper to aluminum as the conductor material started with electrical power distribution cable, where a 50% cost reduction can be realized. Aluminum is also being used by some of the electrical motor manufacturers as the conductor material for windings where extremely long lengths of wire are required.

Aluminum can be die-cast, extruded, or centrifugally cast. These methods allow cooling fins, feet, lifting lugs, and other parts to be cast with more precise dimensions than can be done with iron. The thermal conductivity of aluminum is about four times that of cast iron. This higher thermal conductivity allows an aluminum frame motor to dissipate heat better than a cast iron frame motor. The density of aluminum is 38% of that of cast iron. The lower density of aluminum results in a frame motor weighing about 40% less than a cast iron frame motor with the same output power.

Cast iron tends to break when subjected to mechanical shock or tensile stress, while aluminum tends to bend. Therefore, mounting feet and cooling fins of aluminum frame motors would be less likely to break off when subjected to mechanical shock or tensile stress. When subjected to most harsh environments, aluminum will form a thin oxide on its surface that inhibits further corrosion. As a result, aluminum is more resistant to corrosion than cast iron in most environments.

## TEST EQUIPMENT

The following test equipment was utilized during the laboratory testing.

- Associated Jade, Model MX-9216, salt-spray chamber
  - Construction Material: Lucite
  - Insulation: Double wall design
  - Temperature Control: Thermostat at 35°F for chamber  
Thermostat at 49°F for salt spray
  
- Lebow Associates, Inc., Model 1104-2K, rotating shaft torque sensor
  - Torque Range: 50-2,000 lb-in.
  - Linearity: ±0.1% of full scale
  - Shaft Speed Sensor: Magnetic pickup producing 60 pulses per shaft revolution
  
- Roller-Smith, wattmeter
  - Range: 0-0.75/1.5 kW
  
- Weston, Model 904, ampmeter
  - Range: 0-2.5/50 amperes
  
- Weston, Model 433, voltmeter
  - Range: 0-75/150 volts
  
- Weston, Model 327, current transformer
  - Input: 0-10/20/30/50/100 amperes
  - Output: 0-5 amperes
  
- Leeds & Northrup Co., potentiometer
  - Range: 0-64 mV
  
- Biddle, megohm meter (megger)
  - Range: 0-1,000 MΩ at 500 volts DC

## TEST PROCEDURES

The following test procedures were used to determine the effect of salt fog environments on motors with aluminum frames. Tests were performed in accordance with Method 509 of MIL-STD-810B, which is intended to accelerate the effect of salt spray on test items.

1. The test motors were photographed both assembled and disassembled prior to testing.
2. The insulation impedance of the test motors was measured using a megger.

3. The input voltage, current, and power of the motors were recorded with no load on the motor shaft.

4. The test motors were then placed in the salt fog chamber and subjected to a salt-spray environment for 80 hours. The salt fog was generated from water containing 5 percent by weight of salt.

5. The test motors were then removed from the salt spray chamber and allowed to dry out for 70 hours.

6. Steps 2 through 5 were repeated for a total of four salt fog and dry out cycles.

7. The insulation impedance of the test motors was measured using the megger.

8. The input voltage, current, and power of the motor were recorded with no load on the motor shaft.

9. The motors were then photographed both assembled and disassembled.

10. The input voltage, current, and power, and the output torque and shaft speed were recorded at different mechanical loads from 0 to 2.5 times the rated output power of the motors.

11. A pair of thermocouples were embedded in the windings of the motor. The motor was then run at one-third of rated output power for 1 hour, and the winding temperature was recorded.

12. Step 11 was repeated at two-thirds of rated output power and at full rated output power.

#### TEST RESULTS

Figures 1, 2, and 3 show one of the motors for testing prior to the salt fog testing. After subjecting the motors to the salt environment the steel shaft was badly corroded, as can be seen in Figure 4. The aluminum frame shows almost no corrosion (Figures 5 and 6); however, the painted surfaces on the motor blistered.

The shaft (Figure 4) was corroded enough by the end of the testing to keep it from rotating when electrical power was supplied to the motor. When the shaft was broken free, the motor operated normally. The environmental testing was conducted with the motor de-energized. If the motor had been running during the environmental testing, the shaft would not have corroded enough to inhibit rotation.

The no-load characteristics of the motor did not change during the environmental testing.

Figures 7, 8, and 9 show the electrical characteristics of the 3-hp, 1,800-rpm aluminum frame motor for different mechanical loads. These characteristics were not changed by the environmental testing.

