3.10 USE AND CONSTRUCTION OF NEW FACILITIES, K. Anttila (The State Institute for Technical Research, Helsinki, Finland)

I Vertical Beam Tube

Construction

In 1971 a vertical beam tube was constructed to increase possibilities in using the FiR 1 reactor, especially in taking neutron radiographs.

The most suitable location for the beam tube was determined by using gold foil activation. It was found on top of the radial graphite reflector near the end of the thermal column. The constructional details of the vertical beam tube are shown in the picture.

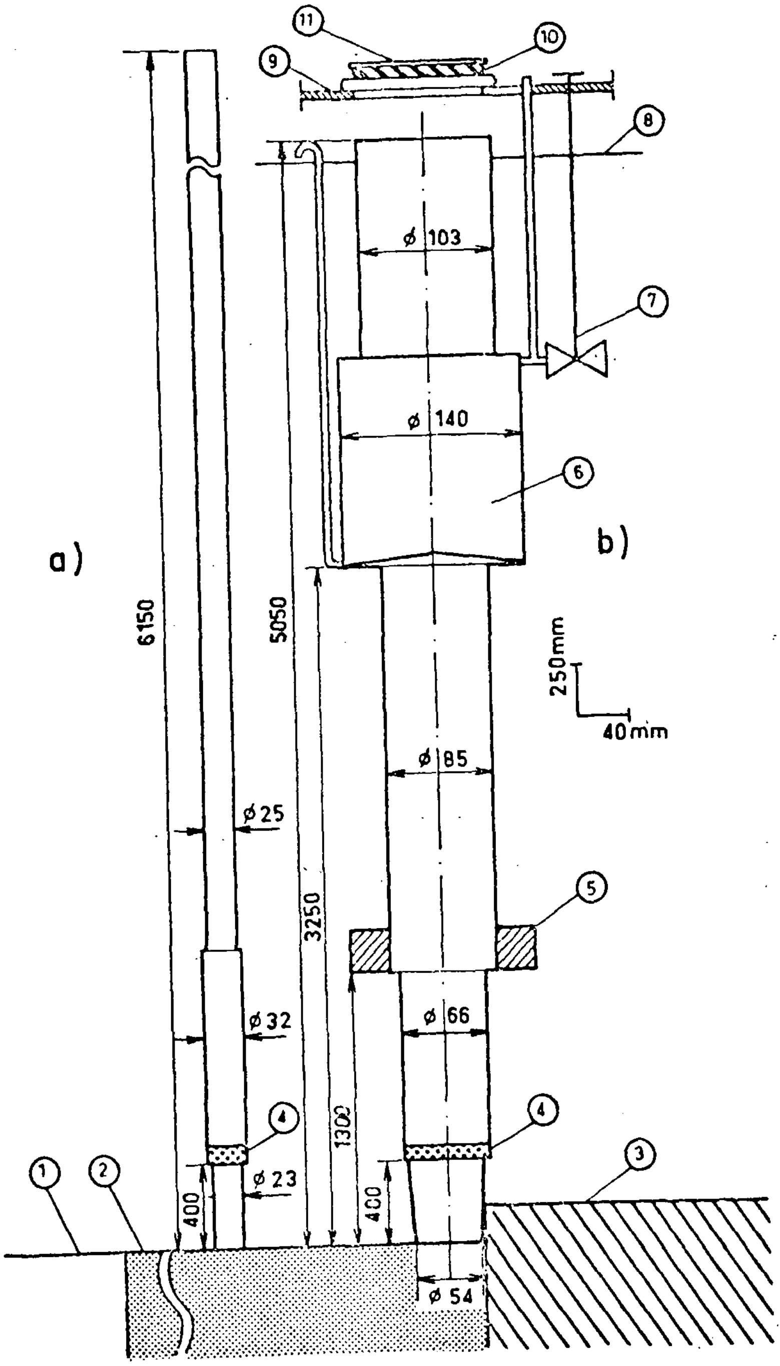
The vertical beam tube has a water shutter using reactor tank water for fast neutron and gamma shielding when the beam is not in use. When the shutter is open, shielding against fast neutron scattering from the object is obtained by using a 10 cm thick cylindrical aluminum cover containing boric acid.

