

IMPORTANT TO SAFETY
NON-ENVIRONMENTAL IMPACT RELATED

THREE MILE ISLAND NUCLEAR STATION
UNIT NO. 1 EMERGENCY PLAN IMPLEMENTING PROCEDURE 1004 33
POST ACCIDENT SAMPLE ANALYSIS

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THREE MILE ISLAND NUCLEAR STATION
UNIT NO. 1 EMERGENCY PLAN IMPLEMENTING PROCEDURE 1004.33
POST ACCIDENT SAMPLE ANALYSIS

1.0 PURPOSE

The purpose of this procedure is to provide guidance to technicians involved in the handling and preparation of post accident reactor coolant samples for boron analysis, chloride analysis, pH analysis, gamma isotopic analysis and gas analysis, as described in NUREG 0737. It is designed to provide prompt analytical results for the above mentioned parameters while minimizing technician exposures per the requirements of NUREG 0737. Specifically, these requirements include:

1. Boron analysis completed within 3 hours or less from the time a decision is made to obtain a sample.
2. Gamma isotopic analysis and fission gas analysis for estimation of core damage completed within 3 hours or less from the time a decision is made to obtain a sample.
3. Chloride analysis completed within 96 hours.
4. Hydrogen Gas analysis completed within 3 hours or less from the time a decision is made to obtain a sample.
5. The above sampling and analysis completed without incurring a radiation exposure to any individual in excess of 3 Rem to the whole body or 18 3/4 Rem to the extremities.

All of the above requirements assume a highly radioactive initial sample with a source term as specified in Regulatory Guide 1.4. The Chemistry Coordinator is responsible for implementing this procedure in coordination with implementation of EPIP 1004.15, Post-Accident Reactor Coolant System Sampling.

2.0 REFERENCES

- 2.1 Chemistry Procedure CP N1880
- 2.2 Chemistry Procedure CP N1904
- 2.3 Chemistry Procedure CP N1904.1
- 2.4 Chemistry Procedure CP N1918
- 2.5 Chemistry Procedure CP N1956
- 2.6 Chemistry Procedure CP N1957
- 2.7 Chemistry Procedure CP N1990
- 2.8 Chemistry Procedure CP N1990.1
- 2.9 Emergency Plan Implementing Procedure (EPIP) 1004.9, Radiological Controls During Emergencies
- 2.10 EPIP 1004.15, Post-Accident Reactor Coolant System Sampling

3.0 ATTACHMENTS

- 3.1 Attachment 1 - Post Accident Sample Equipment Inventory
- 3.2 Attachment 2 - Analysis Area Schematic
- 3.3 Attachment 3 - Hydrogen Concentration Calculation
- 3.4 Attachment 4 - IC Instrument Line-Up
- 3.5 Attachment 5 - Auto Ion 100 Controller Programming Form
- 3.6 Attachment 6 - Post Accident Reactor Coolant Sample Summary
- 3.7 Attachment 7 - Density Table for Hydrogen Determination
- 3.8 Appendix A - Guidance for the Estimation of Core Damage
- 3.9 Appendix B - Calculation of Core Damage using RCS Liquid Sampling Results
- 3.10 Appendix C - Calculation of Core Damage using Containment Atmosphere Air Sampling Results

4.0 EMERGENCY ACTION LEVELS

4.1 An emergency condition has been declared and a request has been made for a post accident reactor coolant sample and analysis (samples are obtained per EPIP 1004.15).

5.0 PROCEDURE

: NOTE: Initial steps upon completion. :

5.1 Gas Analysis

5.1.1 Fission Gas

5.1.1.1 Perform Sample Analysis using Chemistry Procedure CP N1990.1 for guidance.

5.1.1.2 Remove syringe containing gas sample from pig C² on cart.

5.1.1.3 In hood No. 1, open lock valve near the syringe tip to equalize pressure and immediately inject 0.5 cc of sample into the 6 cc. gas counting vial H¹. Close lock valve.

5.1.1.4 Place 6 cc. counting vial H¹ into a small plastic bag and store in lead pig C³ until it can be transported to the counting room to be counted.

NOTE: Proceed immediately to Step 5.1.2.

5.1.2 Hydrogen Gas

5.1.2.1 Perform Sample Analysis using Chemistry Procedure CP N1957 for guidance.

5.1.2.2 Open the syringe lock valve and inject the remaining 0.5 cc of gas into the gas chromatograph using plastic pipet guard.

5.1.2.3 Return syringe with needle to lead pig (C²).

- 5.1.2.4 Measure the height of the hydrogen peak from base line.
- 5.1.2.5 When sample has been completed, shut down the recorder by turning the recorder to "Off" and lift the pen.
- 5.1.2.6 Calculate hydrogen concentration using Attachment 3. The sample liquid volume and expansion bulb volume are given in the calculation sheet.

5.2 Boron, Chloride, pH and Gamma Scan Sample Preparation

: NOTE: All dilutions shall be done with (E¹) and (E²) on :
: stir plates to ensure proper mixing. :

- 5.2.1 Utilizing long handled tongs whenever possible, the Chemistry Technician shall remove sample bottle (F) from transport pig (C¹) and place in pig (C⁴) (refer to Attachment 1 and Attachment 2).
- 5.2.2 Remove cap, quickly and carefully pipet 0.1 ml of sample, using Eppendorf pipet (J), from sample bottle (F) to the 1 liter poly bottle (E¹).
- 5.2.3 Discard tip from pipet (J) into lead receptacle (L).
- 5.2.4 Using pipet (K), transfer 1 ml from sample bottle (F) to beaker (I). Discard tip from pipet (K) into lead receptacle (L) and place new 1 ml tip on pipet (K).
Using short handled tongs, transfer beaker (I) from hood 1 to hood 2 and place on boron titrator magnetic stir base. Beaker (I) will be used for Boron Analysis.
- 5.2.5 Using pipet (K), transfer 1 ml from sample bottle (F) to flask I¹ containing 19 ml DI water. Cap the flask and place behind lead brick (X). Flask I¹ will be used for chloride analysis.

- 5.2.6 Using pipet (K), transfer 2 ml (1 ml twice) from sample bottle (F) to vial (H^2) in hole of lead block in the hood. Discard tip from pipet (K^2) into lead receptacle (L). Replace the tip on pipet K. Vial (H^2) will be used to determine pH.
- 5.2.7 Replace cap on sample bottle (F). Using short handled tongs, place sample bottle (F) back into transfer pig (C^1) [previously used for transporting bottle (F)], place on cart and move cart to far side of the lab.
- 5.2.8 Using pipet (K), transfer 1.0 ml from 1 liter poly bottle (E^1) to 1 liter poly bottle (E^2) and 1 ml to vial (G^1). Cap vial (G^1) and cap (E^1) and place (E^1) in the back left corner of hood 1 behind the lead brick.
- 5.2.9 Discard tip from pipet (K) into lead receptacle (L) and place new 1 ml tip on pipet (K).
- 5.2.10 With new tip on pipet (K), transfer 1 ml from bottle (E^2) to vial (G^2) and cap (G^2). Cap (E^2) and discard tip from pipet (K) into lead receptacle (L). Close cover on receptacle (L). Place (E^2) in back left corner of hood 1 behind the lead brick.
- 5.2.11 Place vials (G^1) and (G^2) into individual poly bags and tape bags shut; have (G^1) and (G^2) surveyed with a dose rate instrument.

: NOTE: It may be necessary to remove the sample from the :
: primary laboratory to conduct an accurate dose rate :
: survey due to a high background radiation level in :
: the laboratory. :

NOTE: For guidance, samples reading > 1 mR/hr will be too active for counting on the Geli detector/MCA system. i.e., greater than 15 percent dead time. If both samples read > 1 mR/hr, further dilution of the contents of bottle (E²) is required. Note all subsequent dilutions of (E²) so that correct volume calculations can be performed.

NOTE: If background noble gas levels result in interference with Geli analysis (high deadtime on MCA) insure shield cover on Geli cave is closed and initiate compressed air purge of cave.

NOTE: If background levels do not allow the use of the TMI-1 Ge(Li)/MCA system, analysis may be performed by transporting samples to TMI-2 or establish a Ge(Li)/MCA system out of the high background area.

NOTE: If counting vial (G¹), use the volume of 1 x 10⁻⁴ ml. If counting vial (G²), volume is 1 x 10⁻⁷ ml.

5.3 Gamma Scan

5.3.1 Transport appropriate sample(s) (those reading < 1 mR/hr) to counting room and count on Geli detector/MCA system per CP N1990.1.

NOTE: For a Post Accident Sample, after placing the sample on the detector, check the dead time by starting a count using the MCA keyboard control. The dead time should be < 15 percent.

