CAROLINA POWER AND LIGHT COMPANY

H. B. ROBINSON SEG PLANT

PLANT OPERATING MANUAL

VOLUME 2

PART 5

PLANT EMERGENCY PROCEDURE

PEP-355

CORE DAMAGE ASSESSMENT

REVISION 0

Effective Date 10-16-85

RECOMMENDED BY: Mike Morrow 10-9-85
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1.0 PURPOSE

The purpose of this procedure is to implement Section 4.2, "Accident Assessment Actions", of the H.B. Robinson Emergency Plan.

This procedure provides the means to relate core damage with measurements of radionuclide concentrations and with auxiliary indications (reactor vessel level, core exit thermocouples, containment hydrogen and radiation levels) such that it is possible to distinguish the four major fuel conditions: no damage, clad failure, fuel overheat and core melt.

The approach used is the measurement of fission product concentrations via the post-accident sampling system and isotopic analysis. These results are corrected to account for sample pressures and temperatures, precursor effects and radioactive decay to obtain the total activity release for the various isotopes. These are compared to the initial activity available for release from the core; the quantity and type of isotopes released are used to estimate the type and extent of core damage.

2.0 REFERENCES

2.1 Emergency Plan References

2.1.1 Section 4.2, Accident Assessment Actions

2.2 Referenced Plant Emergency Procedures

2.2.1 PEP-151, Plant Operations Director

2.3 Other References

2.3.1 PEP-253, Collection of Radioactive Samples

2.3.1 Westinghouse Owners Group Document, Core Damage Assessment Methodology, November, 1984, Revision 2

3.0 RESPONSIBILITIES

3.1 The Accident Assessment Team is responsible for performing this procedure.

4.0 DEFINITIONS/ABBREVIATIONS

None Applicable

5.0 GENERAL

It is not necessary to have a complete isotopic analysis or to perform calculations for all isotopes listed on ATTACHMENT 10.1 to estimate core damage.

A single isotope, either Xe-133 or I-131, could be used as a quick and ballpark indication for all three levels of core damage, however, fuel melt is best confirmed by measuring Praseodynium, Lanthanum, Barium, or Strontium isotopes, and fuel overtemperature is best confirmed by measuring Cesium or Tellerium isotopes. Strontium isotopes are included on ATTACHMENT 10.1 for long term damage evaluation, since quantitative analysis of these isotopes may take several days.

In order to determine fuel overheat or melt using noble gas or Iodine isotopes, it is best to have values for Xe-133 or I-131 activity, respectively.

It should be realized that it is unlikely that all isotopes listed on ATTACHMENT 10.1 can be resolved with available detectors.

6.0 INITIATING CONDITIONS

6.1 The Plant Operations Director has decided that this procedure should be implemented.

7.0 PRECAUTIONS AND LIMITATIONS

7.1 Accuracy: The categories of core damage are considered to overlap considerably; this is, however, consistent with the intent of the procedure to provide a generalized estimate of the extent of core damage.

7.2 Spiking Phenomena: If major transients in core power, pressure, or temperature have occurred prior to shutdown, iodine concentrations may indicate a significantly more severe damage state, and should therefore be considered - see ATTACHMENT 10.30.

7.3 Oxygen Concentration: If a significant decrease in containment oxygen concentration has occurred since shutdown, this may indicate a hydrogen burn has occurred, and should be considered in evaluating containment hydrogen levels as an indicator of core damage.

7.4 Steam Generator Tube Rupture or Outside Containment Loss of Coolant Accident: If core activity has been released to systems not covered by the Post Accident Sampling System, (e.g., secondary system, Component Cooling Water), this procedure will give a non-conservative estimate of core damage. This will be noted as auxiliary indicators estimating more severe damage than the isotopic analysis. If accurate samples of these systems are available as well as reasonable estimates of the sample space volume or mass, the methodology of this procedure may be applied to improve the accuracy of the isotopic release estimate of the core damage.

7.0 PRECAUTIONS AND LIMITATIONS (Continued)

7.5 Inadequate Core Cooling Conditions: This procedure will estimate core damage status at time of sampling. If inadequate core cooling occurs after or during sampling, the actual core damage status would be more severe.

8.0 SPECIAL TOOLS AND EQUIPMENT

8.1 Scientific Calculator

9.0 PROCEDURE STEPS

NOTE

Section 9.8 may be implemented independent of Sections 9.1 to 9.7 to estimate core damage status by auxiliary indications.

Additionally, samples are only required from locations consistent with accident conditions. For example, if no coolant has been released to containment, then containment sump and air sample analysis is not required.

9.1 Request the Plant Monitoring Team Leader to sample the Reactor Coolant System, the RHR System, and Containment Atmosphere, and perform isotopic analysis. Accident Assessment Team shall be contacted at the time samples are being drawn so that plant status can be recorded on ATTACHMENT 10.2. Section 9.6 of this procedure should be implemented as samples are being processed. When sample analysis results are transmitted to the Accident Assessment Team, they will complete all remaining items on ATTACHMENT 10.2 and continue in this procedure.

9.0 PROCEDURE STEPS (Continued)

9.2 On ATTACHMENT 10.1, Column 11, enter the sample specific activity (uCi/g or uCi/cc) for each isotope, as determined from the analysis of Step 9.1.

9.3 On ATTACHMENT 10.1, Column 1, enter the time after shutdown until the sample was analyzed (hrs.) from ATTACHMENT 10.2, Lines 6, 12 and 19 for Reactor Coolant System (R), RHR System (S) and Containment Atmosphere (A) for each analyzed isotope.

9.4 Calculate the sample density ratios by completing ATTACHMENT 10.3 (Part A) per the following instructions:

NOTE

If a sample is reported per unit mass (uCi/g), use a density ration = 1.0 on ATTACHMENT 10.1, Column 13.

9.4.1 Lines 1 and 2: Containment Atmosphere temperature and pressure at time of sampling from ATTACHMENT 10.2, Lines 14 and 15.

Lines 3 and 4: Containment Atmosphere sample temperature and pressure from ATTACHMENT 10.2, Lines 7 and 8.

Line 5: Density Ratio = $\frac{\text{Line 2 x Line 3}}{\text{Line 1 x Line 4}}$

Enter calculated value on ATTACHMENT 10.1, Column 13, for each analyzed isotope's atmosphere sample.

9.4.2 Line 6: Use Reactor Coolant System sample temperature from ATTACHMENT 10.2, Line 3 and ATTACHMENT 10.23: Water Density Ration (Temperature vs. Standard Temperature and Pressure).

9.0 PROCEDURE STEPS (Continued)

Line 8: Density Ration = $\frac{\text{Line 7}}{\text{Line 6}}$

Enter calculated value on ATTACHMENT 10.1, Column 13, for each analyzed isotope's Reactor Coolant System sample.

9.4.3 Line 9: Use RHR System Sample temperature from ATTACHMENT 10.2, Line 9 and ATTACHMENT 10.23: Water Density Ratio (Temperature vs. Standard Temperature and Pressure).

Line 10: Use RHR temperature at time of sampling from ATTACHMENT 10.2, Line 8 and ATTACHMENT 10.23: Water Density Ratio (Temperature vs. Standard Temperature and Pressure).

Line 11: Density Ration = $\frac{\text{Line 10}}{\text{Line 9}}$

Enter calculated value on ATTACHMENT 10.1, Column 13 for each analyzed isotope's RHR sample.

9.5 Calculate the mass or volume of the three sample spaces by completing ATTACHMENT 10.3, Parts B and C per the following instructions:

9.5.1 Line 12: Containment water level at time of sampling from ATTACHMENT 10.2, Line 10.

Line 13: Use ATTACHMENT 10.24, Standard Temperature and Pressure H_2O Mass vs. Containment Level to find mass of RHR liquid at standard temperature and pressure.

9.0 PROCEDURE STEPS (Continued)

Line 14: Multiply standard temperature and pressure sump mass by sump density ratio: Line 13 x Line 10. Enter calculated value on ATTACHMENT 10.1, Column 15, for each isotope's RHR sample.

9.5.2 Line 15: If the pressurizer is empty, assume an otherwise filled Reactor Coolant System and multiply the Reactor Coolant System Density Ratio at time of Reactor Coolant System sampling by standard temperature and Pressure Reactor Coolant System mass: Line 7 x (2.28×10^8g).

OR

Line 16: If the pressurizer has a liquid level at time of Reactor Coolant System sampling, multiply the Reactor Coolant System Density Ration by Standard Temperature and Pressure Reactor Coolant System and Pressurizer mass: Line 7 x [(2.28×10^8g) + (ATTACHMENT 2, Line 4)] x (.01) x (3.68×10^7g).

Enter calculated value on ATTACHMENT 10.1, Column 15, for each analyzed isotope's Reactor Coolant System sample.

9.6 Calculate the correction factors for thermal power variation by completing ATTACHMENT 10.4 per the following instructions:

9.6.1 Part A: Equivalent power level for long-lived isotopes (Cs-137, Sr-89, Sr-90)

Line 1: Enter number of effective full power days during current core cycle (i.e., previous three years for a three region core), obtained from operating logs.

9.0 PROCEDURE STEPS (Continued)

Line 2: Enter number of effective full power days expected for current core cycle operation.

Line 3: Equivalent Power Level = $\frac{\text{Line 1}}{\text{Line 2}}$

Enter calculated value on ATTACHMENT 10.1, Column 18, for these three isotopes.

9.6.2 Part B: Equivalent Power Level for short-lived isotopes (Kr-85m, Kr-87, Kr-88, Xe-135, I-132, I-133, I-135, Te-129, La-142, Pr-144).

Line 4: If the reactor thermal power has been constant over the four (4) days prior to shutdown (<10% rated thermal power variation from 4-day average power level), then these isotopes have reached equilibrium concentrations, and the Equivalent Power Level is that fractional power level. (For example, 70% power level is an Equivalent Power Level of 0.70.) Enter the value on ATTACHMENT 10.1, Column 18, for these ten isotopes and continue with 9.6.3.

Otherwise, an Equivalent Power Level Worksheet must be completed for each isotope being analyzed to account for the effects of power changes over the 4-day period. Using plant operating records, determine the power history for previous 96 hours. Whenever core power level has changed by more than 10% of rated thermal power, a separate line on each isotope's Equivalent Power Level Worksheet must be completed.

9.0 PROCEDURE STEPS (Continued)

Instructions for Equivalent Power Level Worksheets, ATTACHMENTS 10.5 through 14:

NOTE

All transient time should be included at the lower power level for conservatism in the calculations.

Column 1: P_j - average thermal power level for interval (MW_t)

Column 2: t_j - duration of core operation at P_j (hrs.)

Column 3: t_j* - duration from end of interval until shutdown (hrs.)

Column 4: $1-[e^{(-\lambda_i \text{ Column } 2)}]$

Column 5: $e^{(-\lambda_i \times \text{ Column } 3)}$

Column 6: Column 1 x Column 4 x Column 5

After completing the necessary lines on each isotope's worksheet to cover the pervious 96 hours, add the values recorded in Column 2 for each isotope and verify the sum is 96 hours.

Add the values in Column 6 and divide the sum by 2300MW. This is the Equivalent Power Level - enter this value on ATTACHMENT 10.1, Column 18 for these ten isotopes.

9.0 PROCEDURE STEPS (Continued)

9.6.3 Part C: Equivalent Power Level for Intermediate-Lived Isotopes [Xe-131m, Xe-133, Xe-133m, I-131, Te-132, Ba-140, La-140].

Line 5: If the reactor thermal power has been constant over the thirty (30) days prior to shutdown (<10% Rated Thermal Power variation from the 30-day average power level), then these isotopes have reached equilibrium concentrations, and the Equivalent Power Level is that fractional power level. (For example, 70% power level is an Equivalent Power Level of 0.70.) Enter the value on ATTACHMENT 10.1, Column 18, for these seven isotopes and continue with 9.6.4.

Otherwise, an Equivalent Power Level Worksheet must be completed for each isotope being analyzed to account of the effects of power changes over the 30-day period. Using plant operating records, determine the power history for the previous 30 days. Whenever core power level has changed by more than 10% of rated thermal power, a separate line on each isotope's Equivalent Power Level Worksheet must be completed.

Instructions for Equivalent Power Level Worksheets, ATTACHMENTS 10.15 through 10.21:

NOTE

All transient time should be included at the lower power level for conservatism in the calculations.

Column 1: P_j - average thermal power level for interval (MW_t)

Column 2: t_j - duration of core operation at P_j (days)

Column 3: t_j* - duration from end of interval until shutdown (days)

9.0 PROCEDURE STEPS (Continued)

Column 4: $1-[e^{(-\lambda_i \text{ Column } 2)}]$

Column 5: $e^{-(\lambda_i \times \text{ Column } 3)}$

Column 6: Column 1 x Column 4 x Column 5

After completing the necessary lines on each isotope's worksheet to cover the pervious 30 days, add the values recorded in Column 2 for each isotope and verify the sum is 30 days.

Add the values in Column 6 and divide the sum by 2300MW. This is the Equivalent Power Level - enter this value on ATTACHMENT 10.1, Column 18 for these seven isotopes.

9.6.4 Part D: Equivalent Power Level for Cs-134
Using the Equivalent Power Level for long-lived isotopes (Line 3) and ATTACHMENT 10.25: Equivalent Power Level for Cs-134 Based on Average Power During Operation, find the Cs-134 Equivalent Power Level. ("Cycle Operation" refers to age of most burned fuel in core.) Enter value on ATTACHMENT 10.1, Column 18 for Cs-134.

9.7 Complete ATTACHMENT 10.1 per the following instructions:

9.7.1 Column 4: $e^{-(\text{Column 2} \times \text{Column 1})}$

9.7.2 Column 5: $e^{-(\text{Column 3} \times \text{Column 1})}$ (if applicable for isotope)

9.7.3 Column 9: (if applicable for isotope)

$$\frac{\text{Column 6} \times \text{Column 7} \times \text{Column 2} \times (\text{Column 4} - \text{Column 5})}{(\text{Column 3} - \text{Column 2})} + (\text{Column 8} \times \text{Column 4})$$

(This is the isotope activity at time of sample.)

