UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 14 1984

Docket Nos.: 50-329 OM, OL
and 50-330 OM, OL

APPLICANT: Consumers Power Company

FACILITY: Midland Plant, Units 1 and 2

SUBJECT: SUMMARY OF OCTOBER 4-7, 1983 AUDIT AND MEETING ON THE MIDLAND HEATING, VENTILATION AND AIR CONDITIONING SYSTEMS

On October 4-7, 1983 NRC staff members from NRR and Region III met with Consumers Power Company and Bechtel to audit and discuss the safety-related portions of the HVAC systems for Midland Plant, Units 1 and 2. Enclosure 1 is a summary of the audit and meeting.

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Enclosure:
As stated

cc: See next page

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Enclosure 1

Staff Design Review and Audit of the Midland HVAC System

On October 4-7, 1983, staff representatives from Region III and NRR met with the applicant (Consumers Power Company) and its architect-engineer (Bechtel Power Corporation - Ann Arbor Office) to audit and discuss the design of the Midland HVAC system. The staff reviewed the structural and systems design, and materials records. Meeting attendees are listed by Attachment A.

I. Structural Design

The review of the structural design of the Midland HVAC system was divided into two parts. First, a review of the HVAC design specifications, design criteria, procedures, and HVAC duct work calculations was performed at the Bechtel (Ann Arbor, MI) office. Second, an audit of the HVAC component support calculations was performed at the Midland plant site.

The Bechtel organization is such that Bechtel resident engineering (Ann Arbor office) developed the HVAC design specifications, design criteria, and procedures. In addition, the calculations to qualify the HVAC duct work was performed by the Ann Arbor office. The Bechtel field engineering used the design procedures to qualify the HVAC component supports onsite as the design and installation of the HVAC system progressed. Details of the resident engineering review and the field engineering review are discussed in the following sections.

HVAC Review Performed at Bechtel (Ann Arbor) Office

On October 4, 1983, the staff met in Ann Arbor, Michigan with Consumers Power and Bechtel to review and audit the Midland HVAC system design. The purpose of the meeting was to evaluate the potential significance of using materials which cannot be determined to conform to their specifications. From a structural integrity standpoint, the staff's purpose was to assess the actual design margins that exist in the HVAC ducting, supports, bolts, and welds to determine if the strength variability of potential material substitutions could affect the ability of the HVAC system to perform its intended function.

Bechtel first explained the division of responsibility between its resident and field engineering groups for the HVAC design. In 1977, the HVAC support design was performed in Ann Arbor. In 1978, Bechtel established a field engineering group to resolve non-conformance reports (NCRs) and other field-related items. Currently, all civil/structural work for HVAC design is performed at the site. Supporting work is performed in Ann Arbor. Bechtel noted that they do not have a separate HVAC design group. The mechanical engineers are responsible for the HVAC systems design and the civil/structural engineers are responsible for the structural design (restraint members, ducting, bolts, stiffeners, etc). The HVAC structural members are designed to the same design criteria as the building steel (AISC Code).

The staff requested the design specification, design criteria, and analytical procedures used for the design of HVAC ducting, supports, and bolts. Attachment B to this report lists the documents reviewed by the staff.

The staff questioned why Bechtel was using an unapproved draft procedure for the design of HVAC supports and ducting. Bechtel stated that the procedure they have used was based on separate memoranda and individual procedures that were formally issued. The draft design guide was a compilation of the separate procedures. Bechtel stated that they intend to formally issue the draft design guide for HVAC supports by October 31, 1983.

The staff asked if Bechtel follows the design rules of SMACNA standards. Bechtel stated that they do not use SMACNA standards; rather, they use a generic design as shown in drawings C-842 through C-849.

Bechtel explained the seismic design approach for the HVAC system. The M-151A design specification stipulates that the ducting span between supports shall not exceed 8 feet (2 feet for a cantilever). This "8 ft" criterion is applicable for all HVAC rectangular duct sizes. If the 8-ft criterion is exceeded, the M-151 specification requires that the exceedance be noted on the drawings. A unique calculation would subsequently be performed using the design guide to qualify the exceedance. Bechtel noted that in reviewing their HVAC drawing, there were approximately 170 spans that exceeded the 8-ft criterion (affecting 340 supports). The largest span that exceeded the 8-ft criterion was approximately 11 feet.

