DISTRIBUTION AFTER ISSUANCE OF OPERATING LICENSE

NRC FORM 195 (2-76)

U.S. NUCLEAR REGULATORY COMMISSION

NRC DISTRIBUTION FOR PART 50 DOCKET MATERIAL

DOCKET NUMBER: 50-269/270/287

FILE NUMBER:

TO:	FROM:	DATE OF DOCUMENT
Mr. Edson G. Case	Duke Power Co. Charlotte, N. C. 28242 William O. Parker	12/30/77
		DATE RECEIVED: 01/04/78

☒ LETTER ☒ ORIGINAL ☐ COPY ☐ NOTORIZED ☒ UNCLASSIFIED	PROP	INPUT FORM	NUMBER OF COPIES RECEIVED
			1 SIGNED

DESCRIPTION	ENCLOSURE
1p	Consists of response to questions forwarded in NRC's ltr of 11/23/77 concerning the Steam Generator Tube Leakage Safety Assessment Rept... 21p
PLANT NAME: OCONEE UNITS 1 - 3 jcm 01/04/78	1 ENCL

FOR ACTION/INFORMATION

SAFETY BRANCH CHIEF: (7)	SCHWENCER

INTERNAL DISTRIBUTION

REG FILE
NRC PDR
I & E (2)
OELD
HANAUER
CHECK
EISENHUT
SHAO
BAER
BUTLER
GRIMES
J. COLLINS
J. MCGOUGH

EXTERNAL DISTRIBUTION

LPDR: WALHALLA S.C.
TIC
NSIC
ACRS 16 CYS SENT CATEGORY B

CONTROL NUMBER

780040069

DUKE POWER COMPANY
POWER BUILDING
422 SOUTH CHURCH STREET, CHARLOTTE, N. C. 28242

WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

TELEPHONE: AREA 704
373-4083

December 30, 1977

REGULATORY DOCKET FILE COPY

RECEIVED
JAN 4 1978
U.S. NUCLEAR REGULATORY COMMISSION
Mail Section

Mr. Edson G. Case, Acting Director
Office Of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. A. Schwencer, Chief
Operating Reactors Branch #1

RE: Oconee Nuclear Station
Docket Nos. 50-269, -270, -287

Dear Sir:

The attached information is in response to questions forwarded in your letter of November 23, 1977 concerning the Steam Generator Tube Leakage Safety Assessment Report which was forwarded by my letter of September 9, 1977.

Very truly yours,

William O. Parker

William. O. Parker, Jr.

RLG/mlr

Attachment

780040069

QUESTION 1:

For your LOCA analysis with concurrent steam generator tube rupture, provide the following information:

a. State the phase of LOCA recovery for which rupture of the steam generator tubes was assumed to occur.

b. Explain how the rupture of 20 tubes could be tolerated without affecting peak clad temperature. Justify your response in light of the Semiscale MOD 1, Test Series 28 results.

c. Explain the effect of the rupture of 20 tubes on the assumed loop water seal. Justify your response in detail.

RESPONSE:

a. In assessing the impact of the effect of steam generator tube rupture on a LOCA, the rupture of the steam generator tubes was assumed at the beginning of core reflooding.

b. As stated in the report, the rupture of 20 tubes could be tolerated if credit were taken for steam flow through the loops during the reflooding phase of the LOCA transient. The use of the loops for venting of the steam produced during core reflooding results in approximately a 70% increase in reflooding rates relative to that calculated in BAW-10103. Rupture of 20 steam generator tubes would reduce the reflooding rates. However, the resulting reflooding rates, obtained assuming loop venting, would be approximately that utilized in BAW-10103. Thus, the peak cladding temperature would be unaffected.

   The results of the Semiscale MOD 1, Test Series 28 experiments do not apply to the Oconee units. In the test series, hot water was injected into the hot legs to simulate the steam generator tube ruptures. The subsequent blockage of the hot leg due to the injection of the hot fluid results in reverse flow through the core. This phenomena would not occur in the Oconee units. The steam generators utilized at Oconee are once through steam generators (OTSG) and would not inject fluid into the hot legs and cause reverse flow through the core.

   The impact of any steam generator tube ruptures during a LOCA would also be minimized by the internal vent valves in the Oconee units. The vent valves provide a direct steam relief path from the upper plenum to the break in the cold leg piping. Thus, the pressure increase in the upper plenum that would occur due to the steam generator tube rupture would be minimized by steam relief through the vent valves. Since the Semiscale MOD 1, Test Series 28 did not include the internal vent valves nor simulate the phenomena expected for a tube rupture in the Oconee units, the results of those tests do not apply.

c. If a loop water seal was assumed to be present at the start of reflooding of the core, rupture of only three steam generator tubes could be tolerated. Rupture of 20 tubes with an assumed loop water seal would result in an increased peak cladding temperature. However, the increased primary system pressure that would occur due to the tube ruptures would probably blow out the loop seal. Once the loops are cleared, reflooding rates on the order of that calculated in BAW-10103 would be obtained for 20 tube ruptures.

QUESTION 2:

The iodine spiking model presented in Appendix A needs to be discussed in more detail, preferably as a separate report. Explain why the model proposed is considered to be conservative. In particular, estimate the probability of a spike exceeding the model occurring at the Oconee plants. Compare these spikes with those observed at other plants and explain differences in the phenomena causing the spike which allow other data to be disregarded. Present an analysis using a correlation derived from all spiking data available.

RESPONSE:

The iodine spiking model presented in Appendix A of the report is an empirical correlation for Iodine-131 activity in the reactor coolant following four iodine spiking transients. The development of an iodine spiking correlation is based on Iodine-131 (since it's the major contribution to the thyroid dose), but it is assumed to equally apply to all iodine nuclides.

The general relationship for the radioiodine concentration in the reactor coolant is:

$$\frac{d\ C(t)}{dT} = \frac{R}{V} - LC\ (t)$$

where: $C(t)$ is the reactor coolant activity ($\mu Ci/g$);

R is the rate of release of iodine activity into the reactor coolant ($\mu Ci/min$);

V is the reactor coolant mass (grams);

L is the total iodine removal rate (min^{-1});

$L = \lambda + \beta + \ell$

- λ is the decay constant (min^{-1})
- β is reactor coolant iodine purification constant (min^{-1})
- ℓ is reactor coolant iodine dilution constant (min^{-1})

t is the time after power or pressure transient (min);

C^* is the steady-state iodine concentration prior to the transient ($\mu Ci/g$);

L^* is the steady-state iodine removal rate prior to the transient (min^{-1});

R^* is the steady-state release rate of iodine activity into the reactor coolant ($\mu Ci/min$).

$$C(o) = C^* = \frac{R^*}{L^*V}$$

The rate of release of iodine activity into the reactor coolant (R) includes all mechanisms of iodine release from the fuel and fuel rod gaps into the reactor coolant that produces the iodine spiking phenomena. The possible mechanisms for the iodine spiking phenomena are the release of iodine from the UO_2 matrix due to thermal and pressure stresses in the fuel and fuel rod cladding or from the inner surfaces of defective fuel rods due to water leaching. Although the exact mechanism of iodine spiking is not understood, the rate of release into the reactor coolant can be determined from operating data.

Assuming the rate of release of iodine activity into the reactor coolant and the total iodine removal rate vary slowly with time, then the above differential equation can be solved for the reactor coolant iodine concentration as a function of time:

$$C(t) = C^* e^{-Lt} + \frac{R}{LV}(1 - e^{-Lt})$$

If some phases of the iodine spiking transient are delayed for a significant period of time following reactor shutdown, the release rate of iodine into the reactor coolant must be corrected for decay of the source within the fuel rod by multiplying the release rate, R, by $e^{-\lambda t}$. The spiking factor (R/R*) is defined as the ratio of the release rate of iodine activity following the iodine spiking transient to the steady-state equilibrium release rate of iodine activity prior to the transient. The spiking factor is introduced into the above equation by multiplying the second term by L*C* V/R*. The concentration of iodine in the reactor coolant can now be seen to be the equation in Appendix A of the report.

The detailed data from four iodine spiking transients at operating reactors is shown in Appendix A, Figures A-1 through A-7. Based on these data, iodine spikes can be identified with four separate phases of each transient as indicated in Appendix A. Analysis of the operating data also shows that for each spiking phase, the spiking factor is a maximum at the start of the phase and gradually decays away with time. The relationship found to approximate the spiking factor (R/R*) for each phase of the spiking transient is also shown in Appendix A. The values for the iodine spiking co-efficient (F_i) for each spiking phase that result in a suitable fit to the data from the four spiking transients are given in Appendix A of the report.

It should be noted that the phases of an iodine spiking transient observed at an operating reactor during normal operating actions may be separated by several hours or even several days, but during an accident transient all spiking phases begin within seconds or minutes of the accident. The separate spiking phases that are associated with the accident transients are superimposed during the start of the transient which has the effect of nullifying the $e^{-\lambda t}$ term that corrects for the decay of the iodine source within the fuel rods.

The conservatism of the iodine spiking correlation described in Appendix A can be verified by comparing the reactor coolant iodine activity predicted by the spiking correlation to the measured activity shown in Figures A-5 through A-8. The predicted iodine activity levels are generally conservative in comparison to the measured coolant activities, especially during the first two hours following the start of the transient, which is the time period of interest in evaluating the most limiting dose consequences of a steam line break or steam generator tube rupture accident. Of the 94 measured data points on Figures A-5 through A-8, only 4 data points have measured values that exceed the values predicted by the spiking correlation. Using these data and a hypergeometric probability distribution, it is estimated that the correlation will predict with a 95% confidence level, iodine concentrations which are correct or conservative approximately 95% of the time.

