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ARAB REPUBLIC OF EGYPT
ATOMIC ENERGY AUTHORITY
HOT LABORATORY CENTER

DESIGN OF EMERGENCY SHIELD

BY
S.E.SOLIMAN

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ABSTRACT

Manufacturing of an emergency movable shield in the Hot Laboratories Center is urgently needed for the safety of personnel in case of accidents or spilling of radioactive materials. In this report, a full design for an emergency shield is presented and the corresponding dose rates behind the shield for different activities (from 1 mCi to 5 Ci) was calculated by using Microshield Computer Code.

1- Introduction

The operators of the Hot Laboratory Center of the Egyptian Atomic Energy Authority (EAEA) are dealing with high level radioactive materials. According to the EAEA safety regulations(1), the back ground in these laboratories should be as low as reasonably achievable (ALARA). The possibility of spilling radioactive isotopes exists. Therefor an emergency movable (transportable) shield is urgently required to insure the safety of personnel who are dealing with the radioactive isotopes and the employees who are working in the hot laboratory center. The specifications of this shield should be suitable for the construction of the radioisotopes laboratory as well as the construction of the buildings of the hot laboratory center. The shield should also be able to surround contaminated areas and gives the necessary safety for the health physists during decontamination process.

2- Description

The shield consists of three lead (bricks) walls framed with U section steel beam. Curved stainless steel boxes with 3 mm wall thickness are welded along the tow neighbor sides of the frame in a form of cub and cone (see Figs. 1, 2 and 3). The walls are hinged together to allow rotation of the shield to be able to surround contaminated areas. The space between the curved stainless steel box and the side of the U beam is filled with lead balls (with 3 mm diameter each). The three walls are almost similar. The only difference between the three walls is that the middle one has an extra inclined part on its top to provide protection for the person who is standing behind the shield. Each of the shield walls is one meter height, one meter width and 0.1 meter thickness. The inclined part is of 0.4 meter height inclined with 30^0 to the vertical plane towards the contaminated area. The walls are settled on I beam wings welded to the main U beam frame and carried on wheels to provide easy movement. A steel rod is connected to the end of the frame to pull the shield from it.

A patch of lead glass with 0.4 m long x 0.2 m width x 0.1 m thickness is fixed in the middle wall to allow the health physist to see the radioactive material he is dealing with. Two tongues with 0.75 m long passing through lead balls with 0.1 m diameter to allow the rotation of the tongues for 360° are also fixed in the middle wall to use them in handling the radioactive material and/or the decontamination stuff.

A general view for the shield is given in Figure (1). Detail drawings for the lead bricks used in the shield are given in Figure(2) while the detail drawing for the shield is given in Figure (3).

3- Design Calculations

Since the middle wall of the shield is the heaviest one and the U section steel beam used for the three walls is the same, the design calculations will concentrate on the middle wall and of course the results will be applicable for the rest of the walls.

3-1- Load calculations

As it was mentioned in the description of the shield, the middle wall consists of two parts. The vertical part and the inclined one.

The weight on the beam will be as m1 + m2 (where m1 is the weight of the vertical part and m2 is the weight of the inclined part in the vertical direction).

$$m1 = \text{density of the lead} \times \text{volume}$$
$$= 11.34 \times 100 \times 100 \times 10 / 1000 = 1134 \text{ kg}$$

$$m2 = (11.34 \times 100 \times 40 \times 10/1000) \cos 30$$
$$= 392.8 \text{ kg}$$

$$mtot = 1134 + 392.8 = 1526.8 \text{ kg}$$

$$mtot = 1527 \text{ kg}$$

$$\text{The weight } (W) = mtot \times 9.8 =$$

$$W = 13743 \text{ kgf.}$$

3-2- Load analysis

The load W on the beam will be uniformly distributed load as it is shown in Figure (4).

3-2-a- Bending moment calculations

Let "a" (see Figure 4) be the distance of the supports from the ends. The bending moment (B.M.) will be minimum only if the positive B.M. is equal to the negative B.M(2). Since the beam is carrying a uniformly distributed load and the two supports are equally spaced from the end, therefore the two reactions are equal RA = RB

From the Figure, $RA = RB = wL/2$

where: RA and RB are the reactions at A and B respectively.
w is the weight per unit length.
L is the length of the beam.

