TECHNICAL EVALUATION REPORT

CONTAINMENT LEAKAGE RATE TESTING

NORTHERN STATES POWER COMPANY
MONTICELLO NUCLEAR GENERATING PLANT

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FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

Mr. T. J. DelGaizo contributed to the technical preparation of this report through a subcontract with WESTEC Services, Inc.

1. BACKGROUND

On August 5, 1975 [1], the NRC requested Northern States Power Company (NSP) to review the containment leakage testing program at the Monticello Nuclear Generating Plant and to provide a plan for achieving full compliance with 10CFR50, Appendix J, where necessary, including appropriate design modifications, changes to technical specifications, or requests for exemption from the requirements pursuant to 10CFR50.12.

NSP replied on September 19, 1975 [2], providing a detailed comparison between the requirements of Appendix J and the containment leakage testing program at the Monticello plant. Subsequently, NSP submitted a License Amendment Request, dated January 30, 1976 [3], and revisions to it, dated May 4, 1976 [4], which proposed changes to the technical specifications for the Monticello plant. NSP supplemented the License Amendment Request with a request for certain exemptions from the requirements of Appendix J in a letter dated May 5, 1976 [5] and proposed modifications to various piping systems in a second letter, also dated May 5, 1976 [6]. The combination of the proposed technical specification changes, requested exemptions, and proposed modifications represented NSP's overall plan for achieving compliance with the requirements of Appendix J.

Following a review of this material by the NRC staff, a meeting was held on October 28, 1976 to discuss certain aspects of NSP's proposals regarding containment leakage testing. The meeting was attended by the NRC, representatives of NSP, and NSP's consultant, the Bechtel Power Corporation. At that time, NSP provided additional information [7] in support of certain previously stated positions.

Finally, on September 2, 1977 [8], NSP submitted an additional License Amendment Request proposing changes to the technical specifications regarding the duration of the Type A test. Supplementary information relative to this proposal was provided on March 20, 1978 [9].

The purpose of this report is to provide technical evaluations of the outstanding submittals regarding implementation of the requirements of

10CFR50, Appendix J, at the Monticello plant. Consequently, technical evaluations of the requests for exemption from the requirements of Appendix J submitted in Reference 5 and technical evaluations of the proposed technical specification changes (applicable to Appendix J) submitted in References 3, 4, 8, and 9 are provided. In addition, technical evaluations of NSP's proposed piping modifications of Reference 6 are provided in accordance with a request that NSP's interpretations of the requirements be confirmed by the NRC before the modifications are made.

2. EVALUATION CRITERIA

Code of Federal Regulations, Title 10, Part 50 (10CFR50), Appendix J, Containment Leakage Testing, was specified by the NRC as the basis for the evaluations. When applied to the following evaluations, the criteria are either referenced or briefly stated, where necessary, to support the results of the evaluations. Furthermore, in recognition of the plant-specific conditions that could lead to requests for exemption not explicitly covered by the regulations, the NRC directed that the technical reviews constantly emphasize the basic intent of Appendix J, that potential containment atmospheric leakage paths be identified, monitored, and maintained below established limits.

3. TECHNICAL EVALUATION

3.1 REQUESTS FOR EXEMPTION

In Reference 5, NSP requested certain exemptions from the requirements of Appendix J. Supplemental information relative to these requests was provided in Reference 7. The following sections provide separate technical evaluations for each of these requests.

3.1.1 Type B Testing of Instrument Lines

NSP stated that Section III.B.1 of Appendix J, under the definition contained in Section II.G.4, could be construed to require testing of instrument lines not equipped with excess flow check valves. In view of this possible interpretation, NSP requested an exemption from Type B testing of 13 instrument lines for which no testing provision was included in the original plant design. The lines in question are used to sense drywell and torus pressure, temperature, and water level, and to generate safeguard signals in the case of the pressure instruments. The small-diameter piping outside containment is connected to sealed transducers.

NSP stated that there is no practical method of testing these penetrations using Type B methods, but that each penetration is tested as part of the Type A test. The associated instrument line outside containment would have to rupture in order for the line to cause leakage to the atmosphere outside containment, and manual isolation valves outside containment can isolate the line in case of a rupture. NSP further stated that modifications to permit testing of these lines could degrade performance of the related safety functions of the instruments.

EVALUATION

Section II.G.4 of Appendix J states:

II.G. "Type B Tests" means tests intended to detect local leaks and to measure leakage across each pressure-containing or leakage limiting boundary for the following primary reactor penetrations:

4. Components other than those listed in II.G.1, II.G.2 or II.G.3 which must meet the acceptance criteria in III.B.3.

Section II.G.4 of Appendix J does not normally require components, other than those in Sections II.G.1, II.G.2, and II.G.3, to be Type B tested. However, Type B testing could be required if these components develop leaks during operation or are otherwise repaired or modified. Since these instrument lines are connected to sealed transducers and are designed to withstand the stresses of LOCA loads, they are considered part of the containment barrier. The integrity of this type of barrier is ensured by exposing the lines to periodic Type A test pressure.

In addition, experience since the publication of Appendix J has shown that passive leakage barriers, such as the Type B containment penetrations, have not been prone to degradation of the leakage boundaries during the periods between Type A tests.

In view of the foregoing discussion, it is concluded that the instrument lines in question do not require Type B testing provided they are exposed to Type A test pressure. No exemption from the requirements of Appendix J is necessary because the intent of Appendix J is satisfied.

3.1.2 Type B Testing of the Drywell Airlock

NSP has requested an exemption from the requirements of Appendix J for both the pressure and frequency of the Type B airlock test. NSP has proposed a 10-psig test in lieu of the required 41-psig (Pa) test and proposes to perform an airlock test every 3 days when the airlock is in use and containment integrity is required, rather than after each use. NSP's basis for this request is that the drywell airlock uses two heavy single-gasketed doors designed to seal with pressure applied from the drywell side. Therefore, installation of temporary bracing on the inner door is required to hold the door closed in order to perform a meaningful test when the airlock is pressurized from within. NSP believes that a 10-psig test pressure permits a valid and safe test to be performed. NSP contends that increasing the test pressure to 41 psig reduces the design margin of the temporary bracing and leads to an artificially high measured leakage rate past the inner door. Also, Since the airlock does not have double-gasketed seals, it must be pressurized for each test, requiring at least 4 hours to perform. NSP has stated that when the airlock is tested at times other than when all Type B and C penetrations are tested (i.e., when the 0.6 La total criteria for all penetrations is applied), an acceptance criteria of 0.025 La at 10 psig would be imposed. This limit is derived by applying the relationship $(Pt/Pa)^{1/2}$ to the airlock leakage criterion of 0.05 La found in the "Standard Technical Specifications for General Electric Boiling Water Reactors."

EVALUATION

Sections III.B.2 and III.D.2 of Appendix J require that containment airlocks be tested at peak calculated accident pressure (Pa) at 6-month intervals and after each opening between the every-6-month tests. These requirements were imposed because airlocks represent potentially large leakage paths more subject to human error than other containment penetrations. Type B penetrations (other than airlocks) require testing in accordance with Appendix J at intervals not to exceed 2 years.

Appendix J was published in 1973. An analysis of airlock events compiled from Licensee Event Reports since 1969 shows that airlock testing in accordance with Appendix J has been effective in prompt identification of airlock leakage, but that rigid adherence to the after-each-opening rule may not be necessary.

Since 1969, there have been approximately 70 reported instances in which airlock-test-measured leakage has exceeded allowable leakage limits. Of these events, 25% were the result of leakage other than that resulting from improper seating of airlock door seals. These failures were generally caused by leakage past door-operating mechanism handwheel packing, door-operating cylinder shaft seals, equalizer valves, or test lines. These penetrations are similar to other Type B or C containment penetrations except that they may be operated more frequently. Since airlocks are tested at a pressure of Pa every 6 months, these penetrations are tested, at a minimum, four times more frequently than typical Type B or C penetrations. The every-6-month test is therefore considered to be both justified and adequate for prompt identification of this leakage.

Improper seating of the door seals, however, is not only the most frequent cause of airlock failures (the remaining 75%), but also represents large potential leakage paths. While testing at a pressure of Pa after each opening will identify seal leakage, seal leakage can be adequately revealed by alternative methods such as pressurizing between double-gasketed seals (for airlocks designed with these seals) or pressurizing the airlocks to pressures less than Pa. Furthermore, experience gained in testing airlocks since the issuance of Appendix J indicates that the use of one of these alternative methods may be preferable to the full-pressure test of the entire airlock.

Airlocks in reactor plants designed prior to the issuance of Appendix J often cannot be tested at Pa without the installation of strongbacks or other temporary bracing or the performance of mechanical adjustments to the operating mechanisms of the inner doors. These operations are necessary because the inner doors are designed to seat with accident pressure on the drywell side of the door and therefore the operating mechanisms were not designed to withstand accident pressure in the opposite direction. When the airlock is pressurized for a local test (i.e., pressurized between the doors), pressure is exerted on the inner door in the opposite direction, causing it to unseat and preventing the conduct of a meaningful test. The temporary bracing or mechanical adjustments prevent the unseating of the inner door, allowing the test to proceed. The installation of the bracing or performance of the adjustments is time consuming (often taking several hours), may result in additional radiation exposure to operating personnel, and may cause degradation to the operating mechanism of the inner door with consequential loss of airlock reliability. In addition, when frequent openings are required over a short period of time, testing at Pa after each opening becomes both impractical (test often take from 4 hours to several days) and accelerates the rate of exposure to personnel and degradation of mechanical equipment.

