Qualification And Testing of Nuclear Safety Related Chilled Water Units

Interim Report - September 2002

By

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Abstract:

Ellis & Watts International, designed, manufactured, seismically and environmentally qualified a family of Nuclear Safety Related Chillers. The largest chiller has a cooling capacity of 250 Tons. The chillers meet all requirements of ASME AG-1, Code on Nuclear Air & Gas Treatment Systems; IEEE-323, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations; IEEE 334, Standard for Type Tests of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations; and IEEE 344, Recommended Practice for Seismic Qualifications of Class 1E Equipment for Nuclear Power Generating Stations. The chillers are factory performance tested to validate the design and to provide actual performance data. This performance data provides the basis for in-service performance testing at actual site conditions.

This paper details the qualification and testing of nuclear safety related chillers. Two sizes, a nominal 250 Ton and a 160 Ton, were used to qualify the chiller family. The chilled water supplied by these units is used in cooling coils in heating, ventilation, air-conditioning equipment in the following areas: Control Building Safety Related Equipment Area, Reactor Building Safety Related equipment Area, Control Room Habitability, and the Post Accident Sampling Room.

This paper provides the details of the design, qualification and testing process. It includes the necessary steps for seismic and environmental qualification. Qualification of all components is addressed, including controls, instruments, compressors, motors and heat exchangers.

Design life of all the components, equipment, and materials are for 40 years, accounting for corrosion, erosion and material degradation. The design requirements were chiller vibration levels shall be sufficiently low to ensure safe operation and avoid undue maintenance. All replacement parts have a minimum useful life of 5 years. The use of R134a refrigerant is used; this is a non-ozone depleting refrigerant with no phase out date in The United States or Canada.

Qualification And Testing of Nuclear Safety Related Chilled Water Units

The effects of radiation on all the materials of construction were considered by E&W when specifying materials used in the fabrication of the chillers. Safety related equipment must be qualified to perform the safety related functions after long periods of exposure to low level radiation and short periods of high radiation following various postulated design basis accidents.

The Safety Related Chiller is capable of operating during and after the application of specified loads and loading combinations of the environmental, radiation, seismic and dynamic conditions, and loading combinations.

Qualification And Testing of Nuclear Safety Related Chilled Water Units

Introduction:

Ellis & Watts International, Inc. is a manufacturer of Safety Related HVAC Equipment, supplying equipment worldwide, including South Korea, China (PRC), Taiwan (ROC), and Russia. The Nuclear Safety related Systems and Equipment supplied includes Air Cleaning Units, Reactor Containment Fan Coolers, Local Air Cooler, Air Handling Systems, Air Conditioning Units, Heaters, Dampers, Controls, Fans, Motors, and related equipment.

Over the past 20 years, as the nuclear industry declined in the United States, qualified component became difficult, if not impossible, to purchase. Ellis and Watts began qualifying equipment and components to meet customer needs. In most cases, commercial dedication was not allowed and a full qualification was necessary.

Chiller Qualification and Test Program;

Ellis and Watts Nuclear Safety Related Chiller Qualification Program is scheduled for completion by December 20, 2002. Eighty (80%) of the program is complete. This paper provides an interim report on the progress of this program. All environmental qualification, seismic testing and analysis is complete. The last phase of the program is performance testing. Two chillers have been performance tested. Twelve chillers will be completely performance tested when the program is concluded. This paper will be revised at the end of 2002 to include all test data and reports not yet completed.

Major Component Description / Function:

The key to qualification of Safety Related Chillers is the design of the critical components. The selection of the components and specification of the materials at the design stage reduces the difficulty of qualification.

Screw Compressor:

The screw compressor is an open type (inlet/outlet), directly driven by a water cooled motor. The compressor housing is machined cast iron to provide minimal clearance for the rotors. The rotors are precision machined and matched to provide for maximum efficiency. The compressor incorporates a complete anti-friction bearing design. The screw compressor uses oil as the primary coolant and to seal the compression chambers. The lubrication system utilizes force feed system to provide lubrication of bearings and shaft seals. A differential oil pressure cutout switch

interlocked with the motor starter to operate only when the required oil pressure is provided to the bearings. All seal materials and gaskets were selected from a material database qualified to or above the environmental conditions, including radiation, of the design specification.

Screw Compressor Motor:

The E&W Nuclear Class IE screw compressor motor operates on 4160 volts / 3 phase / 60 hertz, water cooled jacketed, equipped with anti-friction bearings with an 'ABMA L 10' bearing life, 200,000 hours. The motor equipped with RTD and a maximum acceleration time of 10 seconds. The motors use a direct drive coupling between the motor and the screw compressor. The motor has been previously qualified by E&W.

Evaporator:

The evaporator was designed and built to the requirements of ASME Code Section III. The evaporator is shell and tube design with shell constructed of welded steel. The tubes are enhanced finned copper nickel alloy and rolled into tube sheets of the shell and tube unit. The tubes have a nominal outside diameter of 19 mm (0.75 inch), with a wall thickness of 1.25 mm (0.049 inch) minimum at the tube supports. The evaporator has tubing for chemical cleaning. The removable covers are provided for access to tube bundles, the covers are tapped and vent connections. Eliminators are provided in the cooler to ensure that the liquid refrigerant is not carried over to the compressor.
The evaporator is provided with a refrigerant sight glass and with a safety relief valve.

Condenser:

The condenser was designed and built to the requirements of ASME Code Section III. The condenser design is shell and tube with shell constructed of welded steel. The tubes are enhanced finned copper nickel alloy and rolled into tube sheets of the shell and tube unit. The tubes have a nominal outside diameter of 19 mm (0.75 inch), with a wall thickness of 1.25 mm (0.049 inch) minimum at the tube supports. The condenser has tubing for chemical cleaning. The condenser is complete with pressure relief device and purge valve.

