I/I

LIMITORQUE VALVE ACTUATOR

QUALIFICATION

FOR NUCLEAR POWER STATION SERVICE

REPORT B0058

TESTS CONDUCTED PER

IEEE

382-1972
323-1974
344-1975

PREPARED BY LIMITORQUE CORPORATION

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TABLE OF CONTENTS

APPENDIX

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NUCLEAR QUALIFICATION

1.0 GENERAL

1.1 Purpose

A qualification program was developed to demonstrate that the design of Limitorque's safety related actuators are adequate to insure they will perform their safety related function during a DBE (Design Basis Event) condition in a nuclear power plant.

It is also the intent of the qualifications to satisfy the requirements of NRC Reg. Guides 1.73 and 1.89.

1.2 Method

The various methods of qualification used in this program include experience, analysis, and testing. In the testing phase of this program, IEEE 323-1971, IEEE 323-1974, IEEE 344-1971, IEEE 344-1975, and IEEE 382-1972 were used as guides. The prime effort in qualification is directed toward type tests of complete actuators with experience and analysis being applied to establish the guidelines of the type test and extrapolate the results.

2.0 TEST METHOD

2.1 IEEE Test Guides

IEEE 323 is the general standard for qualifying all Class IE electrical

equipment. IEEE 382 is the specific test guide for valve actuators in Class IE service. IEEE 344, in turn, is the guide for seismic qualification which supports both of the above documents. Both IEEE 323 and IEEE 344 were the first documents released and were later revised to encompass more detail and to update them to more current practice.

IEEE 323-1974 is a general qualification standard that encompasses all electrical equipment in a nuclear plant, whereas IEEE 382-1972 is directed specifically to cover valve actuators. Both documents provide the same guidelines for qualification making them complementary to each other.

The Limitorque environmental qualifications were conducted per IEEE 382-1972 and meet the requirements of IEEE 323-1974 as they apply to valve actuators.

Both IEEE 382-1972 and IEEE 323-1974 address the requirements of pre-aging the equipment to simulate a 40 year life and then delineate LOCA (Loss of coolant accident) conditions that could be expected in a containment chamber for both BWR and PWR reactors. They also establish spray compositions and flows that would be expected to occur.

Both IEEE 382-1972 and IEEE-323-1974 stipulate the same basic qualification parameters, except that in addition IEEE 323-1974 makes mention of vibration aging such as would be experienced by pipe mounted equipment and also suggests margins (criteria over and above expected conditions)

that should be considered to establish a substantial level of safety to the results of the test.

Vibration, although mentioned in IEEE 323-1974, is not defined in relation to either intensity or frequency. Generally, in power plant applications, this vibration would be of low intensity (low acceleration less than 1G) which exist whenever the plant is generating power. The accelerations are not of sufficient intensity to cause actuator failure or malfunction. The only effect low intensity system vibration has on Limitorque equipment is to produce a tendency for fasteners, which are not properly tightened, to become loose. Due to Limitorque's long power plant experience as well as shipboard experience where the vibrations are much more severe, we can discount low intensity system vibration as a potential problem area and, therefore, vibration is not addressed in environmental qualifications.

All of the Limitorque environmental qualifications contain substantial margin as shown later in this qualification.

The qualifications were conducted to encompass the entire family of Limitorque actuators - SMB, SB, SBD, and SMB/HBC in all available unit sizes (SMB-000 to SMB-5). This was accomplished by conducting the qualification testing on a mid size unit (SMB-0) subjecting the actuator to simulated seating loads equivalent to the actuators published unit rating during the test procedure.

2.2 Aging Requirements

2.2.1 Life Aging

The valve actuators are aged where applicable, to place them in their

end of life conditions. This means that the accumulated degradation of 40 years of service is incorporated in the equipment prior to subjecting it to an "accident or DBE" condition. It is the intent of this aging to establish a 40 year qualified life for Limitorque actuators without major maintenance or replacement of any component or lubricant. This aging is broken into four major categories - thermal, mechanical, radiation, and seismic.

2.2.2 Discussion - Aging

In normal operation, thermal aging, mechanical aging, and radiation aging would occur simultaneously throughout the life of the plant. For purposes of this qualification, the thermal aging is the first aging process since it is intended to add conservatism and margin to the qualification.

Thermal aging consists of subjecting the actuator to elevated temperatures for specific lengths of time to simulate any degradation caused to the unit in its installed ambient temperature plus any elevated temperature caused by operation during its 40 year life in a Nuclear Power Generating Plant.

Since metal parts are uneffected by moderate elevated temperatures, only organic parts are considered for thermal aging.

2.2.3 Mechanical Aging

Mechanical aging is the second step of the aging process. Mechanical aging simulates the mechanical wear the actuator would experience

during the 40 year plant life. This consists of stroking the actuator from a set "open" position to "closed" torque seated position and then back to the original open position for a minimum of 500 stroke cycles per the requirements of IEEE 382. The actuator is required to develop its full output rating at the "torque seated" position to simulate its mechanical life.

2.2.4 Radiation Aging

Radiation aging consists of subjecting the entire actuator to gamma radiation equivalent to that which would be experienced in a Nuclear Power Generating Plant during normal life (40 year) plus "Accident or DBE" condition. This is normally accomplished by exposing the unit to irradiation from a colbalt 60 source. Specific irradiation levels vary depending on the location in the Nuclear Plant in which the equipment is installed. Generally, containment actuators are exposed to a total irradiation of 204 megarads and outside containment actuators to a total irradiation of 20 megarads.