For these reasons and in view of NSP's contention that there is difficulty in obtaining meaningful leakage results because of inner door leakage even with the temporary bracing installed at the Monticello plant, testing of the drywell airlock at 10 psig every 3 days when the airlock is in use is an acceptable substitute for testing after each opening. Furthermore, the after-each-opening test requirement of Appendix J was revised in October 1980 to an every-3-day testing requirement. However, NSP's proposal to perform the every-6-month test at 10 psig is unacceptable since the airlock test at a pressure of Pa has been shown to be essential for an accurate accounting of the integrity of the airlock assembly. The every-6-month airlock test should be conducted at a pressure of Pa in accordance with Appendix J.

NSP's extrapolation of the acceptance criteria from 0.05 La for the Pa test to 0.025 La for the 10-psig test is based upon a determination that the leakage rates are related by the ratio of the test pressures to the one-half power. This determination is valid where the characteristics of the leakage are essentially orifice-like. The actual leakage characteristics are somewhat unpredictable but are probably some combination of orifice-like and capillary-like. As can be seen in Appendix A to this report, the correlation between the two test pressures for orifice-like flow is less conservative than the correlation for capillary-like flow, particularly where, as in this case, Pa is considerably larger than Pt.

NSP's use of the acceptance criteria of the Standard Technical Specifications for General Electric Boiling Water Reactors of 0.05 La at Pa is acceptable when airlocks are tested at times other than when all Type B and C penetrations are tested. However, when extrapolating this criterion to the lower pressure (10 psig), the more conservative correlation of Appendix A should be used (Equation A-3) and therefore the acceptance criteria at 10 psig should be 0.007 La rather than 0.025 La.

3.1.3 Type C Testing of Torus and Drywell Motor-Operated Spray or Recirculation Valves

NSP has requested exemption from the Type C testing requirements for motor-operated isolation valves installed in the torus spray or recirculation lines and the drywell spray lines. These lines have no provision for testing or the inner isolation valves are wedge-type gate valves that cannot be tested in the correct direction. NSP's basis for the request is that the penetrations will not constitute a containment leakage path since they will be pressurized by the RHR pumps to a pressure in excess of Pa and no single active failure can prevent pressurization by the RHR pumps.

EVALUATION

The valves that comprise this request for exemption are MO-2006, 2007, 2008, 2009, 2010, 2011, 2020, 2021, 2022, and 2023. The piping configurations are displayed in Figures 1 and 2. Figures 1 and 2 show penetrations X-39A, X-210A, and X-211A. Penetrations X-39B, X-210B, and X-211B are not shown but are essentially identical and, therefore, the technical evaluations associated with the A penetrations apply equally to the corresponding valves of the B penetrations. Because of certain distinctions between the drywell spray line, the torus spray line, and the torus recirculation line, each line is evaluated separately in the following subsections.

3.1.3.1 Drywell Spray Line

NSP's contention that this line does not constitute a containment leakage path because it is always pressurized by the RHR pumps in a post-accident configuration is correct only in that valve MO-2021 is constantly under RHR pump pressure (see Figure 1). Since valves MO-2021 and -2023 are initially shut and remain shut until manually opened by an operator (in order to initiate drywell spray), there is no guarantee that the line between the valves will normally be pressurized or even water-filled.

Valves MO-2021 and -2023 are normally shut valves. They are checked-shut by the safety-injection signal at the start of an accident. This is done to ensure that all low pressure injection flow is initially directed into the reactor vessel and not diverted to drywell spray. Once reactor vessel level has been reestablished, the valves receive an open-permissive signal so that the operator may initiate drywell spray to prevent excessive drywell pressure. Depending upon the extent of increase in drywell pressure, spray may or

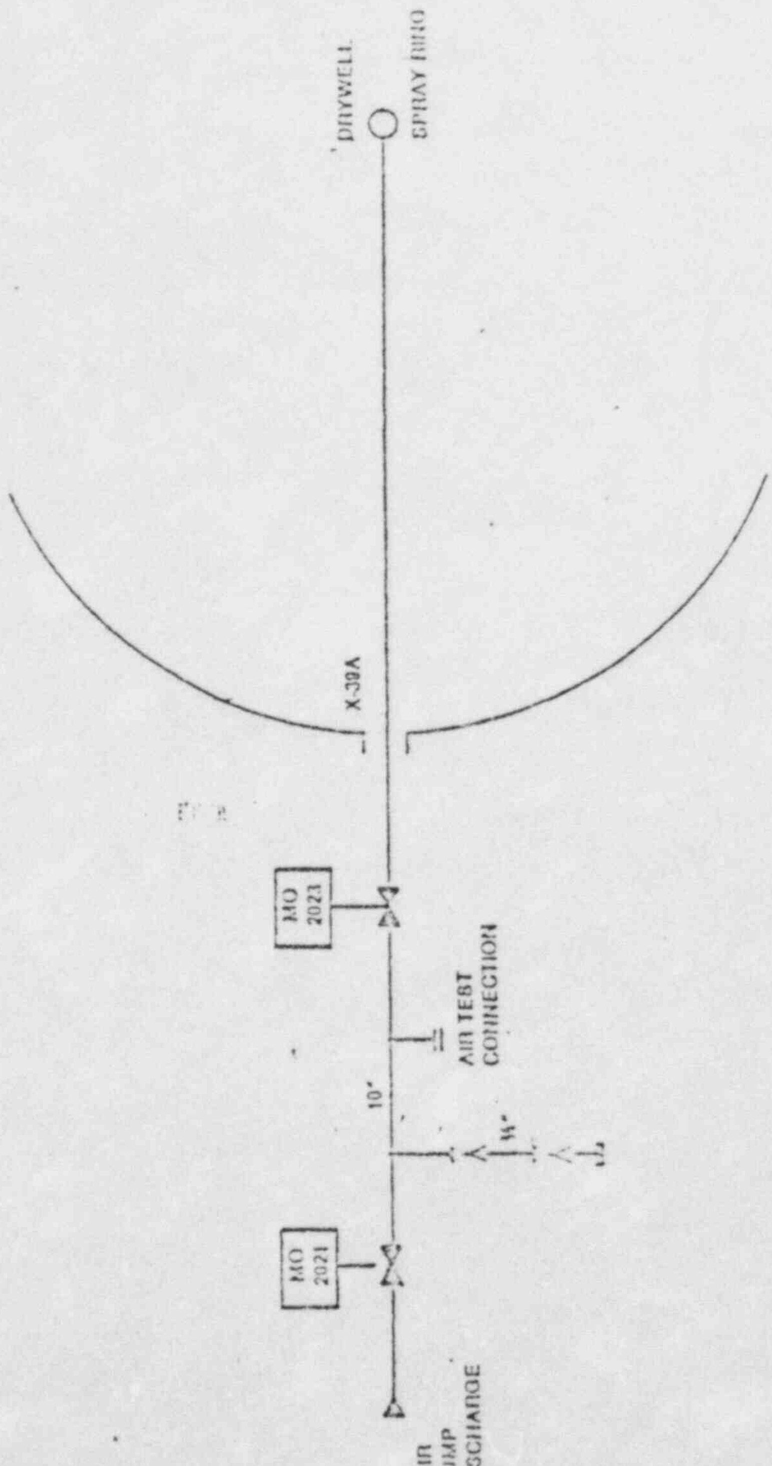

Figure 1. Drywell Spray Line.

