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Design and usage of a Cs137 gamma irradiator for breeding and physiological studies [by] Homer Patrick, R.E. Emerson and H.M. Hyre.

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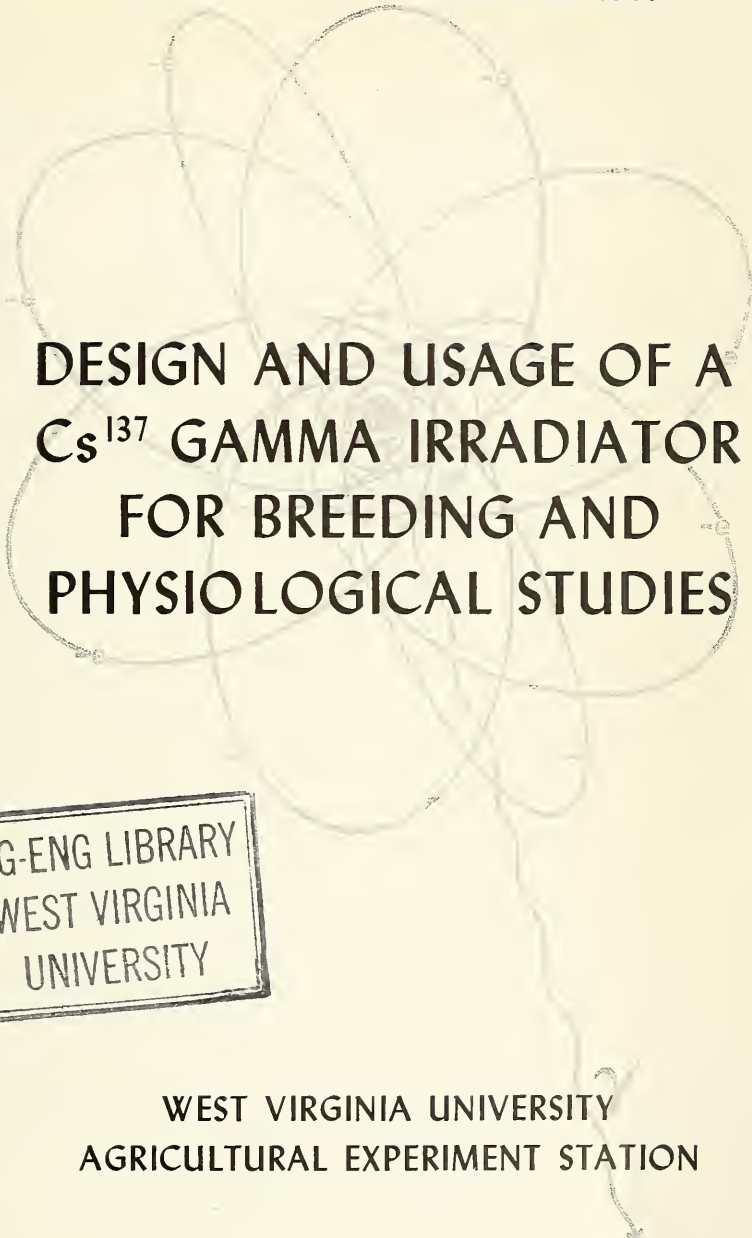


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DESIGN AND USAGE OF A
 Cs^{137} GAMMA IRRADIATOR
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THE AUTHORS

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Design and Usage of a Cs¹³⁷ Gamma Irradiator For Breeding and Physiological Studies

HOMER PATRICK, R. E. EMERSON and H. M. HYRE

Introduction

Although new species or forms rarely occur, scientists know that individuals can appear within a specie which have different characteristics. Although the reason or cause of these changes have not been fully determined, some scientists believe that they are due to cosmic radiation. This belief encouraged investigators to use X-rays and gamma rays experimentally. This has resulted in the production of genetic changes in both animals and plants.

