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IRRADIATION FACILITIES IN THE ISPRA I REACTOR

by

M. BRESESTI and H. NEUMANN

1963

ORGEL Program

Joint Nuclear Research Center
Ispra Establishment (Italy)

Materials Department
Nuclear Chemistry Service

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The authors' names are listed in alphabetical order.

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The facilities for the irradiation of samples, available in the ISPRA I reactor are the following :

1. Isotope trains : 12 tubes in the graphite reflector under the heavy water tank.
2. Pneumatic tubes : 4 tubes delivering the samples in the graphite reflector near the heavy water tank.
3. 4DH1 channel facility : facility installed in a radial channel.

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C O N T E N T S

T A B L E S

F I G U R E S

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The characteristics of the irradiation capsules are also reported.

INTRODUCTION

The ISPRA I is an heavy water moderated and cooled reactor operating at a maximum power of 5 MW. The reactor is fuelled with enriched uranium (U 235 , 90%).
The isotope trains and the pneumatic tubes have been installed in the ISPRA I reactor at the moment of the construction, the 4 DH1 channel facility has been installed later to obtain better irradiation possibilities.
A general view of the experimental installations is shown in fig. 1.
The reported values of the neutron flux have been measured at 5 MW with the core configuration shown in fig. 1.

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NEUTRON FLUX DETERMINATION

The conventional flux nv_0 (Westcott convention) has been determined by irradiation of a 1 mm. in diameter wire of Co/Al alloy (1% of cobalt).

In all the irradiation positions the epithermal component is so low that it is correct to use in place of the effective cross-section $\hat{\sigma}$ for the reaction Co 59 (n, γ) Co 60 the value of $\sigma_{2200\ m/se}$

From an evaluation of the data reported in the literature a value of 37.3 barns has been assumed for the effective cross-sectio

The epithermal activation of cobalt, utilized in the calculation of the cadmium ratio, has been determined irradiating the Co/Al alloy in cadmium boxes with 1 mm. thick walls.

No self-shielding correction had to be applied to the thermal and epithermal activities induced in Co 59.

The Co 60 activity was determined by a 3" x 3" Na I (Tl) crystal previously calibrated evaluating the 1.17 and 1.33 MeV gamma-ray.

The fast flux has been measured by utilizing threshold detectors.

A very simple determination can be carried out by irradiating nickel discs and measuring the activity formed by Ni 58 (n,p) Co 58 reaction.

The Co 58 activity has been determined by measuring the 0.81 MeV gamma-ray with a 3" x 3" Na I (Tl) crystal previously calibrated.

From the measured activity the fast flux can be roughly calculated utilizing the value of the cross-section for the reaction Ni 58 (n,p) Co 58 averaged on a pure fission spectrum.

The value reported in the literature and used in these measurements is $\bar{\sigma}$ = 100 mb.

The precision of this procedure is not very good because the real neutron energy distribution in the graphite reflector is quite different from the shape of a pure fission spectrum.

The neutron energy distribution can be determined by utilizing several detectors of different threshold energy.

In the PH3 pneumatic tube the neutron spectrum with the reactor operating at 3.7 MW has been determined by the following nuclear reactions :

Np	237	(n,f)	
U	238	(n,f)	
Th	232	(n,f)	
S	32	(n,p)	P 32
Ni	58	(n,p)	Co 58
Al	27	(n,p)	Mg 27
Fe	56	(n,p)	Mn 56
Al	27	(n,α)	Na 24

From the activation data the neutron spectrum has been determined by an iterative method utilizing the 7090 IBM computer.

The calculated spectrum is shown in fig. 2.

IRRADIATION POSITION

1. Isotope trains.

The isotope trains consist of 12 aluminium tubes placed in the graphite reflector under the heavy water tank and passing through the reactor.

These tubes are distributed on three planes, 4 tubes on each plane as shown in fig. 3.

The useful diameter of the 4 higher tubes is 3.4 cm ; of the other ones is 2.4 cm.

The useful length of the channels is 2.5 mt.

The introduction and the removal of the samples can be performed only when the reactor is not operating : therefore it is possible to irradiate the samples only for one or more operation cycles. An operation cycle is generally 12 days.

The data of conventional flux $n\bar{v}_0$ and cadmium ratio determined by cobalt irradiation with the reactor operating at 5 MW are reported in table I. These values have been measured in the centre of the channels. For channels placed on the same plane, the average value of the fluxes measured in the single channels is reported.

The neutron flux has a maximum in the centre and decreases by moving away from the centre.

