NUREG-75/087

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 6.5.3 FISSION PRODUCT CONTROL SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Accident Analysis Branch (AAB)

Secondary - Containment Systems Branch (CSB)
Auxiliary and Power Conversion Systems Branch (APCSB)
Structural Engineering Branch (SEB)
Mechanical Engineering Branch (MEB)
Effluent Treatment Systems Branch (ETSB)

I. AREAS OF REVIEW

The descriptions of the primary and secondary containments and of the containment penetrations are reviewed to (a) provide a basis for developing the mathematical model for design basis accident (DBA) 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 the secondary containment ventilation systems. The parameters which must be established and the systems whose functions must be reviewed or understood by the reviewer are outlined below. Many of these areas are the responsibility of other branches and are reviewed by the AAB to provide a general knowledge of the containment systems and their operation following a loss-of-coolant accident (LOCA).

1. Primary Containment Design

The following areas are reviewed:

a. Containment type, e.g., free-standing steel shell, reinforced steel-lined concrete, as described in Sections 3.8.1 or 3.8.2 and 6.2.1 of the applicant's safety analysis report (SAR). The containment type should be known so that the reviewer understands the degree to which positive pressure periods in the secondary containment may be affected by design basis accident heat loads on the primary containment. The need for containment vacuum relief valves may also be indicated by containment type. The CSB has responsibility for evaluating the pressure transient of the primary containment and for reviewing the vacuum relief valve design, where appropriate.

b. Pressure suppression devices, e.g., sprays, subatmospheric operation, suppression pool, ice condenser, as 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 control peak containment pressure and containment

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leakage rate. The CSB is responsible for evaluating the peak containment pressure and containment leakage rate.

c. Fission product cleanup, e.g., sprays with chemical additives, internal ESF filter systems, ice condenser, as described in SAR Sections 6.5.1, 6.5.2, and 6.5.4. Knowledge of these systems is necessary for modeling the system for dose calculations.

d. General design characteristics, e.g., design leakage rate, free volume, fan flow rate across operating floor (ice condenser), peak containment pressure, time into a design basis accident for initiation and rate of hydrogen purge through the containment purge system when this is exhausted into the secondary containment system. (See SAR Sections 9.4, 6.2.5, and Tables 6-1 through 6-4 as appropriate.) Some of these parameters are required for the dose calculations; others are required in establishing the model to be used.

   Hydrogen purge time and purge rate are interface areas with the CSB, as detailed in Section III of this standard review plan (SRP). Verification of other design data may require interfaces with the CSB, the APCSB, or the SEB as noted in Section III.

2. Secondary Containment Design

   The following areas are reviewed:

   a. Containment type, e.g., metal siding, reinforced concrete. (See SAR Section 3.8.4.) The type of secondary containment structure may indicate the effect of varying wind speed (possible exfiltration) and the probable leak tightness of the secondary containment. The SEB has responsibility for reviewing the structural design of the containment. Leak tightness and leakage testing are the responsibility of the CSB.

   b. Physical layout, e.g., volume completely surrounding primary containment, auxiliary building regions treated, main steam tunnel treated (in boiling water reactors), main steam line leakage control system provided (BWR's), 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.

   c. 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, potential for exfiltration under varying wind conditions, filter cooling capability, 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 removal systems may be provided by other AAB reviewers or by the ETSB (filter system). Knowledge of these systems is necessary for modeling the system for the dose calculation. The 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. The MEB has responsibility for evaluating the structural design of the ventilation system.

d. General design characteristics, e.g., negative pressure maintenance during normal operation, free volumes of regions, and leakage rates. (See SAR Sections 6.2.3, 6.5.3, and 9.4.) Knowledge of these parameters is also necessary for developing the mathematical model. The APCSB has responsibility for evaluating systems which maintain negative pressure in secondary containment regions during normal operation. The CSB has responsibility for evaluating secondary containment leakage rates.