Several gamma irradiators containing Cobalt⁶⁰ (Co⁶⁰) are in use in the United States. Some are point sources, such as those used at Brookhaven National Laboratory or at Blandy Research Farm in Virginia, or the tube-type holder which has Co⁶⁰ in tubes held in a position so that they surround the object to be irradiated. This type of arrangement is used at the Universities of Georgia, Florida, and Tennessee. Although it allows high levels of irradiation, the isodose curves are not true circles since there are many small sources located at different distances from the object being irradiated.

A gamma irradiation facility for poultry research should provide a dose-rate high enough for sperm irradiation within the time sperm physiologists are able to maintain the sperm in viable condition; however, the dose-rate should be low enough for use in whole body irradiation in living animal studies. If the dose-rate is high (over 40,000 r/hr.), the error brought about because of the time required to raise and lower the source when only a few roentgens are used will be great, and if too low (50-100 r/hr.), the increased mortality or decreased viability of sperm brought about by holding it for the longer period of time required to obtain enough irradiation as recommended for genetic studies will be excessive because poultry sperm does not remain viable for long periods of time.

The gamma rays emitted by the source should be strong enough to effectively penetrate the samples being irradiated, but not so strong as to hinder insulation (shielding) to any great degree.

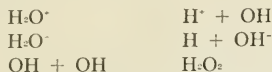
The radionuclide should be available at a reasonable cost and should have a long enough radiochemical half-life so that the decay rate will be of such an order as to not interfere with the irradiation program per season. Also, the radionuclide unit should be easy to fabricate so that a uniform dose-rate can be obtained and leakage controlled. Some radioactive metals pass through the holding equipment (molecular channeling) into the water bath much easier than others and hence require special fabrication methods.

A gamma irradiator is defined as a radionuclide device which emits gamma rays. These rays differ from those emitted by an X-ray facility. X-rays are extra nuclear rays given off when the electrons in the shells are disturbed, whereas gamma rays are intranuclear electromagnetic radiations (photons) which arise from nuclear decay and are shorter in length than X-rays. Some investigators indicate that X-rays and gamma rays are identical except for origin; however, they differ in length and strength and in penetrating power.

When gamma rays penetrate matter, they lose their energy by excitation and ionization of the molecules they contact. Gamma rays interact with matter by a variety of processes such as photodisintegration, Bragg's scattering, formation of isomeric nuclear levels, photoelectric effect, the Compton effect, and pair production (electron and positron production).

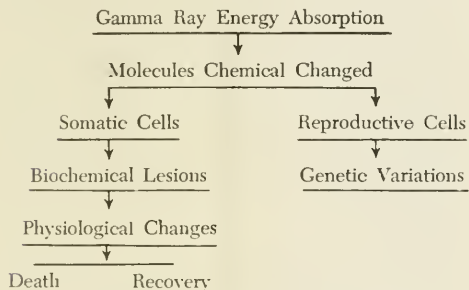
There are two possible explanations for the effect of radiation on living tissue or cells. One is the direct inactivation of some essential component of the cell by ionization (a direct hit on an enzyme system, DNA, etc.). The other possibility would be indirect inactivation by an intermediate which is produced by radiations and then reacts with an essential compound. The water molecule has been considered the choice for energy absorption in which it has been estimated that the free radicals H[•] and OH[•] are formed within 10⁻²² seconds after the passage of a particle or

photon-induced electron through an aqueous medium. Within a microsecond these radicals have either recombined, combined with identical radicals, or reacted with solutes in the system.



The water molecule loses an electron which changes into a positive water ion. The electron is immediately taken up by another molecule of water to give a negative water ion. The hydroxyl radicals, OH, have a strong oxidizing action and attack organic matter. The uncombined hydroxyl radicals combine in pairs to form H₂O₂. The short-lived oxidizing radical, HO₂, is also formed.

The influence of gamma irradiation on a biochemical structure could be a chemical change which results in death of the animal because of improper physiological function, or the change could be in the DNA structure of the reproductive or somatic cells. The change in the DNA of the reproductive cells could cause a genetic variation, whereas changes in somatic cells could result in physiological and biochemical variations that would not influence inheritance.



