WATERFORD 3 SES
PLANT OPERATING MANUAL

LOUISIANA POWER & LIGHT
MIDDLE SOUTH UTILITIES SYSTEM

POM VOLUME 14
POM SECTION 5

NE-5-301
REVISION 0
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EFFECTIVE DATE: ______

TECHNICAL PROCEDURE

ESTIMATION OF FUEL FAILURE
(INTERIM)

PORC Meeting No. 82-33A

Reviewed: ______
PORC Chairman

Approved: ______
Plant Manager-Nuclear

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1.0 PURPOSE

This procedure provides an estimate of the extent of fuel failure. The estimate is based on the I-131 concentration measured in the Reactor Coolant System (RCS).

2.0 REFERENCES

2.1 Waterford 3 FSAR, Chapters 11 and 12

2.2 Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400, Appendix VII, pp. VII-13, 14, U.S. Nuclear Regulatory Commission (Oct. 1975)

2.3 American Nuclear Society, American National Standard Source Term Specification, ANSI N237-1976

2.4 L.L. Bonzon and N.A. Lurie, Best Estimate LOCA Radiation Signature, Part II, pp. 9-13, NUREG/CR-1237 (Jan. 1980)

2.5 A.P. Malinauskas, R.A. Lorenz, H. Allrecht, and H. Wild, LWR Source Terms for Loss-of-Coolant and Core Melt Accident, Proceedings of the CSNI Specialists Meeting on Nuclear Aerosols in Reactor Safety, held at Gatlinburg, Tenn., April 15-17, 1980, NUREG/CR-1724, pp. 38, 39

2.6 Estimate of Failed Fuel Based on I-131 Concentration, Procedure AP/0/A-5500, Duke Power Company

2.7 Determination of Extent of Core Damage, Procedure 78.000.15, Rev. 0, The Detroit Edison Company

3.0 DEFINITIONS

3.1 Fuel Failure - As used in this procedure, fuel failure may range from minor clad damage (resulting in I-131 gap inventory release to RCS) to severe fuel melting (resulting in major portions of the core I-131 inventory being released to the RCS).

3.2 Iodine Spiking - A condition where larger than normal amounts of iodine are released from the fuel to the RCS upon a significant power change, a shutdown, or RCS depressurization.

4.0 RESPONSIBILITIES

4.1 Chemistry

Chemistry personnel are responsible for obtaining an RCS sample and analyzing it for I-131 concentration, using the gamma spectrometer.

4.2 Nuclear Operations Supervisor (NOS)

The NOS is responsible for requesting an RCS sample analysis in accident (or other) conditions which indicate the possibility of fuel failure.

4.3 Nuclear Engineering (NE)

Nuclear Engineering is responsible for maintaining this procedure. NE is also responsible for evaluating the results of this procedure.

5.0 PREREQUISITES

An RCS sample has been drawn and analyzed with the gamma spectrometer for I-131 concentration.

6.0 PRECAUTIONS AND LIMITATIONS

6.1 The amount of fuel failure predicted by this procedure is only an estimate.

6.2 The equations and graph contained in this procedure assume equilibrium full power core iodine concentrations. If this procedure is performed during times of reduced power or near the time of a significant power change, the core iodine inventory must be adjusted accordingly with Attachment 12.1, Power Correction Factor, P_1.

6.3 All values are normalized to normal RCS temperature and pressure. To correct for other RCS temperatures or other RCS sample temperatures use Attachment 12.2, Temperature, Correction Factor, T_1.

6.4 Iodine spiking may occur after a shutdown or significant power change. The spike generally peaks during the period 4 to 8 hours after the power change. I-131 concentrations can increase by a factor of 2 to 25 times above the equilibrium levels during these spikes, although an increase greater than a factor of 10 is unusual and would be seen only on a shutdown. Increases by a factor of 2 or 3 are typical for a significant power change (i.e., 100% to 50% power). Do not interpret this temporary change as fuel failure if there are no other indications of core problems. Other indications which may help identify fuel failures are: indications of inadequate core cooling, loose parts indications, high core-exit thermocouple readings.

6.5 Chemistry samples and analyses should be performed as rapidly as possible after fuel failure is suspected. If more than 16 hours has elapsed, the sample should be corrected for decay to the time at which fuel failure is suspected to have occurred.

