U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.5.3 FISSION PRODUCT CONTROL SYSTEMS AND STRUCTURES

REVIEW RESPONSIBILITIES

Primary - Accident Evaluation Branch (AEB)

Secondary - Effluent Treatment Systems Branch (ETSB)

I. AREAS OF REVIEW

The description of the fission product control systems and structures are reviewed to (a) provide a basis for developing the mathematical model for design basis loss-of-coolant accident dose computations, (b) verify that the values of certain key parameters are within pre-established limits, (c) confirm the applicability of important modeling assumptions, and (d) verify the functional capability of ventilation systems used to control fission product releases. The parameters which must be established for use in the calculation of the radiological consequences of accidents in Chapter 15, and the systems whose functions must be reviewed are outlined below. Many of these areas are the responsibility of other branches and are reviewed by the AEB to provide a general knowledge of the containment systems and their operation following a loss-of-coolant accident (LOCA). The following areas are reviewed:

1. Primary Containment Design

Primary containment characteristics of (1) the containment isolation times and methods, (2) leak rates prior to and following containment isolation if venting, vacuum relief or purging of the containment is permitted (by technical specification) during operation, (3) total and mixing volumes to be assumed from the recirculation characteristics given in safety analysis reports, and (4) the efficiencies of the ESF filters used for post-accident ventilation.

The dose mitigating function of the pressure suppression devices, e.g., subatmospheric operation, suppression pools, is described in Sections 6.2.1 and 6.2.2 of the SAR. The existence and operation of pressure suppression devices should be determined since their existence and performance could affect fission product transport and release, as well as containment pressure and containment leakage rate.

2. Secondary Containment Design

Containment type, e.g., metal siding, reinforced concrete (see SAR Section 3.8.4.). The type of secondary containment structure may affect the potential for exfiltration and the probable leak tightness of the secondary containment.

Physical layout, e.g., volume completely surrounding primary containment, auxiliary building regions treated, main steam tunnel treated (BWR's), main steam line leakage control system provided (BWRs), drawings or plan views defining secondary containment boundary, clarification of which regions are treated by cleanup systems (see SAR Sections 6.2.3, 6.5.3, and 9.3) Knowledge of what regions are treated as part of the secondary containment is essential to establish the mathematical model for dose calculations.

Fission product removal or holdup system design, e.g., regions treated by each system, piping and instrumentation drawings of each system and its operation, fan flow rates, recirculation rate, filter locations and efficiencies, system redundancy, actuation signals, time to reduce region pressures below atmospheric, placement of ducting (see SAR Sections 6.2.3, 6.5.1, and 6.5.3) The reviewer is responsible for determining that each system can perform its functions as claimed to reduce fission product release following a postulated design basis accident. Information on fission product filter systems is provided by the ETSB. Knowledge of fission products removal systems is necessary for modeling the system for the dose calculation. CSB has responsibility for evaluating the pressure transient in the secondary containment to verify secondary containment region pressures following a design basis accident and for reviewing bypass leakage paths. MEB has responsibility for evaluating the structural design of the ventilation system.

General design characteristics, e.g., negative pressure during normal operation, free volumes and mixing regions, and leakage rates (see SAR Sections 6.2.3, 6.5.3, and 9.4). Knowledge of these parameters is necessary for developing the mathematical model.

A secondary review is performed by the Effluent Treatment Systems Branch (ETSB) and the results are used by AEB in the overall review of the fission product control systems and structures. ETSB reviews the efficiencies of filters used in the fission product control systems. The results of the ETSB review are transmitted to AEB for use in the evaluation.

In addition, AEB will coordinate with other branches those evaluations that interface with the overall review of the system. The Containment Systems Branch (CSB) evaluates the containment pressure response and mixing fractions, verifies positive pressure periods, and determines containment leakage rates as part of its primary review responsibility for SRP Sections 6.2.1 and 6.2.6. The Auxiliary Systems Branch (ASB) reviews the ventilation system used to control fission products and the capability to maintain a negative pressure during accident conditions as part of its primary review responsibility for SRP Sections 9.4.1 through 9.4.5. Mechanical Engineering Branch (MEB) reviews the seismic design and quality group classifications for ventilation systems as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2.

The acceptance criteria for the review of those sections and the methods of application are contained in the referenced SRP section of the corresponding primary review branch.

