ENGINEERING EVALUATION OF THE WNP-2

SACRIFICIAL SHIELD WALL

SUPPLEMENT NO. 1

Washington Public Power Supply System
Richland, Washington 99352

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The purpose of this supplement is to formally reply to questions and concerns on the subject report identified by the NRC at a meeting held on August 6, 1980, in Bethesda. Six items remained open at the conclusion of that meeting. These items, listed below, are discussed herein.

- Clarify the original intent of the dimensional tolerances associated with the fabrication of the SSW.
- Provide the as-built dimensional information associated with the out-of-roundness and verticality of the SSW adjacent to the 541'-5" elevation.
- Provide the design margin of the original plug weld design.
- Provide an assessment of the secondary stresses of the proposed partial penetration weld due to its eccentricity.
- Discuss the leachability of lead from the selected shield material and provide the results of the various qualification tests.
- Provide the rationale for leaving known defects in the SSW.

The first four (4) items are discussed in Burns and Roe Technical Memorandum No. 1196. In addition, the calculation of the design margin for the original plug weld design is provided in enclosed sheet 70 of Burns and Roe calculation number 6.19.37.

Additional information on the shield material is provided in Burns and Roe Technical Memorandum No. 1197.

The "Rationale for Leaving Existing Defects in the Sacrificial Shield Wall (SSW)" is provided in an attached paper with the same title.

TECHNICAL MEMORANDUM

BURNS and Roe, Inc.

DATE 8/13/80

TO R. E. Snaith

FROM M. N. Fialkow

SUBJECT W.O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Sacrificial Shield Wall - Evaluation Program
Proposed Correction at Interface El. 541'-5"
Technical Memorandum No. 1196

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Reference: 1. Report by Washington Public Power Supply System entitled "Engineering Evaluation of the WNP-2 Sacrificial Shield Wall," submitted to USNRC August 1980.

INTRODUCTION

A conference on the evaluation of the Sacrificial Shield Wall (SSW) was held at the offices of USNRC in Bethesda, Maryland on August 6, 1980 attended by representatives of USNRC, WPPSS, and Burns and Roe. At the conference, representatives of USNRC requested additional information relative to the proposed correction weld at interface elevation 541'-5".

Information to be furnished by Burns and Roe is included herein under the following headings:

a. Erection tolerances and as-built deviations

b. Comparison of proposed correction with original slot welds

c. Structural analysis of sidestepped load path at interface.

ERECTION TOLERANCES AND AS-BUILT DEVIATIONS

At the conference NRC requested that information be furnished relative to the basis for the tolerances specified in the initial Burns and Roe report (WPPSS-74-2-R2) and relative to the as-built deviations used in the analysis of the correction weld at the interface.

The report addresses fabrication and erection tolerances in Section VI. It describes acceptable tolerance levels with respect to the plumbness of the wall, levelness of the ring beams and circular alignment. In general, deviations of $\pm$ 1/8 inch ($\pm$ 1/4 inch for overall verticality) are indicated to be acceptable. The discussion in Section VI indicates that except for the levelness tolerance at the interface at Elevation 541'-5" which is required to prevent radiation problems, the tolerance requirements were adopted to facilitate proper construction of the SSW. The following quotation from the report summarizes the intent of the tolerance requirements:

> "Calling for specific tolerances on the drawings will serve as a technique to enhance the construction of a series of properly fitted building blocks. However, it is recognized that the above tolerances will be difficult to maintain. Therefore, the contractor will be permitted to submit, for approval, alternate tolerances for achieving the intent of the design."

Information relative to the as-built dimensions of the SSW used in the analysis of the interface correction weld is included in pages 55-61, 64, 65 and 67-69 of Burns and Roe Calculation No. 6.19.37 and in Burns and Roe Technical Memorandum No. 1173. These documents are provided in Attachment 4 of the WPPSS report (Reference 1).

