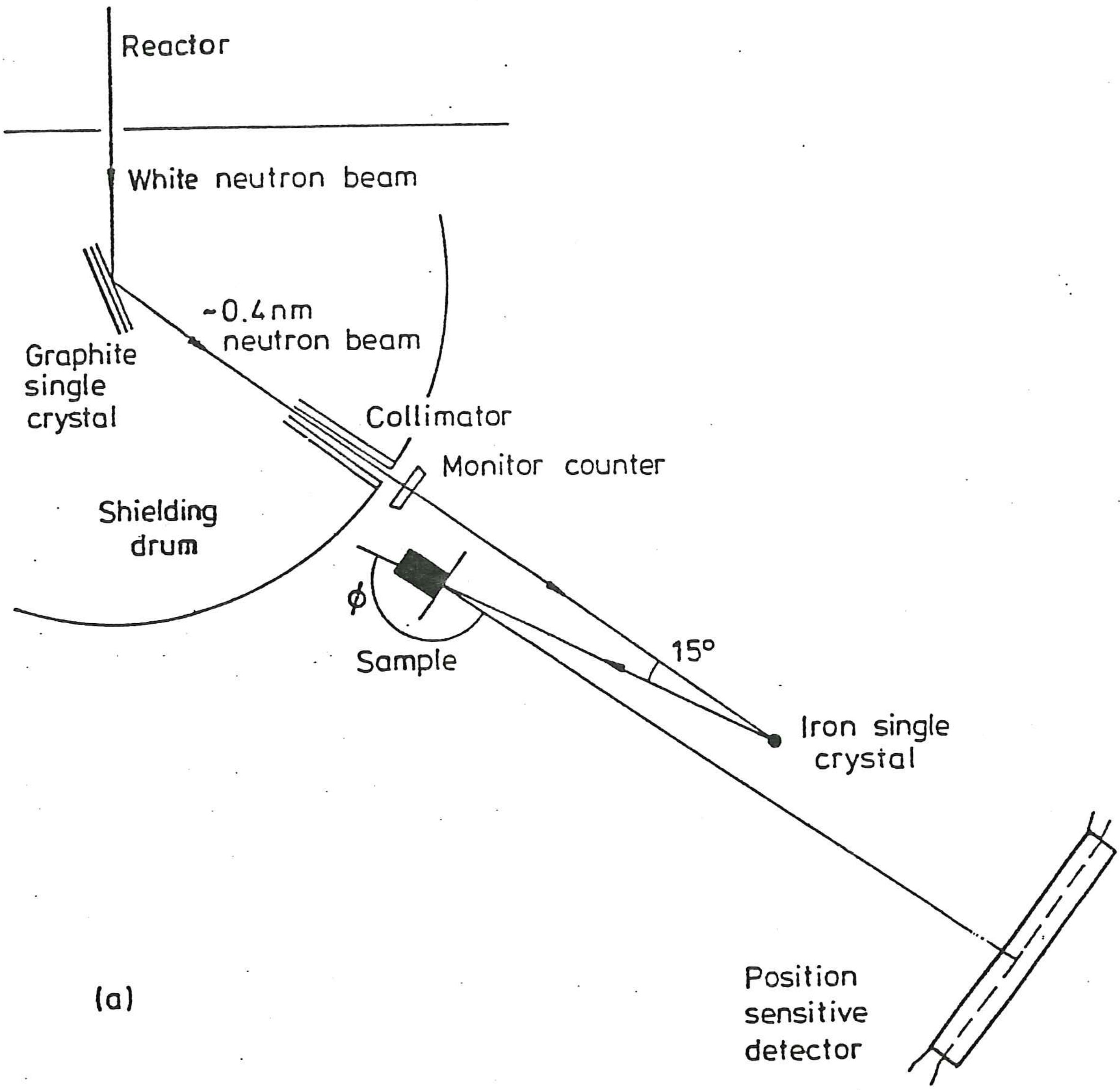


Figure 30.

Schematic diagram of the Double Back Scattering Diffractometer (DBSD) mode of operation

