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The 2000 Curie Cobalt-60 Gamma-Ray Irradiation Facility for Biological Studies

Hirotada YAMAGATA*

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A gamma-ray irradiation facility for biological studies, providing 2000 Curie ^{60}Co source, was installed at the Faculty of Agriculture of Kyoto University in 1967. This facility is composed of a building, a gamma-ray irradiation system and an environment regulation system. The irradiation field shapes nearly a semicircle and is equally divided to three irradiation rooms. All the rooms are separately regulated on the condition of temperature, humidity and illumination. Two control rooms, being adjusted to the same conditions as those of irradiation rooms, are installed for analysis of radiation effects. The source strength of 2000 Ci is divided into 20, 180 and 1800 Ci, which can be selected by remote operation. Three lead filters operated remotely are equipped for each irradiation room, and each of them attenuates dose rate to one tenth. Temperature of the irradiation room is adjustable within the range of 5°～15°C for one room and 15°～30°C for other two rooms, and can be automatically changed with timers. Humidity of those rooms is kept within 50～90 %. Illumination intensity of each room can be controlled to 5000, 500 and 0 lux at the floor. Lighting time also is chosen with timers.

INTRODUCTION

Studies on analysis and utilization of the biological effects of radiation have taken huge strides in recent years, and the satisfactory fruits have been reported one after another in various fields of biological sciences. However, there remain not a few problems to be solved for further progress of the studies.

It seems one of them that the reaction of living things to radiation should be grasped dynamically. It is well known that the biological effects of radiation are remarkably influenced by the metabolic activity of organism[1,2], and that the activity differs not only with different ontogenetic phases and different parts of the organism but also with different environments given to the organism. For instance, the reduced metabolic activity caused by lower temperature gives rise to more drastic injury of radiation through the prolonged cycle time of cell division[3,4]. Thus, for the dynamic grasping of radiation response, it is necessary that the irradiation environments, such as temperature, humidity and intensity of illumination, can be strictly controlled at will.

It appears to be another problem of importance that organic close contacts should be kept among studies in many different fields related to biology. In this sense, it is needed to install an irradiation facility fit for common use of various workers. Of necessity, following conditions must be required for such a facility.

* 山縣 弘忠: Laboratory of Plant Breeding, Faculty of Agriculture, Kyoto University, Kyoto.

Namely, the structure and space are fit for the irradiation of various types of living things from micro to higher organism; dose rate can be changed with extremely wide range at need; continuous irradiation for a fairly long time also can be conducted. Furthermore it is desired for efficient use of the facility that some different kinds of experiment can be carried out at the same time.

In a span of ten years since 1956, gamma-ray irradiation facilities for biological studies were installed at 15 research institutions in this country. However, none of them was built according to thought as described above though each possesses a specific merit. The 2000 Curie ^{60}Co gamma-ray irradiation facility for biological studies introduced in the present paper was planned on the basis of the above mentioned view points, and installed at the Faculty of Agriculture of Kyoto University in 1967.

OUTLINE OF THE FACILITY

1. Structure

Fig. 1 shows the plane and vertical figures of the main part of this facility, which forms underground construction.

As can be seen in Fig. 1, the irradiation field shapes nearly a semicircle with a radius of about 4 m and is divided to three fan-shaped irradiation rooms (A-I, A-II and A-III) and an irradiation space surrounded by them. These rooms and the space are partitioned by adiabatic walls made of a pumice-like substance, "Siporex", except the boundary between A-III and the space. One sides of the walls between A-I and A-II, and A-II and A-III are covered with lead plates of 9 mm in thickness to keep off the radiation leakage from adjoining room. Every irradiation room has a lamp room for illumination above the glass ceiling. Nine dose-rate attenuating filters are equipped in front of the source container, and an acute irradiation device is provided inside the filters.

Two 1.5 m-square control rooms (B-I and B-II) available for check of irradiation effects are arranged on the opposite side to the irradiation field. These also have lamp rooms above the ceiling and are partitioned by a Siporex wall, being adjusted to the same environmental conditions as those of the irradiation rooms: B-I corresponds to A-I, while B-II does to either A-II or A-III through the medium of a transfer device.

