U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.1.5 MINIMUM CONTAINMENT PRESSURE ANALYSIS FOR EMERGENCY CORE COOLING SYSTEM PERFORMANCE CAPABILITY STUDIES

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - None

I. AREAS OF REVIEW

Following a loss-of-coolant accident in a pressurized water reactor (PWR) plant, the emergency core cooling system (ECCS) will supply water to the reactor vessel to reflood, and thereby cool the reactor core. The core flooding rate is governed by the capability of the ECCS water to displace the steam generated in the reactor vessel during the core reflooding period. For PWR plants, there is a direct dependence of core flooding rate on containment pressure; i.e., the core flooding rate will increase with increasing containment pressure. Therefore, as part of the overall evaluation of ECCS performance, the CSB reviews analyses of the minimum containment pressure that could exist during the period of time until the core is reflooded following a loss-of-coolant accident to confirm the validity of the containment pressure used in ECCS performance capability studies. The CSB reviews the assumptions made regarding the operation of engineered safety feature heat removal systems; the effectiveness of structural heat sinks within the containment to remove energy from the containment atmosphere, and other heat removal processes, such as steam in the containment mixing with ECCS water spilling from the break in the reactor coolant system; and in the case of ice condenser containments, mixing with water from melted ice that drains into the lower containment volume. The review is done for all PWR containment types, i.e., dry, subatmospheric, and ice condenser containments.

The CSB will coordinate the review with the Reactor Systems Branch (RSB), which is responsible for determining the acceptability of the mass and energy release data used in the minimum containment pressure analysis (see SRP Section 6.3). This information is derived from the applicant's evaluation of ECCS performance capability in accordance with 10 CFR Part 50, §50.46 and Appendix K to 10 CFR Part 50.

USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

It should be noted that the minimum containment pressure analysis done in connection with ECCS performance evaluation differs from the containment functional performance analysis, in that the conservatisms and margins are taken in opposite directions in the two cases. Thus, the minimum containment pressure analysis required by the regulations for ECCS performance evaluation is not conservative with regard to peak containment pressure in the event of a loss-of-coolant accident and cannot be used to determine the containment design basis.

II. ACCEPTANCE CRITERIA

CSB acceptance criteria is based on meeting the relevant requirements of 10 CFR Part 50, §50.46 and paragraph I.D.2 of Appendix K to 10 CFR Part 50 which requires that the containment pressure used to evaluate the performance capability of a PWR emergency core cooling system shall not exceed a pressure calculated conservatively for that purpose.

The guidelines given below indicate the conservatism that analyses of the containment response to loss-of-coolant accidents should have for determining the minimum containment pressure for ECCS performance capability studies:

1. Calculations of the mass and energy released during postulated loss-of-coolant accidents should be based on the requirements of Appendix K to 10 CFR Part 50 (Ref. 2).

2. Branch Technical Position CSB 6-1, "Minimum Containment Pressure Model for PWR ECCS Performance Evaluation," delineates the calculational approach that should be followed to assure a conservative prediction of the minimum containment pressure.

III. REVIEW PROCEDURES

The review procedures described below are followed for the review of the minimum containment pressure analysis. The reviewer selects and emphasizes material from these procedures as may be appropriate for a particular case. Portions of the review may be carried out on a generic basis or by applying the results of previous reviews of similar plants.

The CSB reviews the analyses in the safety analysis report of the minimum containment pressure following a loss-of-coolant accident. The RSB confirms the validity of the applicant's mass and energy release data. The CSB evaluates the conservativeness of the assumptions used by the applicant regarding the operation of containment heat removal systems and the effectiveness of structural heat sinks, by comparing the applicant's calculational approach to the method outlined in Branch Technical Position CSB 6-1. In certain cases, the CSB may perform confirmatory containment pressure response analyses using the CONTEMPT-LT computer code. In these cases, containment pressure calculated by the CSB is compared to that used in the applicant's evaluation of the performance capability of the emergency core cooling system, to assure that an appropriately conservative value has been used. The CSB advises the RSB of the acceptability of the containment backpressure used in the ECCS performance evaluation.