II. ACCEPTANCE CRITERIA

In establishing the model to be used for estimating the radiological consequences of a design basis loss-of-coolant accident and determining the acceptability of the secondary containment ventilation systems, the following acceptance criteria are used by the AAB.

1. Primary Containment

Primary containment design leakage rates for which credit is given should not be less than 0.1%/day due to difficulties in measuring lower leakage rates. No upper limit has been established for this parameter except, where feasible (e.g., where very high leakage rates could be allowed), leakage rates should be reduced to obtain computed doses from design basis accidents that are well within 10 CFR Part 100 guidelines (e.g., 150 rem thyroid).

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 its volume should be held at a minimum negative pressure differential of 0.25 inch (water), when compared with 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. (For a very leaky secondary containment, the CSB requests the AAB to perform a special exfiltration analysis.) Metal siding structures are acceptable if they can meet all leakage test requirements under varying wind conditions.

Other criteria include specifications for:

a. Mixing test for any recirculation system installed.

b. Intake and return headers on recirculation systems. These should be placed as far away from each other as is practical. The return header should provide a wide distribution over the confinement volume. 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, but a claim for greater than 50% mixing must be supported by adequate test data or a testing program which the applicant proposes to follow, once the system is built, to prove the claim. 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.

III. REVIEW PROCEDURES

The reviewer selects and emphasizes aspects of the areas covered by this review plan as may be appropriate for a particular case. The judgment on 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 a dual containment system 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 pre-established limits, to confirm the correctness of important modeling assumptions, and to verify the functional capability of the secondary containment ventilation systems. Specific system design areas may not be reviewed in detail (filters, sprays, leakage rates, etc.), but the reviewer is responsible for reviewing all related ventilation systems and for selecting a representative dose model for DBA calculations. Therefore, the reviewer covers various areas (containment design, positive pressure periods, filters, etc.) for continuity rather than detail. Digital computer codes (Ref. 1) are used to perform the dose calculations.

All statements referring to "operation" in the following discussion mean operation following a postulated design basis LOCA. Normal operation is so identified.

Where a review area is not the primary responsibility of the AAB, it is assumed that appropriate acceptance criteria are used by the responsible branch and when these criteria are not met, the inadequacies are identified by that branch and the AAB is informed so that appropriate modifications of the model may be made. These areas include:

- Primary containment leakage rate, bypass leakage, and testing of these (CSB).

- Hydrogen purge systems (CSB).

- Secondary containment vacuum maintenance systems (normal operation) (APCSB).

- 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. <u>Primary Containment Design</u>

   a. The primary containment design is studied to familiarize the reviewer with the overall construction (free-standing steel shell; reinforced, steel-lined concrete) and anticipated performance capability of the primary containment (subatmospheric or ice condenser containment, leakage rate limits, etc.). Certain parameters, such as design leakage rate, containment free volume, the existence of 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 curve indicating containment pressure versus time following the accident should be studied. Historically, pressurized water reactor (PWR) containment design leakage rates have been reduced by a factor of two after one day. (See Ref. 3.) If the long-term pressure transient shows the containment pressure is not reduced to one-half within 24 hours, the CSB confirms the validity of the leakage rate before it is used in the dose analysis. On BWR containment systems (including MARK III), the containment design leakage rate is to be used for all time periods following the accident (See Ref. 2) unless advised otherwise by the CSB. 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. Verification is by buckslip, a copy of which is retained in the AAB site analyst's workbook.

   Performance of the hydrogen purge system is reviewed for the purpose of modeling the purge dose calculation. On some systems, the hydrogen purge lines are vented to the recirculation return line of the secondary containment ventilation system. Initiation time for the hydrogen purge and the purge rate are obtained from the CSB.

2. <u>Secondary Containment Design</u>

   a. The secondary containment design is reviewed to determine how it should be modeled for the dose calculations. The ability of the structures to withstand the safe shutdown earthquake or to meet the tornado criteria is the responsibility of the SEB, but the reviewer checks the applicant's SAR to determine what criteria the structures are designed to meet. 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 paid to 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 is determined; it should completely enclose the primary containment. 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. (See Figures 6.5.3-1 through 3 for example diagrams.) These regions may be treated by one or more ventilation systems as shown on Figures 6.5.3-1 and 6.5.3-2.