Operation room is adjacent to the irradiation field on the other side of a thick concrete wall for shelter, being furnished with various apparatus for control, monitor and safety. Air conditioning machines are installed in machine room, and a number of air ducts extend from them to the wall side of all irradiation and control rooms through the duct space or the ceiling of operation room. Lastly, an accessory building composed of a few rooms for management and a green house for plant culture is attached aboveground as another part of this facility.

The leakage of dispersed radiations is kept under 0.2 mR/h. at the surface of the shelter wall in operation room and under 0.01 mR/h. at the surface of the earth.

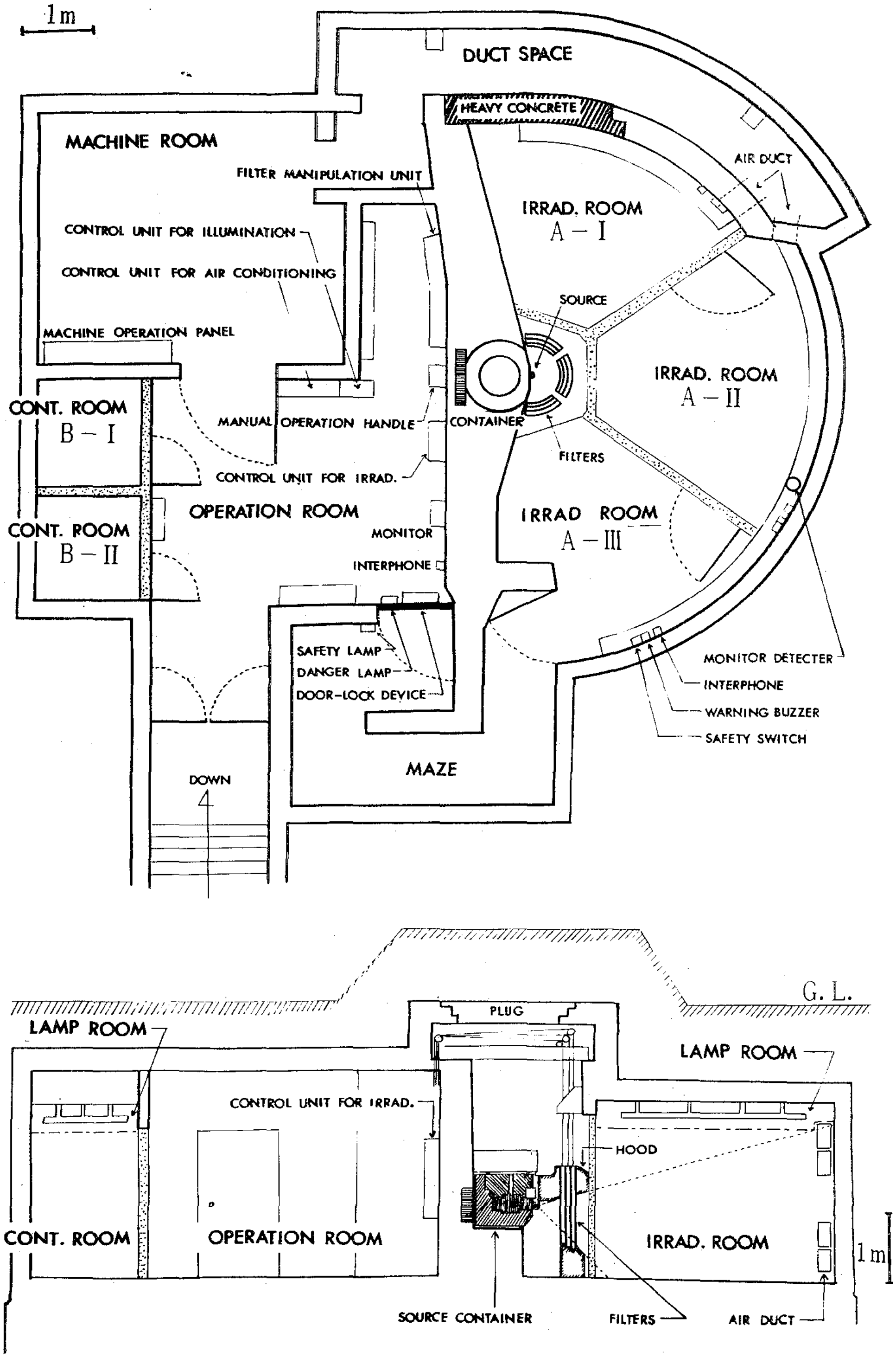

Fig. 1. Plane and vertical figures of the irradiation facility.

