SECTION 5

CONTAINMENT SYSTEM

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SECTION 5 CONTAINMENT SYSTEM

5.1 SUMMARY DESCRIPTION

Units 1 and 2 are structurally isolated. No portion of either containment structural system is shared. However, some parts of the Containment Vessel Air Handling Systems are shared. The following subsections, except the sections concerning the Containment Vessel Air Handling System, are presented for a single Unit and are equally applicable to either Unit.

The total containment for each unit consists of two systems:

a. Primary Containment System consists of a steel structure and its associated engineered safety features systems. The Primary Containment system, also referred to as the Reactor Containment Vessel, is a low-leakage steel shell. The system, including all its penetrations, is designed to confine the radioactive materials that could be released by accidental loss of integrity of the Reactor Coolant System pressure boundary. Systems directly associated with the Primary Containment System include the Safety Injection, Containment Vessel Internal Spray, Containment Vessel Air Handling and Containment Isolation Systems.

b. The Secondary Containment System consists of a Shield Building with its associated engineered safety features systems and the Category I Ventilation Zone with its associated engineered safety features systems.

   The Shield Building is a medium-leakage concrete structure surrounding the Reactor Containment Vessel and designed to provide:

   1. biological shielding for Design Basis Accident conditions;

   2. biological shielding for parts of the Reactor Coolant System during operation;

   3. protection of the Reactor Containment Vessel from low temperatures, adverse atmospheric conditions, external missiles; and

   4. a means for collection, recirculation and filtration of fission-product leakage from the Reactor Containment Vessel following the Design Basis Accident. The Shield Building Ventilation System is the engineered safety feature utilized in the Secondary Containment System. 01150384 01097490

The Category I Ventilation Zone provides a medium-leakage boundary which confines leakage that could conceivably by-pass the Shield Building Annulus. A detailed description of the Auxiliary Building Special Ventilation System, which is associated with the Category I Ventilation Zone, can be found in Section 10.3.4. Potential leakage pathways are discussed in Appendix G.

The Reactor Containment Vessel is a cylindrical steel pressure vessel with hemispherical dome and ellipsoidal bottom which houses the reactor pressure vessel, the steam generators, reactor coolant pumps, the reactor coolant loops, the accumulators of the Safety Injection System, the primary coolant pressurizer, the pressurizer relief tank, and other branch connections of the Reactor Coolant System.

The Reactor Containment Vessel is completely enclosed by the Shield Building. The Shield Building has the shape of a right circular cylinder with a shallow dome roof. An annular space of 5 feet is provided between the wall of the Reactor Containment Vessel and the Shield Building. A 7-foot clearance is also provided between the roofs of the Reactor Containment Vessel and the Shield Building.

The Reactor Containment Vessel is supported on a grout base that was placed after the vessel construction was complete and tested. Both the Reactor Containment Vessel and the Shield Building are supported on a common foundation slab. Appendix E contains a report on the foundation conditions.

Freedom of movement between the Reactor Containment Vessel and the Shield Building is virtually unlimited. With the exception of the support grout placed underneath and near the knuckle sides of the vessel, there are no structural ties between the Containment Vessel and the Shield Building above the foundation slab.

Insulation is not required for the Reactor Containment vessel or the Shield Building.

The Containment Systems are designed to provide protection for the public from the consequences of a Design Basis Accident as defined in Appendix K. The accident is a design condition based on an instantaneous double-ended rupture of the cold leg of the Reactor Coolant System. Pressure and temperature behavior subsequent to the accident was determined by calculations evaluating the combined influence of the energy sources, heat sinks and engineered safety features. These are discussed in detail in Appendix K.

The sources available for the release of energy and materials into the Containment System following a design bases loss of coolant accident are:

Stored heat in the reactor core and internal structures;

Decay heat from the reactor core;

Stored heat in the materials of Reactor Coolant System:

Metal-water reactions;

Hydrogen combustion;

Reactor coolant and its contained corrosion and fission products;

Fission products in the fuel elements of the core.

The amount of energy released by the major sources during the assumed accident is discussed in Appendix K, along with their post-accident time-related influence on the containment. Energy contribution from the secondary steam system was included in the calculation of Reactor Containment Vessel maximum internal pressure.

Since the design, application and evaluation of the engineered safety features systems are discussed fully in Section 6.1, their relation to the Containment Systems design is only summarized in this section.

Engineered safeguards systems are provided to minimize the consequences of the assumed accident by: removing heat from the fuel, inserting negative reactivity into the reactor, decreasing the pressure of the Reactor Containment Vessel by removing thermal energy, removing radioactive material from the post-accident atmosphere of the Reactor Containment Vessel, and removing radioactive material from the leakage through penetrations in the Reactor Containment Vessel. The principal engineered safety features systems provided for these purposes are:

Safety Injection System

Residual Heat Removal System

Containment Vessel Internal Spray System

Containment Vessel Air Handling System

Shield Building Ventilation System

Auxiliary Building Special Ventilation System

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5.2 PRIMARY CONTAINMENT SYSTEM

5.2.1 Design Criteria

5.2.1.1 Containment System Criteria

The Reactor Containment Vessel is designed for a maximum internal pressure of 46 psig and a temperature of 268°F. The Reactor Containment Vessel design internal pressure as defined by ASME Boiler and Pressure Vessel Code is 41.4 psig. The temperature value of 268°F is specifically for the design of the containment shell. Containment atmosphere temperature could exceed this value provided other evaluations such as EQ, FCU heat removal, etc. are acceptable.

The vessel is 105 ft. inside diameter and contains an internal net free volume of 1,320,000 ft^3.

The vessel plate nominal thickness does not exceed 1-1/2″ at the welded joints so the vessel, as an integral structure did not require field stress relieving. Reinforcing plates at penetration openings exceed 1-1/2″ in thickness; however, these were fabricated as penetration weldment assemblies and were stress relieved before they were welded to adjacent vessel shell plates.

The loadings considered in the design of the Reactor Containment Vessel, in addition to the pressure and temperature conditions described above are discussed in Section 12.2.2.

The Reactor Containment Vessel, including penetrations is designed for low leakage. The initial measured leakage rate was approximately 0.02% by weight in 24 hours at a nominal internal pressure of 46 psig.

5.2.1.2 Containment Auxiliary Systems Criteria

5.2.1.2.1 Reactor Containment Vessel Isolation Systems

Criterion: Penetrations that require closure for the containment function shall be protected by redundant valving and associated apparatus (GDC 53).

Isolation valves are provided as required for fluid system lines penetrating containment to assure that:

a. Leakage through all fluid line penetrations not serving accident consequence-limiting systems is minimized by a double barrier. The double barriers take the form of closed pipe systems, both inside and outside the Reactor Containment Vessel, and various types of isolation valves. The double barrier arrangement provides two reliable low leakage barriers between the Reactor Coolant System or containment atmosphere and the environment. The failure of any one barrier will not prevent suitable isolation;

b. Fluid line penetrations normally serving accident consequence limiting systems can be isolated by manual action if the system should malfunction;

c. No single credible failure or malfunction (expected fault condition) occurring in any active system component can result in loss-of-isolation or intolerable leakage.

An isolation actuation system is provided to automatically close fluid line penetrations used during normal operation but not required for engineered safety features functions. The automatic closure occurs upon a Safety Injection signal or manual initiation, EXCEPT for Instrument Air Isolation valves which requires an additional input from Loop A MSIV Auto Closure Signal or High High Containment Pressure Signal. (See Section 7.)

Actuation signals for the containment isolation system are generated by the same pressure transmitters used for safety injection and MSIV closure. The testing of this instrumentation is the same as for the safety injection system.

5.2.1.2.2 Vacuum Relief System

Vacuum relief devices or systems are provided to protect the Reactor Containment Vessel against excess differential pressures. Such differential pressure conditions (vacuum) may exist inside the Containment Vessel if the Containment Air Cooling Systems are operated with a heat removal capability in excess of the heat inputs at any time during normal or post accident operations.

The vacuum relief valves are sized to assure that the Reactor Containment Vessel will not be subjected to an internal pressure in excess of 0.8 psi below the external pressure. The design basis for sizing the relief system has been identified as the inadvertent and simultaneous operation of all Containment Air Cooling Systems during normal operation or following a plant shutdown, when heat inputs to the containment are minimal and the cooling water temperatures produce the largest heat removal rates for the respective cooling systems. The Containment Air Cooling Systems to be included in the analysis are the two full-capacity Containment Internal Spray Systems and the four containment fan-coil units.

5.2.1.3 Containment Penetrations

5.2.1.3.1 General

To maintain designed containment integrity, containment penetrations have the following design characteristics:

a. They are capable of withstanding the maximum internal pressure which could occur due to the postulated rupture of any pipe inside the Reactor Containment Vessel.

b. They are capable of withstanding the jet forces associated with the flow from a postulated rupture of the pipe in the penetration or adjacent to it, while still maintaining the integrity of containment.

c. They are capable of accommodating the thermal and mechanical stresses which may be encountered during all modes of operation and test.

d. Materials of piping penetrations furnished as a part of the Reactor Containment Vessel are either ASME SA-333 GR. 6 or ASME SA-312 TP304 material. All hot penetrations are fabricated of ASME SA-333 Gr 6. The cold penetrations are fabricated of either of the foregoing materials, but in all cases are compatible with the material of the process line which is to be welded directly to the penetration nozzle.

e. The materials for penetrations, including the personnel access air locks, the equipment access hatch, the piping and duct penetration sleeves, and the electrical penetration sleeves, conform to the requirement of the ASME Nuclear Vessel Code and USAS B 31.1 Code for Pressure Piping and applicable code cases. The process and guard pipes were designed, specified, and fabricated in accordance with the Code for Pressurized Piping, ANSI B31.1-1967, without the use of code cases. The flued heads were designed and fabricated in accordance with the ASME Code for Nuclear Vessels, Section IIIB, 1968. The materials specified for penetrations meet the necessary NDT impact values as specified in the ASME Nuclear Vessels Code.

f. They are capable of withstanding pressure induced internally due to heat transfer from the containment atmosphere; i.e., thermally induced pressurization. For a discussion of thermally induced pressurization, see Section 5.2.2.2.2.6.

All Containment Vessel penetrations nozzles are designed to meet the requirements for Class B vessels under Section III of ASME Boiler and Pressure Vessel Code. In compliance with the code, the operating stresses in a containment vessel penetration nozzle caused by the attached penetration assembly are limited to the allowable values given in the code. For earthquake analysis, Section III of the ASME code permits the use of 1.5 times the allowable stress value for the material being used.

The double-bellows expansion joints in the hot-pipe penetration assemblies and the Shield Building flexible seals for all pipes are designed to accommodate the maximum combination of vertical, radial, and horizontal differential movements between the Reactor Containment vessel; the Shield Building and the piping. This design considers the calculated displacements resulting from earthquake, pressure and temperature (as shown in Figure 5.2-1), and also accounts for the actual measured displacement of representative penetration nozzles made during the initial pressure testing of the Containment Vessel.

The shield building flexible seals are designed to withstand the process piping temperature and provide an adequate leak-tight seal consistent with overall allowable Shield Building leakage.

5.2.1.3.2 Hot Penetrations

Hot piping penetration assemblies are provided to:

a. Prevent unacceptable thermal and cyclic stress on Reactor Containment Vessel penetration nozzles;

b. Accommodate thermal movement;

c. Protect containment from the effects of a hot process pipe rupture in the annulus between the Shield Building and the Reactor Containment Vessel.

Where hot penetration assemblies traverse the Shield Building annulus, they are designed to provide considerable margin between code allowable stress values and maximum calculated stresses in the pipe. This was accomplished by using 1.5 times the system design pressure to calculate the pipe wall thickness for the process and guard pipe, using the formula and allowable stresses given in USAS B31.1.0-1967. Under normal B31.1.0 code practice, the system design pressure alone is adequate for calculating the pipe wall thickness. The same procedure was used to set the thickness of the guard pipe and the multiple flued head.

5.2.1.3.3 Main Steam Line Penetration

The main steam line between the anchor inside containment and the first isolation valve outside of containment has a wall thickness selected by using 1.5 times the system pressure and normal code allowable stress values. The main steam anchor inside containment is designed to sustain the full force resulting from a 360° circumferential break of the main steam line. The other requirements previously discussed for a hot-pipe penetration assembly are also met.

5.2.1.4 Containment Vessel Air Handling System

The Containment Vessel Air Handling System consists of the Containment Air Cooling system, the Containment Internal Cleanup System, the Inservice Purge and the purge ventilation system. The function of the Air Cooling system is to remove the heat lost to the Containment Vessel environment during normal operations, from equipment and piping inside the Containment Vessel and during post-accident conditions, to remove energy from the Containment Vessel as required and described in Section 6.1. The function of the Containment Internal Clean-up System is to recirculate containment air through filters to clean up containment atmosphere prior to limited personnel access. The function of the purge system is to provide fresh, tempered air for comfort during maintenance and refueling operations and to purge contaminated air through charcoal filters from either or both Reactor Containment Vessel(s) while shutdown. The function of the Inservice Purge System is similar to that of the purge system except that a smaller volume of air is handled and exhaust air is processed through HEPA filters and charcoal absorbers.

The Containment Air Cooling System is sized such that any three fan coil units will provide adequate heat removal capacity from the Reactor Containment during normal and full-power operation, to maintain interior air temperatures below the maximum temperature allowable at any component, and to obtain temperatures below 104°F in accessible areas during hot standby operation. The fan-coil units are also utilized for emergency cooling under post-accident conditions. Their use for that purpose is described in Section 6.3.

The fan-coil units of the Air Cooling System are utilized to distribute air adequately over equipment and around occupied spaces in the building for ventilation service. Unit heaters or electric heaters provide for heating within the Containment Vessel when required during Mode 5, Cold Shutdown or Mode 6, Refueling.

The purge and ventilation system is sized to provide a reduction of the radioactivity in the Containment Vessel air following normal full-power operation to the level defined by 10CFR20 for a 40 hour occupational work week, within 2-6 hours after reactor shutdown. Purging of the Containment Vessel will normally be accomplished within two hours following the beginning of purge.

Provision is made in the design of the purge and ventilation system for 1½ air changes per hour during refueling and maintenance operations. The Containment System Vent provides for the discharge of air at an elevation near the top of the Shield Building within the influence of the building wake effect, to improve the dispersion of gaseous releases.

5.2.2 Description

5.2.2.1 Primary Containment Auxiliary Systems

5.2.2.1.1 Isolation System

Table 5.2-1 lists the containment penetrations and the isolation provided for each penetration. The seven classes of penetration isolation provided below are used in the Tables in the column designated PENETRATION CLASS.

a. Class 1 (Outgoing Lines, Reactor Coolant System)

   Outgoing lines connected to the Reactor Coolant System are provided with two automatically operated trip valves in series located near the Reactor Containment Vessel (one inside and one outside). A non-automatic isolation valve either locked closed or maintained under direct administrative control is equivalent to an automatic isolation valve.

b. Class 2 (Outgoing Lines)

   Outgoing lines not connected to the Reactor Coolant System, not protected from missiles throughout their length and not required to be open for assumed post-accident conditions are provided with two automatically operated trip valves. At least one valve is external to the Reactor Containment Vessel, the other may be internal or external.

c. Class 3 (Incoming Lines)

   Incoming lines connected to open systems outside the Reactor Containment Vessel are provided with two check valves in series, one located inside and one outside the Reactor Containment Vessel. The internal check valve will be located near the Reactor Containment Vessel shell.

   Incoming lines connected to closed systems outside the containment are provided with at least one check valve located near the Containment Vessel on the inside and a manually operated (local or remote) isolation valve outside the Containment Vessel. In this instance, the closed system outside of containment serves as the secondary containment boundary. The manually operated isolation valve may be closed, if desired.

An automatically operated trip valve or a non-automatic isolation valve either locked closed or maintained under direct administrative control is considered to be the equivalent of a check valve and vice-versa.

d. Class 4 (Missile Protected)

Incoming and outgoing lines which penetrate the Reactor Containment Vessel and are connected to closed systems inside the Reactor Containment Vessel and which have a low probability of being ruptured by the assumed accident, are provided with at least one remotely operated valve located outside the Reactor Containment Vessel.

Steam Generator secondary side isolation valves receive special treatment because their function is not containment isolation for the loss-of-coolant accident but only containment isolation for main steam line rupture within containment. Leakage rate and test requirements may be adjusted accordingly.

e. Class 5 (Normally Closed Lines Open to the Containment)

Lines which penetrate the Reactor Containment Vessel and which can be opened to the Containment Vessel atmosphere but which are normally closed during reactor operation and are provided with two isolation valves in series, two blind flanges, or one isolation valve and one blind flange. One valve or flange is located inside and the second valve or flange is located outside the Reactor Containment Vessel.

Several of the flanges are provided with a double “O”-Ring seal and located in areas of containment which have a low probability of being affected by the assumed accident. Both “O”-Rings are tested separately through installed test connections. In this instance, these “O”-Rings provide the required redundant barrier isolation. Other isolation capabilities in these lines (e.g., valve, damper, flange gasket) provide additional levels of redundancy.

f. Class 6 (Systems Required to Operate in the Post-Accident Condition)

The design and operational criteria for the isolation valves in these systems is governed by the functional requirements of the systems as outlined in the section in which the system is described.

g. Class 7 (Normally Closed Lines with Leakage Returned to Shield Building Annulus)

Class 7 lines are the same as Class 5 lines with the addition of a feature to assure that any small leakage through the isolation system is returned to the Shield Building annulus for processing by the Shield Building Vent System.

Instrument lines associated with closed systems, such as containment pressure instrumentation, which are fabricated to withstand the maximum containment pressure, the maximum containment temperature, and are protected from missiles and dynamic effects are acceptable without containment isolation valves.

The actuation systems for automatic containment isolation are discussed in Section 7. Isolation valves inside containment are equipped with operators and actuation devices capable of operating reliably under post-accident containment conditions. Air Operated Control Valves which are designated as automatic trip isolation valves are designed to either fail closed upon loss of actuation power and/or loss of power to control logic or are provided with a reliable source of actuation power and a “fail-close mode” upon loss of power to control logic.

Motor Operated Valves (MOV) designed as automatic trip isolation valves are designed to fail in the “as is” position on a loss of power. When a MOV is used for containment isolation purposes, a redundant barrier is provided (for example, a closed system, check valve, another MOV, etc.). If two MOVs are used to isolate a containment penetration, they are powered from redundant power supplies to ensure the penetration is isolated in the event of a single active failure.

Certain valves for Class 6 usage (engineered safety features) are excepted from the “fail-close” criterion. The operation of valves in these systems is governed by the functional requirements of the system as outlined in other Sections.

5.2.2.1.2 Vacuum Relief System

Two vacuum breakers are used in each of two large vent lines which permit air to flow from the Shield Building annulus into the Reactor Containment Vessel. The vacuum breakers consist of an air to close, spring loaded to open butterfly valve and a self-actuated horizontally installed, swinging disc check valve as shown in Figure 5.2-3. The vent lines enter the containment Vessel through independent and widely separated containment penetration nozzles.

Vendor-supplied flow versus pressure-drop information was used to ensure that sufficient flow area is available in each line so that the combined pressure drop at rated flow through both valves in series will not result in the differential pressure between Containment and the Shield Building exceeding the permissible pressure. Satisfactory operation of either of the vacuum relief lines is adequate to meet the design conditions.

5.2.2.2 Containment Penetrations

5.2.2.2.1 Electrical Penetrations

The electrical penetration assemblies are designed for field installation. D G O'BRIEN assemblies are installed by welding to the inside end of the nozzle type penetration passing through the Reactor Containment Vessel wall. Conax assemblies are installed by welding to the outside end of nozzle type penetrations.

Each penetration assembly is provided with a single connection to allow pressure testing for leaks. All components of the penetration assemblies are designed to withstand, without damage or interruption of operations, the forces resulting from an earthquake, in addition to the normal and accident design requirements.

All materials used in the design are selected for their resistance to environments existing under normal operation and the DBA.

Figure 5.2-4 shows the configuration of selected D G O'Brien and Conax penetration assemblies. Electrical penetrations are provided for the following purposes:

1. Medium Voltage Power (MVP) - 5000 volt insulation for use on 4160 volt resistance grounded system. 4 provided per unit.

2. Low Voltage Power (LVP) - 600 volt insulation. 16 provided per unit.

3. Instrument and Control (I&C) - 600 volt insulation. 20 provided per unit.

4. Control Rod Drive Power (CRDP) - 1000 volt insulation for use on 140 D-C. 5 provided per unit.

5. Nuclear Instrumentation Systems (NIS) Triaxial Cables. 4 provided per unit.

6. Radiation Monitoring Cables (RM). 1 provided per unit.

7. High Radiation Monitor. 2 provided per unit.

8. Low Voltage Power (LVP) – Power supply conductors for containment hydrogen recombiners. 2 provided per unit.

9. Excore Neutron Flux and Incore Thermocouples. 2 provided per unit.

The design, fabrication and installation of D G O'BRIEN penetration assemblies installed in 1981 is in accordance with the requirements of the 1977 ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NE. The electrical modules of the penetrations are in accordance with the IEEE Standards 317-1976, 323-1974, and 344-1975.

The design, fabrication, and installation of Conax penetration assemblies installed in 1982 and 1983 is in accordance with the requirements of the Winter 1981 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NE. The electrical modules of the penetration assemblies are in accordance with IEEE Standards 317-1976, 323-1974 and 344-1975.

5.2.2.2.2 Piping Penetrations

All piping penetrations listed in Table 5.2-1, except the vacuum breakers, penetrate the Shield Building as well as the Reactor Containment Vessel. All isolation valves that are needed to maintain primary and secondary containment integrity are listed in Table 5.2-1. Both the Reactor Containment Vessel and Shield Building are provided with welded capped spare penetrations for possible future requirements.

All process lines traverse the boundary between the inside of the Reactor Containment Vessel and the outside of the Shield Building by means of piping penetration assemblies made up of several elements. Two general types of piping penetration assemblies are provided; i.e., those that are not required to accommodate thermal movement (designated as cold penetrations in Figure 5.2-5) and those which accommodate thermal movement (designated as hot penetrations in Figure 5.2-6A and Figure 5.2-6B).

Both hot and cold piping penetration assemblies consist of a containment penetration nozzle, a process pipe, a Shield Building penetration sleeve and a Shield Building seal. In the case of a cold penetration, the Containment Vessel penetration nozzle is an integral part of the process pipe, or for instrument tubing and some small bore piping the tube or pipe passes through and is welded to a plate which is in turn welded to the nozzle. For hot penetrations, a multiple-flued head becomes an integral part of the process pipe, and is used to attach a guard pipe and an expansion joint bellows. The expansion joint bellows is welded to the containment vessel penetration nozzle.

At the termination of penetration assemblies on the Shield Building side, a low-pressure leakage barrier is provided in the form of a flexible seal as shown in Figures 5.2-5, 5.2-6A and 5.2-7. These devices provide a flexible closure between the Shield Building penetration sleeve, which is embedded in the Shield Building, and the process pipe. In the case of hot penetrations 8 and 11, a circular plate is used rather than a flexible seal as shown in Figure 5.2-6B. This plate serves as both an anchor and a Shield Building seal.

5.2.2.2.2.1 Hot Penetrations

A hot piping penetration assembly is used when the differential between the normal operating temperature of the fluid carried by a process line and the Reactor Containment Vessel wall temperature would create unacceptable thermal or cyclic stress at the attachment of the Vessel penetration nozzle.

In addition to the elements contained in a cold piping penetration assembly as shown in Figure 5.2-5, a hot assembly has a multiple-flued head, a guard pipe, an expansion bellows and an impingement ring. The multiple-flued head is machined from a solid forging. It is welded into and becomes an integral part of the process line. The inner flue provides support for the guard pipe and the outer flue provides support for the expansion joint bellows. The guard pipe is located concentric to the process pipe, and is cantilever supported by a weld attachment to the inner flue of the flued head. The length of the guard pipe is set so that it extends past the Reactor Containment Vessel penetration nozzle into the Vessel.

Adequate support is provided for the multiple-flued heads and the process line by the shield building which acts as a horizontal and vertical guide. As inferred above, the flued head fitting is the only part of the penetration assembly which comes into contact with the Shield Building at any time. This interaction takes place in one of two ways and is described as follows:

a. For the main steam, feedwater and residual heat removal penetrations, the multiple-flued head passes through a sleeve in the Shield Building as shown in Figures 5.2-6A and 5.2-7. The sleeve acts as a horizontal and vertical guide which allows rotational and axial movements. The piping system and hence the flued head is allowed to rotate or move axially within the Shield Building sleeve but is restrained by the sleeve from moving in any direction perpendicular to the axis of the process line for all seismic, temperature, weight and jet loads. There are no pressure loads that have any effect on the flued head - Shield Building interaction for these assemblies other than the vertical and transverse movements of the Containment Vessel due to internal Vessel pressure. The loads due to this movement are small, being a function of the transverse spring constant of the penetration expansion bellows, and have been considered in the design of the process line, the multiple flued head and the Shield Building sleeve.

The main steam hot penetration assembly analysis for thermal, pressure, seismic and pipe rupture loads was based on an equivalent set of static loads quantitatively representing the dynamic loading conditions. Seismic loads were based on the results of a dynamic model analysis of the main steam piping system. Pressure loads were analyzed for both the process and guard pipes at maximum operating pressure conditions. Jet load on the guard pipe was considered in a worst case manner as a force, equal to the main steam pipe rupture reaction force, acting at the end of the guard pipe. Stress levels due to temperature gradients were developed based on conservatively assumed step function changes in steam temperature at maximum steam flow conditions. These conditions and loads were included in the specification given to the vendor and used in this analysis of the main steam hot penetration. All calculations for the resultant stress distribution were based on finite element computer techniques. The individual load cases were summated to produce a required combination satisfying the total maximum loading conditions. The finite element analysis showed that the resultant stresses were well below the code allowables.

b. For the steam generator blowdown and letdown line penetrations the multiple-flued head is anchored to a sleeve in the Shield Building as shown in Figure 5.2-6B. All movement of the flued head and consequently the process line is restrained at this point. The design of this anchor and the process line considered all loads due to seismic, weight, temperature, pressure and pipe rupture jet effects of both the piping system and the structures.

The spacing between the process pipe supports and the flued heads for systems with hot penetration assemblies was determined for each system by performing stress analyses considering all operating conditions including the OBE, DBE and process pipe rupture. The piping system and all pipe supports, including the flued head assembly (which is an integral part of the process pipe) was modeled in these stress analyses. The flued heads were modeled in the stress analysis as either points of lateral restraint or anchors. Based on the stress analyses results, modifications were made in the location and type of hangers and restraints until satisfactory results were obtained.

After the pipe support locations and types had been determined for thermal, deadweight and seismic conditions, the pipe rupture analysis of each system was performed in accordance with Section 12.2.2.1.9. Additional restraints were added as required to satisfy the pipe rupture criteria as stated in Section 4.6.2. In the pipe rupture analyses, the flued heads were modeled as either points of lateral restraint or anchors as was done for the operating conditions mentioned above.

The loads acting on the flued heads as determined by the above analyses were then included in the flued head assemblies stress analysis. The resultant stress levels in the hot penetration assemblies were maintained well below the allowable values. The results shown for the guard pipe on Table 5.2-2 are typical.

The relative motion between the Shield Building and the process pipe and the Shield Building and the Containment Vessel was determined from the above piping system analyses and the seismic and DBA analyses of the pertinent structures (see Figure 5.2-1). For the large piping hot penetration assemblies as shown in Figure 5.2-6, the Shield Building acts as a guide (lateral restraint) for the flued head assembly, thereby allowing for the relative axial motion between the Shield Building and the process pipe.

Relative motion between the Shield Building and process pipe is due to thermal expansion of the process pipe for the various operating conditions and/or the relative seismic displacements between the Shield Building and the reactor support structure to which the process pipe is anchored. For thermal expansion, the magnitude of these relative displacements varies from 0.25″ to a maximum axial displacement of approximately 1.0″. The maximum relative seismic displacements, which increase with elevation, vary from 0.032″ to approximately 0.110″ for the OBE condition. The relative structural displacements have been modeled in the seismic analysis as well as the relative displacements between the Reactor Building and the Auxiliary Building or Turbine Building, as applicable.

For the small piping hot penetration assemblies, the flued head is anchored at the Shield Building, as shown in Figure 5.2-6B. Because of this design, there is no relative motion between the Shield Building and the penetration assembly.

The relative motion between the Shield Building and the Containment Vessel is due to the DBA pressure and temperature growth of the Containment Vessel as well as the relative seismic displacements between the two structures. These relative displacements will affect only the bellows assembly, and are independent of any process line movements. Relative seismic displacements between the Containment Vessel and the Shield Building at the penetration elevations range from 0.032″ to 0.148″ for the OBE condition. The maximum DBA movement of the Containment Vessel resulting from both pressure and temperature is approximately 1.375″ radially and 0.687″ vertically (this can be seen in Figure 5.2-1). All of the relative displacements between both the Shield Building and process pipe and the Shield Building and the Containment Vessel have been considered in the design of the bellows assembly and the piping system.

The location of the most critical hot process pipe penetration assembly with respect to the largest relative motion which must be accommodated varies with the direction of displacement considered. Each individual bellows assembly has been designed to accommodate the largest relative motion that is possible for any individual occurrence or combination of occurrence. Table 5.2-3 shows the most critical movements for each hot penetration. These are based on a combination of normal operating, DBA and DBE movements.

The expansion joint bellows is attached at one end to the outer flue of the flued head and at the other end to the Reactor Containment Vessel penetration sleeve. The expansion joint is provided with a double layered bellows that has a connection between bellows for integrity testing. An impingement ring is mounted on the guard pipe to protect the expansion joint bellows from jet forces that might result from a pipe rupture inside containment.

ASME Section III Code Case 1330-1 permits the use of bellows-type expansion joints under Section III of the Code for Class B and Class C vessels under the rules of Section III for a Class B vessel (such as the containment vessel) with the following additional requirements [following each requirement is a discussion of how it is satisfied]:

a. The welded joint (longitudinal) in the bellows portion is to be of the type prescribed for Category A in Par. N-462.1 of Section III. This requires the joint to be full-penetration, to be 100% radiographed, and final weld to be also liquid penetrant or magnetic particle examined.

   The manufacturer's fabricating procedure utilizes a fully approved automatic gas tungsten arc weld (GTAW) stainless-to-stainless, full penetration groove weld procedure. This is followed with 100% Radiographic Examination (RT) via an approved procedure prior to forming the convolutions, following with 100% Liquid Penetrant Examination (PT) via a fully approved procedure after forming. The welding was all fully qualified per ASME Section IX, and the results of RT and PT were fully documented.

b. The bellows portion of the joint is to be attached by full butt type circumferential welds having full penetration through the thickness of the bellows to be followed by examination by either PT or MT or PT only if a ‘‘non-magnetic” weld is made.

   Examination of the manufacturer's fabricating detail drawings and their itemized fabricating procedures indicates the double-ply element is attached by a full circumferential weld. The weld was properly qualified and approved, utilizing a procedure (hand GTAW) with a joint configuration very similar to Sketch 1 of Case 1330-1 for joining stainless to carbon steel, (P8 to P1). This entire joint was subsequently inspected using an approved liquid penetrant procedure. The results of this inspection were fully documented.

From the foregoing, it can be readily seen that the design and fabrication fully complies with the requirements of Code Case 1330-1.

All bellows, including those associated with the fuel transfer tube, that are part of containment boundary are fitted with protective covers which are removable for visual inspection.

All flued head materials were given a Charpy V-notch test based on an impact load of 20 ft lbs at 0°F. Process and guard pipes of ASTM-A555 pipe have been radiographed (longitudinal seams) and hydrostatically tested at 1.5 times the process pipe system design pressure prior to fabrication.

The results of the Charpy V-notch tests performed on the materials used for the flued head fittings used in the hot penetrations are as listed on Table 5.2-4.

Since the flued head and guard pipe at the hot penetration are a part of the process pipe, the temperature of the flued head and guard pipe can be monitored by taking the temperature of the process fluid which is approximately the same as the temperature of the process pipe.

Flued heads in the as-forged condition are ultrasonically tested and either magnetic particle or liquid penetrant tested. The process piping to flued head welds are radiographed and either magnetic particle or dye penetrant tested. The guard pipe to flued head welds are also radiographed and the final weld surfaces dye penetrant tested. The bellows are given a soap bubble test while the space between the plies is pressurized with air at 60 psig.

The multiple-flued head with its associated guard pipe and expansion joint bellows provides a leak-tight seal for the extension of the containment boundary where the hot penetration assembly traverses the Shield Building annulus.

Guard pipes are designed, fabricated, and tested in accordance with ANSI B31.1-1967, ASTM A-106, Grade B, ASTM A-155, KC-70, Class I, ASTM A-358, Class I, TP-304, ASTM A-312, TP-316, as applicable. Certified test reports of chemical and physical properties, traceable to heat numbers, were obtained. All welds are 100% radiographed and either dye penetrant or magnetic particle inspected. Allowable stresses are as noted in ANSI B31.1-1967.

The design criterion applied to the hot penetration guard pipes is defined in Table 12.2-13 and is the same as that applied to all Class I piping. The allowable stress values and stress analysis results for normal, upset and faulted loading conditions for the main steam and feedwater guard pipes are shown in Table 5.2-2. The values listed represent the peak values that will occur at any given location in the guard pipe. This table shows that the calculated guard pipe stress levels are well within those allowed by the criteria given in Table 12.2-13 for all loading conditions. The main steam and feedwater penetrations were selected for this study because their failure would have the most severe consequences in the Shield Building Annulus. A review of the design of the other hot penetration guard pipes indicates that calculated stress levels for these guard pipes would be of the same order of magnitude as for the main steam and feedwater guard pipes and well within allowable values as shown in Table 5.2-2.

The expansion joint bellows were designed as part of the containment vessel. All of the bellows are of ASTM-A240, Type 304 materials, designed for a pressure range of -0.8 to 50 psig and a maximum temperature of 268°F. A discussion of the analysis performed for all bellows assemblies is covered in Section 5.2.3.2.2.

5.2.2.2.2.2 Main Steam Line Penetration

The main steam piping penetration assembly, shown in Figure 5.2-7 uses the same elements as a hot piping penetration assembly. In addition, the main steam line is anchored to the interior concrete of the Reactor Containment Vessel. A limit stop designed to control lateral movement but permits axial movement is provided around the main steam line inside containment. This limit stop serves to limit pipe movement in the event of a longitudinal pipe break thus serving to control pipe whip inside containment. The multiple- flued head is also designed to transfer lateral loads that could result in the event of a main steam line rupture exterior to the Shield Building, to a specially designed structural arrangement in the Shield Building.

5.2.2.2.2.3 Equipment and Personnel Access

The equipment hatch and air locks are supported entirely by the Reactor Containment Vessel and are not connected either directly or indirectly to any other structure.

The equipment hatch was fabricated from welded steel and furnished with a double-gasketed flange and bolted dished door. Provision is made to pressure test the space between the double gaskets of its flange.