TABLE I

Values of nv_o and cadmium ratio in the isotope trains at 5 MW

Channels	nv_o $n/cm^2/sec$	cadmium ratio
IS A	7×10^{12}	900
IS B	5×10^{12}	1300
IS C	3×10^{12}	1500

For the channels with higher diameter standard capsules of Renal (99.5% Al - 0.5% Mg), with internal diameter 20 mm. and internal length 50 mm., are utilised. A standard capsule closed by cold welding is shown in fig. 4.

2. Pneumatic tubes

The 4 pneumatic tubes installed in the reactor, named PH 1, PH 2, PH 3 and PH 4, carry the samples in the irradiation positions placed in the graphite reflector, very near to the heavy water tank, as shown in fig. 3.

The time required for the introduction or the removal of the sample is about 1 second.

The samples irradiated in the PH 4 can be directly delivered in 20 seconds to the Nuclear Chemistry Laboratory through an underground tube of about 100 mt length.

Owing to the high temperature of the irradiation positions -about 250°C at 5 MW- it was difficult to find a material that could be used in the preparation of the irradiation capsules.

The VITON B, actually utilized, is a fluoroelastomer with high thermal stability.

However, the simultaneous effect of the temperature and radiation, damages in a short time the elastic properties of the VITON B, and therefore only irradiations of a few hours can be carried out.

An irradiation capsule is shown in fig. 4.

Values of $n v_0$, cadmium ratio and fast flux at 5 MW for the PH 1 and PH 3 positions are reported in Table II.

TABLE II

Values of nv_o, cadmium ratio and fast flux in the PH 1 and PH 3 at 5 MW

pneumatic tube	nv_o $n/cm^2/sec$	cadmium ratio	fast flux $n/cm^2/sec$
PH 1	2.3×10^{13}	60	1.2×10^{11}
PH 3	2.2×10^{13}	74	0.9×10^{11}

3. 4 DH 1 channel facility

As reported above, the irradiations in the isotope trains can be done only for one or more operation cycles and the irradiation in the pneumatic tubes only for a few hours. Moreover the neutron flux in the isotope trains is comparatively low.

Therefore it was necessary to set up a new facility with wider irradiation possiblities.

The facility installed in the 4 DH 1 channel permits to irradiate simultaneously 8 samples closed in spherical aluminium capsules 37 mm in diameter.

These samples can be introduced and recovered from the irradiation positions while the reactor is operating and can be irradiated without any time limitation.

Moreover the facility is cooled by air and water circulation. The facility, named NRX from the name of the Canadian reactor where similar facilities are installed, is shown in fig. 3.

The spherical capsules are shown in fig. 4.

The values of $n\,v_0$, cadmium ratio and fast flux at 5 MW for the 8 positions of the facility are reported in table III.

TABLE III

Values of nv_o, cadmium ratio and fast flux in the 4 DH1 channel facility

at 5 MW

4 DH 1 position	nv_o n/cm²/sec	cadmium ratio	fast flux n/cm²/sec
1	3.2×10^{13}	77	1.5×10^{11}
2	2.8×10^{13}	97	1.1×10^{11}
3	2.1×10^{13}	99	8.0×10^{10}
4	1.9×10^{13}	157	5.0×10^{10}
5	1.2×10^{13}	188	3.3×10^{10}
6	8.1×10^{12}	215	2.0×10^{10}
7	4.5×10^{12}	187	1.5×10^{10}
8	1.9×10^{12}	137	9.2×10^{9}

