

# MULTIPLE SOURCE TELECOBALT THERAPY MACHINE

By

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## INTRODUCTION

While studying radioactive cobalt teletherapy machines and the possibility of obtaining them for U.A.R., it became apparent that existing units suffer from certain disadvantages, namely :

1. the machine is expensive
2. they have to be imported.
3. the cost of the radioactive source is high.
4. due to the high specific activity of the radioactive source only large atomic piles can produce it.
5. the weight of the protecting head is great and concentrated in such a small area that it needs special floor fortification.
6. In case of rotating units, the mechanism for movement needs powerful electric motors which need maintenance.
7. certain elements as tungsten and uranium are used which are not available in every country.
8. the radioactive source has to be shipped abroad for reactivation.
9. the setting up time for each field consumes most of the therapy time as compared with the actual time.
10. in rotation the very lengthy complicated physical calculations necessitate highly trained physicists.

The possibility of constructing cobalt teletherapy units locally was thought of on a new line of physical basis.

### Hypothetical Scheme

The suggested unit aims at 1. combining the advantages of rotation therapy with those of fixed field therapy, i.e. simplicity. 2. minimising the cost of the machine. 3. minimising setting up time. 4. simplifying dose calculation by placing the tumor at a definite point during treatment. 5. producing the the radioactive cobalt source in the Egyptian atomic pile. 6. and using local material available in U.A.R.

The basic idea is to use multiple radioactive sources arranged along the circumference of a circle. All sources are firing at an isocentre where the tumor

must be placed. These sources are of low curie and their suggested number is 4,6,8,10 or one circular linear source.

### Physical calculations

Physical calculations were done to see if this theoretical hypothesis is possible.

If  $I_0$  is the intensity at 1 cm from a point radioactive source and there are a number of identical sources distributed evenly over a ring of radius  $a$ . If  $c$  is the isocentre of a circular cross section of a part under treatment such as the neck, arm or thigh of radius  $b$ , the intensity at any point  $p$  on the skin will be

$$I_p = I_0 \left( \frac{1}{(a+b)^2} + \frac{1}{(a-b)^2} + \frac{2}{a^2 + b^2} + \frac{2}{\sqrt{2} \frac{(a+b)^2 + a^2}{2}} + \frac{2}{\frac{(a-b)^2 + a^2}{\sqrt{2} \frac{2}{2}}} \right)$$

$$I_p = \frac{I_0}{a^2} \left( \frac{1}{(1+K)^2} + \frac{1}{(1-K)^2} + \frac{2}{1+K^2} + \frac{2}{\left(K + \frac{1}{\sqrt{2}}\right)^2 + \frac{1}{2}} + \frac{2}{\left(\frac{1}{\sqrt{2}} - K\right)^2 + \frac{1}{2}} \right)$$

$$I_p = \frac{I_0}{a^2} \left( \frac{1}{(1+K)^2} + \frac{1}{(1-K)^2} + \frac{2}{1+K^2} + \frac{2}{K^2 + \sqrt{2}K + 1} + \frac{2}{K^2 - \sqrt{2}K + 1} \right)$$

$$I_c = \frac{8 I_0}{a^2}$$

$$\frac{I_0}{a^2} = \frac{I_c}{8}$$

$$I_p = \frac{I_c}{8} \left( \frac{1}{(1+K)^2} + \frac{1}{(1-K)^2} + \frac{2}{1+K^2} + \frac{2}{K^2 + \sqrt{2}K + 1} - \frac{2}{K^2 - \sqrt{2}K + 1} \right)$$

$$\therefore \frac{I_p}{I_c} = \frac{1}{8} \left( \frac{1}{1 + K^2} + \frac{1}{(1-K)^2} + \frac{2}{1 + K^2} + \frac{2}{K^2 + 2K + 1} - \frac{2}{K^2 - 2K + 1} \right)$$

If however, the part at the isocentre is oval in contour such as the skull, chest, abdomen, or pelvis, of 2 A and 2 B, and therefore b will vary between A and B. Considering an average patient's cross-section of 30 and 24 cms major axes, K will vary between 0.24 and 0.3 for a ring radius 50 cm and between 0.12 and 0.15 for a ring of radius 100 cms.

	when a = 50 cms		when a = 100 cms	
	K = 0.3	K = 0.24	K = 0.15	K = 0.12
$\frac{I}{(1+K)^2}$	0.59	0.65	0.73	0.8
$\frac{I}{(1-K)^2}$	2.04	1.74	1.38	1.3
$\frac{2}{1+K^2}$	1.84	1.88	1.96	1.99
	4.47	4.27	4.07	4.09