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 APCSB. The systems' ability to maintain negative pressures of sufficient margin under varying wind conditions and operational modes prior to a design basis accident is verified by the APCSB. The AAB reviewer is responsible for reviewing the design of systems maintaining negative pressure following a design basis accident. If an adequate negative differential pressure margin (0.25 inch water gauge) is maintained for all times into the accident (from the time the accident happens), then no positive pressure time period need be assumed in the dose model. All positive pressure periods 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 Standard Review Plan (SRP) 6.5.1. The reviewer should establish that the ESF filter systems are being reviewed by the ETSB. 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. (See Figures 6.5.3-3 and -4.)

(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. (See Figures 6.5.3-5 and -6.) Credit for mixing in 50% of the region is given 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 AAB 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. 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 non-seismic piping or ducting are verified by the CSB.

IV. <u>EVALUATION FINDINGS</u>

The reviewer defines a dose model for the LOCA dose calculations and prepares a table of all the data for the primary and secondary containments to be used in the calculation. The recommended form for tabulation is given in Table 6.5.3-3. This table should include the information needed to model hydrogen purge dose calculations. In addition, the reviewer verifies that sufficient information has been provided and that the review and calculations support conclusions of the following type, to be included in the staff's safety evaluation report:

"The fission product control systems include all structures, ducting, valves, and fans which are used to control leakage of fission products following a postulated design basis accident. The scope of review of these systems included piping and instrumentation diagrams and general arrangement diagrams showing flow in the fission product control systems and areas treated by each system, and descriptive information about each system. 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, and to Regulatory Guide 1.3 (or 1.4), staff technical positions, and industry standards.

"The staff concludes that the designs of the fission product control systems conform to all applicable regulations, guides, staff positions, and industry standards, and are acceptable."

V. REFERENCES

1. Computer codes are currently under development. Documentation will be published as a NUREG report.

2. Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," Revision 2.

3. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors," Revision 2.

Table 6.5.3-1

Example Worksheet:
Primary Containment Information

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
Ice Condenser		
Spray System		
Filter System		
Other		
H_2 Purge Mode (e.g., direct, to recirculation systems, to annulus)		CSB
Purge Initiation Time		
Purge Rate		
Primary Containment Purge:		CSB
Used During Normal Operation		
Valve Arrangement		

Table 6.5.3-2

Example Worksheet:
Secondary Containment Information

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		APCSB

Table 6.5.3-3

Evaluation Findings

Primary Containment Leak Rate

Primary Containment Free Volume

Primary Containment Internal Fission Product Removal System

Primary Containment Subatmospheric Operation

Primary Containment Leakage Paths

Secondary Containment Free Volume

Secondary Containment Total System Flow

Secondary Containment Exhaust Flow

Secondary Containment Mixing Fraction

Secondary Containment Filter Efficiencies

Time Sequence for Operation of Fission Product Removal or Holdup Systems in Total Containment System Following a Postulated Accident

H_2 Purge:

Initiation Time

Purge Rate

Purge Model

Dual Containment

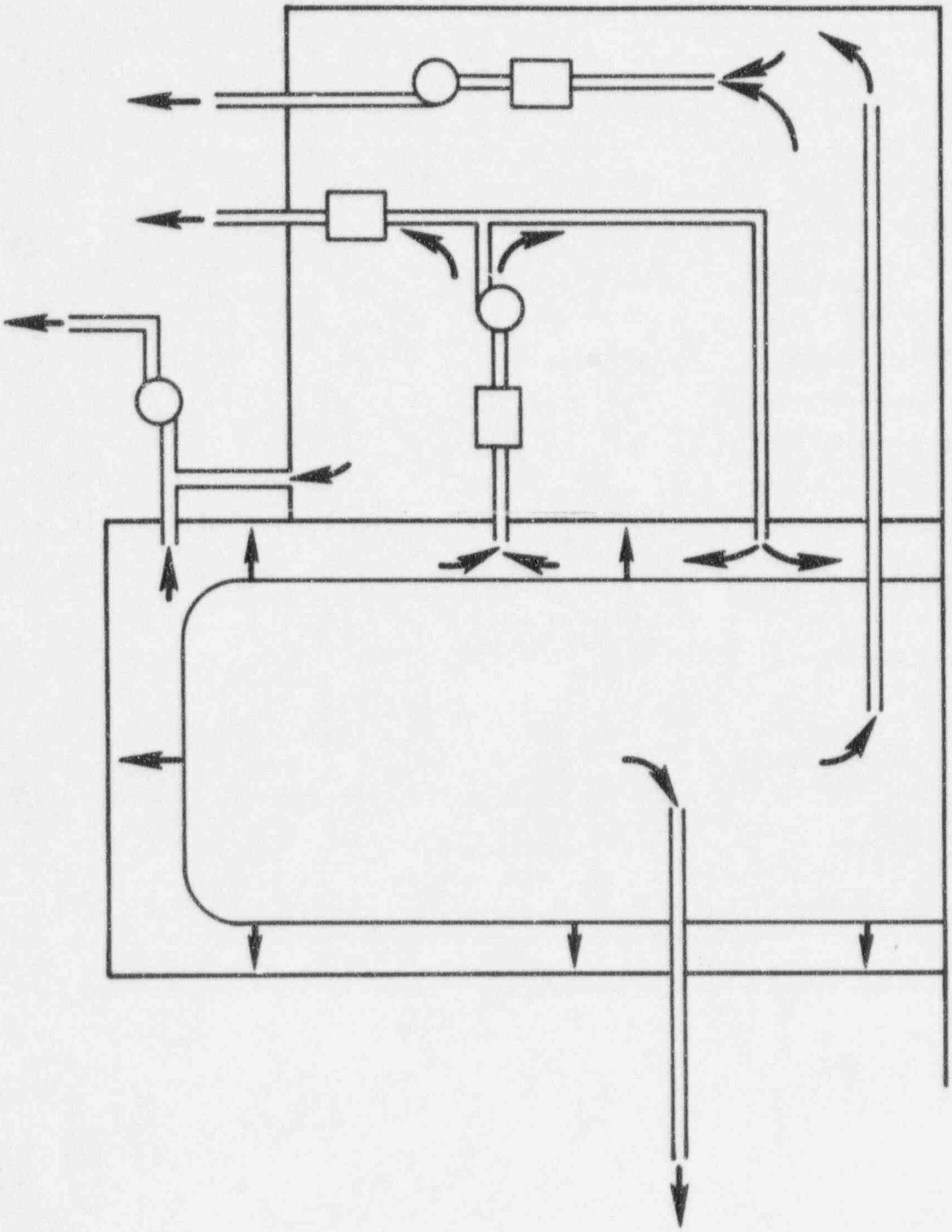