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this SRP section are presented in SRP Section 6.2.1.

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.

VI. REFERENCES

The reference for this SRP section are listed in SRP Section 6.2.1.

BRANCH TECHNICAL POSITION CSB 6-1

MINIMUM CONTAINMENT PRESSURE MODEL
FOR PWR ECCS PERFORMANCE EVALUATION

A. BACKGROUND

Paragraph I.D.2. of Appendix K to 10 CFR Part 50 (Ref. 1) requires that the containment pressure used to evaluate the performance capability of a pressurized water reactor (PWR) emergency core cooling system (ECCS) does not exceed a pressure calculated conservatively for that purpose. It further requires that the calculation include the effects of operation of all installed pressure-reducing systems and processes. Therefore, the following branch technical position has been developed to provide guidance in the performance of a minimum containment pressure analysis. The approach described below applies only to the ECCS-related containment pressure evaluation and not to the containment functional capability evaluation for postulated design basis accidents.

B. BRANCH TECHNICAL POSITION

1. Input Information for Model

a. Initial Containment Internal Conditions

The minimum containment gas temperature, minimum containment pressure, and maximum humidity that may be encountered under limiting normal operating conditions should be used. Ice condenser plants should use the maximum containment gas temperature.

b. Initial Outside Containment Ambient Conditions

A reasonably low ambient temperature external to the containment should be used.

c. Containment Volume

The maximum net free containment volume should be used. This maximum free volume should be determined from the gross containment volume minus the volumes of internal structures such as walls and floors, structural steel, major equipment, and piping. The individual volume calculations should reflect the uncertainty in the component volumes.

d. Purge Supply and Exhaust Systems

If purge system operation is proposed during the reactor operating modes of startup, power operation, hot standby and hot shutdown, the system lines should be assumed to be initially open.

2. Active Heat Sinks

a. Spray and Fan Cooling Systems

The operation of all engineered safety feature containment heat removal systems operating at maximum heat removal capacity; i.e., with all containment spray trains operating at maximum flow conditions and all emergency fan cooler units operating, should be assumed. In addition, the minimum temperature of the stored water for the spray cooling system and the cooling water supplied to the fan coolers, based on technical specification limits, should be assumed.

Deviations from the foregoing will be accepted if it can be shown that the worst conditions regarding a single active failure, stored water temperature, and cooling water temperature have been selected from the standpoint of the overall ECCS model.

b. Containment Steam Mixing With Spilled ECCS Water

The spillage of subcooled ECCS water into the containment provides an additional heat sink as the subcooled ECCS water mixes with the steam in the containment. The effect of the steam-water mixing should be considered in the containment pressure calculations.

c. Containment Steam Mixing With Water from Ice Melt

The water resulting from ice melting in an ice condenser containment provides an additional heat sink as the subcooled water mixes with the steam while draining from the ice condenser into the lower containment volume. The effect of the steam-water mixing should be considered in the containment pressure calculations.

3. Passive Heat Sinks

a. Identification

The passive heat sinks that should be included in the containment evaluation model should be established by identifying those structures and components within the containment that could influence the pressure response. The kinds of structures and components that should be included are listed in Table 1.

Data on passive heat sinks have been compiled from previous reviews and have been used as a basis for the simplified model outlined below. This model is acceptable for minimum containment pressure analyses for construction permit applications, and until such time (i.e., at the operating license review) that a complete identification of available heat sinks can be made. This simplified approach has also been followed for operating plants by licensees complying with Section 50.46(a)(2) of 10 CFR Part 50. For such cases, and for construction permit reviews, where a detailed listing of heat sinks within the containment often

cannot be provided, the following procedure may be used to model the passive heat sinks within the containment:

(1) Use the surface area and thickness of the primary containment steel shell or steel liner and associated anchors and concrete, as appropriate.

(2) Estimate the exposed surface area of other steel heat sinks in accordance with Figure 2 and assume an average thickness of 3/8 inch.

