



**HEALTH PHYSICS ROUTINE AT THE
INSTITUTO DE ENERGIA ATÔMICA**

Gian-María A. A. Sordi

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**COORDENADORIA DE PROTEÇÃO RADIOLÓGICA E DOSIMETRIA
(CPRD)**

**INSTITUTO DE ENERGIA ATÔMICA
SÃO PAULO – BRASIL**

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HEALTH PHYSICS ROUTINE AT THE INSTITUTO DE ENERGIA ATÔMICA*

Gian-Marie A. A. Sordi

ABSTRACT

We describe our routine Health Physics work at the IEAR 1 reactor and the modifications that are being made

This work includes specific tasks in cooperation with other IEA Divisions and Services.

Further we describe our personal dosimetry laboratory, waste disposal and decontamination laboratory, shielding calculation section, dosimetry laboratory, radioactive source and instrumentation calibration.

A short description of plans for our new building for the S.P.R.D. is included.

Finally we talk about the assistance that we give to those external to the IEA.

I - INTRODUCTION

The growth of the "Instituto de Energia Atômica (IEA)" since its foundation has been exponential.

The Health Physics Service has grown together with the IEA because its principal function is to provide technical assistance to the other Divisions and Services in all aspects of radiation, protection, personal health, safety of installations and monitoring for contamination.

Since the reactor, IEAR-1 is potentially our most dangerous source of radiation, we consider it first. We will briefly describe our routine precautions, and the modifications being made in the reactor.

This work benefits in particular two divisions, Operation and Maintenance Reactor Division (D.O.M.R.) and Nuclear Physics Division (D.F.N.)

After the reactor we will consider specific projects with other divisions and services; which are presently:

- Radioactive Material Productions Service (SPMR)
- Radiochemistry Division (DRQ)
- Radiobiology Division (DRB)
- Industrial Radioisotopes Applications Service (SARI)
- Nuclear Metallurgy Division (DMN)

In the third section we will speak about projects of general utility. This includes items such as personnel dosimetry, waste disposal, decontamination, shield design, source calibration and instrumentation. As a supplement we will discuss plans for the new Health Physics and Dosimetry Service (S.P.R.D.)

(*) Presented at the FIRST LATIN AMERICAN CONFERENCE ON PHYSICS IN MEDICINE AND RADIATION PROTECTION. SP. Brazil, 1972

Finally, we discuss our assistance to outside institutions that request our help. Our service includes personnel dosimetry, monitoring of laboratories, cobalt therapy units, X ray machines, etc; and shielding calculations for radioactive sources and for laboratories in which they are used

II – REACTOR BUILDING

The IEAR 1 is a water cooled and moderated reactor of the swimming pool type, designed to operate at 5 MW⁽⁷⁾. Normal operation at present is at 2 MW, 36 hours per week

Our routine monitoring procedures in the reactor building have changed somewhat since the first criticality on 16 Sept 1957. Early procedures were summarized in 1961 by Hehl⁽²⁾ and modifications represent attempts to provide better protection and eliminate non essential tests

One change is that laboratories in the reactor building have been eliminated so that within the building there remains only operators personnel, S P R D personnel and those with experiments directly attached to the reactor beam holes (D F N)

These people must wear lab coats, film badges and pocket dosimeters. Other dosimeters are employed as necessary for example wrist dosimeters and audible dosimeters in cases of high risk

Access is controlled so that all other persons entering the reactor justify their entrance and are registered by an S P R D technician

These persons are given a lab coat and pocket dosimeter

The protection is done by an equipment that in general is fixed and another that is movable

The fixed equipment used at present includes:

1 – Eight ionization chamber, type "jordans" distributed as follows:

- a) Three chambers on the third floor of the reactor building adjoining the swimming pool.
- b) Three on the first floor of the reactor (inner yard) where the beam holes are located together with the experimental apparatus of the D F N and with the radioactive material storage area
- c) Two in the basement of the reactor one being in the sump for the sinks and rooms of the building as well as of the cleaning of ionic resin and another near the left of the swimming pool directed toward the heat exchanger (primary circuit)

