MHD – technologies in spallation target related investigations

IWSMT - 10

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INTRODUCTION

The Institute of Physics of the University of Latvia is one of the research center **in the field of MHD technology** which has been involved in both **theoretical** and applied studies and **experimental** works

The research activities of the Institute are connecteded with:

• **the investigation of MHD phenomena** in incompressible conducting media: channel flows, jet and drop flows, flows around bodies, MHD turbulence, flows caused by the interaction of the current present in the liquid medium with its own magnetic field;

• **the developing new types of MHD-machines**, which could be used for pumping liquid metal heat carrier in the primary radioactive loop of nuclear reactor, spallation neutron sources etc.

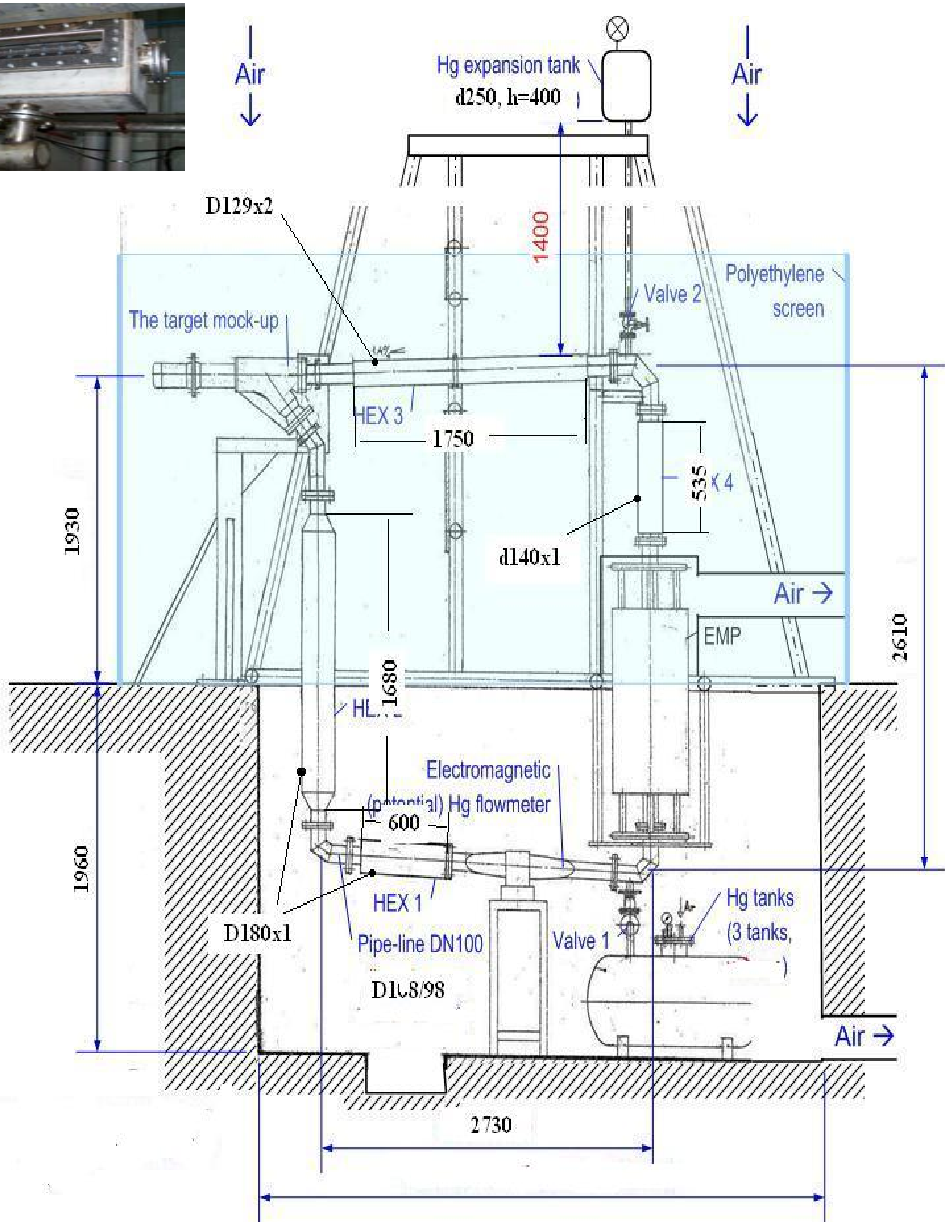
• **the study of effects relevant** to. magnetization of liquid systems as well with heat mass transfer process in paramagnetic solutions, electrolytes, magnetic colloids and biological systems;

• **the activity in the field** of designing, manufacturing, and implementing into various industries the main types of MHD devices; EMPs, flowmeters, throttles, devices for aluminum and its alloys.

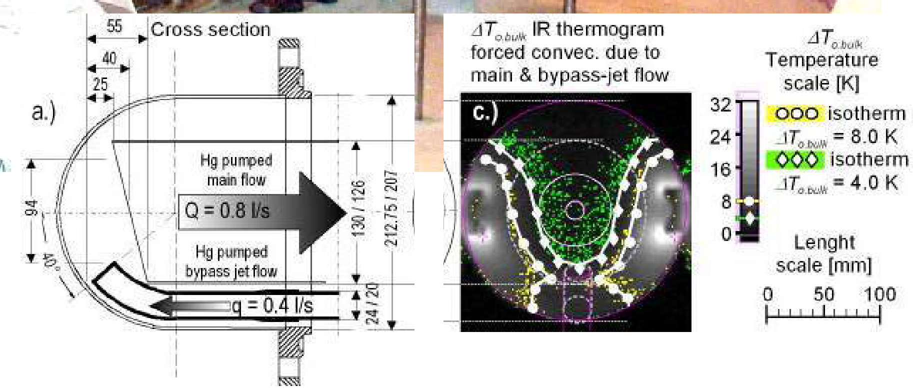
Some examples of Institute activities during the last years related to LM and MHD technology **are presented in this Report**.

The Institute of Physics possesses a special Mercury laboratory complex including a 350m2 experimental hall. The amount of Hg in use reaches 13.10 e3 kg, almost 1m3 mercury. The same can be said about new technologies for Hg chemical treatment /purification/ Mercury is used as an effective modeling material for investigation of a great number metallurgical processes, as well as for thermo hydraulic testing of systems, proposed for other / more aggressive or high temperature/ heavy liquid metals.

Mercury loop DN-100

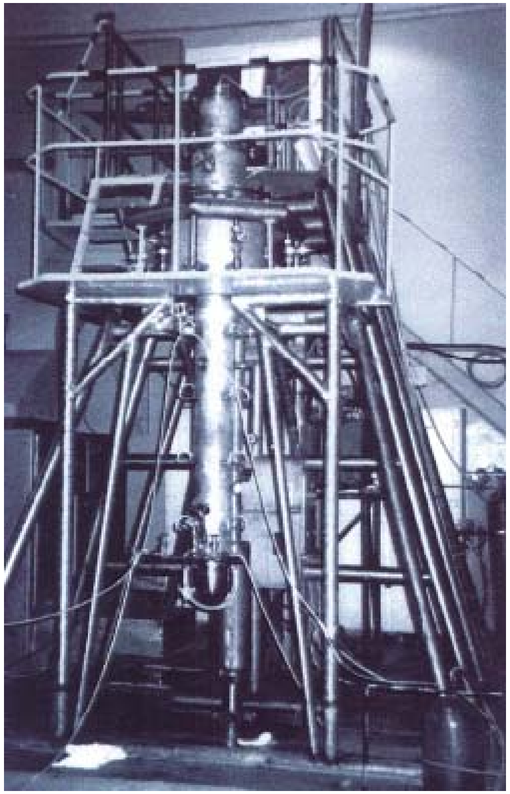


MERCURY LOOP DN 100

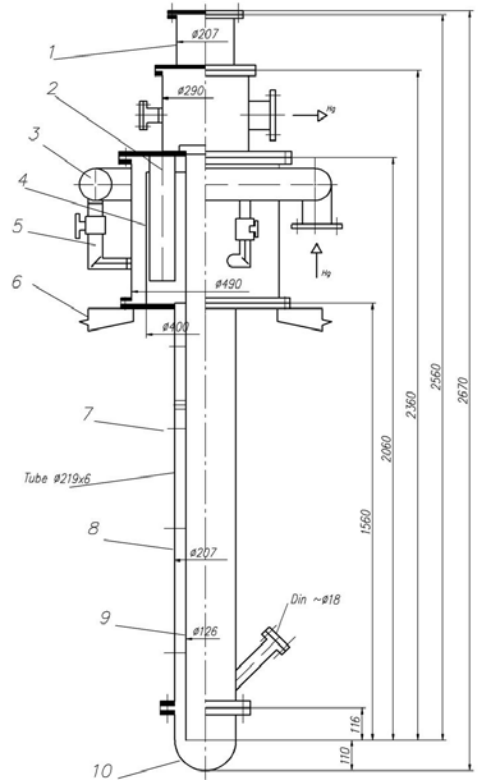


Experimental hall , m²	**-**	**350**
Mass of mercury , tons	**-**	**14**
Hg-loops	**-**	**3**