Two personnel air locks are provided. Each personnel air lock is a double- door welded steel assembly. Quick-acting type equalizing valves are provided to equalize pressure in the air lock when entering or leaving the Reactor Containment Vessel. Provision is made to test pressurize the air locks for periodic leakage rate tests.

The two doors in each personnel air lock are interlocked to prevent both being opened simultaneously and to ensure that one door is completely closed before the opposite door can be opened. Remote indicating lights and annunciators in the control room indicate the door operational status. Each door lock hinge can be adjusted to assist proper seating. A lighting and communication system that can be operated from an external emergency supply is provided within each air lock.

5.2.2.2.2.4 Fuel Transfer Penetration

The fuel transfer penetration provided is for fuel movement between the refueling cavity in the Reactor Containment Vessel and the spent fuel pool. This penetration consists of a 20-inch stainless steel pipe installed inside a 24-inch pipe. The inner pipe acts as the transfer tube.

The outer pipe is welded to the Reactor Containment Vessel. Bellows expansion joints are provided between the two pipes to compensate for any differential movements. A double gasketed blind flange is bolted on the refueling canal end of the transfer tube to seal the reactor containment. The end of the tube outside the containment is closed by a gate valve.

5.2.2.2.2.5 Containment Supply and Exhaust Purge Duct Penetrations

The ventilation system purge duct and make-up duct penetrations are welded directly to the penetration nozzles in a manner similar to the cold piping penetration. The ducts are circular in section and designed to withstand the Reactor Containment Vessel maximum internal pressure. They are provided with isolation valves and blank flanges as described in Section 5.2.2.3.3. The blank flanges were installed to increase the assurance that the penetration will be leak tight.

5.2.2.2.2.6 Thermally Induced Pressurization (GL 96-06)

NRC Generic Letter 96-06 (Reference 32) identified a concern regarding the potential for containment penetration piping over-pressurization due to thermally induced expansion of the internal fluid due to heating from the post-accident containment atmosphere. For containment isolation purposes, several piping penetrations are provided with redundant isolation valves where one valve is on either side of containment. With both valves closed for containment isolation the fluid volume between the two valves is trapped. During a post-accident scenario (such as a LOCA or MSLB), if the containment atmosphere is hotter than the piping, steam can condense on the piping resulting in a potentially significant temperature increase of the trapped fluid. For a non-compressible fluid such as water, the temperature increase can significantly increase the fluid pressure and possibly exceed the capability of the piping.

Reference 33 documents the evaluations performed to assess the thermally induced pressurization issue. The method was used to evaluate the containment penetration piping was as follows:

- Penetrations were initially screened from further consideration based on containing either gas (compressible fluid) or liquid that is normally hotter than the post-accident containment environment.
- Penetrations not initially screened out were further evaluated for configurations precluding over-pressurization due to thermally induced pressurization. Such configurations include the presence of pressure relieving capability such as a relief valve or diaphragm valve, check valve orientation that would vent pressure back to the RCS or the system being in operation during post-accident mitigation (i.e., no trapped fluid).
- After the above evaluations, the following penetrations required a more detailed analysis to determine the maximum internal pressure and to assess the capability of the piping to withstand the maximum pressure.

Penetration 14	CVCS Seal Water Return
Penetration 15	Pressurizer Steam Sample
Penetration 16	Pressurizer Liquid Sample
Penetration 17	RCS Loop Sample
Penetration 35	SI Test Line

Penetration 15, 16 and 17 were determined to be adequate in the current configuration. Modifications were performed to penetrations 14 and 35. More specifically, thermal insulation was added to penetration 14 between containment and the inside isolation valve to minimize the heat-up from the post-accident environment. For penetration 35, a new containment isolation valve was added just inside containment to provide local leakage 01404331 isolation through the penetration and also minimizes heat-up from the post-accident environment condition.

In addition to the containment penetration piping, all piping inside of containment and safety related piping outside of containment was also evaluated for the potential of thermally induced pressurization (Reference 33).

In Reference 34, the NRC documented that the staff was satisfied with the response to GL 96-06 and considers the thermally induced pressurization element of GL 96-06 closed.

5.2.2.3 Containment Vessel Air Handling System

Units 1 and 2 share, as a common facility, some portions of the purge and ventilation system, only the supply fan and ducting are shared. All other portions of the Containment Vessel Air Handling Systems are provided as separate, identical facilities for each Unit. Therefore, the remainder of this section discusses a single Unit, equally applicable to either Unit (except where noted).

5.2.2.3.1 Containment Air Cooling System

The containment air cooling system functions (1) to remove normal heat loss from equipment and piping in the containment during plant operation and maintaining a normal ambient temperature less than 120°F, (2) to remove sufficient heat from temperature monitored equipment to meet the designed thermal gradients, and (3) to depressurize the containment atmosphere to the order of 3 psig and 150°F in the long term post accident. The design performance data and heat removal rates for containment air cooling system are tabulated in Tables 5.2-5 and 5.2-6.

5.2.2.3.1.1 Reactor Coolant Pumps Cooling

The two reactor coolant pumps are single speed centrifugal units driven by air-cooled, three phase induction motors. Each pump is designed to operate at a volute temperature of 650°F and 300°F housing temperature. Cooling air for the pumps is fed into the coolant pump vaults. The air flowing through the vault which houses the pump removes heat from a pump unit at a rate of 900,000 Btu/hr (750,000 Btu/hr from the motor and 150,000 Btu/hr from the uninsulated section) to maintain its temperature below design temperature. The heated air is then discharged into the containment atmosphere. The stator windings of each motor and the thrust and radial oil lubricated bearing, and the seal injection water are temperature monitored. Should the stator temperature exceed a pre-determined value, a high temperature alarm is actuated in the control room.

5.2.2.3.1.2 Control Rod Drive Mechanism Cooling

The chilled water system provides chilled water during normal operation for the control rod drive mechanism (CRDM) shroud cooling coils. Each control rod drive mechanism shroud cooling assembly consists of two 13,000 CFM fans, two cooling coils and a plenum. The CRDM shroud cooling removes the heat from the containment air which then passes over the drive mechanisms.

At least one CRDM shroud cooling fan is operated at all times during reactor operation. Isolation valves for the chilled water supply to the shroud cooling coils are controlled at the control panel near the chiller. These valves remain open at all times during normal reactor operation. Either cooling water or chilled water can be used to supply the shroud cooling coils. The valves will automatically close upon receipt of a safety injection signal from either unit, loss of power, or actuation of the master isolation switch in the main control room.

5.2.2.3.1.3 Reactor Vessel Support Pads Cooling

The reactor vessel is supported on six individual air-cooled support pads. The support pads are hollow box-type built-up plate structures equipped with ten 1/4-inch plate split steel cooling fins welded to the inside walls. Approximate outside dimensions of the pad structures are 15-inches wide x 18-inches high x 58 inches long. The boxes are welded to the top cap plates of six full-length support columns that are embedded in the concrete shield structure. The box structures support the reactor vessel shoes supplied with the vessel. Attachment of the shoes is by means of bolting.

The support pads provide for the vertical and lateral support of the reactor vessel. In addition, the pads provide a means to obtain a suitable temperature gradient between the reactor vessel support points and the supporting concrete and steel structures of the building.

The pads are cooled by an interconnecting forced air duct system embedded in the concrete shield structure.

The pads are structurally designed for (1) reactor vessel vertical loads, (2) radial temperature expansion friction forces of the reactor vessel, (3) lateral seismic and pipe rupture loads, and (4) temperature stresses caused by temperature gradients within the supports pads.

The pad structure was analyzed as a closed box type structure using STRUDL computer codes.

The main purpose of pad-cooling is to maintain a satisfactory temperature profile along the support coordinate, rather than heat-removal from the support system. The optimum operating conditions are such that the temperature at the bottom plate of the rectangular ventilated pad is kept sufficiently low so that heat transferred from the pads into the surrounding concrete becomes negligible. Based on a design temperature of 650°F for the reactor vessel, the design criteria of thermal gradients across the support system are as follows:

1. The minimum temperature at the integral nozzle interface is 300°F, equivalent to a maximum permissible temperature drop of 350°F in the nozzle.

2. The temperature drop across the side walls of the rectangular finned pad must not exceed 150°F.

3. The temperature at the bottom plate of the rectangular pad is 150°F or lower.

Thermocouples were installed in Unit 1 and were used to confirm that criteria (2) and (3) were satisfied.

With an air flow rate of 1500 cfm per support at 120°F available for the pad cooling, a rectangular finned pad as shown in Figure 5.2-10 was designed to satisfy all the criteria mentioned above.

The calculation results based on the dimensions given in Figure 5.2-10 are summarized in Table 5.2-12.

The predicted heat removal rate of 5580 Btu/hr from each wall of the rectangular pad implies an effective nozzle heat transfer area of approximately 4 ft^2 which is believed to be acceptable by investigating the nozzle configuration and the nozzle interface area. The study also indicated that the effective nozzle area for heat transfer is not so sensitive as to change the temperature profile significantly for the designed ventilated pad. It is therefore concluded that the pad-cooling design is adequate.

5.2.2.3.1.4 Reactor Cavity Cooling

The duct work provides air flow from the containment fan coil units to the reactor gap and the neutron detector wells to remove heat from the reactor vessel, the primary concrete, and the neutron detector housing.

A reactor vessel gap cooling fan, being in parallel with a redundant fan of same capacity, delivers 10,000 CFM of cooling air from two fan coil units (supplying its suction) connected in parallel to the reactor cavity with a 24 inch duct which is connected to a distribution ring of 16 inch pipe surrounding the reactor vessel in the bottom. Air flow is uniformly distributed into the gap by means of eight equally spaced 8 inch exits along the ring duct. The cooling air directed upward in the reactor gap is capable of removing heat from the reactor vessel surfaces below the reactor head flange at a rate of 80,000 Btu/hr and 25,000 Btu/hr from the primary concrete.

Duct work is also provided for the neutron detector cooling purpose. For Unit 1 only, a 6000 CFM booster fan is installed in the containment ductwork in order to assure necessary air circulation and cooling to the neutron detector area. Cooling air at 750 CFM from each duct exit is directed to one of the eight neutron detector wells which house the detector housing tubes. The air flow is capable of removing 10,000 Btu/hr from each neutron detector housing and its walls to maintain the housing temperature below 135°F. The heated air is then forced into the containment atmosphere.

5.2.2.3.1.5 Steam Pipe Penetration Through the Shield Building

For hot or steam pipe penetrations a pipe sleeve is embedded in the Shield Building 01514367
concrete. The flued head passes through this pipe sleeve. Bridge lugs of trapezoid cross section, having the top surface area of approximately 1/2 x 36 inches in the axial direction, are welded inside the pipe sleeve to allow a gap of 1/16 inch between lugs and the flued head. The hot penetration design is such that no forced air cooling is necessary. Should local contact of the flued head and a bridge lug happen, analysis indicated that natural convective heat loss to the ambient air at 120°F will result in a maximum temperature of 442°F at the contact, and then asymptotically decreasing to 167°F along the circumferential direction of the conduit.

5.2.2.3.2 Containment Internal Clean-up System

The Containment Internal Clean-up System is sized to reduce the containment airborne activity to a level which would permit two hours of access with reactor at power after the system has been in operation for a period of 32 hours. It is also intended that the units could be operated prior to a plant shutdown to reduce the inventory of fission product activities in the containment atmosphere which would otherwise be removed in the purge system.

5.2.2.3.3 Containment Vessel Purge and Inservice Purge Systems

The purge and inservice purge systems consist of a shared tempered air supply and an exhaust system which discharge through either a purge or a vent filter to the exhaust fan. The fan discharges to the monitored Containment System Vent which extends through the Shield Building annulus to a point approximately five feet above the lower edge of the Shield Building domed roof. The equipment of the purge and ventilation system is located outside the Containment Building. These two systems provide for containment venting and purging:

a. Containment purge system (33,000 cfm), utilizing 36-inch supply and exhaust line used to ventilate containment following reactor shutdown to permit access for inspection and maintenance. One isolation valve and one isolation damper are provided in each supply line and the exhaust line. Each receives an automatic closure signal on receipt of a safety injection or containment high radiation signal. The exhaust and supply ducts also have blank flanges installed inside containment, whenever the reactor is in Mode 1, 2, 3, or 4, which serves the containment function.

b. Containment inservice purge system (4,000 cfm), utilizing 18-inch supply and exhaust lines, which provides charcoal adsorption and particulate filtration of containment air prior to release. This system is used as a low volume normal purge and vent system during cold shutdown and refueling operations. Two containment isolation valves are provided on each supply and exhaust line which receive an automatic closure signal on receipt of a safety injection or containment high radiation signal. The supply and exhaust lines will normally have blank flanges installed where the lines pass through the shield building annulus. When the reactor is in Mode 1, 2, 3, or 4, the blind flanges serve the containment integrity function.

5.2.3 Performance Analysis

5.2.3.1 Primary Containment Auxiliary System

5.2.3.1.1 Isolation System

Assurance that valves of adequate leak tightness are provided for containment isolation service is obtained through the specification and testing of these valves in accordance with valve manufacturer's standard practice MSS-SP-61 "Manufacturer's Standardization Society, Standard Practice Edition 1961." The specified maximum permissible leakage rates, as manufactured, is 1/10 of a standard cubic foot of air per hour per inch of diameter of nominal valve size. Leak tightness of valves over an extended period will be tested as part of the integrated leak-rate tests for the Containment System and as part of the periodic valve operability and leakage tests.

The containment isolation valves have been examined to assure that they are capable of withstanding the maximum potential seismic loads with respect to the following:

a. The design of the overall valve assembly - body, bonnet, yoke, operator, position-indicating limit switches, and other appendages is reviewed for adequacy with respect to the accelerations and resultant loads at the valve location. Insofar as possible, valves are located in a manner to minimize the magnitude of the accelerations to which they will be subjected.

b. For those valves which must operate under seismic loading, the operator forces have been reviewed to assure that system function is preserved.

c. Control wires and piping to the valve operators have been designed and installed to assure that the flexure of the line does not endanger the control system.

Piping extending from containment to the outside isolation barrier (valve or closed system) are designed to the same seismic criteria as the Reactor Containment Vessel and are assumed to be an extension of containment.

In order to qualify as containment isolation, valves or closed systems inside the containment must be located or protected from potential internally generated missiles such that there is no loss of function following an accident. Also, manual or remotely operated valves must be of a type that can be either locked closed or otherwise be maintained under administrative control in the closed position.

All power operated (air, motor) containment isolation valves in non-essential systems are designed to close upon receipt of an automatic isolation signal. No valves change position when the containment isolation is reset. In addition to resetting the containment isolation, manual action is required before valves change position.

Penetrations such as the pressurizer relief tank sample line, the primary system vent header and the reactor coolant drain tanks gas sample line penetrations fall into the Class 2 penetration category and may have both isolation valves located outside the containment as stated in Section 5.2.2.1. The above three penetrations are neither part of the reactor coolant pressure boundary nor connected directly to the containment atmosphere and fall under 1971 GDC Criterion 57. As discussed elsewhere, the PINGP was licensed to the draft 1967 GDC. However, at AEC request during licensing, a review of containment isolation was performed against the criterion in the 1971 GDC. This criterion requires at least one isolation valve to be located outside the containment and as close to the containment as practical. Since small pipes and tubing are more easily damaged by missiles than larger pipe, it was considered prudent to locate these small isolation valves outside containment in an area where there is low missile probability and where testing, maintenance, and observation are more easily accomplished. The area in which the valves are located is in a Class I structure and within the Auxiliary Building Ventilation Zone.

The residual heat removal system outlet line is normally closed during power operation and for this reason no isolation signal has been provided for the isolation valve in this line. This valve is open only during the later stages of plant cooldown, i.e. less than 350°F and 425 psig.

5.2.3.1.2 Vacuum Relief System

A malfunction analysis of Vacuum Breaker System components is presented in Table 5.2-7.

Analysis is performed assuming maximum containment cooling with a single vacuum breaker assembly functioning (Reference 30). The results of the analysis of the system are presented graphically in Figures 5.2-8 and 5.2-9. These results assume that the butterfly isolation valve starts to open at a differential pressure of 0.5 psi (external to internal), and no air flow is credited through the valve assembly until it is fully open.

The following assumptions were used for the analysis:

a. No heat energy being added to the containment atmosphere;

b. Two Containment Vessel Internal Spray Systems each operating at runout flow with 0 psig backpressure in containment with water at 70°F;

c. Four containment fan-coil units operating in fast speed with a cooling water flow rate of 1200 gpm each with inlet water temperature of 32°F and a fouling factor for a clean heat exchanger (assuming all four CFCUs are in fast speed provides margin to account for any other active containment cooling mechanisms such as the CRDM shroud cooling coils).

d. Initial ambient conditions both inside the Reactor Containment Vessel and within the Shield Building annulus at 120°F, 14.7 psia.

The analysis indicates that one vacuum relief assembly is sufficient to prevent the Reactor Containment Vessel from exceeding the maximum permissible external/internal pressure differential (0.8 psi).

Concurrent with the vacuum relief of the Containment Vessel, the pressure in the Shield Building annulus is reduced to between 13.2 and 13.3 psia, resulting in an external/internal pressure differential of 1.5 psi. This is well within the design conditions for the Shield Building.

The analysis has been based on conservative assumptions, for example:

a. No heat sources are assumed within containment. Such a condition would not normally occur coincident with such low cooling-water temperature and 120°F initial ambient air conditions;

b. No credit is taken for heat transferred from the steel shell and surfaces of the containment vessel during the transient;

c. No air flow is assumed to pass through the vacuum breaker assembly until the butterfly isolation valve is fully open; that is, air flow is not assumed as the valve is stroking open.

d. The calculation uses the specification air flow rate vs. differential pressure for the vacuum breaker assembly. As shown in Figure 5.2-12, this is conservative relative to the values from the flow testing.

Under these assumptions, a relatively rapid pressure transient was calculated to occur as the result of inadvertently initiating full cooling. The analysis shows that either vacuum relief valve assembly will terminate this transient before it exceeds 0.8 psi differential pressure.

For the case of a loss-of-coolant accident, it is convenient to include the effects of stored heat, which are well-defined as part of the post accident calculations relating to the effectiveness of the cooling. In this case, it is found that the rate of pressure decrease caused by sustained maximum cooling is far less when atmospheric pressure is approached than for the design basis where heat capacitance was neglected. Thus, if the relief-valves were assumed to open as the result of sustained overcooling, the peak transient pressure differential would be much less than the design value.

Detailed CONTEMPT calculations show that a rapid cooldown with two spray units and four fan coil units initiated at 60 seconds following the LOCA will depressurize the containment vessel to 5 psig in 1,000 seconds. The annulus air pressure would, meanwhile, have reached a quasi-steady state vacuum of about -3 in. W.C. (- 0.108 psig) from operation of one Shield Building Vent System. Continuation of heat removal by all the cooling units beyond 1,000 seconds will cause the containment pressure to decrease further and to approach atmospheric pressure, but at a very moderate and decreasing rate.

The containment pressure is still slightly above atmospheric even at 1 hour. Operation of the containment cooling units can be controlled, and since containment pressure can be monitored it can also be controlled. By not deliberately overcooling and causing the containment pressure to go below atmospheric pressure, the vacuum relief systems will not be required to operate.

Smaller break sizes delay the occurrence of peak pressure and could result in slightly higher containment temperatures, and hence greater initial rates of cooling when the sprays and added fan cooler start, but the results with regard to time of total depressurization would be essentially unchanged.

5.2.3.2 Containment Penetrations

5.2.3.2.1 General

Seismic loads on Containment Vessel penetration nozzles were determined by performing a dynamic nodal analysis of the piping systems. Response spectra at the piping system anchor points were used in this analysis. These response spectra were developed from the results of a dynamic time-history seismic analysis of the plant structures. Differential movement between points in the various structures have been included in the analysis of the piping.

The validity of the computer program used to perform the piping system seismic analysis was proven by comparison with an independent analysis of selected systems performed by recognized consultants.

Loads on Containment Vessel penetration nozzles due to thermal expansion of the pipe, thermal and pressure movements of the Reactor Containment Vessel, and piping system weight were determined by a flexibility analysis of the piping system. This analysis was performed with the aid of a computer program using established methods documented in technical literature. The piping configuration and supports, restraints or anchors on either side of the penetrations were designed to limit the stresses in the Containment Vessel at the penetration nozzle to the criteria defined in Section 12.2.1.5.

5.2.3.2.2 Hot Penetrations

The design movements specified for the penetrations were chosen to include the maximum relative movements of the shield building and containment as well as the movement of the piping due to pressure, temperature and seismic effects. For a one-time movement beyond the design values the bellows would take a minimum of 20 percent additional movement before major deformation would occur.

Stresses resulting from the combination of loads defined in Section 12.2.1.5 were calculated for a typical process pipe in a hot piping penetration assembly using the cross sectional area of the pipe wall thickness as required to meet 1.5 times system design pressure. Comparison of calculated stress values with Code allowable stresses shows:

a. Thermal stresses are less than 50% of allowable;

b. Combined longitudinal stresses are less than 50% of allowable;

c. Hoop stresses are less than 60% of allowable.

The following analysis was performed for all bellows assemblies, including those associated with the fuel transfer tube, that are a part of the containment boundary to establish the critical stresses and deformations.

a. Pressure Stresses

Hoop stresses were calculated in both the convoluted and straight portions of the bellows assemblies and compared to code allowables.

Bellows are subject to a condition of elastic instability or squirm. The condition is equivalent to elastic column buckling where the pressure end load is the column load and the stiffness parameters of the bellows make up the EI term. Since the buckling loads indicated by classical theory are generally greater than those indicated by physical examples, the buckling or squirm pressures for bellows have been established by test. Allowable pressures for bellows were derated by a factor of 2.5 from the experimentally determined values.

b. Critical Deformations

Axial, lateral and angular movements imposed on a joint by seismic, thermal and design basis accident are converted to an equivalent axial traverse per convolution. The critical levels have been established by empirical means. The criterion for joints used as containment seal is 1,000 cycles of this maximum feasible offset condition.

5.2.3.3 Containment Vessel Air Handling System

The Air Handling, Purge and Inservice Purge Systems are shown in Figure 6.3-1, “Containment Air Handling Systems”.

The Containment Cooling System consists of four fan-coil units located in the Reactor Containment Vessel. These will re-circulate and cool the Reactor Containment Vessel atmosphere. The heat sink for the fan coils is provided by the containment and auxiliary building chilled water system or by the cooling water system. During emergency situation the heat sink for the fan coils is provided by the cooling water system. Additional circulating fans are provided as required to insure a positive flow of air to the areas around the CRDMS, the reactor cavity, and reactor primary coolant pump motors.

The Containment Internal Clean-up System is independent of the Containment Cooling System and employs two separate trains of filter units and fans. The units consist of activated charcoal filters with a capacity of approximately 4000 scfm per unit, which will provide a 10% recirculation of containment atmosphere per hour when both units are operating. The flow through the units passes through HEPA filters before entering the charcoal filters.

These units are not considered a part of the engineered safety features, are not missile protected, and are not intended to operate in the post-accident environment.

After cooldown for shutdown entry, the Reactor Containment Vessel is purged, if necessary, using the containment purge or inservice purge system to reduce the concentration of radioactive gases and airborne particulates.

Pressure buildup in containment is of slight concern in this plant. Numerous sources can contribute to a pressure rise; however, leakage from the reactor coolant system and instrument and equipment operational air are the greatest contributors. Instrument air leakage is minor since no constant bleed control valves are used, equipment air leakage will be mainly from control valves and any fitting leaks. A small flow of air will continue to discharge through the containment air monitor to the auxiliary building vent system. The discharge will negate the need for frequent purging of containment and reduce pressure buildup due to instrument air leakage.

The purge and inservice purge systems are designed on the following assumptions:

a. Reactor coolant leakage of 30 lbs/day

b. 1% fuel defects in the core

c. Containment Cleanup System Operation for 32 hours

These assumptions produce a Xe-133 concentration of 4.6×10^{-4} μCi/cc. If I-131 was dispersed in the containment atmosphere, a concentration of 1.2×10^{-7} μCi/cc, would be obtained, however, I-131 has not been reported in other containment atmospheres. The purge systems are designed to reduce the Xe-133 concentration to at least half the 4.6×10^{-4} μCi/cc value.

Prior to normal entry into containment, radiological airborne conditions will be determined and actions will be taken, if necessary, to keep personnel exposures ALARA. Engineering controls such as the containment cleanup system may be used to reduce containment atmosphere radioiodines.

With the single exception of the containment purge system, all of the Containment Air Handling systems are operated remote-manually from the main control room by control switches. The instrumentation associated with each of the systems consists of flow test facilities for initial setup; temperature sensors in the air stream and in the case of the Control Rod Drive Mechanism Cooling Booster Fans, air temperature and fan running alarms.

The Containment Fan Coil Units are also controlled remote-manually from the main control board, but are responsive to safety injection signals so as to switch to an optimum mode to handle a loss of coolant accident. The Containment Fan Coil Units provide for all heat removal, by passing containment air over water cooled coils, the cooled discharge air then feeding the other subsystems of the containment cooling system. On the Containment Fan Coil subsystems, there are temperature sensors in the air and water passages as well as flow sensors in the water passages. During normal plant operation, the chilled water or cooling water flow to the cooling coils is modulated by an orifice on the water return line from each train of Fan Coil Units. A bypass valve around the orifice opens on an “S” signal to return the system to full flow.

Fan coil units inside containment are provided with water from the plant cooling water system when they are operating in their safeguards mode. Portions of the cooling water system serving the fan coil units are designed to tolerate a single active failure, designed as Class I seismic, and are missile protected. With the exception of the initial hours after an accident, Cooling Water System pressure exceeds postulated containment accident pressure. Thus, there is minimal potential for leakage of radioactive material out of the containment via the cooling water system. Any leakage would be detected by the Radiation Monitors and the affected FCU isolated as discussed below.

The cooling water supply lines to the fan coil units are provided with a remote manual motor operated gate valve outside containment. Return lines are provided with a remote manual motor operated gate valve inside containment and a remote manual motor operated globe valve outside containment.

In the event of accident, the cooling water supply and return isolation valves position to full open to satisfy their safeguards function. In the event of a fan coil unit or associated piping rupture the containment remote manual motor operated isolation valves would be closed to prevent the entry of non-borated water into containment. Pressure against the closed isolation valves is maintained by equalizing lines. The water supply for this “seal” is provided by the cooling water system pumps (3 motor driven and 2 diesel driven) which take suction from the Mississippi River.

A lapse of integrity of the cooling water system piping or fan coil units inside containment would be indicated immediately by an increase in containment unidentified leak rate. Leakage would also be evident during periodic inspections of the containment. System pressure tests are conducted in accordance with the Prairie Island ASME Code Section XI Inservice Inspection and Testing Program at least once each inspection interval (10 years).

The containment purge and in-service purge line isolation valves are normally closed during operation. If in-service purging is being performed the valves are closed upon safety injection, manual containment spray, manual containment isolation or on detection of high radiation at the shield building vent stack monitors.

With respect to the testing of the automatic activation instrumentation, and specifically those of the radiation monitors, an actual or simulated signal is used driving it up past its trip point. Since the operation of the inservice purge valves in carrying the test to completion will not interfere with normal operation, the foregoing test is made to completion.

5.2.3.4 Containment Vessel Instrumentation

The containment vessel is provided with redundant instrumentation to provide the control room a continuous indication of the containment vessel pressure, water level and hydrogen concentration.

The redundant instruments are provided per requirements of NUREG-0737, "Clarification of TMI Action Plan Requirements." The addition of containment pressure and water level monitoring instruments are further discussed in Section 7. The addition of the hydrogen concentration monitor is discussed in Section 5.4.2.4.

5.2.4 Inspection and Testing

5.2.4.1 Containment Vessel

5.2.4.1.1 Pre-Operational Quality Assurance and Testing

5.2.4.1.1.1 General Requirements

Test, code, cleanliness, and Quality Assurance requirements accompanied each specification or purchase order for work materials and equipment. Tests performed by the supplying manufacturers are enumerated in the specifications together with the requirements, if any, for test witnessing by an inspector. Fabrication, including final cleaning and sealing, are described together with shipping procedures. Standards and tests were specified in accordance with applicable regulations, recognized technical society codes, and current industrial practices.

5.2.4.1.1.2 Quality Assurance

Fabrication procedures, non-destructive testing, and sample coupon tests for the Containment Vessel are in accordance with ASME Code for Boilers and Pressure Vessels, Section III, Subsection B.

All materials incorporated into the Containment Vessel and airlocks were subject to inspection at mill, shop and field and all materials conformed to the testing requirements of the ASME Code. All seam welds for the containment shell were 100% radiographed. All penetrations nozzles are welded into the shell and were radiographed or inspected by dye penetrant methods where radiographic methods could be ambiguous or difficult to interpret.

The Reactor Containment Vessel design, fabrication, material and testing conformed to all the requirements of the ASME Code and the ASME Code stamp of acceptance has been issued for and applied to the vessel.

During an NRC inspection at another facility, examination by radiography of primary containment liner penetration sleeve-to-process pipe (flued head fitting) welds revealed rejectable defects not originally found by ultrasonic examination. Ultrasonic signals from the weld backing bar apparently masked signals from defects. IE Bulletin 80-08, “Examination of Containment Liner Penetration Welds”, was issued to acquire information from all facilities to determine the generic nature of the problem. The initial Prairie Island responses to IE Bulletin 80-08 (References 22, 23, 24 and 25), identified two penetration butt welds with backing rings (Unit 1 penetration 7A, field welds #8 and #14) which were ultrasonically tested but could not be successfully radiographed as required by IE Bulletin 80-08. Per recommendations made in Reference 26 for the resolution of this issue, Northern States Power provided additional information for staff review in Reference 27. The NRC Staff reviewed the information provided by Reference 27 and found it acceptable (Reference 28). The Prairie Island response to IE Bulletin 80-08 was closed by the NRC Staff in Reference 28.

5.2.4.1.1.3 Testing

The Containment Vessel and Airlocks Specifications required acceptance testing was carried out on the constructed Containment Vessel prior to installation of internals and penetrations.

These tests included soap bubble tests at 5 psig and 41.4 psig, an over-pressure test at 51.8 psig, and an integrated leakage test at 41.4 psig.

After successful completion of the initial soap bubble test, the pneumatic pressure structural test was performed on the Containment Vessel and each of the personnel airlocks at 51.8 psig. Both the inner and the outer doors of the personnel airlocks were tested at this pressure.

After placement of external support concrete, removal of temporary stiffeners, T-ring girder and pipe columns, and placement of internal support concrete (stiffener for knuckle), but prior to fueling the reactor, the over-pressure test (at a pressure of 51.8 psig) was performed to provide assurance that removal of the stiffeners or other changes in the system during construction have not compromised the structural integrity of the Containment Vessel. This test was in accordance with the requirements of paragraph UG-100 of Division 1, Section VIII of the ASME B&PV Code.

The test pressure for this test was determined in accordance with the rules of paragraph N-1314 (d) of Section III and paragraph UG-100 (b) of Section VIII of the Code as stated in Section 5.2.1.

Following the successful completion of the soap bubble and initial over- pressure tests, the leakage test at 46 psig pressure was performed on the Containment Vessel with the personnel airlock inner doors closed.

Pressure was maintained for the length of time required to demonstrate full compliance with the airtightness requirements.

The leakage rate was determined by the “Reference System Method” which consists of measuring the pressure differential between the contained air and that of a hermetically closed reference system within the Containment Vessel. The “Absolute Method” which consists of measuring the temperature, pressure and humidity of the contained air, and making suitable corrections for changes in temperature and humidity was used to confirm the results. The results of both methods were in agreement.

Continuous hourly readings were taken until it was satisfactorily shown that the total leakage during a consecutive 72 hour period did not exceed 0.15 per cent of the total contained weight of air. The actual loss per 24 hours was less than 0.02%.

On September 21, 1973, a report “Containment Vessel Strength Test - June 17, 1973” (Reference 2), was submitted to the NRC. The purpose of this test (a repeat of the over-pressure acceptance test) was to provide assurance that removal of the stiffeners or other changes during construction did not compromise the structural integrity of the containment vessel. A tabulation of penetration displacements is included in Appendix A of Reference 2. A comparison of the above displacements data with Figure 5.2-1 indicates that containment displacement under pressure was somewhat greater than predicted by calculations.

5.2.4.1.2 Periodic Leak Tight Integrity Tests

The specific leakage test program to verify that potential leakage from the containment system is maintained within allowable limits is listed below. All testing is performed in accordance with the 10CFR Part 50, Appendix J, Leakage Rate Testing Program. The type of testing applied to the specific penetrations (Type A, B, or C in Appendix J 10CFR50) is identified in Table 5.2-1.

5.2.4.1.2.1 Integrated Leakage Rate Tests

a. An integrated leakage rate test (Type A test) was performed prior to initial plant operation at the Design Basis Accident peak pressure and at an intermediate test pressure to establish the respective measured leak rate. The minimum test temperature was 50°F.

b. Periodic testing is performed per ANSI/ANS 56.8-1994 and the Appendix J Leakage Rate Testing Program. The test duration is adequate for integrated leakage rate measurements, and the validity and accuracy of the testing results is verified by supplementary means.

c. Fluid systems which, under post-accident conditions, are open to the primary containment atmosphere (as defined by ANSI/ANS 56.8-1994) will be vented to the containment atmosphere prior to the test or, if not vented, provisions are included in the test procedure to account for this. Closure of containment isolation valves will be accomplished by the normal mode of operation.

d. Acceptance Criteria - The maximum allowable leakage rate shall not exceed the limit set forth in the Containment Leakage Rate Testing Program.

e. Frequency of periodic integrated leakage rate tests is specified in the Appendix J leakage rate testing program.

f. Type B and Type C testing will determine leak tightness and the leakage rate if significant leakage during the Type A test is detected.

5.2.4.1.2.2 Isolation Valves and Local Leakage Rate Tests

a. Isolation valves are tested for operability as required by the Inservice Testing Program.

b. Testable isolation valves and other penetrations of the Containment System are leak-tested at a pressure of 46 psig as required by the Appendix J Leakage Rate Testing Program.

c. Bolted double-gasketed seals are tested whenever the seal is closed after having been opened.

d. If the combined leakage rate from all local leakage tests as determined by the sum of the most recent results for each penetration exceeds the limits in the Technical Specifications, repairs and retest are performed to demonstrate reduction of the combined leakage rate to the acceptable value.

“Type B” penetrations include items such as blind flanges, air locks, double bellows seals for certain piping penetrations, flange seals for the equipment hatch, and electrical penetrations of the containment shell. Local leakage rate test procedures for these penetrations are, to the extent practical, conducted in such a manner as to determine whether the penetration seal is leak-tight and to quantify the leakage rate if significant leakage is determined. The normal procedure involves pressurization between seals with leakage rate determined by pressure decay, metering supply flow to maintain equilibrium pressure, or other appropriate methods.