2 – Air-borne continuously monitoring one near the reactor swimming pool and another in the inner yard of the first floor of the reactor

3 – Three spherical neutron dosimeter that detect neutrons up to 14 MeV in energy, placed in the inner yard of the first floor of the reactor

4 – A Geiger-Mueller counter with rate meter and recorder placed in air exhaust of the building, after absolute filters and before the chimney

The Jordan chambers and the remaining air-borne continuously monitoring the latter adjoining the swimming pool are all connected to the scram of the reactor. The recorder of the Geiger counter that measure the activity of the exhaust air is placed in the control panel of the reactor

The reactor modification whose aim is to increase power to 10 MW is going on and is divided in the three following parts:

- 1 – Reform in the ventilation system and in the tightness of the building is already concluded
- 2 – Reform in the water coolant system of the swimming pool, with the introduction of a decay tank for ^{16}N and a second heat exchanger is underway. In consequence we will have two primary and secondary coolant circuits

This part is under construction and we hope to operate at 5 or 6 MW but if necessary we can operate at 10 MW

- 3 – Reform of the reactor's pool is planned

The normal building air exhaust system (figure 1) have "Cambridge" absolute filters with 99.97% minimum efficiency in removing 0.3 micron particles. Also in the case of an accident there is an emergency circuit with active carbon filters, so that the normal exhaust can be turned off and the air passed through the absolute and active carbon filters

To have an adequate safety system so that it is possible to identify immediately an increase of the air radioactive level and the place where it is occurring we have purchased and will install this year the following equipment:

- 1 – An air-borne continuously monitoring with filters to detect iodine that will be placed next to the reactor swimming pool
- 2 – Four detection sets for the building air exhaust system

One is to be placed in the general exhaust system after the filters and before the chimney and the other three are to be placed in the basement, first floor exhaust systems.

- 3 – Two detection sets will be put in the two secondary circuits of the coolant water to give a fast alarm in the case of leakage in the heat exchanger.

Also related to the reactor renovation is the problem of the radiation levels at the swimming pool surface which is discussed in another presentation of this Conference⁽⁴⁾. Under present conditions, with the power increase the radiation level at the reactor surface would be too high.

Portable detectors are represented by several survey meters

For beta and gamma radiation we use Geiger Muller detectors, ionization chamber type cutie pie detectors and for fast and thermal neutrons we use proportional counters with BF_3 detectors

Two monitorings are done daily, one in the morning approximately an hour after the reactor starts and the other in the afternoon two hours before the reactor shuts down.

These monitorings are done adjoining the beam holes, working areas for D F N personnel, reactor control room and the reactor swimming pool

Terminating in the first floor of the reactor (inner yard) we have fourteen beam holes with internal diameters of 6 and 8 inches

Twelve of these beam holes have the other end close to the reactor core⁽⁵⁾ (figure 2) while two beam holes were placed further away in the direction of the thermal wall. If one day the reactor were moved to adjoin this thermal wall, these two beam holes would be utilized instead of the others.

The neutron thermal flux, in the end close to the reactor core, of the twelve beam holes is between 10^{12} and 10^{13} neutrons/cm² sec

The gamma exposure is about 10^8 R/h. We monitor the beam holes that are closed in order to detect possible collimated beams that could come from between the plugs and the walls of the beam holes. This space is full of water is test drained to verify that the space is full.

Most of the beam holes are opened for the execution of experiments done by D F N personnel.

After the exit of the beam hole one puts the experimental apparatus and then a beam catcher. The exposure measurement is done out of the beam trajectory. In view of this one creates a series of places where the personnel should remain to execute their experiments. With the intention of avoiding over exposure of this personnel we monitor these places and we warn the interested party about the exposure levels so that they take the necessary care and thus avoid exceeding the maximum permissible level.

Adjoining the swimming pool and in the control room of the reactor the dose coming from neutrons is insignificant. In tables 1 and 2 and in Figure 3 we give the average level of radiation dose during 1972 for each place monitored.

Still referring to the reactor building, we should mention that we maintain under our control fifty storage tubes for radioactive materials used in the reactor or that await decay.