9.7.4 Column 10: $\dfrac{(\text{Column 8}) \times (\text{Column 4})}{(\text{Column 9})}$

(If applicable for isotopes)

9.0 PROCEDURE STEPS (Continued)

(This is the fraction of the isotope activity due to initial inventory at shutdown.)

NOTE

For isotope with two precursors (Xe-133, Xe-135 and Te-129) add the two precursor values in Column 10 for each sample and subtract 1.0; then apply formula for Column 12 per Step 9.7.5.

9.7.5 Column 12: $\frac{\text{(Column 10)} \times \text{(Column 11)}}{\text{(Column 4)}}$

(This accounts for the calculated precursor contribution and for radioactivity decay since shutdown.)

9.7.6 Column 14: (Column 12) x (Column 13)

(This accounts for density variation of sample with the actual medium.)

9.7.7 Column 16: (Column 14) x (Column 15) x 10^{-6}

(This value is the total activity actually released in the Reactor Coolant System, RHR System or containment atmosphere.)

9.7.8 Column 19: (Column 17) x (Column 18)

(This value is the source term corrected for power history and power level at shutdown.)

9.0 PROCEDURE STEPS (Continued)

9.7.9 Column 20: $\frac{\text{Column 16} \times 100\%}{\text{Column 19}}$

Sum the three values and enter as TOTAL.

(This value is the fraction of the total inventory available which was actually released to the Reactor Coolant System, RHR System and containment atmosphere.)

9.7.10 Column 21: Applicable to noble gases and iodine.

Noble Gases - Divide isotope's Column 20 Total by the Xe-133 Column 20 Total, if available.

Iodines - Divide isotope's Column 20 Total by the I-131 Column 20 Total, if available.

9.7.11 Column 22: Use ATTACHMENTS 10.26 - 10.33 with applicable isotope's Column 20 Total to determine each isotope's estimate of percentage cladding damage.

9.7.12 Column 23: Use ATTACHMENTS 10.34 and 10.35 with applicable isotope's Column 20 Total to determine each isotope's estimate of percentage fuel overheat damage.

9.7.13 Column 24: Use ATTACHMENTS 10.36 - 10.38 with applicable isotope's Column 20 Total to determine each isotope's estimate of percentage fuel melt damage.

9.0 PROCEDURE STEPS (Continued)

9.8 Obtain the following general information from the data provided from the samples, plant operating records, control room personnel, Emergency Response Facility Information System and radiation monitors:

9.8.1 Containment Hydrogen ________% by volume

9.8.2 Containment Radiation Monitors ________ R/hr

9.8.3 Divide (9.8.2) by 2300MW and multiply by .975: ________ R/hr - MWt
(This adjusts the radioactive levels to core power level and containment volume.)

NOTE

Obtain ERFIS traces of the following, if possible.

9.8.4 Reactor coolant pump status: ____________________

____

____

9.8.5 RVLIS duration and depth of uncovery: ____________________

____

____

9.8.6 Thermocouples - superheated steam? Yes / No ____________________
Highest temperatures and duration: ____________________

____

____

____

9.8.7 Reactor Coolant System Pressure: ____________________

____

____

9.0 PROCEDURE STEPS (Continued)

9.9 Core Damage Assessment

Isotopic Analysis: From ATTACHMENT 10.1, Column 22 through Column 24, each isotope analyzed has yielded a percentage of cladding damage, fuel overheat, and/or fuel melt. This information should be analyzed to determine how the majority of isotopes are estimating core damage status. The activity ratios recorded in Column 21 are used with ATTACHMENT 39 to distinguish fuel overheat and clad failure, if required, if Xe-133 and/or I-131 activity values were available. Every isotope should predict the same general damage status; thus if any isotope prediction is significantly different from the average, its calculations should be reverified, and if necessary, disregarded. The core damage status should be estimated as follow:

- No Damage (insignificant isotope release)
- 0 - 50% Clad Failure
- 50 - 100% Clad Failure
- 0 - 50% Fuel Overheat
- 50 - 100% Fuel Overheat
- 0 - 50% Fuel Melt
- 50 - 100% Fuel Melt

Since it is probable that more than one type of damage may have occurred in the large core, it is best to predict a range of estimated core damage. For example, the isotope data might indicate major cladding failure (50 - 100%) with indications of some degree of fuel overheat (< 10%) and the possibility of minor fuel melting (< 1%).

This would be a legitimate prediction of core damage status. It is emphasized that it is not reasonable to predict a specific value of any one category of damage, but rather to predict ranges of values.

9.0 PROCEDURE STEPS (Continued)

Auxiliary Indicators: Following (or prior to) isotopic analysis, other indications should be evaluated to determine a correlation.

- Containment Hydrogen - Use ATTACHMENT 10.40 with the value recorded in Step 9.8.1 to determine the extent of the Zirconium-Water reaction. This should approximately correspond to the estimate of cladding failure.

- Containment Radiation Monitors - Use ATTACHMENT 10.41 with the value recorded in Step 9.8.3 to determine the percentage of noble gas inventory released. Below 0.3% indicates clad failure, up to 52% indicates fuel overheat, up to 100% indicates fuel melt.

The following information applies to the analysis of RVLIS (if in service) and core exit thermocouples, Steps 9.8.4 - 9.8.7.

- Highest clad temperatures will be greater than thermocouple readings - thus if the thermocouple readings are greater than 1300°F, clad failure may have occurred. (1300°F is the lower limit for clad failure.)
- If any Reactor Coolant Pump's are operating, thermocouples will be good indicators of clad temperature - no core damage should occur due to cooling by steam - water forced flow.

If Reactor Coolant Pump's were stopped, the following apply:

- No generalized core damage can occur if the core has not uncovered; so if RVLIS indicates full range and thermocouples indicates no superheated steam, no generalized damage has occurred.
- If RVLIS indicates a liquid level of less than 3.5 ft. in the core OR thermocouples indicate superheated steam, then the core has uncovered and core damage may have occurred depending on the time after shutdown, duration and depth of uncovery.

9.0 PROCEDURE STEPS (Continued)

- o If RVLIS indicates a liquid level between 3.5 ft. and the top of the core, then thermocouple readings should be monitored for superheated steam temperatures to determine if core uncovery has occurred.

9.10 Complete ATTACHMENT 10.22, Report to Plant Operations Director on Core Damage Status, and deliver it to the Plant Operations Director.

10.0 ATTACHMENTS

10.1 Isotope Release Worksheet

10.2 Sample Data

10.3 Sample Space Mass Calculations

10.4 Equivalent Power Level Calculations

10.5 Equivalent Power Level Worksheet for Kr-85m

10.6 Equivalent Power Level Worksheet for Kr-87

10.7 Equivalent Power Level Worksheet for Kr-88

10.8 Equivalent Power Level Worksheet for Xe-135

10.9 Equivalent Power Level Worksheet for I-132

10.10 Equivalent Power Level Worksheet for I-133

10.0 ATTACHMENTS (Continued)

10.11 Equivalent Power Level Worksheet for I-135

10.12 Equivalent Power Level Worksheet for Te-129

10.13 Equivalent Power Level Worksheet for La-142

10.14 Equivalent Power Level Worksheet for Pr-144

10.15 Equivalent Power Level Worksheet for Xe-131m

10.16 Equivalent Power Level Worksheet for Xe-133

10.17 Equivalent Power Level Worksheet for Xe-133m

10.18 Equivalent Power Level Worksheet for I-131

10.19 Equivalent Power Level Worksheet for Te-132

10.20 Equivalent Power Level Worksheet for Ba-140

10.21 Equivalent Power Level Worksheet for La-140

10.22 Report to SEC on Core Damage Status

10.23 Water Density Ration (Temperature vs. Standard Temperature and Pressure)

10.24 Standard Temperature and Pressure H_2O Mass vs. Containment Level

10.25 Equivalent Power Level for Cs-134 Based on Average Power During Operation

10.0 ATTACHMENTS (Continued)

10.26 Relationship of % Clad Damage with % Core Inventory Released of Kr-87

10.27 Relationship of % Clad Damage with % Core Inventory Released of Xe-131m

10.28 Relationship of % Clad Damage with % Core Inventory Released of Xe-133

10.29 Relationship of % Clad Damage with % Core Inventory Released of I-131

10.30 Relationship of % Clad Damage with % Core Inventory Released of I-131 with Spiking

10.31 Relationship of % Clad Damage with % Core Inventory Released of I-132

10.32 Relationship of % Clad Damage with % Core Inventory Released of I-133

10.33 Relationship of % Clad Damage with % Core Inventory Released of I-135

10.34 Relationship of % Fuel Overtemperature with % Core Inventory Released of Xe, Kr, I, Cs or Te

10.35 Relationship of % Fuel Overtemperature with % Core Inventory Released of Ba, Sr or La

10.36 Relationship of % Fuel Melt with % Core Inventory Released of Xe, Kr, I, Cs or Te

10.0 ATTACHMENTS (Continued)

10.37 Relationship of % Fuel Melt with % Core Inventory Released of Ba, Sr or La

10.38 Relationship of % Fuel Melt with % Core Inventory Released of Pr

10.39 Isotopic Activity Ratios of Fuel Pellet and Gap

10.40 Containment Hydrogen Concentration Based on Zirconium - Water Reaction

10.41 Percent Noble Gases in Containment for Containment Volume of 2×10^6 ft^3

SAMPLE DATA

REACTOR COOLANT SYSTEM SAMPLE (R)

1. Date and time sample drawn: ________/________ ________
2. Reactor Coolant System temperature at time of sampling: ________°F
3. Sample temperature when analyzed: ________°F
4. Pressurizer level at time of sampling: ________%
5. Date and time sample analyzed: ________/________ ________
6. Time after shutdown when sample analyzed: ________hrs.*

RHR SYSTEM SAMPLE (S)

7. Date and time sample drawn: ________/________ ________
8. Sump temperature at time of sampling: ________°F
9. Sample temperature when analyzed: ________°F
10. Containment flooded level at time of sampling: ________ in LI-801
    or ________ in LI-802
    or ave $\frac{(LI\text{-}801 + LI\text{-}802)}{2}$
11. Date and time sample analyzed: ________/________ ________
12. Time after shutdown when sample analyzed: ________ hrs.*

CONTAINMENT ATMOSPHERE SAMPLE (A)

13. Date and time sample drawn: ________/________ ________
14. Containment temperature at time of sampling: ________°F
15. Containment pressure at time of sampling: ________ PSIA
16. Sample temperature when analyzed: ________°F
17. Sample pressure when analyzed: ________ PSIA
18. Date and time sample analyzed: ________/________ ________
19. Time after shutdown when sample analyzed: ________ hrs.*

* Normally computer-corrected to time of sampling.

SAMPLE SPACE MASS CALCULATIONS

A. DENSITY RATIOS

CONTAINMENT ATMOSPHERE

1. Containment atmosphere temperature: ________ °F + 460 = ________ R
2. Containment atmosphere pressure: ________ psia
3. Sample temperature: ________ °F + 460 = ________ R
4. Sample pressure: ________ psia
5. Density Ratio = $\frac{\text{Line 2} \times \text{Line 3}}{\text{Line 1} \times \text{Line 4}}$

REACTOR COOLANT SYSTEM

NOTE

If sample activity is reported per unit mass, use density ratio = 1.0 on ATTACHMENT 1.

6. Density ratio for sample (ATTACHMENT 23): ________
7. Density ration for Reactor Coolant System (ATTACHMENT 23): ________
8. Reactor Coolant System Sample density ratio = $\frac{\text{Line 7}}{\text{Line 6}}$ ________

RHR SYSTEM

NOTE

If sample activity is reported per unit mass, use density ratio = 1.0 on ATTACHMENT 1.