The staff asked Bechtel for the basis of the 8-ft span criterion. Bechtel stated that the 8-ft span was conservatively selected to limit all HVAC duct sizes to a rigid frequency range (greater than 33 hertz). The lowest frequency calculated for all the duct sizes was approximately 55 hertz. Thus, the HVAC ducting when limited to an 8-ft span would not be subjected to the resonant peak accelerations induced by the building response during a seismic event.

The staff reviewed the design specification for HVAC installation (M-151). The staff noted in Section 5.0 of the specification that several types of material are listed for sheet metal and structural members. However, the specification does not specify the particular application for which the various materials are to be used. Bechtel stated that no "exotic" materials are specified. The staff noted that some of the structural steel materials do have minimum yield strengths greater than the typical A36 steel yield strength of 36 ksi; however, it was not clear where these materials were used. Bechtel replied that all materials are stated on their design drawings and that all high-strength materials used (if any) are, thus, identifiable.

The staff reviewed the calculation (Calc. No. SQ-180-Q) for the qualification of the ductwork and stiffeners for the maximum loading. The calculation was based on the 8-ft duct span length and assumed a duct yield strength of 30 ksi and a stiffener yield strength of 36 ksi. The calculation was performed for various duct sizes and was based on an empirical formula derived from testing performed for the Limerick plant. In the calculation, the effects of seismic loads were translated into equivalent pressure loads. Bechtel provided the staff with a summary of the HVAC duct analysis results (Attachment C). The summary shows that for all duct sizes the average design margin to failure is approximately a factor of 4. The most limiting duct is a 108" x 16" duct located in the Auxiliary Building which has a design margin of 1.40. The critical failure mode is stiffener buckling.

HVAC Review Performed at Midland Site

On October 5-6, 1983, the staff met with Consumers Power Company and Bechtel at the Midland site. The staff's review of structural aspects of the HVAC system was divided into **five major** aspects:

1) review of the design guide for HVAC supports,

2) review of the HVAC duct calculation for spans greater than 8 ft,

3) review of the HVAC support calculations to determine design margins,

4) visual observation of the HVAC system installed in the plant, and

5) review of test report for HVAC duct seismic qualification.

The procedure used by Bechtel to calculate HVAC support loads is in a draft design guide entitled, "Design Guide for HVAC Supports (DRAFT)," Calc. No. 34-71(Q). In addition, for the qualification of HVAC duct spans greater than 8 ft, Bechtel used the draft design guide entitled, "Design Guide for Nuclear Power Plant Seismic Category I Rectangular HVAC Ducts (DRAFT)." The HVAC ducting within the 8ft-span criterion was qualified by testing performed by Bechtel for the Limerick plant and analytically qualified for Midland in the Calc. No. SQ-180(Q), Rev. 0. The 8-ft criterion was established conservatively for convenience, resulting in a generic HVAC support design based on maximum (8-ft) spans and maximum loadings.

1) Review of HVAC Support Design Guide

The staff reviewed the Draft HVAC Support design guide (calc. No. 34-71 Q). Bechtel noted that the seismic response spectra used for the HVAC support design is conservative. The supports (welded structures) are designed using a damping value of 2% for both OBE and SSE loads. Damping values allowed by Regulatory Guide 1.61 for welded steel structures are 2% for OBE and 4% for SSE. The ratio of the maximum peak acceleration for the SSE at 2% to the maximum peak acceleration for the SSE at 4% is approximately 1.4. Thus, at the maximum peak acceleration, the use of the 2% damping results in an additional design margin of approximately 1.4 for welded steel structures.

The HVAC duct is more rigid than the HVAC supports because of the 8-ft span criterion. Typically, the HVAC duct fundamental beam bending frequency between support spans of 8 ft is approximately 150 hertz (with the lowest frequency approximately 55 hertz) whereas the fundamental frequency of HVAC supports are typically less than 33 hertz.

The welds for HVAC supports are governed by AWS D1.1-72. Weld tensile strength is assumed to be 60 ksi for E60 electrode. For a 3/16" fillet weld the allowable weld strength is equal to:

$$(3/16)(0.707)(0.3)(60,000) = 2386 \text{ lbs/inch}$$

For accident conditions, a 50% increase in the design allowable is used, resulting in an allowable strength of 1.5 x 2386 = 3579 lbs/inch. The design margin to tensile failure is, thus, 1/(0.3)(1.5) = 2.22 at the accident condition allowable weld strength.

