

ASCO Controls, L.P.
VALVE DEPARTMENT
ENGINEERING REPORT

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INVESTIGATION INTO ELIMINATING
 THE USE OF LUBRICANTS
 ON THE NP SERIES OF VALVES.

REPORT NO.	351R2
ENGRG. JOB	71005
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SUBJECT OF THIS REPORT: ASCO NP LINE OF VALVES

Preface:

This report supersedes Engineering Report (ER) 351 R1 and the original version of the report ER 351. This report is being issued to provide additional data and analysis justifying the use of Nicotef coating of the stem and discs of the NP8300 valves. The additional testing discussed in this revision provides a performance comparison between valves using the new design, including the Nicotef coating, and the prior valve constructions which used lubricants. This report also summarizes the relevant portions of the NS qualification program report (AQR 21691) which included valves with the Nicotef coating and includes this information as an appendix to this revised report. This appended NS performance information helps establish qualification for the modified NP valves and eliminates the need for customers to read and evaluate the entire NS qualification program report.

Other portions of the report, that addressed the discontinuance of lubricants for the other valve styles, remains unchanged and in effect. Therefore the sections dealing with the removal of lubricants will continue to be included as part of this report.

Introduction:

Effective May 26, 1999 ASCO discontinued using lubricants during certain assembly steps of the NP series valves. The decision to discontinue using lubricants was driven by the belief of some utilities that lubricants used in the assembly of ASCO Nuclear valves results in sticking of the core to the plug-nut. Although extensive testing performed at ASCO was never successful in replicating the sticking reported in the field, ASCO made the decision to eliminate the use of lubricants, where possible, in order to lessen this concern with the utilities.

Lubricant changes:

ASCO's experience with other lines of valves, including the NS series, has demonstrated that the AC run in oil is not required. Water has proven to be an acceptable substitute for o-ring lubricant in static o-ring applications. The discontinued lubricants and area applied include:

- AC core run in oil (Dow Corning 550)
- O-ring lubricant used on static o-rings (Dow Corning 550)
- Stem Lubricant used on seat/disc assemblies in the 206/208/210 series valves (Neolube and Dow Corning 550)

ASCO will continue to use Neolube and Nyogel 775B for the u-cups/pistons on the NP8321 and NP8344 lines. These lubricants are required on these valves in order to provide proper lubrication and sealing of the dynamic seals. Nyogel 775D will also be used on the threads and flange of the explosion proof enclosure.

ASCO has also modified the standard seats and stems used in the 206/208/210 line of valves. The new seats and stems are plated with Nicotef (a proprietary coating of nickel and Teflon from Nimet Industries) which eliminates the requirement for lubricating the stems.

Since the seat disc is a change in design, ASCO has updated the catalog number of the valves to distinguish the new design. We have also taken this opportunity to standardize on the 8300 series numbering system in place of the prior 206/208/210 series of valves. A cross-reference list of valves is provided in Appendix B of this report.

Testing:

With the exception of the 206/208/210 series of valves, additional testing to support the removal of lubricants was not necessary. The basis for this position is that lubrication of static o-ring is only necessary to assist in the assembly of the valve. Once the o-ring is in place, the lubricant no longer serves any purpose. ASCO has been able to substitute water for this purpose. The main advantage being that once assembled the water evaporates leaving no residue.

In the case of run in fluid on AC cores the primary purpose of this lubricant was to assist in the "wearing in" of the core and plug-nut during initial operation of the valve. As a result of improvements to the surface finishes of the core and plug-nuts ASCO has been able to eliminate the use of lubricant on these surfaces.

Testing was required for the use of the Nicotef as a substitute for the Neolube and DC550 used in the standard construction of the 206/208/210 series valves. Testing was conducted on valves representative of the two valve families, 5/16 and 3/16 inch orifice size valves. Both resilient and metal seated valves were included in the testing.

Table 1 provides a summary of the test samples. Test samples also included equivalent size valves with the standard seat and disc construction to serve as control pieces for comparison with the original qualification testing.

Table 1. Test Specimen Summary

Sample	Catalog No.	Seat Size	Seat Type	Construction
1, 1A	206380-002F	3/16	Metal	Standard
1N, 1AN	NP8300141EF	3/16	Metal	NICOTEF
2, 2A	206380-006F	5/16	Metal	Standard
2N, 2AN	NP8300383EF	5/16	Metal	NICOTEF
3, 3A	206380-006RF	5/16	Resilient	Standard
3N, 3AN	NP8300383ERF	5/16	Resilient	NICOTEF
4, 4A	206380-002RF	3/16	Resilient	Standard
4N, 4AN	NP8300141ERF	3/16	Resilient	NICOTEF

Testing consisted of operating the valves for a minimum of 40,000 on/ off cycles. This number of cycles was intended to repeat previous wear aging testing of the ASCO NP line of valves in ASCO report AQR 67368. This value was thought to conservatively represent the number of cycles a valve would see during its installed life.

Test pressures of 100 psid for the 5/16 orifice and 150 psid for the 3/16-inch orifice were used during the testing. 100 psid represents the maximum rated pressure for the 5/16 orifice valve. Although the 3/16-orifice valve is rated at 200 psi, 150 psid was used due to system limitations. Valves were monitored for leakage and proper operation at approximately 5,000 cycle intervals. Tables 2 and 3 provide a summary of this testing.

Table 2. Valve Seat Leakage Metal Seated Valves

All leakage is in cc/min unless noted. (1 SCFH = 472 cc/min)

Cycles	Initial		5,000		10,000		15,000		20,000	
	Ener.	De-Ener.	Ener.	De-Ener.	Ener.	De-Ener.	Ener.	De-Ener.	Ener.	De-Ener.
1	0	.5 SCFH	0	1.3 SCFH	110	4.5 SCFH	200	6.5 SCFH	90	7.5 SCFH
1A	0	70	0	90	0	15	0	25	2 SCFH	25
1N	190	0	100	1.8 SCFH	90	3 SCFH	190	3.5 SCFH	1.5 SCFH	10.5 SCFH
1AN	190	10	.7scfh	2 SCFH	8.5 SCFH	35	8.5 SCFH	100	8 SCFH	140
2	40	20	0	0	220	30	65	40	45	90
2A	14	4	0	70	230	20	20	.8 SCFH	0	.85 SCFH
2N	0.8 SCFH	90	100	75	110	70	80	80	85	160
2AN	235	50	220	50	1 SCFH	90	1.1 SCFH	150	1.7 SCFH	115

Test Sample	25,000		30,000		35,000		40,000	
	Ener.	De-Ener.	Ener.	De-Ener.	Ener.	De-Ener.	Ener.	De-Ener
1	125	8 SCFH	.5 SCFH	9.5 SCFH	1.1 SCFH	10 SCFH	2 SCFH	11 SCFH
1A	2.5 SCFH	45	4.2 SCFH	85	5.5 SCFH	175	5.25 SCFH	0.35 SCFH
1N	7 SCFH	15 SCFH	11 SCFH	20 SCFH	16 SCFH	20 SCFH	20 SCFH	18 SCFH
1AN	.4 SCFH	8 SCFH	9 SCFH	190	10 SCFH	140	.3 SCFH	12 SCFH
2	33	80	20	70	30	30	30	95
2A	5	1.5 SCFH	0	2 SCFH	60	50	0	3
2N	110	120	70	170	140	90	0.6 SCFH	.25 SCFH
2AN	2.5 SCFH	.4 SCFH	3.7 SCFH	1.5 SCFH	4.5 SCFH	2.5 SCFH	6 SCFH	5 SCFH

Table 3. Valve Seat Leakage Resilient Seated Valves

All leakages are in cc/min unless noted.