These storages, in a horizontal position, are placed in a wall of the first floor of the building (figure 4). In them we put beam hole plugs, collimators, reflector elements, damaged industrial sources, etc.

III - I.E.A. DIVISION AND SERVICES

For each Division and Service that need our collaboration we give technical assistance, equipment, technicians or scientific personnel.

Van de Graaff accelerator of 400 KV and generally use target of tritium to produce a neutron beam of 14 MeV. For protection measurement we placed in that laboratory a tritium detector, neutron spherical dosimeter and a neutron survey meter identical to those we use in the reactor building.

The Radioactive Material Production Service has a chemistry processing laboratory where one produces the radioisotopes, principally used in medicine. Among them we mention ¹³¹I, ¹⁹⁸Au, ²⁴Na, ⁵¹Cr, ⁸²Br, ³²P, ³⁵S. There is still a little production of fission products such as ¹³²I and ¹³⁷Cs but in quantities of order of μ Ci. In this room (figure 5) we have a air borne continuously monitoring and a Geiger Mueller survey meter. In the external corridor we put a hand and clothe monitoring device. In the hot laboratory of this Service and in the semi hot laboratory of the Radiochemistry Division we maintain a rate meter to control personal contamination. Even so as a precaution measurement we monitor daily in the S P M R laboratories and in the D R Q laboratories, principally to control eventual contaminations or leakage on the processing cell. A copy of the report is sent to the respective division head. The radioisotopes processing room is lower in pressure than all the other S P M R areas and the processing cells are at still lower pressure. The air that circulate in the room and in the cell is exhausted through special ducts and passes through filters before leaving by the chimney. Immediately after the filters we put Geiger Mueller counter with rate meter and recorder to control the elimination of radioisotopes.

At the present the new building of S P M R is under construction and we need mention that several time we join with the head of that Service and the responsible engineer for the project to discuss radiation protection measures.

The Radiobiology Division (D R B) section of Radiopharmacy has a labeled compound

laboratory. Principally one uses the radioisotopes ^{131}I and ^{51}Cr . In that laboratory we maintain a hand and clothe monitoring device and a Geiger Mueller survey meter and we do a daily monitoring.

A new building is also under construction for the Radiopharmacy section and we have accompanied this project since the start.

Our major concerns are to enable construction of a facility functionally equipped for isotope handling and chemical treatment, together with safety and ease of decontamination.

The Industrial Radioisotopes Application Service in 1971, started to use appreciable quantities of ^{82}Br as a tracer for experiences done in rivers and sea.

The works is being carried out with the assistance of one or sometimes two S.P.R.D. technician. We give them special clothes such as masks, gloves, etc. and also survey meters to measure the exposure to radiation.

In 1971 we started an effective health physics work in the Division D.M.N. and D.E.Q. because up to that time our work was limited to attending that division only sporadically, as necessary or as solicited. The planning of this routine service has been slow because of the particular characteristics of these two divisions; they work principally with alpha radiation. The instrumentation is in the stage of conclusion. In this conference we will present a work showing the set up of our service in that Division⁽³⁾.

IV - S.P.R.D. INTERNAL SERVICE

Our personal dosimetry laboratory is in development. Until 1970 our personal dosimetry was limited to the pocket dosimeters and film badge dosimeters. In 1971 we started to develop other types of personal dosimeters as the Albedo for neutron and finger ring for the hand.

We have introduced urine analysis to determine uranium concentrations. This is very useful for the D.E.Q. personal. This year we start to introduce this analysis also for D.M.N. personnel. In this meeting we will present a work about this⁽³⁾.

We have also started thermoluminescent dosimetry doing a study given in detail about the comparison between film badge, thermoluminescent (several types) and radiofotoluminescent dosimeters. This study will be presented in this meeting⁽¹⁾.

We introduce also audible pocket dosimeters used by the personnel that work in the reactor near the beam holes or that handle radioactive sources and by personnel that work in radioisotope processing.