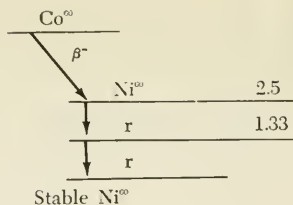
Some investigators use Co⁶⁰ in irradiators because it has greater penetrating power; others prefer Cesium¹³⁷, which has less penetrating power. A summary of the radiochemical properties of Cs¹³⁷ and Co⁶⁰ follows:

Comparative Radiochemistry of Cs¹³⁷ and Co⁶⁰

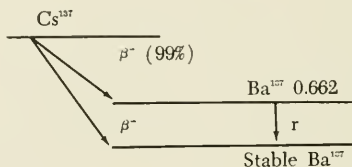
Isotope	Half-life (Years)	Energy (Mev)	
		Beta	Gamma
Cesium ¹³⁷	30	0.52, 1.15	0.032, 0.662
Cobalt ⁶⁰	5.2	0.31	1.17, 1.33

Cs¹³⁷ is a fission product resulting from the fission of uranium, and Co⁶⁰ is produced by neutron activation Co⁵⁹(n,γ)Co⁶⁰.

The decay scheme of Co⁶⁰ is as follows:



Cs¹³⁷ is used in the West Virginia University Agricultural Experiment Station Irradiator. The following decay scheme of Cs¹³⁷ indicates how the gamma ray is produced.



Decay Scheme of Cesium¹³⁷

The decay scheme of Cs¹³⁷ shows that the gamma ray is actually produced when the daughter, Barium^{137m}, decays into stable Barium. The gamma spectra (Figure 1) indicates that the strongest ray produced is 0.662 Mev, with a lesser one of .032 Mev. Also, a 0.52- and a 1.15-Mev beta particle is produced. Cs¹³⁷ is an ideal source to use because it has a long radio half-life (30 years) and produces a 0.662-Mev gamma ray which is strong enough to penetrate through eggs, tubes of semen, and small animals such as mice, rats and chicks, yet weak enough to allow shielding with reasonable ease.

Design of the Gamma Irradiator

The West Virginia University Agricultural Experiment Station gamma irradiator contains 300 curies of Cs¹³⁷ and is designed so that many dose-rates can be obtained (36,000 r/hr. to 25 r hr.). Table 1 indicates the r/hr. along with the holders and tables available.

The irradiator assembly consists of three main parts—the building, the well, and the irradiation tables. The building is of filled concrete block, with reinforced concrete roof and floor slabs, as shown in Figure 2. The well is a 12-inch diameter hole extending 12 feet below the floor level of the building and

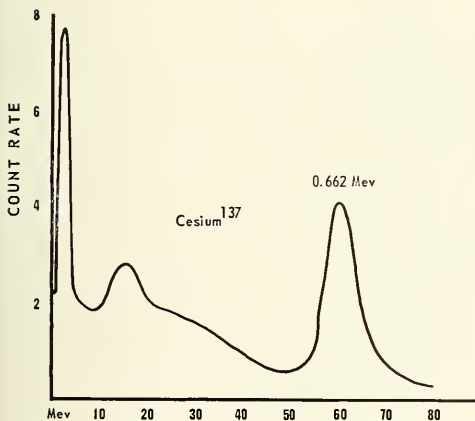
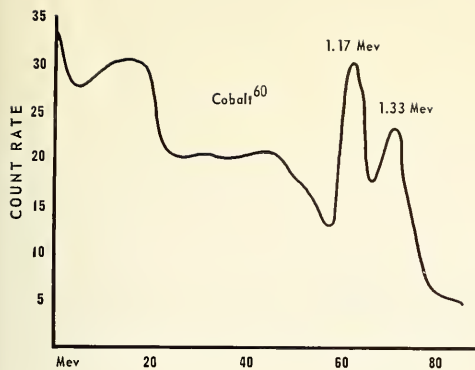


Figure 1. Gamma Spectra of Cobalt⁶⁰ and Cesium¹³⁷.

cased with aluminum pipe. To provide for loading of the irradiator, a 4-inch diameter tube is located directly above the well and extends through the ceiling or roof to ground level. Within the well is a 2-inch diameter aluminum tube which acts as a guide for the capsules containing the irradiation source. The well and its construction details are shown in Figures 2 and 4. The irradiation tables are of three different types and are shown in Figures 5, 6, and 7. The two smaller tables are held in position by clamping them directly to the aluminum well casing, while the third rests on legs and is centered over the well.