Cycles	Initial		5,000 thru 40,000	
Test Sample	Ener.	De-Ener.	Ener.	De-Ener.
3	0	0	0	0
3A	0	0	0	0
3 N	0	0	0	0
3 AN	0	0	0	0
4	0	0	0	0
4A	0	0	0	0
4N	0	0	0	0
4AN	0	0	0	0

Discussion of results

Throughout the 40,000 cycles of the test, there was no binding or failure to shift of any of the test samples. The Nicotef resilient and standard resilient seat test samples, (samples with a 3 or 4 designation), did not exhibit any leakage throughout the testing. The Nicotef metal seated and standard metal seated valves, (samples with a 1 or 2 designation), did exhibit an increase in leakage.

Observations

In general all of the seats exhibited elliptical wear as a result of the side loading of the lever when the valve is cycled. This side loading causes an out of round condition on the seating surface resulting in seat leakage. As recorded in the test results this leakage is more pronounced in the metal seated valves since the resilient seat is able to absorb the side loading without permanent deformation.

Conclusions

Resilient Seated Valves

Both the standard and the Nicotef resilient seats performed well during all of the testing. There was no leakage throughout the testing. Visual observations of both constructions during post-test disassembly and inspection revealed no noticeable differences in the amount of wear between the standard construction and the Nicotef construction.

Metal Seated Valves

The metal seated valves did develop progressively greater leakage during the wear aging. The leakage of the Nicotef seats was higher than the standard constructions. However, the leakage was never enough to cause the cylinder port pressure, which was monitored during the leakage tests, to increase or decrease. ASCO notes that failure, as defined in ASCO nuclear qualification reports, involves a significant change in cylinder port pressure. Specifically, section 6.2.2 of AQR 67368 Appendix A states "All valves must not have a pressure increase at a cylinder port which is required to be vented or a pressure decrease at a cylinder port which is required to be pressurized in excess of 10% of the maximum operating pressure differential".

EFFECT ON QUALIFICATION:

Listed below is a summary of the various qualification phases. The impact on qualification due to the removal of lubricant is provided for each phase.

A. Thermal Aging Simulation:

This testing simulates the effect of time and elevated temperatures on the age sensitive components such as elastomers and coils. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. These lubricants do not enhance or detract from the age sensitive component's resistance to thermal aging. Therefore, removal of these lubricants would have no impact on the performance of these age sensitive components. The Nicotef coating is a proprietary blend of nickel and Teflon. The nickel is unaffected by thermal aging. Teflon is a high temperature material that is unaffected by the amount of thermal aging experienced by the Nicotef coating during this simulation. This conclusion is also supported by the results of the NS testing discussed in Appendix A. Current thermal aging results from the NP qualification program remain valid.

B. Wear Aging Simulation:

This testing subjects the valve to energized/de-energized cycling in order to simulate the wear that a valve would see during its service life. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The effect of using the Nicotef was evaluated during the testing described above. Based on this testing and the NS testing outlined in Appendix A there is no impact on the qualification of the NP valves.

C. Pressurization Aging Simulation:

This testing simulates the effect pressurization of the power plant containment chamber has on valves in particular the external seals. Since none of these modifications affect any of the seals, current pressurization aging results are valid.

D. Radiation Aging Simulation:

This testing simulates the effect of radiation on non-metallic parts of a valve. Since no change has been made to the elastomers in this valve, this portion of the qualification still applies. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating is a proprietary blend of nickel and Teflon. The nickel is unaffected by radiation. Teflon is a fluoropolymer and is susceptible to radiation degradation; however, this degradation does not adversely affect the Teflon's ability to reduce sliding friction between the stem/disc and seat or the ability of the Nicotef to bond to the base materials. This conclusion is based on the qualification test results discussed in Appendix A for valves with the Nicotef coating after radiation aging simulation.

E. Vibration Testing Simulation:

This testing simulates the effect that system induced vibrations would have on a valve throughout the valves service life. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating does not adversely affect the ability of the valve to sustain system-induced vibration. This conclusion is supported by the supplemental wear aging testing discussed above which demonstrates that the Nicotef does not cause binding, failure to shift, unacceptable wear, or unacceptable seat leakage. These conclusions are also supported by the NS testing discussed in Appendix A

F. Seismic Aging Simulation:

This testing is designed to simulate the effect of minor earthquakes during normal plant operations. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating does not adversely affect the ability of the valve to function during the seismic simulation. This conclusion is supported by the supplemental wear aging testing discussed above which demonstrates that the Nicotef does not cause binding, failure to shift, unacceptable wear, or unacceptable seat leakage. These conclusions are also supported by the NS testing discussed in Appendix A

G. Resonance Testing:

This testing is designed to locate the material resonance point of the valve. Since this modification has not called for the introduction of any significant design changes the natural resonance points from previous testing are considered to be valid.

H. Seismic DBE Simulation:

This testing is designed to simulate the conditions that would exist for a pipe-mounted valve as a result of dynamic response of the piping system during a safe shutdown earthquake. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating does not adversely affect the ability of the valve to function during the seismic simulation. This conclusion is supported by the supplemental wear aging testing discussed above which demonstrates that the Nicotef does not cause binding, failure to shift, unacceptable wear, or unacceptable seat leakage. These conclusions are also supported by the NS testing discussed in Appendix A

I. Radiation DBE Simulation:

This testing exposes the valve to levels of radiation that would exist during a design basis event. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating is a proprietary blend of nickel and Teflon. The nickel is unaffected by radiation. Teflon is a fluropolymer and is susceptible to radiation degradation; however, this degradation does not adversely affect the Teflon's ability to reduce sliding friction between the stem/disc and seat or the ability of the Nicotef to bond to the base. These conclusions are supported by the results of the NS testing discussed in Appendix A.

J. Environmental DBE Simulation:

This testing simulates the condition that would exist during a loss of coolant accident/high energy line break event and a post event cool down. Elimination of the run-in oil and use of water as an o-ring assembly aid do not adversely affect valve response to this simulation. The Nicotef coating is a proprietary blend of nickel and Teflon. The nickel is unaffected by the DBE conditions. Teflon is a high temperature fluropolymer. The ability of the Teflon to reduce sliding friction is not adversely affected by these DBE conditions. These conclusions are supported by the results of the NS testing discussed in Appendix A.