Characteristics

The following results of measurements characterize the new vertical beam tube:

- Thermal neutron intensity $1.2 \cdot 10^6$ n/cm^2s
- Cadmium ratio in the beam $R_{Cd} = 9.1$
- Gamma intensity 2.4 R/h
- The useful beam diameter 10 cm
- Typical exposure time 4.4 min with crystallex film and .025 mm Gd - foil

About one half of the thermal neutrons observed at the top of the vertical beam tube have scattered or leaked to the beam from the wall or surrounding water. The results above were obtained with a 60 mm Bi - single chrystal filter near the bottom of the beam tube in order to stop fast neutrons and



a) Aluminum tube used in designing the vertical beam tube

b) Vertical beam tube

1	reactor core
2	radial graphite reflector
3	thermal column
4	Bi - filter
5	Pb - weight
6	water shutter
7	shutter valve
8	water level in the reactor tank
9	reactor tank cover
10	object
11	film cassette

(picture from the licentiate thesis of H. Reijonen) gamma rays. The low gamma intensity and even neutron intensity distribution allow also quantitative measurements from radiography pictures.

Applications of Neutron Radiography

Neutron radiography pictures has been taken at the FiR 1 reactor using neutron beams from the thermal column, radial beam tube and from the vertical beam tube. In order to reveal dynamic phenomena inside various objects a neutron-TV - system was built. This system consists of a scintillator plate, photomultiplier with a gain of 10^6, television camera, monitor and a video tape recorder.

The most important areas of using neutron radiography have until now been the inspection of some special industrial devices and the radiography of radioactive fuel elements. In Finland pictures were taken from Triga-elements, both from radioactive elements and new ones, in order to test the method.

Several other and perhaps new applications for this kind of research were also found , e.g. the research of

- solidification of metal alloys
- diffusion of moisture in concrete
- icing of an automobile carburetor, paths of liquid gasoline and the effect of various additives in gasoline preventing icing, and
- brazed joints between metals

The neutron radiography of thick metal walls, e.g. 2 - 8 cm steel, gives better resolution than gamma radiography.
In addition the use of reactor beam tubes in neutron radiography leads to better quality and economy than the use of portable neutron sources, at least until the production of Cf^{252}-sources will lower the costs of intense neutron sources, perhaps not until after the year of 1980.

II Cold neutron source

Theory

The general idea of the new cold neutron source, which is now under construction at the FiR 1, is based on results of Monte Carlo calculations performed by Mr. H. Kalli (1). Probably the only other attempt to use Monte Carlo method in cold neutron source optimization is the work done by Carter and Holbrough (2) .

In the calculations performed at Otaniemi the shape of the cold neutron source was cylindrical with half-spherical ends and its diameter fixed while its length was optimized in various conditions.