$\frac{2}{K^2 + \sqrt{2}K + 1}$	1.31	1.43	1.61	1.68
$\frac{2}{K^2 - \sqrt{2}K + 1}$	3.0	2.3	2.45	2.35
	4.31	3.73	4.06	4.03

	when a = 50 cms		when a = 100 cms	
	K = 0.3	K = 0.24	K = 0.15	K = 0.12
$\frac{I_p}{I_c}$	8.78	8.00	8.13	8.12
$I_p / I_c$	1.098	1.00	1.016	1.015
	± 4.9 %	0%	0.8%	0.8%

At the isocentre, the dose is contributed from the primary beam and from scattered rays inside the body. The resultant isodose pattern at the isocentre and the tumor site is spherical. The variation in the resultant tumor dose was calculated for different sources and distances as follows when  $b = 15$  cm

Ring of eight sources

Factor	at 50 cms		at 100 cms	
	Value	Percent variation	Factors' value	Percent variation
$\frac{I_{15}}{I_c}$	1.1	5.0 %	1.016	0.8 %
$\frac{I_{12}}{I_c}$	1.06	3.0 %	1.016	0.8 %
$\frac{I_{15}}{I_{12}}$	1.035	1.7 %	1.00	0.0 %

Four sources placed along the

Crossing of major and minor elliptic cross section axes

	At 50 cms		at 100 cms	
	Value	Percent variation	Value	Percent variation
$I_{15}/I_c$	1.12	6.0 %	1.02	1 %
$I_{12}/I_c$	1.064	3.2	1.02	1 %
$I_{15}/I_{12}$	1.05	2.5 %	1.00	0 %

Four sources placed diagonally to the  
patient's cross section

Factor	At 50 cms		At 100 cms	
	Value	Percent variation	Value	Percent variation
$I_{15} / I_c$	1.08	4.0 %	1.015	0.75 %
$I_{12} / I_c$	1.06	3.0 %	1.00	0.4 %
$I_{15} / I_{12}$	1.02	1.0 %	1.00	0 %

A circular linear continuous  
ring source

$I_{15} / I_c$	1.1	5 %	1.022	1.1 %
$I_{12} / I_c$	1.06	3 %	1.014	0.7 %
$I_{15} / I_{12}$	1.830	1.7 %	1.00	0 %

The *penumbra* at the isocentre depends on the size of the source. As the sources which are recommended are of small size, i.e. not more than 5 mm, as compared with the standard 25 mm, the penumbra effect will be small as calculated :

source size	Penumbra
25 mm	37 mm
15 mm	22 mm
12 mm	18 mm
5 mm	7.5 mm

This is a real advantage over the single source units.

The source-aperture distance should be 25 cms which leaves us with the following distances to the isocentre

Source to isocentre	Aperture to isocentre	Source to source
50 cms	25 cms	100 cms
60 cms	35 cms	120 cms
70 cms	45 cms	140 cms
80 cms	55 cms	160 cms
90 cms	65 cms	180 cms
100 cms	75 cms	200 cms

This leaves a sufficient space for the treatment couch with patient lying on top of it to be moved freely in the vertical and horizontal directions.

#### Dose at Isocentre

The underlying idea of this machine is a combination of fixed field treatment and rotation therapy. As the source to isocentre is always fixed, the dose will be independent of the inverse square law. The factors governing the dose at the isocentre will be : 1. the thickness of the absorbing medium between the source and tumor, i. e. tumor skin distance. The bigger this distance, the smaller the dose reaching the tumor as the beam will pass through a thick layer of absorbing medium. While the smaller this distance, the higher the dose at the tumor as it passes through a thin layer of absorbing medium. 2. the size of the field, i.e. the cross section of the beam. The bigger the size of the field, the more the scattering and the dose reaching the tumor will be bigger.

Dose calculations at the isocentre are easily calculated while varying the above two factors one at a time. This can be verified by actual measurements. This simplifies dose calculations markedly as it is only necessary to draw an outline of the cross section of the part under treatment, localize the site and size of the tumor and from the predetermined tables we get straight away the dose contributed from each source, on condition that the tumor is placed at the isocentre. This necessitates that the horizontal and vertical movements of the treatment couch are marked clearly on the planning sheet. So both 1. the planning time and 2. setting up time are minimized and simplified.