Tests of the mock-up of MEGAPIE target (in scale 1:1)



a

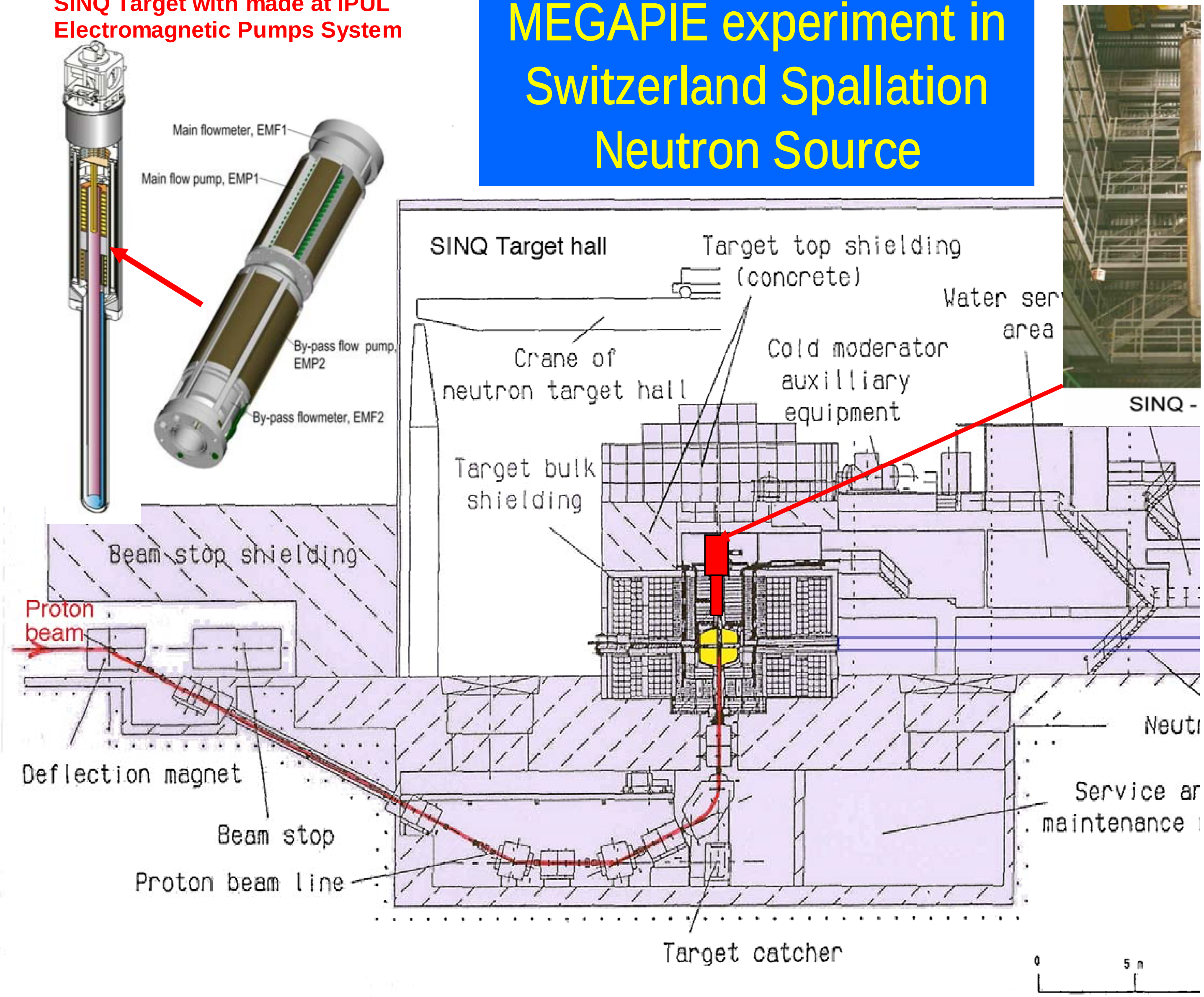


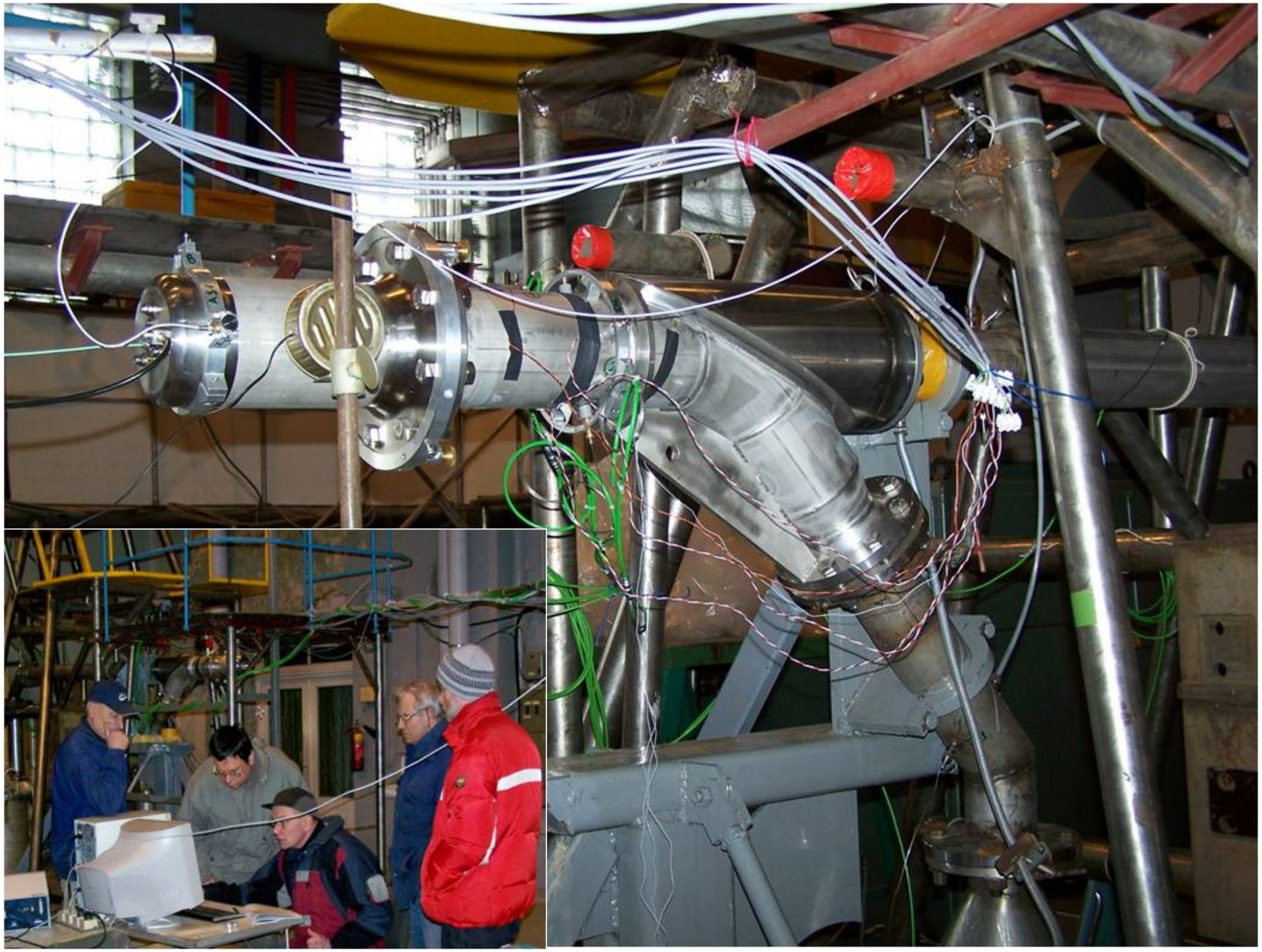
b

View of the Mercury stand (a)and Layout of the SINQ – target mock-up (b)

MEGAPIE experiment in Switzerland Spallation Neutron Source

SINQ Target with made at IPUL Electromagnetic Pumps System





180° return flow Target

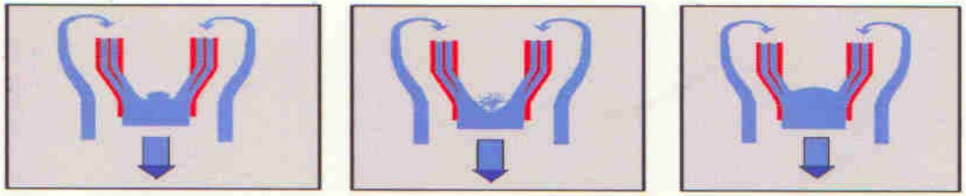
Eurisol project (PSI version)

Hg Modeling of MYRRHA at IPUL

The work has been conducted in Riga to demonstrate the feasibility of the windowless target designed by the MYRRHA team.

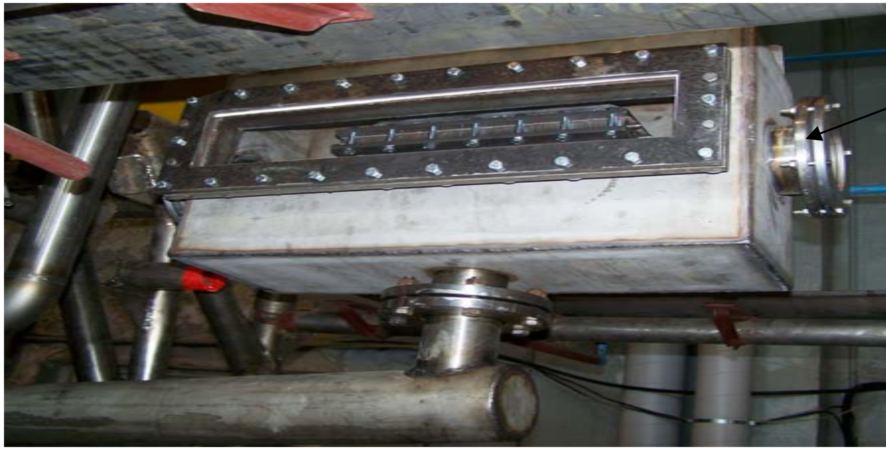
Vertical mercury loop
Volume 100 L; Q - 11 L/s

Full scale model
of windowless target



Free surface structures at different filling levels

Windowless Target
(Eurisol project)

