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DEVELOPMENT ON THE AUTOMATIC APPARATUS FOR RADIOACTIVITY MEASUREMENT AND SORTING OF IRIDIUM-192 RADIATION SOURCES

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(Received July 23, 1985)

An automated apparatus for handling Ir-192 radiography sources of pellet (2.0 mm$\phi \times$ 2.0 mmt) and disc (1.6 mm$\phi \times$ 0.4 mmt) was developed in Japan Atomic Energy Research Institute (JAERI).

The apparatus consists of a mechanical system and a computer system connected with the former. It's function covers important procedures of very small source production, that are measurement of radioactivity, sorting and data processing. Thirty pellets or 76 discs of iridium target are previously arranged at regular in an "irradiation core" for reactor irradiation. The core taken out from the reactor is put on a loading port of the apparatus to let it be treated with two vacuum chucks, one for removing the core and its cap and another for picking up sources one by one full automatically. The loading port has a capacity of up to ten cores.

The efficiency and the accuracy of routine operation have been remarkably improved and data available for quality control was also satisfactorily increased by introducing this apparatus.

Keywords : Ir-192 Source, Radiation Source, Production, Irradiation, Automatic Apparatus, Measurement of Radioactivity, Sorting, Computer Control

イリジウム－192線源用自動測定仕分装置の開発

日本原子力研究所アイソトープ部製造課
加藤　久・佐藤　彰・木暮　広人・石川　勇

（1985年7月23日受理）

日本原子力研究所では，工業用ガンマ線ラジオグラフィに使用するイリジウム－192線源の製造のための自動測定仕分装置を開発した。本装置は，機械系及びコンピュータ系から構成される。コンピュータ系に接続して制御される機械系は，微小なイリジウム－192線源を装塡した照射用コアの供給からイリジウム－192線源の放射能測定，測定値に応じた分類までの全工程を自動的に処理することができる。測定で得られた全てのデータはコンピュータによって集計，解析される。

本装置の導入により，イリジウム－192線源の製造の能率及び測定精度は著しく向上した。

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1. INTRODUCTION

Iridium-192 is a useful radioisotope for non-destructive inspection and instrumentation in various industrial fields. Desirably, an Ir-192 source should be a sphere of a size as small as posible.

The Department of Radioisotopes, JAERI has produced routinely pellet shaped Ir-192 of 2 mm in diameter and 2 mm in thickness with an average radioactivity of about 370 GBq (10 Ci) per piece at the time of arrival at users[1). The quantity of Ir-192 pellets handled reaches 300 to 600 pieces per one production batch, and annual production frequency is six batches.

Iridium pellets irradiated in a nuclear reactor are transferred to one of properly shielded facilities of Radioisotope Production Laboratory, and treated by means of various kinds of remote handling apparatus. Troubles often have occurred during the post-irradiation process due to the handling of a large number of tiny pellets with a manually operated apparatus. Accordingly, introducing of a new automated handling apparatus for Ir-192 pellets has been desired for rationalization of the production.

A new computerized apparatus[2) was developed in order to improve the working efficiency and the measurement accuracy in the post-irradiation process based on the experiences with a semi-automatic apparatus[3) in the past. The apparatus was designed so as to be able to treat also Ir-192 pellets of 1.6 mm in diameter and 0.4 mm in thickness planned to produce for the assembled source[4) in the near future.

The details of the new automated apparatus are described below.

2. OUTLINE OF THE CONSTRUCTION

The automated apparatus consists of a mechanical system and a computerized control system.

The mechanical system is set up in the heavy concrete shielding facility. The function of the mechanical system are summarized as follows: feed of the irradiation cores (See Fig. 1) holding Ir-192 pellets for reactor irradiation, picking up Ir-192 pellets from the irradiation cores, measurement of radioactivity and sorting of Ir-192

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The computerized control system, linked with an ionization chamber for measurement of radioactivity of Ir-192 pellets, performs a sequence control of the whole mechanical system. The system consists of a microcomputer, a CRT display, a control panel and a printer. Manual operation is also possible in case of troubles.

3. FUNCTIONS OF MECHANICAL SYSTEM

Details of the functions of cach part in the mechanical system are described below in sequence.

3.1 Loading port for the irradiation cores :

The loading port shown in Fig. 3 consists of a linear vibrating feeder and a linear chute placed on the former. The speed of feed can be adjusted by a variable governor. Irradiation cores loaded with Ir-192 pellets are placed on the chute by a manipulator. Up to ten pieces of the irradiation cores can be loaded on the chute. The chute is provided with a guide rail in the center. The irradiation cores travel to the gauging station along the guide rail activated by the vibrating feeder. It takes 2∿3 seconds for a core to reach the gauging station. When an irradiation core reaches the gauging station, a pneumatic sensor perceives to make the vibrating feeder stop. The irradiation cores are made of high quality aluminum. Which is annealed in order to prevent thermal deformation due to absorption of beta and gamma-ray from Ir-192 and radiation in the reactor as well. The loading port is shown in Photo. 1.