The iodine spiking correlation described is based on data from the Oconee 1 and Three Mile Island 1 units for four carefully monitored iodine spiking transients. The data was obtained specifically to follow the iodine spiking phenomena. Other radio-chemistry operating data from Oconee and TMI-1, as well as data from other PWR's and BWR's were not utilized in the development of an iodine spiking correlation because of the uncertainty of the data's validity and applicability due to the different reactor types, different fuel, and due to the infrequency of the data samples, which may have missed the peak of the iodine spike. As more data becomes available and as a better understanding of the iodine spiking is developed, the iodine spiking correlation described will be improved to calculate more accurate reactor coolant iodine activity values than those values obtained with the present conservative models.

QUESTION 3:

The expression given on page 12 of your report to calculate the reactor coolant activity as a function of time appears to be incorrect. Indicate how it was derived and assumptions made.

RESPONSE:

The empirical equation used to calculate the iodine concentration in the reactor coolant during iodine spiking transients has been checked and is correct. This equation and the empirically derived value of F_i (iodine spiking coefficients) presented in the report were used on Figures A-3 through A-8. The basis for arriving at this iodine spiking correlation was explained in the response to Question 2.

QUESTION 4:

You assume that only 10% of the iodine contained in the reactor coolant to secondary leak is released to the environment. Explain where the remainder of the iodine is expected to be as a function of time, in view of the fact that the steam generator is assumed dry.

RESPONSE:

The effect of the iodine release fraction (1/DF) on the two-hour thyroid dose at the exclusion area boundary is shown in Table 1 for the transient analysis assumptions and conditions described in the response to Question 1. Case 1 assumes a DF of 1.0 for the entire two-hour period and represents the ultimate in conservatism. Case 2 assumes a DF of 1.0 until the average temperature of the reactor coolant falls to $212^{o}F$ and a DF of 100 thereafter. Case 3 assumes a DF of 10.0 for the entire two-hour period. Since a significant water inventory and a signficant iodine DF is expected to occur well before the average reactor coolant temperature reaches $212^{o}F$, the doses for Case 2 are conservative. Thus, a reasonable dose estimate seems to be bounded by Cases 2 and 3.

The bases for the above dose evaluations are:

1. The iodine activities in the reactor coolant and in the secondary coolant prior to the steam line break accident are, respectively, 3.5 and 0.1 μCi/g of dose equivalent I-131. These are the maximum equilibrium activity levels allowed by the proposed Technical Specifications for the Oconee Nuclear Station.

2. No additional fuel cladding failures occur as a result of the steam line break accident with concurrent steam generator tube ruptures. This is based on the transient analysis of the thermal-hydraulic performance of the primary and secondary coolant loops, described in Section 2 of the report, which shows that the reactor core remains covered at all times during the accident and that the DNBR calculations do not indicate additional failed fuel.

3. The primary-to-secondary mass flow rates used to calculate the curies of iodine entering the secondary system are shown in Tables 2, 3 and 4's (column labelled LEAK RATE). These mass flow rates were obtained from the transient analysis of the thermal-hydraulic performance of the primary and secondary coolant loops, which was described in the response to Question 2.

4. The primary coolant makeup mass flow rates are shown in Tables 2, 3 and 4 (column labelled DILUTION RATE). These mass flow rates were also obtained from the transient analysis described in the response to Question 2. The makeup mass flow rate has the net effect of diluting the reactor coolant iodine activity concentration following the accident.

5. The effect of the "iodine spike" associated with the accident transient is included in calculating the iodine activity in the reactor coolant. The iodine spiking model used to calculate the reactor coolant iodine activity following the accident transient is presented in Appendix A. The reactor coolant iodine activity following the rupture of one steam generator tube is shown in Tables 2, 3 and 4 (column labelled RC ACTIVITY).

5. The effect of the "iodine spike" associated with the accident transient is included in calculating the iodine activity in the reactor coolant. The iodine spiking model used to calculate the reactor coolant iodine activity following the accident transient is presented in Appendix A. The reactor coolant iodine activity following the rupture of one steam generator tube is shown in Tables 2, 3 and 4 (column labelled RC ACTIVITY).

6. The following iodine decontamination factors in the steam generator are assumed in determining the releases for the iodine activity entering the secondary system from the failed steam generator tubes:

   a) Case 1 (Table 2) - DF of 1.0 for 120 minute release;

   b) Case 2 (Table 3) - DF of 1.0 for 59 minutes and a DF of 100 thereafter based on the average reactor coolant temperature falling below $212^{o}F$;

   c) Case 3 (Table 4) - DF of 10.0 for 120 minute release. The steam generator iodine decontamination factors used in the calculations for Cases 1, 2 and 3 are shown, respectively, in Tables 2, 3 and 4 (column labelled DF).

7. The curies of iodine entering the secondary system are calculated by integrating the product of the reactor coolant iodine concentration and the primary-to-secondary mass leak rate over the time period of interest.

8. All the iodine activity in 173,300 lbs. of secondary coolant is assumed to be released to the environment. The transient analysis of Section 2 shows that only 110,000 lbs. of secondary coolant is released to the environment following a steam line break. Therefore, the assumption of the release of 173,300 lbs. of secondary coolant is a conservative assumption. The total curies released to the environment from the secondary coolant are 7.86 curies of dose-equivalent I-131. The 7.86 curies are conservatively added into the environmental release during the first time step of the calculation.

9. The iodine activity associated with a constant primary-to-secondary leak rate of 1 gpm (the maximum leak rate permitted by Technical Specification 3.1.6) in the unaffected steam generator is assumed to be released to the environment. The total curies of dose-equivalent I-131 released to the environment for a steam line break accident with the rupture of one steam generator tube are shown in Tables 2, 3 and 4 (column labelled TOTAL CURIES OUT). The curies of dose equivalent I-131 released to the environment during a particular time step are also shown in Tables 2, 3 and 4 (column labelled DELTA CURIES).

10. The site boundary doses are calculated using the zero to two-hour atmospheric dispersion factor at the Oconee Nuclear Station site boundary (1609 m) corresponding to a ground level release, i.e., X/Q of 1.16×10^{-4} sec/m^3 (per FSAR Section 2.3.2). The dose calculational model is consistent with TID-14844.

Table 1 shows the two-hour tyroid doses at the exclusion area boundary for a steam line break with the concurrent rupture of both one and three steam generator tubes. The transient analysis assumptions for the three tubes ruptured case are given in the response to Question 2. Tables 5, 6 and 7 provide the primary-to-secondary flow rates and the reactor coolant dilution rates for the rupture of three steam generator tubes concurrent with a steam line break for the three cases of steam generator iodine decontamination factors described previously in assumption 6.

Table 1 shows that the radiological dose consequences of a steam line break accident with the concurrent rupture of one or three steam generator tubes are within the 10CFR100 exposure guidelines.

Table 1

Thyroid Dose As A Function of Steam Generator Iodine DF

Steam Line Break With One and Three SG Tubes Ruptured

Case		Two Hour Thyroid Dose At Exclusion Area Boundary	
		One Tube Ruptured (rem)	Three Tubes Ruptured (rem)
1	DF of 1.0 for 120 minutes	84.0	160.0
2	DF of 1.0 for 59 minutes* DF of 100 thereafter	53.1	64.9
3	DF of 10.0 for 120 minutes	8.8	16.4

* For the three tubes ruptured the DF of 1.0 is assumed for 26 minutes

Table 2 - SLB Radiological Consequences With One SG Tube Rupture - Iodine DF Case 1

