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MUC- WHZ - 318
This document consists of 4 pages and 2 figures
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ARGONNE LABORATORY

September 4, 1945

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TO: F. Daniels

FROM: M. L. Goldberger

RE: Be and BeO Piles Using Enriched Uranium

At your request, we have investigated critical sizes and critical amounts of material in BeO piles using UO_2 containing 10% and 20% $U^{235}O_2$. For the sake of completeness, we have carried out the same calculations for Be, U piles.

The same values of the constants used in MUC-WC-MLG-7 are used here with the exception of the scattering cross section of BeO which was taken to be 9.8 b here as compared to the 10.3 b value used previously. The greatest uncertainties in the calculation are the values of the absorption cross section of BeO and the age. It is suggested that these values be determined experimentally before the results quoted here are taken too seriously.

The calculations were carried out assuming that the piles were homogeneous. Then we considered the effect of the proposed method of lumping which consists of hexagonal cylinders 3" between flat sides, with one inch radius holes, into which are put fuel sticks of three quarters inch radius. The bricks are made of pure BeO, the fuel sticks are a mixture of BeO and UO_2. Steam is to be passed through the annular space. We assumed that all the UO_2 formerly spread out uniformly over the entire cell was compressed into the fuel sticks. A preliminary study of the change in thermal utilization and resonance escape probability indicated that lumping has very little effect on the pile characteristics. This can be explained on the basis of the large diffusion lengths in BeO and inside the BeO, UO_2 slugs; the diffusion lengths are several times the linear dimensions of the respective regions, and consequently the neutron distribution is practically flat over the cell. If the cell size were to be increased, the effects of lumping would become more pronounced.

The results are summarized in the following two tables and in the two curves which show the critical mass of UO_2 or U as a function of their percent by weight in the pile. As in the above mentioned memo, the results are given for a bare, spherical pile. Losses are given as percents of the absorption in 25. Losses to Xe and other fission products, steam, tank walls, etc. were neglected throughout. The loss to steam is of the order of 0.05%.

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The symbols used are: L, diffusion length (cm); k, multiplication constant; $\varkappa^2$, negative Laplacian (cm^{-2}); τ, age of neutrons of birth energy 2 Mev (cm^2). $\varkappa^2$ is computed from the characteristic equation:

$$(L^2 \varkappa^2 + 1) = k\, e^{-\tau \varkappa^2}$$

The volume of a critical cylindrical pile of optimum shape may be found by multiplying the volumes given here by 1.14. The dimensions of this critical cylinder may be found from

$$\text{Radius} = 2.405 \sqrt{3/2\varkappa^2}$$

$$\text{Height} = \pi \sqrt{3/\varkappa^2}$$

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BeO Moderator

10% $U^{25}O_2$ / % UO_2	Loss to BeO	Res. Loss in 28	Thermal Loss in 28	Breeding Gain η-1-losses	L^2	k	$\bar{\gamma}^2 \times 10^3$	R_c	Crit. Vol.	Tot. Wt.	Weight UO_2	Weight UO_2 20% Voids
2.0	10.6%	19.7%	4.58%	0.75	154	1.57	1.24	89.2 cm	2.97 m^3	8910 kg	178.2 kg	278 kg
1.2	17.6	13	4.58	0.75	241	1.55	1.00	99.4	4.11	12330	148	231
1.0	21.4	10.4	4.58	0.74	284	1.54	0.91	104	4.71	14180	141.8	221.6
0.9	23.6	10.3	4.58	0.72	307	1.52	0.85	108	5.22	15660	140.9	220
0.8	26.5	9.26	4.58	0.70	337	1.50	0.78	112	5.95	17850	142.8	223
20% $U^{25}O_2$ / % UO_2												
0.7	15.2%	6.56	2.04	0.86	217	1.70	1.28	87.8 cm	2.84 m^3	8520 kg	59.6 kg	93.1 kg
0.6	17.7	5.77	2.04	0.845	247	1.67	1.17	91.8	3.24	9720	58.3	91.1
0.5	21.2	5.00	2.04	0.82	288	1.64	1.04	97.4	3.87	11610	58.1	90.8
0.4	26.6	4.39	2.04	0.77	346	1.58	0.87	106	5.05	15150	60.6	94.7
0.3	35.5	3.53	2.04	0.69	431	1.49	0.66	122	7.61	22830	68.5	107

