Depleted Uranium Disposition Study - Supplement

by

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PREDECISIONAL STUDY

**DEPLETED URANIUM DISPOSITION STUDY -
SUPPLEMENT (U)**

November 1, 1993

Nuclear Materials Planning Support Group

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SUPPLEMENT (U)**

George W. Becker, Jr.
Westinghouse Savannah River Company

October 29, 1993

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ACRONYMS AND ABBREVIATIONS

CSMO	Central Scrap Management Office
DOD	Department of Defense
DP	Defense Programs
DU	Depleted Uranium
DWPF	Defense Waste Processing Facility
EM	Environmental Restoration and Waste Management Programs
FEMP	Fernald Environmental Management Project
GSA	General Services Administration
HEU	Highly Enriched Uranium
HLW	High Level Waste
LEU	Low Enriched Uranium
LWR	Light Water Reactor
NPV	Net Present Value
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
NU	Natural Uranium
ORFO	Oak Ridge Field Office
SR	Savannah River Operations Office
SRS	Savannah River Site
t	Metric Tonne

1. INTRODUCTION AND SUMMARY

The Department of Energy (DOE) Office of Weapons and Materials Planning has requested a supplemental study to update the recent Depleted Uranium (DU) Disposition report¹. The original study identified and evaluated alternative management strategies for materials (principally depleted uranium metal, UO_3 , UF_4 , and residues) stored in numerous containers of various descriptions at the Savannah River Site (SRS) and the Fernald Environmental Management Project (FEMP). Substantial quantities of DU are also stored at the gaseous diffusion plants as UF_6 .

Since the previous report was issued: (1) progress has been made in implementing FEMP's DU Disposition Plan, (2) the 10-year DU demand forecast has changed, (3) new disposal and utilization options have been identified, and (4) a SRS DU disposition decision plan has been initiated. This supplemental study addresses these new disposition alternatives and changes in status.

Since October 1, 1990, when Environmental Restoration and Waste Management Programs took over Fernald, 2,514.5t of excessed DU have been dispositioned; 1477.6t were transferred to Defense Programs (DP) and Department of Defense (DOD) users and the rest was disposed of. A Notice of Availability for 3,820t of FEMP DU was placed in the Commerce Business Daily (April 8, 1992), expressions of interest have been assessed, and the Request for Proposal has been prepared. Most of the remaining 2,603.6t of excessed DU not offered for sale is planned for transfer to the DOD for disposal. This material was produced for and belongs to DOD which is responsible for its disposition. DOD plans to continue disposal at the Barnwell NRC licensed low-level waste disposal site (adjacent to SRS). Paradoxically, the 10^3 t quantities involved could not be similarly disposed of at SRS based on preliminary performance assessment modeling required by DOE Order - 5820.2A for radioactive waste management. Consideration should be given to raising this disposal issue with the DOD and to retention of DU metal destined for disposal by DOD for future use.

DU is mainly used for DOD armor-piercing projectiles and tank armor, radiation shielding, and in nuclear weapons manufactured by DP. Forecast 10-year DU demand is now 2,025t/y, down from 4,100t/y¹. Current DOE inventories can supply 190 years of demand at this level. Canceled plans to add 16,000t to the National Defense Stockpile over the next 10 years and a 95% reduction in DP's programmatic needs account for the change in forecast demand.

The previous conclusion¹ that DU should be stored in a Energy Resource Reserve is still valid. DU has the potential to generate 7.4 billion GWhr of electricity (12,300 X all the nuclear power generated in '90) and produce revenue of \$136,000/kg ('91 dollars) in Pu-DU liquid metal fast breeder reactors. Serious depletion of natural resources for fossil and fissile power plants is expected by the mid 21st century. DU storage until that time would allow the future nuclear power configuration and other potential end-uses to develop. In

¹ Becker, Jr., G. W., DEPLETED URANIUM DISPOSITION, NMP-92-1, March 17, 1992.

addition, the net present value (NPV) cost of indefinite storage of DU is about 1/3 of DU's NPV disposal cost (\$2.5/kg vs \$8.5/kg)¹. Findings for the new utilization and disposal options identified since the last report are:

Utilization

- *LWR Spent Fuel and DOE HLW Shielding:* LWR spent fuel and DOE HLW shipping, storage, and repository disposal containers could use DU for shielding. DU provides higher structural strength and smaller, lighter shielding configurations than lead. The heat conducting ability of DU is about three times higher than stainless steels but one half of leads. This application could potentially utilize all of DOE's excess DU. DU shielding components should be recoverable for potential future use in breeders to generate electrical power. DU shielding costs would be greater than those for lead since lead sells for \$0.73/kg while the conversion ($\text{UF}_6 \rightarrow \text{UF}_4 \rightarrow \text{metal}$) cost is ~\$10/kg² DU.
- *Make Fuel Grade Uranium by Diluting HEU:* DU could be mixed with excess HEU to produce fuel grade uranium for commercial reactors. However, current economics make NU far more attractive than DU for this application. Use of DU is cost effective only if blending costs for DU-HEU (or NU-HEU) are $\geq$ the SWU cost for producing an equivalent amount of fuel from NU. Each dilution option displaces 181.6kg NU per kg of HEU.

Disposal

- *Disposal of DU in SRS Saltstone:* The SRS Saltstone process mixes low-level aqueous waste with flyash and cement. The resultant slurry is poured into large engineered vaults where it solidifies. Filled vaults will be covered with soil and capped with "impermeable" clay. Saltstone disposal of DU would be more costly than deep geological disposal¹ (>\$74 vs ~\$8.5/kg of DU).
- *Disposal of Uranium in SRS DWPF Glass:* The DWPF process encapsulates SRS HLW in borosilicate glass. The DWPF is expected to produce 410 glass cans/y at an operating and transportation/disposal cost of \$1,250/kg of waste. The variable cost of encapsulating SRS DU UO_3 in glass was estimated to be ~\$630/kg of DU.