(3) Model the internal concrete structures as a slab with a thickness of one foot and exposed surface of 160,000 ft^2.

The heat sink thermophysical properties that would be acceptable are shown in Table 2.

Applicants should provide a detailed list of passive heat sinks, with appropriate dimensions and properties.

b. Heat Transfer Coefficients

The following conservative condensing heat transfer coefficients for heat transfer to the exposed passive heat sinks during the blowdown and post-blowdown phases of the loss-of-coolant accident should be used (see Figure 2):

(1) During the blowdown phase, assume a linear increase in the condensing transfer coefficient from $h_{initial}$=8 Btu/hr-ft^2-°F, at t = 0, to a peak value four times greater than the maximum calculated condensing heat transfer coefficient at the end of blowdown, using the Tagami correlation (Ref. 2),

$$h_{max} = 7.25 \left(\frac{Q}{Vt_p}\right)^{0.62}$$

where h_{max} = maximum heat transfer coefficient, Btu/hr-ft^2-°F
Q = primary coolant energy, Btu
V = net free containment volume, ft^3
t_p = time interval to end of blowdown, sec.

(2) During the long-term post-blowdown phase of the accident, characterized by low turbulence in the containment atmosphere, assume condensing heat transfer coefficients 1.2 times greater than those predicted by the Uchida data (Ref. 3) and given in Table 3.

(3) During the transition phase of the accident, between the end of blowdown and the long-term post-blowdown phase, a reasonably conservative exponential transition in the condensing heat transfer coefficient should be assumed (See Figure 2).

The calculated condensing heat transfer coefficients based on the above method should be applied to all exposed passive heat sinks, both metal and concrete, and for both painted and unpainted surfaces.

Heat transfer between adjoining materials in passive heat sinks should be based on the assumption of no resistance to heat flow at the material interfaces. An example of this is the containment liner to concrete interface.

(4) Variations from the above guidelines may be found acceptable if the overall ECCS performance evaluation model results in an acceptable peak calculated fuel cladding temperature.

C. REFERENCES

1. 10 CFR Part 50, §50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors," and 10 CFR Part 50, Appendix K, "ECCS Evaluation Models."

2. T. Tagami, "Interim Report on Safety Assessment and Facilities Establishment Project in Japan for Period Ending June 1965 (No. 1)," prepared for the National Reactor Testing Station, February 28, 1966 (unpublished work).

3. H. Uchida, A. Oyama, and Y. Toga, "Evaluation of Post-Incident Cooling Systems of Light-Water Power Reactors," Proc. Third International Conference on the Peaceful Uses of Atomic Energy, Volume 13, Session 3.9, United Nations, Geneva (1964).

4. Schmitt, R. C., Bingham, G. E., and Manberg, J. A., "Simulated Design Basis Accident Tests of the Carolinas Virginia Tube Reactor Containment - Final Report," IN-1403, Idaho Nuclear Corporation, December 1970.

TABLE 1

IDENTIFICATION OF CONTAINMENT HEAT SINKS

1. Containment Building (e.g., liner plate and external concrete walls, floor, sump, and linear anchors).
2. Containment Internal Structures (e.g., internal separation walls and floors, refueling pool and fuel transfer pit walls, and shielding walls)
3. Supports (e.g., reactor vessel, steam generator, pumps, tanks, major components, pipe supports, and storage racks)
4. Uninsulated Systems and Components (e.g., cold water systems, heating, ventilation and air conditioning systems, pumps, motors, fan coolers, recombiners, and tanks)
5. Miscellaneous Equipment (e.g., ladders, gratings, electrical cables, trays, and cranes)

TABLE 2

HEAT SINK THERMOPHYSICAL PROPERTIES

Material	Density lb/ft^3	Specific Heat Btu/lb-°F	Thermal Conductivity Btu/hr-ft-°F
Concrete	145	0.156	0.92
Steel	490	0.12	27.0