The structural steel used for the HVAC support member is designed in accordance with the AISC, "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings."

In Section 4.5.1 of the Design Guide for HVAC Supports, the allowable stresses for the structural steel and tube sections were given as follows:

Allowable stress in accident conditions:
bending and torsion = 0.9 Fy
shear = 0.5 Fy

where Fy is the material yield strength.

The applicant noted that with regard to Section 4.5.5 of the design guide, their internal design audit had identified that for expansion anchor bolts, the prying action of the baseplate was to be ignored. This item is considered to be open and is to be resolved by Bechtel. In accordance with IE Bulletin 79-02, the effect of prying action of the baseplate on the anchor bolts needs to be considered for the anchor bolt loads.

The staff identified a second concern in the review of the HVAC duct flange bolting. The generic design detail shown on Dwg. No. C-844(Q) specifies a 3/8-inch bolt with a 6-inch maximum spacing for the duct flanges. However, the design guide does not require a calculation for the duct flange bolt loads. Consequently, it was not evident that the 3/8-inch bolts in the duct flanges were qualified for seismic loadings and, thus, the staff was not able to quantify the bolt design margin. At the meeting, Bechtel performed an informal calculation using the worst case loadings and found that the stresses in the flange bolts are acceptable. For a 30 x 30 inch duct with an 8-ft span, the maximum loading resulted in a loading of the bolts to 25% of its ultimate tensile strength. The shear load was shown to be less governing than the tensile load and is, thus, also acceptable. Bechtel stated that they will document the calculation for the 3/8-inch bolts and provide them to the staff when completed.

2) Review of the Calculation for Exceedance of 8-ft Span

The staff reviewed the calculation performed by the Bechtel site engineering when the duct span between supports exceeded the 8-ft maximum criterion provided in the M-151 specification (Calc. No. 34-293(Q) Revision 0). The span of the duct audited was 11.08 ft. The calculation did not calculate the frequency of the duct, but rather used the maximum peak acceleration of the building seismic response spectra to calculate the support loads. The maximum peak accelerations were multiplied by a factor of 1.5 to account for higher mode response contribution. The duct stresses met the allowable of 0.9 Sy for SSE (27,500 psi) and 0.6 Sy for OBE (18,000 psi). Buckling was checked and found acceptable. The shear stress was checked and found to be 6226 psi with an allowable of 0.5 Sy (15,000 psi).

3) Review of Design Margins

The staff reviewed several calculations selected at random for safety-related HVAC supports. The calculated stresses for the structural steel, welds, and expansion anchor bolts are tabulated in Attachment D to this report. The calculated stresses are shown as a percentage of the allowable value (i.e., for an allowable stress of 30,000 psi, a calcualated stress value of 15,000 psi will be tabulated as 0.50). It should be noted that in Calc. No. 648-S 1.26 (Rev. 0) for a structural tube steel member purchased to a yield strength of 46 ksi, the calculation conservatively used a yield strength of 36 ksi. Other conservatisms noted in the calculation included grouping similar member sizes and using the largest loading in each direction (axial, bending, and torsion) for the interaction equation. Similarly, weld sizes were grouped to determine the maximum stress.

In reviewing the ratio of the calculated stress to allowable stress, it can be seen that the anchor bolt and welds tend to be the controlling component in HVAC support design. The structural steel members are generally frequency-controlled. Thus, the stresses in the structural steel members are typically small compared to the allowable stress (10-20 percent of the allowable stress) whereas the stresses in the anchor bolt are typically large relative to the structural steel stress (greater than 50% of the allowable stress). It should be noted that expansion anchor bolts are designed with a margin of safety of four to its tensile capacity (i.e., the allowable stress is equal to one-fourth of its tensile strength). The factor of safety provided in IE Bulletin 79-02 accounts for anchor failure due to bolt slippage, not tensile failure. Thus, the use of substitute material for expansion anchor bolts does not appear to be a significant concern when bolt slippage is more likely to be the mode of failure rather than bolt tensile failure. .