3.2 Gauging station :

The gauging station is placed at the end of the loading port as shown in Fig. 4 and Photo. 2. The gauging tooth of the unit is driven toward an irradiation core by an air cylinder and fix firmly at the gauging position. Fixation of the irradiation core at the proper pellets depending on their radioactivity. The construction of the mechanical system is shown in Fig. 2. The system is operated by the computerized control system.

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3.3 Chuck head and rotary arm

Chuck head moves forwrd and backward along the axis of rotary arm which turns clockwise or counterclockwise by necessary angle to bring the vacuum chuck at proper position. All the movements are actuated with pulse motors. The swing angle is 195 °, and the maximum extension distance is 144 mm.

The chuck head has two vacuum chucks (See Fig. 5 and Photo. 3) for handling Ir-192 pellets (VC-1) and the irradiation cores and their caps (VC-2), which are connected to oilless vacuum pumps. The shape of point of the chuck is well furnished to perform secure suction of Ir-192 pellets and irradiation cores. The chuck VC-1 moves about 10 mm downward onto the irradiation core to suck an Ir-192 pellet, and about 120 mm into the well of the ionization chamber to measure radioactivity. The chuck VC-2 moves about 22 mm to pick up the irradiation core. Vacuum lines have pressure sensors for detecting mischucking. The vacuum chucks are interchangeable with their spares, when they have deteriorated after long operation. The sequence of operation of the vacuum chucks on the chuck head and the rotary arm is as follow.

1) Remove the cap from the irradiation core.
2) Dispose of the cap into the waste tray set on the carriage drive unit.
3) Pick up an Ir-192 pellet from an indicated position in the irradiation core.
4) Transfer the pellet from the initial position on the well type ionization chamber.
5) Insert the pellet into the well of the ionization chamber for radioactivity measurement.
6) Transfer the pellet to sorting position.
7) Drop the pellet in one of three vessels according to intensity of its radioactivity.
8) Return to the initial position and repeat.

Time taken for a single cycle is about 50 seconds except the time for the measurement of radioactivity.

3.4 Sorting unit :

Iridium-192 pellets are classified in three different ranges according to the intensity of radioactivity. The sorting ranges of radioactivity are input previously to the microcomputer which are decided according to shipping time and demands by users. Three vessels for the shipment of Ir-192 pellets are placed at the three sorting positions. The sorting unit is shown in Fig. 2 (b) and Photo. 4.

3.5 Carriage drive unit :

The unit consists of the carriage loading whole the mechanical system, and is placed on the rails on the bench in the shielding facility. The unit can travels a distance of 500 mm by mean of compressed air served with a compressor which is set outside the shielding facility. The unit is shown in Fig. 2 (a).

4. CONTROL SYSTEM BY MICROCOMPUTER

Full automatic operation of the mechanical system is enforced electronically by commands from the microcomputer (Manufacture: Lear Siegler Inc., Model: ADM 3A) shown in Photo. 5. Manual operation from the control panel is also possible for any troubles.

Before starting automatic operation, the measuring system should be checked with a Cs-137 sources. The following data are input in the microcomputer for checking the system (See Table 1).

1) The last data of checking the measuring system. (FROM)
2) Checking data of this time. (TO)
3) Measured value of the checking source (Cs-137) at the last time (REFERENCE).
4) The same as above at this time (READING).

The ratio (R) of the radioactivity of Cs-137 is calculated automatically from these input data by the following equation.

$$R = \text{REFERENCE} \times e^{-0.693 \times t/365.25/30.17} / \text{READING}$$

Where t is the elapsed time between the last time of checking and

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Where t is the elapsed time between the last time of checking and this time, the half-life of Cs-137 is put as 30.17 years and one year is put as 365.25 days.

The process starts with selecting either the sampling mode or the whole lot mode for the radioactivity measurement of Ir-192 pellets. The initial data to be input to the microcomputer are as follows (See Table 1).

1) Measuring data. (FROM)
2) Shipping data. (TO)
3) Minimum value of radioactivity required at shipping time.
4) Lower limit of radioactivity at the time of measurement. (calculated automatically from 1) - 3))
5) Upper limit of radioactivity at the time of shipment.
6) Source type, i.e. the diameter of the pellet, 2.0 mm or 1.6 mm.
7) Number of Ir-192 pellets in an irradiation core, e.g. 30 pieces in case of Ir-192 pellets of 2.0 mm in diameter or 76 pieces in case of 1.6 mm.
8) Measurement time in the well of the ionization chamber. This can be set continuously within a range from 1 to 255 seconds.
9) Calibration factor to obtain radioactivity of Ir-192 pellets.