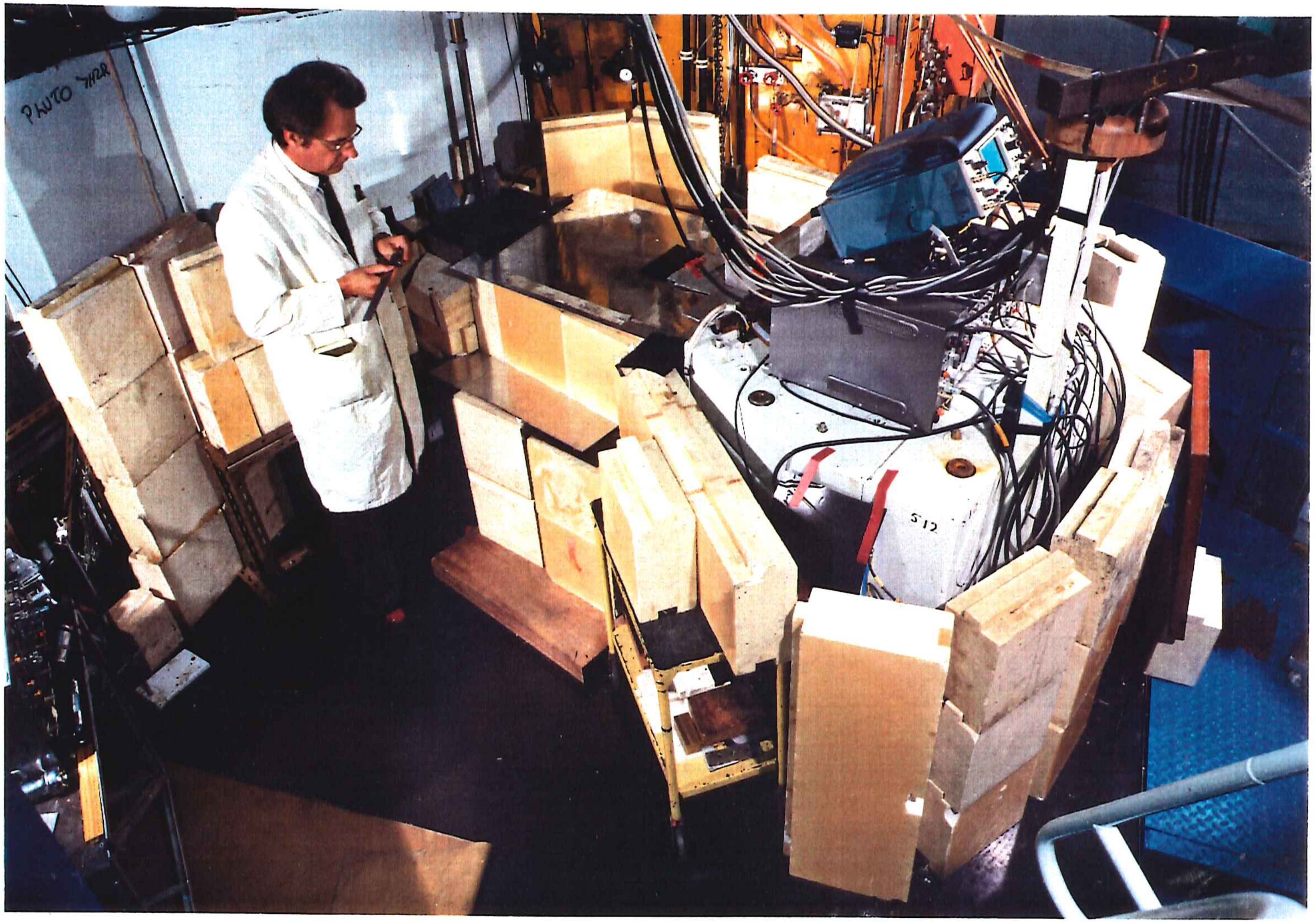
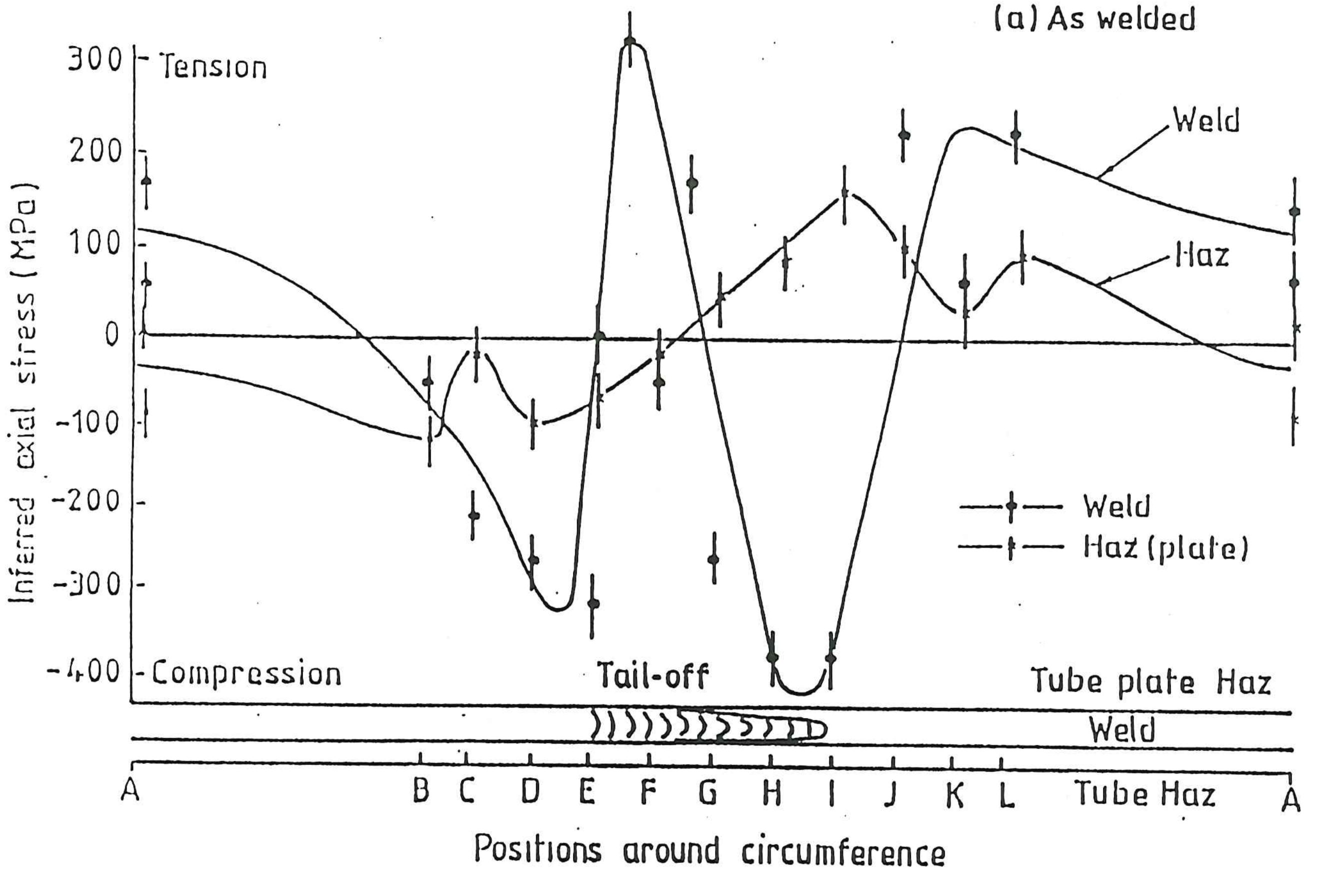


Figure 31.