With preliminary guidance from DOE-Savannah River Operations Office (SR), a proposed SRS DU Disposition Decision Plan and Schedule were developed based on the prioritized steps outlined in Federal property management regulations. Proposed dates for the major steps are summarized in Table 1:

² Boniford, D. (FEMP), Personal Communication

Table 1: Summary Proposed SRS DU Disposition Decision Plan

Disposition Step	Date
1. Utilize within DOE	October 1992
2. Screen other Government Agencies and potential Donees	January 1993
3. Award sales contracts to buyers	August of 1993
4. Storage location decision for materials to be retained	October 11, 1993
5. Begin transfer of materials declared waste to EM	January 1994

The principle storage location options in step 4 of Table 1 are SR, Y-12 and NTS. Consolidation of the proposed uranium Energy Resource Reserve at one site would provide long-term materials management simplifications and savings from duplication of efforts.

2. FEMP DU DISPOSITION STATUS³

FEMP made progress in dispositioning excess DU since the previous study¹. Low grade residues were declared waste and transferred to EM, metal was transferred to the DOD for utilization, and other materials beneficially owned by DOD were reportedly disposed of by the DOD at the Barnwell commercial low-level waste disposal facility. Table 2 shows the 10/1/92 FEMP depleted uranium inventory, inventory changes from October 1, 1990 when Fernald was transferred from DP to EM, and explanations for the changes. It should be noted that an additional 1,957t of the October 1, 1992 metal inventory will be removed by DOD and reportedly disposed of at the Barnwell commercial low-level waste disposal facility.

Table 2: Changes in FEMP DU Inventory, Metric Tons

Form	Inventory 10/1/90 DP/EM Transfer	Inventory 10/1/92	Changes	Explanation
UO ₃	35.0	35.0	0.0	
UF ₄	1,821.1	1,474.6	346.6	Transferred to DOD (Aerojet)
Metal	6,900.3	4,869.0	2,031.3	Key transfers were: 546.6t of 4A product to DOD, 602.2t of recyclable metal to Y-12 and 6.2t of DU to the U. of Washington, and 900.3t of 4A metal removal for DOD.
Residues	<u>181.6</u>	<u>45</u>	<u>136.6</u>	Residues below economic discard limit written off as waste.
Total	8,938.1	6,423.6	2,514.5	

³ Letter per Fax: Kaushiva, S. and Schonegg, E. (WEMCO) to Becker, Jr., G. W. (WSRC), FEMP DU INVENTORY, October 22, 1992.

A positive step was taken towards the sale of DU at the Fernald and Hanford Sites when the Notice of Availability for sale was listed in the Commerce Business Daily. The advertisement asked for expressions of interest from firms that would be interested in acquiring DU. Expressions of interest were also solicited for excess natural and low-enriched uranium from the Fernald and Hanford Sites. Quantities and descriptions of excess FEMP and Hanford DU being offered for potential sale are listed in Table 3.

**Table 3: DU In FEMP Commerce Business Daily
Notice of Availability for Sale**

Site	Description	Mt
FEMP	UO ₃	35
	UF ₄	1,480
	Metal, (19.0 wt. % derby metal, 15.2 wt. % ingots and 65.8 wt. % recyclable metal)	2,310
Hanford Site	UO ₃	142
	Miscellaneous forms of UO ₂	8
	Metal	0.4

Table 4: Updated FEMP DU Disposition Plan

EXCESS DECLARATION	<ul style="list-style-type: none"> • Excess NM Bulletin • Evaluate responses 	Complete Complete
SCREEN OTHER AGENCIES	<ul style="list-style-type: none"> • Start Federal Agency screen • Evaluate responses 	Complete Complete
DOE - SCREEN RESPONSES	<ul style="list-style-type: none"> • Evaluate responses 	Complete
NOTICE OF AVAILABILITY FOR SALE	<ul style="list-style-type: none"> • Solicit expressions of interest, advertise in Commerce Business Daily. • Evaluate expressions of interest. 	Complete Complete Complete
REQUEST FOR PROPOSAL (RFP)	<ul style="list-style-type: none"> • Issue RFP • Evaluate bids 	1-93 4-93
STORE - WASTE DECISION		TBD
DU TO BE RETAINED	<ul style="list-style-type: none"> • Determine materials to be retained • Transfer materials 	
DU DECLARED WASTE	<ul style="list-style-type: none"> • Declaration of waste materials • Characterize • NEPA review • Start shipments to NTS • Shipments to NTS end 	

From interactions with interested parties, indications are that industry may utilize the depleted materials to dilute HEU and produce commercial fuel. The updated FEMP DU Disposition Plan Schedule is in Table 4.

3. DU DEMAND UPDATE

Demand for DU for the next ten years is now expected to be lower than previously forecast due to changes in DP programmatic needs and DOD strategic reserve plans. Y-12 now forecasts⁴ a minimum of 25 t/y for DP programmatic needs during this time period, down 95% from the previous report. The DOD Appropriations Act for FY 91 required that 16,000 t be placed in the National Defense Stockpile (NDS) over the next 10 years. However, on July 18, 1991, Secretary of Defense (Production and Logistics) Colin McMillian issued a press release stating no need for added DU to NDS. This requirement was subsequently repealed by the FY 92 DOD Appropriations Act⁵. Both Carolina Metals and Aerojet have used an averaged of about 1,000t of depleted uranium metal per year for the DOD penetrator program in the past and anticipate no change in the future. These cumulative changes lower forecast DU demand from 4,100 to 2,025 t/y. At this demand level, current DOE DU inventory (~ 380,000 t) would provide a 190 year supply.

4. DISPOSITION: FEDERAL ACQUISITION REGULATIONS

Federal property management regulations, Federal Acquisition Regulations 48 CFR Part 45 Section 603, Reporting, Redistribution, and Disposal of Contractor Inventory, provide the following options (in order of priority) for disposition of inventory no longer needed by the agency or contractor in possession of the inventory:

1. Purchase by contractor

48 CFR 45.603 (a): "Purchase or retention at cost by prime contractor or subcontractor of contractor-acquired property." This step does not apply to excess depleted uranium.

2. Return to supplier

48 CFR 45.603 (b): "Return of contractor-acquired property to supplier." This step does not apply to excess depleted uranium.

3. Use within Government

48 CFR 45.603 (c): "Use within the Government through the use of prescribed screening procedures (see 48 CFR 45.608)." The availability of an excess material for programmatic use by DP or other DOE Program Offices is made known by issuing an Excess Materials Bulletin.