COMPARISON OF PROPOSED CORRECTION WITH ORIGINAL SLOT WELDS

Calculations have been made to compare the capacity of the proposed correction weld with that of the original slot welds. The comparison is made on the basis of the design margin which represents the ratio of the permissible stress to the maximum stress under the design load. The calculations show that for the design panel shear load (327.0 kips tangential and 27.4 kips radial), the design margin is 2.26 for the original slot welds and 2.39 for the proposed correction weld. It is further noted that, whereas the maximum stress in the slot welds prevails over the entire surface of the welds, the maximum stress in the correction

weld occurs only at the extremity of the weld. Thus, the correction weld has additional capacity over that associated with initial yield whereas the capacity of the slot welds is limited to that at initial yield. Summarizing, the proposed correction weld provides greater strength than the original slot welds.

STRUCTURAL ANALYSIS OF SIDESTEPPED LOAD PATH AT INTERFACE

As shown in the calculations (B&R Calculation No. 6.19.37, Attachment 4 of Reference 1) the design of the correction weld has taken due account of the eccentricity of the design shear load with respect to the correction weld. However, question has been raised by NRC as to possible changes in the internal force system in the Sacrificial Shield Wall resulting from the sidestepping of the loads through the correction weld.

Analysis has been made of the perturbations in internal SSW forces which result from the application of moments corresponding to the sidestepping of load at the interface. The overall SSW structural model was investigated for the effect of moments about the vertical axis applied at the nodes of the interface with moment magnitudes equal to the panel shear load times an eccentricity of half the wall thickness (12 inches). The analysis was made for the case of annulus pressures due to feedwater break. The commercially available computer program, STRUDL, was used. The results show that the maximum change in panel shear due to the above application of moment loads is less than 2 percent of the maximum panel shear due to the feedwater break annulus pressures. Thus, the effect on the design panel shear for the correction weld is not significant.

Prepared by M. N. Fialkow
M. N. Fialkow

Approved by J. O'Donnell
J. O'Donnell

BURNS AND ROE, INC.
Headquarters Office–Oradell, N.J.

W.O. No. 3900-03 Date 8/8/80 Book No. SV 489 Page No. 70
Drawing No. S783 Calc. No. 6.19.37 Sheet 1 Cont. on Sheet
By M. Fialkow Checked 8/12/80 Approved 8/12/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

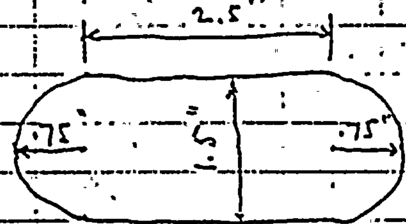
SUBJECT : CORRECTION MEASURES AT INTERFACE EL. 541'-5"

J. COMPARISON OF PROPOSED CORRECTION WITH ORIGINAL SLOT WELDS

1. CONTRACT REQUIREMENT

CONTRACT REQUIRES 4 SLOT WELDS PER 15° PANEL.
AREA OF SLOT WELD IS SHOWN

$A = 2.5 \times 1.5 + \pi \times .75^2 = 5.52 \,\square''$



TOTAL A / PANEL = 4×5.52
$= 22.08 \,\square''$

2. MAXIMUM STRESS DUE TO DESIGN LOADING

a. DESIGN LOADING
REFER TO PAR H3a
$H_e = 27.4^K$ RADIAL
$H_T = 327.0^K$ TANG.

b. STRESSES

$\sigma_e = \frac{27.4}{22.08} = 1.24 \,^{K}/_{\square''}$ RADIAL

$\sigma_T = \frac{327.0}{22.08} = 14.81 \,^{K}/_{\square''}$ TANG.

$\sigma = \left[1.24^2 + 14.81^2\right]^{1/2} = 14.86 \,^{K}/_{\square''}$ RESULTANT

ACCEPTABLE STRESS (LOAD COMB. 5) = $1.6 \times 21 = 33.6 \,^{K}/_{\square''}$

3. DESIGN MARGIN

$D.M. = \frac{33.6}{14.86} = 2.26$

THIS DESIGN MARGIN IS LESS THAN D.M. = 2.39 WITH CORRECTION WELD FOR SAME DESIGN LOADING.