2. Features

This facility was designed mainly on the basis of irradiation of higher plants. At the time of installation, however, thoughtful considerations were made also for diversified studies in various fields related to biology. In respect of the construction, this facility is composed of a building, a gamma-ray irradiation system, an environment regulation system and accessory apparatus. On the other hand, following features can be pointed out as the function of this facility.

(i) **Control of dose rate.** The 2000 Ci of ^{60}Co is divided in the manner of geometric progression into three sources, 1800 Ci, 180 Ci and 20 Ci, any one of which can be chosen easily by remote operation. Furthermore, three dose-rate attenuating filters operated remotely and individually are equipped for each irradiation room. Therefore an extremely wide range of dose rate is obtained in each irradiation room, and besides irradiations of different dose rates can be carried out in respective irradiation rooms at the same time.

(ii) **Control of environmental condition.** Temperature of each irradiation room is independently adjustable at will within the range of 5°~15°C for the room A-I and 15°~30°C for the rooms A-II and A-III, respectively. Illumination condition of each room is also independently changeable in three grades, *i. e.*, 5000, 500 and 0 lux at the floor. Moreover, each of the temperature and the intensity of illumination can be changed within three different grades automatically according to a chosen schedule. Thus the continuous irradiation under nearly natural conditions and the analysis of environmental effects on radiation response can be conducted repeatedly at need in all seasons.

(iii) **Installation of control room.** Since the control rooms that always keep the

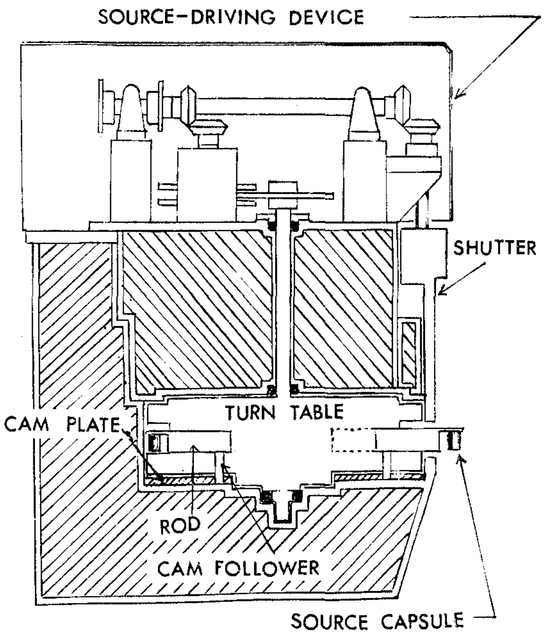

Fig. 2. Vertical section of ^{60}Co-source container.

same environmental conditions as those of corresponding irradiation rooms are arranged, the radiation effect under a given environment can be exactly estimated in details.

GAMMA-RAY IRRADIATION SYSTEM

1. ^{60}Co source

Three following sorts of ^{60}Co source are enclosed in their respective double-capsules of stainless steel, which are loaded in the source container and exposed separately.

a. 1800 Ci ; 15 wafer types with specific activity of 50 Ci/g.

b. 180 Ci ; 6 wafer types with specific activity of 15 Ci/g.

c. 20 Ci ; 2 coin types with specific activity of 11 Ci/g and 2 Ci/g.

Above described strength of each source shows the approximate activity measured on the first of March, 1967.