4 Letter: Wynn, T. H. (DOE FO,OR) to Bilyeu, J. D. (DOE FO,SR), DOE DEPLETED URANIUM DISPOSITION, May 14, 1992.

5 Letter: Law, C. A. (DOD Defense Logistics Agency) to Bilyeu, J. D. (DOE FO,SR), DEPLETED URANIUM DISPOSITION STUDY,

The Screening Category for DOE excess nuclear material not relocated internally would be Special Items, Nuclear Material, Source Material according to 48 CFR 608-1. These materials are normally offered to other Federal agencies. Notification and screening for possible transfer of the subject material to eligible recipients is done in conjunction with the General Services Administration (GSA). Nuclear Regulatory Commission, State, pertinent Federal and Federal agency regulations must be considered for potentially donated nuclear material per 48 CFR 45.608-5 (e). This section also provides for a waiver from this screening process if there are compelling circumstances clearly in the Government's interest or other justification.(48 CFR 45.608-6).

5. Sale of material

41 CFR 101: DOE or its specified contractor may conduct the sale of excess special nuclear, by-product, and source materials.

The notification of availability for sale will be placed in the Commerce Business Daily by the DOE in order to solicit expressions of interest. Interested parties may be furnished additional details at a general information session prior to the formal proposal stage. DOE or its specified DOE contractor, with or without the assistance of the GSA, issue a Request for Proposal (RFP) to potential buyers if the evaluation of expressions of interest warrant.

6. Donation of material

48 CFR 45.603 (f): "Donation to public bodies in lieu of abandonment." Per 48 CFR 45.611 (c), "Surplus property for which a determination has been made under subparagraph (a)(1) and (2)," see step 7, "may however, be donated to public bodies in lieu of abandonment or destruction. All costs incident to donation shall be borne by the donee."

7. Abandonment or destruction

48 CFR 45.603 (g): "Abandonment or destruction" Per 48 CFR 45.611, "(a) Surplus property may be destroyed or abandoned only after every effort has been made to dispose of it by other authorized methods. Before authorizing destruction or abandonment, the plant clearance officer shall determine in writing that- (1) The property has no commercial value and no value to the Government; (2) The estimated cost of care and handling is greater than the probable sale price; or (3) Because of its nature, the property constitutes a danger to public health, safety, or welfare." These same conditions pertaining to DOD materials can be found in 41 CFR 101- 45.901 and in 41 CFR 109 - 45.501 - 1 and 2 for DOE materials.

In 48 CFR 45.601, Definitions, the plant clearance officer is defined as "an authorized representative of the contracting officer assigned responsibility for plant clearance." and plant clearance as "all actions relating to the screening, redistribution, and disposal of contractor inventory from a contractor's plant or

work site. The term *contractor's plant* includes a contractor-operated Government facility."

8. Store for future use or sale

48 CFR 45.612-3, Special storage at the Government's expense: "(a) Contractor inventory may be stored at the Government's expense only when the contracting officer determines that it should be retained in storage for anticipated use."

5. USE WITHIN THE GOVERNMENT

DU is used for DOD armor-piercing projectiles and tank armor, radiation shielding material, and in nuclear weapons manufactured by DP. There is a large current and growing oversupply of DU within the DOE compared to near-term demand, see 2. DU DEMAND UPDATE. However, there are several economically attractive near-term (10-20 years) and long-term potential applications within the province of the DOE that are capable of consuming this excess material.

5.1 Breeder

Within the next century, DU could become a valuable resource if breeder reactors are developed and implemented, see section 2.

5.2 Shielded Shipping, Storage, and Repository Disposal Containers

DOE spent fuel, irradiated targets, and solid high level waste (HLW) forms (e.g., Defense Waste Processing Facility (DWPF) glass and highly active waste from EM Decontamination and Decommissioning (D&D) activities), will require reusable/dedicated shielded casks/containers for shipping, storage and disposal at the HLW repository. Because of its high density, uranium metal would make excellent shielding material for these containers. Oxides of uranium would provide less shielding than lead since the density (ρ) of UO_2 , U_3O_8 and UO_3 are progressively smaller than lead. Approximately 10,000 to 30,000 canisters of defense HLW could be produced from waste stored at SRS, Hanford, and the Idaho Chemical Processing Plant⁶. From the following analysis, shielding these canisters could potentially utilize more than 190,000t of DU.

Licensing, containment cladding for DU shielding material, mechanical performance in DOT tests, shielding and thermal design, integration of DU shielded containers into the DOE HLW program and repository schedule, and fabrication capabilities and cost are apparent issues that must be addressed if DOE would pursue this application. Defense HLW will be stored for an extended time (about 20-40 years) since emplacement of defense HLW in the proposed repository is scheduled after the majority of commercial spent fuel is dispositioned. It is recommended that DU container shielding components be recoverable

6 Report for U.S. DOE by ORNL, INTEGRATED DATA BASE FOR 1990: U.S. SPENT FUEL AND RADIOACTIVE WASTE INVENTORIES, PROJECTIONS, AND CHARACTERISTICS, DOE/RW-0006, REV 6, October 1990.

in order to be available for potential future applications, such as blanket and mixed oxide fuel material for liquid metal fast breeder reactors or in other uses, that may develop.

DU can provide structural strength similar to stainless steel (SS), smaller and lighter shielding configurations, and better heat transfer capability than SS but less than lead's. Mechanical and thermal properties for DU, lead, and 304L stainless steel are listed in Table 5. Material and fabrication costs for DU shielding structures will be considerably higher than for lead; e.g., material cost for DU metal is about \$10/kg² but \$0.73/kg for lead.

