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Title: CRITICAL MASSES OF URANIUM DILUTED WITH MATRIX MATERIAL

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Critical Masses of Uranium Diluted with Matrix Material

By

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ABSTRACT

Critical masses of square-prisms of highly enriched uranium diluted in various X/^{235}U ratios with matrix material and polyethylene were measured. The configuration cores were 22.86-cm and 45.72-cm square and were reflected with 8.13-cm and 10.16-cm thick side polyethylene reflectors, respectively. The configurations had 10.16-cm thick top and bottom polyethylene reflectors. For some configurations, the Rossi-α, which is an eigenvalue value characteristic for a particular configuration, was measured to establish a reactivity scale based on the degree of subcriticality. Finally, the critical mass experiments are compared with values calculated with MCNP and ENDF/B-VI cross-sections.

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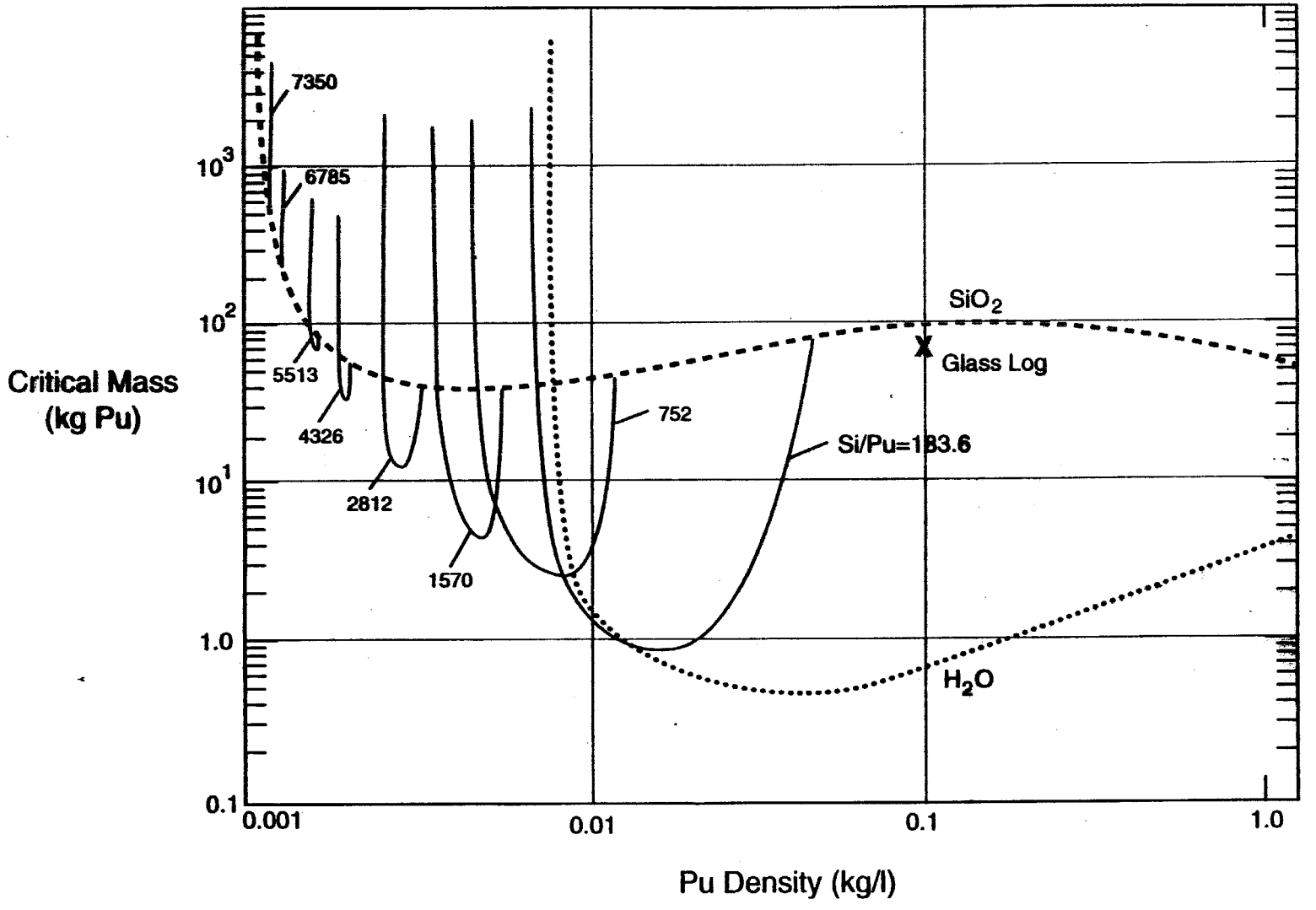
Brief History

