COMMONWEALTH EDISON COMPANY
CALCULATION TITLE PAGE

CALCULATION NO. BYR97-023 PAGE NO.: 1

__X__ SAFETY RELATED ____ REGULATORY RELATED ____ NON-SAFETY RELATED

CALCULATION TITLE:

Determination of RCS Dose Equivalent Iodine-131 Release Rate and Spike Factor Based on Plant Trip Data

STATION/UNIT: Byron 1 SYSTEM ABBREVIATION: RC

EQUIPMENT NO.: (IF APPL.) PROJECT NO.: (IF APPL.)

N/A

REV: 0 STATUS: Approved CHRON NO. N/A DATE: N/A

PREPARED BY: [signature] /M. Marchionda - R.P. DATE: 1-23-97
[signature] / J. Smith - SSE-Prog. 1/23-97

REVISION SUMMARY:

Original issue.

ELECTRONIC CALCULATION DATA FILES REVISED:
(Name ext/size/date/hour: min/verification method/remarks)

```
BYR97023.mcd    18425 bytes 01/23/97 8:34:18 PM Matchcad Version 5.0
IODIN075.xls    50176 bytes 01/23/97 8:51:06 PM Excel Version 5.0
```

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION? ____ YES __X__ NO

REVIEWED BY: [signature] / D. Palmer - R.P. DATE: 1-24-97
/ G. Lahti - NFS

REVIEW METHOD: Detailed review of the original calculation. COMMENTS (C, NC OR CI): ___

APPROVED BY: [signature] / Paul R. Donavin DATE: 1/24/97

9707150275 970703
PDR ADOCK 05000454
P PDR

Exhibit C
NEP-12-02
Revision 4

COMMONWEALTH EDISON COMPANY
CALCULATION TITLE PAGE

CALCULATION NO. BYR97-023 PAGE NO.: 1

__X__ SAFETY RELATED ______ REGULATORY RELATED ______ NON-SAFETY RELATED

CALCULATION TITLE:

Determination of RCS Dose Equivalent Iodine-131 Release Rate and Spike Factor Based on Plant Trip Data

STATION/UNIT: Byron 1 SYSTEM ABBREVIATION: RC

EQUIPMENT NO.: (IF APPL.) PROJECT NO.: (IF APPL.)

N/A

REV: 0 STATUS: Approved CHRON NO. N/A DATE: N/A

PREPARED BY: [signature] /M. Marchionda - R.P. DATE 1-23-97
[signature] / J. Smith - SSE-Prog. 1/23/97

REVISION SUMMARY:

Original issue.

ELECTRONIC CALCULATION DATA FILES REVISED:
(Name ext/size/date/hour: min/verification method/remarks)

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION? ____ YES __X__ NO

REVIEWED BY: [signature] / D. Palmer - R.P. DATE: 1-24-97
[signature] / G. Lanti - NFS 23 Jan 97

REVIEW METHOD: Detailed review of the original calculation. COMMENTS (C, NC OR CI). ____

APPROVED BY: ____________ / ____________ DATE: ____________

COMMONWEALTH EDISON COMPANY
CALCULATION REVISION PAGE

CALCULATION NO. BYR97-023 PAGE NO.: 2

REV: STATUS: CHRON NO. DATE: ________

PREPARED BY: ________________________ DATE: ________

REVISION SUMMARY:

ELECTRONIC CALCULATION DATA FILES REVISED: None
(Name ext/size/date/hour: min/verification method/remarks)

DO ANY ASSUMPTIONS IN THIS CALCULATION REQUIRE LATER VERIFICATION
☐ YES ☐ NO

REVIEWED BY: ________________________ DATE: ______

REVIEW METHOD: Detailed review of original calculation. COMMENTS (C, NC OR CI): ____

APPROVED BY: ________________________ DATE: ______

COMMONWEALTH EDISON COMPANY
CALCULATION TABLE OF CONTENTS

	PROJECT NO. N/A	
CALCULATION NO. **BYR97-023**	REV. NO. 0	PAGE NO. 3
DESCRIPTION	PAGE NO.	SUB-PAGE NO.

PURPOSE/OBJECTIVE:

The purpose of this calculation is to determine the Reactor Coolant System (RCS) Dose Equivalent Iodine-131 (DE I-131) release rates and the iodine spike factors for Byron Units 1 and 2 based on plant reactor trip data. The results of the calculation will be used to support the Byron Unit 1 Cycle 8 Technical Specification Amendment Request (TSAR) to reduce the RCS iodine concentration to 0.2 μCi/gm.

METHODOLOGY AND ACCEPTANCE CRITERIA:

The methodology outlined in the paper presented by Adams and Atwood (Ref. 1) will be used to calculate the pre-trip and post-trip RCS DE I-131 release rates. The RCS DE I-131 activity data utilized in the calculation is taken from previous Byron Units 1 and 2 reactor trips. The concurrent iodine spike factor is calculated as the ratio of the post-trip DE I-131 release rate to the pre-trip DE I-131 release rate. The accident initiated DE I-131 release rate based on the NRC Standard Review Plan (SRP) methodology will be calculated and compared to the plant data.

The purpose of this calculation is to evaluate the DE I-131 release rate based on actual plant data. No acceptance criteria is required. However, since the Byron site allowable primary to secondary leak rate limit was calculated based on the SRP methodology (Ref. 6 and Ref. 8), the DE I-131 release rate ratio based on plant trip data should be below the release rate determined by the SRP methodology (500). For iodine release rate spiking factors higher than 500, values up to 12,000 are acceptable per Ref. 1 and justification for acceptance will be included the Tech Spec Amendment Request discussed above.

ASSUMPTIONS:

1) The purification system decontamination factor (DF) is assumed to be 99 (99% removal efficiency) as recommended in Ref. 1. Even though the DF is specified in B/B UFSAR 9.3.4.1.2.5 as a minimum factor of 10 (90% removal efficiency), using a higher DF is conservative since it will result in higher DE-131 release rates.

2) The CVCS letdown flow (purification system flow) is assumed to be the minimum operating flow of 75 gpm (Ref. 7) for both the pre-trip and post-trip conditions. An assumed letdown flowrate is necessary due to the absence of historical data. A sensitivity study evaluating the impact of CVCS letdown flow on iodine release rates and spiking factor was performed and documented in Attachment C. The spiking factors associated with the minimum normal operating letdown flow (75 gpm) resulted in more conservative (higher) iodine spiking factors.

COMMONWEALTH EDISON COMPANY

The use of a 75 gpm letdown flow allows comparison to the NRC SRP methodology results, which also assumed a 75 gpm letdown flow. Therefore, a CVCS letdown flowrate of 75 gpm is assumed.

3) The effect of boron on the RCS density was assumed to be negligible since the boron mass is less than 1% of the total RCS mass at the beginning of core life.

DESIGN INPUTS

1) The total volume of the RCS is 12,062 ft^3. (Ref. 2)

2) The full power RCS temperature and pressure are 586.2 °F and 2250 psia. (Ref. 2 and 3)

3) The RCS specific volume at full power is 0.02258 ft^3/lbm. (Ref. 4 and Assumption 3)

4) The decay constant for iodine-131 is 3.59×10^{-3} /hr. (Ref. 5)

5) The Purification System Specific volume at 370 psia and 110 °F is 0.01615 ft^3/lb. (Ref. 4, Ref. 5 and Assumption 3)

REFERENCES:

1) "The Iodine Spike Release Rate During a Steam Generator Tube Rupture", James P. Adams and Corwin L. Atwood. Nuclear Technology Vol. 94, June 1994.

2) B/B UFSAR Table 11.1-1, Rev. 0.

3) B/B UFSAR Table 5.1-1, Rev. 6

4) ASME Steam Table, Fifth Edition

5) Byron Operating Procedures BOP CV-17, Rev. 7 and BOP CV-9, Rev. 2.

6) "Radiological Consequences of Main Steam Line Failures Outside Containment of a PWR", NRC Standard Review Plan (SRP) 15.1.5 Appendix A, Rev. 2, July, 1981.

7) B/B UFSAR Table 9.3-2, Rev. 0.

8) ComEd Calculation, ATD-0410, "Allowable Leakrate Calculation for Steam Generator Interim Plugging Criteria", Revision 0, July 31, 1994.

9) NDIT BYR97-068

10) Byron Letter 97-5022, "Applicability of Reactor Trip Iodine Concentration Data to Support Reduced Iodine Technical Specification Change", dated 1/23/97.

CALCULATIONS:

The calculations are contained in Attachment A.

COMMONWEALTH EDISON COMPANY

SUMMARY AND CONCLUSIONS:

Based on Byron Unit 1 and 2 reactor trip data, the steady state and post-trip iodine-131 release rate and iodine spike factor were calculated and summarized below:

Event	Pre-Trip Iodine Concentration (μCi/gm)	Post-Trip Concentration (μCi/gm)	Steady State Release Rate (Ci/hr)	Post-Trip Maximum Release Rate (Ci/hr)	Iodine Spike Factor
1	2.00E-2	1.40E-1	3.52E-1	5.24E+1	149.0
2	2.90E-2	2.90E-1	5.10E-1	1.10E+2	215.5
3	3.00E-3	6.90E-3	5.28E-2	2.35E+0	44.6
4	1.60E-2	3.30E-1	2.81E-1	1.27E+2	451.3
5	6.70E-3	8.00E-2	1.18E-1	3.04E+1	258.6
6	4.51E-4	3.48E-4	7.93E-3	8.50E-2	10.7
7	4.00E-2	2.60E-1	7.04E-1	9.69E+1	137.8
8	3.20E-2	1.90E-1	5.63E-1	7.05E+1	125.4
9	1.20E-2	3.30E-1	2.11E-1	1.27E+2	603.9
10	4.10E-3	6.80E-2	7.21E-2	2.61E+1	361.7
11	7.25E-4	4.70E-4	1.28E-2	1.02E-1	8.0
12	4.70E-4	4.20E-4	8.27E-3	1.11E-1	13.4

The event initiated maximum RCS iodine-131 release rates are lower that that predicted by the SRP methodology (8797 Ci/hr). The largest release rate calculated for Events 4 and 9 is 127 Ci/hr, which is significantly below the NRC SRP calculated value of 8,797 Ci/hr.

All events, with the exception of Event 9, had iodine release rate spiking factors less than the assumed SRP value of 500. Event 9 had a spiking factor of 603.9. Event 9 occurred in Byron Unit 2 Cycle 1 with failed fuel and a very low steady state release rate, which tends to inflate the spiking ratio.

ATTACHMENT A
CALCULATIONS

Variable and Constant Definitions

Ro Pre-trip Steady State Release Rate [Ci/hr]
R Post-trip Steady State Release Rate [Ci/hr]
Rm Maximum post-Trip Iodine Release Rate [Ci/hr]
L_t Total Iodine Removal Rate [1/hr]
L_d Iodine-131 Decay constant [1/hr]
L_p Purification removal constant [1/hr]
Ao Steady State RCS Iodine Inventory [Ci]
Am Maximum Transient RCS Iodine Inventory [Ci]
S Iodine Release Rate Spike Factor
Co Pre-trip DE I-131 Concentration [μCi/gm]
C Post-trip DE I-131 Concentration [μCi/gm]
F Purification System (CVCS Letdown) Flow Rate [gpm]
P Purification System (CVCS Letdown) Flow Rate[kg/hr]
DF Purification System Decontamination Factor
M RCS Mass Inventory [kg]
V RCS Volume [ft^3]
ν RCS Specific Volume [ft^3/lb]
ν_p Purification System Specific Volume [ft^3/lb]

Define units of Curie and microCurie

$$Ci \equiv 1$$

$$\mu Ci \equiv Ci \cdot 10^{-6} \qquad \mu Ci = 1 \cdot 10^{-6} \cdot Ci$$

Calculate RCS Mass Inventory, M

Volume of RCS: $V \equiv 12062 \cdot ft^3$ (Design Input 1)

Specific Volume of RCS: $\nu \equiv 0.02258 \cdot \frac{ft^3}{lb}$ (Design Input 3)

Mass of RCS: $M \quad \frac{V}{v}$ (1 lb = 0.4536 kg)

$M = 2.423 \cdot 10^5 \cdot kg$

Calculate Purification Flowrate, P, Decontamination Factor, DF

Purif. Sys. Spec. Vol: $v_p \quad 0.01615 \cdot \frac{ft^3}{lb}$ (Design Input 5)

Purif. Sys. Flow: $F \quad 75 \cdot \frac{gal}{min}$ (Assumption 2)

$P \quad \frac{F}{v_p}$ (1 ft3 = 7.4805 gal)
(1 lb = 0.4536 kg)
(1 hr = 60 min)

$P = 1.69 \cdot 10^4 \cdot \frac{kg}{hr}$

Decon. Factor: DF 99 (Assumption 1)

Byron Reactor Trip Data

This calculation evaluates the data from 12 reactor trip events at Byron listed in Attachment B. Each event is individually evaluated and designated by i, as follows:

$i := 1..12$

(Ref. 9)
(Ref. 10)

Co_i	C_i
$2.00 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$1.40 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$2.90 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$2.90 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$3.00 \cdot 10^{-3} \cdot \frac{\mu Ci}{gm}$	$6.90 \cdot 10^{-3} \cdot \frac{\mu Ci}{gm}$
$1.60 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$3.30 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$6.70 \cdot 10^{-3} \cdot \frac{\mu Ci}{gm}$	$8.00 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$
$4.51 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$	$3.48 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$
$4.00 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$2.60 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$3.20 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$1.90 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$1.20 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$	$3.30 \cdot 10^{-1} \cdot \frac{\mu Ci}{gm}$
$4.10 \cdot 10^{-3} \cdot \frac{\mu Ci}{gm}$	$6.80 \cdot 10^{-2} \cdot \frac{\mu Ci}{gm}$
$7.25 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$	$4.70 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$
$4.70 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$	$4.20 \cdot 10^{-4} \cdot \frac{\mu Ci}{gm}$

I. Calculate the Pre-trip Steady State Release Rate, Ro

$Ro = L_t * Ao$ (Equation 3 of Ref. 1)

Where: $Ao = M * Co$

$Ro = L_t * M * Co$

Where: $L_t = L_d + L_p$ (Ref. 1)

$L_d \quad 3.59 \cdot 10^{3} \cdot hr^{1}$ (Design Input 4)

$$L_p \quad \frac{P \cdot \left(1 - \frac{1}{DF}\right)}{M}$$ (Ref. 1)

$L_p = 0.069 \cdot hr^{1}$

$L_t \quad L_d \quad L_p$

$L_t = 0.073 \cdot hr^{1}$

$Ro_i \quad L_t \cdot M \cdot Co_i$

See Table A.1 for results of this calculation of Ro_i for each reactor trip event.