Superfeeder:

The superfeeder is an open pool heat exchanger, where a small portion of sub-cooled liquid refrigerant is diverted and allowed to boil off, removing additional heat from the liquid refrigerant before entering the evaporator.

The additional sub-cooling of the refrigerant increases the cooling capacity the evaporator, while the refrigerant vapor used to sub-cool the liquid is injected into the compressor in the suction phase, adding addition refrigerant volume with no addition work input.

Oil Separator:

The oil separator separates entrained droplets of oil are separated by the use of a mist eliminator from the refrigerant gas. The mist eliminator removes oil from the refrigerant gas, only to be collected at the oil reservoir to be sent to the oil cooler, filtered, and pumped back into the rotary screw compressor.

Controls:

Controls are always the difficult to qualify. Sensing elements must be selected and qualified that meet can withstand the environmental conditions and also be compatible with the R-134a refrigerant. The materials must be carefully selected and verified to meet the environmental conditions, specifically the radiation and high temperatures.

The control system designed by E&W employs a microprocessor PLC control panel, the control panel receives analog signals from RTS and PT. The multilin monitors motor operation, current, voltage, FLA, motor winding temp measure within the motor windings, and shaft temperature. The controls measure pressures, temperatures, flow rate, deflection, current, voltage, and phase to ensure the safe operation of the chiller

Seismic Analysis Approach

The seismic analysis was concluded using the standards IEEE-344 and ASME AG-1

The seismic qualification of equipment demonstrated the equipment's ability to perform its safety function during and after a prescribed seismic event. The seismic qualification used a combination of shake table analysis and finite element analysis; this method is prescribed in ASME AG-1. The seismic testing was conducted using an overall qualification program as required by ASME Ag-1 Code and indicated in IEEE STD 323.

Shake table analysis:

The seismic testing demonstrated the operability of the chiller components during and after the prescribed seismic event, these tests consisted of five OBE's and one SSE. Using an independent tri-axial random waveform motion simulator, the waveform had a peak equal to or greater than the ZPA, except at low frequency where the acceleration values of the RRS stay below the ZPA and need not include any frequencies above the ZPA asymptote. The seismic event consisted of

random waveform motion, which is amplitude controlled in 1/3 octave bandwidth from 1 Hz to 50 Hz, the test duration was maintained for a minimum of 30 seconds. The results from shake table motion was analyzed and plotted by a Digital Fourier analyzer using shock responsive sensors.

Seismic Finite Element Analysis:

The finite element model was used to perform modal and stress analysis. The modal analysis demonstrates that the fundamental overall system natural frequency of the safety-related chiller was greater than 40 Hz. The seismic qualification modeled using the specified 'OBE' and 'SSE' response spectra for the chilled water units. The structural analysis was concluded using the standards IEEE-344.

Analysis was used to demonstrate the structural integrity of the safety related water chiller, the rigidity was determined to be greater than 40 hertz, being defined as rigid. Static analysis was used and specified 'OBE', 'SSE', and ZPA loads were applied to the equipment center of mass.

The safety related equipment must maintain structural integrity or remain functional during / after the postulated seismic event. The major components of the unit include the motor, rotary screw compressor, evaporator, condenser, superfeeder, oil separator, oil cooler, oil pump, water, pump, control panel, starter panel, along with piping and associated strainers, valves, and filters.

Seismic Analysis Summary:

Analysis both shake table and finite element, challenges were faced to make all items rigid and able to transmit the forces and reactions to the base. Large additional braces were added in several locations to transmit the forces from the top of the condenser to the thru bottom of the base, and a strict pipe bracing was adhered to insure all components and pipes were fastened securely. Piping design and analysis was conducted using ASME B31.1 Power piping.

Environmental Qualification:

All components have been qualified by E&W to ASME AG-1, Code on Nuclear Air and Gas Treatment and IEEE 323, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations. A summary of E&W's Qualification Report is provided in Appendix II. An overview of Ellis & Watts' Class 1E motor qualification is also provided in Appendix II.

System Operation:

The chillers are flooded bed design. The chiller schematic is provided in Appendix I, along with a typical general arrangement drawing. Note the chillers compact design. The design is based on ease of operation and maintenance in the most compact space. Floor space is always a premium in nuclear power plants. E&W's experience in designing compact air conditioners, chillers and environmental control units for military stationary and mobile applications is reflected in the design. The control panel is located at the end of the unit easily accessible from the aisle. Remote operation, monitoring and fault indication is also provided.

Performance Testing Procedure:

The following pre- requisite tests are to be performed on each chiller:

1.	Water Flow Test	- Calibrates flow sensors
2.	Leak and Pressure Test	- System check for leaks, water side
3.	Electrical Point to Point	- Verifies electrical wiring continuity
4.	Water Flow vs. Pressure	- Calibrates volume flow rate through heat exchangers
5.	Refrigerant Leak Test	- System check for leaks, refrigerant side
6.	4 kV Motor Cooling Loop Test	- Functionality of water cooling loop to motor
7.	Hydraulic System Calibration	- Verifies oil hydraulic system operability
8.	Control System Test	- Verifies the controls can safely operate system
9.	Performance	- Verifies the cooling capacity of unit
10.	Sound	- Documents sound pressure
11.	Pump Vibration	- Verifies pump alignment

Performance testing is conducted in accordance with specification requirements and ARI STD 550/590 Standards.

