TECHNICAL REPORT
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# FINAL REPORT ON THE EVALUATION OF THE QUALIFICATION OF THE MODEL 506UPZ RESIDUAL HEAT REMOVAL (RHR) PUMP MOTOR PROVIDED BY WESTINGHOUSE ELECTRIC CORPORATION FOR USE IN THE H.B. ROBINSON STEAM ELECTRIC PLANT-UNIT 2

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# TABLE OF CONTENTS

## INTRODUCTION AND SUMMARY

This document, designed to assess qualification documentation of Class 1E equipment to the H.B. Robinson Steam Electric Plant-Unit 2 (HBR-2) specific requirements, is divided into four (4) sections, as follow:

SECTION I. EQUIPMENT IDENTIFICATION/QUALIFICATION REQUIREMENTS

SECTION II. QUALIFICATION DOCUMENTATION ASSESSMENT

SECTION III. QUALIFICATION JUSTIFICATION ANALYSIS

SECTION IV. CONCLUSIONS

The RHR pump motors assessed are qualified to the DOR Guidelines for use in HBR-2 and have a qualified life of 25 years at the motor design temperature.

SECTION I. EQUIPMENT IDENTIFICATION/QUALIFICATION REQUIREMENTS

1. **EQUIPMENT DESCRIPTION**

| | | | |
|---|---|---|---|
| **System:** | Residual Heat Removal | **Component I.D.:** | RHR-A, B |
| **Manufacturer:** | Westinghouse | **Equipment Type:** | Motor |
| **Serial No.:** | N/A | **Model No.:** | 506UPZ |
| **Location:** | Reactor Auxiliary Building | | |

**Safety-Related Function:** Drives residual heat removal pump

2. **QUALIFICATION SPECIFICATIONS**

a. **Applicable Standards**

DOR Guidelines: X
NUREG-0588, Cat. I: ____
NUREG-0588, Cat. II: ____

b. **Normal Service Conditions**

| | |
|---|---|
| Temperature: | 105°C (221°F) Motor Design Temperature |
| Pressure: | Atmospheric |
| Relative Humidity: | 20% to 90% |
| Voltage: | 460 VAC |
| Current: | 10 A |
| Frequency: | 60 Hz |

c. **Design Basis Events**

Accident Profile: Radiation only

Source:
MSLB X
HELB ____
LOCA X

| | | | | |
|---|---|---|---|---|
| Operating Time: | 30 days | | | |
| Radiation: | $1x10^6$ rads gamma | | | |
| Submergence: | Yes | ____ | No | X |
| Demineralized Water Spray: | Yes | ____ | No | X |
| Mode: | Active | X | | |
| | Passive | ____ | | |
| | Fail-Safe | ____ | | |

e. <u>Functional Requirements</u>

| | |
|---|---|
| Voltage: | 460 VAC |
| Current Range: | 10 Amperes |

SECTION II. QUALIFICATION ASSESSMENT

1. **QUALIFICATION DOCUMENTATION**

a. Title: Fan Cooler Motor Unit Test

Report No.: WCAP 7829 Date: April, 1972

Source: Carolina Power and Light Company

2. **QUALIFICATION DOCUMENTATION ANALYSIS**

a. Design Basis Event Analysis

The Design Basis Event is elevated radiation levels only.

| | Yes | No* | N/A |
|---|---|---|---|
| 1) Are all peak temperature/pressure and time requirements during the transient phase enveloped? | | | X |
| 2) Are all temperature/pressure and time requirements during the post-accident phase enveloped? | | | X |
| 3) Are margins as applied consistent with those defined in NUREG-0588, IEEE 323-1974, and/or the DOR Guidelines, as applicable? | | | X |
| 4) Are the functional tests as performed adequate to demonstrate that the functional requirements (accuracy, repeatability, insulation resistance, etc.) for the equipment can be met? | | | X |
| 5) Was the normal and accident radiation applied prior to and/or simultaneously with the accident simulation? If yes, to what level? | | | X |
| 6) If submergence is a requirement, does the test demonstrate acceptable operation? | | | X |