“Type C” penetrations involve the valves identified in Table 5.2-1 and the containment leakage rate testing program. Leakage tests for these isolation valves utilize similar test procedures; however, the procedure for a specific set of valves takes into account the equipment arrangement, location and accessibility factors. Similar to the Type B penetrations, the procedure will determine the leakage rate by pressure decay, metering supply flow to maintain equilibrium pressure, or other appropriate methods.

5.2.4.1.2.3 Residual Heat Removal Systems

a. Those portions of the Residual Heat Removal System external to the isolation valves at the containment are hydrostatically tested at 350 psi at each refueling outage.

b. The total leakage from either train shall not exceed two gallons per hour. Visible leakage that cannot be stopped at test conditions shall be suitably measured to demonstrate compliance with this specification.

5.2.4.1.3 Containment Leak Tightness

Continued leak tightness of the containment and penetrations during the operating cycle is inherent to the design, fabrication and periodic testing requirements.

The Containment Vessel is conservatively designed in accordance with the ASME Code for nuclear vessels and was rigorously analyzed for loading conditions of a design basis accident as well as all other types of loading conditions that could be experienced.

The welds and shell plates are designed as an integral independent structural system. No leaks in weld seams are credible once the leak-tight integrity of the vessel has been established. Furthermore, it is implausible to postulate any conditions that would contribute to leakage of the vessel weld seams during normal operation.

As discussed in Section 5.2.4.1.1.2, all seam welds for the steel shell were 100% radiographed. All penetration nozzles are welded into the shell and were radiographed or inspected by dye penetrant methods where radiographic methods could be ambiguous or difficult to interpret.

The Containment Vessel structural integrity test was performed at an over-pressure in accordance with the ASME Code. The initial acceptance leakage rate test was performed at 46.0 psig and the leakage rate was less than 0.02% (by weight) in 24 hours.

In addition to these strident design and fabrication measures, the periodic testing described above in Section 5.2.4.1.2 provide reasonable assurance of continued containment leak tight capability.

5.2.4.2 Electrical Penetrations

Each prototype penetration assembly including connectors was tested to assure the integrity of design and materials. The tests included the following:

a. Leakage Rate Test
b. Pressure Test
c. Environment Test
d. Thermal Test
e. Short Circuit Tests
f. Insulation Resistance Tests
g. Voltage Tests
h. Repeat Leakage Rate Test
i. Electrical Continuity Tests
j. Seismic

Production testing of electrical penetration assemblies consisted of the following:

a. Leakage Rate Test
b. Dielectric Strength Test
c. Insulation Resistance Tests
d. Electrical Continuity Tests

Tests and sequence of test performed on both prototype and production penetrations are listed in Table 5.2-10.

For the electrical penetrations installed during original construction, leakage rate tests were performed using Helium leak detection procedures. Tests were performed at a temperature of 270°F with a helium differential pressure of 52 psig. The acceptance criteria for the maximum allowable leak rate was 1×10^{-6} cc per second. Leakage tests were performed twice during the sequence of tests on prototype model and once on each production unit.

The measured leakage rates during the testing satisfied the acceptance criterion.

Electrical penetrations installed subsequently have been tested per IEEE 317-1976.

5.2.4.3 Containment Vessel Air Handling System

The ventilation isolation valves are included as part of the containment isolation systems listed in Table 5.2-1. In-Service Purge and Containment Vent and Purge Systems normally have blank flanges installed for containment isolation.

The valves immediately outside the Reactor Containment Vessel are conventional butterfly valves, specified to be adequately leak-tight with maximum internal pressure inside the Containment Vessel. The inservice purge valves inside the Reactor Containment Vessel are butterfly valves which are leak-tight with maximum internal pressure on either side of the valves. This permits the space between the two inservice purge isolation valves to be pressurized to the maximum internal pressure at any time to ascertain continued leak tightness. The purge isolation valves will fail in the closed position upon loss of actuating power (electric or air).

The ventilation dampers and valves which perform a containment isolation function are designed for the necessary earthquake loadings. These valves have withstood tests at 0.5g horizontal simultaneous with 0.25g vertical accelerations. Each isolation valve was reviewed during final design of piping systems to determine the extent of support required. Most of the valves are supported by the piping system of which they are a part. Special supports are included for any valves which might require special consideration.

5.2.4.4 Vacuum Relief System

A prototype test on one complete vacuum breaker assembly, including the butterfly isolation valve, have been performed to verify that functional requirements (flow and pressure) are met. The test results are shown on Figure 5.2-12.

The leakage test for the vacuum breaker system is accomplished by pressurizing the piping between the vacuum breaker valve and the butterfly isolation valve. The vacuum breaker assemblies are provided with a test connection in the piping between the vacuum breaker valve and the isolation valve. These valves are leak tested per the Containment Leakage Rate Testing Program.

The vacuum breaker is equipped with an externally mounted, air actuated, spring loaded, fail safe mechanism for testing the vacuum breaker locally during operation. Limit switches indicate full open and full closed positions of the vacuum breaker valve. A test circuit in the controls for the butterfly valve permits testing of the isolation valve.

5.2.4.5 Containment Periodic Inspection

A periodic inservice inspection of the containment vessel is performed to satisfy the requirements of ASME Code, Section XI, Subsection IWE. The inspection program complies with 10CFR50.55a.

5.3 SECONDARY CONTAINMENT SYSTEM

5.3.1 Shield Building Design

5.3.1.1 Design Basis

The Shield Building completely encloses the Containment Vessel, the access openings, the equipment hatch, and that portion of all penetrations that are associated with primary containment. The design of the Shield Building provides for (1) biological shielding, (2) controlled releases of the annulus atmosphere under accident conditions, and (3) environmental protection of the Containment Vessel.

The Shield Building is primarily a shielding structure and as such it is not subjected to the internal pressure loads of a pressure containment vessel. The structure therefore will not be subject to bi-axial tension and cracking due to pressure loads. The reinforcement arrangements are based primarily on the needs to withstand the more conventional structural loads from environmental effects.

The design criteria for the openings are:

a. To provide reinforcement around the openings to carry all loads by frame action. Because the Shield Building wall thickness is set to meet radiation shielding requirements, the thickness is generally in excess of that necessary for structural requirements; therefore, it was necessary to add additional bars around the perimeter of the opening to provide a reinforced concrete frame.

b. To provide for horizontal and vertical shearing forces acting in the plane of the opening, diagonal bars are provided forming an octagonal pattern of reinforcement around the perimeter of the opening.

5.3.1.2 Description

The Shield Building is a reinforced concrete structure of vertical cylinder configuration with a shallow dome roof. An annular space is provided between the Containment Vessel shell and the wall of the Shield Building to permit construction operations and periodic visual inspection of the Reactor Containment Vessel. The volume contained within this annulus is approximately 374,000 cubic feet.

The Shield Building concrete wall is 2′-6″ thick and the dome is 2′-0″ thick for biological shielding requirements. The design bases for shielding requirements for operational radiation protection are discussed in Section 12.3. The results of analysis with respect to assumed post-accident conditions using these design parameters are discussed in Section 14.9.

The normal ambient temperature in the annular space is set by heat loss through the Containment Vessel and Shield Building. The design assures that the Containment Vessel metal temperature can be maintained above 30°F.

A minimum containment shell temperature of 30°F is required per Technical Specifications to provide assurance that an adequate margin above NDTT exists. The containment has a NDTT of 0°F; therefore, this limit provides a margin of not less than 30°F above NDTT. The Technical Specification also specifies a maximum allowable temperature differential between the average containment and annulus air temperatures of 44°F to provide assurance that offsite doses in the event of an accident remain below those calculated in Section 14. Evaluation of data collected during the first fuel cycle of Unit No. 1 showed that the existing limiting containment shell temperature of 30°F and the limiting temperature differential of 44°F between the average containment and annulus air temperature can be approached only when the plant is in Mode 5, Cold Shutdown or Mode 6, Refueling. Additional surveillances, to verify containment air and shell temperatures and annulus air temperature, prior to plant heatup to Mode 4, Hot Shutdown provide assurance that the above cited parameters are within acceptable limits prior to establishing conditions requiring containment integrity (Reference 3).

Following the Design Basis Accident (DBA), heat transferred to the air in the annular space could cause a slight pressure rise. This temperature-induced pressure transient is limited to less than 5″ H_2O by venting the annular space. Conservative assumptions for temperature transmission to the space, and pressure drop in the Shield Building Ventilation system was used in sizing the ventilation system. Following this initial pressure transient, the Shield Building is maintained at a slight negative pressure - approximately 2″ H_2O. The Shield Building seals are designed to accommodate these pressures.

The structure was analyzed to assure adequate strength to accommodate thermal stresses resulting from the above temperature-induced thermal gradients.

The following loadings are considered in the design of the Shield Building:

a. Structure dead load
b. DBA load
c. Live loads
d. Wind load
e. Tornado load
f. Uplift due to buoyant forces
g. Earthquake loads
h. External missiles

5.3.1.3 Performance Analysis

The Shield Building was designed so that its inleakage rate is not greater than the amounts indicated in Figure 5.3-1. The contribution to total leakage rate from the various sources of inleakage, with a differential pressure of 1/4″ of water are shown in Table 5.3-1. These leakage rates will in most cases vary linearly with pressure, and extrapolations made on this basis are shown in Figure 5.3-1.

The design Shield Building leakage rate increased from an estimated 0.6 volume% per day value given in the Facility Description and Safety Analysis Report to the 8.4 volume % per day value given on Table 5.3-1 due to a change in the type of personnel doors. The personnel doors were changed from a bulkhead type to a weather stripped type in order to improve accessibility in view of their anticipated frequent use.

Subsequently, the as-built leakage characteristics of the Unit 1 Shield Building are higher than predicted in Figure 5.3-1. Figure 5.3-1 was based upon a predicted in-leakage rate of 10% per day at a minus 1/4 inch of water. Measured performance of the Shield Building indicates an in-leakage approaching 50% per day at a minus 1/4 inch water. Figure 5.3-2 reflects this higher in-leakage rate.

The increase in the shield building in-leakage affects the long term exhaust flow from the shield building, increasing the exhaust flow from approximately 200 cfm to approximately 1000 cfm. In turn, the larger exhaust flow has a direct effect on the iodine release rate and results in an increase in calculated thyroid dose.

The allowable leakage rate for the primary containment was changed to 0.25 weight percent per day to compensate for the larger long term exhaust flow from the shield building. Initial preoperational tests of the primary containment showed an actual leakage (measured) of 0.0234 weight percent per day at the design basis accident pressure (46 psig).

The Shield Building penetrations for piping ducts and electrical cable are designed to withstand the normal environmental conditions which may prevail during plant operation and also to retain their integrity during and following postulated accidents.

The openings into the Shield Building, including personnel access openings, equipment access openings and penetrations for piping, duct, and electrical cable, are designed for leak tightness consistent with the specified leakage rates for the Shield Building.

The Shield Building is provided with three access openings, one located adjacent to the maintenance air lock, one adjacent to the personnel air lock and one adjacent to the equipment hatch. Each access opening adjacent to an airlock is provided with double inter-locked doors. A bolted, sealed door is provided at the equipment opening.

Pipe penetrations through the Shield Building are sealed with low-pressure flexible closures. For the cold penetrations, a “flexible boot” is installed, this boot consists of a sewn bellows, fabric reinforced, made of hypalon/nylon material with nylon-backed zipper, neoprene coated seams which are attached to a 3″ extension of the penetration sleeve by two stainless steel band clamps at one end. The other end of the bellows is attached to the cold process pipe by two more stainless steel band clamps. A silicone compound is used to seal each end of the bellows to its attachment and is also coated to the external surface of the zipper as a sealant. A prototype suitable for attachment to 8-5/8″ O.D. piping was exhaustively tested for structural integrity at 3 psi. At 6″ W.C. pressure differential, the leakage for this one penetration was found to be 0.01 cfm. This amounts to considerably less than the 500 cubic feet per 24 hours leakage rate listed for the penetrations in Table 5.3-1. The conservative allowance of 500 cubic feet amounts to only 0.1337% of the total building volume in a 24 hour period, relative to a nominal total inleakage of 8.4%/day.

The design pressure for all of these cold penetration flexible boots established per the above prototype test is 3 psi. The design temperature is the same as the piping system temperature. These flexible boots are not being used on any process penetration above 250°F. The material is capable of 300°F temperature.

For the large “hot” penetrations (those where the process piping temperature will exceed 250°F), the corresponding “flexible boot” is a stainless steel expansion joint, one end of which is attached to a 1/2″ thick extension sleeve, field welded to the flued head. The material of this sleeve extension is the same as the flued head. The other end of the expansion joint is welded to a sleeve extension which, in turn is field welded to the Shield Building penetration sleeve. The design is such that the expansion joint, though protected with a light gauge, removable, metallic covering, may be fully exposed for periodic inspection. For small “hot” penetrations (Letdown and Steam Generator Blowdown) the flued head is anchored and sealed at the Shield Building penetration.

Leak testing of these joints is unnecessary. Excessive inleakage into the Shield Building annulus, from these penetrations and others, would be observed during periodic testing of the Shield Building vent system. Surveillance is possible at any time by entering the five foot annulus through double doored access ports.

Flexibility of all cables is provided between the Shield Building and the Containment Vessel so that no damage can occur to the cables or structures due to differential movements between the two structures.

5.3.1.4 Inspection and Testing

5.3.1.4.1 Pre-Operational Testing and Inspection

5.3.1.4.1.1 General Requirements

Appropriate ASTM Material Specifications are cited in the Building Specifications for all construction materials which describe the testing and basis for acceptance of materials. Standards and tests are specified in accordance with applicable regulations and current building practices. The testing of concrete and reinforcing bar welding is referred to in Section 5.3.1.

Inspections were performed as necessary to verify compliance with specifications.

It should be noted that the Shield Building has no significant pressure containing function and, therefore, except for attention to good leak tightness, standard building construction and quality control practices are satisfactory.

5.3.1.4.1.2 Leak Tightness

Provisions have been made to test the leak-tightness of the Shield Building. The leak-tightness will be determined concurrently with the testing of the Shield Building Ventilation System. The testing program of the system is discussed below. Additional discussion of Shield Building Ventilation System Testing can be found in Section 5.3.2.

a. A pre-operational acceptance test was performed and supplemented by analysis that either or both of the redundant trains of the Shield Building Ventilation System are capable of accomplishing the following aspects of their design function following the occurrence of the Design Basis Accident:

    1. to limit the initial positive pressure rise in the Shield Building annulus to 0.5 psi.

    2. to produce a net vacuum everywhere within the Shield Building annulus within three minutes after actuation of the system.

b. This capability has been demonstrated in the absence of accident-related heat sources:

    1. by both systems operating together, and by each system operating independently, with the other system disabled.

    2. under calm wind conditions (5 mph), and again at wind speeds in excess of 20 mph.

c. Each test was initiated from equilibrium conditions by simulation of a safety injection or high containment building pressure signal. The prompt occurrence of net vacuum was measured directly at selected locations during these drawdown tests.

d. The results of these drawdown tests were compared with the results of the analysis, and the analysis model adjusted as necessary to adequately simulate the measured performance of the system.

e. The effects of accident-related heat sources were incorporated in the analysis and it was demonstrated, by means of conservative assumptions where necessary, that the required performance limits would also have been met during actual accident conditions.

f. Each redundant train will be activated separately during these periodic tests to demonstrate its operability.

g. Each system will be determined to be operable at the time of its periodic test if it promptly produces measurable indicated vacuum and obtains equilibrium discharge conditions that demonstrate that shield building leakage is within acceptable limits.

h. The Shield Building Ventilation System is tested to ensure that it will automatically start from a safety injection or a high containment building pressure signal.

5.3.1.4.2 Additional Testing Considerations

The need for an acceptance strength pressure test and possible surveillance strength testing of the shield building was carefully considered during the initial licensing. A review and discussion of the design considerations is presented to substantiate the conclusion that such testing was unnecessary.

Leak tightness provisions were made to test the leak tightness of the Shield Building. The leak tightness was determined concurrently with the testing of the Shield Building Ventilation System. The test determined that the Shield Building does meet the leak rate specified and additionally verifies the leak integrity of the flexible seals on the Shield Building penetrations. Testing requirements for the Shield Building Ventilation System are covered in the Technical Specification.

a. Tornado Considerations

The structure is designed in accordance with the design criteria to withstand the effects of tornadoes (and earthquakes, see Section 12) without loss of capability to perform its safety function. The criteria do not require design provision for strength testing under conditions simulating these natural phenomena, and such a test requirement would be most unusual, even if direct means of simulation were available.

The design calculation significant in the determination of tornado resistance considered the combined frontal pressure effects of the components of a design tornado wind condition: a 300 mph tangential velocity plus a 60 mph velocity of progression. The results of thorough investigation of the non-symmetrical loads and stresses resulting from these frontal pressure effects are described in Section 12.

Primarily as a check calculation for completeness of analysis, the structure was also analyzed for the condition corresponding to an internal pressure of 3 psi, a pressure differential greater than the maximum values reported to be associated with tornadoes. The uniform pressure differential might be construed to relate generally to conditions within the eye of a large tornado.

This 3 psi symmetrical load condition resulted in much lower maximum stresses than those determined for the non-symmetrical loads caused by the design wind condition. Thus, the internal pressure calculation is relevant only in that it demonstrates that a symmetrical load condition is not critical to determination of the tornado resistance of the building.

It is concluded on this basis that a pressure test would not provide a meaningful test of the capability of the structure to withstand a tornado. Neither the function of the structure nor the design tornado conditions relate to pressure vessels; therefore, pressure testing of the structure is not considered relevant in this regard.

b. Pressure Rise Associated with Post-Accident Leakage Collection

The role of the Shield Building in the design basis accident is to provide radiation shielding and in conjunction with the Shield Building Vent System, to collect and process leakage from the containment vessel. The structure is not intended as a pressure vessel, and the small pressure differentials incidental to the collection process do not warrant strength testing of the structure or its penetrations.

The only positive pressure that can be experienced is that due to initial thermal expansion of the containment vessel, and of the air in the annulus before its relief to the atmosphere. The design basis pressure rise, which considers no action of the Shield Building Vent System for the first 36 seconds following the accident, is only 3 inches of water column, or 0.1 psi; the maximum predicted for the case of an exaggerated heat transfer coefficient is 11 inches or 0.4 psi. Following this momentary positive pulse, net vacuum will be established and maintained throughout the annulus by either one or both trains of the shield building Vent System. Initial relief with a low initial positive pressure is assured by action of these redundant engineered safety features plus the outleakage that will occur through the low-leakage structure during the positive pressure interval.

It should be recognized, however that the Shield Building is not designed nor intended to be a pressure vessel; moreover the appropriately calculated peak accident induced pressure (see Appendix G, Section G.3) is no greater in magnitude than the negative pressure induced by test of the SBVS.

Further, although the Shield Building penetration seals have been specified and strength tested to withstand the 3 psi induced pressure differential associated with a tornado, they are all located within the confines of the Auxiliary Building, so that the possibility of subjecting them to that differential is extremely remote, if not impossible.

From a practical engineering standpoint, it appears meaningless to strength test at conditions near its low functional design loading a structure that is designed also to withstand far greater loads from postulated acts of nature.

In conclusion, pressure testing of this structure with regard to post-accident pressure transients seems unnecessary, unprecedented and without purpose.

However, to satisfy a commitment made to the AEC in the FSAR, a one time positive pressure test at approximately 10 inches water column was completed satisfactorily.

c. Accessibility

The only critical parts of the shield building function are the active components of the Shield Building Vent System and the filter units. These are located outside the Shield Building and they are always accessible. The five foot annulus itself, and its penetrations, are also accessible by two access openings having double interlocked doors.

5.3.2 Shield Building Ventilation System (SBVS)

Units 1 and 2 have separate Shield Building Ventilation Systems. The components of each unit are redundant. The remainder of this section, is presented for a single Unit, and is equally applicable to either Unit.

5.3.2.1 Design Basis

The Shield Building Ventilation System is designed to minimize the release of radioactivity from the reactor containment system following the DBA. The system is designed to reduce the release to less than 10% of the limits set forth in 10CFR100 using the ultra conservative TID-14844 assumptions.

The post-accident thermal expansion of the atmosphere within the annulus is prevented from exceeding 3.5″ H_2O positive at any time. Negative pressure is established and maintained within 4.5 minutes of the accident. The rate of expansion and pressurization within the annulus is calculated utilizing the containment shell temperature curve resulting from containment pressure transient studies with only one containment pressure-reducing system operative (one train of Fan Coil Units and one train of Containment Spray).

The capacity of the recirculation fan as selected returns the annulus to a negative condition within three minutes after the re-circulation fan is started. The flow capacity of the filter as selected matches the capacity of the fan and the charcoal bed capacity has been checked to assure adequate capability for removing the long term leakage of radioiodine.

The heating coils are designed to dry the incoming air at 100% saturation by increasing the temperature of the air entering the charcoal bed. The air is then dry enough to support the charcoal adsorber iodine removal efficiency requirements.

The exhaust fan is selected with an appropriate head-capacity characteristic to maintain the Shield Building annulus of approximately 2″ water column negative pressure for calculated Shield Building leakage rates. In order to provide an operating margin, the size and type of exhaust fan has been selected so that its head-capacity curve would allow it to perform its function for in-leakage flows in excess of 300% of the calculated leakage rating of the Shield Building at the negative pressures set by the fan head (see Figure 5.3-1). Further conservatism is inherent in the exhaust fan selection because the door style selected for the personnel doors on the Shield Building, the equipment hatch and the penetration seals are of a type that are somewhat more leak-tight than the models used for the basis of calculation. The actual leakage rate of the Shield Building as determined by test is shown in Figure 5.3-2.

5.3.2.2 Description

5.3.2.2.1 Design Conditions

The Shield Building Ventilation System is a system of fans and ducts for collecting the leakage from the Reactor Containment Vessel penetrations into the annulus of the Shield Building and discharging it through filters (particulate, absolute and charcoal) to the monitored Containment System Vent.

The Shield Building Ventilation System is normally in a standby condition during normal operation of the plant. Dampers located in the system prevent the flow of air through the filters from wind-induced pressure gradients. The filters are thereby retained in a fresh, unloaded condition for maximum efficiency during post-accident usage. The Shield Building Ventilation System discharge dampers are opened and fans are started by a Safety Injection. (Section 6 describes inputs which result in a possible SI signal).

The Shield Building Ventilation system is designed to provide three functions. One is to produce a slightly negative pressure within the annulus within the initial minutes following the loss-of-coolant accident. The second is to ensure the mixing of any Containment Vessel penetration leakage into a large portion of the Shield Building annulus, thereby avoiding potential direct streaming of the radioisotopes to the exhaust duct and hence increasing holdup within the annulus. The third function is to provide long-term cleanup of fission products from the annulus air by recirculation after the loss-of-coolant accident.

The normal temperature of the air within the Shield Building annulus will be approximately the same as the temperature of the air within the Containment Vessel. In the event of a loss-of-coolant accident, the air temperature would increase as the Containment Vessel shell temperature increases. The resultant thermal expansion of the air would pressurize the annulus during the first few minutes after the postulated accident unless suitably relieved.

Drawing slight negative pressure, relieves any pressure from thermal expansion that could cause out- leakage through the Shield Building. Such out-leakage would bypass the Shield Building charcoal filters, but would be picked up by the Auxiliary Building Special Ventilation System charcoal filters.

The pressure transient in the annulus poses no structural hazard to the Containment Vessel or Shield Building. Since the pressure increase in the annulus results from the pressure and temperature transient imposed on the Containment Vessel following the LOCA, the Containment Vessel internal pressure will be positive with respect to the external (annulus) pressure. The Shield Building is capable of structurally accommodating any foreseeable pressure transient of the annulus air.

The amount and rate of thermal expansion of the air during this initial period is dependent upon the rate of rise in temperature of the Containment Vessel shell and the rate of heat transfer from the shell to the air in the annulus. The rate of venting is set by the flow resistance of the filters and the vent ducting and the characteristics of the recirculation fan, which acts as an exhaust fan until the annulus reaches a sub-atmospheric condition and the recirculation dampers opens. While thermal expansion continues, the recirculation fan exhausts the excess volume of air and maintains a negative pressure in the annulus. The negative pressure is sufficiently low so that no internal effects will cause a localized area of the annulus to return to a positive pressure.

When the annulus has been drawn to a negative pressure, the full capacity of the recirculation fan is available to recirculate air within the annulus to ensure mixing. A smaller exhaust fan is then capable of exhausting the in-leakage to the annulus and continues to maintain a negative pressure in the annulus. In-leakage to the annulus is mixed with annulus air and drawn through the filter units to the monitored Containment System Vent Stack. The recirculation fans continue to recirculate the contaminated air of the annulus through the filters for long-term clean-up during the post-accident period.

5.3.2.2.2 System Description

The Shield Building Ventilation System flow diagram is shown on Figure 6.3-1.

The Vent System consists of two full-capacity, redundant, fan and filter systems which share a common Containment System Vent Stack. The Vent exhaust pipe (stack) is located in the Shield Building annulus and extends approximately five feet above the Shield Building. The fans and filters are located in the Auxiliary Building.

Each system is made up of heater elements, particulate (roughing), absolute, and charcoal filters, all in series, and two fans. One fan is used for recirculation and mixing of the Shield Building air volume and one small fan is used to hold the annulus at a slightly negative pressure with respect to the atmosphere.

The discharge of the recirculation fan can either flow to the Containment System Vent Stack through an automatically operated damper, or can be recirculated to the annulus through another automatically operated damper.

The discharge of the small exhaust fan contains a backdraft damper to prevent wind-induced flow of air through the filter. The recirculated discharge from the larger fan in each system is returned to the annulus through ducting designed to enhance circulation within the annulus.

Back-draft dampers are provided in the discharge lines from both fans. These dampers prevent back flow through the ducts when annulus pressure decreases due to cooldown of the air after the thermal expansion transient. When fan head is insufficient to discharge air due to low annulus pressure, the dampers will seat and allow the negative pressure in the annulus to be maintained. The back draft damper in the recirculation duct prevents out-leakage while the annulus is at positive pressure in the unlikely event of a spurious opening of the automatic damper in the recirculation duct.

5.3.2.2.3 Actuation and System Operation

Following a loss-of-coolant accident the Shield Building Ventilation Systems are placed into operation by the Safety Injection Signal. The signal causes the automatically operated dampers in the discharge lines to the Containment System Vent Stack to open. The fans are started early in the emergency power loading sequence for engineered safety features. The negative pressure setting on an annulus differential pressure switch will signal the opening of the recirculation dampers. There are two pressure signals (pressure switches) one per train, which are separated; using separate penetrations for sensing lines and separated (train) wiring. Testing of this system can be carried to completion at any time without affecting plant operations. Hence the “one-out-of one” per train arrangement meets IEEE 279-1968. An auxiliary contact on the recirculation fan in each loop will allow the recirculation damper in that loop to open only if that respective fan is operating. Following initiation of recirculation, the small exhaust fan continues to discharge in-leakage flow (caused by the negative pressure in the annulus) through the filters to the vent stack, thereby holding a negative pressure throughout the annulus as the recirculation fan continues to recirculate filtered air.

As the Containment Vessel shell is cooled by the Containment Air Cooling Systems, the annulus air will begin to cool causing a further reduction in annulus pressure. During this period, if the annulus pressure draws the system below the head capacity of the exhaust fan, a backdraft damper in the exhaust duct will close to prevent backflow.

In the period following cooldown of the annulus air, the negative pressure and discharge flow will be determined by the Shield Building in-leakage rate and the head-capacity performance characteristics of the fans.

5.3.2.2.4 Component Design

5.3.2.2.4.1 Fans

The exhaust and recirculation fans are vaneaxial, direct-connected fans of standard construction. The recirculation fan is nominally rated at 5000 cfm and the exhaust fan at 200 cfm.

5.3.2.2.4.2 Filter Assemblies

The filter assemblies are composite units consisting of electric heating elements, Pre-filter section, HEPA filter section, and an impregnated charcoal bed filter section. Each section is designed as follows:

a. The heating coils are designed to dry the incoming air at 100% saturation by increasing the temperature of the air entering the charcoal bed. The air is then dry enough to support the charcoal adsorber iodine removal efficiency requirements. Temperature sensing devices actuate the heaters in an on-off fashion to prevent over-heating the heater elements.

b. The high-efficiency particulate filters are designed to be capable of removing 99.97 percent minimum of particulate matter 0.3 micron or larger in size. Filter design is water and fire resistant, and meet all requirements of AEC Health and Safety Bulletin 212-1965.

   The units are tested to meet the requirements of MIL Spec 51068, which requires heated air testing at 700°F. These filter assemblies have successfully passed the testing at this temperature which is far greater than those which could be experienced by the filter assemblies as a result of overheating either from fission product decay heat or from a postulated malfunction of an electric heater.

   Radiation resistance of the materials in HEPA filters has shown that the media will lose some tensile strength after exposure, but that filter efficiency is not affected (Reference 4). Tensile strengths are not reduced to the point where filter integrity becomes questionable because of the large margins present in the basic filter design.

c. The iodine filter is an impregnated activated charcoal bed, designed to remove 99.9% minimum of elemental iodine and 95% minimum of methyl iodine. These filters were sized based upon an atmosphere of 150°F, 70% relative humidity, a filter depth of 2 inches and a residence time of 0.25 seconds. The ignition temperature for the charcoal used is greater than 330°C.

The design parameters of charcoal filters in the Shield Building Ventilation System for the Prairie Island Nuclear Power Plant are listed in Table 5.3-3. These design parameters were originally used for equipment sizing and selection, and do not necessarily reflect operating conditions. Filter testing conditions, per the ventilation filter testing program (T.S.5.5.9) envelope expected worst-case operating conditions. (Reference 35)

The Auxiliary Building Special Ventilation System filter assemblies are essentially similar in design parameters.

Figure 5.3-3 shows the arrangement of the filter assemblies and the relative spacing of heaters, filters, etc.

The particulate and charcoal filters have a nominal flow rating of 6000 cfm and are sized to retain the fission products released to the Shield Building following any of the postulated accidents without exceeding a loading of 10 mg/gm for elemental iodine or 3 mg/gm for organic iodine. For sizing criteria, it has been assumed that 10% of the total iodine will occur in the organic form.

The heater control scheme design includes energizing the respective electric heater at the inlet to the filter units at the same time the recirculation fan in the Shield Building Vent System is started. Alarms in the control room annunciate if the humidity in one of the vent system trains rises above 70%. Since the electric heaters, under this mode of control, are always energized when the system operates, this heat contribution to the annulus air of the Shield Building Vent System was included in the computer model analysis performed on the SBVS. However this heat contribution to the Shield Building atmosphere from the electric heater in the Shield Building filter assembly is extremely small compared to the overall heat contribution from the containment vessel itself following the loss of coolant accident.

To preclude the possibility of a heater remaining on under a no flow or low flow condition, interlocks have been provided to trip the respective heater in the event the recirculation fan (SBVS) or Auxiliary Building Special Ventilation System exhaust fan trip. A heater trip is also provided on a low flow condition through the filter. Additional low flow protection is provided to trip the heaters upon observing a high temperature near the downstream face of the heater. Failure of a heater to turn off as a consequence of electrical shorting is prevented by overcurrent trip devices provided on each heater.

Independent and diverse safety features are provided in the heater controls to trip the heaters upon indication of any condition associated with loss of flow or overheating, as was described above. These safety features have been incorporated specifically to prevent continued heater output during the postulated loss-of-flow condition. Therefore an assumed failure of the heaters to turn off upon loss of flow is not regarded as credible.

Normally the filters are cooled by the air flowing through them. Even if the air flow is terminated and the filter train isolated, the filter and filter housing will dissipate fission product decay heat without filter damage. The results of an analysis of the charcoal filter ignition hazard are reported in Section 14.9.7. It is concluded that no ignition problems are anticipated with the charcoal filter design.

To provide further protection against fission product release due to high carbon temperatures, a deluge system is installed in each filter assembly, in the Shield Building Ventilation and Auxiliary Building Special Ventilation Systems. Analysis has shown that the carbon temperatures will not become high enough to cause the release of fission products without the deluge system in operation (see Section 14.9.7). Therefore, the deluge system is unnecessary.

5.3.2.2.4.3 Charcoal Filter Water Deluge Feature

Table 5.3-4 lists the single failure analysis for the charcoal filter water deluge feature. The PAC ventilation filters in the SBVS and the Auxiliary Building Special Vent System are equipped with a water spray nozzle for the charcoal beds. Deluge water is supplied to each of these filters from either the Fire Protection Header or Cooling Water Header. A direct acting solenoid valve has been supplied for each filter just upstream of its spray nozzle. These solenoid valves are normally closed and are energized to open by U.L. approved temperature switches, one switch in the filter and one switch after the filter, either switch will actuate spray. Each temperature switch is set at approximately 250°F, which closes a contact thereby energizing the solenoid. Paddle type flow switches are provided upstream of each solenoid valve for remote indication of water flow in the line. The flow switches serve primarily to alarm inadvertent actuation of the spray system.

5.3.2.2.4.4 Instrumentation and Control

Indicating lights and annunciation are provided in the control room for flow and temperature switches.

The temperature switches and associated alarms are periodically functionally tested. Verification of actuation of the solenoid valves is not required as it is not practical and the operability of the PAC filters is not dependent on the fire protection system per this section and section 14.9.7.

5.3.2.3 Performance Analysis

In order to provide assurance that the system will perform its intended function, extensive analytical evaluations have been performed. These have included evaluations of those system variables that might have significant effects on the system performance.

A detailed study of the mathematical models used to predict the behavior of the system was reported in the preliminary FDSAR. Several minor improvements were made to the computer programs to make them more rigorous, although the added sophistication had only minor effects on predicted system behavior. The Shield Building Ventilation System (SBVS) computer model is discussed in detail in Appendix G. Revision of the computer code to predict SBVS system performance was discussed in “Prairie Island Containment System Special Analysis Report” submitted to the NRC in a letter dated April 9, 1976 (Reference 3). The report also presented the evaluation of computer model accuracy in predicting SBVS performance during power operation in cold weather.

The basic input or forcing function for this analysis is obtained from the Containment Vessel Pressure Transient. The Computer Code used for this latter transient is GOTHIC, as described in USAR Appendix K, which is an NRC-approved methodology. This Code analyzes the Containment pressure following DBA and provides a temperature - time history of the containment vessel wall. See Appendix K for additional information.

The SBVS mathematical model involves the following three transient phenomena which interact with each other:

a. Heat transfer from the steel shell to the air in the annulus and that from the air to the concrete wall of the Shield Building.

b. Pressurization and depressurization of the air in the annulus corresponding to the air temperature and air mass remaining in the annulus.

c. The flow of air through a network of ducts, fans, dampers and the charcoal filter system along with the in- or out- leakage of air through the walls of the Shield Building.