E&W designed a test station specifically for this application. The test stand can be configured to accept any piping setup required. The test stand includes heat exchangers, generators, direction control valves, cooling tanks, cooling towers and independent measurement device to verify the chillers on board monitoring. The test stand provides simulation to test the chillers to plant conditions, such as increased and decreased water flow and heat loads both high and low, as well

as fouled tube conditions.

The tests measured the net cooling capacity and the energy required to chill the water as it passed through the evaporator, cooling is measured in tonnage by water flow rate and the difference in temperature. The heat removed from the chilled water is equal to the product of the chilled water flow rate, the difference in water temperature, and the specific heat of water. The test stand simulates fouling factor on both the evaporator and condenser this is accomplished by either reduced flow rate and or higher heat load applied to evaporator and condenser.

The unit efficiency is calculated using the following loading conditions of: 100%. 75%, 50%, and 25%, from these values the performance curve is plotted using straight line to envelop the load steps. The results were taken from three separate test sets; the test procedure is designed to eliminate any transient effects.

Performance Results:

Currently, E&W has completed testing on one chiller. The results listed in Appendix III shows the Ellis & Watts safety related chiller performed as designed and meets the design conditions, performance and capacity. The control system functioned as designed to provide automatic operation and control without operator interference.

The safety related chiller performance data provides the basis for in-service performance testing at actual site conditions. The testing demonstrates the ability to meet the load steps of 100%, 75%, 50%, and 25%.

The performance results are presented in Appendix III.

Conclusions:

Ellis & Watts is qualified and tested a family of safety related water chillers. The program is approximately eighty percent (80%) complete. Performance testing of the chillers is the last phase of the program and is in process. The chilled water supplied by these units is used in cooling coils in heating, ventilation, air-conditioning equipment in the following areas: Control Building Safety Related Equipment Area, Reactor Building Safety Related equipment Area, Control Room

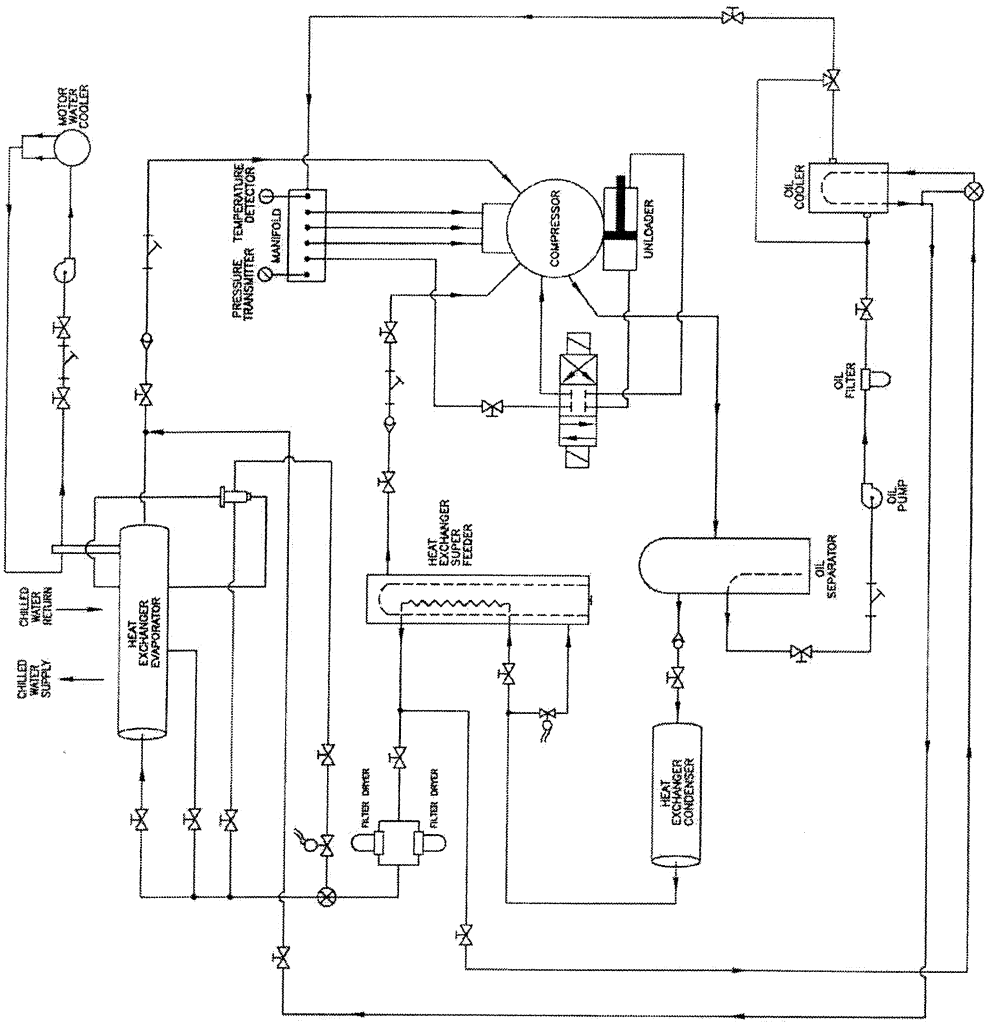
Habitability, and the Post Accident Sampling Room.

Ellis & Watts International, Inc. has engineered, built, seismic qualified, environmentally qualified, and performance tested safety related water chillers for nuclear power plants. The Ellis & Watts Safety Related Water Chiller Series uses proven and reliable methods and technologies along with new state of the art computer controls with touch screen interface.

