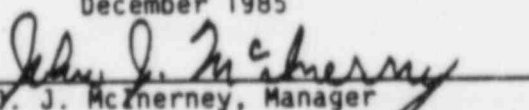WCAP-11021

SPRAY ADDITIVE TANK DELETION
ANALYSIS FOR THE DONALD C. COOK
NUCLEAR PLANT
UNITS 1 AND 2

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1.0 INTRODUCTION, SUMMARY AND CONCLUSIONS

1.1 Introduction

Sodium hydroxide containment sprays currently provide the primary means of reducing the radioiodine concentrations in the containment atmosphere following a design basis large Loss of Coolant Accident (LOCA). This post-LOCA iodine control function can be effectively performed by boric acid sprays and by deposition on containment surfaces. Thus, the spray additive tank (SAT), which contains the sodium hydroxide, the eductor system which delivers the additive to the spray system, and the related testing and maintenance required by the Technical Specifications can be eliminated. Performing the SAT related tests and maintenance required by the Technical Specifications is a resource drain, and handling of sodium hydroxide requires special precautions due to its hazardous nature. There have been cases of sodium hydroxide contamination of ion exchange resins which necessitated their replacement, and SAT dilution resulting in Technical Specification violations. In addition, SAT discharge valves that were inadvertently left closed following maintenance have resulted in Nuclear Regulatory Commission (NRC) enforcement actions and fines. Removal of the SAT and related components can be accomplished by utilizing state-of-the-art radiological analysis techniques and current NRC evaluation criteria.

This report describes the analyses and evaluations which were performed to demonstrate that elimination of the spray additive results in relatively minor impact to the radiological consequences of a postulated loss of coolant accident and that the doses are within the 10CFR10) guidelines.

1.1.1 Background

Historically, following a design-basis LOCA, caustic containment spray (pH 8.5 to 10.5) was needed to meet the offsite dose guidelines of 10CFR100 due to the conservative assumptions and methodologies used by the NRC to calculate offsite thyroid doses.

Analyses performed by Westinghouse utilizing recent changes in NRC methodology (Standard Review Plan 6.5.2, Rev. 1) (Reference 1), combined with knowledge gained from recent studies on the behavior of iodine in the post-LOCA environment, have demonstrated the relatively minor role of the spray additive in meeting the dose guidelines of 10CFR100.

The removal of the SAT introduces the need for adjusting the pH of the Emergency Core Cooling System (ECCS) solution. To minimize chloride-induced stress corrosion cracking of austenitic stainless steel components and to minimize the hydrogen produced by the corrosion of galvanized surfaces and zinc-based paints, the long-term pH of the ECCS solution should be in the range of 7.0 to 9.5. Since the pH of the boric acid ECCS solution, without spray additive, will be approximately 5.0, the chemical additive in the ice condenser ice will be used for long-term recirculation pH control. The ice containment utilizes sodium tetraborate ice which melts following a LOCA, mixes with the boric acid emergency core cooling and spray solutions in the sump, and results in a basic sump solution available for recirculation spray.

The SAT removal analysis for the D. C. Cook Nuclear Plant Units 1 and 2 will not take credit for a change in the iodine source term. The need for basic pH containment spray for fission product control was based on the following assumptions: iodine removal capability of the spray is enhanced at pH values greater than 8.0 and gaseous elemental iodine is the dominant species released from the reactor core (as stated in TID-14844) (Reference 2). While a considerable number of iodine-behavior studies indicate that the form of iodine will be non-volatile iodides, this SAT deletion analysis for D. C. Cook will be based upon the "TID" source terms.

1.1.2 Objectives

The prime objective of this analysis is to provide justification, and obtain NRC concurrence, that the spray additive and therefore the spray additive tank is not required.

Supporting objectives to meeting this primary objective are as follows:

1. Evaluate the containment spray and surface deposition fission product removal effectiveness.

    a. elemental iodine removal.

    b. particulate iodine removal.

2. Perform dose analyses to demonstrate the minor effects of SAT deletion on the radiological consequences of postulated accident conditions.

    The analyses, based on SRP 6.5.2 (NUREG-0800) are to include thyroid doses at the site boundary, low population zone, and in the control room.

3. Determine the adequacy of sodium tetraborate ice for long-term recirculation pH adjustment.

4. Evaluate the potential for chloride induced stress corrosion cracking.

5. Determine the impact of SAT deletion on hydrogen generation and equipment qualification.

1.2 Summary of SAT Deletion Analysis

The SAT Deletion Analysis began with the gathering of general information and specific parameters relevant to the analysis. Most of the information was obtained from the updated D. C. Cook Final Safety Analysis Report (FSAR) (Reference 3). This information is presented in Appendix A.

[

.]a,c The containment consists of an upper compartment, a lower compartment and the ice compartment. [

.]a,c

A determination was then made of the adequacy of sodium tetraborate, contained in the ice, for long-term pH control of the ECCS recirculaton solution. An evaluation was also made of the potential for chloride induced stress corrosion of stainless steel.

[

.]^{a,c} These removel terms contained many conservatisms. Using these calculated coefficients, along with other necessary parameters, a dose analysis was performed.

To complete the analysis, an evaluation was made of the effects of the revised conditions on hydrogen generation and equipment qualifications.

1.3 Conclusions

The fundamental conclusion from this analysis is that the spray additive tank can be removed from the D. C. Cook Units 1 and 2 without significantly affecting the radiological consequences of a postulated LOCA and the calculated doses will remain within the 10CFR100 guidelines. Additional conclusions are:

1. The sodium tetraborate contained in the ice is adequate for long-term pH control of the ECCS recirculation solution.

2. [

]^{a,c}

3. Deletion of the spray additive will have little or no impact on hydrogen generation and equipment qualification.

2.0 SPRAY COVERAGE AND DEPOSITION SURFACE EVALUATION

2.1 Selection of Surface Information

[

]^{a,c}

2.2 Development of Deposition Surface Data

[   ]^{a,c}

Material	SURFACE AREA (FT²)			
	UC*	LC*	Acc. RM.*	Inst. RM.*
Concrete					a,c
Steel Liner-Concrete				
Plate Steel-Concrete				
Concrete-Steel-Liner-Concrete				

---

* UC = Upper Compartment
LC = Lower Compartment
Acc RM = Accumulator Fan Room
Inst RM = Instrumentation Room

The upper compartment of the containment building was assumed to be that which is above the operating floor elevation of 652 feet 7-1/2 inches.

The lower compartment of the containment building was assumed to be that which is below the operating floor level and includes the accumulator fan room and the instrumentation room. The post-LOCA flood-up level was assumed to be elevation 613.5 feet.

[

$:]^{a,c}$

$]^{a,c}$

Additional surface areas considered in the lower compartment are the galvanized surfaces of the conduits, ductwork, and cable trays presented in FSAR Table 14.3.6-3. These are as follows:

	Area (Ft^2)		
Conduits (1 side)	18,850		^{a,c}
Ductwork (1 side)	15,550		
Cable Trays (1 side)	18,777		

In addition to the surfaces considered above, it was determined that 84,000 ft^2 of the surface areas presented in FSAR Table 14.3.1-1 could also be used, with 38,000 ft^2 being in the upper compartment and 46,000 ft^2 in the

lower compartment. These surfaces have a phenolic covering. Also, in FSAR Table 14.3.6-3, a surface area of 27,300 ft^2 is given for galvanized platforms. This is assumed to be in the upper compartment.