The Double Back Scattering Diffractometer mode, with (1d) PSD.



PFR sample VI (as welded): Inferred axial stress variation around circumference in weld region and in HAZ

Figure 32.

Results obtained using the Double Back Scattering Diffractometer (MARX).

The Harwell Small-Angle Scattering Spectrometer

Design

The joint Harwell/SRC funded small-angle scattering (S.A.S.) spectrometer is designed to be installed on the 7H2 hole at the PLUTO reactor. The constraint of accommodating the instrument inside the reactor shell means that the overall length is limited to 5m, giving a maximum specimen-detector distance of 2m and a separation of 2m between the collimating aperture plates. A helical slot neutron-velocity selector occupies about 0.7m.

The detector is being manufactured by LETI with 128 × 128 grid elements with 0.5cm spacing as on the D17 instrument at ILL. The counter assembly can be rotated around the specimen position to a maximum of 30°. The neutron beam passes through a cooled beryllium and bismuth filter situated inside the reactor shield thus reducing the fast neutron and γ-ray fluxes. Calculations of the fluxes of the emergent beam ($\lambda > 4$ Å) and of the resolution of the instrument have been made using a basic collimation divergence of 1cm in 2m, a specimen size of 1 cm^2 and assuming the transmission of the filters to be 0.5 and that of the velocity selector 0.33 with a velocity spread of 10%. The calculated figures and comparable ones for D11 with similar resolution are:

λ (Å)	Flux (n $cm^2 s^{-1}$) Harwell	Flux (n $cm^2 s^{-1}$) Grenoble	Resolution (Å^{-1}) Harwell	Q min Harwell	Q max (Å^{-1}) Harwell
6	2.8×10^4	4×10^6	7×10^{-3}	2.6×10^{-2}	0.26
10	3.5×10^3	5×10^5	4.4×10^{-3}	1.5×10^{-2}	0.16

Data Collection

It is proposed to use a GT42 display system with 32K words of stores and a 1.2M word disc for data collection from the spectrometer. This will enable some existing software written for the GT44 system at Grenoble to be used directly.

Sample Mounting

The sample chamber is designed to be the same as those on D11 at ILL Grenoble an upright cylinder 350 mm diameter × 850 mm long. It will have a variety of "lids" for holding simple stick samples, cryostats and furnaces.

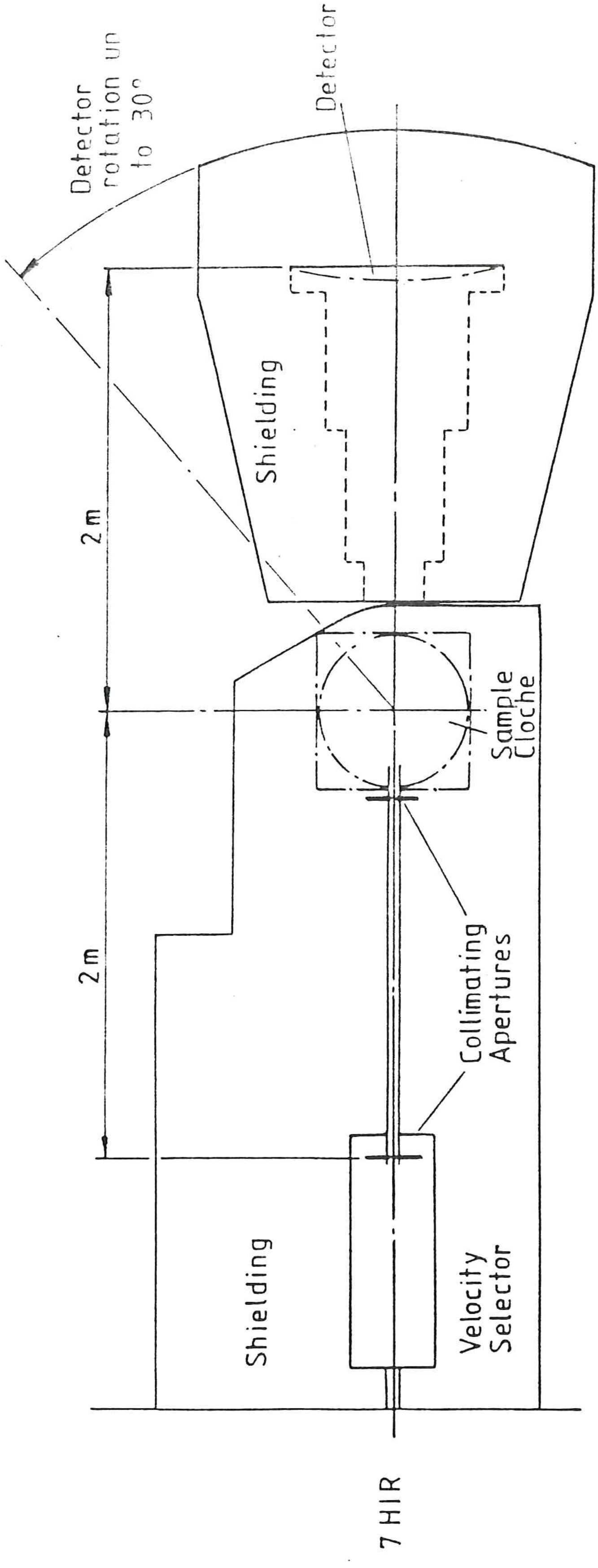


Figure 33.