TIME	LEAK RATE	DILUTION RATE	RC MASS	RC ACTIVITY	DF	DELTA CURIES	TOTAL CURIES OUT
MINUTES	LBS/SEC	LBS/SEC	LBS	MICROC PER GRAM		CURIES	CURIES
0.	.40830E+02	.27650E+02	.52276E+06	.35000E+01	.10000E+01	0.	0.
.10000E+00	.40400E+02	.27650E+02	.52266E+06	.35296E+01	.10000E+01	.42363E+00	.82830E+01
.11670E+00	.40300E+02	0.	.52264E+06	.35346E+01	.10000E+01	.65493E-01	.83493E+01
.23330E+00	.35100E+02	0.	.52237E+06	.35693E+01	.10000E+01	.43031E+00	.87796E+01
.33330E+00	.37500E+02	0.	.52215E+06	.35991E+01	.10000E+01	.36281E+00	.91416E+01
.51670E+00	.31700E+02	0.	.52177E+06	.36530E+01	.10000E+01	.64539E+00	.97870E+01
.58330E+00	.31600E+02	.99400E+02	.52179E+06	.36650E+01	.10000E+01	.57535E-01	.98446E+01
.83330E+00	.21300E+02	.10200E+03	.52313E+06	.38695E+01	.10000E+01	.89553E+00	.10740E+02
.11167E+01	.20000E+02	.10300E+03	.52452E+06	.40623E+01	.10000E+01	.72547E+00	.11466E+02
.46667E+01	.15900E+02	.11010E+03	.54339E+06	.64609E+01	.10000E+01	.10494E+02	.21960E+02
.48333E+01	.15700E+02	.24670E+03	.54502E+06	.65660E+01	.10000E+01	.68253E+00	.22643E+02
.50003E+01	.15500E+02	.17500E+03	.54697E+06	.66724E+01	.10000E+01	.68875E+00	.23331E+02
.51667E+01	.15300E+02	.19590E+03	.54867E+06	.67776E+01	.10000E+01	.69414E+00	.24025E+02
.56667E+01	.14700E+02	.20190E+03	.55419E+06	.70926E+01	.10000E+01	.20911E+01	.26117E+02
.70000E+01	.13100E+02	.21160E+03	.56962E+06	.79255E+01	.10000E+01	.56063E+01	.31723E+02
.73333E+01	.13900E+02	.11340E+03	.57260E+06	.81269E+01	.10000E+01	.15149E+01	.33238E+02
.75000E+01	.14400E+02	.10390E+03	.57395E+06	.82300E+01	.10000E+01	.81467E+00	.34052E+02
.85300E+01	.15630E+02	.12320E+03	.57810E+06	.85317E+01	.10000E+01	.26460E+01	.36699E+02
.10000E+02	.28703E+02	.12350E+03	.59073E+06	.97205E+01	.10000E+01	.13756E+02	.50455E+02
.10417E+02	.20330E+02	.12370E+03	.59331E+06	.99565E+01	.10000E+01	.36210E+01	.54076E+02
.10833E+02	.20400E+02	.11540E+03	.59579E+06	.10194E+02	.10000E+01	.36845E+01	.57761E+02
.11250E+02	.20700E+02	.12410E+03	.59826E+06	.10420E+02	.10000E+01	.38266E+01	.61587E+02
.11667E+02	.21300E+02	.11700E+03	.60077E+06	.10660E+02	.10000E+01	.40072E+01	.65594E+02
.12083E+02	.21300E+02	.11930E+03	.60319E+06	.10890E+02	.10000E+01	.41517E+01	.69746E+02
.12217E+02	.23400E+02	.11460E+03	.60395E+06	.10963E+02	.10000E+01	.14281E+01	.71174E+02
.12483E+02	.23000E+02	.11440E+03	.60540E+06	.11100E+02	.10000E+01	.30169E+01	.74191E+02
.12733E+02	.24200E+02	.11420E+03	.60676E+06	.11243E+02	.10000E+01	.29224E+01	.77113E+02
.12933E+02	.24500E+02	.11430E+03	.60784E+06	.11350E+02	.10000E+01	.24003E+01	.79514E+02
.13000E+02	.24700E+02	.11400E+03	.60820E+06	.11386E+02	.10000E+01	.81005E+00	.80333E+02
.14067E+02	.26400E+02	.11300E+03	.61303E+06	.11955E+02	.10000E+01	.13769E+02	.94102E+02
.15167E+02	.28400E+02	.11100E+03	.61944E+06	.12526E+02	.10000E+01	.15902E+02	.11001E+03
.16317E+02	.30600E+02	.11030E+03	.62506E+06	.13100E+02	.10000E+01	.18827E+02	.12891E+03
.17517E+02	.33100E+02	.10050E+03	.63065E+06	.13697E+02	.10000E+01	.22130E+02	.15105E+03
.18417E+02	.36000E+02	.10610E+03	.63632E+06	.14314E+02	.10000E+01	.27000E+02	.17014E+03
.20217E+02	.39500E+02	.10310E+03	.64196E+06	.14956E+02	.10000E+01	.33127E+02	.21126E+03
.21763E+02	.43630E+02	.99100E+02	.64753E+06	.15643E+02	.10000E+01	.42305E+02	.25357E+03
.21917E+02	.44730E+02	.44780E+02	.64775E+06	.15699E+02	.10000E+01	.39435E+01	.25751E+03
.22117E+02	.43330E+02	.43300E+02	.64775E+06	.15783E+02	.10000E+01	.54895E+01	.26300E+03
.22550E+02	.40500E+02	.40500E+02	.64775E+06	.15965E+02	.10000E+01	.12264E+02	.27567E+03
.23067E+02	.37400E+02	.37400E+02	.64775E+06	.16183E+02	.10000E+01	.13835E+02	.28950E+03
.23750E+02	.34100E+02	.34100E+02	.64775E+06	.16470E+02	.10000E+01	.17099E+02	.30660E+03
.25100E+02	.28900E+02	.28990E+02	.64775E+06	.17037E+02	.10000E+01	.30639E+02	.33724E+03
.26333E+02	.27900E+02	.27930E+02	.64775E+06	.17546E+02	.10000E+01	.26126E+02	.36317E+03
.27400E+02	.27000E+02	.27030E+02	.64775E+06	.17977E+02	.10000E+01	.22436E+02	.38580E+03
.29550E+02	.26100E+02	.26100E+02	.64775E+06	.18433E+02	.10000E+01	.23930E+02	.40974E+03
.29767E+02	.25233E+02	.25200E+02	.64775E+06	.18905E+02	.10000E+01	.25457E+02	.43400E+03
.31100E+02	.24200E+02	.24200E+02	.64775E+06	.19412E+02	.10000E+01	.27060E+02	.46107E+03
.32598E+02	.23200E+02	.23200E+02	.64775E+06	.19958E+02	.10000E+01	.28958E+02	.49002E+03
.33067E+02	.22230E+02	.22200E+02	.64775E+06	.20426E+02	.10000E+01	.25798E+02	.51662E+03
.35450E+02	.21330E+02	.21300E+02	.64775E+06	.20907E+02	.10000E+01	.30307E+02	.54701E+03
.38433E+02	.19600E+02	.19600E+02	.64775E+06	.22014E+02	.10000E+01	.55550E+02	.60256E+03
.41433E+02	.18000E+02	.18000E+02	.64775E+06	.22995E+02	.10000E+01	.53467E+02	.65603E+03
.45117E+02	.16200E+02	.16230E+02	.64775E+06	.24139E+02	.10000E+01	.62111E+02	.71814E+03
.49867E+02	.14303E+02	.14300E+02	.64775E+06	.25526E+02	.10000E+01	.74575E+02	.79271E+03
.56433E+02	.12000E+02	.12010E+02	.64775E+06	.27296E+02	.10000E+01	.93387E+02	.88610E+03
.59167E+02	.11300E+02	.11300E+02	.64775E+06	.27954E+02	.10000E+01	.35641E+02	.92174E+03
.66900E+02	.91600E+01	.91000E+01	.64775E+06	.29736E+02	.10000E+01	.91560E+02	.10133E+04
.84950E+02	.49630E+01	.49630E+01	.64775E+06	.34356E+02	.10000E+01	.19995E+03	.12133E+04
.90300E+02	.49683E+01	.49600E+01	.64775E+06	.34432E+02	.10000E+01	.35217E+01	.12166E+04
.95000E+02	.49600E+01	.49600E+01	.64775E+06	.35116E+02	.10000E+01	.32225E+02	.12490E+04
.10000E+03	.49600E+01	.49600E+01	.64775E+06	.35736E+02	.10000E+01	.32306E+02	.12813E+04
.10500E+03	.49600E+01	.49600E+01	.64775E+06	.36297E+02	.10000E+01	.32329E+02	.13137E+04
.11000E+03	.49600E+01	.49600E+01	.64775E+06	.36304E+02	.10000E+01	.32301E+02	.13460E+04
.11500E+03	.49600E+01	.49600E+01	.64775E+06	.37261E+02	.10000E+01	.32231E+02	.13782E+04
.12000E+03	.49600E+01	.49600E+01	.64775E+06	.37672E+02	.10000E+01	.32124E+02	[illegible]

Table 3 - SLB Radiological Consequences With One SG Tube Rupture - Iodine DF Case 2

