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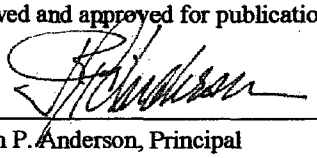
TECHNICAL MEMORANDUM 0706

June 13, 2007

Originators: Andrew H. Thatcher, CHP, Technical Director

Subject: Kodak CFX De-Fueling Man-REM Budget

Revision: 0

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by:  6/15/2007
Barton P. Anderson, Principal Date

1 INTRODUCTION

1.1 Kodak facility de-fueling operations is a complex, multi-step process that is fully detailed in the work plan. Exposures associated with the steps involved in the work plan are estimated in this man rem budget.

1.2 This paper will show that the predicted individual and collective dose do not approach administrative limits and that the extremity limits are a small fraction of the allowable limit.

1.3 BACKGROUND

1.3.1 The CFX has been in operation since 1975 and has been shutdown since June of 2006. The CFX was a sub-critical assembly of uranium 235 utilizing a californium 252 source[1]. The californium source has remained inserted into the CFX for most of the life of the CFX such that the total estimated operational hours are 252,000 at an average power of 5.8 watts. Further details of the CFX assembly and characteristics may be located in the EKC Scoping Study.[2]

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[1] The CFX was designed to never exceed a K_{eff} <0.99.

[2] NEXTEP TM0703 *Eastman Kodak Company CFX Decommissioning Project Scoping Study*, Robert Newman and Ning Zhang

2 SCOPE

2.1 This paper will show that the calculated individual and collective dose does not exceed administrative limits in a maximum worst case condition.

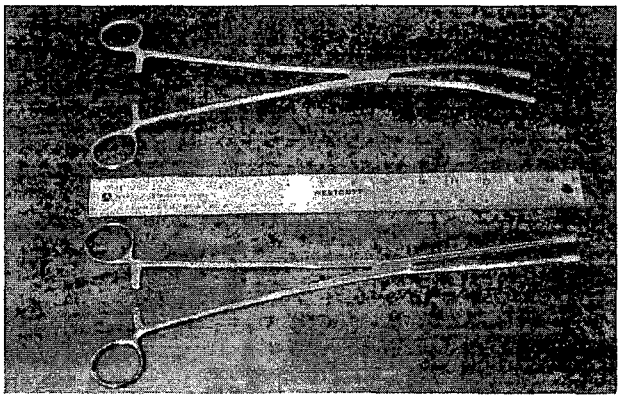
2.2 The calculations are separated into the effective dose for the whole body, subject to a 5 rem/yr regulatory limit and 500 mR/yr administrative limit, and the shallow dose equivalent to the skin and extremities subject to a regulatory limit of 50 rem/yr and an administrative limit of 5 rem/yr.

3 METHODS

3.1 Attachment A is an Excel spreadsheet that details the major steps involved in the de-fueling operations and calculates both a total and individual dose as well as the total and individual extremity dose. Table A-1 provides calculations for gamma dose and Table A-2 contains calculations for dose due to beta radiation.

3.2 Numerous assumptions are necessary when calculating the dose from de-fueling operations. A number of significant assumptions are as follows:

3.2.1 Tongs or other holding utensils will be employed during fuel plate handling. It is assumed that the distance of the extremities will be at least 6" from the source during operations. The actual tongs employed will be 14" in length (effective length 10.5 inches). The reduction in extremity dose with these tongs is approximately a factor of 15. A picture of the modified tongs is presented in Figure 3.1.



14 Inch Modified Tongs for Fuel Plate Handling
Figure 3.1

3.2.2 Specialty tongs will also be used for transfer of the cans from the work table to the scale and to the 2R container.

3.2.3 During assembly removal, individuals are assumed to stand immediately adjacent to the CFX for ease of access to the structure.

3.2.4 In many instances, two individuals are listed as required for a given operation and the estimated dose is doubled as a result. As a practical matter, many operations will only require a single individual with periodic assistance from the 2nd individual.