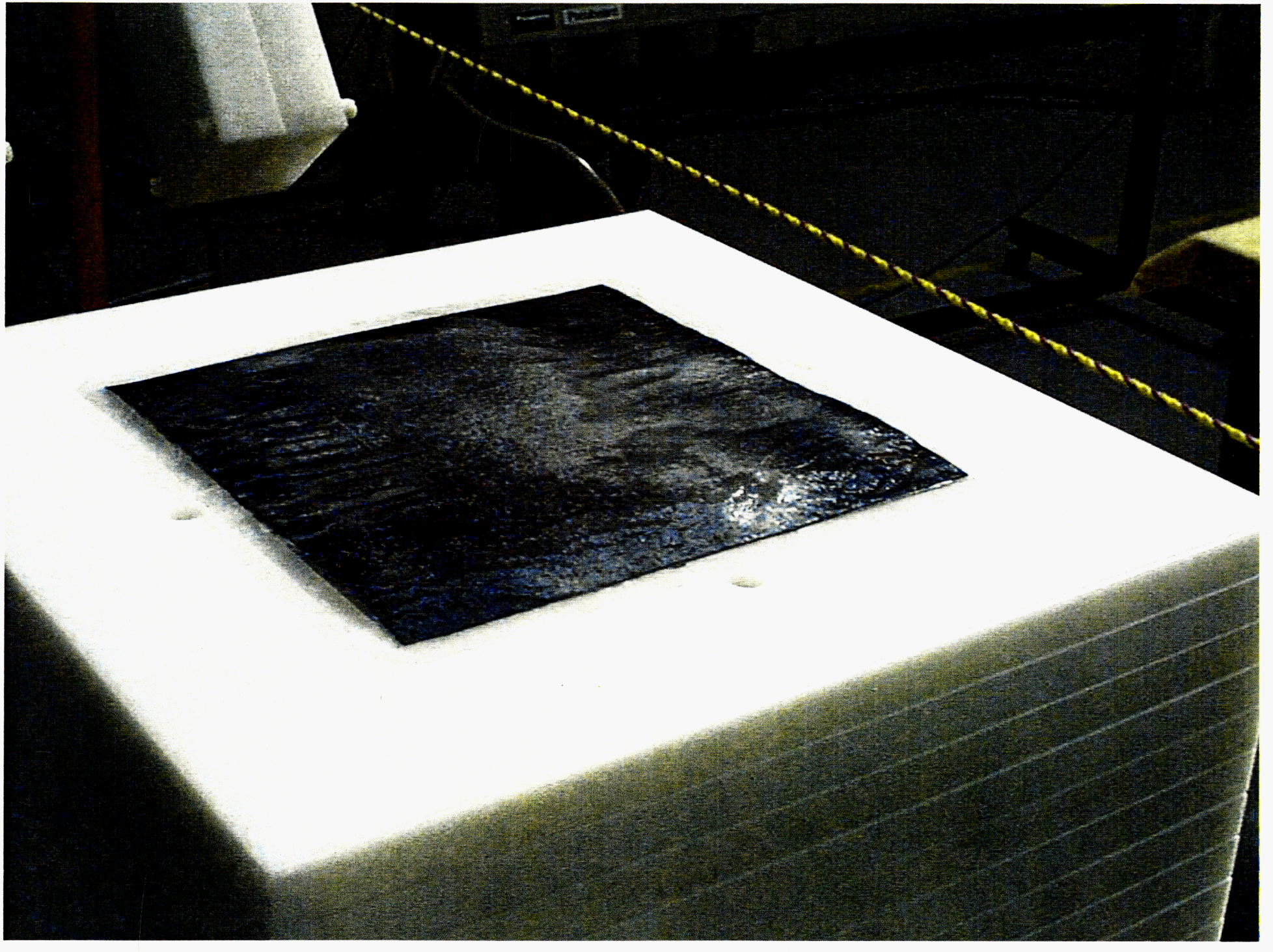
- 1990-1994 B. Briggs and associates performed calculations for TRU waste in storage at the RWMC
- 1995- C. Bowman "Underground Autocatalytic Criticality from Plutonium and Other Fissile Material"
- 1996- 1997 LACEF- Criticality of Mixures of Plutonium, Silicon Dioxide, and Water - Dynamic Behavior

Purpose

- The purpose of these experiments is to test the cross sections
  - » untested materials (SiO_2, MgO, Al_2O_3, CaO)
  - » untested regions
- No experimental critical data that can assure the correctness of calculations

Reflected Critical Mass of Plutonium Metal Mixed With SiO_2 and Water vs Plutonium Density