5.3.2.3.1 Time History Performance of SBVS

The Shield Building Ventilation System Analysis is described in detail in Appendix G and, therefore, it will not be repeated here. However, it is necessary to briefly describe the various periods of the time history performance of the SBVS. The SBVS is not required to operate for normal plant operation. All dampers are normally closed.

Time Period - 1 (Time 0 to Time SBVS Fans Start)

A Safety Injection signal, following the hypothetical LOCA, causes each SBVS fan to start and the associated fan discharge dampers to open. Until the fans start, the containment vessel expands due to the blowdown pressure and temperature increase. The annulus pressure increases due to the decreased volume and increased air temperature. The pressure continues to increase due to the thermal transient following the blowdown until the SBVS fans start.

Time Period - 2 (Time SBVS Fans Start Until Recirculation Set Point Is Reached)

Period 2 (a) (Time SBVS Fans Start To the Time To Reach Zero Annulus Pressure)

During this period, both the large recirculation fan and the small exhaust fan discharge the filtered annulus air to the Containment System Vent Stack. The pressure continues to drop from its positive peak until it reaches a zero value.

Thus, the annulus is at a positive pressure from time zero until this point is achieved (approximately 2.6 minutes). Hereafter, the annulus pressure is negative for the remainder of the LOCA. The exact time required to reach an average zero pressure differential between the SB annulus and the external atmosphere is not the critical consideration in estimating the dose from the SBVS, but rather it is the total SB outflow that must be examined.

Period 2 (b) (Time Annulus Pressure Reaches Zero Until Recirculation Set Point Is Reached)

The large and small fans continue exhausting the filtered annulus air until the “Recirculation Set Point”, (as detected by differential pressure switches that measure the pressure differential between the annulus and the Auxiliary Building Special Ventilation Zone) is reached. Achievement of this negative pressure (-2.0″ WC) causes the opening of the recirculation damper, in the discharge of the recirculation fan.

Realizing that the duration of positive pressure and the time required to achieve a nearly steady negative pressure differential influence the SB outflow, a conservative outflow envelope was selected for dose calculations. (See Table 14.9-1 and Figure 14.9-4). During the 0-20 minute period the calculated SB outflow (Figure 14.9- 4) is approximately 30,000 ft^3. The dose calculations assume an outflow of approximately 53,000 ft^3 in this time period. This margin has been conservatively chosen to accommodate arbitrary deviations from the reference case. For example if it is postulated that the wind increases from 0-30 mph during the period of positive annulus pressure, the average external SB surface pressure might drop by 0.5 in. W.C. relative to the average annulus pressure.

Calculations show that an additional 25000 ft^3 would need to be removed from the annulus to overcome the additional pressure differential change. The effect of the wind change is well within the margin of outflow, and the effect on SBVS dose at the site boundary would be an increase of less than 5% of the effect of wind velocity if plane dispersion is ignored. However, when considering the favorable effect to the X/Q values the overall effect would be to actually reduce the dose.

Time Period - 3 (Time Recirculation Begins To Time Equilibrium Recirculation is Achieved)

When the recirculation damper opens, the discharge flow from the large fan hydraulically splits, part being exhausted through the Containment System Vent Stack and part recirculated to the annulus. The annulus pressure rises slightly though still negative, until the fans reverse this trend once again. All during this time the thermal transient is leveling off and the ratio of exhaust flow to recirculation flow from the recirculation fan is continuously decreasing. This trend continues until equilibrium flow conditions are reached. This time is reached for the DBA in approximately 20 minutes.

Time Period 4 - (Remainder of the LOCA Transient)

The magnitude of this exhaust flow during equilibrium recirculation is equivalent to the Shield Building in-leakage plus primary containment leakage to the annulus. This becomes an important parameter in that it sets the relationship between the amount of filtered exhaust discharged to the environment and that retained and recirculated. Minimizing the Shield Building in-leakage increases the effectiveness of the system during long-term operation.

5.3.2.3.2 Significant Parameters

The significant parameters during the four time periods mentioned earlier are discussed in the same order.

Time Period - 1

a. Fan Starting Time

   The analysis assumes a 36 second delay following a DBA before the fans are started. This time delay allows for the Diesel Generator starting, loading sequence and a conservative margin of an additional 20 seconds.

   With no loss of offsite power the system is in operation in less than 10 seconds and the positive pressure duration is reduced considerably.

   The acceptance test on the Diesel Generator starting and loading sequence verifies the conservatism in this parameter.

b. Heat Transfer Coefficient From the Steel Shell to the Annulus Air

The heat transfer coefficients are derived from well established experimental data. An extensive literature search was made to determine the most appropriate correlation to be used in the analysis. The results of this search indicated that the correlation used in Appendix G, equations G.3-1 to G.3-4 are appropriate. The details of this search are summarized in the Section following the discussion on Significant Parameters.

In addition the extensive heat transfer parameter studies are reported in Appendix G.

Therefore, tests to verify the heat transfer coefficients were not necessary.

c. Instantaneous Expansion of the Shell

The analysis assumes an instantaneous stretching of the containment vessel due to the blowdown pressure peak thus causing instantaneous pressure rise in the annulus. In addition, for the analysis, no relief is granted to the annulus air even after the vessel has contracted as the containment pressure drops.

Time Period - 2

Period - 2(a): The significant parameters during this positive pressure period are as discussed above in Time Period 1, paragraph (b).

Period - 2(b): The only significant parameter during this period is the set point for recirculation initiation. The set point which causes the opening of the recirculation damper is sufficiently low so as to keep the annulus pressure negative following initiation of recirculation and for the remainder of the transient.

Time Periods 3 and 4

The only parameter of any influence is the heat transfer coefficient. This was discussed above in Time Period 1, paragraph (b).

Other Parameters

There are several other parameters of significance which influence the pressure and dose transient more than any of the above discussed parameters. These are discussed below:

a. Shield Building Leakage

The SBVS performance analysis is based on an assumed leak characteristic of the Shield Building of 10%/day at 1/4″ W.C. differential pressure. Measurements made during Unit 1 Plant initial tests indicated an in leakage rate of 50%/day at 1/4 inch water. See Section 5.3.1.3 for additional discussion. The dose analysis is based on an assumed leakage rates shown in Table 14.9-1.

b. Fan Characteristics and Physical Parameters of the System

Manufacturer's shop tests and the "Pull-Down" test demonstrates the capability of the fans to perform its functions.

c. Containment Vessel Leak Rate

The SBVS performance analysis is based on an assumed containment leak rate of 2.5%/day. The dose analysis is based on an assumed containment leakage rate of 0.25 weight % day for the first 24 hours. In reality the containment vessel is specified for a leak rate of less than 0.1% day. Therefore the analysis based on a 0.25%/day has ample margin for the offsite dose evaluations. To accommodate the as-built shield building leakage, the Containment Leakage Rate Testing Program allowable leakage was reduced to 0.25 wt%/day. This effectively reduces calculated doses to original design levels.

5.3.2.3.3 Literature Search On Heat Transfer Coefficient By Natural Convection For A Huge Vertical Plate

The Buckingham's theorem (Reference 5), proved mathematically by Langhaar (Reference 6) and known as the basis of all dimensional analyses, has been extensively applied to fluid mechanics and heat transfer in extending experimental data from a model to its full scale prototype. In applying dimensional analysis, the variables significant to a given problem are formed into dimensionless groups which, (without providing any information about the mechanism of the process) aid in correlating experimental data and developing functional relationships between dimensionless groups. The effect of any dimensional factor can therefore be evaluated from such functional relations.

Lorenz's (Reference 7) analytical solution to natural convection adjacent to a heated vertical wall was the first to incorporate all of the variables significant to natural convection. Correlations involving the Grashof and Prandtl numbers had not been popularized at the time of Lorenz's work, however, his solution reduces naturally to the form of equation (1), as dimensional analysis (Reference 8) has predicted.

$$Nu = c \ (Gr\ Pr)^n. \qquad (1)$$

The correlation shown in equation (1) was further reviewed and supported by many outstanding researchers (References 9, 10, 11) whose effort in the prediction of the constants c and n for laminar and turbulent flow conditions was rather remarkable.

It is well established that the transition of flow pattern from laminar to turbulent flow occurs approximately at 2 feet (Reference 12) from the leading edge of a vertical plate. For turbulent natural convective flow along a vertical wall, a widely accepted equation originally correlated by Nusselt and King (Reference 9), and recommended by Jakob and Linke (Reference 10) is

$$Nu = 0.129\ (Gr\ Pr)^{1/3} \qquad (2)$$

where $10^9 < (Gr\ Pr) < 10^{12}$.

King compared the behavior of the heat transfer on short and long vertical surfaces and led to a conclusion that with an increase in Grashof numbers, Gr, the mean heat transfer per unit area and therefore also the mean coefficient of heat transfer becomes independent of the height. The exponent of 1/3 in equation (2) is naturally consistent with the result of King's observation.

Theoretical studies performed on this topic have also accumulated information enough to support that equation (2) is adequately applicable to a system of higher Grashof numbers, at least up to 10^{15}. Bayley's (Reference 13) theory of applying appropriate temperature and velocity profiles to the boundary layer yielded somewhat different values for c and n, but the solutions are in fair agreement with experimental data in the range of $10^9 < (Gr\ Pr) < 10^{12}$.

$$Nu = 0.10 \ (Gr\ Pr)^{1/3} \qquad (3)$$

for $2 \times 10^9 < (Gr\ Pr) < 10^{12}$,

and $Nu = 0.183\ (Gr\ Pr)^{0.31}$ (4)

for $(Gr\ Pr) < 10^{15}$.

Still in a separate study, Eckert and Jackson (Reference 14). who applied Karman's integral momentum equation for the boundary layer and data on the wall shearing stress and heat transfer in forced convection flow of very low Reynolds numbers derived a semi-empirical equation (equation 5) for the turbulent natural convection along a vertical surface.

$$Nu = 0.021\ (Gr\ Pr)^{2/5} \ . \qquad (5)$$

Since this equation was proved to be in good agreement with experimental data (References 11, 15) in the range of Grashof numbers from 10^{10} to 10^{12}, Eckert suggested that the equation can be used in the case of higher Grashof numbers. Equations (2) (3) and (5) together with experimental data were plotted in Figure 5.3-4 for comparison.

It is of interest to note that theoretical solutions do indicate an exponential relationship between heat transfer coefficient and the characteristic length in higher Grashof numbers. However, discrepancy of analytical solutions, presumably due to the differences in dealing with temperature and velocity profiles (Reference 16) in the boundary layer, are well covered by the empirical equation (2) in which the heat transfer coefficient is independent of the height. In the discussion of the work of Cheesewright (Reference 17) who tended to agree with Eckert's theory, Warner (Reference 18) pointed out that a definite trend toward milder temperature gradient was detected in the very vicinity of the vertical wall and therefore gave substantial credence to Bayley's theory. Incidentally, heat transfer coefficient predicted by using equation (2) is approximately 22% higher than that obtained by Bayley's equation at Grashof number in the order of 10^{14}.

The predicted Grashof numbers for the Prairie Island containment vessels are in the range of 10^{13} to 10^{14} with a vertical height of 130 feet.

Literature survey has indicated that equation (2) is most appropriate for the prediction of heat transfer coefficient of the system because of the minimum deviation from theoretical solutions and experimental data as well.

The turbulent natural convective heat transfer coefficient used in Appendix G (equations G.3-1 to G.3-4) to evaluate the performance of the Shield Building Ventilation System is shown in equation (6).

$$h = 0.196\ (\Delta T)^{1/3} \qquad (6)$$

This equation (6) known in a simplified form, is accurate within 3 percent to equation (2). It is concluded that, with experimental and analytical background, equation (6) or equation (2) is sufficiently accurate for predicting the heat transfer coefficients between the vertical surface of the containment vessel and the bulk annulus air. Naturally, it is also valid for predicting heat transfer coefficient between the annulus air and the vertical wall of the Shield Building.

5.3.2.4 Inspection and Testing

5.3.2.4.1 Quality Assurance

The following inspections and tests were performed to provide assurance that the functional intent of the system is achieved during the manufacture of the components and the construction of the system:

a. All ducting and filter assemblies were given a pneumatic pressure test and leak test.

b. Each filter assembly received a filter performance test. Each HEPA and charcoal filter bank was tested in place to verify performance.

c. Dimensional tolerances on filter assemblies and frame assemblies were checked to assure that suitable gasket compression is uniformly achieved on the filter sealing faces. Periodic tests of the filter assemblies are made in accordance with Technical Specifications and Ventilation Filter Testing Program.

d. The manufacturer has demonstrated, by testing charcoal essentially identical in composition to that furnished with the filter assembly, that the charcoal bed is capable of removing 99.5% of molecular iodine - 131 in the presence of a gaseous concentration of 50 mg per m^3 of non-radioactive molecular iodine or 95.0% of methyl-iodide - 131 in the presence of a gaseous concentration of 5 mg per m^3 of non-radioactive methyl iodide. This performance level was maintained until the amount of non-radioactive I_2 which reached the test unit was equivalent to 100 gm in the full-scale system. Following this loading, air at 70% RH and 150°F was drawn through the test unit at its rated flow for two hours. The integrated I_2-131 removal efficiency for the test unit, including both iodine feed and elution periods, was no less than 99.0% for the molecular iodine - 131 and no less than 95.0% of the methyl iodide - 131. The I_2-131 and CH_3-I-131 activity during feed periods was between 10 and 100 millicurie/gm of non-radioactive I_2 fed.

e. Each charcoal bed filter was assembled at the manufacturer's shop and given a Flow Resistance Test and a Leak Test.

f. A sample of each lot of carbon was tested for iodine collection capability in configuration and at a gas flowrate and conditions comparable with the filter design. The iodine concentration upstream of the bed was 1000 mg/m^3 and the penetration did not exceed 0.01% for a period of 850 seconds.

g. High-efficiency particulate absolute filters were random tested to demonstrate the filter's ability to withstand a pressure differential of 10 inches of water without loss of filtering efficiency.

h. HEPA filters of identical design to those in the filter assemblies were subjected to a rough handling test (3/4 inch amplitude at 200 cycles/min.) following which the filter demonstrated no loss of filtering efficiency.

5.3.2.4.2 Surveillance Tests

Periodic tests of the filter assemblies are made in accordance with the Ventilation Filter Testing Program. Filter efficiency testing is based on maximum air flow (5500 cfm) with a residence time of 0.213 seconds. Per the ventilation filter testing program (T.S.5.5.9), the HEPA filter is tested to 0.05% penetration and system bypass. The time required to test a filter should not exceed 30 minutes, even if it is necessary to probe and retest in the event of excessive leakage; and normal test periods would be much shorter. For this conservative duration of test exposure and an injection rate of 1 gm/min of Dioctyl Phthalate (DOP), a total deposition of approximately 30 gm of DOP would be deposited during each test of an upstream HEPA filter bank. With annual tests over a five year period, the total DOP deposited on the upstream HEPA filter bank would be on the order of 150 gm. (Reference 35)

Since the vapor pressure of DOP is extremely low (2×10^{-4} mm Hg at 170°F), the maximum anticipated post-accident temperature increase in the Shield Building (from 70 to 170°F) could cause negligible release less than 1% of DOP from the HEPA filters. Furthermore, no more than 30 percent of any DOP release that might occur from an upstream HEPA filter could be deposited and retained on the charcoal filter, because of its extremely poor efficiency of adsorption for DOP. If it is assumed that this DOP were all released as a result of post-accident temperature increase and were then caught and retained on the charcoal, the loading on the bed would be less than 1.65×10^{-6} grams of DOP per gram of charcoal. This is a quantity so minute as to be immeasurable - and inconsequential with regard to effectiveness of iodine removal, even if it were arbitrarily assumed in addition that deposition was confined to the outer one percent thickness of each layer of charcoal. It is apparent from this result, and from consideration of the conservatism of the estimate, that the very small amount of DOP contaminant cannot have any effect on the ignition temperature of the charcoal.

The same conservative estimate may be extended to consideration of potential production of methyl iodide by assuming that the total amount of DOP that was presumed to collect on the charcoal reacts completely with the iodine or iodide that is also present on the charcoal, either as initial impregnant or as collected radioactive containment leakage. The effect is again inconsequential because of the minute amount of DOP and the relatively large amount of impregnated iodine. DOP is 74 percent carbon by weight, so the total carbon available for reaction with iodine to form CH_3I is 1.65×10^{-6} or 1.22×10^{-6} grams of carbon per gram of charcoal. The carbon could react with the iodine in the ratio of atomic weights, so the amount of iodine that might be combined organically is:

$$1.22 \, X 10^{-6} \, \frac{\text{gm carbon}}{\text{gm charcoal}} \; X \; \frac{127 \text{ gm iodine}}{12 \text{ gm carbon}} = 1.29 \, X 10^{-5} \, \frac{\text{gm iodine}}{\text{gm charcoal}}$$

The abundance of the initial iodine impregnant in the charcoal is five percent by weight. Thus the maximum fraction of the initial iodine that might be converted to methyl iodide is:

$$\frac{1.29 \times 10^{-5}}{.05} = .026\%$$

The fraction applies identically to the initial iodine impregnant or to the several grams of radioactive iodine that could be deposited on the charcoal during the post-accident period. Under the most adverse conditions, and for consistently conservative assumptions, no more than .026 percent of the iodine might be converted to organic form by the effects of DOP residue.

It is concluded that the extremely small quantities of DOP that will be used in testing of the HEPA filters will have essentially no effect on the functional capabilities of the charcoal filters.

5.3.2.4.3 System Acceptance Tests

In order to prove that the Shield Building Ventilation System (SBVS) would perform in accordance with its design criteria, acceptance tests of the system were performed as described below prior to plant startup.

5.3.2.4.3.1 Pull-down Tests

The Pull-down test was conducted for the following purposes:

a. To verify that the Shield Building Ventilation System produces a measurable vacuum in the annulus within 30 seconds after actuation of the system.

b. To verify that the recirculation valve is opened and recirculation is initiated at -2.0″ W.C. annulus pressure.

c. To verify that the system performance confirms the computer prediction and

d. To determine the leakage rate of the as-built Shield Building with all its penetrations, doors, etc., installed.

The SBVS was initiated with all normal penetrations and doors, etc., installed. The test was ‘‘cold” without any attempt to simulate temperature conditions. The two fans (large recirculation and small exhaust) initially discharged to the containment system vent. When the annulus reached the recirculation mode set-point pressure, the recirculation damper opened. Continuous flow (at the containment system vent) and annulus pressure measurements were made.

a. The annulus pressure measurement verified that measurable vacuum is achieved in less than 30 seconds.

b. Signals from the differential pressure switches and annulus pressure measurement verified that recirculation is initiated at -2.0″ W.C.

c. The pressure and flow measurement as a function of time were compared to curves generated by the computer code for similar conditions. The appropriate curves were developed by the computer using the measured leakage rate of the Shield Building (see (d) below). The comparison verifies that the system performs according to the computer prediction.

d. The steady state flow and pressure measurement determined the Shield Building leakage rate. This measurement provided the bases for Figure 5.3-2.

5.3.2.4.3.2 Other Tests

Additional tests on the Shield Building Ventilation System (SBVS) were performed as follows:

5.3.2.4.3.2.1 For Negative Pressure at Various Locations

This test demonstrated system ability to attain a negative pressure at several representative locations in the annulus.

With Train A first, and then Train B, the SBVS was operated until equilibrium conditions existed. Then accurate differential pressure measurements between the annulus and the Category I Ventilation Zone of the Auxiliary Building were made at the following locations within the annulus.

	UNIT 1		UNIT 2	
	Elevation	Azimuth	Elevation	Azimuth
(a)	708′ - 3″	330° containment vessel	Same as on Unit 1	Equivalent azimuths to reflect Mirror image on Unit 1
(b)	716′ - 0″	45°		
(c)	724′ - 0″	270°		
(d)	734′ - 0″	330°		
(e)	755′ - 0″	280°		
(f)	766′ - 0″	330°		

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Accurate barometric readings were taken at the reference location within the Category I zone and outside the Auxiliary Building. Temperatures were obtained to correct these barometric readings.

In addition to demonstrating the occurrence of sufficient vacuum at all locations of measurement, the results of these tests indicated the magnitude of the actual pressure differences associated with air movement.

5.3.2.4.3.2.2 Tests on Additional Resistance and Inleakage

Additional tests were also performed to evaluate the system response

a. to added flow resistance at different locations in the duct work and
b. to additional inleakage through openings of known sizes.

5.3.2.4.3.2.3 Partially Blocked Discharge Vent

This type of test was performed for both Train A and Train B of the SBVS. The exit from the vent was partially blocked with temporary materials, such that part of the free discharge area is blocked off. Then the time required to draw the annulus down to a sufficiently negative pressure was determined and compared to the computer code for similar resistances.

5.3.2.4.3.2.4 Partially Closed Recirculation Damper

With Train A of the SBVS operating at equilibrium, additional flow restriction was added to the recirculation duct by partial closing of the recirculation damper. Test data was obtained until the check damper to the vent opens. A partially closed recirculation control valve has the effect of causing the annulus to become more negative than in normal operation since in that case, more air would be diverted to the exhaust vent.

5.3.2.4.3.2.5 Additional Flow Resistance

A manometer was connected across the filter section, and a resistance that simulates dirty filters and/or additional flow resistance was placed in the section. Annulus pressure vs time measurements were recorded. Resistance was added until an adequate negative pressure was no longer obtained. The information was then compared to the computer code predictions.

5.3.2.4.3.2.6 Additional Air Inleakage

As a part of the cold pull-down testing procedure, means were provided to introduce rates of air flow into the Shield Building Ventilation System through additional openings of known sizes, to simulate additional in-leakage. This portion of the test started with simulating first a low air in-flow and then was followed by a number of increments of increasing air in-flow. Vent flow was determined at each incremental increase in air in-flow. In this way, the maximum additional air flow at which the annulus can no longer be maintained at a sufficiently negative pressure was determined.

This test was conducted with both large and small fans running, first with Train A only, then Train B.

5.3.2.4.3.3 Updating Computer Code with Test Results

The results from the various tests provided the data that established the actual pressure vs leakage curve as shown in Figure 5.3-2. The expression was then used to update the computer code. When other measured system parameters differed from those initially used in the code, the code was modified to utilize the actual values.

The SBVS computer code describes an exact analytical method to predict pressure change and net air discharge between every two successive statuses in the shield building annulus. The code predicts pressure and flow transients and, therefore, exact analytical solutions.

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5.4 CONTAINMENT SYSTEM EVALUATION

The Containment System consists of a steel Reactor Containment Vessel within a concrete Shield Building and a Shield Building Vent System which, in the event of a loss-of-coolant accident, will produce a vacuum in the Shield Building annulus and will cause all leakage from the Containment Vessel to be mixed in the annulus volume and recirculated through a filter system before its deferred release to the environment through the exhaust fan that maintains vacuum.

The freestanding Containment Vessel is designed to accommodate the maximum internal pressure that would result from the Design Basis Accident. For initial conditions typical of normal operation, 120°F and 15 psia, an instantaneous double-ended break with minimum safety features effectiveness results in a peak pressure of 42.5 psi at 265°F. This was essentially a best estimate case and is strictly historical. The design basis containment pressure analysis is represented in Appendix K.

5.4.1 Integrated Evaluation of the Dual Containment System

An Integrated Evaluation of the Dual Containment System (Reference 19) was performed for the Kewaunee and Prairie Island Containment Systems. Analysis of the transient behavior of the Dual-Containment and its associated engineered safety systems performance indicates that:

a. This Dual-Containment with reliable performance of its safety features produces an overall performance equivalent to a factor of approximately 30 of a containment system with a once-through iodine removal system.

b. Stated differently, for the same given site, this Dual-Containment produces an offsite dose of about 30 times lower than a containment system with a once-through iodine removal system.

c. The performance of the Shield Building Ventilation System over a wide range of system parameters results in significantly lower site- boundary doses than the criteria in 10CFR50.67. 01406407

d. Leakage bypassing the Shield Building Annulus is minimal and most would be collected and filtered by the Auxiliary Building Special Ventilation System. Some potential leakage paths can bypass the Annulus and the ABSVZ. These are discussed in more detail in Appendix G.

e. Extensive testing of the engineered safety systems is not required, and that periodic surveillance testing will adequately assure reliable performance of the systems.

5.4.2 Containment Capability with Respect to Generation of Hydrogen

5.4.2.1 General

A loss-of-coolant accident could be followed by generation of hydrogen from metal-water reaction, radiolysis of water and chemical corrosion of materials by spray liquids.

Analysis has shown that it may be necessary to control the hydrogen concentration to prevent exceeding the lower flammability limit of 4 volume percent at greater than 16 days after the loss of coolant accident. (Reference 36)

5.4.2.2 Hydrogen Gas Generation

During a loss of coolant accident (LOCA), hydrogen gas can be generated from several different sources. The methods for determining a conservative value for each contribution is outlined below. The volume contributed from each source is summed to obtain an overall gas generation. This volume is compared to the containment free air volume to obtain a volume %. Assumptions used in the analysis are consistent with the guidance in NRC Regulatory Guide 1.7 and are shown in Table 5.4-2.

The potential contributors to the generation of hydrogen are the:

a. Metal-Water reaction. The calculation assumes a very conservative initial cladding volume, and a very conservative cladding volume reaction.

b. Radiolysis of the water near the core and in containment. This is a function of the decay heat generation rate and is based on a core thermal power of 1683 MW.

c. Corrosion of zinc and aluminum bearing surfaces. This is discussed in more detail below.

d. Hydrogen Monitors Gas Volume

5.4.2.2.1 Description of Materials

Analysis has been made of the materials in construction and the protective coatings used within the containment, particularly as they affect the potential of hydrogen generation by reaction with spray solution. The hydrogen generation rate from corrosion of materials such as aluminum and the decomposition of zinc-bearing coated surfaces is a function of the corrosion (decomposition) rate which in turn depends on such factors as the spray chemistry, the metal and coolant temperatures, and the surface area exposed to attack. Prairie Island credits a basic pH spray solution for iodine removal in the dose analysis; thus, this is applied to the hydrogen generation analysis.

The amount of materials (which could produce hydrogen during a LOCA) used in containment is administratively controlled to ensure an accurate inventory is maintained. Other materials in contact with the spray solution, such as stainless steel and copper alloys, are not significant with regard to corrosive generation of hydrogen.

5.4.2.2.1.1 Zinc-Bearing Surfaces

Galvanized steel is used for ventilation ducts, gratings, stair treads, etc. The use of these materials is minimized in design and future changes to the extent practical. The original specified coatings for the inner surface of the containment vessel and for structural steel items were 3 mils of Carbo-zinc 11 primer plus a 4 mil finish coat of Phenoline 305. Repainting or touch-up is performed per containment coating manufacturer's recommendations. Further use of coatings containing zinc is minimized.

ORNL experiments indicate that substantial amounts of hydrogen can evolve from such undercoats during the initial conditions of a loss-of-coolant accident. This effect appears to be not greatly dependent on the type of spray solution nor on the amount or type of coating over the primer. The outer coating is reported typically to appear unaffected after exposure conditions which produced measurable release of hydrogen.

The most relevant experiments (ORNL-TM-3342, ORNL Safety Research and Development Program Bimonthly Report for January-February, 1971) involved exposure of vendors' test coupons to spray solution under temperature conditions intended to simulate those of a loss-of-coolant accident in a PWR: 5 minutes at 300°F, 105 minutes at 284°F, and the remainder of a day at 225°F. The hydrogen release from these tests was typically about 60 percent of that released in previous tests in which the exposure temperature was maintained constant at 266°F for 24 hours. The test conditions for both sets of tests were much more severe than those predicted for the design basis accident, and substantially less hydrogen generation would therefore be expected. For analysis purposes the following reaction rates are used.

Without Spray Additive: (See Note 1)

	Hydrogen Generation Rate (scf/ft^2)	
Substance	First Day	After First Day
Zinc Bearing Paint	0.07546	(See Note 2)
Galvanized Surface	0.07546	0.0012745

With Spray Additive:

	Hydrogen Generation Rate (scf/ft^2)	
Substance	First Day	After First Day
Zinc Bearing Paint	0.06562 (See Note 3)	(See Note 2)
Galvanized Surface	0.07546 (See Note 4)	0.0012745

Note 1. Hydrogen production without spray additive is not evaluated because it is not a bounding accident scenario.
Note 2. Consumption of zinc bearing paint is assumed to occur within the first day.
Note 3. It is assumed that hydrogen generation from surfaces containing a zinc bearing primer is calculated using one half the total surface area.
Note 4. Hydrogen production from galvanized surfaces on the first day is neglected.

5.4.2.2.1.2 Aluminum Surfaces

Aluminum is used in components (such as ladders, small shelves, etc.) and the protective coatings associated with the reactor equipment and the reactor building crane.

Aluminum corrosion is only considered when buffered spray solutions are used. In this case, the following reaction rates are used for Aluminum:

Aluminum Components	1 mil on the first day 200 mils/year thereafter

Aluminum paint is assumed to be consumed within the first day.

Hydrogen Generation from aluminum reaction is based on 20 scf hydrogen per pound consumed.

5.4.2.3 Provisions for Mixing of Containment Gases

Four containment dome ventilation fans are provided within each containment to circulate and mix gases during the period following the postulated loss-of-coolant accident when combustible gases could conceivably accumulate. Each fan draws 3000 cfm through an inlet duct located in the dome area of the containment vessel. The discharge from each fan is conveyed downward through separate ductwork and returned to the containment volume near the operating floor.

This system is completely redundant (two fans per train) and satisfies the requirements of engineered safety features. The fans are started manually from the control room. Capability of these systems is demonstrated through normal operation and preventative maintenance practices.

The system ducts and fans are designed as Class I system. Analysis of this system indicates that no areas or pockets will have hydrogen accumulation where the lower flammability limit is reached (Reference 31).

5.4.2.4 Provisions for Sampling

In response to NUREG 0737, hydrogen monitors were added to each containment which continuously monitor and record the containment environment. See Section 7 for further information.

In addition, a sampling line is provided between the isolation valves of each vent penetration, and each of these sampling lines has a normally-closed, remote-manually opened isolation valve within the annulus. A small flow of containment gases can be directed to a hydrogen analyzer from the ducting of the containment dome vent fans; providing reliable indication of the maximum hydrogen concentrations in the containment.

5.4.2.5 Provisions for Reduction of Hydrogen

The Prairie Island hydrogen control system provides two methods of hydrogen reduction, either of which, employed alone, would provide adequate means of hydrogen disposition:

- Hydrogen recombination with oxygen by use of electric hydrogen recombiners inside containment.
- Processing of controlled vent flow by recirculation filtering before its release to the environment.

5.4.2.5.1 Hydrogen Recombination

Note: The hydrogen recombiners have been removed from the Technical Specification requirements (Reference 37).

The electric hydrogen recombiner system consists of two completely redundant subsystems. Each of which is capable of providing the required hydrogen removal capacity. This redundancy ensures that no single active failure can affect both recombiners. Each subsystem consists of a recombiner unit which is located within the plant containment building, a control panel, and a power supply. The latter two components are located outside the containment building in an area which is accessible following a loss-of-coolant accident (LOCA).

5.4.2.5.1.1 Effectiveness of Hydrogen Recombiner System

Figure 5.4-2 is a graph of uncontrolled hydrogen concentration versus post-accident time for 5% metal water reaction (including radiolysis and corrosion sources). This figure shows that hydrogen concentration will reach 4% in approximately 16 days (3.5% in 10 days and 3% in approximately 6 days) with no hydrogen removal by the recombiners. Thus, there is sufficient time following the accident for operators to start at least one of the recombiners.

Each recombiner unit is effectively a constant volume machine with a minimum flow of 100 cfm. Each has a minimum hydrogen removal rate equivalent to a removal efficiency of 98% at a flow rate of 100 scfm with a process gas hydrogen concentration of 4%. Each is free from spontaneous combustion and/or detonation for all modes of operation.

Analysis shows that after the first day, the hydrogen generation significantly decreases, and is well within the capability of a recombiner. Since the recombination rate will exceed the generation rate, the hydrogen concentration will be reduced. Procedures for operation of the recombiner(s) direct operators to start the units when the hydrogen concentration is still low; which allows time for the recombiner(s) to attain recombination conditions. Recombination conditions are obtained within a few hours. Proper operation of the recombiner(s) is verified through monitoring the test thermocouples for proper air temperature, measuring the amount of electric current supplied to the heater banks, and/or a decreasing hydrogen concentration.

5.4.2.5.1.2 System Design

The recombiner unit consists of an inlet pre-heater section, a heater-recombination section, and an exhaust chamber. The unit is completely enclosed and the internals are protected from impingement by containment spray. The inlet and outlet ports employ a louver arrangement to minimize the amount moisture entering the unit.

The heater section consists of four banks of vertically stacked electric heaters, with each bank containing 60 individual U-type heaters. The heaters are conventional-type electric resistance heaters sheathed with Incaloy 800, which is an excellent corrosion-resistant material for this service. To provide a conservative design, these heaters operate with sheath temperatures achieved with commercial heaters and at power densities much lower than their rated power densities. Operation of the unit is virtually unaffected if a few individual heaters fail to function properly. The units are designed for all normal and accident loads, including seismic, and temperature and pressure transients following a LOCA.

Furthermore, although the system is designed to accept a maximum of 75 kW, tests have demonstrated that, at a setting of slightly less than 50 kW, it is capable of attaining recombination conditions in less that 4 hours.

There are three chromel-alumel thermocouples which are installed on the heater by welding and mechanical clips. These thermocouples are required for the periodic functional testing of the system. They are not needed for post accident operation or control, however, tests have demonstrated that they are capable of withstanding the seismic, post accident, and radiation criteria. As a result, the possibility exists that temperature read-out may be available. If so, it is a preferred system for post accident operation.

The system is normally on standby and is initiated manually from the auxiliary building following a loss of coolant accident. The system would be started within several days after a LOCA assuming the design basis metal-water reaction. Assuming a loss of offsite power coincident with the LOCA, the diesel generators would be available to provide the power required to operate the thermal hydrogen recombiners. Turning the recombiners on at an early point would keep the hydrogen concentration as low as possible.

Inadvertent actuation immediately after a LOCA will not damage the recombiners in any manner, nor will their capability to perform their design function be impaired. The electric (thermal) recombiners are completely passive devices. The recombiners heat the containment hydrogen air atmosphere that is introduced into the recombiner, to a temperature of approximately 1150°F, causing recombination of H_2 and O_2 to occur. Hence, the hydrogen volume percent is reduced. The air is then passed to a mixing chamber, in the top of the recombiner, where the hot air is mixed with the cooler containment air to discharge it back into the containment at a temperature of approximately 50°F above ambient.

5.4.2.5.2 Venting to the Shield Building Annulus

Venting will only be necessary if the hydrogen recombiners are not available. Venting would be to the Annulus, where the Shield Building Ventilation System affords the benefit of recycle through charcoal filters. When venting must first be initiated, at least one of two redundant trains of equipment will already be in continuous operation, maintaining vacuum and collecting and processing containment vessel leakage before its discharge to the environment.