4. CONCLUSION

PROPOSED CORRECTION WELD PROVIDES GREATER CAPACITY THAN ORIGINAL SLOT WELDS.

Form BR 8002-2 (5/78)

TECHNICAL
MEMORANDUM

BURNS and ROE, Inc.

DATE 8/15/80

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TO R. E. Snaith

FROM F. S. Weingard

SUBJECT W. O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Sacrificial Shield Wall
NRC Concern: Use of Lead in Shielding Material
Technical Memorandum No. 1197

References:
1) WBGBR-215-9757: "NS-1 BISCO Material Suitability Report", dated 6/9/80
2) WBGBR-215-9758: "Chemical and Physical Properties of BISCO Neutron-Gamma Shielding", dated 6/9/80
3) WBGBR-215-9760: "Irradiation Study of BISCO Boraflex", dated 6/9/80
4) Memo - J. Sherwood (BISCO) to F. S. Weingard: "Information Regarding BISCO NS-1 Shielding Polymer", dated 8/13/80
5) Memo - J. Sherwood (BISCO) to F. S. Weingard: "Special Shielding for the Shim Gap and Sacrificial Shield Wall Problems", dated 3/19/80
6) Memo - J. Sherwood (BISCO) to F. S. Weingard: "Special Material for Shim Gap and Sacrificial Shield Wall Use", dated 3/26/80
7) Verbal Conversation between D. C. Baker, T. Hsui, K. Ronis, and F. S. Weingard: "Containment Temperatures and Containment Flooding", date 8/14/80
8) BRWP-F-79-1031: "Recording and Documentation of Shim Gaps and Shims", dated 12/4/79
9) GO2-80-131: "NRR Approval of WNP-2 SSW Weld Preparation", dated 6/20/80

INTRODUCTION

A meeting was held between Washington Public Power Supply System and the NRC on August 6, 1980 (in Bethesda, Maryland) to discuss release of the repair to the 541' 5" Elevation of the SSW in the WNP-2 primary containment.

INTRODUCTION (CONT'D)

One aspect of this repair involves the placement of shield material into gaps between shims. The shield material selected for this purpose is BISCO Product NS-1 (high density). NS-1 (high density) is a silicone elastomer filled with powdered pure lead (11% by volume) to form a resultant filled polymer of density greater than 150 pcf.

At this meeting, the NRC expressed concern about using lead in the WNP-2 primary containment. Possible concerns intimated are the following: Heavy metals, such as lead, induce metal-water reactions (during LOCA situations) that result in the release of hydrogen; Lead in contact with stainless steel may also initiate stress corrosion cracking in the stainless steel.

DISCUSSION:

In response to the above concern, the following points are made to show that this concern for the aforementioned application is not substantiated:

1) The powdered lead is bound within the matrix of the NS-1 polymer. This is done by uniformly blending pure metallic lead powder into the NS-1 matrix prior to curing. The polymer acts to coat and secure the lead particles, thus entraining and physically binding them into the NS-1 matrix.(*4)

BISCO has conducted long-term thermal aging tests on this NS-1 matrix at various fixed temperatures. At the end of each test period, the durometer, tensile strength, and elongation were measured to analyze changes in the material. This testing was conducted following ASTM standard tests D-676 for durometer, and D-412 for tensile strength and elongation. Minimal changes were observed during 5,160 hours of exposure at 190°C (374°F).(*1)

Certain testing has also been done in excess of 310°C (590°F) for up to one week of observation. No observed melting or crumbling of the materials was observed.(*4)

Evaluations of carbon content, Hydrogen content, and physical condition were also performed after 5,840 test hours at 70°C (158°F), 150°C (302°F), and 225°C (437°F). Recorded data indicates a very slight decrease in carbon and hydrogen content and no physical discernable change in the material.(*1)

2) Lead melting or vaporization within the polymer will not occur at accident conditions with the improbable exception of a direct, short-term, localized, steam and water jet impingement at a shield location during a LOCA.(*7) The melting point of lead is 620°F. The design temperature of the WNP-2 primary containment drywell is 340°F.