Schematic layout of small angle scattering spectrometer plan view

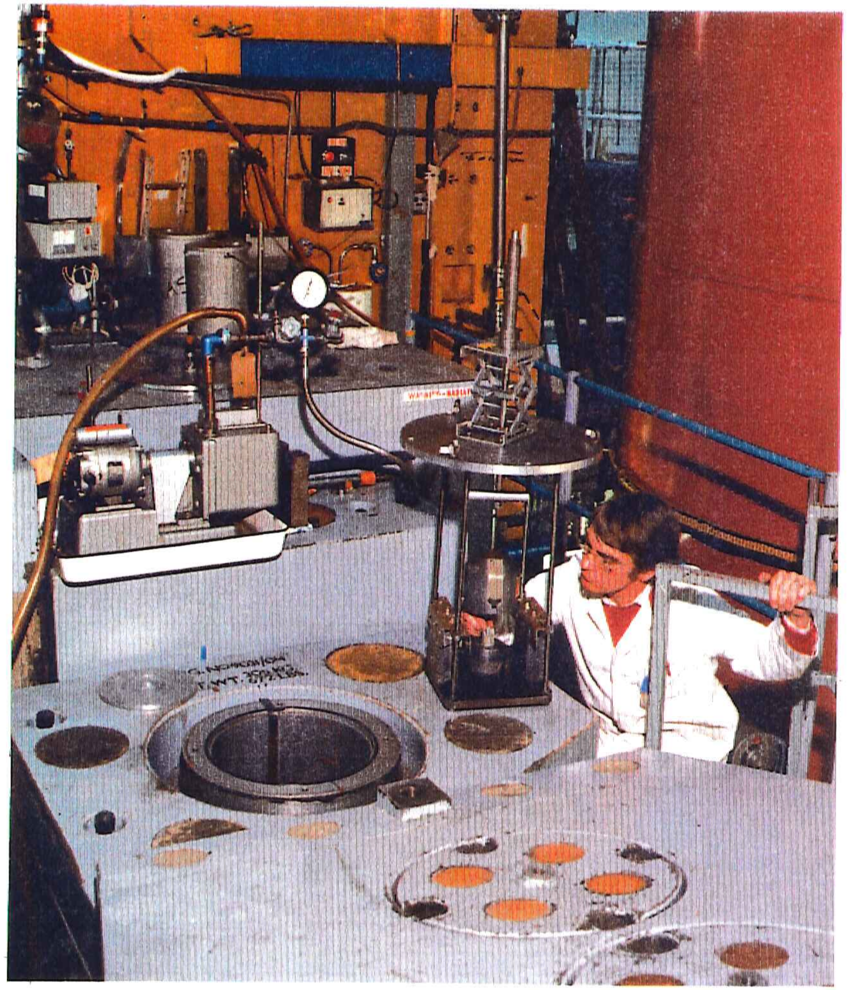


Figure 34.

Preparing to load a sample holder into the SANS Small Angle Scattering Spectrometer

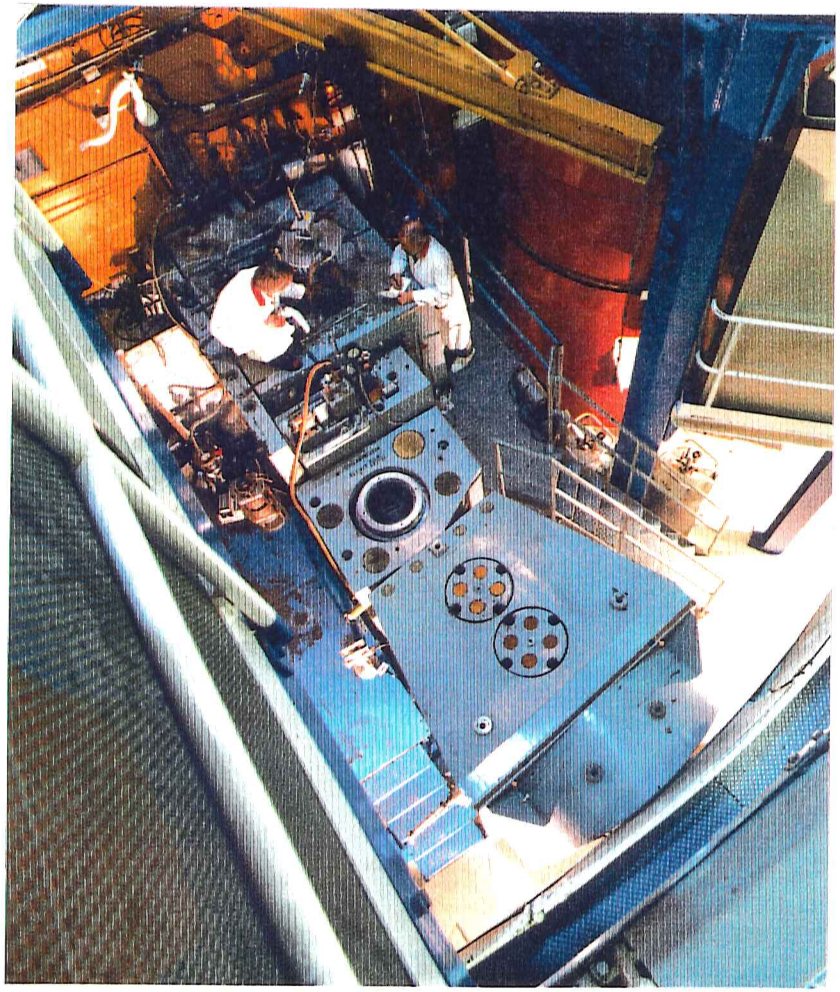


Figure 35.