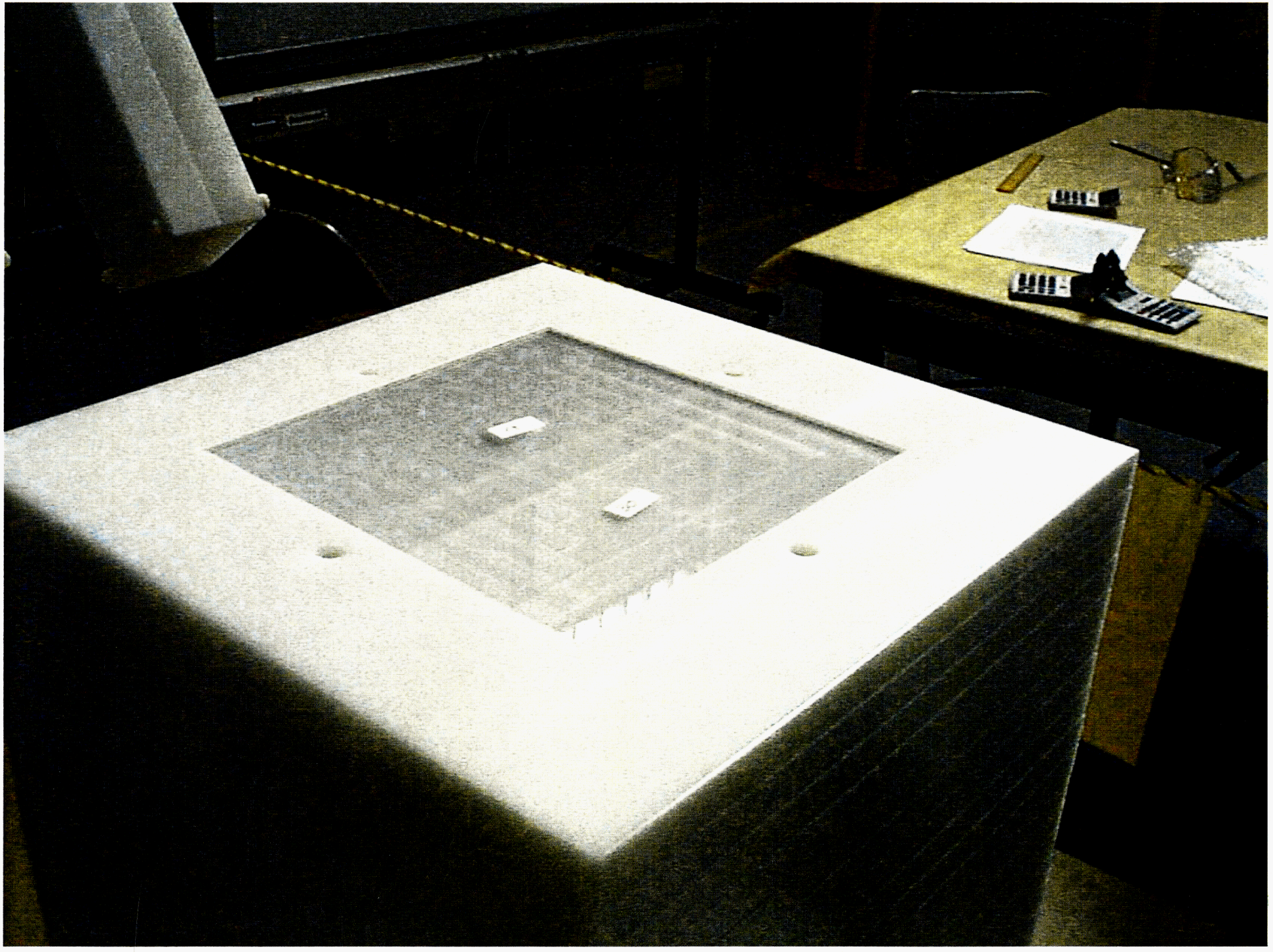




Weight and I. C. of the Foils

Foil #1	68 g	Foil #11	70 g
Foil #2	71 g	Foil #14	66 g
Foil #3	71 g	Foil #18	69 g
Foil #10	70 g	Foil #25	72 g
Foil #15	71 g	Foil #26	69 g

U-235	93.23 w%
U-238	5.37 w%
U-236	0.26 w%
U-234	1.13 w%



SiO_2 Plates

Low neutron absorbing material

Dimensions: 9"x9"x0.25" Weight: 753.3 g

Density = 2.2 g/cc

Chemical Composiiton:

SiO_2	99.997	w%	Cd	<0.01	ppm
Al	14	ppm	Cr	<0.05	ppm
As	<0.002	ppm	Fe	0.2	ppm
B	<0.2	ppm	Mg	0.1	ppm
Ca	0.4	ppm	Li	0.6	ppm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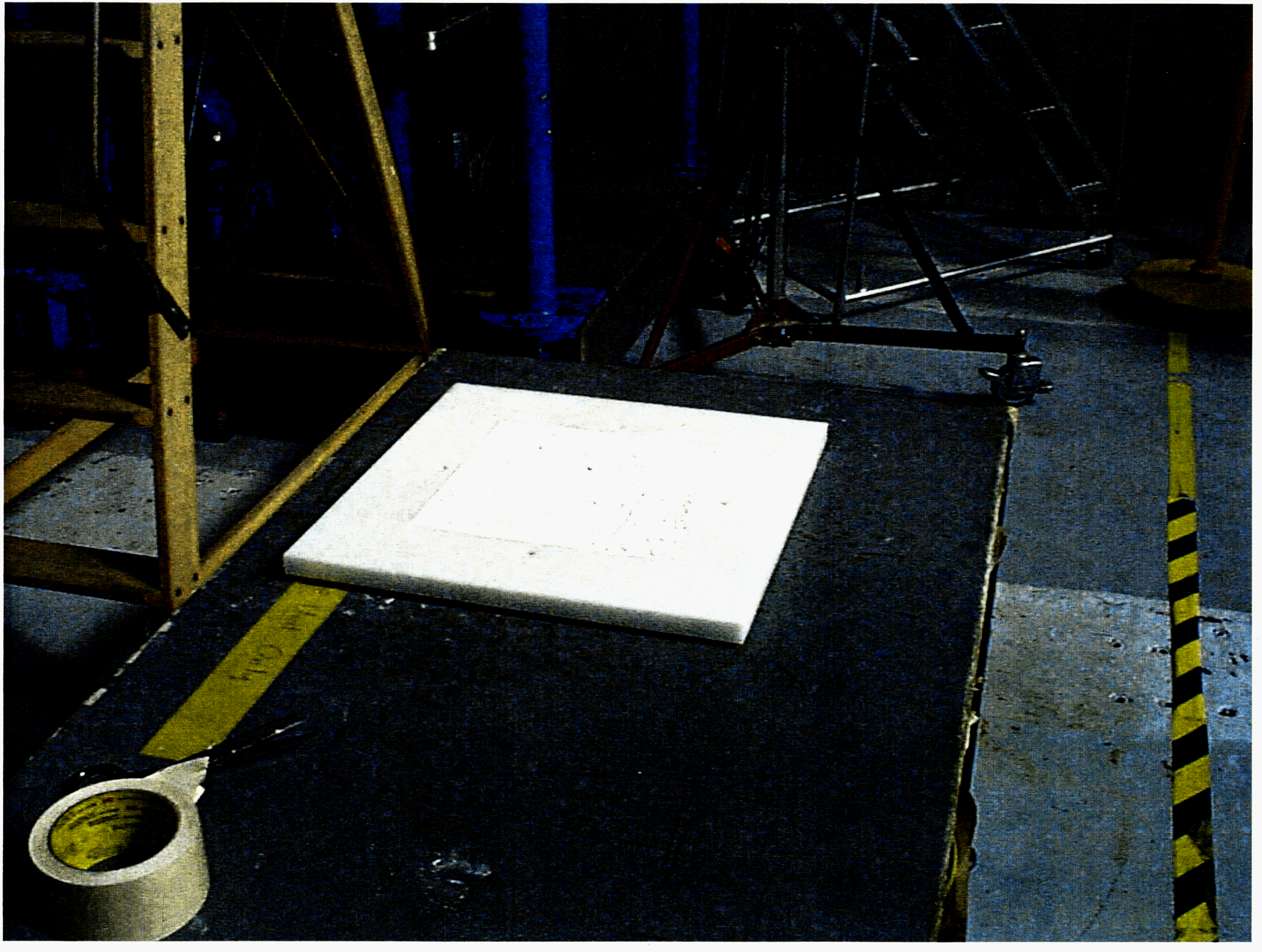
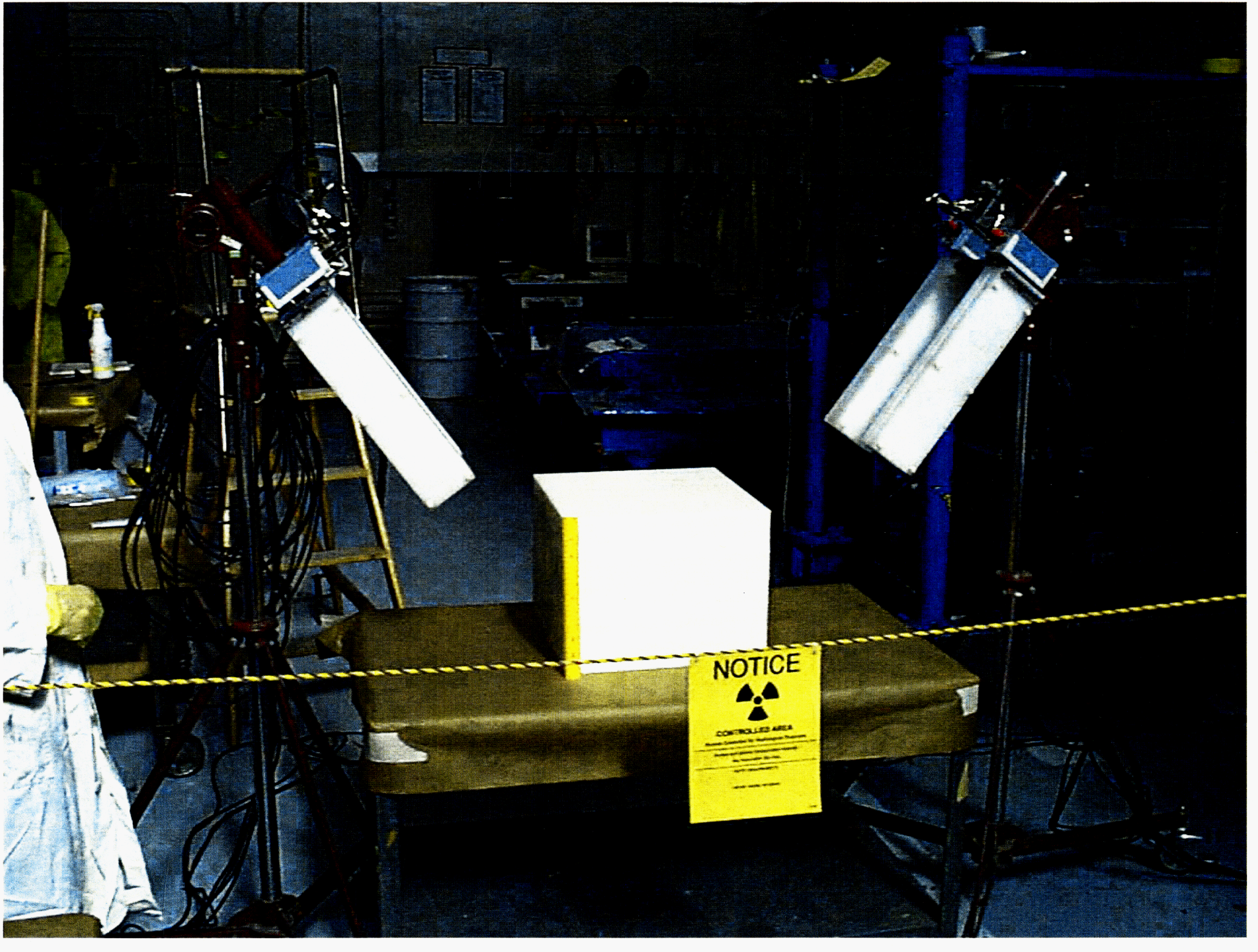