NOTE: Log onto the VT-100 terminal by typing HELLO POSTACCIDENT/SAMPLE. Start the sample count by answering the computer prompts. At the end of the count, SPECTRAN-F will print a report. Record results in Attachment 6.

5.4 Boron Analysis

5.4.1 Perform boron analysis on the contents of the beaker (I) per Chemistry Procedure CP N1904 observing the following cautions and exceptions:

- a. In the calculations given in section 6.0 of Chemistry Procedure CP N1904, sample volume, "S", is 1 ml.
- b. 1 KAP standard for NaOH standardization may be used instead of 3, as specified in CP N1904.
- c. No spiked sample will be run.

: NOTE: If boron concentration is less than 500 ppm and a :
: subsequent analysis as determined by the Chemistry :
: Coordinator is required, Chemistry Procedure CP :
: N1904.1 can be implemented. The accuracy commitment :
: of ± 50 ppm will still be in effect. :

5.4.2 Following titration, pour the contents of beaker (I) down hood sink and flush sink for approximately 2 minutes with demin water.

5.5 Chloride Analysis

Chloride analysis must be completed within 4 days from when the sample was taken. Perform chloride analysis on the contents of flask I' as follows:

5.5.1 Prerequisites

5.5.1.1 Before performing this procedure, the technician shall have a thorough knowledge of CP N1880 and CP N1918.

5.5.1.2 To control exposure from RCS Waste water from the IC Unit, construct a lead cave using available lead bricks surrounding the 500 ml poly bottle. Waste water shall only be allowed to accumulate such that exposure rates do

not exceed 100 mR/hr contact on the lead cave. Radiological Controls will evaluate by surveys. Promptly dispose of water in the sample sink to liquid waste disposal system after each analysis sequence or if exposure rates are found to exceed 100 mR/hr using long handled tongs.

- 5.5.1.3 The IC Unit can be relocated to the east-side countertop to minimize portable shield usage if needed. This should not be necessary if IC Sample pathway is purged with demin water and columns are changed out regularly. Radiological controls will evaluate by surveys after each use.

5.5.2 Apparatus

- 5.5.2.1 In addition to the equipment used in CP N1918, use the following:
- a. Auto Ion 100 Controller by Dionex
 - b. Autosampler by Dionex
 - c. Milton Roy Pump - Model NSI-33R
 - d. Glass or polystyrene Culture tubes by Corning (16 x 125 mm)

5.5.3 Procedure

5.5.3.1 Set up of Ion Chromatograph

- a. Set up per CP N1918 except use valve and tubing connections as shown in Attachment 4.

5.5.3.2 Startup of Ion Chromatograph

- a. Startup per CP N1918

5.5.4 Sample Preparation

5.5.4.1 The required range of chloride detection is .1 - 20 ppm for the undiluted RCS Sample. If the diluted sample reads less than 2.0 ppm, the undiluted concentration cannot be determined within this range. Therefore, if the diluted flask I¹ sample reads less than 2.0 ppm, transfer 10 ml of undiluted sample from sample bottle (F) into the polystyrene tube in the carousel of the Auto-sampler and repeat the analysis.

5.5.5 Sample Analysis

5.5.5.1 Press the control on the Auto Ion 100 Controller for System 1

5.5.5.2 Move from LOCAL to REMOTE on the Conductivity Detector for System 1.

5.5.5.3 Connect the autosampler and minipump to the System 1 interface box.

5.5.5.4 Review Program 5 in the Controller and compare with the written program in Attachment 5 using the following sequence:

DEPRESS [PROG MODE] KEY, DEPRESS [RESET KEY], ENTER PROGRAM NUMBER FIVE (5), DEPRESS [REVIEW] KEY TO REVIEW EACH STEP OF THE PROGRAM.

5.5.5.5 Move to Schedule Mode and enter "6" for the number of samples to be analyzed using the ITERATION and ENTER Key.

5.5.5.6 Move to Run Mode.

5.5.5.7 Turn the Autosampler and Recorder On.

5.5.5.8 Turn on the water source for the Autosampler and adjust the flow using the tube clamp so the reservoir will remain full. Use demineralized water.

5.5.5.9 Turn on the Milton Roy Mini Pump and prime the pump with a syringe to eliminate bubbles and dead space in the sample line. Set the pump to 25 percent pumping efficiency.

5.5.5.10 Pour approximately 10 ml of the following samples into pre-labelled polystyrene tubes. Place the tubes in the carousel of the Autosampler in order of sample number.

Example:

<u>Sample No.</u>	<u>Source</u>	<u>Tube I.D.</u>
1	Blank	1
2	Blank	2
3	STD - (0.10)	3
4	STD - (1.00)	4
5	STD - (2.00)	5
6	SAMPLE	1'

NOTE: Make sure the first sample is directly in line with the pipet arm of the Autosampler.

5.5.5.11 To start the sampling process, press the green START control in the Operation Select section of the Controller. Also press the brown control on the Advanced Chromatography Module for System 1 from LOCAL to REMOTE. These two steps start automatic operation. The Auto Ion 100 Controller is now controlling the entire analysis.

5.5.6 Standardization

5.5.6.1 Standardization of the IC System is required once per 8 hour shift for chlorides.

5.5.6.2 Prior to calibrating the instrument, analyze a demineralized water blank using the above analysis procedure. The chloride result for the blank should be less than 5 ppb. If not, repeat the analysis or contact Chemistry Supervision.

5.5.6.3 Chloride Calibration

- a. Three standards, which contain 0.10, 1.00 and 2.00 PPM chloride, are used to calibrate the recorder.
- b. Analyze the standards using the analysis procedure above.
- c. Prepare a graph of Peak Height vs. Concentration for the standards to show linearity.

5.5.7 Calculation

Calculations of samples and check standards can be done using a factor method.

Measure Peak Heights of Standards (in mm).

Divide the concentration of the standard (PPB or PPM) by the Peak Height (in mm).

Record all numbers and their average. The average is the factor used for calculating unknowns.

Example

<u>Chloride Standards</u>		<u>Peak Heights</u>	
250 PPB	÷	15 mm	= 16.7 PPB/mm
500 PPB	÷	30 mm	= 16.6 PPB/mm
750 PPB	÷	48 mm	= 15.6 PPB/mm
			<u>Σ 48.9</u>

Therefore, $\bar{X} = 48.9 \div 3 = 16.3$ PPB/mm (Factor)

Calculation of unknown by factor method with 1:20 dilution.

Unknown sample:

Chloride Peak Height = 25 mm

Factor = 16.3 PPB/mm

Dilution Factor = 20

Multiply Peak Height x Factor x Dilution Factor

Concentration of Unknown = 25 mm x 16.3 PPB/mm x 20 = 8150 PPB

Calculate percent recoveries of check standards.

$$\frac{\text{Calculated Concentration of Check Standard}}{\text{Absolute Concentration of Check Standard}} \times 100 = \text{Percent Recovery}$$

5.6 pH Measurement

5.6.1 Perform pH measurement on contents of vial H² per

Chemistry Procedure N1900.

6.0 FINAL CONDITIONS

The remainder of this procedure can be done at a later time, to allow the radioactivity level to decay:

- 6.1 Lead pig(s) containing sample bottle (F) must be placed in a locked High Radiation Cubicle (for example, precoat filter room) as directed by the Radiological Controls Coordinator. The exact location must be specified in the space below.

High Radiation Cubicle location: _____

- 6.2 Poly bottles E¹, E² and vial H² must be emptied into the sink and the sink flushed for 5 minutes with demineralized water.
- 6.3 Complete Calculation of Core Damage using Appendix A, Appendix B and/or Appendix C.
- 6.4 Complete Attachment 6, Post Accident Reactor Coolant Sample Summary.
- 6.5 Notify the Shift Supervisor that sampling and analysis of the Post Accident Sample have been completed and relay the results.