II. Calculate Maximum Post-trip DE I-131 Release Rate, Rm

$R = [L_t * (A - Ao*exp(-L_t*t)] / [1-exp(-L_t*t)]$ (Equation 1 of Ref. 1)

The post-trip maximum transient RCS inventory, A, is calculated based on 3 times the maximum post-trip RCS DE I-131 activity, in accordance with Ref. 1.

$A = 3 * C_i * M$ and $Ao = Co * M$ (Ref. 1)

Therefore, the maximum post-trip DE I-131 release rate, Rm, is defined as:

$Rm = [L_t * (3*C_i*M - Co*M*exp(-L_t*t)] / [1-exp(-L_t*t)]$

The values for Lt, Ci, and M are defined in Section I, above.

Assume 2 hrs. from iodine spike initiating event to maximum iodine concentration:

$t = 2 \cdot hr$ (Ref. 1)

$$Rm_i = \frac{L_t \cdot \left(3 \cdot C_i \cdot M - Co_i \cdot M \cdot \exp\left(-L_t \cdot t\right)\right)}{1 - \exp\left(-L_t \cdot t\right)}$$

See Table A.1 for the results of this calculation of Rm_i for each reactor trip event.

III. Calculate Iodine Spike Factor, S

The concurrent iodine spike factor, S, is defined as the ratio of the post-trip release rate (Rm) to the pre-trip release rate (Ro).

$$S_i = \frac{Rm_i}{Ro_i}$$

See Table A.1 for the results of this calculation of S_i for each reactor trip event.

IV. Calculate Iodine Release Rate, Rs, Using SRP Methodology

Steady State RCS DE I-131 Concentration: $Cs \quad 1.0 \cdot \frac{\mu Ci}{gm}$

Calculate steady state DE I-131 activity, As:

$$As \quad Cs \cdot M$$

$$As = 2.423 \cdot 10^{8} \cdot \mu Ci$$

Calculate steady state DE I-131 release rate, Rs:

$Rs = L_t * As$ (Ref. 6)

Where : $L_t = 0.073 \cdot hr^{1}$ (Section I)

$$Rs \quad L_t \cdot As$$

$$Rs = 1.759 \cdot 10^{7} \cdot \frac{\mu Ci}{hr}$$

Per SRP, Ref. 6, an accident initiated spike factor of 500 times is used to calculate the post accident RCS DE I-131 release rate, Rsa:

$Rsa \quad Rs \cdot 500$ (Ref. 6)

$$Rsa = 8.797 \cdot 10^{3} \cdot \frac{Ci}{hr}$$

This is larger than all of the post-accident release rates calculated in Sections I and II above.

TABLE A.1

Ro_i $\frac{Ci}{hr}$	Rm_i $\frac{Ci}{hr}$	S_i
0.352	52.417	148.955
0.51	109.977	215.535
0.053	2.357	44.647
0.282	127.06	451.339
0.118	30.485	258.597
0.008	0.085	10.727
0.704	97.024	137.859
0.563	70.59	125.375
0.211	127.51	603.918
0.072	26.092	361.686
0.013	0.102	7.99
0.008	0.111	13.435

ATTACHMENT B
BYRON REACTOR TRIP DATA

Event	Unit	Cycle	Trip Date	Trip Time	Power at Trip	Co - Pre Trip Iodine (uCi/gm) (Ref. 9)	C - Post Trip Iodine (uCi/gm) (Ref. 9)	Post Trip Iodine (date/time)	Failed Fuel (Y/N)
1	1	1	1/29/86	0:06	98%	2.00E-02	1.40E-01	1/29/86 3:45	Y
2	1	1	9/30/86	9:11	93%	2.90E-02	2.90E-01	9/30/86 11:35	Y
3	1	2	7/29/87	22:11	98%	3.00E-03	6.90E-03	7/30/87 1:10	Y
4	1	2	7/16/88	4:31	98%	1.60E-02	3.30E-01	7/16/88 7:30	Y
5	1	3	1/31/89	9:56	99%	6.70E-03	8.00E-02	1/31/89 12:00	Y
6	1	8	9/11/96	0:17	96.5%	4.51E-04	3.48E-04	9/11/96 2:30	N
7	2	1	7/14/87	18:15	98%	4.00E-02	2.60E-01	7/15/87 0:15	Y
8	2	1	7/25/87	12:16	98%	3.20E-02	1.90E-01	7/25/87 14:15	Y
9	2	1	2/12/88	18:04	94%	1.20E-02	3.30E-01	2/12/88 20:50	Y
10	2	1	12/15/88	10:02	40%	4.10E-03	6.80E-02	12/15/88 12:45	Y
11	2	5	9/24/94	10:12	100%	7.25E-04	4.70E-04	9/24/94 12:20	N
12	2	6	5/23/96	8:04	98%	4.70E-04	4.20E-04	5/23/96 10:20	N

Event	Unit	Cycle	Trip Date	Trip Time	Power at Trip	C0 Pre Trip Iodine (uCi/gm) (Ref. 9)	C1 Post Trip Iodine (uCi/gm) (Ref. 9)	Post Trip Iodine (date/time)	Failed Fuel (Y/N)
1	1	1	1/29/86	0:06	98%	2.00E-02	1.40E-01	1/29/86 3:45	Y
2	1	1	9/30/86	9:11	93%	2.90E-02	2.90E-01	9/30/86 11:35	Y
3	1	2	7/29/87	22:11	98%	3.00E-03	6.90E-03	7/30/87 1:10	Y
4	1	2	7/16/88	4:31	98%	1.60E-02	3.30E-01	7/16/88 7:30	Y
5	1	3	1/31/89	9:56	99%	6.70E-03	8.00E-02	1/31/89 12:00	Y
6	1	8	9/11/96	0:17	96.5%	4.51E-04	3.48E-04	9/11/96 2:30	N
7	2	1	7/14/87	18:15	98%	4.00E-02	2.60E-01	7/15/37 0:15	N
8	2	1	7/25/87	12:16	98%	3.20E-02	1.90E-01	7/25/87 14:15	Y
9	2	1	2/12/88	18:04	94%	1.20E-02	3.30E-01	2/12/88 20:50	Y
10	2	1	12/15/88	10:02	40%	4.10E-03	6.80E-02	12/15/38 12:45	Y
11	2	5	9/24/94	10:12	100%	7.25E-04	4.70E-04	9/24/94 12:20	N
12	2	6	5/23/96	8:04	98%	4.70E-04	4.20E-04	5/23/96 10:20	N

COMMONWEALTH EDISON COMPANY

ATTACHMENT C
CVCS LETDOWN FLOW SENSITIVITY EVALUATION

Purpose and Approach:

The purpose of this sensitivity study is to evaluate the impact of CVCS Letdown flowrate variations on the pre-trip iodine release rate, post-trip iodine release rate, and the release rate spiking factor. The sensitivity study compares the release rate and spiking factor using the minimum and maximum normal operating CVCS letdown flowrate, 75 gpm and 120 gpm, respectively. The purpose of the study is to support Assumption 2.

Methodology and Acceptance Criteria:

The methodology of Attachment C is consistent with Attachment A with the same design inputs and variables. The spreadsheet has no acceptance criteria, but also serves as a validation to Attachment A. The header of the spreadsheet is labelled according to the letdown flowrate.

Assumptions:

All assumptions and design inputs are consistent with those previously stated except letdown flowrate was varied from 75 gpm to 120 gpm.

All twenty eight reactor trip events documented in reference 9 were included in the study. Sample ID's 2, 3, 4, 8, 10, 15, 17, 18, 19, 22, 27, and 28 correspond to events 1 through 12 which were used in Attachment A.

Summary and Conclusions:

Table C-1 summarizes the data for all 28 reactor trip events. Table C-2 documents the pre-trip steady state iodine release rate, post-trip iodine release rate, and spike factor using 75 gpm letdown flowrate. Table C-3 documents the equations used in Table C-2. Table C-4 documents the pre-trip steady state iodine release rate, post-trip iodine release rate, and spike factor using 120 gpm letdown flowrate. Table C-5 documents the equations used in Table C-4.

The effect of letdown flow on pre-trip and post-trip release rate is minimal as illustrated by comparing to the SRP calculated release rate in Attachment A. The SRP methodology calculated a release rate of 8797 Ci/hr. The maximum post trip release rate at 75 gpm letdown is 127 Ci/hr. The maximum

COMMONWEALTH EDISON CCMPANY

post trip release rate at 120 gpm is 132 Ci/hr. The margin to the release rate methodology (8797 Ci/hr) is significant in both cases. By increasing the total removal rate of I-131 (e.g. increasing letdown from 75 gpm to 120 gpm), the ratio of the pre-trip release rates is more greatly affected thant the ratio of the post-trip release rates. In other words, the pre-trip number increases at a higher rate than the post-trip numbers.

Since the pre-trip iodine release rate is the denominator of the spike factor, the minimum letdown flowrate yields the higher iodine spike factor. Using 75 gpm letdown flowrate, the spike factor is higher in every event. For this reason, using 75 gpm is a conservative assumption.

TABLE C-1

Event	Unit	Cycle	Trip Date	Trip Time	Power at Trip	Pre Trip Iodine (uCi/gm)	Post Trip Iodine (uCi/gm)	Post Trip Iodine (date/time)	(No) Failed Fuel (NFF/FF)
1	1	1	1/16/86	4:49	98%	5.20E-03	2.89E-02	1/13/86 14:30	FF
2	1	1	1/29/86	0:06	98%	2.00E-02	1.40E-01	1/29/86 3:45	FF
3	1	1	9/30/86	9:11	93%	2.90E-02	2.90E-01	9/30/86 11:35	FF
4	1	2	7/29/87	22:11	98%	3.00E-03	6.90E-03	7/30/87 1:10	FF
5	1	2	7/31/87	1:53	30%	4.70E-03	1.30E-02	7/31/87 7:40	FF
6	1	2	8/11/87	10:11	97%	6.10E-03	1.60E-02	8/12/87 10:30	FF
7	1	2	4/18/88	21:48	98%	8.20E-03	5.30E-02	4/19/88 8:00	FF
8	1	2	7/16/88	4:31	98%	1.60E-02	3.30E-01	7/16/88 7:30	FF
9	1	2	8/4/88	0:47	98%	2.50E-01	1.70E-01	8/5/88 8:40	FF
10	1	3	1/31/89	9:56	99%	6.70E-03	8.00E-02	1/31/89 12:00	FF
11	1	4	5/3/90	3:00	79%	2.10E-03	1.70E-03	5/3/90 6:45	NFF
12	1	4	8/19/90	4:25	78%	1.60E-03	2.10E-03	8/19/90 6:40	NFF
13	1	4	12/3/90	12:40	98%	2.50E-03	2.10E-03	12/3/90 15:00	NFF
14	1	5	1/29/92	9:01	93%	2.00E-02	2.60E-01	1/30/92 8:16	FF
15	1	8	9/11/96	0:17	96.5%	4.51E-04	3.48E-04	9/11/96 2:30	NFF
16	2	1	4/27/87	16:03	89%	2.00E-02	3.10E-03	4/27/87 18:30	NFF
17	2	1	7/14/87	18:15	98%	4.00E-02	2.60E-01	7/15/87 0:15	FF
18	2	1	7/25/87	12:16	98%	3.20E-02	1.90E-01	7/25/87 14:15	FF
19	2	1	2/12/88	18:04	94%	1.20E-02	3.30E-01	2/12/88 20:50	FF
20	2	1	5/6/88	12:16	94%	1.90E-02	2.90E-01	5/6/88 13:30	FF
21	2	1	7/14/88	1:14	95%	1.50E-02	2.40E-01	7/14/88 9:30	FF
22	2	1	12/15/88	10:02	40%	4.10E-03	6.80E-02	12/15/88 12:45	FF
23	2	2	1/18/90	0:42	99%	5.60E-03	7.60E-02	1/19/90 7:40	FF
24	2	3	12/20/90	4:08	72%	1.50E-03	1.10E-01	12/20/90 6:50	FF
25	2	4	6/10/92	13:25	100%	5.63E-04	4.80E-04	6/10/92 16:00	NFF
26	2	4	5/11/93	22:38	97%	1.10E-03	4.92E-04	5/12/93 6:35	NFF
27	2	5	9/24/94	10:12	100%	7.25E-04	4.70E-04	9/24/94 12:20	NFF
28	2	6	5/23/96	8:04	98%	4.70E-04	4.20E-04	5/23/96 10:20	NFF