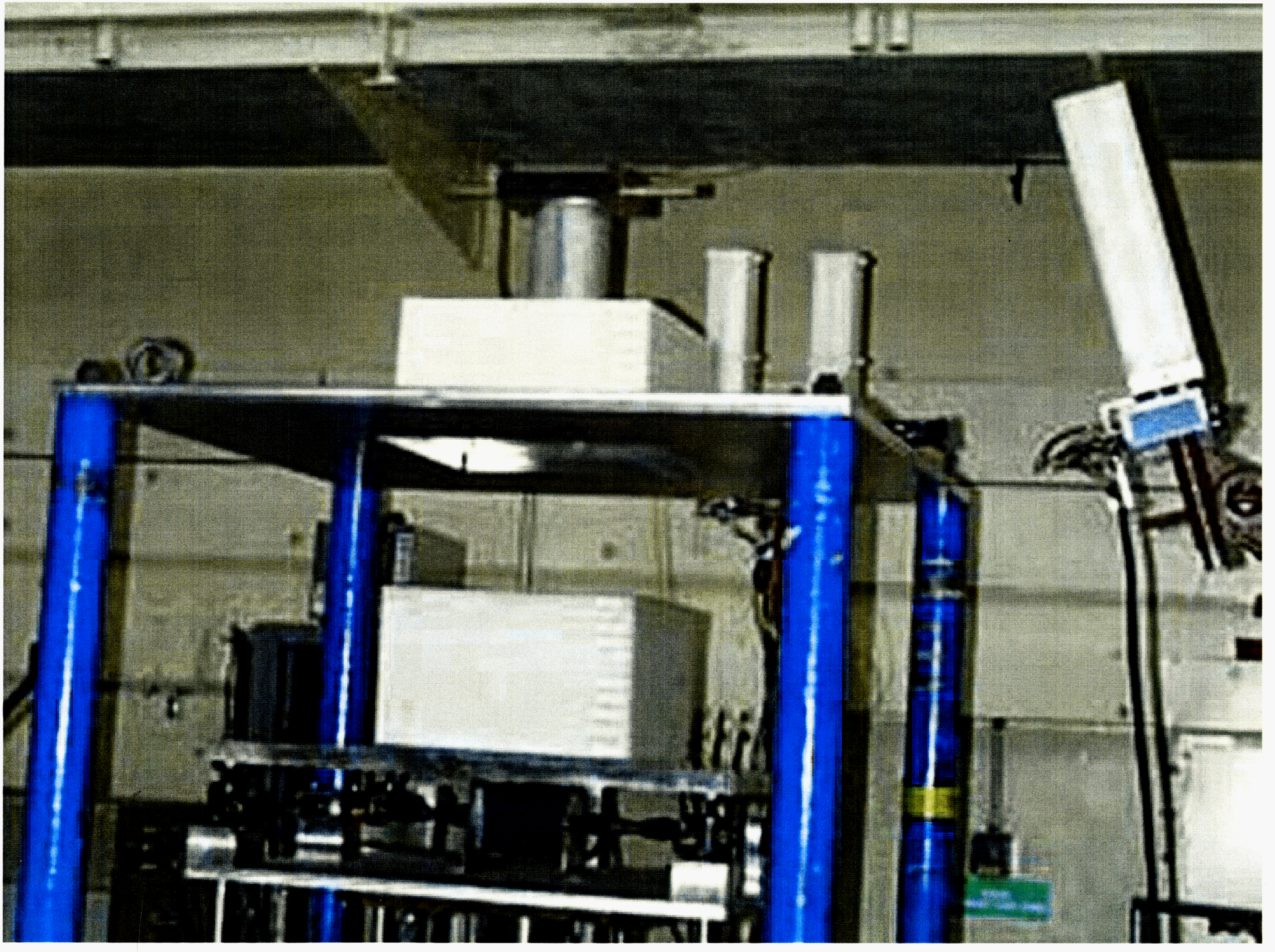
MgO Powder

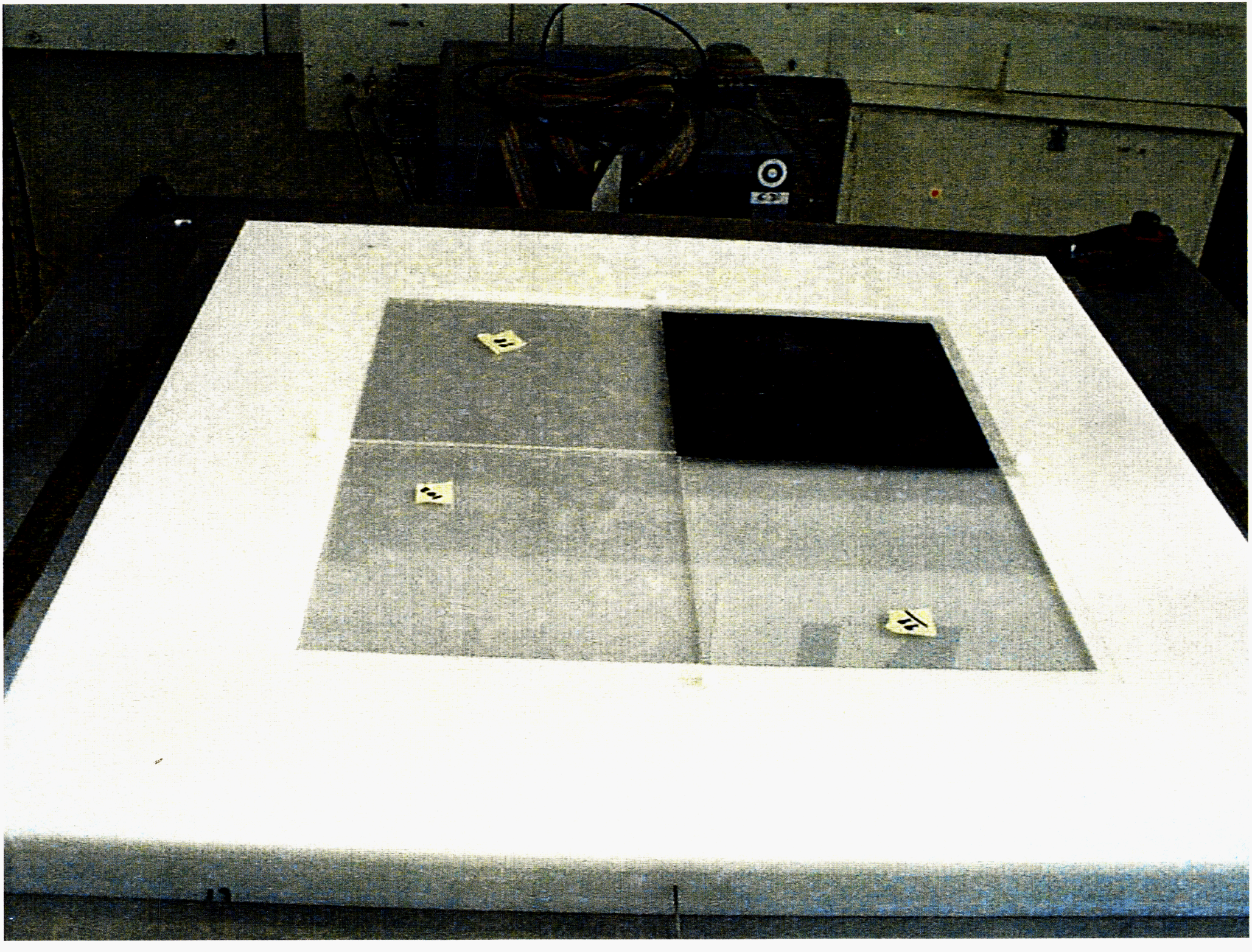
Density = 1.17-1.36 g/cc