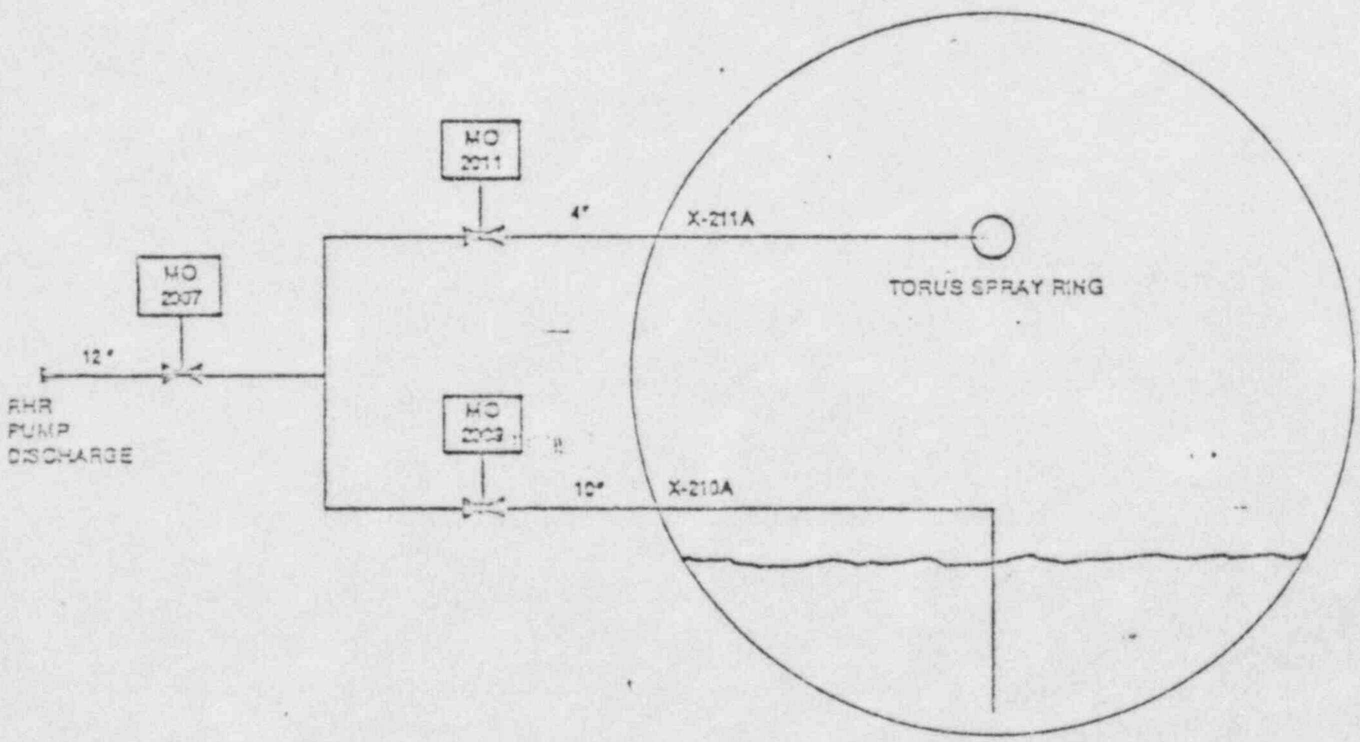

Figure 2. Torus Spray and Recirculation Lines.

may not be initiated. Consequently, the status of the piping between the valves (water-filled, air-filled, pressurized, etc.) cannot be conclusively stated and, for purposes of conservatism, the piping should be considered to be air-filled.

Valves MO-2021 and -2023 are single-wedge gate valves. In the case of valve MO-2021, the RHR water pressure on the upstream side of the disc will cause the downstream side to be forced against its seat, unseating the upstream seating surfaces by the tolerance machined into the disc, at a minimum. This design prevents potential leakage of containment air both by improving the seal of the downstream seat and disc and by pressurizing the valve packing and body-to-bonnet seal with water at pressures greater than peak containment pressure.

In the case of valve MO-2023, however, the valve packing area and the body-to-bonnet seal area may be exposed to containment air pressure since the water seal is not present against this valve. In this case, containment air can escape to the outside atmosphere through either the valve packing or the body-to-bonnet seal.

Since valve MO-2023 can become a source of leakage of containment air to the outside atmosphere, it must be Type C tested in accordance with the requirements of Appendix J. However, since the only potential sources of leakage are the packing and body-to-bonnet areas, the intent of Appendix J is satisfied if these areas are tested in accordance with Appendix J procedures. As can be seen in Figure 1, this testing can be performed by pressurizing the piping between valves MO-2021 and -2023 with air, assuming all detected leakage to be outleakage through the packing or body-to-bonnet seal.

The Licensee should take action to ensure that the intent of Appendix J is satisfied with regard to valve MO-2023 (and similarly valve MO-2022 in the case of penetration X-39B).

3.1.3.2 Torus Spray Line

As discussed in Section 3.1.3.1, it is not possible to conclusively determine whether the line between valves MO-2007 and MO-2011 will be pressurized, water-filled, or air-filled (Figure 2). Unlike the drywell spray line, however, valve MO-2011 is not a single-wedge gate valve but is a globe valve. Without a detailed drawing of valve MO-2011, it cannot be determined on which side of valve MO-2011 the packing is located. Nevertheless, the basic principles involved in the discussion associated with the drywell spray line apply to the torus spray line.

In view of the discussion associated with the drywell spray line and in view of the fact that valve MO-2011 is a globe valve, it is concluded that valve MO-2011 (and similarly MO-2010 in the case of penetration X-211B) should be tested in the direction of its safety function in accordance with Type C testing procedures or should be tested in accordance with Type C testing procedures from any direction which will result in a test of the valve packing and body-to-bonnet seal areas. Valve MO-2007 (and similarly MO-2006 in the case of penetration X-211B) does not require testing because of the water seal supplied by the RHR pumps.

3.1.3.3 Torus Recirculation Line

As can be seen from Figure 2, it is not possible for containment atmosphere to enter the torus recirculation line because the line terminates below the water level of the suppression pool. In this case, regardless of the location of the packing of valve MO-2009, there is no potential path for leakage of containment atmosphere through the recirculation line. Consequently, valve MO-2009 is not a containment isolation valve in accordance with the definition in Section II.B of Appendix J with regard to the recirculation line. However, it should be observed that, with regard to the torus spray line, the packing of valve MO-2009 can be a potential source of atmospheric leakage if valve MO-2011 is open or leaking past its seat and the packing of valve MO-2009 is exposed to the pressure from that direction (see Figure 2).

Valve MO-2009 (and, similarly, MO-2008 in the case of penetration X-210B) does not require Type C testing with regard to the torus recirculation line because this testing is not required by Appendix J. However, if the packing of this valve (and, similarly, MO-2008) is exposed to leakage coming from the thrus spray line, the packing of this valve should be tested in accordance with Type C procedures.

3.1.4 Direction of Test Pressure

In Reference 5, NSP requested an exemption from Appendix J to permit testing in a direction opposite that in which the isolation valves will perform their safety function for penetrations X-18, 19, 25, 26, 27D, 27E, 27F, 41, 48, 205, 214, and 220. NSP stated that testing of these valves in the reverse direction is permissible under the provisions of Section XI, Subsection IWV of the ASME Code, since leaktightness of the valves is not dependent upon the direction of pressurization.

In Reference 7, NSP requested an exemption to permit testing in the reverse direction for three gate valves (inboard supply to RWCU, inboard floor sump discharge, and inboard equipment sump discharge). In the case of these valves, NSP stated that, since they are wedge-type gate valves, leakage measurements may not be conservative relative to leakage measurements made with the valve pressurized from the containment side. NSP's basis for requesting the exemption is that no provision exists to test these three valves in the required direction.

EVALUATION

Section III.C.1 of Appendix J permits testing of isolation valves in the direction opposite to that in which they perform their safety function (reverse-direction testing) provided that the test results will be equivalent to or more conservative than the results obtained by testing in the direction of accident pressure. Consequently, no exemption is required for the penetrations listed in Reference 5 (except for X-18 and X-19, which are corrected by Reference 7 to be gate valves dependent upon direction of test pressure). Documentation of the Licensee's conclusion that reverse-direction testing is equivalent to or more conservative than testing in the direction of accident pressure should be retained on the site for future reference.

However, the lack of provision for leak testing in the required direction is not sufficient justification for exemption of the inboard isolation valve to the reactor water cleanup system, the inboard isolation valve in the floor sump discharge, and the inboard equipment sump discharge valve. Provisions should be made so that these valves may be tested in the direction of accident pressure in order to satisfy the requirements of Appendix J.

3.1.5 Type C Testing of Core Spray Testable Check Valves

NSP requested, as an exemption from Appendix J, to exclude the testable check valves in the core spray lines (two valves, one in each core spray line) from Type C testing requirements. NSP proposes to designate the two motor-operated gate valves located in each core spray line outside containment as the containment isolation valves for these penetrations. The motor-operated gate valves will be tested in accordance with Type C testing procedures.

NSP's basis for this request is that the testable check valves were not designed to seal against low pressure gas leakage and that maintenance attempts have provided only temporary improvement in the capability of the valves to satisfactorily meet the low pressure gas leakage rates. In addition, NSP contends that the core spray penetrations become potential leakage paths for containment atmosphere only when one of the core spray pumps fails to operate after an accident, the associated line breaks outside containment, and the testable check valve in that line fails to seal. In this case, NSP would use the remotely operated gate valves in the line to isolate the potential leak (requiring operator action). The core spray system is protected against seismic events and potential missiles and NSP states that failure of the motor-operated valves to function in the conditions described above is unlikely.

EVALUATION

Under expected post-accident conditions, the containment isolation valves for the core spray penetrations will be open and the core spray system will be in operation at pressures higher than peak containment accident pressure. In this case, there is no possibility for leakage of containment atmosphere. However, if a core spray pump fails to start, the testable check valve would be relied upon to prevent leakage of containment atmosphere if the liquid inventory of the system is exhausted by integrated system leakage before the Type C-tested motor-operated isolation valves are shut. In the case of penetration X-16A (Figure 3), valves MO-1752 and MO-1754 would have to be shut. The configuration of the other core spray penetration (X-16B) is essentially identical to the piping configuration of Figure 3.

NSP contends that it is unlikely that the piping outside containment will fail because of the reliable design of the system. This contention is acceptable, even though there are non-safety-related connections to the core spray system (e.g., the condensate service water system), because, in each instance, the safety-related and non-safety-related boundaries are separated by at least two safety-related check valves in series or a locked-shut safety-related manual isolation valve. Furthermore, periodic inservice testing of the core spray system provides additional assurance that the liquid inventory of the system will not be exhaused before the operator can discover the failure of a pump and either establish flow or shut the motor-operated isolation valves prior to the onset of atmospheric leakage. The core spray check valves are located inside containment, and therefore seat leakage is the only leakage of concern. Type C testing of the motor-operated valves (MO-1752 and MO-1754 in the case of penetration X-16A) will account for any seat leakage path check valve AO-14-13B!