The assumed coating, for the ensuing calculations of the iodine deposition rate constants, is phenoline 305 for steel, concrete, and steel-concrete surfaces and zinc for the galvanized steel surfaces.

The ice condenser is also considered in the analysis. From FSAR Table 14.3.6-3, the ice baskets (zinc surfaces) have a total surface area of 453, 660 ft^2. In this analysis, it is conservatively assumed that [   ]^{a,c} percent of this surface area will be available for iodine deposition, which is [   ]^{a,c}

2.3 Final Surface Areas Considered for Elemental Radioiodine Removal

In summary, the spray and deposition surface areas for this analysis are as follows:

Location	Material	Assumed Coating	Surface Area (Ft²)
Upper Compartment			a,c
Upper Compartment			
Upper Compartment			
Lower Compartment			
Lower Compartment			
Lower Compartment			
Ice Compartment			

3.0 EVALUATION OF THE SUMP pH HISTORY

3.1 Determination of Equilibrium Sump pH

The equilibrium sump pH was analyzed for a minimum and a maximum pH case. The ice melt versus time curve is show in Figure 3-1. The assumptions involved in the analysis are given in Table 3-1. Finally, the sump pH versus time curves are shown in Figure 3-2.

Conclusion

The equilibrium sump pH is within the range of 7 to 9.5 as recomended by BTP MTEB 6-1 to minimize the potential for chloride induced stress corrosion cracking.

3.2 Factors Affecting Adsorption and Desorption of Iodine

Deposition of iodine on containment surfaces depends upon the deposition velocity, the desorption velocity and the ultimate surface loading capacity. These parameters are a function of surface material, surface roughness, and temperature. A discussion of these parameters follows.

Surface Loading

In general, surface loadings increase when steam is present and decrease with increasing temperature. A single monolayer of I_2 deposited on a surface equals 0.3 µg/cm^2 of iodine. Most surfaces are capable of loadings many times greater than this. In fact, loadings greater than 10^4 monolayers have been observed on reacting sur es and up to 10 monolayers on inert surfaces. For the D. C. Cook containment, assuming all surfaces have the same affinity for iodine, the average surface loading is approximately [　]^{a,c} µg/cm^2. [

]^{a,c}

Deposition Velocity

Deposition velocity is a function of surface material, roughness and temperature. Deposition velocity tends to increase in the following order: glass < plastic < metal < paint. Deposition increases with surface roughness for surfaces where the adsorption is physical and increases with increasing temperature up to the point where desorption competes to reduce the net deposition velocity. For some metals, there is little desorption at temperatures less than 150°C. For paint, the amount of irreversibly adsorbed iodine has been observed to vary between 35 and 100% of the initial loading. For the zinc based and phenoline coatings assumed for D. C. Cook, the percent of irreversibly retained iodine is reported to be approximately [

]^{a,c} respectively.

Where surfaces are cold enough to permit condensation, the deposition velocity tends to become less dependent on temperature and more dependent upon the water film on the surface. The water film increases both the deposition velocity and the loading capacity. Both of these effects can be attributed to iodine hydrolysis.

TABLE 3-1

ASSUMPTIONS FOR SUMP pH DETERMINATION

	Case 1 Minimum pH	Case 2 Maximum pH
RHR pump flow rate (gpm)	6000	6000
SI pump flow rate (gpm)	1100	1100
Spray pump flow rate (gpm)	6400	6400
RWST boron concentration (ppm)	2200	2000
Accumulator boron concentration (ppm)	2500	2000
RCS boron concentration (ppm)	2000	0
BIT boron concentration (ppm)	22,500	20,000
Ice boron concentration (ppm)	2150	1800
RWST volume (gal)	420,000	350,000
Accumulator volume (gal)	29052	27792
BIT volume (gal)	900	900
RCS volume (gal)	88958	88958
RWST switch-over volume (gal)	70,000	70,000