II. ACCEPTANCE CRITERIA

In establishing the model for estimating the radiological consequences of a design basis loss-of-coolant accident and determining the acceptability of the fission products control systems and structures, AEB uses acceptance criteria based on the requirements of the following regulations:

A. General Design Criterion 41 (Ref. 1) as it relates to the containment atmosphere cleanup system being designed to control fission product releases to the environment following postulated accidents.

B. General Design Criterion 42 (Ref. 2) as it relates to the containment atmosphere cleanup system being designed to permit periodic inspections.

C. General Design Criterion 43 (Ref. 3) as it relates to the containment atmosphere cleanup system being designed to permit appropriate functional testing.

Specific criteria necessary to meet the relevant requirements of GDC 41, 42, and 43 are:

1. Primary Containment

   Primary containment design leakage rates for which credit is given should not be less than 0.1 percent per day due to difficulties in measuring lower leakage rates. Containment isolation methods and times must be such that the calculated radiological doses resulting from the escape of radioactive material prior to and following isolation after a LOCA do not exceed the dose guidelines of 10 CFR Part 100 (Ref. 4) in accordance with the appropriate sections in SAR Chapter 15.0.

2. Secondary Containment

   To be classified as a secondary containment for the purpose of fission product control, a structure or structures should completely surround the primary containment, and at least should be held at a pressure of 0.25 inch (water), below adjacent regions, under all wind conditions up to the wind speed at which diffusion becomes great enough to assure site boundary exposures less than those calculated for the design basis accidents even if exfiltration occurs.

   Acceptance of other fission product control structures for collection and control of post-accident releases will be determined following consultation with the CSB and the SEB, on a case-by-case basis. The leakage and filtration rates of such structures are acceptable provided that the offsite doses calculated under SRP Section 15.6.5 will meet the dose guidelines of 10 CFR Part 100, and provided that the preoperational testing and appropriate technical specifications are acceptable.

Other criteria include specifications for intake and return headers on recirculation systems. These should be placed as far away from each other as practical. The return header should provide a wide distribution over the secondary containment. The purpose of this placement is to assure some degree of mixing of the return flow in the secondary containment volume before it is again drawn into the system intake.

With judicious placement, up to 50% mixing may be assumed. A claim for greater than 50% mixing must be supported by the applicant to the satisfaction of the staff. Spacing between intake and return headers is reviewed on a case-by-case basis. Adjustments in the mixing fraction to less than 50% may be indicated by some designs. Past practice has been to allow mixing in 50% of the volume between (and within 10 or 20 feet of) the inlet and outlet headers if both have distributed openings or if one has distributed openings and the other is at the top of the containment.

3. Partial Dual Containment

Partial dual containments must meet the same basic requirements as those for secondary containments in order to be given credit for fission product holdup and removal. The fraction of leakage source considered to be treated by such partial fission products control structures is determined after consultation with the CSB and ASB reviewer on a case-by-case basis.

4. Other Fission Product Cleanup Systems

Fission product retention credit assumed by the applicant for other systems, e.g., pressure suppression pools, may be acceptable provided that justification is supplied by the applicant. Such justification should include analytical bases addressing the important physical and chemical variables of the fission product removal and retention processes, supported by experimental verification.

III. REVIEW PROCEDURES

The reviewer selects and emphasizes aspects of the areas covered by this SRP section as appropriate for a particular case. The judgment which areas to be given attention and emphasis in the review is based on an inspection of the material presented to see whether it is similar to that recently reviewed on other plants and whether items of special safety significance are involved.

The purpose of the review of containment systems is to define a model to be used in DBA (specifically, the LOCA) dose calculations, to check that the values of certain key parameters are within established limits, to confirm the correctness of important modeling assumptions, and to verify the functional capability of the primary and/or secondary containment ventilation systems. Therefore, the reviewer covers various areas (containment design, positive pressure periods, filters, etc.) to establish parameters and assumptions for dose calculation utilizing digital computer codes.