During 1972 we intend to extend the internal dosimetry in an experimental character:

- 1 - To the Van de Graaff personnel who work with tritium targets; for this we plan to use the D.R.B. liquid scintillator.
- 2 - To the radioisotope chemical processing and label compound personnel using a lithium-drifted detector and multichannel analyzer that we have on order.

Thermoluminescent dosimetry will be used during this year by I.E.A. personnel, together with film badge dosimeters. By the start of next year we plan to extend it to all external institutions which use our service.

Presently we are investigating audible dosimeters. The Oak Ridge National Laboratory has given us their dosimeter circuit and our Electronic Service is building some experimental models. Depending on the

adaptation to our humid and on the cost, they will be made in sufficient quantities for all I E A personnel, at the present 294. In the future they could also be made for external institutions.

Film badge dosimetry has been done since the IEA's creation, initially by the Oak Ridge National Laboratory and later by us. We will present in this meeting a work about the fading of the film image after developing⁽⁶⁾.

We will examine the films badges developed in the last 10 years. These films are from nine different lots.

Next we give a table showing the distribution of I E A personnel exposures during 1971. These exposures were measured by personnel monitoring film badges produced of Agfa Gevaert.

I.E.A. personnel, accumulated exposure in 1971.

Interval of Exposure	Number of Employees	Percent
Below 100 mR	184	62 %
Between 100 and 500 mR	61	21 %
Between 500 and 1000 mR	17	5,5 %
Between 1000 and 2000 mR	18	6,5 %
Between 2000 and 3000 mR	9	3 %
Between 3000 and 4000 mR	5	2 %

The persons having the higher exposures are connected to the withdrawal of irradiated material from the reactor and to the chemical processing of radioisotopes.

We continue to use the same system of personal yearly index cards to keep the film, as presented by Hehl (figure 6), but we also introduce an additional personal index card for the yearly accumulated exposures during all the user's professional life (figure 7).

The S P M R radioisotope production has increased exponentially year to year and consequently the radioactive wastes followed the same pattern. The details will be seen in a work presented in this meeting⁽⁸⁾. The control methods used up to now have become impractical, forcing us to study new methods.

Most problematic are the effluents resulting from the production of Iodine, which must be stored a relatively long period before it is possible to dilute it in our tanks (capacity of 10 000 liters). This year an expert of the International Atomic Energy Agency (I A E A) will come to help us in this job.

For the next years we must consider an increase in production caused not only by the external market of the I E A, but also by internal consumption because, at the present, the two principal producing services are undergoing expansion. A building is being built specially for radioisotope production and another for the Radiopharmacy Section.

The decontamination work developed until now has followed the pattern of growth of the I E A. The techniques used in the decontamination processes are the conventional ones, with only a few changes during the years, when the literature showed us that a technique had become the preferred. We have a project to develop during this year concerning the study of decontamination techniques for instrumentation, utensils, areas, walls, etc. as well as clothes and persons.

We plan to do a general survey of the techniques used, and then submit them to tests to verify their effectiveness, that is, we should do a comparative critical study of all of them.

As a second part we will try to improve them or to develop new techniques

Since the IEA's creation we have had no accident that resulted in high exposure for IEA personnel or in high cost for decontamination

The biggest accident that we have had was with an Iridium industrial source of 3 Ci

This source was made with Iridium in compacted powder and encapsulated in steel.

During its calibration and introduction in to the shielding it developed a leak that at the time, 12-15, it was not detected

Only in the afternoon was the contamination detected, and the first actions taken. In the accident site the exposures measured with a ionization chamber, (cutie pie type), were 6 mR/h of gamma ray and 240 mR/h of beta rays

The second place of major contamination was the elevator, with 3 mR/h of beta radiation, and the third the entrance floor to the reactor building, where our most sensitive survey meters reading down to 0,01 mR/h detected nothing

The identification was done by smearing, with analysis by the analyzer we proceeded to the decontamination the next day a Saturday, when there was no normal work in the I E A. The ground floors of the reactor building and the adjacent building were treated. On the day of the accident we also monitored all personnel of the two building and we verified that some of them had a light contamination on their shoes. On the same day all powdered sources were eliminated. New ones have been made with metallic Iridium