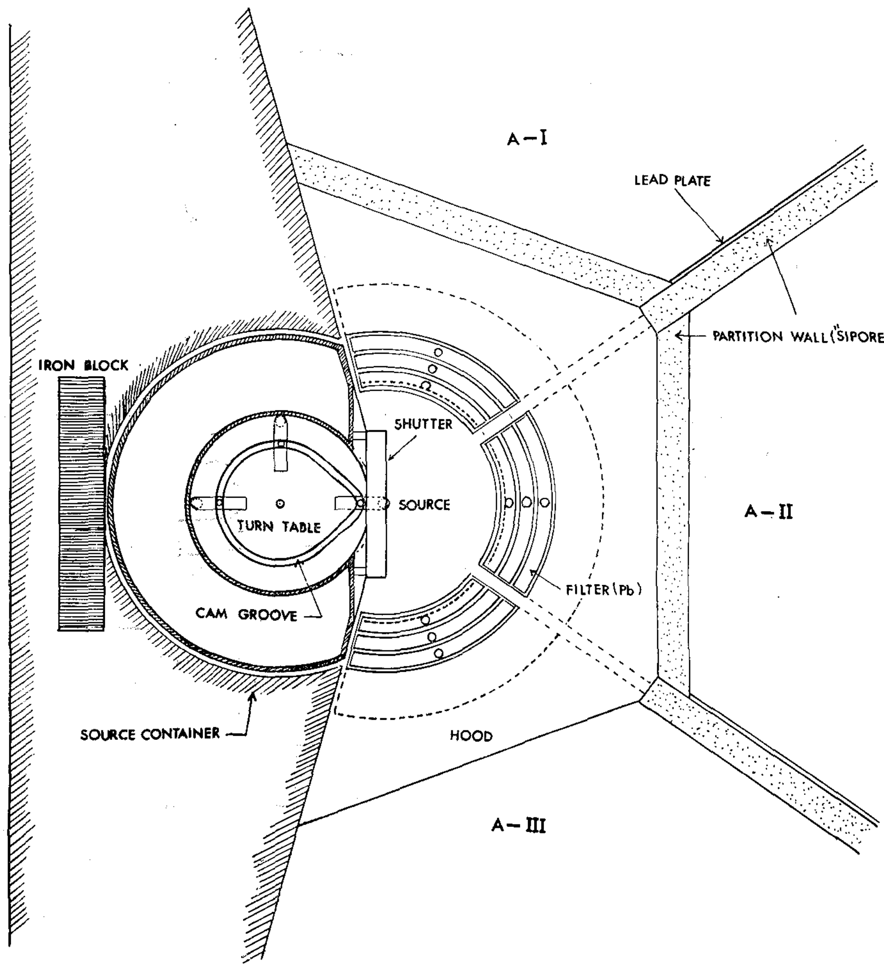

Fig. 3. Cross section of ^{60}Co-source container and its surroundings.

2. Source container and source-driving device

The source container is composed of fixed parts of lead, a turn table of stainless steel and a shutter going up and down as shown in Fig. 2.

The capsules of source are set up at the tops of rods which are held radially in the turn table with an aperture of 90° as Fig. 3 shows. As can be seen in Figs. 2 and 3, each capsule is located in the inner part of the turn table in case of source housing. When the source is exposed, however, the shutter is opened first, then the rod is moved along the egg-shaped cam-groove and finally the capsule juts forth outside of the table. The exposed capsule is located at the height of 1 m from the floor.

The selection, exposure and housing of source are made usually with an electro-motion system through the control unit for irradiation, while remote operation can be conducted also manually through the handle installed in the operation room (Fig. 1). In the case of electro-motion, the time required for exposure is about 22, 37 and 53 sec. for 20 Ci, 180 Ci and 1800 Ci, respectively.

This container, weighing about 7 tons, serves for a transport container, too, and is taken in and out through the plug hole right above (Fig. 1).

3. Filters and filter-driving device

Three dose-rate attenuating lead filters are equipped for each irradiation room as indicated in Fig. 3. Each of the filters is connected with a balancing weight in the operation room by a wire. By manual operation of the weight, it can be easily moved up and down along the split guide of the hood, which serves for limiting the space of irradiation, and it also can be fixed at an optional position.

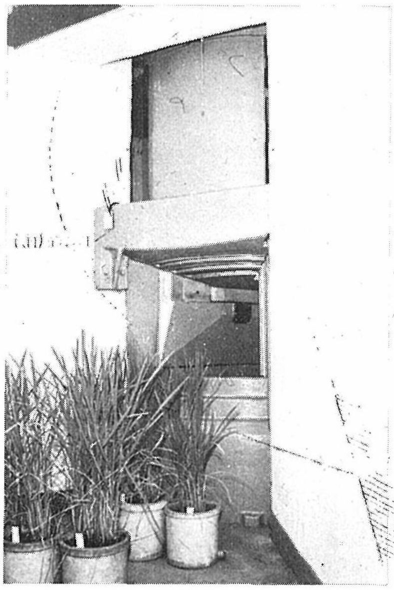

Fig. 4. Shutter-closed source-container and drawn up filters; view from the room A-III.