5.4.2.5.2.1 Vent System Capability

A vent system is provided to accomplish venting of pressurized containment gases to the Shield Building annulus. The system consists of two independent trains; each will vent containment gasses from the ductwork associated with one of the containment dome vent fans and transfer gases by means of positive pressure differential through separate penetrations of the containment vessel. Each penetration has remote-manually operated isolation valves that are normally closed and that can be separately opened to permit venting, or sampling, through either penetration.

Each penetration has a remote-indicating flow meter, located in the annulus and downstream of the throttle valve so as to indicate fractional containment volume vent rate, independent of containment pressure.

The vent relief systems and their power supplies meet the requirements for engineered safeguards.

5.4.2.5.2.2 Analysis of Venting Through Shield Building Annulus

Analysis was originally performed of controlled venting through the Shield Building Ventilation System without pressurizing, and neglecting any effects of the positive pressure differential that would be used to accomplish such venting. Venting is not required to reduce the hydrogen concentration inside of containment following a DBA LOCA. Therefore, this analysis is strictly historical and has not been updated.

5.4.3 Effects of Containment Leakage Bypassing Shield Building Annulus

Any direct leakage through the redundant isolation valves would provide a path that would bypass the Shield Building Ventilation System. The environmental consequences of these postulated leaks are minimized by collection and filtration in the Auxiliary Building Special Ventilation System. It is estimated that a reasonable limit on this mode of leakage will be .025% per day. Based on this value, the two hour site boundary thyroid dose would be increased by 7 Rem with a resultant integrated dose well below the 10CFR100 guidelines.

Leakage and dose information pertains to conditions following a LOCA. Section 14.9 provides the inputs, assumptions and methodology used in the design basis off-site dose analysis for a DBA LOCA. Additional dose information is given in Tables G.4-1 and G.4-2 of Appendix G. Data in these tables are normalized to a 1% per day containment vessel leak rate.

The Auxiliary Building Special Ventilation System (ABSVS) provides a site boundary dose reduction of 10 for the iodine fraction of inleakage for a 90% charcoal filter efficiency, and a dose reduction of 20 for an efficiency of 95%. No dose reduction occurs for the noble gas fraction of inleakage. No credit for dose reduction is taken for delay of radioactive iodine or noble gases in the ABSV zone.

5.4.4 deleted per 99046

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TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
1	PRT Sample to Gas Analyzer	2	VI	3/8″	3/8″	CV31318 CV31319	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
2	PRT Nitrogen Supply	3	III	3/4″	3/4″	RC-5-1 CV31221	Inside Outside	Check RSV-T	Installed Closed	Installed Closed	C	
3A 3B	Spare Inst. (Yellow Containment Press)		 II	3/8″ 3/8″	3/8″ 3/8″	- - - Sealed	Inside Outside	- - - - - -	Capped - - -	Capped - - -	 A (Note 5)	
4	Primary System Vent Header	2	I	1″	2″	CV31434 CV31435	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
5	RC Drain Tank Pump Discharge	2	I	3″	3″	CV31436 CV31437	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
6A	Main Steam Header	4A	V	30″	30″	CV31098 MV32045 MV32016 Safety's/ PORV's Closed System	Outside Outside Outside Outside Inside	RSV-MS RSV RSV Relief Valves	Open Closed Open Closed	Closed Closed Open Closed	A (Note 6)	
6B	Main Steam Header	4A	V	30″	30″	CV31099 MV32047 MV32017 Safety's/ PORV's Closed System	Outside Outside Outside Outside Inside	RSV-MS RSV RSV Relief Valves	Open Closed Open Closed	Closed Closed Open Closed	A (Note 6)	
7A	Main Feedwater Headers	4A	V	16″	16″	MV32023 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
7B	Main Feedwater Headers	4A	V	16″	16″	MV32024 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
8A	Steam Generator Blowdown	4A	V	2″	2″	MV32044 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	

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TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
8B	Steam Generator Blowdown	4A	V	2″	2″	MV32058 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
9	RHR Loop Out	6	VII	10″	10″	MV32165 MV32231 RH-8-1	Inside Inside Inside	RSV RSV Relief	Closed Closed Installed	Closed Closed Installed	A (Note 7)	
10	RHR Loop In	6	VII	10″	10″	MV32066 MV32065 RH-7-1 RH-13-1 RH-14-13 MV32234	Inside Inside Inside Inside Inside Inside	RSV RSV Manual Relief Manual RSV	VCBO Open Closed Installed Closed VCBO	Closed Open Closed Installed Closed Closed	A (Note 7)	
11	CVCS Letdown Line	1	II	2″	2″	CV31325 CV31326 CV31327 CV31339	Inside Inside Inside Outside	RSV-T RSV-T RSV-T RSV-T	Open Open Open Open	Closed Closed Closed Closed	C	
12	CVCS Charging Line	3	II	2″	2″	VC-8-1 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
13A	RCP Seal Water Supply	3	II	2″	2″	VC-8-5 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
13B	RCP Seal Water Supply	3	II	2″	2″	VC-8-4 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
14	RCP Seal Water Return	1	II	3″	3″	MV32199 MV32166	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
15	Pressurizer Steam Sample	1	VI	3/8″	3/8″	MV32400 MV32401	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
16	Pressurizer Liquid Sample	1	VI	3/8″	3/8″	MV32402 MV32403	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
17	RCS Loop B Sample	1	VI	3/8″	3/8″	MV32404 MV32405	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
18	Fuel Transfer Tube	5	V	20″	20″	Blind Flange	Inside	- - -	Installed	Installed	B	

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TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
19	Service Air	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
20	Instrument Air	3	III	2″	2″	CV31741 CV31740	Inside Outside	RSV-MSP RSV-MSP	Open Open	Closed Closed	C	
21	RCDT to Gas Analyzer	2	VI	3/8″	3/8″	CV31545 CV31546	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
22	Containment Air Sample In	6	VI	1″	2″	CV31092 CV31022	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
23	Containment Air Sample Out	6	VI	1″	2″	CV31019 CV31750	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
25A	Containment Vent & Purge Exhaust Duct	5	VI	36″	36″	Blind Flange	Inside	- - -	Installed	Installed	B	5.2.2.3.3
25B	Containment Vent & Purge Supply Duct	5	VI	36″	36″	Blind Flange	Inside	- - -	Installed	Installed	B	5.2.2.3.3
26	Containment Sump "A" Pump Discharge	2	I	3″	3″	CV31438 CV31439	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
27A1 27A2	Steam Generator Blowdown Sample	4A 4A	V V	3/8″ 3/8″	3/″ 3/8″	CV31402 CV31403 Closed System	Outside Outside Inside	RSV-T RSV-T	Open Open	Closed Closed	A (Note 6) A (Note 6)	
27B	Fire Protection	7	IV	4″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
27C1 27C2	Containment Pressure Test Panel	5	VI	1″ 1″	1″ 1″	Blind Flange	Outside	- - -	Installed	Installed	B	
28A	Vessel Injection Safety Injection	6	VII	3″	4″	SI-16-6 SI-16-7 SI-35-8	Inside Inside Inside	Check Check Manual	Installed Installed Open	Installed Installed Open	A (Note 7)	
28B	Cold Leg Safety Injection	6	VII	3″	4″	SI-16-5 SI-16-4 CV31442 CV31445 SI-35-9	Inside Inside Inside Inside Inside	Check Check RSV RSV Manual	Installed Installed Closed Closed Closed	Installed Installed Closed Closed Closed	A (Note 7)	

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TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
29A	Containment Spray	6	VII	6″	6″	CS-19 MV32105 CS-12 CS-26-2 CS-26-4	Outside Outside Outside Outside Outside	Check RSV Manual Manual Manual	Installed Closed Locked Closed Closed Closed	Installed Open Locked Closed Closed Closed	C	
29B	Containment Spray	6	VII	6″	6″	CS-18 MV32103 CS-11 CS-26-1 CS-26-3	Outside Outside Outside Outside Outside	Check RSV Manual Manual Manual	Installed Closed Locked Closed Closed Closed	Installed Open Locked Closed Closed Closed	C	
30A	RHR Suction From Sump B	6	VII	12″	12″	MV32075 Closed System	Inside Outside	RSV - - -	Closed - - -	Open - - -	A (Note 7)	
30B	RHR Suction From Sump B	6	VII	12″	12″	MV32076 Closed System	Inside Outside	RSV - - -	Closed - - -	Open - - -	A (Note 7)	
31	Nitrogen to Accumulator	3	III	1″	2″	CV31441 CV31444 CV31242 CV31440	Inside Inside Inside Outside	RSV RSV RSV RSV-T	Closed Closed Closed Closed	Closed Closed Closed Closed	C	
32A	Component Cooling to 11 RCP	6	V	4″	4″	MV32089 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
32B	Component Cooling to 12 RCP	6	V	4″	4″	MV32091 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
33A	Component Cooling from 11 RCP	6	V	4″	4″	MV32090 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	

TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
33B	Component Cooling from 12 RCP	6	V	4″	4″	MV32092 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
34	Electrical Penetrations		VIII								B	
35	SI and Accumulator Test Line	1	VI	3/4″	3/4″	SI-20-16 SI-35-25	Outside Inside	Manual Manual	Locked Closed Closed	Locked Closed Closed	A (Note 7)	
36D	Inst. (Red Containment Press)		II	3/8″	3/8″	Sealed	Outside	- - -	- - -	- - -	A (Note 5)	
37A	Cooling Water to 13 CFCU	6	V	8″	8″	Closed System MV32378 CL-146-5	Inside Outside Outside	 RSV Vent	 Open Closed	 Open Closed	A (Note 7)	5.2.3.3
37B	Cooling Water to 11 CFCU	6	V	8″	8″	Closed System MV32377 CL-146-1	Inside Outside Outside	 RSV Vent	 Open Closed	 Open Closed	A (Note 7)	5.2.3.3
37C	Cooling Water to 12 CFCU	6	V	8″	8″	Closed System MV32379 CL-146-3	Inside Outside Outside	 RSV Vent	 Open Closed	 Open Closed	A (Note 7)	5.2.3.3
37D	Cooling Water to 14 CFCU	6	V	8″	8″	Closed System MV32380 CL-146-7	Inside Outside Outside	 RSV Vent	 Open Closed	 Open Closed	A (Note 7)	5.2.3.3
38A	Cooling Water from 13 CFCU	6	V	8″	8″	MV32138 MV32139 CL-146-6	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3

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TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
38B	Cooling Water from 11 CFCU	6	V	8″	8″	MV32132 MV32133 CL-146-2	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
38C	Cooling Water from 14 CFCU	6	V	8″	8″	MV32141 MV32142 CL-146-8	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
38D	Cooling Water from 12 CFCU	6	V	8″	8″	MV32135 MV32136 CL-146-4	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
39	Comp Cooling to Excess Letdown Heat Exchanger	4	V	3″	2″	Closed System MV32095	Inside Outside	RSV-T	Open	Closed	A (Note 7)	
40	Comp Cooling from Excess Letdown Heat Exchanger	4	V	3″	2″	CV31252 Closed System	Outside Inside	RSV-T - - -	Open - - -	Closed - - -	A (Note 7)	
41A	Containment Vacuum Breaker	7B	VIII	18″	18″	CV31621 CV31624	Outside Outside	RSV-T VRV	Open Installed	Closed Installed	C	Table 5.2-7
41B	Containment Vacuum Breaker	7B	VIII	18″	18″	CV31622 CV31625	Outside Outside	RSV-T VRV	Open Installed	Closed Installed	C	Table 5.2-7
42A	Post LOCA H2 Control Air Supply and Vent	7 5	IV VI	2″ 2″	2″ 2″	HC-2-2 MV32276 MV32273 CV31927 CV31929	Inside Outside Inside Outside Outside	Check RSV RSV RSV RSV	Installed Closed Closed Closed Closed	Installed Closed Closed Closed Closed	C C	
42B	In-Service Purge Supply	7	VIII	18″	14″	Blind Flange CV31634 CV31633	Outside Inside Outside	- - - RSV-TT RSV-TT	Installed Closed Closed	Installed Closed Closed	B (Note 4)	5.2.2.3.3
42C	Heating Steam Supply	7	IV	4″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
42D	RVLIS Instrumentation		II	6 x 3/16″	6 x 3/16″	Sealed	Outside	- - -	- - -	- - -	A (Note 5)	

TABLE 5.2-1 - (PART A)
UNIT 1 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
42F1	Heating Steam Condensate Return	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
42F2	Heating Steam Return Vent	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
43A	In-Service Purge Exhaust	7	VIII	18″	18″	Blind Flange CV31310 CV31311	Outside Outside Inside	- - - RSV-TT RSV-TT	Installed Closed Closed	Installed Closed Closed	B (Note 4)	5.2.2.3.3
44	Containment Vessel Pressurization (ILRT)	5	VI	6″	10″	Blind Flange	Inside	- - -	Installed	Installed	B	
45	Rx M/U Water to PRT	3	VI	2″	2″	RC-3-1 CV31321	Inside Outside	Check RSV-T	Installed Open	Installed Closed	C	
46A	Auxiliary Feedwater	6	VII	3″	4″	AF-16-2	Inside	Check	Installed	Installed	A (Note 6)	
46B	Auxiliary Feedwater	6	VII	3″	4″	AF-16-1	Inside	Check	Installed	Installed	A (Note 6)	
47	Electrical Penetrations		VIII								B	
48	Low Head Safety Injection to Reactor Vessel	6	VII	6″	6″	SI-26-1 MV32064	Inside Inside	Relief RSV	Installed Open	Installed Open	A (Note 7)	
49A	Inst. (Blue Containment Press)		II	3/8″	3/8″	Sealed	Outside	- - -	- - -	- - -	A (Note 5)	
49B	Demineralized Water	7	IV	2″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
50	Post LOCA H2 Control Air Supply and Vent Lines	7 5	IV VI	2″ 2″	2″ 2″	HC-2-1 MV32274 MV32271 CV31925 CV31923	Inside Outside Inside Outside Outside	Check RSV RSV RSV RSV	Installed Closed Closed Closed Closed	Installed Closed Closed Closed Closed	C C	
	Inst. (White Containment Press)		II	3/8″	3/8″	Sealed	Outside				A (Note 5)	
	Equipment Hatch		VIII								B	
	Personnel Airlock		VIII								B	
	Maintenance Airlock		VIII								B	

TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
1	PRT Sample to Gas Analyzer	2	VI	3/8″	3/8″	CV31344 CV31345	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
2	PRT Nitrogen Supply	3	III	3/4″	3/4″	2RC-5-1 CV31209	Inside Outside	Check RSV-T	Installed Closed	Installed Closed	C	
3A 3B	Spare Inst. (Yellow Containment Press)		 II	3/8″ 3/8″	3/8″ 3/8″	- - - Sealed	Inside Outside	- - - - - -	Capped - - -	Capped - - -	 A (Note 5)	
4	Primary System Vent Header	2	I	1″	2″	CV31733 CV31734	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
5	RC Drain Tank Pump Discharge	2	I	3″	3″	CV31735 CV31736	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
6C	Main Steam Header	4A	V	30″	30″	CV31116 MV32048 MV32019 Safety's/ PORV's Closed System	Outside Outside Outside Outside Inside	RSV-MS RSV RSV Relief Valves	Open Closed Open Closed	Closed Closed Open Closed	A (Note 6)	
6D	Main Steam Header	4A	V	30″	30″	CV31117 MV32050 MV32020 Safety's/ PORV's Closed System	Outside Outside Outside Outside Inside	RSV-MS RSV RSV Relief Valves	Open Closed Open Closed	Closed Closed Open Closed	A (Note 6)	
7C	Main Feedwater Headers	4A	V	16″	16″	MV32028 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
7D	Main Feedwater Headers	4A	V	16″	16″	MV32029 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
8C	Steam Generator Blowdown	4A	V	2″	2″	MV32051 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	

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TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
8D	Steam Generator Blowdown	4A	V	2″	2″	MV32059 Closed System	Outside Inside	RSV-T	Open	Closed	A (Note 6)	
9	RHR Loop Out	6	VII	10″	10″	MV32193 MV32233 2RH-8-1	Inside Inside Inside	RSV RSV Relief	Closed Closed Installed	Closed Closed Installed	A (Note 7)	
10	RHR Loop In	6	VII	10″	10″	MV32167 MV32169 2RH-7-1 MV32235	Inside Inside Inside Inside	RSV RSV Manual RSV	Open VCBO Closed VCBO	Open Closed Closed Closed	A (Note 7)	
11	CVCS Letdown Line	1	II	2″	2″	CV31347 CV31348 CV31349 CV31430	Inside Inside Inside Outside	RSV-T RSV-T RSV-T RSV-T	Open Open Open Open	Closed Closed Closed Closed	C	
12	CVCS Charging Line	3	II	2″	2″	2VC-8-1 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
13A	RCP Seal Water Supply	3	II	2″	2″	2VC-8-5 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
13B	RCP Seal Water Supply	3	II	2″	2″	2VC-8-4 Closed System	Inside Outside	Check - - -	Installed - - -	Installed - - -	C	10.2.3.3.4
14	RCP Seal Water Return	1	II	3″	6″	MV32210 MV32194	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
15	Pressurizer Steam Space Sample	1	VI	3/8″	3/8″	MV32406 MV32407	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
16	Pressurizer Liquid Sample	1	VI	3/8″	3/8″	MV32408 MV32409	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
17	RCS Loop B Sample	1	VI	3/8″	3/8″	MV32410 MV32411	Inside Outside	RSV-T RSV-T	Closed Closed	Closed Closed	C	
18	Fuel Transfer Tube	5	V	20″	20″	Blind Flange	Inside	- - -	Installed	Installed	B	

TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
19	Service Air	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
20	Instrument Air	3	III	2″	2″	CV31743 CV31742	Inside Outside	RSV-MSP RSV-MSP	Open Open	Closed Closed	C	
21	RCDT to Gas Analyzer	2	VI	3/8″	3/8″	CV31732 CV31731	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
22	Containment Air Sample In	6	VI	1″	2″	CV31129 CV31644	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
23	Containment Air Sample Out	6	VI	1″	2″	CV31643 CV31642	Inside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	
25A	Containment Purge Exhaust	5	VI	36″	36″	Blind Flange	Inside	- - -	Installed	Installed	B	5.2.2.3.3
25B	Containment Purge Supply	5	VI	36″	36″	Blind Flange	Inside	- - -	Installed	Installed	B	5.2.2.3.3
26	Containment Sump “A” Pump Discharge	2	I	3″	3″	CV31620 CV31619	Outside Outside	RSV-T RSV-T	Open Open	Closed Closed	C	5.2.3.1.1
27A1 27A2	Steam Generator Blowdown Sample	4A 4A	V V	3/8″ 3/8″	3/8″ 3/8″	CV31412 CV31413 Closed System	Outside Outside Inside	RSV-T RSV-T	Open Open	Closed Closed	A (Note 6) A (Note 6)	
27C1 27C2	Containment Pressure Test Panel	5	VI	1″ 1″	1″ 1″	Blind Flange	Outside	- - -	Installed	Installed	B	
28A	Vessel Injection Safety Injection	6	VII	3″	4″	2SI-16-5 2SI-16-7 Shared Isol. w/Penet 35	Inside Inside	Check Check	Installed Installed	Installed Installed	A (Note 7)	
28B	Cold Leg Safety Injection	6	VII	3″	4″	2SI-16-6 2SI-16-4 CV31517 CV31518	Inside Inside Inside Inside	Check Check RSV RSV	Installed Installed Closed Closed	Installed Installed Closed Closed	A (Note 7)	

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TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
29A	Containment Spray	6	VII	6″	6″	CS-49 MV32114 CS-42 2CS-26-1 2CS-26-3	Outside Outside Outside Outside Outside	Check RSV Manual Manual Manual	Installed Closed Locked Closed Closed Closed	Installed Open Locked Closed Closed Closed	C	
29B	Containment Spray	6	VII	6″	6″	CS-48 MV32116 CS-41 2CS-26-2 2CS-26-4	Outside Outside Outside Outside Outside	Check RSV Manual Manual Manual	Installed Closed Locked Closed Closed Closed	Installed Open Locked Closed Closed Closed	C	
30A	RHR Suction from Sump B	6	VII	12″	12″	MV32178 Closed System	Inside Outside	RSV - - -	Closed - - -	Open - - -	A (Note 7)	
30B	RHR Suction from Sump B	6	VII	12″	12″	MV32179 Closed System	Inside Outside	RSV - - -	Closed - - -	Open - - -	A (Note 7)	
31	Nitrogen Supply to Accumulator	3	III	1″	2″	CV31244 CV31511 CV31512 CV31554	Inside Inside Inside Outside	RSV RSV RSV RSV-T	Closed Closed Closed Closed	Closed Closed Closed Closed	C	
32A	Component Cooling to 21 RCP	6	V	4″	4″	MV32124 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
32B	Component Cooling to 22 RCP	6	V	4″	4″	MV32126 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
33A	Component Cooling Return from 21 RCP	6	V	4″	4″	MV32125 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	
33B	Component Cooling Return from 22 RCP	6	V	4″	4″	MV32127 Closed System	Outside Inside	RSV - - -	VOBO - - -	Open - - -	A (Note 7)	

TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
34	Electrical Penetrations		VIII								B	
35	SI and Accumulator Test Line	1	VI	3/4″	3/4″	2SI-20-16 2SI-35-25	Outside Inside	Manual Manual	Locked Closed Closed	Locked Closed Closed	C	
37A	Cooling Water to 21 CFCU	6	V	8″	8″	MV32386 Closed System 2CL-146-1	Outside Inside Outside	RSV - - - Vent	Open - - - Closed	Open - - - Closed	A (Note 7)	5.2.3.3
37B	Cooling Water to 22 CFCU	6	V	8″	8″	MV32387 Closed System 2CL-146-3	Outside Inside Outside	RSV - - - Vent	Open - - - Closed	Open - - - Closed	A (Note 7)	5.2.3.3
37C	Cooling Water to 23 CFCU	6	V	8″	8″	MV32388 Closed System 2CL-146-5	Outside Inside Outside	RSV - - - Vent	Open - - - Closed	Open - - - Closed	A (Note 7)	5.2.3.3
37D	Cooling Water to 24 CFCU	6	V	8″	8″	MV32389 Closed System 2CL-146-7	Outside Inside Outside	RSV - - - Vent	Open - - - Closed	Open - - - Closed	A (Note 7)	5.2.3.3
38A	Cooling Water from 21 CFCU	6	V	8″	8″	MV32147 MV32148 2CL-146-2	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
38B	Cooling Water from 22 CFCU	6	V	8″	8″	MV32150 MV32151 2CL-146-4	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
38C	Cooling Water from 23 CFCU	6	V	8″	8″	MV32153 MV32154 2CL-146-6	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3

TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
38D	Cooling Water from 24 CFCU	6	V	8″	8″	MV32156 MV32157 2CL-146-8	Inside Outside Inside	RSV RSV Vent	Open Open Closed	Open Open Closed	A (Note 7)	5.2.3.3
39	Comp Cooling Supply to Excess Letdown Heat Exchanger	4	V	3″	3″	MV32130 Closed System	Outside Inside	RSV-T - - -	Open - - -	Closed - - -	A (Note 7)	
40	Comp Cooling Return from Excess Letdown Heat Exchanger	4	V	3″	3″	CV31253 Closed System	Outside Inside	RSV-T - - -	Open - - -	Closed - - -	A (Note 7)	
41A	Containment Vacuum Breakers	7B	VIII	18″	18″	CV31627 CV31630	Outside Outside	RSV-T VRV	Open Installed	Closed Installed	C	Table 5.2-7
41B	Containment Vacuum Breakers	7B	VIII	18″	18″	CV31628 CV31631	Outside Outside	RSV-T VRV	Open Installed	Closed Installed	C	Table 5.2-7
42A	Post LOCA Hydrogen Control	7 5	IV VI	2″ 2″	2″ 2″	2HC-2-1 MV32293 MV32290 CV31924 CV31926	Inside Outside Inside Outside Outside	Check RSV RSV RSV RSV	Installed Closed Closed Closed Closed	Installed Closed Closed Closed Closed	C C	
	Inst. (White Containment Press)		II	3/8″	3/8″	Sealed	Outside				A (Note 5)	
42B	Reactor Vessel Level Instrumentation		II	6 x 3/16″	6 x 3/16″	Sealed - - -	- - -	- - -	- - -	- - -	A (Note 5)	
42E1	Heating Steam Return Vent	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
42E-2	Heating Steam Condensate Return	7	IV	2″	2″	Blind Flange	Inside	- - -	Installed	Installed	B	
44	Containment Vessel Pressurization (ILRT)	5	VI	6″	10″	Blind Flange	Inside	- - -	Installed	Installed	B	
45	Reactor Makeup Water to PRT	3	VI	2″	2″	2RC-3-1 CV31342	Inside Outside	Check RSV-T	Installed Open	Installed Closed	C	
46C	Auxiliary Feedwater to 22 Steam Generator	6	VII	3″	4″	AF-16-3	Inside	Check	Installed	Installed	A (Note 6)	
46D	Auxiliary Feedwater to 21 Steam Generator	6	VII	3″	4″	AF-16-4	Inside	Check	Installed	Installed	A (Note 6)	

TABLE 5.2-1 - (PART B)
UNIT 2 CONTAINMENT VESSEL PENETRATIONS

Penet No.	Description	Penet Class (Note 2)	Penet Group (Note 3)	Nominal Line Size	Approx. Line Size @ Penetration	Valve Number	Inside/ Outside	Valve Type	Normal Op Position (Note 1)	Post-LOCA Position	Type of Test	USAR Section
47	Electrical Penetrations		VIII								B	
48	Low Head Safety Injection to Reactor Vessel	6	VII	6″	6″	2SI-26-1 MV32168	Inside Inside	Relief RSV	Installed Open	Installed Open	A (Note 7)	
49A	Inst. (Blue Containment Press)		II	3/8″	3/8″	Sealed	Outside	- - -	- - -	- - -	A (Note 5)	
50	Post LOCA Hydrogen Control	7 5	IV VI	2″ 2″	2″ 2″	2HC-2-2 MV32295 MV32292 CV31930 CV31928	Inside Outside Inside Outside Outside	Check RSV RSV RSV RSV	Installed Closed Closed Closed Closed	Installed Closed Closed Closed Closed	C C	
51	Fire Protection	7	IV	4″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
52	In-Service Purge Exhaust	7	VIII	18″	18″	Blind Flange CV31314 CV31315	Outside Outside Inside	- - - RSV-TT RSV-TT	Installed Closed Closed	Installed Closed Closed	B (Note 4)	5.2.2.3.3
53	In-Service Purge Supply	7	VIII	18″	14″	Blind Flange CV31636 CV31635	Outside Inside Outside	- - - RSV-TT RSV-TT	Installed Closed Closed	Installed Closed Closed	B (Note 4)	5.2.2.3.3
54	Steam Heating Supply	7	IV	4″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
55	Demineralized Water to Hose Connections	7	IV	2″	4″	Blind Flange	Inside	- - -	Installed	Installed	B	
56	Inst. (Red Containment Press)		II	3/8″	3/8″	Sealed	Outside	- - -	- - -	- - -	A (Note 5)	
	Equipment Hatch		VIII								B	
	Personnel Airlock		VIII								B	
	Maintenance Airlock		VIII								B	

TABLE 5.2-1 PART C
REACTOR CONTAINMENT VESSEL PENETRATIONS
ABBREVIATIONS AND NOTES FOR TABLE 5.2-1

<u>VALVES</u>**

RSV	Remotely-Operated Stop Valve
RSV+RSV	Remotely-Operated Stop Valve in Series
VRV	Vacuum Relief Valve
-T	Tripped Closed on Safety Injection Signal
-TT	Tripped Closed on Safety Injection Signal or High Containment Radiation
-MS	Tripped Closed on Main Steam Isolation Signal
-MSP	Tripped Closed on Loop A Main Steam Isolation Signal or High High Containment Pressure Signal
MANUAL	Manual Valve
VOBO	Valve Open Breaker Open
VCBO	Valve Closed Breaker Open

NOTE 1: OPERATING FUNCTION

Denotes the position of the valve during normal reactor operation. Valve positions may change due to operating procedures, isolation, etc.

NOTE 2: PENETRATION CLASS

Number classifications are defined in Section 5.2.2. Letter designation is defined as follows:

A The isolation system for these penetrations are subject to special consideration on leakage and testing requirements because their principal function is related to rupture of steam generator secondary side systems and not loss of coolant; for loss of coolant accident, the barrier is the steam generator tube sheet and tubes.

B The automatically operated relief valve actuated from containment vacuum qualifies as an isolation valve because increasing pressure causes valve to stay in the closed position. 01501701

NOTE 3: Penetration groups are explained in Appendix G, Section G.2.

NOTE 4: In-Service purge supply and exhaust penetrations normally have a blind flange installed in the annulus.

NOTE 5: Instrumentation lines. No Type B or C testing required (Reference 29).

NOTE 6: Steam, Feedwater, Blowdown and SG Sample lines. Type C testing not required since valves are not relied upon to prevent containment leakage (Reference 29).

NOTE 7: Safety Injection, RHR, Cooling Water, and Component Cooling Water system valves are not relied upon to prevent containment leakage (Reference 29 and 38).

NOTE 8: Table 5.2-1 only includes the credited isolation barriers for each penetration. Vent and drain valves and test connections which form portions of the isolation boundary are not included. These valves are identified and controlled i.a.w. PINGP Operating Procedures.

Table 5.2-2 CALCULATED GUARD PIPE STRESS LEVELS

	Bending Due To Thermal	Thermal ΔT Hoop	Long. Bend. WT	Upset Cond. Long. Bend. WT + OBE	Faulted Condition WT + DBE	WT+ DBE +Press	Thermal Δt + Press Hoop	WT+ DBE+ Rupt. Jet
Allow.	S_A	S_h	S_h	1.2 S_h	1.8 Sh	1.8 Sh	1.2 SH	1.8 Sh
Stress					or Sy	or Sy		or Sy
(PSI)	(26,250)	(17,500)	(17,500)	(21,000)	(31,500)	(31,500)	(21,000)	(31,500)
Main								
Steam	11,655.	11,375.	221.4	226.02	230.6	2211.6	3191.	1806.9
Feedwater	7883.	11,134.	284.7	301.8	318.9	726.9	8014.	2051.3

99044

TABLE 5.2-3 BELLOWS MOVEMENTS - NORMAL, DBA*, SEISMIC (INCHES)

PENETRATION NUMBER	AXIAL DISPLACEMENT	TRANSVERSE DISPLACEMENT
6A (MS)	+1.5	1.6
6B (MS)	+1.4	1.0
7A (FW)	+2.5	0.8
7B (FW)	+2.0	1.0
8A (SGB)	+3.4	1.8
8B (SGB)	+3.4	1.8
9 (RHR)	+2.1	0.4
10 (RHR)	+2.1	0.4
11 (CVCS)	+2.2	0.6

NOTE: Compression of Bellows is +
Extension of Bellows is -

* Pressure movements based on field tests data were larger than the theoretical displacement.

TABLE 5.2-4 CHARPY V-NOTCH TEST DATA FOR FLUED HEAD FITTING MATERIAL

	UNIT #1	**0°F.**
6A	Heat No. 6066057 34-44-54 ft-lb	Full Size-V-Notch
6B	Same Heat 34-44-54 ft-lb	Full Size-V-Notch
7A	Same Heat 44-54-34 ft-lb	Full Size-V-Notch
7B	Same Heat 34-44-54 ft-lb	Full Size-V-Notch
8A	Heat #6730573 30-44-28 ft-lb	Full Size-V-Notch
8B	Same Heat # 30-44-28 ft-lb	Full Size-V-Notch

	UNIT #2	**0°F.**
6C	Heat #6057177 20-16-22 ft-lb	-30°F Full Size-V-Notch
6D	Heat #6066057 26-32-26 ft-lb	0°F
7C	Heat #6066057 44-54-34 ft-lb	0°F
7D	Heat #6066057 44-54-34 ft-lb	0°F
8C	Heat #6730573 30-44-28 ft-lb	0°
8D	Heat #6730573 36-43-38 ft-lb	0°F

TABLE 5.2-5 CONTAINMENT AIR COOLING SYSTEM DESIGN PERFORMANCE DATA

Performance Design Conditions		Normal	Unit 1 AEROFIN Coils Copper-Nickel Tubes note 2	Unit 2 SRC Coils Copper-Nickel Tubes note 3
Heat Load per fan coil unit (at 0.002 fouling factor)	Btu/hr x 10^6	1.86 note 4	54.8 note 1	54.8 note 1
Inlet Air Flow	CFM	62,000	30,000	30,000
Entering Air Temp	°F	120	270	270
Entering Air Density	lbm/ft^3	0.068	-	-
Entering Mixture Density	lbm/ft^3	-	0.1687	0.1687
Air Exit Temperature	°F	90	264 note 1	264 note 1
Air Face Velocity	FPM	414	213	218
Air pressure drop	w.g. @ 0.075 lbm/ft^3	-	0.160	0.10
Water Flow Rate	gpm	ZX/CL 450/900	900	900
Entering Water Temp	°F	85	85	85
Water Velocity	FPS	-	8.26	7.3
Water Exit Temperature (at 0.002 fouling factor)	°F	93.4	210 note 1	207 note 1
Water pressure drop	ft. head	12.5	41.0	39.2
Design Pressure, Internal	psig	150	150	150
Design Pressure, External	psig	-	46	46
Design Temperature	°F	300	300	300

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Note 1: The tabulated values provide a nominal comparison of performance. The overall effect on the safety analysis requires that the cooling water header hydraulic models and two phase flow analysis be performed to evaluate coil performance under accident conditions.

Note 2: Data is based on Aerofin coil performance data.

Note 3: Data is based on Super Radiator Coils (SRC) coil performance data.

Note 4: The Unit 2 SRC coils normal condition heat load is 1.92 BTU/HR x 10^6.

Performance Design Conditions

Spray chemistry: 3000 ppm of boron, as boric acid, with pH adjusted to 7.0 to 10.5 with sodium hydroxide.

Operation mode: Normal; indefinite, air at 120°F, at 30% R.H.

TABLE 5.2-6 ESTIMTAED HEAT LOSSES FROM EQUIPMENT OR HEAT REMOVAL BY THE CONTAINMENT AND COOLING SYSTEM AT NORMAL FULL POWER OPERATION

Equipment	Heat Removal Rate, Btu/hr	Design Temp. °F	Operating Temp. °F
Reactor coolant pumps, two	1,800,000	650	544.5
Steam generators, two	400,000	600 (Steam)	519.1 (Steam)
Pressurizer	100,000	680	653
Control rod drive mechanisms	1,350,000	450	392
Pressurizer relief tank	14,000	340	120
Primary concrete shield	25,000	210	195
Reactor vessel support pads, six	72,000	300[1]	423
Reactor vessel (above seal)	20,000	650	Ave. 568.4
Reactor vessel (below seal)	80,000	650	Ave. 568.4
Piping	120,000		
Contingency	419,000		
Total	4,400,000		

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(1) The design temperature is a maximum of 350°F temperature differential across the Reactor Vessel nozzle. The 300°F is a minimum value based on 650 - 350 = 300°F.