7.0 INITIAL CONDITIONS

7.1 Accident (or other) conditions exist which cause fuel failure to be suspected.

7.2 The Process Radiation Monitor indicates that RCS gross gamma activity is high.

8.0 MATERIAL AND TEST EQUIPMENT

NONE

9.0 ACCEPTANCE CRITERIA

NONE

10.0 PROCEDURE

10.1 Obtain the RCS I-131 concentration from Chemistry and Environmental personnel.

10.2 Calculate the Power Correction Factor, P_1, using Attachment 12.1 if necessary.

10.3 Calculate the Temperature Correction Factor, T_1, using Attachment 12.2 if necessary.

10.4 Correct the RCS I-131 concentration for decay to the time of reactor shutdown or suspected fuel fa[illegible] $A(t_o)$, using Attachment 12.3 if necessary.

10.5 Calculate the corrected RCS I-131 concentration from the sample by:

$$I_c = I \times P_1 \times T_1$$

where: I_c = corrected RCS I-131 concentration
I = measured RCS I-131 concentration (corrected for decay, $A(t_o)$, if necessary)
P_1 = power correction factor
T_1 = temperature correction factor

10.6 Use the result of step 10.5 to evaluate the lower limit, the upper limit and the best estimate of the amount of fuel failure, using Attachment 12.4.

10.7 If the results from step 10.6 place the amount of fuel failure in the region where clad damage and fuel melting may both exist, request that Chemistry personnel analyze the sample for the presence of isotopes of Sr, Ba or La (especially Sr-92 and La-140).

10.8 If the above isotopes are found in greater than normal amounts (based on previous isotopic analyses of the same cycle), bias the estimate of fuel failure toward fuel melting.

11.0 SETPOINTS

NONE

12.0 ATTACHMENTS

12.1 Power Correction Factor

12.2 Temperature Correction Factor

12.3 Decay Correction

12.4 Percent Fuel Failure (% Clad Damage)

12.5 Examples

13.0 COMMITMENTS AND REFERENCES

POWER CORRECTION FACTOR

Case I

To correct the iodine inventory if fuel failure is suspected to have occurred during periods of operation at any power level (except 0%) where the power level has not changed greater than ± 10% within the last 40 days (approximately 5 half-lives of I-131), use the following equation:

$$P_1 = \frac{100}{\text{\% Full Power at time of fuel failure}}$$

Example: The plant has been at 75% full power for the last 30 days when fuel failure is suspected. Therefore:

$$P_1 = \frac{100}{75} = 1.333$$

Case II

To correct the iodine inventory if fuel failure is suspected to have occurred at times other than those in Case I above, use the following equation:

$$P_1 = \frac{100}{\sum_j \left[P_j \left(1 - e^{-0.0862 t_j}\right) e^{-0.0862 t_j^{\circ}}\right]}$$

where: P_j = steady reactor power in period j (%)

t_j = duration of period j (days)

t_j° = time between the end of period j and time of reactor shutdown or suspected fuel failure (days)

> **NOTE**
>
> $\sum_{j=1}^{n} t_j \approx 40$ days; $j = 1, 2, \ldots, n$
>
> 40 days is approximately 5 half-lives of I-131, which gives sufficient accuracy.

POWER CORRECTION FACTOR

Example: The plant was at 75% power for 22 days, 50% power for 17 days and 100% power for 2 days when the reactor tripped and fuel failure was suspected to have occurred during the trip.

> **NOTE**
>
> $\sum t_j \approx 40$ days.

$$P_1 = \frac{100}{\left[75\left(1-e^{-0.0862(22)}\right)\left(e^{-0.0862(19)}\right) + 50\left(1-e^{-0.0862(17)}\right)\left(e^{-0.0862(2)}\right) + 100\left(1-e^{-0.0862(2)}\right)\left(e^{-0.0862}\right)\right.}$$

$$P_1 = \frac{100}{12.3919 + 32.3618 + 15.8358}$$

$$P_1 = \frac{100}{60.6373} = 1.6491$$

TEMPERATURE CORRECTION FACTOR

RCS Temp at time of sample degrees F	Primary Sample Temperature degrees F 80	90	100
100	0.996	0.998	1
150	0.983	0.985	0.987
200	0.966	0.968	0.970
250	0.945	0.947	0.949
300	0.921	0.923	0.924
350	0.894	0.895	0.897
400	0.862	0.864	0.865
450	0.827	0.828	0.830
500	0.787	0.788	0.790
550	0.739	0.740	0.741
560	0.728	0.729	0.731
570	0.717	0.718	0.719
580	0.706	0.708	0.708
590	0.693	0.694	0.695
600	0.680	0.681	0.683

Find the appropriate RCS temperature at the time of suspected fuel failure. Find the primary sample temperature. The intersection of the two numbers is the temperature correction factor, T_1.

