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SUBJECT: Describes program for seismic qualification of HVAC ductwork & suppls info provided by util 870408 & 880310 ltrs & 870701 Section III.3.5 of Rev 1 to performance plan. Qualification of seismic Class I HVAC ductwork & procedure encl.

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Gentlemen:

In the Matter of) Docket Nos. 50-260
Tennessee Valley Authority)

BROWNS FERRY NUCLEAR PLANT (BFN) - SEISMIC QUALIFICATION OF HEATING VENTILATION AND AIR CONDITIONING (HVAC) DUCTWORK AND SUPPORTS - (NRC TAC NO. 00299)

This letter describes the BFN program for the seismic qualification of HVAC ductwork. This material was requested by R. J. Clark's letter dated July 31, 1986, to S. A. White. This letter supplements the information provided by TVA's letters dated April 8, 1987, March 10, 1988, and also supplements section III.3.5 of revision 1 to the BFN Performance Plan which was transmitted by S. A. White's letter dated July 1, 1987, and incorporates resolutions to the NRC staff's concerns as discussed in our meeting held on March 18, 1988.

Enclosure 1 to this letter describes the BFN program for resolving this issue. Enclosure 2 provides the basis for 1.5 factor design allowable bending stress used in the interim operability criteria. Enclosure 3 is the BFN Class I HVAC duct and duct support seismic qualification interim operability acceptance criteria. TVA requests your review of this program and the issuance of a written statement documenting the program's acceptability.

Please refer any questions regarding this submittal to M. J. May, Manager, BFN Site Licensing, (205) 729-3570.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

R. Gridley

R. Gridley, Director
Nuclear Licensing and
Regulatory Affairs

Enclosures
cc: See page 2

D030
1/1

MAY 04 1988

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ENCLOSURE 1

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT
UNIT 2
QUALIFICATION OF SEISMIC CLASS I HVAC DUCTWORK AND SUPPORTS

This report gives TVA's plan to qualify the as-configured seismic Class I HVAC ductwork installation.

Issue

Design deficiencies were identified in TVA's Significant Condition Report No. SCRBFNCEB8603 that was issued during February 1986. Subsequent walkdowns of the HVAC ductwork were performed by TVA, and discrepancies were noted between as-constructed installations and the original design.

Background

Initially, HVAC ducts and duct supports at BFN were fabricated to industry standards without consideration of seismic loads. In 1970, the need for HVAC ducts to be designed for earthquake loads was identified. As a result, modification of existing HVAC ducts and supports was initiated. A HVAC seismic design criteria was issued in July 1970 and transmitted to the BFN Project Manager for implementation. The duct construction was based on the Sheet Metal and Air-Conditioning National Association (SMACNA) standards, with both the pocket-lock and companion-flange types being used. Several field evaluations (at least one per unit) were made by design engineers to review the as-built installations against the design criteria. Recommendations were made as a result of the field evaluations and changes were made accordingly.

In January 1986, a significant condition report was written against the design criteria (BFN-50-721) used for installation and qualification of supports for the HVAC system. That report questioned whether the design criteria was adequate to ensure the necessary seismic qualification of the HVAC system. In addition, field investigations of the HVAC system led to concerns that significant discrepancies might exist between the as-built system and the requirement of the design criteria.

Resolution

The scope of this activity involves 11,500 ft of ductwork, ranging in size from 6 in. to 30 in. diameter round ducts, and 5 in. x 6 in. to 72 in. x 84 in. rectangular ducts. There are 935 deadweights, 463 two-way and 137 three-way supports for the duct systems.

[illegible]

As-built sketches are generated as part of the walkdown effort and will document key attributes of the systems including the locations of supports and attachments, as well as their construction details and anchorage. The key attributes for the ducts which will be documented are routing, size, construction, location, and types of attachments.

The technical design criteria has been revised to include the correct weight of the ducts, and the duct system's natural frequency calculation methods have been modified to reflect test results. Additionally, the revised criteria now addresses cantilevered ducts and DBE (SSE) loads, and the allowable stresses are based on the AISC and the SMACNA standards.