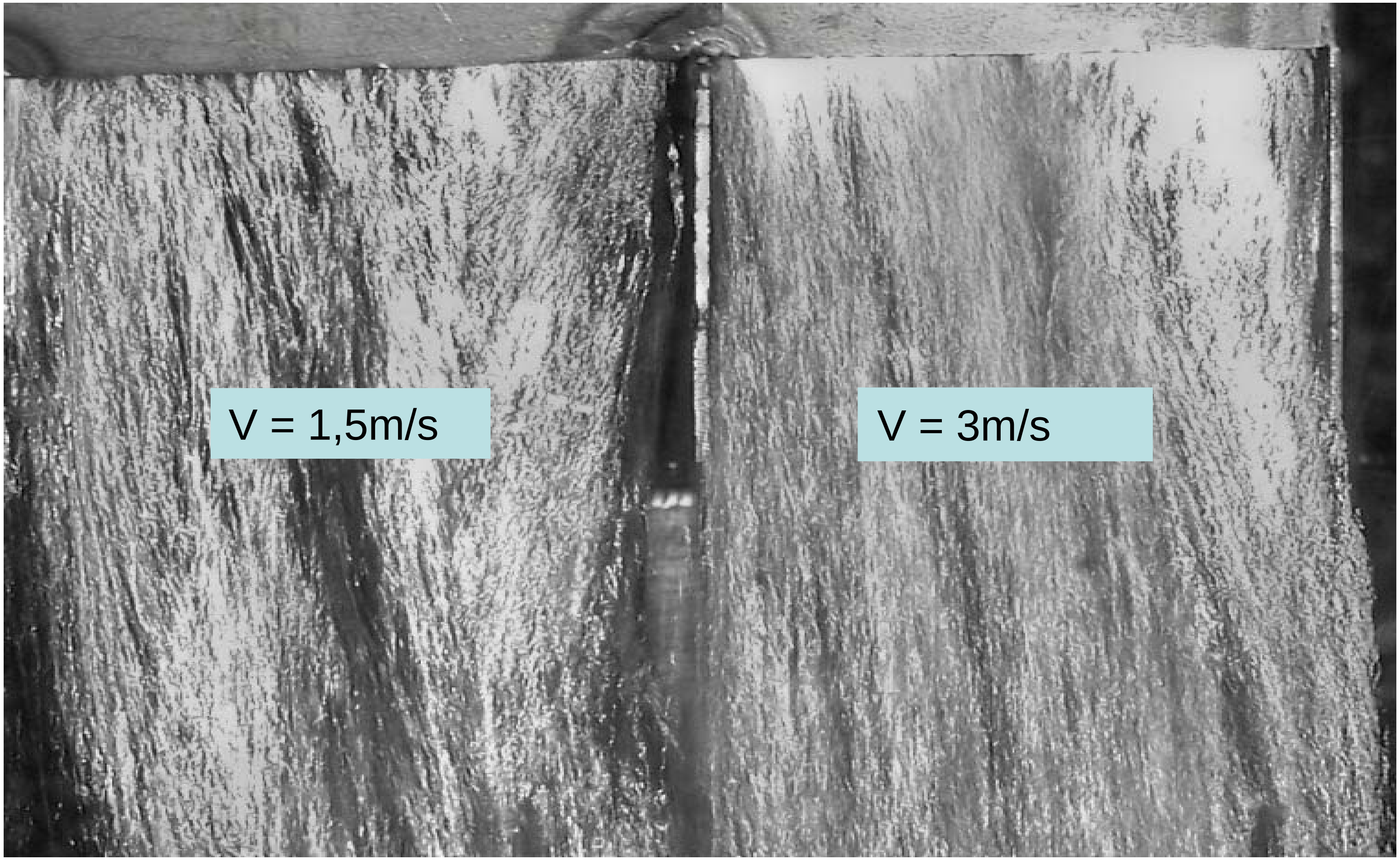


Body of the Target

Film of the Mercury
(600 x 18 mm)

(Velocity of Mercury in the film - up to 2m/s, flow rate – 11L/s)

Distribution of the Hg velocity in the film depend on hydraulic resistances in the inlet of the Target body



Universal Electromagnetic Mercury Cleaning Plants

Description

The universal industrial plant is a set of technological MHD units for mercury purification. It was created as a result of application of the electromagnetic contactless method of mixing a mercury droplet flow with reagents in MHD equipment.

The plant has the following advantages:

— high productivity and metal purification efficiency;

— simple design (no moving parts and sealings);

— reliable and easy to use;

— sealed and ecologically clean.

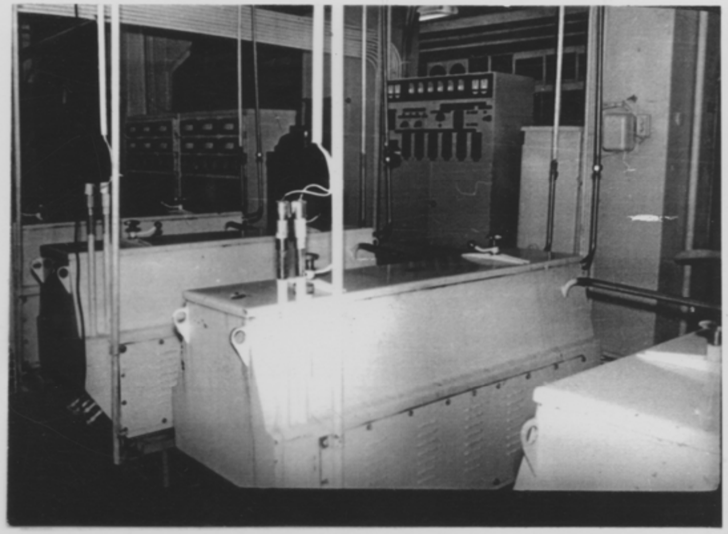
The sets of the unit is successfully used in industrial plants in Russia and abroad.

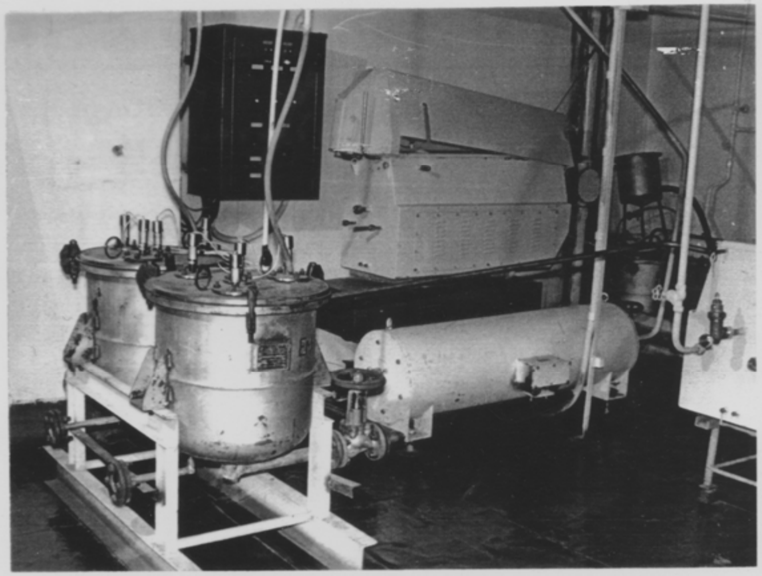
Main Technical Characteristics

— mercury purity, % – 99.9995
— productivity, t/h – 0.1–0.5
— consumed power, kW – 15.

Areas of Application

The equipment can be used at mercury producing or processing factories as well as in laboratories.





