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LEAD

for

RADIATION SHIELDING

radioactive isotopes
reactors
radium
x-rays

NATIONAL LEAD COMPANY

F-95-55

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N15100

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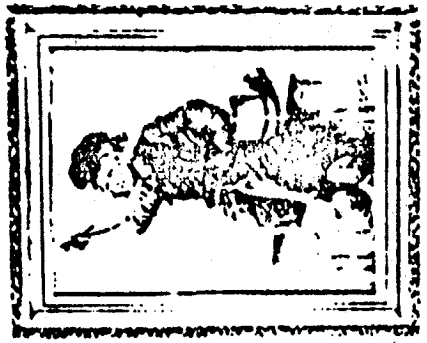

The "Dutch Boy" trade mark, which has identified National Lead Company products since 1907, is synonymous with protection in the minds of millions. It is, as well, a symbol of quality, a pledge of dependable service.

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RADIATION SHIELDING

Materials for protective purposes have long been major items in the portfolio of products of National Lead Company. Paints ... to protect wood, masonry and metal structures from deterioration by weathering are in this category. Bearing metals to protect machinery parts from the wear and tear of friction, may be in point. Lead wool and calking lead to protect against damage by leakage in pipe joints and natural "rubs" also qualify, as do lead mats placed under buildings to protect the structures from the effects of vibration. Lead sheathing and sheeting is used to protect underground and underwater cables from attack by heavy stresses and corrosive elements. Lead in many fabricated forms is of vital importance in the chemical industry, protecting all manner of equipment from attack by corrosive substances. Lead sheet is relied upon to practically all X-ray installations to shield personnel from harmful radiations.

It must then be seen that devising, producing and marketing "materials of protection" is an old story at National Lead Company.

Out of this background, this long and varied experience, National Lead Company comes well prepared to meet the needs of a new industry based upon the splitting of the atom.

The shielding problems associated with atomic energy and its by-products are, of course, somewhat similar to those of x-rays and radium, but they are greatly magnified by wider use and higher intensities.

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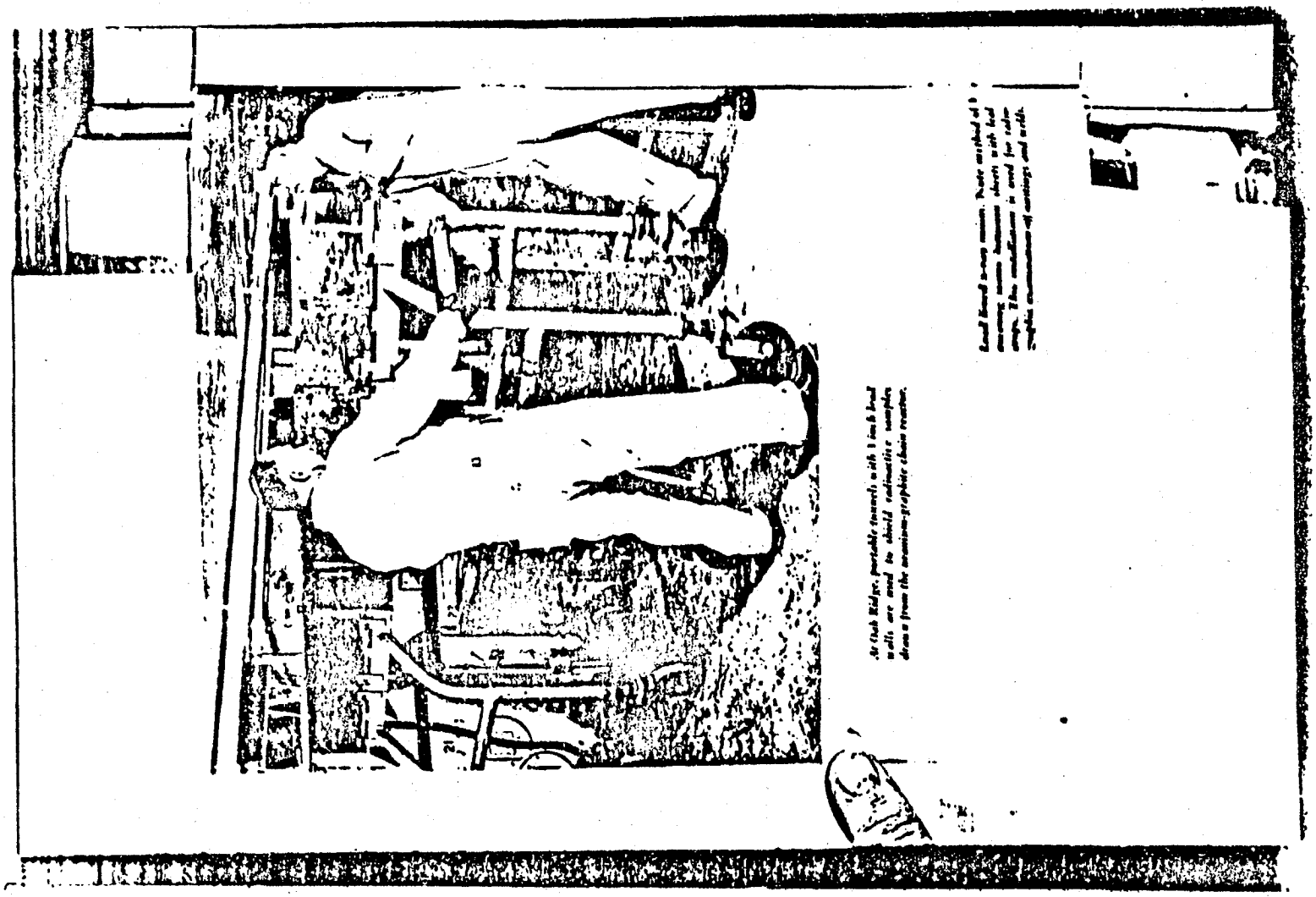