DISCUSSION (CONT'D)

It should be noted, however, that even when the material, NS-1 (high density) is subject to high degrees of fire, it has been observed that the lead particles tend to agglomerate in the mixture and bind to each other rather than come out of the matrix. It is reported that the NS-1 compound will begin to Char at 1,000 to 1,100°F., but it is to be noted that the thermal mass of the material and the surrounding massive heat sink (SSW) will keep this charing action to a minimum at these temperatures. It is significant to note that the material will maintain its body at a temperature higher than that of the melting point of lead for a short period of time.(*4)

3) BISCO NS-1 (high density) exhibits stability under both high temperatures and high radiation conditions. The bulk of BISCO's radiation testing has been conducted at the University of Michigan Ford Nuclear Reactor. These tests have included both high rate and long-term tests in or adjacent to the core of the reactor as well as long-term testing in the spent fuel area - primarily a gamma source.(*4) (*1)

The shield material has been found to withstand gamma exposures up to 2×10^{11} rad-gamma (with a concurrent neutron flux of approximately 10^{14} nvt).(*2) Properties such as tensile strength, elongation, elastic modulus, hardness, and de-gassing were found acceptable after these tests.(*3)

4) Lead is not soluble in BWR environment water. Long-term water soaking in the typical spent fuel pool environment or under simulated LOCA conditions have no major observable effects on BISCO NS-1 products. One such product is Boraflex(R) which is NS-1 binder filled with Boron Carbide (.5 to 50% by volume) as opposed to NS-1 binder filled with lead (11% by volume).(*4) Testing performed on Boraflex(R) can be used to qualify NS-1 (high density) for such properties as water resistance and filler leachability.

Extended testing on Boraflex(R) has shown that there is little or no change in material over very long periods of observation. This data is detailed in BISCO's documentation package on the Boraflex(R) material and is verified by information provided by sources in the industry at Dow Corning Corporation and the General Electric Company.(*4)

Tests on Boraflex(R) included measuring tensile strength, elongation, hardness, and de-gassing up to 1.06×10^{10} rads exposure in dionized and boronated water soak environments.(*3)

DISCUSSION (CONT'D)

Halogen and boron leachability analyses in irradiated environments have also been performed. Analytical results of the leachability tests strongly suggest the efficient encapsulant function of the NS-1 polymer in preventing dissolution of contained soluble species.(*4) Since lead is insoluble, any leaching of the lead to the primary containment environment is highly improbable.

It should also be noted that there are no recoverable accident scenarios that entail flooding the primary containment above the shield location elevation of 541' 5".(*8)

Boraflex(R) has been licensed for use in spent fuel racks by the NRC under the following docket numbers: 50-266, 50-301, and 50-220. Licensing is pending for the following docket numbers: 50-329, 50-410, 50-330, 50=391, 50-390, 50-382, 50-269, 50-270, 50-282, and 50-306.(*6)

5) The total volume of shield material needed to fill the forty identified gaps is approximately 0.20 cubic feet. Since the shield material contains lead 11% by volume, this corresponds to .022 cubic feet of lead. The gaps vary in size and are fairly evenly distributed throughout the 360° circumference at the 541' 5" Elevation.(*9)

It should also be noted that once the gaps are filled with NS-1 (high density), the outer SSW openings of the gaps shall be welded shut with a 2 inch circumferential weld around the SSW as called out in the corrective action plan for the SSW plug weld deficiency. The inner openings of the gaps will either have been sealed by existing shims (15 cases) or sealed with back damming for the gap "fills" greater than 3/32 inch as called out in the shielding corrective action plan.(*10) It can thus be established that a very small quantity of shield material will have an extremely limited accessibility to the primary containment environment.

The amount of NS-1 (high density) needed to repair the concrete void deficiency need not be addressed for this particular concern as the shield material meets all the aforementioned points in this memorandum and there will be no accessibility to the primary containment environment since the shield material will be enclosed within the steel confines of the SSW compartments.

6) BISCO NS-1 polymer with lead has been widely used at various nuclear power plants in this country.