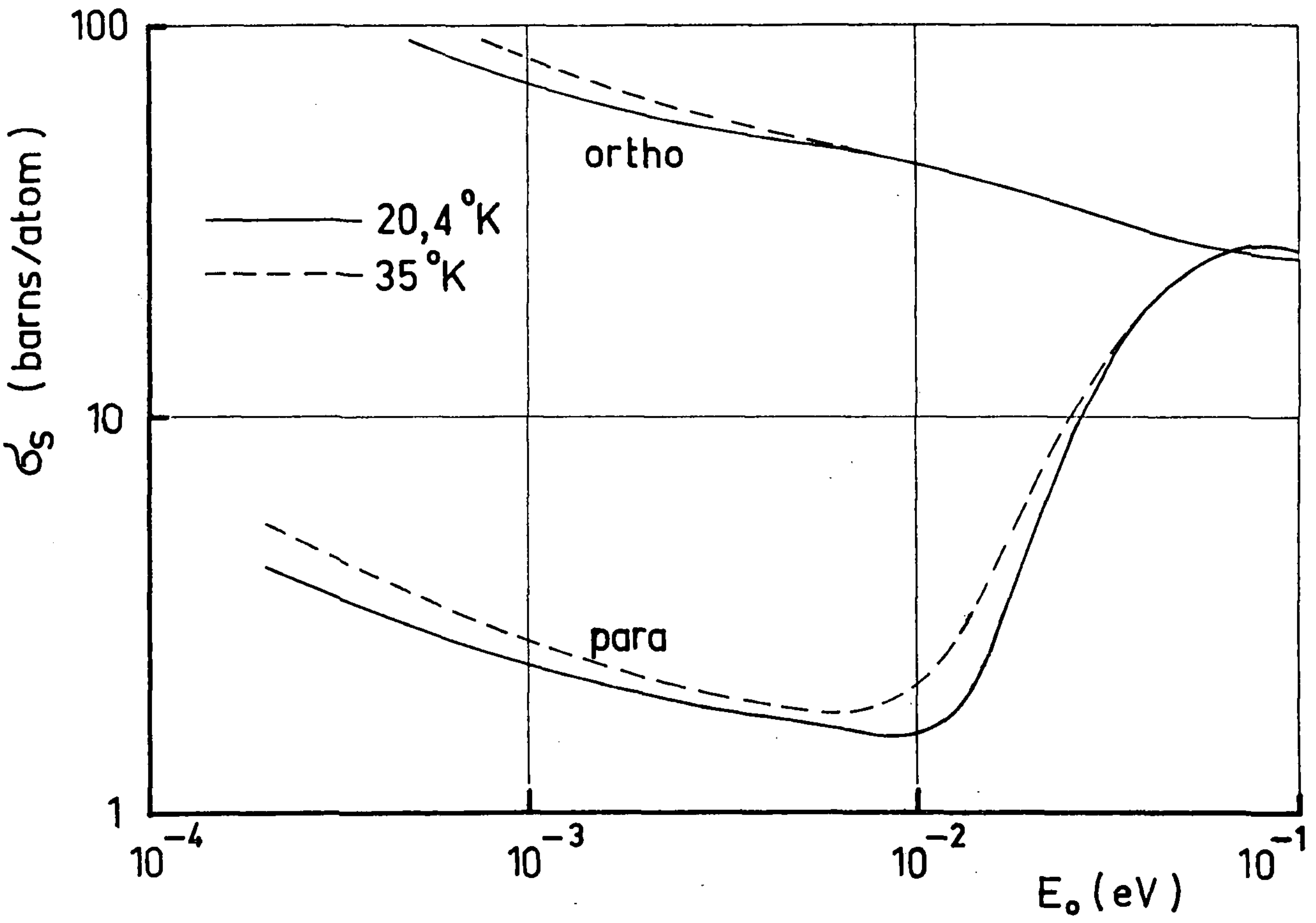
In these calculations two different temperatures were used for hydrogen:

1) 35 °K with different pressure values and

2) 20.4 °K (boiling point) with liquid hydrogen density.

In both cases the optimal length was about 40 cm, i.e. the source should be relatively long because the diameter was 11 cm, and hence the optimal cold neutron source differed radically from the previous cold neutron sources.

The behaviour of molecular hydrogen in slowing down neutrons at low temperatures depends very much on the spin correlations in the hydrogen molecule which split hydrogen into two components: para- and orthohydrogen. The difference between these can be seen most clearly in the peculiar energy dependence of the scattering cross sections of the components.



Scattering cross section for para- and orthohydrogen
at 20.4 and 35 °K
(obtained by using the scattering model of Koppel&Young (3))

In the Monte Carlo calculations this behaviour was included in the UNIVAC 1108 computer runs by varying the relative para/orthohydrogen abundance and using the Koppel&Young scattering model.

The result was that parahydrogen seems to be a better cold neutron source material in the Triga beam tube geometry. This result is in contradiction with some esrlier results which underlines the fact that actual geometrical configuration must be taken into account. In our laboratory the shortest and most popular explanation is, that in parahydrogen neutrons become cold in the usual way and then they easily leak out of the source because parahydrogen is relatively transparent for cold neutrons.

It is still fortunate that hydrogen, which is rich in parahydrogen, is in thermodynamical equilibrium at low temperatures and thus causes no technical problems.

References:

1. H. Kalli: Monte Carlo calculations of a hydrogen
   cold neutron source

   Report TKK-F-A167 (1971)
   (intended for publication in Acta Polytechnica Scandinavica)

2. P. Carter and D. Holbrough: "COSMIC", a Monte Carlo program for thermal neutron re-thermalization studies AERE-R 6658 (1971)

3. J.U.Koppel, J.A.Young: Nukleonik, Band 8, Heft 1, 40-45 (1966)

Although the best gaseous hydrogen moderator in equilibrium at 35 °K is about 20 % worse than the best hydrogen moderator at 20.4 °K with liquid density, the inter-molecular forces in liquid hydrogen may change the calculated results. There are also reasons suggesting advantages in using gaseous hydrogen.