Constants:

Operating Temperature 1800° K

$\eta = 2.1$

$\tau = 222\ cm^2$

σ_s BeO $= 9.8$ b

σ_a BeO $= 0.004$ b

$\sigma_a\ 25O_2 = 200$ b

$\sigma_t\ 25O_2 = 218$ b

$\sigma_a\ 28O_2 = 1.03$ b

$\sigma_t\ 28O_2 = 17.2$ b

$\rho_{BeO} = 3\ gm/cm^3$

σ_{tr} BeO $= 9.55$ b

$N_{BeO} = 0.0722 \times 10^{24}$ mol./cm^2

$L^2_{BeO} = 1670\ cm^2$

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Be Moderator

16% U^{25} %U	Loss to Be	Res. Loss in 28	Thermal Loss in 28	Breeding Gain η-1-losses	L^2	k	$\mathcal{H}^2 \times 10^3$	R_c	Crit. Vol.	Tot. Wt.	Weight U	Weight U 20% Voids
2.5	17.7%	17.4%	3.77%	0.71	113	1.51	2.03	69.7 cm	1.42 m^3	2630 kg	65.7 kg	103 kg
2.25	19.8	16.3	3.77	0.70	124	1.50	1.92	71.7	1.54	2850	64.2	100
2.1	21.1	15.4	3.77	0.695	131	1.50	1.85	73	1.63	3020	63.4	99.1
2.0	22.2	14.8	3.77	0.69	136	1.49	1.80	74	1.70	3145	62.9	98.3
1.75	25.5	13.6	3.77	0.67	147	1.47	1.63	77.8	1.97	3640	63.7	99.5
1.5	29.8	12.1	3.77	0.63	172	1.44	1.45	82.5	2.35	4350	65.2	102
1.25	35.9	11.0	3.77	0.59	198	1.39	1.19	91.0	3.15	5830	72.9	114
20% U^{25} %U												
1.3	17.2%	8.54%	1.67%	0.83	112	1.65	2.51	62.7 cm	1.03 m^3	1911 kg	24.8 kg	38.8 kg
1.2	18.7	8.09	1.67	0.82	120	1.64	2.39	64.3	1.11	2060	24.7	38.6
1.1	20.4	7.63	1.67	0.80	129	1.62	2.26	66.1	1.21	2240	24.6	38.4
0.9	25.1	6.60	1.67	0.77	153	1.58	1.93	71.5	1.53	2830	25.5	39.8
0.8	28.2	6.10	1.67	0.74	168	1.55	1.75	75.1	1.77	3280	26.3	41.1
0.7	32.2	5.52	1.67	0.71	186	1.51	1.55	79.8	2.13	3940	27.6	43.1

Constants:

Operating Temperature 900° K

$\eta = 2.1$ $\quad \sigma_t^{25} = 355$ b $\quad \rho_{Be} = 1.85$ gm/cm^3

$\tau = 100$ cm^2 $\quad \sigma_a^{28} = 1.46$ b $\quad \sigma_{tr}{}^{Be} = 4.63$ b

$\sigma_s^{Be} = 5.0$ b $\quad \sigma_t^{28} = 9.6$ b $\quad N_{Be} = 0.124 \times 10^{24}$ atoms/cm^2