Purification of the mercury


Contr. Room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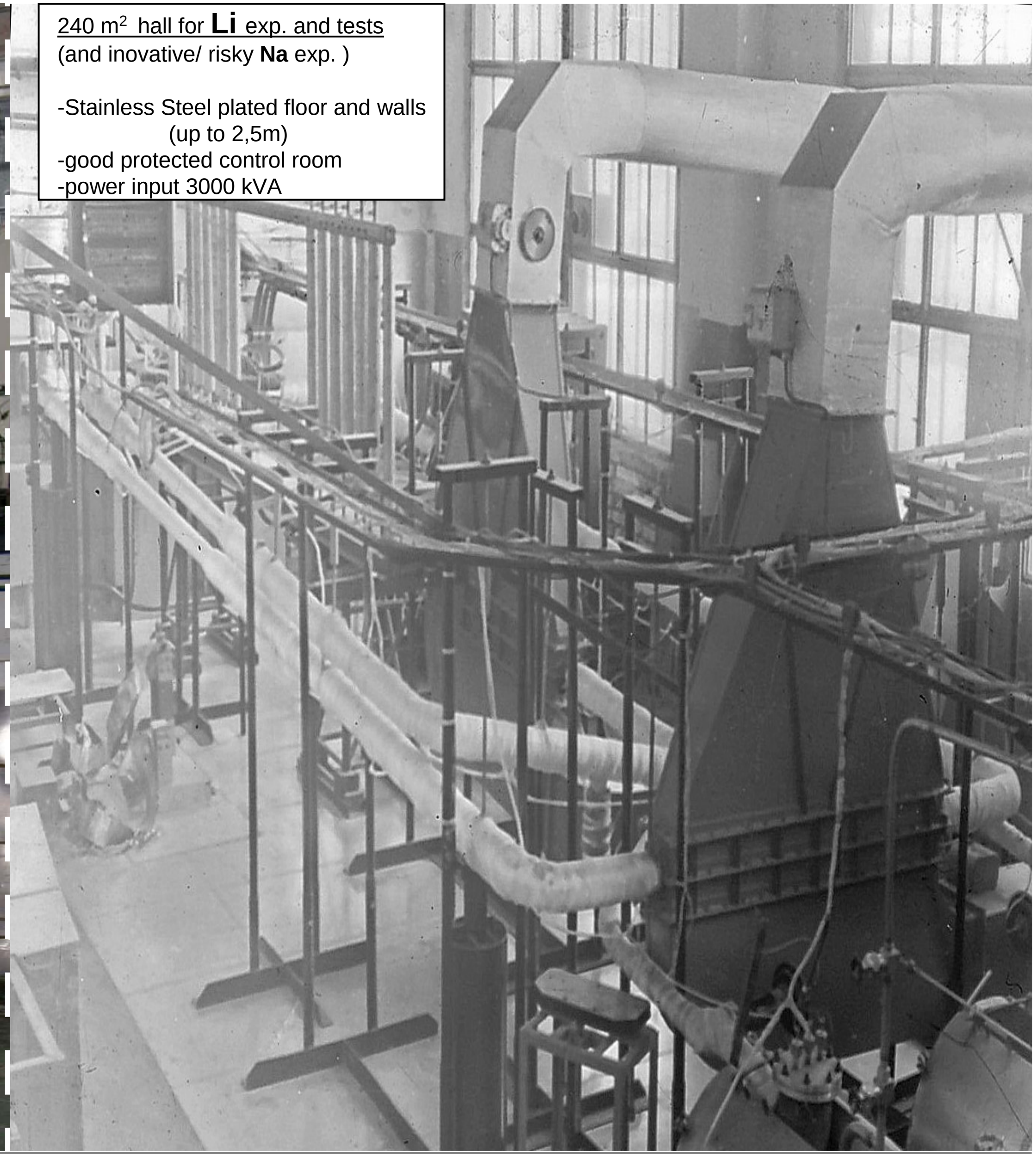
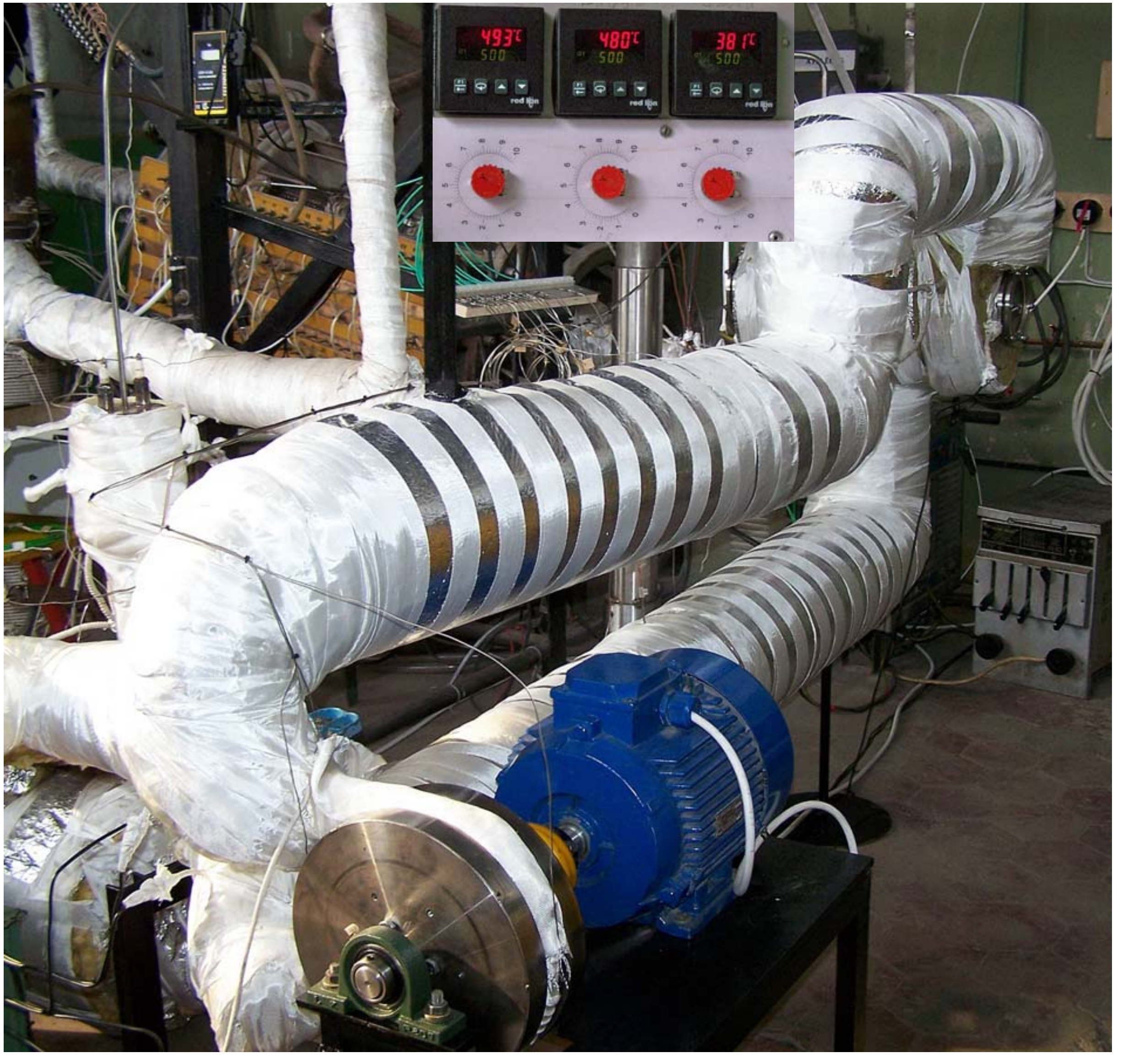
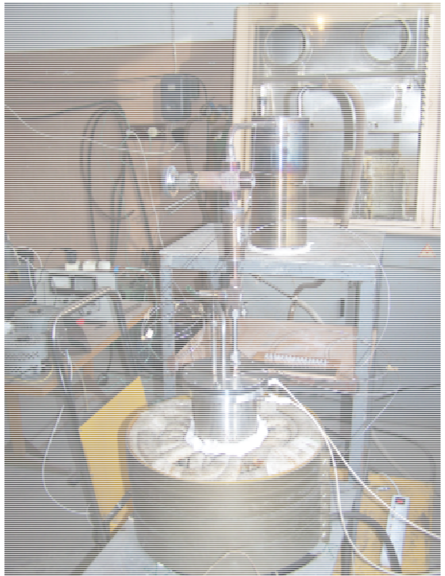
SS
SS

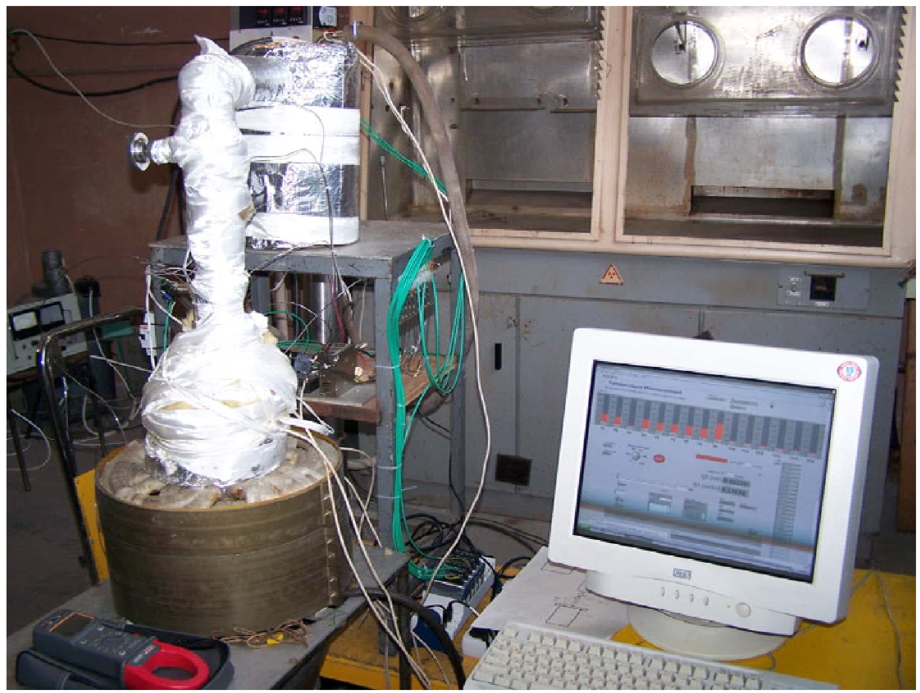

240 m^2 hall for **Li** exp. and tests
(and inovative/ risky **Na** exp.)
-Stainless Steel plated floor and walls
(up to 2,5m)
-good protected control room
-power input 3000 kVA



PbBi loop for investigation prototype of 100kW Target body

EURISOL project (CERN), max. Temperature - 600°

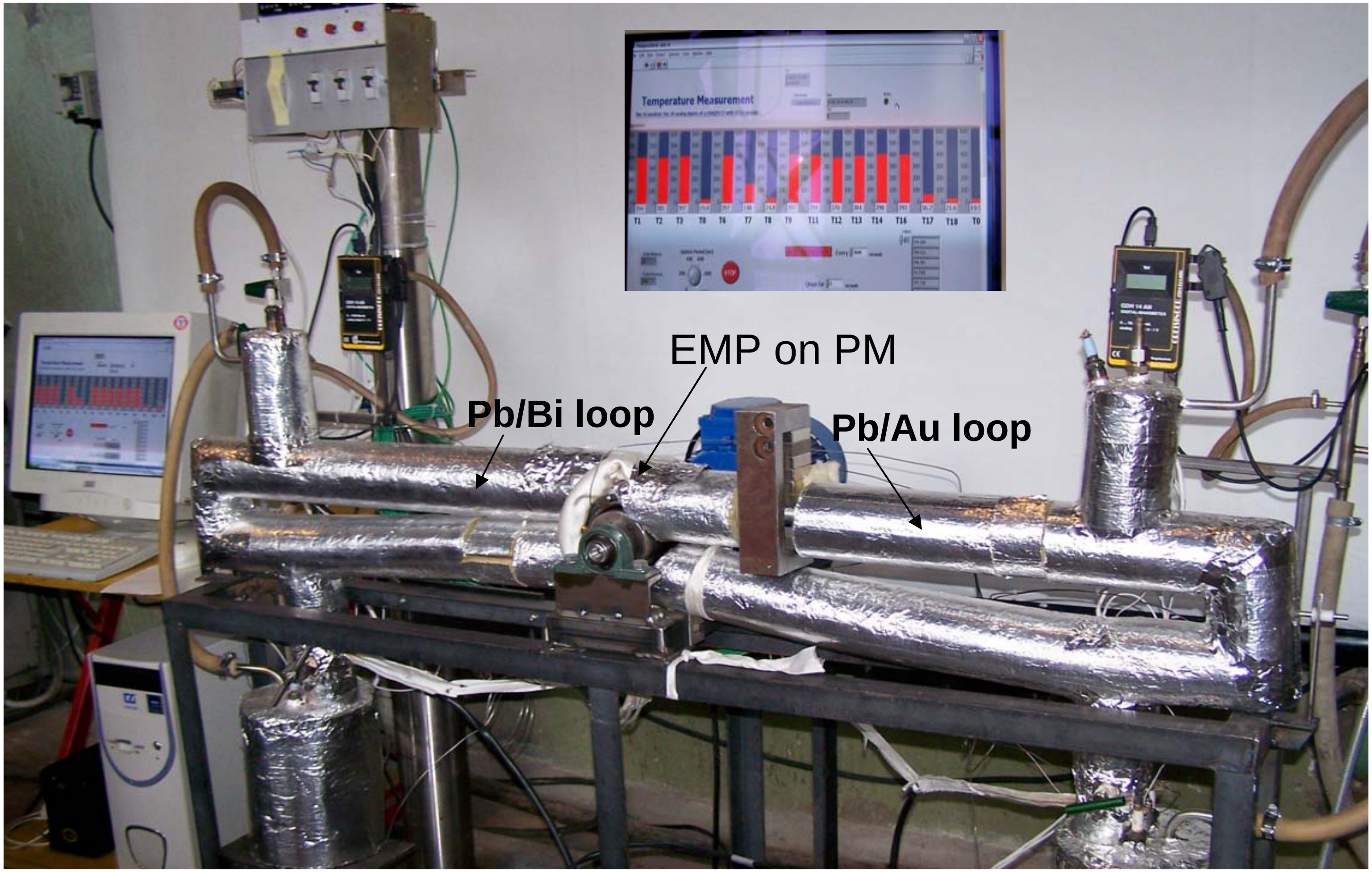




Production of the PbAu alloy

Misins move.mov

PbAu ingots



Twin PbAu – PbBi loop

(velocity of LMs – up to 1m/s; operating temperature - 450°C; 400°C and 350°C)