NOTE

Normal primary sample temperature is approximately 80 degrees F. Use this temperature if no other information is available.

NOTE

If the RCS or sample temperature falls between the values listed above, little error will be introduced by using the closest value.

DECAY CORRECTION

If less than 16 hours have elapsed from the time of reactor shutdown (or from the time fuel failure is suspected to have occurred), failure to correct the sample for decay will introduce less than 5% error.

$$XI = A(t_o) = A(t_s)\, e^{0.0862 \Delta t}$$

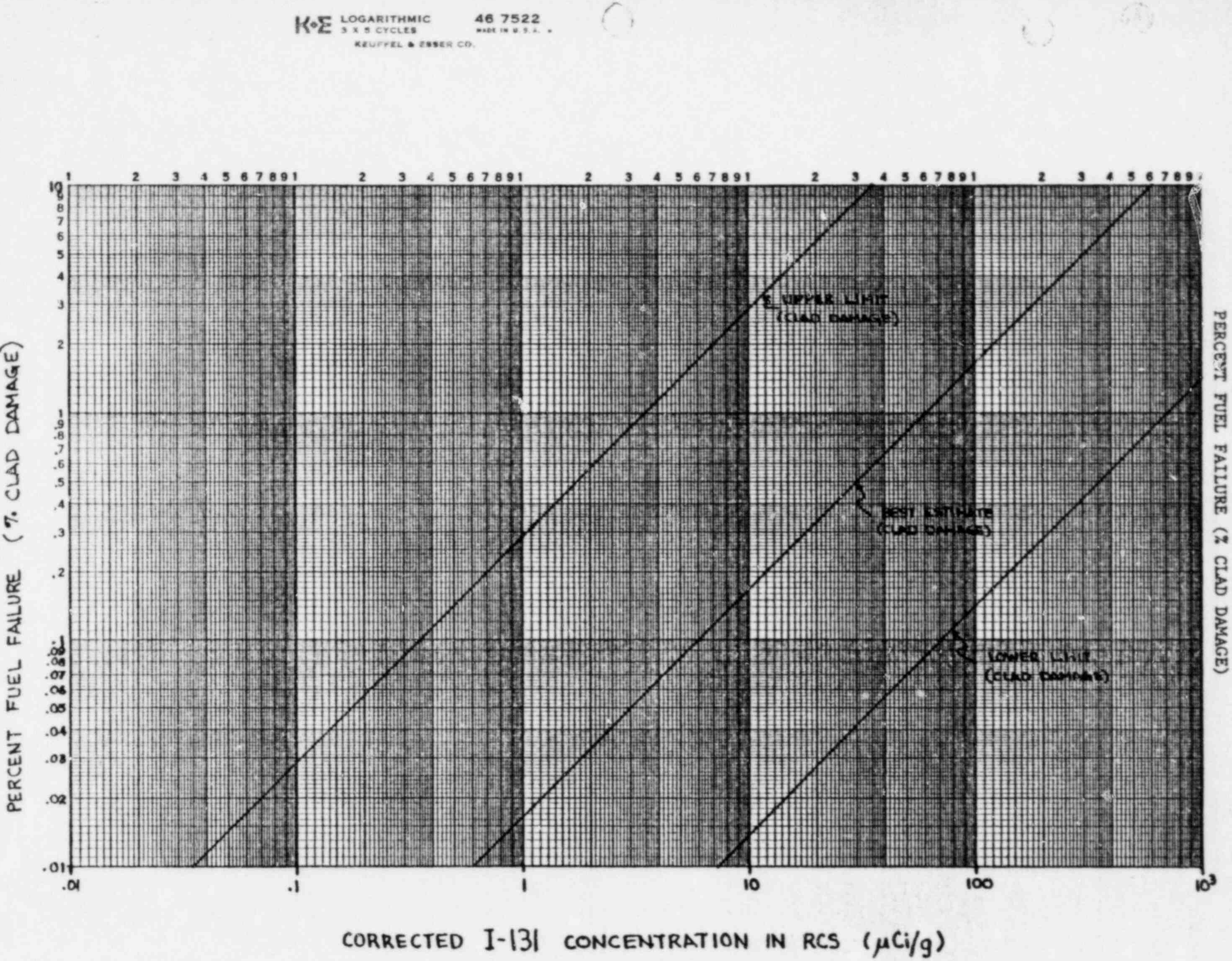
where: t_o = time of shutdown or suspected fuel failure