FIGURE 3-1

D.C. COOK ICE MASS MELT-OUT VERSUS TIME
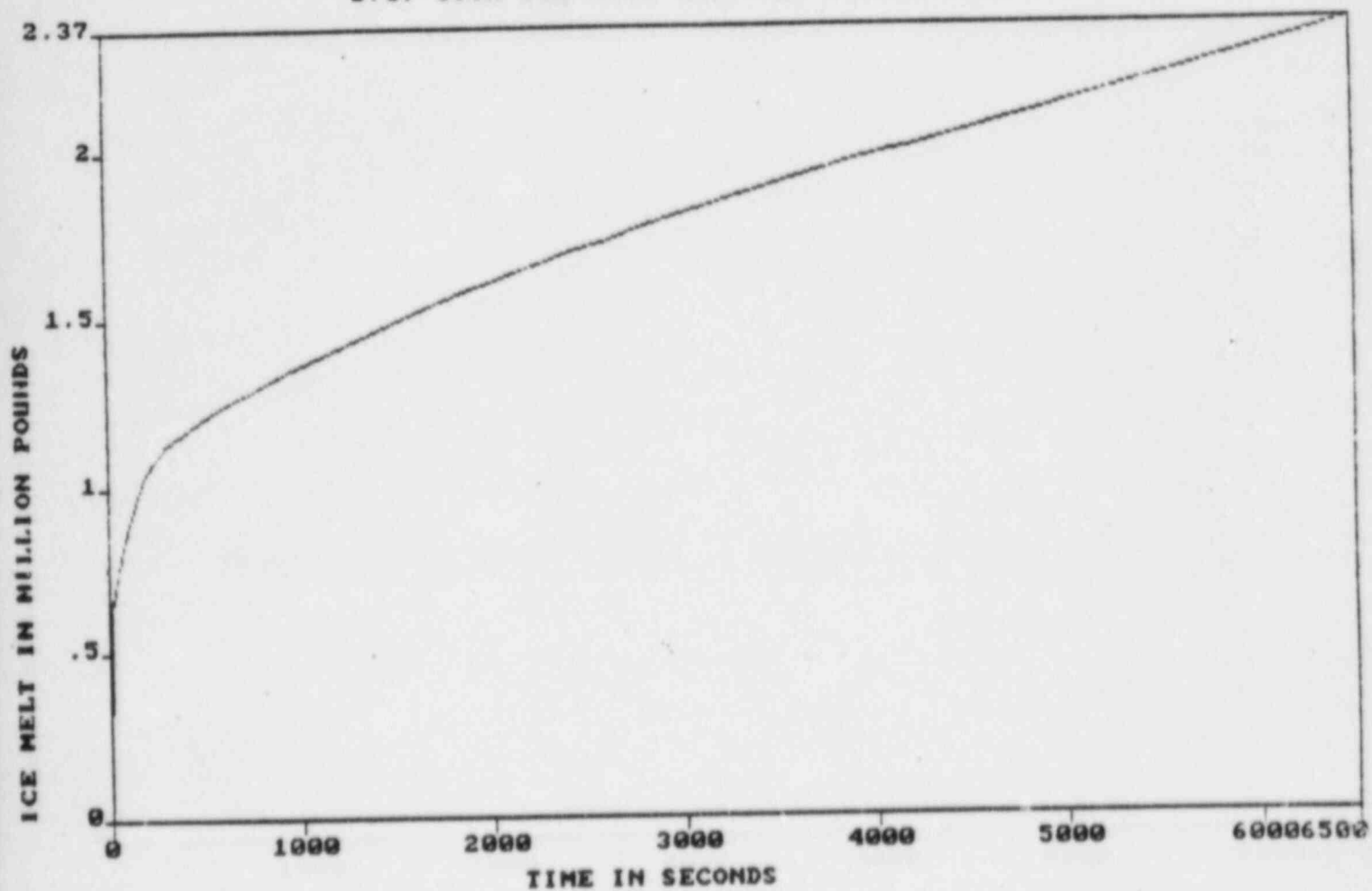
FIGURE 3-2

SUMP pH VERSUS TIME - D. C. COOK

FIGURE 3-1

D.C. COOK ICE MASS MELT-OUT VERSUS TIME

3-4
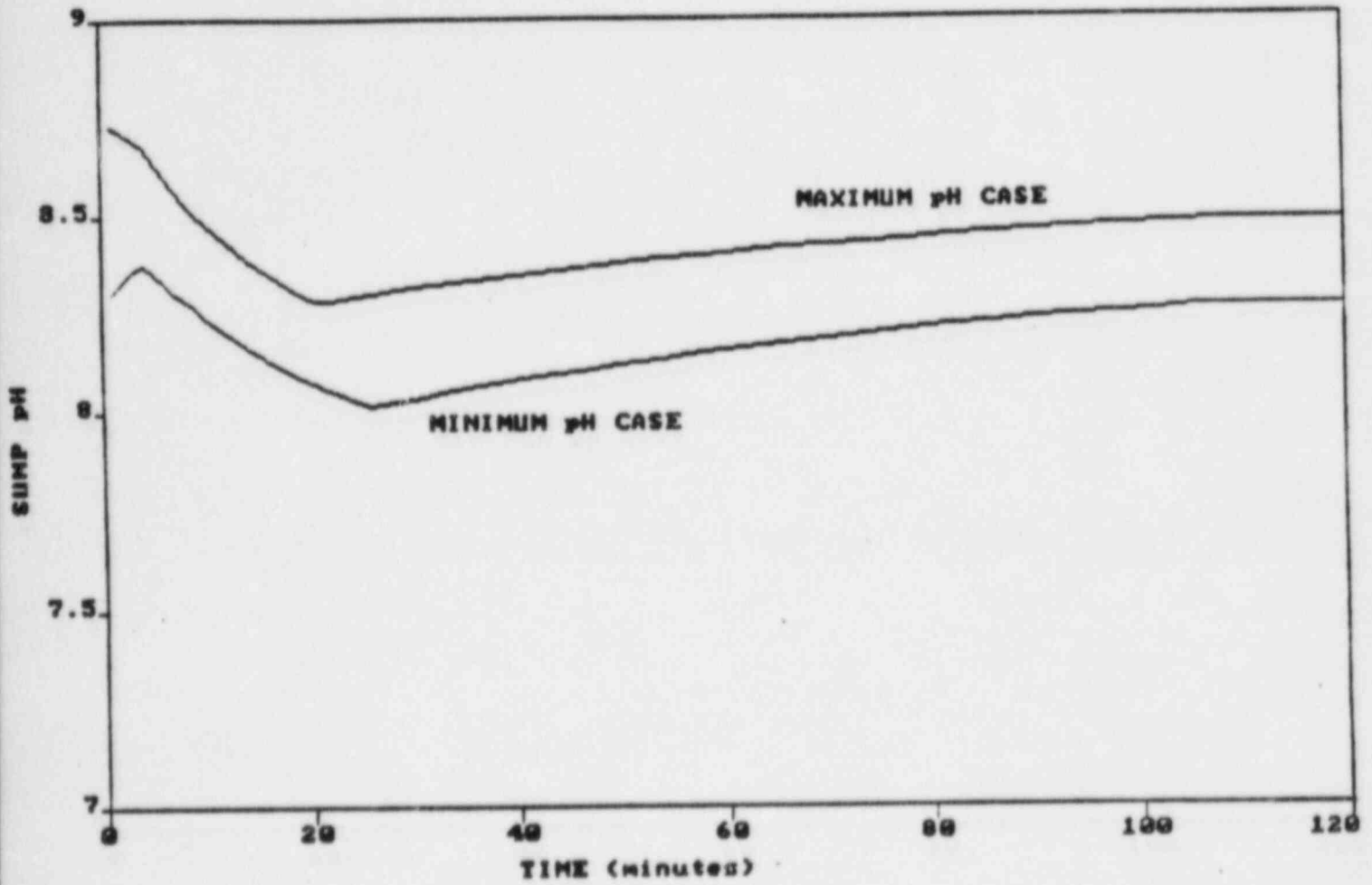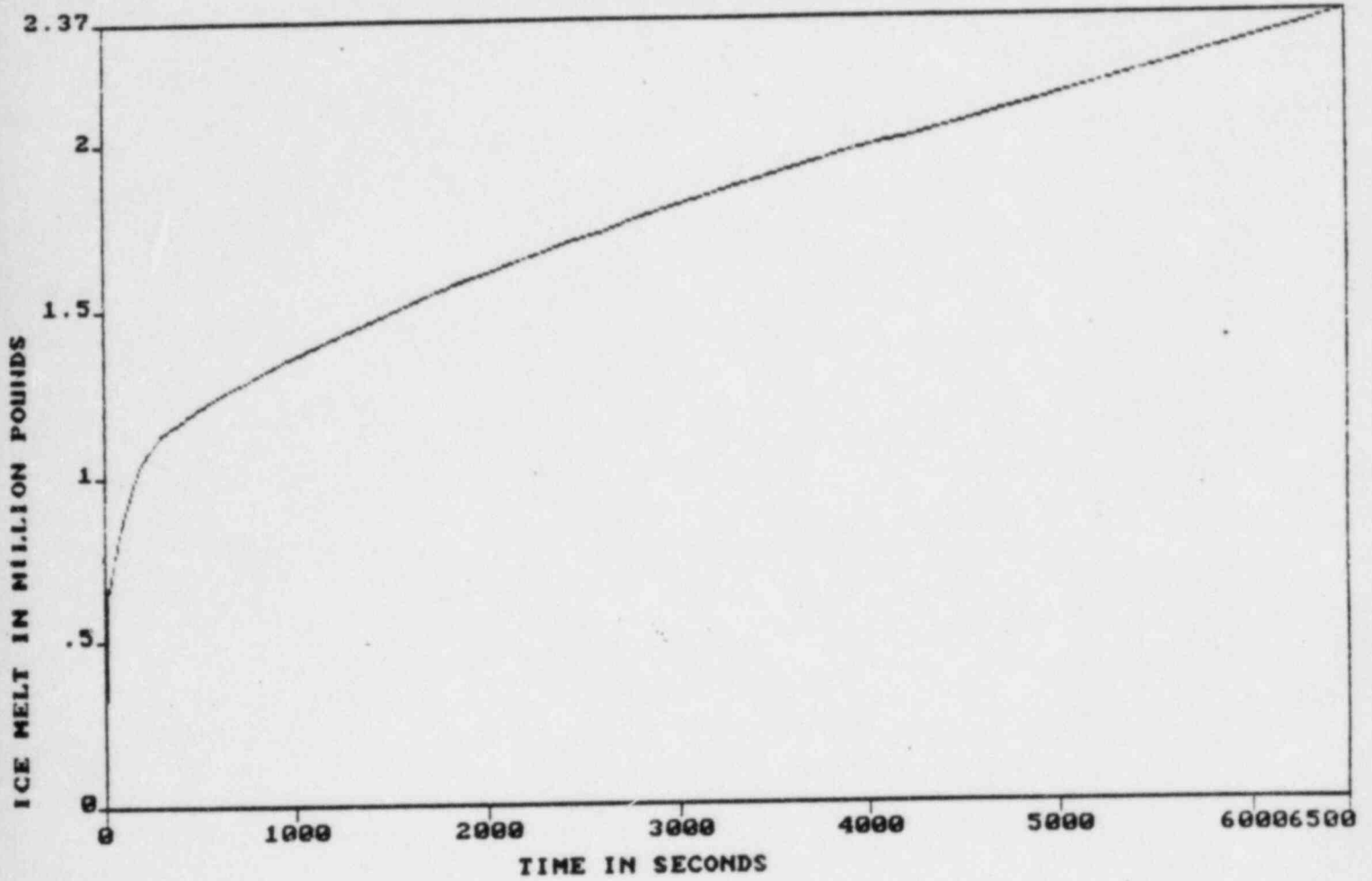
4.0 DEVELOPMENT OF RADIOIODINE REMOVAL COEFFICIENTS
AND DECONTAMINATION FACTORS