ANALYSIS OF THE STRONG MAGNETIC FIELD INFLUENCE ON THE CORROSSION OF EUROFER STEEL IN Pb17Li MELT FLOWS

Three sessions are lead each at 550 ^{0}C, during 2 000 h, at flow velocity 2,5-5.0 cm /s, B=1.7T. (EURATOM Projects)

Two sessions are lead each at 515 ^{0}C (One during 1500 h, second -3000 h, B=1.8 T). (ERAF project)

80 samples have been tested and analyzed

Macrostructure of non- washed samples without magnetic field (a) and with magnetic field (b)

a) On the surface of sample without magnetic field are seen corrosion products, traces, layers.

b) The surface has a wavy macrostructure (On the surface are clearly visible strips), that testifies to development of the local corrosion processes.

Liquid metal Pb-17Li loop
T = 550^{0}C

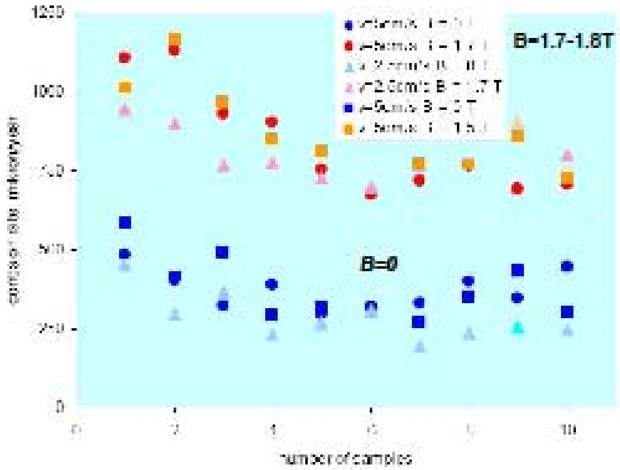
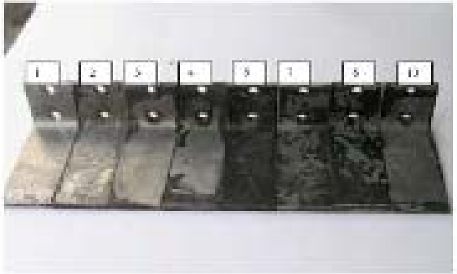
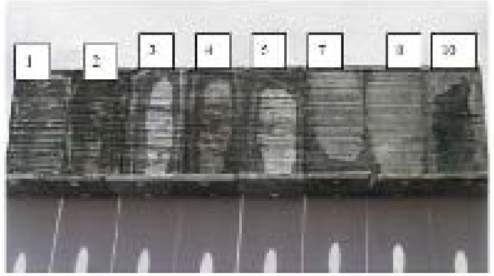


Fig. 6. Comparison of corrosion rate of EUROFER samples in magnetic field and without magnetic field.



EUROFER steel samples located in zone out of magnetic field (B = 0)



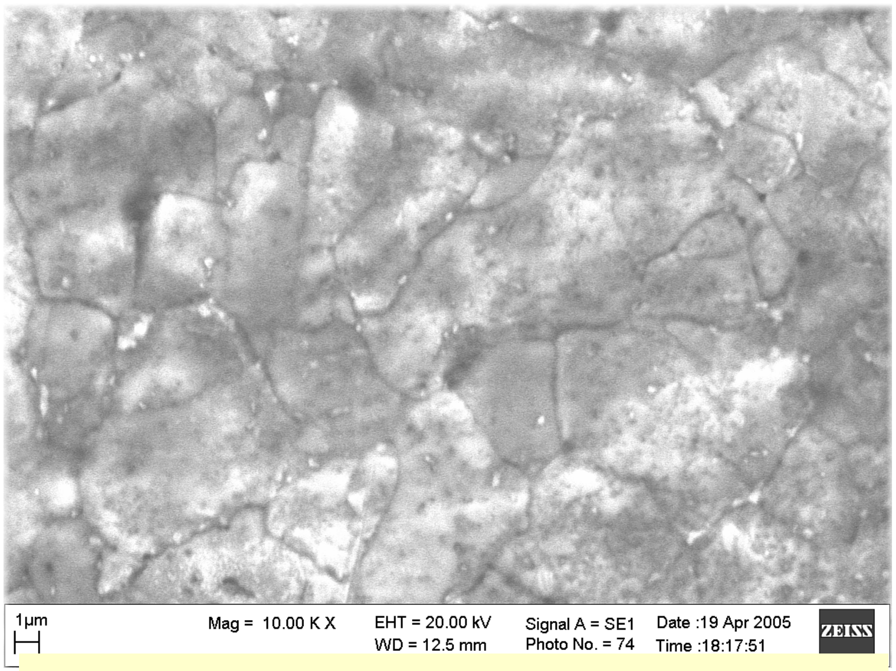
EUROFER steel samples located in zone with magnetic field (B = 1.7 Tesla)

University of Latvia
Institute of Physics

Macrostructure of unwashed samples with magnetic field B=1.7T(a) and without magnetic field , B=0T (b).

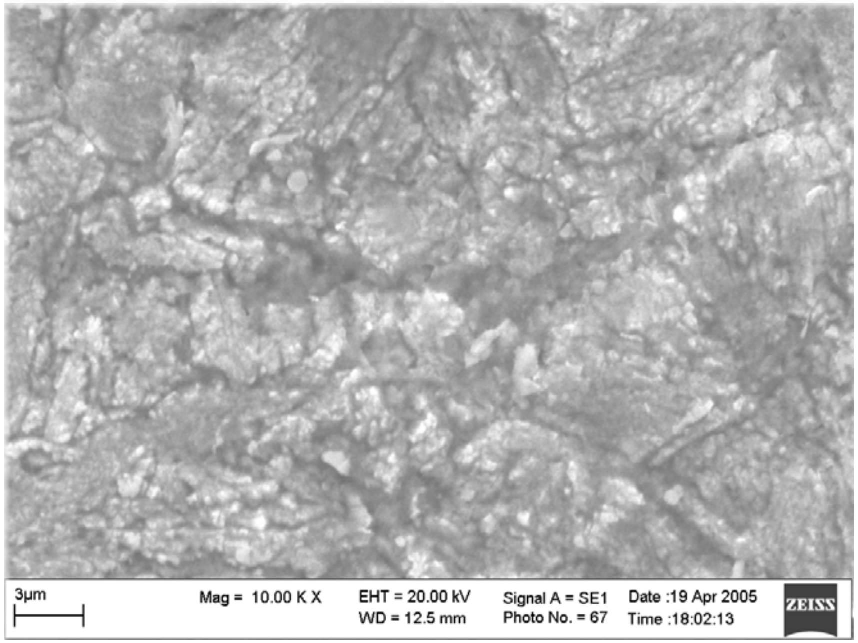
Structure of steel surface (sample Nr1) after contact with PbLi alloy without magnetic field (a) and with magnetic field (b), SEM, x10 000

a)

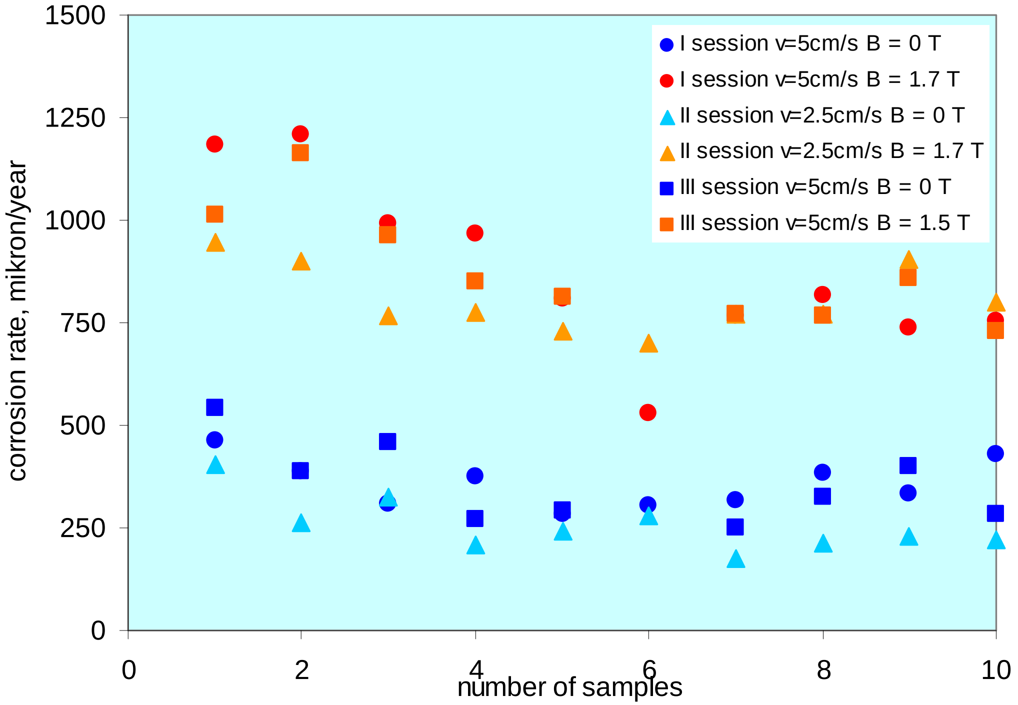


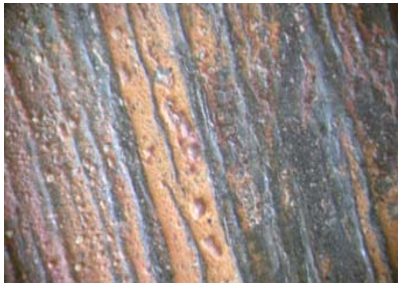
a). Grain boundaries are seen very good, but interaction with grain boundaries did not result in increase of width and depth of boundaries. It does not lead to more intensification of intergranular attack.