After all these conditions have beeen input in the microcomputer, the device can be started along the sequential operation. Movement of whole the mechanical system can be discontinued by pushing the stop switch during any stage of the operation in case of any troubles to prevent the growth of the trouble.

The CRT display indicates some kinds of data during the measurement, i.e. the number of Ir-192 pellets per one irradiation core, the pattern of the arrangement of Ir-192 pellets in the irradiation cores, radioactivity of individual Ir-192 pellet, results of classification and the growth of the histogram showing the intensities of radioactivity and the number of contents.

The results are collected, analyzed and stored by the microcomputer. The results processed by the microcomputer are fed to the printer connected with the microcomputer for the utilization of the data. These data contain not only the number, the average radioactivity, the standard deviation, the histogram of all Ir-192 pellets processed, but also these values of three groups. An example of data is shown in Table 2. Values of radioactivity are those at the time of measurement.

The schematic diagram showing the arrangement of whole system is shown in Fig. 6.

5. RESULTS AND DISCUSSION

Iridium-192 sources must be produced in a large mass to meet the amount of its consumption. The time required per one batch for the post-irradiation procedures of Ir-192 pellets has been two days by a manual apparatus, and the procedures have been changed frequently due to tiredness of operators. The time required was shortened into six hours by using the automatic apparatus, and the post-irradiation process was rationalized.

The new apparatus can reproduce accurately a measurement position in the well of ionization chamber. Therefore the accuracy of radio activity measurement improved than a manual operation.

The features of the new computerized apparatus are to prevent the occurence of radioactive contamination due to vibration of Ir-192 pellets, to keep view of Ir-192 pellets from operators during the operation and to enable operators to select the radioactivity measurement mode and size of the Ir-192 pellet. In the post-irradiation process, the procedures must be as gentle as possible, because the iridium metal pellets used as the target scatter a great deal of radioactive minute powder of Ir-192 from their surface. The irradiation cores are vibrated on the feed port for their transfer to the fixed station, but vibration stops to minimize vibration hour until next core is fed. Furthemore, the irradiation cores loaded with Ir-192 pellets always are covered by the caps before the radioactivity measurement. Therefore a trace of contamination only locally occurs at the extremes of chucks and in vacuum lines. But radioactive contamination of the vacuum pump is prevented with filters. The apparatus has a structure, which does not conceal Ir-192 pellets from a view of operators, for instance not to send Ir-192 pellets behind or inside some parts of the apparatus. These features facilitate to solve any kinds of troubles by recovery of Ir-192 pellets from the apparatus. The average exposure does of the apparatus per one batch is 5×10^4 Gy with a handling quantity of 200 TBq (5400 Ci), and annual does reachs 3×10^5 Gy. The feed port and the gauging station receive a highest does of 1×10^5 Gy in the apparatus. Under such circumstances the apparatus will suffer shown in Fig. 6.

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a less damage than the past apparatus did. Consequently the new apparatus is expected to be durable for a longer life-time.

The data of the distribution of the radioactivity in the irradiation cores were obtained in details by using the automatic apparatus. The distribution of the radioactivity in the irradiation core is greatly affected by the arrangement of iridium targets in an irradiation core due to a large neutron absorption cross section of iridium. An example of these is shown in Fig. 7, where the numerals are normalized to radioactivities.

Since the automatic apparatus was installed in the production facility in August 1983, any troubles have never been recognized and the satisfying results have been obtained until June in 1985.

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Table 1 An example of input data to microcomputer

DATE (FROM)	83-3- 4
DATE (TO)	84-6-12
REFERENCE	0.1480
READING	0.144
RATIO	0.998
DATE (FROM)	84-6-12
DATE (TO)	84-8- 6
MINIMUM FOR SHIPMENT	9
LOWER LIMIT	15.04
UPPER LIMIT	16.72
SOURCE TYPE	2.0
SAMPLES PER CORE	30
MEASUREMENT TIME	3
CALIBRATION FACTOR	45.90

Table 2 An example of output data from microcomputer

	TOTAL	GROUP 1	GROUP 2	GROUP 3
NUMBER	355	83	112	160
MEAN	16.46	14.06	15.98	18.05
DEVIATION	1.75	0.61	0.47	0.90
MAXIMUM	20.57			
MINIMUM	12.86			

Activity	Frequency	
11	0	
12	3	*
13	36	******************
14	42	*********************
15	53	**************************
16	87	***
17	50	*************************
18	58	*****************************
19	22	***********
20	4	**
21	0	
22	0	