In summary, the removal coefficients are as follows:

For elemental iodine spray removal

$$\lambda_s = [\qquad]^{a,c} \; hr^{-1} \text{ in the Upper Containment}$$
for boric acid spray

$$\lambda_s = [\qquad]^{a,c} \; hr^{-1} \text{ in the Lower Containment}$$
for boric acid spray

For particulate iodine removal

$$\lambda_p = [\qquad]^{a,c} \; hr^{-1} \text{ in the Upper Containment}$$
until a DF of $[\quad]^{a,c}$ is reached

$$\lambda_p = [\qquad]^{a,c} \; hr^{-1} \text{ in the Upper Containment}$$
after a DF of $[\quad]^{a,c}$ is reached

$$\lambda_p = [\qquad]^{a,c} \; hr^{-1} \text{ in the Lower Containment}$$
until a DF of $[\quad]^{a,c}$ is reached

$$\lambda_p = [\qquad]^{a,c} \; hr^{-1} \text{ in the Lower Containment}$$
after a DF of $[\quad]^{a,c}$ is reached

For elemental iodine deposition

$$\lambda_n \text{ (Sprayed Region)} = [\qquad]^{a,c} \; hr^{-1} \text{ in the Upper}$$
Containment

$$\lambda_n \text{ (Sprayed Region)} = [\qquad]^{a,c} \; hr^{-1} \text{ in the Lower}$$
Containment

$$\lambda_n \text{ (Unsprayed Region)} = [\qquad]^{a,c} \; hr^{-1} \text{ in the Ice}$$
Compartment

4.1 Elemental Iodine Spray Removal

The elemental iodine spray removal term (λ_s) was determined using the Westinghouse "CIRCUS" computer code (Reference 4). Input parameters to the code included plant power, containment free volumes, containment temperatures, spray flow rates, fall heights, spray temperature, etc. Using a boric acid spray resulted in $\lambda_s = [\quad]^{a,c}$ hr^{-1} in the Upper Containment and $[\quad]^{a,c}$hr^{-1} in the Lower Containment.

4.2 Particulate Iodine Spray Removal

The particulate iodine removal terms (λ_p) were calculated in accordance with NUREG-CR-0009 (Reference 5) which gives:

$$\lambda_p = \frac{3hF}{2V} \frac{E}{d}$$

$$
\begin{aligned}
\text{where} \quad h &= \text{Drop Fall Height} \\
F &= \text{Spray Flow Rate} \\
V &= \text{Volume Sprayed} \\
E &= \text{Single Drop Collection Efficiency} \\
d &= \text{Drop Diameter}
\end{aligned}
$$

From the D. C. Cook FSAR pages, 6.3-5 and 6.3-12 and Table 14.3.1-1:

$$
\begin{aligned}
\text{Upper:} \quad h &= 85.0 \text{ ft} \\
F &= 2000 \text{ GPM} \\
V &= 746,829 \text{ ft}^3
\end{aligned}
$$

$$
\begin{aligned}
\text{Lower:} \quad h &= 50.0 \text{ ft} \\
F &= 1175 \text{ GPM} \\
V &= 365,614 \text{ ft}^3 \text{ (includes dead ended compartments)}
\end{aligned}
$$

From NUREG/CR-0009:

$$\frac{E}{d} = 0.1 \text{ cm}^{-1} \text{ for } C/C_0 \geq 0.01$$

$$\frac{E}{d} = 0.01 \text{ cm}^{-1} \text{ for } C/C_0 < 0.01$$

where C/C_0 = Ratio of present concentration to initial concentration

The particulate removal constants are given below:

$\lambda_p = [$ $]a,c$
$\lambda_p = [$ $]^{a,c}$
$\lambda_p = [$ $]^{a,c}$
$\lambda_p = [$ $]^{a,c}$

Thus, $\lambda_p =$
[

$]^{a,c}$

4.3 Elemental Iodine Deposition Removal

The elemental iodine deposition coefficients were calculated using the spray coverage and deposition surfaces previously determined.

These removal rate constants were calculated in accordance with NUREG/CR-0009 which gives:

$$\lambda_n = \frac{k_g A}{V}$$

where λ_n = Removal rate constant due to surface deposition (sec^{-1})

$\quad\quad\quad k_g$ = Average mass transfer coefficient (cm/sec)

$\quad\quad\quad A$ = Surface area for wall deposition (cm^2)

$\quad\quad\quad V$ = Volume of contained gas (cm^3)

Revising this equation for use with desired units gives:

$$\lambda_n = 118 \, \frac{k_g A}{V}$$

with λ_n in hr^{-1}
       k_g in cm/sec
       A in ft^2
       V in ft^3

The values used for mass transfer coefficients were derived from those given in NUREG/CR-0009 by taking [$]^{a,c}$ percent of the values judged to be applicable for phenoline and zinc surfaces. A value of [$]^{a,c}$ cm/sec was added to the deposition velocities in the sprayed regions in accordance with NUREG/CR-0009. The results are as follows:

   k_g (Phenoline) = [$]^{a,c}$
   k_g (Zinc base) = [$]^{a,c}$
   k_g (Zinc base) = [$]^{a,c}$
        (unsprayed)

The surface areas and assumed coatings used in the calculation were those derived previously and are as follows:

Location	Coating	Surface Area (ft^2)
Upper compartment		a,c
Upper Compartment		
Lower Compartment		
Lower Compartment		
Ice Compartment		

The following volumes were used in the calculations:

Upper Compartment (sprayed) = 746,829 ft^3
Lower Compartment (sprayed) = 365,614 ft^3
Ice Compartment (unsprayed) = 122,400 ft^3

For conservatism, the total volume for the lower compartment was used even though an estimated 140,000 ft^3 of this would be flooded in a post-LOCA situation.