### Construction of the Machine

The multiple radioactive sources, each inside a separate capsule are mobile inside separate tubes, so that when the machine is on, they are opposite the apertures, while in the Off position they are withdrawn by a weight away inside a concrete block. This weight moves up and down a well against gravity by a small electric motor, so that in case of power failure the sources are automatically withdrawn into the safe position.

The opening opposite each source is guarded by lead blocks which can be adjusted to form the necessary aperture and act as adjustable diaphragm. These lead blocks are fixed to two steel wheels which are made to rotate in opposite directions by a handle. This pairing of the wheels and their opposing movements simplifies the construction and minimizes the cost and effort as compared with the heavy cones that are used with some units. Two indicators show the width and length of the irradiating field by registering the movement of the wheels.

The treatment couch can be a surgical operation table which can be raised and lowered by lever worked by the foot. The pedestal should be marked in cms and its top should have midline mark and is made of detachable pieces, so that the proper segment under the part to be treated is removed. The whole table is moved in and out of the circular treatment head on rails and can be fixed in the required position.

The control panel contains 1. a switch to actuate the motor against the weight so as to bring the sources in the ON position. 2. a count-down stop watch which is switched on when the sources come opposite the apertures and at the end of the predetermined time switches off the motor, so as to let the sources retract by the weight inside the protective concrete block.

The viewing between the control room and treatment room is through a window having a glass tank full of 77 % solution of zinc bromide in water. Its

density is 2.5 grams/cc at 20 degrees cent. Its transmission of light is 97 % of an equal length of water. Forty grams of hydrazine hydrobromide are added to each 100 gallons to decolorize it as under the action of ionizing radiation, the solution becomes yellow due to the liberation of bromine. The thickness of the solution and the shielding wall made of concrete of 2.3 gm/cc density to give 10 m r / week is as follows for the cobalt sources ;

	At 3 metres	At 4 metres	At 5 metres
concrete wall	75 cms	70 cms	67 cms
mercuric bromide window	66 cms	62 cms	59 cms

*Physicist's calculating simulator* should be exactly of the same size and shape of the circular treatment head and treatment couch with the radioactive sources being replaced by electric lamps. The patient is represented by the cross section of his body at the level of the tumor and drawn in the normal dimensions on a perspex plate and the tumor is marked. The patient's midline must coincide with table midline. Then the mobile table carrying this plate is moved up and down and sideways till the tumor is put in the isocentre. The diaphragms are opened till the suitable opening size covering the tumor-bearing area is reached. Then the physicist writes down 1. the tumor skin distance for all the fields 2. the source skin distance for all the fields. 3. the size of the fields 4. the tumor dose contributed by each source. 5. the position of the treatment table in relation to the treatment head, i.e. how many cms up and down and to either right or left. 6. The points of entry of at least three fields are marked on the skin of the patient.

## DISCUSSION

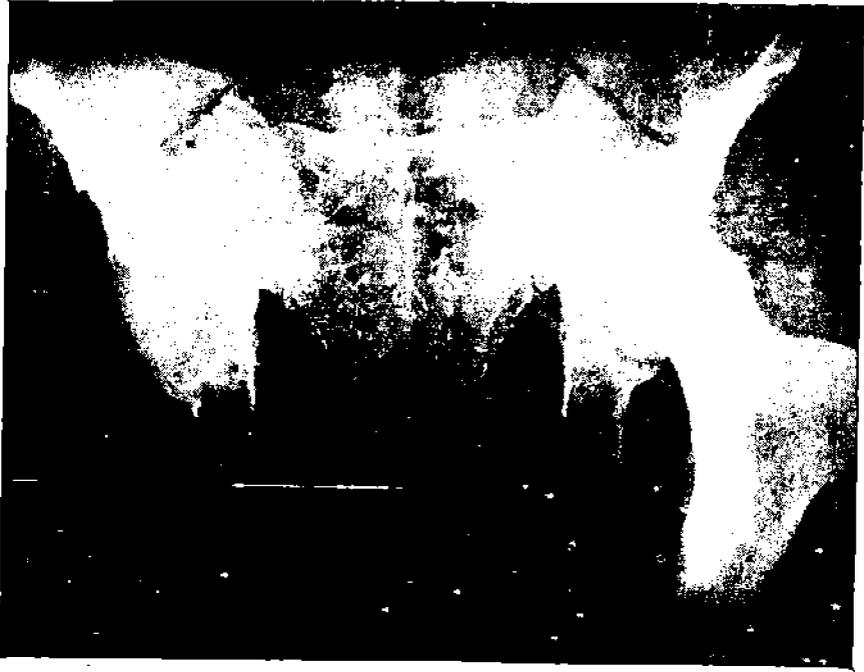
It is seen that it is possible to construct such a multi-source cobalt therapy machine with the following advantages :-

1. low initial cost of machine and sources.
2. no maintenance costs.
3. low reactivation cost.
4. protection problems are simplified.
5. concrete is used as the shielding material.
6. Gravity is used for the source movements.
7. No motors are needed.

