71-9217

SIEMENS

June 6, 2000
PCR:00:018

U.S. Nuclear Regulatory Commission
Attn: Mr. M.D. Waters, Project Manager
Licensing Section, NMSS/SFPO/SLID
Mail Stop 13 D 13
11545 Rockville Pike
Rockville, Maryland 20852

Dear Mr. Waters:

Subject: **Additional information for the Re-certification of the ANF-250 Packaging (Docket 71-9217)**

Ref.: 1. Letter, P.C. Rieke to C.R. Chappell, Renewal of the Certificate for the ANF-250 packaging, dated January 26, 2000

Ref.: 2. Letter, P.C. Rieke to M.D. Waters, same subject, dated May 4, 2000

As per our recent telephone conversations concerning the re-certification of the ANF-250 packaging, I am submitting two copies of some pages that include changes/corrections to the consolidated Safety Analysis Report (SAR) as submitted in Reference 1. Most of these changes were necessary due to scanning errors from older documents that were not available electronically. Changes or corrections that were made for other reasons will be documented in this correspondence. I am also including a copy of the document referenced in Section 9 on page 9-1, item 4. Our consolidate SAR indicated it was attached, but I inadvertently left it off.

In Reference 2, I attempted to provide a basis for where each section of the consolidated SAR was drawn from including a paragraph by paragraph referencing for Section 6. I'm afraid in my efforts to do so, that our files of the various submittals over the years mistakenly represented some errors as to what exactly was sent in and when. As it turns out, the notation of a section identified as being drawn from our July 17, 1998 submittal actually came from our June 2, 1998 submittal. I apologize for this error.

One of the changes in the attached pages was the number referenced as the maximum allowed calculated k-effective for this package. The references are from the June 2, 1998 submittal. In this submittal, the bias adjustment was presented a different way. The data from the calculation results has not changed, however how it is presented has. In the June 2, 1998 submittal, we show the bias corrected maximum k-effective for both the heterogeneous (pellet) calculation and the homogeneous (powder) calculation (i.e. k-effective + 2σ + bias) . Currently, we changed this data to show the maximum limit for calculated k-effective + 2σ

Siemens Power Corporation

2101 Horn Rapids Road
Richland, WA 99352

Tel: (509) 375-8100
Fax: (509) 375-8402

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which is 0.95 minus the bias as indicated in Section 6.3.6 of the consolidated SAR. This limit was inadvertently switched when first indicated at the bottom of page 6-10 in section 6.3.6 as 0.9461 for homogeneous cases and 0.9443 for heterogeneous cases instead of the corrected page attached. This number (0.9443) was then mistakenly reproduced as such on page 6-28 in section 6.4.3 instead of the correct number 0.9461.

I apologize for the confusion and mistakes made in these instances and appreciate your thorough review in finding them. If there are any other questions or needs that you have in your review, please feel free to call me at 509-375-8186.

Very truly yours,

Philip C. Rieke

Philip C. Rieke
Transportation and Packaging Engineer
Regulatory Compliance

/pg

Enclosures

Case ID	k_{eff}	
	Avg.	Std. Dev.
b-bmb25k	1.00256	0.00244
b-bmb26k	1.01009	0.00220
b-bmb27k	1.00547	0.00241
b-bmb28k	1.00551	0.00243
b-bmb29k	1.00973	0.00225
b-bmb30k	1.01132	0.00233
b-bmb31k	1.01283	0.00229
b-bmb32k	1.00783	0.00234
b-bmb33k	0.99621	0.00221
b-bmb34k	1.00319	0.00253
b-bmb35k	0.99743	0.00237
b-bmb36k	0.99307	0.00254