The following results were obtained for the elemental iodine surface deposition removal rate constants:

λ_n (Upper Compartment, sprayed) = [   ]^{a,c}
λ_n (Lower Compartment, sprayed) = [   ]^{a,c}
λ_n (Ice Compartment, unsprayed) = [   ]^{a,c}

4.4 Iodine Retention Limits in Sump Solution

Partition coefficients and decontamination factors (DF) are developed from the standard review plan (NUREG-0800), Section 6.5.2, using the following relationship:

$$DF = 1 + \frac{V_s}{V_c} H$$

where   DF = Ratio of the total iodine in the sump liquid and containment atmosphere to that in the containment atmosphere

   H = Equilibrium iodine partition coefficient (this is obtained from Figure 6.5.2-1 of SRP Section 6.5.2).

   V_s = Volume of liquid in containment sump and sump overflow (140,000 ft^3 is assumed)

   V_c = Containment net free volume less V_s (1,234,843-140,000 = 1,094,843 ft^3 used in this analysis)

Decontamination factors for selected pH levels were calculated to be:

pH	Partition Coefficient	DF
7.5	500	64.9
8.0	1600	206
8.5 or greater	5000	640

5.0 RADIOLOGICAL CONSEQUENCES

5.1 LOCA Dose Analysis

With the deletion of additive from the containment spray solution, the potential thyroid doses due to containment leakage during a postulated Loss-of-Coolant Accident (LOCA) had to be redetermined.

The thyroid doses currently presented in the D. C. Cook FSAR are based on the use of the containment sprays as the primary means of removal of elemental iodine from the containment atmosphere. With the elimination of spray additive, the effectiveness of the sprays in removing airborne elemental iodine is significantly reduced and credit is taken for deposition as the primary removal mechanism. The dose analysis is performed using the Westinghouse TITAN computer code and is modelled using source term assumptions from NUREG-0800 Section 6.5.2 which specifies the use of 50% of core iodines airborne in the containment if deposition removal rate terms are utilized. This is a change from Regulatory Guide 1.4 which assumes that half of this 50% core iodine released to the containment atmosphere plates out instantaneously on containment surfaces but no further deposition removal occurs.

The parameters used in the analysis are presented in Table 5-1 and are the same for both Units 1&2. The following doses were determined:

	LOCA Containment Leakage Thyroid Dose (rem)	10CFR100 Limits (rem)
Exclusion Area Boundary (0 - 2 hours)	146	300
Low Population Zone (0 - 30 days)	107	300
Control Room (0 - 30 days)	26.2	30*

_____

*Based on NUREG-0800, Section 6.4.

5.2 Identification of Conservatisms

The following conservatisms were incorporated in the SAT Deletion Analysis of Section 5.1.

1. The analysis conservatively assumed that only [   ]^{a,c} percent of the surface area of the ice baskets would be available for iodine deposition. Also, no credit was taken for the ice condenser wall areas shown in FSAR Table 14.3.6-3 as 29,500 ft^2.

2. Conservative estimates were used for the assumed surface areas below the post-LOCA flood line which were omitted from the calculations.

3. The smallest reported deposition velocity for each type of surface coating was used in determining the iodine deposition removal term.

4. The elemental iodine deposition coefficient was reduced further by a factor of [   ]^{a,c}

5. The volume term used in calculating the iodine deposition coefficient in the lower compartment includes an estimated 140,000 ft^3 which is eventually flooded.

6. A decontamination factor cutoff for particulate iodine removal was set at [100]^{a,c} in the dose calculations.

7. At a decontamination factor of [   ]^{a,c} for elemental iodine, spray removal is assumed to stop and the deposition removal rates are assumed to be reduced to [ ]^{a,c} of their original values.

8. At a decontamination factor of [   ]^{a,c} for elemental iodine, deposition removal is assumed to stop.

9. No credit is taken for iodine removal by the ice beds during the accident blowdown phase.

10. No credit is taken for removal of particulate iodine by the ice beds.

11. Credit for removal of elemental iodine by the ice beds is limited to 30% efficiency.

5.3 Control Room Air Intake Flow Limits

Additional analysis was performed to determine the upper limit for the control room air intake flow associated with the 30 rem control room dose limit. Using the parameters from Table 5-1, except for Items 18 & 19 (filtered air intake flow and control room recirculation flow) which were adjusted to obtain a control room thyroid dose of 30 rem, the limit on control room filtered air intake is 900 cfm.

The 900 cfm limit was determined using the dose conversion factors from Regulatory Guide 1.109 (Reference 6) (Item 15 on Table 5-1) which were obtained from NUREG-0172. These dose conversion factors ae based primarily on ICRP Publication No. 2.

A more recent document providing dose conversion factors is ICRP Publication No. 30 (Reference 7) which supersedes ICRP Publication No. 2. The dose conversion factors for iodine isotopes of interest are:

	R.G. 1.109	ICRP No. 30
I-131	1.49×10^6 rem/Ci	1.07×10^6 rem/Ci
I-132	1.43×10^4 rem/Ci	6.29×10^3 rem/Ci
I-133	2.69×10^5 rem/Ci	1.81×10^5 rem/Ci
I-134	3.73×10^3 rem/Ci	1.07×10^3 rem/Ci
I-135	5.60×10^4 rem/Ci	3.14×10^4 rem/Ci

Considering that ICRP Publication No. 30 was issued with the statement that it supersedes ICRP Publication No. 2, it is appropriate to use it as a basis for conservatively calculating doses. If the dose conversion factors from ICRP Publication No. 30 (Reference 7) are used, the control room filtered air intake can be as high as 1300 cfm without the thyroid dose exceeding 30 rem.