9. Density ratio for sample (ATTACHMENT 12): ________
10. Density ratio for RHR System (ATTACHMENT 23): ________
11. RHR System sample density ratio = $\frac{\text{Line 10}}{\text{Line 9}}$ ________

SAMPLE SPACE MASS CALCULATIONS

B. RHR SYSTEM MASS

12. Containment Level: ________ LI-801 in
or ________ LI-802 in
or ave $\frac{(\text{LI-801} + \text{LI-802})}{2}$ in

13. Sump mass (Standard Temperature and Pressure) (ATTACHMENT 24)
________ g

14. Sump mass (temp. corrected): ________ g

C. REACTOR COOLANT SYSTEM

15. No level indicated on pressurizer:
Reactor Coolant System Mass = $(2.28 \times 10^{8}) \times$ Line 7 ________ g
OR

16. Level indicated on pressurizer:
Reactor Coolant System Mass =
$[(2.28 \times 10^{8}) + (\%\ \text{PZR Level})(0.01)(3.68 \times 10^{7})] \times$ Line 7 ________ g

EQUIVALENT POWER LEVEL CALCULATIONS

A. EQUIVALENT POWER LEVEL FOR LONG-LIVED ISOTOPES

1. Effective full power days in core cycle ________ effective full power days
2. Expected effective full power days for this core cycle ________
3. Equivalent power level $\frac{\text{Line 1}}{\text{Line 2}}$ ________

B. EQUIVALENT POWER LEVEL FOR SHORT-LIVED ISOTOPES

4. Equivalent power level = $\frac{\text{Thermal Power}}{\text{2300 MW}}$ ________

C. EQUIVALENT POWER LEVEL FOR INTERMEDIATE-LIVED ISOTOPES

5. Equivalent power level = $\frac{\text{Thermal Power}}{\text{2300 MW}}$ ________

D. EQUIVALENT POWER LEVEL FOR Cs-134 FROM ATTACHMENT 25

____

EQUIVALENT POWER LEVEL WORKSHEET FOR Kr-85m

ISOTOPE: Kr-85m

$\lambda_i (hr^{-1})$: 0.155

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ______________
(should be 96 hours)

Σ(C6) ______________

Equivalent Power Level = Σ (C6)/2300 = ________________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Kr-87

ISOTOPE: Kr-87

$\lambda_i (hr^{-1})$: 0.545

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ________________
(should be 96 hours)

Σ(C6) ________________

Equivalent Power Level = Σ(C6)/2300 = ____________________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Kr-88

ISOTOPE: Kr-88

$\lambda_i (hr^{-1})$: 0.244

(C1) Pj	(C2) tj	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ (C2) ____________
(should be 96 hours)

Σ (C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Xe-135

ISOTOPE: Xe-135

$\lambda_i (hr^{-1})$: 0.0762

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ (C2) ____________
(should be 96 hours)

Σ (C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR I-132

ISOTOPE: I-132

$\lambda_i (hr^{-1})$: 0.301

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ (C2) ______________
(should be 96 hours)

Σ(C6) ______________

Equivalent Power Level = Σ (C6)/2300 = ______________________

EQUIVALENT POWER LEVEL WORKSHEET FOR I-133

ISOTOPE: I-133

$\lambda_i (hr^{-1})$: 0.0333

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ (C2) ____________
(should be 96 hours)

Σ (C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR I-135

ISOTOPE: I-135

$\lambda_i (hr^{-1})$: 0.105

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________
(should be 96 hours)

Σ(C6) ____________

Equivalent Power Level = Σ (C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Te-129

ISOTOPE: Te-129

$\lambda_i (hr^{-1})$: 0.598

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________
(should be 96 hours)

Σ(C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR La-142

ISOTOPE: La-142

$\lambda_i (hr^{-1})$: 0.450

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________
(should be 96 hours)

Σ(C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Pr-144

ISOTOPE: Pr-144

$\lambda_i (hr^{-1})$: 2.41

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________ Σ(C6) ____________
(should be 96 hours)

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Xe-131m

ISOTOPE: Xe-131m

λ_i (hr^{-1}): 0.0582

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________ Σ(C6) ____________
(should be 30 days)

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Xe-133

ISOTOPE: Xe-133

$\lambda_i (hr^{-1})$: 0.132

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________
(should be 30 days)

Σ(C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ____________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Xe-133m

ISOTOPE: Xe-133m

$\lambda_i (hr^{-1})$: 0.316

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________ Σ(C6) ____________
(should be 30 days)

Equivalent Power Level = Σ(C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR I-131

ISOTOPE: I-131

λ_i (hr^{-1}): 0.0862

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ______________ Σ(C6) ______________
(should be 30 days)

Equivalent Power Level = Σ(C6)/2300 = ________________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Te-132

ISOTOPE: Te-132

$\lambda_i (hr^{-1})$: 0.213

(C1) P_j	(C2) t_j	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ____________
(should be 30 days)

Σ(C6) ____________

Equivalent Power Level = Σ(C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR Ba-140

ISOTOPE: Ba-140

$\lambda_i (hr^{-1})$: 0.0544

(C1)	(C2)	(C3)	(C4)	(C5)	(C6)
Pj	tj	t_j^*	$1-e^{-\lambda_i t_j}$	$e^{-\lambda_i t_j^*}$	(C1)*(C4)*(C5)

Σ(C2) ____________ Σ(C6) ____________
(should be 30 days)

Equivalent Power Level = Σ(C6)/2300 = ________________

EQUIVALENT POWER LEVEL WORKSHEET FOR La-140

ISOTOPE: La-140

$\lambda_i (hr^{-1})$: 0.413

(C1) Pj	(C2) tj	(C3) t_j^*	(C4) $1-e^{-\lambda_i t_j}$	(C5) $e^{-\lambda_i t_j^*}$	(C6) (C1)*(C4)*(C5)

Σ(C2) ______________ Σ(C6) ______________
(should be 30 days)

Equivalent Power Level = Σ (C6)/2300 = ________________________

REPORT TO PLANT OPERATIONS DIRECTOR ON CORE DAMAGE STATUS

PEP-355 has been completed and based on sample analysis and auxiliary indications (radiation levels, core temperatures, RVLIS, and containment hydrogen levels) the core damage status is as follows:

CLAD DAMAGE: Estimated % __________ Basis __________

____

____

NOTE

Loss of Fission Product Barrier - Refer to PEP-101 for possible upgrading of emergency classification. YES ______ NO ______

FUEL OVERHEAT: Estimated % __________ Basis __________

____

____

FUEL MELT: Estimated % __________ Basis __________

____

____

Qualitative indications agree with sample analysis: YES ______ NO ______

COMMENTS: __________________________________

____

____

____

____

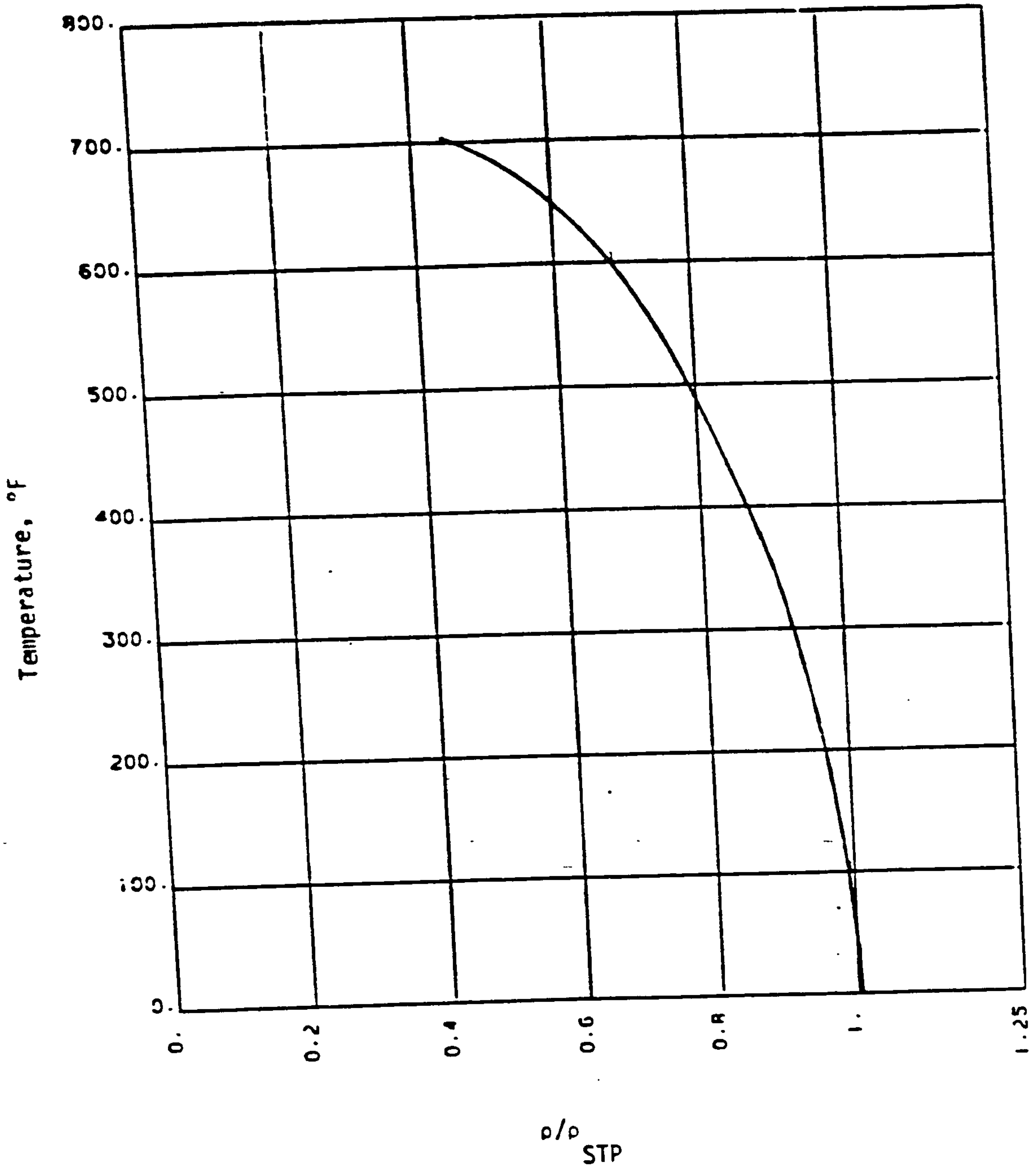
Initiated By: ____________________

* Reviewed By: ____________________

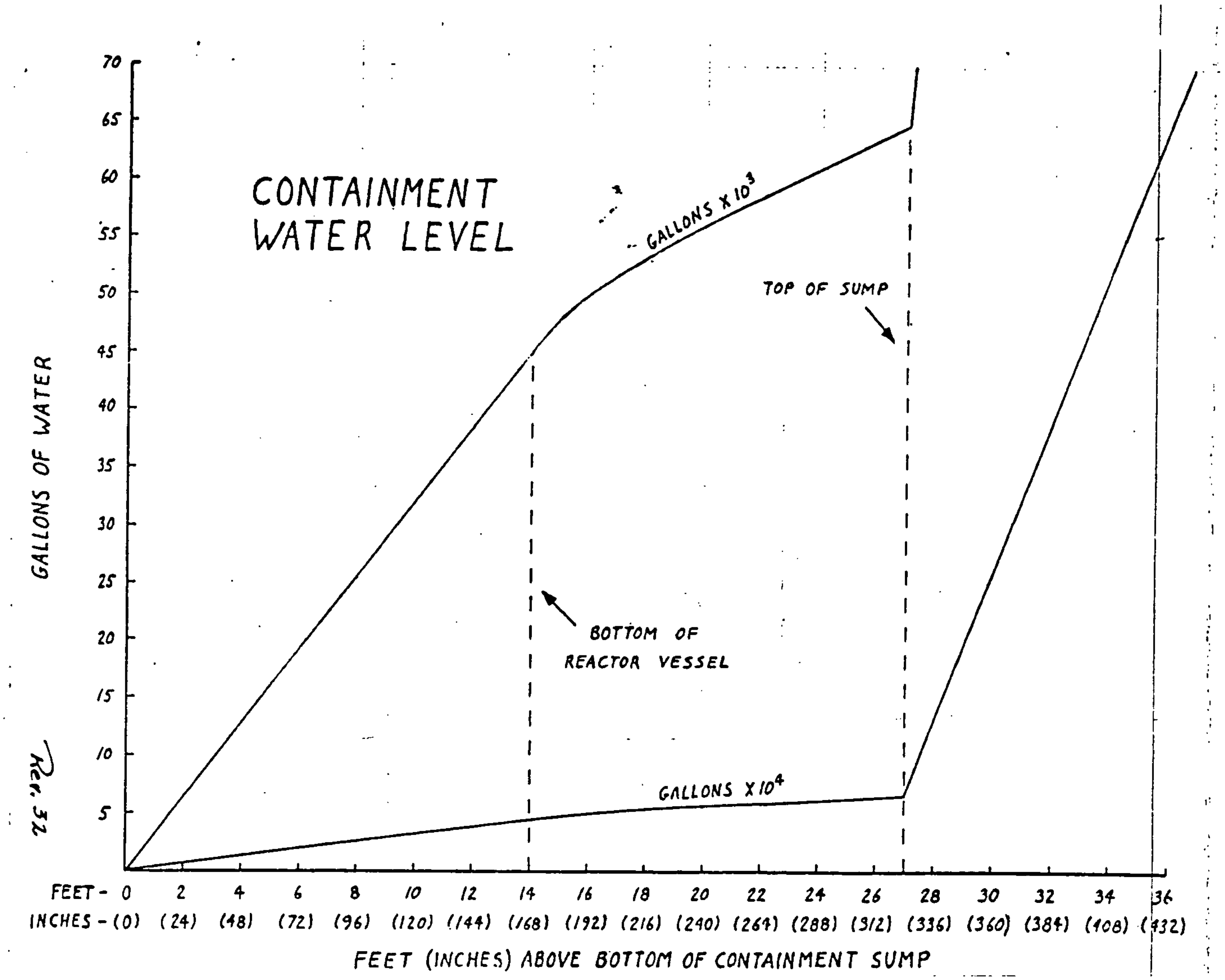
Approved By: ____________________
Team Leader

* Optional at discretion of Team Leader

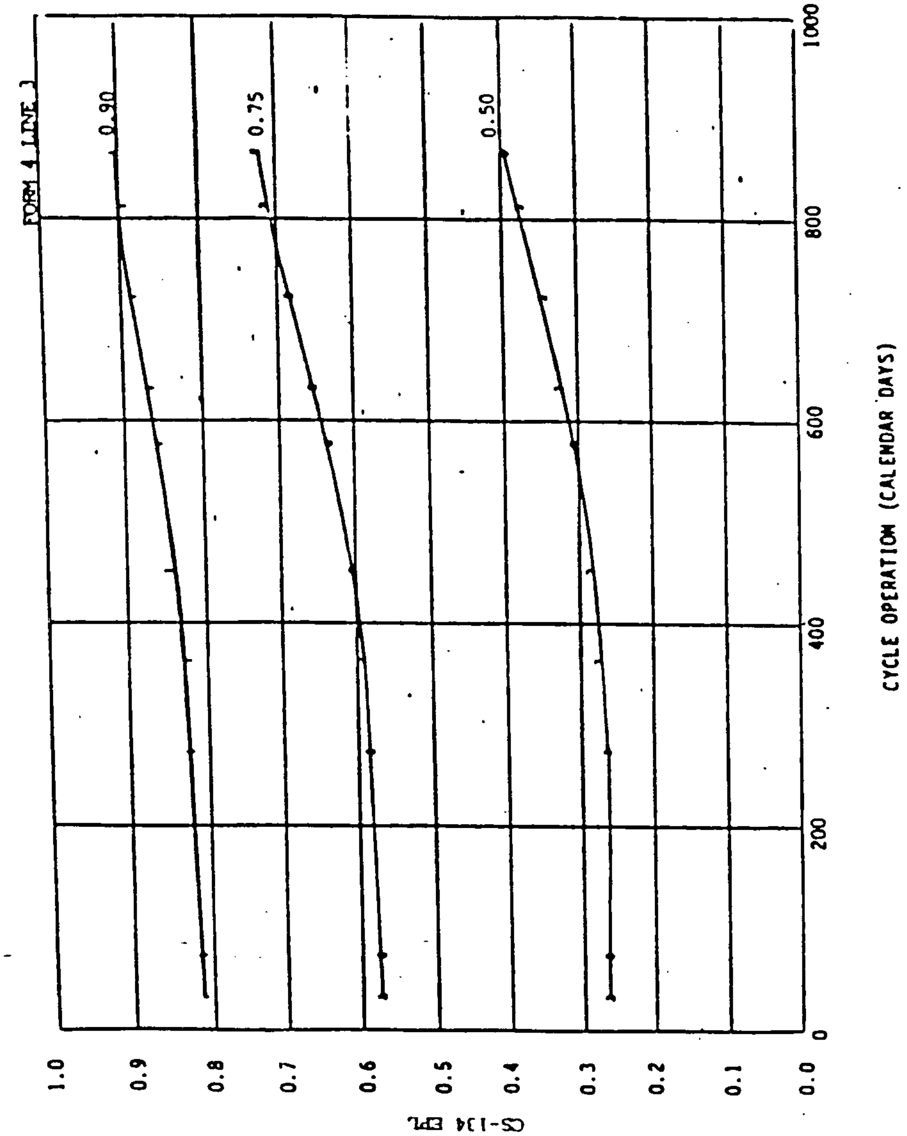
WATER DENSITY RATIO (TEMPERATURE VS. STP)