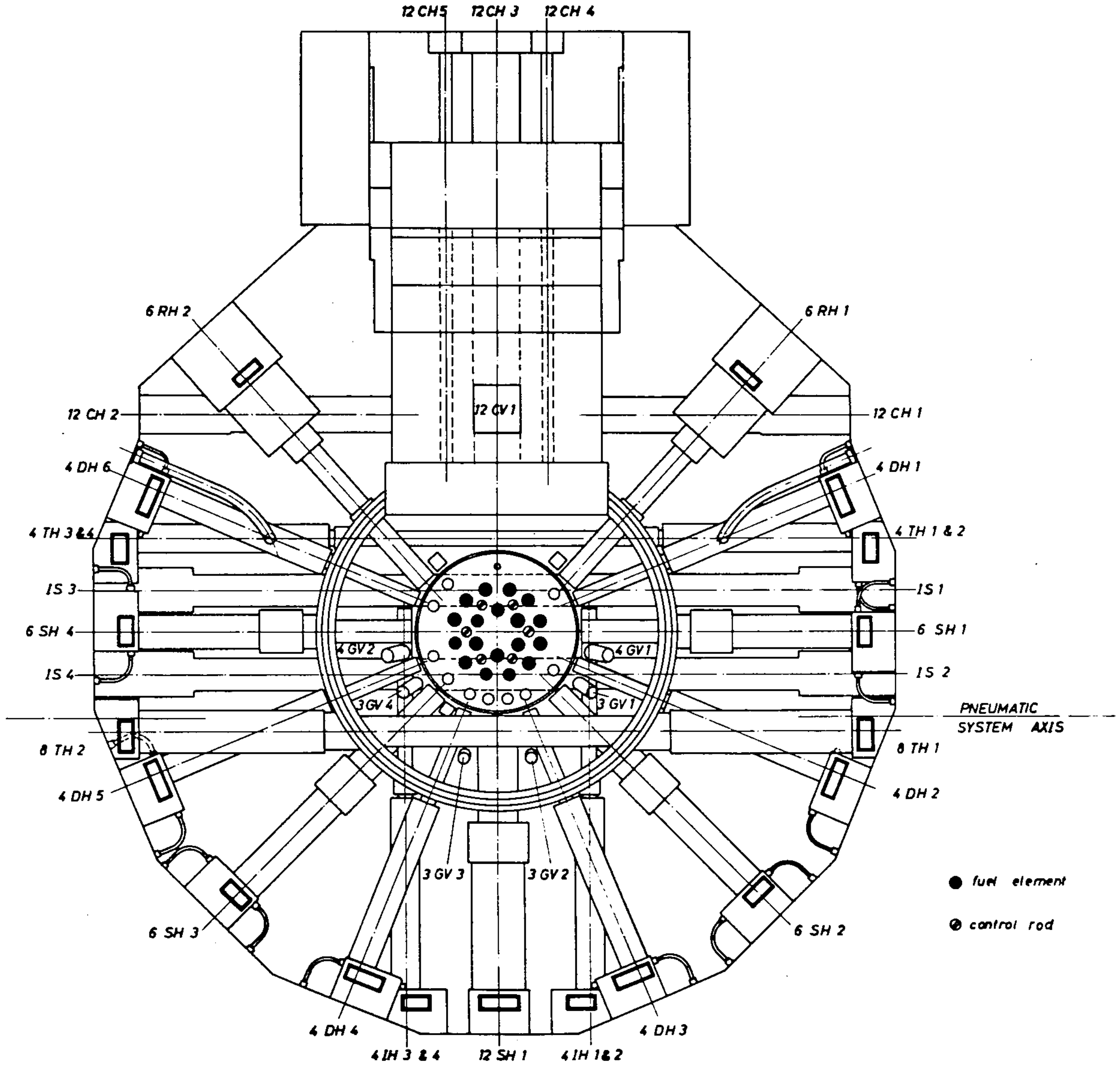


Fig. 1 General view of the experimental installations

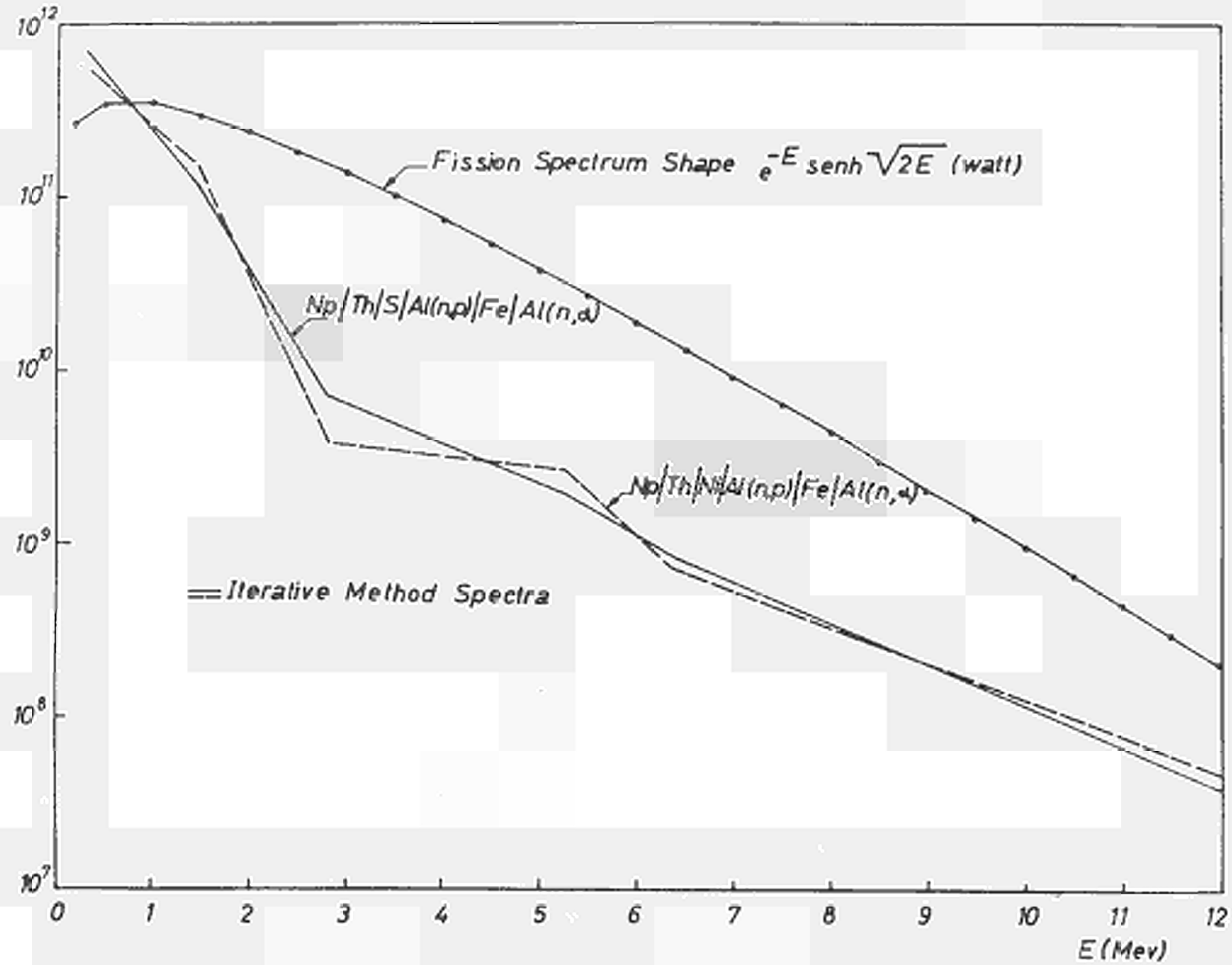