TABLE 5-1
PARAMETERS USED IN LOCA CONTAINMENT LEAKAGE DOSE ANALYSES

Parameter

1. Fraction of Core Radioiodines   50
   Initially Airborne in the
   Containment, %

2. Activity Released to Containment
   Atmosphere, Ci

   Isotope

Isotope	Activity
I-131	4.15×10^7
I-132	6.36×10^7
I-133	9.44×10^7
I-134	1.10×10^8
I-135	8.56×10^7

3. Iodine Species Split, %
   (SRP 6.5.2, Reference 1)

a.	Elemental	95.5
b.	Organic	2.0
c.	Particulate	2.5

4. Containment Volumes, ft^3

a.	Upper compartment	746,800
b.	Lower compartment	365,600
c.	Ice compartment	122,400

TABLE 5-1 (Cont)
PARAMETERS USED IN LOCA CONTAINMENT LEAKAGE DOSE ANALYSES

Parameter

5. Containment Leakage Rate,
   Vol. %/day

a.	0 - 6 min.	0.25
b.	6 - 20 min.	0.18
c.	20 min. - 24 hr.	0.25
d.	1 - 30 days	0.18

6. Recirculation Fans

a.	Number of units (Assumed Available)	1
b.	Flow rate, CFM	41,800
c.	Start delay time, min.	10

7. Iodine Removal Constants, hr^{-1}

   a. Elemental iodine
      spray (upper compartment)[a]   [ ]^{a,c}
      spray (lower compartment[a]   [ ]^{a,c}
      deposition (upper compartment)[b]   [ ]^{a,c}
      deposition (lower compartment)[b]   [ ]^{a,c}
      deposition (ice compartment)[b]   [ ]^{a,c}
   b. Organic iodine   [ ]^{a,c}
   c. Particulate iodine
      upper compartment   [ ]^{a,c}
      lower compartment   [ ]^{a,c}

8. Iodine Decontamination Factors

   a. Elemental iodine   [ ]^{a,c}
   b. Organic iodine   [ ]^{a,c}
   c. Particulate iodine   [ ]^{a,c}

TABLE 5-1 (Cont)
PARAMETERS USED IN LOCA CONTAINMENT LEAKAGE DOSE ANALYSES

<u>Parameter</u>

9. Fraction of Containment Volume
   Sprayed, %

Upper compartment	100
Lower compartment	100
Ice compartment	0

10. Ice bed removal efficiency   0.3
    for elemental iodine[c]

11. Ice bed melt-through time, min.   20

12. Atmospheric Dispersion Factors
    (χ/Q), sec/m^3

    a. Exclusion Area Boundary

0 - 2 hrs	3.15×10^{-4}

    b. Low Population Zone

0 - 24 hrs	7.5×10^{-5}
1 - 5 days	2.6×10^{-6}
5 - 30 days	7.9×10^{-7}

    c. Control Room - includes occupancy factor

0 - 8 hrs (occ. factor = 1.0)	5.97×10^{-4}
8 - 24 hrs (occ. factor = 1.0)	3.52×10^{-4}
1 - 4 days (occ. factor = 0.6)	1.34×10^{-4}
4 - 30 days (occ. factor = 0.4)	3.94×10^{-5}

TABLE 5-1 (Continued)
PARAMETERS USED IN LOCA CONTAINMENT LEAKAGE DOSE ANALYSES

Parameter

13. Breathing Rate for Off-Site Dose Determination, m^3/sec

0 - 8 hrs	3.47×10^{-4}
8 - 24 hrs	1.75×10^{-4}
1 - 30 days	2.32×10^{-4}

14. Breathing Rate for Control Room 3.47×10^{-4}
    Dose Determination, m^3/sec

15. Inhalation Dose Conversion Factors,
    rem/Ci (Reg. Guide 1.109, Reference 6)

I-131	1.49×10^6
I-132	1.43×10^4
I-133	2.69×10^5
I-134	3.73×10^3
I-135	5.6×10^4

16. Control Room Volume, ft^3 62,356

17. Control Room Unfiltered
    Inleakage, CFM   10.0

18. Control Room Filtered
    Air Intake, CFM   770

TABLE 5-1 (Cont)
PARAMETERS USED IN LOCA CONTAINMENT LEAKAGE DOSE ANALYSES

<u>Parameter</u>

19. Control Room Recirculation
    Flow, CFM
       0-10 min.   9,930
       After 10 min.   4,630

20. Control Room Intake/Recirculation
    Filtration Efficiency (0-10 min.)
    a. Elemental Iodine   0.78
    b. Organic Iodine   0.67
    c. Particulate Iodine   0.90

21. Control Room Intake/Recirculation
    Filtration Efficiency (After 10 min.)
    a. Elemental Iodine   0.95
    b. Organic Iodine   0.89
    c. Particulate Iodine   0.99

---

a. Value assumed to be zero once DF of [   ]^{a,c} is reached.

b. Value assumed to be [ ]^{a,c} of original once a DF of [   ]^{a,c} is
    reached.

c. Credit for removal of elemental iodine by the ice beds is limited to the
    time beginning when the recirculation fan starts and ending when
    melt-through of the first ice bed occurs.

6.0 EFFECTS OF REVISED CONDITIONS ON HYDROGEN GENERATION AND EQUIPMENT QUALIFICATION

6.1 Effects on Hydrogen Production from Zinc and Aluminum Corrosion

The corrosion rates of zinc and aluminum are functions of solution pH.
Deletion of the spray additive will decrease the pH of the injection spray
from approximately 9 to 5 and decrease the equilibrium pH of the sump solution
from approximately 9.3 to 8. In general, decreasing pH reduces the corrosion
of aluminum and tends to increase the corrosion of zinc. A discussion of
aluminum and zinc corrosion follows.

Aluminum Corrosion

Based on the guidance of References 8 and 9, the corrosion rate of aluminum is
seen to be a strong function of pH, with the rate decreasing with decreasing
pH. Corrosion in solutions with pH in the range of 4 to 5 is insignificant.
The corrosion rate during spray recirculation (pH > 8.0) will not be
significantly different than the rate used in the FSAR analysis. Since the
hydrogen contribution from aluminum is small, any change in the aluminum
corrosion rate will not significantly effect the aggregate hydrogen production.

Zinc Corrosion

The corrosion of zinc is a function of pH and temperature, and temperature is
by far the more influential parameter. The following equation is suggested
(Reference 10) to predict the hydrogen production rate constant, k:

$$K = \exp\left(-8.07 - 2.84x_3 - 0.229x_1x_3 - 0.177x_1x_2x_3\right)$$

where $x_1 = \dfrac{pH - 7}{3}$ for $4 \leq pH \leq 10$

$x_2 = \dfrac{ppm\ Boron - 3000}{1000}$ for 2000 ppm $\leq$ ppm Boron $\leq$ 4000 ppm

$$x_3 = [\ (1/T) -0.0027 \ ] \ / \ 0.0004$$

T = absolute temperature

and $\quad k = scm/m^2 - hr$

The following cases were evaluated:

1. Current FSAR, pH = 9.3, 2200 ppm Boron
2. SAT Deletion injection spray, pH = 5, 2200 ppm Boron
3. SAT Deletion recirculation spray, pH = 8.0, 2200 ppm Boron

The results of these cases are shown in Figure 6-1. The graph shows a small increase in the long-term corrosion rate for pH 5 versus pH 8 or 9.3. This condition would exist only if the equilibrium sump solution pH was not increased to 8. Comparing the corrosion rates for pH 9.3, and 8 shows no significant difference. Hence, with the sump solution pH raised to 8, the long term hydrogen production rate, due to zinc corrosion, will be indistinguishable from the rate presented in the FSAR for pH 9.3.

Conclusion

The deletion of the spray additive will have no net effect on the production of hydrogen from the corrosion of aluminum and zinc in the post-LOCA environment.

6.2 Equipment Qualification

Deletion of the SAT will not affect equipment qualification (EQ) and the existing EQ will be applicable to SAT Deletion.