General view of the SANS Small Angle Scattering Spectrometer

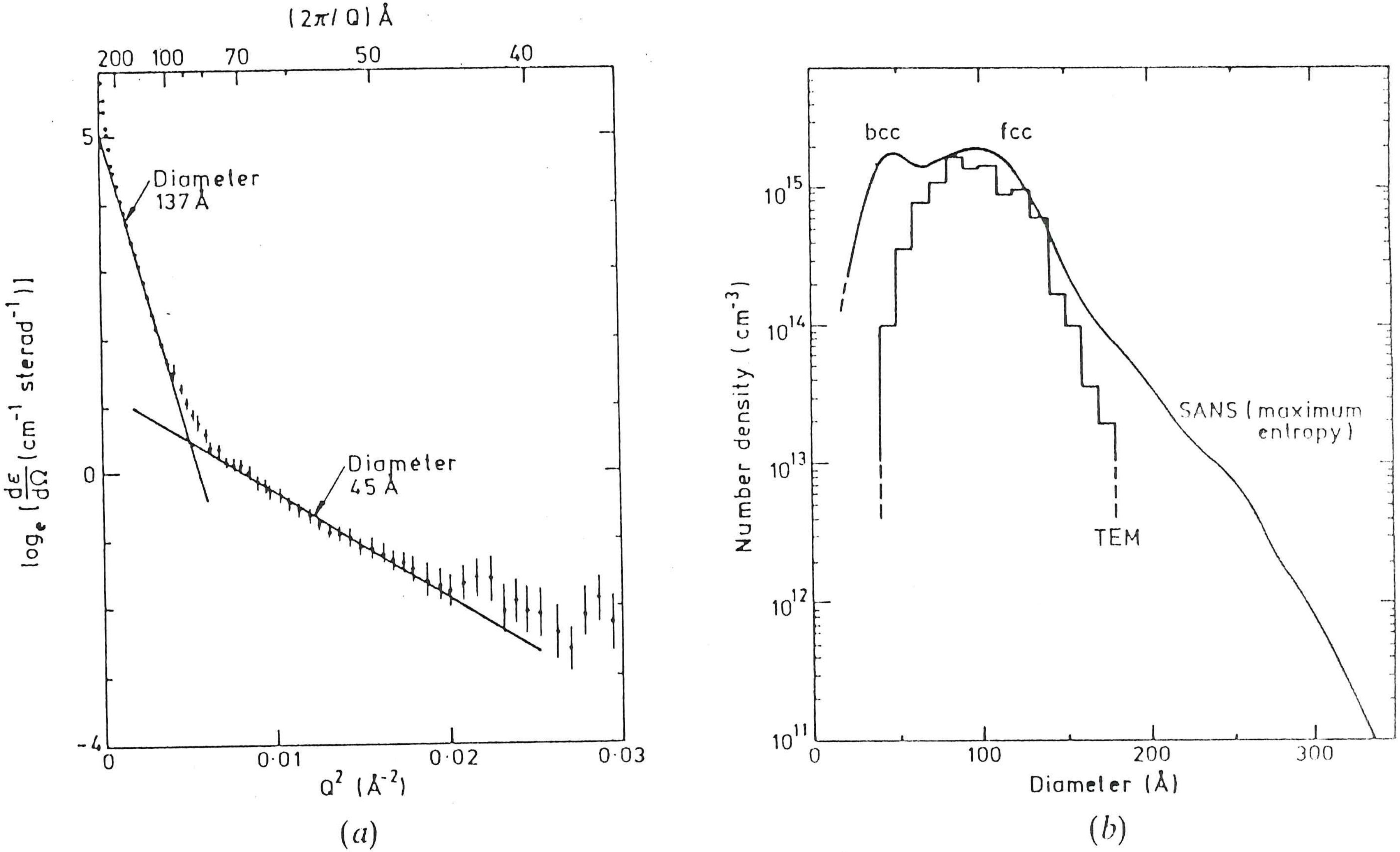


Figure 36.

The observation of copper clusters in steel after ageing. In (a) is shown the Guinier plot of the logarithm of the absolute Small Angle Neutron Scattering cross section against the square of the scattering vector. In (b) is the same data transformed to a number density distribution, compared to a transmission Electron Microscopy (TEM) results.

INTERNATIONAL NEUTRON RADIOGRAPHY NEWSLETTER

NEUTRON RADIOGRAPHY FACILITIES, DIDO REACTOR, HARWELL, ENGLAND

D.H.C. Harris and W.A.J. Seymour

1. Introduction

There are two Neutron Radiography installations (see figure 37) on the DIDO reactor at AERE Harwell. Firstly the Thermal Neutron Radiography facility (6HGR9) which is used extensively for the non destructive testing of industrial as well as nuclear reactor components. Secondly the Cold Neutron Radiography facility (6H) which is used exclusively for the examination of industrial objects, both by conventional static radiography on X-ray film and by real time dynamic imaging employing a TV camera and monitor.

A description and the operating parameters of the two facilities are given below followed by a short summary of the main applications.

2. The DIDO Reactor

The DIDO reactor is heavy water cooled and moderated and uses 80% ^{235}U enriched fuel in the form of concentric tubes. It operates at a reactor power of 26MW with 25 fuel elements each containing 205g of ^{235}U. Peak neutron fluxes in the core are 1.9 x 10^{14} fast neutrons $cm^{-2}s^{-1}$ and 2.5 x 10^{14} thermal neutrons $cm^{-2}s^{-1}$. DIDO has 28 vertical hole facilities and 16 horizontal beam tubes. The main reactor uses are for material testing and isotope production, mainly the vertical holes and neutron beam studies (including radiography) on the horizontal beams.

3. The Thermal Neutron Radiography Facility (6HRG9)

The thermal neutron beam is obtained from the graphite reflector of DIDO via a 150mm diameter horizontal radial beam tube. The beam is defined by a boral (B_4C) lined stainless steel collimator followed by a floodable tube, a 200mm thick lead beam stop and finally a pneumatically operated shutter.