Table 5: Mechanical and Thermal properties of DU, Stainless Steel, and Lead

	SS annealed	U α phase	Pb
MECHANICAL			
β Thermal Expansion Coefficient, $^{\circ}\text{F}$	9.6×10^{-6}	13.8×10^{-6}	16.4×10^{-6}
Yield Strength, psi	30,000	20,000	1,900
Tensile Strength, psi	80,000	50,000	2,500
Hardness, Brinell	150	?	5
Tensile Modulus of Elasticity, psi	2.8×10^7	2.8×10^7	2.0×10^6
THERMAL			
$k/\rho C_p$ Thermal "Diffusion", ft^2/h	0.16	0.44	0.93

Shielding material requirements for DU versus Pb or Fe were estimated for a prototypical shielding container for SRS DWPF glass canisters. Dose at the surface of the reference DWPF glass can is about 10,000 mrem/h⁷ and 88% of this dose comes from Cs/Ba-137's 662 kev gamma. Estimated shielding container wall thicknesses and weights needed to attenuate this Cs/Ba-137 dose to 200 mrem/h (DOT's 49 CFR 174.441 shipping package external surface dose rate limit), are in Table 6. The prototypical shielding container for SRS DWPF glass canisters was assumed to be a 2'-4" ID x 12' right cylinder. Details of the 2' OD x 10' reference DWPF glass can are in Table 10.

5.3 Power Reactor Fuel Manufacture

DU can be mixed with excess highly enriched uranium (HEU) to produce UF₆ feed material for fabrication of fuel for commercial nuclear power reactors. This disposition option has emerged since significant quantities of HEU may become available as the DOE Weapons Complex downsizes and HEU becomes available from the former Soviet Union with the ending of Cold War hostilities. On August 31, 1992 President George Bush announced⁸ an initial agreement between the U.S. and former Soviet Union representatives for the U.S. DOE to purchase no less than 10t/y of weapons grade HEU (reported to be 94% U-235) in the first five years of the arrangement and no less than 30t/y thereafter. Under the

7 Baxter, R. G., DEFENSE WASTE PROCESSING FACILITY WASTEFORM AND CANISTER DESCRIPTION, DP-1606, Rev. 2, December 1988.

8 NuclearFuel, Special Issue, SPECIAL REPORT, McGraw-Hill, Inc., September 2, 1992.

Table 6: U, Pb, and Fe Estimated Shielding Needs For SRS DWPF Glass Canisters Assuming Cs/Ba-137 (662 keV γ) Radiation Limiting

Shielding Container	U	Pb	Fe
Wall Thickness, cm	3.46	6.87	18.33
Weight, t	6.29	7.84	17.25

$$\text{Attenuation}^9 = (r_c + r_s)^{1/2} [E_1(\mu t) + (a + (1 - b)) e^{-\mu t (1 - b)}]$$

t = Shielding wall thickness, cm

r_c = Glass can radius = 12 in.

r_s = Shield container outside radius = $[14 + (t + 2.54)]$ in.

a, b = Material Berger Build-up constants¹⁰, dependent on γ energy

μ = Material Attenuation coefficient¹¹ (cm^{-1}), dependent on γ energy, cm^{-1}

E_1 = Exponential Integral, tabulated values

Metal	a	b	μ/ρ	Density $\rho, \text{g/cc}$
U	0.226	-0.0675	0.127	19.07
Pb	0.289	-0.0554	0.11	11.3
Fe	0.9035	0.0674	0.0733	7.8

agreement the DOE will dilute HEU to reactor grade uranium for sale as commercial reactor fuel. Reportedly the former Soviet Union may have 500t available for sale. Issues that must be addressed if DOE would pursue this application are: (1) the actual amount of HEU ultimately available for this end-use, (2) DOE versus commercial capabilities and costs for producing fuel grade UF_6 from DU UF_6 and HEU metal, and (3) the strategy for introducing product that minimizes impacts upon the U.S. uranium mining companies and Uranium Enrichment Activity (UEA).

Two important alternatives for producing fuel grade UF_6 are: (A) use depleted uranium or (B) use natural uranium (NU) to blend with HEU. The basis for the analysis, summarized on Table 7, is; (1) the full cost of HEU (as UF_6), (2) a nominal HEU quantity of 1,000t (93% U-235) for ease of scaling the values in Table 7, (3) a nominal blending cost of \$6/kg, and (4) the full cost of 3.5 % U-235 UF_6 produced from NU for the value of product. Key observations are:

- net revenue of about \$860 per kg of DU would be generated for the DOE,
- 55% and 62% of the full cost of producing HEU UF_6 would be recovered in case A and B, respectively,

9 Glasstone, S. and Sesonske, A., NUCLEAR REACTOR ENGINEERING, D. Van Nostrand Co., NY, 1967.

10 Jaeger, R. G. (ed.), ENGINEERING COMPENDIUM ON RADIATION SHIELDING, Vol. 1, Springer - Verlag Inc., NY, 1968.

11 Courtney, J. C. (ed.), A HANDBOOK OF RADIATION SHIELDING DATA, ANS/SD-76/14, July 1976.

- based on forecast Uranium Enrichment Activity (UEA) operations¹² about 7.5y of uranium mining industry and UEA demand would be displaced,
- both cases displace 181.6kg NU per kg of HEU, and
- this disposition option for DU would at most utilize a fraction of DOE's large current and growing oversupply DU UF₆ inventory (currently about 350,000 t)
- Current economics make NU far more attractive than DU for this application. Assuming the value of "blended" enriched U would be set by the cost of NU and SWU to produce equivalent enriched U, use of DU is cost effective in the unlikely case that blending cost for DU-HEU (or NU-HEU) is $\geq$ the SWU cost for producing an equivalent amount of fuel from NU.

Metric ton and dollar quantities in Table 7 scale with the quantity of HEU.

Table 7: Economic Comparison of Using NU vs DU to Produce 3.5% U-235 Fuel From HEU

	t	Cost/kg	Millions	t	Cost/kg	Millions
HEU ^a	1,000	\$42,500.00	\$42,500	1,000	\$42,500.00	\$42,500
NU ¹³	32,090	\$31.25	\$1,003	0	\$31.25	\$0
DU	0	\$0.00	\$0	27,121	\$0.00	\$0
Blend	33,090	\$6.00	\$199	28,121	\$6.00	\$169
Revenue ^a	33,090	\$835.25	\$27,639	28,121	\$835.25	\$23,488
Net t NU Displaced	181,604			181,604		
Net			(\$16,063)			(\$19,180)

a Costs were calculated for the value of \$117/SWU for separative work between 0.711 to 10.5 % U-235 enrichment and \$922/SWU for enrichment > 10.5% U-235 and \$31.25/kg for NU¹⁴.