TABLE 5.2-7 SINGLE FAILURE ANALYSIS - VACUUM BREAKER SYSTEM

Component	Malfunction	Comments
Butterfly Valve	Fails to open	Two systems provided. Each system consists of one butterfly valve and one self-actuating swing disc check valve. Evaluation based on operation of one system.
Swing Disc Check Valve	Fails to open	
Butterfly Valve	Fails open on loss of air or electrical power.	Each system consists of one air to close, spring loaded to open, remote operated butterfly valve in series with a self-actuating swing disc check valve. These two valves in series are sufficient to satisfy the single failure criteria.
Swing Check Valve	Fails to close	
Instrumentation and Control	Loss of pressure switch Loss of DC Loss of isolation signal	Butterfly valve will fail to close but check valve will still provide the required isolation.

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TABLE 5.2-10 ELECTRICAL PENETRATIONS TEST (INCLUDING CONNECTORS)

	PROTO-TYPE TEST						PRODUCTION TEST					
Sequence & Test	MVP	LVP	I&C	CRDP	NIS	RM	MVP	LVP	I&C	CRDP	NIS	RM
1. Dye Penetrant	X	X	X	X	X	X	X	X	X	X	X	X
2. Continuity							X	X	X	X	X	X
3. Seismic	X	X	X	X	X	X						
4. Helium Leakage	X	X	X	X	X	X						
5. Environ-mental	X	X	X	X	X	X						
6. Continuous Current	X	X		X								
7. Interrupting Fault	X	X										
8. Insul. Resistance	X	X	X	X	X	X	X	X	X	X	X	X
9. Diel. Strength	X	X	X	X	X	X	X	X	X	X	X	X
10. Helium Leakage	X	X	X	X	X	X	X	X	X	X	X	X
11. Continuity	X	X	X	X	X	X						
12. Steam Pressure	X	X	X	X		X						
13. Insul. Resistance	X	X	X	X	X	X						
14. Diel. Strength	X	X	X	X	X	X						
15. RF Test					X	X						

The above sequence of tests is applicable to the original containment electrical penetrations provided by D.G. O'BRIEN, Inc. Electrical penetrations installed subsequently (D.G. O'BRIEN and CONAX) have been tested per IEEE 317-1976. 99154

TABLE 5.2-12 REACTOR VESSEL SUPPORT STRUCTURE COOLING DATA

Design Reactor Vessel Temperature, t_w	650°F
Air Flow Rate Per Pad	1500 cfm
Bulk Air Temperature, $t\phi$	120°F
Predicted Heat Transfer Coefficient	6.7 Btu/hr-ft2
Fin Efficiency, η	0.406
Predicted Nozzle Interface Temperature, t_i	423°F
Predicted Temperature at the Top of the Side Walls of the Finned Pad, t_R	252°F
Predicted Temperature at the Bottom of the Side Walls of the Finned Pad, t_L	133°F
Heat Dissipation Rate Per Each Wall of the Finned Pad, q''_t	5580 Btu/hr

99044

TABLE 5.3-1 SHIELD BUILDING LEAKAGE RATES

(Based upon Data presented in the Report
NAA-SR-10100, Conventional Buildings for Reactor Containment)

Source of Leakage	Leakage Rate * (Cubic Feet in 24 Hours)	Leakage Rate * (Percent of Annulus Volume in 24 Hours)	
Concrete Surface of Wall & Dome	10	2.67×10^{-3}	
Construction Joints	20	5.35×10^{-3}	
Cracks in Concrete:			
a Temperature Cracks	50	13.37×10^{-3}	
b. Shrinkage Cracks	3	0.8×10^{-3}	
c. Earthquake Cracks	Negligible	Negligible	
d. Stress Cracks at Springline	2000	0.535	
Penetrations (All)	500	0.1337	99045
Equipment Door	30	8.02×10^{-3}	
Personnel Door -2	28,800	7.7	
	-	-	
Total Leakage (In leakage to Shield Building Vent System)	31,413	8.4	99045
		= = =	

* At 1/4I W.C. Differential pressure and 374,000 cu. ft. annulus free volume.

TABLE 5.3-3 DESIGN PARAMETERS OF CHARCOAL FILTERS IN THE SHIELD BUILDING VENTING SYSTEM AND THE AUXILIARY BUILDING SPECIAL VENTILATION SYSTEM

Adsorber Design Details & Parameters [1]

Adsorber Drawers	18
Trays per Drawer	2
Bed Depth	2″
Face Area of Tray	23-7/8″ x 7-7/8″
Depth of Tray	26″
Air Resistance - in. wg.	1.15
Air Flow Rating - CFM	
Adsorber or tray	400
Equiv. 2′ x 2′ face area	1200
Type of Charcoal	Activated Coconut Shell
Maximum Air Velocity	40 fpm
Construction Material	Carbon Steel
Gasket Material	Closed Sponge Neoprene base (grade SCE-43 per ASTM D 1056) and cured adhesive which is resilient water resistant and resistant to a minimum temperature of 250°F

01514367

[1] This is design information, See VFTP (T.S. 5.5.9) for actual testing parameters.

TABLE 5.3-3 DESIGN PARAMETERS OF CHARCOAL FILTERS IN THE SHIELD BUILDING VENTING SYSTEM AND THE AUXILIARY BUILDING SPECIAL VENTILATION SYSTEM
Page 2 of 2

<u>**Material Sizes**</u>

Casing Thickness	Double 16 gage, ribbed
Casing Face Flange	11 gage
Spacers, Caps & Dividers	20 gage
Perforated Screens	
Material	26 gage 304 stainless steel
Blank Overlay	
side edges	1/2″
side edges	1/2″
Cover gasket (thickness)	
free	3/8″
compressed	1/8″
Face Dimensions (nom)	24″ x 8″
Charcoal Volume - ft^3	1.45 $\pm$ 0.05
Face Gasket	
width	7/8″
thickness	1/2″
Mfg. Tolerances	
Face Dimensions	+ 0, -1/8″
Squareness (Diag.)	+ 1/16″

TABLE 5.3-4 SINGLE FAILURE ANALYSIS-CHARCOAL FILTER WATER DELUGE FEATURE

Component	QA Type	Malfunction	Remarks	
Solenoid Valve	I	Fails to open	High temperature alarm in control room coincident w/no flow alarm. Also radiation monitor in exhaust stack.	
Solenoid Valve	I	Opens Inadvertantly	Flow is annunciated in control room. Operator must take action to close disch. damper and shutdown fan.	
Temperature Switch	I	Fails to function	Multiple temperature switches provided for each filter.	99045
Flow Switch	I (*)	Fails to indicate flow	High temperature alarm to water flow.	99045
Pipe Failure	I	Loss of water supply	Operator must take action to shutdown exhaust fan and close discharge damper it high temperature alarms.	
Filter Heater	I (Supplied w/filter)	Overheat due to loss of air flow	Heater automatically trips if recirculation fan trips, or on high temperature downstream of the heater or on low air flow.	99045

* Pressure Boundary only 99045

TABLE 5.4-2 SOURCE AND ASSUMPTIONS FOR HYDROGEN CALCULATIONS

Coolant Absorption of Radiation from Fuel	**Most Conservative Estimate Using Safety Guide 7**
Halogens in fuel	50%
Noble Gases in fuel	0
Other fission products in fuel	99%
Gamma energy fraction absorbed in water	.10
Beta energy fraction absorbed in water	0
$G(H_2)$, molecules/100 ev	0.50
Sources in Coolant	
Halogens in coolant	50%
Noble Gases in coolant	0
Other fission products in coolant	1%
Gamma energy fraction absorbed	1.0
Beta energy fraction absorbed	1.0
$G(H_2)$ molecules/100 ev	0.50
Initial Zirconium-Water Reaction	$\geq$5 times Appendix K value

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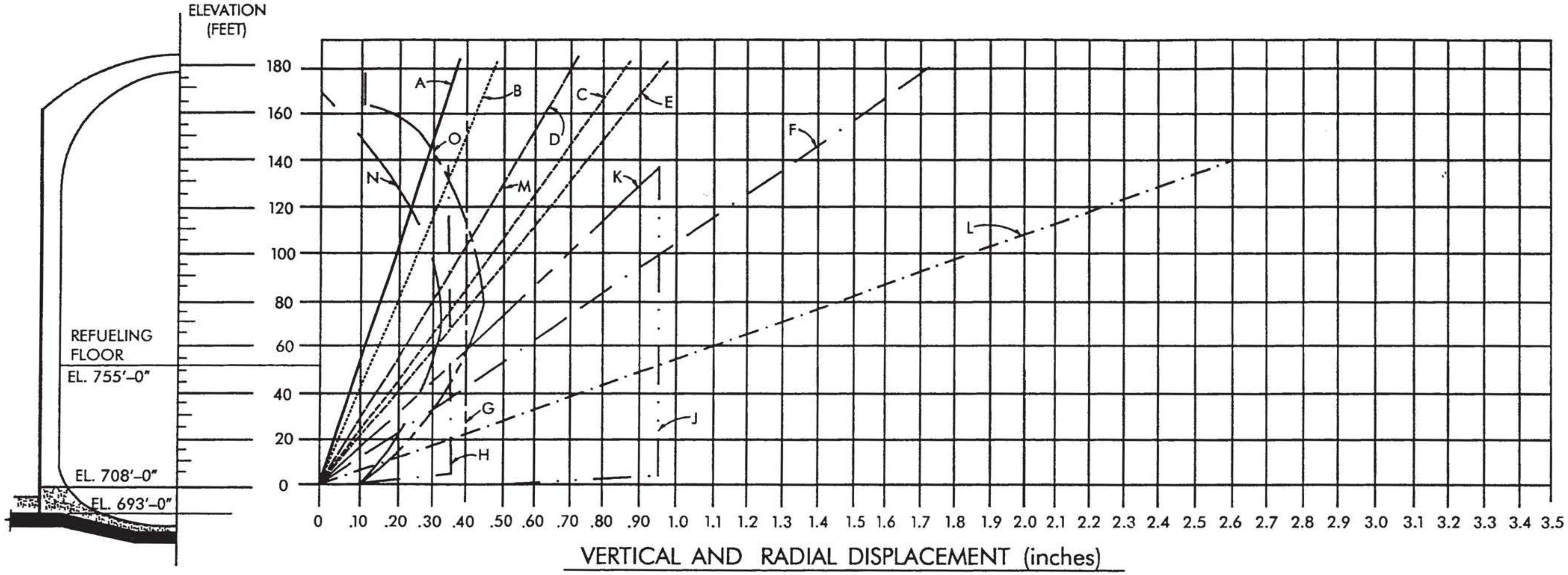
REVISIONS



NOTE: TEMPERATURE DISPLACEMENTS OF CONCRETE SHIELDS ARE NEGLIGABLE.

LEGEND

A: CONTAINMENT VESSEL HORIZONTAL DISPLACEMENT DUE TO DESIGN EARTHQUAKE

B. SHIELD BUILDING HORIZONTAL DISPLACEMENT DUE TO DESIGN EARTHQUAKE

C. MAXIMUM RELATIVE HORIZONTAL DISPLACEMENT BETWEEN CONTAINMENT VESSEL AND SHIELD BUILDING DUE TO DESIGN EARTHQUAKE.

D. CONTAINMENT VESSEL HORIZONTAL DEFLECTION DUE TO MAXIMUM HYPOTHETICAL EARTHQUAKE

E. SHIELD BUILDING HORIZONTAL DEFLECTION DUE TO MAXIMUM HYPOTHETICAL EARTHQUAKE

F. MAXIMUM RELATIVE HORIZONTAL DISPLACEMENT BETWEEN CONTAINMENT VESSEL AND SHIELD BLDG. DUE TO MAXIMUM HYPOTHETICAL EARTHQUAKE

G. CONTAINMENT VESSEL HORIZONTAL RADIAL DIPLACEMENT DUE TO INTERNAL PRESSURE (46 PSI)

H. CONTAINMENT VESSEL HORIZONTAL RADIAL DISPLACEMENT DUE TO TEMPERATURE INCREASE (30°F–120°F)

J. CONTAINMENT VESSEL HORIZONTAL RADIAL DISPLACEMENT DUE TO M–LA TEMPERATURE INCREASE (30°–250°)

K. CONTAINMENT VESSEL VERTICAL DISPLACEMENT DUE TO TEMPERATURE INCREASE (30°F–120°F)

L. CONTAINMENT VESSEL HORIZONTAL RADIAL DISPLACEMENT DUE TO M–LA TEMPERATURE INCREASE (30°–250°)

M. CONTAINMENT VESSEL VERTICAL DISPLACEMENT DUE TO INTERNAL PRESSURE (46 PSI)

N. MAXIMUM TORNADO DISPLACEMENT OUTWARD

0. MAXIMUM TORNADO DISPLACEMENT INWARD

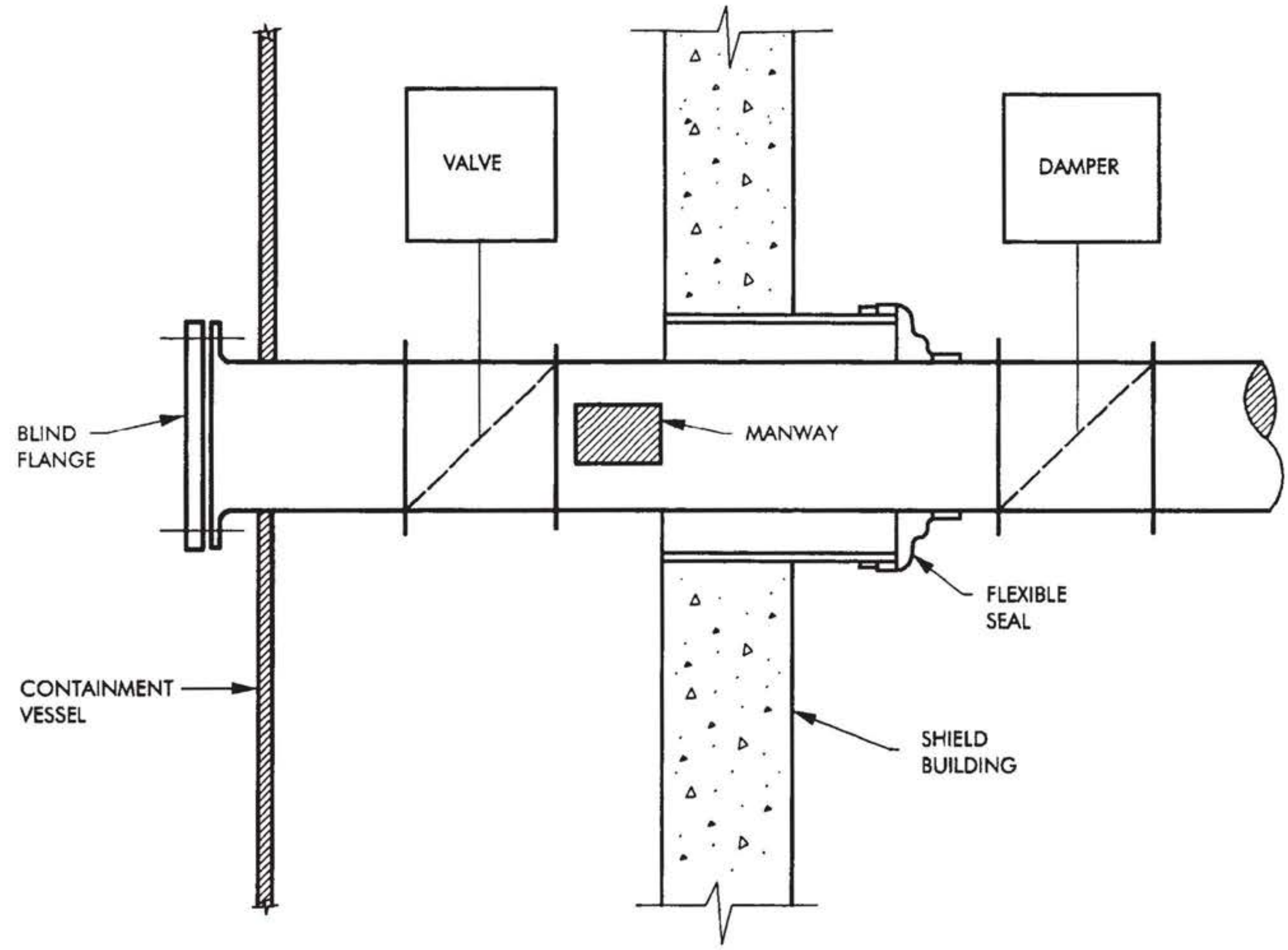
DWN TAM	DATE 6–23–99	SIGNIFICANT NO.							
CHECKED		GROUP	1	2	3	4	5	a	6
PROJECT NO. ETNSUR									
APP'D & CERT.									
CAD FILE U5201.DGN									

REACTOR BUILDING CALCULATED DISPLACEMENT DUE TO EARTHQUAKE, PRESSURE AND TEMPERATURE

NORTHERN STATES POWER COMPANY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
RED WING, MINNESOTA

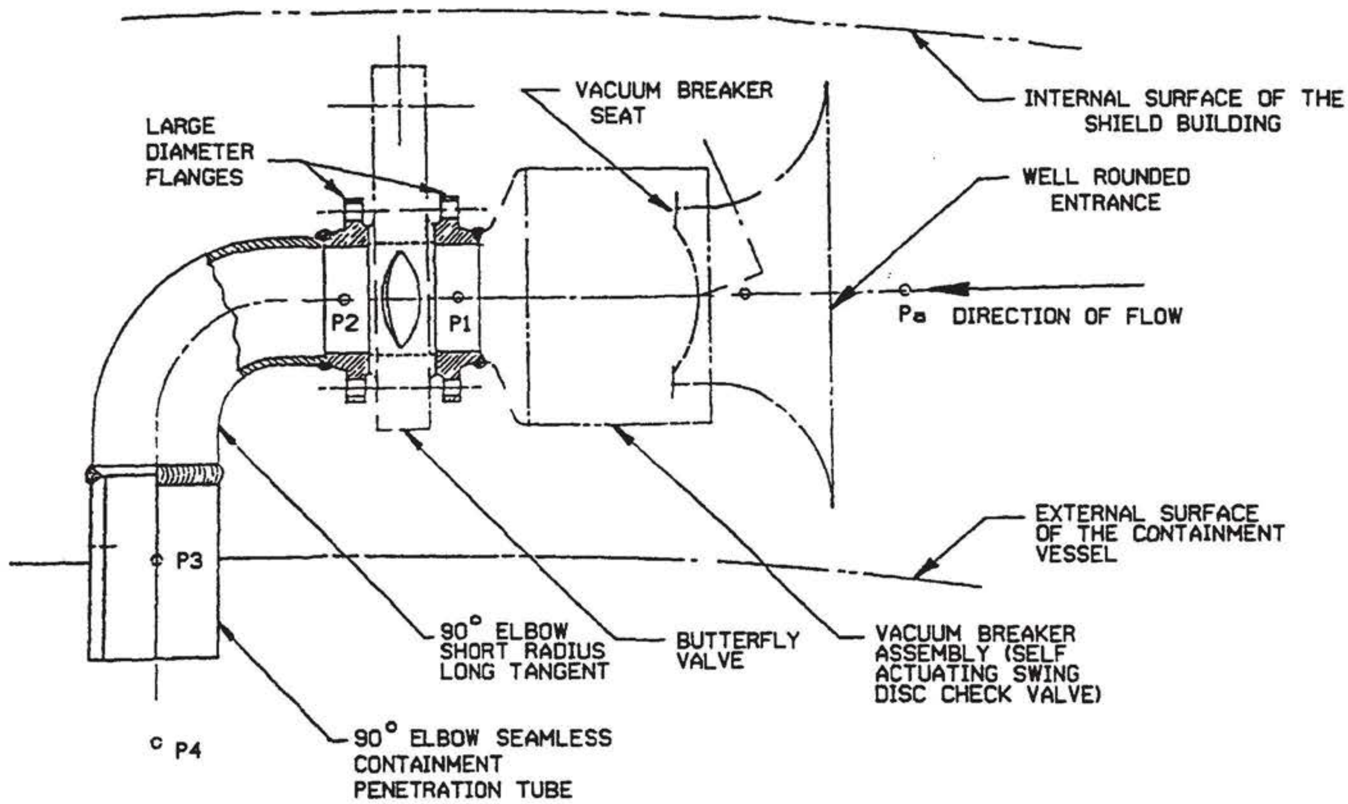
SCALE NONE

FIGURE 5.2-1 REV. 18



CONTAINMENT PURGE AND SUPPLY SYSTEM

DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE U5202.DGN		**FIGURE 5.2-2 REV. 18**



VACUUM RELIEF SYSTEM (TYPICAL ASSEMBLY)

DWN T.MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE U05203.DGN		FIGURE 5.2-3 REV. 18

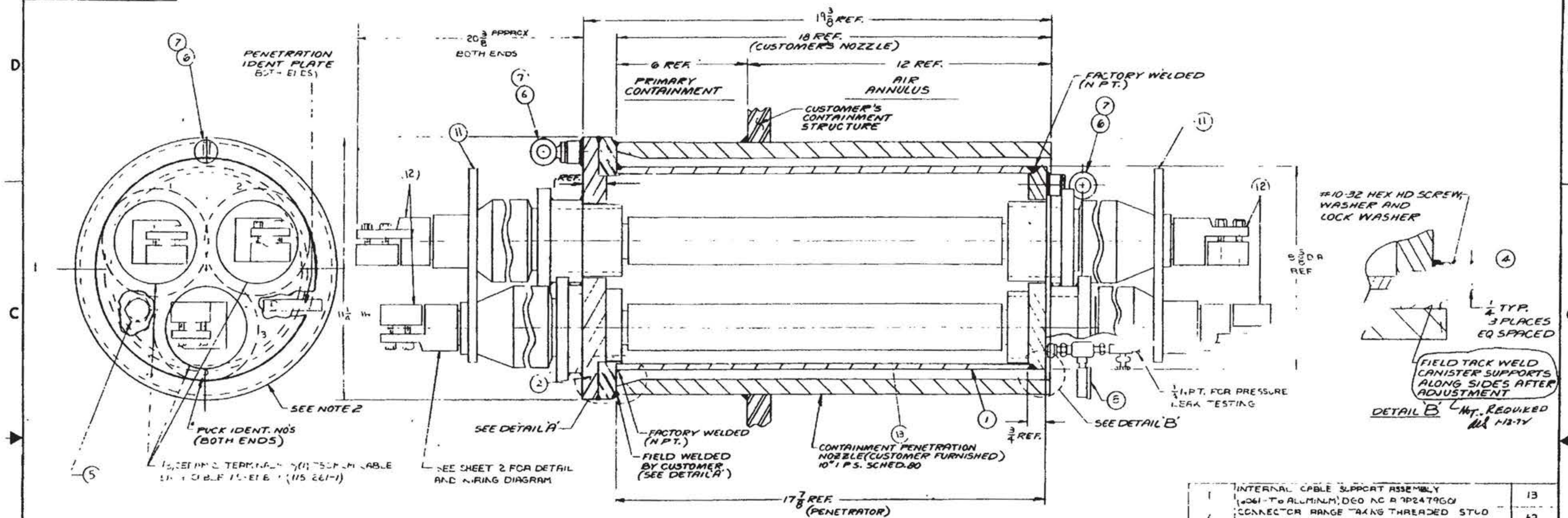
X-HIAW-188-1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	E	REDRAWN & REVISED/ECO 1168	17AUG71	EJN

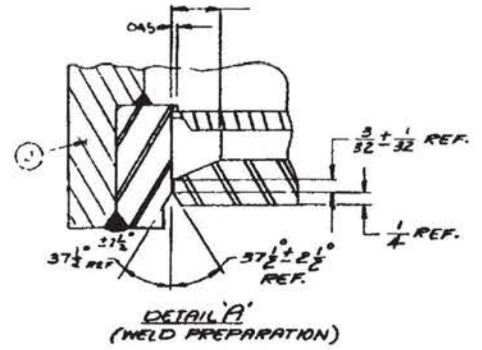
REVISIONS

F AS BUILT-
REV. ITEM #5 BILL
OF MATERIALS

PER DRR P1-03064
DWN: BB 5/6/03
CHK'D: CMR 5-28-03
MOD#: 79L058
FILMED 6-7-03



NOTES.
1. ALL EXTERNAL CARBON STEEL SURFACES WILL BE PROTECTIVE COATED PER MP-PC-102 WITH TILE CLAD II PRIMER, MFD. BY SHERWIN WILLIAMS CO.
2. THIS VIEW IS OF THE END INSIDE THE CONTAINMENT. THE AIR ANNULUS END IS A MIRROR IMAGE.



DETAIL 'A' (WELD PREPARATION)

QTY	DESCRIPTION	ITEM
1	INTERNAL CABLE SUPPORT ASSEMBLY (6061-T6 ALUMINUM) DGO NO R19P2479G01	13
6	CONNECTOR RANGE TAKING THREADED STUD TYPE BURNDY #NDR 0644T12 (SHIPPED LOOSE)	12
2	BUSHING INSULATED SUPPORT ASSEMBLY (NEMA G10 EPOXY GLASS) DGO NO R19P2487G01	11
123FT	750MCM 5KV CABLE 9/64 HTK INS 6/64 NS JACKET 61 STRAND (KERITE) 1.597 NOM O.D.	10
6	CERAMIC TERMINAL ASSEMBLY DGO NO R19P2303G01-G02-G03	9
1	PRESSURE GAUGE ASSY (SHIPPING AND STORAGE) D.G.O. NO. R19P2499G01	8
A/R	WASHER 5/16 ID X 1/16 THK. D.G.O. NO. PS00C2M0013 (CARBON STEEL)	7
2	REMOVABLE LIFTING EYEBOLT (CARBON STEEL) DGO NO. PS00C2A0029	6
1	½" PLUG (STAINLESS STEEL OR BRASS)	5
3	CANISTER ASSEMBLY SUPPORT (TYPE 304 ST STL PER ASTM A-479) DGO No R19A2316P01	4
1	AIR ANNULUS GAS CARRIER (304L STAINLESS STEEL PER ASTM A-240)	3
1	PRIMARY CONTAINMENT GAS BARRIER (304L STAINLESS STEEL PER ASTM A-240)	2
1	PENETRATION ASSY CANISTER 8" IPS SCHED. 20 (ASTM A333 GR1 CARBON STL.)	1

"F"

R19D2451G
NORTHERN ST PWR CO
PRAIRIE ISLAND
NEXT ASSY | USED ON
APPLICATION

MATERIAL/HEAT TREAT/FINISH
SEE ABOVE

DRAWN FMS DATE 8-12-71
CHKD GJN DATE 17AUG71
ENGR R.J. BUTTERS DATE 8-17-71
APPROVED 8/18/71

D. G. O'Brien, Inc.

ITEM 1 - MEDIUM VOLTAGE POWER
(3) 750 MCM FIELD COND'S
PENETRATIONS A3, A7, D5, D9

SIZE	CODE IDENT NO	DWG NO	REV
D	17476	R19D2249G	E

SCALE -- SHEET 1 OF 2

DWN BB DATE 5/6/03
CHECKED
PROJECT NO.
APP'D & CERT.
FILMED

SIGNIFICANT NO.	0630				E270 9010	3	
GROUP	1	2	3	4	5	CL	6

ITEM 1- MEDIUM VOLTAGE POWER
(3) 750 MCM FIELD COND'S.
PENETRATIONS A3,A7,D5,D9

NORTHERN STATES POWER COMPANY
Xcel Energy
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
REDWING MINNESOTA

SCALE | REV F
X-HIAW-188-1

XH1880I.DGN

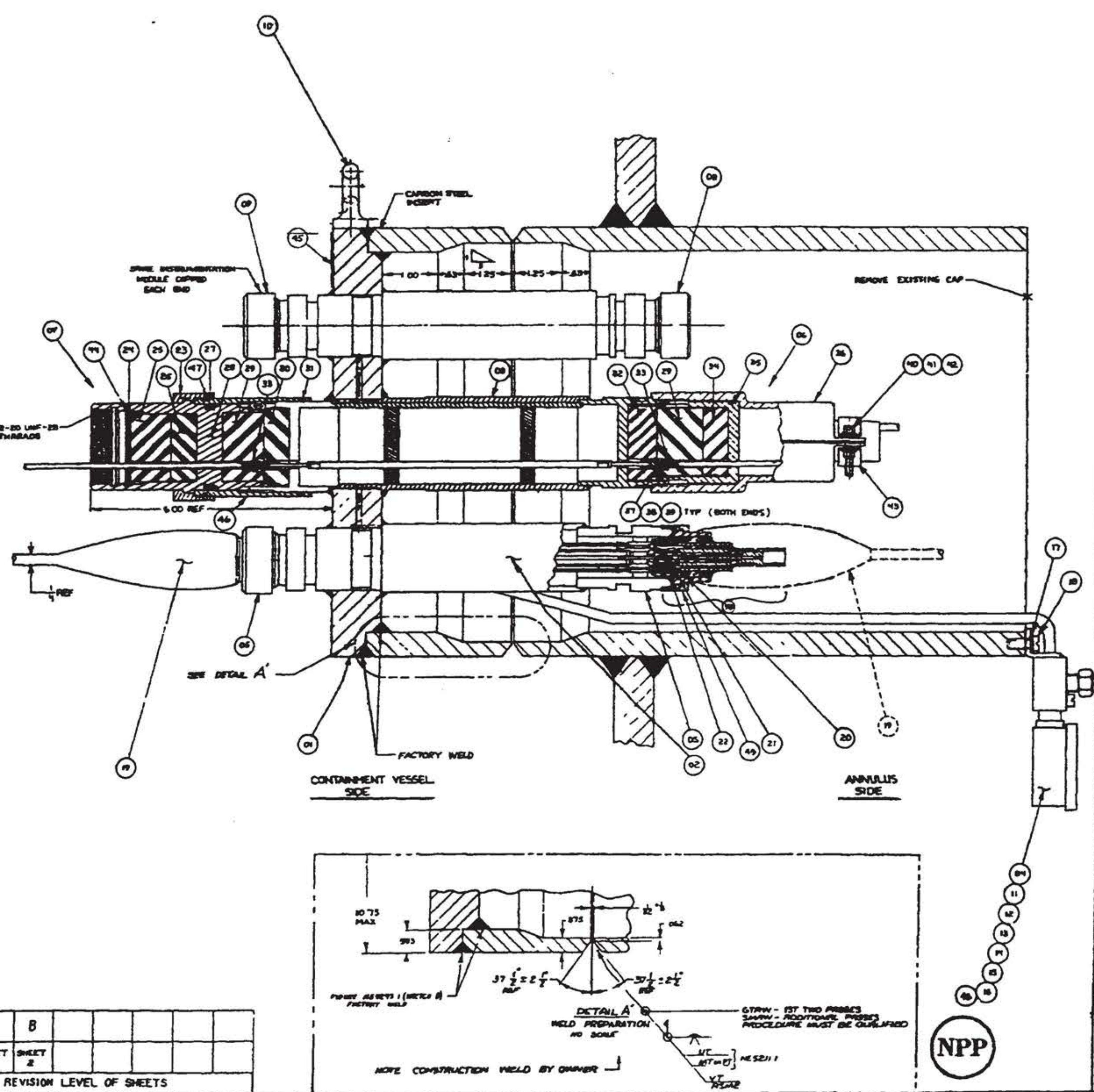
FIGURE 5.2-4A REV. 27

...\vernsfx\new_usars\U05204A.dgn 04/28/2005 10:02:03 AM

NOTES
1 DRAWING IS FOR ELECTRICAL PENETRATI . AID AND DR
2 REFERENCE CONTROLLED TECHNICAL MANUAL X HIAW 188 95
3 FOR SEISMIC SUPPORT / TEST APPARATUS SEE X HIAW 188 98

	REV	DESCRIPTION		DATE	APPROVED
	A	ECO # 2690-722			
	B	REVISED/ECO # 2745-777	LAM		
	C	REVISED/ECO # 2690-806	TY	10-11-80	
	D	REVISED/ECO # 2690 810	ML		
	E	REVISED/ECO # 2690 813	ML		
	F	REVISED/ECO # 2690 888	LAM		
	G	REVISED ECO # 2690-924			