The neutrons emerge into a large lead cell of wall thickness 250mm which contains manipulating tongs and a lead glass viewing window. Vertical access for objects up to 260mm diameter and 1.8m length is provided together with rotation about the vertical access. The cell will support a 20 ton radioactive fuel handling flask. The pneumatic 20mm thick boral, lead and steel shutter is used with an automatic timer for repetitive short exposures. The film cassette and small non-active objects for examination are inserted from the side. The total number of exposures is approximately 20,000 per year.

Operating Parameters

Flux in graphite reflector		1×10^{13} $cm^{-2}S^{-1}$
Flux at object		$8 \times 10^{7} n^{2} cm^{-2} s^{-1}$
Cadmium ratio		100
Gamma ray content of beam		650rem h^{-1}
Beam size at object		170mm dia
L/D ratio		160
Exposure times:	Direct method. GD foil + single coated film	1 min.
	Transfer method. In foil + Industrex CX film	5 - 10 mins
Film development:	Kodak LX24B using standard times and temperature.	

The main industrial application is the neutron radiography on a production basis of gas turbine blades for aircraft engines. The blockages in the cooling channels are detected using the well established Gd doping technique and direct imaging by Gd foil and film in contact.

The nuclear work undertaken includes dimensional checks on irradiation rigs used in the Harwell reactors, and neutron radiography of fuel elements. The indium foil image transfer technique is used for radioactive samples and Gd foil and film for non-active objects.

The Cold Neutron Radiography Facility (6H)

Neutrons from the 150mm diameter in pile end of the reactor beam tube pass through a series of 100mm diameter x 75mm long filters set into the stainless steel boral lined collimator. This filter assembly consists of three bismuth single crystals to remove gamma rays and four sintered beryllium blocks to remove thermal and fast neutrons. The filters are mounted in an evacuated copper jacket and cooled to liquid nitrogen temperature to give a five fold increase in transmission of cold neutrons.

The neutron beam on leaving the reactor shield is then collimated further by a 90mm diameter hole set in a rotatable 300mm thick beam switch. The beam then continues through external concrete radiation shielding and enters a 200mm diameter evacuated beam tube which links the radiation shielding to the first radiography station just inside the reactor building wall. At this point the constraints on the size of object to be examined are: neutron beam centre line to floor 1.25m, height floor to ceiling 4m, length in direction of netron beam 2m and width perpendicular to beam 4m. The beam is allowed to continue through the wall of the reactor building along a helium filled flight tube to a second radiography station, "the blockhouse", situated 25m from the reactor face. The dimensions of the blockhouse which limits the size of objects are: neutron beam centre line to floor 680mm, height floor to ceiling 1.6m, length in direction of neutron beam 1.7m and width perpendicular to beam 3.4m.

Due to the filters the beam is virtually gamma ray and fast neutron free and so staff are able to manipulate objects, film cassettes and neutron video equipment without elaborate shielding requirements.

Operating Parameters

Flux at reactor end of beam tube 1×10^{14} thermal $ncm^{-2}s^{-1}$

	Reactor Wall Position	Blockhouse Position
Cold neutron flux	$7 \times 10^{6} ncm^{-2}s^{-1}$	$3 \times 10^{5} ncm^{-2}s^{-1}$
Cadmium ratio	> 1000	> 1000
Gamma ray content	$1.5 remh^{-1}$	$60 mremh^{-1}$
Beam size	200mm dia	300mm dia
L/D ratio	100	300

Exposure times:-		
Gd foil + single coated film	3 - 10 min	-
Gd oxysulphide screen + double coated film	15s - 2 min	1 - 5 min

Film Development:-

Kodak LX24B using standard times and temperatures

Video Camera:-

25mm S.I.T. camera with LiZnS (Ag) scintillator NE 426.

Applications

Real time studies using the neutron video camera includes the observation and measurement of two phase flow of coolant in the reflood of P.W.R. tubes and lubricant flows in automobile, aircraft and motor cycle engines.

The static work using conventional Gd foil and film techniques has included measurements of packing densities of catalysts in tubes, verification of 'O' ring seals in vacuum cases and the effectiveness of the dissolving out of wax core material in ion beam accelerator grids.

