Failure Analysis Report

for

(Generation Company)
(Station)

Purchase Order Number XXXX
(Dated XX/XX/XXXX)
Report N-XXXX-FA, Revision 0
Schulz Electric Company Job Number N-XXXX
Motor ID Number – 3SYZ0XXXX-A2-XX
150 Ft-Lb AC MOV Motor

Prepared By:

(Schulz Electric Company)
Purpose

The purpose of this report is to provide XXXX Generation Company with objective data that can be used as a basis for determining root cause failure of this motor. The data contained in this report has been assembled from the results of the Incoming Tests and Inspections performed in accordance with Schulz Electric Company's Shop Instructions as delineated in Shop Traveler N-XXXX. If there are any discrepancies between the data in this report and those within Shop Traveler N-XXXX, the Shop Traveler and Incoming Motor Tests and Inspections documentation have overriding authority.

Methodology

Although the actual cause of a failure may not always be apparent, the performance of tests and inspections of the component or components, which have failed may give indications as to the possible source of the failure. To provide reasonable assurance as to the disposition of this motor, several motor parameters were measured through various test methods, including:

- Visual Inspections
- Insulation Resistance Measurements
- Winding Resistance Measurements
- Material Analysis

The parameters’ acceptance criteria were established industry standards (e.g. NEMA MG-1) and/or the manufacturer’s data (where available). All results and deficiencies were noted and documented.

The motor was tested in accordance with Schulz Electric Company’s 10 CFR 50 Appendix B QA program using calibrated test equipment traceable to NIST Standards or other nationally recognized standards.

Any material or metallurgical analysis was performed by vendors on Schulz Electric Company’s approved vendor list in accordance with their 10 CFR 50, Appendix B QA Program.

History

The following information was provided by (Station) personnel upon Schulz Electric Company request.

- The motor was installed in May, 1994. It is stroked open and closed on a monthly basis. The stroke time is approximately 50 seconds in each direction.
- The last megger was believed to have been performed in October of 2000. In addition, the MOV was likely VOTES tested and had a post maintenance stroke performed at that time. The actuator has been removed and replaced every 18 months since May of 1994. The same motor has been reused during this time period.
- The motor failed during the closing stroke. It started to stroke closed and then caused a breaker trip at about 10 seconds into the stroke. The breaker tripped immediately upon the second attempt to stroke the MOV.
- There were no voltage or current anomalies reported.
- The stem was lubricated every 18 months. The actuator (not the motor) is replaced every RFL (every 18 months). The last actuator replacement was performed in October of 2000.
- The breaker tripped on ground fault.
The Limitorque operator would normally prevent any over-thrusts (stalls) from occurring. This operator is controlled by a torque switch in the closing direction and by a limit switch in the open direction. A motor stall would result in loss of power (thermals\(^1\)), which would be noted by operations. No such loss occurred (as noted above, this motor stroked normally in the closed direction for about 10 seconds before tripping on high current\(^2\)).

### Component Inspection

When Schulz Electric Company personnel received the motor, several incoming visual inspections were performed which included nameplate data, endbells and bolts, the stator frame, leads (including markings and connections) with the following results:

- The motor nameplate was verified against purchase order XXXXXXXX with no discrepancies
- Overall, visually the motor was in good condition with no loose bolts or abnormal conditions noted
- All leads were oil soaked and frayed
- The seal appeared to be in good condition
- The shaft and keyway were in fair condition with some acceptable wear
- Shaft runout and endplay were within tolerance

Electrical tests were then performed to determine the condition and integrity of the windings.

- An insulation resistance test was performed using the acceptance criteria of \(> 1.5\ \text{M}\Omega\). The result was 0 M\(\Omega\), indicating a short to ground in either the leads or the windings.
- Polarization Index (PI) was not performed due to the unsatisfactory insulation resistance.
- The winding resistance was taken on each of the Phases with an ambient temperature recorded at 20.6°C. Acceptance Criteria is all three phases within 5% of the average.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Resistance ((\Omega))</th>
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<tbody>
<tr>
<td>1-2</td>
<td>15.96</td>
</tr>
<tr>
<td>1-3</td>
<td>12.18</td>
</tr>
<tr>
<td>2-3</td>
<td>4.77</td>
</tr>
<tr>
<td>Avg.</td>
<td>10.97</td>
</tr>
</tbody>
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The inconsistency of the readings is typically a sign of a phase to phase short and probably several turn-to-turn shorts of phase 2-3.

Once all electrical and visual inspections were complete, the motor was disassembled. The bearings, endbell and shaft were in good condition with no discrepancies noted.