3.2.5 The time to perform operations is conservatively biased high.

3.2.6 The distance assumed for effective dose calculations is biased low.

3.2.7 No efficiency improvements were considered in performing the repetitive tasks associated with handling the plates and filling the canisters for loading.

3.2.8 No credit is provided for the reduction of beta dose by the wearing of one to two pair of gloves.

3.2.9 The background dose rate in the cavity (>1m from CFX or fuel plates) will be less than 1 mrem/hr and is not considered in the overall man rem budget.

3.3 Supporting calculations from both the CFX as well as individual fuel plates for the gamma dose are performed using the Microshield Code[3] and are included as Attachment B for the estimated dose rate at 6". Additional calculations of dose from the CFX, 6M drums, and fuel plates may be found in the following technical memos (TM): TM0519[4], TM0702[5], TM0603[6].

3.4 Beta dose calculations were performed using the Varskin V2.0 computer code[7].

4 RESULTS

4.1 Table 4.1 displays the overall results. The Excel spreadsheet is analyzed by each step from a dose standpoint. Each step is summed individually and collectively for both effective and extremity dose.

Table 4.1
Man-Rem Budget Summary

Individual Total Effective Dose Equivalent (rem)	Combined Total Effective Dose Equivalent (rem)	Individual Shallow Dose Equivalent (rem)	Combined Shallow Dose Equivalent (rem)
0.089	0.150	3.4	6.2

4.2 The estimated Total Effective Dose Equivalent (TEDE) to the single individual with greatest exposure is approximately 0.09 rem, well less than both the administrative limit and the regulatory limit. In addition, that same individual is estimated to receive a shallow dose equivalent (SDE) of 3.4 rem, well less than the administrative and regulatory limit.

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3 Grove Engineering, Microshield Code, Version 5.03.

4 NEXTEP TM05-19, *Kodak CFX Core Residual Activity and Dose Modeling*, D. Thatcher, CHP.

5 NEXTEP TM0702 *Exposure Rate Estimates from Kodak MTR Plates in a 6M-55 Container*, A.H. Thatcher, CHP

6 NEXTEP TM0603 *Exposure Rate Estimates from Kodak MTR Fuel Plates*, A.H. Thatcher, CHP.

7 Durham, J.S. VARSKIN MOD 2 and SADDE MOD 2: *Dose from Skin Contamination*. NUREG/CR-5873. 1992.

4.3 The results show that the whole body dose is not a critical issue as the worst case estimated effective dose is less than 100 mrem for a single individual. Practical considerations for ALARA therefore focus on limiting the extremity dose. Plexiglas containers are made for the temporary storage of the Type II and Type III plates to eliminate the beta dose. An open ended box is also made for the canisters so that beta exposure from the plates will be greatly diminished.

4.4 For the CFX, the reflector material will be left in place during decommissioning to eliminate the beta dose during operations near the CFX. Lead shielding will be placed outside of the reflector to reduce the gamma component of dose as well as reduce the very minor contribution from bremsstrahlung[8]. In addition, while the top reflector must be removed the gain access to the plates, temporary Plexiglas shields under lead sheets will be placed over the baskets not being removed.

5 CONCLUSIONS

5.1 The estimated Total Effective Dose Equivalent (TEDE) to the single individual with greatest exposure is approximately 0.09 rem, well less than both the administrative limit and the regulatory limit. In addition, that same individual is estimated to receive a shallow dose equivalent (SDE) of 3.4 rem, well less than the administrative and regulatory limit (Section 4.2).

[8] Bremsstrahlung contributions were estimated as ~3 mrem/hr using the ISO-PC code.