The safety related chiller has been engineered, built, qualified and tested under ASME NQA-1 Quality assurance Program. Every unit is dedicated for its safety-related function in accordance with EPRI NP-5652 before shipment. The seismic integrity qualification is under IEEE STD 344, and meets rigidity and below maximum allowable stress. The environmental qualification researched all materials to determine the safety related functions after long periods of exposure to low level radiation and short periods of high radiation following various postulated design basis accidents.

The Safety Related Chiller is capable of operating during and after the application of specified loads and loading combinations of the environmental, radiation, seismic and dynamic conditions, and loading combinations.

Appendix I
Chiller Schematic


MOTOR WATER COOLER
PRESSURE TRANSMITTER
TEMPERATURE DETECTOR
MANIFOLD
COMPRESSOR
UNLOADER
OIL COOLER
OIL FILTER
OIL PUMP
OIL SEPARATOR
HEAT EXCHANGER SUPER FEEDER
CHILLED WATER RETURN
CHILLED WATER SUPPLY
HEAT EXCHANGER EVAPORATOR
FILTER DRYER
FILTER DRYER
HEAT EXCHANGER CONDENSER

Appendix II

Ellis & Watts IEEE 323 ENVIRONMENTAL QUALIFICATION PLAN

Qualification And Testing of Nuclear Safety Related Chilled Water Units

1.0 Introduction

Environmental qualification will be performed in accordance with the applicable documents, codes and regulations listed in the contract specification. Typical examples are listed below. The date of issue invoked for these standards in the contract procurement specification will be used.

a. IEEE 323, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

b. IEEE 334-1974 Standard for Type Testing of Continuous Duty Class 1E Electric Motors for Nuclear Power Generating Stations.

c. IEEE 382, Standard For Qualification of Safety Related Valve Actuators.

d. IEEE 383, Standard For Type Test of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations.

The contract procurement specification describing the equipment requirements for this program is considered the superseding environmental qualification document. It is expected that this document will describe how the general environmental qualification reference documents apply to the current program.

2.0 Environmental Conditions

Ellis and Watts will rely on the contract procurement specification to describe the environmental conditions for which the equipment will be qualified and to make the distinction between mild and harsh environments.

If the contract procurement specification does not make the distinction between mild and harsh, Ellis and Watts will use the following criterion for mild and harsh environment classification.

2.1 Mild Environmental Conditions

Temperature:	104°F maximum normal up to 122°F during accidents.
Pressure:	prevailing atmospheric normal at equipment elevation.
Radiation Dose:	less than 1.0×10^5 (40 year TID)

2.2 Harsh Environmental Conditions

Temperature:	122°F normal maximum with higher temperatures during accident conditions.
Pressure:	Significantly above atmospheric
Radiation Dose:	greater than 1.0×10^5 rads (40 year TID)

3.0 Qualification Method

Equipment will be qualified for its intended operating environment as described below.

3.1 Equipment Located In Mild Environment

An earthquake is the only design basis event of consequence for equipment located in a mild environment. Seismic qualification is addressed in the Ellis and Watts seismic qualification documents for this program.

Radiation exposure in a mild environment is negligible and no significant aging mechanisms have been identified. There is no significant thermal exposure, wear, or cyclic aging for equipment located in a mild environment.

For equipment located in a mild environment with no significant aging mechanisms, establishment of a qualified life and pre aging prior to seismic testing is not required. Ellis and Watts intends to conduct no environmental testing for equipment located in a mild environment.

Environmental qualification will be accomplished by specifying the quality assurance requirements and surveillance practices appropriate for safety related equipment as called for by the contract procurement specification. Ellis and Watts will provide certification of compliance to the procurement specification requirements for equipment located in a mild environment.

If a qualification report is required for safety related equipment located in a mild environment it will consist of a listing of organic materials and a brief paragraph demonstrating their suitability for the application. A report is not required for non safety equipment in a mild environment.

3.2 Equipment Located In Harsh Environment

For equipment located in a harsh environment Ellis and Watts will, to the greatest extent possible, use components which have been previously qualified for harsh environment service. In some cases, components similar to previously qualified components may be recommended. In all cases, any differences between the service conditions of the current and previous program will be identified and the suitability of the previous qualification for the current program will be demonstrated by analysis.

Typically a harsh environment test report will contain a comparative analysis of environmental conditions between the former and current contracts to demonstrate the suitability of the previously qualified components for the current program. In cases where the new program has greater performance requirements Ellis and Watts will provide an analysis that will justify use of the previously qualified component or recommend a new harsh environment test program as described in our technical proposal.

The environmental qualification report will also contain a table listing all electrical components and elastomeric mechanical components. The table will provide information the component's safety classification, description, location, and function.

Copies of test reports used for previous qualifications will be provided in the qualification report for this contract as needed. No new thermal aging, seismic testing or radiation testing is planned for any component unless such testing is specifically described in the Ellis and Watts proposal for this contract.

Components which are being newly qualified will be provided with sufficient documentation to substantiate their qualification for nuclear safety related service in Ellis and Watts equipment being provided for this contract.

A maintenance / replacement schedule will be developed for safety related components having a qualified life less than 40 years.

4.0 Summary

Ellis and Watts equipment will be qualified for nuclear safety related service as required by the contract procurement specification and as clarified in the Ellis and Watts Technical Proposal.

Ellis & Watts 1E Motor Qualification

1.0 INTRODUCTION

This document presents test results on the motorette and prototype motor qualification program conducted by Ellis and Watts. This program was conducted in order to establish 1E qualification for the Ellis and Watts motor design. The qualification process described herein is in accordance with IEEE Standards 323, 334 and IEEE Recommended Practice 344. Testing performed for this program is for motors serving outside of containment areas.