b)



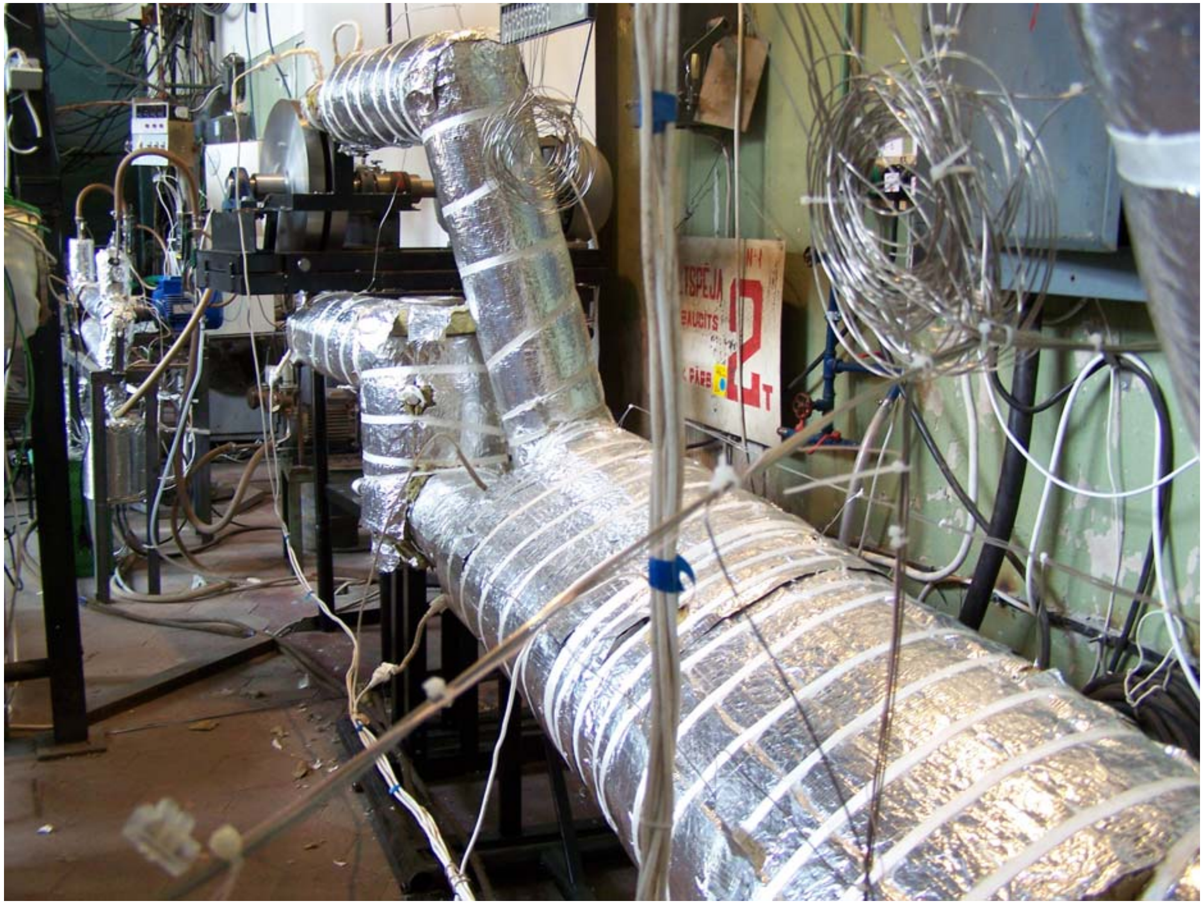
b). In the presence of the magnetic field there is a strong destruction of grains in fine parts and fast dissolution of interfaces volumes The size of structural elements is about 1 μm.





Comparison of corrosion rate of EUROFER samples in magnetic field and without magnetic field (operating temperature 5600C ± 100C)

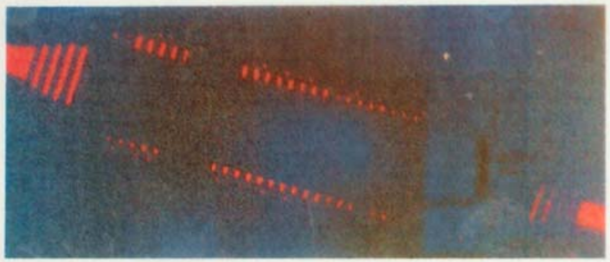
Microstructure of unwashed samples N4,session I with magnetic field B=1.7T(a) and without magnetic field , B=0T (b) cleaned from Pb17Li.



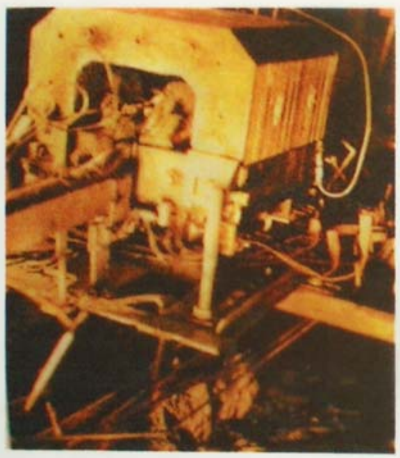
Long run (5000hr) PbLi corrosion stand

(velocity of LM 0,15 – 1,0 m/s; operating temperature up to 550°C, B = 1.8T)

TEST OF ELECTROMAGNETIC PUMPS IN THE VACUUM CHAMBER



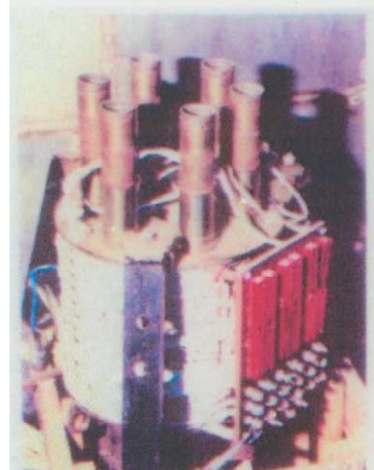
Channel of EMP, working temperatūra 975 ^{0}C



Li leakage after channel cracking

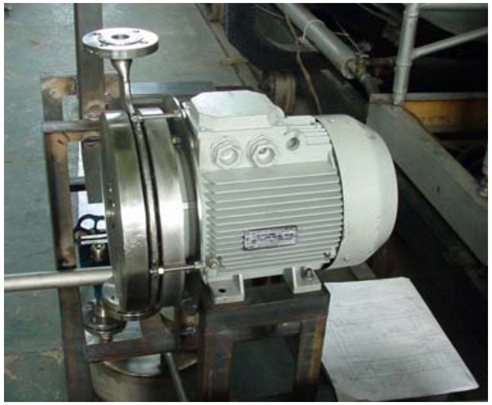
ELECTROMAGNETIC PUMPS FOR SPACE NUCLEAR REACTORS

Cylindrical induction high temperature Li pump (1000 ^{0}C under vacuum)



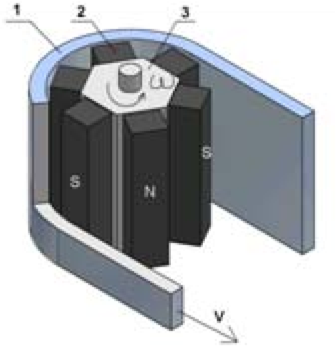
High temperature (1000 ^{0}C) multichannels (6 and 12) pumps for thermo-emission reactor's cooling system

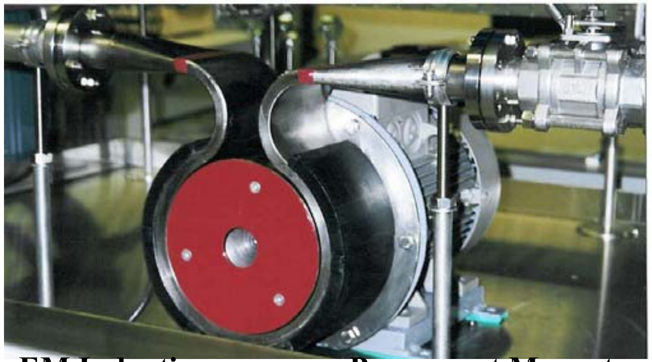
Electromagnetic induction pumps on permanent magnets



Discs type EM Induction pump on
Permanent Magnets for lead (Pb)
Operating temperature 500^{0}C