The winding temperature at rated load was 175°F. This temperature is well below the 221°F rating of the insulation used on the windings.

## CONCLUSIONS

1. Aluminum frame motors will sustain minimal corrosion in environments similar to those at Naval Shore Facilities.
2. Aluminum frame motors weigh around 40% less than a cast iron frame motor.
3. Aluminum frame motors dissipate the internally generated heat as well as the cast iron frame motor designs.
4. The use of aluminum frame motors instead of cast iron frame motors will reduce the chances of breaking the cooling fins or mounting feet when the motor is subjected to mechanical shock or tensile stress.
5. The steel shaft and bearings of electrical motors will corrode in corrosive environments, and if the shaft is not rotated, the corrosion will build up to a level that will freeze the shaft. Periodic operation of motors in corrosive environments will prevent seizure of the shaft.

## RECOMMENDATIONS

1. Aluminum frame motors can be used as replacements for cast iron frame motors.
2. Aluminum frame motors should be used instead of cast iron motors for installations where weight must be minimized.
3. Aluminum frame motors should be used instead of cast iron motors where there is a corrosive environment.

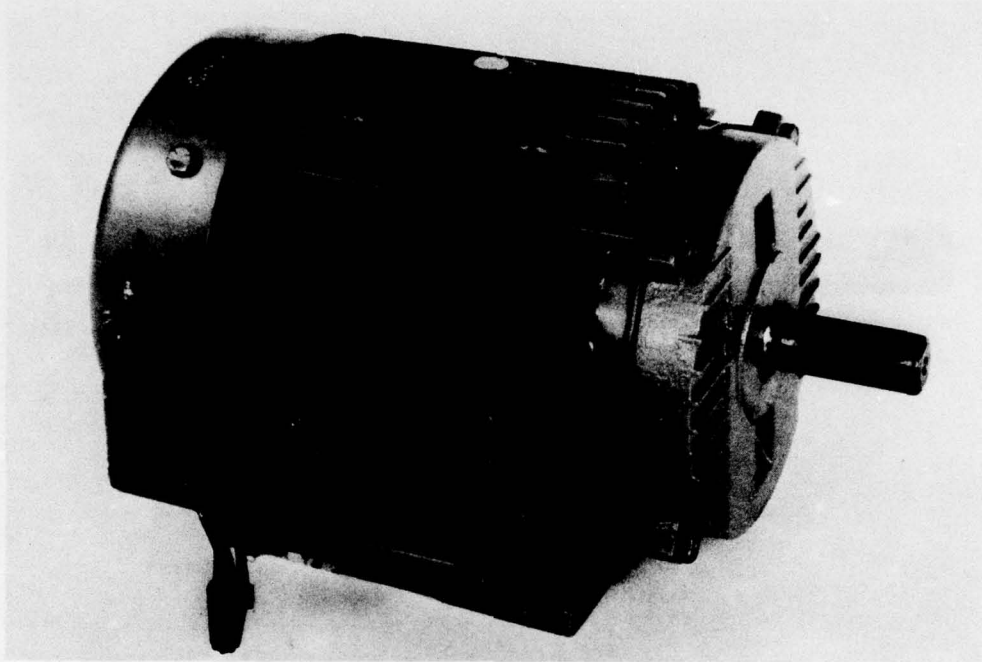


Figure 1. Electrical motor with aluminum frame prior to testing.