It is concluded that the core spray testable check valves (AO-14-13A and AO-14-13B) are not relied upon to prevent the escape of containment air to the outside atmosphere. This conclusion is based on the determination that, under normal circumstances, containment outleakage is absolutely precluded by operation of the core spray system and, in the unlikely event that a core spray pump fails to start, the design features of the system and periodic inservice testing provide adequate assurance that the Type C-tested motor-operated isolation valves can be shut prior to the onset of containment atmospheric leakage.

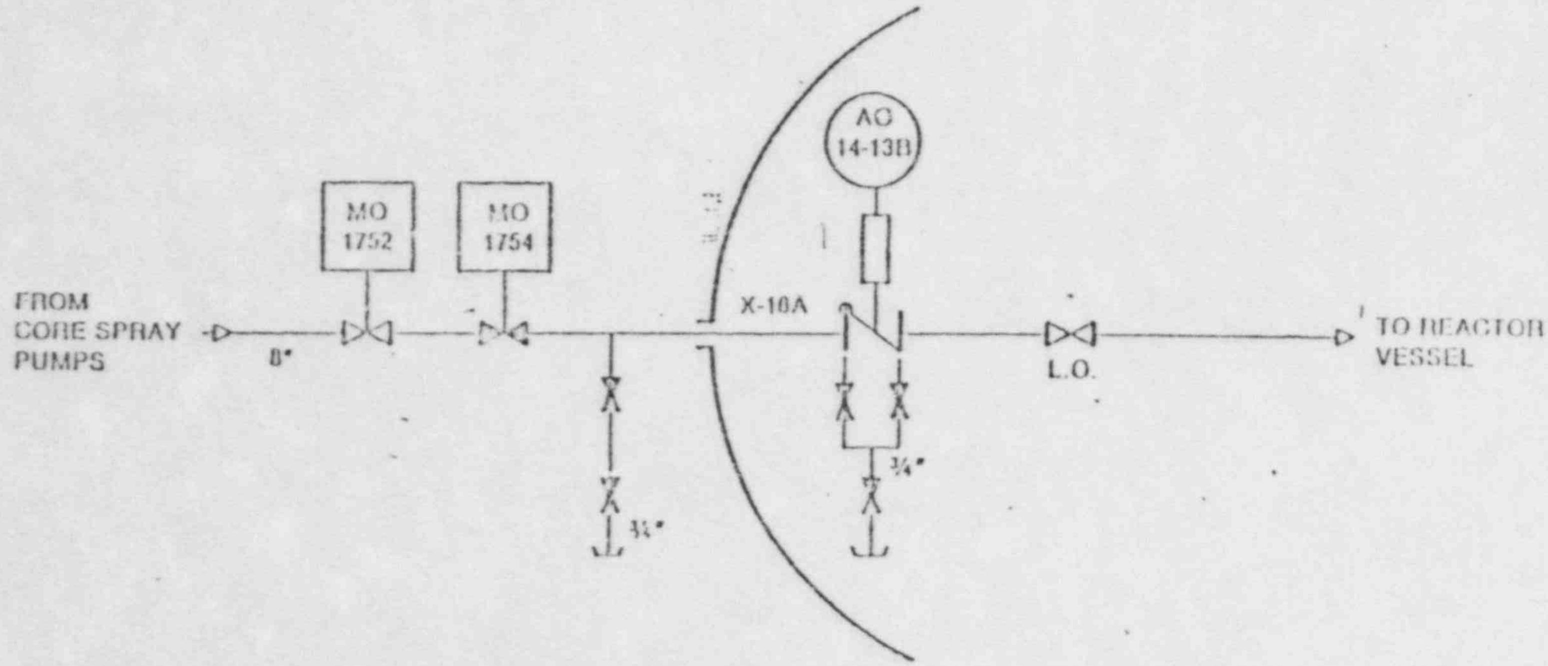

Figure 3. Penetration X-16A.

Since the core spray testable check valves (AO-14-13A and AO-14-13B) are not relied upon to perform a containment isolation function, they are not containment isolation valves as defined by Section II.B of Appendix J and do not require Type C testing. No exemption from the requirements of Appendix J is necessary. The Licensee should verify that appropriate post-accident emergency procedures require the operator to isolate an idle core spray loop by shutting the appropriate motor-operated isolation valves as soon as it is determined that there is no core spray flow and that flow cannot be established.

3.1.6 Type C Testing of Low Pressure Coolant Injection Testable Check Valves

NSP requested, as an exemption from Appendix J, to exclude the testable check valves in the low pressure coolant injection (LPCI) supply lines (two valves, one in each LPCI supply line) from Type C testing requirements. NSP proposes to designate the two motor-operated gate valves located in each LPCI supply line outside containment as the containment isolation valves for these penetrations. The motor-operated gate valves will be tested in accordance with Type C testing procedures.

NSP's basis for this request is that the testable check valves were not designed to seal against low pressure gas leakage and that maintenance attempts have provided only temporary improvement in the capability of the valves to satisfactorily meet the low pressure gas leakage rates. Further, NSP stated that these lines would be pressurized by the RHR pumps in the post-accident condition and that no single active failure could prevent pressurization of the lines by the RHR pumps to pressures higher than calculated peak accident pressure (Pa). All components of the RHR system are protected from seismic events and potential missiles.

EVALUATION

Under normal post-accident conditions, the LPCI testable check valves (AO-10-46A and AO-10-46B) will be open and pressurized by the RHR pumps to pressures higher than Pa. No single active failure can cause a loss of this pressure and therefore the valves are not relied upon to perform a containment isolation function. In this condition, the valves are not containment isolation valves as defined in Section II.B Appendix J and do not require Type C testing.

In the unusual case that one of the LPCI loops is intentionally secured while containment integrity is still of concern, motor-operated isolation valves outside containment would be shut. In the case of penetration X-13A (Figure 4), valves MO-2013 and MO-2015 would be shut. The configuration of the other LPCI penetration (X-13B) is essentially identical to the piping configuration of Figure 4.

As can be seen from Figure 4, valves MO-2013 and MO-2015 are capable of isolating any leakage past the testable check valve AO-10-46B. Since they will be tested in accordance with Type C testing procedures, the requirements of Appendix J will be satisfied. Because of the testing of MO-2013 and MO-2015, testable check valve AO-10-46B is again not relied upon to perform a containment isolation function and therefore Type C testing of this valve is not necessary. A similar situation exists for testable check valve AO-10-46A, where the other LPCI cooling loop is secured.

In view of the preceding, it is concluded that the LPCI testable check valves are not relied upon to perform a containment isolation function, whether the LPCI cooling loop is in operation or not, provided that the motor-operated isolation valves outside containment are Type C tested as proposed by NSP. In this case, valves AO-10-46A and AO-10-46B do not require Type C testing in accordance with Appendix J and no exemption is necessary.

3.1.7 Type C Test Pressure for Main Steam Isolation Valves

NSP requested, as an exemption from Appendix J, to continue testing main steam isolation valves (MSIVs) (penetrations X-7A through X-7D) at 25 psig in accordance with current technical specifications instead of 41 psig (Pa) as required by Appendix J. NSP's basis for the request is that the MSIVs must be tested by pressurizing between the valves, which tends to lift the inboard valves off their seats at pressures in excess of 25 psig, thereby invalidating the test results. Testing at 25 psig will not unseat the inboard valves, and

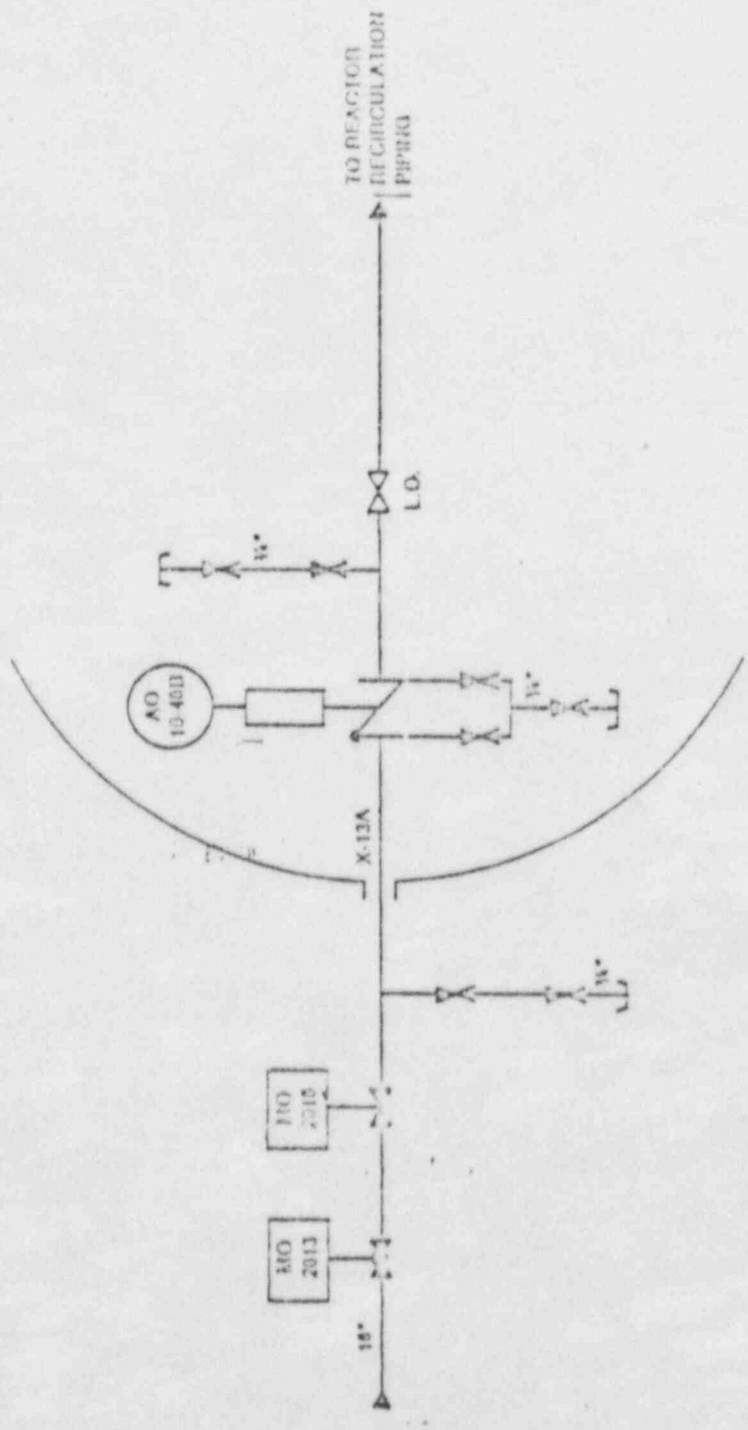

Figure 4. Penetration X-13A.

therefore a valid test can be conducted with leakage acceptance criteria based upon a 25-psig test.