Fig. 2 Fast neutron spectrum in the PH 3 pneumatic tube

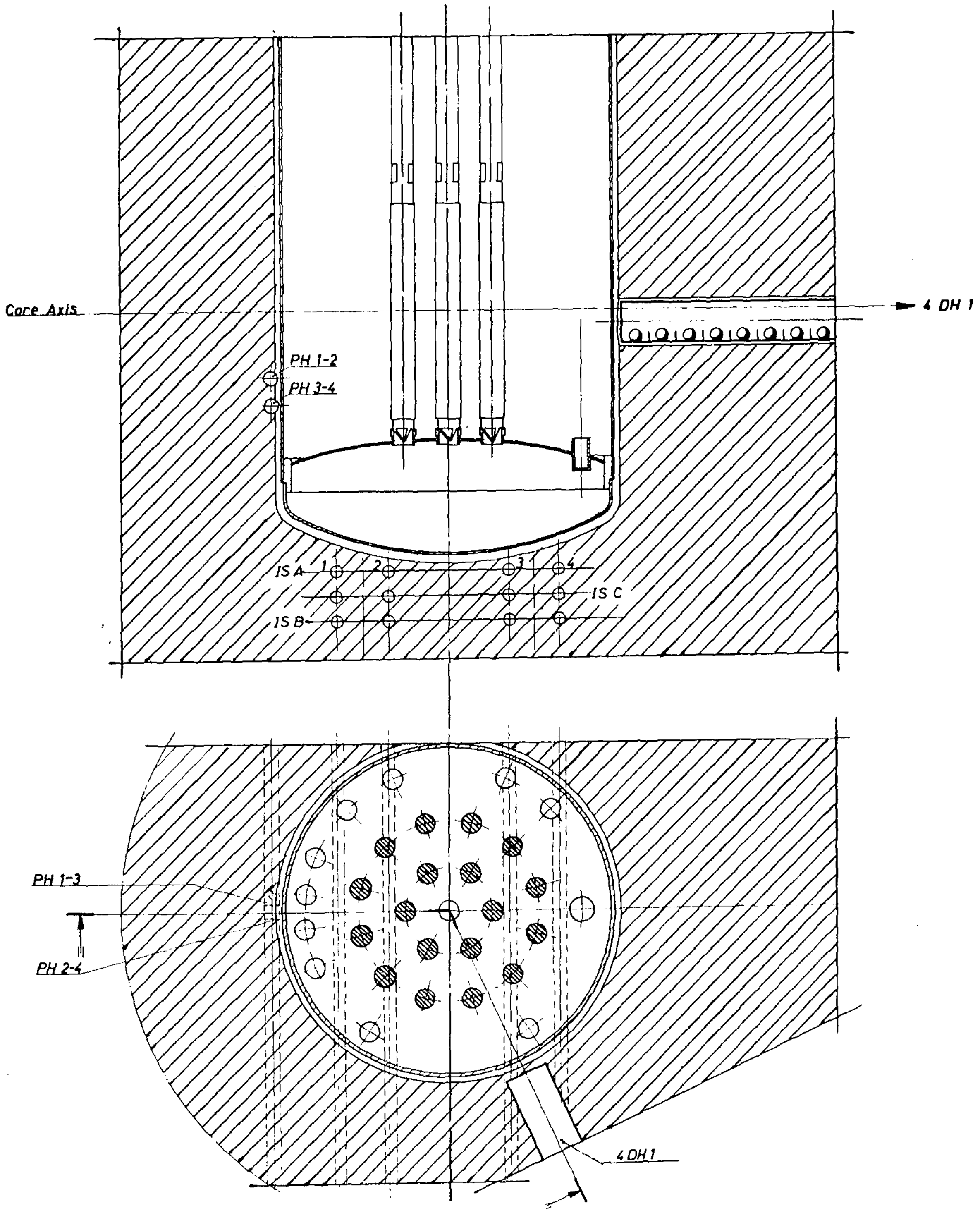
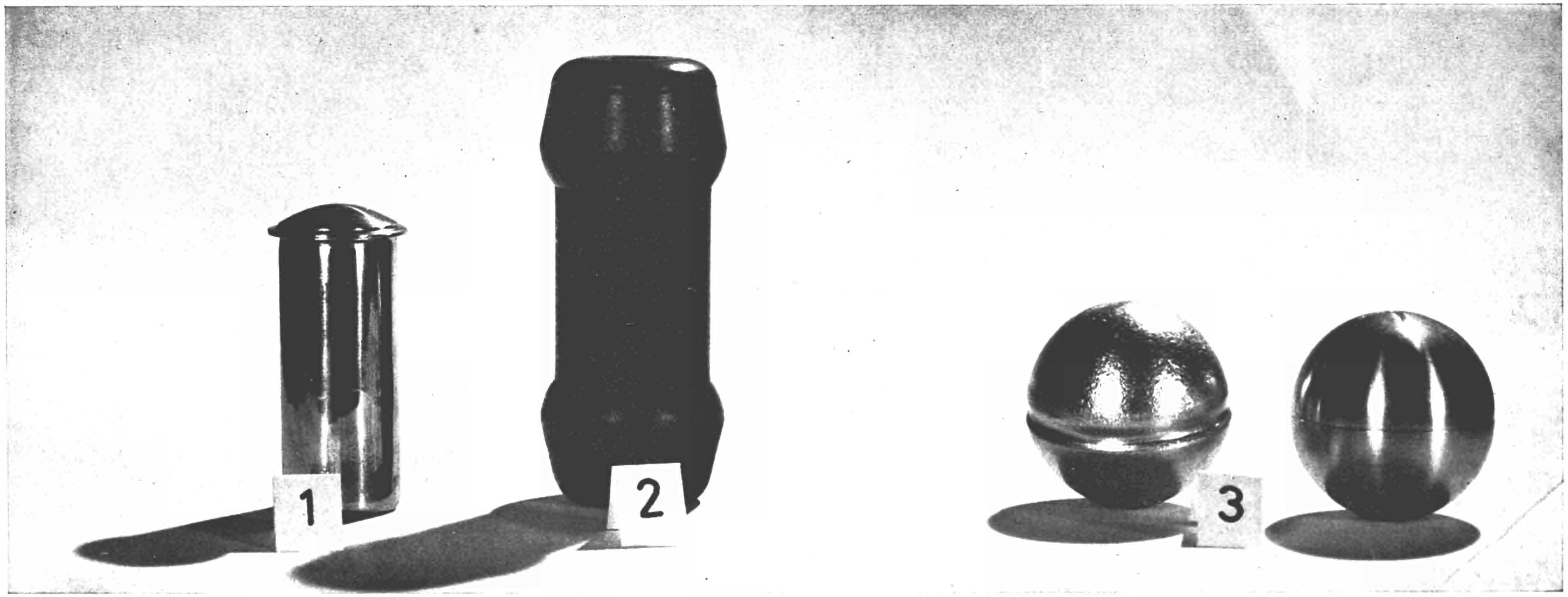


Fig. 3 General view of the irradiation facilities



1) Isotope trains 2) Pneumatic tubes 3) 4 DH 1 Chanel

Fig. 4 Irradiation capsules