Calculation No. BYR97-023
Attachment Attachment: C
Revision No. 00
Page No. Page 3 of 9

	A	B	C	D	E	F	G	H	I
1	Sample ID:	Maximum Post-Trip Iodine (3x Sample)	R_0 Pre-Trip Steady State Release Rate (Ci/hr)	Post Trip Release Rate R (Ci/hr)	Spike Factor [R/R_0]	R/ MWe	Pre-Trip Iodine (uCi/ml)	Post-Trip Iodine (uCi/ml)	% Reactor power
2	Unit-1								
3	1	8.67E-02	9.15E-02	1.07E+01	1.17E+02	9.28E-03	5.20E-03	2.89E-02	98.0%
4	2	4.20E-01	3.52E-01	5.24E+01	1.49E+02	4.55E-02	2.00E-02	1.40E-01	98.0%
5	3	8.70E-01	5.10E-01	1.10E+02	2.15E+02	1.01E-01	2.90E-02	2.90E-01	93.0%
6	4	2.07E-02	5.28E-02	2.35E+00	4.46E+01	2.04E-03	3.00E-03	6.90E-03	98.0%
7	5	3.90E-02	8.27E-02	4.54E+00	5.49E+01	1.29E-02	4.70E-03	1.30E-02	30.0%
8	6	4.80E-02	1.07E-01	5.55E+00	5.18E+01	4.87E-03	6.10E-03	1.60E-02	97.0%
9	7	1.59E-01	1.44E-01	1.97E+01	1.37E+02	1.72E-02	8.20E-03	5.30E-02	98.0%
10	8	9.90E-01	2.81E-01	1.27E+02	4.51E+02	1.10E-01	1.60E-02	3.30E-01	98.0%
11	9	5.10E-01	4.40E+00	3.82E+01	8.68E+00	3.32E-02	2.50E-01	1.70E-01	98.0%
12	10	2.40E-01	1.18E-01	3.04E+01	2.58E+02	2.62E-02	6.70E-03	8.00E-02	99.0%
13	11	5.10E-03	3.69E-02	4.27E-01	1.16E+01	4.60E-04	2.10E-03	1.70E-03	79.0%
14	12	6.30E-03	2.81E-02	6.39E-01	2.27E+01	6.97E-04	1.60E-03	2.10E-03	78.0%
15	13	6.30E-03	4.40E-02	5.38E-01	1.22E+01	4.67E-04	2.50E-03	2.10E-03	98.0%
16	14	7.80E-01	3.52E-01	9.92E+01	2.82E+02	9.07E-02	2.00E-02	2.60E-01	93.0%
17	15	1.04E-03	7.93E-03	8.50E-02	1.07E+01	7.50E-05	4.51E-04	3.48E-04	96.5%
18	Unit-2								
19	16	9.30E-03	3.52E-01	-1.04E+00	-2.95E+00	-9.94E-04	2.00E-02	3.10E-03	89.0%
20	17	7.80E-01	7.04E-01	9.69E+01	1.38E+02	8.40E-02	4.00E-02	2.60E-01	98.2%
21	18	5.70E-01	5.63E-01	7.05E+01	1.25E+02	6.12E-02	3.20E-02	1.90E-01	98.0%
22	19	9.90E-01	2.11E-01	1.27E+02	6.03E+02	1.15E-01	1.20E-02	3.30E-01	94.0%
23	20	8.70E-01	3.34E-01	1.11E+02	3.32E+02	1.00E-01	1.90E-02	2.90E-01	94.0%
24	21	7.20E-01	2.64E-01	9.19E+01	3.48E+02	8.23E-02	1.50E-02	2.40E-01	95.0%
25	22	2.04E-01	7.21E-02	2.61E+01	3.61E+02	5.54E-02	4.10E-03	6.80E-02	40.0%
26	23	2.28E-01	9.85E-02	2.90E+01	2.94E+02	2.49E-02	5.60E-03	7.60E-02	99.0%
27	24	3.30E-01	2.64E-02	4.27E+01	1.62E+03	5.05E-02	1.50E-03	1.10E-01	72.0%
28	25	1.44E-03	9.91E-03	1.24E-01	1.25E+01	1.05E-04	5.63E-04	4.80E-04	100.0%
29	26	1.48E-03	1.94E-02	6.82E-02	3.53E+00	5.99E-05	1.10E-03	4.92E-04	97.0%
30	27	1.41E-03	1.28E-02	1.02E-01	7.98E+00	8.66E-05	7.25E-04	4.70E-04	100.0%
31	28	1.26E-03	8.27E-03	1.11E-01	1.34E+01	9.64E-05	4.70E-04	4.20E-04	98.0%

	A	B	C	D	E
1	Sample ID:	Maximum Post-Trip Iodine (3x Sample)	R_0 Pre-Trip Steady State Release Rate (Ci/hr)	Post Trip Release Rate R (Ci/hr)	Spike Factor [R/R_0]
2	Unit-1				
3	1	=3*H3	=(G3*17.5934)	=(130)*((B3)-(0.8647*G3))	=D3/C3
4	2	=3*H4	=(G4*17.5934)	=(130)*((B4)-(0.8647*G4))	=D4/C4
5	3	=3*H5	=(G5*17.5934)	=(130)*((B5)-(0.8647*G5))	=D5/C5
6	4	=3*H6	=(G6*17.5934)	=(130)*((B6)-(0.8647*G6))	=D6/C6
7	5	=3*H7	=(G7*17.5934)	=(130)*((B7)-(0.8647*G7))	=D7/C7
8	6	=3*H8	=(G8*17.5934)	=(130)*((B8)-(0.8647*G8))	=D8/C8
9	7	=3*H9	=(G9*17.5934)	=(130)*((B9)-(0.8647*G9))	=D9/C9
10	8	=3*H10	=(G10*17.5934)	=(130)*((B10)-(0.8647*G10))	=D10/C10
11	9	=3*H11	=(G11*17.5934)	=(130)*((B11)-(0.8647*G11))	=D11/C11
12	10	=3*H12	=(G12*17.5934)	=(130)*((B12)-(0.8647*G12))	=D12/C12
13	11	=3*H13	=(G13*17.5934)	=(130)*((B13)-(0.8647*G13))	=D13/C13
14	12	=3*H14	=(G14*17.5934)	=(130)*((B14)-(0.8647*G14))	=D14/C14
15	13	=3*H15	=(G15*17.5934)	=(130)*((B15)-(0.8647*G15))	=D15/C15
16	14	=3*H16	=(G16*17.5934)	=(130)*((B16)-(0.8647*G16))	=D16/C16
17	15	=3*H17	=(G17*17.5934)	=(130)*((B17)-(0.8647*G17))	=D17/C17
18	Unit-2				
19	16	=3*H19	=(G19*17.5934)	=(130)*((B19)-(0.8647*G19))	=D19/C19
20	17	=3*H20	=(G20*17.5934)	=(130)*((B20)-(0.8647*G20))	=D20/C20
21	18	=3*H21	=(G21*17.5934)	=(130)*((B21)-(0.8647*G21))	=D21/C21
22	19	=3*H22	=(G22*17.5934)	=(130)*((B22)-(0.8647*G22))	=D22/C22
23	20	=3*H23	=(G23*17.5934)	=(130)*((B23)-(0.8647*G23))	=D23/C23
24	21	=3*H24	=(G24*17.5934)	=(130)*((B24)-(0.8647*G24))	=D24/C24
25	22	=3*H25	=(G25*17.5934)	=(130)*((B25)-(0.8647*G25))	=D25/C25
26	23	=3*H26	=(G26*17.5934)	=(130)*((B26)-(0.8647*G26))	=D26/C26
27	24	=3*H27	=(G27*17.5934)	=(130)*((B27)-(0.8647*G27))	=D27/C27
28	25	=3*H28	=(G28*17.5934)	=(130)*((B28)-(0.8647*G28))	=D28/C28
29	26	=3*H29	=(G29*17.5934)	=(130)*((B29)-(0.8647*G29))	=D29/C29
30	27	=3*H30	=(G30*17.5934)	=(130)*((B30)-(0.8647*G30))	=D30/C30
31	28	=3*H31	=(G31*17.5934)	=(130)*((B31)-(0.8647*G31))	=D31/C31

	F	G	H	I
1	R/ MWe	Pre-Trip Iodine (uCi/ml)	Post-Trip Iodine (uCi/ml)	% Reactor power
2				
3	=D3/(1175*I3)	='[IODIN075.XLS]Unit Trips'!G2	='[IODIN075.XLS]Unit Trips'!H2	='[IODIN075.XLS]Unit Trips'!F2
4	=D4/(1175*I4)	='[IODIN075.XLS]Unit Trips'!G3	='[IODIN075.XLS]Unit Trips'!H3	='[IODIN075.XLS]Unit Trips'!F3
5	=D5/(1175*I5)	='[IODIN075.XLS]Unit Trips'!G4	='[IODIN075.XLS]Unit Trips'!H4	='[IODIN075.XLS]Unit Trips'!F4
6	=D6/(1175*I6)	='[IODIN075.XLS]Unit Trips'!G5	='[IODIN075.XLS]Unit Trips'!H5	='[IODIN075.XLS]Unit Trips'!F5
7	=D7/(1175*I7)	='[IODIN075.XLS]Unit Trips'!G6	='[IODIN075.XLS]Unit Trips'!H6	='[IODIN075.XLS]Unit Trips'!F6
8	=D8/(1175*I8)	='[IODIN075.XLS]Unit Trips'!G7	='[IODIN075.XLS]Unit Trips'!H7	='[IODIN075.XLS]Unit Trips'!F7
9	=D9/(1175*I9)	='[IODIN075.XLS]Unit Trips'!G8	='[IODIN075.XLS]Unit Trips'!H8	='[IODIN075.XLS]Unit Trips'!F8
10	=D10/(1175*I10)	='[IODIN075.XLS]Unit Trips'!G9	='[IODIN075.XLS]Unit Trips'!H9	='[IODIN075.XLS]Unit Trips'!F9
11	=D11/(1175*I11)	='[IODIN075.XLS]Unit Trips'!G10	='[IODIN075.XLS]Unit Trips'!H10	='[IODIN075.XLS]Unit Trips'!F10
12	=D12/(1175*I12)	='[IODIN075.XLS]Unit Trips'!G11	='[IODIN075.XLS]Unit Trips'!H11	='[IODIN075.XLS]Unit Trips'!F11
13	=D13/(1175*I13)	='[IODIN075.XLS]Unit Trips'!G12	='[IODIN075.XLS]Unit Trips'!H12	='[IODIN075.XLS]Unit Trips'!F12
14	=D14/(1175*I14)	='[IODIN075.XLS]Unit Trips'!G13	='[IODIN075.XLS]Unit Trips'!H13	='[IODIN075.XLS]Unit Trips'!F13
15	=D15/(1175*I15)	='[IODIN075.XLS]Unit Trips'!G14	='[IODIN075.XLS]Unit Trips'!H14	='[IODIN075.XLS]Unit Trips'!F14
16	=D16/(1175*I16)	='[IODIN075.XLS]Unit Trips'!G15	='[IODIN075.XLS]Unit Trips'!H15	='[IODIN075.XLS]Unit Trips'!F15
17	=D17/(1175*I17)	='[IODIN075.XLS]Unit Trips'!G16	='[IODIN075.XLS]Unit Trips'!H16	='[IODIN075.XLS]Unit Trips'!F16
18				
19	=D19/(1175*I19)	='[IODIN075.XLS]Unit Trips'!G18	='[IODIN075.XLS]Unit Trips'!H18	='[IODIN075.XLS]Unit Trips'!F18
20	=D20/(1175*I20)	='[IODIN075.XLS]Unit Trips'!G19	='[IODIN075.XLS]Unit Trips'!H19	='[IODIN075.XLS]Unit Trips'!F19
21	=D21/(1175*I21)	='[IODIN075.XLS]Unit Trips'!G20	='[IODIN075.XLS]Unit Trips'!H20	='[IODIN075.XLS]Unit Trips'!F20
22	=D22/(1175*I22)	='[IODIN075.XLS]Unit Trips'!G21	='[IODIN075.XLS]Unit Trips'!H21	='[IODIN075.XLS]Unit Trips'!F21
23	=D23/(1175*I23)	='[IODIN075.XLS]Unit Trips'!G22	='[IODIN075.XLS]Unit Trips'!H22	='[IODIN075.XLS]Unit Trips'!F22
24	=D24/(1175*I24)	='[IODIN075.XLS]Unit Trips'!G23	='[IODIN075.XLS]Unit Trips'!H23	='[IODIN075.XLS]Unit Trips'!F23
25	=D25/(1175*I25)	='[IODIN075.XLS]Unit Trips'!G24	='[IODIN075.XLS]Unit Trips'!H24	='[IODIN075.XLS]Unit Trips'!F24
26	=D26/(1175*I26)	='[IODIN075.XLS]Unit Trips'!G25	='[IODIN075.XLS]Unit Trips'!H25	='[IODIN075.XLS]Unit Trips'!F25
27	=D27/(1175*I27)	='[IODIN075.XLS]Unit Trips'!G26	='[IODIN075.XLS]Unit Trips'!H26	='[IODIN075.XLS]Unit Trips'!F26
28	=D28/(1175*I28)	='[IODIN075.XLS]Unit Trips'!G27	='[IODIN075.XLS]Unit Trips'!H27	='[IODIN075.XLS]Unit Trips'!F27
29	=D29/(1175*I29)	='[IODIN075.XLS]Unit Trips'!G28	='[IODIN075.XLS]Unit Trips'!H28	='[IODIN075.XLS]Unit Trips'!F28
30	=D30/(1175*I30)	='[IODIN075.XLS]Unit Trips'!G29	='[IODIN075.XLS]Unit Trips'!H29	='[IODIN075.XLS]Unit Trips'!F29
31	=D31/(1175*I31)	='[IODIN075.XLS]Unit Trips'!G30	='[IODIN075.XLS]Unit Trips'!H30	='[IODIN075.XLS]Unit Trips'!F30

