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TECHNICAL REVIEW OF WSRC-TR-93-614 CRITICALITY SAFETY EVALUATION FOR DISASSEMBLY BASIN SAND FILTER (U)

by

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SAVANNAH RIVER TECHNOLOGY CENTER
Applied Technology Section
Applied Physics Group

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C. E. Apperson, Manager, APG — Date

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TECHNICAL REVIEW OF WSRC-TR-93-614

Criticality Safety Evaluation for Disassembly Basin Sand Filter (U)

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INTRODUCTION

The study documented in WSRC-TR-93-614 (Reference 1) performed an evaluation of the criticality potential associated with the Disassembly Basin Sand Filter for K and L Areas. The document reviewed incorporated results of calculations documented in the engineering calculation N-CLC-K-00151 (Reference 2).

Analyses of the contents of disassembly basin sludge has indicated that the sludge contains fissile material in excess of subcritical mass limits as specified in ANSI/ANS standards (References 3 and 4). Previous studies (listed in the reference section of the reviewed document) had determined that the fissile material can not collect into a critical configuration in the basin. Since the sand filter is intended to remove suspended particles from the basin water and could serve as a mechanism to collect the fissile material into a critical configuration, the study examined conditions under which criticality could occur in the sand filter. The study shows that criticality is not considered possible in the sand filter.

This review emphasized the technical accuracy and presentation of the evaluation. The evaluation was also examined for the elements required for NCSEs by Reference 5. The review was performed in accordance with the NRTSC technical review requirements and procedures (References 6 and 7) (See Appendix A)and the E7 Manual technical review requirements (References 8 and 9). The technical review (per the E7 manual) of the engineering calculation (N-CLC-K-0151) was previously performed by this reviewer.

DISCUSSION

WSRC-TR-93-614 presents an evaluation, based on engineering calculations documented in N-CLC-K-00151, in the format specified by WSRC-IM-93-13. The evaluation focused on determining the geometry configurations under which the fissile material in the basin, having all been transferred to the sand filter, would be critical. Very conservative assumptions were used, including:

- Treating the fissile material as fissile material only, without accounting for the presence of ^{238}U and iron in the sludge. Those elements act as neutron posions.
- All fissile material in the basin is transferred to the sand filter.
- Best estimate and conservative (2.6 x BE) values of fissile material content.

The review consisted of

- a careful reading of the draft document and the final version,
- verification that the results of the engineering calculation, N-CLC-K-00151, are accurately reflected by the evaluation,
- suggestions to the author of additional discussion items and material to be included from the engineering calculation to make the document more complete, and
- editorial suggestions to the author

No additional calculations were performed as part of this review.

NCSE Required Elements

WSRC-IM-93-13 (Reference 4) specifies a set of required elements for an NCSE. That set of elements corresponds to the elements required by DOE Orders and Standards, such as DOE Order 5480.24 and DOE-STD-3007-93. The elements are listed below, along with an assessment of how they are implemented in the NCSE.

Introduction	The purpose and scope of the study were indicated in the Introduction and Summary sections.
Description	A brief description of the sand filter and its operation was provided in the Description section. References for sand filter layout and construction were indicated.
Requirements Documentation	A statement of requirements documentation was provided in the Requirements Documentation section.
Methodology	The methodology used was indicated and discussed in the Methodology section.
Discussion of Contingencies	Since the evaluation showed criticality is not possible, the Discussion of Contingencies section indicated no need for such discussion.
Evaluation of Results	The calculational results from N-CLC-K-00151 are discussed in the Evaluation and Results section. The results are also briefly discussed in the Summary section and the Conclusions section and are interpreted as no possibility of criticality.
Design Features (Active and Passive) and Administratively Controlled Limits & Requirements	The section is provided, although noting, since there is no possibility of criticality, there are no administrative limits required. Discussion of aspects of sand filter operation is provided as reinforcement of the basis of the "no criticality possible" conclusion
Summary and Conclusion	The Summary section and the Conclusions section discusses the results presented in the Evaluation and Results section, indicating that criticality is not a concern for the sand filter.
References	Appropriate references are listed.
Appendices	No appendices were required

The elements required by WSRC-IM-93-13 are satisfied.

SUMMARY AND CONCLUSIONS

The evaluation is excellently presented and well supports the conclusion that criticality is not a concern in the sand filter, unless significant changes are made in Disassembly Sand Filter operations.