The motor qualification program was conducted in two phases. The first phase consists of the thermal aging of motorettes in order to establish a qualified life for the insulation system. Phase two consisted of prototype motor testing (type tests) as described in Section 6 of IEEE 334

The purpose of the type test program was to demonstrate that the Ellis and Watts motor is capable of surviving a representative design basis event (DBE) and remaining functional for a specific time period after the DBE. The design basis events considered for this program are seismic and high energy line break (HELB) outside containment. The complete qualification test plan is described in Ellis and Watts Document ENG-600 which is Appendix 10 to this

report.

2.0 APPLICABLE DOCUMENTS

IEEE 101	Guide For The Statistical Analysis Of Thermal Life Test Data.
IEEE 117	Standard Test Procedure For Evaluation Of Systems Insulating Materials For Random - Wound AC Electric Machinery.
IEEE 323	Standard For Qualifying Class 1E Equipment For Nuclear Power Generating Stations.
IEEE 334	Standard For Type Tests Of Continuous Duty Class 1E Motors For Nuclear Power Generating Stations.
IEEE 344	Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.
UL 1446	Standard For Safety, Systems Of Insulating Materials.
ASME NQA-1	Quality Assurance Program Requirements For Nuclear Facilities.
QC 4000	Ellis and Watts Quality Assurance Manual
ENG-600	Ellis and Watts Qualification Test Plan For 1E Motor.

3.0 QUALIFICATION TEST SUMMARY

3.1 PHASE 1

Phase 1 of the qualification program has established a qualified life for the Ellis and Watts insulation system of 44 years (385,440 hours) at a 152°C design temperature. As indicated in Section 3.2.1 of ENG-600 (Appendix 10), initial test plans were to qualify the insulation system for 44 years at a 130°C maximum temperature.

Note that 130°C represents the performance of a Class B insulation system per NEMA MG1 1.12.43. However, actual test results conclude a higher temperature qualification at 152°C for 44 years. Motorette insulation system samples were used and the motorettes were subjected to the battery of simulated aging tests described in IEEE 117. These tests consist of heat aging, vibration, and moisture (in that sequence).

In addition to IEEE 117 tests, the Ellis and Watts program added the cold shock test described in UL 1446. The cold shock was performed just before placing the motorettes into the humidity chamber.

Ten motorettes were taken through repeated cycles of heat, vibration, cold shock and humidity at each test temperature (220°C, 260°C, and 280°C) until the motorettes failed. Failure was determined by the voltage test described in Section 2.3 of IEEE 117.

After the motorettes failed, the number of cycles and the total number of hours of heat aging were recorded as test results. This data is provided as an average for each group of motorettes at each temperature. With this information a regression line for the insulation system was obtained using the analytical methods described in IEEE 101-1987. The curve developed from this data allowed the projection of a qualified life at a given motor temperature.

The insulation system was tested against a previously qualified, UL recognized Class H (180°C) control group. The life of the Ellis and Watts system exceeded the minimum life requirements of the Class H control group. A 44 year (385,440 hours) motor life is established by extrapolating the insulation system regression line to a 152°C maximum operating temperature. The Ellis & Watts motors are designed for a Class B maximum temperature rise.

As a comparison, extrapolation of the regression line to 140°C maximum operating temperature indicates a qualified life of 109 years. The 140°C maximum temperature is derived from a 50°C

ambient plus 90°C temperature rise by resistance at service factor load.

Motorette test results are contained in Appendix 1 to this document. A complete description of the Phase 1 test procedures can be found in paragraphs 5.0 through 5.5 of the qualification test plan (Ellis and Watts Document ENG-600).

3.2 PHASE 2

After the 40 year minimum qualified life of the insulation system was established, the next phase of the program was to conduct simulated aging and design basis event testing on a prototype motor. The prototype motor (serial number 137037) used in the qualification program is a 7.5 horsepower, 1750 RPM, totally enclosed air over (TEAO) design in a 215T frame.

A TEAO motor requires air movement over its frame. In order to correctly simulate a minimal air velocity for a TEAO frame, the air velocity over the same size TEFC frame was measured. A small centrifugal blower was used to simulate this minimum airflow during most of the tests that required prototype motor operation.

This method of providing air movement over the TEAO frame was conservative because the velocity provided by the small centrifugal blower was slightly less than that measured over the TEFC frame and actual TEAO applications provide air velocities far greater than the integral fan on a TEFC motor.

Phase 2 results are summarized below. The testing was conducted in the sequence listed in paragraphs 3.2.1 through 3.2.10.

1.1.1 The prototype motor was subjected to thermal aging per Section 9 of IEEE 334-1974 to an equivalent of 44 (40 + 10% margin) years at 152°C operating temperature. Based on the average life characteristic of the insulation system (established in Phase 1) the required number of thermal aging hours was determined to be 1698 at a selected aging temperature of 240°C. This testing was performed by Eltek International Inc. and is documented in Appendix 2 to this report. Thermal aging is described in paragraph 7.1 of the qualification test

plan (Ellis and Watts Document ENG-600).

3.2.2 Mechanical aging was by means of the one hour mechanical vibration test described in paragraph 9.5 of IEEE 334 and paragraph 2.2.3 of IEEE 117. This test was performed by Eltek International and is documented in Appendix 2 to this report. Only the stator winding and frame were subjected to thermal aging and the mechanical vibration aging. After these first two steps in the test program the prototype motor was reassembled and the complete motor, including the lubricant, bearing and seal system was subjected to all subsequent testing.