6.3.6 Bias

The bias and its standard deviation were calculated using the methods described in Reference 4. These methods use standard analysis of variance principles. The average over all cases of the KENO k_{eff} and its variance (square of standard deviation) are calculated. The average of the average k_{eff} (grand average) is weighted by the reciprocal of its variance. Since all k_{eff} results have similar standard deviations, all 20 cases have nearly equal weights. The average value of the variance is taken as the "within class" variance. The variance of the average k_{eff} data, weighted as for the grand average, is taken as the "between class" variance. The "within class" variance is subtracted from the "between class" variance to yield the variance of the class effect. Since the true value for all cases is assumed to be 1.0 (critical), the class effect (the change in average k_{eff} from case to case) is also the bias and the variance of the class effect is the variance of the bias. A zero variance of the bias would mean that the bias is constant from case to case. The bias uncertainty may still be calculated and used if desired, but it should be recognized that the uncertainty of the bias uncertainty will be relatively large.

Based on the data in Table 6.3 and the methodology documented in Reference 4, the calculational bias has been determined to be 3.85 E-3 for heterogeneous (pellet) calculations. The bias is 5.69E-3 for homogeneous (powder) calculations and is based on the data in Table 6.4. These values for the bias are non-conservative and must therefore be added to the KENO.Va calculated k_{eff} +2σ when establishing upper limits on k_{eff}. In other words, the maximum allowed calculated k_{eff}+2σ is 0.9443 for homogeneous cases and 0.9461 for heterogeneous cases.

Table 6.21 Undamaged Container Array Evaluation

Case	Description Array size and Vol% Interspersed Mod.	k_{eff}		
		Average	σ	Ave. + 2σ
	No Vermiculite & Wet Voids Evaluation			
nc	Normal pellet array, 15x14x4 Pellet diameter is 0.5" V_{water}/V_{fuel} = 0.502 & no vermiculite	.8377	.0031	.8438
nc.01	As above with 1 vol% water in void spaces	.8520	.0030	.8579
nc.02	As above with 2 vol% water in void spaces	.8734	.0036	.8805
nc.03	As above with 3 vol% water in void spaces	.8659	.0026	.8710
nc.04	As above with 4 vol% water in void spaces	.8697	.0031	.8760
nc.05	As above with 5 vol% water in void spaces	.8702	.0030	.8762
nc.06	As above with 6 vol% water in void spaces	.8628	.0032	.8692
nc.10	As above with 10 vol% water in void spaces	.8188	.0028	.8245
	Wet Vermiculite Evaluation			
ncv	Normal pellet array, 15x14x4 Pellet diameter is 0.5" V_{water}/V_{fuel} = 0.523 & dry vermiculite.	.8987	.0032	.9052
ncv.01	As case ncv with 1 vol% water in vermiculite	.8912	.0033	.8978
ncv.02	As case ncv with 2 vol% water in vermiculite	.9026	.0031	.9089
ncv.05	As case ncv with 5 vol% water in vermiculite	.8680	.0027	.8734
ncv.10	As case ncv with 10 vol% water in vermiculite	.8015	.0036	.8087
ncv.70	As case ncv with 70 vol% water in vermiculite	.5480	.0031	.5542

Five times the number of undamaged containers allowed in a shipment must have a k_{eff} less than 0.9461 at undamaged conditions. Based on this criterion, the maximum number of containers in a pellet shipment is 168.

Proposed TI for Shipping Pellets

The transport index for criticality safety is set such that five times the allowed number of containers at undamaged conditions and two times the allowed number of containers at damaged conditions must have a k_{eff} less than 0.9461.

Damaged conditions : array size = 8x7x3 = 168
Undamaged conditions : array size =15x14x4 = 840

TI=(50/84)=0.6

6.4.4 <u>Pellets with Enrichments < 1.0 wt%</u>

6.4.4.1 Arrays of Undamaged Packages for Pellet Shipment with Enrichments ≤1.0 wt%

Data from Application dated March 1980.