REFERENCES

1. M. A. Rosser, **Criticality Safety Evatuation for Disassembly Basin Sand Filter (U)**, WSRC-TR-93-614, May 1994

2. M. A. Rosser, "Calculations for Sand Filter Criticality Safety Evaluation", N-CLC-K-00151, Revision 0, March 1994

3. "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors", ANS-8.1-1983, October 7, 1983

4. "American National Standard for Nuclear Criticality Control of Special Actinide Elements", ANS-8.15-1981, November 9, 1981

5. WSRC-IM-93-13, Rev.1, **Westinghouse Savannah River Company Nuclear Criticality Safety Manual (U)**

6. MANUAL 1Q34, **NRTSC QUALITY ASSURANCE MANUAL**, January 1991

7. NRTSC QA Procedure QAP II-14, "TECHNICAL REVIEW", August, 1991

8. Procedure Manual E7, Revision 5, **Conduct of Engineering and Technical Support (U)**

9. Procedure 2.40 (E7 Manual), Revision 0, "Design Verification and Checking" (U)

ATTACHMENT A
NRTSC REVIEW SHEET

OSR 24-K7

TASK TITLE NCSE FOR DISASSEMBLY SAND FILTER TASK NUMBER N/A

ITEM REVIEWED WSRC-TR-93-614 PAGE 1 OF 1
(Attach additional pages as necessary; marked-up pages are acceptable.)

1. Areas reviewed *(identify clearly each area reviewed).*

Logic, clarity, accuracy, and applicability of presentation
Consistency of data values presented with engineering calulation N-CLC-K-00151
Adequacy of methodology chosen
Consistency with WSRC-IM-93-13

2. Approaches used to perform the review.

Read the document carefully.
Evaluated adequacy of methodology used (hand calculations and KENO-V.a scoping calculations.
(This reviewer performed the E7 review of the engineering calculation, N-CLC-K-00151)
Checked for consistency with N-CLC-K-00151
Discussed editorial suggestions with author
Confirmed implementation of suggested improvements in final version of document

3. Questions, comments to be resolved.

None:

__X__ I agree with the technical content   _____ I disagree with the technical content.

__X__ I accept the conclusions and recommendations

_____ I do not accept the conclusions and recommendations for the following reasons:

Reviewer Signature Raymond L Reed Date 4 / 27 / 94

ATTACHMENT B
WSRC-TR-93-614 (Text and Tables)

CRITICALITY SAFETY EVALUATION FOR DISASSEMBLY BASIN SAND FILTER (U)

INTRODUCTION

As a result of the Reactor Division's disassembly basin cleanup program, it has been determined that fissile isotopes are present in the sludge that has accumulated at the bottom of the disassembly basins (References 1 through 5). Good criticality safety practices require that the potential for obtaining a critical configuration with this fissile material be evaluated. As part of this process, the disassembly basin sand filter system has been identified as a potential area of concern. Because disassembly basin water flows through the sand filter, it is conceivable that fissile material, from the basin, could accumulate in the sand filter. As is documented in Reference 13, and shown in Table 1 of this document, previous calculations have indicated that the mass of some fissile isotopes in the basin sludge exceeds subcritical mass limits. This report documents the criticality safety evaluation that was performed to address the possibility of forming a critical configuration within the sand filter. This evaluation is applicable to K and L Areas, since the fissile masses listed in Table 1 are bounding for both areas. Applicability to P Area will be examined following the completion of sludge sample analyses for that Area.

SUMMARY

Although it is conceivable that fissile material could accumulate in the sand filter, because of the required fissile mass and necessary critical geometries it is highly unlikely that a critical configuration could be assembled. The mass of fissile material required for criticality, for present and anticipated sand filter geometries and operational characteristics, is much greater than that available in the sludge, as indicated by sludge sample analyses. In short, there is no identified mechanism by which a critical configuration could be assembled in the disassembly basin sand filter.

DISCUSSION

Description - Sand Filter Operation

The sand filter is an 11 foot diameter tank containing a sand-anthracite filter medium (References 6, 7 and 12). The filter consists of an 18" layer of anthracite on top of an 18" layer of sand (Reference 12). Water from the disassembly basin is circulated through the sand filter to remove suspended particulates and maintain the clarity of the water. Water is removed from and returned to the basin at various locations.