APPENDIX A

SUMMARY OF QUALIFICATION TEST RESULTS FOR
ASCO NS-2 SOLENOID VALVES WITH NICOTEF COATING

1. INTRODUCTION

Two parallel qualification programs were initiated in late 1989 to qualify the NS-2 line of solenoid valves. The NS-2 series was developed to expand and enhance those areas of performance upon which previous qualification efforts were based. Six of the NS-2 test specimens utilized the Nicotef coating system to reduce friction between the valve seats and discs. The six test specimens are identified in Table 3.1. The qualification test program is documented in ASCO Test Report No. AQR-21691. This summary test report contains excerpts from the full report that are relevant to the performance of the Nicotef coating system used on these six test specimens. In summary, the six valves performed acceptably throughout the entire test program except for a cracked spring in one specimen identified during post-DBE baseline testing. The performance of these six valves provides evidence that the Nicotef coating system is an acceptable design change for similar NP valves.

Three groups (A, B, and C) of eleven ASCO Catalog NS-2 solenoid valves were subjected to a qualification test program in accordance with ASCO qualification specifications. Six of these valves (2 per group) used the Nicotef coating system. The qualification test program consisted of a series of six sequential aging simulation phases; thermal aging, wear aging, pressurization aging, radiation aging, vibration aging and seismic OBE aging. The aging phases were followed by three sequential Design Basis Event (DBE) simulations; radiation, seismic SSE, and environmental DBE. Only the B and C Group valves were exposed to the environmental DBE simulation. In addition, a resonance search was conducted prior to the vibration aging. Baseline testing was performed prior to the start of the aging phases, and was repeated at the conclusion of each aging phase with the exception of pressurization aging. At the conclusion of the post environmental DBE baseline test, the test valves were disassembled and visually inspected for component degradation caused by the various exposure environments.

Testing was conducted during the period from June, 1991, through May, 1996. Thermal aging simulation, wear aging, pressurization aging, baseline testing, vibration aging, seismic OBE aging, seismic DBE, and resonance search testing were all performed at the facilities of Automatic Switch Co., in Florham Park, NJ. Radiation aging simulation and Radiation DBE exposure were conducted at the facilities of Isomedix, Inc., Parsippany, NJ. Environmental DBE simulation was performed at the facilities of Wyle Labs., Norco, CA.

2. SCOPE

The program was conducted in accordance with ASCO qualification specifications, which were written to comply with the requirements and suggestions, contained in the following documents:

- 2.1 IEEE 323-1983, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations".
- 2.2 IEEE 344-1987, "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations".
- 2.3 IEEE 382-1985, "IEEE Standard for Qualification of Actuators for Power Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants".
- 2.4 IEEE 627-1980, "IEEE standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations".
- 2.5 10 CFR 21, "Reporting of Defects and Non-Compliances".
- 2.6 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants".
- 2.7 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants".
- 2.8 US NRC Regulatory Guide No. 1.73, "Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants".
- 2.9 US NRC Regulatory Guide No. 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants".
- 2.10 US NRC Regulatory Guide No. 1.100, "Seismic Qualification of Electric Equipment for Nuclear Power Plants".
- 2.11 ASCO documents for Acceptance and production testing contained in Appendices AI, AII, and AIII of Appendix A.

3. EQUIPMENT DESCRIPTION

Six of the thirty-three valve test specimens utilized the Nicotef coating and were considered to be representative of the NS8300/8302 generic valve family.

TABLE 3.1
NS-2 TEST SPECIMENS WITH NICOTEF COATING

TEST VALVE NO.	VALVE GENERIC FAMILY	VALVE CATALOG NO.	DESCRIPTION
2A 2B 2C	NS8302	NS8302203G	AC, leaded molded coil, with alternate epoxy, steel body, explosion-proof/ watertight solenoid enclosure, normally open, direct acting 3-way construction with Nicotef metal seating
11A 11B 11C	NS8300	NSEL830081F	DC, leaded molded coil, with alternate epoxy, brass body, watertight solenoid enclosure, normally closed, direct acting, 3-way construction, Nicotef metal seating, with Electronic Power Reduction module

4. TEST PROGRAM PROCEDURES AND RESULTS

The test items were constructed in accordance with standard ASCO Catalog NS-2 valve assembly and inspection procedures. Following a visual inspection which verified that the valves had not suffered any damage in handling during manufacture, they were subjected to initial baseline tests followed by the qualification test phases, as described below.

4.1 AGING SIMULATION PHASES

The aging portion of the qualification test program consisted of six sequential phases; designed to simulate the most severe expected levels of all potentially degrading conditions associated with both normal and abnormal service.

4.1.1 THERMAL AGING

The valves with the Nicotef coating system were installed in a non-circulating air oven and while energized were subjected to 140 °C for the following times: test specimens 2A and 2C – 2.4 days, test specimen 2B – 4.8 days, 11A and 11C – 11.9 days, and 11B – 23.8 days. Provision was made in the test set-up such that all valves could be energized and pressurized for cycling, as required in the test specification. Cycling during aging is described in section 4.1.2. When the valves were not being cycled, the solenoids were continuously energized at 120 Vac. In addition, maximum operating pressure differential was applied to each valve throughout this test phase.

4.1.2 WEAR AGING

Wear aging of the valves was performed in two stages. The first 4,000 cycles were done while thermal aging the valves with the temperature adjusted to 70 °C (158°F). The inlet pressure on the 2A, 2B, and 2C specimens was also adjusted to 100 psi. The inlet pressure on valves 11A, 11B, and 11C specimens were also adjusted to 150 psi. The remainder of the 36,000 wear cycles was then performed at 24 °C (76 F) and 100 psi inlet pressure followed by the Post Wear Aging Baseline Testing. At the conclusion of the wear aging, baseline tests were performed.

4.1.3 PRESSURIZATION AGING

At the conclusion of the wear aging phases the test valves had their inlet and cylinder ports plugged so as not to subject them to atmospheric pressure during the containment pressurization aging phase. The valves were then exposed to pressurization cycles between 0 and 80 psig in two stages. The first stage was one 24-hour dwell at a simulated atmospheric pressure of 80 psig, followed by 14 cycles from 0-80 psig, with a three-minute, minimum, dwell at 80 psig. All valves were de-energized during this phase of testing. Both external leakage and seat leakage were checked at the conclusion of this test.

4.1.4 RADIATION AGING

At the conclusion of the pressurization aging the test valves were all subjected to baseline tests and sent to Isomedix, Inc. for the radiation aging portion of the program. The simulation consisted of exposure to a cobalt- 60 source of gamma radiation with an average energy of 2.5 Mev. The 2A and 11A and 2C and 11C specimens were exposed to at least 20 megarads and the 2B and 11B specimens were exposed to at least 40 megarads. Pipe plugs were installed in the pressure, cylinder, and exhaust ports of the valves. The valves were maintained de-energized during this exposure period. At the completion of this simulation the valves were returned to the ASCO facility and subjected to a baseline test.