Of the total irradiation dosage, four megarads simulates normal life radiation exposure and the remainder is the "accident" condition exposure. Since the accident condition is considered to have been co-incidental with a seismic event, the normal life irradiation can be applied prior to seismic aging with the remainder applied following seismic aging. Limitorque test experience clearly demonstrates that for Limitorque actuators there is no difference on the equipment as a result of where irradiation occurs in the aging sequence.

2.2.5 Seismic Aging

Seismic aging is comprised of subjecting the test actuator to mechanical vibration to simulate an earthquake situation. In order to assure that the worst case condition has been used, it is necessary to determine if any natural frequency resonance exists in the frequency range of interest. A resonant frequency search from 1 to 33 hz frequency range is conducted. If no resonance is evident, the seismic aging can be performed at the appropriate "G" level at any frequency between 1 - 33 hz and equally simulate seismic conditions as far as the actuator is concerned.

During the seismic dwells, the unit is stroked to simulate operating a valve to the torque seated position (usually full closed) and back to the opposite unseated position (usually full open) to verify that the actuator would perform satisfactorily during this event. Due to limitations of the available "shaker tables", the stroke of the actuator is normally limited to a shorter stroke time for the seismic aging. The length of stroke of the actuator during a seismic dwell is not related to the seismic aging and operation is meant to verify the operability of the actuator. The actuator is fixtured to develop its rated thrust and torque at the simulated valve seated position.

2.3 Accident Environmental Simulation

2.3.1 General

The environmental accident condition is simulated by exposing the actuator to a steam-temperature-pressure condition with possible spray

exposure. IEEE 382-1972, Table 1 on Page 12 outlines the environmental conditions for actuators located in the containment chamber of a PWR and Table 2 on the same page outlines the environmental conditions for actuators located in the containment chamber of a BWR. Limitorque, in pursuing its Nuclear Qualification Program, used these tables in establishing both radiation and environmental chamber test parameters.

In addition, the actuators were exposed to two pressure-temperature transients to include additional margin in the test results. Further, the tests were conducted with saturated steam instead of superheated steam which subjects the actuators to pressures much in excess of those seen during an actual accident condition.

Due to the "unsealed actuator" design, this over-pressure forces additional moisture into insulating materials and in effect adds considerable conservatism (margin) to the qualification test.

2.3.2 Steam Line Break

In recent months, Nuclear Power Generating Plant designers have been addressing the possibility of a main steam line break (MSLB) in the containment chamber of a PWR which does not significantly effect the qualification pressure as seen during a LOCA but does increase the temperature substantially. The temperatures indicated by the Nuclear Industry vary from plant to plant with the highest known to date of 492^{O} including margin. In all cases, this high superheated temperature

lasts only a few minutes after which the ambient temperature of the containment chamber rapidly diminishes to levels stipulated for a LOCA in IEEE 382-1972.

2.3.3 Test Parameters

In containment chamber environmental qualifications, as suggested by IEEE 382, the tests were conducted for 30 days. The first four days of the test encompass the most severe conditions of the DBE. During the next 10 days, environmental conditions lessen and tend to be nominal for valve actuator service. The remaining 16 days of exposure are intended to increase confidence level (See Note - Part III, Section (4), Page 12 of IEEE 382-1972).

2.3.4 Discussion - Outside Containment Qualification

Outside Containment Valve Actuator Qualification parameters are not described by IEEE 382-1972. An accident condition for an outside containment valve actuator would be caused by a steam line break which would allow steam to impinge on the actuator for a short duration. Due to the location of the actuators (Outside Containment) substantial pressures could not be established thereby limiting the temperatures seen by the actuators. Typically, this pure steam environment would have ambient temperatures of 220^{o}F (pressure of 2 psig). Since the steam impingement is of short duration, Limitorque conducted a 16 day test including two transients which would provide ample margin to qualify the Limitorque valve actuator for outside containment service.

2.4 Environmental Qualification Acceptance Criteria

The basic function of a valve actuator during a nuclear accident condition is to provide the required torque and/or thrust to actuate a valve to either the open or closed position, as required. Also, it is required that limit switches and torque switches function properly to provide control of the equipment without producing malfunction. All qualifications conducted by Limitorque have been directed toward the actuator providing its rated thrust/torque and that both the limit switch and torque switch are providing the proper control. The remainder of information obtained during the qualification is considered informative.

3.0 ACTUAL AGING PARAMETERS

3.1 General

A. IEEE 382-1972 stipulates test requirements necessary to demonstrate the adequacy of a valve actuator to provide the rated mechanical force during life cycling, seismic aging, and a Post-LOCA transient. The valve actuator is aged to the end of 40 year life by:

1. Thermal aging
2. Mechanical aging (cycling)
3. Radiation aging (exposure to gamma irradiation)
4. Seismic aging

3.2 Thermal Aging

3.2.1.1 Discussion

Thermal aging is incorporated in the overall test plan to place the equipment in its end of life condition so that the effect of the DBE test can best be evaluated.

Each material of the actuator responds differently to thermal aging depending upon its chemical composition. Some materials, such as metalic parts, do not respond at all, while other materials, such as motor insulation, respond in proportion to the thermal rating of material vs. the thermal environment in which it is located.

Life aging of organic materials used in motor insulation can be accelerated by exposing the components to elevated temperatures for short periods of time. This is determined from a thermal regression curve (Arrhenius Equation) which plots failure life against temperature exposure by plotting a line parallel to the failure life curve from a point representing the average ambient temperature and desired life. The thermal regression curve for Limitorque Class RH and typical Class B motors, established per IEEE 101-74 and 117-74 are discussed below.