ATTACHMENT A
Beta and Gamma Dose Calculations

Table A-1
Gamma Dose Calculations

Gamma contribution	personnel involved	Distance (ft) for effective dose	time (minutes)	Dose Rate (mrem/hr)	Maximum Effective Dose (mrem)	Whole Body Dose (mrem)	Dose Rate (mrem/hr)	Total Extremity Dose SDE (mrem)	Maximum Extremity Dose for a single individual (mrem)
Cavity Preparation									
Concrete Block removal	4	2 to 3'	75	9.00	11.95	12.00	9.00	12.00	3.00
WEP removal	2	1+	10	20.00	3.33	6.67	20.00	6.67	3.33
Remove Cf-252 source housing and support structure above the support structure housing	1	1	15	28.00	7.00	7.00	28.00	7.00	7.00
Disassembly									
Remove hex nuts for each of 4 control rods	1	1	10	28.00	4.67	4.67	28.00	4.67	4.67
Remove the set screws to the guide tubes	1	1	10	28.00	4.67	4.67	90.00	15.00	15.00
Remove upper support structure	2	1	5	28.00	2.33	4.67	28.00	4.67	2.33
Remove any additional tube penetrations that may pose a fuel plate removal obstacle	1	1	5	28.00	2.33	2.33	90.00	7.50	7.50
Remove poly above CFX	2	1	4	28.00	1.87	3.73	320.00	42.67	21.33
Remove two front angle supports	2	1	5	28.00	2.33	4.67	50.00	8.33	4.17
Back off screws for pressure plates 24 total	1	1	10	28.00	4.67	4.67	90.00	15.00	15.00
Remove reflector material surrounding CFX if possible	2	1	5	28.00	2.33	4.67	320.00	53.33	26.67
Place lead bricks around CFX - tape into place	2	1	5	28.00	2.33	4.67	320.00	53.33	26.67
Fuel Removal									-
Remove type III fuel plates	1	1	2	28.00	0.93	0.93	110.00	3.67	3.67
A Remove 29 type I plates	2	1	10	28.00	4.67	9.33	110.00	36.67	18.33
time to clean off plates	2	1	15	1.20	0.30	0.60	100.00	50.00	25.00
Remove and clean 4 type II plates	1	1	2	2.00	0.07	0.07	7.00	0.23	0.23
Prepare 1st stack, place into can and seal can	2	1.5	5	14.00	1.17	2.33	100.00	16.67	8.33
Record weight of can A	1	1.5	1	14.00	0.23	0.23	100.00	1.67	1.67
Place can A into drum 1	1	1	2	30.00	1.00	1.00	100.00	3.33	3.33
Place lids on 2R and drum and seal	2	1	10	2.00	0.33	0.67	10.00	3.33	1.67
Remove 1st drum to hoist area	2	1.5	5	1.50	0.13	0.25	10.00	1.67	0.83
B remove remaining fuel from first basket	2	1	2.413793	28.00	1.13	2.25	110.00	8.85	4.43
time to clean off plates	2	1	3.62069	1.20	0.07	0.14	100.00	12.07	6.03
Remove type I plates from second basket	2	1	8	20.00	2.67	5.33	110.00	29.33	14.67
time to clean off plates	1	1	12	1.20	0.24	0.24	100.00	20.00	20.00
prepare 2nd stack, place into can and seal can	2	1.5	5	14.00	1.17	2.33	110.00	18.33	9.17
record weight of can B	1	1.5	1	14.00	0.23	0.23	100.00	1.67	1.67
place can B into drum #2	1	1	2	30.00	1.00	1.00	100.00	3.33	3.33
Remove and clean 4 type II plates	1	1	2	2.00	0.07	0.07	7.00	0.23	0.23
Place lids on 2R and drum and seal	2	1	10	2.00	0.33	0.67	10.00	3.33	1.67