The section of shielding calculations is developing its routine activities, giving assistance to the I E A divisions and services that need this kind of protection and also to external Institutions. For example, for the reactor rebuilding program we calculated the thickness of concrete that must be put over the nitrogen decay tank that will be installed during the second stage of the project

Also being calculated are the lead thickness necessary for storage or transport of radioactive sources, industrial or otherwise. We also perform calculations for the D F N of the beam catcher necessary to absorb the radiation beam leaving the beam hole after passing the experimental apparatus

Related to dosimetry, we have purchased an absolute ionization chamber (Attix model) which we plan to put in operation as soon as its laboratory building is ready, hopefully this semester. At the start, in addition to it using to calibrate industrial sources, we will use it to calibrate our instrumentation, because it has an intercomparison chamber to extend the energy range

At the present our instruments are principally calibrated through four French calibrated sources with activity errors of 3%, one 100 mCi and another 10 Ci of ^{60}Co and also one 100 mCi and another 10 Ci of ^{137}Cs . These activities refer to the date of delivery, about three years ago. All are of the industrial type

The industrial sources made by D O M R are calibrated with one of our instruments, in turn calibrated with these sources. At the present, for easier movement, better protection and less waste of time they are being calibrated with an ionization chamber built by our D O M R and immersed in the swimming pool of the reactor. This chamber was initially calibrated with the French sources

Finally we mention that we are working on the preparation of a plan for the future S P R D building. This plan should be ready to be submitted for approval by March. This is not an easy job because the routine development of the S P R D is dependent on the development of the I E A, and on external demand. If we plan a small building we are risking that it become inadequate in the next few years, but if we build a big building, depending on the development, it might become inhabited by ghosts

V – JOBS DONE FOR EXTERNAL ENTITIES

Whenever solicited we give Health Physics assistance to external Institutions. One of the services that we offer is external personnel dosimetry with film badges. At the present we have more than eight hundred users belonging to more than twenty firms.

At present we do not have laws that require personnel dosimetry for each worker who has the possibility of exceeding a determined level; this means that these users have solicited our services spontaneously, being conscious of the necessity of this kind of service.

High exposures recorded by the film badges are very rare, and generally happen in Institutions that have many employees and many film badge users.

It happens, however, that in all cases that it was possible for us to investigate, the high exposures were not taken by the users. Rather they put the film in front of a source without remaining near by themselves.

We don't know the reasons that lead these persons to do this. Maybe they want to have proof of our effectiveness.

A fact that leaves us more apprehensive is that those responsible in the firm do not pay attention to these incidents and do not investigate the reasons.

Other firms, conversely, are excessively worried about personnel dosimetry. This is the case, for instance, with a big industrial firm with only a small number of film badge users. They practically only use radioactive sources, as level detectors.

The exposure level of their personnel never has exceeded the film badge background, this is, 10 mR.

Once a monthly film badge from one of their personnel presented a exposure of 35 mR. As is generally known, exposure below a hundred mR measured by a film badge must be viewed with doubt, because the fluctuation in the density, due the film's condition before development, gives a big error.

Some time later the firm sent us the plan of an oven, the room where it was installed, and also the adjacent room, with all the details, informing us that the oven was controlled by a radioactive source and asking us if the exposure taken by the mentioned person could be due to his remaining beside the oven at a certain distance for half an hour. By fate, the result of the calculation gave us 35 mR. We sent the firm the calculation as well as the result.

Another occurrence that is worthwhile to tell is that a firm one day solicited us to give it the accumulated exposure taken by one of its X ray machine operators. The person had never had exposures higher than the film badge background. Reason of the solicitation: that operator contracted tuberculosis and took the case to the courts thinking that the disease was provoked by the radiation.

Another type of service that we do for external Institutions is the survey of the radiation levels in the laboratories where there are radioactive sources, X rays machines, cobaltotherapy etc. This service is solicited by the client. We do this type of survey in several Hospitals.

Related to this type of assistance we have a case that is worth while to tell. In an hospital we found an X ray machine, used for chest radiography. It was very old, its brand Keleket.