Each filter reduces the intensity of gamma rays from ^{60}Co source to one tenth, so that four different orders of dose rate can be obtained for one exposure of source.

4. Acute irradiation device

The acute irradiation device provided in the space surrounded by the filters is prepared for high dose-rate irradiation of smaller materials. It is composed of a semicircle plate to put materials, plate-driving parts and two poles serving both as support and guide. By manual operation of a handle, the plate can be moved up and down within the range between 2 cm and 72 cm from the bottom of exposed capsule, and can be fixed at every position desired. This device bears the load weighing 20 kg.

5. Safety system

The system for safety is composed of following devices and instruments.

(i) A key for interlocking. Key switches on the control unit for irradiation (controller), the door of maze and the cover of manual operation handle are joined electrically as a series circuit, and opened or closed by the same key. Besides the key can be never drawn out unless it is turned to the safety side.

(ii) Mechanical interlock device. This device consists of a rod above the door of maze, the source shutter and the mechanical joint between the two. The rod locks the door when the shutter is opened.

(iii) Safety switch. A safety switch is provided in each irradiation room (Fig. 1). These switches form a series circuit together with the controller, and prevent the exposure of source with priority to the operation through the controller.

(iv) Warning buzzer. A warning buzzer is also provided in each irradiation room (Fig. 1). It gives warning at the time that the source-open button on the controller has been pushed or the cover of manual operation handle has been opened.

(v) Monitor. The monitor provided in the operation room indicates the dose rate at the ionized-chamer detecter in room A-II (Fig. 1). When the dose rate exceeds the value which was previously chosen within the range from 0.1 mR/h. to 100 mR/h., the monitor locks the door of maze with an electro-motion system and lights the danger lamps of monitor itself, controller and maze door (Fig. 1).

(vi) Electro-motion lock device. This device is set up above the door of maze (Fig. 1) and locks the door according to electric signals from both the monitor and the movement of source shutter. When the electric current is interrupted during exposure of source, the locked situation is continued.

(vii) Interphone. An interphone is installed in each irradiation room and used for commumication with the operation room (Fig. 1).

(viii) Extrication door. A small door for urgent use is furnished in the door of maze. It can be opened only from maze side.

6. Control unit for irradiation (Controller)

The controller is fixed on the shelter wall (Fig. 1). The key switch, buttons and many kinds of pilot lamps are all graphically arranged on the front surface, while three timers and an integrating timemeter are set up on the side surface. Each timer has a maximum time of 30 hours to be chosen and a minimum scale of one minute. When a chosen time is over, the source is housed automatically. An irradiation irrespective of the timer also can be conducted of course. The integrating timemeter works with timer and is used for record of irradiation time. It can integrate the time to the extent of 10^4 hours.

7. Power supply for urgent use

In the operation room, a battery is prepared as the power supply for urgent use. Therefore, timers and the pilot lamps of safety system work even at the time of electric-current interruption.

8. Dose-rate distribution

On 12 th of June in 1968, dose rates at many points of each irradiation room were measured with flouroglass dosimeter under several different combinations of source and filter. The measurement revealed an exact attenuating effect of each filter and little influence of the radiation leakage from adjoining room. Dose rates at the height of 1 m, the same level as source, under the condition of 1800 Ci-source exposure and no filter use are demonstrated in Table 1. These data indicate that the dose rate decreases practically in inverse proportion to the square of distance from the source in all the rooms and directions, and that the partition wall faced to the source causes about 20 % decrease of dose rate in both A-I and A-II.

Table 1. Dose rate[1] at the same height as the source in the irradiation room (R/min).

Irrad. room	Direction from[2] the source	Distance from the source (m)		
		1	2	3
A–I	a	24.65	6.00	2.78
	b	26.04	6.15	2.76
	c	21.55	5.98	2.76
A–II	a	20.91	4.95	2.33
	b	23.61	6.74	2.73
	c	22.27	5.55	2.60
A–III	a	29.92	7.49	3.55
	b	30.15	7.94	3.44
	c	30.74	7.75	—

1) Measured on the 12th of June in 1968 under the exposure of 1800 Ci-source and the use of no filter.
2) a, b and c mean the direction of left, center and light tetrasector of each irradiation room, respectively.