3.2.1.2 Containment

THERMAL LIFE OF LIMITORQUE RH MOTOR INSULATION

AT VARIOUS TEMPERATURES PER EQUATION

$$\text{LOG LIFE} = \frac{5122}{Ta} - 5.8930$$

Degrees Centigrade	Degrees Kelvin	Life Hours	% Life Increase
180	453	259,324	
100	373	69,008,000	239
90	363	164,889,000	251
80	353	413,919,000	265
70	343	1,096,338,000	281
60	333	3,078,799,000	299
50	323	9,216,906,000	

Referring to the life table established above, it is noted at 60°C that average life failure would occur in 3,078,799,000 hours. Forty years of service at an ambient temperature of 60°C (Typical of containment continuous ambient temperatures) is equal to .01% of the average failure life. Degradation to the insulation system would be proportional to the percentage of failure life which as can be seen above is a very small figure with the expected degradation negligible. This means that artificial life aging of Limitorque Class RH motors for purposes of environmental qualification would be unnecessary. Although heat aging was theoretically unnecessary, no actual test data was available to support this position at the time so heat aging was included in our test program.

Heat aging was based on the average ambient containment temperature only without regard for the motor thermal rise. This was done because the motor temperature rise would create insignificant degradation. To illustrate this, a typical motor (5'#) with an average stroke time of 30 seconds and a typically average motor run load of 1'# would experience a motor temperature rise of approximately 2°C. Considering the number of valve strokes normally required over the 40 year life of the power plant, the additional motor aging incurred by valve operation would be extremely negligible and can be disregarded.

The RH insulated motor was heat aged at 180°C for 100 hours which per the above life table theoretically ages the motor for 135 years based on 60°C average ambient temperature and proportioning to the thermal life figures above.

3.2.1.3 Outside Containment

THERMAL LIFE OF A TYPICAL LIMITORQUE CLASS B MOTOR

INSULATION AT VARIOUS TEMPERATURES

PER THE EQUATION

$$\text{LOG LIFE} = \frac{4675.475}{Ta} - 7.045$$

Degrees Centigrade	Degrees Kelvin	Life Hours	% Life Increase
100	373	309,000	
			220
90	363	684,000	
			230
80	353	1,584,790	
			243
70	343	3,855,870	
			256
60	333	9,896,000	
			270
50	323	26,925,000	
			290
40	313	78,100,000	

Referring to the life table established above, it is noted at 50°C that average life failure would occur in 26,925,000 hours. Forty years of service at 50°C (Typical of outside containment continuous ambient temperature) is equal to 1.3% of the failure life.

Degradation to the insulation system would be proportional to the percentage of failure life which as can be seen above is a very small figure with the expected degradation negligible. This means that artificial life aging of Limitorque Class B motors for purposes of environmental qualification would be unnecessary. The motor, however,

did receive some accelerated aging by virtue of being installed on the actuator during the actuator thermal aging at 165°F (73.9°C) for 200 hours and an average 97.5°C for 144 hours during the mechanical cycling.

At the time of our qualification testing program (November 1974) there were and still are no IEEE 382 standards to provide guidelines on test profiles and parameters for outside containment quaification. Concurrent with our test program, the IEEE 382 subcommittee working group was in process of writing a revised IEEE 382 standard which was intended to provide aging as well as transient profiles and parameters for "outside containment" qualification testing.

When we began our test program, the IEEE subcommittee discussions had progressed to the point of general agreement that acceptable pre-test environmental and mechanical aging was achieved by exposing an entire actuator and motor to 165°F, 100% RH for 200 hours in addition to applying a total of 2,000 simulated operating cycles, keeping the motor at a temperature of approximately 97/98°C. Since the IEEE subcommittee was investigating actuator aging and was considered an authority on the subject, Limitorque accepted the aging procedure.

3.2.2 <u>Switch Materials</u>

Expanding on Section 3.2.1.1, thermal aging is a function of the thermal rating of the material in question. When considering the phenolic insulation material used for switches, U.L. was the only reference that could be found that addresses thermal rating/life of plastics.

Underwriters Laboratory has conducted detailed studies into many phenolics deriving a published temperature index. This index is considered the maximum temperature at which the material can be used continuously. An article titled "A New Temperature Index: Who Needs It" published in September 1970 in "Modern Plastics" discusses the index and indicates how it was established. The article indicates that the temperature index was established at the point where the property of impact strength, tensile strength, or dielectric strength reduced to one-half of its new value at the conclusion of 6×10^4 hours.

The switch material we are using is a molded phenolic which has a temperature index of $150^{\circ}C$. Since a valve actuator is an intermittent operating device and does not run continuously, it would be safe to assume the aging characteristic follows the $10^{\circ}C$ rule.

Considering a $60^{\circ}C$ ambient as the base for an aging temperature, the switch material would reach its 50% property (the same base as U.L. used) in 3.07×10^7 hours. Forty year life would represent 1.2% of available life. Since degradation would be directly proportional to life, it becomes obvious that degradation would be negligible and for purposes of qualification, artificial aging could be disregarded without effecting the results of the qualification.

3.2:3 Seals

Limitorque actuators for Nuclear Plant application are designed to permit them to survive normal and accident conditions without depending

on absolute sealing. In fact, the ambient is not absolutely restricted from entering the actuator. The seals are of no importance for qualification and, therefore, require no consideration for the qualification.

3.2.4 Metal Components

Metal components are unaffected by aging and would not respond to thermal aging. No effort was made to thermally age the metal components.

3.3 Mechanical Aging

Prior to subjecting the complete valve actuators to mechanical aging, the unit was mounted on a torque stand and the torque switch was calibrated to obtain the rated output torque. The test stem was chosen with acme threads to obtain the rated thrust or slightly above. This simulates seating of a valve exposing the test unit to comparable loads as would be expected during valve operation.