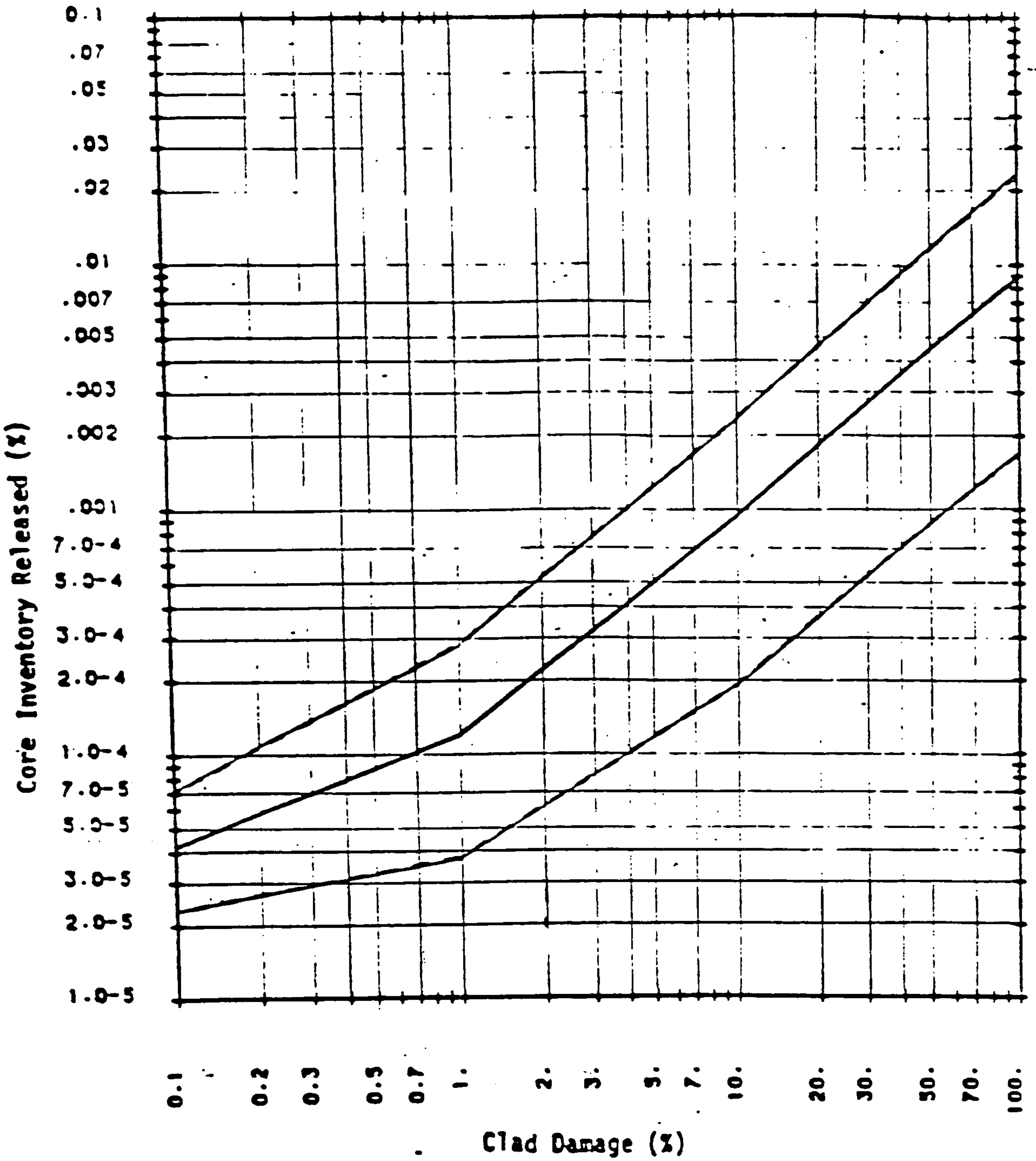
STP H_2O MASS VS. CONTAINMENT LEVEL



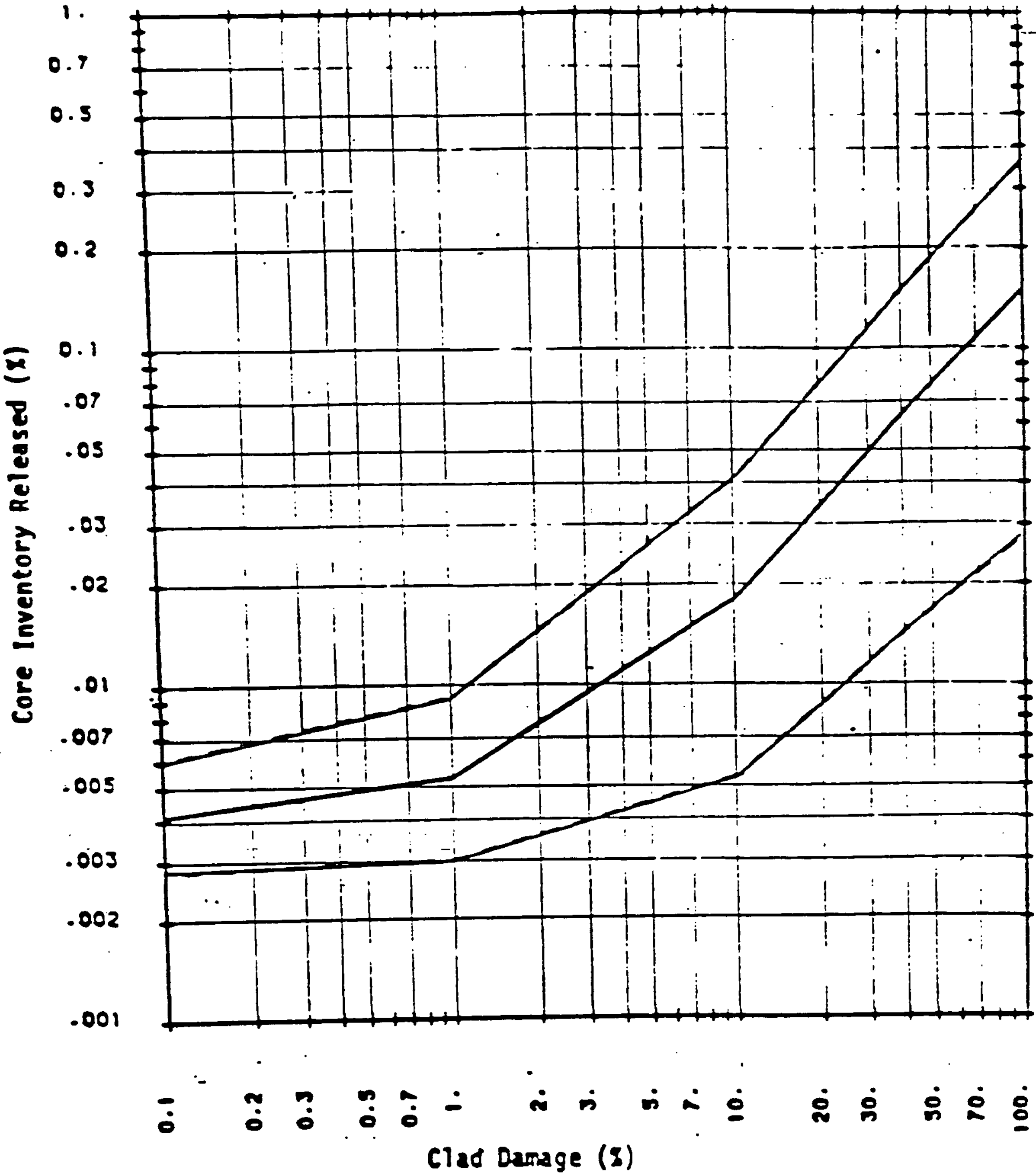
EFFECTIVE POWER LEVEL FOR Cs-134 BASED ON AVERAGE POWER DURING OPERATION



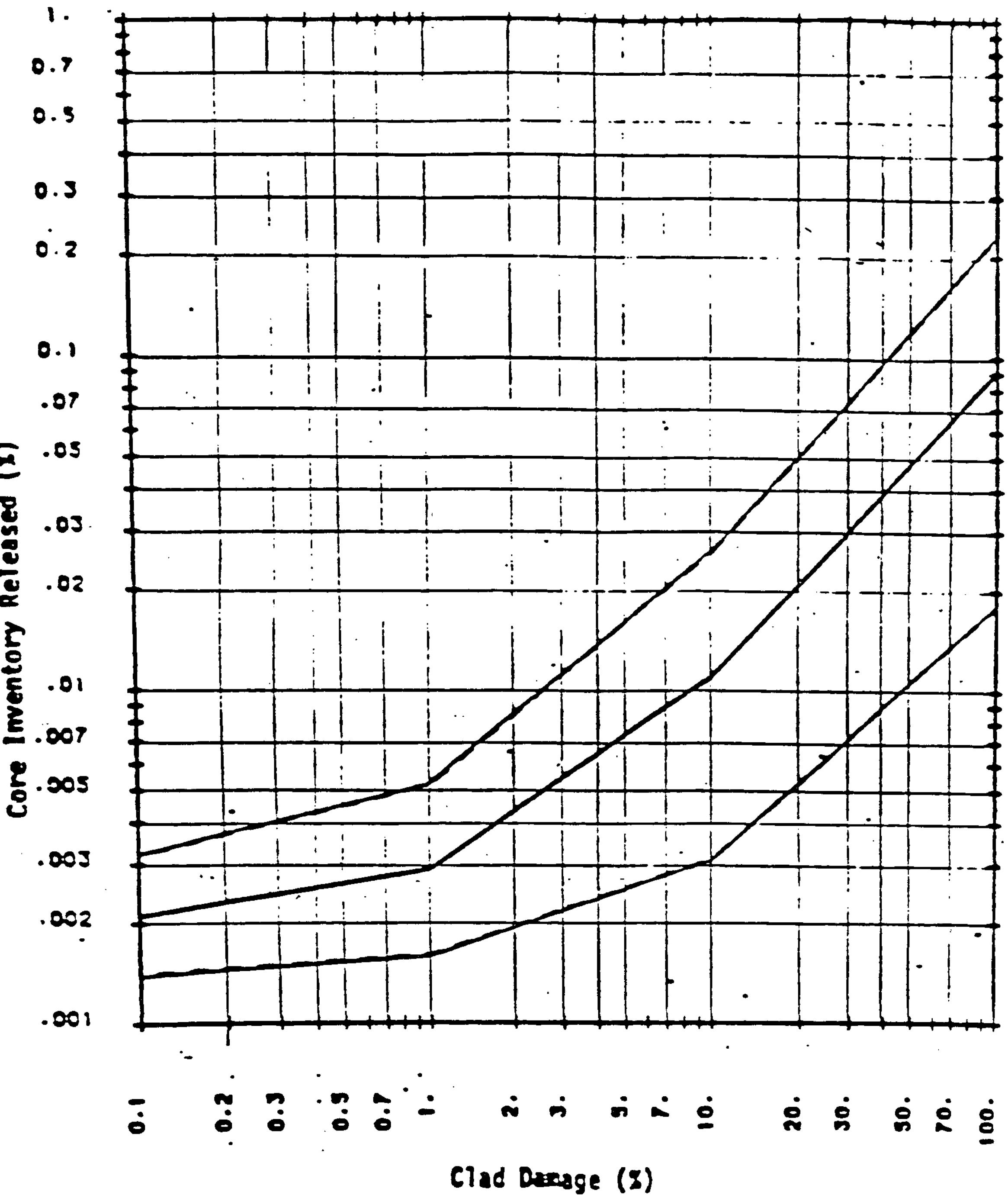
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF Kr-87