The design and nature of the sand filter is such that water comes into the sand filter from above and hits a 2.5' square plate that distributes the water over the entire surface of the sand mixture. This serves to uniformly distribute any particulates in the water and, thus, should eliminate, or at least reduce, the potential for localized accumulations of basin particulates. The flow of basin water to the sand filter is approximately 715 gpm (Reference 12). The sand filter is backwashed to a settler tank per management direction, or when the pressure drop across it becomes excessive. According to DPSOL 105-3723A, a sand filter is normally backwashed each day. However, discussions with technical support personnel have indicated that the present frequency is approximately once per week (References 14, 15 and 16).

It is expected that a new type of sand filter will be put into service in the near future. This new sand filter will differ from the present sand filter in that it has a diameter of 6', instead of 11', and it will have a reduced flow, because the new version puts several sand filters in parallel. Otherwise, the new sand filter will be similar to the present sand filter. This evaluation is applicable to the smaller sand filter.

Description - Fissile Isotope Mass in the Basin Sludge

References 4 and 5 discuss the basin sludge cleanup process in detail. The best estimate and conservative fissile mass values for the sludge are provided in Table 1. The conservative mass estimates were obtained by adding isotope measurement uncertainties and sludge volume uncertainties to the best estimate masses. The mass values given in Table 1 are bounding for K and L Areas. The applicability to P Area will be evaluated when P Area sludge sample analyses become available.

Requirements Documentation

In addition to the general requirements documentation that is applicable to all criticality safety evaluations (Reference 11), ANS-8.15, "American National Standard for Nuclear Criticality Control of Special Actinide Elements", is applicable to this evaluation. Sludge analyses indicate the presence of several special actinide elements (References 1 through 5).

Methodology

For this evaluation, analytical (i.e. - hand) calculations that made use of national standard subcritical limits were performed to estimate the mass of fissile material (in this case U-235) required to achieve criticality in the sand filter. This was done by calculating, for a given sand filter radius, the mass of U-235 required to reach the areal density subcritical limit for aqueous U-

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WSRC-TR-93-614 (Text and Tables)

235 mixtures. The areal density limit (see Table 1) was used in this evaluation because it is most applicable to the assumed sand filter configuration (i.e. - an aqueous layer, of varying thickness, containing fissile material). The calculated U-235 mass, since it corresponds to a subcritical limit, will still produce a subcritical configuration, but it provides a good lower estimate of the mass required for an actual critical configuration. The details of these analytical calculations are provided in Calculation # N-CLC-K-00151 (Reference 13).

In order to provide independent support for the above analytical work and to allow a more detailed treatment of the sand filter arrangement, supplemental calculations were performed using the KENOSA-PC criticality safety computer code (Reference 9). To do this, the sand filter was modeled as a cylinder containing four distinct layers of material:

1. 12" water layer
2. 18" anthracite layer
3. 18" sand layer
4. 12" water layer

The fissile material in the sand filter was assumed to have settled in the anthracite and sand layers to varying depths. The fissile mass used in these calculations is that corresponding to the fissile isotopes in the K disassembly basin sludge. Where explicit modeling of isotopes was not possible, an equivalent U-235 mass was used. The actual fissile isotope masses used in the KENOSA-PC calculations are given in Table 1. Calculations were performed for various cylinder radii and various depths of fissile isotope penetration into the filter medium. The details of these KENOSA-PC calculations are also contained in Calculation # N-CLC-K-00151 (Reference 13). It should be noted that the KENOSA-PC code is not a SRS-certified criticality safety code, but it is adequate for scoping calculations. It is for this reason that the KENOSA-PC results will only be used as additional information in support of the analytical results.