Of the four types of rays or particles involved in atomic disintegrations — alpha, beta, gamma and neutron — we are concerned here with gamma and neutron emission. Alpha particles can be stopped by a few inches of air or a sheet of paper. Beta particles, faster and more penetrating than alphas, are usually absorbed by an inch or so of wood.

Gamma rays are another kettle of fish with. High energy gammas will not be completely stopped by even a foot thickness of any dense material. On the other hand a quarter inch lead sheet will absorb low energy gamma radiation.

Neutrons produced in an atomic pile or accelerator are uncharged particles that will interact with atomic nuclei in various materials. According to their energy levels, neutrons are classified as very fast, fast, slow and thermal.

Metallic cadmium or hydrogenous materials such as water or paraffin are generally used as shielding against neutrons. However, since gamma rays are emitted when neutrons are absorbed, it is still necessary to provide a shield of lead or some other dense material. The use of protective shielding is advised in all cases, regardless of the type of radiation, the thickness of the shield depending upon the penetrating power of the rays.

The most important factor in the absorption of radiation is density. Lead, with a specific gravity of 11.35 is the densest commonly available material.

In the usual gamma radiation ranges, lead is considerably more effective than iron, for example, which has a specific gravity of "8." There are a few other materials of even greater density than lead but these are generally used as shielding because of their use in the quantities in which they would be needed.



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Since it is a metal, lead has an advantage over aggregates such as concrete and other types of masonry in that when properly fabricated, it is of uniformity high density and especially so when the lead has been formed by extrusion, drawing or rolling processes. Moreover, the normally smooth surface of metallic lead is not prone to collect dirt or other substances which may become contaminated. Should contamination occur, it may be removed with a cleaning agent such as nitric acid in four parts of water.

One of the commonest forms of lead for barrier purposes is brick. As furnished by National Lead Company, the brick is produced by an extrusion process in regular lead pipe presses equipped with proper dies.

National Lead supplies brick of many types and sizes, the most popular being 2" x 4" x 8" and 2" x 3" x 6". One type has the contour of the conventional building brick with all sides flat. Another is a curved brick, with all significant gaining and tracking faces either concave or convex. Specially-cut brick of this curved type are made for cornering. With these so-called "interlocking" brick there is no practical limit on size or shape in wall-type shields.