TABLE 3

UCHIDA HEAT TRANSFER COEFFICIENTS

Mass Ratio (lb air/lb steam)	Heat Transfer Coefficient ($Btu/hr\text{-}ft^2\text{-}F°$)	Mass Ratio (lb air/lb steam)	Heat Transfer Coefficient ($Btu/hr\text{-}ft^2\text{-}F°$)
50	2	3	29
20	8	2.3	37
18	9	1.8	46
14	10	1.3	63
10	14	0.8	98
7	17	0.5	140
5	21	0.1	280
4	24		

Figure 1
Area of Steel Heat Sinks Inside Containment

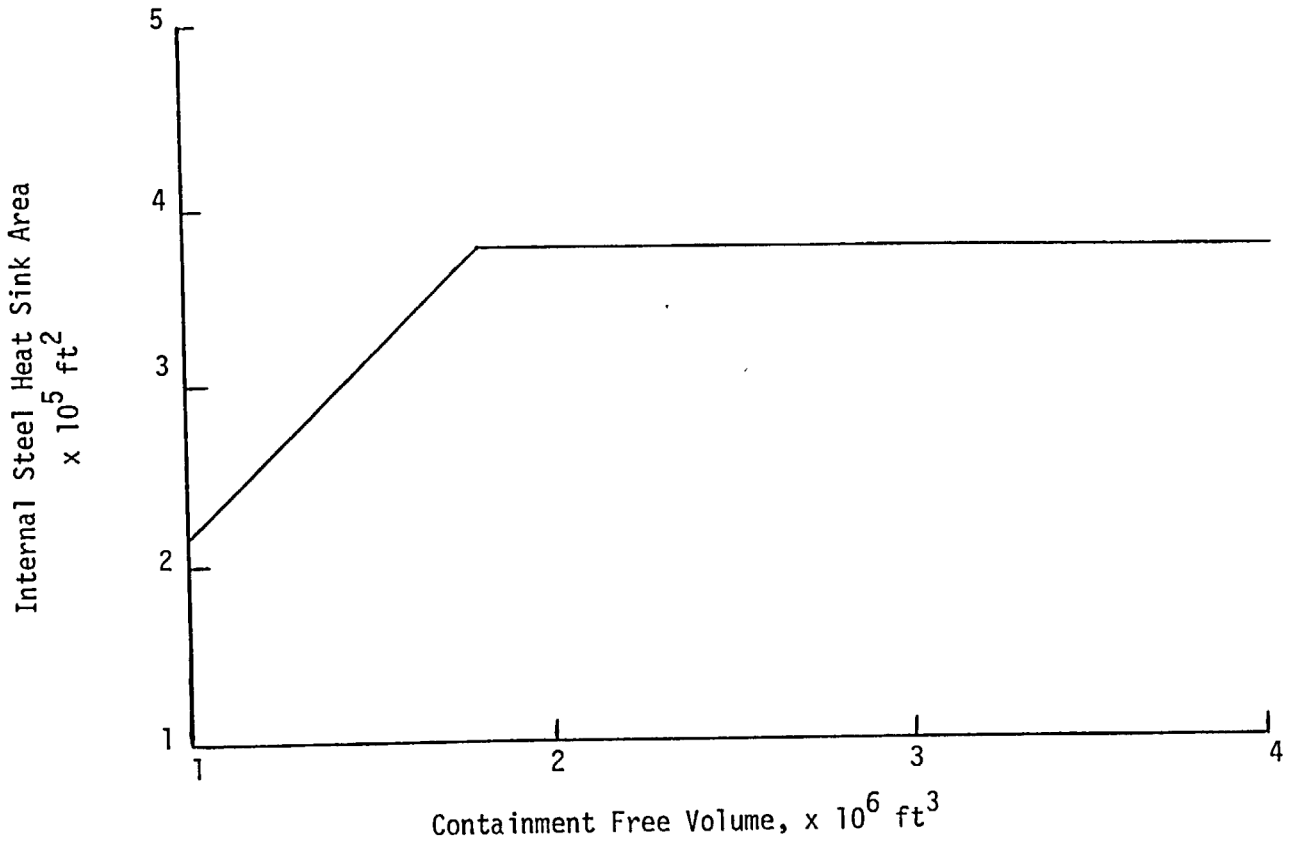
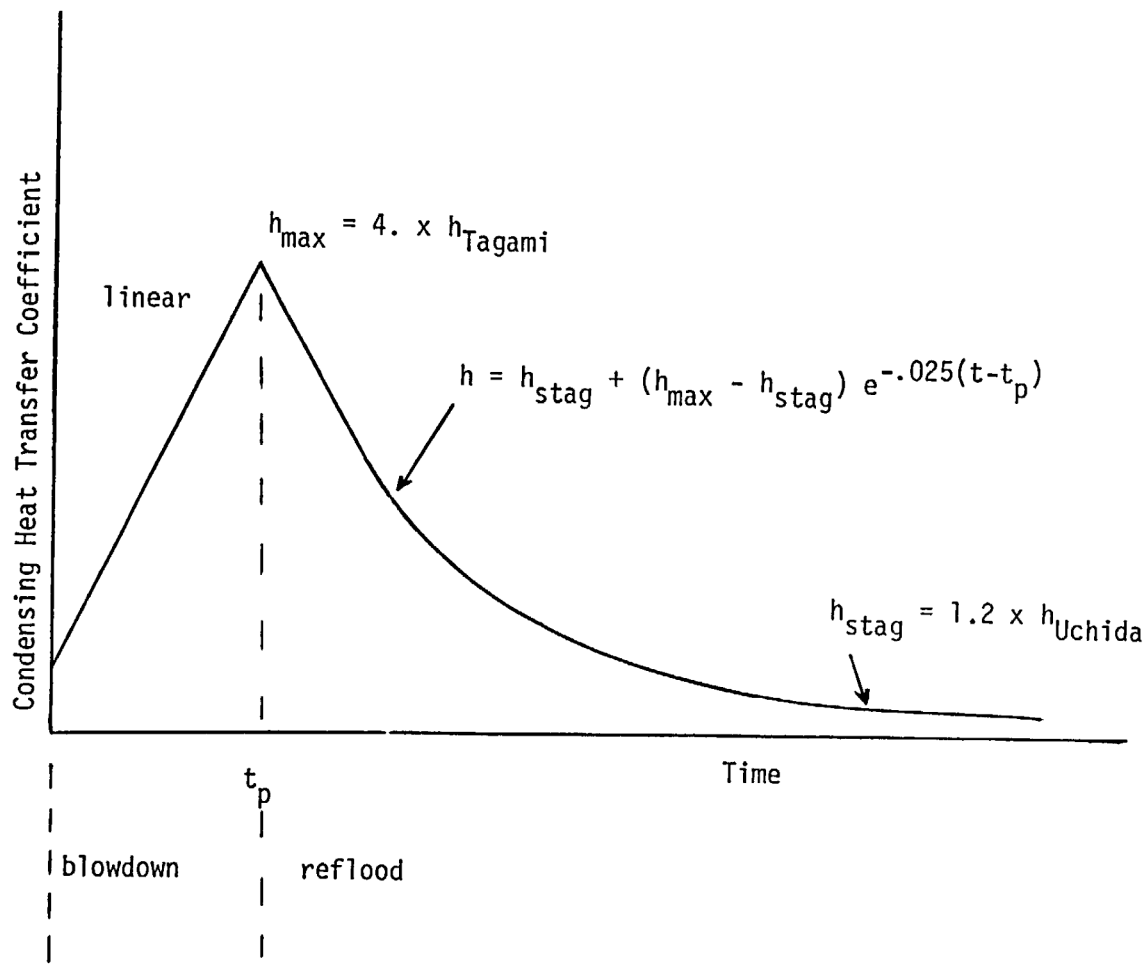


Figure 2

Condensing Heat Transfer Coefficients for Static Heat Sinks