The FSAR requires that essential HVAC systems remain functional for all plant conditions. The design criteria used in the qualification are based on AISC and SMACNA allowables which assure that their HVAC systems remain functional. The approach used for qualification of the duct systems is to evaluate 100 percent of the ductwork and supports against the design criteria stress levels for DBE (SSE) loads. Those ducts or supports that do not meet the design criteria will be evaluated against the interim operability criteria. Those which did not meet the design criteria, but are within the interim operability criteria, will be modified to the design criteria after restart. Those which do not meet the interim operability criteria will be modified to the design criteria unless specifically requested and approved by NRC on a case-by-case basis before restart. A comparison of design and operability criteria is summarized in table 1.

Licensing Issue

This program utilizes interim operability acceptance criteria for ducts and duct supports.

Justification

The duct stress interim operability criteria are based on test data (see table 1 and enclosure 2). The duct support interim operability criteria are the same as the pipe support interim operability criteria, which are similar to Sequoyah Nuclear Plant's (SQN's) large bore pipe support operability criteria. Approval of the Sequoyah operability criteria is documented in NUREG-1252. A comparison between SQN's and BFN's operability criteria is provided as table 2.

The HVAC qualification is comprehensive and provides assurance that the ducts and supports will remain functional. Those modifications which are required to meet the design criteria will be completed prior to restart following the next refueling outage.

ENCLOSURE 1

TABLE 1
BROWNS FERRY UNIT 2
HVAC
CRITERIA COMPARISON CHART

ADDRESSES	DESIGN CRITERIA	OPERABILITY CRITERIA	REMARKS
ALLOWABLE DUCT STRESS RECTANGULAR DUCTS	8,000 PSI PER SMACNA	12,000 PSI	BASED ON TEST DATA REPORTS TVA-CEB-79-7 AND MA 2-79-1
ROUND DUCTS	10,000 PSI PER SMACNA	15,000 PSI	BASED ON TEST DATA REPORTS TVA-CEB-79-7 AND MA 2-79-1
ALLOWABLE SUPPORT STRESS - TENSION AND BENDING	PER AISC UP TO $0.9S_Y$	SMALLER OF $1.2S_Y$ OR $0.7S_U$	SAME AS PIPE SUPPORT OPERABILITY CRITERIA
ALLOWABLE SUPPORT STRESS - COMPRESSION, AXIAL AND BENDING	PER AISC UP TO $0.9S_Y$	$0.9P_{CR}$	SAME AS PIPE SUPPORT OPERABILITY CRITERIA
SHEAR	PER AISC - UP TO $0.52S_Y$	SMALLER OF $0.72S_Y$ OR $0.42S_U$	SAME AS PIPE SUPPORT OPERABILITY CRITERIA
ALLOWABLE WELD STRESS SHEAR	PER AISC UP TO $.52S_Y$ BASE METAL	$0.42S_U$ BASE METAL	BASED ON ASME III SUBSECTION NF, APPENDIX F, FOR SUPPORTS
ALLOWABLE BOLT STRESS (TENSION)	PER AISC UP TO $0.56S_Y$ OF BOLT	S_Y WHEN NOT AVAILABLE $0.7S_U$	SAME AS PIPE SUPPORT OPERABILITY CRITERIA
ALLOWABLE CONCRETE EXPANSION ANCHORS FACTOR OF SAFETY WEDGE AND SHELL TYPE	WEDGE TYPE-4 SHELL TYPE 5 FOR TENSION 4 FOR SHEAR	ALL TYPES 2	SAME AS PIPE SUPPORT OPERABILITY CRITERIA