The maximum cold neutron intensity from gaseous moderator does not increase any more if the pressure is increased above 13 - 15 atm. Pressures as low as this do not prevent using a gaseous moderator and, in addition, one parameter would be gained for experimental optimization. The pressure values obtained agree with the values given for the DR 3 facility in Risö, Denmark. However, the Risö source, which also is under construction at present, will be much shorter, perhaps because of cooling problems.

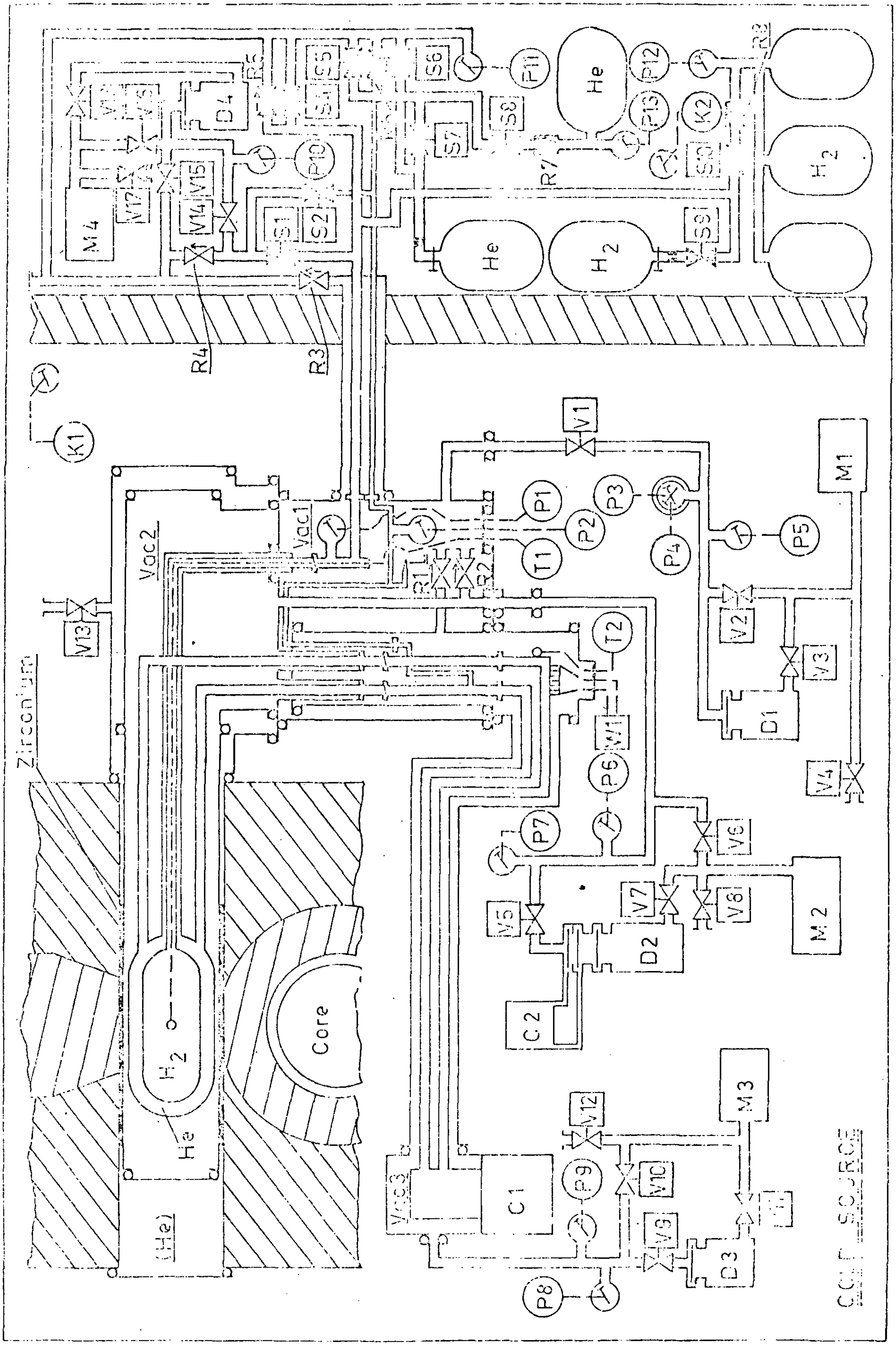
General description

The new cold neutron source at FiR 1 will be a gaseous hydrogen moderator cooled by a stream of cold helium gas from a cryogenerator.