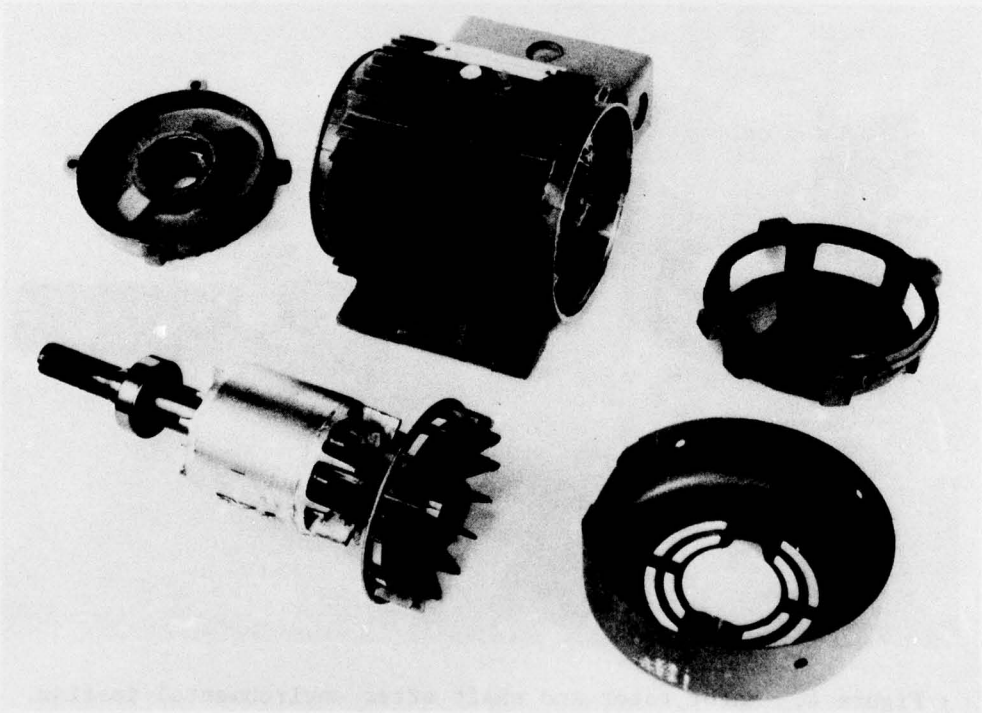


Figure 2. Disassembled aluminum frame motor prior to testing.

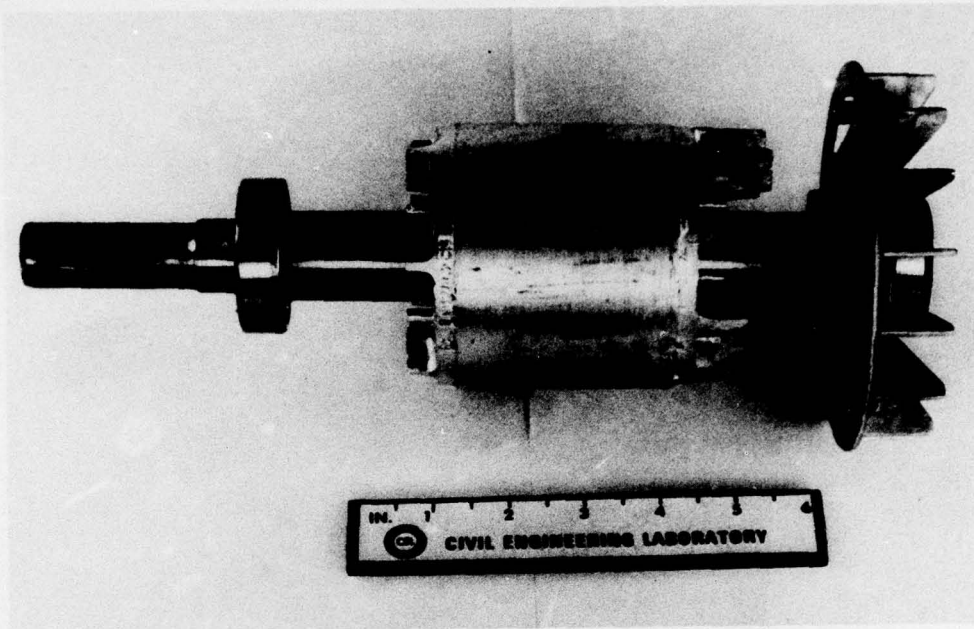


Figure 3. Motor rotor and shaft prior to environmental testing.