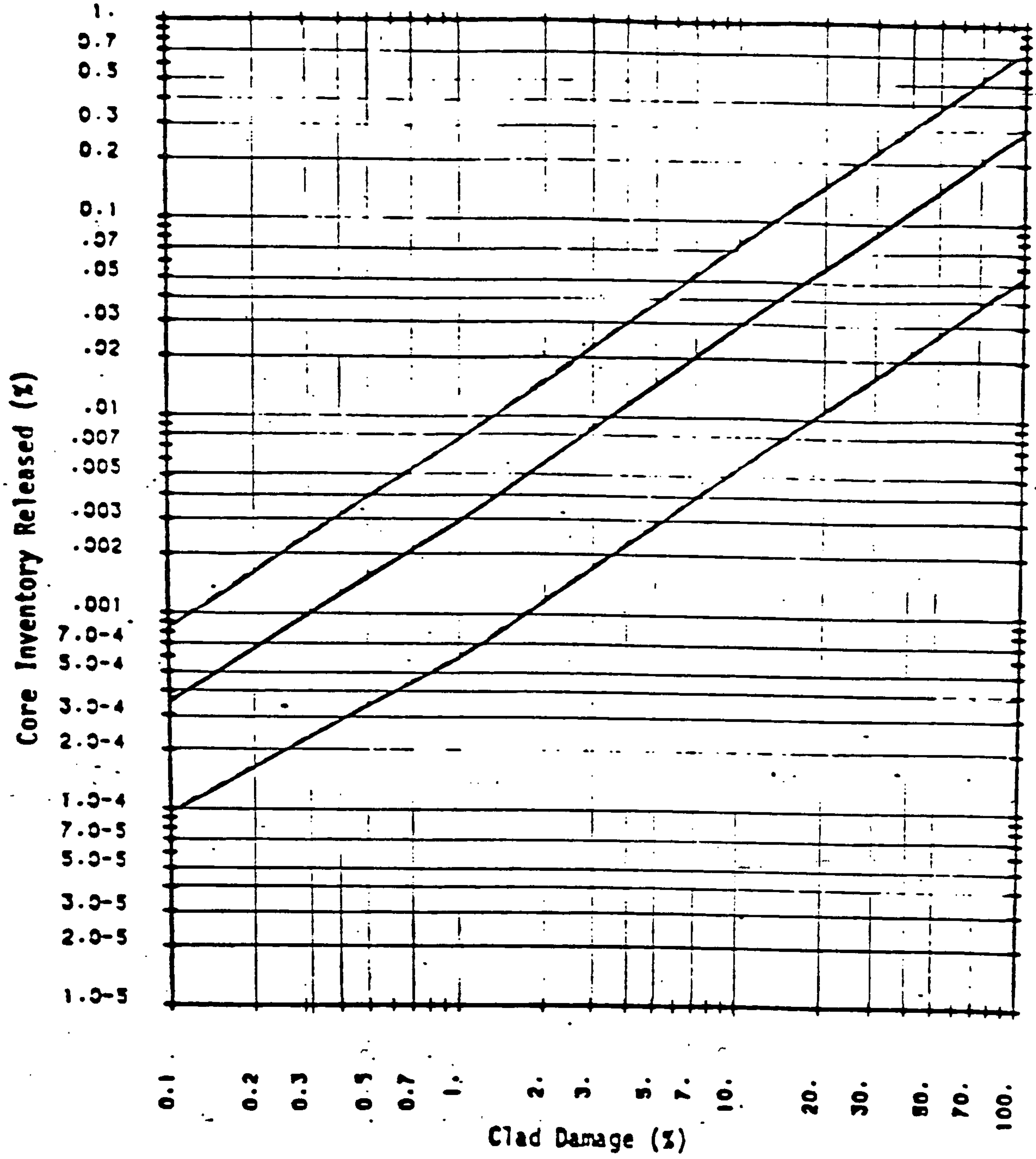
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF Xe-131m



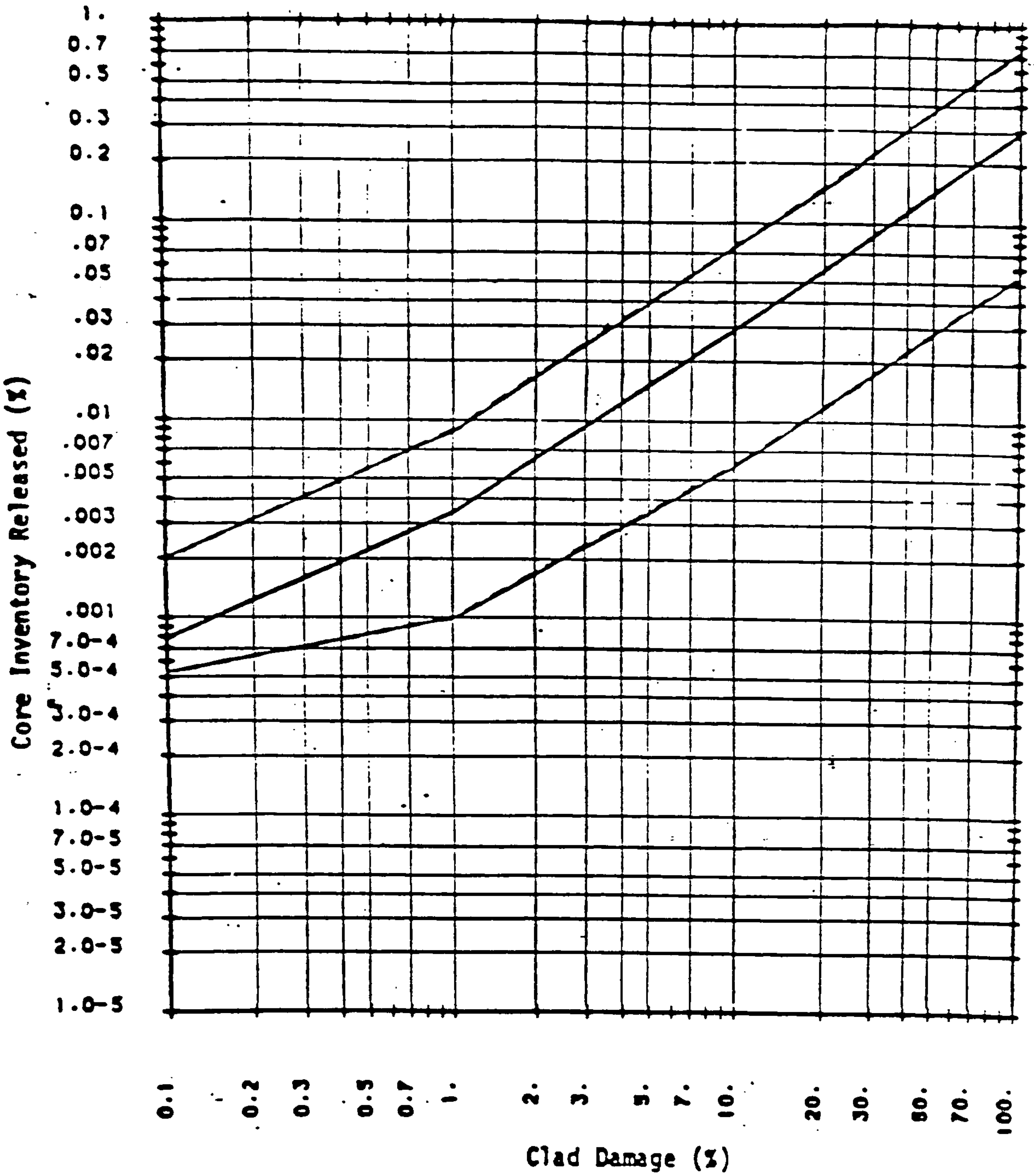
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF Xe-133



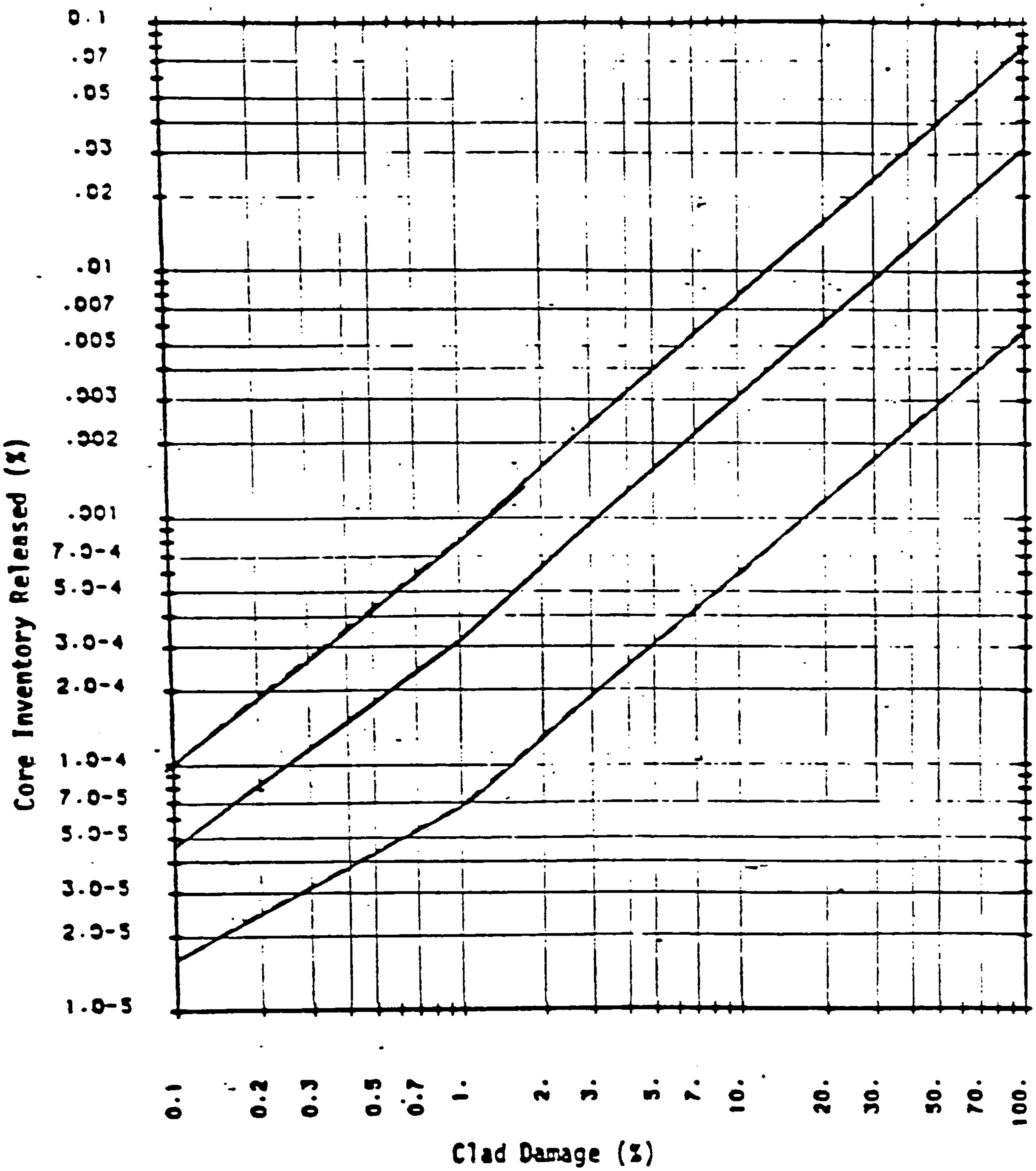
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF I-131



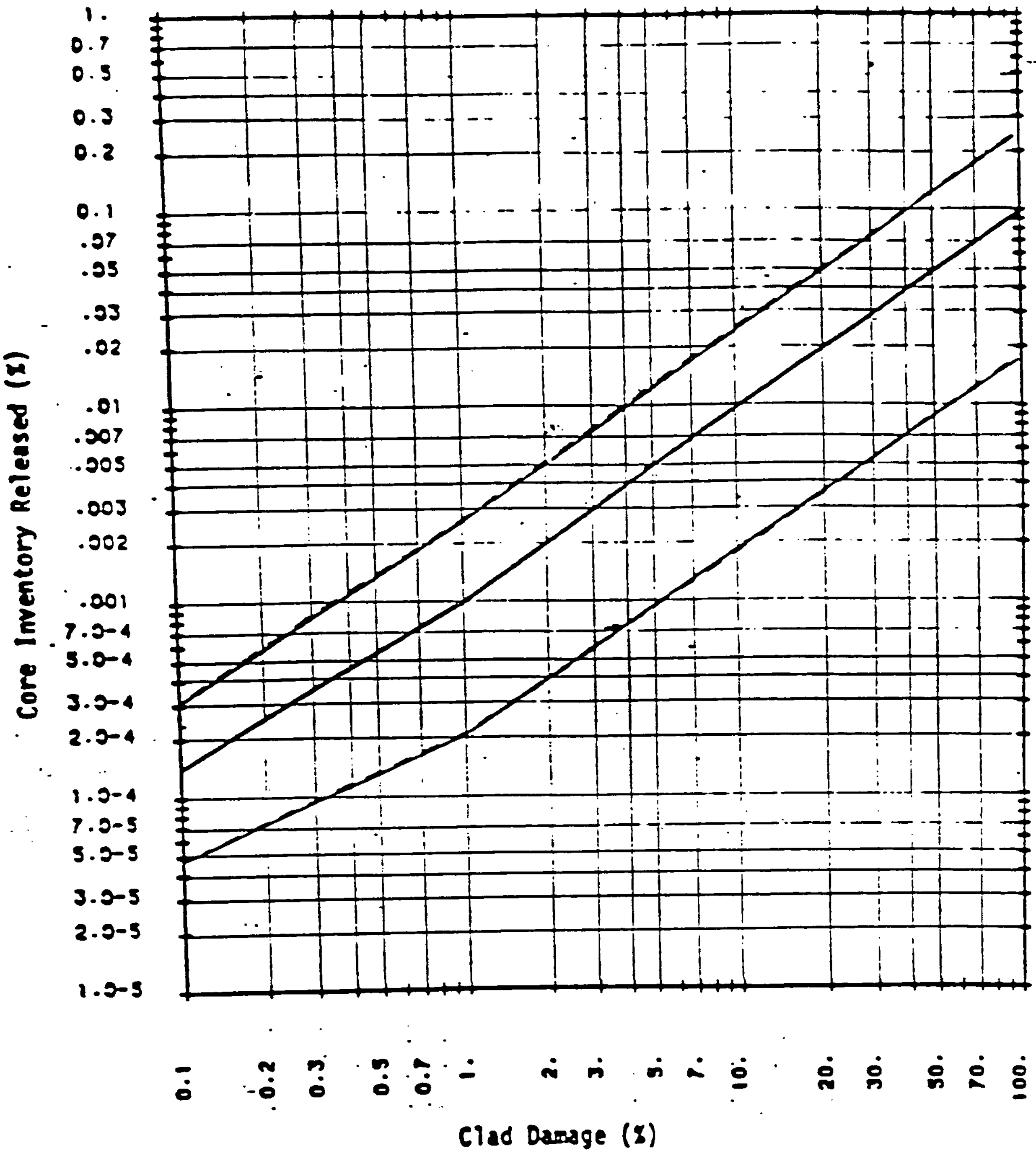
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF I-131 WITH SPIKING