Moment around A

From the geometry of Figure (4), we find that the maximum negative B.M. will be at the two supports, whereas the maximum positive B.M. will be at the middle of the beam. Now B.M. at A,

$$MA = -(wa \times a/2) = -wa2/2 \quad \ldots\ldots (1)$$

Bending moment at the middle of the beam,

$$MM = RA\,[(L/2) - a] - [(wL/2) \times L/4]$$
$$= (wL/2)(L/2) - wL2/8 \quad \ldots\ldots (2)$$

Equating (1) and (2):

$$wa2/2 = wL/2\,(L/2 - a) - wL2/8$$

$$a2 = L2/2 - La - L2/4 = L2/4 - La$$

i.e. $$a2 + La - L2/4 = 0$$

i.e. $a = [-L + \sqrt{L^2+4 \times L^2/4}] / 2$

$= - 0.5L + 0.707L = 0.207 L$ (taking + sign)

Since $L = 100$ cm
$a = 20.7$ cm

i.e. the supports should be at a distance of 20.7 cm from the ends of the wall.

Bending Moment;

The bending moment diagram is shown in Figure (4-C) and the values are as the following:

$MA = MB = - wa^2/2 = -(w/2)(0.207 L)^2 = 0.0215 wL^2$

i.e. $MA = 0.0215 (13743) (1)^2$
$MA = MB = 295.47$ kgf.m

$MM = - (wL/2)(1/4) + (wL/2)(L/2 - a)$
$= - wL^2/8 + wL/2 (0.5L - 0.207 L)$
$= - wL^2/8 + wL/2 \times 0.293 L = 0.0215 wL^2$
$= 0.0215 \times 13743 \times (1)^2$
$= 295.47$ kgfm

3.2.b. Shear Force Calculations

$FC = FD = 0$

The maximum shear force will be at the supports(3) (see figure 4-a)

$FA = 0 - w \times 0.207 L + 0.5 wL$
$= 0.293 wL$
$= 0.293 \times 13743 \times 1 = 4026.699$ kgf

Shear Stress = FA/A (where A is the cross sectional area)
(from the standard tables A= 14.2 cm2 for U beam with 10 cm width).

i.e. Shear Stress = 4026.699/14.2

Shear Stress = 283.57 kg/cm2

i.e. the design maximum shear stress = 2.84 kg/mm2

From the tables, the yield stress for the material is 27 kg/mm2

Since the design (calculated) shear stress is much less than the yield stress for the material; this means that we have a safe design.

The chosen wheel must be able to withstand a load not less than 500 kg.

4)- Dose Rate Behind The Shield

The dose rate behind the shield was calculated for different activities for the spilled radioactive isotopes.
Microshield Computer Code(4) was used for these calculations.

The following assumptions were used ;

1)- the radioactive source was considered as point
2)- the build up factor was taken = 1
3)- the activity of the source is ranging from 1 mCi to 5 Ci
4)- the distance between the source and the shield = 20 cm
5)- the distance between the person and the shield = 20 cm
6)- the lead brick thickness = 10 cm

The calculated dose rate for each activity is given in the following table (Table-1) while the calculation details using the Microshield computer code are given in Appendix - A.

Table: 1. Different Dose Rate Behind the Shield at 20 cm Distance From the Shield Due to Different Radio-Activities.

Activity Ci	Dose Rate mr/hr	Sv/hr
1 x 10 E-3	6.9 E-3	6.9 E-8
5 x 10 E-3	3.5 E-2	3.5 E-7
1 x 10 E-2	6.9 E-2	6.9 E-7
5 x 10 E-2	3.5 E-1	3.5 E-6
1 x 10 E-1	6.9 E-1	6.9 E-6
5 x 10 E-1	3.5	3.5 E-5
1	6.9	6.9 E-5
2	13.8	13.8 E-5
3	20.7	20.7 E-5
4	27.6	27.6 E-5
5	34.5	34.5 E-5

ACKNOWLEDGEMENT

The author would like to thank Prof. A. El-Rasoul of the Hot Laboratory Center and Prof. H. F. Aly the Deputy Chairman of the Atomic Energy Authority, Cairo, Egypt for their advises and guidance of this work. Acknowledgement should also be extended to Prof. S. Marie the chairman of the Hot Laboratory Center for his encouragement to finish this work.

References

1- IAEA, Basic Safety Standards for Radiation Protection, Safety Series No. 292, IAEA, Vienna (1988).

2- R. S. Khurmi,"Strength of Materials" S. CHAND and COMPANY LTD, Ram Nagar, New Delhi (1982).

3- V. Feodosy, "Strength of Materials", MIR Publishres, 1974.

4- Micro Shield Computer Code. Ver. 3.02, Long Island Lighting-# 031 N.Y. U.S.A. 1990.