IEEE 382-1972 requires a minimum of 500 cycles. During the period of conducting the various qualification tests, the industry considered increasing the number of aging cycles to 2,000. The IEEE 382 subcommittee during this same interim adopted 2,000 aging cycles for insertion in the new draft of the IEEE-382 document. As a result, aging for the BWR qualification (600376A), which had already been completed before the new mechanical aging considerations took place, consisted of subjecting the unit to 500 stroke cycles for mechanical aging. The PWR qualification (600456) consisted of subjecting the unit to 1,208 cycles prior to the temperature-pressure transients with the remainder of 2,002 cycles after

completion of the 30 day environmental exposure. The Outside Containment Qualification (B0003) consisted of subjecting the unit to 2,000 cycles during the normal aging sequence. In all cases, the actuator was cycled from an "open" position (controlled by a limit switch) to a torque seated "close" position and back to the "open" position. The actuator was required to produce its full output rating at the "torque seated" position.

At the conclusion of the temperature-pressure environmental exposure in all of the qualifications, the actuators were disassembled and inspected. In all cases, there were no signs of wear, but did show the normal polishing showing the gearing had been "run in".

3.4 Radiation Aging

IEEE 382-1972, Part III, Page 11, suggests that all irradiation be accomplished prior to seismic aging, or alternatively divide the irradiation into two or more parts; one conducted prior to seismic (4 M rads) and the other after seismic aging (200 M rads).

In our BWR Report (600376A), the actuator was subjected to 4 megarads prior to seismic aging with the remaining 200 megarads applied after seismic aging. In the PWR Report (600456), all radiation aging was applied following seismic aging. In our outside containment report (B0003), the entire actuator was subjected to the full 20 megarads irradiation prior to seismic aging. In fact, during the B0003 test, two motors with Class B insulation, in addition to the motors on the actuators,

were also qualified and were subjected to 204 megarads prior to seismic aging. This high radiation level was incorporated to determine the affect of very high radiation on the Limitorque Class B insulation system. In all cases, there was no noticeable detrimental effect of radiation on any component in any of the test sequences or radiation level employed.

3.5 Seismic

During the environmental qualifications, each of the actuators was seismically aged to insure that no physical weakness exists in the actuator that would affect the qualification.

In the several environmental qualifications we have conducted, we have noted that preaging (thermal, mechanical, or irradiation up to 204 megarads) has no affect on the ability of the Limitorque valve actuator to qualify to a seismic test.

Although all Limitorque actuators, type SMB/SB/SBD/SMC/HBC are a generic family, they do not all possess the same center of gravity. To insure that the actuator picked as "representative" of the actuator family truly represents the entire family, a seismic envelope was constructed (Report B0037 - "Seismic Qualification Envelope").

3.5.1 Early Tests

Since the seismic aging conducted for both the BWR and PWR were conducted prior to release of IEEE 344-1975, the detail procedures we are currently using were not followed. However, as shown below, it did not effect the validity of the results.

The great number of seismic tests we have conducted have shown no resonances or cross couple effects exist below 33 Hz, permitting single axis testing per the second paragraph of Section 6.6.6, Page 22 of IEEE 344-1975 (lack of resonances or cross coupling make the dwell frequency unimportant since it would be equivalent of repeated static loading). The only difference between the seismic aging conducted for both PWR and BWR qualifications and current day seismic testing is the search for cross couple effects, which does not add to the seismic aging of the actuator. The seismic aging conducted for the qualifications is equal to current day testing.

3.5.2 Analysis - Internal Resonance

Considering the possibility of resonance occurring in the internal components of the Limitorque valve actuator, an engineering evaluation shows that the elements used in the construction of Limitorque actuators are rigid members with closely spaced supports with resonant frequencies much in excess of 33 Hz. This same stipulation is true with cross coupling since resonance is required before cross coupling could exist.

3.5.3 Resonance Search Below 5 Hz .

Some of the earlier seismic tests did not include resonance or cross couple searches below 5 Hz. This was due to the fact our engineering evaluation concluded that resonances below 5 Hz would not occur in a Limitorque valve actuator. Also, the test equipment used for these earlier tests was unstable and would provide erroneous information below 4 to 5 Hz, so no search below 5 Hz was included.

More recent tests conducted on a hydraulic table with resonance and cross coupling search from 1 to 33 Hz have verified our previous evaluation that Limitorque valve actuators have no resonances or cross coupling below 5 Hz nor as proved by earlier tests up to 33 Hz.

3.5.4 Discussion - Cross Coupling

Several of the Aero Nav lab report data indicates the possibility of cross coupling existing in the Limitorque valve actuator. These tests were conducted on a mechanical table that was subject to "cross talk". An investigation conducted on the table alone showed that accelerations existed in other than the axis of excitation. In fact, the mapping of the table showed that it also had a rotary motion as well as a rocking motion.

During the seismic test shown in Report 5-6167-5, matching accelerometers were mounted on the table and the Limitorque actuator in each of the three axis. Comparison of the readings of the accelerometers on the table to the matching accelerometers on the unit shows the Limitorque actuator following the table motion. This indicates there is no cross coupling in the actuator and that the accelerations measured in axis other than the one excited are created by the table. Recent seismic tests on a hydraulic table verify that there is no cross coupling or resonance from 1 to 33 Hz.

3.5.5 Switch Chatter Monitoring

The switches used in Limitorque actuators have been monitored on several seismic tests checking for switch chatter. Most of the tests were

conducted using an 8 millisecond "chatter" relay with recent tests checking for "chatter" of 1 millisecond duration. No chatter has yet been detected.

