Latvijas Universitātes aģentūra

Latvijas Universitātes
Fizikas Institūts

Publiskais pārskats

2007.gads

Misija

Latvijas Universitātes Fizikas institūta (LU FI) misija ir iedibināta vēsturiski: zinātniskie pētījumi magnētiskajā hidrodinamikā (MHD) un ar to saistītās zinātnes nozarēs un ar to saistītu pielietojumu realizēšana un arī jauno speciālistu sagatavošanu šajās zinātnes nozarēs. LUFI darbojas kopējies Latvijas Universitātes misijas kontekstā.

Latvijas Universitātes Fizikas institūta īsa vēsture.

LU FI atrodas Salaspilī, Miera ielā 32. dibināts 1946.g. kā Latvijas PSR ZA Fizikas un matemātikas institūts, no 1950.gada Latvijas ZA Fizikas institūts, Latvijas Universitātes Fizikas institūts kopš 1997.

Direktori: 1946-1948 N.Brāzma ; 1948-1967 I.Kirko; 1967-1991 J.Mihailovs; 1992-1993 I.Bērsons; 1994-1997 O.Lielausis; 1998-2000 A.Gailītis.

Kopš 2001.g. direktors J.E.Freibergs. Zinātniskās padomes priekšsēdētājs A.Gailītis. Akadēmiskais personāls pašlaik ir 48 (asistenti, pētnieki un vadošie pētnieki), no tiem 6 habilitētie dokt., 35 doktori.

2006. gada 1. maijā LU Fizikas institūts atbilstoši Likumam par zinātnisko darbību tika reorganizēts par LU aģentūru.

LU FI darbības 2007.gada pamatmērķi ir sekojoši:

- Uzturēt LU FI kā vadošo pētniecības centru magnētiskajā hidrodinamikā un ar to saistītās zinātnēs gan Latvijā, gan Eiropā un izveidot LU FI par atzītu pētniecības iestādi Pasaules zinātniskajā telpā.
- Uzlabot sadarbību ar LU Fizikas un matemātikas fakultāti zinātnē un jauno speciālistu audzināšanā un arī ar radniecīgām fakultātēm RTU.
- Pastiprināt sadarbību ar ārzemju zinātniekiem jo sevišķi ar Franču zinātniekiem, kā arī ar Vācu, Lielbritānijas un Nīderlandes zinātniekiem.
- Turpināt strādāt pie **Ampēra iniciatīvas** projekta sagatavošanas.

Atbilstība prioritārajiem virzieniem.

Materiālzinātne (nanotehnoloģijas funkcionālo materiālu iegūšanai un jaunas paaudzes kompozītmateriāli);
Enerģētika – videi draudzīgi atjaunojamās enerģijas veidi, enerģijas piegādes drošība un enerģijas efektīva izmantošana.

Lietišķo pētījumu virzieni: šķidro metālu tehnoloģijas jaunas paaudzes kodolreaktoriem un kodolsintēzes reaktoriem (enerģijas ražošanas un piegādes drošība); MHD saules enerģijas pārveidotājs (videi draudzīgi atjaunojamās enerģijas veidi); MHD tehnoloģiju izmantošana jauna veida metālu sakausējumu iegūšanai (materiālzinātne); magnētiskie šķidrumi, magnētiskā lauka izmantošana nanoierīču vadīšanai, magnētisko parādību un kapilāro parādību mijiedarbība (nanotehnoloģijas funkcionālo materiālu un ierīču iegūšanai); starpnozaru pētījumi – magnētiski vadāmu nanoierīču izmantošana biomedicīnā.

Latvijas Universitātes dibināta Latvijas Universitātes aģentūra „Latvijas Universitātes Fizikas institūts” ; 17.03.2006.g. Latvijas Universitātes Senāta lēmums Nr.177
Reģistrēts LR VID ar kodu LV90002112199; reģistrēts Nodokļu maksātāju reģistrā ar kodu 90002112199

LR IZM Zinātniskās institūcijas reģistrācijas apliecība Nr.551021

LU FI ir 6 zinātniskās struktūrvienības:
Fizikālās hidromehānikas lab. (vad. E.Platacis), Siltuma un masas pārneses lab. (E.Blūms), MHD tehnoloģijas lab. (A.Bojarēvičs), MHD mašīnu teorijas lab. (A.Šiško), Elektrovirpuļplūsmu lab. (J.Freibergs), Teorētiskās fizikas lab. (A.Gailītis).

Direkcija
Grāmatvedība
Enerģētikas un saimniecības dienests

Vidējais zinātniskā personāla skaits	44,0 2006 gadā PLE izteiksmē
Vidējais zinātnisko darbinieku skaits	74,0 2006 gadā PLE izteiksmē

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Direktora vietnieks	**Dr.fiz. A.Gailītis**
Tālrunis	67945821
e-pasts	gailitis@sal.lv
Direktora palīdze	**Maija Broka**
Tālrunis	67944700
Fakss	67901214
E-pasts	mbroka@sal.lv
Atrodas	Salaspilī, Miera ielā 32
Pasta adrese	Miera ielā 32, Salaspils-1, LV-2169
Sadarbības fakultātes	Fizikas un matemātikas fakultāte
Akadēmiskā personāla skaits (asist., pētn., v.pētn., .) uz 01.01.2007 . tsk.	**53**
doktori	**35**
habilitētie doktori	**6**

LU FI izdod starptautisku žurnālu "Magnētiskā hidrodinamika" (kopš 1965, tagad angļu valodā, iznāk 4 reizes gadā; galvenais redaktors A.Cēbers).

LU FI organizē regulāras starptautiskas konferences.

Institūtā 2007.gadā 5 īstenoti 6.*Ietvara programmas* projekti un 3 (ERAF) projekti

Magnetic flow tomography in technol,ogy geophysics and ocean flow research MAGFLOTOM	Commission of the EC Research DG	Contract No.028670 Specific target project
Production of a liquid metal limiter for plasma in ISTOK Tokomak, Lisbon, Portugal (production of pumps, flow meters etc.)	Fixed contribution contract with EURATOM , EC 6 Framework Programm-	FU06-CT-2004-00078
European Isotope Separation On-Line Radiactive Ion Beam facility (EURISOL DS)	EC 6 framework Programm	Contract 515768 (RIDS)
Virtual European Lead Laboratory (Vella)	FP6:Contract type: Integrating activities implemented as integrated Infrastructure activities	Project reference 36469. NUWASTE-2005/6-3.2.3.1-1 2006.10.01-2009.09.30
Investigation of the heat transfer between a heated proton beam window and the LBE flow in the KILOPIE mock-up of MEGAPIE target model using the HETSS measuring technique Thermohydraulic tests of the MEGAPIE Electromagnetic Pumps System in LBE, PSI	FP6 MEGAPIE-TEST CONTRACT N° FIKW-CT-2001-00159 MEGAPIE - TEST	*Piedalās kā apakšizpildītājs*

ERAF projekti

Reģistrācijas nr.	***Nosaukums***	***Vadītājs***	**Īstenošanas periods**
Nr.VPD1/ERAF /CFLA/05/APK /2.5.1./000004/004	“MHD tehnoloģija svina-litija eitektiska sakausējuma iegūšanai un pielietošanai kodolsintēzes reaktoru sistēmās”.	J.Freibergs	2006-2008
VPD1/ERAF /CFLA/05/APK /2.5.1./000002/002	Ferītu nanodaļiņas un koloīdi termomagnētiskās dzesēšanas sistēmām un audu hipertermijai” .	E.Blūms	2006-2008
VPD1/ERAF /CFLA/05/APK /2.5.1./000001/001	Koksnes biomasas vietējo resursu racionāla izmantošana siltuma ražošanai kombinētā koksnes un gāzveida kurināmā degšanas procesā	M.Zaķe	2006-2008

Starptautiskās sadarbības projects OSMOZE

Plūsmu un pārneses procesu izpēte elektromagnētiski levitētā pilienā	*Dr. Jānis Priede*	*Dr. Jacqueline Etay*
	LU Fizikas institūts	*CNRS , Francija*

Institūtā 2007.gadā realizētas 1 valsts pētījumu programmas projekts un 3 sadarbības projekti

