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DISCUSSION OF IODINE REMOVAL EFFICIENCIES FOR INDIAN POINT UNIT 3

On August 13, 1969, an atomic safety and licensing board rendered an initial decision ordering that a provisional construction permit be issued to Consolidated Edison Company to build the Indian Point Unit 3 nuclear power plant. Although all of the board members joined in making all of the requisite safety findings for the issuance of the provisional construction permit, two members added certain reservations as to the adequacy and sufficiency of the data in the record respecting the applicant's and the staff's estimates of the efficiencies of the proposed iodine removal system in the unlikely event of a design basis accident. These two members stated that their conclusion of adequate assurance of safety in this regard rested upon the belief that this matter could and would be resolved by the Commission; and they recommended that additional data be presented to the Commission, in advance of the consideration of an operating license for the facility, for a determination of adequate safety margins for the proposed filter-spray iodine removal system.

In a Memorandum and Order, dated December 24, 1969, the Commission requested that the staff submit the calculations underlying its proposed approach to the question of iodine removal efficiencies for the Indian Point Unit 3 plant. A discussion paper prepared by the Division of Reactor Licensing in response to that request is provided herewith.

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Commissioners

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Consolidated Edison filed its application for an operating license for Indian Point Unit 3 on December 4, 1970. A public hearing regarding the issuance of an operating license for Indian Point Unit 2, an essentially identical nuclear unit, is presently underway.

I would like to discuss this matter at an early information meeting.

(Signed) HLP

Harold L. Price
Director of Regulation

Enclosure
Discussion Paper

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DISCUSSION OF IODINE REMOVAL EFFICIENCIES
FOR INDIAN POINT NUCLEAR GENERATING UNIT 3

FOREWORD

In a Memorandum and Order, dated December 24, 1969, the Commission requested that the staff submit the calculations underlying its proposed approach to the question of iodine removal efficiencies for the Indian Point Unit 3. The following is a discussion of this topic prepared by the Division of Reactor Licensing.

I. INTRODUCTION

In evaluating the acceptability of proposed sites for nuclear power reactors and the design bases for engineered safety features, we consider the potential radiological consequences of loss-of-coolant accidents. In these evaluations, the fraction of the fission products contained in the reactor core assumed to be released from the reactor into the containment atmosphere and available for leakage from the containment to the environment is based on the calculational model suggested in TID-14844. In TID-14844 it is stated that:

"In accidents of the 'maximum credible' type, it is usually assumed that the radioactive materials . . . would be dispersed in the coolant through melting or rupture of fuel elements and then find passage to the outer containment barrier through breaches in the coolant system At the same time, a certain amount of airborne fission products would be removed by such phenomena as absorption, deposition, plate-out and steam condensation within the reactor building or containment structure."

Specifically, for the model suggested in TID-14844 it is assumed that (1) 100% of the noble gases, 50% of the halogens, and 1% of the solids in the core fission product inventory are released into the containment, and (2) 50% of the iodines that are released into the containment is adsorbed onto internal surfaces of the reactor building or adheres to internal components, and is thus not available for leakage from the containment to the environment.

For plants in which the containment is equipped with a chemical additive spray system, we also calculate the amount of the iodines that would be removed from the containment atmosphere by the spray, based on

the specific physical characteristics of the proposed system and containment. The assumption suggested in TID-14844 that 50% of the iodines released from the core is not available for leakage because of adsorption and adherence to surfaces (referred to herein as the "plateout factor") is an arbitrary assumption and not based on a detailed analysis of each plant, whereas we calculate the magnitude of the spray removal factor specifically for each plant.

In subsequent sections of this paper we discuss the general properties of iodine removal mechanisms, describe the specific model used in calculating the spray removal factor for iodines, assess the conservatism of the assumption of an instantaneous plateout factor by use of a time-dependent plateout model, discuss the interaction of spray removal and plateout mechanisms, and compare the overall iodine reduction factor calculated for the Indian Point Nuclear Generating Unit 3 using the assumed plateout factor of two with that calculated using a time-dependent plateout model.