TIME MINUTES	LEAK RATE LBS/SEC	DILUTION RATE LBS/SEC	RC MASS LBS	RC ACTIVITY MICROC PER GRAM	DF	DELTA CURIES CURIES	TOTAL CURIES OUT CURIES
0.	.46030E+02	.27650E+02	.52276E+06	.35080E+01	.10000E+01	0.	0.
.10000E+00	.40400E+02	.27650E+02	.52266E+06	.35296E+01	.10000E+01	.42383E+00	.42838E+01
.11670E+00	.40300E+02	0.	.52264E+06	.35346E+01	.10000E+01	.65693E-01	.83493E+01
.23330E+00	.35100E+02	0.	.52237E+06	.35693E+01	.10000E+01	.43031E+00	.87796E+01
.33330E+00	.37500E+02	0.	.52215E+06	.35991E+01	.10000E+01	.36261E+00	.91416E+01
.51670E+00	.31700E+02	0.	.52177E+06	.36530E+01	.10000E+01	.64539E+00	.97870E+01
.53330E+00	.31600E+02	.99400E+02	.52179E+06	.36650E+01	.10000E+01	.57935E-01	.98446E+01
.83330E+00	.21300E+02	.10200E+03	.52313E+06	.36695E+01	.10000E+01	.89553E+00	.10740E+02
.11167E+01	.20000E+02	.10300E+03	.52452E+06	.46623E+01	.10000E+01	.72547E+00	.11466E+02
.16667E+01	.15930E+02	.11010E+03	.54339E+06	.64609E+01	.10000E+01	.10494E+02	.21960E+02
.43333E+01	.15700E+02	.24670E+03	.54502E+06	.65668E+01	.10000E+01	.68253E+00	.22643E+02
.50000E+01	.15500E+02	.17500E+03	.54697E+06	.66724E+01	.10000E+01	.68875E+00	.23331E+02
.51667E+01	.15330E+02	.19590E+03	.56067E+06	.67776E+01	.10000E+01	.69414E+00	.24025E+02
.56667E+01	.14730E+02	.20190E+03	.55419E+06	.74926E+01	.10000E+01	.20911E+01	.26117E+02
.70000E+01	.13190E+02	.21160E+03	.56962E+06	.79255E+01	.10000E+01	.56063E+01	.31723E+02
.73333E+01	.13903E+02	.11380E+03	.57260E+06	.81269E+01	.10000E+01	.15149E+01	.33238E+02
.75000E+01	.14430E+02	.10390E+03	.57335E+06	.82308E+01	.10000E+01	.81467E+00	.34052E+02
.80000E+01	.15630E+02	.12320E+03	.57810E+06	.85317E+01	.10000E+01	.26468E+01	.36699E+02
.10000E+02	.20710E+02	.12350E+03	.59073E+06	.97235E+01	.10000E+01	.13756E+02	.50455E+02
.10417E+02	.20330E+02	.12370E+03	.59331E+06	.99545E+01	.10000E+01	.36210E+01	.54076E+02
.10833E+02	.20400E+02	.11540E+03	.59574E+06	.10194E+02	.10000E+01	.36045E+01	.57761E+02
.11250E+02	.20780E+02	.12410E+03	.59826E+06	.10428E+02	.10000E+01	.38266E+01	.61587E+02
.11667E+02	.21383E+02	.11760E+03	.60077E+06	.10660E+02	.10000E+01	.40072E+01	.65594E+02
.12083E+02	.21300E+02	.11930E+03	.60319E+06	.10890E+02	.10000E+01	.41517E+01	.69746E+02
.12217E+02	.23430E+02	.11460E+03	.60395E+06	.10963E+02	.10000E+01	.14201E+01	.71174E+02
.12483E+02	.23600E+02	.11440E+03	.60540E+06	.11140E+02	.10000E+01	.30169E+01	.74191E+02
.12723E+02	.24280E+02	.11420E+03	.60676E+06	.11243E+02	.10000E+01	.29224E+01	.77113E+02
.12933E+02	.24530E+02	.11430E+03	.60784E+06	.11350E+02	.10000E+01	.24803E+01	.79514E+02
.13050E+02	.24730E+02	.11430E+03	.60820E+06	.11386E+02	.10000E+01	.81805E+00	.80333E+02
.14067E+02	.26430E+02	.11300E+03	.61383E+06	.11955E+02	.10000E+01	.13769E+02	.94102E+02
.15167E+02	.28430E+02	.11150E+03	.61944E+06	.12526E+02	.10000E+01	.15902E+02	.11000E+03
.16317E+02	.30620E+02	.11030E+03	.62506E+06	.13108E+02	.10000E+01	.18027E+02	.12891E+03
.17517E+02	.33120E+02	.10850E+03	.63065E+06	.13697E+02	.10000E+01	.22136E+02	.15105E+03
.18817E+02	.36030E+02	.10410E+03	.63632E+06	.14314E+02	.10000E+01	.27048E+02	.17814E+03
.20217E+02	.39530E+02	.10310E+03	.64194E+06	.14956E+02	.10000E+01	.33127E+02	.21126E+03
.21783E+02	.43600E+02	.99130E+02	.64753E+06	.15643E+02	.10000E+01	.42305E+02	.25357E+03
.21917E+02	.44720E+02	.44780E+02	.64775E+06	.15699E+02	.10000E+01	.39435E+01	.25751E+03
.22117E+02	.43370E+02	.43300E+02	.64775E+06	.15781E+02	.10000E+01	.58895E+01	.26340E+03
.22550E+02	.40500E+02	.40500E+02	.64775E+06	.15965E+02	.10000E+01	.12206E+02	.27567E+03
.23067E+02	.37430E+02	.37400E+02	.64775E+06	.16193E+02	.10000E+01	.13885E+02	.28950E+03
.23750E+02	.34130E+02	.34100E+02	.64775E+06	.16476E+02	.10000E+01	.17099E+02	.30660E+03
.25100E+02	.28930E+02	.28930E+02	.64776E+06	.17037E+02	.10000E+01	.30639E+02	.33724E+03
.26383E+02	.27930E+02	.27100E+02	.64776E+06	.17546E+02	.10000E+01	.26126E+02	.36337E+03
.27400E+02	.27030E+02	.27030E+02	.64776E+06	.17977E+02	.10000E+01	.22436E+02	.38580E+03
.28550E+02	.26100E+02	.26105E+02	.64775E+06	.18433E+02	.10000E+01	.23930E+02	.40974E+03
.29767E+02	.25200E+02	.25206E+02	.64775E+06	.18905E+02	.10000E+01	.25857E+02	.43580E+03
.31100E+02	.24200E+02	.24210E+02	.64775E+06	.19412E+02	.10000E+01	.27068E+02	.46107E+03
.32550E+02	.23230E+02	.23210E+02	.64775E+06	.19950E+02	.10000E+01	.28958E+02	.49002E+03
.33867E+02	.22200E+02	.22200E+02	.64775E+06	.20426E+02	.10000E+01	.25790E+02	.51662E+03
.35450E+02	.21300E+02	.21300E+02	.64775E+06	.20907E+02	.10000E+01	.30307E+02	.54781E+03
.38433E+02	.19600E+02	.19630E+02	.64775E+06	.22014E+02	.10000E+01	.55560E+02	.60256E+03
.41433E+02	.18000E+02	.18030E+02	.64775E+06	.22995E+02	.10000E+01	.53467E+02	.65603E+03
.45117E+02	.16200E+02	.14830E+02	.64775E+06	.24139E+02	.10000E+01	.62111E+02	.71816E+03
.49867E+02	.14300E+02	.14300E+02	.64775E+06	.25520E+02	.10000E+01	.74576E+02	.79271E+03
.56433E+02	.12000E+02	.12800E+02	.64775E+06	.27290E+02	.10000E+01	.93347E+02	.88610E+03
.59107E+02	.11230E+02	.11130E+02	.64776E+06	.27954E+02	.10000E+01	.70377E+00	.88680E+03
.66900E+02	.91430E+01	.91100E+01	.64775E+06	.29736E+02	.10000E+01	.91080E+00	.88778E+03
.89450E+02	.49600E+01	.49630E+01	.64775E+06	.34356E+02	.10000E+01	.19995E+01	.88972E+03
.93003E+02	.49600E+01	.49600E+01	.64775E+06	.34432E+02	.10000E+01	.36217E-01	.88975E+03
.95800E+02	.49630E+01	.49600E+01	.64775E+06	.35116E+02	.10000E+01	.32225E+00	.89030E+03
.10000E+03	.49630E+01	.49630E+01	.64775E+06	.35736E+02	.10000E+01	.32306E+00	.89048E+03
.10500E+03	.49600E+01	.49600E+01	.64775E+06	.36297E+02	.10000E+01	.32329E+00	.89072E+03
.11000E+03	.49600E+01	.49600E+01	.64775E+06	.36834E+02	.10000E+01	.32301E+00	.89105E+03
.11500E+03	.49600E+01	.49600E+01	.64775E+06	.37261E+02	.10000E+01	.32231E+00	.89137E+03
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4 - SLB Radiological Consequences With One SG Tube Rupture - Iodine DF Case 3