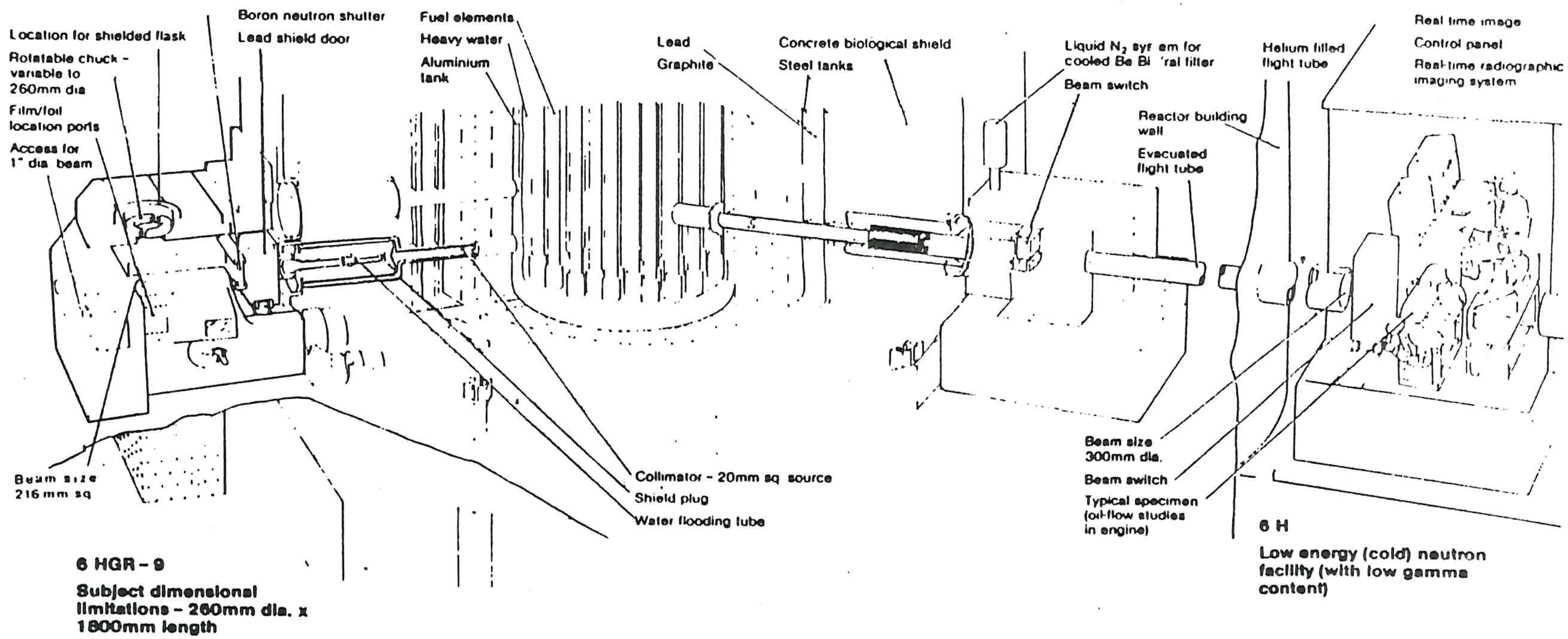


FIG 37. LAYOUT OF THE TWO NEUTRON RADIOGRAPHY FACILITIES ON THE DIDO REACTOR

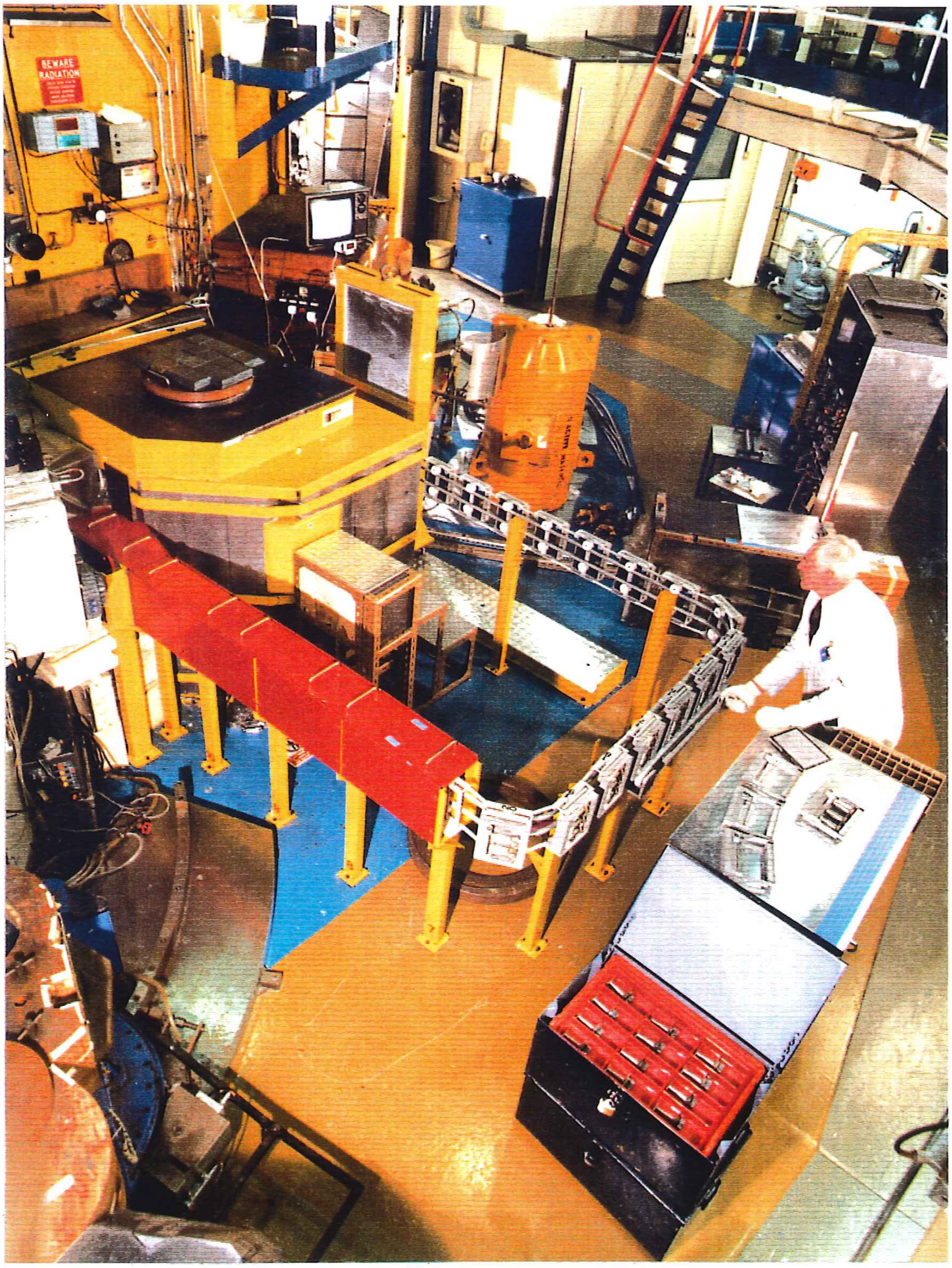


Figure 38.

The Thermal Neutron radiography facility showing film cassettes and turbine blades mounted on the "railway"

Figure 39.