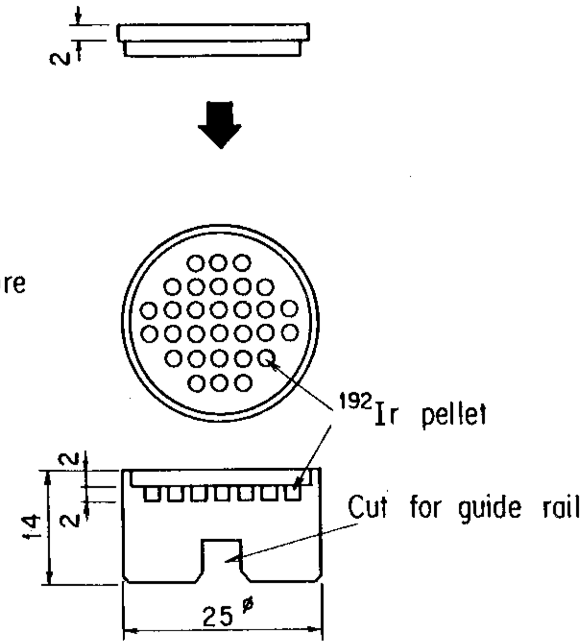


Fig. 1 Irradiation core

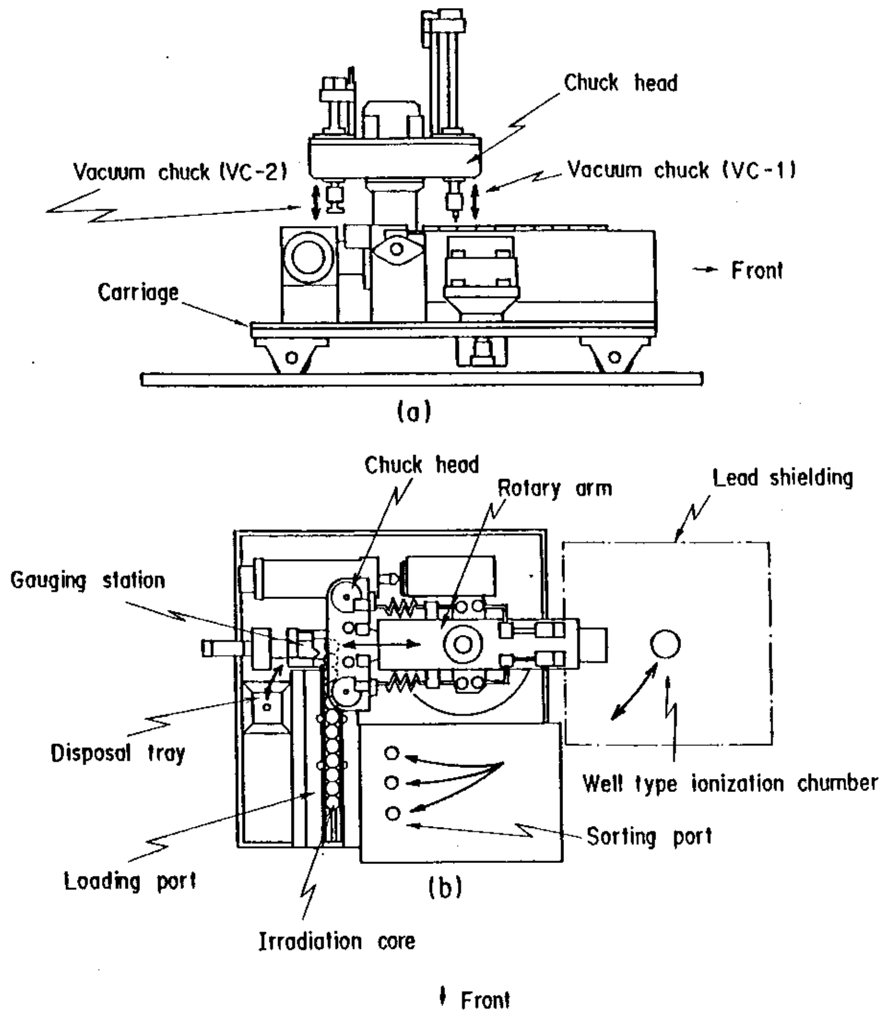


Fig. 2 Construction of automatic control apparatus
Arrows show sequential movements of vacuum chucks
(a) : Side view
(b) : Top view