This irradiator is housed in a cellar-type reinforced concrete and filled cement block building (Figure 2). The 6-inch reinforced concrete roof is covered with soil. The structure is electrically heated

and all metal parts (except electrical fixtures) of the irradiator are constructed of aluminum or stainless steel.

The Cs¹³⁷ source is enclosed in a 9-inch aluminum structure resembling a rolling pin (Figure 3). The source (300 curies of Cs¹³⁷) is sealed in a stainless steel capsule which was designed and constructed by the Oak Ridge National Laboratory as shown in Table 2 (ORNL-LR-DWG 2339A). The capsule containing the cesium source is located midway in the aluminum "rolling pin" so that the unit could be installed with either end in the up or down position. This rolling pin design was used because it could be gripped easily during loading, and the ball-type end allowed the usage of a simple gripper to connect with the stainless steel cable used for raising or lowering. The rolling pin functions up and down in an aluminum type (pipe) with a micro-switch pin indicator-and-stopper to signal the position of the source as shown in Figure 4. The Cs¹³⁷ unit is placed into the 1-foot diameter aluminum well by way of the irradiator loading tube in the roof. This reduces loading time and provides for greater protection during loading.

The specimen to be irradiated is placed in the holders as shown in Figures 5 and 6 or placed on the tables as shown in Figures 7 and 8. The dose-rates of these holders or tables are presented in Table 1. The holders and tables provide a wide range of dose-rates for irradiation studies. Figure 8 shows a table which provides eight levels of irradiation per hour and is so designed that all eight tables can be operated at one setting. The electric motors used in all the tables or holders are gear-reduction motors.

This gamma irradiator is, for all practical purposes, a point source; hence, the isodose curves are perfect circles.

Table 1
Irradiation Rates and Holders or Tables

No. Holders or Tables	Shown in Figure	Size Holder or Table	r/hr.
8 Holders (14) ^o . . .	5	8 test tubes 3/4" diameter	36,000
12 Holders (7) ^o . . .	6	12 test tubes 1 1/4" diameter	3,600
18 Tables (1) ^o . . .	7	8" tables 6-8 rats or chicks per table	180
8 Tables (3) ^o . . .		8" tables 6-8 rats or chicks (one at each level as shown)	800, 700 600, 400 200, 100 50, 25

^oRevolutions per minute of each table or holder.