ENCLOSURE 1

TABLE 2
BROWNS FERRY UNIT 2
HVAC
CRITERIA COMPARISON CHART

ADDRESSES	BROWNS FERRY UNIT 2 HVAC INTERIM OPERABILITY ACCEPTANCE CRITERIA	SEQUOYAH UNIT 2 PIPE SUPPORTS INTERIM OPERABILITY CRITERIA
ALLOWABLE SUPPORT STRESS TENSION AND BENDING	SMALLER OF $1.2S_Y$ OR $0.7S_U$	SMALLER OF $1.2S_Y$ OR $0.7S_U$
ALLOWABLE SUPPORT STRESS COMPRESSION, AXIAL AND BENDING	$0.9P_{CR}$	$0.9P_{CR}$
SHEAR	SMALLER OF $0.72S_Y$ OR $0.42S_U$	SMALLER OF $0.72S_Y$ OR $0.42S_U$
ALLOWABLE WELD STRESS SHEAR	$0.42S_U$	$0.42S_U$
ALLOWABLE CONCRETE EXPANSION ANCHORS FACTOR OF SAFETY WEDGE AND SHELL TYPE	ALL TYPES 2	ALL TYPES 2
ALLOWABLE BOLT STRESS (TENSION)	S_Y (WHEN NOT AVAILABLE $0.7S_U$) (SEE NOTE 1)	S_Y

NOTE 1: WHEN THE YIELD STRESS OF THE BOLT MATERIAL IS NOT SPECIFIED (e.g., ASTMA307), THE ALLOWABLE STRESS SHALL BE 70 PERCENT OF THE MINIMUM SPECIFIED ULTIMATE STRENGTH.

ENCLOSURE 2

BASIS FOR THE 1.5 FACTOR DESIGN ALLOWABLE BENDING STRESS USED FOR INTERIM OPERABILITY CRITERIA

For long-term operation of the BFN safety-related HVAC systems, ducts and supports will be analyzed and modified, as necessary, to maintain compliance with applicable code allowable stresses. However, to permit interim operation before these modifications are made, interim operability criteria were established. For this purpose, a factored allowable stress (equal to 1.5 X design allowable stress) was developed, consistent with an evaluation of duct capacity beyond that predicted by normal code levels.

To determine the value of the multiplying factor, the following steps were taken:

- Review TVA's test data to establish seismic accelerations at failure.
- Calculate the failure stress of test specimens using the failure seismic accelerations and the analytical procedure used to qualify the ductwork.
- Select the lowest failure stress from all test specimens and reduce this failure stress further by subtracting off operating stresses such as pressure and seismic stresses in other directions not simulated in the tests.
- Establish that the lowest failure bending stresses is at least two times the code allowable stress.
- Select 1.5 as the multiplying factor for interim operability.

Details of the tests and the results of the calculations are described below.

The test program was conducted by TVA (Reference. 1), in which a range of 12 full sized, insulated rectangular ducts were tested to failure when subjected to single axis, random multifrequency dynamic loading. The ducts were fabricated to Sheet Metal and Air-Conditioning National Association (SMACNA) standards, identical with those used at BFN, having 20 or 22 gauge thickness and fabricated with either companion angle or pocket lock type joints. Pocket lock ducts are connected by the use of crimped pockets at the end of each duct segment. Companion angle ducts have angle iron sections attached to the ends of each duct segment which serve as flanges for bolting the ducts together. Duct spans were equivalent to those specified in the TVA Design Guide for seismic qualification of HVAC ductwork, which was developed from SMACNA standards and used seismic response spectra peaks for load determination. In order to simulate these conditions, the test fixtures used variable stiffness supports which enabled tuning of the system frequency to the peak of the Required Response Spectrum (RRS), therefore producing the most severe loading condition. This spectrum had a zero period acceleration of approximately 1.5g and a peak of 6.4g from 8 to 12 Hz. Strain gages and accelerometers were mounted on the shake table and duct specimen to measure input excitation and response. System frequencies and damping values were confirmed by sine sweep testing. After random multifrequency testing at the RRS level, input was incrementally applied until either duct failure or the shake table limit occurred.

The range of duct size and thickness tested are shown below:

TYPE CONSTRUCTION	DUCT SIZE	SKIN THICKNESS	DUCT LENGTH	SPAN LENGTH
Companion Angle	60" x 24"	20 ga. (0.0359")	31.3'	28'
Companion Angle	24" x 60"	20 ga. (0.0359")	23.5'	16'
Companion Angle	48" x 18"	22 ga. (0.0299")	27.5'	26'
Companion Angle	18" x 48"	22 ga. (0.0299")	19.5'	14'
Companion Angle	36" x 24"	22 ga. (0.0299")	23.5'	22'
Companion Angle	24" x 36"	22 ga. (0.0299")	23.5'	16'
Pocket Lock	60" x 24"	20 ga. (0.0359")	31.3'	28'
Pocket Lock	24" x 60"	20 ga. (0.0359")	23.5'	16'
Pocket Lock	48" x 18"	22 ga. (0.0299")	27.5'	26'
Pocket Lock	18" x 48"	22 ga. (0.0299")	19.5'	14'
Pocket Lock	36" x 24"	22 ga. (0.0299")	23.5'	22'
Pocket Lock	24" x 36"	22 ga. (0.0299")	19.5'	16'