3.5.6 Resonance Search Acceleration Level

Resonance searches and cross coupling searches were conducted at a fractional g level sufficient to excite any resonances that might exist. The Aero Nav seismic tests were conducted on a mechanical table that is excited by counter-rotating adjustable weights. Adjustment of these weights can be accomplished only when the table is not operating. As the frequency of excitation is increased, the acceleration level is also increased. During these seismic tests, resonance and cross coupling search scans were conducted at g levels of .1 to 1.0 g to minimize the number of times the weights are reset. In our recent seismic tests with a hydraulic table, the g level during the resonance-cross couple scan is retained at .2 g.

4.0 ENVIRONMENTAL TEST

4.1 General

4.1.1 Qualification Summary

To provide full qualification of the Limitorque valve actuator for the Nuclear Industry, we chose to conduct four environmental qualifications and supporting seismic data consisting of:

A. Containment Chamber of BWR (Report 600376A)

B. Containment Chamber of PWR (Report 600456)

C. Outside Containment (either BWR or PWR) (Report B0003)

D. Limited Qualification DC Actuators (Report B0009)

E. Seismic Qualification Envelope (Report B0037)

During recent months, a short-term test (Report B0027) was conducted to establish information that would permit existing qualifications to be used for the postulated accident of a steam line break.

4.1.2 Design Philosophy

In all cases the philosophy of using an actuator that did not require complete integrity of sealing was used. In fact, containment units include "T" drains to permit them to breathe.

Limitorque adopted this philosophy to minimize maintenance man-hours in a containment chamber which would be necessary to replace seals on a periodic schedule and the extremely difficult chore of assuring the actuator doesn't leak when exposed to an external pressure which would actually be the responsibility of the utility once the actuator shipped from the manufacturer's plant.

The second reason for adopting this philosophy is to provide additional confidence in Limitorque valve actuators by eliminating the concern that any one of the several seals or gaskets might start leaking during plant operation which in all probability would assure failure of a "sealed" actuator in event of a DBE.

4.1.3 Mounting Position

The mounting position of the actuator was chosen with the limit switch compartment up and the motor horizontal. This is considered the worst possible position because it allows any condensate that collects in the unit to flow through the motor to provide the most damaging effect on its insulation system.

4.1.4 Generic Qualification

Generic qualification means qualifying a group (family) of actuators by subjecting a valve actuator representative of the family to the aging and environmental criteria indicated in this report. The qualification of the Limitorque Size SMB-0, as reported in the documentation of each of the four tests, was used to generically qualify all sizes of Limitorque operators for the environmental test conditions in accordance with IEEE 382-1972. The Size SMB-0 actuators is an average mid-size unit, and all other sizes of the type SMB, SB, SBD, and SMB/HBC are also deemed qualified. All sizes are constructed of the same materials with components designed to equivalent stress levels, same clearances and tolerances with the only difference being in physical size which varies corresponding to the differences in unit rating.

4.1.5 Environmental Parameters

In addition to the aging discussed in Section 3, the valve actuator, during environmental testing, is exposed to two thermal-pressure transients instead of the one that would be actually experienced during

a Nuclear Accident to introduce additional conservatism in the test. Our Reports 600376A and 600456 for inside containment and B0003 for outside containment all included in the attached appendices reflect the result of qualifications to the above parameters.

4.1.6 Reduced Voltage

No effort was made to introduce reduced voltage testing in the environmental qualification becaose it would not have created the most severe operating condition on the actuator. The test actuator is sized to obtain the maximum output torque and thrust as well as developing the maximum torque it would see in the heaviest loaded normal application.

During normal sizing for a reduced voltage application, the motor sizing is increased to provide the required motor torque at the reduced voltage. In actual service, at 100 percent voltage, this motor is lightly loaded subjecting it to a much less severe duty cycle than the motor tested environmentally. Since the environmental qualification subjected the test motor to a more rigorous condition than the motor in actual service, the motor that possibly might be subjected to reduced voltage is covered by the qualification.

4.1.7 Electrical Measurements

The current voltage and power measurements tabulated in each of the qualifications show some inconsistencies. Those inconsistencies have no effect on qualification since the purpose of the test was to demonstrate operability throughout the qualification, which was achieved. These measurements have no meaning in relation to an actual unit installed in a Nuclear Power Generating Plant since the power and current requirements would differ from application to application and could not be compared to the test unit.

4.1.8 Acceptance Criteria

IEEE 323-1974, Section 3, Page 8, stipulates:

"Equipment Qualification. The generation and maintenance of evidence to assure the equipment can operate on demand to meet the system performance requirements."

In relation to valve actuators, this means that the actuator be capable of opening or closing a valve on demand.

4.1.9 Actuator Loading During Qualification

In all Limitorque qualifications, prior to mechanical aging, the torque switch was set to obtain the units nominal torque and thrust ratings and left at this setting for the entire qualification. The thrust was measured prior to and following mechanical aging. It was measured in the case of the PWR qualification, immediately after installation in the test chamber, during the steam-chemical exposure, at conclusion of the environmental test and finally at the conclusion of the post load cycling, all by means of a test stem operating against a load cell mounted external to the test chamber.

The thrust remained substantially constant, with minor differences attributed to change of friction between the stem nut and test stem.

4.2 BWR Qualification Report 600376A

4.2.1 Actuator Loading

The valve actuator tested included a self-contained thrust tube and was arranged to trip by torque switch to simulate seating of a valve. The

actuator was cycled during the BWR environmental qualification at the times shown in the report, being subjected to the simulated valve seat load each time.

The torque switch was set at 1-7/8 prior to mechanical aging and retained at this setting throughout the entire qualification. Thrust was not measured, however, it can readily be determined by referring to the PWR Report 600456 that the torque switch does retain its calibration even when exposed to higher pressures and temperatures. It is logical to assume the actuator was subjected to its rated thrust and torque throughout this qualification.