4.1.5 RESONANCE SEARCH

At the completion of the radiation aging simulation, the test valves were mounted to a shaker table and subjected to resonance search tests. The valves were attached to the table in accordance with normal mounting procedures. The table input motion was controlled by an accelerometer mounted adjacent to the valve location. A triaxial output accelerometer was mounted on an extended part of the valve in a position suitable to record the response in each of the three orthogonal axes. The motion measured by this accelerometer was compared to the input level values, and a resonance was declared when the ratio of the output to the input motion exceeded 2.

The valves were subjected to continuous sinusoidal motion having an acceleration level of 0.75 'g'. The frequency was then swept in each axis, separately, from 1 to 100 to 1 Hz at a rate of 1 octave per minute. The valves were energized at 120 V AC, or 132 V dc, during the sweep from 1 to 100 Hz; they were de-energized during the 100 to 1 Hz sweep. The valve maximum operating pressure differential (MOPD) was applied during the entire test phase.

Any resonance values identified were subsequently incorporated into the SSE tests and operability was demonstrated at these values, as well as the SSE RIM requirements, out to 100 Hz.

4.1.6 VIBRATION AGING

Following the resonance search tests the valves were subjected to vibration aging by the continuous application of a single frequency sinusoid in each of the three orthogonal axes. This test was similar to the resonance search tests, except that the sweep frequency was from 5 to 100 to 5 Hz at a rate of two octaves per minute. This was continued for a total of 90 minutes, in each axis. The valves were alternately energized and de-energized every 15 minutes at either 120 V AC or 132 V dc, as applicable. MOPD was applied throughout the entire test.

4.1.7 SEISMIC OBE AGING

At the conclusion of the vibration-aging phase of the test, and with the valves still in their original mounting and connection configuration, they were subjected to OBE aging tests. This was accomplished by performing two sinusoidal sweeps at 2/3 the fragility RIM levels shown in Figure 4.3.

Each sweep was from 2 to 35 to 2 Hz, at a rate of 1 octave per minute, in each orthogonal axis, separately. One sweep was performed with the valves energized at either 120 Vac or 132 Vdc; one sweep was performed with the valves de-energized. MOPD was applied throughout the testing.

For convenience, the seismic SSE level tests were conducted at the conclusion of the OBE level tests.

4.2 DESIGN BASIS EVENT (DBE) SIMULATION PHASES

The design basis event portion of the qualification test program consisted of three sequential exposure phases. These were designed to simulate the most severe expected levels of all potentially degrading conditions associated with postulated accident environments for nuclear power generating stations. The three simulations were seismic SSE, DBE radiation exposure, and environmental DBE exposure.

4.2.1 SEISMIC SSE

Immediately following the seismic OBE aging testing, seismic SSE simulation testing was performed by single frequency, single axis, continuous sinusoidal tests at 1/3 octave intervals as indicated in Figure 4.1 and the resonance frequency values that were not encompassed by the 1/3 octave intervals.

The input motion was applied to each orthogonal axis, separately, with the peak acceleration applied for a minimum period of 15 seconds at either the levels shown in Figure 4.1 or the point where a 10% change in the cylinder inlet port pressure occurred. Each valve was operated through two complete de-energize to energize to de-energize cycles at each test frequency, while powered at either 102/60 Vac or 90 Vdc. These tests were performed once with the valve pressurized to its maximum operating pressure differential and then repeated with each valve pressurized to either 10 psig or its minimum operating pressure, whichever was greatest.

A full baseline performance test was performed at the conclusion of this series of tests.

4.2.2 DBE RADIATION EXPOSURE

At the conclusion of the seismic SSE simulation the test valves were all subjected to baseline tests and again sent to Isomedix, Inc. for the accident radiation (DBE) portion of the program. The simulation consisted of exposure to a cobalt-60 source of gamma radiation with an average energy of 2.5 Mev. and a total dose of 180 megarads. Pipe plugs were again installed in the pressure, cylinder, and exhaust ports of the valves. The valves were maintained de-energized during this exposure period.

At the completion of this simulation the valves were returned to the ASCO facility and subjected to a baseline test.

4.2.3 ENVIRONMENTAL DBE EXPOSURE

Upon completion of the post radiation DBE simulation baseline testing, the test samples with B and C suffixes were forwarded to Wyle Laboratories of Norco, California. The test samples were subjected to the Environmental DBE simulation. The test samples were installed into a test chamber and subjected to a 30 day exposure to steam, chemical spray, and clear water spray simulating a combined Loss Of Coolant accident / High Energy Line Break event and post-event cool down. Figure 4.1 shows the actual temperature / and figure 4.2 shows the pressure profiles for this simulation.

Upon completion of the DBE environmental simulation the valves were subjected to a portion of the baseline test conducted at Wyle Labs. The valves were then returned to ASCO where the balance of the base line testing was performed at ASCO.

4.3 BASELINE TESTING

At various points throughout the test program, the test valves were subjected to baseline testing to determine their condition. This was used for comparison of performance characteristics at other points in the program.

The baseline tests were performed at the following points during the conduct of the program:

- Initial - before the first thermal aging phase
- Post-wear aging - subsequent to both wear aging cycles, prior to the pressurization aging tests
- Post-radiation aging - subsequent to radiation aging exposure
- Post-seismic - subsequent to seismic DBE tests
- Post-DBE radiation - subsequent to DBE radiation exposure
- Post-DBE environmental - subsequent to the environmental DBE exposure

The baseline testing procedure for those specimens with the Nicotef coating is summarized in Table 4.3. Section 5 contains data for those portions of the baseline test relevant to performance of the Nicotef coating. Section 5 also summarizes overall performance during the environmental DBE simulation.

Table 4.3

**OPERATION TEST PROCEDURE:
BULLETINS NS8300, NS8302**

DESCRIPTION: 3-Way direct acting solenoid valves.

GENERAL: 1. Check general construction and appearance of valve.

TEST MEDIUM: Air.

TEST VOLTAGE & CURRENT: 1. All AC valves are to be tested using 102/60-test voltage.
2. All DC valves are to be tested using .154 test current.

COIL TESTS: 1. A.C. - Energize solenoid and check milliampere reading. Value should be .250.
2. D.C. - Energize solenoid and check voltage reading. Value should be 74.6.
3. Dielectric test - Test voltage to be twice the rated voltage plus 1000 volts AC for a period of one (1) minute. Any evidence of damage, arcing, breakdown or current leakage in excess of 0.5 milliampere (Test light sensitivity setting) is to be recorded.

EXTERNAL LEAKAGE: Apply seam test solution to all joints and pressurize valve to 10 PSI both energized and de-energized. Any bubbling or foaming is to be noted and recorded.
Repeat test at M.O.P.D.

NOTE: To avoid seat leakage or noise caused by the possible presence of dirt or loose chips, blow air at maximum operating pressure thru the valve before proceeding with tests below.

SEAT LEAKAGE (HIGH PRESSURE) Check valve for seat leakage at maximum operating pressure. Allowable leakage:

Resilient Seats: 0
Metal Seats: 1.5 SCFH

NOISE TEST: During the operational tests, check valve for noise. Any chattering or rattling in excess of normal AC hum is to be recorded. Valve should be tested at test voltage first, but voltage may be increased to full line voltage if necessary to pass the Noise Test Only.