PMP principle scheme



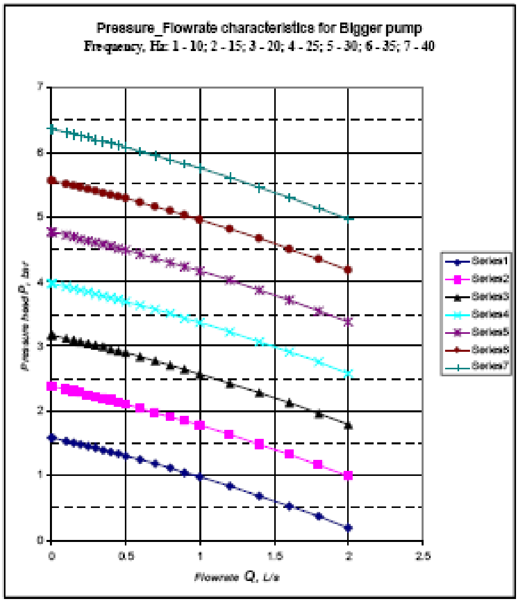


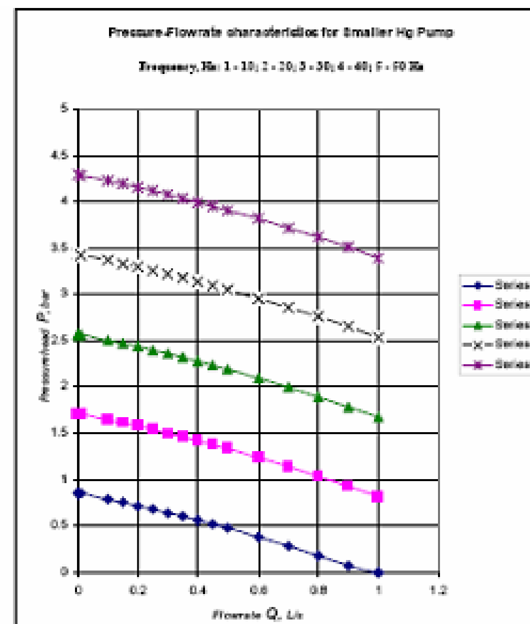
EM Induction pump on Permanent Magnets
For In-Ga-Sn eutectic alloy
Developed pressure 3 bars
Provided flow rate 2.5 L/s)

EM Induction Pump on Permanent Magnets for Mercury
Operating temperature up to200 ^{0}C
Developed pressure P = 6 bar, provided flowrate Q = 13 L/s (175 kg/s);
Motor power for pump drive 90 kW

Comparison of Design concepts of Electromagnetic Induction Pumps

Flat and Cylindrical linear pump	Permanent magnets pump
Main advantage: No moving parts	**Main disadvantage:** Rotating magnetic system
Rather complicated construction, bigger overall dimensions of active part and the weight: *Laminated ferrous yokes* with slots for layout of 3-phase windings for generating alternating traveling magnetic field . Rather complicated construction of the annular channel for cylindrical pump with laminated ferrous yoke inside. Practically is not repairable (if sort-circuiting).	**Much simpler construction, smaller overall dimensions of active part and the weight:** ***No windings at all !!!*** Alternating traveling magnetic field is generated by system of rotating permanent magnets with alternating polarity fixed on *solid ferrous base*. Magnetic system can be easily reassembled
Electrical parameters and efficiency: Lower efficiency and rather low power coefficient cos **f** ≤ 0.3 for linear inductors. Rather expensive power supply – 3-phase transformer with variable voltage for adjusting the productivity of pump.	**Electrical parameters and efficiency:** Much higher efficiency. At using permanent magnets no energy consumption is needed for creating magnetic field, and additionally, much stronger magnetic field can be generated in the same non-magnetic gap. High power coefficient cos **f** ≈ 0.8 of standard industrial AC motor for pump drive through standard frequency converter for adjusting the productivity of pump by rotation speed of magnetic system.
Negative end effects: In both pumps design concepts the negative longitudinal end effects exist. In cylindrical pump *negative transversal end effect does not exist* due to azimuthally symmetry.	**Negative end effects:** The negative transversal end effect exists. *The negative longitudinal end effect does not exist.*



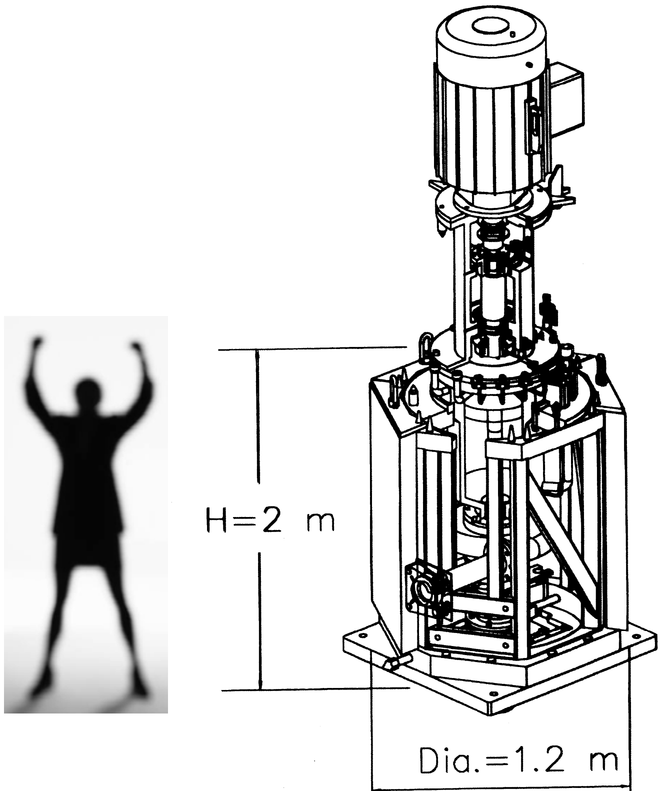


Two pumps for mercury (Hg) provided for ORNL (USA)

(smaller pump: P = 2.5; Q = 0.8 L/s)

(bigger pump: P = 5.0; Q = 1.5 L/s)

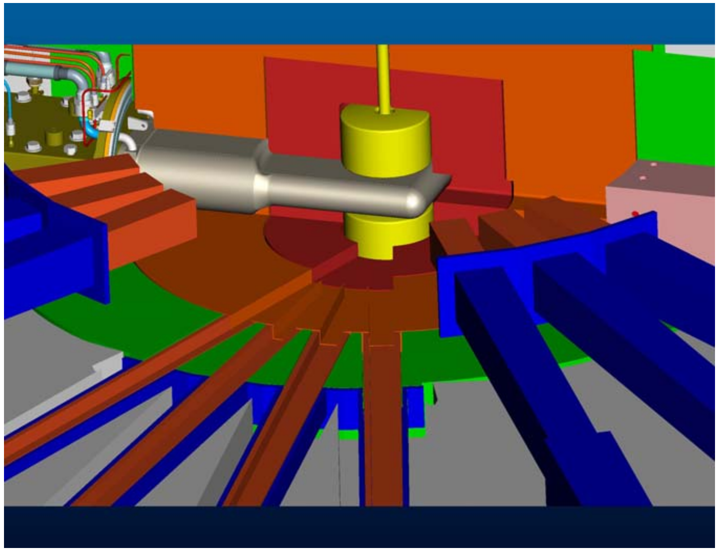
SNS mechanical pump



Pressure **P=6 bar**, flow rate **Q= 20 L/s**

EM pump on rotating permanent magnets for mercury.

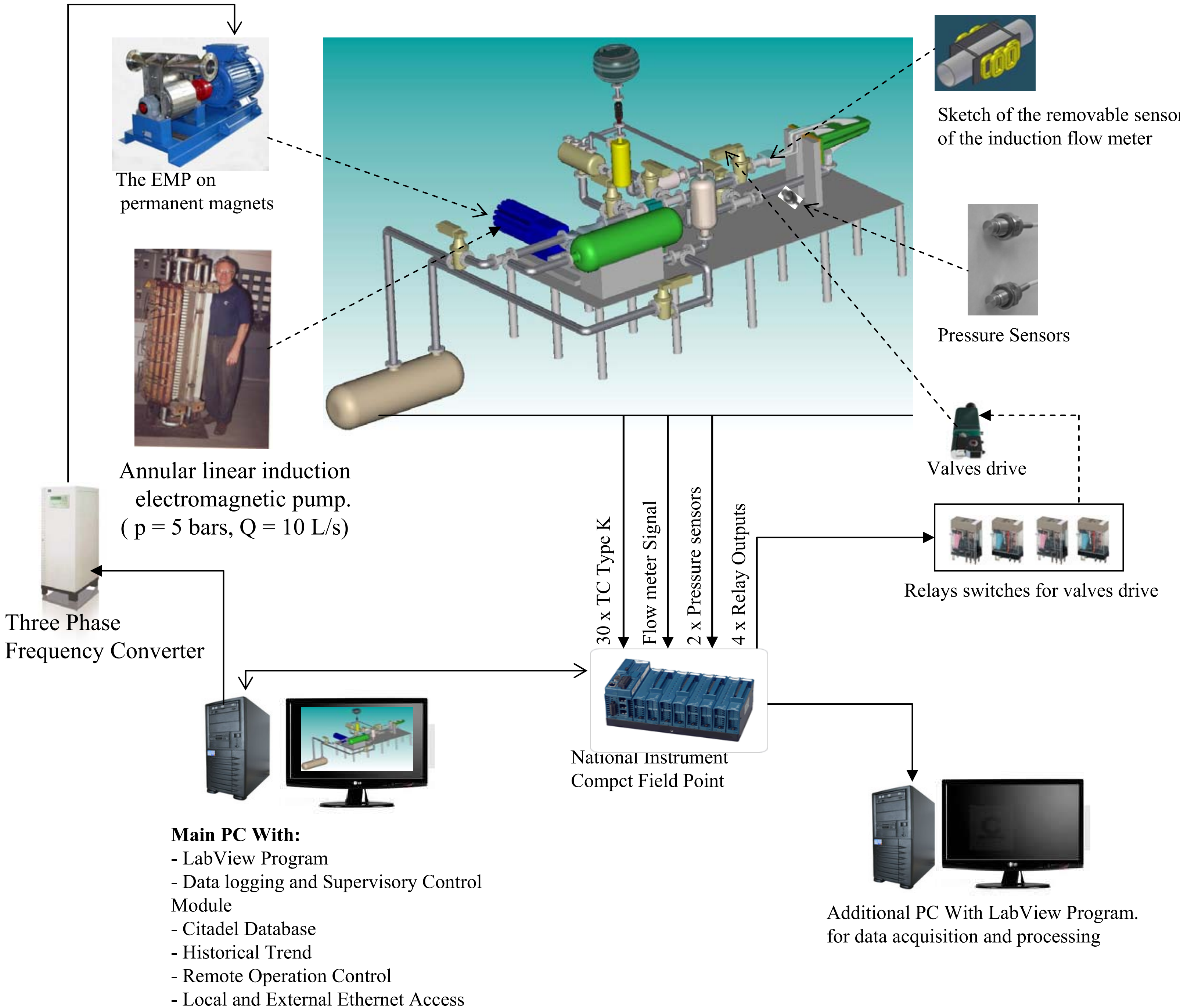
Pressure ***P = 6 bar***; Flow rate ***Q = 13 L/s (175 kg/s)***;
Motor power for pump drive ***50 kW***



The mercury process loop and target carriage systems will incorporate the experience gained from the first target station. One change will be the use of magnetic-drive pumps. This technology has advanced since the FTS mercury loop was designed. ***Figure below is a prototype of a permanent magnet drive pump developed at the Institute of Physics of the University of Latvia for the ESS program.*** A permanent-magnet-drive type of mercury pump is also currently being developed by the Japanese pulsed source facility (J-PARC) project for its mercury system. This type of pump is expected to be simpler and have fewer problems than the mechanical-drive pump.