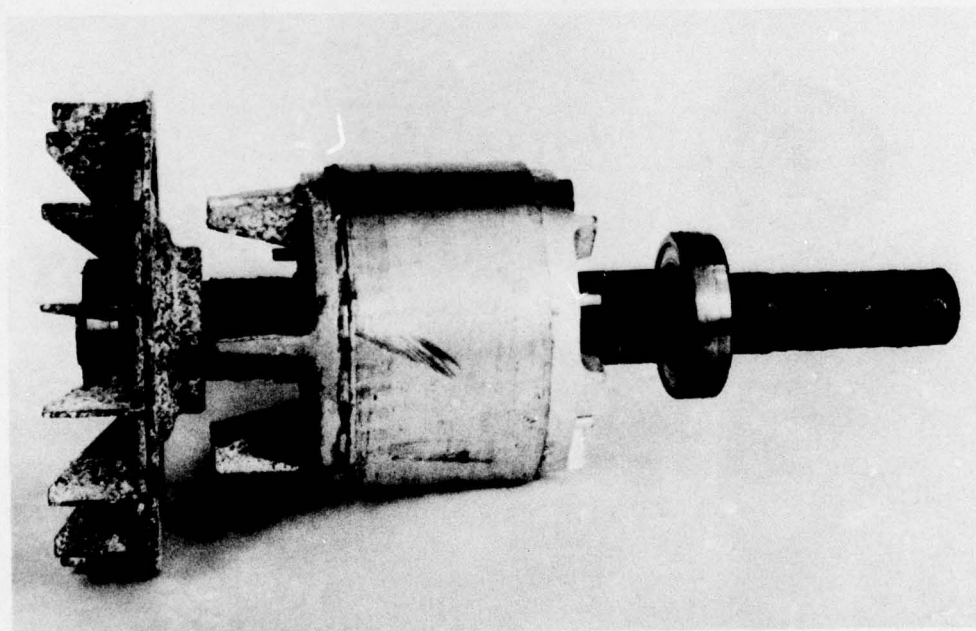


Figure 4. Motor rotor and shaft after environmental testing.

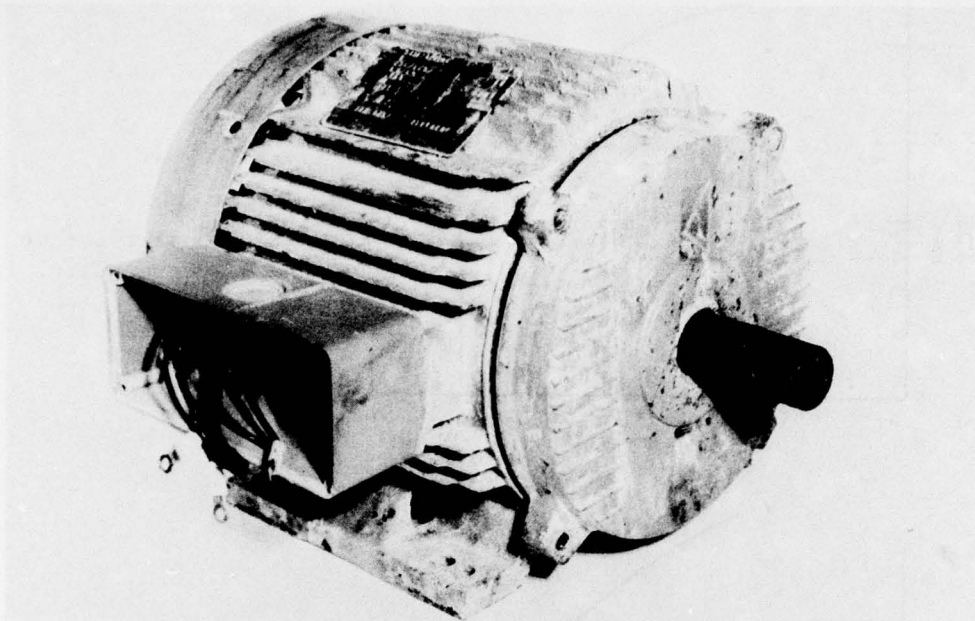


Figure 5. Aluminum frame motor after environmental testing.