Reģistrācijas numurs	***Nosaukums***	***Vadītājs***
Valsts pētījumu programma 1-23/49 1-23/37 Projekts 5	Modernu funkcionālu 8 mikroelektronikai, nanoelektronikai, fotonikai, bi-omedicīnai un konstruktīvo kompozītu, kā arī to atbilstošo tehnoloģiju izstrāde Nanodaļiņu, nanostrukturālu materiālu un plāno tehnoloģiju izstrāde funkcionālo materiālu un kompozītu izveidei	E.Blūms E. Cēbers
Sadarbības projekti 1.Nanomateriāli un nanotehnoloģija 2.06.0029.2.09	Mīkstie magnētiskie materiāli un nanotehnoloģijas Difūzā un konvektīvā nanodaļiņu pārneses neizometriskos ferrokoloīdos kapilāri porainās vidēs MHD metodes dispersās fāzes sadalīšanai un homogenizācijai kompozītos ar metālisku matricu	A.Cēbers E.Blūms J.Gelfgats

Institūtā 2007.gadā īstenoti 11 Latvijas Zinātnes padomes finansētie projekti

Bucenieks I. *05.1466*	*Aprēķinu metožu un izgatavošanas tehnoloģijas modernizācija elektromagnētisko sūkņu sistēmām šķidrā metāla neitronu atskaldīšanas iekārtās*
Freibergs J. *05.1381*	*Impulsa, siltuma un masas pārneses procesi aksiāli simetriskās plūsmās hidrodinamikā un magnetohidrodinamikā*
Gailītis A. *05.1388*	*Sfēriska MHD Dinamo eksperimenta izveide*
Geļfgats J. *05.1378*	*Liela apjoma šķidras elektrovadošas vides stacionāras un nestacionāras kustības ierosināšanas un slāpēšanas MHD metožu fizikālās likumsakarības*
Valdmanis J.. *04.1111*	*Elektriskas un magnētiskas iedarbes procesu vadība izkausēta metāla un cietas metāliskas sieniņas robežapgabalā*
Koļesņikovs J. *05.1379*	*Konvektīvās un nobīdes šķidrā metāla plūsmas regulēšana ar elektromagnētiskiem masas spēkiem*
Lielausis O. *05.1380*	*Šķidrs metāls kā darba ķermenis plazmas ierobežotājos un korpuskulāro plūsmu pārveidotājos*
Priede J. *05.1465*	*Nestabilitātes un pāreja uz turbulenci elektrovadošo šķidrumu plūsmās ārējos magnētiskajos laukos*
Šiško A. *05.1382*	*Stipra magnētiskā lauka iespaids uz elektrovadošas šķidrās un cietās vides mijiedarbības procesiem*
Zaķe M. *05.1384*	*Siltuma un masas pārneses pētījumi kombinētā gāzveida un cietā kurināmā degšanas procesā ārējo spēku laukā*
Gorbunovs L. *05.1375*	*Liela diametra silīcija monokristālu audzēšanas procesa fizikālā modelēšana rotējošā magnētiskā laukā*

Institūta zinātnisko darbinieku publikācijas

5. Institūta (augstskolas) SCI publikāciju skaits un nosaukums 2007.gadā, 22 publikācijas

Grāmatas - 2

1. Magnetohydrodynamics: Historical Evolution and Trends'.
Series: Fluid Mechanics and Its Applications , Vol. 80. Molokov, S.; Moreau, R.; Moffatt, H.K. (Eds.), 2007, 415 p., Hardcover. ISBN: 978-1-4020-4832-6

Nodaļas grāmatā

I. V. Bojarevics and K. Pericleous. Numerical Modelling for Electromagnetic Processing of Materials.
II O.Lielausis, E.Platacis Past and present of liquid metal MHD in Riga
III Agris Gailitis, Olgerts Lielausis, Gunter Gerbeth and Frank Stefani Dynamo Eksperiments

2. Agris Gailitis, Gailitis Dynamo. In: Encyclopedia of Geomagnetism and Paleomagnetism eds. D.Gubins and E. Herrero-Bervera. Springer, Berlin. 1997

SCI Publikācijas

1. A. Mezulis, E. Blums, The presence of microconvective instability in optically induced gratings, *Journal of Non-Equilibrium Thermodynamics* **32** (2007), 331 – 340.

2. Th. Volker, E. Blums, S. Odenbach, Heat and Mass Phenomena in Magnetic Fluids, *GAMM-Mitteilungen* **30** (2007), No.1, 185 – 194.

3. „Convective phenomena in large melts including magnetic fields", Journal of Crystal Growth, Volume 303, Issue 1, 1 May 2007, Pages 211-220.
4. Stefani, F., Gailitis, A., Gerbeth, G., Gundrum, Th., Xu, M**.** Forward and inverse problems in MHD: Numerical and experimental results GAMM-Mitteilungen 30 (2007), 159-170
5. R.Krishbergs. Distribution of temperature in the slot of an induction MHD pump. Magnetohydrodynamics, 2007, No. 3, pp. 345-353.
6. Votyakov, E. V., Kolesnikov, Y., *at al.* (2007) Structure of the wake of a magnetic obstacle. *Phys. Rev. Lett.* 98 (14), 144504.
7. Andreev, O., Kolesnikov, Yu., *at al.* (2007) Experimental study of liquid metal channel flow under the influence of a non-uniform magnetic field. *Phys. Fluids* 19, 039902.
8. Votyakov, E. V., Zienicke, E., Kolesnikov, Y., (2007) Constrained flow around a magnetic obstacle. *J. Fluid Mech.* (*submitted*).
9. Yu.Gelfgat, A.Mikelsons, K.Krumins, A.Pedchenko. The influence of large non-magnetic gaps on the transversal end-effect in the linear induction pump. Magnetohydrodynamics, 2007, vol.43, No.1, pp.111-117.
10. M. Abricka M., Gelfgat Yu., Krūmiņš J. The influence of combined electromagnetic fields on the heat and mass transfer in a cylindrical vessel with the melt. Magnetohydrodynamics, 2007, vol.43, No.2, p.173-181.
11. Pedchenko A., Gelfgat Yu. I. Study of the Influence of Current Frequency and Non-Magnetic Gap Value on the Efficiency of Al-Alloys Stirring in Metallurgical Furnaces. – Magnetohydrodynamics, 2007, vol.43, no.3, p.363-376.
12. L.Gorbunov. Some Features of the Horizontal Magnetic Field Influence on the Growth of Large-Diameter Silicon Single Crystals. . Magnetohydrodynamics, 2008 (in press).

13. L. Gorbunov. Single crystal growth from a crusible with skull. Magnetohydrodynamics 49
14. V. Galindo, I. Grants, R. Lantzsch, O. Pätzold and G. Gerbeth. Numerical and experimental modeling of the melt flow in a traveling magnetic field for vertical gradient freeze crystal growth. – *J.Crystal Growth*, vol. 303, issue 1, 2007, p. 258-261
15. 3. R. Lantzsch, V. Galindo, I. Grants, C. Zhang, O. Pätzold, G. Gerbeth and M. Stelter. Experimental and numerical results on the fluid flow driven by a traveling magnetic field, - *J.Crystal Growth*, vol. 305, issue 1, July 2007, p. 249-256.
16. 4. J.Priede, I.Grants and G.Gerbeth. Inductionless magnetorotational instability in a Taylor-Couette flow with a helical magnetic field. - *Physical Review E* (2007), vol.75, No.4, 047303
17. I.Grants and G.Gerbeth. The suppression of temperature fluctuations by a rotating magnetic field in a high aspect ratio Czochralski configuration. (2007) Accepted for publication in *J.Crystal Growth*
18. M.Belovs, A.Cēbers. Buckling of twisted ferromagnetic filaments (iesniegts Phys.Rev.Lett.)
19. K.Ērglis, D.Zhulenkovs, A.Sharipo, A.Cēbers. Elastic properties of DNA linked flexible magnetic filaments. Journal of Physics:Cond.Mat., 2008 (accepted)
20. K.Ērglis, L.Alberte, and A.Cēbers. Thermal fluctuations of non-motile magnetotactic bacteria in AC magnetic fields. Phys.Rev.E (submitted)
21. V.Jeudy, C.Gourdon,A.Cebers, T.Okada. Pattern formation in type-I superconducting films. J.Appl.Phys. – 2007,v.101- 09G118.