FIGURE 6.5.3-1

PWR Dual Containment

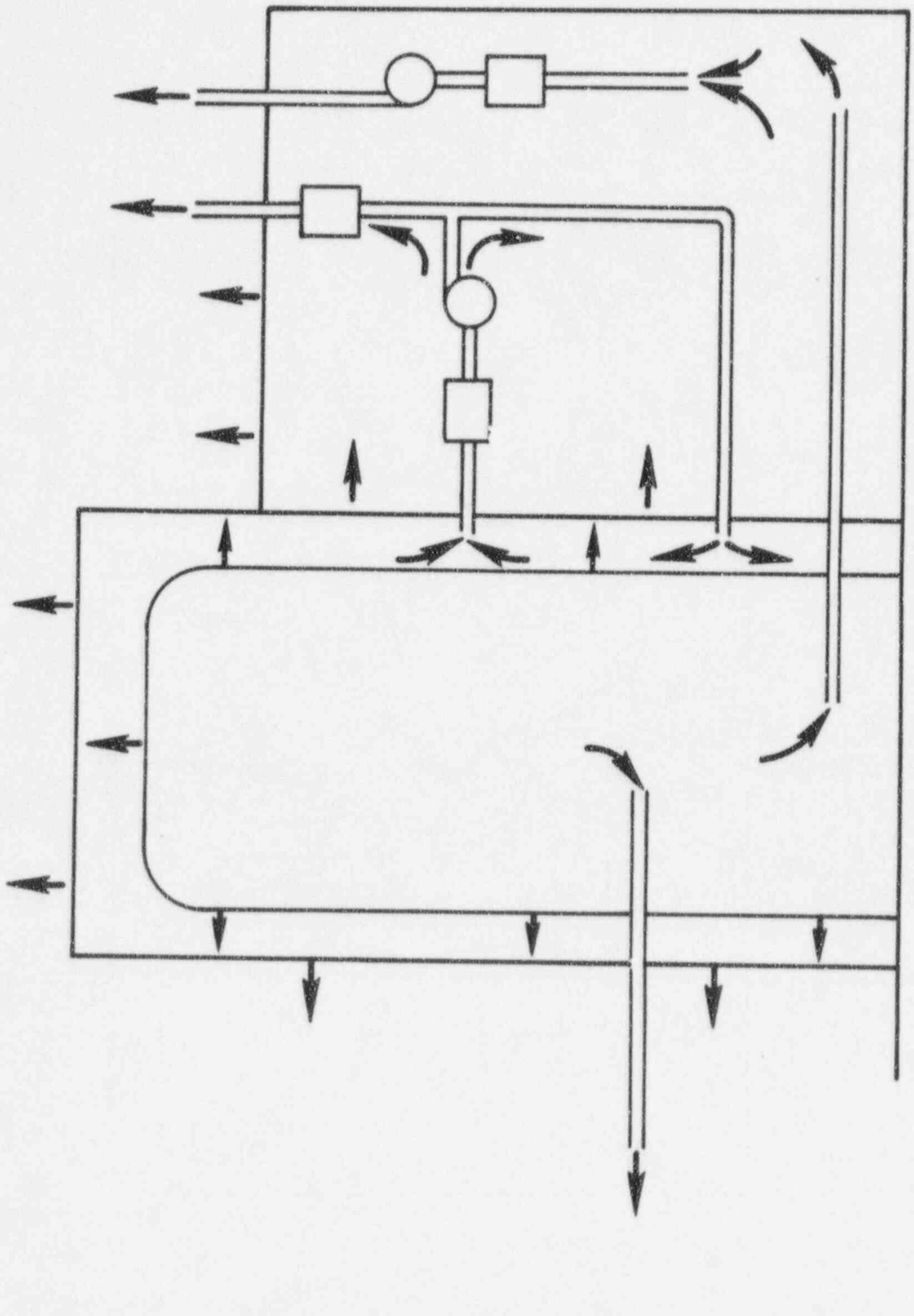