TIME	LEAK RATE	DILUTION RATE	RC MASS	RC ACTIVITY	DF	DELTA CURIES	TOTAL CURIES OUT
MINUTES	LBS/SEC	LBS/SEC	LBS	MICROC PER GRAM		CURIES	CURIES
0.	.48000E+02	.27650E+02	.52276E+06	.35000E+01	.10000E+02	0.	0.
.12000E+00	.46400E+02	.27650E+02	.52266E+06	.35296E+01	.10000E+02	.42303E-01	.79024E+01
.11670E+00	.40300E+02	0.	.52264E+06	.35346E+01	.10000E+02	.65493E-02	.79089E+01
.23330E+00	.35100E+02	0.	.52237E+06	.35693E+01	.10000E+02	.43031E-01	.79520E+01
.33330E+00	.37500E+02	0.	.52215E+06	.35991E+01	.10000E+02	.36201E-01	.79882E+01
.51670E+00	.31700E+02	0.	.52177E+06	.36530E+01	.10000E+02	.64539E-01	.80527E+01
.53330E+00	.31600E+02	.99400E+02	.52179E+06	.36656E+01	.10000E+02	.57535E-02	.80585E+01
.63330E+00	.21300E+02	.10200E+03	.52313E+06	.38695E+01	.10000E+02	.89553E-01	.81480E+01
.11167E+01	.20000E+02	.10300E+03	.52452E+06	.40623E+01	.10000E+02	.72547E-01	.82206E+01
.46667E+01	.15900E+02	.11010E+03	.54339E+06	.64689E+01	.10000E+02	.10495E+01	.92700E+01
.48333E+01	.16700E+02	.24670E+03	.54502E+06	.65668E+01	.10000E+02	.68253E-01	.93383E+01
.50000E+01	.15500E+02	.17500E+03	.54697E+06	.66724E+01	.10000E+02	.68875E-01	.94071E+01
.51667E+01	.15330E+02	.19590E+03	.54867E+06	.67776E+01	.10000E+02	.69414E-01	.94765E+01
.56667E+01	.14730E+02	.20190E+03	.55419E+06	.70926E+01	.10000E+02	.20911E+00	.96857E+01
.70000E+01	.13100E+02	.21160E+03	.56962E+06	.79255E+01	.10000E+02	.56063E+00	.10246E+02
.73333E+01	.13900E+02	.11300E+03	.57260E+06	.81289E+01	.10000E+02	.15149E+00	.10398E+02
.75000E+01	.14400E+02	.10390E+03	.57395E+06	.82360E+01	.10000E+02	.81467E-01	.10479E+02
.80000E+01	.15636E+02	.12520E+03	.57810E+06	.85317E+01	.10000E+02	.26468E+00	.10744E+02
.10000E+02	.20700E+02	.12350E+03	.59073E+06	.97205E+01	.10000E+02	.13756E+01	.12120E+02
.10417E+02	.20300E+02	.12370E+03	.59331E+06	.99585E+01	.10000E+02	.36210E+00	.12482E+02
.10833E+02	.20430E+02	.11540E+03	.59578E+06	.10194E+02	.10000E+02	.36845E+00	.12850E+02
.11250E+02	.20780E+02	.12410E+03	.59826E+06	.10428E+02	.10000E+02	.38266E+00	.13233E+02
.11667E+02	.21330E+02	.11700E+03	.60077E+06	.10663E+02	.10000E+02	.40872E+00	.13633E+02
.12083E+02	.21330E+02	.11935E+03	.60319E+06	.10893E+02	.10000E+02	.41517E+00	.14049E+02
.12217E+02	.23400E+02	.11460E+03	.60395E+06	.10963E+02	.10000E+02	.14281E+00	.14191E+02
.12483E+02	.23500E+02	.11440E+03	.60540E+06	.11100E+02	.10000E+02	.30169E+00	.14493E+02
.12733E+02	.24200E+02	.11420E+03	.60676E+06	.11243E+02	.10000E+02	.29224E+00	.14785E+02
.12933E+02	.24500E+02	.11400E+03	.60784E+06	.11350E+02	.10000E+02	.24003E+00	.15025E+02
.13000E+02	.24700E+02	.11400E+03	.60820E+06	.11386E+02	.10000E+02	.81665E-01	.15107E+02
.14067E+02	.26400E+02	.11390E+03	.61343E+06	.11955E+02	.10000E+02	.13769E+01	.16484E+02
.15167E+02	.28400E+02	.11140E+03	.61944E+06	.12526E+02	.10000E+02	.15982E+01	.18082E+02
.16317E+02	.30600E+02	.11033E+03	.62506E+06	.13108E+02	.10000E+02	.18827E+01	.19965E+02
.17517E+02	.33100E+02	.10850E+03	.63065E+06	.13697E+02	.10000E+02	.22138E+01	.22179E+02
.18817E+02	.36003E+02	.10610E+03	.63632E+06	.14314E+02	.10000E+02	.27088E+01	.24888E+02
.20217E+02	.39500E+02	.10310E+03	.64196E+06	.14956E+02	.10000E+02	.33127E+01	.28200E+02
.21783E+02	.43600E+02	.99100E+02	.64753E+06	.15643E+02	.10000E+02	.42355E+01	.32431E+02
.21917E+02	.44739E+02	.44700E+02	.64775E+06	.15699E+02	.10000E+02	.39435E+00	.32825E+02
.22117E+02	.43330E+02	.43360E+02	.64775E+06	.15783E+02	.10000E+02	.58895E+00	.33414E+02
.22550E+02	.40500E+02	.40500E+02	.64775E+06	.15965E+02	.10000E+02	.12266E+01	.34641E+02
.23367E+02	.37430E+02	.37480E+02	.64775E+06	.16183E+02	.10000E+02	.13835E+01	.36024E+02
.23750E+02	.34100E+02	.34100E+02	.64775E+06	.16476E+02	.10000E+02	.17899E+01	.37734E+02
.25100E+02	.23900E+02	.28900E+02	.64775E+06	.17037E+02	.10000E+02	.30639E+01	.40798E+02
.26333E+02	.27900E+02	.27900E+02	.64775E+06	.17546E+02	.10000E+02	.26126E+01	.43411E+02
.27483E+02	.27000E+02	.27030E+02	.64775E+06	.17977E+02	.10000E+02	.22436E+01	.45654E+02
.28550E+02	.26103E+02	.26100E+02	.64775E+06	.18433E+02	.10000E+02	.23938E+01	.48048E+02
.29767E+02	.25280E+02	.25200E+02	.64775E+06	.18905E+02	.10000E+02	.24857E+01	.50554E+02
.31100E+02	.24200E+02	.24200E+02	.64775E+06	.19412E+02	.10000E+02	.27068E+01	.53261E+02
.32550E+02	.23260E+02	.23200E+02	.64775E+06	.19952E+02	.10000E+02	.28958E+01	.56156E+02
.33867E+02	.22200E+02	.22200E+02	.64775E+06	.20426E+02	.10000E+02	.25798E+01	.58736E+02
.35450E+02	.21300E+02	.21366E+02	.64775E+06	.20987E+02	.10000E+02	.30387E+01	.61775E+02
.38433E+02	.19600E+02	.19560E+02	.64775E+06	.22014E+02	.10000E+02	.55558E+01	.67330E+02
.41433E+02	.18000E+02	.18000E+02	.64775E+06	.22995E+02	.10000E+02	.53467E+01	.72677E+02
.45117E+02	.16200E+02	.16200E+02	.64775E+06	.24139E+02	.10000E+02	.62111E+01	.78888E+02
.49167E+02	.14300E+02	.14300E+02	.64775E+06	.25526E+02	.10000E+02	.74575E+01	.86345E+02
.56433E+02	.12020E+02	.12000E+02	.64775E+06	.27296E+02	.10000E+02	.93387E+01	.95684E+02
.59167E+02	.11300E+02	.11300E+02	.64775E+06	.27954E+02	.10000E+02	.35641E+01	.99240E+02
.66900E+02	.91600E+01	.91608E+01	.64775E+06	.29736E+02	.10000E+02	.91588E+01	.10841E+03
.89450E+02	.49630E+01	.49683E+01	.64775E+06	.34356E+02	.10000E+02	.19995E+02	.12840E+03
.96000E+02	.49630E+01	.49638E+01	.64775E+06	.34632E+02	.10000E+02	.35217E+01	.12875E+03
.95600E+02	.49600E+01	.49600E+01	.64775E+06	.35116E+02	.10000E+02	.32225E+01	.13194E+03
.10000E+03	.49600E+01	.49600E+01	.64775E+06	.35736E+02	.10000E+02	.32306E+01	.13521E+03
.10500E+03	.49620E+01	.49600E+01	.64775E+06	.36297E+02	.10000E+02	.32329E+01	.13844E+03
.11000E+03	.49600E+01	.49600E+01	.64775E+06	.36804E+02	.10000E+02	.32381E+01	.14167E+03
.11500E+03	.49600E+01	.49630E+01	.64775E+06	.37261E+02	.10000E+02	.32231E+01	.14489E+03
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5 - SLB Radiological Consequences With Three SG Tubes Ruptured - Iodine DF Case 1

TIME	LEAK RATE	DILUTION RATE	RC MASS	RC ACTIVITY	DF	DELTA CURIES	TOTAL CURIES O
MINUTES	LBS/SEC	LBS/SEC	LBS	MICROC PER GRAM		CURIES	CURIES
0.	.14400E+03	.27650E+02	.52276E+06	.35000E+01	.10000E+01	0.	0.
.33300E-01	.12770E+03	.27650E+02	.52255E+06	.35214E+01	.10000E+01	.43262E+00	.82926E+01
.83300E-01	.12720E+03	.27650E+02	.52226E+06	.35536E+01	.10000E+01	.61781E+00	.89104E+01
.10000E+00	.12380E+03	.27650E+02	.52215E+06	.35643E+01	.10000E+01	.20626E+00	.91167E+01
.11670E+00	.12030E+03	0.	.52204E+06	.35751E+01	.10000E+01	.20179E+00	.93185E+01
.21670E+00	.99700E+02	0.	.52130E+06	.36400E+01	.10000E+01	.11038E+01	.10422E+02
.48330E+00	.10250E+03	0.	.51976E+06	.38133E+01	.10000E+01	.28402E+01	.13263E+02
.51670E+00	.97900E+02	0.	.51956E+06	.38349E+01	.10000E+01	.37712E+00	.13640E+02
.53330E+00	.95600E+02	.99450E+02	.51952E+06	.38457E+01	.10000E+01	.18265E+00	.1382[illegible]02
.70000E+00	.71300E+02	.10200E+03	.51969E+06	.39544E+01	.10000E+01	.16101E+01	.15432E+02
.75000E+00	.68100E+02	.10200E+03	.51978E+06	.39872E+01	.10000E+01	.42073E+00	.15853E+02
.13333E+01	.57700E+02	.10400E+03	.52119E+06	.43706E+01	.10000E+01	.46719E+01	.20525E+02
.41167E+01	.48100E+02	.11000E+03	.53022E+06	.61771E+01	.10000E+01	.24648E+02	.45173E+02
.41667E+01	.47900E+02	.33330E+03	.53074E+06	.62079E+01	.10000E+01	.56956E+00	.45743E+02
.43333E+01	.47300E+02	.15800E+03	.53273E+06	.63105E+01	.10000E+01	.19025E+01	.47646E+02
.45000E+01	.46700E+02	.20910E+03	.53410E+06	.64128E+01	.10000E+01	.19215E+01	.49567E+02
.61667E+01	.41000E+02	.22240E+03	.55129E+06	.74334E+01	.10000E+01	.19241E+02	.60808E+02
.65000E+01	.39600E+02	.23230E+03	.55503E+06	.76317E+01	.10000E+01	.40971E+01	.72985E+02
.75000E+01	.36400E+02	.21960E+03	.56630E+06	.82238E+01	.10000E+01	.12193E+02	.85097E+02
.85000E+01	.32900E+02	.25170E+03	.57836E+06	.88069E+01	.10000E+01	.12135E+02	.97232E+02
.10000E+02	.27700E+02	.25790E+03	.59856E+06	.96700E+01	.10000E+01	.17459E+02	.11469E+03
.11667E+02	.39700E+02	.24566E+03	.62037E+06	.10596E+02	.10000E+01	.23919E+02	.13861E+03
.13333E+02	.51800E+02	.23260E+03	.63970E+06	.11470E+02	.10000E+01	.35354E+02	.17396E+03
.15000E+02	.63800E+02	.22100E+03	.65660E+06	.12293E+02	.10000E+01	.47905E+02	.22187E+03
.23333E+02	.53900E+02	.53900E+02	.69590E+06	.16195E+02	.10000E+01	.28104E+03	.50291E+03
.31667E+02	.43900E+02	.43900E+02	.69590E+06	.19484E+02	.10000E+01	.29582E+03	.79873E+03
.40000E+02	.34000E+02	.34000E+02	.69590E+06	.22302E+02	.10000E+01	.27501E+03	.10737E+04
.40833E+02	.33000E+02	.33000E+02	.69590E+06	.22544E+02	.10000E+01	.25420E+02	.10992E+04
.41667E+02	.32500E+02	.32500E+02	.69590E+06	.22763E+02	.10000E+01	.25120E+02	.1124[illegible]E+04
.50000E+02	.27500E+02	.27500E+02	.69590E+06	.25142E+02	.10000E+01	.23985E+03	.1364[illegible]E+04
.58333E+02	.22500E+02	.22500E+02	.69590E+06	.27170E+02	.10000E+01	.21449E+03	.15786E+04
.66666E+02	.17500E+02	.17500E+02	.69590E+06	.28936E+02	.10000E+01	.18144E+03	.17601E+04
.70833E+02	.15000E+02	.15000E+02	.69590E+06	.29708E+02	.10000E+01	.76180E+02	.18363E+04
.75000E+02	.15000E+02	.15000E+02	.69590E+06	.30424E+02	.10000E+01	.71375E+02	.19076E+04
.83333E+02	.15000E+02	.15000E+02	.69590E+06	.31725E+02	.10000E+01	.14456E+03	.20522E+04
.91667E+02	.15000E+02	.15000E+02	.69590E+06	.32798E+02	.10000E+01	.14524E+03	.21974E+04
.10000E+03	.15000E+02	.15000E+02	.69590E+06	.33672E+02	.10000E+01	.14479E+03	.23422E+04
.10833E+03	.15000E+02	.15000E+02	.69590E+06	.34374E+02	.10000E+01	.14346E+03	.24857E+04
.11667E+03	.15000E+02	.15000E+02	.69590E+06	.34927E+02	.10000E+01	.14171E+03	.26274E+04
.12000E+03	.15000E+02	.15000E+02	.69590E+06	.35898E+02	.10000E+01	.55472E+02	.26829E+04