| | Yes | No* | N/A |
|---|---|---|---|
| 7) Was the requirement for demineralized water spray enveloped? | | | X |
| 8) Were all known synergisms accounted for in the test sequence? | | | X |
| 9) If failures occurred during the test program, are adequate justifications provided in the form of a failure analysis such that the qualification is not negated? | | | X |

b. <u>Normal Service Conditions Analysis</u>

| | Yes | No* | N/A |
|---|---|---|---|
| 1) Does the aging analysis provided in the supporting documentation provide for a 40-year qualified life at the HBR-2 defined service temperature? | | X | |
| 2) Was the aging analysis performed using Arrhenius techniques? | | X | |
| 3) Is the aging analysis auditable? | | X | |
| 4) Was the radiation requirement accomplished by the radiation test? | X | | |
| 5) If any radiation exemptions were utilized, are they auditable? | | | X |
| 6) Did the equipment perform successfully at the extremes of its normal service conditions (temperature, radiation, pressure, voltage, current, humidity, etc.) as required by IEEE 323-1974 and NUREG-0588? | X | | |
| 7) Were the functional tests performed adequate to demonstrate operability parameters as seen in service? | X | | |
| 8) Are the acceptance/failure criteria clearly defined? | X | | |

| | Yes | No* | N/A |
|---|---|---|---|
| 9) If failures occurred during the test program, are adequate justifications provided in the form of a failure analysis such that the qualification is not negated? | | | X |
| 10) Are all known synergisms accounted for in the test program? | | | X |

* All questions marked "No" require additional analysis to justify qualification. Section III of this report contains the additional analysis to resolve the qualification deficiencies and justify qualification.

3. CONCLUSIONS AND RECOMMENDATIONS

Reference 1.a fulfills all the requirements of the DOR Guidelines, except for those items listed in Paragraph 4, below.

4. OUTSTANDING ITEMS REQUIRING RESOLUTION

- Time-Temperature Effects
- Radiation Analysis

Section III of this document contains analysis to resolve these items.

## SECTION III. QUALIFICATION JUSTIFICATION ANALYSIS

Where qualification parameters are not clearly defined, when new research highlights potential problem areas, or when the plant requirements are not met, analysis must be performed to augment the existing qualification documentation. The intent of this section is to summarize the results of this analysis. From these results, a specific program is recommended, if required, to maintain the qualification status of the Class 1E equipment.

For the RHR pump motors, the following areas were analyzed:

- o 1.0 Time-Temperature Effects
- o 2.0 Radiation Analysis

### 1.0 TIME-TEMPERATURE EFFECTS

Aging effects on all Class 1E equipment must be considered and included in the qualification program. For time-temperature effects, the present state-of-the-art allows artificial acceleration of these effects associated with organic materials by increasing the temperature. The deterioration due to these effects is judged to be insignificant for metallic materials. Therefore, the aging of the Class 1E equipment will be based on its nonmetallic materials.

For many organic materials, it is known that the degradation process can be defined by a single temperature-dependent reaction that follows the Arrhenius equation (References 1 and 2):

$$k = A \exp(-Ea/k_B T) \qquad (1)$$

where,

$k$ = reaction rate

$A$ = frequency factor

exp = exponent to base e

$Ea$ = activation energy

$k_B$ = Boltzmann's Constant

$T$ = absolute temperature

It is further noted that, for many reactions, the activation energy can be considered to be constant over the applicable temperature range. Equation (1) can be transformed into a form which yields an acceleration factor.

The acceleration factor is defined as $t_2/t_1$.