Where a review area is not the primary responsibility of the AEB, appropriate acceptance criteria in applicable SRP sections are used by the responsible branch and the AEB is informed where inadequacies are identified so that appropriate modifications of the model may be made. These areas include:

- primary containment leakage rate, bypass leakage, and testing of these (CSB)
- secondary containment vacuum maintenance systems (normal operation) (ASB)
- secondary containment pressure response (post-accident) (CSB)
- containment isolation (CSB)
- structural design of containments (SEB) and systems (MEB)
- engineered safety feature filter systems (ETSB)

1. Primary Containment Design

   a. The primary containment design is studied to familiarize the reviewer with the overall construction and anticipated performance capability of the primary containment. Certain parameters and design features, such as design leakage rate, purge/vent systems leakage rate prior to containment isolation, containment free volume, internal fission product cleanup systems, should be noted for later use (see example of worksheet, Table 6.5.3-1). The performance capability of the internal fission product cleanup systems (if any) should be verified (see SAR Sections 6.5.1, 6.5.2, and 6.5.4).

   b. The transient response of the containment pressure following the accident should be studied. Historically, pressurized water reactor (PWR) containment design leakage rates have been reduced by a factor of two at one day into the accident (Ref. 5), whereas, boiling water reactor (BWR) containment design leakage rates were assumed to be constant for all time periods following the accident (Ref. 6). The reviewer should verify with CSB that these modeling assumptions are valid for each case reviewed. For those containments designed to reach subatmospheric pressure at some time less than 30 days after the accident, the CSB verifies the time required to reach subatmospheric pressure.

2. Secondary Containment and Other Fission Product Control Structures Design

   a. The design of the secondary containment and other fission product control structures is reviewed to determine how it should be modeled for the dose calculations. The reviewer also ascertains that the applicant has considered the question of potential exfiltration from regions of the secondary containment under varying wind conditions, especially if the structure has a leakage rate greater than 100%/day. The anticipated leakage rate from each region is noted (see example of worksheet,

Table 6.5.3-2), and special attention is paid to the accuracy of the proposed leakage testing if the leakage rates are less than 10% per day. (No facility reviewed to date has a proposed secondary containment leakage rate of less than 10% per day. Experience indicates that 10% per day may be difficult to achieve in actual practice.)

b. The boundary of the secondary containment and other fission product control structures are determined. Usually, the secondary containment boundary is composed of more than one region, e.g., a shield building (concrete) or enclosure building (metal siding) around the primary containment and all or parts (emergency core cooling pump rooms, etc.) of the auxiliary building. These regions may be treated by one or more ventilation systems.

c. For PWR containments and BWR MARK III containments, the annular region between the shield building or enclosure building and the primary containment may be held at a negative pressure relative to adjacent areas by a vacuum exhaust system during normal operation. Since this system is used during normal operation, it may appear in the SAR under auxiliary systems. The exhaust system may also treat the auxiliary building regions which are part of the secondary containment; but if these regions are maintained at a negative pressure during normal operation, it is most likely done with the auxiliary building ventilation system. Both the vacuum exhaust and auxiliary building ventilation systems fall under the purview of the ASB. The systems' ability to maintain a negative pressure of sufficient margin under varying wind conditions and operational modes prior to a design basis accident is verified by the ASB. The AEB reviewer consults with the ASB reviewer to verify the design of systems maintaining negative pressure following a design basis accident. If an adequate negative differential pressure (0.25 inch water gauge) is achieved within 60 seconds from the time the accident, then no positive pressure time period need be assumed in the dose model. All positive pressure periods at any time in the secondary containment regions are treated as direct outleakage periods following an accident, and no credit is given for filters or recirculation systems. The CSB verifies the positive pressure periods. The large reactor buildings around older BWR containments are usually maintained at a negative pressure during normal operation, and the dose model used for these cases has not assumed any positive pressure period.

d. The exhaust systems used to maintain the negative pressure differential following the accident should be sized to meet the negative pressure criterion for the inleakage rate and the conservatively calculated heat load for the regions treated by each, and analyses to this effect should be presented by the applicant. The pressure response analyses are reviewed by the CSB. The functional capability of the filter design associated with the exhaust system is reviewed by the ETSB under SRP Section 6.5.1. The reviewer should consult with the ETSB concerning filter system efficiencies. The exhaust systems may be one of several designs. Common designs are:

(1) Straight exhaust through charcoal and HEPA filters. Primary containment leakage to these regions is assumed to go directly to the filter with no mixing or holdup in the region being filtered.

(2) Recirculation system with split in flow (some exhausted through filters and some recirculated to the region being treated). Primary containment leakage to the region being treated is assumed to be directly to the intake of the recirculation fan. There, a fraction of it (the ratio of exhaust to total flow) is exhausted through the filters; the balance is then assumed to return to the region being treated. The placement of the system intake and return headers is examined to determine that return flow from the fans does not have a direct path to the intake again. Credit for mixing in 50% of the region is given for fission products returned by the recirculation system to the secondary volume if the header placement is satisfactory.