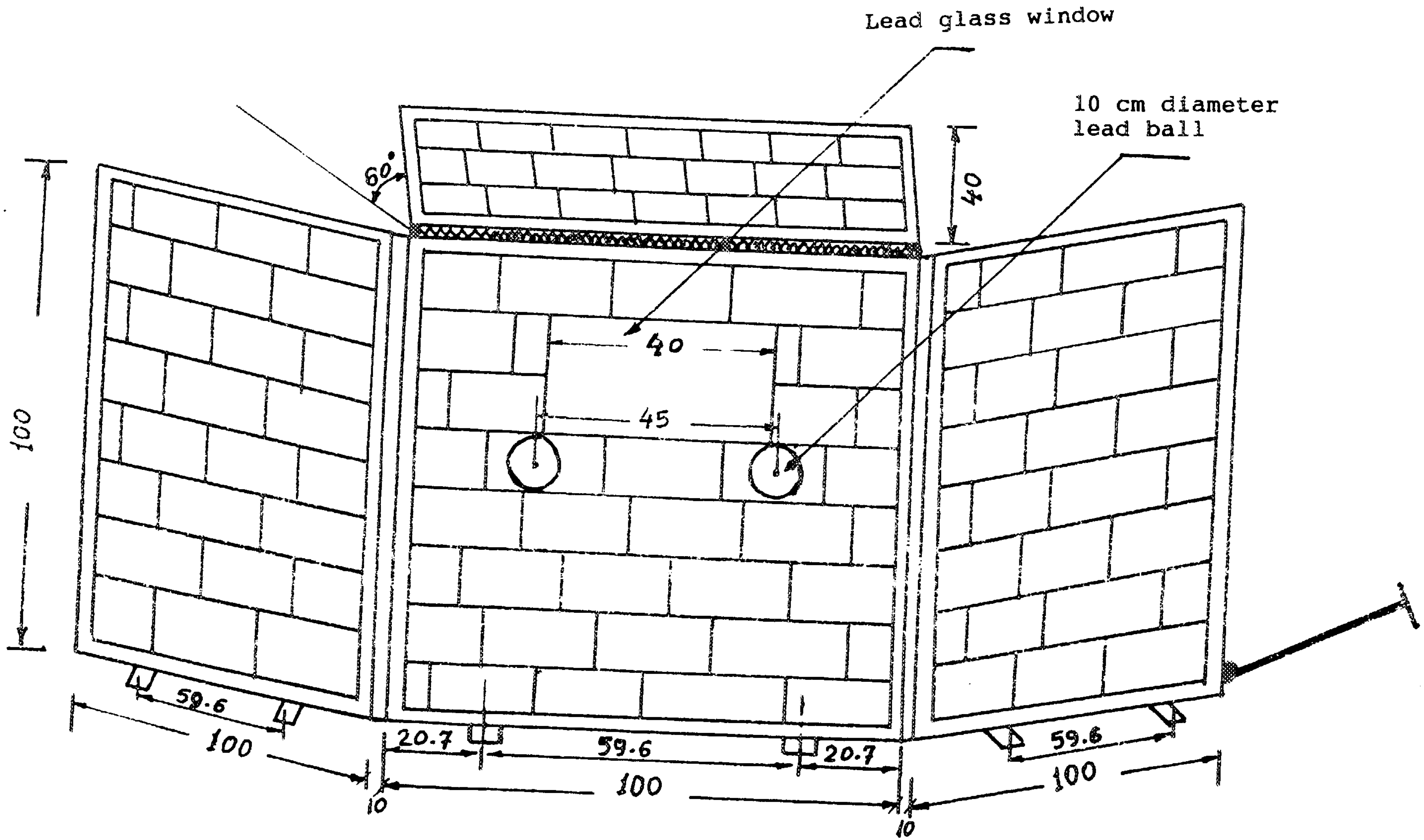


Fig. 1. General view for the shield. DIM. IN cm.