The equation is:

$$t_2/t_1 = \exp\ (-(Ea/k_B)(1/T_1 - 1/T_2)) \qquad (2)$$

where,

$t_1$ = accelerated aging time at temperature $T_1$

$t_2$ = normal service time at temperature $T_2$

exp = exponent to base e

Ea = activation energy (eV)

$k_B$ = Boltzmann's Constant ($8.617 \times 10^{-5}$ eV/$^{o}$K)

$T_1$ = accelerated aging temperature ($^{o}$K)

$T_2$ = normal service temperature ($^{o}$K)

The transformation of the reaction rate form of the Arrhenius equation to an acceleration form is accomplished as follows:

Life is assumed to be inversely proportional to the chemical reaction rate (References 1 and 2). In terms of life, and after converting to Napierian base logarithm, Equation (1) becomes:

$$\ln\ (\text{life}) = (Ea/k_B)(1/T) + \text{Constant} \qquad (3)$$

Equation (3) has the algebraic form:

$$y = mx + b \qquad (4)$$

where,

y = ln (life)

x = 1/T

m = $Ea/k_B$, constant for single dominant reactions

b = constant

The constants, m and b, can be estimated by fitting experimental data in the form of ln (life) versus 1/T into the above simple linear relationship.

The derivation of an acceleration factor is accomplished by taking the difference between any two points of the linear relationship.

Thus, if we substitute t for life into Equation (3), we obtain:

$$\ln t = (Ea/k_B)(1/T) + \text{Constant} \quad (5)$$

For the set of points $(t_1, T_1)$, Equation (5) becomes:

$$\ln t_1 = (Ea/k_B)(1/T_1) + \text{Constant} \quad (6)$$

For the set of points $(t_2, T_2)$, Equation (5) becomes:

$$\ln t_2 = (Ea/k_B)(1/T_2) + \text{Constant} \quad (7)$$

Subtracting Equation (6) from Equation (7) yields:

$$\ln t_2 - \ln t_1 = (Ea/k_B)(1/T_2) + \text{Constant} - (Ea/k_B)(1/T_1) - \text{Constant} \quad (8)$$

Simplifying and rearranging Equation (8) yields:

$$\ln (t_2/t_1) = -(Ea/k_B)(1/T_1 - 1/T_2) \quad (9)$$

Taking antilogarithm yields:

$$t_2/t_1 = \exp (-(Ea/k_B)(1/T_1 - 1/T_2)) \quad (10)$$

Equation (10) is the same as Equation (2).

The qualified life of the nonmetallics in the equipment is determined by solving Equation (10) for $t_2$.

$$t_2 = t_1/\exp ((Ea/k_B)(1/T_1 - 1/T_2)) \quad (11)$$

Since, in most cases, it is not practical to independently accelerate the time-temperature effects of each nonmetallic material, a determination is made as to which material has the lowest activation energy. The time-temperature effects are then accelerated based upon

the lowest activation energy for conservatism. This assures that the degradation of each age-sensitive component is accelerated to at least the equivalent degradation as that to be encountered during the operating life.

## 1.1 Specific Analysis of Time-Temperature Effects

The subject motors were not tested as complete units; however, all the constituent components were tested as components or in their intended function in the test (see Appendix I).

The subject insulation system was aged prior to the design basis event for 504 hours at 200°C. Using Equation (11):

$$\text{Qualified Life} = t_1/\exp((Ea/k_B)(1/T_1 - 1/T_2))$$

where,

$t_1$ = 504 hours

exp = exponent to base e

Ea = 0.99 eV (Reference 3)

$k_B$ = $8.617 \times 10^{-5}$ (Boltzmann's Constant)

$T_1$ = 200°C

$T_2$ = service temperature

To account for heat rise associated with the motor operation, the design temperature shall be used. Using the Class A design temperature (105°C) gives a qualified life of 25 years.

Based on the best available data for a grease (Ea = 1.43 - Ref. 4) similar to that which is used in this system, the expected life at 105°C is greater than 64 years; however, the qualified life of the lubricant is dependent on operating time and speed and is not totally addressed by the Arrhenius equation. Because of aging factors other than time and temperature, the manufacturer's recommended maintenance procedures should be followed.