3.2.3 A routine performance test was conducted per IEEE 112 Form A1 as described in paragraph 7.3 of the qualification test plan (ENG-600). This test is documented in Appendix 3 to this report. The data sheet in Appendix 3 also shows baseline functional test data on the prototype motor (serial no. 13703) prior to thermal aging. This test was conducted with the motor unloaded both prior to and after thermal aging. There is no significant difference in the two sets of data indicating that the motor was functioning properly after thermal aging and vibration.

3.2.4 The motor was exposed to a radiation dose of 3.4×10^7 rads. The radiation exposure was by performed by Isomedix Operations Inc. The radiation source was Cobalt 60. Documentation of the radiation exposure is contained in Appendix 4 to this document. Paragraph 7.4 of the qualification test plan (ENG-600) describes the radiation exposure requirements.

3.2.5 Additional mechanical aging was simulated by cyclic operation as described in paragraph 7.5 of the qualification test plan (ENG-600). Documentation of the cyclic operation test is contained in Appendix 5 to this report. The prototype motor was started and stopped under full load 520 times which would be equivalent to starting the motor approximately once a month over a 40 year life. In addition to these starts, it is estimated that the prototype motor was stopped and started another 20 to 30 times in the course of the other testing.

Additional testing of an E&W 1E motor, the Mechanical aging by cyclic operation as described in 7.5 of the qualification test plan was extended to a total of 1040 start/stop operations. The motor successfully completed the cycles. Documentation of the cyclic operation of the motor is contained in Appendix 5 to this report.

3.2.6 Seismic tests were conducted with the motor operating under load. The test consisted of 5 generic OBEs and 1 SSE as described in paragraph 7.6 of the qualification test plan (ENG-600). These tests were conducted at Wyle Laboratories in Huntsville, Al. The motor performed successfully through all seismic tests. Detailed results of the seismic testing are contained in Wyle Test Report Number 43030-1 Revision A which is Appendix 6 to this document.

3.2.7 The high energy line break simulation (HELB) was also performed at Wyle Laboratories as described in paragraph 7.7 of the qualification test plan (ENG-600). The motor operated under load for a period of six hours in the HELB chamber at temperatures which exceeded the required time / temperature profile. The HELB simulation results are also documented in Wyle Test Report Number 43030-1, Revision A .

3.2.8 A post accident endurance test was conducted to simulate operation of the motor for 100 days, under load in an elevated temperature environment. Results of this test are included in Appendix 7 to this document. Paragraph 7.8 of the qualification test plan (ENG-600) describes the post accident endurance test.

3.2.9 A final routine performance test was conducted as described in paragraph 7.3 of the qualification test plan (ENG-600). This test is documented in Appendix 8 to this report.

3.2.10 At the completion of the above testing the motor was disassembled for a visual inspection as described in paragraph 7.10 of the program test plan. Results of the visual inspection are presented in Appendix 9 to this document. Paragraph 7.10 of the qualification test plan (ENG-600) describes the visual inspection.

4.0 SYNERGISTIC EFFECTS

During the age conditioning process it was considered impractical to simulate the effects of simultaneous environments in search of synergistic effects. The testing sequence employed in this qualification program in conjunction with the conservatism in test parameters will adequately account for possible synergistic effects. There are no known synergistic effects that the motor would be susceptible to.

5.0 LUBRICANTS, BEARINGS & SEAL SYSTEM

The Ellis and Watts motor design uses ball bearings that are sized in accordance with the methods described in the Anti Friction Bearing Manufacturers Association (AFBMA) Standard No. 9. Paragraph 5.3 of IEEE 334 indicates that the AFBMA standards are based on testing and are therefore acceptable as a basis for normal service qualification. Bearing maintenance and replacement schedules for Ellis and Watts motors are also determined by AFBMA Standards. These schedules are somewhat application specific however recommended replacement intervals are provided in the operation and maintenance manuals for each motor. Additional evaluation has been performed to optionally allow the use of a metallic grease shield in the motor bearings in lieu of a non-metallic which was originally qualified in this program. A metallic shield will be less susceptible to the degrading effects from exposure to the environments described in this document.

The lubricant used in the Ellis and Watts motor design is Chevron SRI-2. This grease was tested for radiation endurance by Chevron Oil Co. to a total dose of 2×10^8 rads and has a long record of successful application in the nuclear power industry. In addition to this previous testing, SRI-2 grease was used for prototype motor testing as documented in this report including design basis event and post event endurance testing.

The Ellis and Watts motor design uses a non-metallic shaft seal. This seal was subjected to the same prototype testing as the bearings and lubricant. Replacement criteria for this seal is described in the operation and maintenance manual for each motor.

The lubricant, bearing and seal system successfully completed the prototype motor testing program documented in this report. There was no reconditioning of any kind done on the lubricant, bearing or seal system during the course of the prototype qualification program. No lubricant was added and no bearings or seals were replaced. The condition of these items is described in Appendix 9 to this report.

6.0 QUALITY ASSURANCE PROVISIONS

This testing program covers the qualification of a safety related 1E electrical component. For such a program the requirements of 10CFR50 Appendix B and ASME NQA-1 apply. The Ellis and Watts QA program is in compliance with these documents. Ellis and Watts QA manual QC4000N documents the implementation of these requirements at our facility. The reporting requirements of 10CFR PART 21 also apply to qualification program of this nature.

This qualification test program was conducted in accordance with the applicable requirements of the QA standards mentioned above.