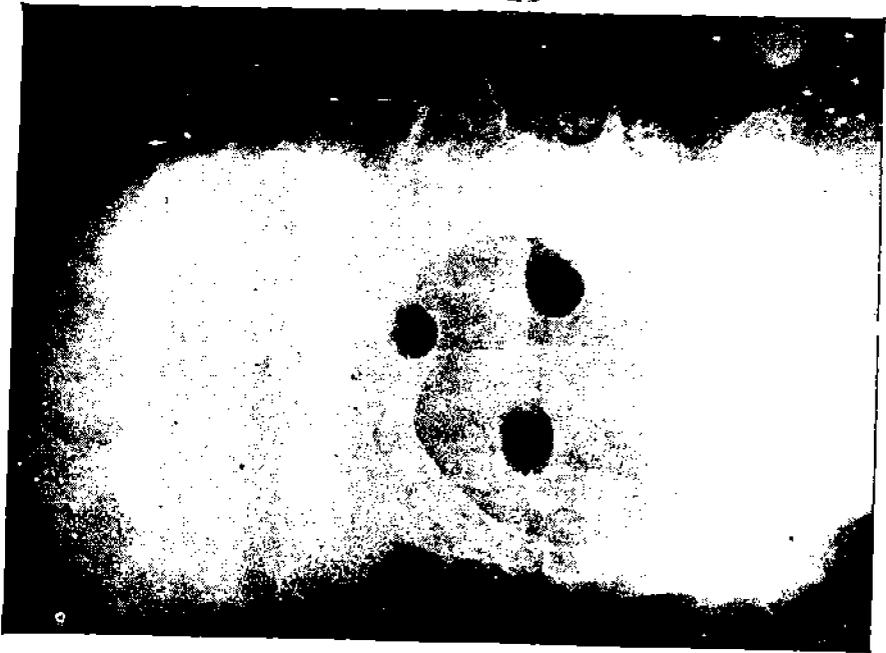
8. In case of war, the radioactive sources can be withdrawn inside the well.
9. Making the sources and their reactivation can be done in the Egyptian atomic pile.
10. the penumbra is small.
11. physical planning is simplified.
12. setting up time is shortened.
13. this unit can be constructed locally and by local material.
14. The radioactive sources of low curie, i.e. 200 or 300 curies and of small dimensions, i.e. about 5 mm. are used in the suggested machine.
15. The firms are now trying to decrease both the weight and price of present teletherapy machines by cancelling the obstructing lead shield and recommending thickening of the walls.

#### REFERENCES

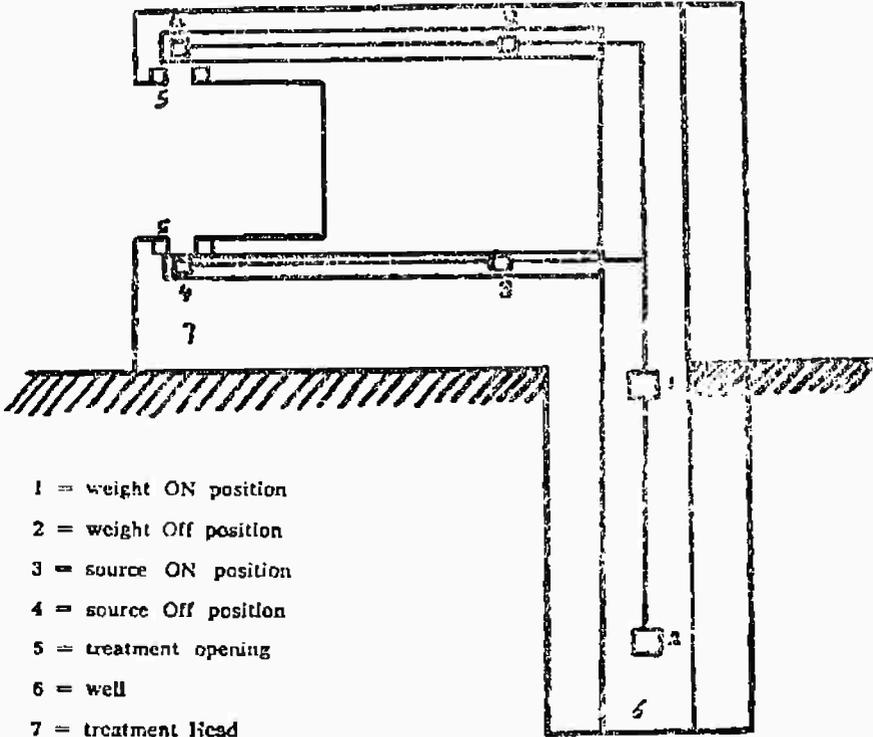
1. CADE S. Malignant disease and its treatment by Radium Wright Bristol.
2. MEREDITH W.J. Radium Dosage 1949  
Livingstone, Edinburgh.
3. WILSON C.W. Radium Therapy 1945  
Chapman, London.