Table 6 - SLB Radiological Consequences With Three SG Tubes Ruptured - Iodine Case 2

TIME MINUTES	LEAK RATE LBS/SEC	DILUTION RATE LBS/SEC	RC MASS LBS	RC ACTIVITY MICROC PER GRAM	DF	DELTA CURIES CURIES	TOTAL CURIES O CURIES
0.	.14400E+03	.27650E+02	.52276E+06	.35000E+01	.10000E+01	0.	0.
.33300E-01	.12770E+03	.27650E+02	.52255E+06	.35214E+01	.10000E+01	.43262E+00	.82926E+01
.83300E-01	.12720E+03	.27650E+02	.52225E+06	.35536E+01	.10000E+01	.61781E+00	.89104E+01
.10000E+00	.12380E+03	.27650E+02	.52215E+06	.35643E+01	.10000E+01	.26626E+00	.91167E+01
.11670E+00	.12030E+03	0.	.52204E+06	.35751E+01	.10000E+01	.20179E+00	.93185E+01
.21670E+00	.99700E+02	0.	.52138E+06	.36400E+01	.10000E+01	.11038E+01	.10422E+02
.48330E+00	.16250E+03	0.	.51976E+06	.38133E+01	.10000E+01	.28402E+01	.13263E+02
.51670E+00	.97900F+02	0.	.51956E+06	.38349E+01	.10000E+01	.37712E+00	.13640E+02
.53330E+00	.95600E+02	.99450E+02	.51952E+06	.38457E+01	.10000E+01	.18265E+00	.13822E+02
.70000E+00	.71300E+02	.10230E+03	.51969E+06	.39544E+01	.10000E+01	.16101E+01	.154[illegible]E+02
.75000E+00	.68100E+02	.10200E+03	.51978E+06	.39872E+01	.10000E+01	.42073E+00	.15[illegible]E+02
.13333E+01	.57700E+02	.10400E+03	.52119E+06	.43706E+01	.10000E+01	.46719E+01	.20525E+02
.41167E+01	.48100E+02	.11000E+03	.53022E+06	.61771E+01	.10000E+01	.24648E+02	.45173E+02
.41667E+01	.47900E+02	.33330E+03	.53074E+06	.62079E+01	.10000E+01	.56956E+00	.45743E+02
.43333E+01	.47300E+02	.15680E+03	.53273E+06	.63105E+01	.10000E+01	.19025E+01	.47646E+02
.45000E+01	.46700E+02	.20910E+03	.53418E+06	.64128E+01	.10000E+01	.19215E+01	.49567E+02
.61667E+01	.41000E+02	.22240E+03	.55129E+06	.74334E+01	.10000E+01	.19241E+02	.68808E+02
.65000E+01	.39800E+02	.23230E+03	.55503E+06	.76317E+01	.10000E+01	.46971E+01	.72905E+02
.75000E+01	.36400E+02	.21960E+03	.56630E+06	.82238E+01	.10000E+01	.12193E+02	.85097E+02
.85000E+01	.32900F+02	.25170E+03	.57836E+06	.88069E+01	.10000E+01	.12135E+02	.97232E+02
.10000E+02	.27700E+02	.25790E+03	.59856E+06	.96700E+01	.10000E+01	.17459E+02	.11469E+03
.11667E+02	.39700E+02	.24560E+03	.62037E+06	.10596E+02	.10000E+01	.23919E+02	.13861E+03
.13333E+02	.51800E+02	.23260E+03	.63970E+06	.11470E+02	.10000E+01	.35394E+02	.17396E+03
.15360E+02	.63800E+02	.22100E+03	.65660E+06	.12293E+02	.10000E+01	.47965E+02	.22187E+03
.23333E+02	.53900E+02	.53900E+02	.69590E+06	.16195E+02	.10000E+01	.28104E+03	.50291E+03
.31667E+02	.43900E+02	.43930E+02	.69590E+06	.19484E+02	.10000E+01	.29582E+03	.79873E+03
.40000E+02	.34000E+02	.34000E+02	.69590E+06	.22302E+02	.10000E+01	.27501E+03	.10737E+04
.40833E+32	.33000E+02	.33000E+02	.69590E+06	.22544E+02	.10000E+03	.50352E+00	.10742E+04
.41667E+02	.32500E+02	.32500E+02	.69590E+06	.22783E+02	.10000E+03	.25120E+00	.10745E+04
.50000E+02	.27500E+02	.27500E+02	.69590E+06	.25142E+02	.10000E+03	.23985E+01	.10769E+04
.58333E+02	.22500E+02	.22500E+02	.69590E+06	.27170E+02	.10000E+03	.21449E+01	.10[illegible]E+04
.66666E+02	.17500E+02	.17500E+02	.69590E+06	.28936E+02	.10000E+03	.18144E+01	.10[illegible]9E+04
.70833E+02	.15000E+02	.15000E+02	.69590E+06	.29708E+02	.10000E+03	.76100E+00	.10816E+04
.75000E+02	.15000E+02	.15000E+02	.69590E+06	.30424E+02	.10000E+03	.71375E+00	.10823E+04
.83333E+02	.15000E+02	.15000E+02	.69590E+06	.31725E+02	.10000E+03	.14456E+01	.10838E+04
.91667E+02	.15000E+02	.15000E+02	.69590E+06	.32790E+02	.10000E+03	.14524E+01	.10852E+04
.10000E+03	.15000E+02	.15000E+02	.69590E+06	.33672E+02	.10000E+03	.14479E+01	.10867E+04
.10833E+03	.15000E+02	.15000E+02	.69590E+06	.34374E+02	.10000E+03	.14346E+01	.10881E+04
.11667E+03	.15000E+02	.15000E+02	.69590E+06	.34927E+02	.10000E+03	.14171E+01	.10895E+04
.12000E+03	.15000E+02	.15000E+02	.69590E+06	.35894E+02	.10000E+03	.55472E+00	.10901E+04

Table 7 - SLB Radiological Consequences With Three SG Tubes Ruptured - Iodine DF Case 3