H AS BUILT
INCORPORATE DWG INTO SYSTEM PER MDR PL 129
DWN JUN 24 81
CHK PAS 10 2 81
PROJ BOYLES
FILMED 10 2081



G	B
SHEET 1	SHEET 2

REVISION LEVEL OF SHEETS

			FIND NO.	QTY PER PLUG	PART NO.	DESCRIPTION	MATERIAL	SOURCE	REMARKS
		1	50		C32P2018G01	GLASS SEALED SUB-ASS'Y (INSIDE / OUTSIDE)		D G O'BRIEN	
		1	49		R14B2886P01	COUPLING RING (INSIDE / OUTSIDE)	BRASS CDA-360	D G O'BRIEN	
			48	REF	SS 400 7 4	FEMALE CONNECTOR	SST	SWAGELOK MFG CO	
3			47			10-32 UNF-2A, SET SCREW (1/4 LONG) (INSIDE)		D.G O'BRIEN	(CUP POINTS)
1			46		C42D8075P02	COUPLING RING (INSIDE)	BRASS, CDA 360	D.G O'BRIEN	
			45	1	R31C2143P	PENETRATION NAMEPLATE (INSIDE)	SST	D.G O'BRIEN	
1			44		RR 488-5	RETAINING RING (INSIDE)	SST	SPIRALOCK	
1			43		C32D2056P16	CABLE CLAMP STRAP (PAIR) (OUTSIDE)	SST	D.G O'BRIEN	7 DIA BUNDLE DIA
2			42		———	HEX HEAD SCREW #10-32 X 1" LONG (OUTSIDE)	SST	ACCURATE FASTENERS	
2			41		#50-FC-1032	HEX NUT #10-32 (SELF-LOCKING) (OUTSIDE)	SST	STANDARD PRESSED ST CO	
4			40		———	FLAT WASHER #10 (7/16 O D) (OUTSIDE)	SST	ACCURATE FASTENERS	
2			39		MS 3198-16-16A	#16 SOCKET CONTACT CRIMP (INSIDE / OUTSIDE)	BRASS	TRI STAR	GOLD PLATED
36			38		C13P1036G03	#16 SOCKET ASSEMBLY (INSIDE / OUTSIDE)	CHROMEL	D.G O'BRIEN	
36			37		C13P1036G04	#16 SOCKET ASSEMBLY (INSIDE / OUTSIDE)	ALUMEL		
1			36		C32C2170P01	COUPLING RING (OUTSIDE)	BRONZE 85-5-5-5		CDA-836
1			35		C32C2125P76	PLUG SLEEVE (OUTSIDE)	BRONZE 85-5-5-5		CDA-836
1			34		C32C2085P104	CABLE GROMMET (OUTSIDE)	DOW CORNING SYLGARD		
2			33		C32B2049P03	RETENTION WASHER (INSIDE / OUTSIDE)	BRASS CDA 360		
1			32		C32C2060P26	INTERFACIAL SEAL (OUTSIDE)	DOW CORNING SYLGARD		DC-170 TYP
1			31		MS 9068 140	O-RING (COUPLING RING) (INSIDE)	ELASTOMER	PARKER	5604-70
1			30		C32C2060P25	INTERFACIAL SEAL (INSIDE)	DOW CORNING SYLGARD	D.G O'BRIEN	DC-170 TYP
1			29		C32C2161P01	INSULATOR, PLUG SKIRT (INSIDE)	POLYSULFONE		P3500
1			28		C42B2074P01	PLUG SKIRT (INSIDE)	BRASS CDA 360		
1			27		MS 9068-135	O-RING (PLUG SKIRT) (INSIDE)	ELASTOMER	PARKER	5604-70
1			26		C32C2095P103	CABLE GROMMET (INSIDE)	DOW CORNING SYLGARD	D.G O'BRIEN	DC-170 TYP
1			25		C42B2060P04	CABLE GUIDE (INSIDE)	POLYSULFONE	D G O'BRIEN	
2			24		C42B2032P03	WAVE SPRING WASHERS (INSIDE)	ST STEEL	SPEC	
1			23		C42D8075P01	COUPLING RING (INSIDE)	BRASS CDA 360	D.G O'BRIEN	TYP
		1	22		MS9068-119	ELASTOMERIC O-RING (INSIDE / OUTSIDE)	ELASTOMER	PARKER	5604-70
		1	21		C13P1026G02	SOCKET CONTACT, #16 (INSIDE / OUTSIDE)	BRASS	D G O'BRIEN	
		1	20		R18A2287P02	AIR SPACE GASKET (INSIDE / OUTSIDE)	DOW CORNING SYLGARD		DC-170
		1	19		C41P1006G01	COAX TERMINATION KIT (M06) (INSIDE / OUTSIDE)	———		
			18	2	———	1/4-20 UNF-2A X .50 LG MACHINE SCREW	SST	ACCURATE FASTENERS	
			17	2	———	1/4 LOCK WASHER (OUTSIDE)	SST	ACCURATE FASTENERS	
			16	REF	SS-400 P	PLUG (OUTSIDE)	SST ASTM 479	SWAGELOK MFG CO	
			15	REF	SS-4 E	MANIFOLD BLOCK (OUTSIDE)	SST	CAJON	
			14	REF	J-M12	GAUGE PS1-1/4-18 NPT MALE BOTTOM (OUTSIDE)	———	GLOBE INSTRUMENT CO	
			13	REF	SS-4H2	BELLOWS VALVE (OUTSIDE)	———	NUPRO MFG CO	
			12	REF	400-8-4	FEMALE ELBOW (OUTSIDE)	ASTM 479	SWAGELOK MFG CO	
			11	REF	———	1/4 TUBING SST 304 (OUTSIDE)	ASME SA-213	D G O'BRIEN	
			10	1	81894 ED-28	EYEBOLT 5/8-16 THD X 1 1/4 LG 1" I.D. X 1 66 O.D. EYE	CARBON STEEL	N HAMPSHIRE SUPPLY	
			09	4	R19P2384G02	RECEPTACLE CAP ASSEMBLY (INSIDE)	BRASS	D G O'BRIEN	
			08	4	R19P2384G01	RECEPTACLE CAP ASSEMBLY (OUTSIDE)	ALUMINUM		
			07	1	C42P1025G01	PLUG ASSEMBLY M62 (INSIDE)	———		
			06	1	C32P1026G02	PLUG ASSEMBLY M62 (OUTSIDE)	———		
			05	8	R19P1010G06	PLUG ASSEMBLY M06 (INSIDE - OUTSIDE)	———		
			04	1	R31P5005G05	PRESSURE GAUGE ASS'Y	———		
			03	REF	R31P0039G01	MODULE ASS'Y M62	———		
			02	REF	R31P0020G01	MODULE ASS'Y M06	———		
			01	1	R31E5064G01	PENETRATION MODULE / FLANGE ASSEMBLY	———		
					R31E5059G01	INSTALLATION INSTR PENETRATION ASS'Y	———		

LIST OF MATERIALS

X-HIAW-188-96

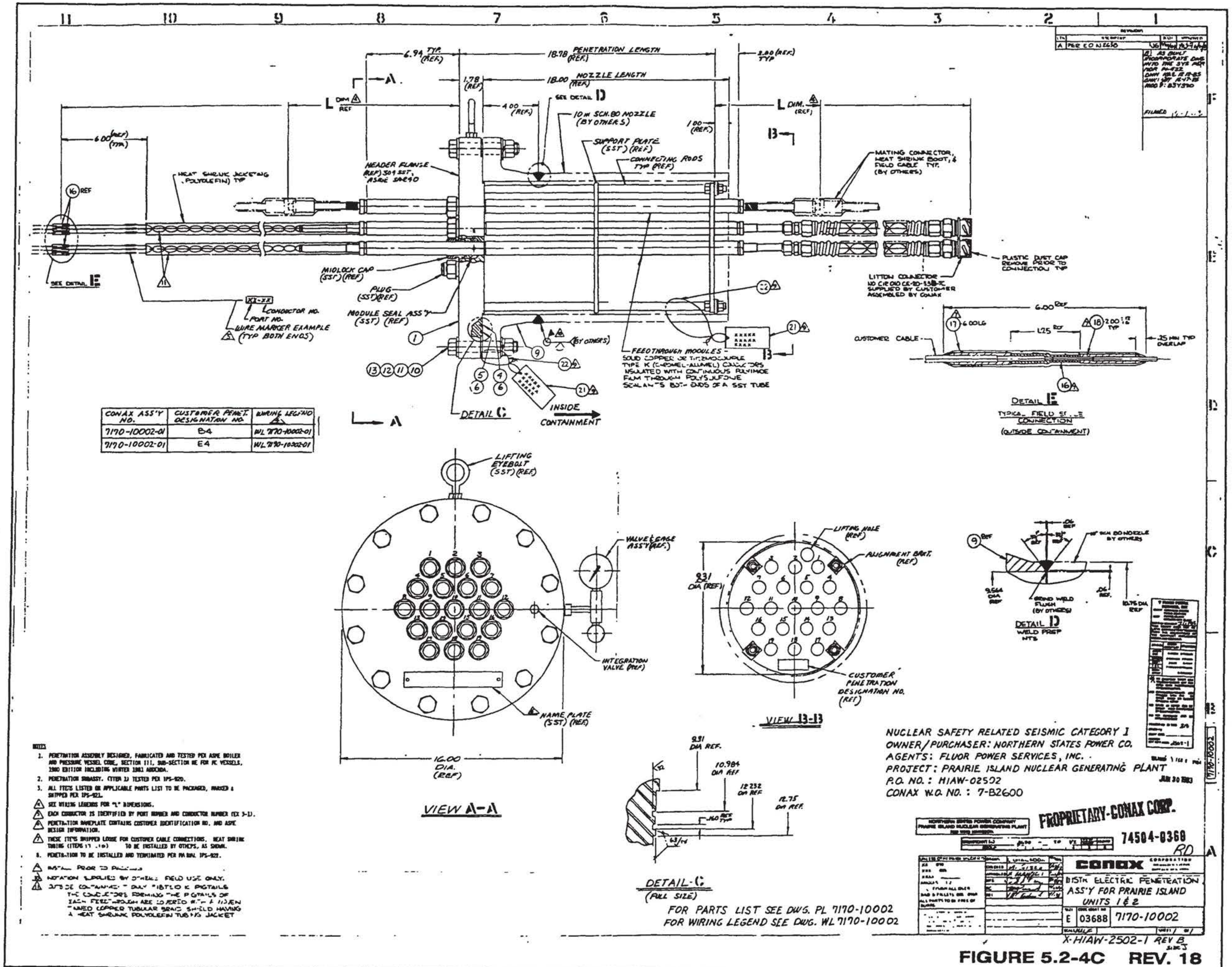
D. G. O'Brien, Inc

INSTALLATION INSTRUMENTATION PENETRATION

SEE MATERIAL COLUMN

17476 R31E5059G H

FIGURE 5.2-4B REV. 18



CONAX ASS'Y NO.	CUSTOMER PENET. DESIGNATION NO.	WIRING LEGEND
7170-10002-01	B4	WL 7170-10002-01
7170-10002-01	E4	WL 7170-10002-01

NOTES

1. PENETRATION ASSEMBLY DESIGNED, FABRICATED AND TESTED PER ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, SUB-SECTION NE FOR MC VESSELS, 1980 EDITION INCLUDING WINTER 1981 ADDENDA.
2. PENETRATION SUBASSY. (ITEM 1) TESTED PER IPS-920.
3. ALL ITEMS LISTED ON APPLICABLE PARTS LIST TO BE PACKAGED, MARKED & SHIPPED PER IPS-921.

NUCLEAR SAFETY RELATED SEISMIC CATEGORY I
OWNER/PURCHASER: NORTHERN STATES POWER CO.
AGENTS: FLUOR POWER SERVICES, INC.
PROJECT: PRAIRIE ISLAND NUCLEAR GENERATING PLANT
P.O. NO.: HIAW-02502
CONAX W.O. NO.: 7-B2600

FOR PARTS LIST SEE DWG. PL 7170-10002
FOR WIRING LEGEND SEE DWG. WL 7170-10002

PROPRIETARY-CONAX CORP.

74504-0369

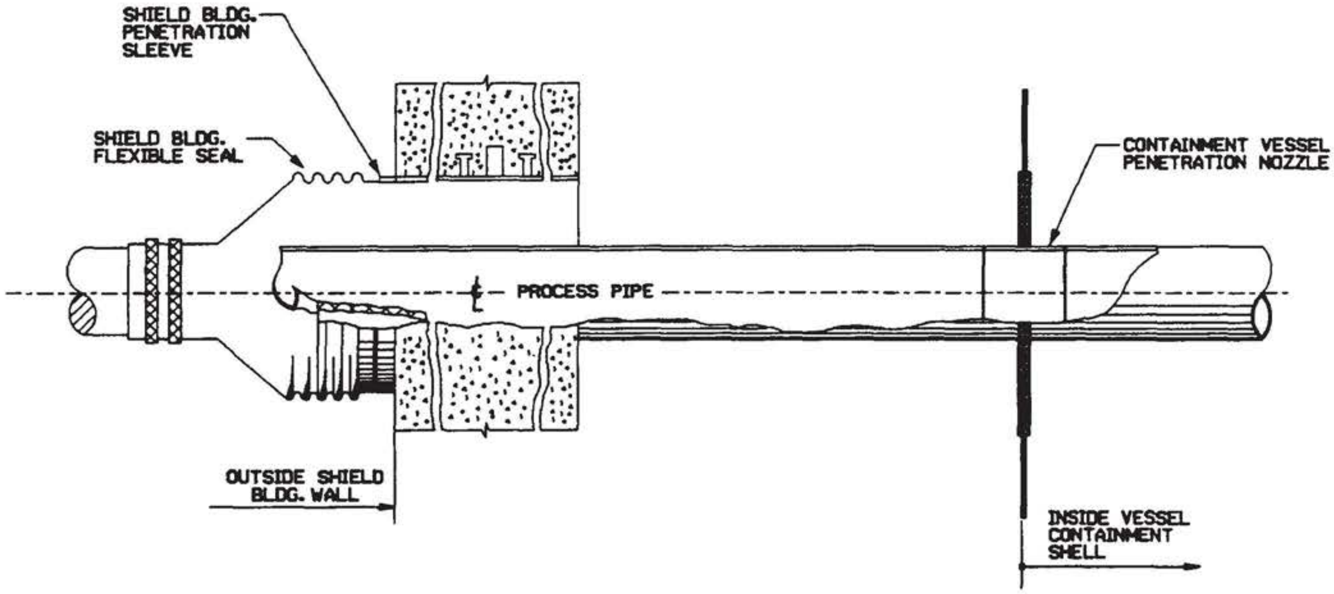
CONAX CORPORATION

ELECTRIC PENETRATION ASS'Y FOR PRAIRIE ISLAND UNITS 1 & 2

E 03688 7170-10002

X-HIAW-2502-1 REV B

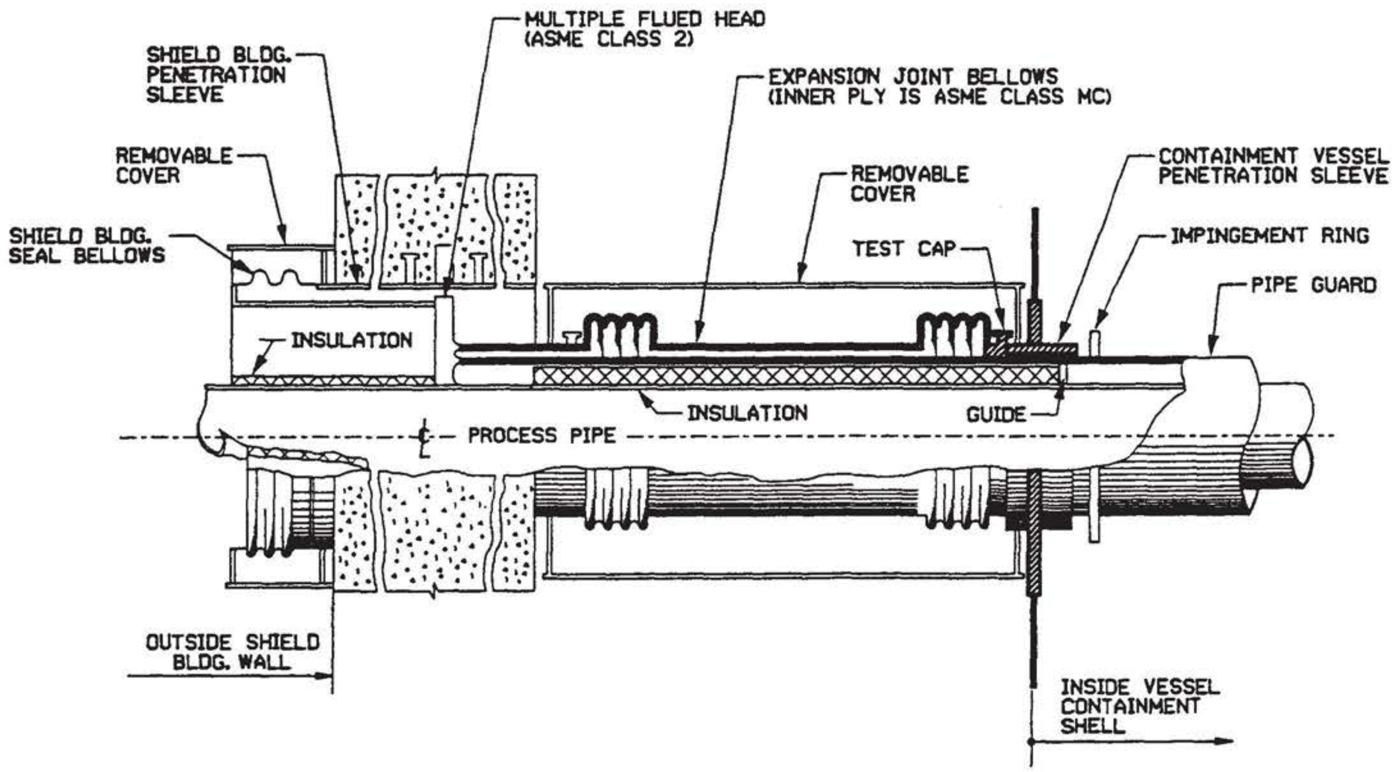
FIGURE 5.2-4C REV. 18



COLD PIPING PENETRATIONS ASSEMBLY

COLD PIPING PENETRAIONS ASSEMBLY

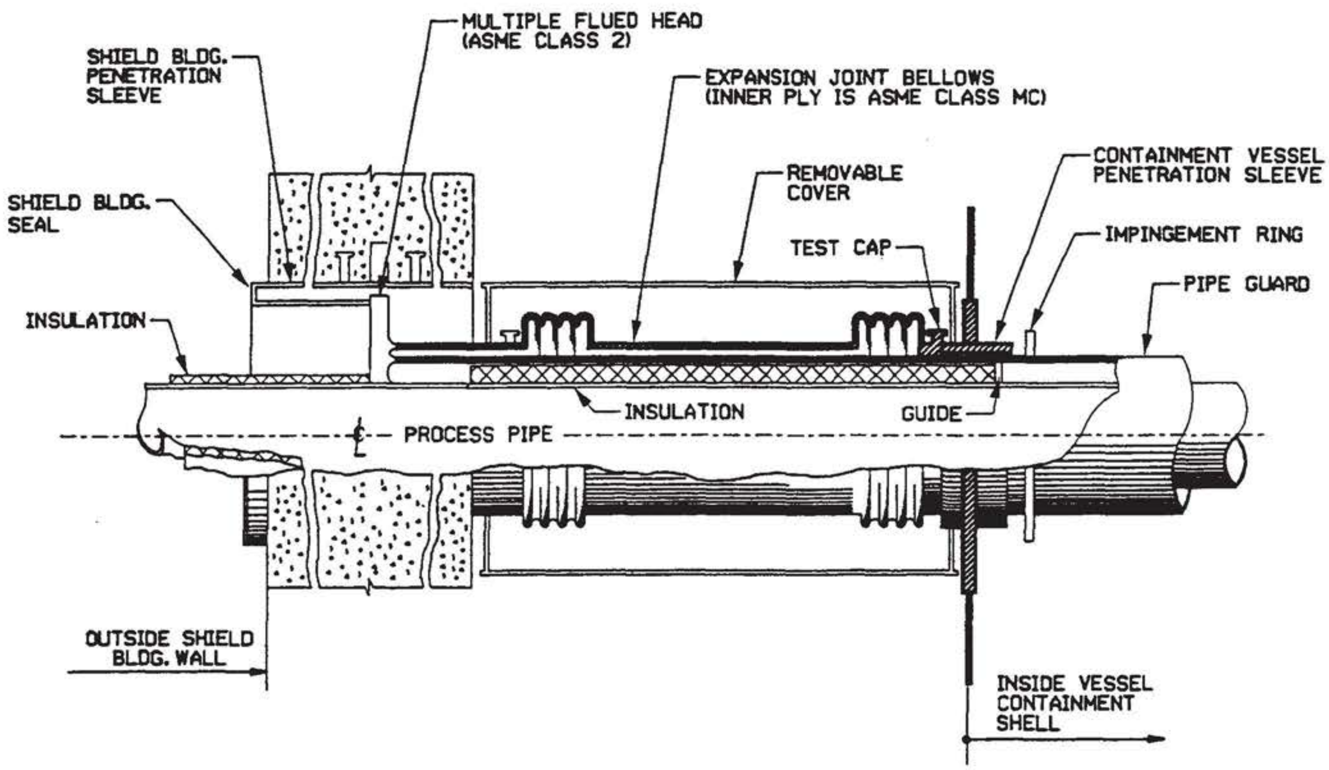
DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE	
CHECKED	CAD FILE U05205.DGN		**FIGURE 5.2-5**	**REV. 21**



HOT PIPING PENETRATIONS ASSEMBLY

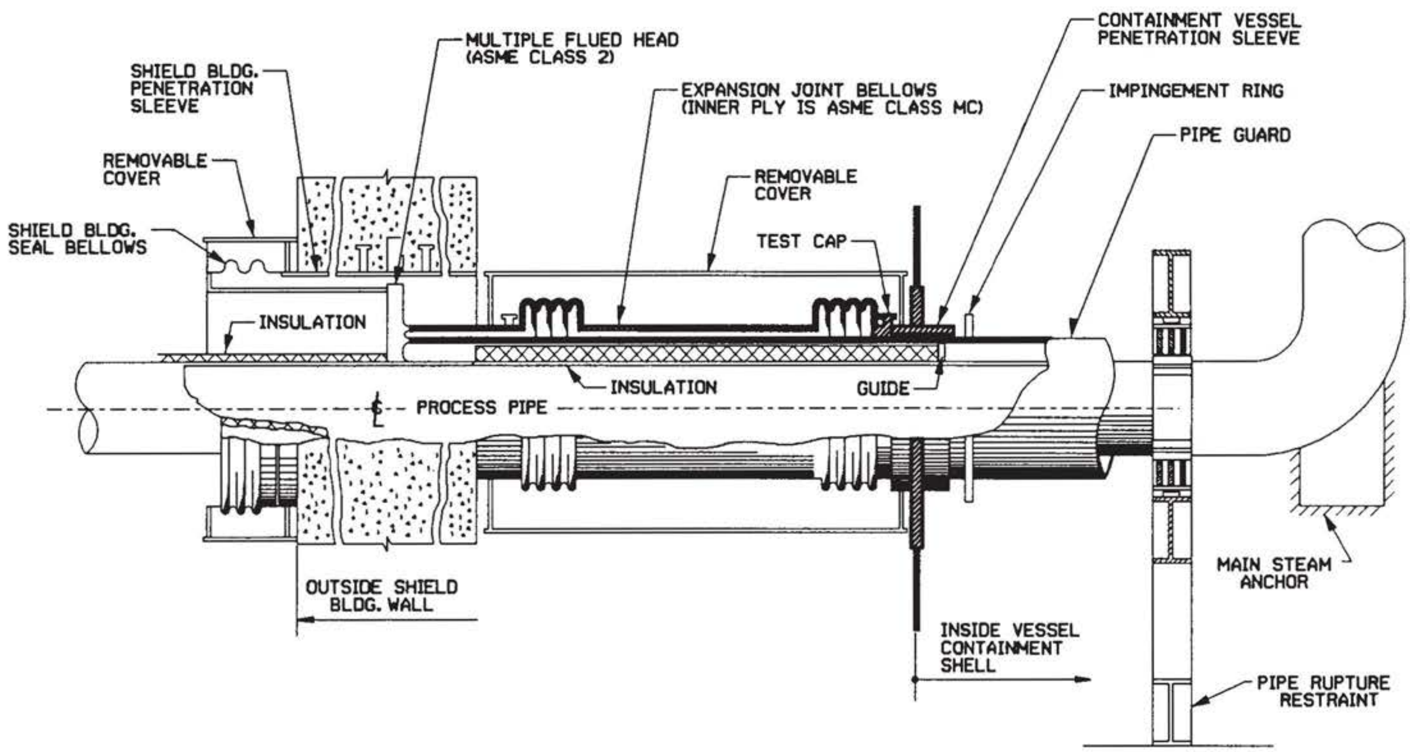
HOT PIPING PENETRATIONS ASSEMBLY

DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE U05206A.DGN		**FIGURE 5.2-6A REV. 18**



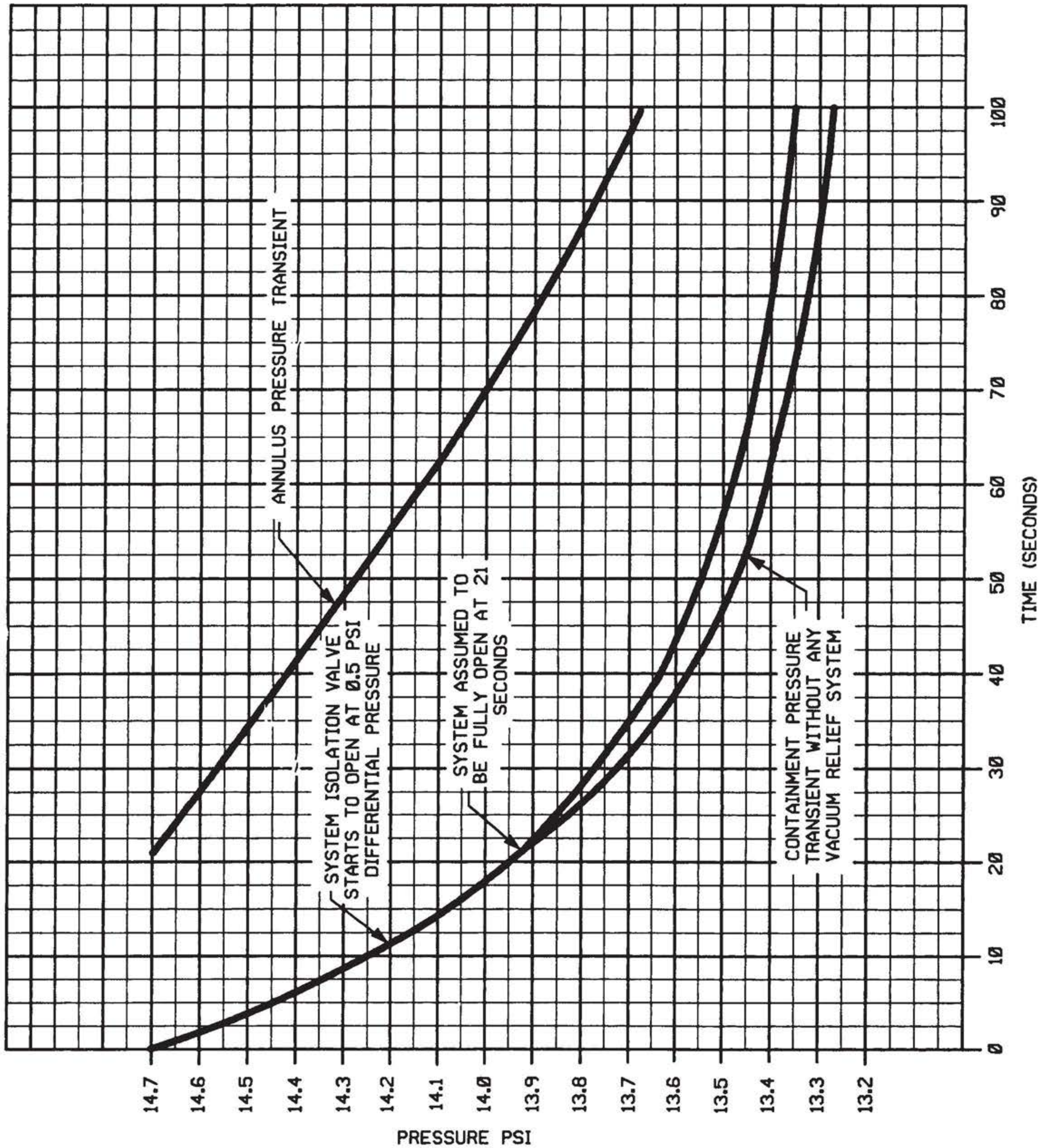
SMALL LINE
HOT PIPING PENETRATIONS ASSEMBLY

DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY	SCALE: NONE	
CHECKED	CAD FILE U05206.DGN	PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	FIGURE 5.2-6B	REV. 18



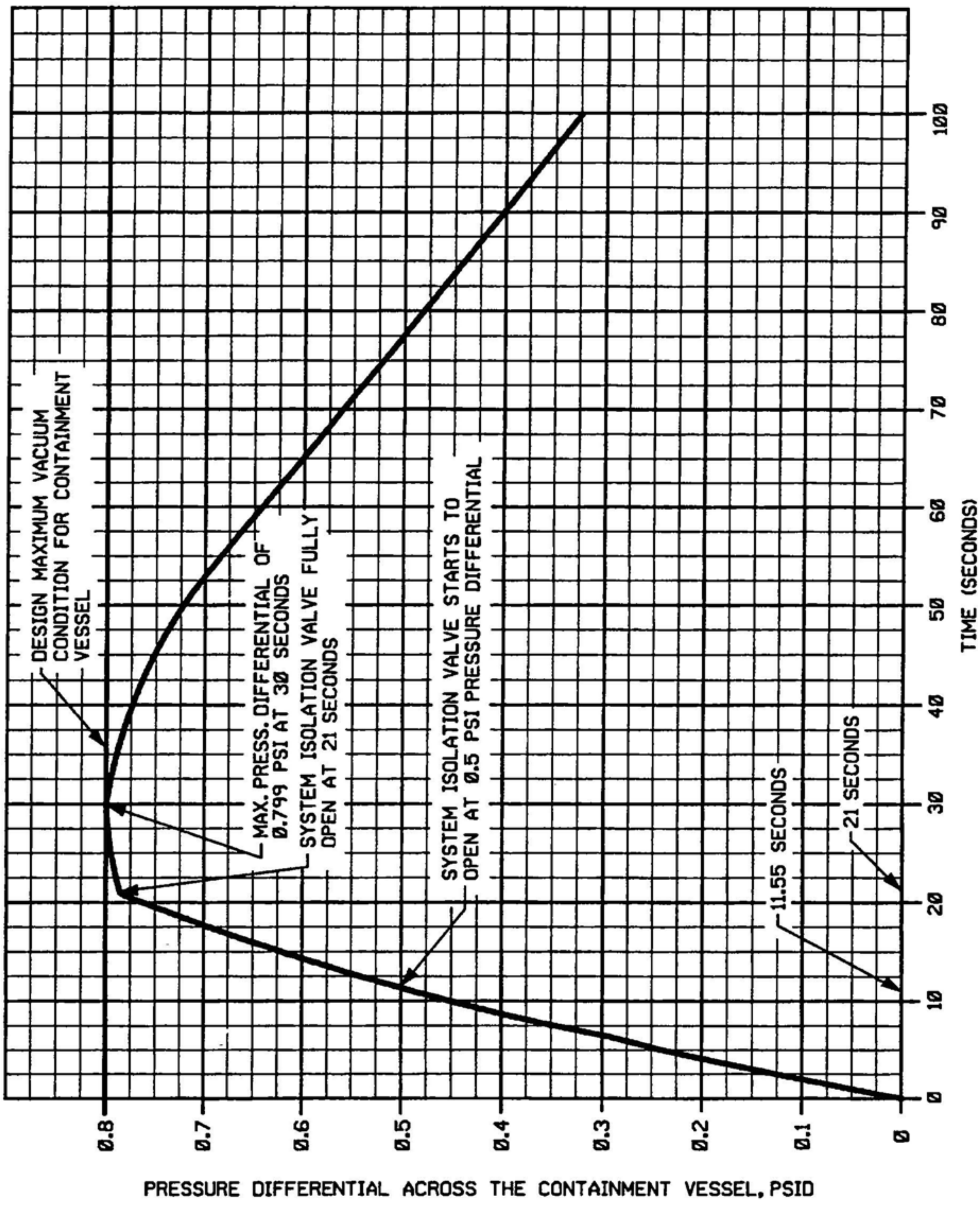
MAIN STEAM PIPING PENETRATIONS ASSEMBLY

DWN T. MILLER	DATE 11-12-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE	
CHECKED	CAD FILE U05207.DGN		**FIGURE 5.2-7**	**REV. 20**



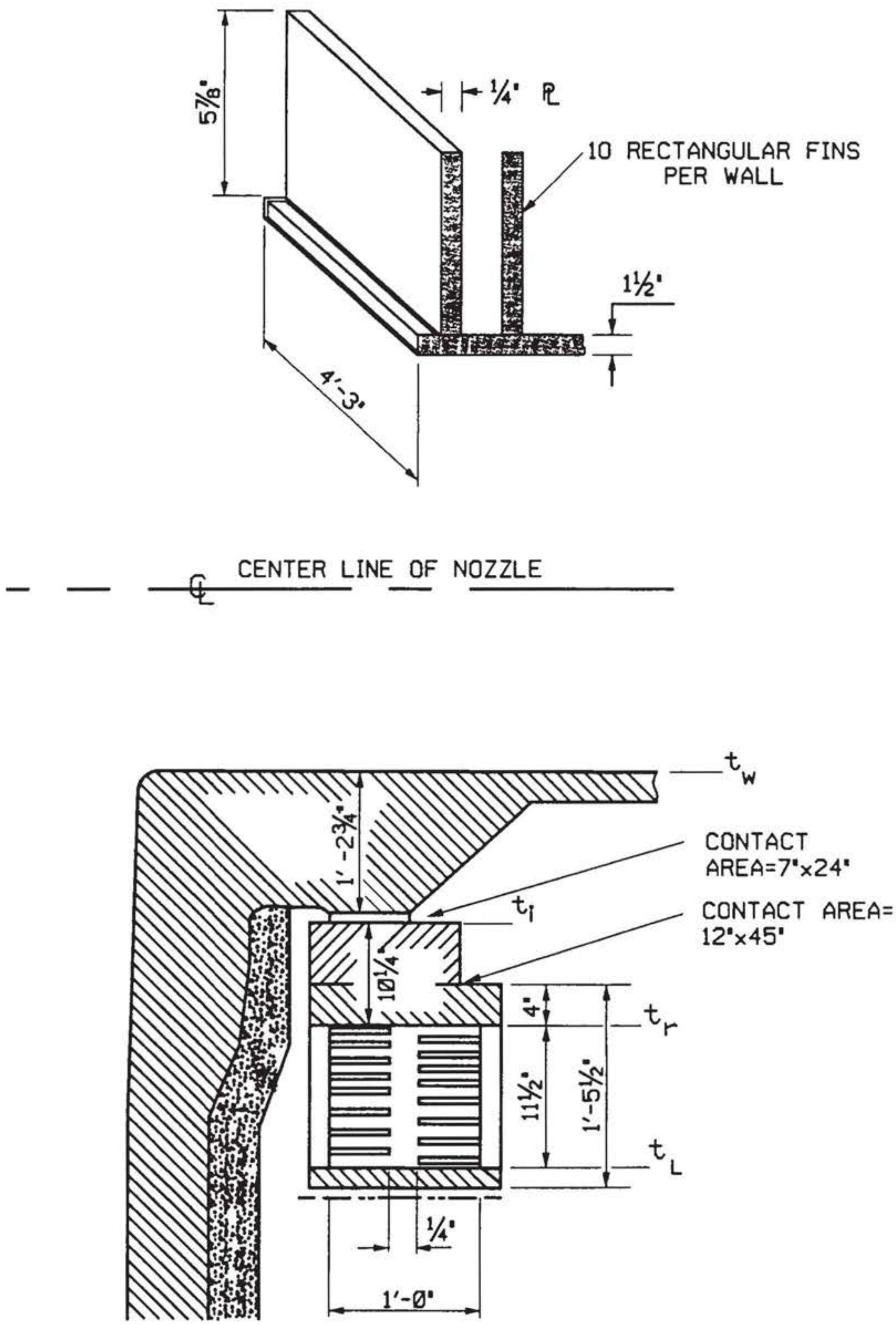
CONTAINMENT AND ANNULUS
PRESSURE TRANSIENT

DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY	SCALE: NONE
CHECKED	CAD FILE FIG528.DGN	PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	FIGURE 5.2-8 REV. 22



DIFFERENTIAL PRESSURE ACROSS REACTOR CONTAINMENT VESSEL STEEL SHELL
WITH ONE VACUUM RELIEF SYSTEM

DWN T. MILLER	DATE 6-23-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE UØ5209.DGN		FIGURE 5.2-9 REV. 23