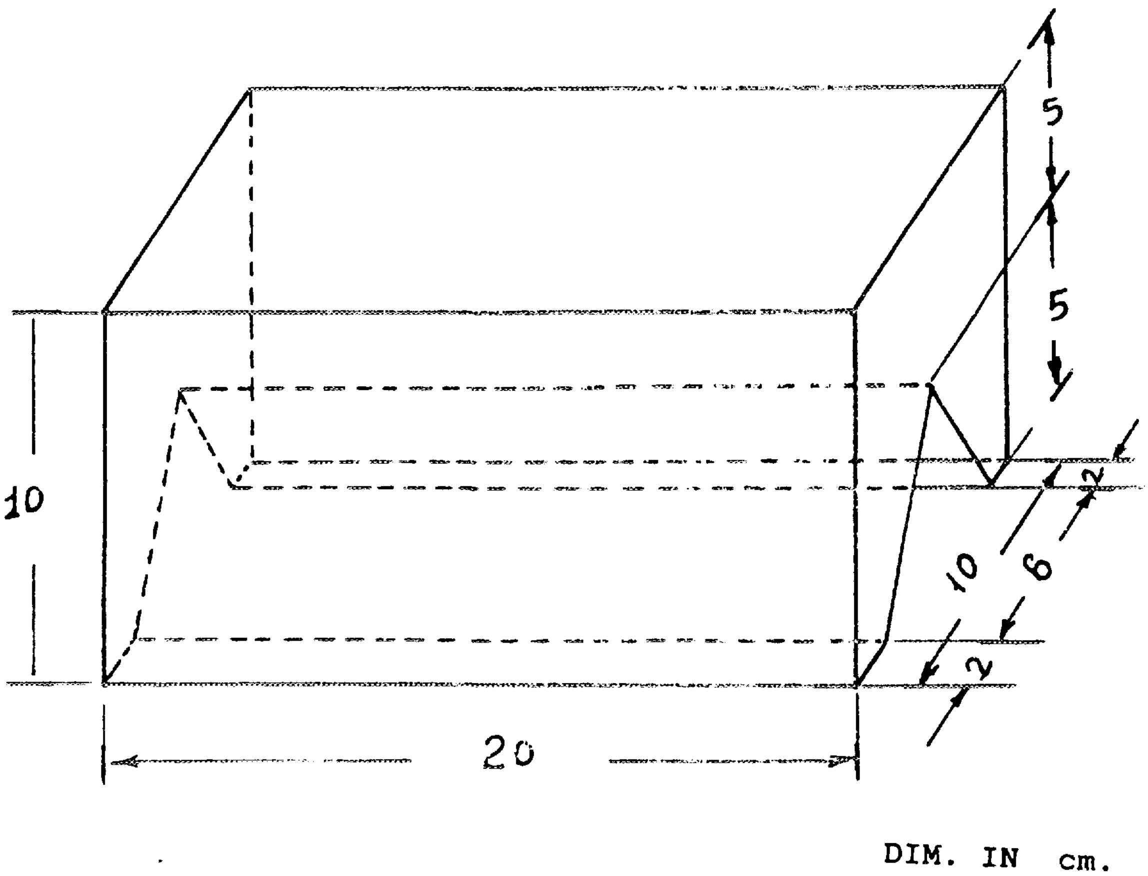
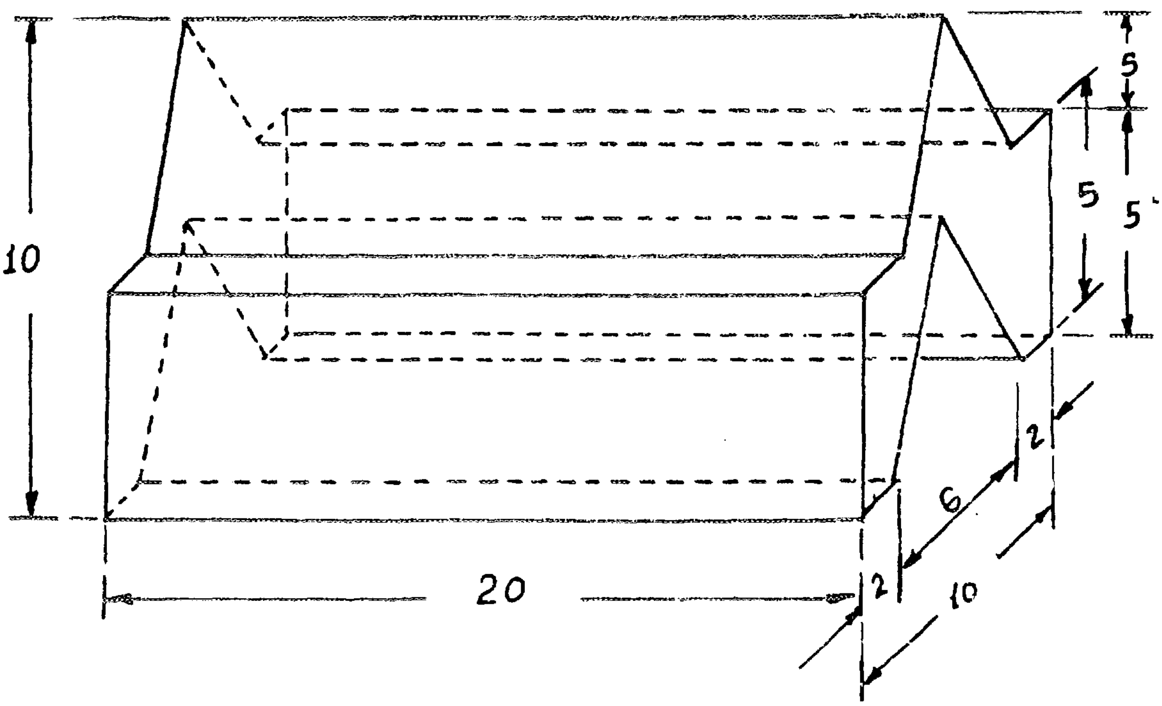
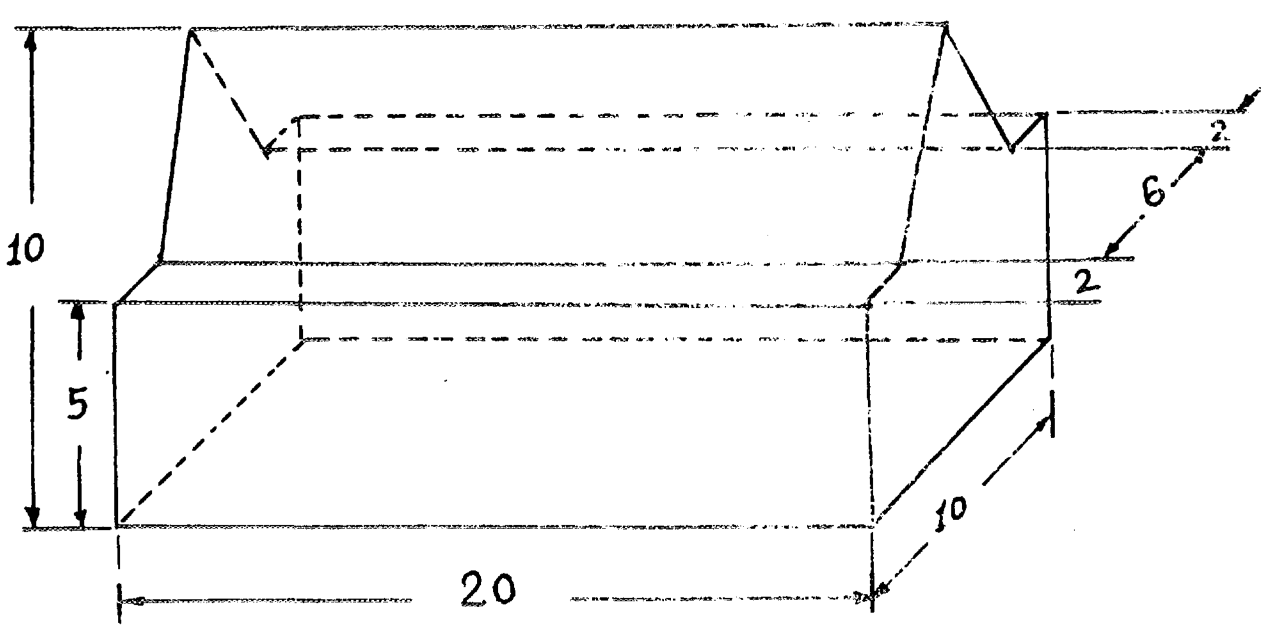