ENVIRONMENT REGULATION SYSTEM

1. Illumination apparatus

The illumination of every irradiation and control room depends upon a number of highly efficient fluorescent lamps installed in lamp room. The intensity of illumination in each room can be adjusted independently to any of 5000, 500 and 0 lux at the floor, and also can be automatically changed with two timers prepared for each irradiation room. Those timers having a minimum scale of 20 minuits are provided in the control unit for illumination (Fig. 1). The lighting time is chosen on timers at will within the extent of 24 hours in total and repeated automatically at a cycle of 24 hours. The lighting time as well as the time put out is recorded continuously even during stoppage of the electric current.

Automatical change of the intensity is made in every two corresponding rooms; A-I and B-I (System 1), A-II and B-II (System 2), and A-III and B-II (System 3). Transfer between System 2 and 3 is conducted with a switch on the control unit.

2. Air conditioning apparatus

Air conditioning mechanism is composed of four systems, namely, the same three systems as those in illumination mechanism shown above and another one for all lamp rooms. As to the machinery, three sets of chilling unit, four sets of air conditioner and five sets of both heater and humidifier are installed in connection with the machine-operation panel (Fig. 1). Fresh air is taken in through the ventilation tower built aboveground.

The temperature of each irradiation room is regulated independently and that of every two rooms belonging to the same system is changed together. In case of automatic operation, the change of temperature is made within three different grades through a timer prepared for each of System 1, 2 and 3. Those three timers provided on the control unit for air conditioning (Fig. 1) have a minimum scale of one minute and it is permitted to choose the duration time of temperature at will within the extent of 24 hours in total. Thus the chosen temperature is repeated automatically at a cycle of 24 hours as is done in the illumination apparatus. Transfer of System 2 to 3 or 3 to 2 depends upon the duct change operated remotely by oil-pressure levers set up in the control unit.

Several characteristics of the air conditionung apparatus are as follows.

(i) **Condition of temperature and humidity.** Following conditions are obtained at need in all seasons.

a. System 1 (A-I and B-I): the temperature of each room is independently adjustable at will within the range of 5°~15°C, and the relative humidity is kept within 50~90 % in both rooms.

b. System 2 and 3 (A-II, A-III and B-II): the temperature of each room is independently adjustable at will within the range of 15°~30°C, and the relative humidity is kept within 50~80 % in all the rooms.

c. System for lamp rooms: the temperature of all lamp rooms is always kept under 29°C.

(ii) **Distribution of temperature.** In the area over 70 % of available floor in each irradiation and control room, difference of temperature is kept less than 2°C at a horizontal level lower than 1.2 m and kept less than 5°C in vertical direction.

(iii) **Response.** The maximum time required for the end that a chosen temperature attains to the stationary value is about 30 minuits for ascent and about 60 minuits for descent.

(iv) **Ventilation.** The frequency of ventilation by fresh air is more than two times per hour in both A-I and B-I, and is more than seven times per hour in other three rooms. The wind velocity in each room is not over 1 m/sec. at 1 m in height.

(v) **Recording.** Both the temperature and the humidity of every irradiation and control room are continuously recorded with an electronic strip chart temperature-humidity recorder provided in the control unit.

(vi) **Device for automatic return.** This is the device available for the automatic return after the interruption of electric current. When the electric current was sent again after the stoppage, the functions of the air conditioning apparatus are restored to the former state in set order, and finally the electric circuits of the illumination apparatus are closed.

ACCESSARY APPARATUS

Following instruments are prepared in this facility as accessary apparatus.

a. Ionized chamber surveymeter
b. Scintillation surveymeter
c. Fluoroglass dosimeter
d. Grating spectrophotometer
e. Multipurpose polygraph
f. Continuous infrared CO_2 analyser

Of these instruments, the grating spectrophotometer is used for biochemical analysis of irradiated materials, and both the multipurpose polygraph and the continuous infared CO_2 analyser are available for the trace of various physiological reactions of living things during irradiation. In addition, a set of industrial television is going to be installed as the monitor of the source and the materials in course of irradiation.

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