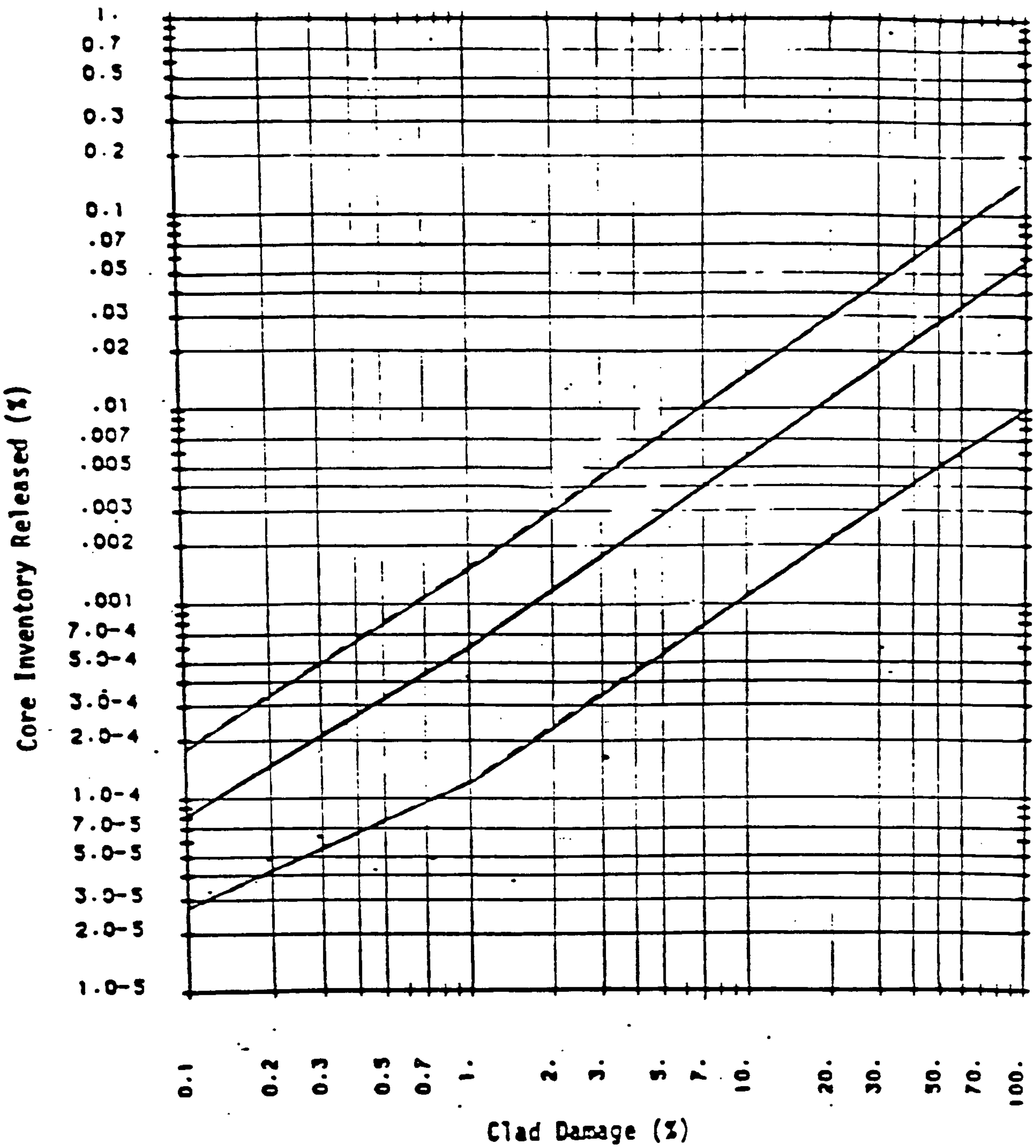
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF I-132



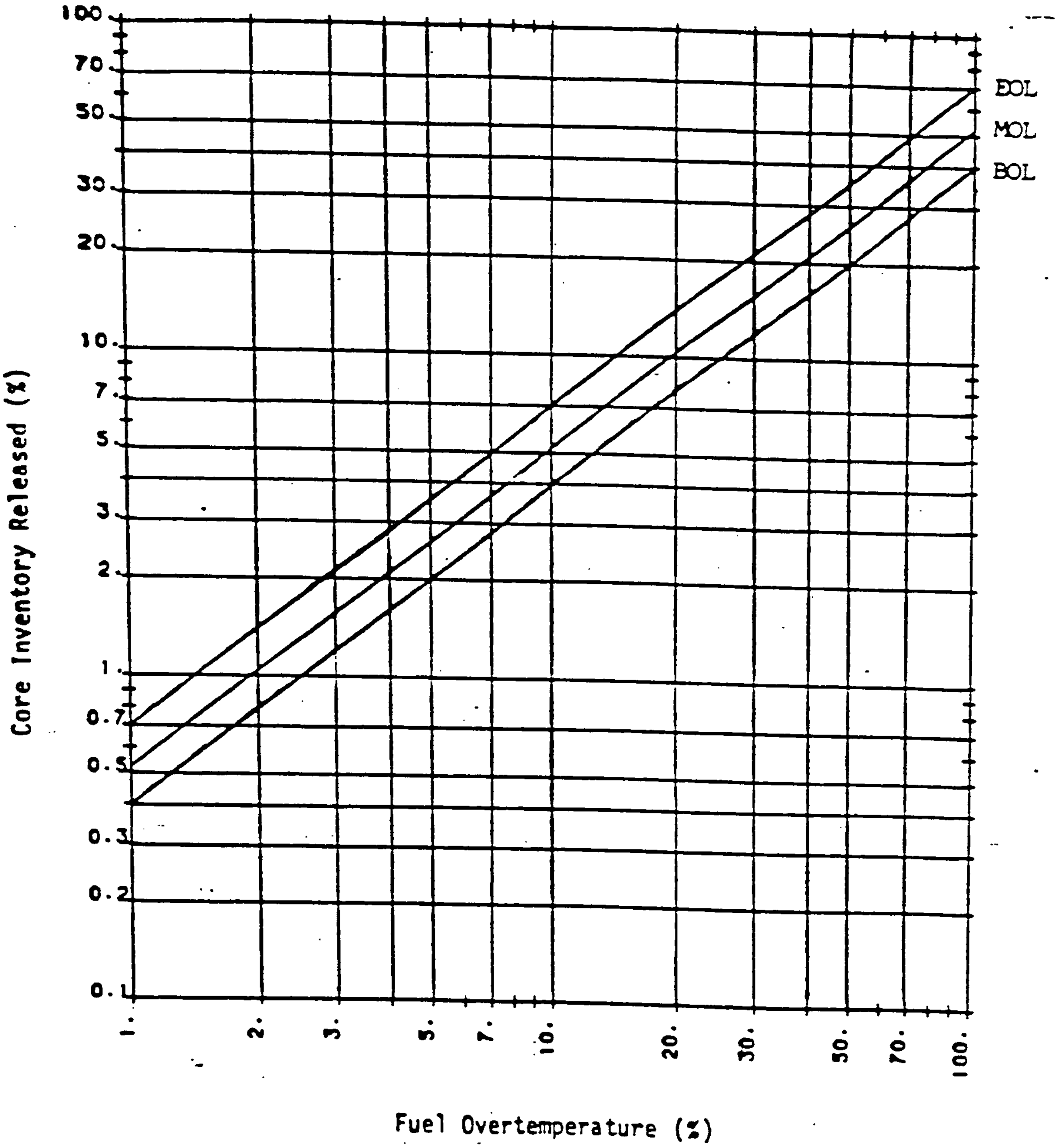
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF I-133