Fig. 2.a. General view for a lead brick used in the first raw of the shield.



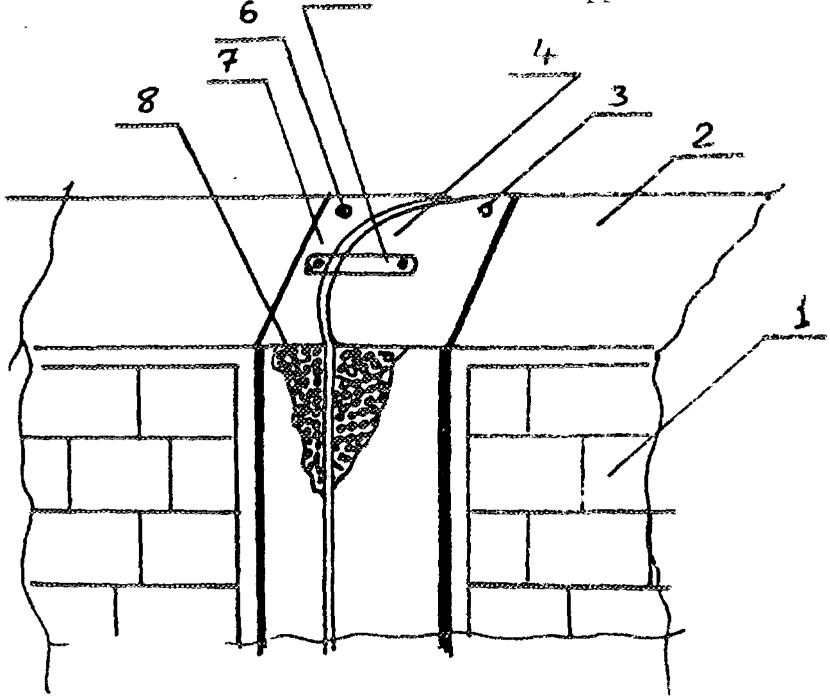
DIM. IN cm.