ATTACHMENT 1

POST ACCIDENT SAMPLE EQUIPMENT INVENTORY

<u>DESIGNATION</u>	<u>EQUIPMENT</u>	<u>AMT. REQ.</u>	<u>AMT. IN LOCKER</u>
A	4" Thick x 24" long x 12" high laminated glass shield	1	
B	Spill catch pan 24" x 24" x 2" deep	1	
C ¹	Lead pig for liquid sample bottle	1	
C ²	Lead pig for gas (syringe) sample	1	
C ³	Lead pig for fission gas vial	1	
C ⁴	Lead pig for hood No. 1	1	
D ¹	Magnetic stir base	1	
D ²	Magnetic stir base	1	
E ¹	1 liter poly bottle containing 1000 ml DI water and stir bar	1	
E ²	1 liter poly bottle containing 1000 ml DI water and stir bar	1	
F	125 ml sample bottle containing sample (on portable cart)	1	
G ¹	10 ml counting vial containing 9 ml of DI water	1	
G ²	10 ml counting vial containing 9 ml of DI water	1	
H ¹	6 cc gas counting vial with cap septum	1	
H ²	Cut glass vial and brick	1	
I	250 ml beaker containing 99 ml DI water and stir bar	1	
I ¹	70 ml flask containing 19 ml DI water and stir bar	1	
J	0.1 ml eppendorf pipet w/tip on center isle counter top	1	

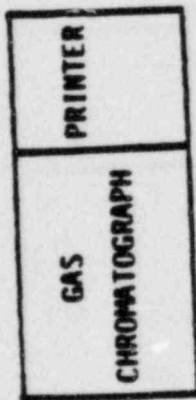
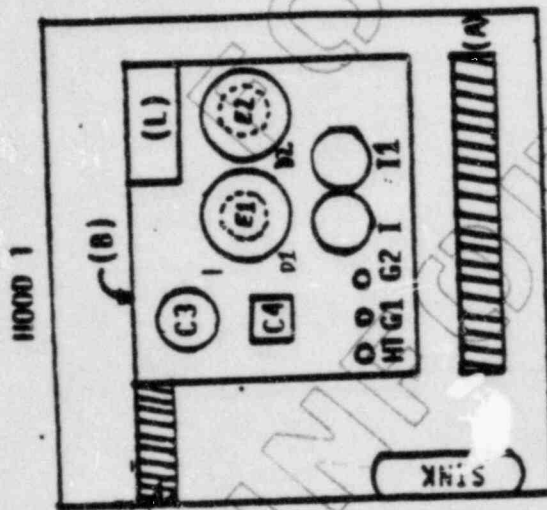
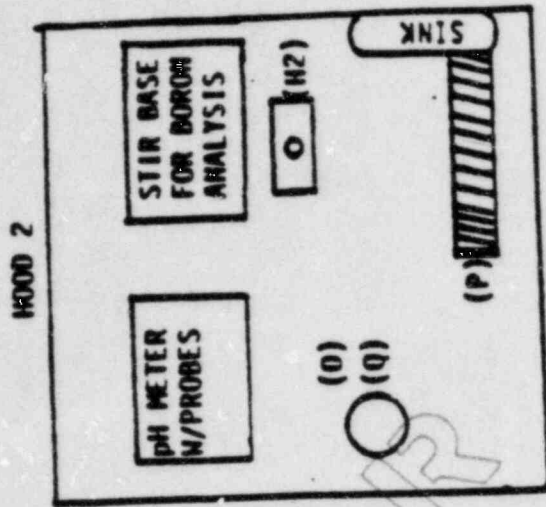
ATTACHMENT 1 (Cont'd)

POST ACCIDENT SAMPLE EQUIPMENT INVENTORY

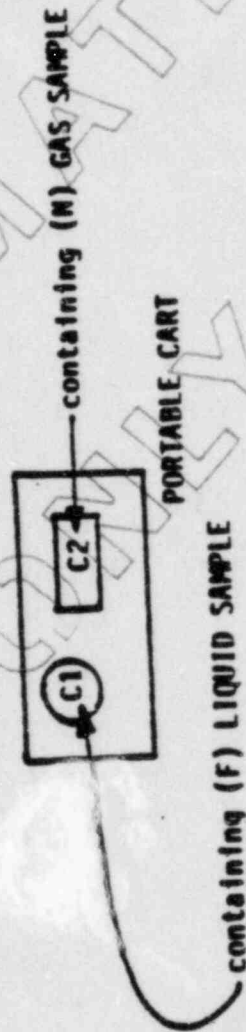
<u>DESIGNATION</u>	<u>EQUIPMENT</u>	<u>AMT. REQ.</u>	<u>AMT. IN LOCKER</u>
K	1.0 ml eppendorf pipet w/tip on center isle counter top	1	
L	Lead pig for used pipet tips and syringe	1	
N	1 ml locking syringe with 8 1/2" needle and plastic pipet guard	1	
O	Stirrer base for boron analysis	1	
P	Laminated glass shield 12" x 12" x 4" thick	1	
T	3' long handled tongs	1	
U	Short handled tongs	1	
V	Poly bags	1	
W	Roll of tape	1	
X	Lead bricks	20	

Inventory Check By _____
Date _____

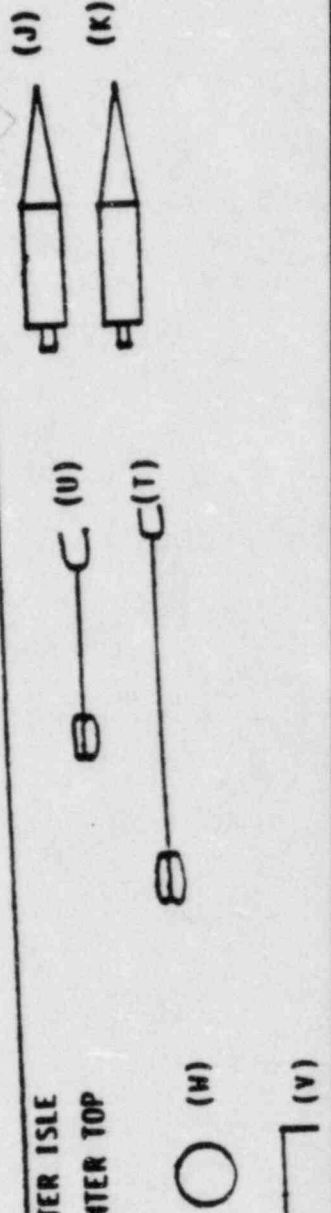
ATTACHMENT 2: Analysis Area Schematic



COUNTER TOP



CENTER ISLE
COUNTER TOP



ATTACHMENT 3

HYDROGEN CONCENTRATION CALCULATIONS

A. Hydrogen Analysis

	Peak Height (mm)	Attenuator Setting	Volume Injected
Sample:	_____	_____	_____
Standard:	_____	_____	_____

1. Percent Hydrogen = $\frac{(\% \text{ Standard Conc.})(\text{Sample Peak Height})(\text{VF})(\text{AF})}{\text{Standard Peak Height}}$ = _____

Where: AF = $\frac{\text{Attenuator Setting for Sample}}{\text{Attenuator Setting for Standard}}$

VF = $\frac{\text{Volume of Standard Injected}}{\text{Volume of Sample Injected}}$