The operation high voltage was changeable from 60 to 90 KV, the medium time of each operation was a second and the miliampere level completed unknown. Reason: this machine was very old and was not

normally in use, but one day it became necessary to use it. We called the representatives that repaired the machine, but they were not able to repair the ammeter. The very representatives had not determined the milliamperes level when operating but had informed the Institution that it was possible to operate the machine in that condition.

A third assistance that we offer is shielding calculations for rooms of cobalt therapy, X rays etc.

Among these the most unusual was calculation of a complete laboratory for cobalt therapy where the interested person, in addition to giving the necessary data for this type of calculation, informed us that it was his intention to build the walls with diabase. Then our biggest problem was to discover what diabase was. Finally we found the mean composition of this rock in the Encyclopedia Britannica, and the variation of its density, which depends on its chemical composition, in an article by J. J. Jakesky, published in Exploration Geophysics. After that we could proceed with the calculation.

We conclude that the very users are completely uninformed about the possible biological effects of radiation, about the meaning of maximum permissible dose and about the basics of personnel dosimetry.

We are sure that in a short time these flaws will be cured because the National Commission on Nuclear Energy has spent several years worrying about standards and licensing for the use of radioisotopes, leading us to believe that in a short time it will not be permitted to give radioactive materials to the unprepared person.

SERVIÇO DE PROTEÇÃO
RADIOLÓGICA E DOSIMETRIA

NÍVEL DE RADIAÇÃO

ÁREAS DE TRABALHO

DATA
06/03/72

HORA

OPERAÇÃO Nº
001/71 a 251/71

POTÊNCIA
2 MW

MÉDIA

LOCAL	BETA-GAMA nr/h	NEUTRONS LENTOS		NEUTRONS RÁPIDOS		DOSE COR. mrad/h
		Leitura	n/cm ² .s	Leitura	n/cm ² .s	
A	0.10					0.10
B	2.06					2.06
C	5.60					5.60
D	7.50					7.50
E	2.42					2.42
F	0.48		11		24	3.88
G	2.04		19		39	7.66
H	18.72		18		252	53.02
I	3.00		22		38	8.48
J	1.50		12		34	6.34
K	0.70		7		14	3.66
L	0.24		3		5	0.95
M	0.15		2		5	0.86
N	0.22		3		5	0.83
O	6.08		21		85	15.98
P	0.37		12		30	4.71
Q	3.12		7		22	6.22
R	48.35		23		72	59.11
S						
T						

DETETORES

NC 2650/613
NC 2650/612
NC 2650/611
NC 2600/5088
NC 2675/4035
NC 2646/T-31
NC 2675/2650
NC 2646/T-70
NC 2112
DN3 - 474

TÉCNICO
[Assinatura]

RESPONSÁVEL

OBSERVAÇÕES.

Table 1

SERVIÇO DE PROTEÇÃO
RADIOLOGIA E DOSIMETRIA

NÍVEIS DE RADIAÇÃO

BEAM-HOLES

DATA

06/08/72

HORA

OPERAÇÃO Nº

00171-231/71

POTÊNCIA

2 MW

MÉDIA

Nº	Beta-Gama mr/h		Neutrons Lentos n/cm ² s		Neutrons Rápidos n/cm ² s		Dose Tot. mrem/h
	Leitura	Leitura	Leitura	Leitura	Leitura	Leitura	
1	0.10	9			37		2.65
2	1.53	13			56		11.03
3 #							
4 #							
5 #							
6 #							
7	0.10	5			14		2.08
8	0.10	2			9		1.31
9 #	0.10	2			4		0.67
10 #							
11 #							
12	0.16	88			732		105.31
13 #							
14 #							