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\(^1\) Schulz Electric Company assumes that these are thermal overloads that trip the breaker after some finite time during an over-current condition.

\(^2\) Schulz Electric Company assumes that this was actually a ground fault trip.
A portion of the rotor shorting ring and fins was broken loose from the pulley-end of the rotor and were laying loose in the motor housing. The fins showed signs of burning, and charring. Some of the balancing knobs were completely burned away (see photo below).

The rotor appeared to have come to rest in the orientation shown above based on the copper splatter and burning exhibited on one of the rotor fins (the one with the yellow dot). The rotor appears to have stopped while the electrical failure was in progress.
Closer view of the electrical damage area shown above. The copper splatter on the damaged fin can be seen more clearly. Since there appears to be clearance between the fin and the conductors, it is evident that the rotor stopped turning prior to power being secured to the motor.
As can be seen by the two photos shown above, there appears to be clearance between the rotor fins and the end-turns of the stator. When the rotor is rotated approximately 200° in the counterclockwise direction, however, it becomes clear that the rotor fins do come in contact with the end-turn stator insulation (see photo below).

The rotor fin with the yellow dot to the left is the same rotor fin that is assumed to have come to rest adjacent to the electrical failure. This fin and the fins adjacent to it, come into contact with the end-turn insulation when rotated.
With the rotor removed, the stator was inspected more thoroughly. The final electrical failure was a ground within the slot of the stator; however, it appears that the winding initially had a turn-to-turn failure. The turn-to-turn short generated excessive heat within the coil that caused burning of the conductors and insulation, which in turn, involved the adjacent coils (phase-to-phase). The burning progressed down the coil into the slot until the slot liner burned through and the coil shorted to ground (stator core). When the coil shorted to ground, the breaker tripped.

Much of the insulation at the edge of the failure area shows signs of abrasion but no burning which is not characteristic of a failure of this sort. 200° counter clockwise from this failure there is an area where the insulation has been worn away, but no electrical failure has occurred.
The above photo shows abrasion of the insulation. It is apparent that the rotor fins had contacted this area as well as the area where the motor failed electrically. The abrasion is omni-directional which is evidence that the rotor had been contacting the end-turn in both the open and closed direction (both clockwise and counter-clockwise).

While the photo to the left is not very clear, it shows a metal nameplate that is attached to the windings. This nameplate shows signs of having been rubbed by a metallic object in both the clockwise and counter-clockwise directions. Two of the rotor fins have evidence of metal-to-metal contact during operation.
The photo below is of the drive end of the rotor. One section of the end-ring has completely separated from the rotor bars and from the rotor itself. The interior casting is highly carbonized and porous (similar to lava rock) but is not powdery. The white area on the edges is clean magnesium and is newly broken. These areas are not carbonized nor is there any excessive porosity. The steel laminations are discolored from heat and the rotor body appears to have swollen. The end-ring has separated from the rotor body along the entire inner dimension of the rotor. This separation has caused the outward protrusion of the rotor fins.
The opposite side of the rotor does not show any sign of separation, however, there is one area that is showing the possible early stages of the failure that occurred on the drive end.
The magnesium “growth” on the opposite drive end of the rotor has actually displaced the rotor fin such that it is no longer perpendicular to the rotor body.
Metallurgical Analysis

Lab report LR-1088.
Conclusion

It is Schulz Electric Company's opinion that the motor failure was due to rotor casting failure caused by internal scaling in the magnesium microstructure, which caused distortion of the rotor end-ring. This internal scaling was caused by prolonged moisture at an elevated temperature combined with internal casting porosity.

Recommendations

For motors that have this style of magnesium cast rotors, it is recommended that during the replacement or maintenance cycle for the operators, the motor be disassembled and inspected for any signs of the onset of this type of future failure. Evidence of possible degradation would be an open rotor bar detected during a growl test or single phase open rotor bar test, evidence of "growths" from the end rings, signs of cracks in the end rings or rotor bars and separation of the end ring from the rotor body. While the motor is apart, the rotor should be recoated to prevent moisture intrusion. Though during operation the motor may not show any sign of degradation prior to failure, it is possible that the motor will provide indication of imminent failure. Those signs could be that the motor is taking longer to cycle the valve (as rotor bars fail there could be an increase in the "slip" frequency), the current may be somewhat higher (due to increased slip) or the motor has trouble forward or reverse seating the valve due to inadequate torque. The operational signs may be harder or even impossible to detect as they may be masked by, or attributed to, the same symptoms that are normal mechanical maintenance items.