6. SALE OF EXCESS MATERIAL

In the past, commercial demand for DU has been small compared to the internal needs of DOD for production of armor-piercing projectiles and tank armor, radiation shielding material, and DP for production of nuclear weapons. Civilian applications (e.g. ballast,

12 Lemons, T. R. et. al., THE ULTIMATE DISPOSITION OF DEPLETED URANIUM, K/ETO-44, ORNL, December 1990.

13 NuclearFuel, CURRENT URANIUM PRICING INDICATORS, McGraw-Hill, Inc., April 13, 1992.

14 Parks, P. B. and Allender, J. S., PRODUCTION COSTS OF HEU (U), WSRC-RP-89-667, Addendum 1, January 1991.

counterweights, radiation shielding) are limited due to the high cost depleted uranium compared to lead (\$10/kg² DU vs \$0.73/kg Pb), NRC licensing requirements, and its small residual radioactivity. However, the same new near-term (10-20 years) and long-term potential applications discussed in USE WITHIN THE GOVERNMENT section are also applicable in the potential sale of DU to the nuclear power industry.

6.1 Breeder

Within the next century, DU could become a valuable resource if Pu-DU liquid metal fast breeder reactors are developed and implemented, see section 2.

6.2 LWR Spent Fuel Shipping, Storage, and Repository Disposal Containers

As discussed in the USE WITHIN THE GOVERNMENT section, DU can provide smaller and lighter shielding configurations than conventional materials, steel and lead. This application can utilize all current and future DU generated by the UEA. Based on forecast⁵ spent fuel arisings in the next 20 years and Pressurized (PWR) and Boiling (BWR) Water Reactor assembly characteristics¹⁵, about 105,000 BWR and 80,000 PWR spent fuel assemblies will have accumulated. Order of magnitude estimates of potential demand for DU as a shielding material for transportation and storage of these assemblies are: (1) ~10⁴t of DU for transportation cask shielding materials and (2) ~10⁶t for shielding plugs for spent fuel dry storage caissons. Again, it is recommended that DU shielding components be recoverable in order to be available for potential future applications, such as blanket and mixed oxide fuel material for liquid metal fast breeder reactors or in other uses, that may develop. Material and fabrication costs for DU shielding structures will be considerably higher than for lead; e.g., the conversion (UF₆→UF₄→metal) cost for DU is about \$10/kg² but \$0.73/kg for lead. Other issues involved with this application are addressed in section 5.2 Shielded Shipping, Storage, and Repository Disposal Containers.

6.3 Power Reactor Fuel Manufacture

DU can be mixed with excess highly enriched uranium (HEU) to produce UF₆ feed material for fabrication of fuel for commercial nuclear power reactor fuel as discussed in the USE WITHIN THE GOVERNMENT section. However, current economics make NU far more attractive than DU for this application, see Section 5.3. Each dilution option displaces 181.6kg NU per kg of HEU.

7. LONG-TERM STORAGE FOR FUTURE APPLICATIONS

This supplemental report is in agreement with the previous conclusions¹ that depleted uranium should be stored in a Energy Resource Reserve. Storage was preferred over disposal due to DU's potential value for breeder reactors and the relative cost of storage vs. disposal. Serious depletion of natural resources for fossil and fissile power plants is expected by the mid 21st century. DU storage until that time would allow the future nuclear power configuration and other potential end-uses to develop. In addition, the net present

¹⁵ US DOE Report, SPENT FUEL STORAGE FACT BOOK, DOE/NE-0005 (UC-85), April 1980.

value (NPV) cost of indefinite storage of currently excess DU is about one-third of DU's NPV disposal cost (\$2.5/kg vs \$8.5/kg)¹. These costs were obtained by analyzing a broad range of storage and disposal technology options; near-surface RCRA-type and isolated deep geological disposal and above grade warehousing and retrievable shallow-land storage at an arid site.

The alternative of using excess DU to mix with excess HEU to produce fuel grade UF₆ for power reactor fuel manufacture would consume only a fraction of DOE's excess DU inventory. In addition, this alternative would be very costly (\$115/kg) compared to long-term storage for other future applications.

A major portion of the DOE DU UF₆ inventory could be utilized by the shielding option. Storage of DU would be required for the technology, competitive economics, and substantial demand for the shielding option to be developed. If the shielding end-use is developed it is recommended that DU container shielding components be recoverable in order to be available for potential economically attractive future applications such as blanket and mixed oxide fuel material for liquid metal fast breeder reactors or in other uses that may develop.

8. ABANDONMENT OR DESTRUCTION OF EXCESS MATERIAL

In the previous report¹, a broad range of disposal technologies were assessed; near-surface RCRA-type and isolated deep geological disposal. The NPV cost for disposal was found to be triple the NPV cost for perpetual storage, see the LONG-TERM STORAGE FOR FUTURE APPLICATIONS section. Two additional options for disposing of SRS's excessed UO₃, dispose of material through SRS's Y-Area Saltstone or S-Area DWPF glassification processes, have been suggested¹⁶ for analysis. The following analysis shows that these options would be very costly.

8.1 Dispose of SRS UO₃ in Saltstone

The SRS Saltstone process mixes low-level aqueous waste ("decontaminated" HLW supernate and sludge from the F and H Area wastewater Effluent Treatment Facility) with flyash and cement. The resultant slurry is poured into large engineered vaults where it solidifies. Filled vaults will eventually be covered with native soil and capped with "impermeable" clay. Saltstone composition is in Table 8.

Preliminary estimates of the amount of uranium that could be placed in saltstone based only on protection of groundwater to the 4 mrem/y Environmental Protection Agency (EPA) limit¹⁷ are in Table 9. These values are based on saltstone groundwater modelling done by

16 Letter: Bilyeu, J. D. (DOE FO/SR) to Gould, T. H. (WSRC), DEPLETED URANIUM DISPOSITION REPORT, NMP-92-01, September 9, 1992.

17 Inter-Office Memo: Wilhite, E. L. (WSRC) to Becker, G. W. (WSRC), ESTIMATED URANIUM LIMITS IN SALTSTONE, September 24, 1992.