TIME MINUTES	LEAK RATE LBS/SEC	DILUTION RATE LBS/SEC	RC MASS LBS	RC ACTIVITY MICROC PER GRAM	DF	DELTA CURIES CURIES	TOTAL CURIES CURIES
0.	.14400E+03	.27650E+02	.52276E+06	.35000E+01	.10000E+02	0.	0.
.83300E-01	.12770E+03	.27650E+02	.52255E+06	.35214E+01	.10000E+02	.43262E-01	.79833E+0
.83360E-01	.12720E+03	.27650E+02	.52225E+06	.35536E+01	.10000E+02	.61781E-01	.79650E+0
.10000E+00	.12300E+03	.27650E+02	.52215E+06	.35643E+01	.10000E+02	.20626E-01	.79857E+0
.11670E+00	.12030E+03	0.	.52204E+06	.35751E+01	.10000E+02	.20179E-01	.80058E+0
.21670E+00	.99700E+02	0.	.52138E+06	.36400E+01	.10000E+02	.11038E+00	.81162E+0
.48330E+00	.10250E+03	0.	.51976E+06	.38133E+01	.10000E+02	.28402E+00	.84003E+0
.51670E+00	.97900E+02	0.	.51956E+06	.38349E+01	.10000E+02	.37712E-01	.84380E+0
.53330E+00	.95600E+02	.99450E+02	.51952E+06	.38457E+01	.10000E+02	.18265E-01	.84562E+0
.70000E+00	.71300E+02	.10200E+03	.51969E+06	.39544E+01	.10000E+02	.16101E+00	.861[illegible]E+0
.75000E+00	.66100E+02	.10230E+03	.51978E+06	.39872E+01	.10000E+02	.42073E-01	.86[illegible]E+0
.13333E+01	.57700E+02	.10400E+03	.52119E+06	.43706E+01	.10000E+02	.46719E+00	.91265E+0
.41167E+01	.48100E+02	.11000E+03	.53022E+06	.61771E+01	.10000E+02	.24648E+01	.11591E+0
.41667E+01	.47900E+02	.33330E+03	.53074E+06	.62079E+01	.10000E+02	.56956E-01	.11648E+0
.43333E+01	.47300E+02	.15880E+03	.53273E+06	.63105E+01	.10000E+02	.19025E+00	.11839E+0
.45000E+01	.46700E+02	.20910E+03	.53418E+06	.64128E+01	.10000E+02	.19215E+00	.12031E+0
.61667E+01	.41000E+02	.22240E+03	.55129E+06	.74334E+01	.10000E+02	.19241E+01	.13955E+0
.65000E+01	.39800E+02	.23230E+03	.55583E+06	.76317E+01	.10000E+02	.40971E+00	.14364E+0
.75000E+01	.36400E+02	.21960E+03	.56630E+06	.82230E+01	.10000E+02	.12193E+01	.15584E+0
.85000E+01	.32900E+02	.25170E+03	.57836E+06	.88869E+01	.10000E+02	.12135E+01	.16797E+0
.10000E+02	.27700E+02	.25790E+03	.59856E+06	.96700E+01	.10000E+02	.17459E+01	.18543E+0
.11667E+02	.39700E+02	.24560E+03	.62037E+06	.10596E+02	.10000E+02	.23919E+01	.20935E+0
.13333E+02	.51400E+02	.23260E+03	.63978E+06	.11470E+02	.10000E+02	.35354E+01	.24470E+0
.15000E+02	.63800E+02	.22100E+03	.65660E+06	.12293E+02	.10000E+02	.47965E+01	.29261E+0
.23333E+02	.53900E+02	.53900E+02	.69590E+06	.16195E+02	.10000E+02	.28104E+02	.57365E+0
.31667E+02	.43900E+02	.43900E+02	.69590E+06	.19484E+02	.10000E+02	.29582E+02	.86947E+0
.40000E+02	.34000E+02	.34000E+02	.69590E+06	.22302E+02	.10000E+02	.27501E+02	.11445E+0
.40833E+02	.33000E+02	.33000E+02	.69590E+06	.22544E+02	.10000E+02	.25428E+01	.11699E+0
.41667E+02	.32500E+02	.32500E+02	.69590E+06	.22783E+02	.10000E+02	.25120E+01	.11950E+0
.50000E+02	.27500E+02	.27500E+02	.69590E+06	.25142E+02	.10000E+02	.23985E+02	.14349E+0
.58333E+02	.22500E+02	.22500E+02	.69590E+06	.27170E+02	.10000E+02	.21449E+02	.16[illegible]4E+0
.66666E+02	.17500E+02	.17500E+02	.69590E+06	.28936E+02	.10000E+02	.18144E+02	.1[illegible]0E+0
.70833E+02	.15000E+02	.15000E+02	.69590E+06	.29708E+02	.10000E+02	.76180E+01	.19070E+0
.75000E+02	.15000E+02	.15000E+02	.69590E+06	.30424E+02	.10000E+02	.71375E+01	.19784E+0
.83333E+02	.15000E+02	.15000E+02	.69590E+06	.31725E+02	.10000E+02	.14456E+02	.21229E+0
.91667E+02	.15000E+02	.15000E+02	.69590E+06	.32798E+02	.10000E+02	.14524E+02	.22682E+0
.10000E+03	.15000E+02	.15000E+02	.69590E+06	.33672E+02	.10000E+02	.14479E+02	.24130E+0
.10833E+03	.15000E+02	.15000E+02	.69590E+06	.34374E+02	.10000E+02	.14346E+02	.25564E+0
.11667E+03	.15000E+02	.15000E+02	.69590E+06	.34927E+02	.10000E+02	.14171E+02	.26981E+0
.12000E+03	.15000E+02	.15000E+02	.69590E+06	.35898E+02	.10000E+02	.55472E+01	.27536E+0

QUESTION 5:

Your report states that operator action to switch off the safety injection would be conservative because it results in minimum dilution. Justify that this action is conservative. Explain the effect of delaying this action. The concern is that continuation of the safety injection will keep the system pressure at a higher level and would result in higher releases, in spite of the increased dilution.

This appears to be particularly important for the cases of one and three tube failures for which the leak rate is calculated to be increasing at a high rate at the time that the safety injection is switched off.

Analyze this accident assuming different times for operator action (e.g., 10 min., 20 min., etc.)

RESPONSE:

The leak flow through the upper ends of the broken tubes was caculated through the Zaloudek model, or proportional to $P_2 - \gamma P_2'$ (P_2 = node 2 pressure, P_2' = saturation pressure at node 2 temperature T_2, γ = a constant). Since T_2 continues to decrease, $P_2 - \gamma P_2'$ will increase when P_2' decreases faster than P_2. However, the upper limit of this leak rate is the orifice flow model prediction, which is proportional to the ΔP across the broken tube, or between the primary and secondary side of the steam generator. At 600 seconds, the two predictions are already very close, Zaloudek model predicting $\sim$ 16 lbm/sec and the orifice flow less than 20 lbm/sec (for the one tube leakage case). The leak flow through the lower tubes are shown to increase even though ΔP across the tube is constant. This is due to increase in the path density.

An effect of delaying the time of operator action until the pressurizer liquid level reaches the nominal level ($\sim$20 minutes) has been studied. The original computer analysis of one tube failure was continued beyond the 600 seconds into the accident without assuming operator action to switch off safety injection or auxiliary feedwater. At 725 seconds, the empty, but steam filled, pressurizer, which is controlling the pressure of the RCS, started filling up with colder RCS water. This resulted in a large sudden depressurization in the pressurizer due to the thermodynamic equilibrium model assumption in the CFAFT 2 code. Hence, the case was analyzed beyond 725 seconds using hand calculations.

It was assumed that the flow into the pressurizer was HPI flow minus the leak flow. Furthermore, it was conservatively assumed that the steam in the pressurizer did not mix or transfer heat to the incoming subcooled liquid from the RC piping. Thus, the steam was assumed to undergo an adiabatic compression (Cp/Cv=1.3). The pressure rise in the primary RCS was assumed to be the same as in the pressurizer. The leak rate was calculated using an orifice flow equation (C_d = 1.0) for the upper tube leakage while a similar equation was used for the lower tube leakage.

$W \propto \frac{\Delta P}{\nu}$ = where: W = flow rate

ΔP = pressure difference between primary and secondary side of steam generator.

ν = liquid specific volume

The proportionality constant for the above equation was obtained using the CFAFT2 calculated leak rate at 725 seconds. It was also assumed that the secondary pressure remains constant at the value obtained at 725 seconds.

A uniform cooldown of RCS coolant was calculated considering the sources of heat addition, removal and thermal capacitance.

At 1307 seconds, the level in the pressurizer was calculated to be at the nominal setpoint level. The following operator action is now postulated.

1. Start spray in the pressurizer.
2. Open the unaffected S.G. bypass to condenser.
3. Shut off the auxiliary feedwater flow to the affected S.G. and divert it to the unaffected S.G. to maintain its level.
4. Put HPI system on manual mode to maintain level in the pres-urizer.
5. Switch on DHRS when average coolant temperature is below 280^{o}F and pressure below 265 psia.

The sprayed water is assumed to be in thermodynamic equilibrium with the steam in the pressurizer. The pressure thus obtained was considered applicable to the reactor coolant system. After this time, the leak rates were calculated using the orifice equation methods as described earlier while conservatively assuming that the affected steam generator secondary remains at atmospheric pressure for the rest of the transient. The RCS cooldown was calculated by considering the sources of energy addition (core decay heat, primary pumps, HPI flow), energy removals (dump to condenser, DHRS, leak flow) and the thermal capacitance (metal and primary liquid).

The calculated leak rates, RCS coolant temperature, and RCS pressure beyond 600 seconds are shown in the Figures 1 through 3 respectively. The average coolant temperature of 212^{o}F is reached by 3450 seconds. The primary pressure reaches 25 psia by 5368 seconds corresponding to a total leak rate of 4.82 lbm/sec which was assumed constant thereafter. Once the RCS temperature falls near 212^{o}F, the secondary side of the steam generator would start filling with water.

For the case where three tube ruptures were assumed, the CRAFT run was extended to 15 minutes without switching off safety injection or auxiliary feedwater, the pressurizer pressure increased from 242 psia at 10 minutes to 326 psia at 15 minutes. The leak rate increased from 27.7 lbm/sec. to 63.8 lbm/sec. over this same time period. The average RCS temperature dropped from 350^{o}F to $\sim$285^{o}F.