Suitcases were filled with a cell-weighted mixture representing a generic UO_2 pellet lattice with water to equal 1149 g H. The cell-weighted mixture was prepared using CSAS routines and BONAMI, NITAWL, and XSDRNPM. A 0.5" pellet diameter was modeled because previous

Appendix 6A

KENO Model for Damaged Array, Powder Shipment

The most reactive damaged array model used in the March 1990 applications is listed.

```
POWDER SHIPMENTS IN ANF-250-, IIXI2X4 ARRAY, FIXED H, DAMAGED
READ PARAMETERS

TME=60.0 GEN=83 NPG=3OO LIB=41 TBA=2.0 FLX=YES FDN=YES XSI=YES NUB=YES PWT=YES PLT=NO

END PARAMETERS

READ MIXT SCT=1
MIX= 1
' U02-WATER, 1149.1 GM H, 120 KG U PER ANF-250
92235 2.591910E-04
92238 4.862395E-03
8016  1.603187E-02
1001  1.157741E-02
MIX= 2
' CARBON STEEL
6012 3.921682E-03
26000 8.350009E-02
MIX= 3
' INTERSPERSED WATER, 4 VOL
8016 1.3352-3 1001 2.6704-3
MIX=4
' REFLECTOR WATER
8016 3.337967E-2
1001 6.675933E-2
END MIXT
READ GEOMETRY
' U.02 POWDER SHIPMENT WITH 1149 GM H, 120 KG U
' POWDER INSERT IS 50.13" LONG, INCLUDING 0.38" THK AL LID THE INNER
' CONTAINER IS 57.0" LONG (INSIDE)
' CENTER THE INSERT INSIDE THE INNER CONTAINER
' THUS, 3.435' SPACE TO BOTTOM & LID
UNIT 1
COM=" POWDER INSERT, 49.06 INCH REGION BELOW FLANGE "
'  ID = 9.5625 +/- 0.0625, USE 9.625'
CYLI 1 1  12.2238 2P62.3062
' ADD 0.0750" THK CARBON STEEL WALL OF POWDER INSERT
CYLI 2 1 12.4143 2P62.3062
' ADD INTERSPERSED MODERATOR TO 11.380" FLANGE DIAM
CYLI 3 1 14.4526 2P62.3062
' ADD CAR  STL BOTTOM FLANGE OF POWDER INSERT, 0.19" THK
CYLI 2 1 14.4526 62.3062 -62.7888
' ADD INTERSPERSED MODERATION, 3.435" AT BOTTOM, DIAM TO 11.5"
CYLI 3 1 14.605 62.3062 -71.5137
' ADD 0.0598" CAR STL WALL, ALSO ADD 0.25" BOTTOM OF INNER CONTAINER
CYLI 2 1 14.7569 62.3062 -72.1487
' INTERSPERSED MOD TO 20.5" ID, ALSO ADD 3.125" AT -Z
CYLI 3 1 26.035 62.3062 -80.0862
' ADD 0.0598" CAR STL DRUM WALL & BOTTOM
CYLI 2 1 26.1869 62.3062 -80.2381
' ENCLOSE IN CUBOID
CUBO 3 1 4P26.1869 62.3062 -80.2381
UNIT 2
COM= " POWDER INSERT, REGION NEAR INSERT UPPER FLANGE"
' POWDER ID=9.625" $ FLANGE THICKNESS = 0.38"
CYLI 1 1 12.2238 2PO.4826
```

```
 ' ADD CAR STL FLANGE TO 11.38" DIAM
CYLI 2 1 14.4526 2PO.4826
'  ADD MODERATION TO 11.5" DIAM & TO BOTTOM
'  OF INNER CONTAINER FLANGE, SPACE AT +Z = 3.435 - 0.5=2.935
' NOTE: THE ALUM LID OF THE POWDER INSERT NOT MODELED
CYLI 3 1 14.605 7.9375 -0.4826
' ADD 0.0598" CAR  STL WALL
 CYLI 2 1 14.7569 7.9375 -0.4826
' ADD MODERATION TO 20.5" DRUM ID
CYLI 3 1 26.035 7.9375 -0.4826
' ADD DRUM WALL
CYLI 2 1 26-1869 7.9375 -0.4826
' ENCLOSE IN MODERATION CUBOID
CUBO 3 1 4P26.1869 7.9375 -0.4826
UNIT 3
COM= " FLANGE & LID OF INNER CONTAINER"
' INTERSPERSED MODERATION IN INNER CONTAINER
CYLI 3 1 14.605 0.0 -1.27
'  FLANGE OD=15.5", LID OD=14.75", USE 14.75" FOR BOTH
CYLI 2 1 18.733 2P1.27
'   INTERSPERSED MOD TO 20.5"ID, ALSO ADD 5.5" AT +Z
CYLI 3 1 26.035 15.24 -1.27
' ADD 0.0598" CAR STL WALL & LID
CYLI 2 1 26-1869 15.9319 -1.27

' ENCLOSE IN CUBOID
CUBO 3 1 4P26.1869 15.3919 -1.27
UNIT 4
COM="  COMPLETE ANF-250 PACKAGE  "
ARRAY 1 3R0.0
GLOBAL
UNIT 5
ARRAY 2 3R0.0
REPL 4 2 6R3.0 10
END GEOMETRY
READ ARRAY
ARA=1 NUX=1 NUY=1 NUZ=3
FILL 1 2 3 END FILL
ARA=2 NUX=11 NUY=12 NUZ=4
FILL F4 END FILL
END ARRAY
READ START
NST=1
END START
READ BOUNDS
ALL=VACUUM
```