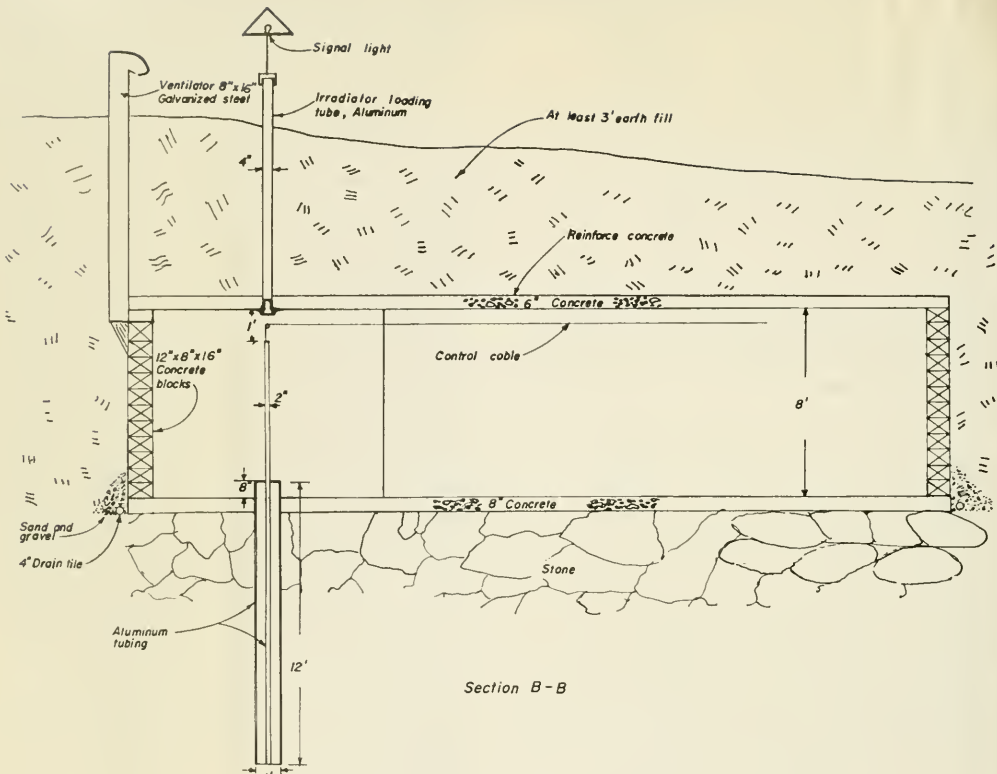


Figure 2. Gamma Irradiator Laboratory Building.

Any irradiation program requires a thorough understanding of the strength of the irradiator and also some biological index to base or use as a standard. The decrease in spleen weight of chicks 21 days old or 200-gram rats, the serum phosphatase level in chicks, or the amount of irradiation required to reduce fertility 50 per cent in breeding hens inseminated with irradiated sperm are indexes used at the West Virginia Station (Table 2). The common expression for irradiation studies are LD 50 for fertility, LD 50 for spleen weight, and LD 50 for phosphatase—which means the amount of irradiation required to reduce fertility, spleen weight, or phosphatase 50 per cent.

The data in Table 2 on the influence of gamma irradiation on spleen weight, serum alkaline phosphatase and Se^{75} retention of cockerels three weeks of age demonstrate that this irradiator which allows many groups of animals and different dose rates can

produce more usable data than most irradiators. Also, the energy level is such that a high level of irradiation can be used in animal work without causing high early mortality. The trends in the present data are similar to reported results but uniformity is improved.

This gamma irradiator offers several advantages over some existing units:

1. The Cs^{137} has a half-life of more than 30 years as compared to Co^{60} with a half-life of 5.27 years. The long half-life of Cs^{137} allows seasonal studies to be made without large changes in irradiation rates being made. Also, the need for replacement of the radioactivity is reduced greatly.

2. The gamma ray of 0.662 Mev of the Cs^{137} irradiation as compared to 1.33 Mev of Co^{60} gives the Cs^{137} unit enough energy to penetrate tissues, but it is not difficult to insulate.