2. Calculation of cc's of gas

Sample Temperature (°F) from TI 1023 _____

RCS Pressure from PI 1103 (psig) _____

RCS Temperature (call control room) _____

Vacuum Pressure using PI 1104 [14.7 - (in. Hg ÷ 2.036)] _____

Final Pressure using PI 1104 (14.7 + gauge) _____

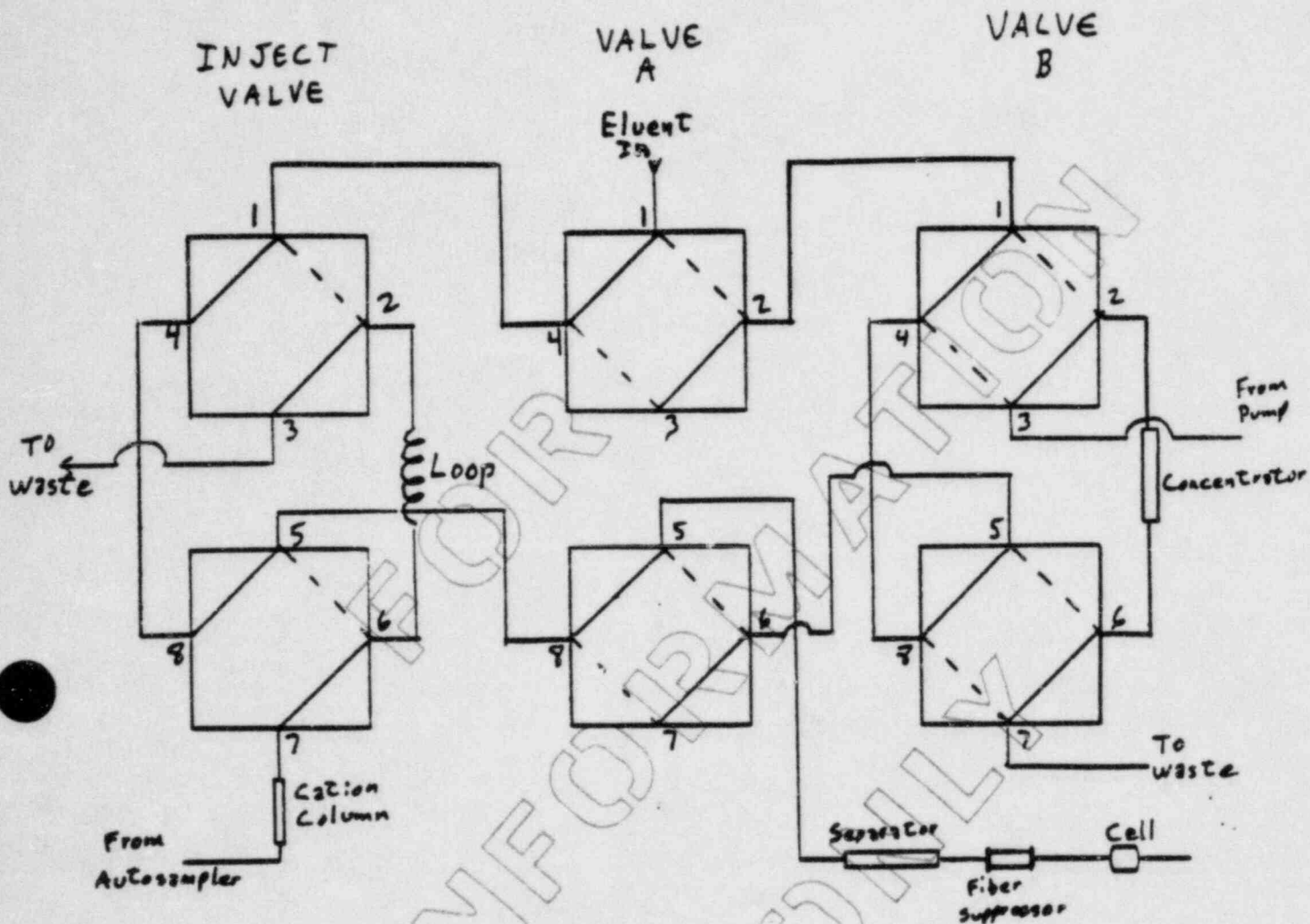
Density (from Attachment 7, Density Table for Hydrogen Determination) _____

cc Hydrogen = $\frac{(\% \text{ Hydrogen})(400 \text{ ml})}{100} \times \frac{492}{\text{Sample Temp. } ^\circ\text{F} + 460} \times$

$\frac{\text{Final Pressure} - \text{Vacuum Pressure}}{14.7} =$ _____

3. Calculation of cc's of Gas/Kg

cc/Kg Hydrogen = $\frac{(\text{cc hydrogen})(1000 \text{ ml})}{(65)(\text{Density})}$



/ Indicates valve is in LOAD or OFF
 - - - Indicates valve is in INJECT or ON

AutoIon™ 100 Controller Programming Form

SYSTEM NO. _____

SAMPLE Post Accident Analysis of Chlorides

PROGR/ AND. _____

COLUMNS AS3ELUENT 0.003 M Na₂CO₃ / 0.002 N NaOH

DATE _____

REMARKS 100 µl Loop

REV _____

STEP	TIME (min)	ANALYTICAL PUMP		CHROMATOGRAPHY MODULE				CONDUCTIVITY DETECTOR				RELAYS				AC OUTLETS	
		Flow Rate (mL min ⁻¹)	Eluent No.	Temp Select	LOAD INJ	A OFF/ON	B OFF/ON	Temp Comp (%/°C)	Auto Offset OFF/ON	Mark OFF/ON	Range µS	1 Sampler	2 Pump	3	4	1	2
1	0.0	2.8	1	X	LOAD	OFF	OFF	1.7	OFF	X	3	OFF	OFF				
2	0.4	↓	↓	↓	LOAD	↓	↓	↓	OFF	↓	↓	ON	OFF				
3	0.5	↓	↓	↓	LOAD	↓	↓	↓	OFF	↓	↓	ON	ON				
4	3.5	↓	↓	↓	LOAD	↓	↓	↓	ON	↓	↓	ON	ON				
5	3.7	↓	↓	↓	INJ	↓	↓	↓	ON	↓	↓	ON	OFF				
6	3.8	↓	↓	↓	INJ	↓	↓	↓	ON	↓	↓	OFF	OFF				
7	13.8	↓	↓	↓	LOAD	↓	↓	↓	OFF	↓	↓	OFF	ON				
8	16.7	↓	↓	↓	LOAD	↓	↓	↓	OFF	↓	↓	OFF	OFF				
9	16.9	↓	↓	↓	LOAD	↓	↓	↓	OFF	↓	↓	OFF	OFF	— END RUN			
10																	
11																	
12																	
13																	
14																	
15																	

ATTACHMENT 7: DENSITY TABLE FOR HYDROGEN DETERMINATION

DENSITY, g/cc, of Water

RCS Avg. Temp (T _{av}) °F	Saturated Liquid (0)	Pressure of Compressed Liquid from PI1103					
		500	1000	1500	2000	2500	3000
32	0.9999	1.0015	1.0030	1.0049	1.0068	1.0084	1.0100
40	0.9999	1.0015	1.0030	1.0049	1.0068	1.0084	1.0100
50	0.9993	1.0008	1.0024	1.0043	1.0062	1.0078	1.0094
60	0.9987	1.0002	1.0018	1.0033	1.0049	1.0071	1.0087
70	0.9974	0.9990	1.0005	1.0021	1.0037	1.0059	1.0081
80	0.9962	0.9977	0.9993	1.0008	1.0024	1.0046	1.0068
90	0.9949	0.9965	0.9980	0.9996	1.0012	1.0030	1.0049
100	0.9931	0.9946	0.9962	0.9977	0.9993	1.0008	1.0024
110	0.9906	0.9922	0.9937	0.9952	0.9968	0.9983	0.9999
120	0.9888	0.9903	0.9919	0.9934	0.9949	0.9965	0.9980
130	0.9857	0.9873	0.9888	0.9903	0.9919	0.9934	0.9949
140	0.9833	0.9848	0.9864	0.9879	0.9894	0.9909	0.9925
150	0.9803	0.9818	0.9833	0.9848	0.9864	0.9876	0.9888
160	0.9773	0.9788	0.9803	0.9818	0.9833	0.9848	0.9864
170	0.9738	0.9752	0.9767	0.9782	0.9797	0.9812	0.9827
180	0.9702	0.9711	0.9726	0.9744	0.9761	0.9779	0.9797
190	0.9667	0.9682	0.9696	0.9714	0.9732	0.9749	0.9769
200	0.9632	0.9647	0.9661	0.9679	0.9696	0.9711	0.9726
210	0.9592	0.9635	0.9621	0.9638	0.9655	0.9670	0.9685
212	0.9580	0.9595	0.9609	0.9626	0.9644	0.9661	0.9679
220	0.9552	0.9566	0.9580	0.9598	0.9615	0.9632	0.9650
230	0.9512	0.9526	0.9540	0.9560	0.9580	0.9595	0.9609
240	0.9467	0.9481	0.9495	0.9515	0.9535	0.9552	0.9569
250	0.9423	0.9436	0.9450	0.9470	0.9489	0.9506	0.9523
260	0.9373	0.9389	0.9406	0.9425	0.9445	0.9462	0.9478
270	0.9329	0.9346	0.9362	0.9381	0.9400	0.9417	0.9434
280	0.9281	0.9297	0.9313	0.9332	0.9351	0.9370	0.9389
290	0.9233	0.9251	0.9270	0.9289	0.9308	0.9324	0.9340
300	0.9180	0.9199	0.9217	0.9235	0.9254	0.9270	0.9286
310	0.9127	0.9146	0.9164	0.9182	0.9201	0.9217	0.9233

ATTACHMENT 7: DENSITY TABLE FOR HYDROGEN DETERMINATION (Cont'd)