Since oxygen is present in both the U02 pellet and the water between pellets, CSAS assigns #8016 to the first occurrence (in U02) and #4 (which is the sequence number) to the oxygen in water.

Since the Vw/Vf is 2.0 and since there is no gap or clad, the unit cell is 1/3 fuel and 2/3 water. The atom densities for the heterogeneous cell are weighted accordingly to yield the following homogeneous cell atom densities.

HOMOGENEOUS CELL ATOM DENSITIES

92235	3.91942E-04
92238	7.35280E-03
8016	1.54895E-02
4	2.22532E-02
1001	4.45063E-02

The homogeneous cell atom densities are used in KENO along with cell weighted cross sections from XSDRNPM.Unweighted cross sections were used for the carbon steel, stainless steel, and interspersed water in the model.Unweighted H and 0 were designated by 100102 and 801602 in the KENO model. NITAWL was used to combine the weighted and unweighted cross sections into one working library read by KENO. An example of the input to this second NITAWL run is listed below.

NITAWL INPUT FOR FINAL WORKING LIBRARY

```
0$$ 6 7 8 11 18 19 9 0 20
1$$ 0 0 8 5 3R0 0 2R0 -1 0
T
2$$ 801602 100102 6012 26000 24304 25055 26304 28304
92235 92238 8016 4 1001
T
```