Remove drum to hoist area	2	1.5	5	1.50	0.13	0.25	10.00	1.67	0.83
C Remove remaining fuel from 2nd basket	2	1	2.413793	28.00	1.13	2.25	110.00	8.85	4.43
time to clean off plates	2	1	3.62069	1.20	0.07	0.14	100.00	12.07	6.03
Remove type I plates from third basket	2	1	8	20.00	2.67	5.33	110.00	29.33	14.67
time to clean off plates	1	1	12	1.20	0.24	0.24	100.00	20.00	20.00
prepare 3rd stack, place into can and seal can	2	1.5	5	14.00	1.17	2.33	110.00	18.33	9.17
record weight of can B	1	1.5	1	14.00	0.23	0.23	100.00	1.67	1.67
place can C into drum #3	1	1	2	30.00	1.00	1.00	100.00	3.33	3.33
Remove and clean 4 type II plates	1	1	2	2.00	0.07	0.07	7.00	0.23	0.23
Place lids on 2R and drum and seal	2	1	10	2.00	0.33	0.67	10.00	3.33	1.67
Remove drum to hoist area	2	1.5	5	1.50	0.13	0.25	10.00	1.67	0.83
D Remove 20 plates from basket 3	2	1	6.896552	28.00	3.22	6.44	110.00	25.29	12.64
time to clean off plates	2	1	10.34483	1.20	0.21	0.41	100.00	34.48	17.24
Remove 9 type I plates from basket 4, clean and place on table	2	1	3.103448	28.00	1.48	2.90	110.00	11.39	5.69
time to clean off plates	2	1	4.655172	1.20	0.09	0.18	100.00	15.52	7.76
Prepare stack, place into can and seal can	2	1.5	5	14.00	1.17	2.33	100.00	16.67	8.33
Record weight of can D	1	1.5	1	14.00	0.23	0.23	100.00	1.67	1.67
Place can D into drum 4	1	1	2	30.00	1.00	1.00	100.00	3.33	3.33
Remove and clean 4 type II plates	1	1	2	2.00	0.07	0.07	7.00	0.23	0.23
Place all 18 type II plates into Can E and E seal can	2	1	5	8.00	0.33	0.67	27.00	4.50	2.25
Record weight of Can E	1	1.5	1	4.00	0.07	0.07	27.00	0.45	0.45
Place can E into drum 4	1	1	2	8.00	0.27	0.27	27.00	0.90	0.90
Place lids on 2R and drum and seal	2	1	10	3.00	0.50	1.00	10.00	3.33	1.67
Remove drum to hoist area	2	1.5	5	2.00	0.17	0.33	10.00	1.67	0.83
F Remove remaining fuel from basket 4	2	1	10	28.00	4.67	9.33	110.00	36.67	18.33
clean off and stack	2	1	15	1.20	0.30	0.60	100.00	50.00	25.00
Prepare stack, place into can and seal can	2	1.5	5	14.00	1.17	2.33	100.00	16.67	8.33
Record weight of Can F	1	1.5	1	14.00	0.23	0.23	100.00	1.67	1.67
Place Can F into drum 5	1	1	2	30.00	1.00	1.00	100.00	3.33	3.33
Remove all remaining type III fuel from G CFX	2	1.5	10	1.50	0.25	0.50	110.00	36.67	18.33
Prepare stack, place into can and seal can	2	1.5	5	3.10	0.28	0.52	100.00	16.67	8.33
Record weight of Can G	1	1.5	1	3.10	0.05	0.05	100.00	1.67	1.67
Place can G into drum 5	1	1	2	6.60	0.22	0.22	100.00	3.33	3.33
Place lids on 2R and drum and seal	2	1	10	3.00	0.50	1.00	10.00	3.33	1.67
Remove drum to hoist area	2	1.5	5	2.00	0.17	0.33	10.00	1.67	0.83
Remove all 5 drums from cavity and place in loading dock	2	1.5	120	3.00	6.00	12.00	10.00	40.00	20.00
				Total Dose	99.28	148.88		876.12	497.62