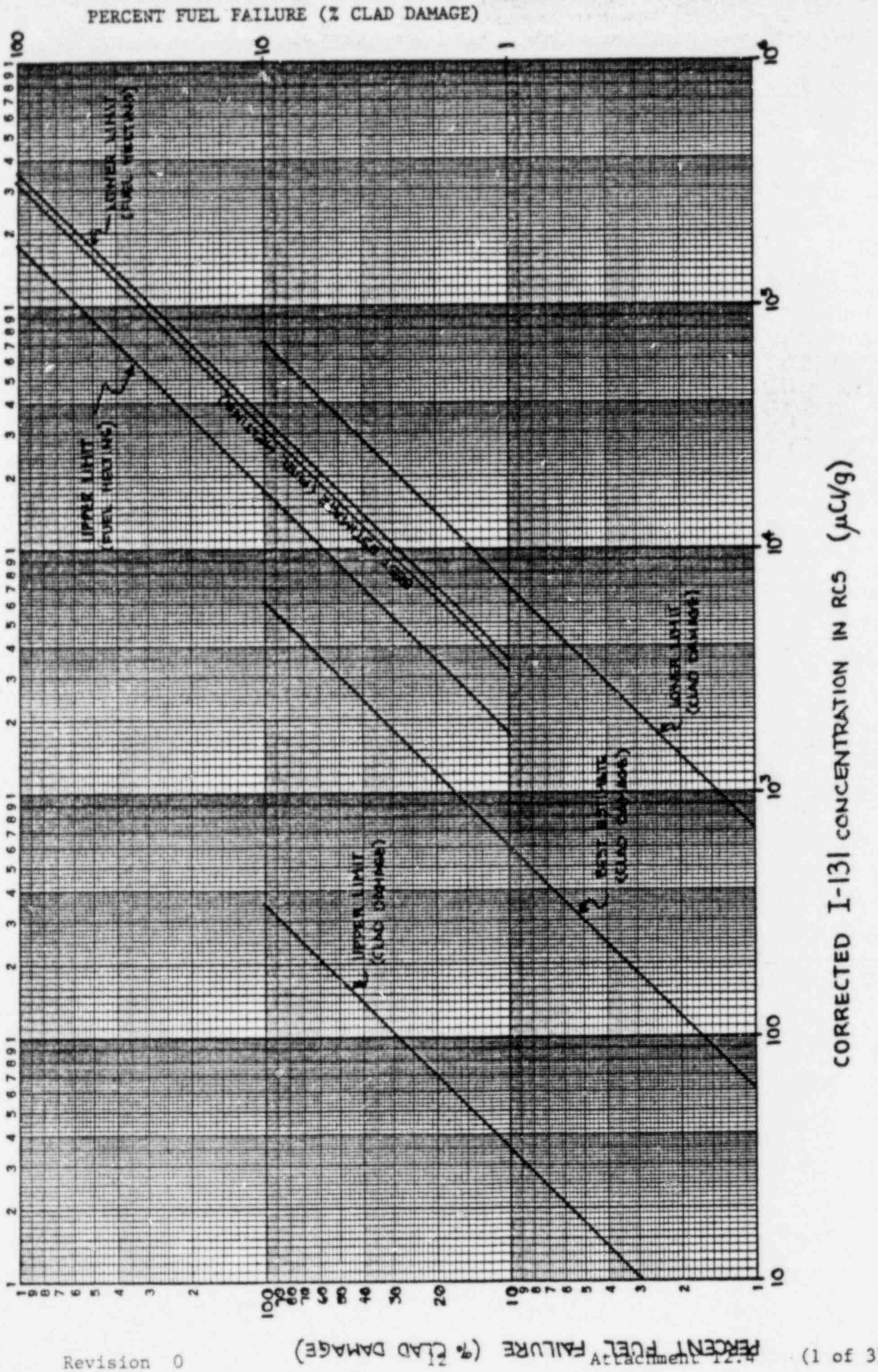
t_s = time of sample analysis

$\Delta t = t_s - t_o$ = time from shutdown or suspected fuel failure to sample analysis (days)

$A(t_o)$ = activity (μCi/g) at t_o

$A(t_s)$ = measured sample activity (μCi/g)