TABLE C-4

	A	B	C	D	E	F	G	H	I
1	Sample ID:	Maximum Post-Trip Iodine (3x Sample)	R_0 Pre-Trip Steady State Release Rate (Ci/hr)	Post Trip Release Rate R (Ci/hr)	Spike Factor [R/R_0]	R/MWe	Pre-Trip Iodine (uCi/ml)	Post-Trip Iodine (uCi/ml)	% Reactor power
2	Unit-1								
3	1	8.67E-02	1.45E-01	1.12E+01	7.71E+01	9.72E-03	5.20E-03	2.89E-02	98.00%
4	2	4.20E-01	5.58E-01	5.48E+01	9.81E+01	4.76E-02	2.00E-02	1.40E-01	98.00%
5	3	8.70E-01	8.09E-01	1.15E+02	1.42E+02	1.05E-01	2.90E-02	2.90E-01	93.00%
6	4	2.07E-02	8.37E-02	2.48E+00	2.97E+01	2.16E-03	3.00E-03	6.90E-03	98.00%
7	5	3.90E-02	1.31E-01	4.78E+00	3.64E+01	1.36E-02	4.70E-03	1.30E-02	30.00%
8	6	4.80E-02	1.70E-01	5.85E+00	3.44E+01	5.13E-03	6.10E-03	1.60E-02	97.00%
9	7	1.59E-01	2.29E-01	2.07E+01	9.03E+01	1.79E-02	8.20E-03	5.30E-02	98.00%
10	8	9.90E-01	4.46E-01	1.32E+02	2.97E+02	1.15E-01	1.60E-02	3.30E-01	98.00%
11	9	5.10E-01	6.98E+00	4.22E+01	6.05E+00	3.67E-02	2.50E-01	1.70E-01	98.00%
12	10	2.40E-01	1.87E-01	3.18E+01	1.70E+02	2.73E-02	6.70E-03	8.00E-02	99.00%
13	11	5.10E-03	5.86E-02	4.65E-01	7.94E+00	5.01E-04	2.10E-03	1.70E-03	79.00%
14	12	6.30E-03	4.46E-02	6.81E-01	1.53E+01	7.44E-04	1.60E-03	2.10E-03	78.00%
15	13	6.30E-03	6.98E-02	5.85E-01	8.38E+00	5.08E-04	2.50E-03	2.10E-03	98.00%
16	14	7.80E-01	5.58E-01	1.04E+02	1.86E+02	9.47E-02	2.00E-02	2.60E-01	93.00%
17	15	1.04E-03	1.26E-02	9.29E-02	7.39E+00	8.20E-05	4.51E-04	3.48E-04	96.50%
18	Unit-2								
19	16	9.30E-03	5.58E-01	-8.92E-01	-1.60E+00	-8.53E-04	2.00E-02	3.10E-03	89.00%
20	17	7.80E-01	1.12E+00	1.01E+02	9.08E+01	8.79E-02	4.00E-02	2.60E-01	98.20%
21	18	5.70E-01	8.93E-01	7.38E+01	8.26E+01	6.41E-02	3.20E-02	1.90E-01	98.00%
22	19	9.90E-01	3.35E-01	1.33E+02	3.97E+02	1.20E-01	1.20E-02	3.30E-01	94.00%
23	20	8.70E-01	5.30E-01	1.16E+02	2.19E+02	1.05E-01	1.90E-02	2.90E-01	94.00%
24	21	7.20E-01	4.19E-01	9.59E+01	2.29E+02	8.60E-02	1.50E-02	2.40E-01	95.00%
25	22	2.04E-01	1.14E-01	2.72E+01	2.38E+02	5.79E-02	4.10E-03	6.80E-02	40.00%
26	23	2.28E-01	1.56E-01	3.03E+01	1.94E+02	2.60E-02	5.60E-03	7.60E-02	99.00%
27	24	3.30E-01	4.19E-02	4.46E+01	1.06E+03	5.27E-02	1.50E-03	1.10E-01	72.00%
28	25	1.44E-03	1.57E-02	1.35E-01	8.56E+00	1.15E-04	5.63E-04	4.80E-04	100.00%
29	26	1.48E-03	3.07E-02	8.16E-02	2.66E+00	7.16E-05	1.10E-03	4.92E-04	97.00%
30	27	1.41E-03	2.02E-02	1.13E-01	5.59E+00	9.62E-05	7.25E-04	4.70E-04	100.00%
31	28	1.26E-03	1.31E-02	1.20E-01	9.16E+00	1.04E-04	4.70E-04	4.20E-04	98.00%

(Release Rate (120))

Calculation No. BYR97-023
Attachment Attachment C
Revision No 00
Page No. Page 7 of 9

	A	B	C	D	E
1	Sample ID:	Maximum Post-Trip Iodine (3x Sample)	R_0 Pre-Trip Steady State Release Rate (Ci/hr)	Post Trip Release Rate R (Ci/hr)	Spike Factor [R/R_0]
2	Unit-1				
3	1	=3*H3	=(G3*27.9026)	=(135.5)*((B3)-(0.7941*G3))	=D3/C3
4	2	=3*H4	=(G4*27.9026)	=(135.5)*((B4)-(0.7941*G4))	=D4/C4
5	3	=3*H5	=(G5*27.9026)	=(135.5)*((B5)-(0.7941*G5))	=D5/C5
6	4	=3*H6	=(G6*27.9026)	=(135.5)*((B6)-(0.7941*G6))	=D6/C6
7	5	=3*H7	=(G7*27.9026)	=(135.5)*((B7)-(0.7941*G7))	=D7/C7
8	6	=3*H8	=(G8*27.9026)	=(135.5)*((B8)-(0.7941*G8))	=D8/C8
9	7	=3*H9	=(G9*27.9026)	=(135.5)*((B9)-(0.7941*G9))	=D9/C9
10	8	=3*H10	=(G10*27.9026)	=(135.5)*((B10)-(0.7941*G10))	=D10/C10
11	9	=3*H11	=(G11*27.9026)	=(135.5)*((B11)-(0.7941*G11))	=D11/C11
12	10	=3*H12	=(G12*27.9026)	=(135.5)*((B12)-(0.7941*G12))	=D12/C12
13	11	=3*H13	=(G13*27.9026)	=(135.5)*((B13)-(0.7941*G13))	=D13/C13
14	12	=3*H14	=(G14*27.9026)	=(135.5)*((B14)-(0.7941*G14))	=D14/C14
15	13	=3*H15	=(G15*27.9026)	=(135.5)*((B15)-(0.7941*G15))	=D15/C15
16	14	=3*H16	=(G16*27.9026)	=(135.5)*((B16)-(0.7941*G16))	=D16/C16
17	15	=3*H17	=(G17*27.9026)	=(135.5)*((B17)-(0.7941*G17))	=D17/C17
18	Unit-2				
19	16	=3*H19	=(G19*27.9026)	=(135.5)*((B19)-(0.7941*G19))	=D19/C19
20	17	=3*H20	=(G20*27.9026)	=(135.5)*((B20)-(0.7941*G20))	=D20/C20
21	18	=3*H21	=(G21*27.9026)	=(135.5)*((B21)-(0.7941*G21))	=D21/C21
22	19	=3*H22	=(G22*27.9026)	=(135.5)*((B22)-(0.7941*G22))	=D22/C22
23	20	=3*H23	=(G23*27.9026)	=(135.5)*((B23)-(0.7941*G23))	=D23/C23
24	21	=3*H24	=(G24*27.9026)	=(135.5)*((B24)-(0.7941*G24))	=D24/C24
25	22	=3*H25	=(G25*27.9026)	=(135.5)*((B25)-(0.7941*G25))	=D25/C25
26	23	=3*H26	=(G26*27.9026)	=(135.5)*((B26)-(0.7941*G26))	=D26/C26
27	24	=3*H27	=(G27*27.9026)	=(135.5)*((B27)-(0.7941*G27))	=D27/C27
28	25	=3*H28	=(G28*27.9026)	=(135.5)*((B28)-(0.7941*G28))	=D28/C28
29	26	=3*H29	=(G29*27.9026)	=(135.5)*((B29)-(0.7941*G29))	=D29/C29
30	27	=3*H30	=(G30*27.9026)	=(135.5)*((B30)-(0.7941*G30))	=D30/C30
31	28	=3*H31	=(G31*27.9026)	=(135.5)*((B31)-(0.7941*G31))	=D31/C31

(Release Rate (120))

Calculation No. BYR97-023
Attachment Attachment C
Revision No 00
Page No. Page 8 of 9