Table A-2
Beta Dose Calculations

Beta contribution	personnel involved	Distance (feet)	time (minutes)	Dose Rate (mrem/hr)	Total Extremity Dose SDE (mrem)	Maximum Extremity Dose for a single individual SDE (mrem)
Cavity Preparation						
Concrete Block removal	4	2 to 3'	75	<<1		
WEP removal	2	1+	10	<<1		
Remove Cf-252 source housing and support structure above the support structure housing	1	1	15	<<1		
Disassembly						
Remove hex nuts for each of 4 control rods	1	1	10	<<1		
Remove the set screws to the guide tubes	1	1	10	<<1		
Remove upper support structure	2	1	5	<<1		
Remove any additional tube penetrations that may pose a fuel plate removal obstacle	1	1	5	<<1		
Remove poly above CFX	2	1	4	<<1		
Remove two front angle supports	2	1	5	<<1		
Back off screws for pressure plates 24 total	1	1	10	<<1		
Remove reflector material surrounding CFX if possible	2	1	5	<<1		
Place lead bricks around CFX - tape into place	2	1	5	<<1		
Fuel Removal				<<1		
Remove type III fuel plates	1	0.5	2	700.0	23.3	23.3
A Remove 29 type I plates	2	0.5	10	700.0	233.3	116.7
time to clean off plates	2	0.5	15	700.0	350.0	175.0
Remove and clean 4 type II plates	1	0.5	2	700.0	23.3	23.3
Prepare 1st stack, place into can and seal can	2	0.5	5	700.0	116.7	58.3
Record weight of can A	1	0.5	1	700.0	11.7	11.7
Place can A into drum 1	1	0.5	2	700.0	23.3	23.3
Place lids on 2R and drum and seal	2	1	10	200.0	66.7	33.3
Remove 1st drum to hoist area	2	1.5	5	200.0	33.3	16.7
B remove remaining fuel from first basket	2	0.5	2.413793	700.0	56.3	28.2
time to clean off plates	2	0.5	3.62069	700.0	84.5	42.2
Remove type I plates from second basket	2	0.5	8	700.0	186.7	93.3
time to clean off plates	1	0.5	12	700.0	140.0	140.0
prepare 2nd stack, place into can and seal can	2	0.5	5	700.0	116.7	58.3
record weight of can B	1	0.5	1	700.0	11.7	11.7
place can B into drum #2	1	0.5	2	700.0	23.3	23.3
Remove and clean 4 type II plates	1	0.5	2	700.0	23.3	23.3
Place lids on 2R and drum and seal	2	1	10	200.0	66.7	33.3
Remove drum to hoist area	2	1.5	5	200.0	33.3	16.7
C remove remaining fuel from first basket	2	0.5	2.413793	700.0	56.3	28.2
time to clean off plates	2	0.5	3.62069	700.0	84.5	42.2
Remove type I plates from second basket	2	0.5	8	700.0	186.7	93.3
time to clean off plates	1	0.5	12	700.0	140.0	140.0
prepare 2nd stack, place into can and seal can	2	0.5	5	700.0	116.7	58.3
record weight of can B	1	0.5	1	700.0	11.7	11.7
place can B into drum #2	1	0.5	2	700.0	23.3	23.3
Remove and clean 4 type II plates	1	0.5	2	700.0	23.3	23.3
Place lids on 2R and drum and seal	2	1	10	200.0	66.7	33.3
Remove drum to hoist area	2	1.5	5	200.0	33.3	16.7