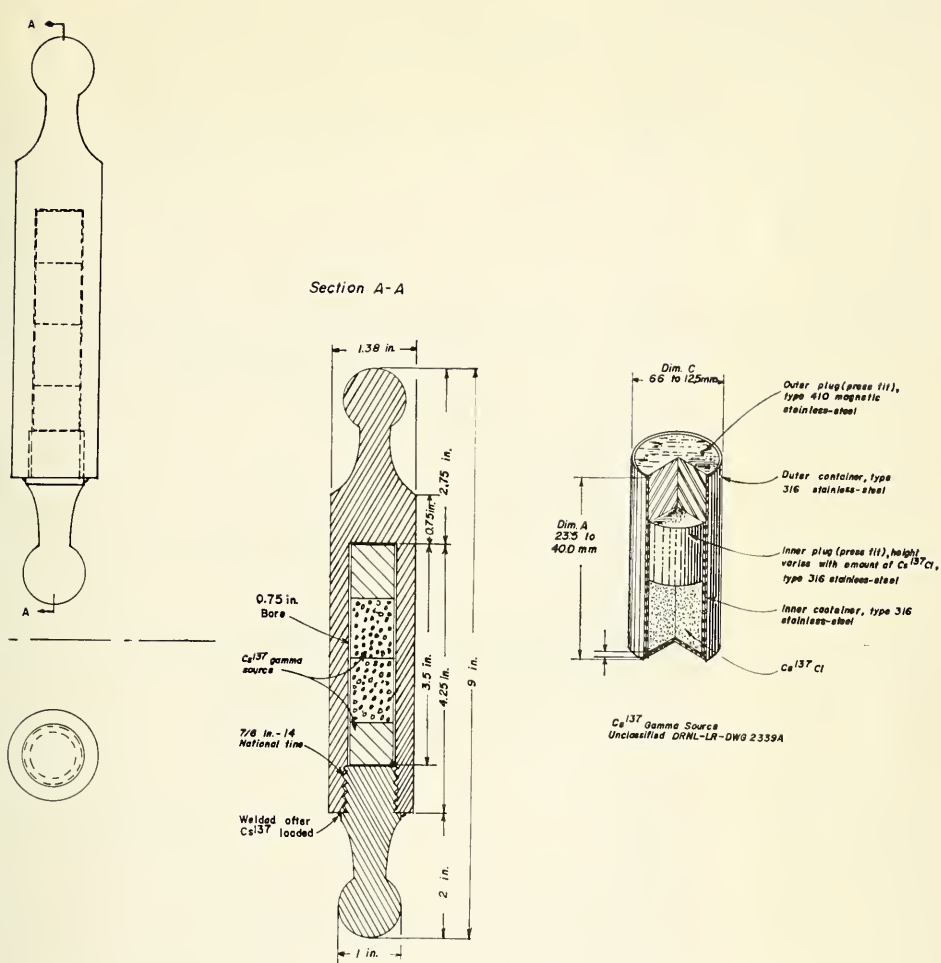


Figure 3. Cs¹³⁷ Capsule.

5. This irradiator allows many levels of irradiation to be obtained at one setting, yet gives uniform dose to each sample or specimen.

6. This irradiator is a point source; therefore, a high dose rate can be obtained.

5. The source holder is so designed that leakage is almost not possible and handling is very easy.

6. The underground construction allows uniform temperature, insulation to be maintained with ease, as well as freedom from noises. This is very important in handling animals in strange quarters.