II. SUMMARY AND CONCLUSIONS

For the Indian Point 3 reactor, both we and the applicant used the same equation to calculate the iodine removal effectiveness of the containment sprays. The differences between the calculated removal constants obtained by the applicant and by us arise because we use more conservative values for several of the parameters in the equation to allow for possible system degradation and uncertainties in

the selection of the appropriate parameters. In Section IV we discuss these differences and conclude that our calculation is sufficiently conservative that the performance of the actual system will exceed that calculated.

On the basis of our consideration of a conservative model for time-dependent plateout of iodine in the containment, we find that in the absence of sprays the airborne iodine concentration available for leakage from the containment averaged over the initial two-hour period following a design basis loss-of-coolant accident calculated using the more realistic, but still conservative, time-dependent model would be less than that obtained by applying the instantaneous plateout factor of two suggested in TID-14844.

We have considered the combination of containment sprays and the plateout process acting simultaneously as iodine removal mechanisms and find that, because of the conservatism provided in the time-dependent plateout model, even in the presence of the sprays, iodine removal by plateout should occur at a rate equal to or greater than that obtained using the instantaneous plateout assumption.

We have compared the overall iodine reduction factor for the Indian Point 3 reactor calculated using our present assumptions, including the plateout factor suggested by TID-14844, with that calculated using a time-dependent plateout model including consideration of the

competing effects of simultaneous removal by sprays. In both cases we used our calculated value for the spray removal constant. We find that the two-hour iodine reduction factor calculated by the more realistic time-dependent plateout model slightly exceeds that calculated using the instantaneous plateout model. (The two-hour removal constant is the controlling factor in determining the effect of the spray system and plateout mechanism on the calculated off-site doses for comparison with the 10 CFR 100 guidelines.)

We conclude that the calculational methods used in our safety evaluation of the potential consequences of the design basis loss-of-coolant accident for Indian Point 3 reactor are appropriately conservative.

III. IODINE REMOVAL (GENERALIZED MODEL)

The rate of depletion of the airborne iodine concentration by one or more iodine removal processes (such as sprays, filters, or plateout) is directly proportional to the residual airborne (gas phase) iodine concentration, thus

$$\frac{dc}{dt} = -\lambda c \quad [1]$$

where c = gas phase iodine concentration at time t
 t = time
 λ = iodine removal constant (proportionality constant)

The fraction of iodine remaining airborne at any time is obtained by integration of equation [1] over the time of operation. This gives

$$c = c_0 e^{-\lambda \Delta t} \quad [2]$$

where c = airborne iodine concentration at time t

c_0 = initial airborne iodine concentration

Δt = duration of operation of iodine removal process(es)

The reciprocal of the fraction remaining at any time, or the ratio of the initial to final airborne iodine concentrations, is designated as the decontamination factor (DF)

$$DF = \frac{c_0}{c} \quad [3]$$

For the purpose of calculating doses, the time-averaged mass of iodine released from the containment building with the engineered safety systems operative is used. This is obtained by integration of equation [2] over the appropriate time limits.

$$\begin{aligned} M &= Lc_0 \int_0^{\bar{t}} e^{-\lambda t} dt \\ &= \frac{Lc_0}{\lambda} [1 - e^{-\lambda \bar{t}}] \end{aligned} \quad [4]$$

where M = total mass of iodine available for leakage

\bar{t} = time of operation

L = leakage rate

The mass of iodine which would be released in the absence of a removal system is

$$\begin{aligned} M' &= Lc_0 \int_0^{\tilde{t}} dt \\ &= Lc_0 \tilde{t} \end{aligned} \quad [5]$$

The dose reduction factor (DRF) for iodine given by the engineered safety systems is the ratio of the mass of iodine that would be released in the absence of a removal system to the mass that would be released with the system operative

$$\begin{aligned} DRF &= M'/M \\ &= \lambda \tilde{t} / (1 - e^{-\lambda \tilde{t}}) \end{aligned} \quad [6]$$

The above equations for the overall decontamination factor and for the time-averaged dose reduction factors are both based on the conservative assumption of a puff release; that is, it is assumed that the mass of iodine released is present initially at its maximum concentration and is decreased by the time-dependent removal mechanisms. The effect of radiological decay is treated separately in the dose calculation.