Where a "brick width" barrier is sufficient for any particular shielding setup, the advantage of the curved type is obvious — there are no straight vertical or horizontal joints that need blocking as may be the case with conventional brick.

Both types of brick stack compactly and may be used in building bunkers of any practicable height with little risk of toppling.

It should be emphasized here, perhaps, that extruded brick as produced by National Lead Company have a through-and-through uniform density which may or may not be true with gravity cast brick. Also the finish and the profile of extruded brick generally are smoother and cleaner than is the case with the cast variety.

In addition to brick, National Lead Company produces lead shipping containers, carriers, safes and other "housing" for radioactive materials, as well as "ray proof" containers for the safe keeping of film. As a leading maker of lead products, the Company has the facilities for manufacturing virtually any type of lead radiation barrier. A nation-wide network of plants and warehouses offers assurance of prompt, freightsaving deliveries ●

Typical straight-side and curved lead brick produced by extrusion process by National Lead Company.

Two lead brick size 2" x 4" x 8" — one cast in an open mold (right), the other extruded through a die in a hydraulic press (left) — were sawed in half lengthwise, to show internal structure. After planing and buffing, the halves were photographed. The photos were retouched to kill highlights and achieve uniform tone on both brick. The sink and shrink-hole were not touched.



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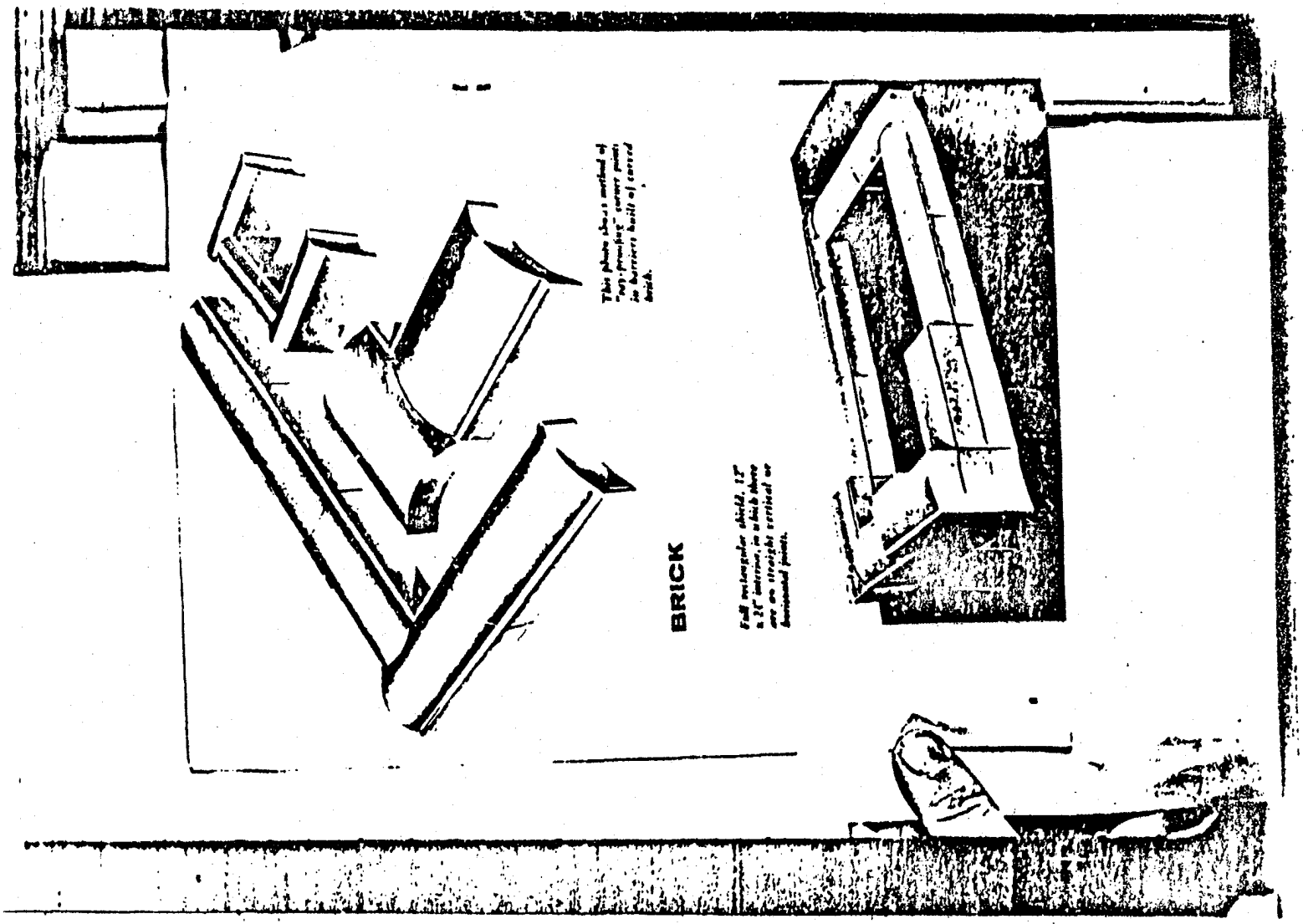
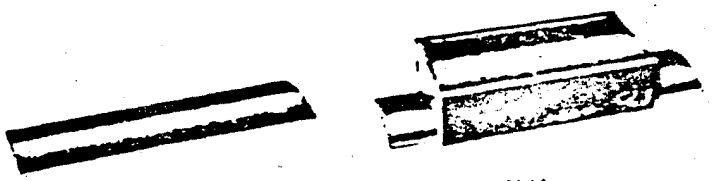
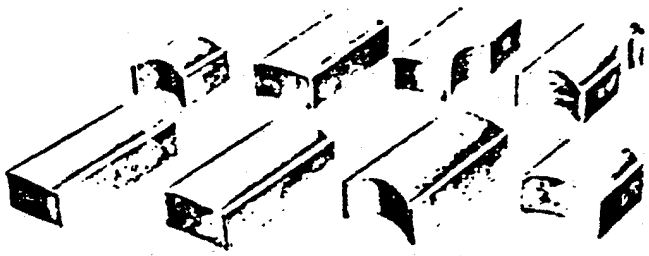