The onset and mode of failure depended upon the type of duct joint. With companion angles, at levels of excitation corresponding to the RRS, small tears and buckled regions ranging from small creases to approximately 1 square foot areas originated at duct corners usually near the mid-span with very little propagation until failure levels were experienced. General failure was a gradual, ductile mode with no complete separation or breaching of the pressure boundary.

Pocket lock type ducts also exhibited very high capacities. The pocket lock connections are more flexible than the companion angle type and allowed a certain amount of relative displacements between duct sections. This effect greatly increased the energy absorption of these ducts. At RRS levels, no failures occurred, though residual sagging of the duct was present due to the loosening of the pocket lock connections. Ultimate failure of the ducts occurred as either plastic hinge formation within the span or separation of the individual duct sections at the pocket lock connections.

The ultimate capacities, in the form of peak accelerations, for the test specimens are shown below:

FAILURE RUN	DUCT SIZE	TEST AXIS	PEAK ACCL. (g)	CALCULATED FAILURE STRESS (ksi)
Companion Angle				
35	60" x 24"	Major	10.2	45.0
41	36" x 24"	Major	10.5	28.2
43	48" x 18"	Major	11.2	38.5
56	60" x 24"	Minor	14.0	51.7
64	48" x 18"	Minor	12.3	34.8
71	36" x 24"	Minor	13.6	29.2

FAILURE RUN	DUCT SIZE	TEST AXIS	PEAK ACCL. (g)	CALCULATED FAILURE STRESS (ksi)
Pocket Lock				
83	36" x 24"	Major	12.0	28.5
95	48" x 18"	Major	16.2	45.2
105	60" x 24"	Major	14.5	48.5
112	36" x 24"	Minor	12.0	25.2
120	48" x 18"	Minor	11.5	27.2
131	60" x 24"	Minor	16.0	45.7

Structural damping was also measured in the testing program. The companion angle type ducts showed an average of 6.8 percent critical damping, due in part to the energy absorption associated with the gaskets and bolts used to connect the sections. The pocket lock type ducts showed an average of 9.6 percent damping. The higher damping can be attributed to the flexibility associated with the crimping used in securing the pockets which connect the sections.

The failure accelerations experienced in the test program greatly exceeded the required values for the appropriate duct suspension elevations at BFN. The peak BFN amplified response spectrum is 3.6g at 7 percent damping, compared to the test 6.4g at this damping. Furthermore, at the time when failure was actually induced, each specimen had experienced the equivalent of several safe shutdown earthquakes, since the fragility testing occupied several runs above the RRS level, which itself was almost 80 percent higher than the BFN maximum RRS. It may be concluded that the testing was fully representative of the installed duct construction and test levels and durations were considerably in excess of required response levels.

Analysis of the test results, using the acceleration levels sustained at failure and the SMACNA, reference 2, four-corner effective section method, indicated a bending stress at failure ranging from 25.2 to 51.7 ksi as shown in the last column of the above table. However, the testing did not include operational or accident condition parameters such as pressure and seismic excitation in other axes.

These effects were calculated by conventional structural analysis and subtracted from the minimum failure stress of 25.2 ksi, giving a value for the maximum applied load bending capacity of 16.3 ksi.

Since the SMACNA allowable bending stress is 8.0 ksi (Reference 2) for normal design purposes, then this maximum applied load capacity is 2.04 times the design allowable stress. A factor of 1.5 was selected for use as the operability criterion resulting in a factor of safety of 1.33 based on conservative methods and tests.

REFERENCES:

1. Summary Report for HVAC Ducts Seismic Qualification, TVA Report No. MA2-79-1, June 16, 1979.

2. Rectangular Industrial Duct Construction Standards, Section 9, SMACNA, 1980.