EVALUATION

The main steam system design in most operating BWR plants necessitates leak testing the MSIVs by pressurizing between the valves. The MSIVs are angled in the main steam lines to afford better sealing in the direction of accident leakage. A test pressure of Pa acting on the inboard disc lifts the disc off the seat resulting in excessive leakage into the reactor vessel. This consideration gave rise to establishing a pressure lower than Pa (25 psig) that would permit testing without unseating the inboard valve discs. Since testing of the MSIVs at a reduced pressure results in a conservative determination of the leakage rate through the valves at Pa because of the design of the valves, the proposed exemption request is acceptable.

3.1.6 <u>Lines Terminating Below the Surface of the Suppression Pool</u>

In Reference 7, NSP indicated that it believed that Appendix J does not require testing of the isolation valves in penetrations where the line terminates below the surface of the suppression pool. NSP's reasoning was that the penetrations do not communicate with the containment atmosphere since they are provided with an effective water seal. In addition, no provision for testing these valves was included in the original plant design.

EVALUATION

Appendix J requires local leakage testing of containment isolation valves in certain categories or systems identified in Sections II.H or III.A.1.(d). Section II.H defines containment isolation valves as those valves relied upon to perform a containment isolation function.

Containment penetrations in a BWR that terminate below the minimum water level of the suppression pool do not communicate with the containment atmosphere and therefore cannot become a source of gaseous leakage at any time during the post-accident period because they are effectively water sealed by the liquid inventory of the suppression pool. Consequently, these valves are not relied upon to perform a containment isolation function and their testing is not a requirement of Appendix J. NSP's conclusion that these valves do not require Type C testing or exemption from Appendix J is acceptable.

3.1.9 Proposed Increase in the Value of La

In Reference 7, NSP requested that the value of La be increased from the present 1.2% per day to 1.5% per day. NSP based this request on actual tests performed for the NRC which have shown that the correction factor of 0.8 used in deriving the 1.2% figure was unnecessary.

EVALUATION

The value of La, although relevant to containment leakage testing in accordance with Appendix J, is not derived in accordance with Appendix J. This report addresses only exemption requests and technical specification changes necessary to implement Appendix J at the Monticello plant. Consequently, this particular request is not evaluated and is left for the appropriate branch of the NRC to address.

3.2 PROPOSED PIPING MODIFICATIONS TO PROVIDE FOR TYPE C TESTING

In Reference 6, NSP provided proposed piping modifications to allow for Type C testing of certain containment penetrations not originally designed to permit this testing. NSP requested confirmation by the NRC of the overall acceptability of its interpretation of the regulations and the proposed resolution of the areas of non-conformance prior to beginning detailed engineering work and committing funds for the modifications. An evaluation of each of these proposed modifications is provided in the following paragraphs.[1]

1. Several of the following evaluations do not specifically address venting of the upstream side of the valves to be tested because, although a vent path may not be shown on a particular modification sketch, an upstream vent path is normally available somewhere in the system and the licensee has probably already identified the available vent path. If these vent paths cannot be identified, a vent fitting may need to be added to ensure that the opposite side of a valve being tested is properly vented.

3.2.1 Instrument Air Isolation Control Valve

NSP stated that this control valve may be tested in the reverse direction using sections of piping installed as part of a plant modification to supply nitrogen to the drywell instrument air header. NSP stated that testing in the reverse direction will yield a conservative leakage rate measurement. NSP further indicated that, if this testing is found to be impractical using this method, a test connection and stop valve can be added to the instrument air line to permit Type C testing.

EVALUATION

Testing of control valve CV-1478 satisfies the Appendix J Type C testing requirement for penetration X-22, and testing in the reverse direction using the nitrogen makeup line or testing in the forward direction using the proposed modification of an additional stop valve and test connection (located between the penetration and CV-1478) is acceptable. Therefore, the proposed modification is acceptable.

3.2.2 Cooling Water Supply and Return to Drywell Fan Coolers

NSP proposed to modify the cooling water supply and return lines to the drywell fan coolers by adding a manual stop valve and test connection on each side of valve MO-1426 (penetration X-24) and RBCC-15 (penetration X-23).

EVALUATION

Type C testing of valve MO-1426 satisfies the Appendix J requirement for penetration X-24 and testing of RBCC-15 satisfies the requirement for penetration X-23. In addition, NSP's proposed modifications will adequately permit Type C testing of these valves and are therefore acceptable.

3.2.3 TIP Ball Valves and Purge Supply Valve

NSP proposed to install an additional ball valve and test fitting between the penetration and the existing ball valves for penetrations X-35A, X-35B, and X-35C (TIP containment penetrations). Also, NSP proposes to add a stop [illegible] and test fitting between penetration X-3[illegible] and the existing check valve in the TIP purge penetration.

EVALUATION

NSP's proposed modifications will adequately permit required testing for these penetrations. The modifications are acceptable (see Note 1 on p. 22).

3.2.4 <u>CRD Hydraulic Return Inboard Check Valves</u>

NSP proposed to add test fittings to both sides of check valve CRD-34 to permit testing of that valve. Outboard check valve CRD-31 is presently testable (penetration X-36).

EVALUATION

Provision should be made for testing the inboard check valve CRD-34 in addition to the outboard valve CRD-31. However, only the test fitting between CRD-34 and CRD-35 should be added, since a test fitting already exists between CRD-34 and CRD-31. Although the existing test fitting between CRD-34 and CRD-31 is outside containment and is probably not convenient from the standpoint of testing CRD-34, the addition of a second fitting in the same run of pipe inside containment is not appropriate since it will add another penetration to this system where it is not functionally essential. This proposed modification is acceptable except for the addition of a second test fitting between valves CRD-34 and CRD-31.

3.2.5 <u>Standby Liquid Control System Inboard Check Valve</u>

NSP proposed to add test fittings on both sides of check valve XP-7 (penetration X-42) to permit testing of that valve. The outboard check valve XP-6 is already testable.

EVALUATION

Valve XP-7 should be made testable. As stated in Section 3.2.4, however, a test fitting already exists between valves XP-7 and XP-6 so the addition of a second fitting in this portion of the line is not appropriate. The proposed modification is acceptable with the exception of the addition of the second test fitting between XP-7 and XP-6.

3.2.6 HPCI and RCIC Turbine Exhaust Lines

The piping configurations of the HPCI and RCIC turbine exhaust lines (with vacuum breakers) are identical. This evaluation discusses NSP's proposal regarding the HPCI system but applies equally to the similar proposal for the RCIC system.

NSP proposed to provide improved testing capability for the HPCI turbine exhaust line by installing one of two potential modifications. The first modification would add a motor-operated valve and test fitting between stop-check valve HPCI-10 and penetration X-221. The alternative proposal would add two remotely operated isolation valves with test fitting in the vacuum breaker line between the vacuum breakers and the turbine exhaust line upstream of penetration X-221. NSP stated that the check valves currently serving as containment isolation valves in the HPCI turbine exhaust line (HPCI-10 and HPCI-9) have a history of excessive leakage. Only valve HPCI-9 is currently tested. The addition of the motor-operated valve downstream of HPCI-10 would provide an additional valve that would be Type C tested and would become the containment isolation valve for this line. Alternatively, by adding the two remotely operated stop valves (with capability to test each) in the vacuum breaker line (these valves would receive Group 4 isolation signals), leakage of torus atmosphere into the turbine exhaust line would be precluded, and therefore the exhaust line would be water sealed by torus water against the existing check valves (HPCI-10 and HPCI-9).

EVALUATION

Since the HPCI turbine exhaust line terminates below the water level of the suppression pool, the problem of testing this line for leakage of containment atmosphere is solved either by adding testable isolation valves in the vacuum breaker line or by adding an additional isolation valve downstream of HPCI-10 as proposed by NSP.