For bench or table barrier installations, using curved brick, requiring full-area surface contact, suitable lengths of lead "foundation strip," on which to lay first course of brick, are available.



WEIGHT OF LEAD SHIELDING

Lead weighs 11 lbs. per cubic inch—710 lbs. per cubic foot. A conventional flat-sided lead brick 2"x4"x8" weighs 20.2 lbs. A small, flat-sided lead brick 2"x4"x8" weighs 19.66 lbs.

NATIONAL LEAD COMPANY CURVED BRICK

	Regular size	*Small size*
Model A, Standard brick	25.25 lbs.	14.33 lbs.
Model B, Header male	26.25 lbs.	14.88 lbs.
Model C, Header female	26.25 lbs.	14.88 lbs.
Model D, Header, half-brick male	13.50 lbs.	7.33 lbs.
Model E, Header, half-brick female	13.50 lbs.	7.88 lbs.
Model L, Male brick	26.25 lbs.	15.25 lbs.
Model M, Left corner brick, female	25.75 lbs.	15.05 lbs.
Model N, Right corner brick, female	25.75 lbs.	15.05 lbs.

Lead as sheet form weighs approximately one pound per each 1/64" of thickness per square foot. Thus so-called "4-lb." lead (eight pounds per square foot) is approximately ⅛" thick. The standard size for lead sheet weighing sheet or sheet pounds per square foot is 4'x8'x⅛". The standard size for lighter sheet is 4'x8'x1/16".

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CASKS

Lead (steel-jacketed) Exposure Radiation Cell (approx. 13,500 lbs.) of complex construction.

Lead (steel-jacketed) Transfer Cask (approx. 3,000 lbs.) equipped with drainage duct in "hot" cavity.

Lead safe for storing Cobalt-60. This is virtually a solid lead cube, approximately 20" x 20" x 20" with five extruded lead "drawers" with small cavities in which the radioactive material is kept. Safe weighs about 5,200 lbs.

Typical lead "pig" or cask used for storage of radioactive materials.