OPERATIONAL TESTS: 1. Operate valve at least 10 times at maximum operating pressure.
2. Operate valve from maximum operating pressure down to minimum operating pressure.

SEAT LEAKAGE (LOW PRESSURE) Check seat leakage at 10 psi. Allowable leakage:
Resilient Seats: 0
Metal Seats: 1.5 SCFH

4.4 POST TEST VISUAL INSPECTION OF TEST ITEMS

Following the completion of all required testing; the test valves were disassembled and visually inspected for evidence of degradation resulting from exposure to the environments of this program.

5. SUMMARY OF PROGRAM RESULTS AND CONCLUSIONS

Table 5.1 summarizes the major test parameters and the simulated test levels.

TABLE 5.1
SUMMARY OF MAJOR TEST PARAMETERS & QUALIFICATION LEVELS

<u>TEST PHASE</u>	<u>TEST PARAMETERS</u>	<u>LEVEL SIMULATED*</u>
Thermal Aging Simulation (REF: Section 4.1)	2A & 2C - 140°C for 2.4 days 2B - 140°C for 4.8 days 11A & 11C - 140°C for 11.9 days 11B - 140°C for 23.8 days while energized	2A, 11A, 2C & 11C - 10 years while energized in a 45°C (113°F) ambient temperature. 2B & 11B - 20 years while energized in a 45°C (113°F) ambient temperature.
Wear Aging Simulation (REF: Section 4.1.2)	40,000 cycles	40,000 de-energize to energize to de-energize cycles
Pressurization Aging Simulation (REF: Section 4.1.3)	Fifteen ambient pressure excursions to 80 psig	Fifteen containment pressurization cycles from atmospheric pressure to 80 psig
Radiation Aging Simulation (REF: Section 4.1.4)	A & C Series - 20 x 10 ⁶ rads; B-Series - 40 x 10 ⁶ rads of gamma radiation. Rate not to exceed 1.0 x 10 ⁶ rad/hour.	2A, 11A, 2C & 11C – at least 21 x 10 ⁶ rads 2B & 11B - at least 41 x 10 ⁶ rads
Vibration Aging Simulation (REF: Section 4.1.6)	5 to 100 to 5 Hz continuous sinusoidal sweeps, 0.75 g's, sweep rate of 2 octaves/min., total duration 10 minutes in each (3) axis.	Normal plant induced vibration that could reasonably be expected to occur during the life of the valve.
Seismic Aging (OBE) Simulation (REF: Section 4.1.7)	Two sweeps from 2 to 35 to 2 Hz at a rate of 1 octave/min.	Five typical operating basis earthquakes with up to 3 g peak acceleration.
Seismic DBE (SSE) Simulation (REF: Section 4.2.1)	Single frequency, single axis continuous sinusoidal dwell tests at 1/3 octave intervals from 1 to 100 Hertz and any resonant frequencies not encompassed by the 1/3 octave intervals up to 15 g's.	Fragility levels are indicated in qualification test report Appendix H.
Radiation DBE Simulation (REF: Section 4.2.2)	1.8 x 10 ⁸ rads of gamma radiation	1.8 x 10 ⁸ rads minimum dose of gamma radiation. 1.66 x 10 ⁸ rads with 10% margin
Environmental DBE Simulation (REF: Section 4.2.3)	30 day LOCA/HELB simulation. Peak ambient temperature of 492°F and peak ambient pressure of 113 psig.	Temperature/Pressure profile as shown in figure 4.2.1 and 4.2.2

FIGURE 4.1

ENVIRONMENTAL QUALIFICATION PARAMETERS FOR COMBINED LOSS OF COOLANT
ACCIDENT (LOCA)/HIGH ENERGY LINE BREAK (HELB) SIMULATION
REQUIRED VS ACTUAL TEMPERATURE (F) PROFILE

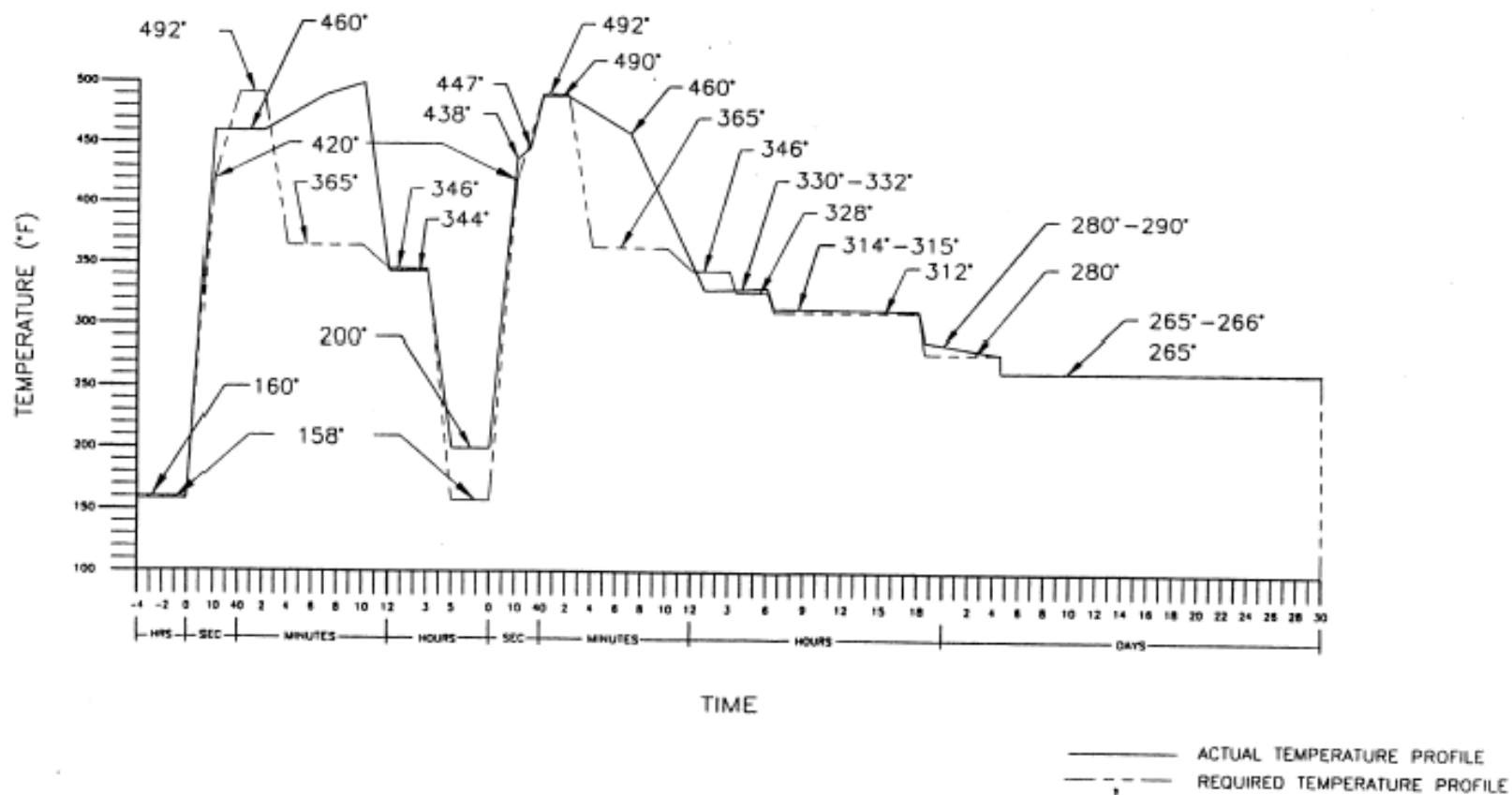


FIGURE 4.2

ENVIRONMENTAL QUALIFICATION PARAMETERS FOR COMBINED LOSS OF COOLANT
ACCIDENT (LOCA)/HIGH ENERGY LINE BREAK (HELB) SIMULATION
REQUIRED VS ACTUAL PRESSURE (PSIG) PROFILE