Publikācijas starptautisko konferenču izdevumos (SCI proceedings)

Fifth Baltic Heat Transfer Conference, September 19 – 21, 2007, Sankt-Petersburg, Russia,

1. A. Mezulis, E.Blums, G.Kronkalns, Magnetoconvective intensification of heat transfer from a cylinder in magnetic fluid, In: *Advances in Heat Transfer, Proceedings. of the Baltic Heat Transfer Conference*, September 19 – 21, 2007, Sankt-Petersburg, Russia, Publ. House of St.Petersburg State Polytechnical University 2, p. 184 – 191.

2. D. Zablotsky, V. Frishfelds, E. Blums. Numerical study of thermomagnetic convection in cylinder under the magnetic field of a solenoid, In: *Advances in Heat Transfer, Proceedings. of the Baltic Heat Transfer Conference,* September 19 – 21, 2007, Sankt-Petersburg, Russia, Publ. House of St.Petersburg State Polytechnical University 2, p. 301 - 308.

3. E.Blums, G.Kronkalns, M.M.Maiorov, Microconvection and mass transfer induced by spherical filter elements in non-isothermal ferrocolloids, In: *Advances in Heat Transfer, Proceedings. of the Baltic Heat Transfer Conference,* September 19 – 21, 2007, Sankt-Petersburg, Russia, Publ. House of St.Petersburg State Polytechnical University 2, p. 333 - 340.

4. M. M. Maiorov, E. Blums, G. Kronkalns, Thermal dissipation of energy of low-frequency alternate magnetic field in magnetic fluid, In: *Advances in Heat Transfer, Pro-ceedings. of the Baltic Heat Transfer Conference,* September 19

– 21, 2007, Sankt-Petersburg, Russia, Publ. House of St.Petersburg State Polytechnical University 2, p. 178 - 193.

5. I. Barmina, A. Desnickis, M. Zake, The Influence of Electric Field on the Development of the Swirling Flame Velocity Field and Combustion Characteristics, Proceedings of 5-BHTC, Sankt-Peterburg, 2007, pp. 480-486.
6. I. Barmina, A. Desnickis, M. Zake, The effect of Combustion Dynamics on the Formation of Pollutant Emissions by Co-firing the Wood Biomass with Gaseous Fuel, Proceedings of 5-BHTC, Sankt-Peterburg, 2007, pp. 589-597.

1. Eleventh International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007

7. A. Mezulis, E. Blums, G. Kronkalns, Magnetoconvective heat transfer from a cyl-inder under the effect of a nonuniform magnetic field, In: *11th International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007, abstracts*, paper 4P12.

8. D.Zablotsky, V. Frishfelds, E. Blums, Numerical investigation of thermomagnetic convection in heated cylinder under the magnetic field of a solenoid, In: *11th International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007, abstracts*, paper 4P5.

9. M.M.Maiorov, E. Blums, G. Kronkalns, The heat generation by an alternating magnetic field of low freqency in a ferrofluid: the dependence of energy dissipation on temperature, In: *11th International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007, abstracts*, paper 2P22.

10. V. Frishfelds, E. Blums, Drift of nonuniform ferrocolloid through cylindrical grid by magnetic force, In: 1*1th International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007, abstracts*, paper 4O3.

11. Izolda Segal, Alla Zablotskaya, Edmunds Lukevics, Michail Maiorov, Dmitry Zablotsky, Elmars Blums, Irina Shestakova, Ilona Dumbracheva, Synthesis and Bio-logical Properties of Iron Oxide Based Magnetoliposomes with Siloxyvalkylamine Cover, In: *11th International Conference on Magnetic Fluids, Košice, Slovakia, July 23 - 27, 2007, abstracts*, paper 1P27.

International Baltic Sea Region con-ference "Functional materials and nanotechnologies-2007, Institute of Solid State Physics, University of Latvia, April 2-4, Riga 2007:

12. Mezulis, E. Blums, G. Kronkalns, Magnetoconvective intensification of heat transfer from a heated body in magnetic fluid, In: *International Baltic Sea Region con-ference "Functional materials and nanotechnologies-2007,* Institute of Solid State Physics, University of Latvia, April 2-4, Riga 2007, p. 35.

13. O. Petričenko, E. Blūms, M. Maiorovs, A. Cēbers, Synthesis of magnetic nanopar-ticles and their properties, In: *International Baltic Sea Region conference "Functional materials and nanotechnologies-2007,* Institute of Solid State Physics, University of Latvia, April 2-4, Riga 2007, p. 36.

14. E. Blums, G. Kronkalns, M. M. Maiorov, The heater with cobalt ferrite nanoparti-cles utilizing a low frequency magnetic field, , *In: International Baltic Sea Region conference "Functional materials and nanotechnologies-2007*, Institute of Solid State Phys-ics, University of Latvia, April 2-4, Riga 2007, p. 108

10th Biennial Conference on Environmental Science and Technology, CEST-2007, Cos island Greece, 2007.

15. I. Barmina, A. Desņickis, M. Zaķe, Electric Field Effect on the Wood Biomass Co-fire and the Formation of Polluting Emissions, Proceedings of 10th Biennial Conference on Environmental Science and Technology CEST-2007, Cos island Greece, Cos island. 2007.
16. I. Barmina, A. Desņickis, M. Gedrovics, M. Zaķe, Co-firing of Renewable with Fossil Fuel for the Cleaner Heat Energy Production, Proceedings of 10th Biennial Conference on Environmental Science and Technology, CEST-2007, Cos island Greece, 2007.

"Siltumenerģētika un siltumfizika" 2007, Rīga- ref.

17. I . Barmina, A. Desņickis, M. Gedrovičs, M. Purmals, M. Zake**,** Experimental Study of Multi-Fuel Firing for the Effective and Environmentally Friendly Heat Production, Proceedings of Power and Electrical Engineering International Scientific Conference, RTU, 2007, pp.1-10.

MEGAPIE technical meeting, FZK, April 16-17, 2007, Karlsrue, Vācija.

18. S.Ivanov, A.Flerov, N.Jēkabsons, S.Dementjevs, „Experience of electromagnetic flowmeters development and operation", MEGAPIE technical meeting, FZK, April 16-17, 2007, Karlsrue, Vācija.

2-nd International workshop on Measuring Techniques for Liquid Metal Flows, April 23 - 24, 2007, Dresden, Germany.

19. S.Ivanov, A.Flerov, N.Jēkabsons, S.Dementjevs, „Experience of development and operation of electromagnetic flowmeters for MEGAPIE target", 2-nd International workshop on Measuring Techniques for Liquid Metal Flows, April 23 - 24, 2007, Dresden, Germany, http://www.fzd.de/db/Cms?pNid=1471
20. I.Bucenieks, „Experimental Measurements of Sensitivity of Cylindrical rotary induction flow meter on permanent magnets", 2-nd International workshop on Measuring Techniques for Liquid Metal Flows, April 23 - 24, 2007, Dresden, Germany, http://www.fzd.de/db/Cms?pNid=1471

"IV Workshop on Materials for HLM-cooled Reactors and Related Technologies". CNR, Roma, May 21-23rd, 2007

21. I.Bucenieks, J.Freibergs, E.Platacis "Evaluation of Parameters of Powerful Electromagnetic Induction Pumps on Permanent Magnets for Heavy Liquid Metals" "IV Workshop on Materials for HLM-cooled Reactors and Related Technologies". CNR, Roma, May 21-23rd, 2007
22. J. Freibergs, E. Platacis "Liquid metal research activities at Institute of Physics, University of Latvia.", "IV Workshop on Materials for HLM-cooled Reactors and Related Technologies". CNR, Roma, May 21-23rd, 2007

23th Scientific Conference, Institute of Solid State Physics, University of Latvia, February 13-15, 2007, Riga,

23. A.Šiško, F.Muktupāvela, R.Krishbergs, E.Platacis. Theoretical analysis of stationary steel corroding interaction with the laminar $Pb_{17}Li$ melt flow. Abstracts of the 23th Scientific Conference, Institute of Solid State Physics, University of Latvia, February 13-15, 2007, Riga, p,52.