	F	G	H	I
1	R/MWe	Pre-Trip Iodine (uCi/ml)	Post-Trip Iodine (uCi/ml)	% Reactor power
2				
3	=D3/(1175*I3)	='[IODIN075.XLS]Unit Trips'!G2	='[IODIN075.XLS]Unit Trips'!H2	='[IODIN075.XLS]Unit Trips'!F2
4	=D4/(1175*I4)	='[IODIN075.XLS]Unit Trips'!G3	='[IODIN075.XLS]Unit Trips'!H3	='[IODIN075.XLS]Unit Trips'!F3
5	=D5/(1175*I5)	='[IODIN075.XLS]Unit Trips'!G4	='[IODIN075.XLS]Unit Trips'!H4	='[IODIN075.XLS]Unit Trips'!F4
6	=D6/(1175*I6)	='[IODIN075.XLS]Unit Trips'!G5	='[IODIN075.XLS]Unit Trips'!H5	='[IODIN075.XLS]Unit Trips'!F5
7	=D7/(1175*I7)	='[IODIN075.XLS]Unit Trips'!G6	='[IODIN075.XLS]Unit Trips'!H6	='[IODIN075.XLS]Unit Trips'!F6
8	=D8/(1175*I8)	='[IODIN075.XLS]Unit Trips'!G7	='[IODIN075.XLS]Unit Trips'!H7	='[IODIN075.XLS]Unit Trips'!F7
9	=D9/(1175*I9)	='[IODIN075.XLS]Unit Trips'!G8	='[IODIN075.XLS]Unit Trips'!H8	='[IODIN075.XLS]Unit Trips'!F8
10	=D10/(1175*I10)	='[IODIN075.XLS]Unit Trips'!G9	='[IODIN075.XLS]Unit Trips'!H9	='[IODIN075.XLS]Unit Trips'!F9
11	=D11/(1175*I11)	='[IODIN075.XLS]Unit Trips'!G10	='[IODIN075.XLS]Unit Trips'!H10	='[IODIN075.XLS]Unit Trips'!F10
12	=D12/(1175*I12)	='[IODIN075.XLS]Unit Trips'!G11	='[IODIN075.XLS]Unit Trips'!H11	='[IODIN075.XLS]Unit Trips'!F11
13	=D13/(1175*I13)	='[IODIN075.XLS]Unit Trips'!G12	='[IODIN075.XLS]Unit Trips'!H12	='[IODIN075.XLS]Unit Trips'!F12
14	=D14/(1175*I14)	='[IODIN075.XLS]Unit Trips'!G13	='[IODIN075.XLS]Unit Trips'!H13	='[IODIN075.XLS]Unit Trips'!F13
15	=D15/(1175*I15)	='[IODIN075.XLS]Unit Trips'!G14	='[IODIN075.XLS]Unit Trips'!H14	='[IODIN075.XLS]Unit Trips'!F14
16	=D16/(1175*I16)	='[IODIN075.XLS]Unit Trips'!G15	='[IODIN075.XLS]Unit Trips'!H15	='[IODIN075.XLS]Unit Trips'!F15
17	=D17/(1175*I17)	='[IODIN075.XLS]Unit Trips'!G16	='[IODIN075.XLS]Unit Trips'!H16	='[IODIN075.XLS]Unit Trips'!F16
18				
19	=D19/(1175*I19)	='[IODIN075.XLS]Unit Trips'!G18	='[IODIN075.XLS]Unit Trips'!H18	='[IODIN075.XLS]Unit Trips'!F18
20	=D20/(1175*I20)	='[IODIN075.XLS]Unit Trips'!G19	='[IODIN075.XLS]Unit Trips'!H19	='[IODIN075.XLS]Unit Trips'!F19
21	=D21/(1175*I21)	='[IODIN075.XLS]Unit Trips'!G20	='[IODIN075.XLS]Unit Trips'!H20	='[IODIN075.XLS]Unit Trips'!F20
22	=D22/(1175*I22)	='[IODIN075.XLS]Unit Trips'!G21	='[IODIN075.XLS]Unit Trips'!H21	='[IODIN075.XLS]Unit Trips'!F21
23	=D23/(1175*I23)	='[IODIN075.XLS]Unit Trips'!G22	='[IODIN075.XLS]Unit Trips'!H22	='[IODIN075.XLS]Unit Trips'!F22
24	=D24/(1175*I24)	='[IODIN075.XLS]Unit Trips'!G23	='[IODIN075.XLS]Unit Trips'!H23	='[IODIN075.XLS]Unit Trips'!F23
25	=D25/(1175*I25)	='[IODIN075.XLS]Unit Trips'!G24	='[IODIN075.XLS]Unit Trips'!H24	='[IODIN075.XLS]Unit Trips'!F24
26	=D26/(1175*I26)	='[IODIN075.XLS]Unit Trips'!G25	='[IODIN075.XLS]Unit Trips'!H25	='[IODIN075.XLS]Unit Trips'!F25
27	=D27/(1175*I27)	='[IODIN075.XLS]Unit Trips'!G26	='[IODIN075.XLS]Unit Trips'!H26	='[IODIN075.XLS]Unit Trips'!F26
28	=D26/(1175*I28)	='[IODIN075.XLS]Unit Trips'!G27	='[IODIN075.XLS]Unit Trips'!H27	='[IODIN075.XLS]Unit Trips'!F27
29	=D29/(1175*I29)	='[IODIN075.XLS]Unit Trips'!G28	='[IODIN075.XLS]Unit Trips'!H28	='[IODIN075.XLS]Unit Trips'!F28
30	=D30/(1175*I30)	='[IODIN075.XLS]Unit Trips'!G29	='[IODIN075.XLS]Unit Trips'!H29	='[IODIN075.XLS]Unit Trips'!F29
31	=D31/(1175*I31)	='[IODIN075.XLS]Unit Trips'!G30	='[IODIN075.XLS]Unit Trips'!H30	='[IODIN075.XLS]Unit Trips'!F30

(Release Rate (120))

Calculation No. BYR97-023
Attachment Attachment C
Revision No. 00
Page No. Page 9 of 9

THE IODINE SPIKE RELEASE RATE DURING A STEAM GENERATOR TUBE RUPTURE

NUCLEAR FUEL CYCLES

Calculation No.	BYR97-023
Attachment	Attachment: D
Revision No.	00
Page No.	Page 1 of 11

JAMES P. ADAMS and CORWIN L. ATWOOD
Idaho National Engineering Laboratory, EG&G Idaho, Inc.
P.O. Box 1625, Idaho Falls, Idaho 83415

Received May 10, 1990
Accepted for Publication October 16, 1990

The U.S. Nuclear Regulatory Commission (NRC) requires utilities to determine the response of a pressurized water reactor (PWR) to a steam generator tube rupture (SGTR) as part of the safety analysis for the plant. The SGTR analysis includes assumptions regarding the presence of fission product iodine in the reactor coolant resulting from iodine spikes. To get a better understanding of iodine spiking, reactor trip and associated radiochemistry data were collected from 26 PWRs. These data were compared against validation criteria to determine their applicability to an investigation of the magnitude of an iodine spike following a reactor trip. The applicable data and the results of a statistical analysis are presented. Conclusions are made from this analysis of iodine spiking following reactor trips concerning the magnitude of a spike during an SGTR and compared with the NRC analysis criteria. The conclusion is then made that the iodine release rate expected during an SGTR, on the basis of the analysis of the data base, is much less (by a factor of 15 or more) than that specified by the NRC for analysis of this accident type.

I. INTRODUCTION

In pressurized water reactors (PWRs), water in the primary coolant system is pressurized to prevent it from boiling. This high-pressure water is circulated through heat exchanger tubes in the steam generators where its heat is transferred to lower pressure secondary coolant, producing steam, which is used to generate electrical power. The tubes represent a large fraction of the reactor coolant system (RCS) boundary, and rupture of these tubes can result in a direct path to the environment for primary coolant (containment bypass) through either the atmospheric dump valves or secondary relief valves. Since the primary coolant can carry radioactive materials, a steam generator tube rupture (SGTR) accident has been designated as a design-basis accident for PWRs and is analyzed as part of a plant's final safety analysis report (FSAR). The U.S. Nuclear Regulatory Commission (NRC) regulations regarding the FSAR for PWRs are listed in 10CFR50 (Ref. 1). Guidelines are provided for interpretation of these regulations in the Standard Review Plan[2] (SRP).

An iodine spike is a temporary increase in the concentration of fission product iodine that sometimes occurs as a result of a large reactor power or RCS pressure change. The iodine, a fission product released to the coolant, comes either as a product of the fissioning of tramp uranium on the fuel element cladding surface or from the fuel itself, being released through tiny holes in the cladding of otherwise undamaged fuel rods. The cladding defects can occur during the manufacturing process or as a result of corrosion during operations (e.g., hydriding). This iodine (specifically, ^{131}I) represents the principal source of radiation potentially leaked to the environment during an SGTR.

Reference 2 describes two different scenarios to be assumed in the analysis of an SGTR. The first includes the assumption that an iodine spike occurs prior to initiation of the SGTR. The second includes the assumption that the SGTR occurs coincident with the iodine spike. In each case, the SRP provides guidelines regarding the magnitude of the iodine spike and the consequent RCS iodine concentration that are assumed in the analysis of this transient. An earlier study[3] compared the SRP guidelines for an SGTR with preexisting iodine spike and iodine spiking data from operating PWRs.

The SRP guidelines governing analysis of the second scenario (SGTR with coincident iodine spike) specify that the iodine concentration is to be assumed to result from an SGTR-initiated iodine spike that increases the iodine release rate (the rate at which the iodine is released from the fuel element to the RCS coolant) to a value that is 500 times the steady-state release rate. Reference 2 further directs that the steady-state release rate (used in this calculation) should be based on an RCS iodine concentration of 1 μCi/g, the technical specification limit. This paper contains the results of a study conducted to evaluate this guideline and to determine the probability that an iodine spike of a given magnitude will occur as a result of an SGTR. These results were published previously in Ref. 4.

II. ANALYSIS

The objective of this study is to determine the probability that an SGTR would result in an iodine spike of a given magnitude. In the analysis below, this probability is considered to be equal to the probability that a reactor trip would result in an iodine spike of the same magnitude. The methodology used in this study was

1. to develop a data base of reactor trips and associated radioiodine concentrations from commercial PWR operations
2. to bound the magnitude of the maximum iodine concentration following the trip
3. to bound the release rate from the fuel to the RCS during each event
4. to estimate the desired probabilities.

II.A. Iodine Spiking Data Base

Fewer than 10 SGTR events have occurred in U.S. PWRs. The uncertainties associated with a statistical analysis of this small number of events would be so large that the results would not be useful to predict the behavior of future iodine spiking events. However, an SGTR occurring during power operations would result in a reactor trip, which is a large power excursion. Reference 5 indicates that "This (iodine) increase is often observed during power increases and reactor coolant depressurizations following power decreases." Since it is this power excursion that causes the iodine spike, it is assumed that the probability that an *SGTR event* results in an iodine spike of a given magnitude is equal to the probability that a *reactor trip* would result in an iodine spike of the same magnitude. This assumption—that the reactor trip causes the iodine spike rather than anything else associated with the SGTR itself—allows a much larger data base to be developed.

There are other phenomena that can affect the iodine spike, specifically a power increase or a pressure transient, that could affect the validity of this assumption. The power increase (e.g., if the reactor is quickly brought back to power following a spurious trip) may be ignored since it is highly unlikely that reactor operators would attempt power operations following an SGTR-induced scram.

There is a pressure transient inherent with a reactor trip because the principal heat source is immediately lost when the control rods are inserted and the heat sink is maintained until the main steam stop valves can be closed. The effects of this pressure transient are inherently included in this data base.

Additional pressure transients may occur as the operators attempt to bring the plant to a safe shutdown condition. However, it is expected that operators would require some time to diagnose the transient and initiate depressurization (~0.5 h). Buildup of the iodine is exponential, and thus, a large fraction of the concentration increase would occur prior to the operator-initiated depressurization. Therefore, it is considered that any perturbing effects of a subsequent depressurization transient are relatively small and are adequately covered by the conservatism built into the analysis.

One phenomena not taken into account is the possibility that iodine may plate out onto reactor surfaces and thus not be measurable during the transient. It has been observed[6] that at acidic pH conditions, iodine can plate out under water, and this may perturb the measurement of iodine in the RCS. However, since the iodine spiking data were obtained during normal power operations, any plateout of iodine during these measured transients may be expected to also exist during an SGTR, and the measured iodine release rate may be interpreted as an "effective" release rate and used as such.

Iodine spiking data resulting from reactor trips were collected from 26 PWRs. These plants were selected from all regions of the country and from all three PWR vendors. For each plant, Table I lists the operating utility, vendor, time frame from which the data were collected, and the number of events that ultimately satisfied the validation criteria. Of the plants used in this study, 14 (50%) were Westinghouse (W) design, 5 (20%) were Babcock & Wilcox (B&W) design, and 7 (30%) were Combustion Engineering (C-E) design.

Five specific criteria were used to ensure that the data could be compared among plants and that the resulting data base would be valid. The criteria are

1. sufficient steady-state power prior to the trip to ensure an adequate buildup of iodine. The specific criterion used was a minimum of 5 days at steady-state power operation, resulting in a minimum of 35% of the steady-state ^{131}I concentration. In nearly all cases, the steady-state power operation lasted several weeks to several months rather than the minimum 5 days.
2. knowledge of the steady-state iodine concentration

TABLE I

PWR Plants Used in This Study

Plant	Utility	NSSS Vendor	Time Frame	Number of Events
Arkansas Nuclear One-1	Arkansas Power and Light Company	B&W	1976 to 1989	3
Arkansas Nuclear One-2	Arkansas Power and Light Company	C-E	1980 to 1989	18
Calvert Cliffs-1	Baltimore Gas and Electric Company	C-E	1979 to 1989	5
Calvert Cliffs-2	Baltimore Gas and Electric Company	C-E	1979 to 1989	1
Catawba-1	Duke Power Company	W	1986 to 1988	3
Catawba-2	Duke Power Company	W	1986 to 1988	5
Cook-1	Indiana & Michigan Electric Company	W	1983 to 1989	4
Cook-2	Indiana & Michigan Electric Company	W	1984 to 1989	2
Crystal River-3	Florida Power Corporation	B&W	1977 to 1989	0
Haddam Neck	Connecticut Yankee Atomic Power Company	W	1984 to 1989	6
McGuire-1	Duke Power Company	W	1986 to 1988	6
McGuire-2	Duke Power Company	W	1986 to 1988	6
Millstone-2	Northeast Utilities Service Company	C-E	1984 to 1989	6
Millstone-3	Northeast Utilities Service Company	W	1987 to 1989	2
North Anna-1	Virginia Power Company	W	1978 to 1989	14
North Anna-2	Virginia Power Company	W	1980 to 1989	7
Oconee-1	Duke Power Company	B&W	1986 to 1988	0
Oconee-2	Duke Power Company	B&W	1986 to 1988	1
Oconee-3	Duke Power Company	B&W	1986 to 1988	0
Palisades	Consumers Power Company	C-E	1980 to 1989	12
Prairie Island-1	Northern States Power Company	W	1974 to 1989	7
Prairie Island-2	Northern States Power Company	W	1975 to 1989	7
San Onofre-2	Southern California Edison Company	C-E	1984 to 1989	11
San Onofre-3	Southern California Edison Company	C-E	1984 to 1989	8
Surry-1	Virginia Power Company	W	1972 to 1989	24
Surry-2	Virginia Power Company	W	1973 to 1989	10

3. availability of at least one posttrip chemistry sample taken 2 to 6 h after trip
4. no posttrip RCS perturbation (e.g., recriticality) prior to the RCS sample
5. availability of all requisite transient information (purification flow, trip date and time, posttrip sample date and time).

These criteria are discussed in more detail in Ref. 4.