The primary concerns of equipment qualification are protection of the stainless steel components of the emergency core cooling system (ECCS) from chloride-induced stress corrosion cracking (CISCC), failures of electrical components required to operate post-LOCA, and failures of containment coatings which could jeopardize the ECCS by flaking or peeling off, clogging the emergency sump and other flow paths, and thus restrict the flow of emergency core cooling water. A discussion of these aspects of EQ follows.

Protection of Stainless Steel

To minimize occurrence of CISCC, Standard Review Plan 6.1.1 with BTP-MTEB 6-1 (Reference 1) requires that the pH of the sump solution be in the range of 7 to 9.5. However, the time required to make the pH adjustment is not specified. The available references recommend that the pH adjustment be made within the range of 4 (Reference 11) to 48 (Reference 12) hours. The D. C. Cook pH adjusting system, using sodium tetraborate ice, will begin the adjustment immediately, and will complete the pH adjustment within 2 hours. Thus, the use of sodium tetraborate ice for pH adjustment satisfies the most stringent time and pH requirements.

Testing of Electrical Components

One of the prime objectives for electrical equipment testing is to determine the ability of the seals to exclude the containment environment from the interior of the component. To maximize the challenge to the seal materials, high pH sprays have been traditionally used for testing. The typical pH range is from approximately 8 to as high as 11.

The chemical environment for the D. C. Cook units with SAT Deletion is far less severe than the typical environment.

Testing of Containment Coatings

Coatings are used in the containment to provide corrosion protection for metals and to aid in the decontamination of surfaces during normal operation. In addition, the D. C. Cook units with SAT Deletion will utilize containment surfaces for fission product retention post-LOCA. Coatings that peel off in the short term post-LOCA may not be available for fission product deposition.

Like electrical equipment, coatings are also tested with a high pH solution to maximize the potential deterioration of the coating. Coatings also show better resistance to mild acid solutions (pH 4 to 5) than to alkaline solutions (Reference 13).

Conclusion

Deletion of the SAT from the D. C. Cook units will have no adverse effects on the qualification of safety-related equipment.

FIGURE 6-1

HYDROGEN PRODUCTION RATE CONSTANTS
FOR ZINC CORROSION

RATE CONSTANT FOR ZINC CORROSION
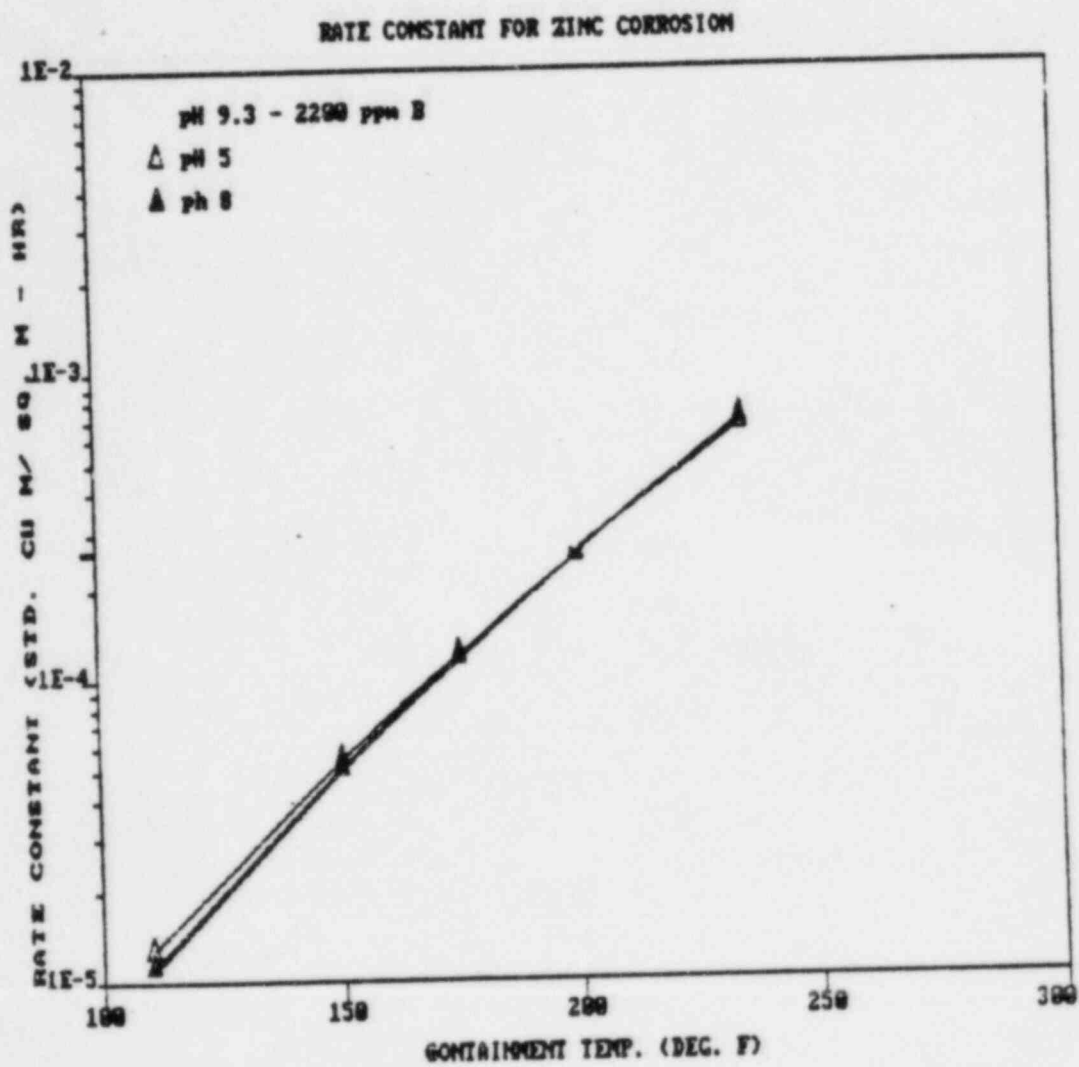
7.0 REFERENCES

1. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants", NUREG-0800.

2. "Calculation of Distance Factors for Power and Test Reactor Sites", TID-14844.

3. Final Safety Analysis Report for the Donald C. Cook Nuclear Plant, Units 1&2, updated.

4. "CIRCUS Computer Code - Calculation of Vapor Phase Elemental Iodine Removal in the Reactor Containment by Chemical Additive Spray", WCAP-8659.

5. "Technological Bases for Models of Spray Washout of Airborne Contaminants in Containment Vessels", NUREG/CR-0009.

6. "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", Regulatory Guide 1.109.

7. ICRP Publications 30, Supplement to Part 1, "Limits for Intakes of Radionuclides by Workers".

8. "Corrosion Study for Determining Hydrogen from Aluminum and Zinc During Post Accident Conditions", WCAP-8776 (Non-Proprietary).

9. "Hydrogen Releases from Corrosion of Aluminum and Zinc", BNL-NUREG-24532.

10. "The Relative Importance of Temperature, pH and Boric Acid Concentration on Rates of H_2 Production from Galvanized Steel Corrosion", NUREG-/CR-2812.

11. "Calculational Error Affecting the Design Performance of a System for Controlling pH of Containment Sump Water Following a LOCA", IE Bulletin 77-04.