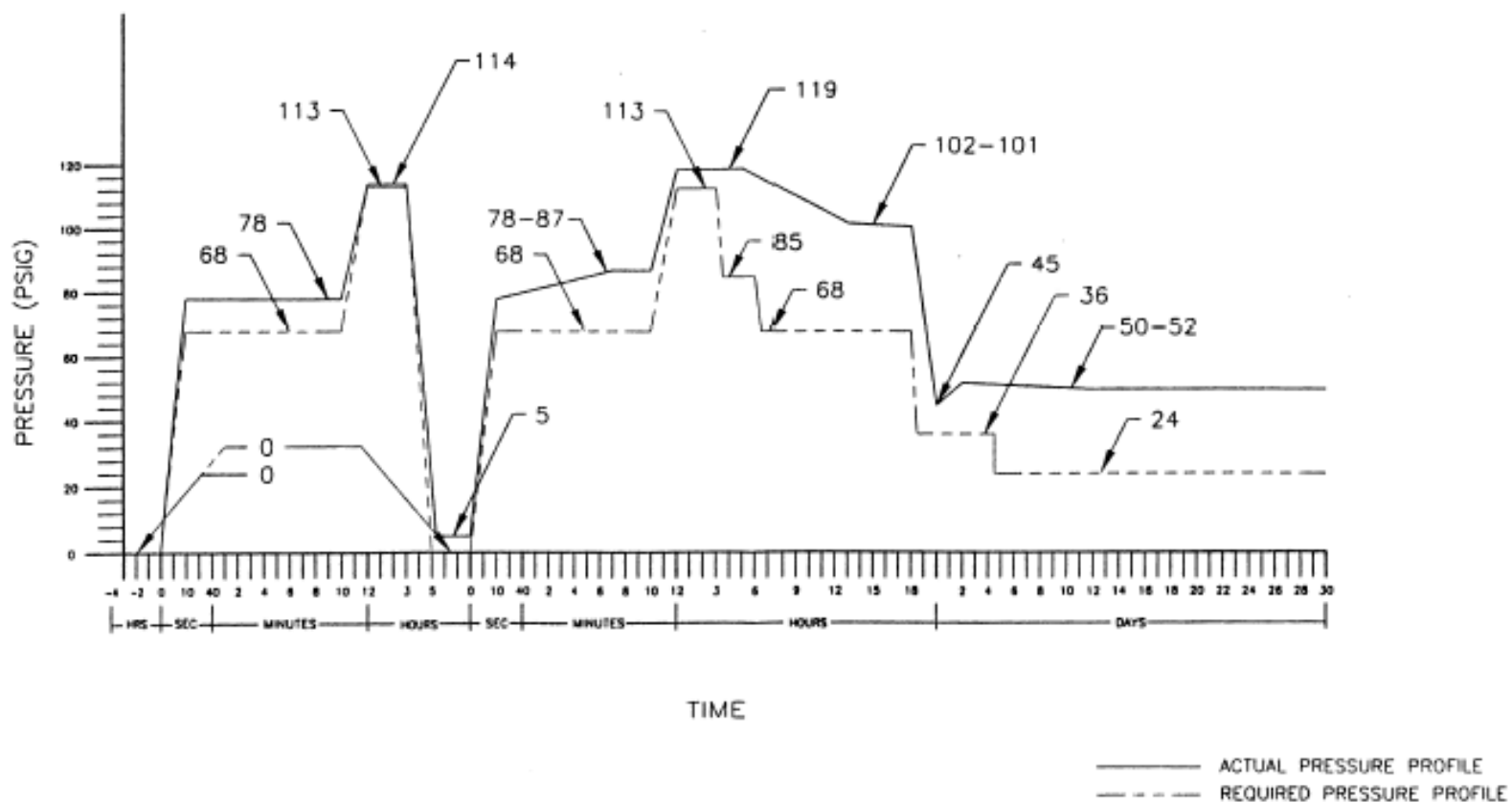
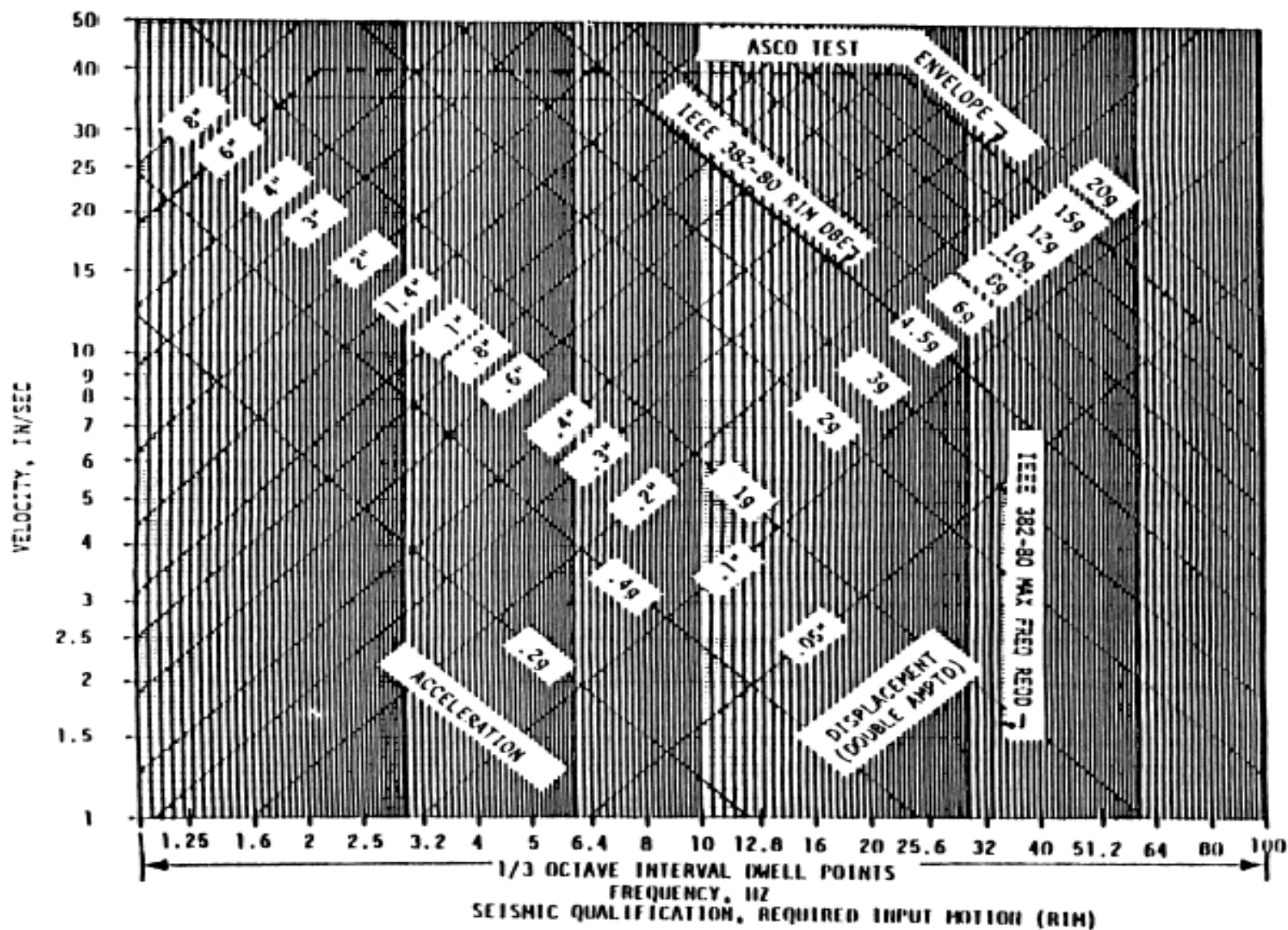