4) Visual Observation of HVAC Systems

The staff inspected several areas of the Midland plant where safety-related HVAC systems are installed. The purpose of the visual tour was to gain a better understanding of the installed HVAC structural design and to observe and identify any potentially critical areas.

The staff noted that extensive use of room coolers is made at Midland, and thus the amount of HVAC ducting actually used in the Midland plant is small compared to other nuclear plants. Approximately 8000 lineal feet of safety-related ductwork is used at Midland.

The areas of the plant viewed by the staff were:

a) Diesel Generator Building,
b) ESF Pump Room (B),
c) Fuel Handling Area,
d) Inside Containment,
e) Switch Gear Room,
f) Lower Cable Spreading Room,
g) Upper Cable Spreading Room,
h) HVAC Equipment Room, and
i) Control Room

Staff comments and observations during the tour follow for each area inspected.

a) Diesel Generator Building

The 8-ft-span criterion appears to be met and appears very conservative for the large ducting in this building. The duct looks very rigid. The supports and duct appear overdesigned. The welds and bolts appear to be the critical component for the HVAC structural integrity.

b) ESF pump Room B

The 8-ft span criterion appears to be met. Room coolers have been used in all ESF Pump Rooms. The only ducting in the room is a round 10-inch (10-gauge) duct used for cooler exhaust.

c) Fuel Handling Area

The 8-ft span criterion appears to be met. The supports and duct look similar to those in the diesel generator building.

d) Inside Containment

Reactor building fan coolers have been used inside containment. There is very little ducting, except for two long vertical round ducting (approximately 3 feet O.D.) along containment wall. The containment spray lines are routed in front of the vertical ducting. The ducting is not safety related but is seismically supported. In two locations the duct spans appear to exceed the 8-ft criterion. If the ducting fails, the containment spray lines could be impacted. The ducting was not installed by Zack.

e) Switch Gear Room

An HVAC support was found severed. An attached tag identified that a material sample was taken by MPQAD (RIII sample for testing by Franklin Institute).

f) Lower Cable Spreading Room

No significant observations.

g) Upper Cable Spreading Room.

No significant observations.

h) HVAC Equipment Room

The seismic building response in the horizontal direction could be amplified significantly in the top floor of the control tower. A large quantity of heavy HVAC equipment and large size ducting is suspended from the ceiling.

i) Control Room

A large quantity of HVAC ducting is suspended from the ceiling. The ducting is very tightly packed, and it was difficult to see supports above the ducting. The Independent Design and Construction Verification Program being performed by the TERA Corporation provides for third party assessment of the control room HVAC system.

5) Review of HVAC Ductwork Test Report

On October 6, 1983, the staff reviewed a report on testing of HVAC ductwork specimens performed by Bechtel for the Limerick Generating Station. The test results were used to develop the empirical formula utilized in the design guide, "Design Guide for Nuclear Power Plant Seismic Category I Rectangular HVAC Ducts."

The testing was performed by Hales Testing Laboratories of Oakland, California. The testing was based on A526 and A527 ductwork material with a minimum yield strength of 36 ksi. The significant conclusions of the testing included the following results.

- Failure modes of the ducts were not catastrophic and there was a great reserve strength after failure.
- Pressure loading was the most important loading. Live load and seismic loads were less important.
- Effects of seismic loads can be simulated by pressure loads.
- The primary failure modes of rectangular ducts were by corner crippling of sheet and by stiffener buckling.
- Live load stresses in the sheet and stiffeners were low.

The staff's review of the test report, and of the design guide for HVAC ductwork which was developed from the test results, resulted in the following concern:

The design specification (M-151) requires that HVAC duct material A526 and A527 be provided with a minimum yield strength of 30 ksi. (Note: the ASTM Specification for A526 and A527 does not require a minimum yield strength). Zack purchase orders were reviewed and found to have specified a 30 ksi minimum yield stress. Several invoices were also reviewed and the A526 and A527 material for safety-related ducting was found to have met the 30 ksi minimum yield strength. However, the design guide for HVAC ductwork states that the minimum yield strength should be 36 ksi. The empirical formula in the design guide is not based on a specific minimum yield strength but includes a term, Fy, for the applicable material minimum yield strength. However, the design tables which were generated using the empirical formula and provided in the design guide are based on a 36 ksi minimum yield strength. Thus, it is not clear to the staff that the design guide (which was apparently developed for Limerick) has been properly used for the Midland HVAC duct calculations where the duct spans exceed 8 ft. The design guide does appear to have been properly used for the qualification of the 8-ft span as reviewed in Calc. No. SQ-180(Q), Rev. 0. However, the staff has not seen evidence that the design guide was used in the duct stress calculation for the approximately 170 duct spans which exceeded the 8-ft criterion. The staff requested that the applicant provide these additional calculations which used the design guide for HVAC duct calculations where the 8-ft span criterion was exceeded.