Anatomical Phantom

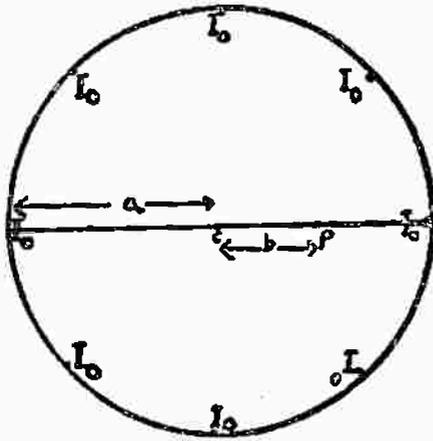




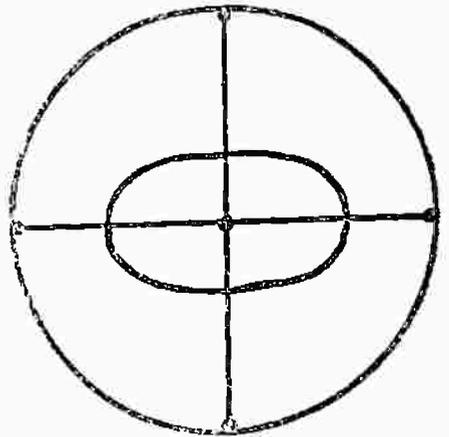
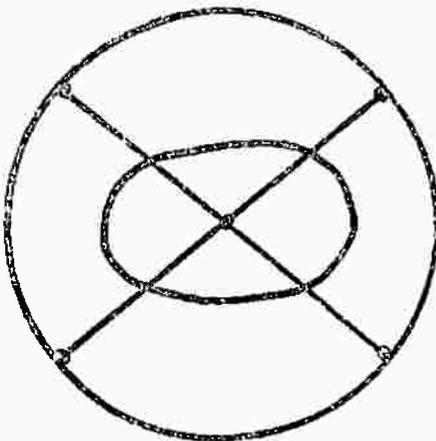


- 1 = weight ON position
- 2 = weight Off position
- 3 = source ON position
- 4 = source Off position
- 5 = treatment opening
- 6 = well
- 7 = treatment head

Cross Section of Apparatus



$c$  = isocentre  
 $a$  = radius of rmg  
 $b$  = radius of cross section of circular part of patient  
 $p$  = intensity on skin  
 $I_0$  = intensity 1 cm from source



Four Sources Placed

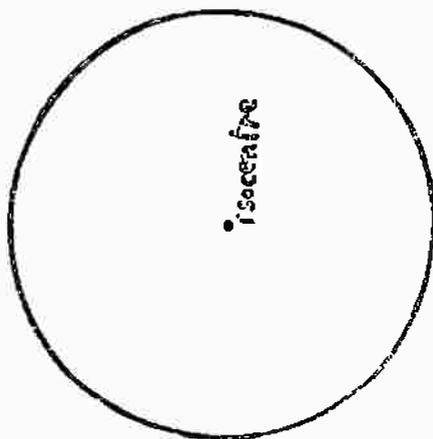
2. Diagonally.

1. along crossing of major and minor elliptic cross section axes.

Single Source Fixed



Single Source Rotation



Multiple Sources