The KENO-VA model for the most reactive case is listed below.

```
PELLET SHIPMENTS IN ANF-250, 5.0%ENR, DAMAGED ARRAY
READ PARAMETERS
TME=60.0 GEN=83   NPG=500 LIB=41 TBA-2.0
FLX=YES FDN=YES   XS1=YES NUB=YES PWT=YES
PLT=NO
END PARAMETERS
READ MIXT SCT=1
MIX=1
'HOMO MIXTURE, 0.35" DIM, Vw/Vf=2.0, 5.0% enr
92235 3.91942E-04
92238 7.3528OE-03
8016  1.54895E-02
4   2.22532E-02
1001 4.45063E-02
MIX=2
'CARBON STEEL
6012            3.921682E-03
26000           8.350009E-02
MIX= 3
' SS304
24304           1.742958E-02
25055           1.736443E-03
26304           5.935923E-02
28304           7.718178E-03
MIX= 4
'WATER BETWEEN SUITCASES, 0%  801602 3.337967E-12        100102    6.675933E-12
END MIXT
READ GEOMETRY
UNIT I
' 7.75" WIDE X 4.87" TALL X 24.88" LONG FUEL REGION IN SUITCASE
CUBO 1 1 2P9.8424 2P6.1848 2P31.5976
' ADD 0.0598" SS WALL EXCEPT AT -Y
REPL 3 1 3R0.1519 0.0 2R0.1519 1
' ADD MODERATION TO BASE DIMS
CUBO 4 1 2P11.9 6.3368 -6.1849 2P33.655
'  ADD STEEL FLANGE (16 GAGE) & 0.12" BASE PLATE
CUBO 3 1 2P11.9 6.3368 -6.6416 2P33.655
UNIT 2
COM=" TWO EDGE-EDGE SUITCASES IN INNER CONTAINER"
 ARRAY 1 -11.9 -6.6416 -67.31
'  INSIDE LENGTH OF INNER CONTAINER = 57.25"-O.25" - 57.0"
' 0.5" IS IN THE UNIT WITH THE FLANGE
```

```
' LENGTH OF TWO SUITCASES = 53"
' CENTER THE SUITCASES IN THE 57" REGION
CYLI 4 1 14.605 71.12 -72.39
' ADD 0.0598" CAR STL WALL, ALSO ADD 0.25" BOTTOM OF INNER CONTAINER
CYLI 2 1 14.7569 71.12 -73.025
'  INTERSPERSED MOD TO 22.5" ID, ALSO ADD 4.125" AT -Z
'  FOR DAMAGED CONDITIONS, USE 20.5" ID & 3.125"
CYLI 4 1 26.035 71.12 -80.9625
'  ADD 0.0598" CAR STL DRUM WALL & BOTTOM
CYLI 2 1 26.1869 71.12 -81.1144
' ENCLOSE IN CUBOID
CUBO 4 1 4P26.1869 71.12 -81.1144
UNIT 3
COM=" FLANGE & LID OF INNER CONTAINER"
'   INTERSPERSED MODERATION IN INNER CONTAINER
CYLI 4 1 14.605 0.0 -1.27
'  FLANGE OD=15.5", LID OD=14.75", USE 14.75" FOR BOTH
CYLI  2 1 18.733 2P1.27
'  INTERSPERSED MOD TO 22.5"ID, ALSO ADD 6.5" AT +Z
'  FOR DAMAGED CONDITIONS, USE 20.5" ID & 5.5"
CYLI 4 1 26.035 15.24 -1.27
'  ADD 0.0598" CAR STL WALL & LID
CYLI 2 1 26.1869 15.3919 -1.27
' ENCLOSE IN CUBOID
CUBO 4 1 4P26.1869 15.3919 -1.27
UNIT 4
COM=" COMPLETE ANF-250 PACKAGE"
ARRAY 2 3R0.0
GLOBAL
UNIT 5
ARRAY 3 3R0.0
END GEOMETRY
READ ARRAY
ARA=1 NUX=1 NUY=1 NUZ=2
FILL F1 END FILL
ARA=2 NUX=1 NUY=1 NUZ=2
FILL 2 3 END FILL
ARA=3 NUX=9 NUY=10 NUZ=3
FILL F4 END FILL
END ARRAY
READ START
NST=1
END START
READ BOUNDS
ALL=WATER
END BOUNDS
END DATA
```

Sample computer inputs from the 1998 applications

```
Case ncv.01
=csas2x
' parm=chk
ANF-250 normal cond. 14x15x6 array 0.5" pellets vw/vf=0.502
27group latt
'MIX=1
uo2  1  0.98 293  92235 5.0   92238 95.0  end
'MIX=2
' CARBON STEEL
c    2  0  3.921682E-03  end
fe   2  0  8.350009E-02  end
'MIX= 3
' SS304
crss  3 0  1.742958E-02  end
mn    3 0  1.736443E-03  end
fess  3 0  5.935923E-02  end
```