In the one tube rupture case, it was stated that water should start accumulating in the affected generator well before the RCS temperature fell to 212^{o} F. No CRAFT run was run far enough in time to show this. For the three tube case, the liquid volume was shown to increase from zero at 10 minutes to 134 ft^{3} at 15 minutes even though the RCS temperature is calculated to be greater than 285^{o}F over this time period. It is also true that the liquid mass is really never zero at any instant in time. The simple one node control volume in CRAFT causes the liquid volume to be zero earlier in the transient.

The operator would have taken action before 15 minutes, but if he should wait until then, he would act to depressurize the system as shown for the one tube rupture case. The conditions in the RCS at 900 seconds for the case of three tubes assumed ruptured, are similar to those in the RCS at 2000 seconds for the case of one ruptured tube. Even though the rate of depressurization is much faster for the three tube case, it is assumed that the rate of depressurization is the same as in the one tube case resulting in a pressure of 70 psia in $\sim$ 2450 seconds. Similarly, the leak rate would drop to 33 lbm/sec over this same time period with a temperature of close to 212^{o}F.

If the rate of depressurization continues as in the one tube case, pressure would decrease to $\sim$ 25 psia by $\sim$ 4250 seconds. The leak rate would then be approximately three times that of the one tube case or 15 lbm/sec. Assuming that the operator now has control of the safety injection and maintains a level in the pressurizer, the leak rate would continue at this rate and tend to fill the secondary side of the affected steam generator with water.

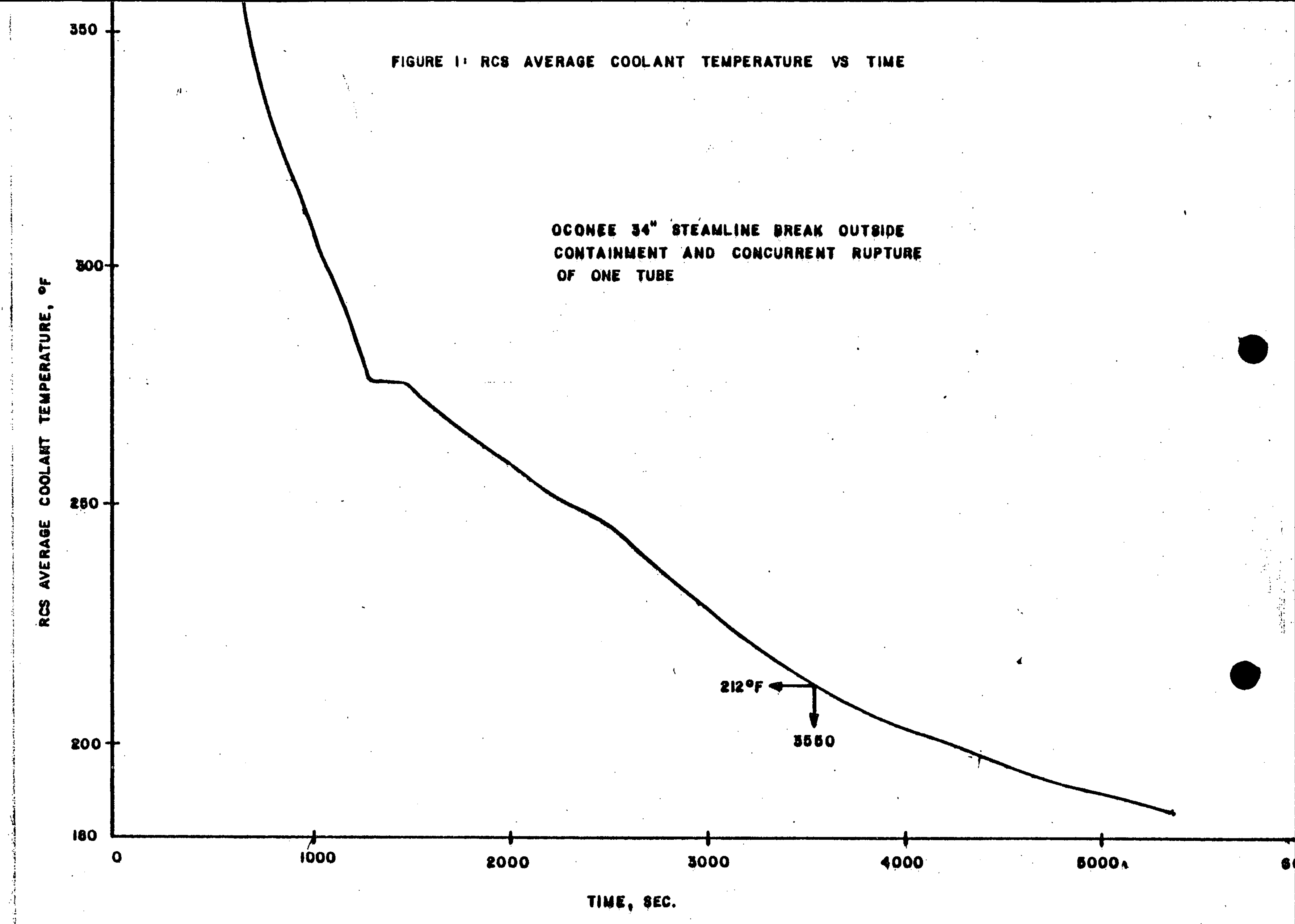
FIGURE I: RCS AVERAGE COOLANT TEMPERATURE VS TIME
OCONEE 34" STEAMLINE BREAK OUTSIDE CONTAINMENT AND CONCURRENT RUPTURE OF ONE TUBE
RCS AVERAGE COOLANT TEMPERATURE, °F
350
300
250
200
180
212°F
3550
0
1000
2000
3000
4000
5000
TIME, SEC.

FIGURE 2: TOTAL LEAK RATE VS TIME

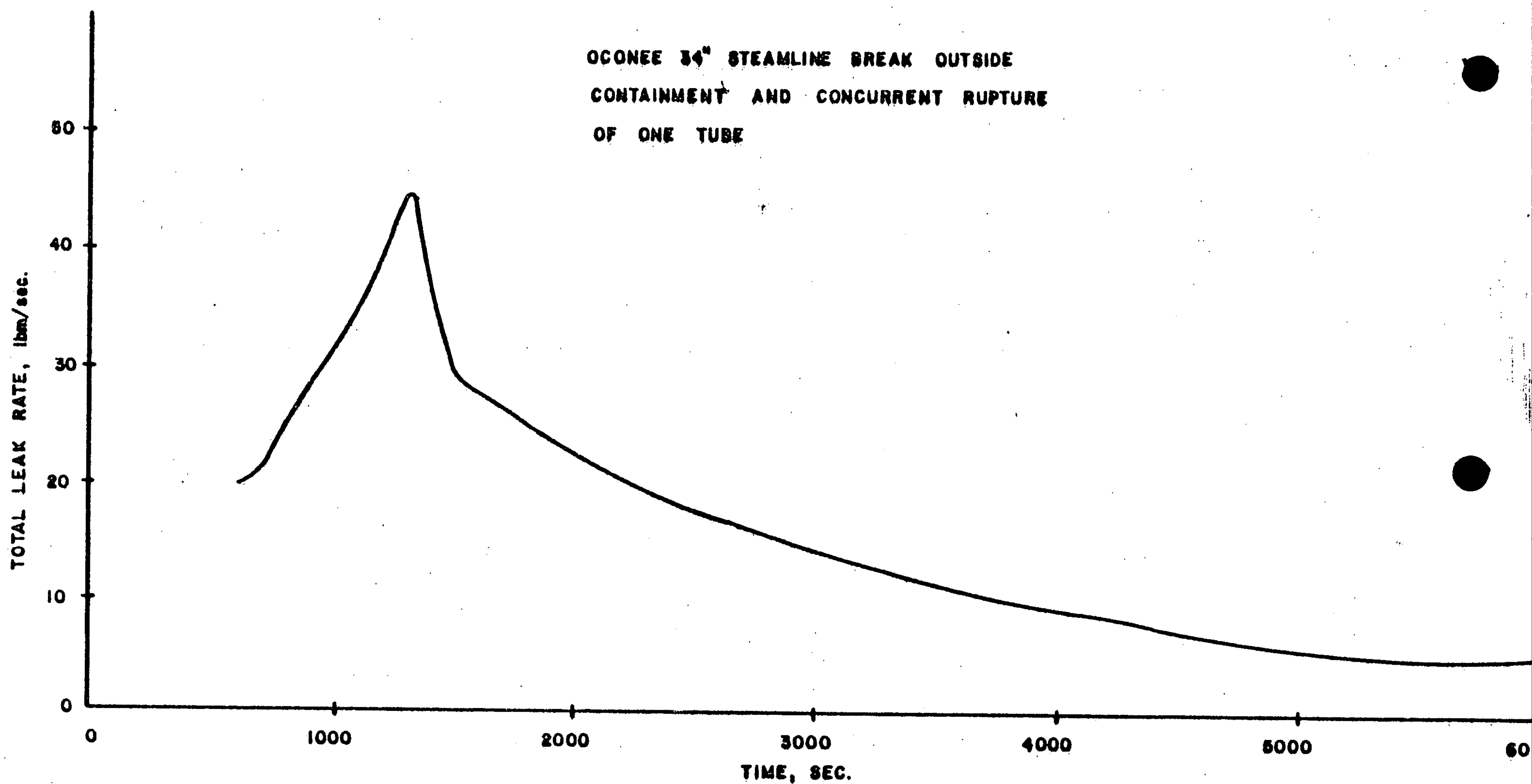

FIGURE 3: PRESSURIZER PRESSURE VS TIME