If the first solution is chosen (the addition of a motor-operated valve between HPCI-10 and penetration X-221, upstream of the connection to the vacuum breaker line), provisions to automatically shut this valve when the HPCI turbine is no longer in operation must be included. In addition, check valve HPCI-10 or HPCI-9 would continue to require Type C testing since a single active failure could prevent the shutting of the new motor-operated valve and therefore one of the check valves would still be relied upon to perform a containment isolation function. Furthermore, the addition of this motor-operated valve could result in overpressurization of the HPCI exhaust line should the valve inadvertently shut during operation of the HPCI turbine. Consequently, this alternative does little to improve the reliability of line isolation from the standpoint of containment atmospheric leakage and could possibly cause a loss of reliability due to malfunction or operator error.

The addition of the redundant isolation valves in the vacuum breaker line eliminates the need for the check valves (HPCI-10 or HPCI-9) to be able to seal against leakage of gases. Once the vacuum breaker line has been sealed, the entrance of gaseous atmosphere into the exhaust line is prevented by the suppression pool level. However, the signal which will isolate the vacuum breaker line must be designed so that the vacuum breaker function of the line is not precluded when needed to prevent the collapse of the exhaust line. Consequently, the addition of a motor-operated isolation valve and a test connection downstream of HPCI-10 (or RCIC-10) is acceptable provided that the valve will be automatically shut after an accident whenever the HPCI (or RCIC) system is not in operation. The addition of redundant isolation valves in the vacuum breaker lines is acceptable provided that provisions are made to ensure that the vacuum breaker function is not isolated when it is needed to prevent collapse of the exhaust line.

It should be noted that both of the alternatives presented by NSP for modifying this penetration leave the vacuum breakers themselves exposed to containment atmosphere through penetration X-217. Since the vacuum breakers may be potential sources of leakage into the reactor building, it would be preferable if the redundant isolation valves in the vacuum breaker line were located between penetration X-217 and the vacuum breakers. Although the lack of inadequate space or other physical constraints may preclude this modification as an option, it is suggested as a possible alternative, if practical.

3.2.7 Demineralized Water Supply to the Drywell

NSP proposed to provide for testing of the manual isolation valves in the line to penetration X-20 by adding a test connection between valves DM-57 and DM-58.

EVALUATION

This proposed modification is acceptable provided that valve DM-58 is capable of being tested in the reverse direction in accordance with Appendix J (i.e., the direction of testing of the valve is independent of the direction in which the test pressure is applied). Assuming DM-58 is capable of reverse-direction testing, the modification is acceptable (see Note 1 on p. 22).

3.2.8 Service Air Supply to the Drywell

NSP proposed to add a test connection between isolation valves AS-39 and AS-40 and to install an additional stop valve in the line to the service air supply to the RCIC room.

EVALUATION

The installation of an additional stop valve and the test connection between valves AS-39 and AS-40 will adequately provide for testing of penetration X-21, provided that valve AS-39 is capable of being tested in the reverse direction. Assuming that AS-39 is capable of reverse-direction testing, the proposed modification is acceptable (see Note 1 on p. 22).

3.2.9 Torus Instrument Air Supply Control Valve

NSP proposed to install test connections on both sides of control valve [illegible] in order to test penetration X-229B in accordance with Appendix J.

EVALUATION

The addition of the test connections on both sides of control valve CV-7956 will adequately provide for the testing of penetration X-229B. The proposed modification is acceptable (see Note 1 on p. 22).

3.3 PROPOSED TECHNICAL SPECIFICATION CHANGE REQUESTS

In Reference 3, NSP submitted proposed changes to the technical specifications for the Monticello plant to correct areas of non-conformance with Appendix J which had been identified in Reference 2. However, Reference 4 completely replaced the changes proposed in Reference 3. Subsequently, additional proposed changes were provided by Reference 8, with supplemental information in support of these proposed changes being submitted in Reference 9.

The following paragraphs provide technical evaluations of the changes proposed in References 4 and 8, as supplemented by Reference 9, which are applicable to Appendix J.

3.3.1 Limiting Conditions for Operation

Technical evaluations of the proposed changes to the Limiting Conditions for Operation submitted in Reference 4 are contained in Table 1. Specifications 3.7.A.5, 6, 7, and 8 and 3.7.B.1 are outside the scope of Appendix J and therefore have not been evaluated.

3.3.2 Surveillance Requirements

Technical evaluations of the proposed changes to the Surveillance Requirements submitted in Reference 4 are contained in Table 2. Specifications 4.7.A.2, 5, 6, 7, and 4.7.B.1 are outside the scope of Appendix J and therefore have not been evaluated.

3.3.3 Monticello Containment Penetrations

In Reference 4, NSP submitted a revised Table 4.7.1 (Monticello Containment Penetrations), along with explanatory notes, identifying all penetrations that are tested in accordance with Appendix J. Further information on the development of the requirements to test these penetrations was submitted by NSP in Reference 7. The table has been reviewed and found to be acceptable subject to certain modifications based on the determination of acceptability of specific exemption requests evaluated in Section 3.1 of this report and the proposed piping modifications evaluated in Section 3.2 of this report.

3.3.4 Duration of the Type A Test

In Reference 8, NSP proposed to change the technical specifications for the Monticello plant to terminate the containment integrated leakage rate test (Type A test) in less than 24 hours. NSP proposed a test duration of at least 8 hours and the accumulation of at least 20 sets of data at approximately equal intervals. The proposed method would allegedly accumulate enough data to verify that the measured leakage rate, at the 95% confidence level, would be less than the test acceptance criteria. Additional information relative to this proposal was provided by NSP in Reference 9.

EVALUATION

The question of performing Type A tests in less than 24 hours is being reviewed by the NRC staff on a generic basis. Consequently, NSP's proposal is not evaluated as part of this report.

Table 1

Proposed Changes to the Limiting Conditions for Operation

Spec. No.	NSP's Proposed Wording	App. J Sect. Applicable	FRC Evaluation
3.7.A.3	3. Containment leakage rates shall be limited to: a. An overall integrated leakage of: 1. ≤ La (1.2 percent by weight of the containment air per 24 hours) at Pa (41 psig), or 2. ≤ Lt at a reduced pressure of Pt. (20.5 psig).	II.K II.I II.M II.J	This proposed revision is acceptable. It conforms to the requirements and definitions of Appendix J with the exception of the requirements for the testing of main steam isolation valves. A request for exemption from the Type C testing requirements of Appendix J with regard to the main steam isolation valves was submitted by NSP in Reference 5. FRC found this exemption request to be acceptable in Section 3.1.7 of this report.
	b. A combined leakage rate of 0.6 La for all penetrations and valves (except main steam isolation valves) subject to Type B and C tests when pressurized to Pa.	III.B.3 III.C.3	The value of La (1.2 percent by weight of the containment air per 24 hours) is a typical value for a containment such as the containment at the Monticello plant. The limit of 11.5 scf per hour for main steam isolation valves has been found by past experience to be a valid criteria for the acceptable leakage from these valves.
	c. 11.5 scf per hour for any one main steam isolation valve when tested at 25 psig.		
	When either (a) the overall integrated containment leakage rate exceeding 0.75 La or 0.75 Lt, as applicable, or (b) with the measured combined leakage rate for all penetrations and valves subject to Type B and C tests exceeding 0.6 La, or (c) a main steam isolation valve leak rate exceeding 11.5 scf per hour, restore the leakage rate (s) to within acceptable limit (s) prior to increasing the reactor coolant temperature above 212 F.		
3.7.A	4. The containment airlock shall be operable with: a. Both doors closed except when the airlock is being used for normal entry and exit, then a least one airlock door shall be closed.		Subsection b of this proposed revision is unacceptable and should be modified such that the overall leakage rate is limited to 0.007 La as discussed in Section 3.1.2 of this report. The remainder of the proposed revision is considered acceptable although the evaluation of these items is outside the scope of Appendix J.
	b. An overall airlock leakage rate of ≤ 0.05 La at 10 psig.	III.B.3 III.C.3	
	c. All interlocks function as designed.		

Table 2

Proposed Changes to the Surveillance Requirements

Item No.	NSP's Proposed Wording	App. J Sect. Applicable	FRC Evaluation
4.7.A.3	3. The containment leakage rates shall be demonstrated at the following test schedule and shall be determined in conformance with the criteria specified in Appendix J of 10CFR50 using the methods recommended in ANSI N45.4-1972:		
	a. During the first refueling outage following the adoption of this specification, a Type A test shall be performed at a pressure Pt of 20.5 psig and a second test performed at a pressure of Pa of 41 psig. The maximum allowable test leakage rate, Lt, shall be determined in accordance with Section III.A.4(a) (1)(c) of Appendix J.	III.A.4	The proposed specification is in accordance with Appendix J except that this testing is generally done during the containment preoperational tests. Since the value of Lt was not determined at the Monticello plant during preoperational testing, there is no known reason why it cannot be done subsequently. The proposed specification therefore is acceptable. (Note: The NRC staff is presently moving toward a requirement that Type A tests be performed only at a pressure of Pa. Any technical specification changes of this nature should be made in full review of this potential regulation change.)
	b. Following the test specified in 4.7.A.3.a above, three Type A tests shall be conducted at 40 ± 10 month intervals during shutdown at either Pa or Pt during each 10-year service period. One of these tests shall be conducted during the shutdown for each 10-year plant inservice inspection.	III.D.1.(a)	The proposed specification is in accordance with Appendix J and is acceptable.
	c. If any Type A test fails to meet the acceptance criteria of 0.75 Lt for reduced pressure tests at Pa, the test schedule shall be reviewed and approved by the Commission. If two such consecutive tests fail to meet the acceptance criteria, a Type A test shall be performed at least every 18 months until two consecutive Type A tests meet the acceptance criteria at which time the schedule specified in 4.7.A.3.B may be resumed.	III.A.6	The proposed specification is in accordance with Appendix J and is acceptable.