At the Donald C. Cook and Davis Besse projects, it was used within the containment in combination with approximately 12% volumetric fill of powdered metallic lead as radiation shielding for penetration seals and pressure barriers. On Davis Besse Unit 1, material usage totalled in excess of 50,000 pounds.(*4)

DISCUSSION (CONT'D)

At the Waterford Project, NS-1 neutron shielding was used as specialized ex-core neutron shields around the neutron flux detectors. Material usage in this application approximated 10,000 pounds placing the material into voids.(*4)

NS-1 neutron shielding was used on the Materials Test Reactor at Idaho Falls to provide a horizontal neutron shield that would be compressible to eliminate a gap shine problem through the joining surfaces of the concrete shield block assemblies. In addition to providing the basic neutron shielding properties, the NS-1 material also supports more than 40 tons of concrete shielding over the top of the reactor.(*4)

One other major use of NS-1 now being delivered by BISCO is the current material they are providing for the LaSalle project in Illinois, Units 1 and 2. In this case, they are manufacturing neutron shielding collars to be placed external to the sacrificial shield wall pressure doors to provide a full neutron attenuation equivalent to that of the normal concrete sacrificial shield wall. Under this condition the neutron shielding will be exposed to certain amounts of direct radiation as well as high temperatures yet it is designed to be relatively easy to handle by one man as modular assemblies. BISCO is currently in production on this material and expect to be inplacing 25 to 30 tons of material per unit.(*4) The material will use NS-1 as the basic binding polymer.

CONCLUSION

In conclusion, the shield material to be used in the SSW, BISCO Product NS-1 (high density), will not release its 11% lead filled contents to the primary containment environment. This is due to the NS-1 polymer's ability to maintain mechanical and structural integrity at elevated temperatures and high radiation exposures, and the polymer's resistance to leaching in water-soak environments.

Attachment I provides a material properties data sheet (supplied by BISCO).

(#6)

MATERIAL PROPERTIES

PRODUCT TYPE:	NS-I (High Density)
POLYMER, DESCRIPTION:	Dimethyl Polysiloxane (Synthetic Rubber)
DENSITY, COMPOSITE:	2.4 gm/cc (150#/cu.ft.) nominal

COMPOSITION:	Polymer	
H - Wt.%	4.4%	1.4 gm/cc
C - Wt.%	17.5%	
O - Wt.%	37.0%	(87#/cu.ft.)
Si - Wt.%	41.1%	

FILLER TYPE:	Powdered Lead
FILL %, VOLUME:	11% nominal
COMPOSITE FLAME SPREAD:	
ASTM E-84	• Less than 25
ASTM E-162	• Less than 20 Flame Spread
ASTM E-119	• Tested for 5 hours duration (FM 24963)
TENSILE STRENGTH:	• 300 psi initial
ELONGATION:	• 100% initial
DUROMETER:	• over 60 Shore A initial
RADIATION RESISTANCE:	• over 1 x 10^{11} Rads
DATA FROM:	Kircher & Bowman "Effects of Radiation on Materials & Components", pages 90 to 100 University of Michigan Test - Complete
HALOGEN CONTENT:	Complies with requirements of Reg. Guide 1.36
SUPPLIED AS:	A 2 liquid and powder system designed to be field blended and proportioned. Installs as a liquid and cures together at room temperature within 10 hours of mixing at 25°C (77°F). See BISCO Mixing and Installation Procedure.

Prepared by: F. S. Weingard
Lead Nuclear/Mechanical Engineer

Approval: R. Baldwin
Nuclear Group Supervisor

Approval: R. Keating
Supervising Metallurgical Engineer

RATIONALE FOR LEAVING EXISTING DEFECTS IN THE SACRIFICIAL SHIELD WALL (SSW)

I. Introduction

A review of the as-built quality of the SSW revealed the presence of a number of weld defects per AWS D1.1.

Some of the defects were detected after completion of the structure by visual inspection, the method of examination originally specified. These defects do not meet the original design, weld quality criteria. Other defects were detected by ultrasonic testing (UT), an examination method more sensitive and stringent than the original inspection criteria. These defects do not meet AWS D1.1 criteria for volumetric inspection. However it should be noted that these defects would not have been found by the contract inspection methods, and structures built using only visual inspection for welds during fabrication would be expected to contain subsurface defects.