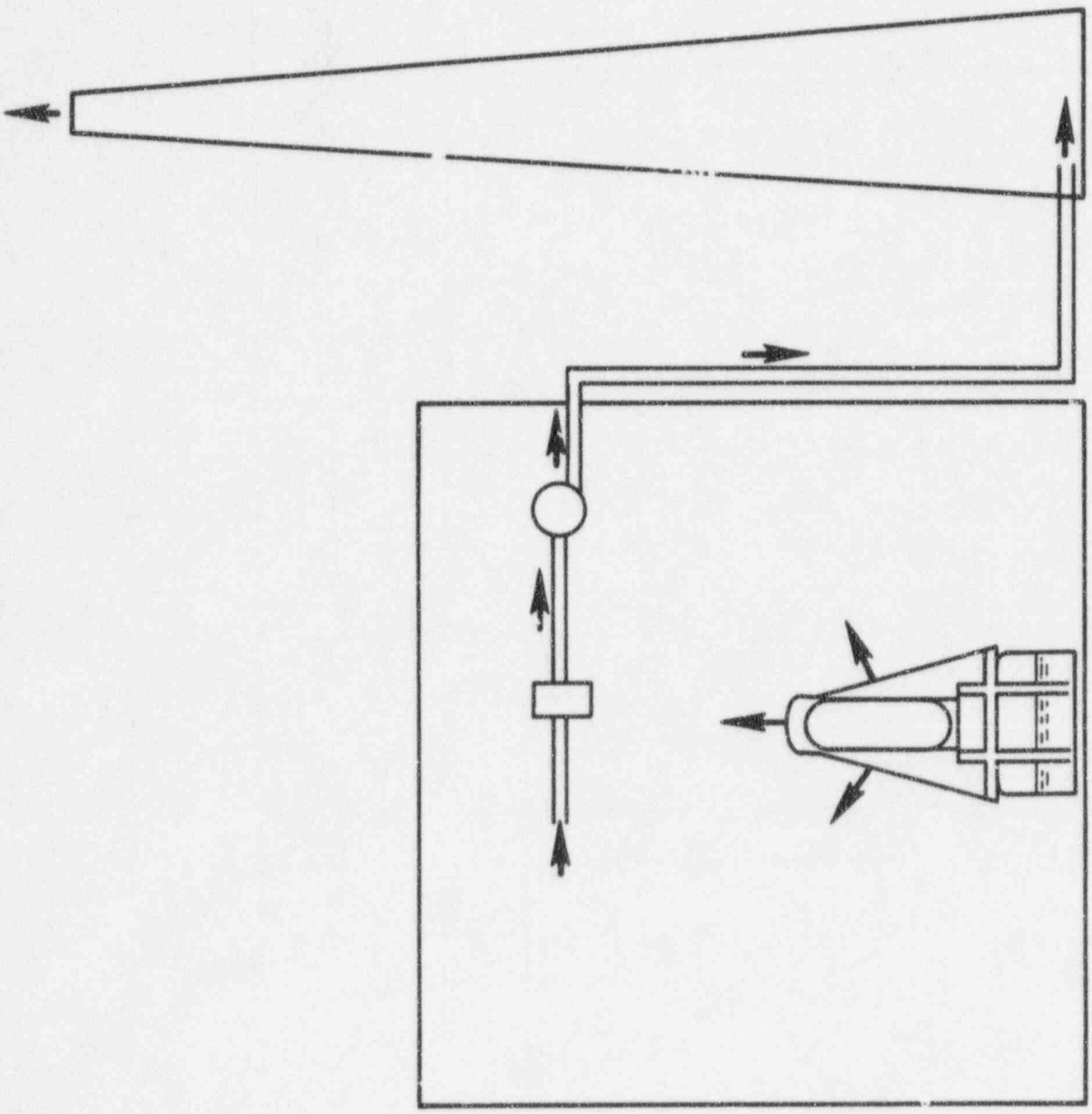
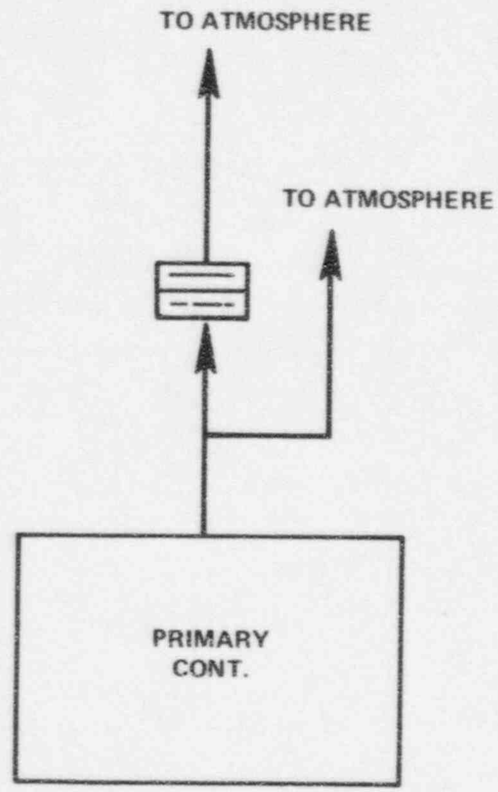