DATA AND ANALYSIS FOR NUCLEAR CRITICALITY SAFETY

1. Criticality Safety Criteria, *W. Marshall (CEGB-UK), P. D. Clemson (BNFL-UK), G. Walker (UKAEA-Warrington)*

INTRODUCTION

This paper describes three criticality safety criteria for use with computed values of k_{eff}. Two of the criteria are currently used in safety submissions within the UK; the third could be employed if additional statistical refinement were required. It is legitimate to use any one of the criteria, provided the associated data are chosen prudently. It is stressed that other formulations could be equally acceptable.

CRITERION 1

$$k_N + E_{PD} + E_{SM} + E_R + 3\sigma_N < L \ . \tag{1}$$

This criterion[1] is used with the UK Monte Carlo code MONK.[2] k_N, σ_N are computed values of k_{eff} and its standard deviation for the new case. E_{PD} and E_{SM} are allowances for errors due to program, data, specification, and modeling of the system. E_R allows for the possible existence of situations more reactive than that modeled, and L is a limit < unity which can give additional pessimism, or impose a particular shutdown margin.

E_{PD} values have been obtained[3] for many systems from validation comparisons between calculated and experimental results. Values for the other allowances are selected by the assessor. The overall confidence level for the criterion cannot be stated, because some of the allowances confound systematic and random effects. Prudent choice of values can offset this problem, and will ensure adequate safety.

This criterion has been used by BNFL in submissions for process plant which have been accepted by the Nuclear Installations Inspectorate.

CRITERION 2

$$k_N + S_T + 3\sigma_T < L \ . \tag{2}$$

This criterion[4] is currently used by CEGB for AGR fuel. Systematic and random effects are separated to give totals S_T and σ_T. S_D and σ_D, the effects due to errors in data and code, are obtained[5] from the (k_i, σ_i, M_i), i = 1 . . . n, of the n relevant validation comparisons, where M is number of stages:

$$\bar{k} = \sum_1^n k_i(\sigma_i)^{-2} \Big/ \sum_1^n (\sigma_i)^{-2} \tag{3}$$

$$(\bar{\sigma})^2 = \sum_1^n (\sigma_i)^2 M_i \Big/ \sum_1^n M_i \tag{4}$$

$$S_D = 1 - \bar{k} \tag{5}$$

$$(\sigma_D)^2 = \left[\frac{n \sum_1^n (k_i - \bar{k})^2(\sigma_i)^{-2}}{(n-1)\sum_1^n (\sigma_i)^{-2}}\right] - (\bar{\sigma})^2 \ . \tag{6}$$

Data[3] for low-enriched U/UO_2 rods in water lead[6] to S_D = 0.0, σ_D = 0.011.

$$S_T = S_D + S_a + S_b + \ldots \tag{7}$$

$$\sigma_T = \left[\sigma_N^2 + \sigma_D^2 + \sigma_a^2 + \sigma_b^2 + \ldots\right]^{1/2} \ , \tag{8}$$

where a, b, . . . are separate effects external to the code.

This criterion has been used in transport submissions approved by the UK Competent Authority. It has also been used in assessments for power stations accepted by the Nuclear Installations Inspectorate.

CRITERION 3

$$k_N + S_T + t_{p\nu}\sigma_T < L \ . \tag{9}$$

This gives a more precise treatment of confidence level, allowing for the limited availability of validation comparisons. $t_{p\nu}$ is Student's t at a confidence level of p for ν degrees-of-freedom. ν is obtained from the individual degrees-of-freedom f_N, f_D, f_a . . . of the components of σ_T by application[6] of Welch's[7] analysis.

$$\nu = \frac{\sigma_T^4}{\left[\sigma_N^4/(f_N+2) + \sigma_D^4/(f_D+2) + \sigma_a^4/(f_a+2) + \ldots\right]} - 2 \ ; \tag{10}$$

f_N and f_D are equal to (M_N − 1) and (n − 1), respectively.