4.2.2 <u>Discussion - Spray</u>

Paragraph 4.5.1, Category III of IEEE 382-1972 indicates a prime concern for injection of chemicals into the environmental chamber with little regard for spraying pure water. In the stiuplated BWR LOCA conditions, at the high temperature levels, the steam is in a superheated condition, which would mean that any water spray applied, whether in the environmental chamber or actual containment chamber, would immediately flash into steam. Saturated steam conditions occur only at the lower temperatures.

The BWR qualification conducted at Franklin Institute was accomplished with low quality steam throughout the entire test. During the low temperature portions of the test, a heated pool of water and daily injections of steam insured complete saturation of the chamber atmosphere. It becomes obvious the surfaces of the valve actuator were completely wetted by water with their being incapable of holding more fluid.

4.3 PWR Qualification Report 600456

IEEE 382-1972, Part III, Page 11, suggests that all irradiation be accomplished prior to seismic aging or alternately divide the irradiation into two or more parts; one conducted prior to seismic (4 M rads) and the other after seismic aging (200 M rads).

In our PWR Report (600456), we describe that the sequence was thermal aging, mechanical aging, seismic aging, radiation aging, and environmental qualification. This did not apply the life radiation prior to seismic aging as it had already been established that the sequence used relative to radiation aging was unimportant in terms of actuator response. This aging sequence was further justified by our Report B0003. During the outside containment qualification (B0003) two motors with Class B insulation were subjected to 204 megarads irradiation prior to seismic aging and environmental qualification. No problems were experienced with these motors during the qualification even though they were subjected to irradiation well in excess of the level recommended for Class B insulation.

4.4 Superheat Temperature Test

Recently, in the Nuclear Industry, parameters have been established to accommodate the possibility of a Main Steam Line Break driving containment chamber temperatures up to 492^{o}F for a short period of time (few minutes). Pressures remain substantially the same. Due to the heavy metal sections of the actuator, which act as a heat sink, Limitorque theorized that the internal areas of the actuator would not exceed saturated steam temperature during the few minutes it would be exposed to the high superheated

temperature. In interest of verifying this theory, Limitorque conducted a 6 hour superheat test subjecting an actuator to superheated temperatures of up to 385°F at a pressure of 66 psig. The actuator was not connected electrically to permit use of thermo couples on limit switches and in several locations in the limit switch compartment. Report B0027 describes the test and proved the actuator acts as a heat sink, maintaining saturated steam temperatures corresponding to the test chamber pressure, even with elevated ambient temperatures for short durations of time. This test proves that the existing BWR (600376A) and PWR (600456) containment qualifications are applicable and qualify Limitorque valve actuators for a Main Steam Line Break DBE.

4.5 Outside Containment

Outside containment ambient conditions during a Nuclear Accident are not defined in IEEE 382-1972, IEEE 323-1974, or for that matter, in any official standardization document currently known to Limitorque. Prior to conducting this test, Limitorque contacted reactor manufacturers and consultants to determine conditions that might be expected in this area. It was determined that a steam line break could create saturated steam temperatures at pressures only slightly exceeding atmospheric pressure for short duration. On basis of this information, Limitorque established the conservative 16-day qualification as shown in Report B0003.

The SMC-04 actuator, although of different housing material, would be qualified for outside containment service by the SMB outside containment qualification, Report B0003.

The primary effect on qualification created by the above mentioned variation in the SMC-04 would be in mechanical cycling, seismic capabilities, and the effect of radiation. Mechanical cycling tests under simulated valve loads, irradiation exposure and seismic testing of the SMC-04 demonstrates the actuator reacts the same as the SMB to the above parameters supporting the fact the SMC-04 is qualified by Report 80003. These additional test reports are available at Limitorque for audit purposes.

4.6 D.C. Actuator

In relation to the Nuclear D.C. actuator, a need arose for a qualification for a BWR Nuclear Generating Plant for specific environmental conditions. This resulted in the qualification Report 80009. Test conditions consist of a temperature-pressure transient to 340°F (120 psig) in a pure steam ambient holding for one hour and slowly dropping temperature to a low of 212°F at the end of seven hours and holding for the remainder of the test (25 hours from start of test). The test irradiation level was 10 megarads.

On provision the radiation level is suitable, due to the severity of the pressure and temperature profiles, this would qualify the Nuclear D.C. actuator for outside containment service or limited inside containment use.

4.7 Seismic Qualification Envelope

After considering the generic line of Limitorque valve actuators and

unit combinations, it was decided that to demonstrate a true generic qualification for actuators for use in Nuclear Power Generating Power Plants, it was necessary to perform additional seismic tests enveloping the entire Limitorque actuator line. The Seismic Qualification Envelope B-0037 includes seismic tests of typical and the most severe actuator configurations and unit combinations that would be supplied for Nuclear Plant Service. Since these seismic tests are to demonstrate the validity of the generic family concept, they were not subjected to aging or any other environmental qualification requirements. It is intended that the Seismic Qualification envelope be used to support the above environmental qualifications and not be used as qualifications in and of itself. These tests, however, do qualify the equipment to IEEE 344-1975 because as previously mentioned, preaging has no effect on Limitorque actuators.

It has to be recognized that the various physical combinations and cg relationships in the unit sizes constituting the generic Limitorque actuator line has an effect on seismic qualification that does not effect other areas of environmental qualification.

5.0 CONCLUSION

Mid-size Limitorque valve actuators were subjected to four complete environmental qualifications consisting of BWR, PWR, Outside Containment, and D.C. Qualifications. Each qualification exposed the actuator to thermal and mechanical aging, radiation aging, seismic aging, and environmental transient profile test. To investigate the effect of the recently conceived steam line break, an actuator was subjected to a very

high superheated temperature to demonstrate that the electrical components of the actuator never exceeded the saturated temperature corresponding to the ambient pressure for the short duration of the test. This short term test proves the existing qualifications envelope the steam line break DBE for superheated temperatures as high as 492^{o}F for a few minutes.