24. A.Shishko, E,Platacis, R.Kroshbergs, J.Valdmanis. Influence ofMHD Effects on Steel Corrosion in Pb-17Li Flow. FDMP 2007, Abstracts Proceedings First International Seminar on Fluid Dynamics and Material Processing, Algieres/USTHB 2007, pp. 55.
25. E.Platacis, A.Shishko, F.Muktepavela. Testing of Eurofer, SiC/SiC composites and different protective coatings at operational temperatures, velocieties and pressures: magnetic field effect on EUROFER corrosion in Pb-17Li flow at 550 oC (cooperation with FZK, ENEA). EUROATOM Workshop „Developmeny of activities of Association EUROATOM-University of Latvia (AEUL) in relation to EFDA Programme". October 24-25, 2007.

26. A.Cebers, K.Erglis. Elasticity of cytoskeleton and motion of magnetotactic bacteria in AC magnetic fields. Joint Meeting of the Biophysical Society 52nd Annual Meeting and 16th International Biophysics Congress, Long Beach, USA, 2008 (accepted).
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Paul Scherer Institute	*Switzerland*	*Production of a system of electromagnetic pumps (pumps, flow meters) for PbBi alloy.*
Corus Research, Development and Technology	*The Netherlands*	*A research roject – Induction Evaporation for PUD coatings (a theoretical investigation).*
SCHOTT AG	*Germany*	*Fesible study for the MHD facility with permanent magnets for the glass technology*
Center for Automatice R&D CIDAUT Foundation for R&D in Automative Sector	*Spain*	*A research roject for liquid aluminium pumps on rotating permanent magnets*
Commissariat a l’energie atomique Departement de technologie nucleaire	*France*	*Assesment of possibility to design and develop pf EM pump related to m3 irradiation devices*
Forschungszentrum Dresden - Rossendorf e.V.	*Germany*	*System of electromagnetic pump*

Īstenots 1 tirgus orientētais pētījums

IZM 1-25/27	Mākslīgi regulējamā temperatūras režīma paņēmiena pilnveidošana un aparatūras izstrāde bišu slimību apkarošanai	A.Romančuks

LU Fizikas institūta doktoranti – 3

K.Kravalis – vadītājs dr.fiz. Imants Bucenieks
G.Lipsbergs – vadītājs dr.fiz. Agris Gailītis
A.Desņickis – vadītāja dr.fiz. Maija Zaķe

LU Fizikas institūta maģistranti – 2

D.Zablockis - vadītājs dr.hab. fiz. Elmārs Blūms
I.Kaldre- vad. A.Bojarevičs

LU Fizikas institūta bakalaura darbu izstrādātaji

Aija Dreimane (RTU Ķīmijas fakultāte)
Līga Tiļuga (LU Fizikas u n matemātikas fakultāte)

Fizikas institūta darbības rezultāti:

Dr.Phys. Maija Zaķes grupas darbs:

Laika posmā no 07.07 līdz 07.08. ir veikts zinātniski-pētnieciskais darbs saistībā ar diviem projektiem, kuru vadītājs ir vad. pētn. Maija Zaķe. Pirmais projekts „VPD1/ERAF/CFLA/05/APK/2.5.1./000001/001" „Koksnes biomasas vietējo resursu racionāla izmantošana siltuma ražošanai kombinētā koksnes un gāzveida kurināmā degšanas procesā", ir lietišķo pētījumu projekts, kura mērķis ir izveidot mazas jaudas (līdz 50 kW) vietējās apkures katlu, siltuma ražošanai izmantojot kombinēto fosilā gāzveida kurināmā (propāns, dabas gāze) un atjaunojamā kurināmā (dažādu struktūru koksnes biomasa) degšanas procesu. Procesa izveidei tika veikti kombinētā degšanas procesa eksperimentālie pētījumi, mainot koksnes mitrumu un struktūru, kā arī papildus pievadītā siltuma padevi, kas veidojas, sadegot fosilam kurināmam. Pētījumu rezultāti ir aprobēti vairākās starptautiskās konferencēs, kā arī publicēti dažādos zinātniskos izdevumos (sk. lit. sarakstu). Izmantojot lietišķo pētījum rezultātus, ir izstrādāts vietējās apkures katla projekts, kā arī izgatavots un aprobēts vietējās apkures katls (1. z.im), kura darbības pamatprincipi ir apkopoti patenta pieteikumā, kas ir iesniegts ekspertīzei.

Vienlaikus ar pētījumiem, kas ir saistīti ar ERAF projekta izpildi pārskata periodā tika veikti arī pētījumi saistībā ar ZP projekta Nr.05.1384 „Siltuma un masas pārneses pētījumi kombinētā gāzveida un cietā kurināmā degšanas procesā ārējo spēku laukā (vispārējais projekts ar jauno zinātnieku un doktorantu piedalīšanos)" izpildi. Dotais projekts apvieno fundamentālos degšanas procesa dinamikas pētījumus dažāda tipa liesmu virpuļplūsmās, izmantojot šo plūsmu kontrolei ārējo lauku (elektriskā, magnētiskā) un liesmas mijiedarbības efektus, kā arī lietišķos pētījumus, kas saistīti ar nepieciešamību ierobežot siltumnīcas efektu un skābo lietu izraisošo degšanas produktu (CO_2, NO_x) veidošanos degšanas procesā, izmantojot šim nolūkam gāzveida fosilā un cietā atjaunojamā kurināmā kombinēto degšanas procesu. Pārskata periodā pamatā tika veikti pētījumi, kas ir saistīti ar ārējā elektriskā lauka un liesmas mijiedarbību, veicot detalizēts siltuma un masas pārneses procesu pētījumus un to izmaiņas ārējo spēku laukā. Pētījumu rezultāti ir aprobēti vairākās starptautiskās konferencēs (sk. Lit. pielikumu). Ir sākti arī sagatavošanas darbi, lai veiktu detalizētus liesmas un magnētiskā lauka mijiedarbības pētījumus.

1. **zīm.** Vietējās apkures katls siltuma ražošanai kombinētā degšanas procesā.

Projekta vadītājs Dr.hab.phys. Jurijs Geļfgats

Liela apjoma šķidras elektrovadošas vides stacionāras un nestacionāras kustības ierosināšanas un slāpēšanas MHD metožu fizikālās likumsakarības

1. Noteiktas dažādu MHD iedarbību elektrodinamiskās un hidrodinamiskās likumsakarības alumīnija un tā sakausējumu maisīšanas iekārtās, ja starp metālu un plakanu lineāru skrejoša lauka induktoru ir liela nemagnētiska sprauga. Noteikti racionālākie MHD iedarbības veidi praktiskai izmantošanai reālās iekārtās 10- un 20-tonnu metalurģiskām krāsnīm. (J.Geļfgats, J.Krūmiņš)

2. Eksperimentāli pierādīts, ka šķidru metālu kausējumus var maisīt ar divfāzu augstas frekvences MHD ierīcēm un noteikti šādu maisītāju racionālie parametri. Pirmoreiz ar ultraskaņas ātruma mērītāju izpētīta plūsmu konfigurācija un intensitāte šķidru metālu kausējumos. (A.Bojarevičs, A.Pedčenko)

3. Izmantojot alvas sakausējumu (T = 900-1000 ^{0}C), eksperimentāli pierādīts, ka MHD maisītājus, kuros izmanto pastāvīgos magnētus, var izmantot dažādās tehnoloģiskās iekārtās. (A.Bojarevičs, J.Geļfgats)

EURISOL DS (European Isotope Separation On-Line Radiactive Ion Beam facility)

RIDS

Contract number 515768

Engineering design and construction of a function Hg – loop

INTRODUCTION.

Different liquid metal (LM) technologies will always remain the closest neighbors to liquid metal MHD. In last five years LM have became attractive to a new branch of nuclear technology – spallation neutron generation. LM is serving as the working medium (for neutrons generation) and in the same time as the heat carrier.

The Institute of Physics of the University of Latvia (IPUL) is one of the main research centers in the field of MHD technology which has been involved in both theoretical and applied studies and experimental work.

The Institute of Physics possesses a special Mercury laboratory complex including a 350m^2 experimental hall. The amount of Hg in use reaches 13.10 ^{3} kg, almost 1m^3 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

It is the right place directly here to remember on the ideas about windowless liquid metal (LM) targets. It was mentioned that in SINQ by special magnets the proton beam is bent upwards. In principle, the beam could be bent also downwards and target against an open free LM surface. On a definite phase IPUL was collaborating with the Belgian Nuclear Research Centre on design and verification experiments for Windowless Spallation Target of the ADS Prototype MYRHA, planed as a small high-performance irradiation facility with fast neutron fluxes up to 10^{13} n/cm^2/s.