(3) Other variations on the recirculation system are (a) filters in the recirculation line, (b) filters in both the recirculation line and the exhaust line, and (c) high exhaust flow to reduce the negative pressure to several inches water gauge, and then no exhaust with recirculation only for some time period.

The sizing of the system fans for the volumes they are maintaining at a negative pressure may be critical in determining the ratio of exhaust flow to recirculation flow. Past history shows secondary containment structures are considerably more leaky than applicants anticipated (2 to 5 times as great as anticipated), and fan exhaust flows have been increased after testing to account for this. (When identical flow rates are predicted for two volumes which differ by a factor of 10 or more, it is difficult to believe that the negative pressure differential will be the same for both volumes.) The flow rates, negative pressure differential, and volumes are noted and the appropriate AEB reviewer and CSB reviewer (pressure response only) consulted for verification before performing dose calculations.

The systems should be reviewed to determine volumes treated, system operation, fan flow rates, and filter efficiencies. All the applicant's claims should be verified by appropriate staff members as noted on Table 6.5.3-2 of this SRP section. Leakage fractions from the primary containment to each volume should be identified and stated in the technical specifications. Completeness of information, adequacy of technical specifications and testing methods, and the adequacy and maintenance of the integrity of the secondary containment negative pressure considering failures of nonseismic piping or ducting are verified by the CSB.

IV. EVALUATION FINDINGS

The reviewer defines a dose model for the LOCA dose calculations to be performed under SRP Section 15.6.5 and prepares tables of the data of the primary containment and other fission product control structures to be used in the calculation. In addition, the reviewer verifies that sufficient information has been provided and that the review and calculations which are performed under SRP Section 15.6.5 support conclusions of the following type, to be included in the staff's safety evaluation report:

> The staff concludes that the fission product control systems and structures are acceptable and meet the relevant requirements of General Design Criteria 41, 42, and 43. This conclusion is based on the following:
>
> The fission product control systems and structures for mitigation of offsite doses resulting from design basis LOCA have been reviewed. The review has included the applicant's proposed design criteria and design bases for each system and the applicant's analysis of the adequacy of those criteria and bases. The applicant's analyses of the manner in which the designs of the fission product control systems conform to the proposed design criteria have also been reviewed.
>
> The basis for acceptance in the staff review has been conformance of the applicant's designs, design criteria, and design bases for the fission product control systems and necessary auxiliary supporting systems to the Commission's regulations as outlined in 10 CFR Part 50, Appendix A, General Design Criteria 41, 42, and 43, staff technical positions, and industry standards.
>
> The applicant's design of the fission product control systems has been reviewed to assure that the parameters presented in Tables 6.5.3-1 and 6.5.3-2 are appropriate for calculation of the post LOCA doses as outlined in SRP Section 15.6.5.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP Section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup."

2. 10 CFR Part 50, Appendix A, General Design Criterion 42, "Inspection of Containment Atmosphere Cleanup System."

3. 10 CFR Part 50, Appendix A, General Design Criterion 43, "Testing of Containment Atmosphere Cleanup Systems."

4. 10 CFR Part 100, "Reactor Site Criteria."

5. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors."

6. Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Boiling Water Reactors."

Table 6.5.3-1

Primary Containment Parameters

Data Description	Parameter Value	Staff Verification
Type of Structure		SEB
Primary Containment Design Leak Rate		CSB
Bypass Leakage Fraction to Volumes		CSB
1.		
2.		
3.		
Primary Containment Free Volume		CSB
Primary Containment Subatmospheric Operation		CSB
Primary Containment Internal Fission Product Removal Systems:		AAB
Filter System		
Other		
Primary Containment Purge/Vent Operation:		CSB
Leakage During Normal Operation		
Valve Arrangement		
Accident Leakage Via Purge/Vent System Prior to Containment Isolation		

Table 6.5.3-2

Secondary Containment Parameters

Data Description	Parameter Value	Staff Verification
For each Secondary Containment Region:		
Type of Structure		SEB
Free Volume		CSB
Mixing Fraction		AAB
Design Leak Rate		CSB
Annulus Width (where applicable)		CSB
For each Ventilation System:		
Total Recirculation Flow		AAB
Exhaust Flow		AAB
Filter Placement		AAB
Filter Efficiencies		ETSB
Header Placement		AAB
Time Sequence for Operation Following an Accident or		CSB
Operation of System Prior to an Accident if Used During Normal Operation		ASB