Fig. 2.b. General view for a lead brick used in the intermediate raws of the shield.



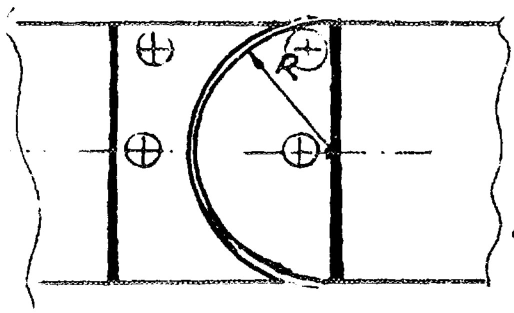
DIM. IN. cm.

Fig. 2.c. General view for a lead brick used in the last raw of the shield

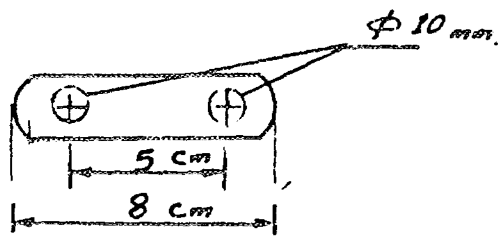


1- Lead bricks
2- U-Steel beam
3,6- 10 mm hole to fill the stainless steel hinge with the lead-balls
4,7- Stainless steel curved box filled with lead balls
8- Lead balls with 3 mm diameter

General view for the stainless steel boxes welded to tow nieghbor sides of the steel frame.