DENSITY, g/cc, of Water

RCS Avg. Temp (T _{av}) °F	Saturated Liquid (0)	Pressure of Compressed Liquid from PI1103					
		500	1000	1500	2000	2500	3000
320	0.9076	0.9094	0.9112	0.9132	0.9153	0.9166	0.9180
330	0.9019	0.9040	0.9060	0.9074	0.9096	0.9112	0.9127
340	0.8964	0.8984	0.9004	0.9022	0.9040	0.9058	0.9076
350	0.8904	0.8924	0.8944	0.8964	0.8984	0.9004	0.9024
360	0.8845	0.8865	0.8884	0.8909	0.8934	0.8949	0.8964
370	0.8787	0.8806	0.8826	0.8852	0.8879	0.8899	0.8919
380	0.8725	0.8744	0.8763	0.8789	0.8816	0.8838	0.8860
390	0.8659	0.8677	0.8696	0.8725	0.8753	0.8777	0.8801
400	0.8594	0.8612	0.8631	0.8659	0.8687	0.8715	0.8744
410	0.8529	0.8548	0.8566	0.8594	0.8621	0.8647	0.8673
420	0.8457	0.8473	0.8489	0.8520	0.8552	0.8580	0.8607
430	0.8387	0.8402	0.8417	0.8451	0.8484	0.8511	0.8539
440	0.8317	0.8332	0.8347	0.8382	0.8417	0.8446	0.8475
450	0.8257	0.8272	0.8287	0.8323	0.8360	0.8391	0.8422
460	0.8173	0.8194	0.9215	0.8257	0.8300	0.8343	0.8387
470	0.8090	0.8111	0.8049	0.8173	0.8215	0.8257	0.8300
480	0.8009	0.8029	0.8049	0.8090	0.8131	0.8173	0.8215
490	0.7730	0.7950	0.7969	0.8009	0.8049	0.8090	0.8131
500	0.7852	0.7871	0.7891	0.7930	0.7969	0.8009	0.8049
510	0.7738	0.7757	0.7776	0.7814	0.7852	0.7891	0.7930
520	0.7664	--	0.7664	0.7720	0.7776	0.7814	0.7852
530	0.7556	--	0.7556	0.7610	0.7664	0.7701	0.7738
540	0.7450	--	0.7450	0.7503	0.7556	0.7610	0.7664
550	0.7348	--	--	--	0.7450	0.7485	0.7520
560	0.7248	--	--	--	0.7348	0.7399	0.7350
570	0.7151	--	--	--	0.7248	0.7314	0.7382
580	0.7026	--	--	--	0.7119	0.7199	0.7281
590	0.6904	--	--	--	0.6994	0.7057	0.7119
600	0.6787	--	--	--	0.6875	0.6949	0.7026
610	0.6647	--	--	--	0.6702	0.6787	0.6875

ATTACHMENT 7: DENSITY TABLE FOR HYDROGEN DETERMINATION (Cont'd)

DENSITY, g/cc, of Water

RCS Avg. Temp (T _{av}) °F	Saturated Liquid (0)	Pressure of Compressed Liquid from PI1103					
		500	1000	1500	2000	2500	3000
620	0.6485	--	--	--	0.6538	0.6647	0.6759
630	0.6331	--	--	--	0.6357	0.6485	0.6619
640	0.6161	--	--	--	--	--	0.6459
650	0.5977	--	--	--	--	--	0.6306
660	0.5762	--	--	--	--	--	0.6091
670	0.5524	--	--	--	--	--	0.5804
680	0.5252	--	--	--	--	--	0.5562
690	0.4884	--	--	--	--	--	0.5151
700	0.4341	--	--	--	--	--	0.4462

FOR INFORMATION ONLY

APPENDIX A: GUIDANCE FOR THE ESTIMATION OF CORE DAMAGE

(1) Fuel Damage shall be reported as follows:

Substantiated Calculation	0%	0 - 10%	11 - 50%	51 - 100%
To be reported as	No damage	Minor	Intermediate	Major

For example, results of G = 50%, F = 10% and M = 3% shall be reported as intermediate cladding failure with minor fuel overheating and minor fuel melt.

(2) Substantiate calculations using Table 1, Supporting Plant Parameters for Estimation of Core Damage

(3) Consult Table 2, Additional Considerations, for guidance

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APPENDIX A (Cont'd)

TABLE 1: SUPPORTING PLANT PARAMETERS FOR ESTIMATION OF CORE DAMAGE

NO FUEL DAMAGE	<ul style="list-style-type: none"> - Absence of higher than normal concentrations of Xe-133, Xe-135, Kr-88, Kr-85 - Hotleg temperature < 700°F - Saturation margin monitor > 25°F - Normal containment and/or RCS hydrogen levels - Justification for high radiation readings - I-131 and I-133 should not be used to verify "no fuel damage" condition - If 100%, fuel overheat and fuel melting are also likely
CLADDING FAILURE	<ul style="list-style-type: none"> - Use noble gas activity especially if RCS purification system has been operating during fuel failure - Slightly higher than normal RCS letdown (RM-L1) radiation levels (< 10% cladding failure) - Significant increase (> 8000 cpm) on RM-L1 (> 10% cladding failure) - Significant increase (> 100 mR/hr) in containment area radiation levels (> 10% cladding failure) - Hotleg temperatures > 700°F (> 10% Cladding Failure) - RCS pressure transients (> 10% Cladding Failure)
FUEL OVERHEAT	<ul style="list-style-type: none"> - RCS hotleg temperature > 900°F - Saturation margin monitor < 25°F - Higher than normal levels of hydrogen in RCS and containment atmosphere - High radiation (> 10 R/hr) in containment (RM-22/23)
FUEL MELTING	<ul style="list-style-type: none"> - RCS hotleg temperature > 900°F for a long period - Saturation margin monitor < 25°F - Measurable quantities of barium, tellurium and ruthenium in RCS - Higher than normal levels of hydrogen in RCS and containment atmosphere - High radiation (> 10 R/hr) in containment (RM-22/23)

APPENDIX A (Cont'd)

TABLE 2: ADDITIONAL CONSIDERATIONS

- (a) If the cladding failure and fuel overheating estimates based on Iodine and Noble Gas are significantly different (i.e., Iodine and Noble Gas estimates are in different groups of the reporting matrix), recheck the estimates and if necessary obtain new samples to determine new concentrations. If the results remain the same, rely on Noble Gas estimates unless the Iodine estimates are considered to be more reliable due to Noble Gas losses.
- (b) In the event the core damage estimate is determined after a containment purge operation, ensure that the noble gas and hydrogen concentrations are corrected to reflect the initial concentrations prior to the purge operation.
- (c) The samples taken during the later stages of the accident may provide for a more accurate core damage estimate, than those taken in the early stages of the accident.
- It must be noted that equilibrium samples are not available from all sample locations at the time of sampling. Under actual conditions the samples analyzed initially may be significantly different than those samples analyzed during equilibrium conditions. This is due to the fact that the fission products may not distribute uniformly at all locations and also due to the fact that maximum core degradation may not have occurred at the time of sampling. Therefore, the samples taken during the later stages of the accident may provide for a more accurate core damage estimate than those taken in the early stages of the accident.

APPENDIX A (Cont'd)

- (d) Because of the chemistry of Iodine, the Iodine method should not be used for loss of coolant accidents that release large quantities of Iodine to the containment atmosphere (i.e., ruptured pipes, welds, valves or fittings). Should the Noble Gas method yield consistently higher results and Iodine losses be suspected, the core damage estimate should be based solely on the Noble Gas method and verified by other plant indicators.

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INFORMATION
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APPENDIX B: CALCULATION OF CGRE DAMAGE USING RCS LIQUID SAMPLING RESULTS

 : NOTE: For the purpose of this procedure, all radionuclides :
 : shall be decayed back to reactor shutdown prior to :
 : core damage. This may be performed automatically :
 : with the Canberra by assuming reactor shutdown as the :
 : sample time when prompted by the computer. :
 : -----

1.0 Plant Data

Average power level for last 22 days
 up until the estimated time of fuel failure (P) _____ %

Average RCS temperature (T_{ave}) at estimated
 time of fuel failure _____ °F

RCS sampling system pressure from PI1103 _____ psig

If reactor power has changed more than 10% in the last 22 days:

Power before the change (P_1) (P_1) = _____ %

Power after the change (P_2) (P_2) = _____ %

Time to make the change (T) (T) = _____ hours

Time from completion of change to when fuel
 damage is suspected to have occurred (c) = _____ hours

2.0 RCS Sampling Analysis Results

a. RCS Liquid Data

 : NOTE: 1 $\mu\text{Ci/cc}$ = 1 $\mu\text{Ci/g}$:
 : -----

I-131 = _____ $\mu\text{Ci/g}$

I-133 = _____ $\mu\text{Ci/g}$

Ba-140 = _____ $\mu\text{Ci/g}$

Cs-134 = _____ $\mu\text{Ci/g}$

Cs-137 = _____ $\mu\text{Ci/g}$

Ru-103 = _____ $\mu\text{Ci/g}$

Te-129m = _____ $\mu\text{Ci/g}$

Te-132 = _____ $\mu\text{Ci/g}$

APPENDIX B (Cont'd)

2.2 RCS Noble Gas Data

: NOTE: 1 $\mu\text{Ci/Kg}$ of coolant = $(\mu\text{Ci/cc or } \mu\text{Ci/g})(1000)$:

Kr-85 = _____ $\mu\text{Ci/Kg}$

Kr-88 = _____ $\mu\text{Ci/Kg}$

Xe-133 = _____ $\mu\text{Ci/Kg}$

Xe-135 = _____ $\mu\text{Ci/Kg}$

3.0 Equivalent Liquid RCS Activity Concentrations

These calculations are only required when primary coolant has been released from the RCS into other system components e.g., RC make-up tank, sump. Calculate equivalent activity concentrations (A_e) for I-131, I-133 and Ba-140 as follows where:

A_e = equivalent RCS activity concentration in $\mu\text{Ci/gram}$

A = activity concentration for each system sampled in $\mu\text{Ci/gram}$

M = liquid mass (g) in each component sampled

: NOTE: Equivalent concentrations are not required for :
: cesium, ruthenium and tellurium. :

3.1 Obtain the density from Attachment 7 and calculate M_i for each component sampled as:

$$M_i = (\text{volume in gallons})(\text{density})(3785)$$

APPENDIX B (Cont'd)

$$3.2 \quad A_{eI-131} = \frac{(A_{I-131} M_1 + A_{I-131} M_2 + \dots + A_{I-131} M_i)}{(2.17 \times 10^8 \text{ g})} = \text{_____ } \mu\text{Ci/gram}$$

$$3.3 \quad A_{eI-133} = \frac{(A_{I-133} M_1 + A_{I-133} M_2 + \dots + A_{I-133} M_i)}{(2.17 \times 10^8 \text{ g})} = \text{_____ } \mu\text{Ci/gram}$$

$$3.4 \quad A_{eBa-140} = \frac{(A_{Ba-140} M_1 + A_{Ba-140} M_2 + \dots + A_{Ba-140} M_i)}{(2.17 \times 10^8 \text{ g})} = \text{_____ } \mu\text{Ci/gram}$$

4.0 Power Level Inventory Correction

Calculate the power correction factor (x) as follows where:

$$P_1 \text{ (from plant data section)} = \text{_____ } \%$$

$$P_2 \text{ (from plant data section)} = \text{_____ } \%$$

$$T \text{ (from plant data section)} = \text{_____}$$

$$c \text{ (from plant data section)} = \text{_____}$$

$$t = \left[\frac{T}{2} + c \right] \div 24 = \text{_____}, t = \text{_____} \text{ hours}$$

4.1 If there has been less than 10% power change in the last 22 days:

$$X = 100 \div (\text{average power level})$$

4.2 If there has been greater than 10% power change in the last 22 days, X must be calculated for each isotope as follows:

$$4.2.1 \quad X_{I-131} = \frac{100}{P_1(e^{-0.0864t}) + P_2(1-e^{-0.0864t})} = \text{_____}$$

$$4.2.2 \quad X_{I-133} = \frac{100}{P_1(e^{-0.796t}) + P_2(1-e^{-0.796t})} = \text{_____}$$

$$4.2.3 \quad X_{Ba-140} = \frac{100}{P_1(e^{-0.0542t}) + P_2(1-e^{-0.0542t})} = \text{_____}$$

APPENDIX B (Cont'd)

5.0 Estimation of Degree of Cladding Failure

5.1 Using I-131 and 133, estimate the percent of rods with ruptured cladding releasing their gap activity (G) as follows:

$$G = [(1.863 \times 10^{-2})(A_{e_{I-131}})(X_{I-131})] - [(8.31 \times 10^{-3})(A_{e_{I-133}})(X_{I-133})]$$

where A_e is the activity from Section 3.0 (or Section 2.1 if RCS hasn't leaked)

X is the power correction factor from Section 4.0.

$$G = [1.863 \text{ E-}2(\quad)(\quad)] - [8.31 \text{ E-}3(\quad)(\quad)]$$

$$G = \underline{\hspace{2cm}} \%$$

5.2 If leakage from the RCS has occurred, calculate estimates of (G) using containment atmosphere air sampling results per Appendix B provided no leakage from the RCS has occurred. Utilize the individual noble gas activities obtained from the RCS gas sample to calculate estimates of (G) as follows. If the sample was taken less than 20 hours after reactor shutdown, calculate (G) using Kr-88. If the sample was taken more than 20 hours after shutdown, calculate (G) using Xe-133.

$$G = \left[\frac{\text{corrected RCS noble gas activity}}{100 \text{ percent theoretical noble gas gap release}} \right] (100)$$

$$= \left[\frac{(A)(X)}{A_{(100)}} \right] (100)$$

where: A is the individual noble gas activity from Section 2.2

X is the power correction factor from Section 4.0

A_{100} values are obtained from the following table

A_{100}	
Kr-88	$= 3.995 \times 10^5 \text{ } \mu\text{Ci/Kg}$
Xe-133	$= 3.943 \times 10^7 \text{ } \mu\text{Ci/kg}$

APPENDIX B (Cont'd)

G = _____ %

 : NOTE: If (G) is greater than 100 percent, then fuel over- :
 : heat has probably occurred releasing additional acti- :
 : vity from the fuel. Values greater than 100 percent :
 : shall be reported as 100 percent. :

6.0 Estimation of Extent of Fuel Overheat

6.1 Using I-131 and I-133, estimate the percent of fuel rods that are overheated with activity being released from the fuel (F) as follows:

$$F = [(1.864 \times 10^{-4})(A_{I-133})(X_{I-133})] - [(3.64 \times 10^{-5})(A_{I-131})(X_{I-131})]$$