Table 2 (Cont.)

Spec. No.	NSP's Proposed Wording	App. J Sect. Applicable	FRC Evaluation
4.7.A.3 (Cont.)	d. The accuracy of each Type A test shall be verified by a supplemental test which: 1. Confirms the accuracy of the test by verifying that the difference between the supplemental data and the Type A test data is within 0.25 Lt for reduced pressure tests at Pt or within 0.25 for La for peak pressure test at Pa. 2. Is of sufficient duration to establish accurately the change in leakage rate between the Type A test and the supplemental test. 3. Requires the rate that gas is injected into the containment or bled from the containment during the supplemental test to be equivalent to at least 25 percent of the leakage rate measured during the Type A test.	III.A.3	The proposed specification is in accordance with Appendix J and is acceptable.
	e. Type B and Type C tests shall be conducted at intervals no greater than 24 months, except for tests of the containment airlock, and shall include all testable components listed in Table 4.7.1.	III.D.2 III.D.3	The proposed specification is in accordance with Appendix J and is acceptable. Table 4.7.1 is evaluated separately in Section 3.3.3 of this report.
	f. Type B and Type C tests shall be conducted at Pa, except for main steam isolation valves and the airlock.	III.B.2 III.C.2	The proposed specification is in accordance with Appendix J and is acceptable. Evaluations of the test pressures for MSIVs and airlocks are contained in Sections 3.1.7 and 3.1.2 of this report, respectively.

Table 2 (Cont.)

Spec. No.	NSP's Proposed Wording	App. J Sect. Applicable	FRC Evaluation
4.7.A.4	4. The containment airlock shall be demonstrated operable by: a. At least once per 6 months by conducting an overall airlock leakage test at 10 psig and by verifying that the overall leakage rate is within its limit. If the airlock is in use, and containment integrity is required, the airlock shall be tested every three days or after each use, whichever interval is greater	III.B.2 III.D.2	The proposed specification is not an acceptable exemption to the requirements of Appendix J. In Section 3.1.2 of this report, FRC found that the 6-month test at a pressure of Pa is essential to an accurate accounting of the integrity of the airlock assembly and must be performed. FRC further found that NSP's proposal to test the drywell airlock at 10 psig every 3 days when the airlock is in use and containment integrity is required is acceptable. This proposed specification should be modified accordingly.

4. CONCLUSIONS

The outstanding licensing submittals regarding the implementation of 10CFR50, Appendix J, Containment Leakage Testing, at the Monticello plant have been evaluated, including requests for exemption from the requirements of Appendix J, proposed piping modifications in order to conduct required testing, and proposed technical specification changes relative to the containment leakage testing program. The following conclusions have been reached:

Requests for Exemption

- Instrument lines do not require Type B testing provided they are exposed to Type A test pressure.
- Testing of the drywell airlock at 10 psig every 3 days when the airlock is in use is acceptable because it satisfies the testing requirements of Appendix J.
- A proposal to perform the every-6-month airlock test at 10 psig rather than at Pa is not acceptable. The every-6-month airlock test should be performed at a pressure of Pa in accordance with Appendix J.
- A more conservative extrapolation for the correlation of airlock test results at 10 psig to results at Pa should be used. The acceptance criteria at 10 psig should be 0.007 La versus 0.025 La.
- Testing of the drywell spray and torus spray and recirculation line isolation valves is required by Appendix J as follows:

  MO-2006, 2007, 2020, and 2021: No testing required because of a water seal from the RHR pumps under post-accident conditions.

  MO-2008 and 2009: No testing required because of a liquid seal by the level of water in the suppression pool, provided the packing of these valves is not exposed to leakage coming from the spray line.

  . MO-2010, 2011, 2022, and 2023: Should be Type C tested in the direction of accident pressure or pneumatically tested so that the valve packing and body-to-bonnet seals are exposed to test pressure.

- No exemption from Appendix J is necessary for the reverse-direction testing of isolation valves of penetrations X-25, 26, 27D, 27E, 27F, 41, 48, 205, 214, and 220 since Appendix J permits this testing.

- Exemption from the requirements of Appendix J to permit reverse-direction testing of the inboard isolation valves of the reactor water cleanup system, the floor sump discharge, and the equipment sump discharge is not acceptable. These valves should be tested in the direction of accident pressure.

- The core spray testable check valves are not relied upon to perform a containment isolation function and do not require Type C testing provided that the motor-operated isolation valves outside containment are Type C tested as proposed by NSP and that emergency procedures require closure of these valves as soon as it is determined that core spray flow cannot be established.

- The LPCI testable check valves are not relied upon to perform a containment isolation function and do not require Type C testing provided that the motor-operated isolation valves outside containment are Type C tested as proposed by NSP.

- Continued testing of MSIVs at 25 psig in lieu of the 41 psig is an acceptable exemption from the requirement of Appendix J because it results in a conservative determination of the leakage rate of the valves.

- Isolation valves in lines terminating below the level of the suppression pool do not require testing in accordance with Appendix J because these valves are not relied upon to perform a containment isolation function.

- A requested change in the value of La was not evaluated because the value of La was not derived in accordance with Appendix J.

Proposed Piping Modification

- The proposed modification to permit testing of the instrument air isolation control valve is acceptable.

- The proposed modification of the cooling water supply and return lines for the drywell fan coolers is acceptable.

- The proposed modification of the TIP penetrations is acceptable.

- The proposed modifications to permit testing of the CRD hydraulic return inboard check valves is acceptable with the exception that the addition of a second test fitting between valves CRD-34 and CRD-31 should not be included.

- The proposed modification to permit testing of the standby liquid control system inboard check valve is acceptable with the exception that the addition of a second test fitting between valves XP-7 and XP-6 should not be included.

- The proposed modification to add a motor-operated isolation valve downstream of HPCI-10 (plus a test connection) is acceptable provided that the valve will be automatically shut after an accident whenever the HPCI system is not in operation. Alternatively, the addition of redundant isolation valves in the vacuum breaker line is acceptable provided that the vacuum breaker function of this line is not lost.

- The proposed modification to add a motor-operated isolation valve downstream of RCIC-10 (plus a test connection) is acceptable provided that the valve will be automatically shut after an accident whenever the RCIC system is not in operation. Alternatively, the addition of redundant isolation valves in the vacuum breaker line is acceptable provided that the vacuum breaker function of this line is not lost.

- The proposed modification to permit testing of the manual isolation valves in the demineralized water supply to the drywell is acceptable provided that valve DM-58 is capable of being tested in the reverse direction.

- The proposed modification to permit testing of the isolation valves in the service air supply to the drywell is acceptable provided that valve AS-39 is capable of being tested in the reverse direction.

- The proposed modification to permit testing of the torus instrument air supply control valve is acceptable.

Proposed Technical Specification Changes

- Applicable portions of the proposed changes to the Limiting Conditions for Operation were found to be acceptable with exception of the acceptance criteria for testing airlocks at 10 psig, which should be modified in accordance with Section 3.1.2 of this report.

- Applicable portions of the proposed changes to the Surveillance Requirements were found to be acceptable with exception of the requirements for testing airlocks, which should be modified in accordance with Section 3.1.2 of this report.

- The revised Table 4.7.1 (Monticello Containment Penetrations) is acceptable, subject to certain modifications based upon the findings of Sections 3.1 (requests for exemption) and 3.2 (proposed piping modifications) of this report.

o A proposal to terminate the containment integrated leakage rate test (Type A test) in less than 24 hours was not evaluated because this issue is being reviewed by the NRC staff on a generic basis.

5. REFERENCES

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3. L. J. Wachter (NSP)
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7. Summary of Meeting to Discuss Monticello 10CFR50,
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   Letter to Director, NRR
   March 20, 1978

APPENDIX A

CONVERSION OF REDUCED PRESSURE AIR LEAKAGE MEASUREMENTS TO EQUIVALENT FULL PRESSURE AIR LEAKAGE

FFR

JULY 17, 1980

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APPENDIX A. AIR TO AIR LEAKAGE CONVERSION

In pneumatic leakage testing in which application of Pa psig is called for by Appendix J, it is sometimes necessary to request an exemption that permits pneumatic testing at a lower pressure, Pt psig. The leakage rate, Lt, measured under test conditions must then be converted mathematically to the leakage rate, La, that would occur if the pressure were equal to Pa. It is essential that the conversion be conservative. That is, the calculated value of La must not be lower than the actual leakage rate at Pa would be. On the other hand, the conversion should not be more conservative than necessary in the light of available data, because excessive conservatism could frequently result in the interpretation that a given leak exceeds its maximum allowable limit when in fact it would not exceed that limit if Pa were actually applied.

The meaning of the expression "if Pa were actually applied" should be carefully considered. The assumption is made that the geometry and dimensions of the leakage path would be the same with Pa applied as with Pt applied, or that any changes in geometry would not increase the leakage rate. In the case of airlock doors in which Pt is applied in the reverse direction, opposite to the direction in which Pa would be applied under function conditions, the use of the reverse direction of application of pressure is expected to tend to open the seal and increase the leakage rate. Under function conditions, in which pressure is applied in the forward direction, the seal should be improved if it changes at all. The expression "if Pa were actually applied" in this case means "if Pa were actually applied in the forward (normal for function) direction." In the case of valves and other penetrations, it is essential that increasing the applied pressure from Pt to Pa not change the geometry so as to increase the leakage rate. For example, increasing the pressure on a closed valve should tend to improve its sealing at the surfaces that provide the seal, and also in any other potential leakage paths such as valve stem or packing that may have a connection to the applied pressure. Such other potential leakage paths are of course absent in valve designs in which the stem and packing have a connection only to the downstream side of the valve.