Within EURISOL – DS, a liquid metal /LM/ spallation target with a power of several Megawatt is designed to provide neutrons to a fission target. The target station that allows the full intensity of a 4 MW proton beam to be used for RIB production will require new advanced technology. It is a critical component of EURISOL

For a power density above 10^3 MW/m^3 the windowless, free – surface, molten LM-jet is proposed as a target since it avoids the very serious lifetime – shortening damage caused by the power proton beam in any system.

In the case of the spallation neutron sources, mercury has been chosen as the most promising high-Z target and coolant material.

In order to develop windowless target it is necessary to investigate hydrodynamics of liquid metal (Hg) jet.

Our Institute of Physics becomes more and more involved in corresponding investigations.

Evaluation of the optimal engineering design of the Hg-loop components (electro-magnetic pump, flow meter, piping, diagnostic and control elements), as well developing and manufacture Hg-loop for testing EURISOL Target components was one of the IPUL main tasks.

In parallel in accordance with Dr. Y. Kadi (CERN) recommendations transverse film target has been considered.

I INGENEERING DESIGN AND CONSTRUCTION OF A FUNCTION Hg – LOOP

At the moment, the only available Hg – loop – installation running in the order of the necessary mass flows exists at IPUL, fig.1.1

Fig.1.1 Mercury stand

The loop was formerly used to run Hg – loop experiment, especially under gas bubble injection simulation a two phase flow. At the moment modifications is done preparing the installations for run of experiments under integration of a 1:1 model of the EURISOL targets /PSI version as a windowless cross flow target developed at IPUL/ planned to run in the next decades. These targets experiments are scheduled to start in April 2008. First discussions about possible hydrodynamics and thermal hydraulics EURISOL Targets experiments at IPUL turned out in preliminary layout of the Hg – loop shown by fig.2.

There is an arrangement of the loop in a line. i.e. the equipment and separate units are connected in series via pipes providing convenient assembling and easy operation. All parts of the loop shown in fig.1.2 are either still in place, have to be changed, have to be moved from other running installations or be newly designed and manufactured.

For maximum flexibility during the experimental phase, the 1:1 models of the EURISOL target as main units of the Hg – loop are connected by flanges.

Our Hg – loop is arranged vertically, fig.3.

The skeleton of the loop is formed by:

- loop assembly;
- electromagnetic pump;
- electromagnetic conductive flow meter;
- heat exchangers;
- supply and expansion tanks as
- model of the target.
-

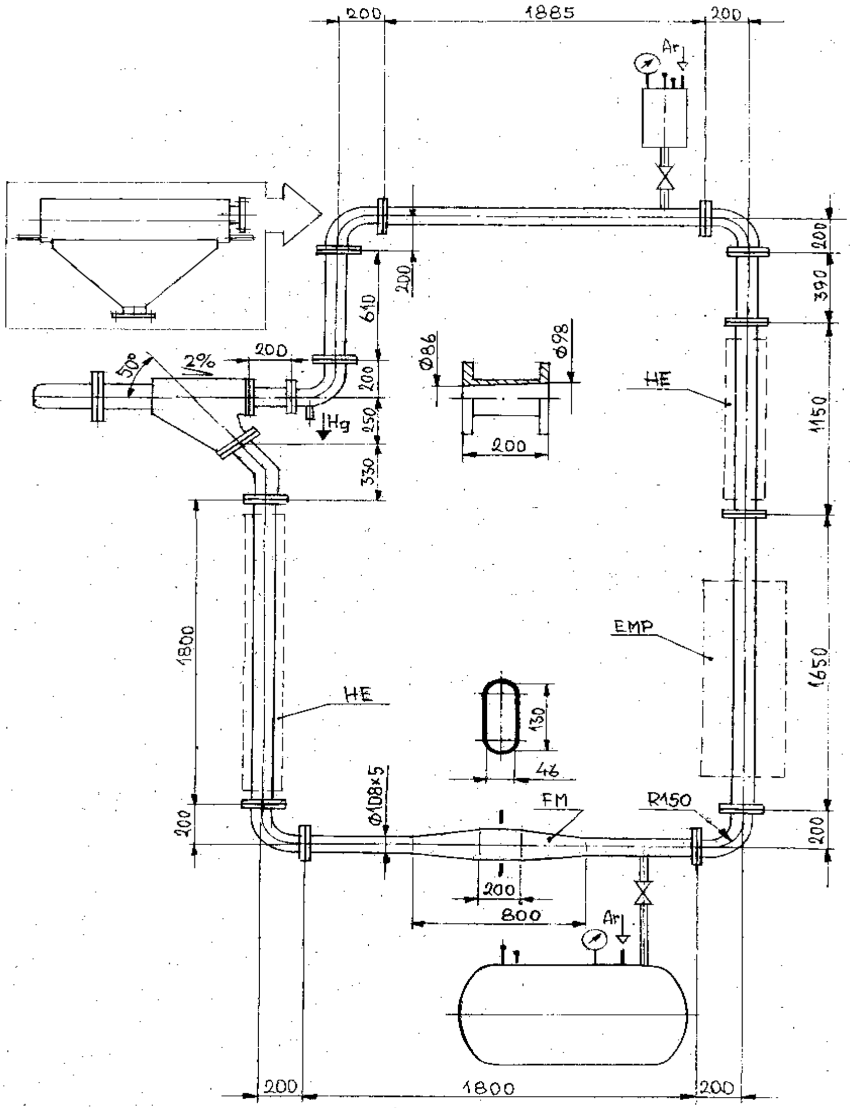

Fig.1.2. Principle layout of the hg – loop

Loop assembly is stainless steel tubes 108 mm in diameter and almost 10 m in length.

The most important component of the loop is pump for providing a flowrate in the loop.

The use of electromagnetic pumps is attractive because the ability to obtain hermetically sealed systems. EM pumps can be designed in a large number of types and configurations. Detailed analysis of all types to obtain the best selection for each application would be a prodigious task. Each of the types of pumps is adapted to a certain field of operation.

In accordance with demands for needed parameters and results of hydraulic estimations the cylindrical induction pump have been installed in the loop, fig.13.

Cylindrical induction pumps have large outputs which can obtain several thousand m^3/hr at differential pressures of the order of 10 to 15 bars. These pumps have a strong conduct made-up of two concentric tubes. The annular pump has not the side effect present in flat pump. The windings consist of thoroidal coils whose axes are concentric with the axis of the annular duct. Windings are normally located only in the stator because the inaccessibility of the core. In principle the annular pump is identical to the flat pump.

Many factors affect pump size, but the limitation is generally winding temperature and boiling temperature of mercury in the channel. Winding temperature is a function of winding power loss, fluid temperature, heat sink temperature, and the thermal properties of the path through which the loss passes from windings to heat sink.

There is high energy consummation in the secondary circuit, i.e. liquid mercury and channel walls. When the pump is operating, the duct of the pump is quickly heated, it is necessary to cool the channel of the pump, because unstable stagnation zones inside a channel can reach the boiling temperature of mercury, which through a building of hydrodynamic perturbations, will affect the entire velocity field.

Induction high-power pumps have certain inherent disadvantages and limitations. Because of remarkable eddy current losses in secondary circuit poly-phase induction pumps are not suitable for mercury systems with low boiling temperature. While the liquid metal is passing through the channel the temperature of the metal increases at $\Delta T = \frac{P_a}{Qc_{Hg}} = 57.7^o C$, where P_a is the power losses in secondary circuit, Q is the mass flow rate, c_{Hg} is the heat capacity of mercury. For higher pressure it is necessary that the mercury flows with a sufficient flow-rate to remove thermal power. The experience shows than it is very important to eliminate the stagnation zones in the channel and to provide for good contact between the liquid metal in the working zone and the channel or sidebars because the stagnation zones can warm up to boiling temperature of mercury. Because installed EMP in the loop is provided with independent cooling system.

