Proposed - For Interim Use and Comment

U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER^{TM} iPWR DESIGN

BRANCH TECHNICAL POSITION 6-2

MINIMUM CONTAINMENT PRESSURE MODEL FOR PWR ECCS PERFORMANCE EVALUATION

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of component integrity issues related to engineered safety features

Secondary - None

A. BACKGROUND

In the mPower^{TM} integral pressurized-water reactor, which has no high pressure injection system for emergency core cooling, containment back-pressure directly impacts the ability to inject water into the reactor vessel during a loss-of-coolant accident (LOCA).

Title 10 of the *Code of Federal Regulations* (CFR), Part 50, Appendix K, Paragraph I.D.2, requires that the containment pressure used to evaluate the performance capability of a pressurized-water reactor emergency core cooling system (ECCS) not exceed a pressure calculated conservatively for that purpose. It further requires the calculation to include the effects of operation of all installed pressure-reducing systems and processes. Therefore, the following branch technical position has been developed as guidance in a minimum containment pressure analysis. The approach described applies only to the ECCS-related containment pressure evaluation pursuant to 10 CFR 50.46(a)(1)(ii) 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 encountered under limiting normal operating conditions should be used

    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 such internal structures as walls and floors, structural steel, major equipment, and piping. The individual volume

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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. 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.

3. Passive Heat Sinks

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

Data on passive heat sinks have been compiled from previous conventional light-water reactor (LWR) reviews and used as a basis for the simplified model outlined below; however, conventional LWRs lack mPower^{TM}'s Ultimate Heat Sink (UHS) tank sitting on the containment dome and the in-containment refueling water storage tank (RWST) that provides both ECCS water supply and a large structural heat sink by its passive water capacity inside containment. A complete identification of available heat sinks is required for review of a design certification or combined license application.

i. Use the surface area and thickness of the primary containment steel shell or steel liner, anchors, and concrete, as appropriate.

ii. Estimate the exposed surface area of other steel heat sinks in accordance with Figure 1 and assume an average thickness of 9.53 mm (3/8 inch).

iii. Model the internal concrete structures as a slab with a thickness of 30.5 cm (one foot) and exposed surface of 15,000 m^2 (160,000 ft^2).

iv. Model the RWST as a water tank in a steel shell using the surface area, wall thickness, and tank diameter.

v. Model the external UHS tank with surface area in contact with the containment dome, wall thickness of containment dome, and UHS water inventory.

Acceptable heat sink thermo-physical properties are shown in Table 2.

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

B. <u>Heat Transfer Coefficients</u>. 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 LOCA should be used:

i. 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, $h_{max}=72.5(Q/Vt_p)^{0.62}$

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.

ii. 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 and given in Table 3.

iii. 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 this 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 is the containment liner to concrete interface.

iv. Variations from these guidelines may be acceptable if the overall ECCS performance evaluation model produces an acceptable peak calculated fuel cladding temperature.

C. REFERENCES

1. 10 CFR 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).

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 kg/m^3 (lb/ft^3)	Specific Heat kJ/kg-°K(Btu/lb- °F)	Thermal Conductivity W/m-°K(Btu/hr-ft- °F)
Concrete	2330 (145)	0.654 (0.156)	1.6 (0.92)
Steel	7850 (490)	0.503 (0.12)	47 (27.0)

RWST and UHS tank Water Inventories

TABLE 3 UCHIDA HEAT TRANSFER COEFFICIENTS

Mass Ratio $\frac{\text{kg (lb) air}}{\text{kg (lb) steam}}$	Heat Transfer Coefficient W/m^2-°K (Btu/hr-ft^2- °F)	Mass Ratio $\frac{\text{kg(lb) air}}{\text{kg(lb) steam)}}$	Heat Transfer Coefficient W/m^2-°K (Btu/hr-ft^2- °F)
50	12 (2)	3	165 (29)
20	46 (8)	2.3	211 (37)
18	52 (9)	1.8	262 (46)
14	57 (10)	1.3	358 (63)
10	80 (14)	0.8	557 (98)
7	97 (17)	0.5	795 (140)
5	120 (21)	0.1	1590 (280)
4	137 (24)		