The remaining components of the fan motors, mechanical frame, end bells, shaft, rotor (less windings), and bearings are all metallic in nature and are not subject to any aging due to time-temperature effects, with the exception of the bearings. The subject bearing system is of the rolling ball type. Rolling element bearings are not infinite life devices.

In accordance with AFBMA Standard No. 9, a large group of identical bearings, identically loaded, operated at the same speed, and properly lubricated, will have a failure rate as a function of operating time, not as a function of time-temperature effects. Therefore, a true "qualified life" cannot be established for randomly operated units.

Manufacturers normally recommend that the bearings be treated as a replaceable element by the end user. A maintenance program should be established in accordance with the manufacturer's instruction manual to maintain the bearing and lubrication system qualification.

## 2.0 RADIATION ANALYSIS

A radiation analysis of the motor is required. During the test program (see Appendix I), the motor components were irradiated to a level of $2x10^8$ rads gamma. The postulated total integrated dose for the motors at HBR-2 is $1.1x10^6$ rads gamma (normal plus accident dose, with margin). Although the radiation testing was not performed on the motor as a complete unit, a review of the nonmetallics and the test report indicates all the radiation-sensitive components were irradiated to levels in excess of those postulated at HBR-2.

## 3.0 REFERENCE AUDITABILITY

In accordance with IEEE 323-1974, the references listed below contain the most applicable data currently available at Patel Engineers and are auditable upon request.

1. "IEEE Guide for the Statistical Analysis of Thermal Life Test Data," IEEE 101-1972, Library Code 102-82.

2. Handbook of Engineering Fundamentals, Wiley, 1975, Library Code 103-82.

3. "Thermalastic Epoxy Insulation for Large AC Motors," Westinghouse Electric Corporation, Application Data 3170, September, 1971, Library Code 283-83.

4. "Wires and Cords for Original Equipment Manufacturers," General Electric Company, No. WCC-2, Library Code 137-82.

5. Chevron Teknifax on Chevron SRI Grease, Chevron USA, Inc., G-10, May, 1979, Library Code 157-82A.

SECTION IV. CONCLUSIONS

Based on the comparison of the qualification test documentation to the normal and accident service conditions postulated for the Reactor Auxiliary Building, the motor is judged to possess a 25-year qualified life at HBR-2.

This conclusion is based on analyses performed in the following areas:

- Time-Temperature Effects - Based on the lowest activation energy obtained, 0.99 eV, and using the temperatures specified in Paragraph 1.1, Section III, the equipment possesses a qualified life of greater than 25 years. However, the manufacturer's maintenance procedures should be followed to maintain qualification for the bearings and lubricant.

- Radiation Analysis - Each of the materials and the test report were reviewed to ascertain the radiation test level. It was determined that the components were irradiated to a level of $2 \times 10^8$ rads, as compared with a requirement of $1.1 \times 10^6$ rads.

TABLE I. LIST OF NONMETALLIC MATERIALS AND THEIR AGING MECHANISMS

| Item No. | Item/Manufacturer | Mfg. Rating | Service Environmental Conditions | Materials | Aging Mechanisms | | | Qualified Life (Years) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Radiation Threshold (Rads Gamma) | Activation Energy (eV) | Cycling | |
| 1.0 | Motor, Westinghouse Model 506 UPZ | 460 VAC 10 Amperes | | | | | | |
| 1.1 | Motor Insulation | | | Thermalastic Epoxy Class F | $2.0 \times 10^8$ Test | 0.99 (Ref 3) | | 25 years |
| 1.2 | Motor Leads | | | Silicone Rubber | $2.0 \times 10^8$ Test | 1.68 (Ref 4) | | 1814 years |
| 1.3 | Grease, Westinghouse #773A 773G05 | | | Chevron BRB-2 | $2.0 \times 10^8$ (Test) | 1.43 (Ref 5) | | See Paragraph III, 1.1 |
| 1.4 | Remaining Components | | | Metallic | N.A.S. | | | N.A.S |

N.A.S. - Not age sensitive