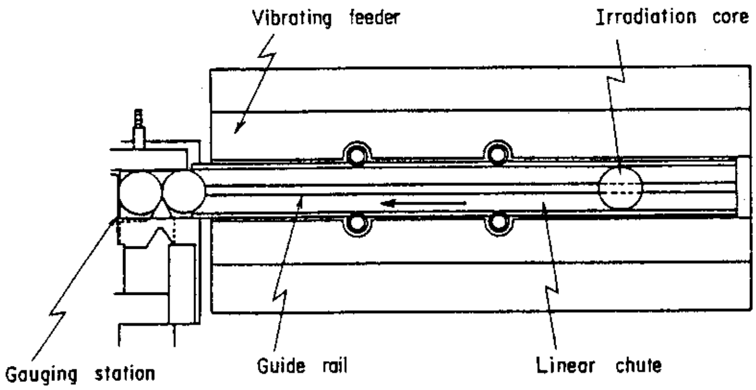


Fig. 3　Loading port for irradiation core

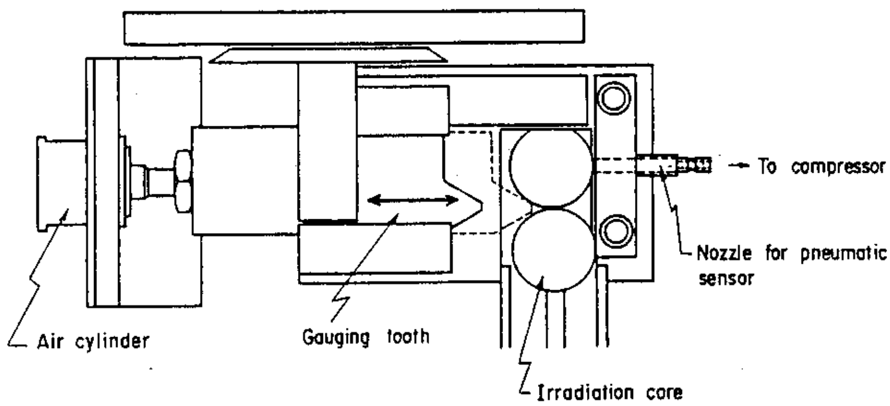


Fig. 4　Gauging station

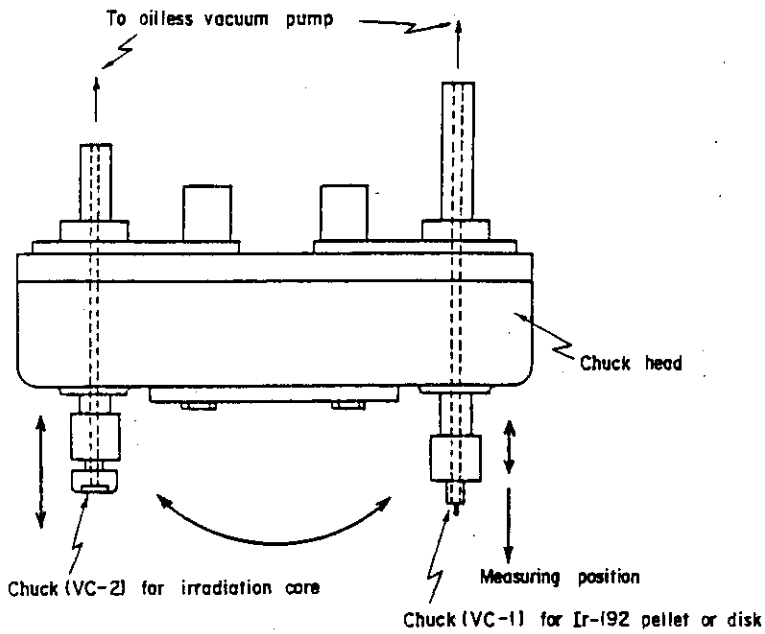


Fig. 5　Vacuum chucks

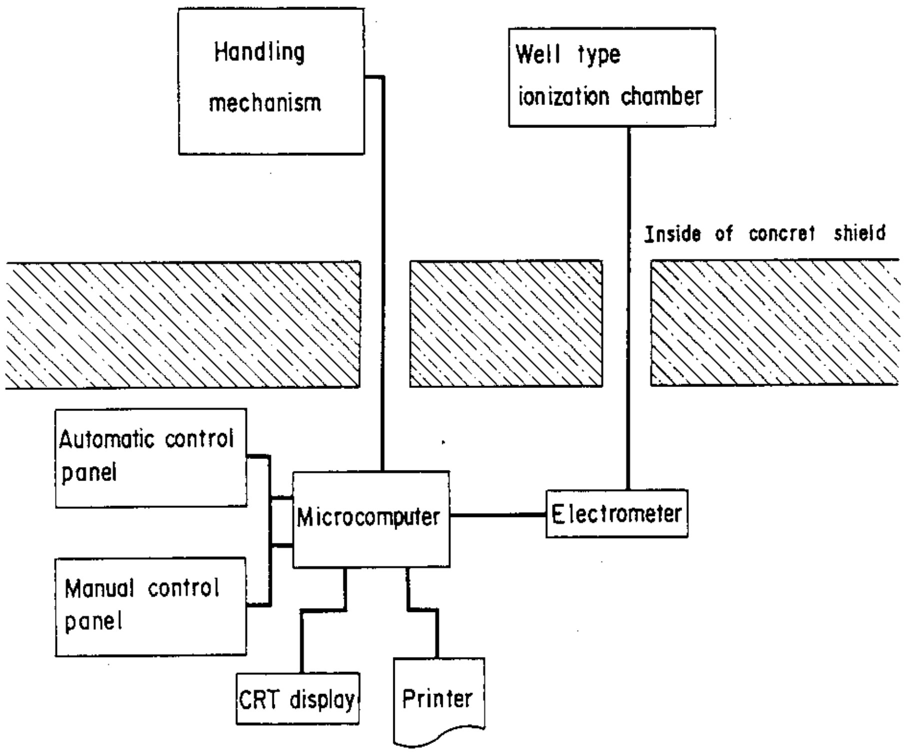