These five criteria were applied to each reactor trip event, and only those events meeting the criteria were included in the data base. The resultant data base is listed in Table II. Included in the table are the plant name, nuclear steam supply system (NSSS) vendor, the trip date, percentage of reactor power prior to trip, the pretrip iodine concentration, posttrip (2 to 6 h after trip) maximum measured concentration, and the calculated iodine release rate for each of the transient events. The release rate in this table is based on the bounded maximum iodine concentration (three times the measured posttrip concentration as discussed in Sec. II.B) and an assumed time after trip of 2 h (discussed in Sec. II.C).

II.B. Bounding Analysis for Maximum Iodine Concentration

An analysis was performed to bound the actual maximum iodine concentration for each iodine spike event. This analysis is necessary because, in most cases, RCS samples are taken infrequently (in some cases only every 4 h and in others, only every 24 h) rather than continuously during the iodine spike.

The data used in this bounding analysis were obtained from licensee event reports (LERs). Twenty-four iodine spiking events were extracted from the LERs with multiple RCS coolant samples; these events were used to estimate the time dependence of the concentration. The maximum iodine concentration was bounded for each event by interpolation (where possible) or extrapolation of the data. Based on the results of this bounding analysis, it is judged that the *maximum* iodine concentration resulting from a reactor trip is no more than a factor of 3 greater than *any* value measured 2 to 6 h after trip. This analysis is discussed in detail in Ref. 4. Thus, the bounded maximum values are the measured values (Post-I in Table II), conservatively multiplied by a factor of 3 and used to calculate the iodine release rates as discussed in Sec. II.C.

TABLE II

Iodine Release Rate Following a Reactor Trip

Event Number	Plant	NSSS Vendor	Trip Date	Power (%)	Pre-I[a] (μCi/g)	Post-I[b] (μCi/g)	$R3(2)$[c] (Ci/h)
1	ANO-1[d]	B&W	800822[e]	100	5.64E−01[f]	1.44E+01	5.53E+03
2	ANO-1	B&W	801208	75	2.46E−01	7.43E+00	2.86E+03
3	ANO-1	B&W	850531	100	7.02E−02	3.32E+00	1.28E+03
4	ANO-2	C-E	800129	100	2.61E−01	1.11E+00	3.36E+02
5	ANO-2	C-E	800624	100	1.28E−01	3.00E−01	8.48E+01
6	ANO-2	C-E	800724	100	1.27E−01	4.39E−01	1.30E+02
7	ANO-2	C-E	810217	100	1.23E−01	1.11E+00	3.47E+02
8	ANO-2	C-E	810820	100	3.62E−01	4.81E−01	1.20E+02
9	ANO-2	C-E	811123	100	5.05E−02	1.79E−01	5.30E+01
10	ANO-2	C-E	811221	95	6.47E−02	2.46E−01	7.36E+01
11	ANO-2	C-E	840617	100	4.06E−02	1.94E−01	5.89E+01
12	ANO-2	C-E	840720	100	3.08E−02	1.53E−01	4.66E+01
13	ANO-2	C-E	840828	100	2.98E−02	1.71E−01	5.25E+01
14	ANO-2	C-E	841026	100	4.43E−02	2.36E−01	7.22E+01
15	ANO-2	C-E	850204	100	5.51E−02	3.88E−01	1.20E+02
16	ANO-2	C-E	850813	100	9.25E−02	6.83E−01	2.12E+02
17	ANO-2	C-E	860211	100	5.75E−02	9.00E−01	2.86E+02
18	ANO-2	C-E	860421	100	4.80E−02	8.74E−01	2.79E+02
19	ANO-2	C-E	870909	100	5.06E−03	6.07E−03	1.47E+00
20	ANO-2	C-E	881201	100	7.82E−02	5.45E−01	1.69E+02
21	ANO-2	C-E	890418	100	4.17E−02	5.31E−01	1.68E+02
22	CalClf-1	C-E	810116	92	3.24E−03	1.70E−03	3.01E−01
23	CalClf-1	C-E	820711	84	3.59E−03	2.64E−02	9.56E+00
24	CalClf-1	C-E	830126	100	2.86E−02	4.48E−01	1.66E+02
25	CalClf-1	C-E	830919	96	2.15E−02	2.75E−01	1.01E+02
26	CalClf-1	C-E	870911	100	4.23E−02	3.95E−01	1.44E+02
27	CalClf-2	C-E	870301	95	7.44E−02	8.58E−01	3.15E+02
28	Catawba-1	W	860419	100	4.70E−03	3.88E−03	1.00E+00
29	Catawba-1	W	860514	100	5.50E−03	3.15E−02	1.18E+01
30	Catawba-1	W	870409	100	3.90E−03	3.54E−03	9.59E−01
31	Catawba-2	W	870128	100	8.10E−04	1.89E−03	6.56E−01
32	Catawba-2	W	870506	100	6.10E−04	9.34E−04	3.02E−01
33	Catawba-2	W	870727	90	3.80E−04	2.91E−04	7.23E−02
34	Catawba-2	W	880626	100	6.10E−04	6.80E−04	2.00E−01
35	Catawba-2	W	880929	95	4.60E−04	7.88E−04	2.60E−01
36	Cook-1	W	860722	90	2.40E−03	5.67E−02	2.34E+01
37	Cook-1	W	861122	90	2.10E−03	4.84E−01	2.10E+02
38	Cook-1	W	870604	90	2.20E−03	2.99E−01	1.30E+02
39	Cook-1	W	881123	90	1.00E−04	8.00E−04	3.36E−01
40	Cook-2	W	841119	96	1.20E−03	8.00E−04	1.89E−01
41	Cook-2	W	860201	80	1.40E−03	3.06E−02	1.26E+01
42	HadmNk	W	851110	100	1.30E−02	2.37E−01	7.41E+01
43	HadmNk	W	851121	100	6.80E−03	8.96E−02	2.79E+01
44	HadmNk	W	860604	97	8.60E−03	8.93E−03	2.16E+00
45	HadmNk	W	860617	98	4.30E−03	1.01E−02	2.87E+00
46	HadmNk	W	860830	100	5.50E−03	1.08E−02	2.99E+00
47	HadmNk	W	870416	100	8.40E−03	1.00E−01	3.10E+01
48	McGui-1	W	860105	100	7.87E−03	3.00E−01	1.22E+02
49	McGui-1	W	860924	100	5.30E−03	3.30E−02	1.30E+01
50	McGui-1	W	870415	100	5.60E−03	1.10E−01	4.27E+01

See footnotes at end of table.

(Continued)

TABLE II (Continued)

Event Number	Plant	NSSS Vendor	Trip Date	Power (%)	Pre-I (μCi/g)	Post-I (μCi/g)	*R3* (2) (Ci/h)
51	McGui-1	W	880323	100	5.50E−03	1.70E−01	6.86E+01
52	McGui-1	W	880416	100	6.90E−03	1.40E−01	5.64E+01
53	McGui-1	W	880620	100	1.10E−02	6.20E−01	2.52E+02
54	McGui-2	W	860115	100	6.50E−03	4.10E−02	1.55E+01
55	McGui-2	W	860722	93	1.60E−03	3.60E−02	1.41E+01
56	McGui-2	W	860827	100	3.70E−03	7.30E−02	2.86E+01
57	McGui-2	W	870120	100	5.90E−03	9.10E−02	3.48E+01
58	McGui-2	W	870916	100	9.50E−02	5.80E−01	2.21E+02
59	McGui-2	W	880112	89	1.50E−02	2.80E−01	1.10E+02
60	Mill-2	C-E	841115	100	5.04E−02	1.05E+00	3.68E+02
61	Mill-2	C-E	841128	100	6.19E−02	7.04E−01	2.44E+02
62	Mill-2	C-E	860812	100	4.09E−03	5.25E−03	1.42E+00
63	Mill-2	C-E	870723	100	8.30E−03	8.77E−02	3.03E+01
64	Mill-2	C-E	871116	100	1.60E−02	1.35E−01	4.45E+01
65	Mill-2	C-E	881025	100	1.08E−02	1.55E−01	5.41E+01
66	Mill-3	W	881005	100	1.17E−03	6.79E−01	2.79E+02
67	Mill-3	W	881022	100	3.22E−03	3.14E−01	1.28E+02
68	NoAnna-1	W	781024	100	4.50E−02	9.73E−03	9.53E−01
69	NoAnna-1	W	781214	98	4.10E−02	3.93E−02	9.63E+00
70	NoAnna-1	W	800618	100	3.00E−03	3.55E−02	1.18E+01
71	NoAnna-1	W	810624	100	6.50E−02	2.59E−01	8.25E+01
72	NoAnna-1	W	810710	100	7.60E−02	8.45E−01	2.82E+02
73	NoAnna-1	W	810803	100	8.30E−02	8.24E−01	2.74E+02
74	NoAnna-1	W	830606	100	4.40E−02	9.37E−01	3.16E+02
75	NoAnna-1	W	841114	100	3.00E−03	3.00E−03	7.47E−01
76	NoAnna-1	W	841231	100	4.00E−03	2.40E−03	4.49E−01
77	NoAnna-1	W	851024	100	8.00E−03	5.74E−02	1.89E+01
78	NoAnna-1	W	860223	100	4.00E−03	1.11E−01	3.76E+01
79	NoAnna-1	W	860326	100	4.00E−03	1.33E−01	4.51E+01
80	NoAnna-1	W	860520	100	4.00E−03	1.98E−01	6.73E+01
81	NoAnna-1	W	860531	100	4.00E−03	1.16E−01	3.93E+01
82	NoAnna-2	W	810122	100	5.00E−03	3.02E−01	1.03E+02
83	NoAnna-2	W	810306	100	1.00E−02	4.03E−01	1.37E+02
84	NoAnna-2	W	810606	100	1.50E−02	2.60E−01	8.74E+01
85	NoAnna-2	W	811209	100	1.40E−02	2.22E−01	7.45E+01
86	NoAnna-2	W	830227	100	1.30E−02	1.59E−01	5.31E+01
87	NoAnna-2	W	860529	100	1.00E−03	1.00E−03	2.49E−01
88	NoAnna-2	W	860629	100	1.00E−03	1.00E−03	2.49E−01
89	Ocon-2	B&W	870420	87	2.40E−02	1.60E−01	5.86E+01
90	Palis	C-E	800826	88	7.10E−02	7.28E−01	2.82E+02
91	Palis	C-E	800928	81	4.50E−02	2.58E−01	9.76E+01
92	Palis	C-E	801009	96	2.01E−01	9.18E−01	3.44E+02
93	Palis	C-E	801223	99	5.00E−02	3.04E−01	1.15E+02
94	Palis	C-E	810115	98	1.16E−01	7.64E−01	2.91E+02
95	Palis	C-E	821016	100	5.00E−02	5.60E−01	2.17E+02
96	Palis	C-E	821028	90	8.40E−02	1.36E−01	4.38E+01
97	Palis	C-E	830126	97	4.00E−02	1.70E−01	6.30E+01
98	Palis	C-E	830519	99	5.60E−02	1.35E−01	4.94E+01
99	Palis	C-E	850811	98	1.10E−02	8.80E−03	2.33E+00
100	Palis	C-E	870620	100	8.70E−02	4.70E−01	1.83E+02
101	Palis	C-E	870710	94	5.70E−02	1.90E−01	7.16E+01
102	PrIsl-1	W	770107	100	1.10E−03	6.40E−02	1.35E+01
103	PrIsl-1	W	780831	100	2.52E−02	1.15E+00	2.43E+02
104	PrIsl-1	W	790608	100	6.88E−03	1.79E−01	3.77E+01
105	PrIsl-1	W	791115	64	7.24E−04	6.66E−02	1.42E+01

(Continued)

TABLE II (Continued)