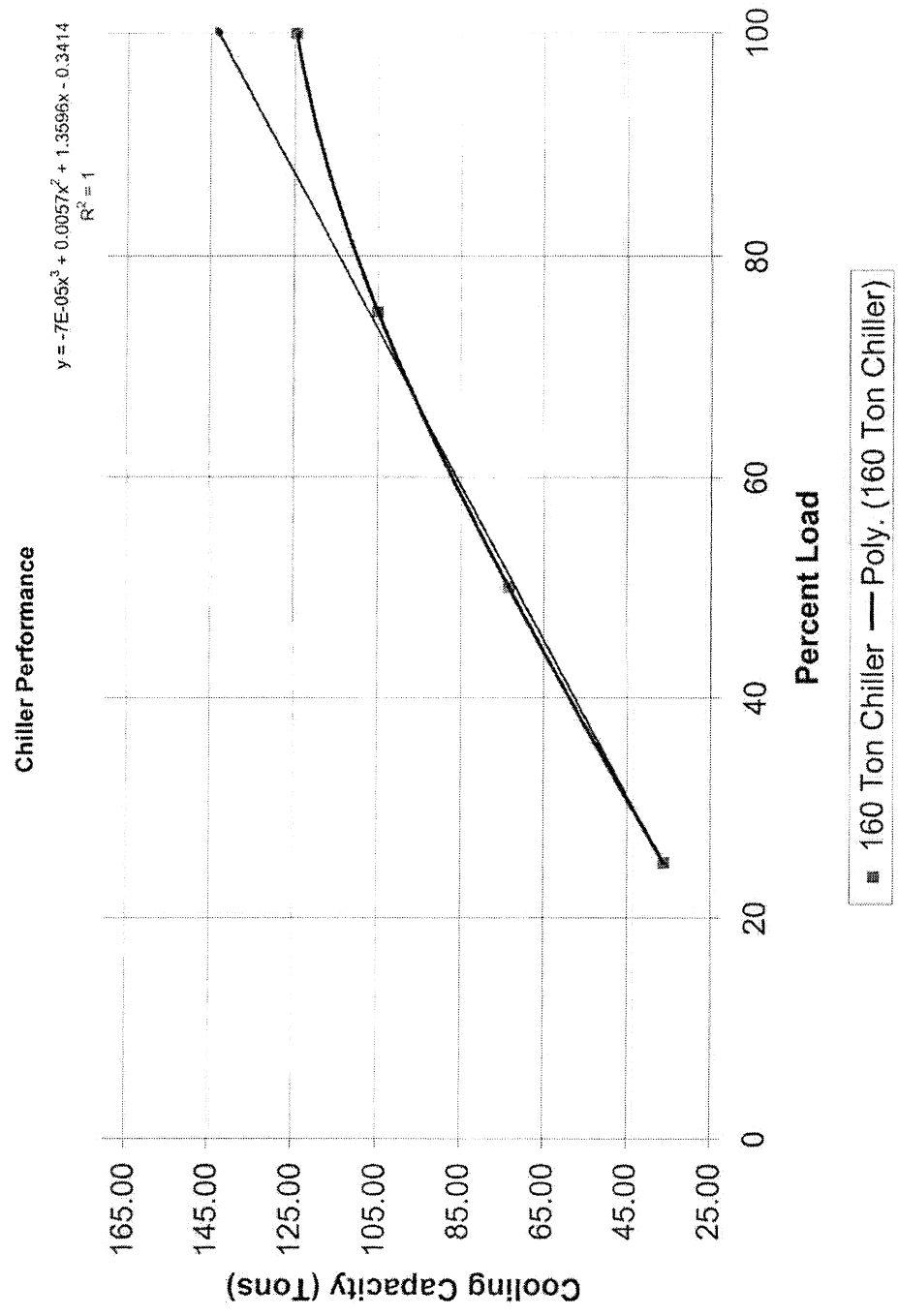
7.0 CONCLUSION

Based on the successful completion the tests described in this test program and on the fact that these tests are in accordance with applicable IEEE Standards and Recommended Practices, it is concluded that the Ellis and Watts motor is qualified for 1E service in accordance with IEEE 323, 334 and 344.