Fig. 6 Schematic diagram of the automatic apparatus

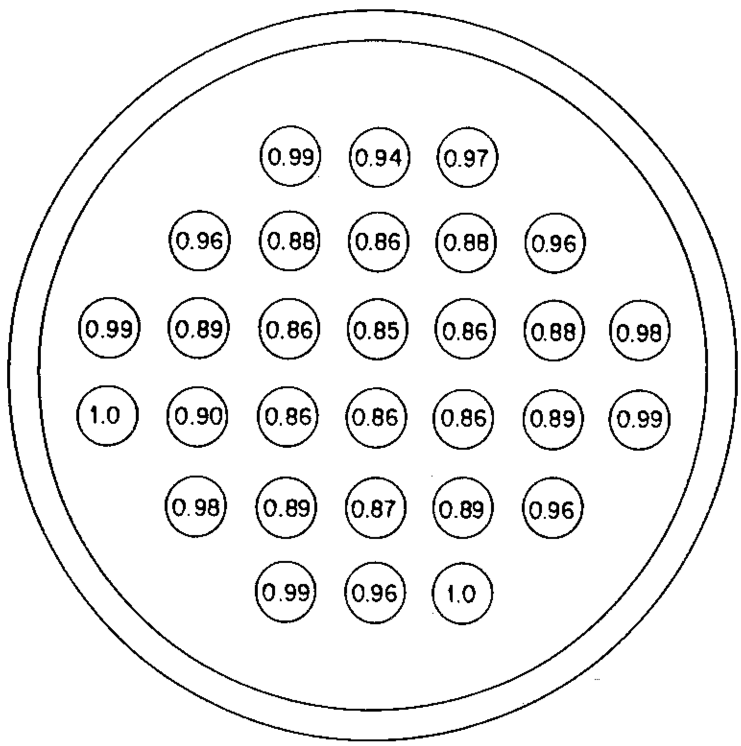


Fig. 7 An example of radioactivity distribution of Ir-192 in the irradiation core. The maximum activity is normalized to 1.0