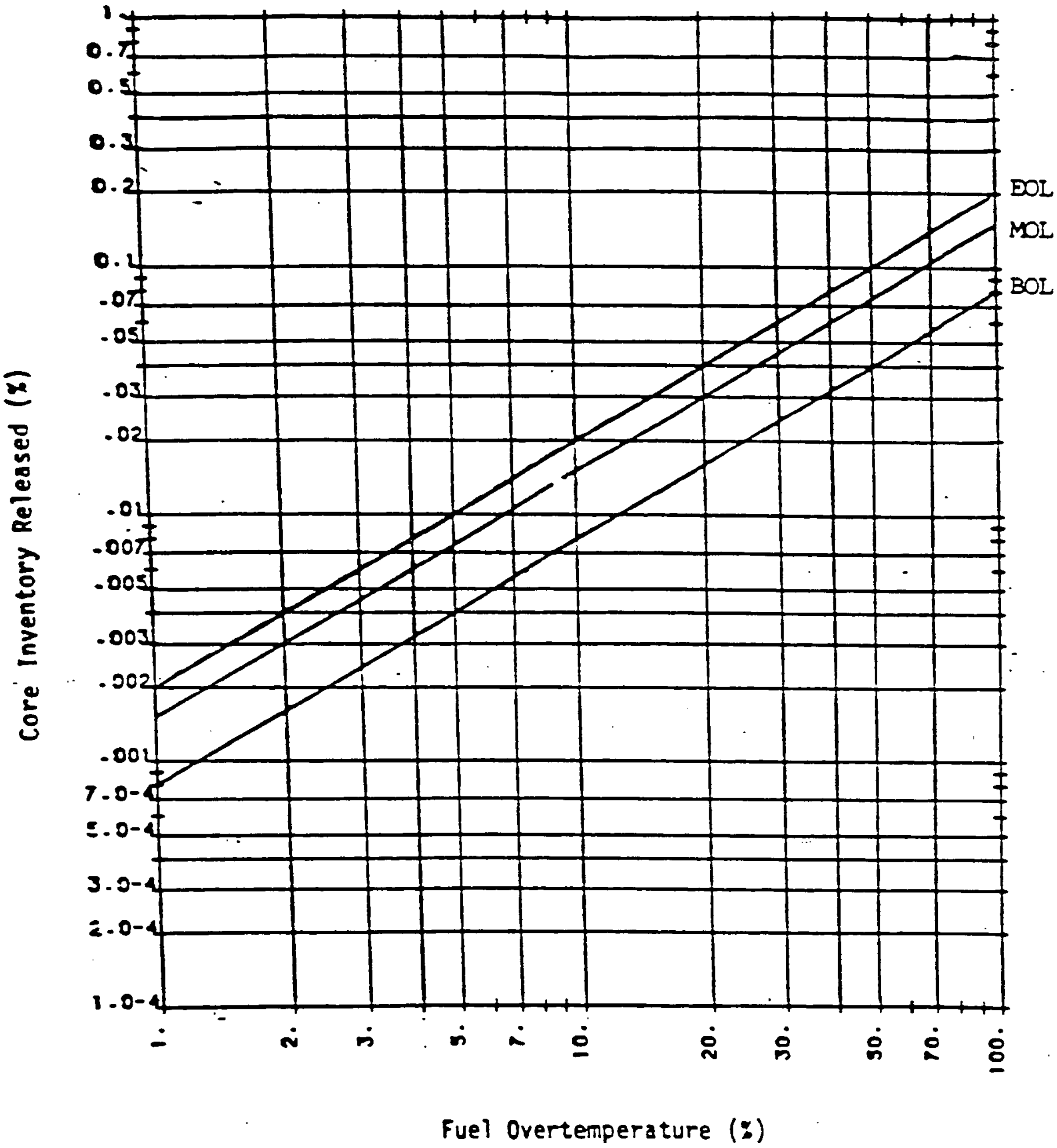
RELATIONSHIP OF % CLAD DAMAGE WITH % CORE INVENTORY RELEASED OF I-135



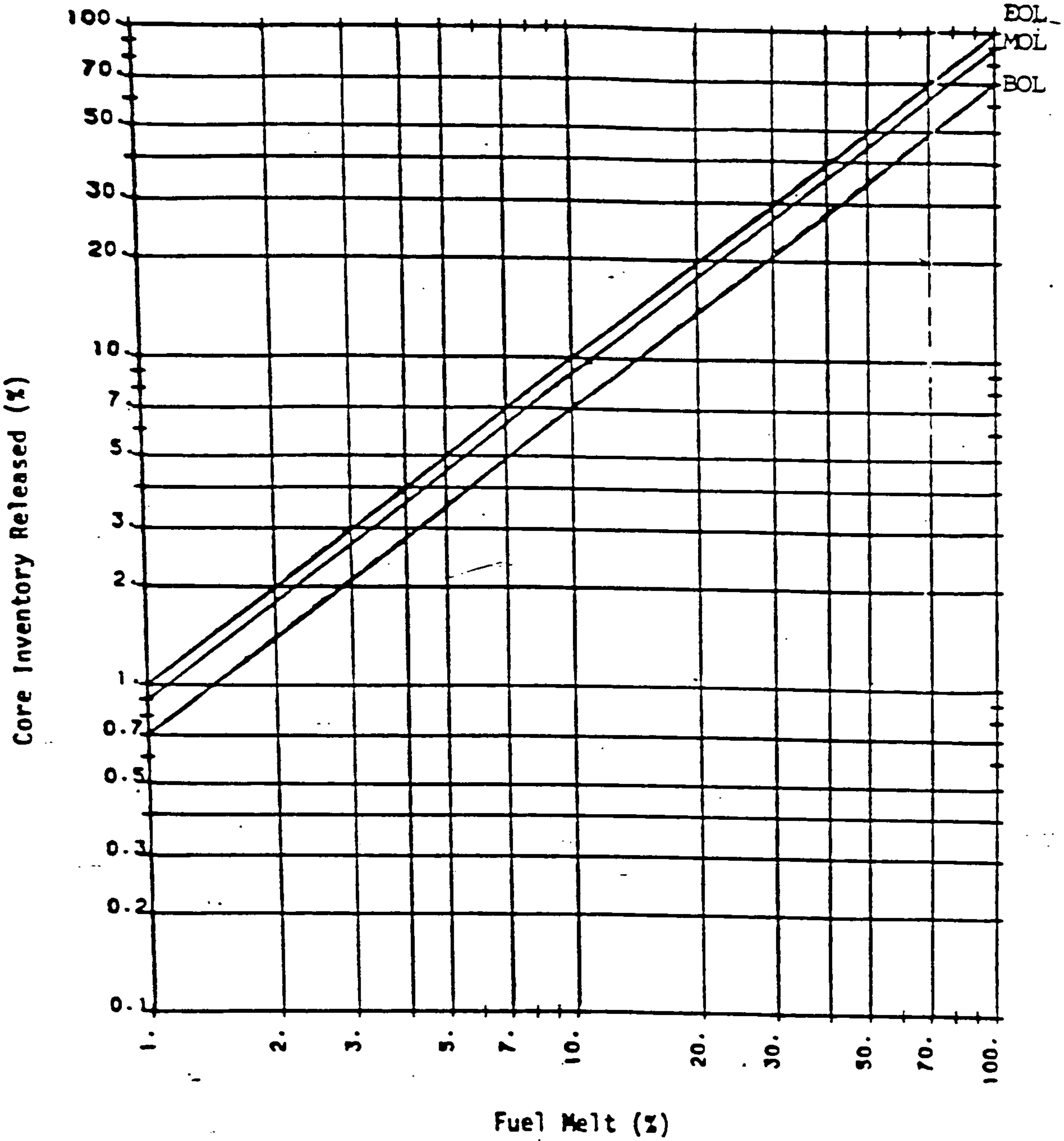
RELATIONSHIP OF % FUEL OVERTEMPERATURE WITH % CORE INVENTORY RELEASED OF Xe, Kr, I, Cs OR Te



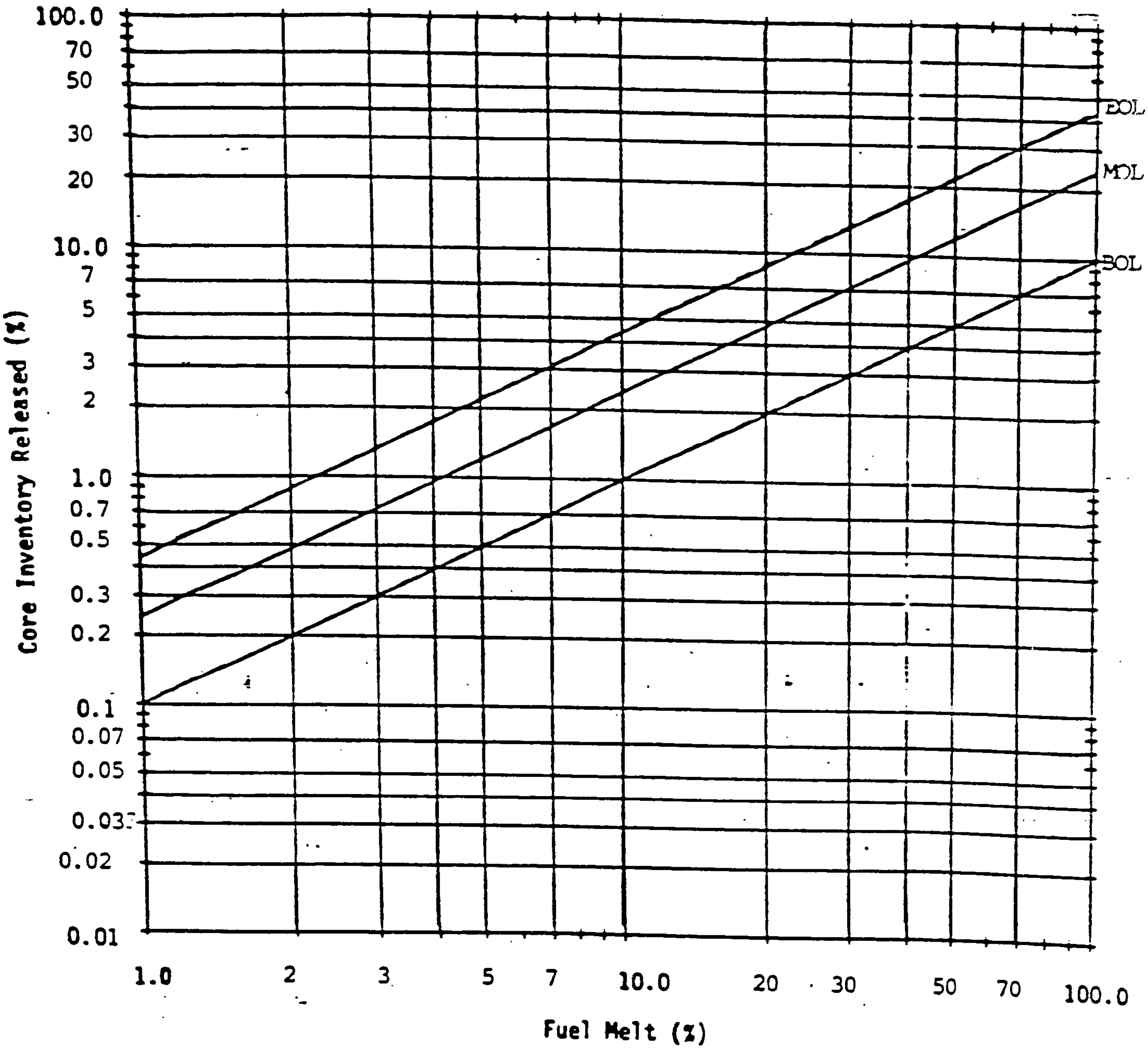
RELATIONSHIP OF % FUEL OVERTEMPERATURE WITH % CORE INVENTORY RELEASED OF Ba, Sr OR La



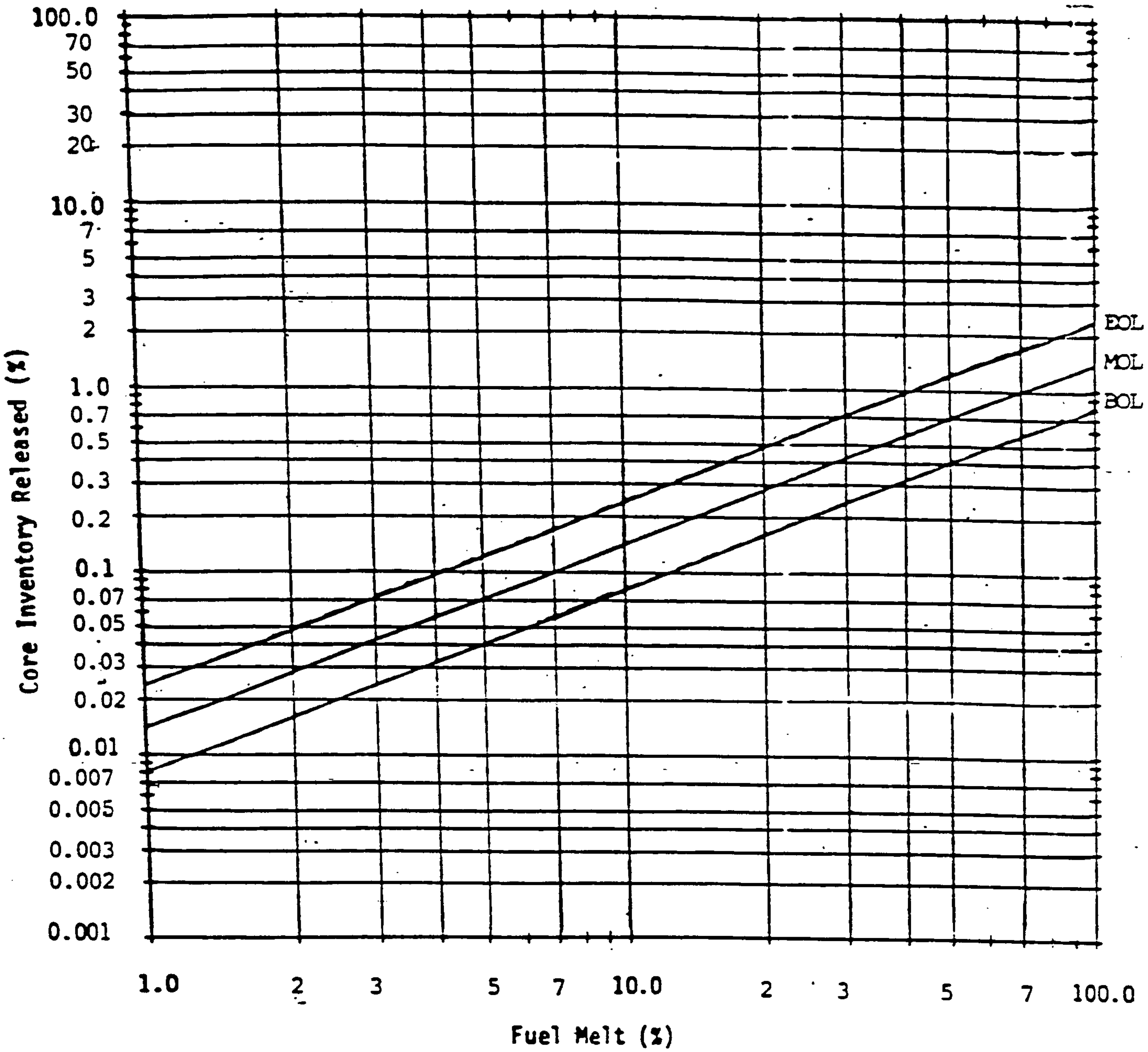
RELATIONSHIP OF % FUEL OVERTEMPERATURE WITH % CORE INVENTORY RELEASED OF Xe, Kr, I Cs OR Te



RELATIONSHIP OF % FUEL MELT WITH % CORE INVENTORY RELEASED OF Ba, Sr OR La



RELATIONSHIP OF % FUEL MELT WITH % CORE INVENTORY RELEASED OF Pr



ISOTOPIC ACTIVITY RATIOS OF FUEL PELLET AND GAP

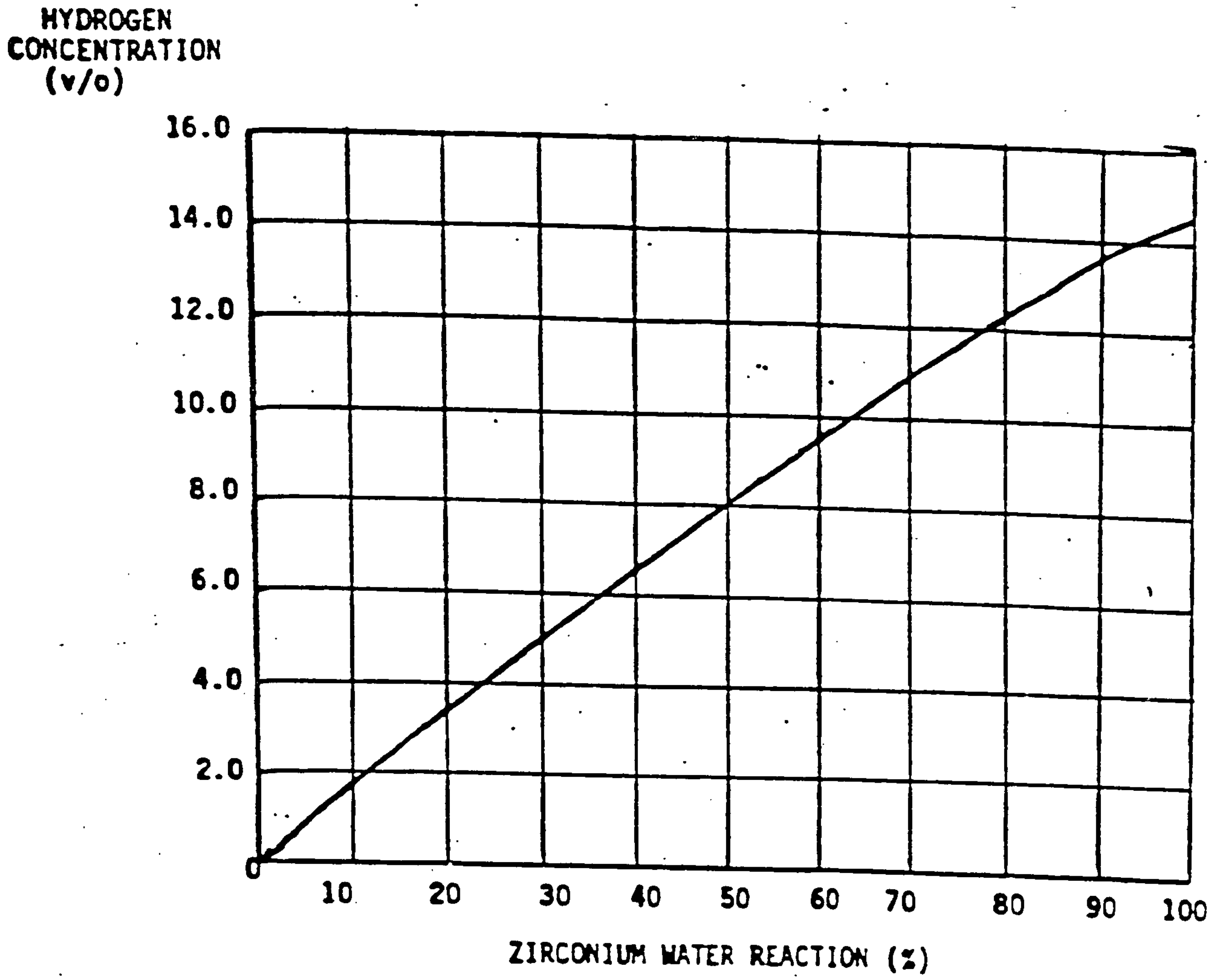
NUCLIDE	FUEL PELLET ACTIVITY RATIO	GAP ACTIVITY RATIO
Kr-85m	0.11	0.022
Kr-87	0.22	0.022
Kr-88	0.29	0.045
Xe-131m	0.004	0.004
Xe-133	1.0	1.0
Xe-133m	0.15	0.096
Xe-135	0.19	0.051
I-131	1.0	1.0
I-132	1.5	0.17
I-133	2.1	0.71
I-135	1.9	0.39

$$\text{Noble Gas Ratio} = \frac{\text{Noble Gas Isotope Inventory}}{\text{Xe-133 Inventory}}$$