Evaluation and Results

The results of the analytical calculations are provided in Table 2. Note that the U-235 mass required for the 11' and 6' diameter sand filter cases is much greater than the equivalent U-235 mass available in the K Area sludge. The equivalent U-235 mass in the basin is obtained by summing the equivalent U-235 mass values for each fissile isotope. The equivalent U-235 mass for an isotope is obtained by dividing the isotope's mass by its subcritical mass limit and multiplying the result by the U-235 subcritical mass limit. The fact that the required mass is greater than the available mass means that criticality is not possible in the present

and future sand filters, under expected operating conditions. Criticality is possible if all of the sludge fissile mass is allowed to accumulate in a smaller area of the sand filter, contrary to expected operating behavior. For the best estimate U-235 equivalent mass (1.411 kg), all of the fissile isotopes must preferentially accumulate within a circular region in the sand filter that has a radius less than 35 cm (1.15 ft). For the best estimate mass + uncertainty case (U-235 equivalent mass = 3.67 kg), the radius of the circular region must be less than 60 cm (1.97 ft). The 35 cm circle is 4.4% of the surface area of the 11' diameter sand filter and 14.7% of the surface area of the 6' diameter sand filter. For the 60 cm circle, the percentages are 12.8% and 43.1%, respectively.

The results of the supporting KENOSA-PC calculations are given in Table 3. Recall that the fissile mass used in these calculations corresponds to the best estimate mass plus uncertainties for the K Area sludge. The results indicate very good agreement between the analytical and numerical (i.e. - computer code) methods. From the Table 3 results, one can see that, for those radii corresponding to the 11' and 6' diameter sand filters, the resulting configurations are significantly subcritical. Also, as in the analytical case, the specified fissile mass would have to preferentially accumulate in the sand filter within a circular area that has a radius less than 60 cm. In addition, it appears that the critical fissile isotope penetration depth is approximately 15 cm. For the purposes of this evaluation, it was assumed that a keff + 3 sigma value greater than or equal to 0.95 corresponds to a critical system.

Both calculational methods indicate that criticality is not possible in the present and future sand filters, given the maximum available fissile mass in the sludge and the operating characteristics of the sand filters. Both methods also agree as to the extent of preferential accumulation that is required to make criticality possible, under ideal conditions. There is no identified mechanism by which the necessary amount of fissile material could accumulate in the required critical configuration.

In addition to the above calculational results, there are some favorable aspects of the sand filter problem which were not included in this evaluation that will further increase the overall level of criticality safety associated with sand filter operation:

- This evaluation did not consider those materials in the sludge that are neutron absorbers, such as U-238 and iron. The presence of these materials will serve to decrease the reactivity of any configuration.
- As was mentioned earlier, the sand filter is backwashed per management direction or when the pressure drop across it reaches a preset level. This operation moves material from the sand

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filter to the settler tank and, thus, helps to prevent large accumulations of fissile material in the sand filter.

Discussion of Contingencies

Since the results of this evaluation indicate that criticality is not possible, implementation of the double contingency principle is not applicable for sand filter operation. Therefore, no discussion of contingencies is required.

Design Features and Administratively Controlled Limits and Requirements

Since the results of this evaluation indicate that a sand filter criticality is not possible, no criticality safety operating limits are required. This evaluation, however, does take credit for one design feature of the sand filter. The sand filter is designed such that the water that comes into the filter tank is spread over the entire surface of the filter medium. This also serves to spread the fissile isotopes in the water over the entire filter surface. This distribution of fissile material over a large surface area helps prevent the formation of a critical configuration. Any changes in this sand filter design feature would invalidate the conclusions of this evaluation and would require that a new evaluation be performed.

<u>CONCLUSION</u>

The formation of a critical configuration in the sand filter is not considered possible. The fissile mass required to satisfy the areal density requirements for the sand filter geometry is greater than the total disassembly basin sludge fissile mass that is available to be sent to the sand filter. For the fissile mass that is available, no mechanisms have been identified by which this mass is concentrated into the required critical configuration within the sand filter. As a result, there are no criticality safety operating limits required for the sand filter. Any sand filter modifications or changes in operational characteristics that affect the assumptions made in this evaluation will require a re-examination of the criticality safety aspects of the sand filter.