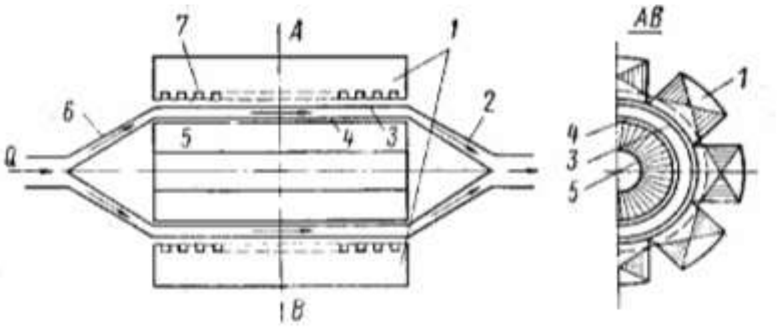

Fig. 1.3 The principle scheme of cylindrical linear induction pump.
1 – inductor; 2, 6 – inlet and outlet diffusers; 3,4 – coaxial cylinders of annular channel; 5 – inner passive ferrous core; 7 – slots

In order to ensure required parameters /flow rate, pressure/ rather powerful annular inductive electromagnetic pump have been chosen and installed in Hg-loop for target models experiments, fig. 1.4. The pump develops 5 x 10e5 N/m² of pressure at a flow rate of 10L/s, fig.1.5.

Fig. 1.4. Cylindrical induction electromagnetic pump
(p = 5 bars, q = 10 l/s)

In order to ensure a stable temperature of Hg flow in the loop two heat exchangers /HE/ are installed in the loop – one before /after EMP/ model of target and another one – after target model. The HE operates with cooling water in annular space between tube of loop and causing. Flow rate of water in the HEs is adjustable. That’s can remove power up to 50 kW. It is necessary to note EMP with cooling system is provided too.

The supply tank /see fig.2./ contains $7x10^3$ kg of mercury.

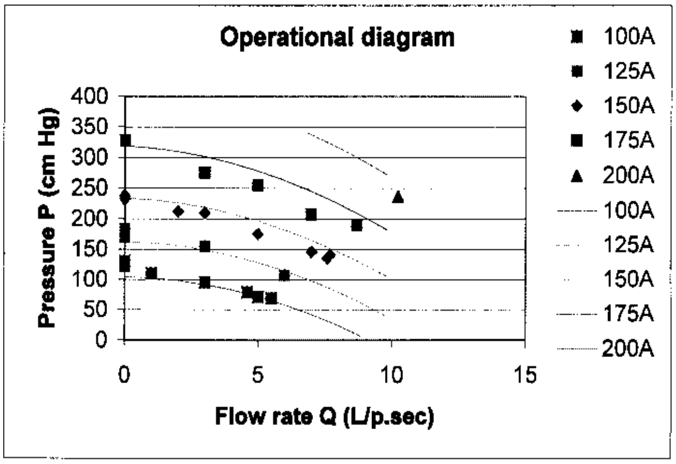

Fig.1.5. P-Q characteristics of EM pump

Flowmeter. For measuring a flow rate in the loop during experiments the conductive electromagnetic flowmeter, which was calibrated using Ventury tube, was used, fig.6.

One of the main advantages of EM conductive flow meter in comparison with inductive EM flowmeter is its simple design: simply on some part of the loop's tube outer constant transverse magnetic field is imposed. Other advantages of conductive flowmeter in comparison with inductive flow meter are following:

- rather high sensitivity and more easy measuring of constant potential difference in comparison with measuring rather small alternating signals in the case of inductive flowmeter;
- measured linear with flow rate signal does not depend on the electrical conductivity of liquid metal, which can change with temperature.

The only disadvantage of conductive electromagnetic flow meter is necessity to provide electrical contact with liquid metal in the channel of flow meter and ensuring a stable contact resistance of channel's walls; they should be either electrically isolated from inside or fully wetted.

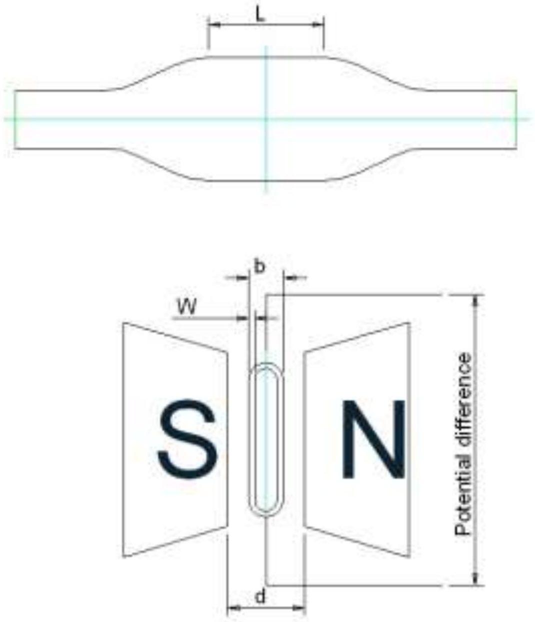

Fig.1.6 . Principle scheme of the conductive flowmeter

Except these parts other supplementary parts and devices are necessary for operating and monitoring the flow rate in the loop. So vacuum system and gas pressure system are needed for filling the loop with mercury and draining the mercury out from the loop, pressure taps and manometers are needed for measuring pressure developed by pump and evaluating the hydraulic resistance of the loop.

Pressure developed by pump is measured at the inlet and outlet of pump's channel by pressure meters FGP Sensors: XPM10 – A1 (5 bars), but overpressure in the loop-by manometer installed in the expansion tank.

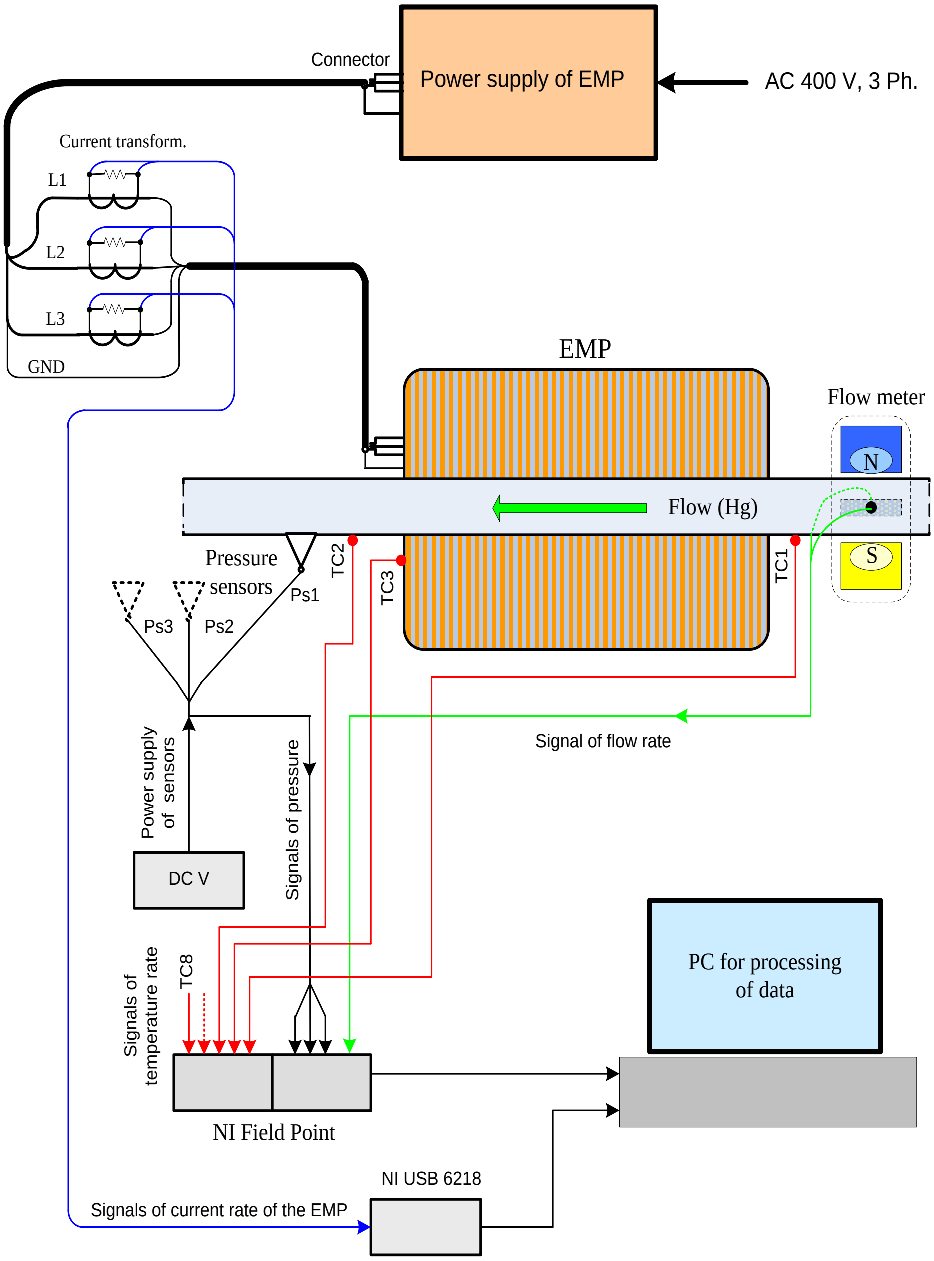

Fig.1.7 Data acquisition and monitoring system

In fig. 1.7 data acquisition and monitoring system is shown. Signals of corresponding sensors /pressure meters, flow meter, thermocouples/ are led to NI Field Point. Output of Field Point is connected to PC LAN. EMP a.c. signals come of Current transformers to alternating voltage data analyzer NI USB, which output is connected to PC USB port. Incoming in PC digital measurement signals are processing by Lab View program.