Interra¹⁸ and on estimated uranium isotopic distributions in SRS soluble waste¹⁹. These estimated values may be revised by the DOE-5820.2A required Saltstone Performance Assessment, which is currently underway. The dose-equivalent estimated limit for only DU is 0.494 nCi/g of saltstone or a loading of 0.145 wt % DU in saltstone. Based on the saltstone variable cost from the recent SRS Waste Cost Analysis²⁰ (\$107/t of saltstone) the variable cost of disposing of DU in Saltstone would be \$74/kg of DU. In addition, fixed costs for new facilities, equipment, and new operational and support personnel required to introduce UO₃ into the Saltstone process would be required.

Table 8: DU Saltstone Composition

Component	Weight %	Component	Weight %
Flyash	46.0	Water	30.2
Cement	11.5	NaNO ₃	6.0
NaOH	1.9	NaNO ₂	1.5
NaAl(OH) ₄	1.3	Na ₂ SO ₄	0.7
Other	0.755	DU	0.145

Table 9: Estimated Uranium Limits in SRS Saltstone.

U Isotope	Limit ppm of Saltstone	Limit nCi/g of Saltstone	Ingestion Dose, mrem/pCi of Isotope	Specific Activity, Ci/g of Isotope	Ing. Dose mrem/g of Saltstone
233	0.0176	0.17	2.7×10^{-4}	9.66×10^{-3}	0.0459
234	0.0193	0.12	2.6×10^{-4}	6.23×10^{-3}	0.0312
235	2.31	0.05	2.5×10^{-4}	2.16×10^{-5}	0.0125
236	0.773	0.05	2.5×10^{-4}	6.47×10^{-5}	0.0125
238	149.0	0.05	2.3×10^{-4}	3.36×10^{-7}	<u>0.0115</u>
Dose Equivalent DU	1450.0	0.494	2.3×10^{-4}	3.40×10^{-7}	0.114

8.2 Dispose of SRS UO₃ in DWPF Glass

The DWPF process encapsulates SRS HLW insoluble solids and soluble radioisotopes removed from HLW supernate (Cs/Ba-137, Sr/Y-90, etc.) in borosilicate glass. The DWPF is expected to produce 410 glass cans per year. Reference parameters of the DWPF can and glass product are in Table 10.

- 18 Wilhite, E. L. (WSRC) to Sturm, H. F. (WSRC), SALTSTONE DISPOSAL VAULT PERFORMANCE EFFECT OF FORMULATION VARIATION, DPST-88-332, February 29, 1988.
 19 Fowler, J. R. (WSRC) to Wright, W. V. (WSRC), UPDATE OF CHEMICAL AND RADIOCHEMICAL COMPOSITION OF DECONTAMINATED SOLUBLE WASTE FROM THE PRECIPITATION PROCESS, DPST-82-759, August 6, 1982.
 20 Street, G. H. et. al., SRP WASTE COST ANALYSIS, WSRC-92-631, May 5, 1992.

Table 10: Reference DWPF Glass Can Parameters

Parameter	Value	Parameter	Value
Overall length, in.	118	Inside volume, ft ³	26.0
Outside diameter, in.	24	Glass volume, ft ³	22.1
Wall thickness, in.	3/8	Empty weight, lb	1,100
Material	304L SS	85% fill weight, lb	4,800
Waste loading, wt %	28		

In the following analysis it is assumed that DWPF borosilicate glass can be loaded with 28 wt% of DU. Canister fills are limited to 85% due to mechanical considerations. Based on costs from the recent SRS Waste Cost Analysis¹⁹, the DWPF operating and ultimate transportation/disposal cost per kg of encapsulated waste is expected to be \$1,250/kg. In the SRS Waste Cost Analysis variable portion of operating costs was generally assumed to be 25% of the total. Therefore the estimated cost of this disposal option for SRS DU UO₃ would be about \$630/kg of DU. In addition, new facilities and equipment would be required to introduce UO₃ into the DWPF process.

9. PROPOSED SRS DU DISPOSITION DECISION PLAN

9.1 SRS Status

Since the last report, SRS has initiated efforts to disposition excess uranium materials listed in Table 11 via the steps outlined in Section 4. DISPOSITION: FEDERAL ACQUISITION REGULATIONS. Nuclear material advertisements for the Commerce Business Daily have been prepared²¹ and an excess nuclear materials bulletin soliciting interest within the DOE for these materials has been issued by SRFO. The largest portion of these excess uranium materials is the 36,000 DU UO₃ drums.

As reported previously, these 35,000 drums of depleted UO₃ are stored in eight warehouses at various locations across the SRS. Several of the buildings are old and deteriorating from the weather. Six of these warehouses are about 40 years old. Mechanical strength and containment deterioration due to corrosion are major concerns for these 1,600 lb. drums. Inadequate and cramped storage area also prevents (1) visual inspection of the containers for corrosion damage, (2) counting of drums for nuclear material inventory purposes, and (3) visual inspection of the tamper indicating seals which attach the drum lids as required by DOE Order 5633.3, Control and Accountability of Nuclear Materials. SRS's proposed Improved Uranium Containment project to provide a centrally located, secure, and environmentally sound facility to properly store these drums for 50 years was put on hold in FY90 pending resolutions of uncertainties such as potential future DOE utilization of SRS DU, consolidation of excess uranium at a site other than SRS, and sale or transfer to other Government Agencies or other qualified donees.

²¹ Olson, C. E. (WSRC), NUCLEAR MATERIAL ADVERTISEMENTS FOR THE COMMERCE BUSINESS DAILY, WSRC-RP-92-1105, September 18, 1992.

9.2 SRS DU Disposition Decision Plan

A proposed SRS DU Disposition Decision Plan and Schedule (Figure 1 and Table 12) were put together with preliminary guidance from Savannah River Operations Office. The plan consists of work element descriptions and scheduling that follows the steps discussed in Section 4. **DISPOSITION: FEDERAL ACQUISITION REGULATIONS.** A preliminary assignment of responsibility, input, approval and receipt of plan deliverables to Savannah River Operations Office, Westinghouse Savannah River Company, Office of Weapons and Materials Planning, and General Services Administration is also included on Table 12. Preliminary dates for the major steps of the SRS DU Disposition Decision Plan are in Table 1.