An assessment of the structural integrity of the SSW in the as-built condition concluded that all known defects will not prevent the structure from performing its design functions, and therefore do not require repair.

In general, further repair activities beyond those identified as necessary in the original report are considered to present more potential for detrimental effects on the SSW than for benefits to be gained.

The completed SSW represents a highly restrained structure with the fabrication sequence completed. To perturbate this structure with additional welding and localized preheats where repair is not required for design function should be avoided. Specifically, repair of structurally non-significant defects under these conditions has the potential for creating additional defects, such as cracks, which are more harmful than the defects under consideration. Elaborate precautions have been specified for the required weld repair at elevation 541'-5" to minimize such concerns.

Some defects are inaccessible and/or extensive disassembly, welding out of sequence and rework would be required for repair.

Additionally, access to many areas of the SSW is limited by subsequent attachments that restrict the working conditions for normal repair activities.

However, in consideration that some undersized fillet welds have a significant reduction in their load bearing capacity, the Supply System has elected to repair some defects of this type.

Specific defect considerations are discussed below.

II. Defects Not Being Repaired

A. Electroslag Weld Indication

Of the 73 electroslag welds examined by UT under Task Force direction, one contained an unacceptable indication. The rejectable indication was a large reflector located in a permanent steel backing shoe.

The defect is difficult to repair because of installed piping interference.

The defect is not considered structurally significant for the following reasons:

- The structural assessment provided in the original report,
- It is located in the backing shoe, and
- The weld function is redundant in that other weld joints in that vicinity have the capability and responsibility of transmitting the relevant loads.

B. Incomplete Penetration in Shielded Metal Arc Welds (SMAW)

These defects were found by UT, directed by the Task Force. Of six welds examined, one was rejected for incomplete penetration in the weld root of a single bevel weld.

The defect has been assessed to be structurally acceptable using the conservative static analysis discussed in the original report.

Repair would require extensive excavation, preheating and rewelding with the potential for creating additional and more serious defects.

C. Incomplete Penetration in Flux Cored Arc Welds (FCAW)

Seven double bevel T-welds were examined by UT. Six were found to have incomplete penetration in the root.

Two single bevel welds were also found to have incomplete penetration in the root by UT examination.

These defects have been found to be structurally acceptable using the conservative static analysis discussed in the original report.

The double bevel T-welds are located inside the SSW. Their repair would require removal of external plates, redesign of the joint configuration, preheating and rewelding.

The single bevel joints are accessible, but extensive excavation, preheating and rewelding would be required.

In both cases, a potential for creating additional defects by the repair exists.

D. Workmanship Defects Identified by Visual Inspection

The following defect categories were identified by visual inspection of the outside of the SSW:

- o Porosity
- o Undercut
- o Arc Strikes
- o Overlap
- o Crater Fill
- o Excess Reinforcement
- o Localized Lack of Fusion
- o Convex Fillet.

As discussed in the original report, none of these defects are structurally significant.

Repair would require grinding or arc air gouging, preheating and rewelding. In the case of overlap and arc strikes, rewelding would be necessary if the material thickness were reduced below the design thickness.

Similarly, there is a potential for creating additional defects during repair as discussed before.

III. Repair of Structurally Significant Defects

The following defect categories were identified by visual inspection:

- o Undersize fillet welds

- o Underfill on a butt weld.

The undersized fillet welds were assessed in the original report for their potential for causing failure of the SSW by plastic collapse. It was concluded that failure by plastic collapse will not occur.

Some of the undersized fillets have an effective loss of load bearing cross section on the order of 50% or more. Because of the

large reduction in cross-sectional area of some of these welds, the Supply System will re-inspect the undersized fillet welds, carefully determine the amount by which they are undersized, and repair those welds which have a reduction of load bearing cross section in excess of 25%, provided that the repair has a minimum potential for creating additional defects.

The underfill on the butt weld was not significant and will not be repaired for similar reasons discussed above.