K&E LOGARITHMIC 3 X 5 CYCLES 46 7522
KEUFFEL & ESSER CO.
UPPER LIMIT (CLAD DAMAGE)
BEST ESTIMATE (CLAD DAMAGE)
LOWER LIMIT (CLAD DAMAGE)
PERCENT FUEL FAILURE (% CLAD DAMAGE)
CORRECTED I-131 CONCENTRATION IN RCS (µCi/g)
.01
.1
1
10
100
10³


PERCENT FUEL FAILURE (% CLAD DAMAGE)
LOWER LIMIT (FUEL MELTING)
UPPER LIMIT (FUEL MELTING)
UPPER LIMIT (CLAD DAMAGE)
BEST ESTIMATE (CLAD DAMAGE)
LOWER LIMIT (CLAD DAMAGE)
CORRECTED I-131 CONCENTRATION IN RCS (μCi/g)
PERCENT FUEL FAILURE (% CLAD DAMAGE)

DERIVATION OF EQUATIONS FOR GRAPH

$A_{I-131} = 8.46 \times 10^5 P \gamma_i$ Ci

P = 3560 MWt

i = 0.028 for I-131

$A_{I-131} = 8.43 \times 10^7$ Ci

FSAR Table 12.2-12 $\quad A_{I-131_{max}} = 8.96 \times 10^7$ Ci $= 8.96 \times 10^7 \mu$Ci

RCS Mass (FSAR Table 11.1-1) = 5.56×10^5 lb_m = 2.52×10^8 g

Equilibrium Full Power Core I-131 Inventory = $3.56 \times 10^5 \mu$Ci/g

Best-Estimate Fission Product Release Fractions for I-131

Gap Release*		
Lower Limit	Nominal	Upper Limit
0.001	0.017	0.20

Meltdown Release*		
Lower Limit	Nominal	Upper Limit
0.492	0.883	0.983

Fuel Failure	UL (μCi/g)	BE (μCi/g)	LL (μCi/g)
0.1% clad	3.56×10^{-1}	6.05×10^{0}	7.12×10^{1}
1% clad	3.56×10^{0}	6.05×10^{1}	7.12×10^{2}
10% clad	3.56×10^{1}	6.05×10^{2}	7.12×10^{3}
100% clad	3.56×10^{2}	6.05×10^{3}	7.12×10^{4}
1% melt	1.75×10^{3}	3.15×10^{3}	3.50×10^{3}
10% melt	1.75×10^{4}	3.15×10^{4}	3.50×10^{4}
100% melt	1.75×10^{5}	3.15×10^{5}	3.50×10^{5}

* The upper limit of the release (gap or meltdown) produces the lower limit of predicted fuel failure. The lower limit of release produces the upper limit of predicted fuel failure.

EXAMPLES

I. The plant was at 75% power for 22 days, 50% power for 17 days, and 100% power for 2 days when the reactor tripped due to an RCP trip. Fuel failure is suspected to have occurred during the reactor trip.

Solution: These are the same conditions as in Attachment 12.1; therefore:

$P_1 = 1.6491$

1. RCS sample reads 10 μCi/g I-131

2. $P_1 = 1.6491$

3. Calculate T_1

   RCS temp = 550 degrees F (at time of sample)
   Sample temp = 90 degrees

   $T_1 = 0.740$

4. Decay correction is not necessary.

5. Calculate corrected I-131 concentration:

   $I_C = I \times P_1 \times T_1$
   $= (10\,\mu Ci/g)(1.6491)(0.740)$
   $I_C = 12.20\,\mu Ci/g$

6. From Attachment 12.4:
   LL 0.016% clad damage
   BE 0.205% clad damage
   UL 3.500% clad damage

EXAMPLES

II. The plant has been operating at 100% power for the last 53 days when a pressurizer safety valve inadvertently opens. The reactor trips on low pressurizer pressure. Fuel damage is suspected as a result of the transient. A chemistry sample is taken 1 hour after the reactor trips.

T_{AVG} = 600 deg F I_{I-131} = 350 μCi/g T_{Sample} = 80 deg. F

1. 350 μCi/g
2. P_1 is not needed because the plant was at 100% power for a long period and at the time of trip.
3. Find T_1 from Attachment 12.2.
4. Decay correction is not required.
5. $I_C = I \times P_1 \times T_1 = 350 \times 1 \times 0.680$

   I_C = 238 μCi/g
6. From Attachment 12.4:

   LL 0.34% clad damage
   BE 4.00% clad damage
   UL 70.00% clad damage