'Real time' image of a coleus plant using cold neutrons (in a 30cm dia. beam position) and NE 426 screen (25 × 25cms) viewed by SIT camera, photographed direct from the TV monitor with 1/8 sec. exposure

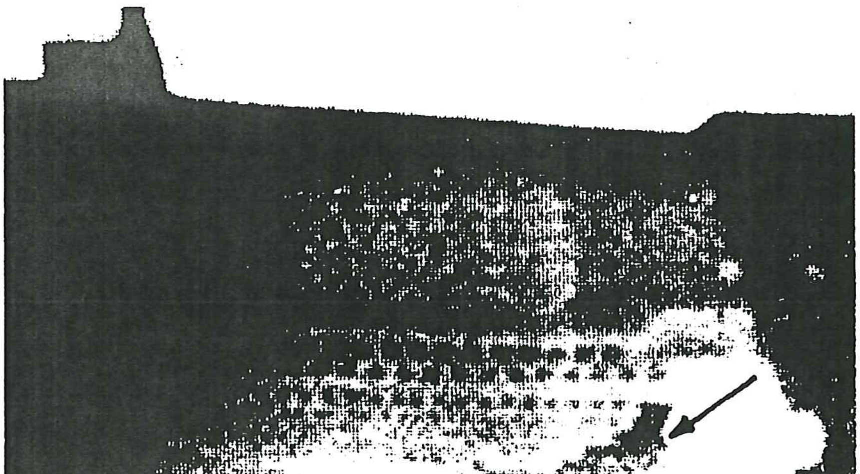


Figure 40.

Neutron fluorograph of aeroengine turbine blade showing some residual core material in an airway (arrowed). A frame store allowed exposure of 20 secs. to reduce mottle due to neutron statistics

ANCILLARY ITEMS FOR SALE

LOT NUMBER	ITEM	NUMBER OFF
1.	NEUTRON CAMERA ie Film holder with scintillator	4
2.	JACACADDY - Hydraulic lift platform	3
3.	COPPER MONOCHROMATOR on set of arcs	1
4.	ELECTRIC HOIST SWL 1 tonne	1
5.	BERYLLIUM FILTER ASSEMBLY	1
6.	QUARTZ BLOCKS for filter assembly	3
7.	FISSION CHAMBER	1
8.	SPECTROMETER BASE	1
9.	NEUTRON GUIDE - Copper	1
10.	TERMINAL Type EKB	1
11.	SET OF BRASS ARCS - Large	3
12.	SET OF ALUMINIUM ARCS - Large	2
13.	SET OF STEEL ARCS - Large	1
14.	SET OF BRASS ARCS - Medium	1
15.	BORAX & RESIN BLOCKS 12" square x 6" thick	120
16.	LEAD BLOCKS 2" thick	60
17.	MINILIFT Wire rope hoist SWL 10 cwt	1
18.	THOR CRYOGENICS Temperature controller model 3010	4
19.	OXFORD INSTRUMENTS Precision temperature controller	3
20.	OXFORD INSTRUMENTS Temperature controller type DTC2	3
21.	THOR CRYOGENICS Power Supply type 6010	1
22.	THOR CRYOGENICS Electronic programme model 2020	1
23.	OXFORD INSTRUMENTS Power Supply	1
24.	OXFORD INSTRUMENTS Sweep generator - electromechanical	1
25.	CRYOGENIC ASSOCIATES Temperature controller model 100A	1
26.	OXFORD INSTRUMENTS Gas & temperature controller for Cold Finger type CF100	1
27.	20TH CENTURY Mass Spectrometer leak detector	1
28.	AIR PRODUCTS DISPLEX unit with basic expander module type DE202	1
29.	FURNACE with TANTALUM Element	2
30.	THOR CRYOGENICS - 6 Tesla superconducting magnet	1
31.	BOC CRYOPRODUCTS - Liquid helium cryostat	3
32.	THOR CRYOGENICS - Small helium cryostat with wide neck	1

ANCILLARY ITEMS FOR SALE

LOT NUMBER	ITEM	NUMBER OFF
33.	OXFORD INSTRUMENTS - Large helium cryostat for Centre Stick	1
34.	A S SCIENTIFIC PRODUCTS - Large helium cryostat for Beryllium filter spectrometer, with insert for Ortho-Para hydrogen experiment	1
35.	CRYOGENIC ASSOCIATES - Variable temperature helium cryostat type CT14	2
36.	STATEBOURNE - Liquid helium storage dewar type HD30	2
37.	T B T Helium cryostat with Vanadium tails	1
38.	OXFORD INSTRUMENTS - Helium cryostat with variable temperature Centre Stick	1
39.	OXFORD INSTRUMENTS - Cold Finger type CF100	1
40.	STATEBOURNE - Mild Steel 160 litre liquid nitrogen storage dewars	6
41.	STATEBOURNE - Stainless Steel 160 litre liquid nitrogen storage dewars	1
42.	UNION CARBIDE - Mild Steel 160 litre liquid nitrogen storage dewars	4
43.	LIQUID HELIUM - Transfer syphons - miscellaneous	10
44.	VACUUM PUMP SETS - Various	3
45.	DETECTORS BF_3 - ceramic end window, 31cm active length x 5cm diameter x 70cm Hg pressure	15
46.	DETECTORS BF_3 - ceramic end window, 16cm active length x 5cm diameter x 70cm Hg pressure	4
47.	DETECTORS BF_3 - 25cm active length x 5cm diameter x 70cm Hg pressure	8
48.	DETECTORS BF_3 - 31cm active length x 2.5cm diameter x 140cm Hg pressure	14
49.	DETECTORS ^3He - miscellaneous	10
50.	FISSION CHAMBERS - ^{235}U - various diameters	10