The removal half-life for a specific mechanism is defined as that period of time required to reduce the airborne iodine concentration to one-half its initial value. The removal half-life ($t_{1/2}$) and the iodine removal constant can be related by use of equation [2], and

$$t_{1/2} = 0.693/\lambda \quad [7]$$

The formation and persistence of two relatively unremovable species of iodine has also been considered by the staff. These include (1) organic iodides and other gaseous iodine compounds (e.g., hypiodous acid) that are difficult to remove by either sprays or filters and (2) iodine attached to solid and liquid aerosols that are difficult to remove by sprays (particulates). In terms of total core inventory, 2.5% of the total iodine inventory is assumed to be in the form of gaseous unremovable species and 1.25% of the total iodine inventory is assumed to be associated with airborne particulates. These assumptions are conservative estimates derived from calculations and experimental results.* In designs where high-efficiency particulate aerosol (HEPA) filters are provided, the removal of particulate-associated iodine is assumed to proceed at the same rate as that of elemental iodine.

IV. CHEMICAL ADDITIVE SPRAY SYSTEMS

The model for iodine depletion in the containment considered in TID-14844 does not include consideration of sprays containing chemical additives, charcoal adsorbers, or similar engineered safety features. Most current reactor plants, however, do employ

* Reports BMI-1781, BMI-1816 and BMI-1829 - "Studies of Organic Iodide Formation under Nuclear Accident Conditions," BNWL-319 - "Review of McHugh Iodide Behavior in Systems Containing Airborne Radioiodine." BNWL-1187 - "Nuclear Safety Quart. Report, May-July 1969, Battelle Northwest Laboratory; ORNL-4374 - "Annual Report, Nuclear Safety Program, Oak Ridge National Lab (1968).

iodine reduction systems of these types and the staff has developed conservative analytical models for evaluation of their performance under accident conditions.

The equation used to calculate the iodine removal constant for chemical additive spray systems, developed by Griffiths*, is

$$\lambda_s = \frac{6 v_D f \rho}{V_c d} \quad [8]$$

where λ_s = iodine removal constant for spray system
 v_D = overall iodine deposition velocity into spray drop
 f = flow rate of spray
 $\rho = \frac{h}{u} = \frac{\text{fall height}}{\text{average drop velocity}} = \text{drop residence time}$
 V_c = effective containment volume
 d = drop diameter

For the Indian Point 3 reactor, both we and the applicant have based our calculations of spray effectiveness on the Griffiths model. We calculate a spray iodine removal constant of 4.9 hr^{-1} . The applicant calculates a value of 32 hr^{-1} . The differences in the calculated removal constants arise because we use more conservative values for several of the parameters in Eq [8] to allow for possible system degradation and uncertainties in the parameters used. The following

* V. Griffiths: The Removal of Iodine from the Atmosphere by Sprays
U.K. Atomic Energy Estab., AHSB(S) R45 (1963)

is a brief discussion of the differences between the values we believe appropriate for the Indian Point 3 reactor and those used by the applicant.

a. Deposition Velocity (v_D)

The different values used by the applicant and by us for this term are the result of differences in the assumed magnitude of the iodine partition factor (defined as the equilibrium ratio of the mass of iodine in a unit volume of liquid to the mass in an equal volume of air); with a consequent difference in the uptake velocity into the drop. The overall deposition velocity is given by

$$\frac{1}{v_D} = \frac{1}{v_G} + \frac{1}{k_L H} \quad [9]$$

where

v_D = overall deposition velocity

v_G = gas film deposition velocity

k_L = liquid film transfer coefficient

H = iodine partition factor

For very large values of the partition factor the second term on the right hand side of the equation becomes negligible, and the overall deposition velocity is approximately equal to the gas film deposition velocity. As the numerical value of the partition factor decreases (lower solubility) the overall deposition velocity

is decreased and the uptake velocity into the drop becomes the controlling factor (liquid film resistance).