Event Number	Plant	NSSS Vendor	Trip Date	Power (%)	Pre-I (μCi/g)	Post-I (μCi/g)	$R3$ (2) (Ci/h)
106	PrIsl-1	W	801111	100	1.47E−04	1.09E−04	1.42E−02
107	PrIsl-1	W	810831	100	2.87E−04	2.58E−04	3.76E−02
108	PrIsl-1	W	850915	100	1.00E−04	3.42E−02	7.35E+00
109	PrIsl-2	W	750121	45	5.28E−05	3.90E−05	5.04E−03
110	PrIsl-2	W	791101	100	7.35E−04	7.40E−04	1.14E−01
111	PrIsl-2	W	801020	100	4.36E−04	4.95E−04	7.88E−02
112	PrIsl-2	W	810516	100	1.37E−04	2.15E−04	3.77E−02
113	PrIsl-2	W	811205	100	2.63E−04	2.30E−04	3.33E−02
114	PrIsl-2	W	820325	100	3.40E−04	2.85E−04	4.01E−02
115	PrIsl-2	W	860728	100	2.00E−04	3.20E−02	6.86E+00
116	SanOno-2	C-E	840104	100	7.89E−02	2.36E−01	8.07E+01
117	SanOno-2	C-E	850518	100	1.38E−02	5.72E−02	2.10E+01
118	SanOno-2	C-E	850801	100	1.32E−02	7.47E−02	2.69E+01
119	SanOno-2	C-E	850820	100	1.72E−02	5.14E−02	1.76E+01
120	SanOno-2	C-E	850912	100	1.60E−02	6.98E−02	2.47E+01
121	SanOno-2	C-E	851018	100	1.17E−02	5.90E−02	2.12E+01
122	SanOno-2	C-E	860109	100	4.01E−02	3.25E−01	1.25E+02
123	SanOno-2	C-E	860812	100	9.89E−02	1.20E+00	4.46E+02
124	SanOno-2	C-E	860913	60	7.43E−02	1.70E+00	6.69E+02
125	SanOno-2	C-E	861210	100	6.86E−02	1.66E+00	6.53E+02
126	SanOno-2	C-E	870205	100	7.61E−02	2.04E+00	8.05E+02
127	SanOno-3	C-E	840106	100	4.27E−01	2.16E+00	8.05E+02
128	SanOno-3	C-E	840601	100	4.03E−01	1.99E+00	7.47E+02
129	SanOno-3	C-E	840611	100	5.05E−01	2.61E+00	9.83E+02
130	SanOno-3	C-E	860412	100	4.55E−02	7.51E−02	2.48E+01
131	SanOno-3	C-E	860726	100	6.47E−02	2.65E−01	9.82E+01
132	SanOno-3	C-E	860[illegible]4	94	4.70E−02	1.92E−01	7.13E+01
133	SanOno-3	C-E	870621	100	9.58E−02	5.26E−01	1.99E+02
134	SanOno-3	C-E	880219	100	4.49E−02	5.64E−02	1.74E+01
135	Surry-1	W	770726	100	2.20E−02	6.93E−01	2.22E+02
136	Surry-1	W	800603	100	7.00E−03	2.30E−01	7.38E+01
137	Surry-1	W	810822	100	7.60E−02	1.98E+00	6.34E+02
138	Surry-1	W	811125	100	1.82E−01	5.07E+00	1.63E+03
139	Surry-1	W	811216	100	5.90E−02	8.12E−01	2.58E+02
140	Surry-1	W	820325	100	1.60E−01	5.57E+00	1.79E+03
141	Surry-1	W	820413	100	1.79E−01	5.14E+00	1.65E+03
142	Surry-1	W	820425	100	1.30E−01	3.12E+00	9.99E+02
143	Surry-1	W	820713	100	1.15E−01	8.97E+00	2.89E+03
144	Surry-1	W	820824	100	9.30E−02	8.20E+00	2.65E+03
145	Surry-1	W	821104	100	6.20E−02	2.65E+00	8.52E+02
146	Surry-1	W	821129	100	1.29E−01	5.18E+00	1.67E+03
147	Surry-1	W	830914	100	1.10E−02	5.35E−01	1.72E+02
148	Surry-1	W	840106	100	5.60E−02	9.22E−01	2.94E+02
149	Surry-1	W	840206	100	7.40E−02	1.44E+00	4.60E+02
150	Surry-1	W	840613	100	3.60E−02	1.18E+00	3.79E+02
151	Surry-1	W	840926	80	3.30E−02	6.31E−01	2.01E+02
152	Surry-1	W	850126	100	1.01E−01	1.49E−01	3.98E+01
153	Surry-1	W	850804	100	2.60E−02	1.44E+00	4.64E+02
154	Surry-1	W	860107	97	2.40E−02	1.72E+00	5.55E+02
155	Surry-1	W	870516	100	6.00E−03	3.30E−03	5.58E−01
156	Surry-1	W	870807	100	4.00E−03	3.30E−03	7.34E−01
157	Surry-1	W	870920	100	7.00E−03	2.42E−01	7.77E+01
158	Surry-1	W	880216	100	9.00E−03	9.30E−01	3.00E+02
159	Surry-2	W	771108	100	2.00E−04	3.00E−04	8.04E−02
160	Surry-2	W	780624	100	5.00E−04	3.00E−04	5.54E−02

(Continued)

TABLE II (Continued)

Event Number	Plant	NSSS Vendor	Trip Date	Power (%)	Pre-I (μCi/g)	Post-I (μCi/g)	$R3$ (2) (Ci/h)
161	Surry-2	W	821010	100	2.00E−03	6.70E−02	2.15E+01
162	Surry-2	W	830208	100	2.00E−03	1.82E−01	5.87E+01
163	Surry-2	W	830412	100	3.00E−03	5.35E−01	1.73E+02
164	Surry-2	W	830620	100	3.00E−03	3.31E−01	1.07E+02
165	Surry-2	W	840113	100	3.00E−04	2.00E−03	6.22E−01
166	Surry-2	W	841029	[illegible]	2.00E−04	2.00E−04	4.81E−02
167	Surry-2	W	841211	100	[illegible].00E−04	3.00E−04	8.04E−02
168	Surry-2	W	860511	100	[illegible].00E−04	2.00E−04	4.81E−02

[a]Pre-I is the measured steady-state iodine concentration before trip.
[b]Post-I is the maximum measured iodine concentration 2 to 6 h after trip.
[c]$R3$ (2) is the iodine release rate based on bounded maximum iodine concentration and assumed 2 h time from trip to maximum concentration.
[d]ANO = Arkansas Nuclear One; CalClf = Calvert Cliffs; HadmNk = Haddam Neck; McGui = McGuire; Mill = Millstone; NoAnna = North Anna; Ocon = Oconee; Palis = Palisades; PrIsl = Prairie Island; SanOno = San Onofre.
[e]Read as August 22, 1980.
[f]Read as 5.64×10^{-1}.

II.C. Calculation of Iodine Release Rate

The release rate of ^{131}I from the fuel to the RCS, shown in Table II, was determined from the data using the following equation[7]:

$$R = \frac{L_t[A - A_0 \exp(-L_t t)]}{1 - \exp(-L_t t)} , \quad (1)$$

where

R = transient iodine release rate (Ci/h)

L_t = total iodine removal rate (h^{-1})

A = maximum transient RCS iodine inventory (Ci)

A_0 = steady-state RCS iodine inventory (Ci)

t = time from iodine spike initiating event to maximum iodine concentration (h),

and

$$L_t = L_d + L_p , \quad (2)$$

where

L_d = ^{131}I decay constant = 3.59×10^{-3} h^{-1}

L_p = purification removal constant

$= \frac{F(1 - 1/DF)}{M}$

F = purification system flow rate (kg/h)

M = RCS mass inventory (kg)

DF = purification system decontamination factor.

The pretrip steady-state release rate R_0 is given by

$$R_0 = L_t A_0 . \quad (3)$$

This equation is derived from Eq. (1) by calculating the limit as $t \to \infty$ and letting $A = A_0$.

In all cases included in the table, the purification flow was constant before and during the transient. Additionally, the purification system decontamination factor was assumed to be 99 (i.e., 99% of the radioactive iodine was assumed to be removed from the purification flow stream by the demineralizers). This assumption is judged acceptable because purification systems typically remove nearly all of the radioactive iodine from the fluid stream, and small variations in the decontamination factor do not significantly affect the magnitude of the purification removal constant.

Using the time from reactor trip to maximum measured iodine concentration in the equation results in an average release rate that can be used to estimate the average transient RCS iodine concentration during an SGTR event. The absence of samples taken immediately after reactor trip means that the actual time of the maximum concentration cannot be determined. Because of this, a second release rate was calculated assuming that the maximum concentration occurred 2 h after reactor trip. This 2-h time period is judged to be adequately conservative, but much better data would be required to confirm this. However, Lewis et al.[8] indicate that the maximum measured iodine concentration occurred sometime after 3 h in specific spiking events in Canada deuterium uranium (CANDU) reactors. Voilleque[9] indicates a time delay of 6 h in one PWR. Seven of the 24 events (used to bound the maximum iodine concentration in this study) included samples taken before and after 2 h after scram. In all seven events, the maximum iodine concentration occurred sometime after 2 h. The calculated release rate increases as the assumed time to maximum concentration decreases; thus, the time of 2 h was used in this analysis. This release rate (based on the bounded maximum iodine concentration and using 2 h in the equation) is listed for each event as $R3(2)$ in Table II.

The release rate must be normalized to account for differences in reactor size because the amount of iodine being released from the fuel into the RCS is a function of the number of fuel rods in the core and the iodine inventory in those fuel rods. The SRP normalizes this number to the steady-state release rate by specifying that the release rate during the transient be 500 times larger than that which, during steady-state operation, results in an RCS concentration of 1.0 μCi/g. This methodology is difficult to assess because the number of reactor trips that occur with an RCS concentration near 1.0 μCi/g is too small to be used in this analysis. Assessing the SRP methodology (comparing the ratio of the bounded iodine spike release rate and the pretrip steady-state release rates to the SRP value of 500) using all trips results in extremely large ratios (up to 12 000), not because the absolute posttrip release rate (ratio-numerator) is high but rather because the steady-state release rate (ratio-denominator) is so low. This is illustrated in Fig. 1, which shows the release rate ratio (R/R_0) plotted against the initial iodine concentration. All ratios >500 result from initial concentrations <0.3 μCi/g.

A different normalization method is proposed, namely to divide the release rate by the steady-state core power [in megawatts(electric)]. Assuming that the ratio of "leaking" to intact fuel rods is approximately constant between PWRs, the release rate depends on the amount of iodine in the defective rods, which, in turn, depends on the pretrip power level. If one also assumes that PWRs usually are base-load plants and operate at full power, one could normalize the release rate using the number of fuel rods in the core. However, the pretrip power level was known for each of the events in the data base, whereas the number of fuel rods was not. Therefore, the release rate was normalized using the power level. Using pretrip core power to normalize the release rate is a valid method of comparing release rates among the various plant sizes while eliminating the artificiality of assuming a single steady-state iodine concentration. Thus, each release rate in Table II was divided by the pretrip core electric power level prior to performing the statistical analysis discussed in Sec. III.

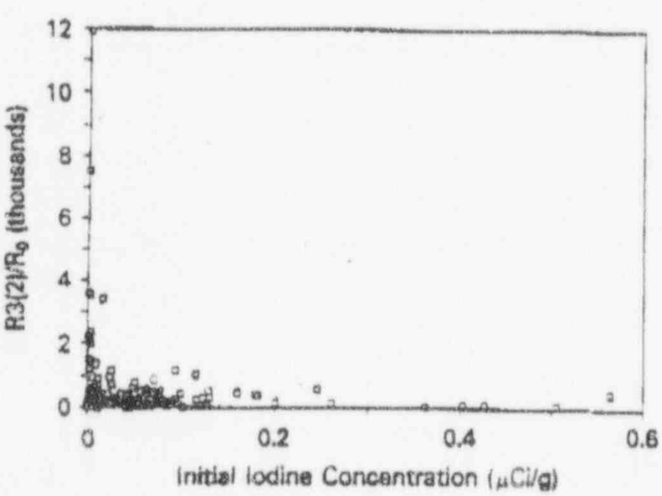

Fig. 1. Bounded release rate ratio compared to initial iodine concentration.

III. PROBABILITY DISTRIBUTIONS FOR THE RELEASE RATE

A statistical analysis was performed on the data base in Table II to estimate the probability distribution of the normalized release rate associated with an iodine spike caused by a reactor trip. It was assumed that the events represent a random sampling of the iodine spiking that has occurred and is expected to occur in commercial PWRs. No attempt was made to correlate the data to either specific plants or fuel manufacturers. The results from this statistical analysis are cumulative probability distributions, which are measures of the probability that an SGTR would result in an iodine spike with magnitude less than a given value. Both the nominal probability distribution and the 95% confidence limit probability distribution were calculated using nonparametric statistical analysis methods.

The statistical methodology used to analyze the data base was as follows. The nominal probability corresponding to the k'th release rate out of a total of 168 events is $k/169$. The 95% confidence lower bounds on the cumulative probability of each point are found using the methodology discussed in Refs. 10 and 11. The results are independent of any assumption regarding the shape of the probability distribution of iodine concentrations or of iodine release rates.