Appendix III

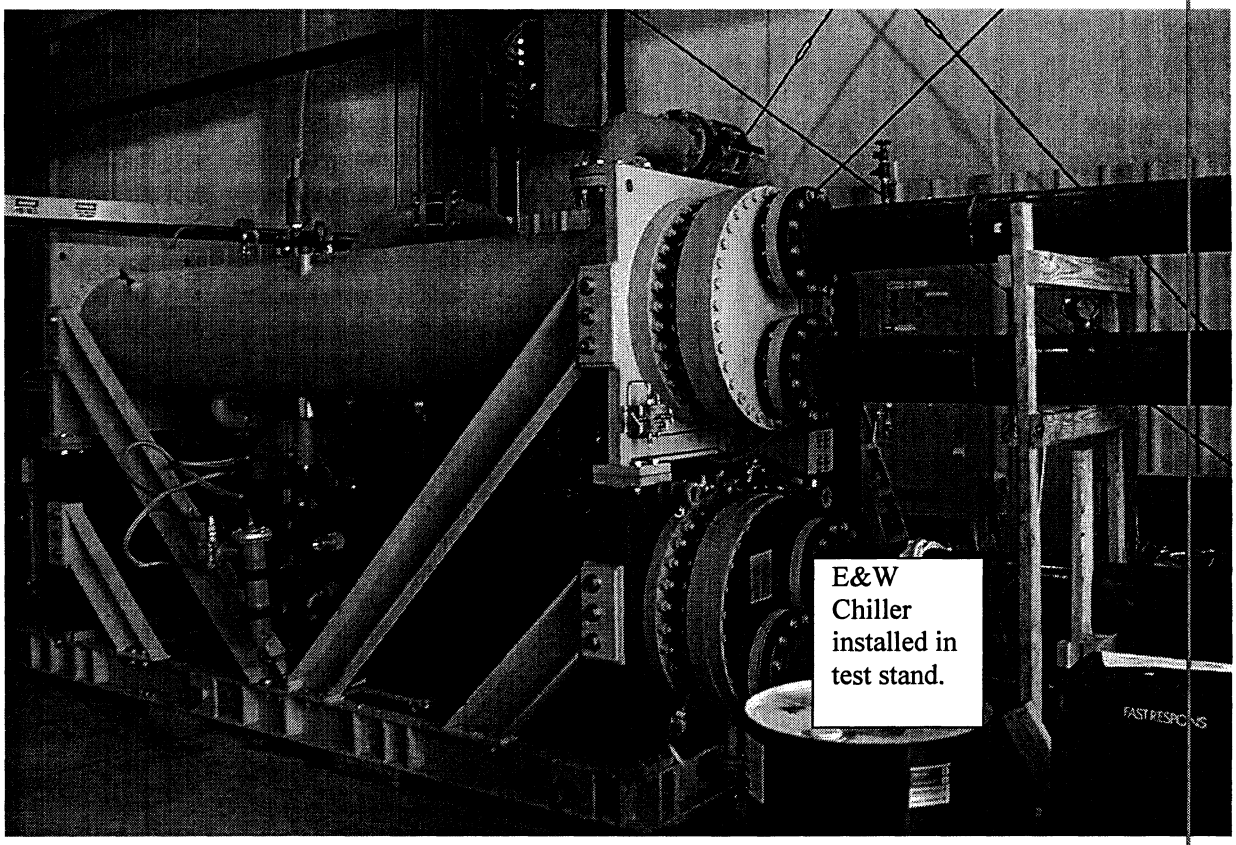
Performance Test Results

Safety Related Chilled Water Unit

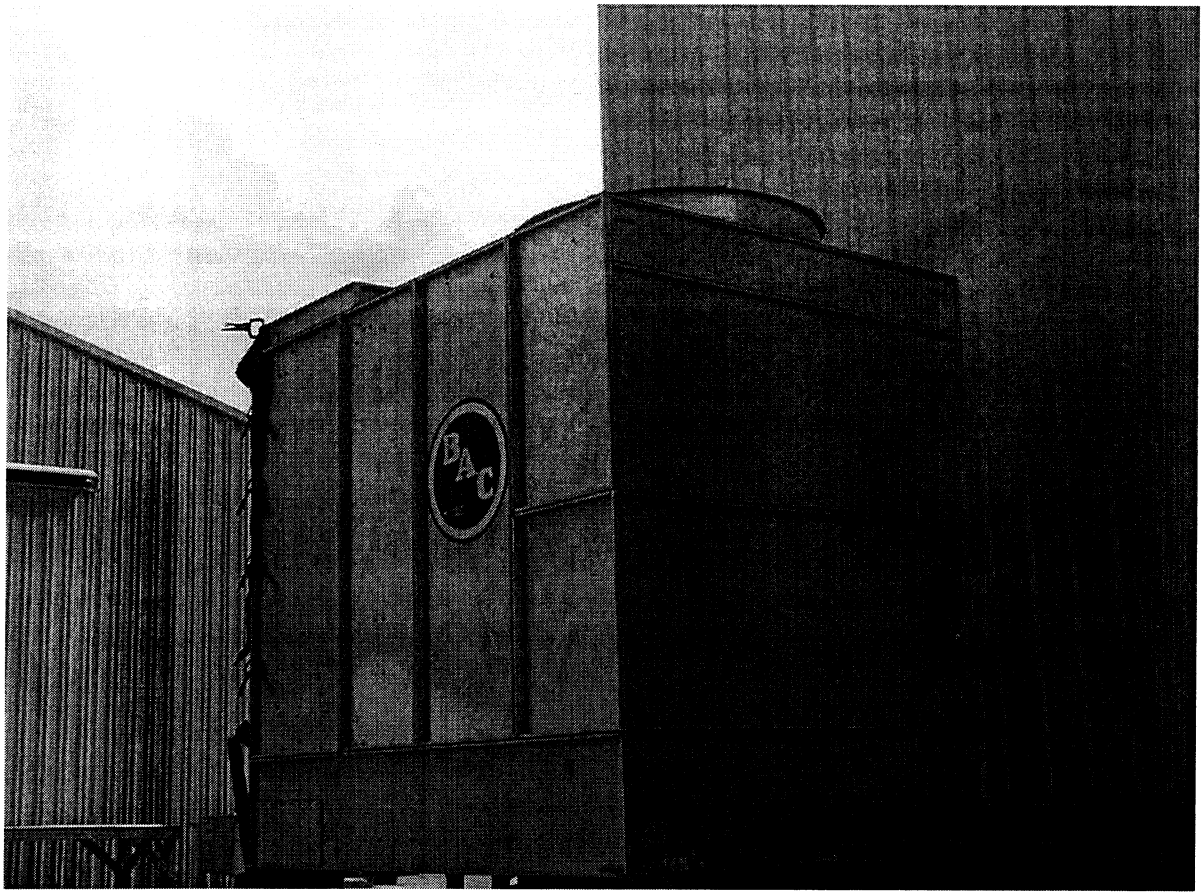

Chiller Performance
y = -7E-05x^3 + 0.0057x^2 + 1.3596x - 0.3414
R^2 = 1
Cooling Capacity (Tons)
165.00
145.00
125.00
105.00
85.00
65.00
45.00
25.00
0
20
40
60
80
100
Percent Load
160 Ton Chiller
Poly. (160 Ton Chiller)

Appendix IV

Photographs of Test Unit



250 ton Safety Related Chiller on Test Stand



Cooling Tower