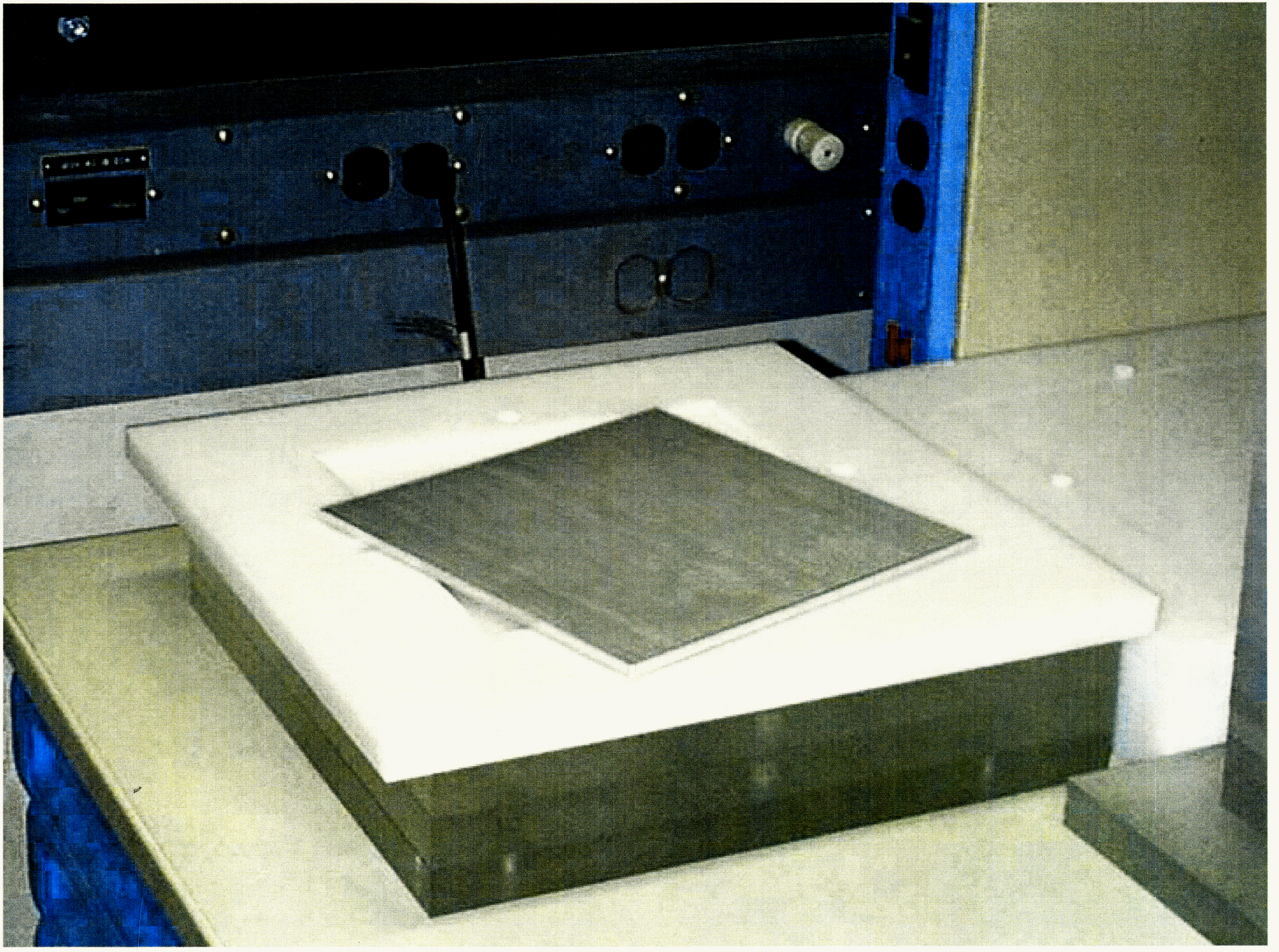
Element Composition (in Percent)

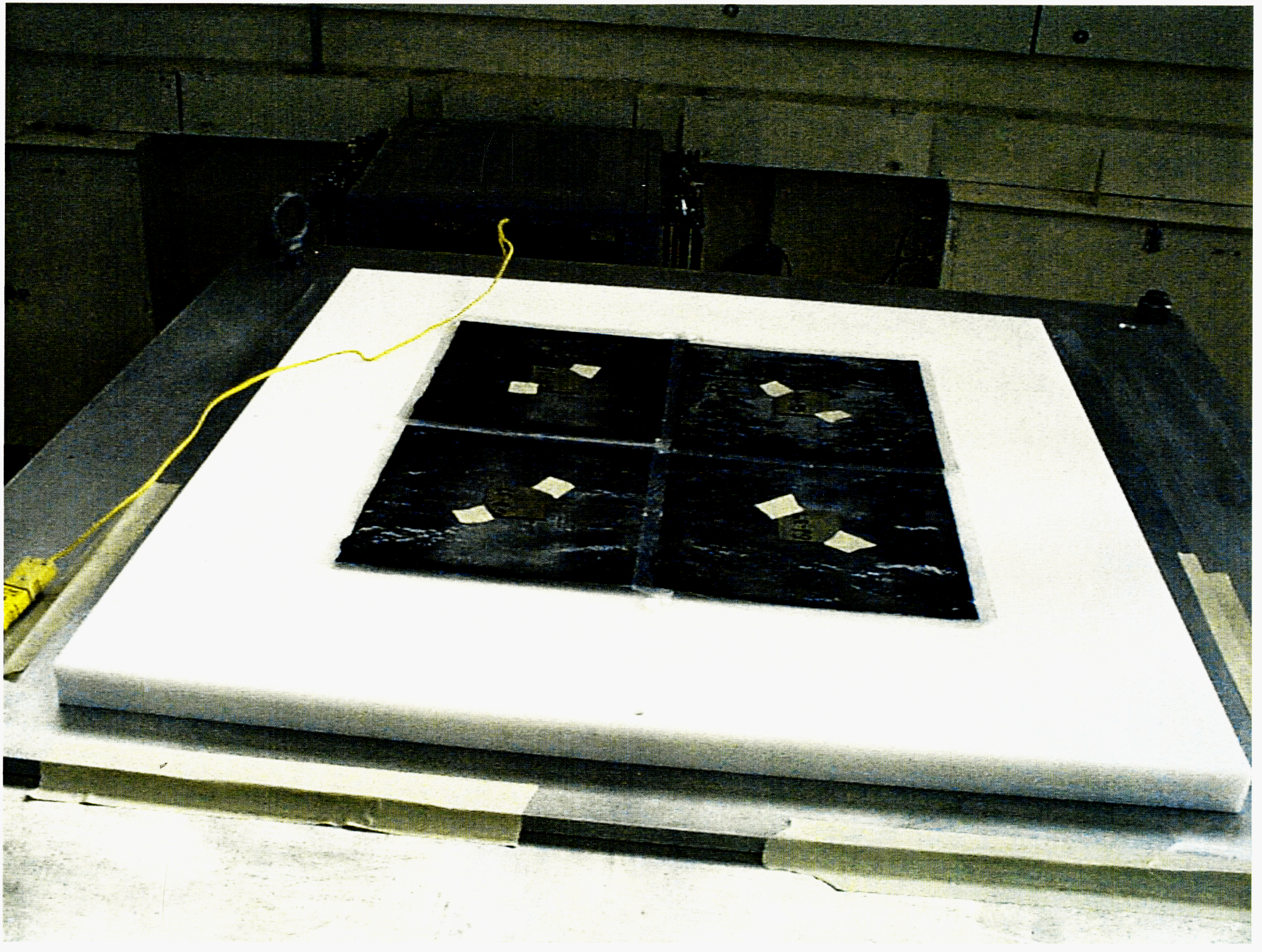
MgO	97-98.2	CaO	0.9-1.0
SiO_2	0.4-0.5	Fe_2O_3	0.2-0.3
Al_2O_3	0.1-0.2	Cl	0.01-0.02
SO_3	0.01-0.02		
Loss on Ignition	0.25-0.5		