INSTRUMENTOS

NC 2650/613

NC 2650/612

NC 2650/611

NC 2650/3098

NC 2633/3035

NC 2646 T-57

NC 2633/3036

NC 2646 T-18

NC 2112

DN 5 - 474

MÉTODOS

portáteis

RESPONSÁVEL

OBSERVAÇÕES: # Abaixo da Co. Bloqueadas

Table II

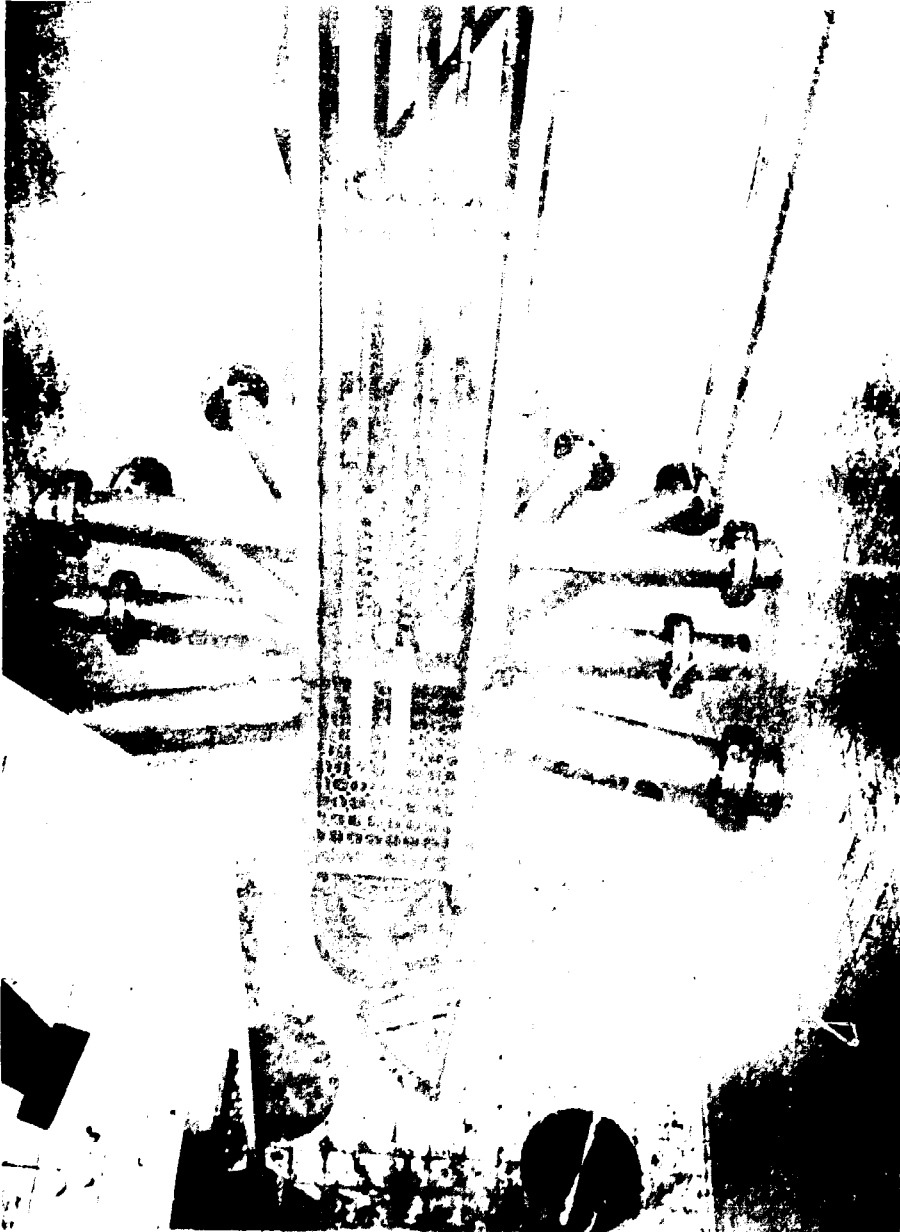


Figure 2

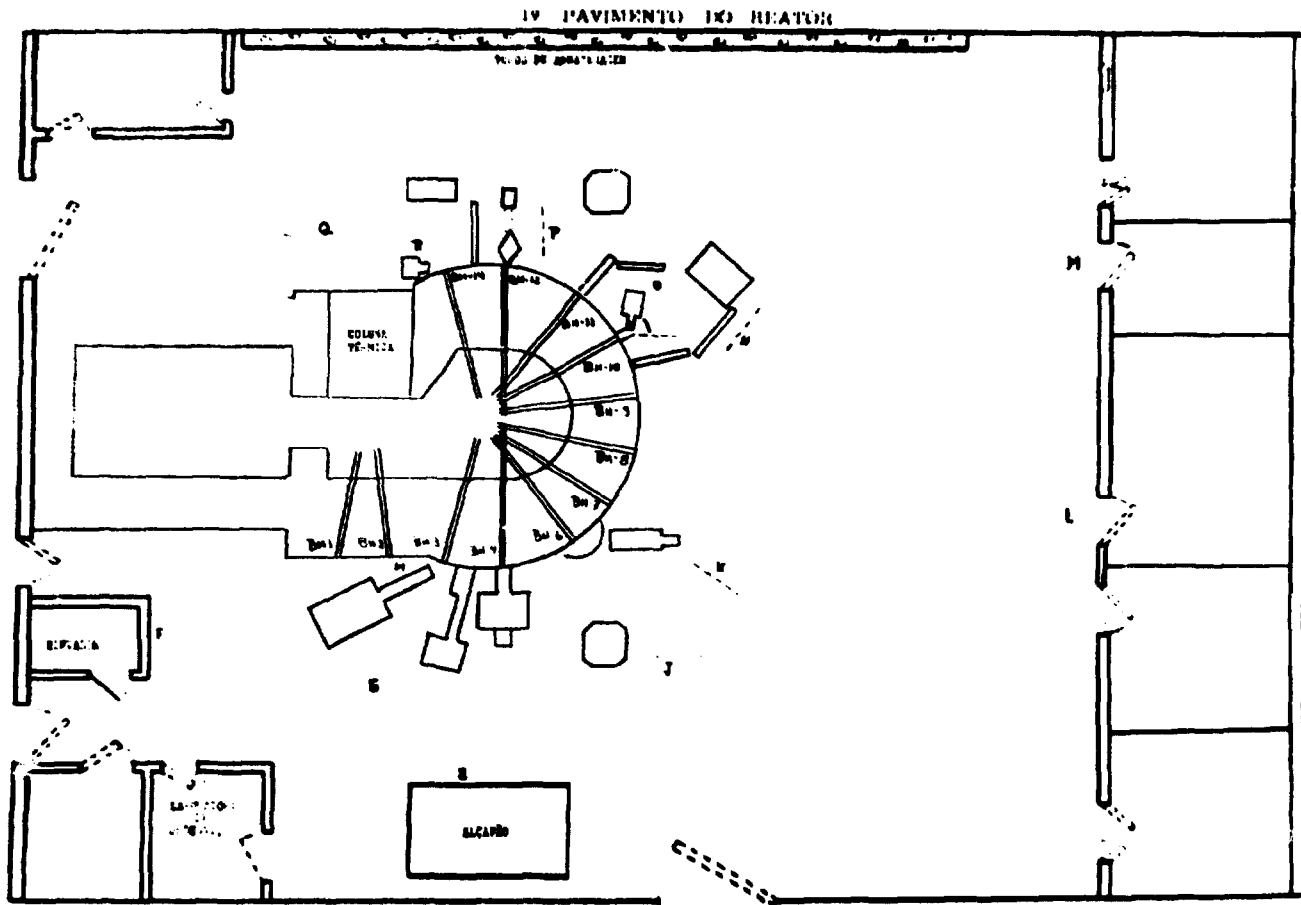


Figure 3



Figure 4



Figure 5

RESUMO

Descrevemos nosso trabalho de rotina de Proteção Radiológica no reator IEAR 1 e as modificações que estão sendo feitas

Esse trabalho inclui serviços específicos prestados em outras Divisões e Setores do IEA. Além disso descrevemos nosso Laboratório de Dosimetria Pessoal, Laboratório de Descontaminação e Disposição de Resíduos, Seção de Cálculo de Blindagem, Laboratório de Dosimetria e Calibração de Fontes Radioativas e Instrumentos

Incluímos uma rápida descrição dos planos para o novo prédio do S P R D

Finalmente, falamos sobre a assistência prestada a outras instituições que não o IEA

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