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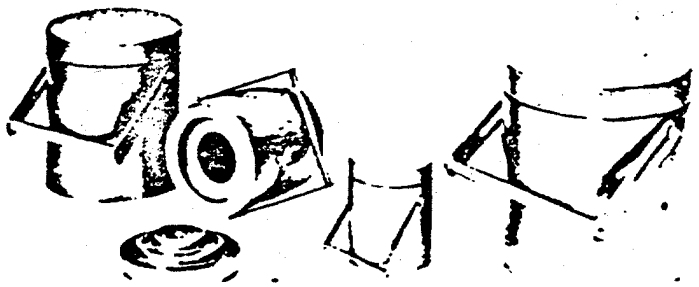

SHIPPING CONTAINERS FOR RADIOACTIVE MATERIALS

We manufacture a complete line of stainless steel-clad lead containers for shipping radioactive isotopes. The standard cartons shown here have ½", 1", 1½" and 2" lead protection. Cartons in all these sizes are 11½" diameter, the depths varying from 21½" in the largest size to 11½" in the smallest. Weights range from 98 lbs. down to about 6 lbs. Handles are designed to lock down on cover in transit. They may also be easily removed for convenient insertion of container in larger storage casks.

These shipping containers are of top quality construction throughout. The lead shield is fabricated by a special method to eliminate all possibility of porosity.

SPECIAL HI-HARD BRICK

Where extra conditions are severe, that is, where brick are subject to much mechanical abuse in erection or dismantling of furnace, we are prepared to furnish special lead brick with a Brinell hardness about four times greater than that of conventional brick. That is to say, whereas regular lead has a hardness of 4, this special product has a hardness of approx. 17. The small amount of antimony contained in Hi-Hard brick affects a slight reduction in the density — from 11.35 to 11.11. In other words, an increase in hardness of about 400% is obtained which represents 98.20% of the shielding efficiency (density) of regular lead.



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REQUIRED LEAD SHIELDING THICKNESS FOR GAMMA RAYS

The table below, prepared by the National Bureau of Standards, is frequently used in determining the thickness of lead shielding needed for shielding from gamma ray sources in laboratories.

To use the table select the column for the energy required. (Use next higher figure if exact value is not given.) The entry gives thickness in centimeters of lead for different source strengths at 1 meter for 8 hours per day or give 40 milliroentgens. Then add algebraically the correction terms for other working ranges or times to obtain the shield thickness required.

Example: Shield is needed for handling 500 millicuries of radioactive material emitting 1.8 million electron volts (Mev) gamma rays at a maximum working distance of 50 cm, and 4 hours per day.

Shield thickness = 8.68 + 2.77 − 1.99 = 9.46 cm of lead
(a) (b) (c)

in which a = from entry, b = correction for distance range = 50 cm, c = correction for 4 hours per day.

ENERGY (MeV)

ACTIVITY	0.5	0.6	0.8	1.0	1.5	2.0	2.5	3.0	4.0
10 mc	−0.14	−0.36	−0.27	−0.11	0.37	0.78	1.15	1.40	1.70
20 mc	−0.09	0.00	0.41	0.76	1.57	2.16	2.63	2.91	3.21
50 mc	−0.01	0.47	1.31	1.90	3.15	4.00	4.57	4.90	5.20
100 mc	0.06	0.82	1.99	2.77	4.34	5.38	6.05	6.41	6.71
200 mc	0.10	1.17	2.67	3.63	5.54	6.77	7.52	7.92	8.21
500 mc	0.17	1.64	3.57	4.78	7.12	8.60	9.47	9.91	10.21
1 c	0.23	1.99	4.25	5.65	8.31	9.93	10.95	11.41	11.71
2 c	0.28	2.35	4.93	6.52	9.51	11.37	12.42	12.92	13.22
5 c	0.36	2.81	5.82	7.66	11.09	13.21	14.37	14.91	15.21
10 c	0.41	3.17	6.50	8.52	12.28	14.59	15.85	16.42	16.72
20 c	0.47	3.52	7.18	9.39	13.48	15.98	17.32	17.93	18.23
50 c	0.54	3.99	8.08	10.54	15.06	17.81	19.27	19.92	20.22
100 c	0.60	4.34	8.76	11.40	16.25	19.20	20.75	21.43	21.72
DISTANCE RANGE	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS
20 cm	0.26	1.64	3.16	4.02	5.55	6.44	6.85	7.00	7.00
50 cm	0.11	0.71	1.36	1.73	2.39	2.77	2.95	3.01	3.01
1 m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 m	−0.11	−0.71	−1.36	−1.73	−2.39	−2.77	−2.95	−3.01	−3.01
5 m	−0.26	−1.64	−3.16	−4.02	−5.55	−6.44	−6.85	−7.00	−7.00
10 m	−0.37	−2.35	−4.52	−5.76	−7.94	−9.21	−9.80	−10.01	−10.01
EXPOSURE TIME HR/DAY	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS	PLUS
1	−0.17	−1.08	−2.04	−2.60	−3.59	−4.16	−4.42	−4.52	−4.52
2	−0.11	−0.71	−1.36	−1.73	−2.39	−2.77	−2.95	−3.01	−3.01
4	−0.06	−0.35	−0.68	−0.87	−1.20	−1.39	−1.47	−1.51	−1.51
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	+0.09	+0.56	+1.09	+1.37	+1.89	+2.20	+2.34	+2.39	+2.39