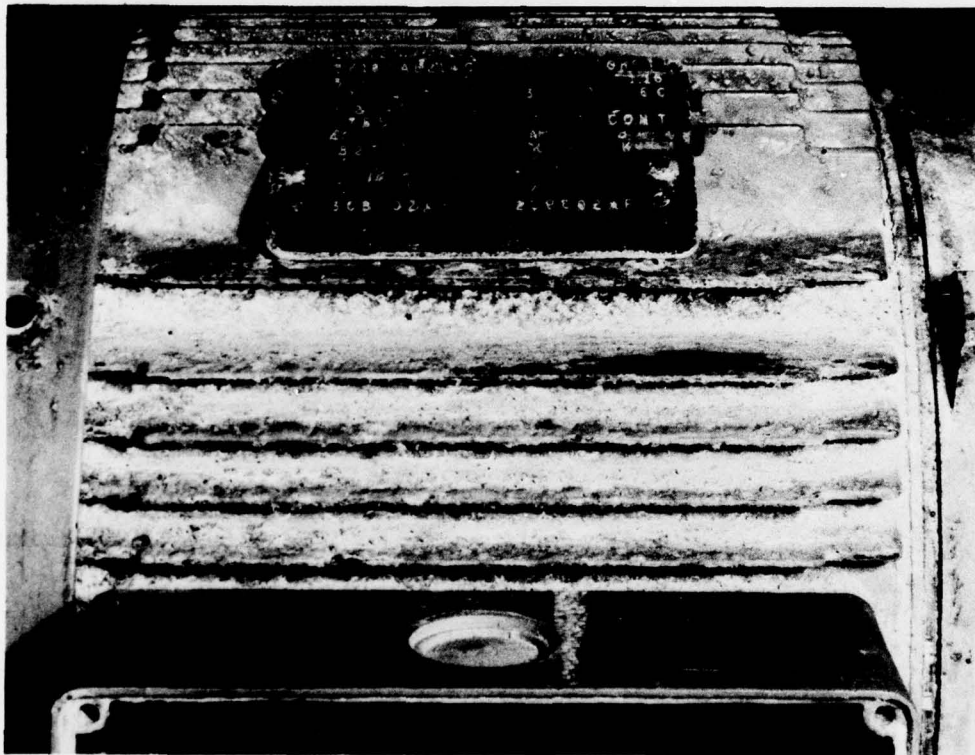


Figure 6. Effects of the environmental testing on the aluminum frame.

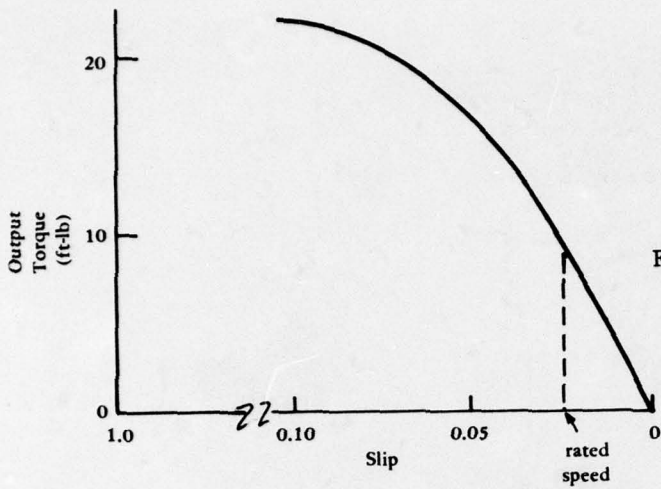


Figure 7. Output torque versus slip.

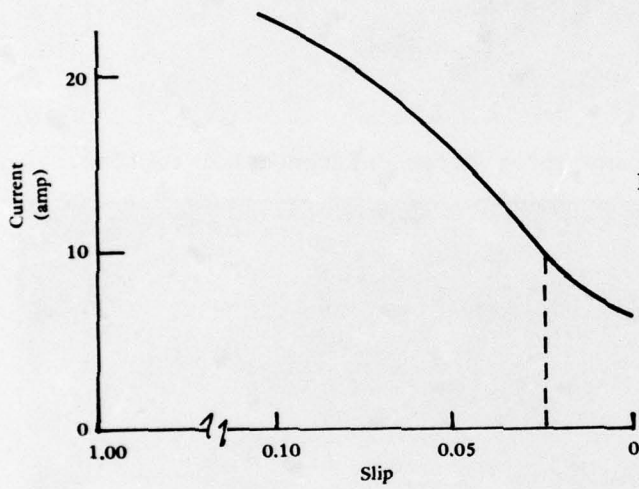


Figure 8. Input current versus slip.

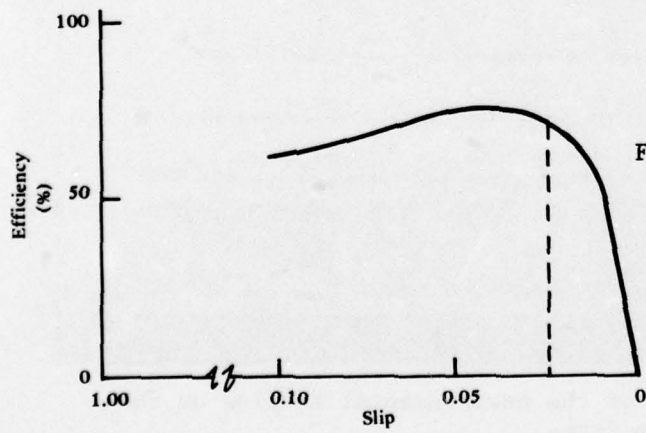


Figure 9. Motor efficiency versus slip.

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