$\sigma_a^{Be} = 0.006$ b

$\sigma_a^{25} = 345$ b $\quad L^2{}_{Be} = 773$ cm^2

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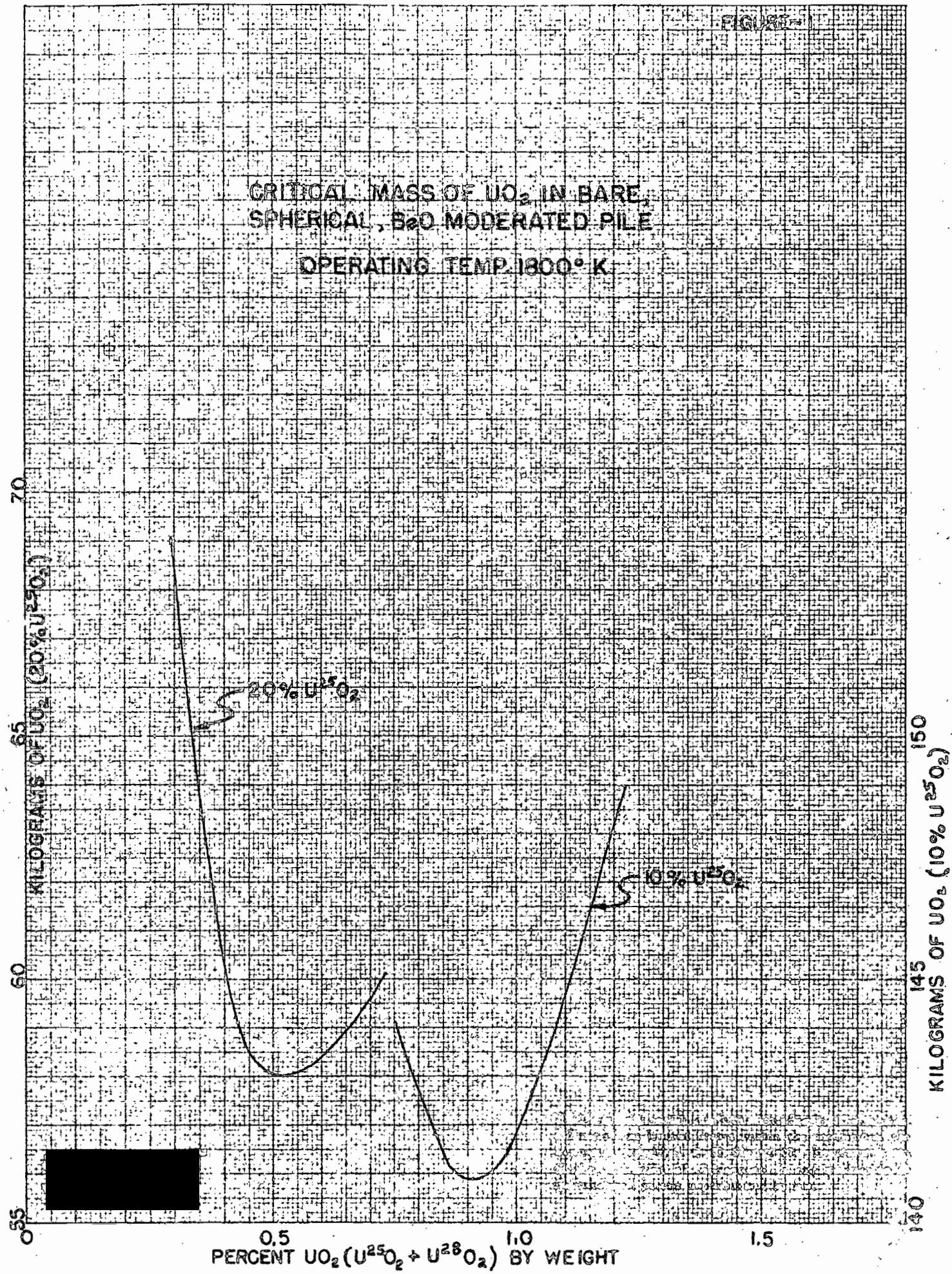
FIGURE-1