NOTES

(1) Source activity is quoted in millicuries or curies, where 1 curie is that amount of radioactive material that disintegrates at the rate of 3.7×10^{10} disintegrations per second. However, the table is computed on the further assumption that each disintegration yields one gamma photon of the indicated energy. Thus real lead requirements where the disintegrations are complex. More accurate calculations can be made by alternate methods when the disintegration scheme is known.

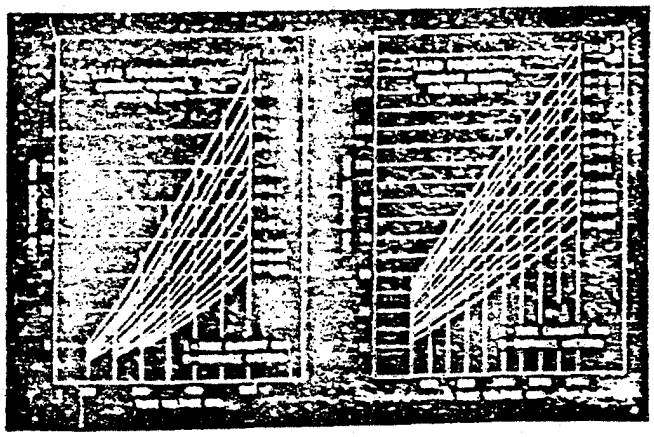
(2) The calculations ignore the shielding relative to that amount of shielding under study in an enclosure.

(3) This lead shielding table is intended to be used as a guide to rapid estimates of temporary shielding requirements in the laboratory. It is not permissible to calculate the maximum permissible exposure time for personnel from data given in this table. For more precise calculations by experienced persons, more detailed calculations by conventional methods are required.

LEAD EQUIVALENTS OF VARIOUS MATERIALS

MATERIAL	MASS DENSITY, G PER CU CM	LEAD EQUIV. MM	CORRESPONDING THICKNESS OF MATERIAL, MM. X-RAYS EMITTED AT PEAK VOLTAGES OF 100 KV.	125 KV.	150 KV.	175 KV.	200 KV.	GAMMA RAYS
Iron	7.9	1	11	12	12	11		25
		2	25	27	28	26		7
		3	37	40	42	39		15
		4	50	55	55	52		
		5			68	65		19
		6			78	75		23
		7						27
		8						30
Concrete	2.3	1	85	90	90	85		16
2 parts ballast		2	160	150	155	135		32
2 parts sand		3	230	210	215	180		48
1 part cement		4	295	275	270	220		64
		5			320	255		80
		6			360	285		96
		7				320		112
		8						128

Lead thickness required for protection against narrow beam gamma rays from sources between 1.1 and 2.6 MV, and between 2.6 and 3.6 MV, for various distances between the tube target and operator.