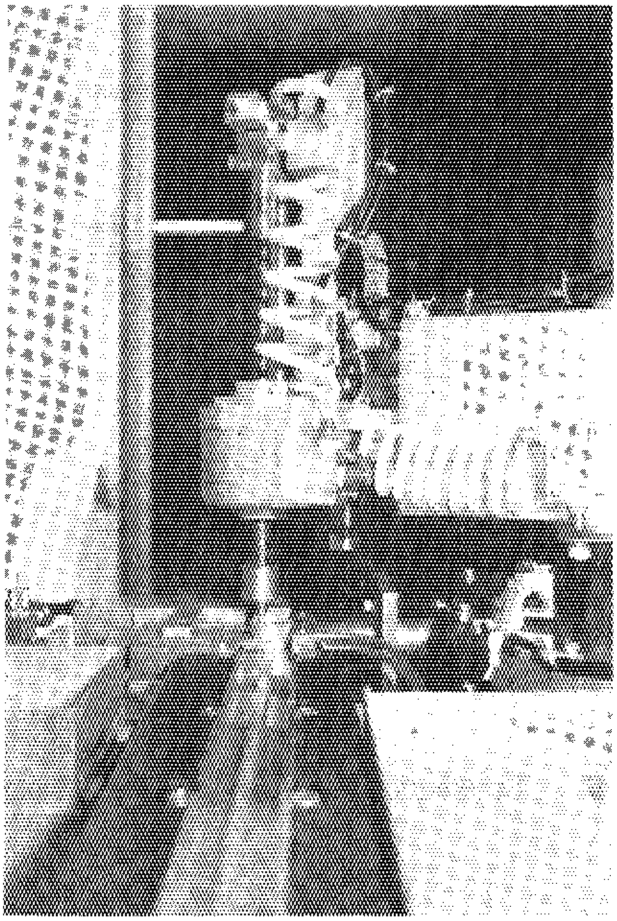


Photo. 1 Loading port for irradiation core

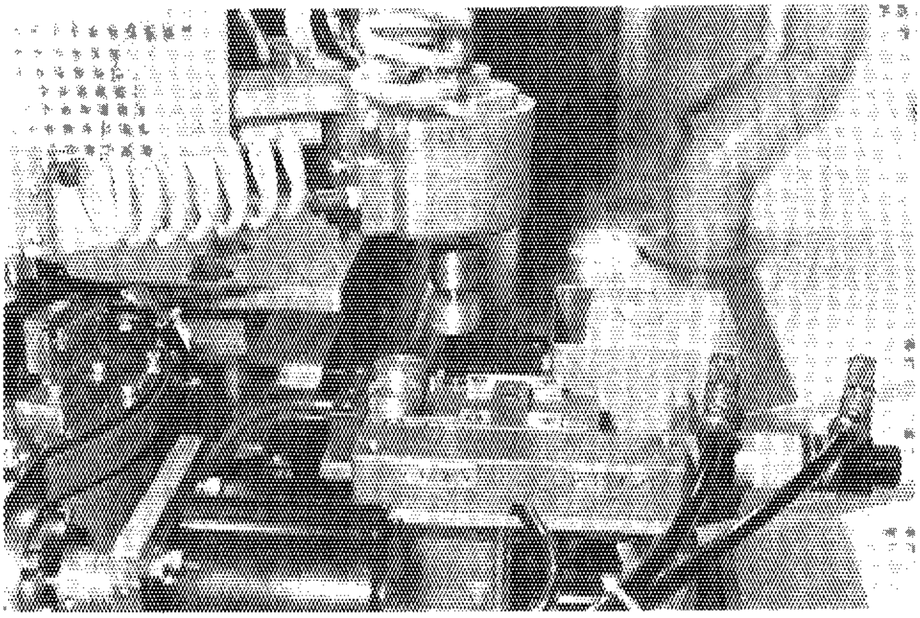
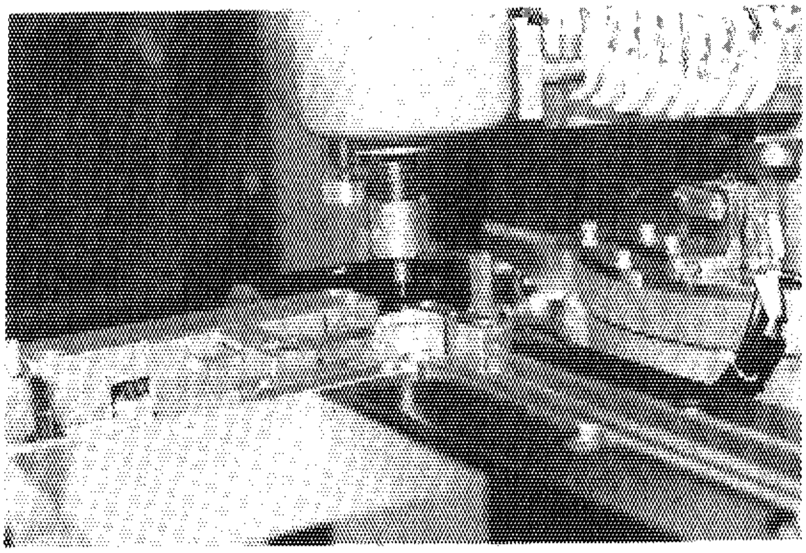
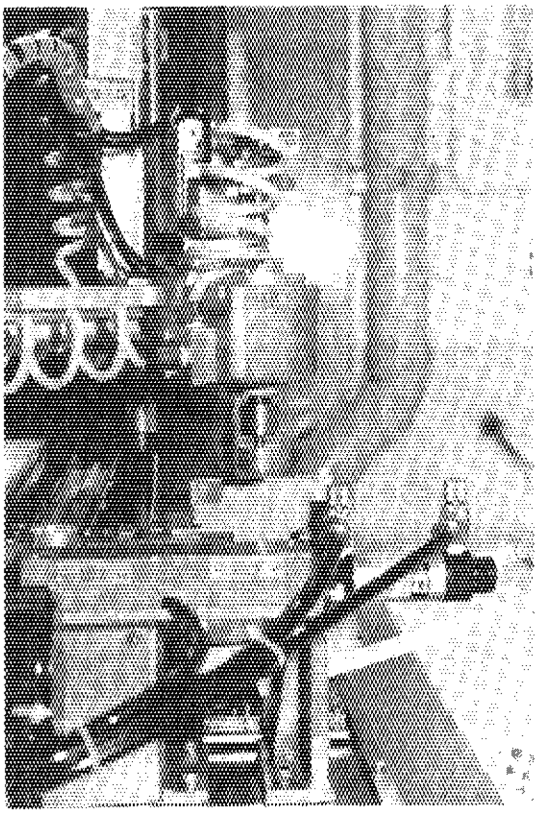