All the qualifications were conducted per IEEE 382-1972 and meet the requirements of IEEE 323-1974 and IEEE 344-1975 as they apply to valve actuators. Further, since the actuators performed satisfactorily without maintenance throughout the various qualifications, the Limitorque valve actuators are fully qualified for use in Nuclear Power Generating Plants.

6.0 DESIGN LIFE

The inside containment and outside containment actuators are of the same basic design and construction with some differences in material to permit the actuator to withstand the more severe containment chamber DBE conditions. These differences consist of use of different phenolic insulating material for the switches, a special motor insulation system, Viton seals instead of Buna N, elimination of all external aluminum parts and the use of "T" drains and grease relief valve to accommodate the extreme temperatures and pressures of containment DBE environments.

6.1 Lubricant

Life expectancy of the lubricants would be difficult to access due to the many variables that would differ from unit to unit located in the

same Nuclear Plant. However, on provision the lubricant is maintained per Limitorque Procedure LC8 and not subjected to contamination, it would have a design life expectancy of 40 years.

6.2 Switches

It has been noted that irradiation of 204 M rads does effect the appearance of the gray switch insulating material provided for containment chamber service. This slight change of appearance of the material has no measurable effect on its insulating properties. Short-term development tests conducted on non-irradiated switches show they respond identically to irradiated switches when subjected to the same environmental conditions. Since the containment switches in the units that were qualified were also exposed to the 204 megarads gamma irradiation, the design life expectancy of the containment switches as well as outside containment switches is 40 years.

7.0 QUALIFIED LIFE

Since the entire actuator, including motor, lubricant, seals, and switch components were subjected to the same detrimental elements and actions it would be expected to see in its 40 years life, and further since at the conclusion, the unit was subjected to a simulated LOCA condition without failure with verification that a DBE condition of steam line break is equal to the LOCA condition, the Limitorque valve actuator is considered qualified for 40 years.

8.0 INSTALLATION

Limitorque Corporation Release SMBI-170, "Instruction and Maintenance Manual" provides installation information. Relating to containment chamber actuators, in addition to the above, install the two motor drains as indicated on the tag on the actuator and after the equipment is powered, remove the Silica Gel from the limit switch compartment.

9.0 LUBRICATION

The "Lubrication Data" from LC8 included in the appendix describes recommended lubrication maintenance. Recognizing the fact that access to containment chambers of Nuclear Plants are limited, the lubrication inspection frequency can be varied to match the containment chamber maintenance period of 12 to 18 months.

10.0 MAINTENANCE

10.1 It is recommended that Limitorque valve actuators be operated periodically, not less than twice a year to maintain a coating on operating parts and also to remix the grease to maintain it in proper condition.

10.2 Maintenance Procedure

During maintenance periods, perform the routine maintenance functions indicated on Limitorque Maintenance Procedure, Form LC9, included in Appendix A.

NOTED NOV 0 3 1983 J.A. FOULK

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STONE AND WEBSTER ENGINEERING CORPORATION
ENGINEERING & DESIGN COORDINATION REPORT

PAGE 1 OF 3

E & DCR NO. P01,895

PROJECT/CLIENT 3 NMP2/NMPC			JOB ORDER NO. 4 12177
P.O. NO. (S&W) 5 NMP2-P304R	REASON CODE (S) 6 D, A, T	EQUIP. I.D. NO.(S)/SYS. CODE (S) 7 N/A	
REFERENCE DOCUMENTS: 8 NMP2-P304R		SUPPLIER (OR SUBSUPPLIER) NAME 9 Velan	
DESCRIPTION SUMMARY 10 Hydrostatic Test Clarification		REMARKS 11 Supercedes E&DCRs P01,416 & P01,597	

PROBLEM DESCRIPTION 12

The requirements of Rev. 2, Addendum 4 to Rev. 2, E&DCR No. P01,416, and E&DCR No. P01,597 are unclear and contradictory as to the difference between the disc hydrostatic test according to MSS-SP-61 for structural integrity and the seat tightness test for seat leakage:

Actual Requirement	Specified Requirement	Documentation
① Hydro Disc Test (MSS-SP-61)	① Hydro Shell and Seat Tightness Test	① Hydrostatic Seat Test
② Hydro Seat-Tightness Test (SWEC)	② Seat Test	② Hydrostatic Seat Tightness Test
	③ Globe under-the-seat, hydrostatic seat tightness Test	
	④ Gate hydrostatic seat tightness Test	

12

INITIATOR	AREA/DEPT DIV	TEL. EXT.	DATE	DATE NEEDED	APPROVED	ENGR. RESP.
13 H Adels	Power	4514	5/12/83	5/27/83	14 [illegible]	15 PG

PROBLEM SOLUTION 16

Please refer to Pages 2 and 3

No CEF Required

16

AFFECTED DOCUMENT NUMBERS	TYPE	STATUS	RELATED ACTIVITIES	QA CAT	CLIENT APP REQ'D ☐ NR ☒
17 NMP2-P304R	S	C	18 N/A	19 I	26 REF DATE

ANSWERED BY 20 H. J. Adels DATE 5/24/83	SUB ITEM 01	WORK RESP 27
	SUB ITEM 02	WORK RESP 27
RESP. LEAD ENGR. 21 [signature] DATE 6/8/83	EQ RELEASE NO. 28 000,000	EQ RELEASE NO. 28
MATERIALS ENGR. 22 NR TM/JJP DATE	WBS NO. 29	WBS NO. 29
EQUIP. SPEC. 23 [signature]/TM/JJP DATE 6/8/83	WORK COMPLETION 30 NWR ☐	DATE
QSD OR EA 24 [signature] DATE 6/10/83	INSP. REPORT NO/SIG 31	DATE
PROJ. ENGR. 25 [signature] DATE 11/2/83	FINAL WORK TRACKING CLOSURE 32	DATE