Although t is greater than the corresponding factor from the normal distribution, it can be shown that an excessive penalty is only incurred when (a) only two or three validation comparisons exist, and simultaneously (b) σ_D is the dominant contributor to σ_T.

The confidence level treatment offered by this criterion makes it suitable for analyses of total risk.

COMPARISON OF THE CRITERIA

Assume that (a) 100 stages were used for a hypothetical MONK 4 calculation for AGR elements in water, giving σ_N = 0.015, (b) the worst situation was represented, and was modeled accurately, (c) there were no sources of error outside the program.

Recommended[3] values of E_{PD} and L are 0.03 and 0.95. From the assumptions above, E_{SM} = E_R = 0.0. Criterion 1 becomes

$$k_N < 0.95 - 0.03 - 3(0.015) = 0.875 \ . \tag{11}$$

For Criterion 2, S_D is 0.0, σ_D is 0.011. No "external" allowances are required, so S_T is 0.0, σ_T is 0.0186. Then,

$$k_N < 0.95 - 3(0.0186) = 0.894 \ . \tag{12}$$

Equation (10) gives ν = 44.2. At the 99.9% level, t is 3.285, and Criterion 3 becomes

$$k_N < 0.95 - (3.285)(0.0186) = 0.889 \ . \tag{13}$$

The criteria thus give similar results for this example.

STATISTICAL LIMITATIONS

The true statistical distributions of the variables used in criticality calculations are not known exactly. Thus, calculated confidence levels are not precise. For the same reason, statistical treatments more complex than those above may not give real improvements.

CONCLUSIONS

If it is not possible to separate the systematic and random effects which must be allowed for, prudent use of Criterion 1 is acceptable.

If separation of systematic and random contributions is possible, use of Criterion 2 is preferable.

Criterion 3 should be used if a more precise statistical treatment is required, because Student's t distribution is used to calculate confidence limits for k_{eff}. The formula needed for number of degrees-of-freedom has been derived.

Criterion 3 could be used in analyses of total risk.

Data for use with the criterion must be appropriate to the particular situation being studied.

Additional statistical refinements may not lead to real improvements in the quality of the final information.

1. K. C. RUSHTON, "The Monte Carlo Code MONK—A Guide to Its Use for Criticality Calculations," SRD R88 (1978).

2. V. S. W. SHERRIFFS, "MONK—A General Purpose Monte Carlo Neutronics Program," SRD R86 (1977).

3. G. WALKER, "The Monte Carlo Code MONK—Validity for Use in Criticality Calculations," SRD R87 (to be published).

4. D. W. ANDERSON, D. J. WESTERN, and W. MARSHALL, "A Criticality Safety Criterion for CEGB AGR Fuel," GDCD/NP 1109 (1977).

5. K. C. KENDALL, "The Use of the Code MONK on Some Critical Assemblies to Support the Validation of MONK for Critical Conditions," TCWP/P121/8 (1974).

6. W. MARSHALL, "A Discussion of the Statistical Treatment Used in the CEGB Criticality Safety Criterion for AGR Fuel," NHS/N40/79 (1979).

7. B. L. WELCH, *Biometrika*, 34, 28 (1947).

2. Sheba: A Solution Critical Assembly, *R. E. Malenfant, H. M. Forehand, J. J. Koelling (LASL)*

Sheba, a clean geometry critical assembly employing fuel of 4.8% enriched uranium as the fluoride, was constructed during 1980. The primary applications of the machine are to evaluate accidental criticality alarm detectors for enrichment plants, to provide radiation spectra and intensity measurements to benchmark calculations on a low-enrichment solution system, and to provide radiation fields to calibrate personnel dosimetry. Although not in the immediate experimental plan, it is intended to work toward a solution burst machine. Even the name, Sheba, is the acronym for Solution High Energy Burst Assembly. To that end, experiments following the radiation measurements are aimed at evaluating prompt critical quench mechanisms in a bare, cylindrical, low-enriched solution. Design, construction, and applications of Sheba are discussed.