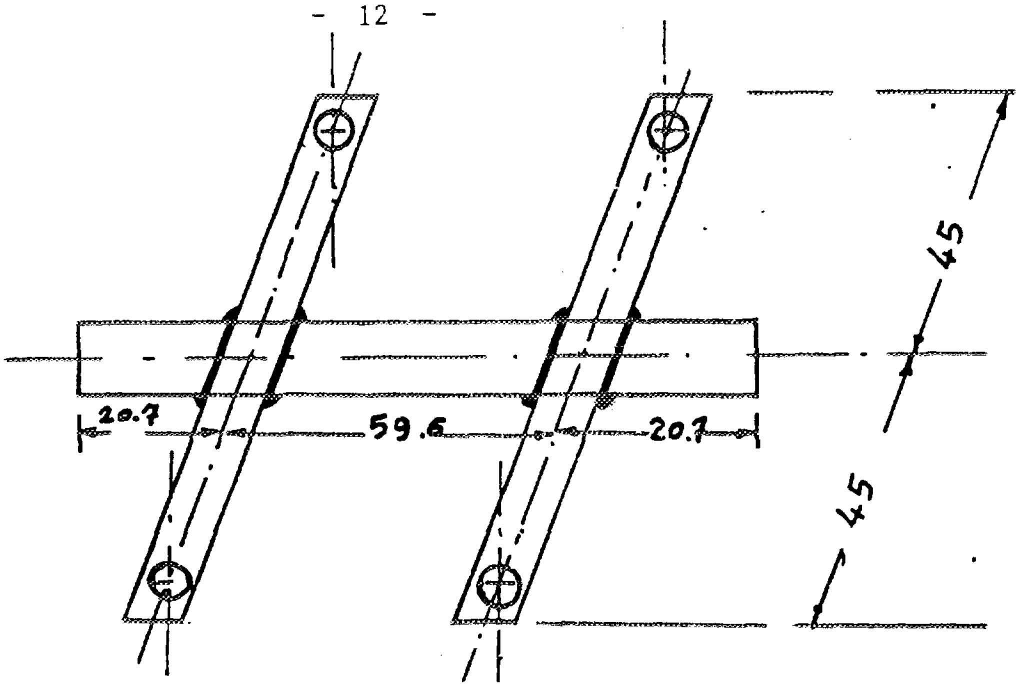


Top view for the stainless steel curved boxes, Items No. 4 & 7



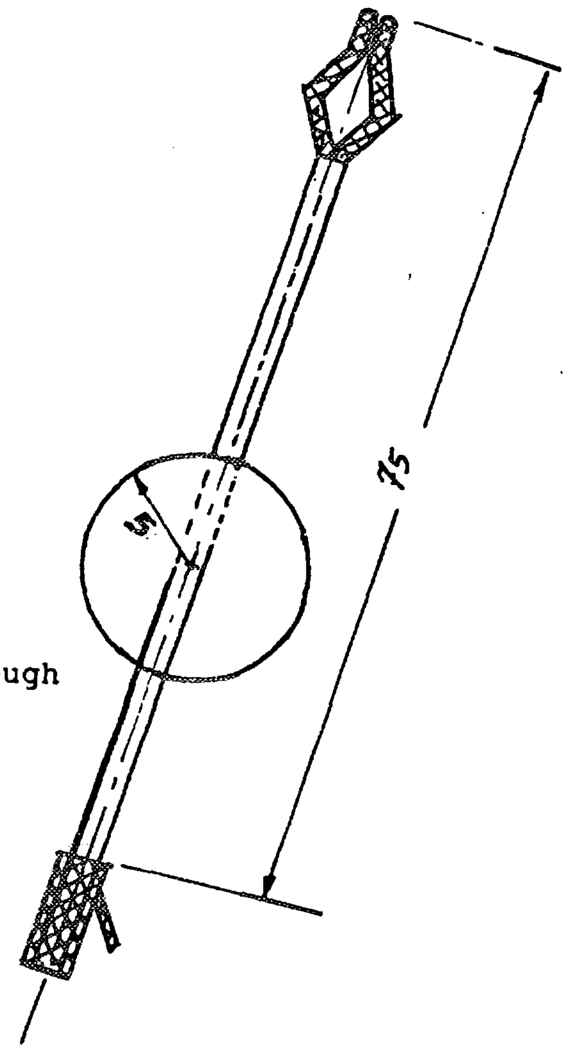
Steel grid (Item No. 5) with 8 cm long and 3 mm thickness, the grid has tow 10 mm holes. The grid is fixed to the stainless steel boxes by using tow M8 bolts and nuts.

Fig. 3. Detail drawing for the components of the shield.



General view for welding the I beam wings to the steel frame.

DIM. IN cm.



75 cm long tongue passing through 10 cm diameter lead ball.

Cont. Fig. 3.