Table 11: Excess SRS Uranium Materials to be Offered

MATERIAL	METRIC TONS	COMMENTS
UO ₃	19,417	Oxide powder from Pu-239 production stored in 36,000 drums.
	11.5	Miscellaneous oxide in 41 drums
	19,428.5	
DU metal	301	50,566 Mark 31A bare DU cores
	609	48,180 Mark 31B bare DU cores
	687	115,194 Mark 31As, each clad with about 175g Al and 9g Ni.
	962	76,694 Mark31Bs, each clad with about 310g Al and 15g Ni.
Total	2,615	
LEU	3	Mark 15 production residues (uranium oxide in filter media) in 74 and 55 gal drums.
	95	UO ₃ in 372 drums recovered from Mark 15 campaigns.
Total	98	
NU metal	20	About 4,940 unclad metal fuel rods from 305-M test pile.
	15	1,016 unclad Mark25A and unclad 1,022 Mark25B

9.3 SRS Storage Options

The following discussion assumes that the bulk of SRS's UO₃ DU will not be dispositioned by steps 1, 2, and 3 in Table 1 and will require long-term storage. In the previous report long-term retrievable storage of DU in a Energy Resource Reserve is preferred over disposal because of DU's potential value for breeder reactors. In addition, the net present value (NPV) cost of indefinite storage of currently excess DU was estimated

to be about one-third of DU's NPV disposal cost (\$2.5/kg vs \$8.5/kg)¹. These costs were obtained by analyzing a broad range of storage and disposal technology options; near-surface RCRA-type and isolated deep geological disposal and above grade warehousing and retrievable shallow-land storage at an arid site. Serious depletion of natural resources for fossil and fissile power plants is expected by the mid 21st century. DU storage until that time would allow the future nuclear power configuration (e.g., breeder reactors) to develop.

Based on the proposed SRS Disposition Decision Plan a decision on the long-term storage location for SRS materials remaining after sales activities is scheduled for October 1993. The options for future long-term storage of SRS's DU are:

1. SRS's proposed FY 93 Improved Uranium Containment capital line item (\$24.4 million) to provide a centrally located, secure, and environmentally sound facility to store as many as 50,000 drums of "low-level radioactive" excess uranium, such as the 35,000 drums of SRS DU UO₃, for 50 years. Justification for this project is discussed in Section 9.1.
2. Transfer UO₃ drums as well as other excess uranium materials left after step 1, 2, and 3 of Table 1 are completed to another DOE site.
 - a. Return materials to Y-12, the Central Scrap Management Office (CSMO), for uranium scrap. The CSMO is currently developing a plan for storing DU, LEU and NU DOE Program Material, On Loan or Lease, and Commercial Licensee located at education facilities^{22,23}. It is understood that the significant quantities of uranium scrap located at DP facilities (SRS, Rocky Flats, Hanford, etc.) may also be considered in a comprehensive CSMO storage plan for Y-12. ORFO and the uranium CSMO planning results should be available prior to completion of the proposed SRS Disposition Decision Plan.
 - b. Transfer SRS materials to the semi-arid NTS for retrievable shallow-land storage. This option was analyzed in the previous report.

Consolidation of the proposed uranium Energy Resource Reserve at one site during the transition to Complex 21 would provide long-term materials management simplifications and savings from duplication of efforts. It is recommended that SRFO monitor ORFO and the uranium CSMO planning efforts to consolidate DOE uranium scrap at Y-12 in order to integrate Savannah River plans in a timely and cost effective manner.

22 Becker, Jr., G. W. (WSRC), UNIVERSITY NORMAL URANIUM SLUG DISPOSITION STUDY, NMP-92-04, August 21, 1992.

23 Becker, Jr., G. W. (WSRC), UNIVERSITY NORMAL URANIUM SLUG DISPOSITION STUDY - UNIVERSITY RESPONSES, NMP-92-05, September 1, 1992.

Figure 1: Proposed SR DU Disposition Plan

1. USE WITHIN GOVERNMENT**1.1 INTERNAL****1.1.1 EXCESS NUCLEAR MATERIAL BULLETIN**

Formal notification of excess nuclear materials availability to the DOE/Contractor Complex. Responses will be assessed. Net amount of material for further disposition considerations will be defined.

STATUS Done, 9/10/92 to 10/10/92.

FROM 9/10/92
TO 10/12/92

RESPONSIBLE SR
INPUT DP-27
APPROVE SR
RECIPIENT Field Offices, DP-27

1.2. SCREEN OTHER GOVERNMENT AGENCIES**1.2.1 SCREENING DECISION**

A DOE decision will be made concerning whether or not screening for use by other Government Agencies by the General Services Administration will be pursued.

STATUS Done, GSA will Screen

FROM 9/10/92
TO 9/10/92

RESPONSIBLE SR
INPUT DP-27
APPROVE SR
RECIPIENT

1.2.2 DEFINE EXCESS MATERIALS FOR SALE

Prepare material descriptions for GSA screening.

STATUS Initiated, Preliminary listing

FROM 10/22/92
TO 10/28/92

RESPONSIBLE WSRC
INPUT SR
APPROVE SR
RECIPIENT GSA

1.2.3 REQUEST GSA SCREEN

Interface with GSA and request screen.

STATUS Initiated by SR on 10/5/92.

FROM 10/22/92
TO 10/28/92

RESPONSIBLE SR
INPUT
APPROVE SR
RECIPIENT GSA Regional office

1.2.4 GSA SCREENS GOVERNMENT AGENCIES

GSA completes process.

STATUS

FROM 10/27/92
TO 12/28/92

RESPONSIBLE GSA
INPUT SR, WSRC
APPROVE
RECIPIENT SR

1.2.5 GSA SCREENS FOR DONATION

GSA completes process. This option of donating material outside of the Government is exercised as the last step prior to either extended storage or abandonment of disposal.

STATUS

FROM 12/4/92
TO 1/18/93

RESPONSIBLE GSA
INPUT SR, WSRC
APPROVE SR
RECIPIENT SR

2. SALE OF MATERIAL**2.1 SOLICIT INTEREST****2.1.1 CHARACTERIZE FOR SALE**

Characterize materials for sale.