Figure 1

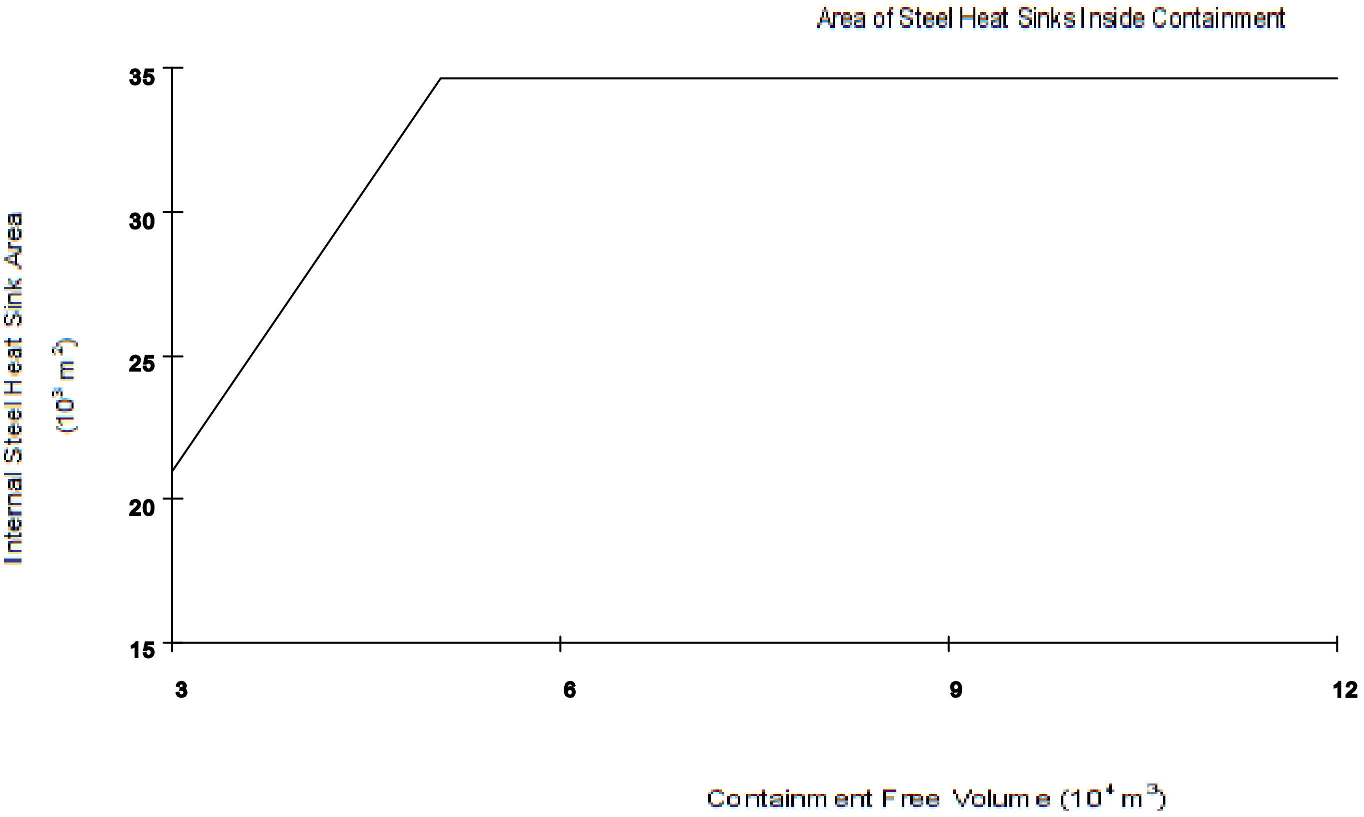
Area of Steel Heat Sinks Inside Containment
Internal Steel Heat Sink Area
(10³ m²)
35
30
25
20
15
3
6
9
12
Containment Free Volume (10⁴ m³)

Figure 2

Condensing Heat Transfer Coefficients for Static Heat Sinks