where A is the activity from Section 2.1

X is the power correction factor from Section 4.0

$$F = [1.684 \text{ E-4} (\quad) (\quad)] - [3.64 \text{ E-5} (\quad) (\quad)]$$

F = _____ %

7.0 Estimation of Extent of Fuel Melt

7.1 Using Ba-140, estimate the percent of fuel rods with molten fuel (M) as follows:

$$M = 0.002 (A_{Ba-140}) (X_{Ba-140})$$

where A is the activity from Section 2.1

B is the power correction factor from Section 4.0

$$M = 0.002 (\quad) (\quad) = \quad \%$$

APPENDIX B (Cont'd)
TABLE 1
Density Correction Factor K

RCS Avg. Temp (T _{AVE})	Saturated Liquid (0)	Pressure of Compressed Liquid from P11103					
		500	1000	1500	2000	2500	3000
32	0.9999	1.0015	1.0030	1.0049	1.0068	1.0084	1.0100
40	0.9999	1.0015	1.0030	1.0049	1.0068	1.0084	1.0100
50	0.9993	1.0008	1.0024	1.0043	1.0062	1.0078	1.0094
60	0.9987	1.0002	1.0018	1.0033	1.0049	1.0071	1.0087
70	0.9974	0.9990	1.0005	1.0021	1.0037	1.0059	1.0081
80	0.9962	0.9977	0.9993	1.0008	1.0024	1.0046	1.0068
90	0.9949	0.9965	0.9980	0.9996	1.0012	1.0030	1.0049
100	0.9931	0.9946	0.9962	0.9977	0.9993	1.0008	1.0024
110	0.9906	0.9922	0.9937	0.9952	0.9968	0.9983	0.9999
120	0.9888	0.9903	0.9919	0.9934	0.9949	0.9965	0.9980
130	0.9857	0.9873	0.9888	0.9903	0.9919	0.9934	0.9949
140	0.9833	0.9848	0.9864	0.9879	0.9894	0.9909	0.9925
150	0.9803	0.9818	0.9833	0.9848	0.9864	0.9876	0.9888
160	0.9773	0.9788	0.9803	0.9818	0.9833	0.9848	0.9864
170	0.9738	0.9752	0.9767	0.9782	0.9797	0.9812	0.9827
180	0.9702	0.9711	0.9726	0.9744	0.9761	0.9779	0.9797
190	0.9667	0.9682	0.9696	0.9714	0.9732	0.9749	0.9769
200	0.9632	0.9647	0.9661	0.9679	0.9696	0.9711	0.9726
210	0.9592	0.9635	0.9621	0.9638	0.9655	0.9670	0.9685
212	0.9580	0.9595	0.9609	0.9626	0.9644	0.9661	0.9679
220	0.9552	0.9566	0.9580	0.9598	0.9615	0.9632	0.9650
230	0.9512	0.9526	0.9540	0.9560	0.9580	0.9595	0.9609
240	0.9467	0.9481	0.9495	0.9515	0.9535	0.9552	0.9569
250	0.9423	0.9436	0.9450	0.9470	0.9489	0.9506	0.9523
260	0.9373	0.9389	0.9406	0.9425	0.9445	0.9462	0.9478
270	0.9329	0.9346	0.9362	0.9381	0.9400	0.9417	0.9434
280	0.9281	0.9297	0.9313	0.9332	0.9351	0.9370	0.9389
290	0.9233	0.9251	0.9270	0.9289	0.9308	0.9324	0.9340
300	0.9180	0.9199	0.9217	0.9235	0.9254	0.9270	0.9286
310	0.9127	0.9146	0.9164	0.9182	0.9201	0.9217	0.9233
320	0.9076	0.9094	0.9112	0.9132	0.9153	0.9166	0.9180
330	0.9019	0.9040	0.9060	0.9074	0.9096	0.9112	0.9127
340	0.8964	0.8984	0.8904	0.9022	0.9040	0.9058	0.9076
350	0.8904	0.8924	0.8944	0.8964	0.8984	0.9004	0.9024
360	0.8845	0.8865	0.8884	0.8909	0.8934	0.8949	0.8964
370	0.8787	0.8806	0.8826	0.8852	0.8879	0.8899	0.8919
380	0.8725	0.8744	0.8763	0.8789	0.8816	0.8838	0.8860
390	0.8659	0.8677	0.8696	0.8725	0.8753	0.8777	0.8801
400	0.8594	0.8612	0.8631	0.8659	0.8687	0.8715	0.8744
410	0.8529	0.8548	0.8566	0.8594	0.8621	0.8647	0.8673
420	0.8457	0.8473	0.8489	0.8520	0.8552	0.8580	0.8607
430	0.8387	0.8402	0.8417	0.8451	0.8484	0.8511	0.8539
440	0.8317	0.8332	0.8347	0.8382	0.8417	0.8446	0.8475
450	0.8257	0.8272	0.8287	0.8323	0.8360	0.8391	0.8422
460	0.8173	0.8194	0.8215	0.8257	0.8300	0.8343	0.8387
470	0.8090	0.8111	0.8049	0.8173	0.8215	0.8257	0.8300
480	0.8009	0.8029	0.8049	0.8090	0.8131	0.8173	0.8215
490	0.7730	0.7950	0.7969	0.8009	0.8049	0.8090	0.8131
500	0.7852	0.7871	0.7891	0.7930	0.7969	0.8009	0.8049
510	0.7738	0.7757	0.7776	0.7814	0.7852	0.7891	0.7930
520	0.7664	--	0.7664	0.7720	0.7776	0.7814	0.7852
530	0.7556	--	0.7556	0.7610	0.7664	0.7701	0.7738
540	0.7450	--	0.7450	0.7503	0.7556	0.7610	0.7664
550	0.7348	--	--	--	0.7450	0.7485	0.7520
560	0.7248	--	--	--	0.7348	0.7399	0.7350
570	0.7151	--	--	--	0.7248	0.7314	0.7382
580	0.7026	--	--	--	0.7119	0.7199	0.7281
590	0.6904	--	--	--	0.6994	0.7057	0.7119
600	0.6787	--	--	--	0.6875	0.6949	0.7026
610	0.6647	--	--	--	0.6702	0.6787	0.6875
620	0.6485	--	--	--	0.6538	0.6647	0.6759
630	0.6331	--	--	--	0.6357	0.6485	0.6619
640	0.6161	--	--	--	--	--	0.6459
650	0.5977	--	--	--	--	--	0.6306
660	0.5762	--	--	--	--	--	0.6091
670	0.5524	--	--	--	--	--	0.5804
680	0.5252	--	--	--	--	--	0.5562
690	0.4884	--	--	--	--	--	0.5151
700	0.4341	--	--	--	--	--	0.4462

APPENDIX C: CALCULATION OF CORE DAMAGE USING CONTAINMENT ATMOSPHERE
AIR SAMPLING RESULTS

: NOTE: For the purpose of this procedure, all radionuclides :
: shall be decayed back to reactor shutdown prior to :
: core damage. This may be performed automatically :
: with the Canberra by assuming reactor shutdown as the :
: sample time when prompted by the computer. :

1.0 Plant Data

Average power level for last 22 days up
until the estimated time of fuel failure (P) (P) = _____ %

Average RCS temperature (T_{ave}) at estimated
time of fuel failure _____ °F

RCS sampling system pressure from PI 1103 _____ psig

If reactor power has changed more than 10% during the last 22 days:

Power before the change (P_1) (P_1) = _____ %

Power after the change (P_2) (P_2) = _____ %

Time to make the change (T) (T) = _____ hours

Time from completion of change to when fuel
damage is suspected to have occurred (c) = _____ hours

2.0 Containment Air Gamma Scan Results

Kr-85 = _____ $\mu\text{Ci}/\text{Std cc}$

Kr-88 = _____ $\mu\text{Ci}/\text{Std cc}$

Xe-133 = _____ $\mu\text{Ci}/\text{Std cc}$

Xe-135 = _____ $\mu\text{Ci}/\text{Std cc}$

3.0 Equivalent Containment Air Noble Gas Activity Concentration

These calculations are only required when fission gases have been
released from the RCS into containment through leakage or venting.

Calculate equivalent activity concentrations (A_e) for Kr-88 and Xe-133 as
follows where:

A_e = equivalent containment air noble gas concentration in $\mu\text{Ci}/\text{Std cc}$
35.0

APPENDIX C (Cont'd)

A_c = specific noble gas activity concentration of containment air in $\mu\text{Ci/cc}$ (STP conditions)

A_{RCS} = specific noble gas activity concentration of reactor coolant system in $\mu\text{Ci/Kg}$ of liquid

p_r = containment pressure at sample time in psig (from control room)

t_p = containment temperature at sample time in $^{\circ}\text{F}$ (from control room)

$$3.1 \quad A_e = \left[\frac{(6.0202 \times 10^{10}) \left(\frac{p_r + 14.7}{14.7} \right) \left(\frac{492}{t_p + 460} \right) (A_c)}{6.0202 \times 10^{10} \text{ cc}} \right] + \left[(2.17 \times 10^5) (A_{RCS}) \right]$$

$$= \left[\frac{6.0202\text{E}10 \left(\frac{+ 14.7}{14.7} \right) \left(\frac{492}{+ 460} \right) A_c}{6.0202\text{E}10} \right] + \left[2.17\text{E}5 (A_{RCS}) \right]$$

$$A_e \text{ Kr-88} = \text{_____} \mu\text{Ci/Std cc}$$

$$A_e \text{ Xe-133} = \text{_____} \mu\text{Ci/Std cc}$$

4.0 Power Level Inventory Correction

Calculate the power correction factor (X) as follows where:

$$P_1 \text{ (from plant data, section 1)} = \text{_____} \%$$

$$P_2 \text{ (from plant data, section 1)} = \text{_____} \%$$

$$T \text{ (from plant data, section 1)} = \text{_____} ^{\circ}\text{F}$$

$$c \text{ (from plant data, section 1)} = \text{_____} \text{ hours}$$

$$t = \left[\frac{T}{2} + c \right] + 24, \quad t = \text{_____} \text{ hours}$$

4.1 If there has been less than 10% power change in the last 22 days:

$$X = 100 + (\text{average power level})$$

4.2 If there has been greater than 10% power change in the last 22 days, (X) must be calculated for each isotope as follows:

$$4.2.1 \quad X_{\text{Kr-88}} = \frac{100}{P_1 \left(e^{-5.9396t} \right) + P_2 \left(1 - e^{-5.9396t} \right)} = \text{_____}$$

APPENDIX C (Cont'd)

$$4.2.2 \quad X_{Xe-133} = \frac{100}{P_1 \left(e^{-0.1315t} \right) + P_2 \left(1 - e^{-0.1315t} \right)}$$

5.0 Estimation of Degree of Cladding Failure

Estimate the percent of rods with ruptured cladding releasing their gap activity (G) for the individual noble gas as follows where:

A_e is activity from section 3

X is the power correction factor from section 4

 : NOTE: If time of sampling was less than 20 hours after :
 : reactor shutdown, calculate (G) using Kr-88. If :
 : the sample was taken more than 20 hours after shut- :
 : down, calculate (G) using Xe-133. :

5.1 Multiply (A_e) by (X) then determine (G) from Figure 1 or 2.

5.1.1 For Kr-88, (A_e)(X) = () () = _____. G = _____%

5.1.2 For Xe-133, (A_e)(X) = () () = _____. G = _____%

 : NOTE: If (G) is greater than 100%, the fuel overheat has :
 : probably occurred releasing additional activity from :
 : the fuel. Values greater than 100% shall be reported :
 : as 100%. :

6.0 Estimation of Extent of Fuel Overheat

Estimate the percent of fuel rods that are overheated with activity being released from the fuel (F) using the corrected activities for the individual noble gases and Figures 1 and 2 as follows:

6.1 Obtain the (A_e) (X) product for each noble gas from section 5.

Determine (F) from Figures 1 and 2.