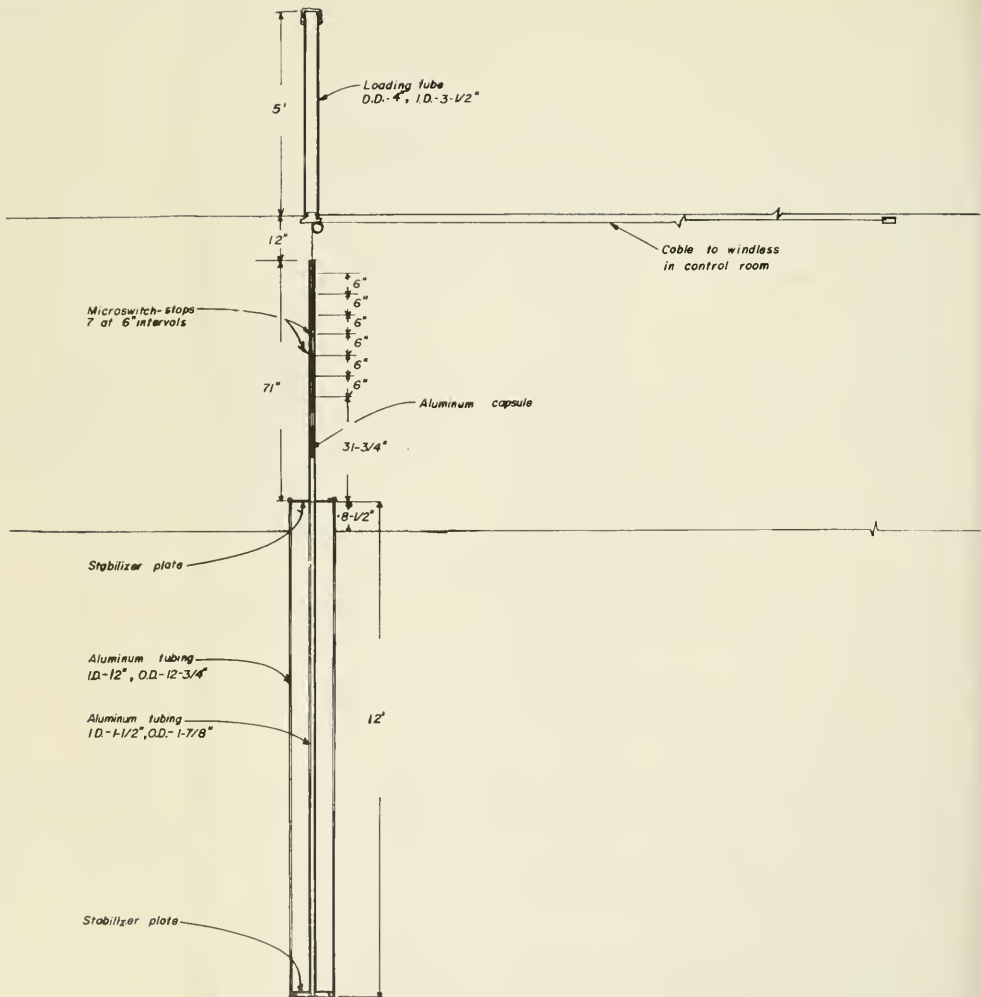


Figure 4. Cs¹³⁷ Well and Microswitch Positions.

Table 2
Influence of Gamma Irradiation, Spleen Weight, Serum Alkaline Phosphatase and Se⁷⁵ Retention in 3-week-old Cockerels

Total Dose (r) of Gamma Irradiation	1600	1400	1200	800	400	200	100	50	0
Dose rate r/hr.	800	700	600	400	200	100	50	25	0
White Leghorn Cockerels (21 days old)									
Spleen ^o									
Avg. Wt. (gms)	.038	.036	.041	.038	.049	.066	.071	.092	.11
Se ⁷⁵ content	6.45	7.55	8.25	12.6	16.1	17.2	28.1	27.8	27.9
Alkaline Phosphatase ^o	73	138	168	138	168	182	196	218	240

^oResults obtained 24 hours post irradiation. Phosphatase expressed as Sigma Units of alkaline phosphatase, per ml. of blood serum. Se⁷⁵ expressed as per cent of a standard containing a known amount of Se⁷⁵.

Table 3
The LD 50 of Irradiated Sperm*

Breed	Roentgens Required to Reduce Fertility 50%
Rhode Island Reds	1733
New Hampshires	1821
White Leghorns	2033
Average	1862

^oThe semen was diluted 50-50 with a phosphate ringers solution and subjected to different levels of irradiation using the hold which provided 3,600 r/hr. The hens were artificially inseminated with the semen after treatment and fertility were determined. The average level of irradiation required to reduce fertility 50 per cent was found to be 1862 r.

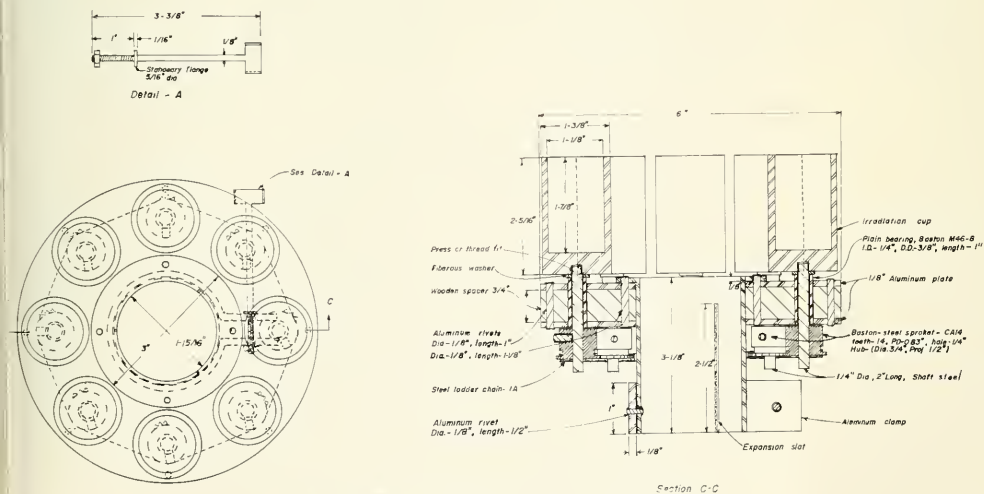


Figure 5. High Level (36,000 r/hr) Holders.