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44	
	1.70
	3.21
	5.20
	6.71
	8.21
	10.21
	11.71
	13.22
	15.21
	16.72
	18.23
	20.22
	21.72
2.15	
	7.00
	3.01
	0.00
	-3.01
	-7.00
	10.01
2.15	
	4.52
	3.01
	-1.51
	0.00
	2.39

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Photon Absorption as a Function of Energy

In addition to portable shielding as typified by the lead items described here, National Lead Company produces heavy materials such as barites and magnetite for mixing with concrete in the construction of massive shielding.

Information on these high density materials may be obtained by writing National Lead Co., 111 Broadway, New York 6, N.Y.

While no permanent or "mobile" shielding have not been fully explored, a paste type lead shielding material has been developed by National Lead Company. This is a high viscosity, high density paste made by combining dry red lead with a non-drying oil, with ingredients added to insure uniform and lasting dispersion of solids in the liquid. A gallon of this paste shielding weighs 29.2 lbs. The specific gravity is 3.5

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NLI 115792

NATIONAL LEAD COMPANY

BRANCH SALES OFFICES

Atlanta Branch	National Lead Company, 100 Bishop St., N.W., Atlanta	ELgin 7361
Boston Branch	National Lead Company, 111 Broadway, New York 6	REctor 2-9400
Baltimore Branch	National Lead Company, 211 West Henrietta St., Baltimore 3	PLaza 2-6900
Boston Branch	National Lead Company of Mass., 900 Albany St., Boston 6	GArrison 7-1000
Chicago Branch	National Lead Company, 900 West 18th St., Chicago 80	CAnal 6-3700
	National Lead Company, 3301 Griffin St., Detroit 11	TRinity 4-0168
	National Lead Company, 800 North Third St., Milwaukee 3	BRoadway 6-4870
Cincinnati Branch	National Lead Company, 659 Freeman Ave., Cincinnati 3	PArkway 1-7970
	National Lead Company, 1320 Heyburn Building, Louisville 2	JAckson 3341
Cleveland Branch	National Lead Company, 1776 Columbus Road, Cleveland 13	PRospect 1-4060
	National Lead Company, Buffalo Office 779 Walden Ave., Depew, N.Y. REgent 6810	
	National Lead Company, 1136 River Ave., Pittsburgh 12	FAirfax 1-2333
Pacific Coast Branch	Morris P. Kirk & Son, Inc., 2717 South Indiana St., Los Angeles 23	ANgelus 2-1101
	Morris P. Kirk & Son, Inc., 1050 Horton St., Emeryville 8	OLympic 3-7533
	Morris P. Kirk & Son, Inc., 5909 N.W. 61st Ave., Portland 10	CApitol 1956
	Morris P. Kirk & Son, Inc., 3614 Airport Way, Seattle 4	MAin 0975
	Morris P. Kirk & Son, Inc., 977 South South West St., Salt Lake City 4	EMpire 4-6436
	Morris P. Kirk & Son, Inc., 1102 West Washoe St., Phoenix	Alpine 8-0922
Philadelphia Branch	National Lead Company, 2607 E. Cumberland Street, Phila. 25	GArfield 6-0600
St. Louis Branch	National Lead Company, 722 Chestnut St., St. Louis 1	CHestnut 1-8785
	National Lead Company, 1806 West 13th St., Kansas City 1	VIctor 0507
	National Lead Company, 516 Tchoupitoulas St., New Orleans 12	CAnal 9948
	National Lead Company, 2810 "A" St., Omaha 7	ORchard 2202
Southwestern Branch	National Lead Company, 939 Terminal St., Dallas 2	PRospect 8335
Canada	Canada Metal Company Ltd., 721 Eastern Ave., Toronto 8	Gladstone 4644
	Canada Metal Company Ltd., 6265 Notre Dame St. East, Montreal	Claireal 3653
	Canada Metal Company Ltd., 1428 Granville St., Vancouver 2, B.C.	Marine 1367
	Canada Metal Company Ltd., 901 Chambers St., Winnipeg	74-7455
South America	National Lead Company, S. A. Avenida Presidente Roque Saenz Pena 567, Buenos Aires, Argentina	

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