FIGURE 6.5.3-2



BWR With Stack

FIGURE 6.5.3-3



Standard Model

FIGURE 6.5.3-4

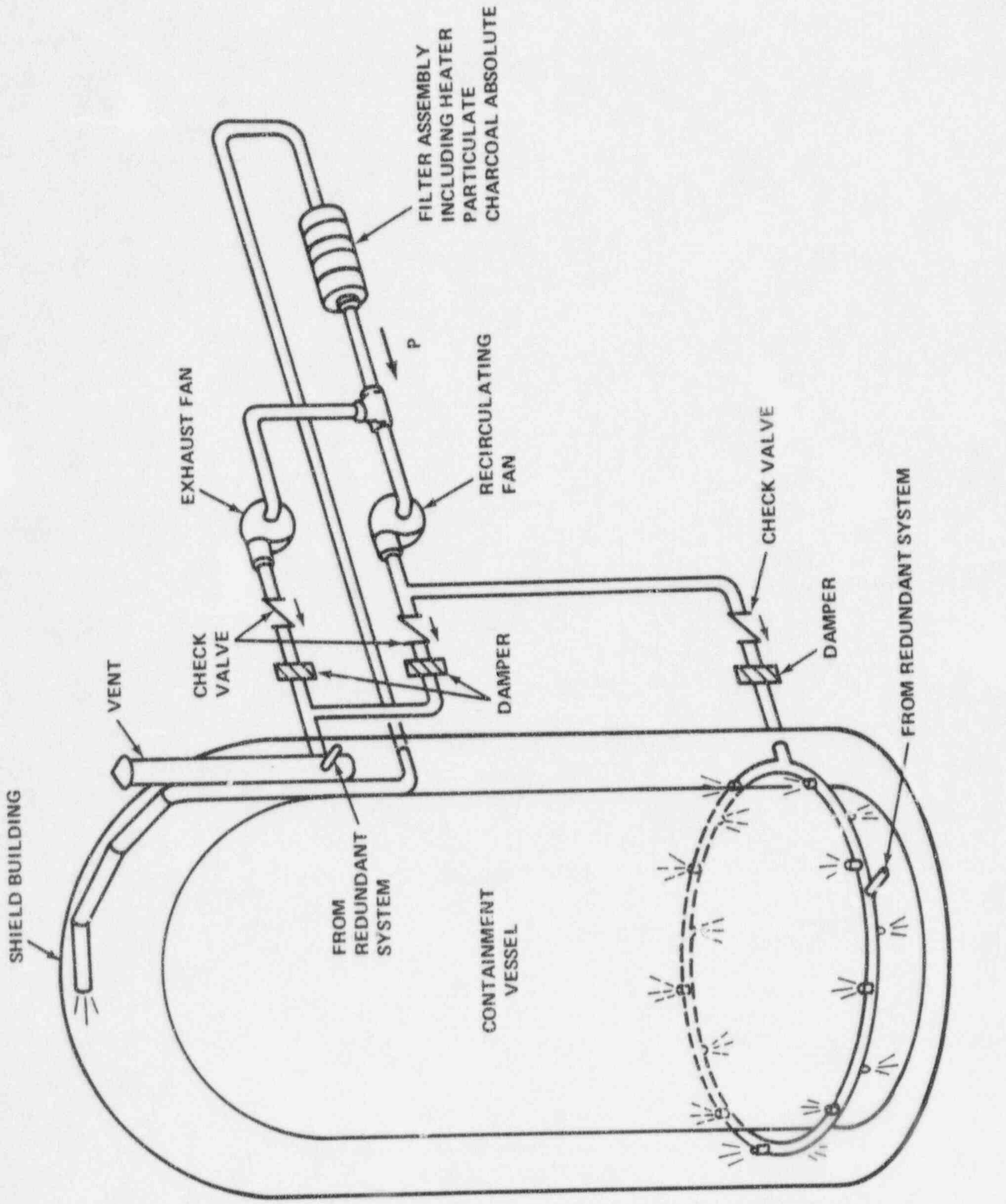
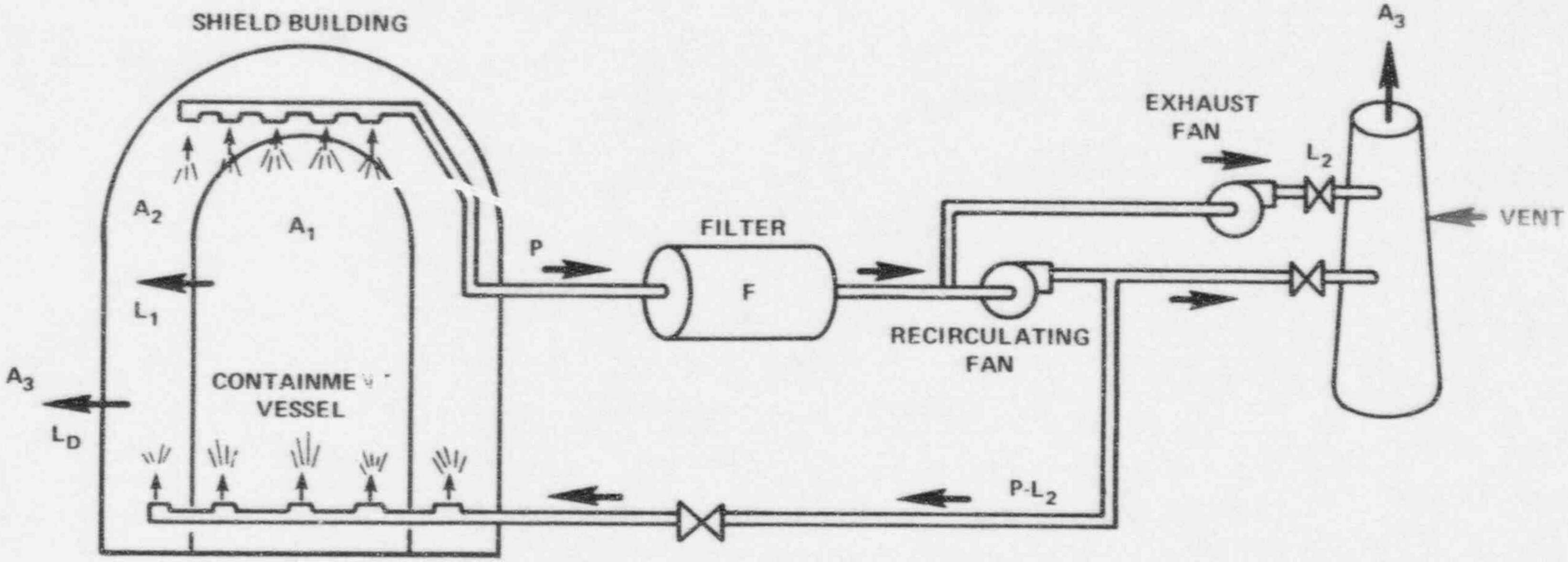

SHIELD BUILDING
VENT
CHECK VALVE
EXHAUST FAN
FILTER ASSEMBLY
INCLUDING HEATER
PARTICULATE
CHARCOAL ABSOLUTE
P
RECIRCULATING FAN
DAMPER
CHECK VALVE
DAMPER
FROM REDUNDANT SYSTEM
FROM REDUNDANT SYSTEM
CONTAINMENT VESSEL

FIGURE 6.5.3-5



System Schematic

FIGURE 6.5.3-6

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SRP 6.5.4