D	Remove 20 plates from basket 3	2	0.5	6.896552	700.0	160.9	80.5
	time to clean off plates	2	0.5	10.34483	700.0	241.4	120.7
	Remove 9 type I plates from basket 4, clean and place on table	2	0.5	3.103448	700.0	72.4	36.2
		2	0.5	4.655172	700.0	108.6	54.3
	Prepare stack, place into can and seal can	2	0.5	5	700.0	116.7	58.3
	Record weight of can D	1	0.5	1	700.0	11.7	11.7
	Place can D into drum 4	1	0.5	2	700.0	23.3	23.3
	Remove and clean 4 type II plates	1	0.5	2	700.0	23.3	23.3
E	Place all 16 type II plates into Can E and seal can	2	0.5	5	700.0	116.7	58.3
	Record weight of Can E	1	0.5	1	700.0	11.7	11.7
	Place can E into drum 4	1	0.5	2	700.0	23.3	23.3
	Place lids on 2R and drum and seal	2	1	10	200.0	66.7	33.3
	Remove drum to hoist area	2	1.5	5	200.0	33.3	16.7
F	Remove remaining fuel from basket 4, clean off and stack	2	0.5	10	700.0	233.3	116.7
		2	0.5	15	700.0	350.0	175.0
	Prepare stack, place into can and seal can	2	0.5	5	700.0	116.7	58.3
	Record weight of Can F	1	0.5	1	700.0	11.7	11.7
	Place Can F into drum 5	1	0.5	2	700.0	23.3	23.3
	Remove all remaining type III fuel from CFX	2	1	10	700.0	233.3	116.7
	Prepare stack, place into can and seal can	2	1.5	5	700.0	116.7	58.3
G	Record weight of Can G	1	0.5	1	700.0	11.7	11.7
	Place can G into drum 5	1	0.5	2	700.0	23.3	23.3
	Place lids on 2R and drum and seal	2	1	10	200.0	66.7	33.3
	Remove drum to hoist area	2	1.5	5	200.0	33.3	16.7
	Remove all 5 drums from cavity and place in loading dock	2	1.5	120	200.0	800.0	400.0
	Total Dose					**5,396.6**	**3,019.1**

ATTACHMENT B

Microshield Calculations at 6" from the CFX and an Individual Fuel Plate

Conversion of calculated exposure in air to dose
FILE: C:\MS5\DATA\KODAK\POSTSD~1\TYPE1 MS5
Case Title: MTR plate exposure
This case was run on Wednesday, June 6, 2007 at 11:45:49 AM
Dose Point # 1 - (18,16,6) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	5.109e+004	7.857e+004
Photon Energy Fluence Rate	MeV/cm²/sec	3.074e+004	4.692e+004
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5.979e+001	9.129e+001
Absorbed Dose Rate in Air	mGy/hr	5.219e-001	7.970e-001
"	mrad/hr	5.219e+001	7.970e+001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.228e-001	9.515e-001
o Opposed	"	4.929e-001	7.525e-001
o Rotational	"	4.929e-001	7.525e-001
o Isotropic	"	4.361e-001	6.657e-001
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.595e-001	1.007e+000
o Opposed	"	6.246e-001	9.540e-001
o Rotational	"	6.246e-001	9.540e-001
o Isotropic	"	4.655e-001	7.106e-001
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5.495e-001	8.394e-001
o Posterior/Anterior	"	4.820e-001	7.360e-001
o Lateral	"	3.539e-001	5.400e-001
o Rotational	"	4.305e-001	6.573e-001
o Isotropic	"	3.646e-001	5.566e-001

Microshield External Exposure Calculations at 6" from a Type I Fuel Plate
Figure B-1

Conversion of calculated exposure in air to dose
FILE: C:\MS5\DATA\KODAK\POSTSD~1\CFXCUBE.MS5
Case Title: CFX as a cube
This case was run on Wednesday, June 6, 2007 at 11:33:31 AM
Dose Point # 1 - (48.16,5.16,5) cm

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	3.774e+004	8.509e+004
Photon Energy Fluence Rate	MeV/cm²/sec	2.284e+004	5.075e+004
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	4.438e+001	9.867e+001
Absorbed Dose Rate in Air	mGy/hr	3.874e-001	8.614e-001
"	mrad/hr	3.874e+001	8.614e+001
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4.621e-001	1.028e+000
o Opposed	"	3.660e-001	8.134e-001
o Rotational	"	3.660e-001	8.134e-001
o Isotropic	"	3.238e-001	7.197e-001
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4.894e-001	1.089e+000
o Opposed	"	4.636e-001	1.031e+000
o Rotational	"	4.636e-001	1.031e+000
o Isotropic	"	3.456e-001	7.682e-001
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4.078e-001	9.075e-001
o Posterior/Anterior	"	3.578e-001	7.957e-001
o Lateral	"	2.629e-001	5.839e-001
o Rotational	"	3.196e-001	7.106e-001
o Isotropic	"	2.708e-001	6.018e-001

Microshield External Exposure Calculation at 6" from CFX
Figure B2