NOTICE
CONTROLLED AREA









Experimental Results

Diluent	X/ ^{235}U H/ ^{235}U	Mass of Uranium	Extrapolated Critical Mass
SiO_2/CH_2	Si/ ^{235}U=42 H/ ^{235}U=312	2196 g	2878 g
	Si/ ^{235}U=21 H/ ^{235}U=156	2233 g	2285 g

Experimental Results (Cont.)

Diluent	X/ ^{235}U H/ ^{235}U	Mass of Uranium	Extrapolated Critical Mass
Al/CH_2	Al/ ^{235}U = 60 H/ ^{235}U = 159	2604 g	2609 g
MgO/ CH_2	Mg/ ^{235}U =18 H/ ^{235}U = 160	2878 g	2951 g

KENO-Va Results

	Pu-239 concentration	Kinf
SiO_2	0.20 g Pu-239/lb	1.00844
	0.25	1.11525
MgO	0.20	1.23570
	0.25	1.32796
Al	0.50	0.72271
	0.75	0.86322

Table III. Critical masses and parameters of uranium diluted systems.

Final measured configuration			Critical configuration			keff
Diluent	X/^{235}U, H/^{235}U	Mass of Uranium (g)	Extrapolated critical mass g of U	Core average density (g/cc) U	Core average density (g/cc) diluent	
SiO_2/ polyethylene	Si/^{235}U = 42, H/^{235}U = 312	2196	2878	0.071	For SiO_2 density = 0.74 For CH_2 density = 0.64	
SiO_2/ polyethylene	Si/^{235}U = 21, H/^{235}U = 156	2233.1	2285.3	0.149	For SiO_2 density = 0.77 For CH_2 density = 0.66	1.002 Exp 1.0070 Cal ± 0.0015 ENDF/B-V[5]
Al/ polyethylene	Al/^{235}U = 60, H/^{235}U = 159	2604	2609.1	0.145	For Al density = 0.93 For CH_2 density = 0.66	1.001 Exp 1.0016 Cal ± 0.0004 ENDF/B-VI[6]
MgO/ Polyethylene	Mg/^{235}U = 18, H/^{235}U = 160	2878	2950.8	0.145	For MgO density = 0.42 For CH_2 density = 0.64	1.0009 Exp 1.0435 Cal ± 0.0004 ENDF/B-VI[7]
Gd/ Polyethylene	Gd/^{235}U = 0.09, H/^{235}U = 230	1951.3	1958.3	0.146	For Gd density = 0.008 For CH_2 density = 0.96	0.9976 Exp 1.00149 Cal ± 0.0005 ENDF/B-VI
Gd/ Polyethylene	Gd/^{235}U = 0.046, H/^{235}U = 228	1811.0	1893.6	0.15	For Gd density = 0.004 For CH_2 density = 0.96	1.0025 Exp 1.00602 Cal ± 0.0005 ENDF/B-VI
Gd/ Polyethylene	Gd/^{235}U = 0.18, H/^{235}U = 245	2801.0	2872.8	0.141	For Gd density = 0.016 For CH_2 density = 0.96	0.9905 Exp 1.00354 Cal ± 0.0005 ENDF/B-VI
Fe/ Polyethylene	Fe/^{235}U = 4.51, H/^{235}U = 224	1388	1408.9	0.154	For Fe density = 0.15 For CH_2 density = 0.96	0.9973 Exp 1.0096 Cal ± 0.0003 ENDF/B-VI[7]
Polyethylene	H/^{235}U = 220	1251.0	1301.4	0.157	For CH_2 density = 0.96	1.0050 Exp 1.0146 Cal ± 0.0005 ENDF/B-VI
Polyethylene	H/^{235}U = 471	1319.0	1331.6	0.073	For CH_2 density = 0.96	0.9969 Exp 0.9909 Cal ± 0.0004 ENDF/B-VI
Polyethylene	H/^{235}U = 239	2233.1	2454.3	0.145	For CH_2 density = 0.96	1.0079 Exp 1.0137 Cal ± 0.0005 ENDF/B-VI

Conclusions

- MCNP calculations with matrix materials agreed quite well with experimental results.
- MCNP calculations with polyethylene yielded a bit higher keff.
- Future experiments will include other materials (CaO, concrete, Fe, etc.) in contact with HEU, ^{233}U, ^{239}Pu.