FIGURE 4.3



Performance Summary
Valve Sample 2A
ASCO Catalogue No. NS83022036

BASELINE TESTING VALVE SAMPLE NO. 2A ASCO CATALOG NO. NS8302203G TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21690 REV 4 & ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR							
		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 100 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	lwr gd cap Note 1	
SEAT LEAKAGE HIGH PRESSURE @ 100 PSIG	ENERGIZED ALLOWED 1.5scfh	190cc/min Note 2	140cc/min Note 2	100cc/min Note 2	140cc/min Note 2	170cc/min Note 2	
	DE-ENERGIZED ALLOWED 1.5scfh	180cc/min Note 2	1.0scfh Note 2	.8scfh Note 2	.8scfh Note 2	.7scfh Note 2	
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOWED 1.5scfh	50cc/min Note 2	0	0	20cc/min Note 2	20cc/min Note 2	
	DE-ENERGIZED ALLOWED 1.5scfh	0	10cc/min Note 2	10cc/min Note 2	10cc/min Note 2	10cc/min Note 2	
OPERATIONAL: 10X @ 100 PSIG 100 TO 0 PSIG		passed	passed	passed	passed	passed	
NOISE TEST		passed	passed	passed	passed	passed	
DROP OUT (ADC)	@ MAXIMUM PRESSURE 100 PSIG	63vac	66vac	66vac	67vac	68vac	
SHIFT TIME	FILL @ 100 PSIG	150ms	190ms	160ms	150ms	170ms	
	DISCHARGE @ 100 PSIG	370ms	370ms	390ms	360ms	390ms	

Performance Summary: Based on the performance of valves 2B and 2C, valve is considered to be fully qualified.

Note 1: External leakage detected at the lower guide cap. Leakage not enough to affect performance of valve.

Note 2: Seat leakage within acceptable limits as defined in AQS21691/R3 - Section 6.2.3.

Performance Summary
Valve Sample 2B

ASCO Catalogue No. NS83022036

BASELINE TESTING VALVE SAMPLE NO. 2B ASCO CATALOG NO. NS8302203G TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21691 REV 3 & ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR							
		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 100 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	end cap lwr gd cap Note 1	end cap Note 1
SEAT LEAKAGE HIGH PRESSURE @ 100 PSIG	ENERGIZED ALLOWED 1.5scfh	.5scfh	20cc/min	70cc/min	15cc/min	30cc/min	100cc/min
	DE-ENERGIZED ALLOWED 1.5scfh	80cc/min	.9scfh	1.0scfh	1.2scfh	1.3scfh	.9scfh
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOWED 1.5scfh	40cc/min	20cc/min	0	0	0	0
	DE-ENERGIZED ALLOWED 1.5scfh	5cc/min	20cc/min	20cc/min	20cc/min	20cc/min	40cc/min
OPERATIONAL: 10X @ 100 PSIG 100 TO 0 PSIG		passed	passed	passed	passed	passed	passed
NOISE TEST		passed	passed	passed	passed	passed	passed
SHIFT TIME	FILL @ 100 PSIG	120ms	140ms	130ms	190ms	130ms	192ms
	DISCHARGE @ 100 PSIG	370ms	380ms	350ms	390ms	390ms	396ms

Performance Summary: The valve acceptably performed throughout the qualification program including baseline tests and environmental DBE simulation.

Note 1: External leakage was detected at the lower guide cap/body and end cap/body joint. The leakage was not enough to affect the performance of the valve.

Performance Summary
Valve Sample 2C
ASCO Catalog No. NS8302203G

BASELINE TESTING VALVE SAMPLE NO. 2C ASCO CATALOG NO. NS8302203G TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21691 REV 3 & ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR							
		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 100 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	SBSA Note 1	end cap Note 1
SEAT LEAKAGE HIGH PRESSURE @ 100 PSIG	ENERGIZED ALLOW: 1.5scfh	80cc/min	20cc/min	30cc/min	0	10cc/min	20cc/min
	DE-ENERGIZED ALLOW: 1.5scfh	30cc/min	1.3scfh	1.5scfh	1.4scfh	1.3scfh	4scfh Note 2, 3
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	0
	DE-ENERGIZED ALLOW: 1.5scfh	0	45cc/min	30cc/min	30cc/min	10cc/min	40cc/min Note 2
OPERATIONAL: 10X @ 100 PSIG 100 TO 0 PSIG		passed	passed	passed	passed	passed	passed Note 3
NOISE TEST		passed	passed	passed	passed	passed	passed
SHIFT TIME	FILL @ 100 PSI G	140ms	160ms	130ms	160ms	180ms	Note 4
	DISCHARGE @ 100 PSIG	340ms	380ms	400ms	390ms	380ms	396ms

Performance Summary: During the post test inspection, the upper spring was found to have cracked. Analysis by Battelle Labs identified trace amounts of chemicals on the springs in the vicinity of the fracture. The chemicals are not typical of what is in the 17-7 PH stainless steel springs. The report suggests that the chemical spray solution may have been contaminated.

Note 1: External leakage detected at solenoid base sub-assembly/body and end cap/body joints. Leakage not enough to affect performance of the valve.

Note 2: Seat leakage within acceptable limits as defined in AQS21691/R3 - Section 6.2.3.