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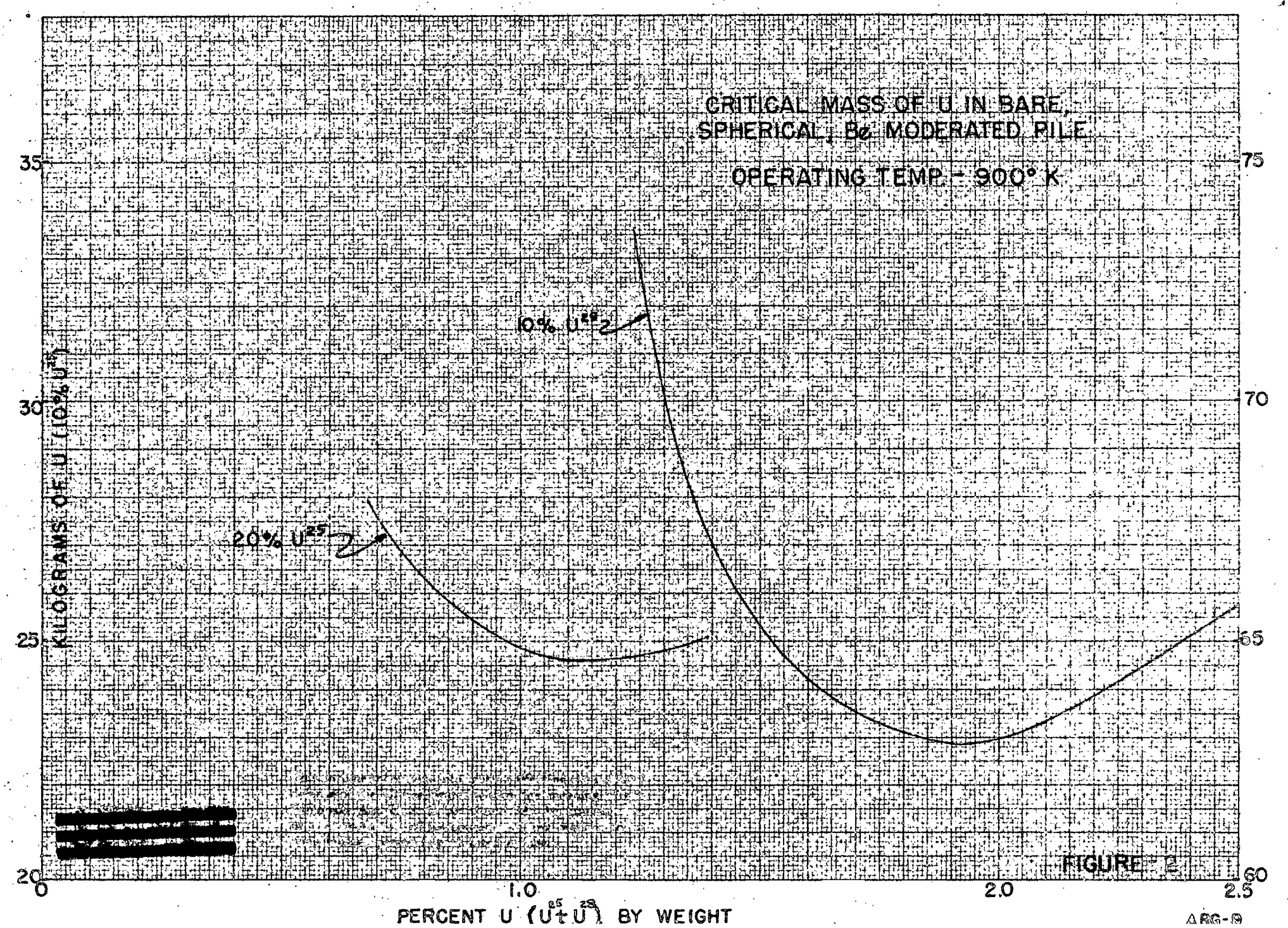

FIGURE 2

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