Calculations and tests showed that the operating pressures can be contained in cylinders with spherical ends using moderate wall thicknesses of some suitable aluminum alloys. A wall thickness of 5 mm has been found to be sufficient.

The schematic picture shows the main features of the planned cold neutron source. The H_2 container including the filling line will be completely surrounded by the helium coolant for safety reasons. The pressures of the moderator and coolant will also be about the same.

Three separate vacuum systems provide the necessary thermal insulation. All components for handling the H_2 and helium gases are situated in a special shelter outside the reactor building. Buffer spaces for reducing the pressure rises during the warm - up of the cold neutron source are also situated in this shelter.


COLD SOURCE
Zirconium
(He)
He
H2
Core
Vac1
Vac2
Vac3
C1
C2
K1
K2
R1
R2
R3
R4
R7
R8
T1
T2
W1
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
P12
P13
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
V12
V13
V14
V15
V17
M1
M2
M3
M4
D1
D2
D3
D4
S1
S2
S4
S5
S6
S7
S8
S9
S10
He
H2
He
H2
H2

Cold Neutron Source

1. H_2 System:	P 1	H_2 pressure
	S 1	Evacuating valve
	R 5	Safety valve
	S 4	Dumping valve
	S 9	Filling valve
	S 10	Buffer space valve
	R 8	Check valve
	P 12	Buffer pressure
	T 1	Moderator temperature
2. He System:	T 2	Coolant return temperature
	W 1	Heater
	L	Defined H_2 -monitor leak
	P 2	He pressure
	S 2	Evacuating valve
	R 6	Safety valve
	S 5	Dumping valve
	S 7	Filling valve
	S 8	Buffer space valve
	R 7	Check valve
	P 13	Buffer pressure
3. Cooling System:	C 1	Philips cryogenerator
	M 3	Mechanical vacuum pump
	D 3	Diffusion pump
	P 8	Thermotron
	P 9	Ionization gauge
	V 9	Main valve
	V 10	Bypass valve
	V 11	Prevacuum valve
	V 12	Pressurizing valve
	R 1	Safety valve

4. Main vacuum:	M 2	Mechanical pump
	D 2	Diffusion pump
	C 2	Baffle cooling machine
	P 6	Thermotron
	P 7	Ionization gauge
	V 5	Main valve
	V 6	Bypass valve
	V 7	Prevacuum valve
	V 8	Pressurizing valve
	R 2	Safety valve
5. Sniffing and protection vacuum:	M 1	Mechanical pump
	D 1	Diffusion pump
	P 5	Thermotron
	P 3	Ionization gauge
	P 4	H_2 partial pressure
	V 1	Main valve
	V 2	Bypass valve
	V 3	Prevacuum valve
	V 4	Pressurizing valve
	R 3	Safety valve
6. Auxiliary pump:	M 4	Mechanical pump
	D 4	Diffusion pump
	P 10	Thermotron
	V 14 V 15	Main valves
	V 16	Bypass valve
	V 18	Prevacuum valve
	V 17	Pressurizing valve
	R 4	Safety valve
7. Exhaust line:	S 6	Filling valve
	P 11	Exhaust line pressure
8. Hydrogen monitor:	K 1	Reactor hall monitor
	K 2	Shelter monitor
9. Protection belt:	V 13	Filling valve

III Neutron diffractometer

The small neutron diffractometer at the FiR 1 will be completely re-designed to achieve better radiation shielding, accuracy, efficiency and automation degree.

Inside the beam tube for thermal neutrons there will be collimators of boric acid and lead, a one degree Soller collimator, a collimator of boron carbide which can be filled with water and a 25 cm long monochromator made of four pyrolythic graphite single chrystals. The wave length of neutrons will be adjustable from 1.0 to 1.4 Å.

Two stepping motors will turn two rotating tables placed on top of each other and the accuracy of angle of these tables is 1/100 degrees. The outer end of the beam tube will be shielded and the neutron shield of a He^3 neutron detector has been made of polythene, boron carbide and boric acid.

To obtain automatic programmable measurement Reactor Laboratory has bought a Supernova minicomputer which has 8000 memory locations at present to control the diffractometer operation and other facilities too .