Summary of Unresolved Audit Findings

The following is a summary of the unresolved concerns identified by the staff in the structural aspects of the HVAC design audit performed for the Midland plant. These need to be resolved before a final determination of the design margin can be established.

1) It is not evident that Bechtel is properly using the design guide for HVAC ductwork to qualify the ductwork when the span between supports exceeds 8 feet. The applicant will provide a clarification of the design guide procedure.

2) The two seismically supported HVAC ductworks which are not safety related are routed vertically along the containment wall appear to have duct spans exceeding the 8-ft criterion. The applicant will provide the basis for assuring that the duct has been properly qualified for seismic loads.

3) The expansion anchor bolts in the HVAC support baseplates appear to be the most limiting component in the HVAC structural design. Prying action of the baseplate on the bolts have been ignored according to the design guide for HVAC supports. The applicant will provide the effect of the prying action on the bolts in order to establish its impact on the bolt design margin.

4) The qualification of HVAC duct flange bolts (3/8") has not been properly documented for the applicable loadings. The applicant will provide a documented calculation to qualify the 3/8" duct flange bolts in order to establish the bolt design margin.

A follow up meeting will be scheduled to discuss these unresolved findings.

II. Systems Design

The NRC's systems review of the Midland HVAC design was performed to assess functional design requirements of these systems and to verify whether or not the conclusions stated in Section 9.4 of the Midland SER (NUREG-0793, May 1982) are still valid for the actual HVAC system design at Midland.

On October 4, 1983 in Ann Arbor, the staff reviewed the latest drawing revisions of the Midland HVAC systems and compared them with the earlier drawing revisions upon which the staff's FSAR review had been based. A particular focus of this review was on transition points and isolation capabilities between safety-related and non-safety-related portions of the systems as described in the FSAR in order to assure that any changes had been appropriately considered in the design of the structural supports.

The systems design reviewer also participated in the HVAC tour at the Midland site on October 5, 1983.

III. Materials Review

Material aspects of the Midland HVAC systems were audited October 6-7, 1983 at the Midland site. The purpose of the review and audit was to verify that the materials incorporated into the construction met the requirements called out in the design and procurement documents.

The identification of materials for use in the Midland HVAC systems is contained in Bechtel Technical Specification 7220-M-151A(Q), "Seismic Class 1 Heating Ventilation and Air Conditioning Equipment and Ductwork Installation for the Consumers Power Company, Midland Plant Units 1 and 2, Midland, Michigan." Revisions to this Specification had been made during construction to incorporate into the Specification those deviations that were considered to be acceptable. These deviations were originally accepted by QC documents such as Supplier Deviation Deficiency Requests (SDDRs), Specification Change Notices (SCNs), and Field Change Requests (FCRs). Revision 16 to the Specification was in effect during this audit.

Procurement packages for HVAC materials were also reviewed during the audit.

IV. Staff Conclusions

Staff conclusions resulting from this audit will be provided by separate report in early 1984, after a further meeting to discuss resolution of the unresolved items from the structural review.