The applicant has made the assumption that the deposition velocity (transfer velocity of iodine from the atmosphere into the liquid) is controlled solely by the relatively rapid exchange across the stagnant gas film surrounding the spray drops. This assumption is valid only if the iodine partition factor is very large.

For the specific case of a spray solution using sodium hydroxide as an additive, we have adopted a value for the partition factor of 3×10^3 , calculated from the theoretical work of Eggleton* and based on a total iodine concentration equal to a release of 25% of the core iodine inventory and a spray solution pH of 8.0 at a temperature of 100°C (212°F).

Using the above method, we have calculated an overall iodine deposition velocity of 4 cm/sec for the Indian Point 3 case, compared with a value of 7 cm/sec used by the applicant.

b. Flow Rate (f)

The evaluations by both the applicant and by us are based on the rated flow rate through only one of the two spray subsystems.

* A.E.J. Eggleton: A Theoretical Examination of Iodine - Water Partition Coefficients. U. K. Atomic Energy Agency, AERE-R-4887 (1967)

(It is assumed that the other subsystem fails, in accordance with the single failure criterion.) The applicant has used the full flow rate while we have reduced this value arbitrarily by 10% to allow for local fluid density and viscosity variations, for possible system damage, and for possible system design and/or construction faults.

c. Fall Height (h)

The applicant has used the minimum distance from the spray headers to the operating deck floor as the average free fall height for all spray drops. We have reduced this value by 15%, based on calculations considering the smaller fall height over a portion of the area caused by intrusion of the pressurizers and other equipment into the volume covered by the sprays, and also considering the decreased trajectory of those drops that strike either walls or interior surfaces.

d. Effective Containment Volume (V_c)

The uncertainties associated with this parameter are primarily those concerned with uniformity of distribution and of mixing in the gas phase. The applicant has used the entire free volume of the containment, neglecting these effects. We have used a value for containment volume which is 30% less than the numerical value used by the applicant, based on experimental results reported for the

compartmented Containment Systems Experiment (CSE) installation at the Battelle Northwest Laboratory, on the results of theoretical modeling, and on consideration of the effect of local gas phase depletion due to "channel effects" by successive drops.*

e. Drop Diameter (d)

There is a large uncertainty associated with the selection of the appropriate diameter of the spray drops because:

- (1) No measurements of drop diameters and drop size spectra have been made for the installed nozzles under simulated post-accident conditions.
- (2) Drop collision and coalescence are predicted for nearly 20% of all drops on the basis of cloud physics models, yielding both a larger effective diameter for the resultant drops and a skewed drop size distribution.
- (3) An increase in drop diameters may occur as a result of steam condensation. The effect may increase the diameter of the larger drops by from 5 to 10%.

The applicant has used a surface mean drop diameter of 1000 microns, based on an experimental size determination with water at ambient air

* BNWL-1009 "Nuclear Safety Quarterly Report, Nov. 1968-Jan. 1969," Battelle Northwest Laboratory

temperature and pressure and with a minimum pressure drop across the system of 30 lbs/sq. inch. We used a surface mean drop diameter of 1350 microns as released from the nozzle, based on data from both the Oak Ridge National Laboratory and the Battelle Northwest Laboratory that indicate that this value is more appropriate for the nozzles used,* and further modified by consideration of the above uncertainties in drop coalescence and steam condensation. Because of these combined uncertainties we used a maximum expected drop diameter of 2000 microns, or twice the value stated by the applicant.

V. IODINE REMOVAL BY PLATEOUT

A second removal mechanism for iodine in the containment is by irreversible deposition on internal surfaces ("plateout"). Molecular iodine passes from the gaseous phase directly into the solid phase without a liquid transition phase at a relatively low temperature and is therefore deposited readily on a variety of surfaces in the containment. We have reviewed the experimental and theoretical information available on the mechanism of iodine plateout, and have evaluated the factors affecting the magnitude of the reduction by plateout of the iodine released from the fuel following a loss-of-coolant accident (LOCA).

In the calculational method suggested in TID-14844, instantaneous plateout of 50% of the halogens released is assumed, so that this

* ORNL-TM-2412-Part VII: "Design Considerations of Reactor Containment Spray Systems."

fraction never becomes available for leakage. We have attempted to assess the degree of conservatism associated with this assumption by use of a time-dependent plateout model.