For testing distribution in film of liquid metal the following system is proposed, fig. 1.8.:

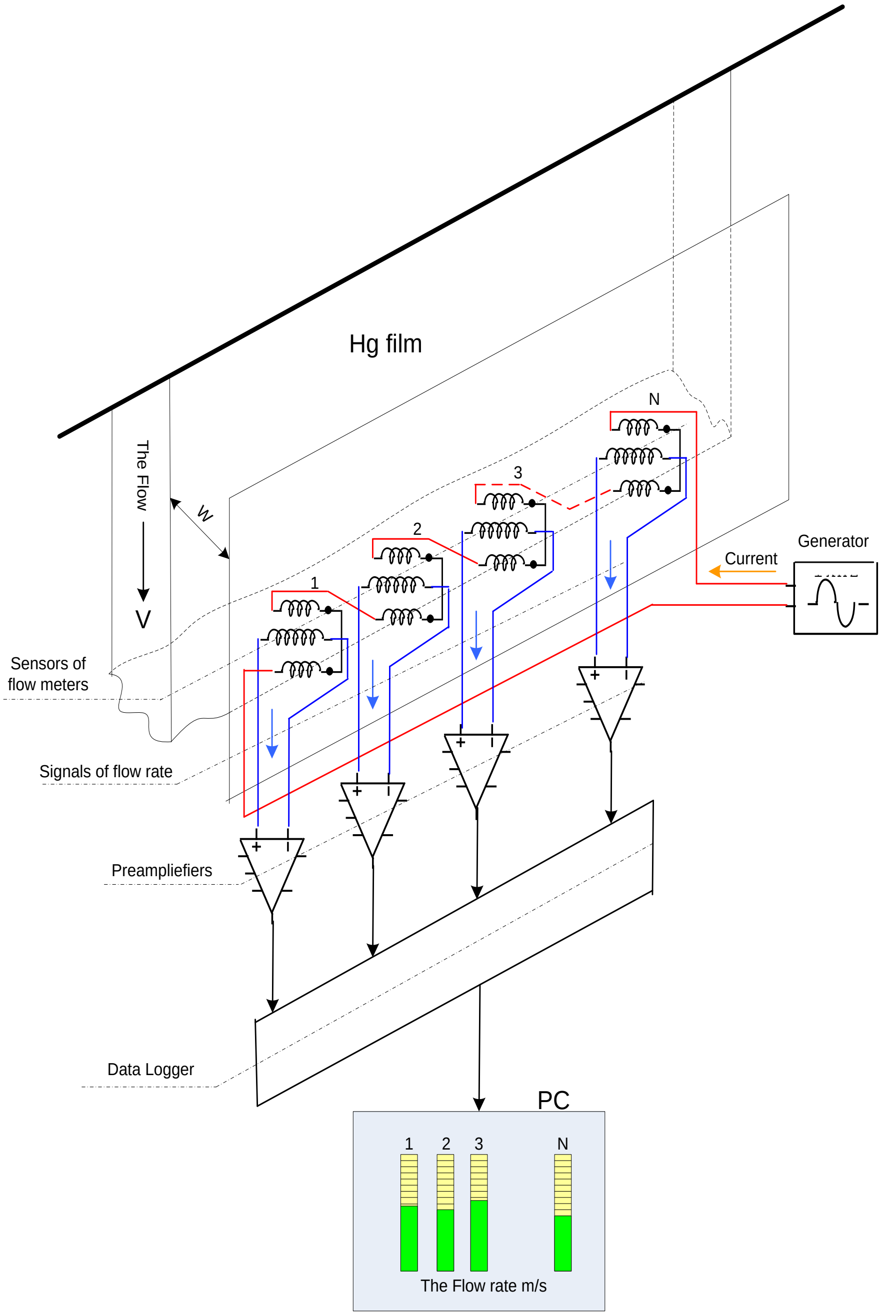

Fig. 1.8. Principal scheme for testing of velocity distribution in LM film

Measuring of velocity and velocity distribution in mercury “film” flow

Description of measuring devices:

1. Mercury film.
2. Sensors of flow meters – 1, 2, 3, ….N, which are installed upon electrically non-conducting plate in direction transversal to the flow. Plate with sensors is located at the distance W from mercury film.
3. Measuring coils of sensors for pre-amplifying of signals with filters.
4. Sinusoidal current generator for the feeding of magnetic field inducing coils.
5. Data logger – data analyzer and A/D converter, for example, NI USB 6218, for measured velocity signals processing in order they can be transferred to PC for further processing.
6. PC computer with installed LabView program.

Short description of operating principle of measuring scheme.

All magnetic field inducing coils of sensors 1, 2, 3, ….N are connected in series and are energized from one the same sinusoidal current generator for getting equal induced magnetic fields in all sensors. In its turn, in each sensor its coils pair are connected in such way that their induced magnetic fields are mutually compensated when there is nor mercury film flow or, if we assume that film is not moving, then also in measuring coil no e.m.f. will be induced (in ideal case signal will be $E = 0$). In the case when there is mercury film flow, then the secondary magnetic field induced in the film will shift the distribution of magnetic field of primary magnetic field in the film flow direction, and as a result the mutual compensating magnetic field for each coils pairs diminishes and in measuring coil the signal is induced, which is proportional to the de-compensation. The value of de-compensation in specified range is proportional to the flow velocity in film, but the value e.m.f. induced in measuring coils will be proportional to the velocity of film flow.

Note: The theory of induction flow meters are described in corresponding literature.

If in the film flow in its width direction the velocity will be non-uniform, then discussed scheme with corresponding layout of sensors gives possibility for measuring the distribution of this velocity.

During above mentioned period the reconstruction of existing Hg – loop is realized and

commissioned. Practically it is prepared for thermo - hydrodynamics tests of EURISOL Target mock-ups at parameters closed to real ones.

As abovementioned two different versions of the Liquid Metal Target will be installed and tested on the reconstructed Hg – loop: one -180° bend coaxial flow target (PSI version) and second – windowless transverse flow film target (IPUL version).