Photo. 2 Gauging station



(a)



(b)

Photo. 3 Vacuum chuck

(a) : VC－1 for Ir－192 sources

(b) : VC－2 for irradiation cores

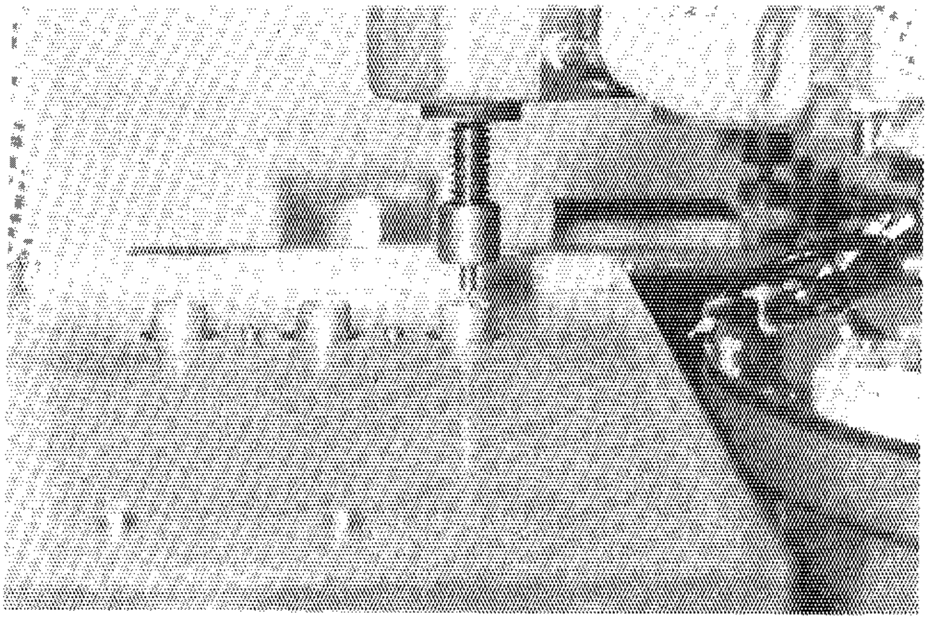


Photo. 4 Sorting port

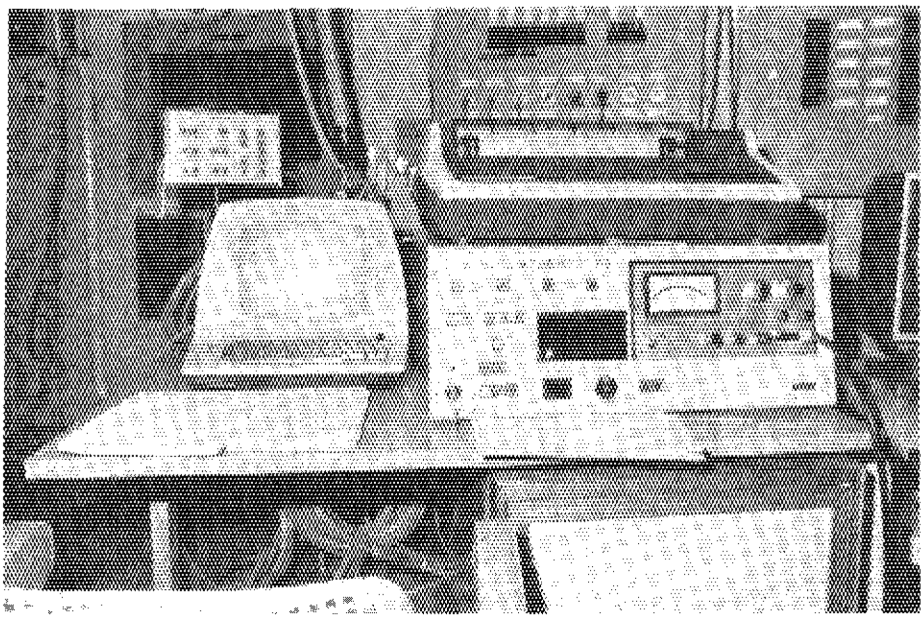


Photo. 5 Operation console