Attachment A

NRC HVAC Audit
Attendance

I. Ann Arbor Meeting

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Jon Rysdon	Bechtel Civil, AAO
D. R. Anderson	Bechtel Resident Project Engineer
F. Hawkins	NRC-RIII
Dennis England	CPC Nuc. Lic.
J. N. Leech	CPCo Licensing
V. P. Provenzano	CPCo Licensing/Legal
D. Terao	NRC/MEB
W. T. LeFave	NRC/DSI/ASB
Darl S. Hood	NRC/DL/LB4
Frank Hand	CPCo/Civil Consultant
G. D. Eichenberger	CPCo/Material
S. S. Petel	Bechtel/AL
John Gunning	Bechtel/Lic.
Rob Burg	Bechtel/Licensing
Arun Amin	Bechtel/Mech.
W. H. Nielson	Bechtel Construction (AZ)
G. L. Richardson	Bechtel/Proj. Mgt.
Glen E. Crosby	Bechtel/QA
F. H. Lentz	CPCo/QA
James E. Baiers	Clark, Klein
P. V. Regupathy	Bechtel/Civil
Douglas M. Witt	TERA
E. M. Hughes	Project Engineer
R. C. Hollar	Bechtel PQE
G. Borsteins	Bechtel-Mech. Staff
R. Nicolaus	Bechtel-Mech.
B. Heiberger	CP MPQAD-HOACA
D. Scribner	Bechtel/Civil Staff
R. L. Tenteberg	CPCo/Mechanical Proj. Eng.
Terry Postlewait	CPCo/Mech. Proj. Engrg.

Attachment A (Continued)

II. Midland Site Meeting

Name	Organization
J. G. Balayer	CPCo, SMO
Gary Tree	BPCO Civil Resident
Carl Miller	BPCO Resident QE
David Terao	NRC/NRR/MEB
Darl Hood	NRC/NRR/DL/LB4
F. Hawkins	NRC/RIII
W. T. LeFave	NRC/NRR/ASB
Frank Hand	CPCo Civil
James Baiers	Clark, Klein
D. T. Scribner	Bechtel/Civil Staff
B. J. Boulton	CPCo, Proj. Engr. - Jackson
B. Heiberger	MPQAO-HVACA
D. England	CPCo Legal/Licensing
V. P. Provenzano	CPCo Legal/Licensing
Sol Esperanzh	Bechtel RE HVAC
A. Amin	Bechtel/Mechanical
Andrew Fok	Bechtel/Civil
Tom Supplee	Bechtel R. E. Plant Design HVAC
C. D. Sellers	NRC/NRR/MTEB

Attachment B
List of Documents Reviewed

Documents Reviewed at 10/4/83 Meeting

1. Design Specification "Technical Specification for Seismic Class I Heating, Ventilating, and Air Conditioning Equipment and Ductwork Installation," Revision 15 (including SCN 32-36). Specification No. 7220-M-151A(Q).
2. Design Criteria "Civil and Structural Design Criteria for the Midland Nuclear Plant, Units 1 and 2," Revision 12, Specification No. C-501(Q).
3. Design Procedures "Design Guide for Nuclear Power Plant Seismic Category I Rectangular HVAC Ducts (DRAFT)," dated April 15, 1978.
4. Calculations for ductwork/stiffeners, Calculation No. SQ-180(Q), dated 5/16/83, Rev. 0.
5. Drawings C-842 thru C-849 (generic duct construction details); C-850 thru C-999 (duct support details); C-1200 (duct support details); C-1300 (duct support details)
6. HVAC Hanger Log (computer listing) - uncontrolled document

Documents Reviewed at 10/5/83 Meeting

1. Calculations "Design Guide for HVAC Supports (DRAFT)," Calc.No. 3471(Q)
2. Calc.No. 34-62 (Q) dated 8-25-82
3. Calc.No. 34-39 (Q) dated 11/5/81
4. Calc.No. 21G (4.413)(Q) Rev. 0
5. Calc.No. 21G (4.146)(Q) Rev. 0
6. Calc.No. 29D.276 (Q) Rev. 0
7. Calc.No. 648-S 1.26 (Q) Rev. 0
8. Calc.No. 21F (3.136)(Q) Rev. 0
9. Calc.No. 21I (6.95 (Q)
10. Calc.No. 34-292 (Q) Rev. 0

Design Specifications

11. Design Specification Q-7 (Containment Building Response Spectra)
12. "Report on Testing of Class 1 Seismic HVAC Duct Specimens for the Limerick Generating Station, Units 1 and 2," April 1976.