STATUS

FROM 9/11/92
TO 11/19/92

RESPONSIBLE WSRC
INPUT SR, DP-27
APPROVE SR, DP-27
RECIPIENT Interested Parties

2.1.2 NOTICE OF AVAILABILITY

Prepare NOA.

STATUS Draft completed

FROM
TO 9/10/92

RESPONSIBLE WSRC
INPUT SR
APPROVE SR
RECIPIENT DP-27

2.1.3 COMMERCE BUSINESS DAILY

Place advertisement.

STATUS

FROM 1/10/93
TO 3/16/93

RESPONSIBLE DP-27
INPUT SR
APPROVE DP-27
RECIPIENT CBD

2.1.4 INFORMATION MEETING

Information meeting to furnish additional details prior to the formal proposal stage.

STATUS

FROM 3/17/93
TO 3/18/93

RESPONSIBLE SR
INPUT WSRC
APPROVE
RECIPIENT Interested parties

2.1.5 DECISION TO SELL MATERIAL

Assess expressions of interest and decide whether to sell.

STATUS

FROM 3/19/93
TO 4/1/93

RESPONSIBLE DP-27
INPUT SR
APPROVE DP-27
RECIPIENT

Table 12

2.2 REQUEST FOR PROPOSAL**2.2.1 REQUEST FOR PROPOSAL**

Prepare RFP.
STATUS

FROM 4/2/93
TO 5/13/93

RESPONSIBLE SR
INPUT DP-27
APPROVE SR, DP-27
RECIPIENT Interested Parties

2.2.2 NEPA REVIEW FOR SALE

Preliminary analysis of risks to health and environment and a determination of type of NEPA documentation that may be required.
STATUS

FROM 5/14/93
TO 7/8/93

RESPONSIBLE WSRC
INPUT
APPROVE SR, DP-27
RECIPIENT SR, DP-27

2.2.3 SOLICIT BIDS

Send out RFP to interested parties.
STATUS

FROM 5/14/93
TO 7/8/93

RESPONSIBLE WSRC
INPUT
APPROVE SR, DP-27
RECIPIENT Interested Parties

2.2.4 ASSESS BIDS

Assess proposals from interested parties.
STATUS

FROM 7/9/93
TO 8/5/93

RESPONSIBLE SR, DP-27
INPUT WSRC
APPROVE SR, DP-27
RECIPIENT

2.3 DECISION**2.3.1 AWARD CONTRACT(S)**

Award contracts.
STATUS

FROM 8/6/93
TO 8/19/93

RESPONSIBLE SR
INPUT
APPROVE SR, DP-27
RECIPIENT Interested Parties

2.3.2 SHIP TO BUYER(S)

Material preparation, packaging, and transfer to buyer(s).
STATUS

FROM
TO

RESPONSIBLE WSRC
INPUT SR
APPROVE SR
RECIPIENT

3. DISPOSITION DETERMINATION**3.1 STORAGE OR DISPOSAL****3.1.1 DISPOSITION DECISION**

Document the basis for continued storage for future use or disposal. 45 CFR 612-3 (a) "Contractor inventory may be stored ... when the contracting officer determines that it should be retained in storage for anticipated use." per 45.611 (a) "The plant clearance officer shall determine in writing that - (1) The property has no commercial value and no value to the Government; (2) The estimated cost of care and handling is greater than the probable sale price; "

STATUS Partially done, DU Disposition Report. and Supplement Disposition Report.

FROM 11/1/92
TO 4/16/93

RESPONSIBLE SR
INPUT WSRC
APPROVE SR, DP-27
RECIPIENT

4. DISPOSITION**4.1 DISPOSAL OF MATERIAL****4.1.1 DECLARATION OF WASTE**

Declaration of selected materials as waste. Interface with EM to arrange terms of transfer of material (e.g., treatment, characterization, packaging, and shipping requirements.) The following is based on waste being sent to NTS in same manner as FEMP DU waste materials..

STATUS

FROM 8/20/93
TO 9/18/93

RESPONSIBLE SR
INPUT WSRC
APPROVE DP-27
RECIPIENT EM

4.1.2 CHARACTERIZATION

Characterize selected materials with respect to isotopics, physical, chemical, RCRA components, etc.

STATUS Not hazardous

FROM 9/17/93
TO 11/19/93

RESPONSIBLE WSRC
INPUT SR
APPROVE SR
RECIPIENT EM

Table 12

4.1.3 NEPA REVIEW BY EM	FROM 11/12/93 TO 1/6/94	RESPONSIBLE WSRC INPUT SR APPROVE SR RECIPIENT SR
Preliminary analysis of risks to health and environment and a determination of type of NEPA documentation that may be required. STATUS		
4.1.4 TRANSFER MATERIAL TO EM SITE	FROM 1/6/94 TO	RESPONSIBLE WSRC WM&ER INPUT SR ER&WM and APPROVE SR ER&WM and RECIPIENT
Package selected waste materials and ship material to selected EM site. STATUS		
4.2 STORAGE FOR FUTURE USE		
4.2.1 ALTERNATIVE STORAGE LOCATION	FROM 8/20/93 TO 10/11/93	RESPONSIBLE WSRC INPUT SR, DP-27 APPROVE SR, DP-27 RECIPIENT SR
Analysis of alternate storage options. Assuming UO3 is retained for future use, the current options are: continued storage at SR or other site, e.g. transfer to a ORFO facility or to the NTS. STATUS Partially done.		
4.2.2 NEPA REVIEW FOR STORAGE	FROM 6/6/93 TO 7/29/93	RESPONSIBLE WSRC INPUT SR, DP-27 APPROVE SR, DP-27 RECIPIENT SR
Preliminary analysis of risks to health and environment and a determination of type of NEPA documentation that may be required. STATUS		
4.2.3 FACILITATE LONG TERM STORAGE PLAN	FROM 10/14/93 TO	RESPONSIBLE SR INPUT APPROVE RECIPIENT
STATUS		

**DISTRIBUTION FOR NMP-92-06, Rev. 1
DEPLETED URANIUM DISPOSITION STUDY - SUPPLEMENT (U)**

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NMPS File, 703-42A