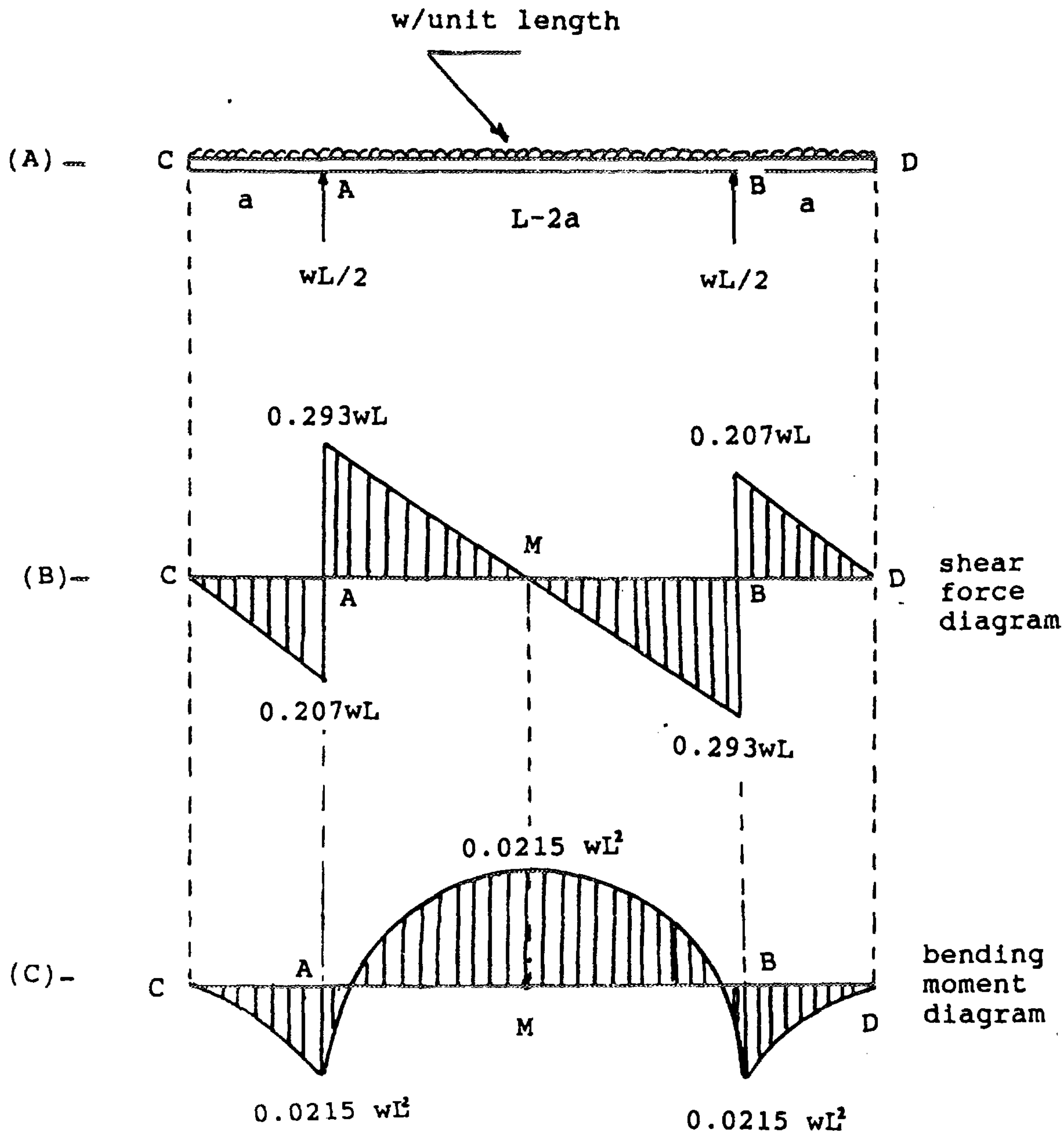


Fig. 4. Shear force and bending moment diagrams.

CASE: emer-1

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	3.700e+07	2.570e+00	4.637e-03
2	1.180	3.700e+07	1.226e+00	2.279e-03
3	.695	6.035e+03	1.299e-06	2.675e-09
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	TOTALS:	7.401e+07	3.796e+00	6.915e-03

CASE: emer-2

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 5.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.850e+08	1.285e+01	2.318e-02
2	1.180	1.850e+08	6.132e+00	1.139e-02
3	.695	3.018e+04	6.496e-06	1.338e-08
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	TOTALS:	3.700e+08	1.898e+01	3.458e-02

CASE: emer-3

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 1.0000e-02 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	3.700e+08	2.570e+01	4.637e-02
2	1.180	3.700e+08	1.226e+01	2.279e-02
3	.695	6.035e+04	1.299e-05	2.675e-08
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	TOTALS:	7.401e+08	3.796e+01	6.915e-02

CASE: emer-4

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 5.0000e-02 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.850e+09	1.285e+02	2.318e-01
2	1.180	1.850e+09	6.132e+01	1.139e-01
3	.695	3.018e+05	6.496e-05	1.338e-07
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	TOTALS:	3.700e+09	1.898e+02	3.458e-01

File: EMER-5.MSH

CASE: emer-5

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 1.0000e-01 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	3.700e+09	2.570e+02	4.637e-01
2	1.180	3.700e+09	1.226e+02	2.279e-01
3	.695	6.035e+05	1.299e-04	2.675e-07
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TOTALS:		7.401e+09	3.796e+02	6.915e-01

File: EMER-6.MSH

CASE: emer-6

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 5.0000e-01 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.850e+10	1.285e+03	2.318e+00
2	1.180	1.850e+10	6.132e+02	1.139e+00
3	.695	3.018e+06	6.496e-04	1.338e-06
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	TOTALS:	3.700e+10	1.898e+03	3.458e+00

File: EMER-7.MSH

CASE: emer-7

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 1.0000e+00 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	3.700e+10	2.570e+03	4.637e+00
2	1.180	3.700e+10	1.226e+03	2.279e+00
3	.695	6.035e+06	1.299e-03	2.675e-06
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	TOTALS:	7.401e+10	3.796e+03	6.915e+00

File: EMER-8.MSH

CASE: emer-8

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 2.0000e+00 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	7.400e+10	5.139e+03	9.273e+00
2	1.180	7.400e+10	2.453e+03	4.557e+00
3	.695	1.207e+07	2.598e-03	5.351e-06
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	TOTALS:	1.480e+11	7.592e+03	1.383e+01

CASE: emer-9

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 3.0000e+00 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.110e+11	7.709e+03	1.391e+01
2	1.180	1.110e+11	3.679e+03	6.836e+00
3	.695	1.811e+07	3.898e-03	8.026e-06
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	TOTALS:	2.220e+11	1.139e+04	2.075e+01

File: EMER-10.MSF

CASE: emer-10

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 4.0000e+00 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.480e+11	1.028e+04	1.855e+01
2	1.180	1.480e+11	4.905e+03	9.115e+00
3	.695	2.414e+07	5.197e-03	1.070e-05
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	TOTALS:	2.960e+11	1.518e+04	2.766e+01

CASE: emer-11

BUILDUP FACTOR: 1.0 (no buildup)

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Co-60: 5.0000e+00 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.336	1.850e+11	1.285e+04	2.318e+01
2	1.180	1.850e+11	6.132e+03	1.139e+01
3	.695	3.018e+07	6.496e-03	1.338e-05
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	TOTALS:	3.700e+11	1.898e+04	3.458e+01