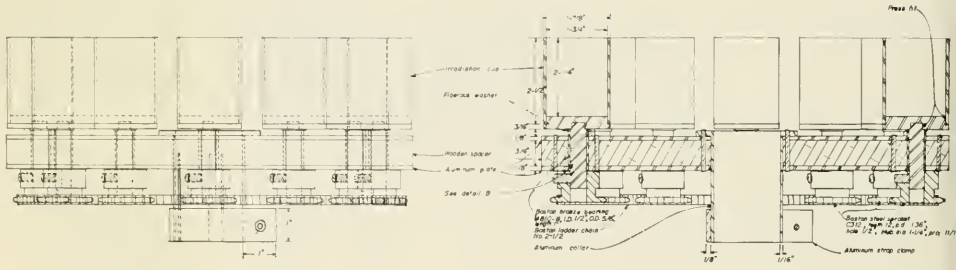
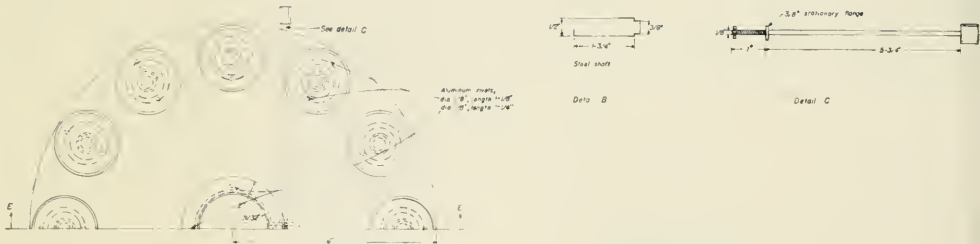
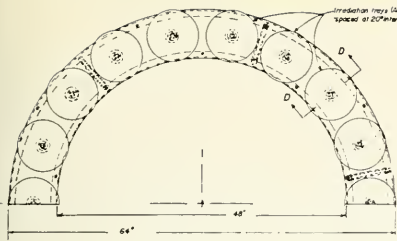
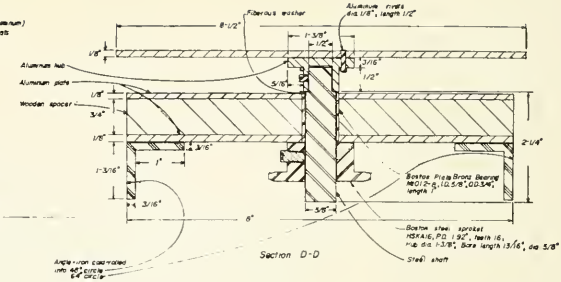


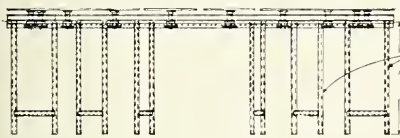
Figure 6. Holding Table (3,600 r/hr.).



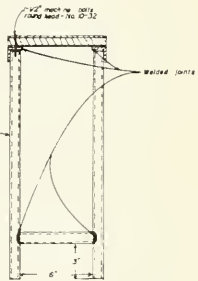
Half of Top View



Section D-D



The legs are constructed of 3/4" brass pipe which has washer joints at 60" intervals



Detail-H

Figure 7. Irradiation Holding Units (180 r/hr.).

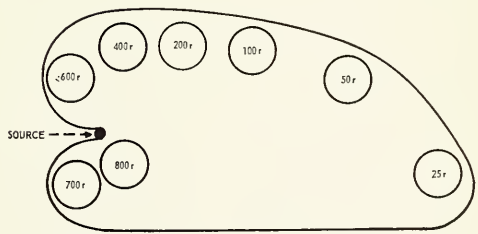


Figure 8. Multiple Dose-Rate Table Top.