Attachment C

Summary of HVAC Duct Analysis Results(3)

Dust Size (inches)(1)	Sheet Metal Gauge	Stiffener	Allowable Pressure (psi) Sheet Metal	Allowable Pressure (psi) Stiffener	Governing Allowable Pressure (psi)	Calculated Worst Loading (psi)(2)	Design Margin
Control Room (Aux Bldg)							
60x26	18	L2x2x3/16	0.86	0.69	0.69	0.294	2.35
36x26	16	L1½x1½x1/8	1.40	1.40	1.40	0.301	4.65
Diesel Generator Bldg							
60x60	16	L2x2x3/16	1.082	0.691	0.69	0.253	2.73
30x40	16	L1½x1½x1/8	1.322	1.40	1.32	0.253	5.22
Service Water Pump Structure							
72x44	16	L3x3x3/16	1.064	1.102	1.102	0.230	4.79
72x24	18	L3x3x3/16	0.865	1.102	0.865	0.223	3.88
52x44	16	L2x2x1/16	1.237	0.98	0.98	0.230	4.26
42x26	18	L1½x1½x1/8	1.111	0.94	0.94	0.223	4.22
28x26	18	L1½x1½x1/8	1.408	1.04	1.04	0.223	4.66
Auxiliary Building							
108x16	14	C 3x5.0	1.14	0.47	0.47	0.335	1.40
108x16	14	C 5x6.7	1.14	1.25	1.14	0.628	1.75
60x32	18	L2x2x3/16	1.15	0.69	0.69	0.326	2.12
38x38	16	L1½x1½x3/16	1.44	1.22	1.22	0.330	3.70
76x40	16	L3x3x3/16	1.04	0.97	0.97	0.254	3.82
50x40	16	L2x2x3/16	1.25	1.08	1.08	0.259	4.17
54x36	18	L2x2x3/16	0.98	0.89	0.89	0.320	2.78
28x14	18	L1x1x1/8	1.41	1.05	1.05	0.234	4.49
24x24	18	L1x1x1/8	1.56	1.59	1.56	0.223	7.00
12x6	18	L1x1x1/8	2.59	11.10	2.59	0.234	11.07
60x36	16	L3x3x3/16	1.15	1.70	1.15	0.593	1.94

(1) Largest duct size for the same gauge sheet metal and stiffener.

(2) Worse case loading is Dead Load + P + W, where P = operating pressure, W = wind load. The worst case loading bounds seismic load combinations.

(3) Summary of results from Bechtel Calc. No. SQ-180(Q) dated 5/16/83. Stresses due to dead load, seismic load, wind and internal pressures are converted to equivalent internal pressure loads for comparison.

Attachment D

Ratio of Calculated to Allowable Stresses for HVAC Ducts and Supports

Location	Calc. No.	Description	Calculated Stress / Allowable Stress
Control Room	21 G (4.4143)	W 6 x 12	0.23
		L 3 x 3 x ¼	0.19
		L 2 x 2 x ¼	0.13
		L 2 x 2 x ¼	<0.13
		L 3½ x 3½ x ¼	0.05
		weld	0.76
		weld	0.10
		weld	0.61
		weld	0.51
Control Room	21 G (4.146)	all structural members	0.48
		weld	0.03
		anchor bolt	0.50
Control Room	29 D 276	L 3 x 3 x ¼ (all)	0.33
		W 6 x 12	0.04
		TS 2 x 2 x ¼	0.04
		weld	0.42
		weld	0.73
		weld	0.57
Service Water Bldg	648-S126	TS 3 x 3 x ¼	0.15
		TS 2 x 2 x ¼	0.09
		L 2 x 2 x ¼	0.13
		weld	0.03
		weld	0.12
		weld	0.68
		weld	0.06
		weld	0.35
		anchor bolt	0.40
		anchor bolt	0.88
		anchor bolt	0.64
		anchor bolt	0.80
Auxiliary Bldg	21 F (3.136)	L 2 x 2 x ¼	0.13
		TS 2 x 2 x ¼	0.14
		weld	0.04
		weld	0.20
		weld	0.15
		weld	0.04
		anchor bolt	0.58
		anchor bolt	0.34

Attachment D (Continued)

Location	Calc. No.	Description	Calculated Stress / Allowable Stress
Auxiliary Bldg	21 I (6.95)	TS 4 x 4 x ¼	0.32
		TS 2 x 2 x ¼	0.48
		L 2 x 2 x ¼	0.36
		PL ½ x 18	0.13
		weld	0.40
		weld	0.35
		weld	0.15
		weld	0.24
		weld	0.29
		weld	0.25
		weld	0.10
		weld	0.23
		weld	0.32
		L 4 x 4 x ½	0.44 (shear controlling)

REFERENCE b