<u>REFERENCES</u>

1. Tovo, L.L., "Results of K-Area Vertical Tube Storage Basin Sludge Analyses (U)", SRTC-ADS-93-0335, June 16, 1993.
2. Tovo, L.L., "Results of K-Area Machine Basin and Transfer Bay Sludge Analyses (U)", SRTC-ADS-93-0359, July 29, 1993.
3. Tovo, L.L., "Results of L-Area Disassembly Basin Sludge Analyses (U)", SRTC-ADS-93-0411, September 30, 1993.
4. Rosser, M.A., "Criticality Safety Evaluation for L Area Disassembly Basin Cleanup (U)", RRD-RED-930373, October 6, 1993.
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6. Drawing #S5-1-8509, Revision 28.
7. "Savannah River Site Production Reactor Safety Analysis Report (U)", WSRC-SA-10003, July 10, 1991.
8. "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors", ANS-8.1-1983, October 7, 1983.
9. "KENO5A-PC: Monte Carlo Criticality Program with Supergrouping", <u>RSIC Computer Code Collection</u>, CCC-548A/B, May 1991.
10. "American National Standard for Nuclear Criticality Control of Special Actinide Elements", ANS-8.15-1981, November 9, 1981.
11. <u>Westinghouse Savannah River Company Nuclear Criticality Safety Manual</u>, WSRC-IM-93-13, Revision 1, July 1, 1993.
12. "MONOSCOUR® Automatic Filter - Specifications", BPF8211686, Sheet 15.
13. Rosser, M.A., "Calculations for Sand Filter Criticality Safety Evaluation", Calculation # N-CLC-K-00151, March 9, 1994.
14. "Disassembly Basin Filtration Facility Operation (U)", DPSOL 105-3723A-K, Rev. 15, PCN-02, March 2, 1994.
15. "Disassembly Basin Filtration Facility Data", DPSOL 105-3723B-K, Rev. 8, October 10, 1978.
16. Personal Communication with W.R. Lindenberger, April 13, 1994.

ATTACHMENT B
WSRC-TR-93-614 (Text and Tables)

TABLE 1

K DISASSEMBLY BASIN FISSILE MASSES

Isotope	Best Estimate Mass (grams)	Conservative Mass (grams)	Subcritical Mass Limit (grams)	Subcritical Mass Limit Reference	Mass in KENO Calculation (grams)
U-233	0.7	1.8	500	ANS-8.1	1.8
U-235	906.9	2357.9	700	ANS-8.1	2859.1
Pu-239	191.3	497.4	450	ANS-8.1	497.4
Pu-241	3.8	9.9	200	ANS-8.15	9.9
Am-242m	3.3	8.6	13	ANS-8.15	*
Cm-243	1.9	4.9	90	ANS-8.15	*

* U-235 mass in the KENO calculations was increased by an amount equivalent to Am-242m and Cm-243 since Am-242m and Cm-243 are not available in the cross section library used with KENO.

NOTES:

1. Subcritical areal density limit for U-235 = 0.40 g/cm^2 (ANS-8.1).
2. Conservative mass is based on an assumed 30% uncertainty in basin sample analyses and a doubling of sludge depth estimate (Multiplicative Factor = 2.6).
3. The mass values in the above Table are bounding for K and L Areas.

TABLE 2

U-235 MASS REQUIRED TO REACH AREAL DENSITY SUBCRITICAL LIMIT VS. SAND FILTER RADIUS

Sand Filter Radius (cm)	U-235 Mass (kg)
167.64 (11' Diameter)	35.3
150.0	28.3
100.0	12.6
91.44 (6' Diameter)	10.5
80.0	8.0
70.0	6.2
60.0	4.5
50.0	3.1
40.0	2.0
35.0	1.5

NOTE: For K Area Disassembly Basin Sludge:

Best Estimate U-235 Equivalent Mass = 1.411 kg
Best Estimate + Uncertainty = 3.67 kg

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TABLE 3

KENO5A-PC RESULTS

Cylinder Radius (cm)	Fissile Layer (cm)	keff	Sigma	keff + 3 Sigma *
167.64	5.0	0.31188	0.00616	0.33034
167.64	25.0	0.21867	0.00194	0.22450
167.64	70.72	0.11087	0.00064	0.11277
91.44	5.0	0.63677	0.01136	0.67083
91.44	25.0	0.57012	0.00501	0.58516
91.44	70.72	0.32678	0.00145	0.33112
60.0	5.0	0.81231	0.01291	0.85103
60.0	15.0	0.95132	0.01147	0.98574
60.0	25.0	0.91979	0.00723	0.94147
60.0	35.0	0.83733	0.00782	0.86080
60.0	70.72	0.59799	0.00478	0.61233
50.0	15.0	1.06155	0.01180	1.09693
40.0	15.0	1.17012	0.01390	1.21181

* Compare to K_{crit} = 0.95 to determine critical configurations.

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END