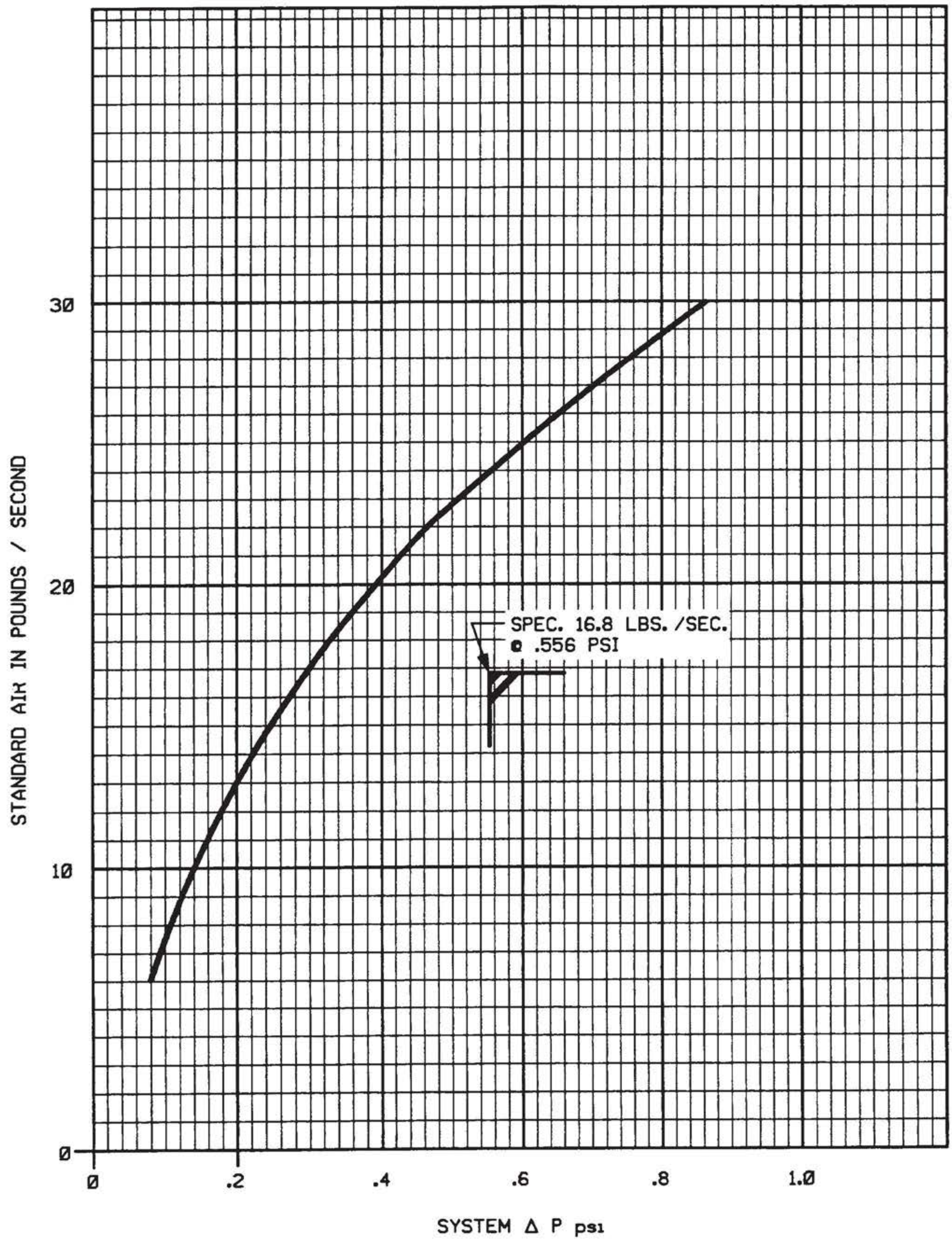


SCHEMATIC OF REACTOR
VESSEL SUPPORT

DWN T. MILLER	DATE 11-4-99	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE U05210.DG		**FIGURE 5.2-10 REV. 20**

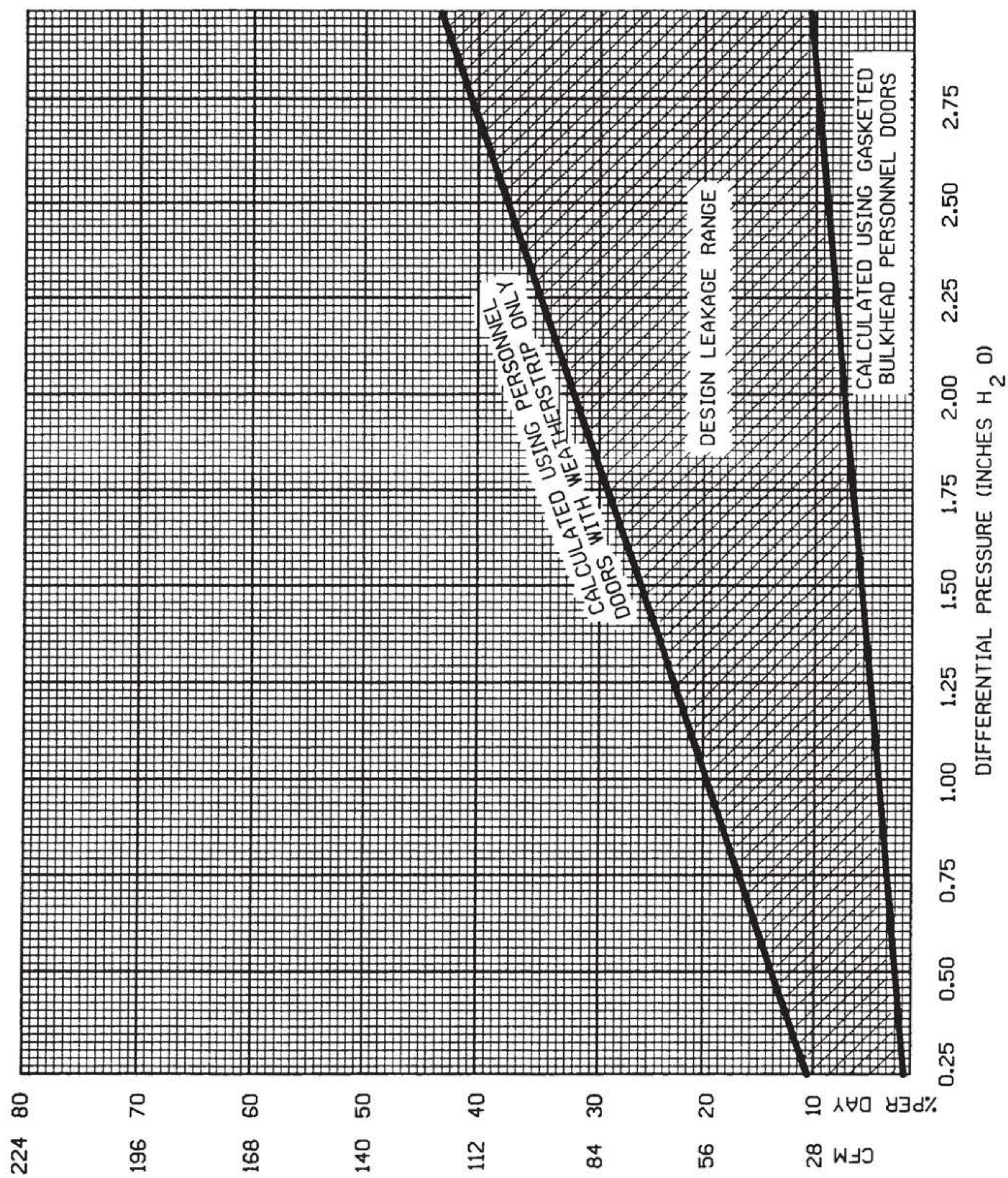
FIGURE 5.2-11, REV. 29
IS
DELETED

01032788



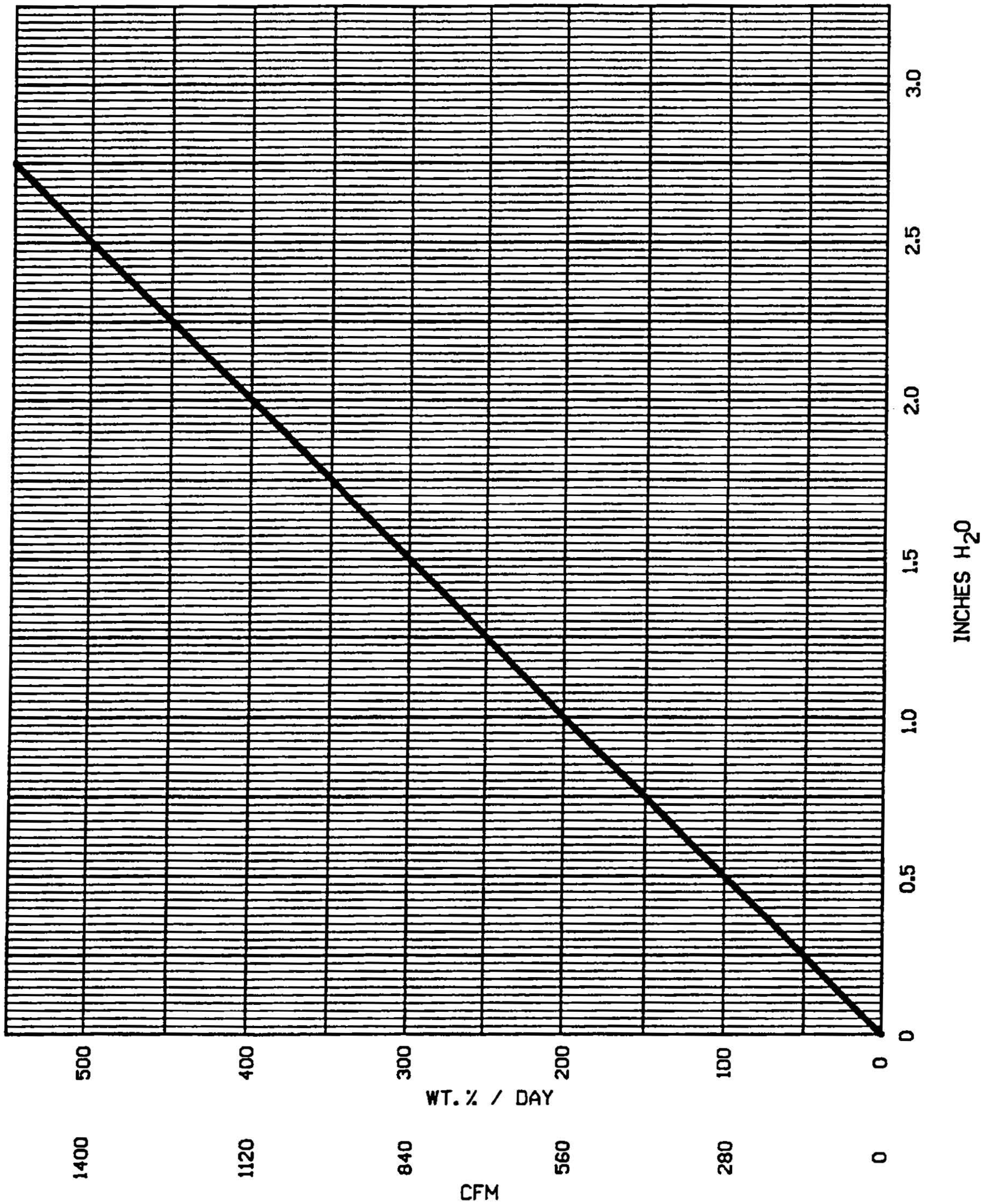
VACUUM BREAKER ASSEMBLY FLOW TEST RESULTS

DWN T. MILLER	DATE 8-15-00	NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	SCALE: NONE
CHECKED	CAD FILE U05212.DGN		FIGURE 5.2-12 REV. 23



SHIELD BUILDING LEAKAGE RATE

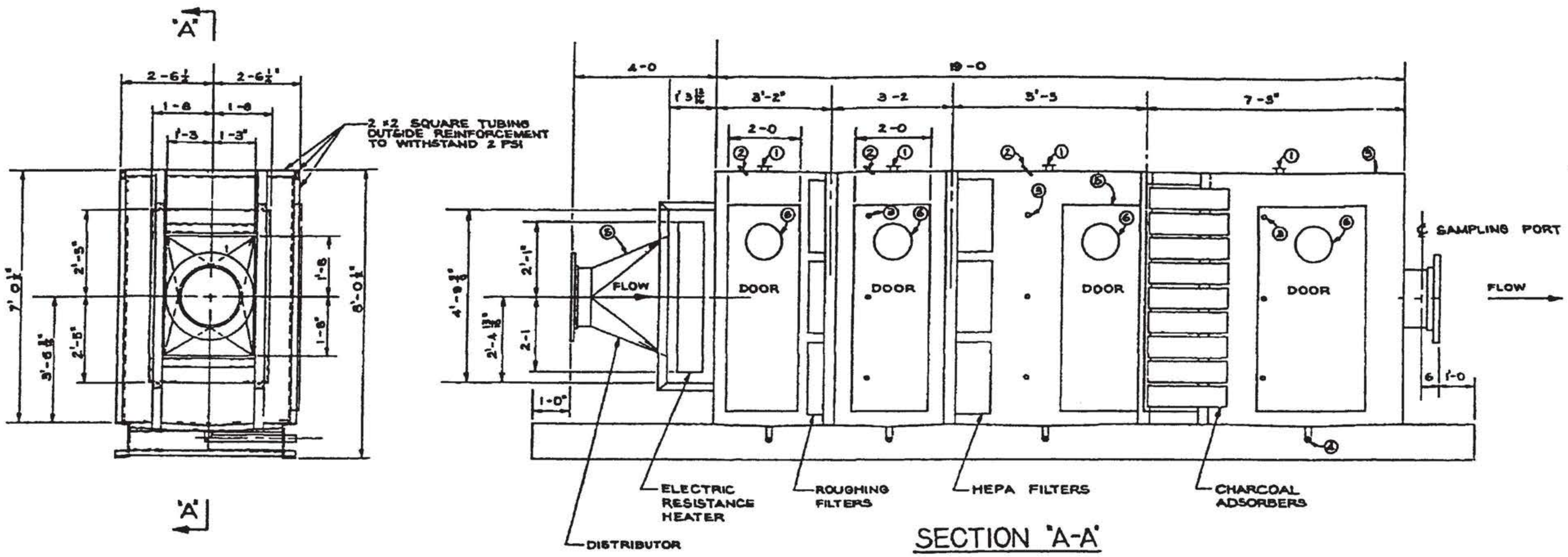
DWN J.D. SULLIVAN	DATE 6-23-99	NORTHERN STATES POWER COMPANY	SCALE: NONE
CHECKED	CAD FILE U05301.DGN	PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	**FIGURE 5.3-1 REV. 18**



SHIELD BUILDING IN LEAKAGE RATE
(FROM TECHNICAL SPECIFICATION 4.4)

DWN J.D. SULLIVAN	DATE 6-23-99	NORTHERN STATES POWER COMPANY	SCALE: NONE
CHECKED	CAD FILE U05302.DGN	PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING MINNESOTA	FIGURE 5.3-2 REV. 18

REVISIONS



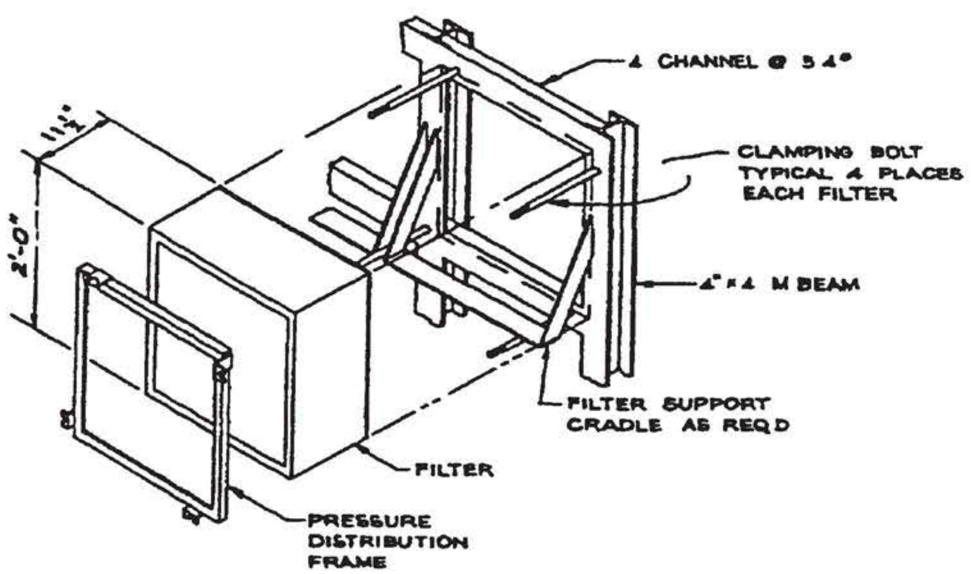
SECTION 'A-A'

NOTES:

1. VAPOR PROOF, EXPLOSION PROOF RECESSED LIGHTS SUPPLYING 150 CP OVER FILTER FACE.
2. WATER FOG SPRAY NOZZLES INSTALLED IN TOP OF HOUSING SO AS TO BLANKET ENTIRE UPSTREAM SURFACE OF EACH FILTER BANK AT A RATE OF 0.6 GPM PER SQUARE FOOT OF FILTER FRONTAL AREA WITH DROPLET SIZES OF 5 TO 10 μ
3. 1½ CAPPED SAMPLING NOZZLES
4. 2" DRAIN CONNECTION FOR EACH COMPARTMENT
5. 7 GAGE CARBON STEEL HOUSING PLATE ALL AROUND
6. 1 FT DIA WIRE-REINFORCED GLASS WINDOW

DOORS GASKETED WITH NEOPRENE MATERIAL PER MIL SPEC R 900
ALL FITTINGS AND WINDOWS DESIGNED AND INSTALLED TO WITHSTAND 2 PSI PRESSURE

HEPA FILTERS PER MIL-F-0051068B (MU)
ROUGHING FILTER 85% EFFICIENT USING THE NATIONAL BUREAU OF STANDARDS, DILL DUST-SPOT METHOD



TYPICAL CLAMPING ARRANGEMENT FOR HEPA FILTERS
SCALE NONE

DWN TAM	DATE 6-23-99	SIGNIFICANT NO.							
CHECKED		GROUP	1	2	3	4	5	CL	6
PROJECT NO. ETNSUR									
APP'D & CERT.									
CAD FILE: U05303.DGN									

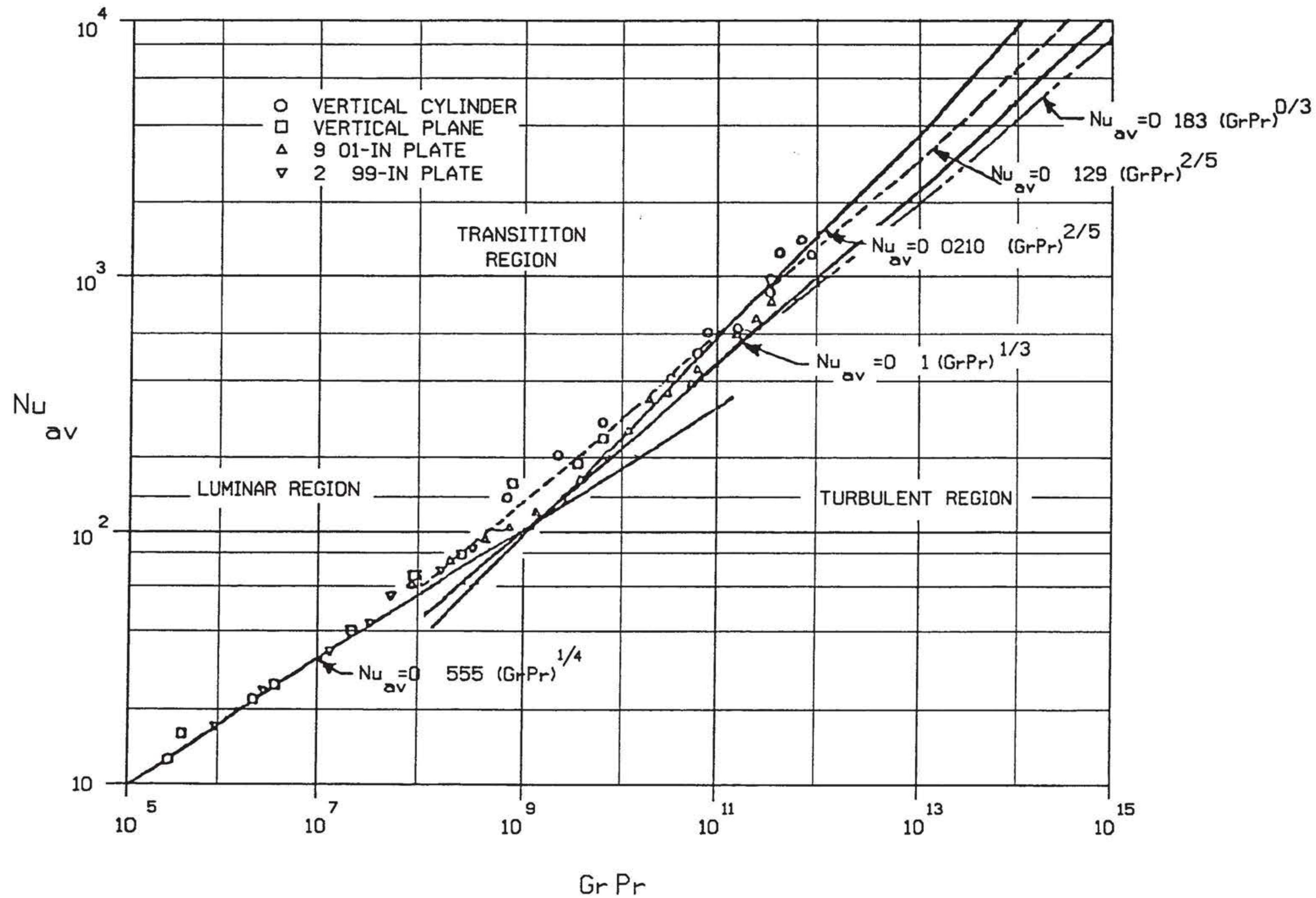
PAC FILTER MODULE

NORTHERN STATES POWER COMPANY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
RED WING, MINNESOTA

SCALE NONE

FIGURE 5.3-3 REV. 18

REVISIONS



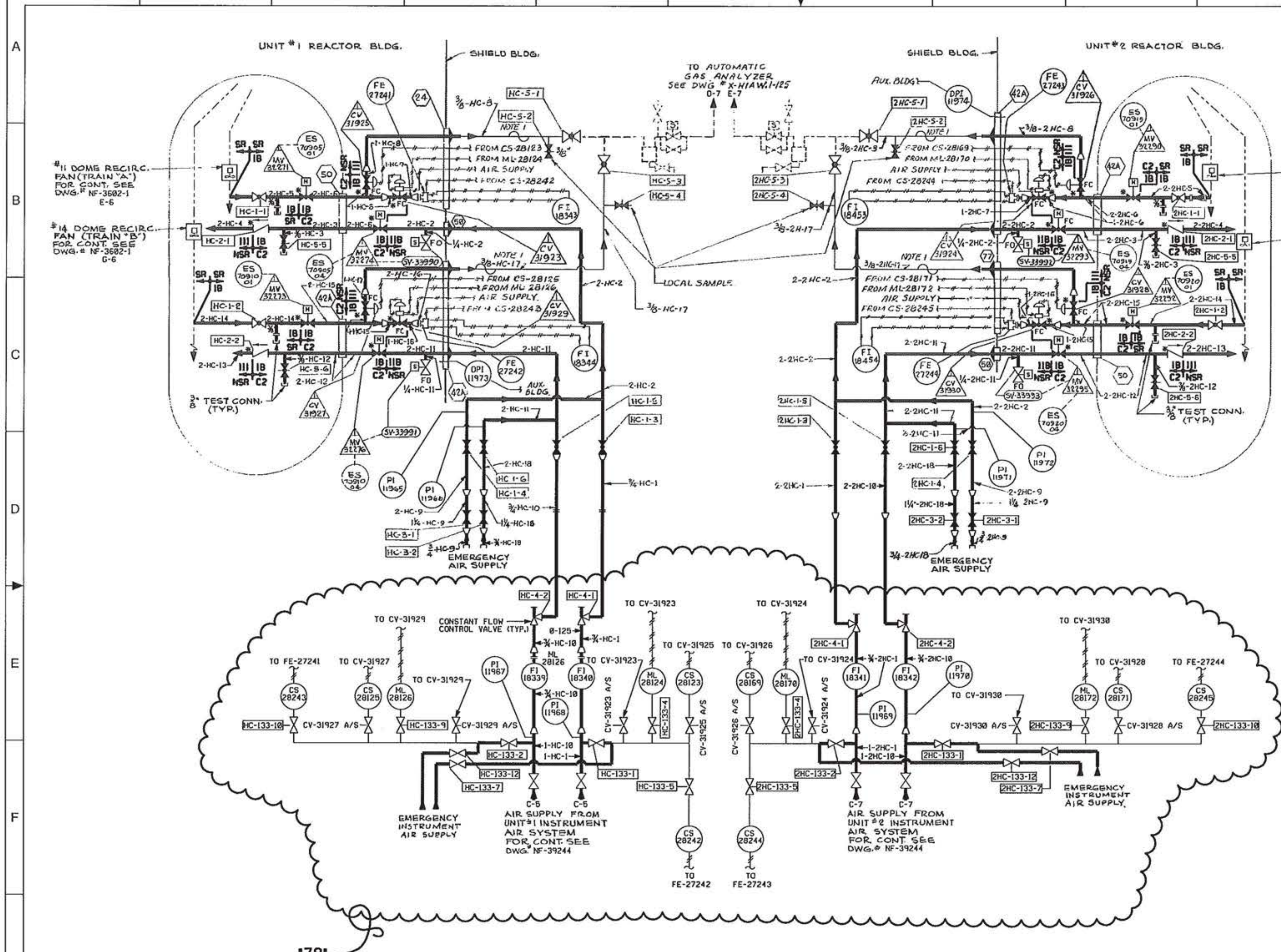
SYMBOLS

C	CONSTANT
Cp	SPECIFIC HEAT AT CONSTANT PRESSURE, Btu/lb m°F
Gr	GRASHOF NUMBER, $\frac{g B \Delta T L 3}{v 2}$
g	GRAVITATIONAL ACCELERATION, 4.17 x 10 ^{8}ft/hr ^{2}
h	HEAT TRANSFER COEFFICIENT, Btu/hr ft ^{2}° F
k	THERMAL CONDUCTIVITY, Btu/hr ft°F
L	CHARACTERISTIC LENGTH, FT
n	EXPONENT
Nu	NUSSELT NUMBER, $\frac{hL}{K}$
Pr	PRANDTL NUMBER, $\frac{Cpu}{K}$
T	TEMPERATURE, °F
e	SPECIFIC WEIGHT, lb m/ft ^{3}
B	EXPANSION COEFFICIENT, °F- 1
Δ	INCREMENT
m	ABSOLUTE VISCOSITY, lb m/ft hr
v	$\frac{m}{e}$

SUBSCRIPTS:

av	AVERAGE
f	AVERAGE VALUE

DWN TAM	DATE 6-23-99	SIGNIFICANT NO.							
CHECKED		GROUP	1	2	3	4	5	CL	6
PROJECT NO. ETNSUR		AVERAGE NUSSELT NUMBER FOR FREE-CONVECTION FLOWS ON A VERTICAL PLATE							
APP'D & CERT.									
CAD FILE: U05304A.DGN									
NORTHERN STATES POWER COMPANY PRAIRIE ISLAND NUCLEAR GENERATING PLANT RED WING, MINNESOTA		SCALE NONE							
		FIGURE 5.3-4 REV. 18							



LEGEND

(50) — DENOTES CONTAINMENT & SHIELD BUILDING PENETRATION NUMBER

LO DENOTES LOCKED OPEN

FO DENOTES FAIL OPEN

FC DENOTES FAIL CLOSE

CAT. 1 DENOTES CATEGORY 1 VENTILATION ZONE

* VALVES IN ACCORDANCE WITH SECTION III 1971 NUCLEAR CODE SUBSECTION MC

REFERENCE PIPING DWG. NOS.

HYDROGEN CONTROL SYS.- NF-39329

INSTRUMENT AIR SUPPLY- NF-39771-4

SAMPLING SYSTEM - NF-39297-3

REACTOR BUILDING VENTILATION UNIT 1 - NF-39602-1

REACTOR BUILDING VENTILATION UNIT 2 - NF-39602-2

INSTRUMENT AIR PIPING UNIT 1 & 2 - NF-39244

WASTE DISPOSAL SYSTEM UNIT 1 & 2 - XH-1-125

LEGEND

C2 NSR / IB III CLASS BREAK / QA TYPE

C1 - SAFETY- RELATED; ISI CLASS 1

C2 - SAFETY-RELATED; ISI CLASS 2

C3 - SAFETY-RELATED; ISI CLASS 3

SR - SAFETY-RELATED FLUID BOUNDARY; NON-CODE CLASS

NSR - NON-SAFETY-RELATED

IA,IB,IC,IIA,IIB & III DENOTES PIPING QA TYPES.

NOTES:

1. CONTAINMENT AIR SAMPLE LINES HEAT TRACED FROM SHIELD BLDG. PENETRATIONS TO STEAM CONDENSATE COLLECTION POT.
2. FOR VALVE POSITIONS SEE OPS MANUAL C PROCEDURE CHECKLIST.
3. UNLESS OTHERWISE SHOWN, CLASS BOUNDARIES STOP AT VENT AND DRAIN VALVES WITH DOWNSTREAM ITEMS (e.g., PIPE, CAPS, ETC.) CLASSED AS NON-SAFETY-RELATED.
4. FOR SYMBOLS SEE XH-1-105, NF-39214.
5. CLASS BREAKS INDICATE ISI CLASS BOUNDARIES PER PROCEDURE FP-E-RTC-02

INTERLOCK LOGIC DIAGRAMS
UNIT-1 NF-40776-1
UNIT-2 NF-40776-2

ACCOUNT NO.
40-70-1-04 (UNIT 1)
41-70-2-04 (UNIT 2)

PROJECT NO. 21-6197

FLOW DIAGRAM
POST LOCA HYDROGEN CONTROL SYS
UNIT 1 & 2

NORTHERN STATES POWER COMPANY
Xcel Energy
PRAIRIE ISLAND NUCLEAR GENERATING PLANT

SCALE NONE | REV 78

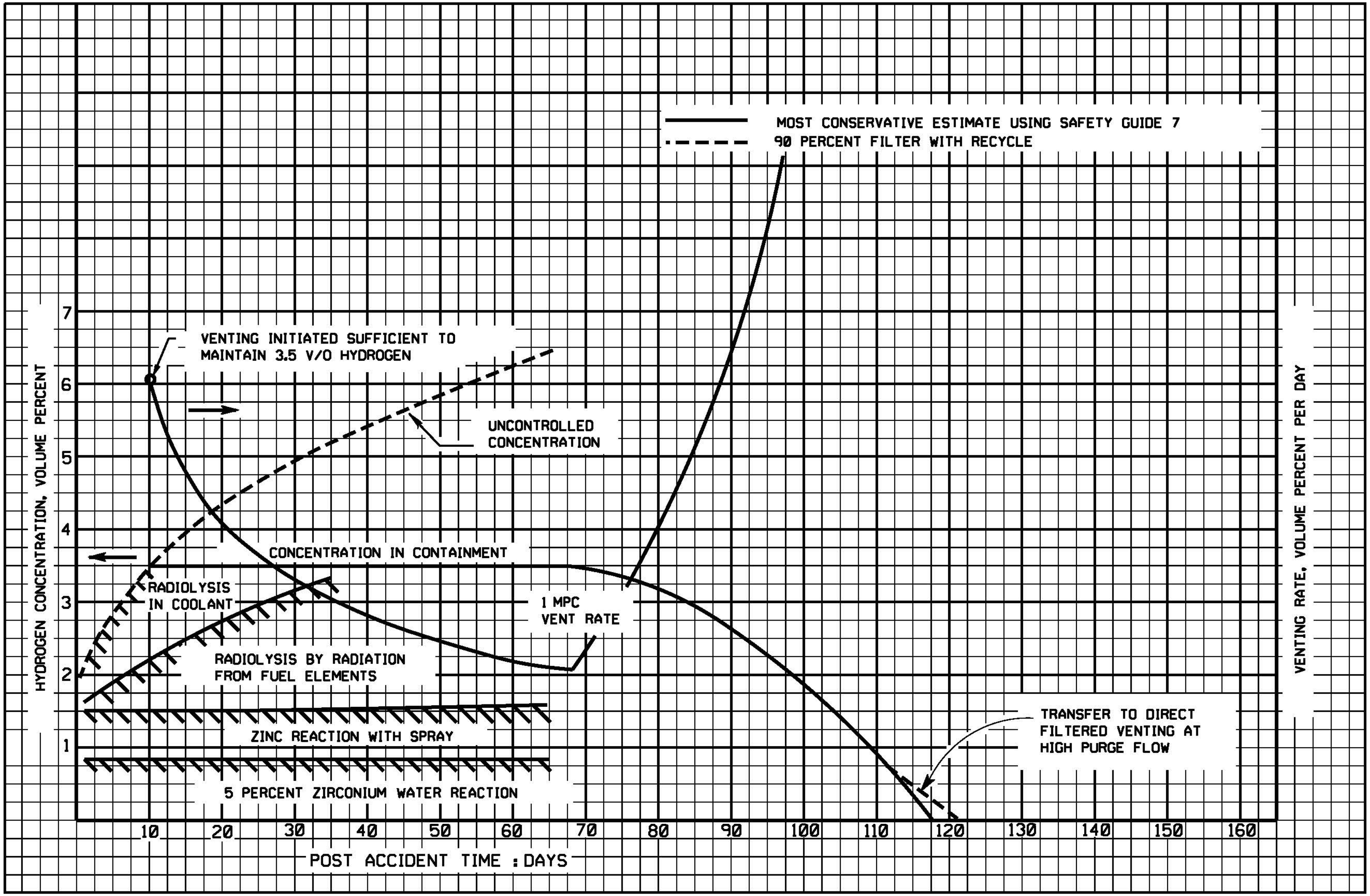
NF-39251

NF-39251

01429088

FIGURE 5.4-1 REV. 33

CAD FILE: U05401.DGN



DWN TAM	DATE 6-23-99	SIGNIFICANT NO.						
CHECKED		GROUP	1	2	3	4	5	CL 6
PROJECT NO. ETNSUR								
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CAD FILE: U05402.DGN								

HYDROGEN CONTROL BY PURGING AND VENTING THROUGH SHIELD BUILDING VENTILATION SYS. WITHOUT PRESSURE INCREASE

NORTHERN STATES POWER COMPANY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
RED WING, MINNESOTA

SCALE NONE | REVISED 5-13-11

FIGURE 5.4-2 REV. 32

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