Note 3: Blowby detected due to damaged spring.

Note 4: Not able to record fill time due to damaged spring and resultant blowby.

Baseline Testing

Valve Sample 11
ASCO Catalog No. NSEL830081F

BASELINE TESTING VALVE SAMPLE NO. 11A ASCO CATALOG NO. NSEL830081F TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21691 REV 3 & ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR							
		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 150 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	end cap Note 1	
SEAT LEAKAGE HIGH PRESSURE @ 150 PSIG	ENERGIZED ALLOW: 1.5scfh	110cc/min	20cc/min	30cc/min	10cc/min	20cc/min	
	DE-ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	
	DE-ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	
OPERATIONAL: 10X @ 150 PSIG 150 TO 0 PSIG		passed	passed	passed	passed	passed	
NOISE TEST		passed	passed	passed	passed	passed	
SHIFT TIME	FILL @ 150 PSIG	.26sec	.26sec	.24sec	.28sec	.30sec	
	DISCHARGE @ 150 PSIG	.68sec	.74sec	.68sec	.69sec	.78sec	

Based on the performance of 11B and 11C, valve 11C is considered qualified.

Note 1: External leakage detected at end cap gasket – leakage was not enough to affect performance of valve.

Baseline Testing
Valve Sample 11B
ASCO Catalog No. NSEL830081F

BASELINE TESTING VALVE SAMPLE NO. 11B ASCO CATALOG NO. NSEL830081F TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21691 REV 3 & ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR							
		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 150 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	SBSA	end cap SBSA Note 3
SEAT LEAKAGE HIGH PRESSURE @ 150 PSIG	ENERGIZED ALLOW: 1.5scfh	35cc/min	.35scfh	110cc/min	30cc/min	30cc/min	15cc/min
	DE-ENERGIZED ALLOW: 1.5scfh	35cc/min	10cc/min	10cc/min	30cc/min	20cc/min	10cc/min
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	0
	DE-ENERGIZED ALLOW: 1.5scfh	0	0	0	0	0	0
OPERATIONAL: 10X @ 150 PSIG 150 TO 0 PSIG		passed	passed	passed	passed	passed	150-35psi passed
NOISE TEST		passed	passed	passed	passed	passed	passed
SHIFT TIME	FILL @ 150 PSIG	.26sec	.26sec	.22sec	.26sec	.28sec	.26sec
	DISCHARGE @ 150 PSIG	.68sec	.68sec	.64sec	.68sec	.76sec	.76sec

Performance Summary:

During Environmental DBE Simulation, Valve was energized to perform cycle 12. Valve failed to operate Ref. SOA 013). Post Environmental DBE was performed using a replacement coil and bypassing the p ower reduction module. Valve was acceptable.

Note 3:

External leakage detected at end cap/body and SBSA/body joint. Leakage is not significant enough to affect performance of the valve.

Baseline Testing
Valve Sample 11C

ASCO Catalog No. NSEL830081F

BASELINE TESTING
VALVE SAMPLE NO. 11C
ASCO CATALOG NO. NSEL830081F
TESTING CONDUCTED IN ACCORDANCE WITH QUALIFICATION SPECIFICATION AQS 21691 REV 3 &
ASCO TEST PROCEDURE BULLETIN TP-3-046 TEST MEDIUM: AIR

		INITIAL	POST WEAR AGING	POST RADIATION AGING	POST SEISMIC DBE	POST RADIATION DBE	POST ENVI. DBE
EXTERNAL LEAKAGE @ 10 & 150 PSIG (ENERGIZED & DE-ENERGIZED)		passed	passed	passed	passed	SBSA Note 2	endcap Note 2
SEAT LEAKAGE HIGH PRESSURE @ 150 PSIG	ENERGIZED ALLOW: 1.5scfh	.6scfh	130cc/min	.7scfh	.5scfh	.5scfh	150cc/min
	DE-ENERGIZED ALLOW: 1.5scfh	110cc/min	20cc/min	30cc/min	0	0	5cc/min
SEAT LEAKAGE HIGH PRESSURE @ 10 PSIG	ENERGIZED ALLOW: 1.5scfh	5cc/min	0	5cc/min	0	0	0
	DE-ENERGIZED ALLOW: 1.5scfh	5cc/min	0	.5scfh	50cc/min	3.0scfh Note 3	.95scfh
OPERATIONAL: 10X @ 150 PSIG 150 TO 0 PSIG		passed	passed	passed	passed	passed	passed
NOISE TEST		passed	passed	passed	passed	passed	passed
SHIFT TIME	FILL @ 150 PSIG	.26sec	.28sec	.28sec	.28sec	.28sec	.26sec
	DISCHARGE @ 150 PSIG	.66sec	.78sec	.72sec	.74sec	.70sec	.76sec

Performance Summary:

During Environmental DBE, while performing cycle 22, the valve vented cylinder pressure. Post Environmental baseline testing with replacement coil and bypassing the module was acceptable.

Note 2:

External leakage detected at solenoid base sub-assembly and end cap/body joints. Leakage was not enough to affect performance of the valve.

Note 3:

Seat leakage within acceptable limits as defined in AQS21691/R3 - Section 6.2.3.

APPENDIX B

ASCO Controls, L.P.

APPENDIX B TO VALVE ENGINEERING REPORT351 R2

Cross reference list between NP8300 catalog number system and 206/208/210 system:

NP8300 catalog number system	206/208/210 catalog number system
WATERTIGHT AC VOLTAGE	
NP8300 181 E	206380 001
NP8300 141 E	206380 002
NP8300 142 E	206380 003
NP8300 381 E	206380 004
NP8300 382 E	206380 005
NP8300 383 E	206380 006
NP8300 123 E	206380 007
NP8300 384 E	208266 006
NP8300 385 E	208266 007
NP8300 386 E	208266 008
NP8300 243 E	208266 005
EXPLOSION PROOF AC VOLTAGE	
NPEF8300 181E	206832 001
NPEF8300 141 E	206832 002
NPEF8300 142 E	206832 003
NPEF8300 381 E	206832 004
NPEF8300 382 E	206832 005
NPEF8300 383 E	206832 006
NPEF8300 123 E	206832 007
NPEF8300 384 E	210036 006
NPEF8300 385 E	210036 007
NPEF8300 386 E	210036 008
NPEF8300 243 E	210036 005
EXPLOSION PROOF DC VOLTAGE	
NPEF8300 181 E	206381 001
NPEF8300 141 E	206381 002
NPEF8300 142 E	206381 003
NPEF8300 381 E	206381 004
NPEF8300 382 E	206381 005
NPEF8300 383 E	206381 006
NPEF8300 123 E	206381 007
NPEF8300 384 E	208448 006
NPEF8300 385 E	208448 007
NPEF8300 386 E	208448 008
NPEF8300 243 E	208448 005

Notes: For resilient seat models add an "R" suffix to the last letter in the valve model number (Only available in brass body valves).

- (1) Normally closed operation, suffix F, Normally open operation, suffix G
Universal operation, suffix U
- (2) For Viton Construction substitute "V" for "E" in catalog number.