Iodine plateout, or transport to reactor surfaces with subsequent retention or washdown, can occur in several regions of the facility. First, iodine removal may occur in the core region, either by deposition on fuel cladding or core internals or by direct steam transport to surfaces. In this case the removal may be considered to occur instantaneously, since the fraction of iodine removed does not reach the containment. Although there is considerable evidence that some iodine retention would occur by these mechanisms, because of uncertainties as to the magnitude of these effects, we conservatively assume for purposes of this discussion that no plateout or deposition occurs in the core region. Next, iodine deposition may occur during transport from the core to the primary containment. This is very likely, since progressively cooler surfaces are encountered. However, again because of uncertainties as to the magnitude of this effect, we conservatively assume in this discussion that no plateout occurs during this phase. Finally, plateout may occur on the various surfaces in the primary containment by a time-dependent mechanism at the same time as, and in direct competition with, iodine removal by engineered safety systems. It is only this final stage of iodine plateout that is considered here.

The results of considerable experimental and theoretical work concerning the plateout of iodine under LOCA conditions have been published. Plateout occurs in the primary containment under conditions which, in general, are amenable to experimental investigation. Reasonably accurate estimates of its magnitude and time dependence are possible. From these data, extrapolation of the experimental results to conditions not specifically covered by these experiments (for example, to systems where the effects of plateout and spray removal are combined) is possible.

The principal experimental work on iodine plateout and deposition under simulated reactor accident conditions can be divided into three types:

- (1) Small-scale laboratory tests have been performed on a large number of different types of materials and on various surface coatings at the Battelle Memorial Institute and summarized in Reports BMI-1863 (Fission Product Deposition on Primary Surfaces), BMI-1865 (Fission Product Deposition on Containment System Surfaces) and BMI-1874 (Development of Reactive Coatings).
- (2) Applied engineering tests have been conducted in the Containment Research Installation (CRI) at the Oak Ridge National Laboratory and at the Contamination-Decontamination Experiment (CDE) facility at Idaho Nuclear Corporation. The CRI is a fission product release and containment facility. The containment volume is approximately 135 ft³ and is capable of being fitted with liners of various materials. Results are reported in the publications of the ORNL.

Nuclear Safety Program. The CDE facility is designed to study the transport and plateout of fission products released from melted fuel in an 86 ft³ vessel under saturated steam conditions. Initial results were reported in IN-1172 (Fission Product Behavior Under Simulated Loss-of-Coolant Accident Conditions).

- (3) Relatively large-scale experiments have been performed at the Containment Systems Experiment (CSE) facility at the Battelle Northwest Laboratory. The results are summarized in Report BNWL-943 (Fission Product Transport by Natural Processes in Containment Vessels). The CSE system has a volume of greater than 20,000 ft³. The containment atmosphere, surfaces and convection patterns of reactor containments can be simulated.

Most experiments in which plateout from either an air atmosphere or a saturated steam-air atmosphere (all in the absence of sprays) was investigated yielded values of the initial iodine plateout half-life in the range from 2 to 15 minutes. For a variety of release conditions in comparison tests at the Battelle Northwest Laboratory, plateout half-lives ranging from about 3 to 15 minutes were observed, with the longer times for extremely large iodine concentrations. In meltdown experiments in the CDE an initial iodine plateout half-life of eight minutes was reported. Extrapolation of these results to a large PWR with a different ratio of surface area to volume yields anticipated iodine plateout half-lives ranging from 10 to 20 minutes if only the area of the outer walls is considered.

available for deposition, and much shorter half-lives if all the available surface area is included (e.g., steam generators and other equipment, piping, compartment walls, and floor surfaces).

The actual rate of deposition of iodine on containment surfaces depends on a number of variables, including the containment geometry, the nature of specific containment surfaces, the containment atmosphere from which deposition occurs, the specific driving forces (e.g., temperature and concentration gradients, and steam flux), and the gas phase halogen concentration.