Table III is a listing of the normalized bounded release rates and the calculated nominal probability and 95% confidence limit probability distributions. These same results are illustrated in Fig. 2, which shows the two probability distributions plotted against the release rate and expanded to emphasize probabilities >0.5. The interpretation of the results can be illustrated by considering the 90th percentile, the value that exceeds 90% of the normalized release rates from all possible SGTR events of the type considered. The nominal value (best estimate) of the 90th percentile is given by event 152, 0.679 Ci/h·MW(electric). (Note: The event numbers in this table are for the ordered release rates; identical event numbers in different tables do not imply the same event.) This value of 0.679 corresponds to probability 0.899, or 90% when rounded. The 95%

Calculation No.	BYR97-023
Attachment	Attachment: D
Revision No.	00
Page No.	Page 9 of 11

TABLE III

Statistical Analysis of the Iodine Release Rate

Event Number	$R3(2)/P$[a] (Ci/h·MW)	Nominal Probability	95% Confidence Limit	Event Number	$R3(2)/P$ (Ci/h·MW)	Nominal Probability	95% Confidence Limit
1	9.69E−06[b]	0.006	0.000	51	1.93E−02	0.302	0.245
2	2.73E−05	0.012	0.002	52	2.11E−02	0.308	0.251
3	6.15E−05	0.018	0.005	53	2.25E−02	0.314	0.256
4	6.15E−05	0.024	0.008	54	2.25E−02	0.320	0.262
5	6.32E−05	0.030	0.012	55	2.30E−02	0.325	0.268
6	6.40E−05	0.036	0.016	56	2.42E−02	0.331	0.273
7	7.09E−05	0.041	0.020	57	2.45E−02	0.337	0.279
8	7.23E−05	0.047	0.024	58	2.60E−02	0.343	0.284
9	7.26E−05	0.053	0.028	59	2.72E−02	0.349	0.290
10	7.71E−05	0.059	0.033	60	2.75E−02	0.355	0.296
11	1.03E−04	0.065	0.037	61	2.95E−02	0.361	0.301
12	1.03E−04	0.071	0.042	62	3.48E−02	0.367	0.307
13	1.51E−04	0.077	0.046	63	3.62E−02	0.373	0.313
14	1.75E−04	0.083	0.051	64	4.20E−02	0.379	0.318
15	1.78E−04	0.089	0.056	65	4.40E−02	0.385	0.324
16	2.18E−04	0.095	0.061	66	4.78E−02	0.391	0.330
17	2.27E−04	0.101	0.066	67	4.79E−02	0.396	0.335
18	2.63E−04	0.107	0.070	68	5.05E−02	0.402	0.341
19	2.79E−04	0.112	0.075	69	5.10E−02	0.408	0.347
20	2.79E−04	0.118	0.080	70	5.11E−02	0.414	0.353
21	3.30E−04	0.124	0.085	71	5.33E−02	0.420	0.358
22	3.54E−04	0.130	0.090	72	5.43E−02	0.426	0.364
23	5.03E−04	0.136	0.095	73	5.63E−02	0.432	0.370
24	5.73E−04	0.142	0.101	74	5.82E−02	0.438	0.376
25	7.27E−04	0.148	0.106	75	5.95E−02	0.444	0.381
26	7.97E−04	0.154	0.111	76	6.12E−02	0.450	0.387
27	8.36E−04	0.160	0.116	77	6.18E−02	0.456	0.393
28	8.37E−04	0.166	0.121	78	6.22E−02	0.462	0.399
29	8.74E−04	0.172	0.126	79	6.36E−02	0.467	0.405
30	9.40E−04	0.178	0.132	80	6.48E−02	0.473	0.411
31	1.07E−03	0.183	0.137	81	6.82E−02	0.479	0.416
32	1.63E−03	0.189	0.142	82	6.87E−02	0.485	0.422
33	1.71E−03	0.195	0.147	83	7.24E−02	0.491	0.428
34	3.00E−03	0.201	0.153	84	7.33E−02	0.497	0.434
35	3.71E−03	0.207	0.158	85	7.52E−02	0.503	0.440
36	4.92E−03	0.213	0.163	86	7.53E−02	0.509	0.446
37	5.15E−03	0.219	0.169	87	8.11E−02	0.515	0.452
38	1.03E−02	0.225	0.174	88	8.35E−02	0.521	0.458
39	1.08E−02	0.231	0.179	89	8.41E−02	0.527	0.463
40	1.10E−02	0.237	0.185	90	8.58E−02	0.533	0.469
41	1.12E−02	0.243	0.190	91	8.93E−02	0.538	0.475
42	1.19E−02	0.249	0.196	92	9.22E−02	0.544	0.481
43	1.19E−02	0.254	0.201	93	9.23E−02	0.550	0.487
44	1.31E−02	0.260	0.207	94	9.32E−02	0.556	0.493
45	1.32E−02	0.266	0.212	95	9.46E−02	0.562	0.499
46	1.33E−02	0.272	0.218	96	9.79E−02	0.568	0.505
47	1.41E−02	0.278	0.223	97	9.88E−02	0.574	0.511
48	1.58E−02	0.284	0.229	98	9.95E−02	0.580	0.517
49	1.60E−02	0.290	0.234	99	1.04E−01	0.586	0.532
50	1.91E−02	0.296	0.240	100	1.12E−01	0.592	0.529

See footnotes at end of table.

(Continued)

TABLE III (Continued)

Event Number	$R3(2)/P$[a] (Ci/h·MW)	Nominal Probability	95% Confidence Limit	Event Number	$R3(2)/P$ (Ci/h·MW)	Nominal Probability	95% Confidence Limit
101	1.14E−01	0.598	0.535	136	3.63E−01	0.805	0.753
102	1.15E−01	0.604	0.541	137	3.71E−01	0.811	0.759
103	1.19E−01	0.609	0.547	138	3.74E−01	0.817	0.766
104	1.26E−01	0.615	0.553	139	3.76E−01	0.822	0.772
105	1.27E−01	0.621	0.559	140	3.84E−01	0.828	0.779
106	1.27E−01	0.627	0.565	141	3.91E−01	0.834	0.785
107	1.37E−01	0.633	0.571	142	4.04E−01	0.840	0.792
108	1.40E−01	0.639	0.578	143	4.06E−01	0.846	0.798
109	1.40E−01	0.645	0.584	144	4.23E−01	0.852	0.805
110	1.48E−01	0.651	0.590	145	4.43E−01	0.858	0.812
111	1.52E−01	0.657	0.596	146	4.68E−01	0.864	0.818
112	1.53E−01	0.663	0.602	147	4.85E−01	0.870	0.825
113	1.70E−01	0.669	0.608	148	5.89E−01	0.876	0.832
114	1.81E−01	0.675	0.614	149	5.93E−01	0.882	0.838
115	1.87E−01	0.680	0.620	150	5.94E−01	0.888	0.845
116	1.95E−01	0.686	0.627	151	6.08E−01	0.893	0.852
117	1.96E−01	0.692	0.633	152	6.79E−01	0.899	0.859
118	1.97E−01	0.698	0.639	153	7.10E−01	0.905	0.866
119	2.06E−01	0.704	0.645	154	7.32E−01	0.911	0.873
120	2.14E−01	0.710	0.651	155	7.32E−01	0.917	0.880
121	2.2[illegible]E−01	0.716	0.658	156	8.12E−01	0.923	0.887
122	2.21E−01	0.722	0.664	157	8.93E−01	0.929	0.894
123	2.35E−01	0.728	0.670	158	1.09E+00	0.935	0.901
124	2.42E−01	0.734	0.676	159	1.28E+00	0.941	0.908
125	2.48E−01	0.740	0.683	160	1.53E+00	0.947	0.916
126	2.5[illegible]E−01	0.746	0.689	161	2.08E+00	0.953	0.923
127	2.80E−01	0.751	0.695	162	2.11E+00	0.959	0.931
128	2.80E−01	0.757	0.702	163	2.13E+00	0.964	0.938
129	2.85E−01	0.763	0.708	164	2.29E+00	0.970	0.946
130	3.07E−01	0.769	0.714	165	3.39E+00	0.976	0.954
131	3.15E−01	0.775	0.721	166	3.42E+00	0.982	0.963
132	3.25E−01	0.781	0.727	167	3.70E+00	0.988	0.972
133	3.30E−01	0.787	0.733	168	6.62E+00	0.994	0.982
134	3.34E−01	0.793	0.740				
135	3.54E−01	0.799	0.746				

[a] $R3(2)/P$ is the iodine release rate calculated using the bounded iodine concentration and the 2-h assumption, divided by the pretrip power.
[b] Read as 9.69×10^{-4}.

confidence upper bound on the 90th percentile is given by event 158, 1.09 Ci/h·MW(electric). With 95% confidence, it is expected that 90% (or from the table, 90.1%) of all SGTRs will result in an iodine spike with a normalized release rate <1.09 Ci/h·MW(electric). Thus, the use of the data to determine the probability of concentrations resulting from future events depends on the desired level of confidence. If nominal probability values suffice, they can be used (e.g., the nominal 90% value). If a higher degree of confidence is required, the 95% confidence probability distribution may be used.

The 90th percentile release rate is 0.679 Ci/h·MW(electric), resulting in an absolute release rate of 679 Ci/h for a 1000-MW(electric) plant. The 95% confidence bound on the 90th percentile is 1.[illegible]9 Ci/h·MW(electric), resulting in an absolute release rate of 1090 Ci/h for a 1000-MW(electric) plant. The SRP value for this size plant (based on an initial RCS concentration of 1.0 μCi/g and a 500-fold increase in release rate) is calculated in Ref. 4 to be 16 300 Ci/h. This appears to be overly conservative and could be reduced, from this analysis, by a factor of ~15. If a higher level of assurance is deemed appropriate, a higher percentile (and, therefore, a higher normalized concentration) could be used.

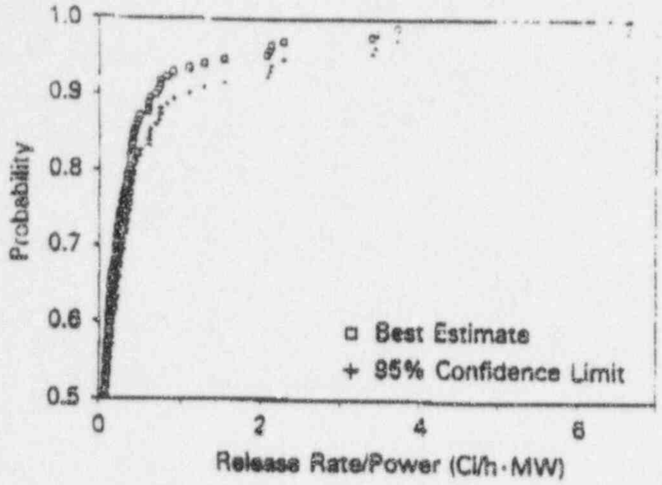

Fig. 2. Probability distributions for the bounded and normalized release rate (expanded).

IV. CONCLUSIONS

An in-depth study of the radioiodine response of a PWR to a reactor trip has been presented, based on data from a wide variety of PWRs, including all NSSS vendors and all sections of the country. The expected radioiodine response in the RCS during an SGTR event is inferred from these data. The data indicate that the iodine release rate assumed in the calculation of an SGTR event could be reduced substantially (e.g., by a factor of 15) and still result in a conservative analysis. An alternate formalism is proposed for use in analysis of this accident type wherein an absolute release rate, normalized to plant power, is used, rather than the 500-fold increase in steady-state release rate as now specified by the SRP. The 95/90% (95% confidence, 90th percentile) value of 1.09 Ci/h·MW(electric) is recommended for consideration as a replacement for the current iodine release rate specification for an SGTR with coincident iodine spike.

ACKNOWLEDGMENT

This work was performed under the auspices of the U.S. Department of Energy under contract DE-AC-07-76ID01570.

REFERENCES

1. "Leakage Rate Testing of Containments of Light-Water-Cooled Nuclear Power Plants," *Code of Federal Regulations*, Title 10, Part 50 (1979).

2. "Standard Review Plan," NUREG-0800, Rev. 2, U.S. Nuclear Regulatory Commission (1981).

3. J. P. ADAMS and M. B. SATTISON, "Frequency and Consequences Associated with a Steam Generator Tube Rupture Event," *Nucl. Technol.*, 90, 168 (1990).

4. J. P. ADAMS and C. L. ATWOOD, "Probability of the Iodine Spike Release Rate During an SGTR," EGG-NERD-8648, EG&G Idaho, Inc. (Sep. 1989).

5. R. J. LUTZ and W. CHUBB, "Iodine Spiking—Cause and Effect," *Trans. Am. Nucl. Soc.*, 28, 649 (1978).

6. E. C. BEAHM, S. R. DAISH, W. E. SHOCKLEY, and J. HOPENFELD, "Iodine Partitioning in Pressurized Water Reactor Steam Generator Accidents," *Nucl. Technol.*, 90, 16 (1990).

7. R. J. LUTZ, Jr., "Iodine Behavior Under Transient Conditions in the Pressurized Water Reactor," WCAP-8637, Westinghouse Electric Corporation (1975).

8. B. J. LEWIS, D. B. DUNCAN, and C. R. PHILLIPS, "Release of Iodine from Defective Fuel Elements Following Reactor Shutdown," *Nucl. Technol.*, 77, 303 (1987).

9. P. G. VOILLEQUÉ, "Measurements of Radioiodine Species in Samples of Pressurized Water Reactor Coolant," *Nucl. Technol.*, 90, 23 (1990).

10. N. L. JOHNSON and S. KOTZ, *Discrete Distributions*, Sec. 3.7.2, Eq. 28, John Wiley & Sons, New York (1969).

11. M. HOLLANDER and D. WOLFE, *Nonparametric Statistical Methods*, p. 56, John Wiley and Sons, New York (1973).

James P. Adams (BS, physics, Brigham Young University, 1968; PhD, physics, Iowa State University, 1972) has been at the Idaho National Engineering Laboratory (INEL) since 1979, working in reactor safety research. His interests include integral pressurized water reactor response as well as fission product release and transport during design basis and severe core damage accidents. He is currently a scientific specialist in the Nuclear Engineering Group.

Corwin L. Atwood (AB, mathematics, Princeton University, 1962; PhD, mathematics, Cornell University, 1968) taught statistics and mathematics at several universities for 10 years. Since 1977, he has been at INEL, where he now holds the rank of principal scientist in the Statistics and Reliability Engineering Group. His interests include data analysis, probabilistic risk assessment, and statistical computing.