7.0 REFERENCES (Cont)

12. "Chemistry Criteria and Specifications", Westinghouse Standard Information Package, Volume 5-1, (Proprietary Class 2).

13. "Evaluation of Protective Coatings for Use in Reactor Containment", WCAP-7198-L (Proprietary Class 2).

APPENDIX A
PARAMETERS AND INFORMATION USED IN D.C. COOK
SAT DELETION ANALYSIS

I. General Information

A. SAR sections (latest revision) describing the radiological consequences evaluation of a LOCA, the containment spray system, and post-LOCA hydrogen production and control.

   This information is presented in the following sections of the D.C. Cook Units 1&2 FSAR (updated):

   14.3   - Loss of Coolant Accident (LOCA)

   14.3.5 - Radiological Consequences

   6.3.1 - Containment Heat Removal Systems

   6.3.2 - Containment Spray System

   6.3.2 - Containment Air Purification and Cleanup - Iodine Removal System

   14.3.6 - Hydrogen in the Containment After a LOCA

B. Containment drawings showing the spray header and nozzle layout.

The following drawings were provided by American Electric Power in the August 27, 1985 transmittal.

1-5427-7 Unit 1 Containment Spray System Lower Spray Piping

2-5427-5 Unit 2 Containment Spray System Lower Spray Piping

1-5428-6 Unit 1 Containment Spray System RHR Spray Piping

2-5428-6 Unit 2 Containment Spray System RHR Spray Piping

II. Specific Information

The following information was obtained mainly from the D. C. Cook FSAR (updated).

A. Containment Spray System

1. Spray flow rate

Upper Containment: 2000 gal/min - page 6.3-5

Lower Containment: 900 gal/min - page 6.3-5

275 gal/min to fan rooms in the lower volume outer annulus - page 6.3-5

NOTE: These values include the 26 gal/min which is initially diverted through the eductor. Page 6.3-5.

2. Duration of spray injection phase.

Minimum of 20 minutes - Figure 14.3.5-3.

3. Time delay, if any, to begin spray recirculation.

   Page 6.2-14 of the updated FSAR shows a delay of 219 seconds (3.65 min.) until the containment spray pump is restarted.

4. Boron concentration in the refueling water.

   Unit 1: Greater than 1950 ppm Boron-Technical Specification 3.5.5.

   Unit 2: 2000 to 2200 ppm Boron-Technical Specification 3.5.5.

5. Boron concentration in the ice.

   1800 ppm (minimum) - Technical Specification 3.6.5.1.

   2150 ppm (upper-bound) - per plant personnel. Both units.

6. Spray fall height.

   Upper containment: 85 feet - Page 6.3-12

   Lower containment: 50 feet - Page 6.3-12

B. Containment

   1. Net free volume.

      From Table 14.3.1-1:

      Upper containment: 7.47E(05) cubic feet

      Lower containment: 2.49E(05) cubic feet

Dead-End: 1.16E(05) cubic feet

Ice compartment: 1.22E(05) cubic feet

Total: 1.23E(06) cubic feet

2. Fraction of volume that is sprayed.

98.7 percent - Page 14.3.5-12

3. Leak rate.

0.25 percent per 24 hours - Page 5.7-5

4. Maximum water inventory in the sump following a LOCA.

RCS: 93,960 gals (Page 14A-20)

Minimum accum: 6948 gals. Maximum: 7263 gals.

Technical specification Page 3/4 5-1.

Minimum RWST: 350,000 gals. Maximum: 420,000 gals.
FSAR Table 6.2-4

Minimum Total: 450,908 gals. Maximum: 521,223 gals.

5. Description and inventory of all surfaces (square feet), location
(above or below op. deck, submerged or above water), and type of
coating (galvanized, zinc base, epoxy, phenolic paint, etc). Include
paint manufacturer and trade name.

A containment heat sink study performed for D. C. Cook Units 1 and 2,
providing a summary of surface areas inside containment, was supplied
by American Electric Power (AEP).

In addition, conservative estimates of galvanized surfaces were provided by AEP. With the flood-up elevation of 613.5 feet, the estimates are as follows:

Conduits (1 side):   18,850 ft^2 total.
                        Assume [   ]^{a,c} of this total is submerged.

Ductwork (1 side):   15,550 ft^2 total.
                        Assume [   ]^{a,c} ft^2 of this total is
submerged.

Cable Trays (1 side):   18,777 ft^2 total.
                        Assume [   ]^{a,c} of this total is submerged.

Reference: Table 14.3.6-3, Unit 2 Updated FSAR

Coatings

Steel: Carboline 11 primer (86% Zn, 14% ethyl silicate binder)
            Phenoline 305 finish

Concrete: Carboline 195 surfacer
            Phenoline 305 concrete primer
            Phenoline 305 finish

C. Source Term

1. Core equilibrium iodine inventory.

   50 percent of the values in Table 14.1-3 will be used:

   I-131: 4.13E(07) curies

I-132: 6.33E(07) curies

I-133: 9.38E(07) curies

I-134: 10.96E(07) curies

I-135: 8.51E(07) curies

NOTE: The above values are based on a core power level of 3391 MWt. Unit 2 is licensed to 3411 MWt. The values will be adjusted accordingly.

D. Control Room

1. HVAC flow diagram and description of operation.

The control room design parameters are from a licensee event report (LER-85-007) supplied by American Electric Power.

2. Air flow rates and filter efficiencies for intake and recirculation units for post-accident operation.

Air Flow Rates

Filtered Air Intake - 770 CFM
Recirculation
   0 - 10 Min - 9930 CFM
   After 10 Min - 4630 CFM

Filter Efficiencies

	(0 - 10 Min)	(After 10 Min)
Elemental Iodine	0.78	0.95
Organic Iodine	0.67	0.89
Particulate Iodine	0.90	0.99

Supplied by AEP per 8-27-85 transmittal and via telecon.

3. Any time delays?

   A 10 minute time delay is taken to switch from two train to one train system operation per AEP 8-27-85 transmittal.

4. Free volume

   62,356 cubic feet (includes HVAC and computer room) - NS-OPLS-OPL-85

5. Location of intakes

   In Auxiliary Building wall at elevation 657 feet, 3 inches - Page 14.4.12-1.

E. Site Parameters

X/Q (sec/cubic meter)

From Table 14.3.5-5:

   At the site boundary (0-2 hrs): 3.2E-04

   At the LPZ (0-24 hrs): 7.5E-05

   (1-5 days): 2.6E-06

   (5-30 days): 7.9E-07

F. Hydrogen Production

1. Hydrogen production rate equations.

   The information presented in Figures 14.3.6-3, 14.3.6-4, and 14.3.6-7 will be used for production rates.

2. Containment temperature transient used in hydrogen analyses.
   The information presented in Figure 14.3.6-8 will be used.

3. Containment volume percent H_2 vs time.
   Figure 14.3.6-6 will be used.

4. Hydrogen accumulation vs time for aluminum corrosion and for zinc corrosion.
   Figures 14.3.6-1 and 14.3.6-2 will be used.

G. Ice Bed - Total Ice

2,371,450 pounds (minimum) - Technical Specification 4.6.5.1.