The overall plateout phenomenon can be divided into two successive processes: (1) transport to surfaces and (2) adsorption on surfaces. As stated above, the staff analysis conservatively assumed that plateout only occurs on the inside surface of the primary containment. It was further assumed that transport to surfaces occurs only by a natural convection process and the large additional transport driving force that would be provided by the flow of steam to the colder surfaces of the containment building was neglected.* This transport by flowing steam would be expected to account for a major portion of the iodine transfer to surfaces under actual post-LOCA conditions, adding further conservatism to the staff model.

* The calculational model used by the staff is closely analogous to that used in BNWL-943 "Fission Product Transport by Natural Processes in Containment Vessels."

The adsorption process in the primary containment building has been evaluated as a function of both surface temperatures and type of material. The iodine deposition rates used for the containment surfaces are conservatively chosen as representative values for specific materials, maximum expected air temperatures, and airborne iodine concentrations typical of those expected in the containment following a LOCA.*

For the large containment volumes typical of modern PWR plants, we have calculated that the removal half-life by plateout is 10 to 20 minutes. This value should be considered as an upper limit because of the various factors of conservatism introduced, and a more realistic evaluation model involving steam transport and rapid removal probably would yield a plateout half-life of two minutes or less. For the time-dependent plateout model described above, the airborne iodine concentration available for leakage averaged over the initial two-hour period following a LOCA is less than that which is obtained by applying the assumption of an instantaneous plateout factor of two suggested in TID-14844. For the initial two hour period, our calculation of the time-averaged reduction in iodine available for leakage achieved by plateout alone, using appropriately conservative parameters, yields a time-averaged reduction factor which varies from about four to six for typical large containments. This value varies in proportion to the

* Experimental investigations studying the plateout behavior of iodine on surfaces under laboratory conditions have been completed at both Idaho Nuclear Corporation and at the Battelle Memorial Institute (BMI-1865).

containment surface to volume ratio. The corresponding iodine decontamination factors (defined in Section III) due to a plateout effect of this magnitude range from 10 to 100 for the initial two-hour period following a release. The total reduction of airborne iodine possible by plateout is limited to decontamination factors of about 100 because the available surfaces become saturated with iodine.

VI. COMBINED IODINE REMOVAL PROCESSES

For cases in which two or more iodine removal processes are operating simultaneously, two questions arise: (1) Does the action of any mechanism affect the others so as to alter any of the assumptions used in estimating the magnitude of the individual processes operating independently? (2) What is the overall combined effect on iodine reduction of two or more removal mechanisms operating simultaneously?

We have considered the specific case of the interaction of sprays and plateout in terms of overall iodine removal. In terms of the effect of the sprays on plateout, the sprays may decrease the flow of steam to surfaces by increasing condensation but would also increase the turbulent (convective) flow and mixing characteristics within the containment. However, in the evaluation of the conservatism of the plateout assumption (see Section V), the contribution of steam transport already has been neglected completely and the treatment of convective flow does not include the effect of turbulence induced by the sprays.

Therefore, the rate of iodine transport to surfaces calculated by the techniques described in Section V should always be smaller than the actual value, even during a period when containment sprays are in operation. Iodine removal from the gas phase by plateout is therefore expected to occur at a rate equal to or greater than the values given in Section V.

Adsorption of iodine on surfaces is generally enhanced by addition of a water film. For surfaces wetted by chemical additive sprays, the reduction of liquid film resistance would further increase the uptake and transport velocity to the surface of the material. Therefore, deposition rates for iodine on surfaces wetted by spray would be expected to be larger than for the corresponding surface either dry or wetted only by steam condensation.

Finally, the combined effect of several iodine removal processes operating simultaneously is considered. If each of these removal processes can be considered independent, and the rate only a function of the gas phase iodine concentration, then

$$\frac{dc}{dt} = -c \sum_i \lambda_i \quad [10]$$

where λ_i = iodine removal constant for mechanism i

and the overall iodine removal constant is equal to the summation of the several constants. This is applicable only to a well-mixed atmosphere, such as would be expected in the containment following a LOCA.