6.1.1 For Kr-88, (A_e)(X) = _____, F = _____%

6.1.2 For Xe-133, (A_e)(X) = _____, F = _____%

APPENDIX C (Cont'd)

7.0 Approximation of Extent of Fuel Cladding Oxidation

The amount of fuel cladding oxidation (Z) is used in support of the estimate of the extent of fuel overheating. The fuel cladding oxidation approximation is made using the standard cubic feet (SCF) of H₂ in the RCS, the SCF H₂ in the containment and SCF H₂ consumed in a hydrogen burn, if one occurs.

7.1 Calculate the SCF H₂ in RCS as follows where:

H_{2R} is the H₂ concentration in the RCS in Std cc/Kg (from Attachment 3, EPIP 1004.33).

$$7.1.1 \quad \text{SCF H}_2 \text{ in RCS} = (H_{2R})(7.66) = \underline{\hspace{2cm}} \text{ std cubic ft.}$$

7.2 Calculate the SCF H₂ in containment as follows where:

H_{2C} is the H₂ concentration in containment air in percent (from control room, recorders AR-42R/43R)

P is containment pressure at sample time in psig (from control room)

T is containment temperature at sample time in °F (from control room)

7.2.1 SCF H₂ in Containment =

$$= \frac{(\%H_{2C} + 100)(2.126 \times 10^6 \text{ ft}^3) \left(\frac{492}{T + 460} \right) \left(\frac{P + 14.7}{14.7} \right)}{\hspace{2cm}} \text{ standard cubic feet}$$

7.3 If a hydrogen burn has occurred, the standard cubic feet of hydrogen consumed in the burn (SCF H_{C_B}) must be estimated as follows where:

H_A is the H₂ remaining after the burn, in SCF

H_B is the H₂ present before the burn, in SCF

T_A is the average containment temperature after the burn, in °F

APPENDIX C (Cont'd)

T_B is the average containment temperature before the burn, in °F

H_{2A} is the H_2 concentration in containment after the burn, in %

H_{2B} is the H_2 concentration in containment before the burn, in %

P_A is the containment pressure after the burn, in psig

P_B is the containment pressure before the burn, in psig

7.3.1 Calculate the SCF H_{2B} before the burn as follows:

$$\begin{aligned} \text{SCF } H_{2B} &= (H_{2B} + 100)(2.12 \text{ E6}) \left(\frac{492}{460 + T_B} \right) \left(\frac{P_B + 14.7}{14.7} \right) \\ &= (\quad + 100)(2.12 \text{ E6}) \left(\frac{492}{460 + \quad} \right) \left(\frac{\quad + 14.7}{14.7} \right) \\ &= \quad \text{standard cubic feet} \end{aligned}$$

7.3.2 Calculate the SCF H_{2A} after the burn as follows:

$$\begin{aligned} \text{SCF } H_{2A} &= (H_{2A} + 100)(2.12 \text{ E6}) \left(\frac{492}{460 + T_A} \right) \left(\frac{P_A + 14.7}{14.7} \right) \\ &= (\quad + 100)(2.12 \text{ E6}) \left(\frac{492}{460 + \quad} \right) \left(\frac{\quad + 14.7}{14.7} \right) \\ &= \quad \text{standard cubic feet} \end{aligned}$$

7.3.3 Estimate SCF H_{cB} as follows:

$$\begin{aligned} \text{SCF } H_{cB} &= H_{2B} - H_{2A} = (\quad) - (\quad) \\ &= \quad \text{standard cubic feet} \end{aligned}$$

7.3.4 Approximate the amount of fuel cladding oxidation as follows:

$$\begin{aligned} Z &= \frac{\text{SCF } H_2 \text{ in RCS} + \text{SCF } H_2 \text{ in containment} + \text{SCF } H_{cB}}{3.95 \text{ E5}} \\ &= \frac{(\quad) + (\quad) + (\quad)}{3.95 \text{ E5}} \\ &= \quad \text{percent} \end{aligned}$$

FIGURE 1

K2-88 RELEASES vs ACCIDENT CATEGORIES

900 $\mu\text{Ci}/\text{ft}^3$
K2-88
Containment Air

700

500

300

100

RELEASE FROM FUEL

FUEL OVERHEAT

10%

50%

100%

1.4 $\mu\text{Ci}/\text{ft}^3$
K2-88
Containment Air

1.0

0.6

0.2

RELEASE FROM GAP

CLADDING DAMAGE

10%

50%

40.0

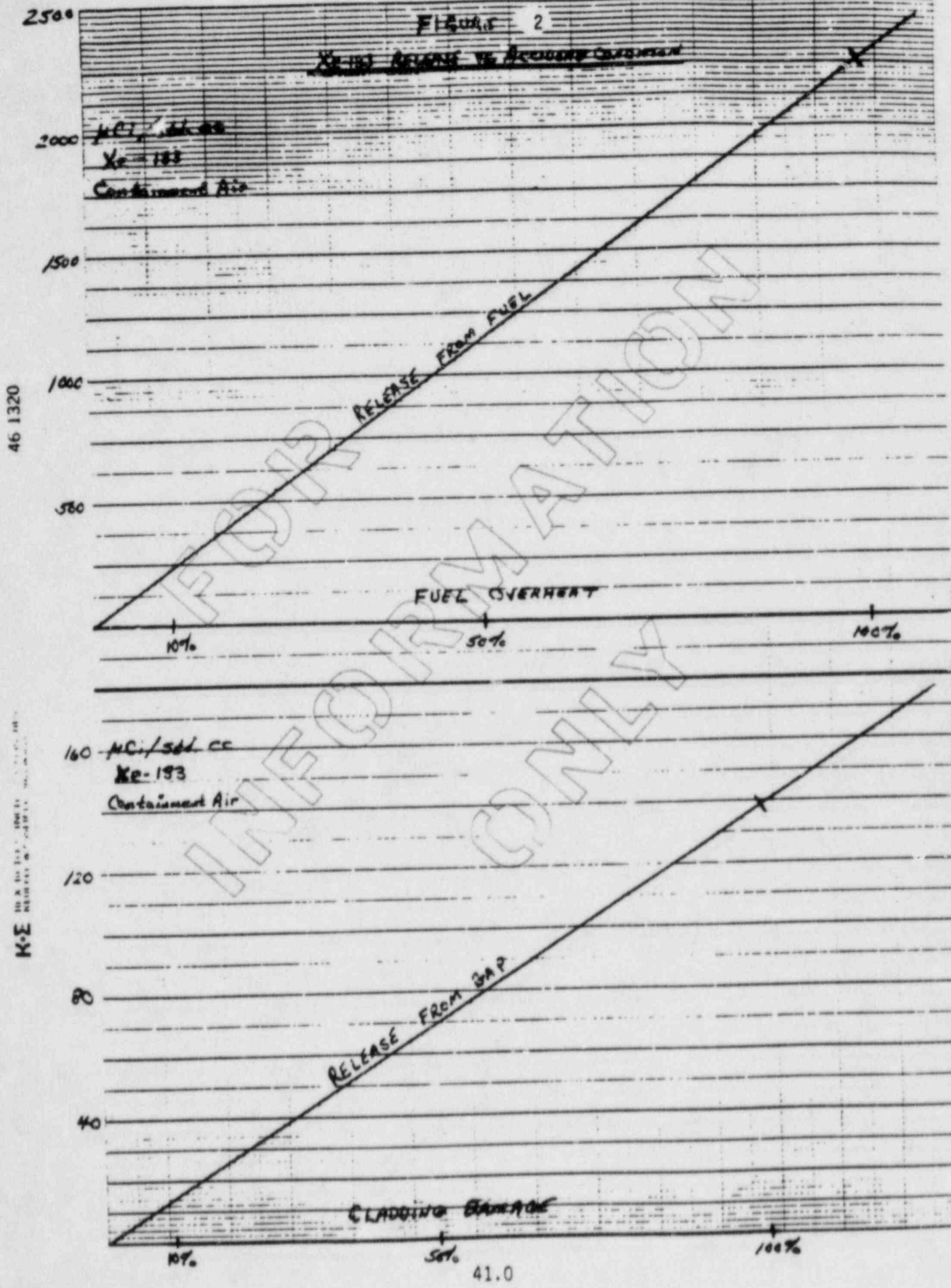
100%

46 1320

K2-88
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FIGURE 2



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K-E

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