Reference 1, which is ASME Code, Section XI, paragraph IWV-3423 (e), states the following rule for tests at less than function differential pressure:

> "Leakage tests involving pressure differentials lower than function pressure differentials are permitted in those types of valves in which service pressure will tend to diminish the overall leakage channel opening, as by pressing the disk into or onto the seat with greater force. Gate valves, check valves, and globe-type valves having function pressure differential applied over the seat, are examples of valve applications satisfying this requirement. When leakage tests are made in such cases using pressures lower than function maximum pressure differential, the observed leakage shall be adjusted to function maximum pressure differential value. This adjustment shall be made by calculation appropriate to the test media and the ratio between test and function pressure differential, assuming leakage to be directly proportional to the pressure differential to the one-half power."

In the discussion below, it is shown that if (a) the test medium is air, (b) Pa is appreciable compared to one atmosphere, and (c) the leakage path is such as to produce laminar viscous flow (i.e., capillary-like rather than orifice-like), the calculation appropriate to this test medium yields a substantially higher calculated value of La than would be obtained by assuming leakage to be directly proportional to the pressure differential to the one-half power.

For air flow through an orifice, assuming uniform flow velocity over the orifice area, the mass flow rate per unit orifice area is ρv, where ρ is the density of air in the orifice and v is velocity in the orifice. Assuming that the discharge pressure is Pat = 1 atmosphere and the source pressure is Po, where Po and Pat are both absolute pressures, ρv is given by

$$(\rho v)^2 = \frac{2\gamma g}{\gamma - 1} \frac{Pat^2}{R_o T} \left(\frac{Po}{Pat} - 1 \right) G \qquad \text{(A-1)}$$

where γ = 1.4 is the specific heat ratio for air, g = 32.2 ft/sec^2 is the acceleration of gravity, T is source (upstream, at Po) temperature (°R), P is absolute pressure (psf), R_o = 53.26 ft-lb/lb°F is the gas constant for air and G is given by

$$G = \left(\frac{Pe}{Pat}\right)^2 \frac{x^{\frac{\gamma-1}{\gamma}}\left(x^{\frac{\gamma-1}{\gamma}} - 1\right)}{\left(\frac{Po}{Pat} - 1\right)} \qquad \text{(A-2)}$$

$$x = \frac{Po}{Pe}$$

Pe = Pat for subsonic flow

Pe = 0.5283 Po for choked flow

Choked flow occurs when

$$\frac{Pat}{Po} \leq \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma}{\gamma-1}} = 0.5283$$

$\sqrt{G}$ is proportional to $\rho v/\sqrt{Po-Pat}$. Values of $\sqrt{G}$ are listed in Table A-1. $\sqrt{G_o}$, the limiting value of $\sqrt{G}$ for small (Po-Pat), is $\sqrt{(\gamma-1)/\gamma}$ = 0.5345.

In Table A-1, inspection of $\sqrt{G}/\sqrt{G_o}$ shows the accuracy of the assumption that for an orifice-like leakage flow resistance, leakage mass flow rate is proportional to pressure difference to the one-half power. For example, if Po = 60 psig (Po-Pat = 60 in Table A-1), $\sqrt{G}/\sqrt{G_o}$ = 1.210. Extrapolation of mass flow rate measured with Pt = 15 psig to mass flow rate predicted for Pa = 60 psig will underestimate the mass flow rate by the factor 0.968/1.210 = 0.80, or 20%.

The foregoing argument tacitly assumes that the orifice coefficient is = 1.0. However, the same conclusion concerning extrapolation from low values of Pt to high values of Po can be drawn if the orifice coefficient is assumed to be constant, i.e., independent of Po. Consequently,

Table A-1. $\sqrt{G}$ for Various Values of Po - Pat for Orifice. (Pat taken = 15 psia.)

Po - Pat (psi)	$\sqrt{G}$	$\sqrt{G}/\sqrt{G_o}$
0.01	0.5345	1.000
1	0.5332	0.998
5	0.5282	0.988
13.3	0.5185	0.970
13.4*	0.5184	0.970
15 *	0.5176	0.968
20 *	0.5230	0.978
25 *	0.5346	1.000
30 *	0.5490	1.027
35 *	0.5648	1.057
40 *	0.5811	1.087
45 *	0.5977	1.118
50 *	0.6143	1.149
55 *	0.6307	1.180
60 *	0.6470	1.210

*Choked flow

For leakage paths that are known to be entirely orifice-like, the assumption that leakage mass flow rate is proportional to pressure difference to the one-half power gives a reasonably accurate correlation, underestimating the leakage mass flow rate by at most 20% for Pa $\leq$ 60 psig. To correct the underestimate, the factor $(\sqrt{G}/\sqrt{G_o})_a/(\sqrt{G}/\sqrt{G_o})_t$ has to be applied, where a and t mean Po = Pa and Pt, respectively. References 2, 3, and 4 discuss the conversion formulas to be applied for various fluids (e.g., air and water) for various types of leakage path. For viscous flow of a gas, the mass flow rate from a source at absolute inlet pressure P_1 to absolute outlet pressure P_2 is proportional to $(P_1^2 - P_2^2)$. The proportionality factor is C/uT, where C is a function of geometry, T is absolute temperature, and u is viscosity (which is a function only of temperature).

Assuming that test pressure Pt psig is applied at the same temperature as that at which function pressure Pa psig is applied, and assuming further that the downstream pressure is one atmosphere, Pat psia, then the ratio of the mass flow rates is

$$\frac{\dot{m}a}{\dot{m}t} = \frac{(Pa + Pat)^2 - (Pat)^2}{(Pt + Pat)^2 - (Pat)^2} \qquad (A-3)$$

If the temperatures are not the same, the right side of Equation (A-3) has to be multiplied by

$$\frac{\mu(Tt)\cdot Tt}{\mu(Ta)\cdot Ta} \qquad (A-4)$$

Assuming that Tt = Ta, Table A-2 shows the ratio $\dot{m}a/\dot{m}t$ for various values of Pa and Pt, along with values of $(Pa\ psig/Pt\ psig)^{1/2}$. Pat is taken to be 15 psia in calculating $\dot{m}a/\dot{m}t$.

Table A-2. $\dot{m}a/\dot{m}t$ for Various Values of Pa and Pt.

Pt (psig)	$\dot{m}a/\dot{m}t$ Pa=50 (psig)	55	60	$(Pa/Pt)^{1/2}$ 50	55	60	$\frac{(\dot{m}a/\dot{m}t)}{(Pa/Pt)^{1/2}}$ 50	55	60
5	22.86	26.71	30.86	3.16	3.32	3.46	7.2	8.1	8.9
15	5.93	6.93	8.00	1.83	1.91	2.00	3.2	3.6	4.0
25	2.91	3.40	3.93	1.41	1.48	1.55	2.1	2.3	2.5
35	1.76	2.05	2.37	1.20	1.25	1.31	1.5	1.6	1.8
45	1.19	1.39	1.60	1.05	1.11	1.15	1.1	1.3	1.4

In all cases, the assumption that mass flow rate is proportional to pressure differential to the one-half power is unconservative for purely viscous flow. For Pa = 60 psig and Pt = 5 psig, it is unconservative by a factor of 8.9.

RECOMMENDED PROCEDURE

Any one of the following procedures, A, B, or C should be adopted.

A. Test Program

An extensive test program, covering several components of each type for which a correlation from Pt to Pa is sought, should be performed, in which sufficient experimental data showing the relation between Pt and leakage mass flow rate are obtained to permit a conservative empirical correlation to be established. Care must be taken to ensure that experimental orifice-like leaks are not used to represent actual, potentially capillary-like or viscous leaks.

B. Conservative Theoretical Correlation

Use Equation (A-3) as the correlation formula, including the factor (A-4) if necessary.

C. Measure Leakage Characteristic

For a given penetration, several values of Pt may be applied, so that an empirical correlation can be established. A statistical analysis of the data would be required to ensure at a 95% confidence level, that the predicted value of $\dot{m}\bar{a}$ is not exceeded by the actual value of $\dot{m}a$.

REFERENCES

1. ASME Code, Section XI, paragraph IWV-3423(e).

2. Amesz, J., "Conversion of Leak Flow-Rates for Various Fluids and Different Pressure Conditions," 1966, EUR 2982.e, ORGEL Program, Ispra Establishment, Italy.

3. Maccary, R.R., DiNunno, J.J., Holt, A.E., and Arlotto, G.A., "Leakage Characteristics of Steel Containment Vessels and the Analysis of Leakage Rate Determinations," May, 1964, Division of Safety Standards, AEC, TID-20583.

4. Cottrell, Wm. B., and Savolainen, A.W., editors, "U.S. Reactor Containment Technology," ORNL-NSIC-5, Aug. 1965. Chapter 10, "Performance Tests," R.F. Griffin and G.H. Dyer. Sections 10.4.5 and 10.4.6 adapted from Reference 3.