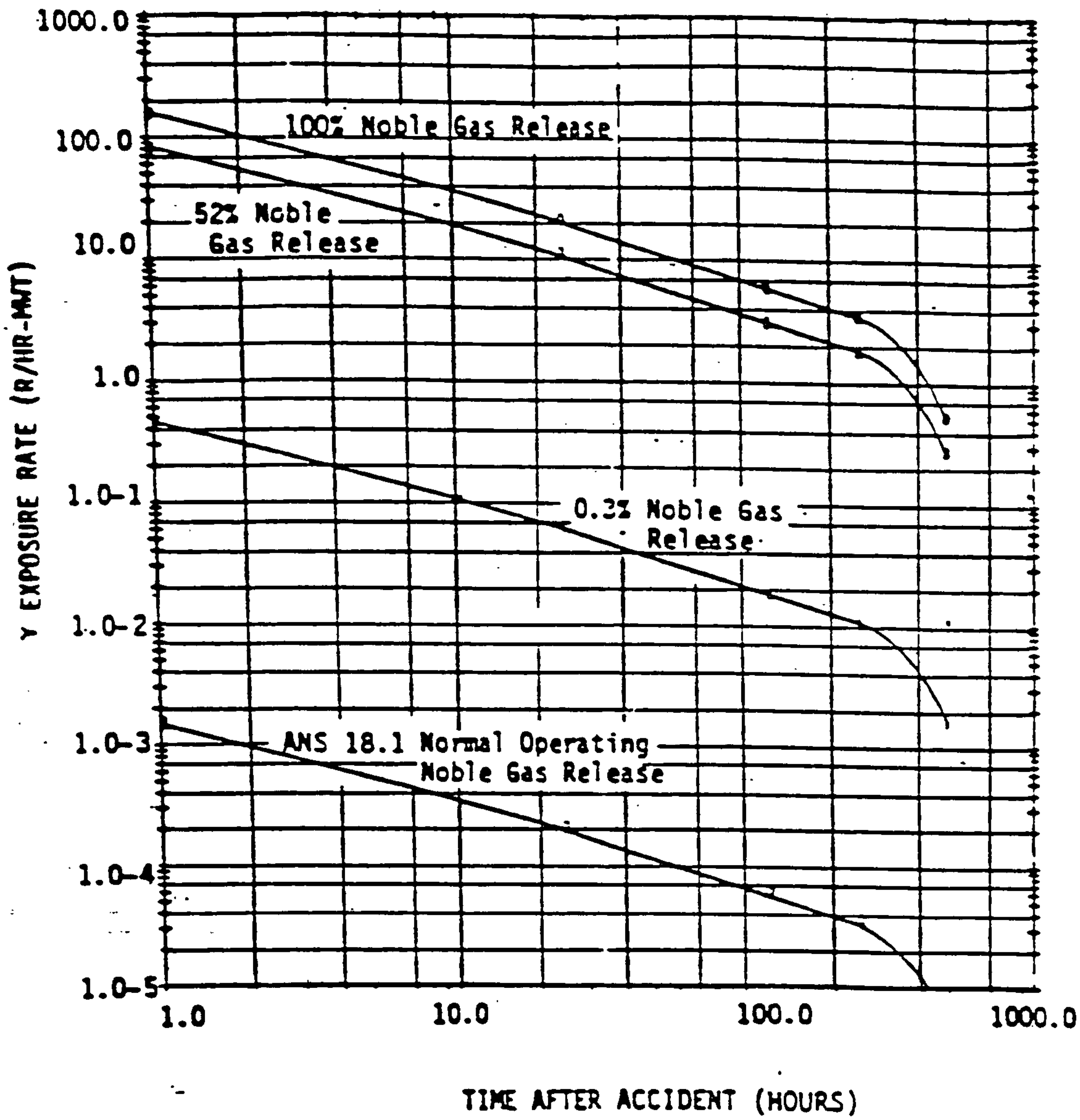
$$\text{Iodine Ratio} = \frac{\text{Iodine Isotope Inventory}}{\text{I-131 Inventory}}$$

The measured ratios of various nuclides found in reactor coolant during normal operation is a function of the amount of "tramp" uranium on fuel rod cladding, the number and size of "defects" (i.e., "pin holes"), and the location of the fuel rods containing the defects in the core. The ratios derived in this report are based on calculated values of relative concentrations in the fuel or in the gap. The use of these present ratios for post accident damage assessment is restricted to an attempt to differentiate between fuel overtemperature conditions and fuel cladding failure conditions. Thus the ratios derived here are not related to fuel defect levels incurred during normal operation.

CONTAINMENT HYDROGEN CONCENTRATION BASED ON ZIRCONIUM WATER REACTION



PERCENT NOBLE GASES IN CONTAINMENT FOR CONTAINMENT VOLUME OF 2 x 10^6 FT^3



ATTACHMENT 10.1 ISOTOPE RELEASE WORKSHEET

Isotope	Sample	Precursor	1 t - Time after S/D	2 λ_B - Isotope decay const	3 λ_A - Precursor decay const	4 $e^{-\lambda_B t}$	5 $e^{-\lambda_A t}$	6 K - Branching ratio	7 Q^0_A - Precursor source term (100% RTP EOL)	8 Q^0_B - Isotope source term (100% RTP EOL)	9 Q^1_B - Isotope activity at time t	10 Ft - Fractional activity	11 Sample activity μCi/g or μCi/cc	12 μQ^1_B - Decay corrected activity	13 DR - Density ratio	14 K^0_B - Temp/press corrected activity	15 Sample mass or volume	16 Isotope activity at shutdown	17 100% EOL source term	18 EPL - Equivalent power level	19 Source term	20 Release %	21 Activity ratio	22 Clad damage %	23 Fuel overheat %	24 Fuel melt %
Kr-85m	R			.158								1.0							1.43×10^{7}							
	S			.158								1.0							1.43×10^{7}							
	A			.158								1.0							1.43×10^{7}							
																					TOTAL					
Kr-87	R			.547								1.0							2.62×10^{7}							
	S			.547								1.0							2.62×10^{7}							
	A			.547								1.0							2.62×10^{7}							
																					TOTAL					
Kr-88	R			.248								1.0							3.65×10^{7}							
	S			.248								1.0							3.65×10^{7}							
	A			.248								1.0							3.65×10^{7}							
																					TOTAL					
Xe-131m	R	I-131		.00246	.00359			.008	6.34×10^{7}	4.04×10^{5}									4.04×10^{5}							
	S	I-131		.00246	.00359			.008	6.34×10^{7}	4.04×10^{5}									4.04×10^{5}							
	A	I-131		.00246	.00359			.008	6.34×10^{7}	4.04×10^{5}									4.04×10^{5}							
																					TOTAL					
Xe-133	R	I-133		.00548	.0341			.976	1.27×10^{8}	1.27×10^{8}									1.27×10^{8}							
		Xe-133m		.00548	.0128			1.0	1.82×10^{7}	1.27×10^{8}																
	S	I-133		.00548	.0341			.976	1.27×10^{8}	1.27×10^{8}									1.27×10^{8}							
		Xe-133m		.00548	.0128			1.0	1.82×10^{7}	1.27×10^{8}																
	A	I-133		.00548	.0341			.976	1.27×10^{8}	1.27×10^{8}									1.27×10^{8}							
		Xe-133m		.00548	.0128			1.0	1.82×10^{7}	1.27×10^{8}																
																					TOTAL					
Xe-133m	R	I-133		.0128	.0341			.024	1.27×10^{8}	1.82×10^{7}									1.82×10^{7}							
	S	I-133		.0128	.0341			.024	1.27×10^{8}	1.82×10^{7}									1.82×10^{7}							
	A	I-133		.0128	.0341			.024	1.27×10^{8}	1.82×10^{7}									1.82×10^{7}							
																					TOTAL					
Xe-135	R	Xe-135m		.0728	2.87			1.0	2.7×10^{7}	2.38×10^{7}									2.38×10^{7}							
		I-135		.0728	.104			.70	1.11×10^{8}	2.38×10^{7}																
	S	Xe-135m		.0728	2.87			1.0	2.7×10^{7}	2.38×10^{7}									2.38×10^{7}							
		I-135		.0728	.104			.70	1.11×10^{8}	2.38×10^{7}																
	A	Xe-135m		.0728	2.87			1.0	2.7×10^{7}	2.38×10^{7}									2.38×10^{7}							
		I-135		.0728	.104			.70	1.11×10^{8}	2.38×10^{7}																
																					TOTAL					
I-131	R			.00359								1.0							6.34×10^{7}							
	S			.00359								1.0							6.34×10^{7}							
	A			.00359								1.0							6.34×10^{7}							
																					TOTAL					
I-132	R	Te-132		.307	.00892			1.0	9.52×10^{7}	9.52×10^{7}									9.52×10^{7}							
	S	Te-132		.307	.00892			1.0	9.52×10^{7}	9.52×10^{7}									9.52×10^{7}							
	A	Te-132		.307	.00892			1.0	9.52×10^{7}	9.52×10^{7}									9.52×10^{7}							
																					TOTAL					
I-133	R			.0341								1.0							1.27×10^{8}							
	S			.0341								1.0							1.27×10^{8}							
	A			.0341								1.0							1.27×10^{8}							
																					TOTAL					
I-135	R			.104								1.0							1.11×10^{8}							
	S			.104								1.0							1.11×10^{8}							
	A			.104								1.0							1.11×10^{8}							
																					TOTAL					
Pr-144	R	Ce-144		2.41	1.02×10^{-4}			1.0	6.9×10^{7}	9.6×10^{7}									7.93×10^{7}							
	S	Ce-144		2.41	1.02×10^{-4}			1.0	6.9×10^{7}	9.6×10^{7}									7.93×10^{7}							
	A	Ce-144		2.41	1.02×10^{-4}			1.0	6.9×10^{7}	9.6×10^{7}									7.93×10^{7}							
																					TOTAL					
Cs-134	R			3.96×10^{-5}								1.0							1.51×10^{7}							
	S			3.96×10^{-5}								1.0							1.51×10^{7}							
	A			3.96×10^{-5}								1.0							1.51×10^{7}							
																					TOTAL					
Cs-137	R			2.64×10^{-6}								1.0							6.9×10^{6}							
	S			2.64×10^{-6}								1.0							6.9×10^{6}							
	A			2.64×10^{-6}								1.0							6.9×10^{6}							
																					TOTAL					
Te-129	R	Sb-129		.605	.161			.827	2.05×10^{7}	2.14×10^{7}									2.14×10^{7}							
		Te-129m		.605	8.47×10^{-4}			.680	5.16×10^{6}	2.14×10^{7}																
	S	Sb-129		.605	.161			.827	2.05×10^{7}	2.14×10^{7}									2.14×10^{7}							
		Te-129m		.605	8.47×10^{-4}			.680	5.16×10^{6}	2.14×10^{7}																
	A	Sb-129		.605	.161			.827	2.05×10^{7}	2.14×10^{7}									2.14×10^{7}							
		Te-129m		.605	8.47×10^{-4}			.680	5.16×10^{6}	2.14×10^{7}																
																					TOTAL					
Te-132	R			.00892								1.0							9.52×10^{7}							
	S			.00892								1.0							9.52×10^{7}							
	A			.00892								1.0							9.52×10^{7}							
																					TOTAL					
Sr-89	R			5.48×10^{-4}								1.0							5.08×10^{7}							
	S			5.48×10^{-4}								1.0							5.08×10^{7}							
	A			5.48×10^{-4}								1.0							5.08×10^{7}							
																					TOTAL					
Sr-90	R			2.83×10^{-6}								1.0							4.7×10^{6}							
	S			2.83×10^{-6}								1.0							4.7×10^{6}							
	A			2.83×10^{-6}								1.0							4.7×10^{6}							
																					TOTAL					
Ba-140	R			.00226								1.0							1.11×10^{8}							
	S			.00226								1.0							1.11×10^{8}							
	A			.00226								1.0							1.11×10^{8}							
																					TOTAL					
La-140	R	Ba-140		.0172	.00226			1.0	1.11×10^{8}	1.11×10^{8}									1.11×10^{8}							
	S	Ba-140		.0172	.00226			1.0	1.11×10^{8}	1.11×10^{8}									1.11×10^{8}							
	A	Ba-140		.0172	.00226			1.0	1.11×10^{8}	1.11×10^{8}									1.11×10^{8}							
																					TOTAL					
La-142	R	Ba-142		.450	3.78			1.0	1.03×10^{8}	9.52×10^{7}									9.52×10^{7}							
	S	Ba-142		.450	3.78			1.0	1.03×10^{8}	9.52×10^{7}									9.52×10^{7}							
	A	Ba-142		.450	3.78			1.0	1.03×10^{8}	9.52×10^{7}									9.52×10^{7}							
																					TOTAL					

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