BACKGROUND

Goodyear Atomic Corporation had requested the assistance of the Oak Ridge National Laboratory in the evaluation of the spacing for nuclear criticality alarm detectors for enrichment plants. Due to uncertainties in the calculation and the high cost of safety through conservatism, Goodyear and ORNL requested that LASL run a solution critical to evaluate neutron and gamma leakage from a solution of relatively low-enrichment uranyl fluoride. An extension of the experiments to evaluate personnel dosimetry was obvious. It is interesting to note that all accidents since 1958

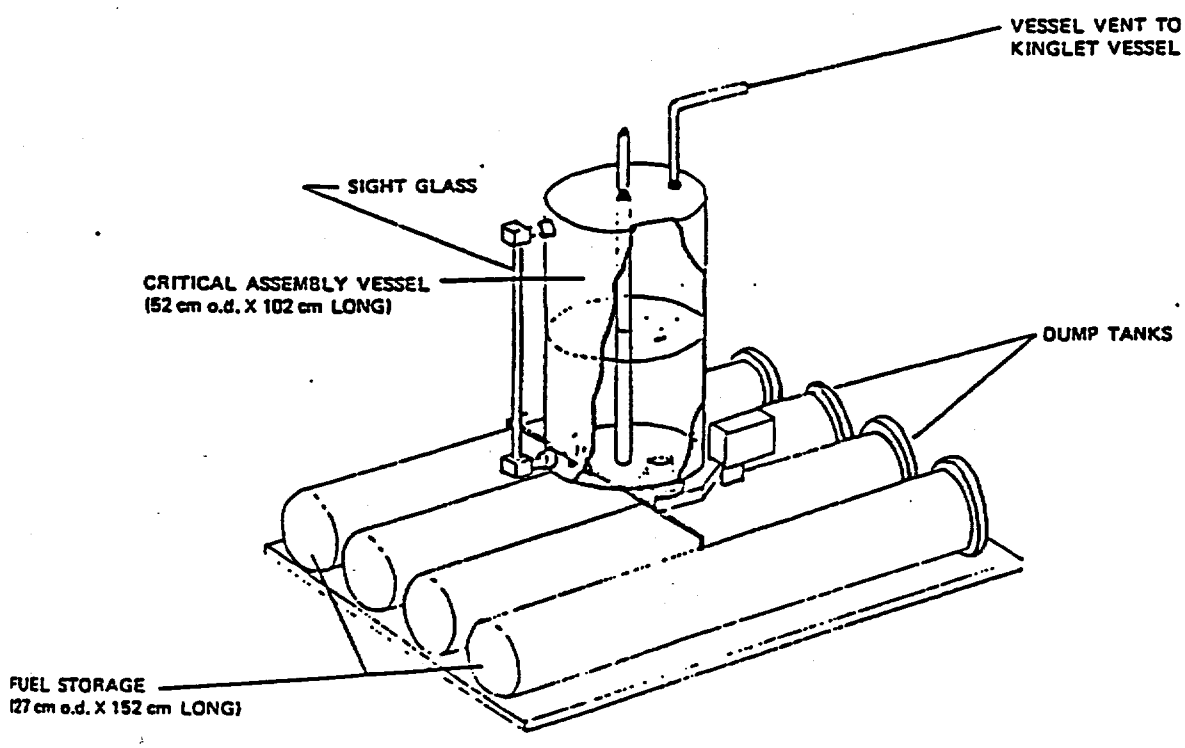

Fig. 1. Sheba: A solution critical assembly.