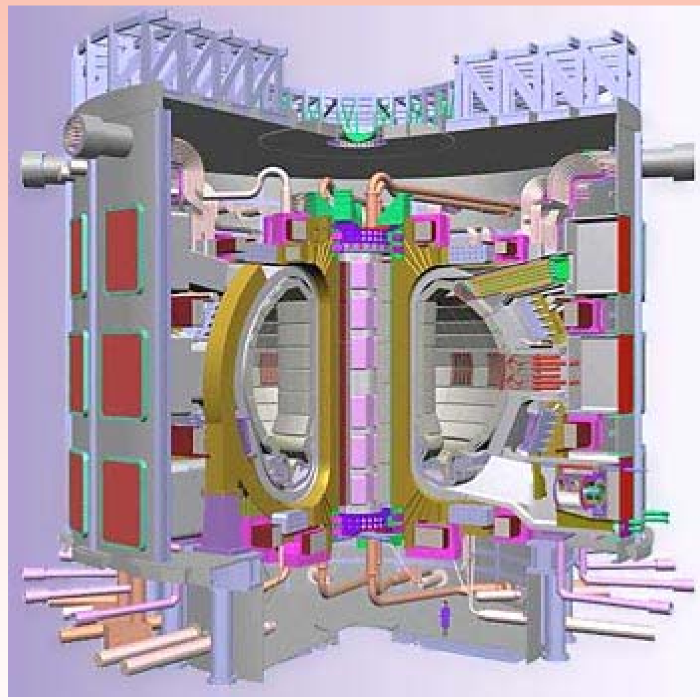
Parameters of the pump for mercury for ESS project

Provided flow rate	170 kg/s (13 L/s)
Developed pressure head:	5 bar
Nominal Hg operating temperature	25º C
Maximal Hg operating temperature:	200 º C
AC motor power for pump drive	50 kW

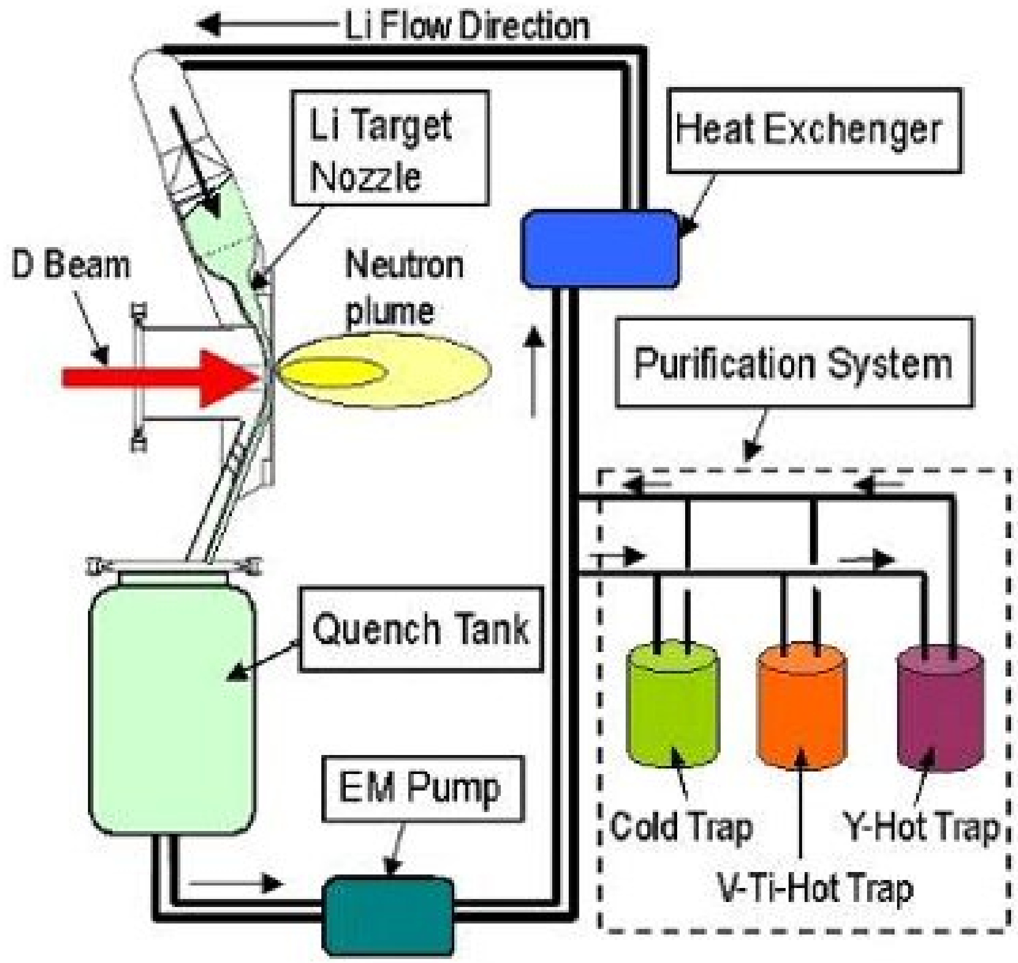


The EMP on permanent magnets
Annular linear induction electromagnetic pump.
(p = 5 bars, Q = 10 L/s)
Three Phase Frequency Converter
Sketch of the removable sensor of the induction flow meter
Pressure Sensors
Valves drive
Relays switches for valves drive
30 x TC Type K
Flow meter Signal
2 x Pressure sensors
4 x Relay Outputs
National Instrument Compct Field Point
Main PC With:
- LabView Program
- Data logging and Supervisory Control Module
- Citadel Database
- Historical Trend
- Remote Operation Control
- Local and External Ethernet Access
Additional PC With LabView Program.
for data acquisition and processing

Thank you for your attention !

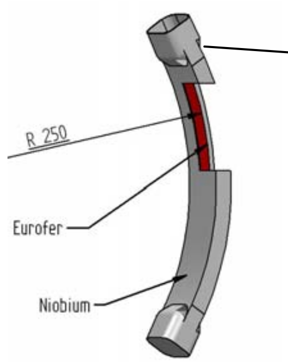


Principal scheme of IFMIF

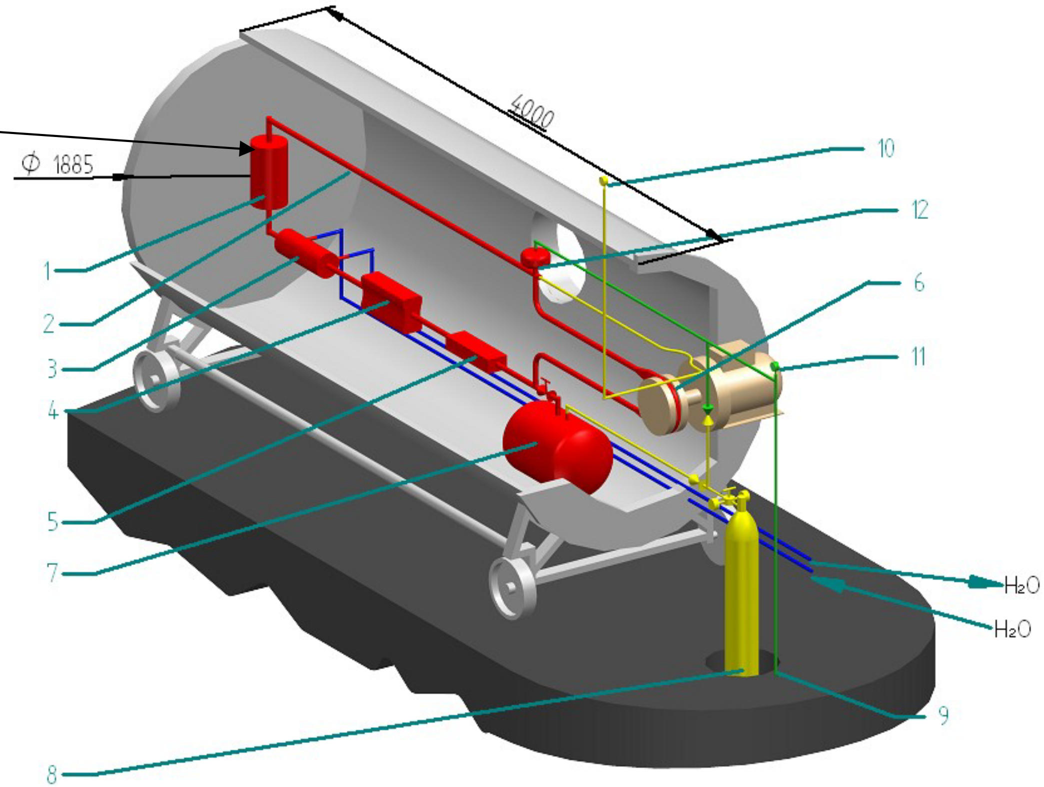


Prototype loop PbBi for the EURISOL 100 kW Liquid Metal

Principal scheme of Li loop for corrosion and impurity control investigations



Test section



1 – test section; 2 – Li loop; 3 – heat exchanger; 4 – electromagnetic pump; 5 – flowmeter; 6 – electromagnetic pump with permanent magnets; 7 – storage tank; 8 – Ar vessel; 9 – outlet to vacuum pump; 10 – manometer; 11 – vacuum meter; 12 – expansion tank.

Thank you for your attention !