The fraction of iodine removed from the gas phase by each different mechanism is proportional to its removal (rate) constant, and the total iodine reduction for two or more simultaneous processes is always greater than that obtained by one mechanism alone. When the rate constants for both plateout and spray removal are of comparable magnitude, the plateout process will actually remove half or more of the gas phase iodine. On the other hand, when the spray removal constant becomes very much larger than the plateout deposition constant, nearly all of the gas phase iodine reduction is due to the sprays alone and very little is due to plateout. A comparison can be made of the overall effect of two different combined mechanisms based on the overall iodine reduction factors achieved over a specified time period. On this basis, we have compared the effect of

- (1) A time-dependent plateout mechanism, in conjunction with sprays, operating on the total release fraction specified in TID-14844 (50% halogens) with
- (2) An instantaneous plateout factor of two, in conjunction with the identical spray system, and operating on the same initial release.

The comparison for the Indian Point 3 reactor, applying the data we used specifically for this unit, is given in Section VII (following).

When the spray removal constant becomes very large ($\lambda_s > 15 \text{ hrs}^{-1}$), as in the model proposed by the applicant for the Indian Point 3 reactor, the contribution of the plateout effect to overall iodine removal is very small. Therefore, if a very large spray removal constant were to be assumed, then it would be appropriate to neglect the plateout and calculate the total iodine reduction factor on the basis of spray removal alone operating on the entire halogen release fraction.

VII. COMPARISON EXAMPLES

In the following two examples we compare the overall iodine reduction factor for the Indian Point 3 reactor calculated using our present assumptions, including the plateout factor suggested by TID-14844, with that calculated by applying a time-dependent plateout model. In both cases, the spray removal constant used is that calculated by the model discussed in Section IV above. The two-hour iodine reduction factor calculated using the more realistic time-dependent plateout model slightly exceeds that calculated using the TID-14844 model for instantaneous plateout. Therefore, for the Indian Point 3 case, the currently assumed model of instantaneous plateout of 50% of the airborne iodine concentration represents the more conservative model, especially in view of the conservative assumptions used in deriving

the removal constant for time-dependent plateout. Both examples assume an instantaneous puff release and operation of the spray system over the entire time period.

A. Current Model Used for Site Evaluation Purposes for Indian Point 3

Assumptions:

1. 50% of core iodine inventory is released (TID-14844).
2. 50% of the released iodine is removed instantaneously by plateout (TID-14844).
3. 25% of the core iodine inventory is initially available in airborne form in the containment.
4. 10% of this initial airborne iodine concentration is in the form of organic iodides that are not removed by the sprays (2.5% of core inventory).
5. The chemical additive spray system reduces the removable iodine fractions (22.5% of core iodine inventory) with a removal constant $\lambda_s = 4.9 \text{ hr}^{-1}$.

Results:

1. The time-averaged gas phase (airborne) iodine concentration, including both removable and nonremovable iodine species, for the initial two-hour period is 4.8% of the entire core inventory, and the two-hour iodine reduction factor is 5.2.

2. The two-hour decontamination factor (ratio of initial to final iodine concentration) is 10, with the residual iodine concentration consisting essentially of the unremovable fraction:

B. Model Using Finite Plateout Time

Assumptions:

1. 50% of core iodine inventory is released (TID-14844).
2. The airborne iodine is removed by plateout with a half-life of 10 minutes (removal constant $\lambda_p = 4.3 \text{ hrs}^{-1}$) for a duration of 30 minutes.*
3. 5% of the initial airborne iodine concentration is in the form of nonremovable species (2.5% of core iodine inventory and the same total quantity as in example above).
4. The chemical additive spray system reduces the removable fraction simultaneously with plateout, with a removal constant $\lambda_s = 4.9 \text{ hr}^{-1}$.

Results:

1. The time-averaged gas phase (airborne) iodine concentration, including both removable and nonremovable iodine species, for the initial two-hour period is 4.5% of the entire core inventory. The two-hour iodine reduction factor is 5.5, based on 25% of the core inventory.

* After 30 minutes, the saturation of available surfaces is assumed to limit further plateout (see p. 19 above).

2. The two-hour decontamination factor is 10, with the residual iodine concentration consisting essentially of the unremovable fraction.