STATUS
C - WILL BE INCORPORATED
N - WILL NOT BE INCORPORATED
I - NO CHANGE

DESCRIPTION (01) 33	REMARKS (01) 34 CANCEL P01,416 & P01,597
DESCRIPTION (02) 33	REMARKS (02) 34

Page: 1-47

Delete: Lines 40.26 through 40.41

Add:

Hydrostatic Tests

All valves shall be hydrostatically tested by the Seller for shell and disc structural integrity. The shell hydrostatic test shall be in accordance with:

1. Subarticle NB-3500 and Article NB-6000 for ASME III Code Class 1 valves.

2. Subarticle NC-3500 and Article NC-6000 for ASME III Code Class 2 valves.

3. Subarticle ND-3500 and Article ND-6000 for ASME III Code Class 3 valves.

The disc hydrostatic test for structural integrity shall be in accordance with MSS-SP-61 for ASME III Code Class 1, 2, and 3 valves.

The shell hydrostatic test for globe and gate valves shall be conducted with the valve open but not backseated. Following the test, the valve shall be backseated and the packing and stuffing box inspected for leakage.

For globe valves, the under-the-seat hydrostatic seat-tightness test shall be performed at not less than 115 percent of the maximum differential pressure specified on the Motor-Operated Valve Data Sheet by Engineers. For valves tested through May 31, 1983, the nominal pressure for which the hydrostatic seat-tightness test is performed may be recorded in lieu of the actual pressure at which the test is performed. For valves tested after May 31, 1983, the actual pressure at which the hydrostatic seat-tightness test is performed shall be recorded.

For gate valves, the hydrostatic seat-tightness test shall be performed at the maximum differential pressure specified on the Motor-Operated Valve Data Sheet by Engineers with a tolerance of ±10 percent. The actual pressure at which the hydrostatic seat-tightness test is performed shall be recorded.

Page: 1-57

Add: after line 49.57:

43. Hydrostatic Seat-Tightness Test

Verify that the actual or nominal pressure has been recorded and meets the requirements under TESTS.

Page: A4-4 of Addendum 4 to Revision 2

Delete: Lines 5.9 and 5.10

Add:

Hydrostatic Disc Test Reports	-	-	-	1	-	-

Page: A4-4 of Addendum 4 to Revision 2

Add: after line 5.10:

Hydrostatic Seat-Tightness Test Reports	-	2	-	1	-	-

NOTED JUN 1 7 1983 J.A. FOULK

A521065

STONE AND WEBSTER ENGINEERING CORPORATION
ENGINEERING & DESIGN COORDINATION REPORT

PAGE 1 OF 1

E & DCR NO. P12,356

PROJECT/CLIENT: NMP2/NMPC	JOB ORDER NO.: 12177
P.O. NO (S&W): P304R,S	REASON CODE (S): A
EQUIP. I.D. NO.(S)/SYS. CODE (S): N/A	
REFERENCE DOCUMENTS: SPEC. NMP2-P304R & P304S	SUPPLIER(OR SUBSUPPLIER) NAME: VELAN
DESCRIPTION SUMMARY: SEISMIC REQUIREMENTS	REMARKS: NONE

PROBLEM DESCRIPTION

SPECIFICATIONS STATE THAT THE SEISMIC CERTIFICATE OF COMPLIANCE MUST INCLUDE A SUMMARY, OF THE CALCULATION OR TEST METHOD, WHICH INCLUDES CODE REFERENCES AND EQUATIONS. HOWEVER, THE INCORPORATION OF EQUATIONS INTO THE SUMMARY IS OPTIONAL.

INITIATOR	AREA/DEPT	TEL EXT	DATE	DATE NEEDED BY	APPROVED	ENGR. RESP.
J. SZUKICS	DIV. 4610	3867	6-7-83	6-20-83	[signature]	PG

PROBLEM SOLUTION

INCORPORATE THE FOLLOWING CHANGE INTO SPECIFICATIONS NMP2-P304R REV. 2 (PAGE 1-21 LINE 19.4) AND NMP2-P304S REV. 2 (PAGE 1-23 LINE 20.8):

DELETE: AND EQUATIONS.

ADD: AND (OPTIONALLY) EQUATIONS.

CEF NOT REQUIRED

AFFECTED DOCUMENT NUMBERS	TYPE	STATUS
P304R	S	C
P304S	S	C

RELATED ACTIVITIES: N/A
QA CAT: I
CLIENT APP: REQ'D ☐ NR ☒
REF / DATE:

		Date
ANSWERED BY	J. Szukics	6-7-83
RESP. LEAD ENGR.	[signature]	6/14/83
MATERIALS ENGR.	NR TM/JJP	
EQUIP. SPEC.	[signature] /TM/JJP	6/14/83
QSD OR EA	J. Reilly	6/15/83
PROJ. ENGR.	[signature]	6/14/83

SUB ITEM	WORK RESP	SUB ITEM	WORK RESP
01		02	

EQ RELEASE NO. / EQ RELEASE NO.
WBS NO. / WBS NO.
WORK COMPLETION NWR ☐ DATE
INSP. REPORT NO/SIG DATE
FINAL WORK TRACKING CLOSURE DATE

STATUS
C - WILL BE INCORPORATED
N - WILL NOT BE INCORPORATED
I - NO CHANGE

DESCRIPTION (01)
REMARKS (01)
DESCRIPTION (02)
REMARKS (02)