II TRANSVERSE FLOW FILM TARGET

In parallel transverse flow film target at Institute of Physics of University of Latvia is considered, fig. 2.1

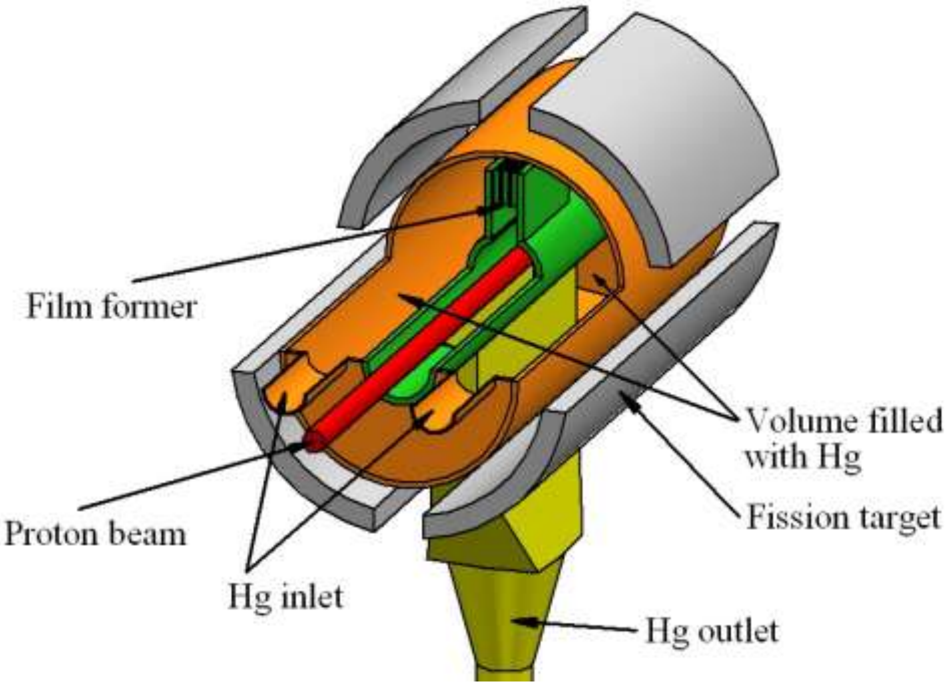

Fig.2.1. Principle layout of the Transverse flow film target

As a basis of Transverse flow film target /TFT/ is liquid metal, for example Hg, film, which flow through special device /film former/ perpendicularly to proton beam. Film former /injector/ is main parts of proposed device. There are problems to get stable LM and homogeneous film with needed dimensions – 20mm in width and 500 - 600mm in length. Because serious experiments with different injectors have been carried out.

In parallel different mock-ups of injector of transverse flow film target (injectors with square shapes of cells, with round shapes of cells, with parallel separated inner structure) have been designed, fabricated and tested on special InGaSn – loop, fig.11. Nevertheless there are problems to stabilize the film of liquid metal, especially in frontal part of beam entrance into it.

Modules of  with rectangular	transverse film injectors  cell inner structure	Test chambers  	InGaSn test loop of transverse film target module  P=1,5 bar; Q~1.5 l/s
 with round cell	 inner structure		
 with parallel	 separator inner structure		

Fig. 2.2.

More or less stable and homogeneous InGaSn film on the injector with parallel separator inner structure have been obtained, /see fig.1 2.2/.

That is why the theoretical estimations and modeling of injector with parallel separator inner structure was next step of our activities.

III OBSERVED PROBLEM WITH FREE-FALLING LIQUID FILM SRHINKAGE

During the spring of 2007 IPUL performed several attempts to establish stable freefalling liquid InGaSn eutectic film in their experimental facilities . These efforts were a part of IPUL project for introduction of novel full scale Hg liquid film neutrino spallation target.

Several rectangularly shaped (approx. 10x100mm) jet inlets with differently shaped nozzle openings were tested for maximum Hg volume fraction in jet. Finally, the inlet with multiple stripped bar openings for the jet was chosen since it's production of almost 100% metal in the jet (no gas inclusions).

However, the shape of free falling unconstrained InGaSn jet was rather unacceptable the jet evidently shrunk during it's fall down, with large changes in jet sectional shape,

Figure 1. Also, Plateau Reileight instability may trigger rather unstable jet behavior on it's lower part. Deformed shape of liquid metal film as well as oscillations of free jet surface due to unpredictable proton beam scattering are unwelcome and in some cases can be even critical for spallation target operation

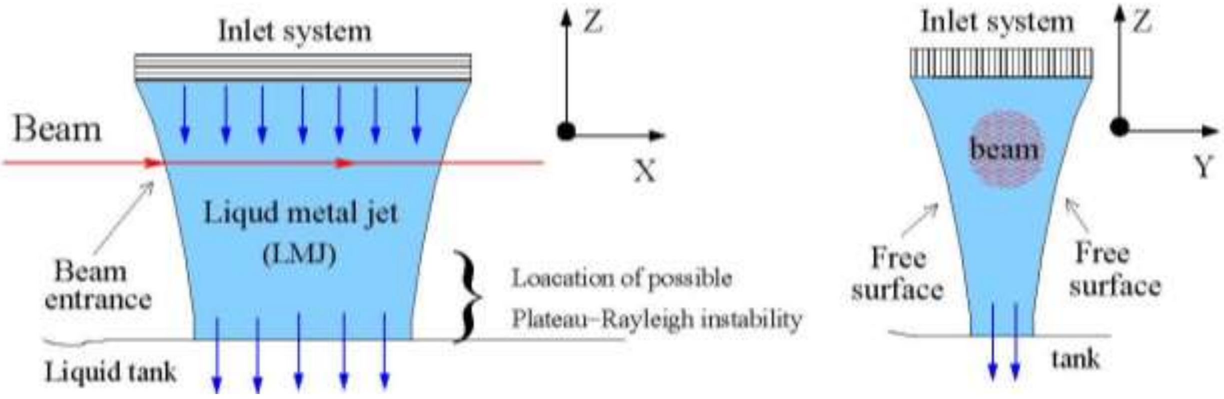

Fig 3.1. Schematic drawing of free/ unconstrained jet film development with possible proton beam entrance location

The origin of jet shape changes is related to Bernoulli's theorem which is considered to be an acceptable assumption for our jet. The theorem for any pair of sections Si, Sj with respective normal oriented along vertical Z-axis states

$$\frac{U_i^{\,2}}{2} + gz_i = \frac{U_j^2}{2} + gz_j = C(x, y)$$

(1)

where Ui, Uj are local velocity in sections i, j crossing streamlines. Let's choose coordinate system so that S_0 is located on injector outlet on z = 0 while S_1 lying downstream, z = Δh, Figure 3. 2. Assume potential flow on inlet with U_1 = const, than C(x, y) = const too, therefore Eq. (1) reads

$$\frac{U_1^2}{2} = \frac{U_2^2}{2} - gh \tag{2}$$

Eq. (2) combined with jet continuity condition

$$SU = S_1U_1 = S_2U_2 = Q_{tot} \tag{3}$$

relates cross-sectional ratio of the jet with it's inlet velocity, U1

$$\frac{S_2}{S_1} = \left(1 + \frac{2gh}{U_1^2}\right)^{-1/2} \tag{4}$$

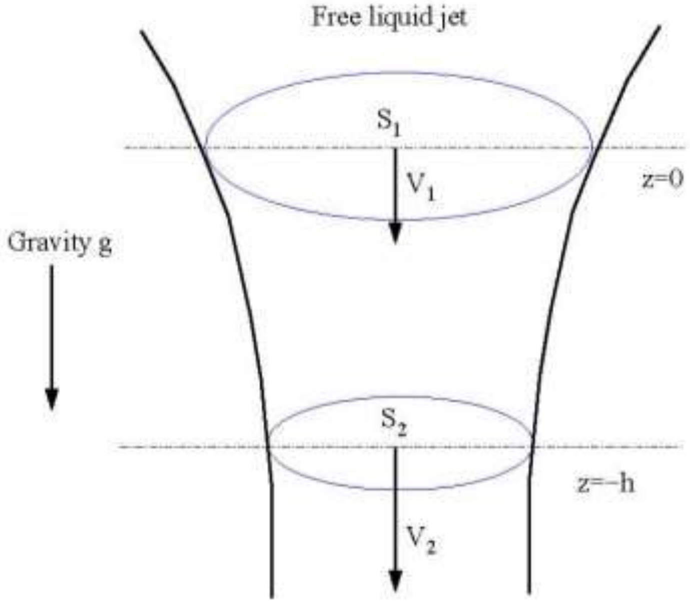

Fig.3.2 Free falling jet

Numeric example. Consider jet average velocity on to be 0.5 (m/s). For h = 2.5cm Eq. (4) yields: S_2/S_1=0.58, i.e. free jet area is reduced by about 40%, which is rather noticeable change. In the case of noncircular liquid film the shorter jet edges which are perpendicular to the beam direction will shrink more as long ones, oriented along the beam.

CONCEPT OF PARTIALLY CONSTRAINED JET

One of possible approaches to reduce tilt of liquid film surface on beam entrance point is to constrain jet in the beam direction on both sides by solid surfaces, Figure 3..3. The shape of constraint planes can be chosen by the aid of numeric simulations. For our first approximation deviation of constraint surface from Z-axis, δ, will follow the ideal jet law Eq. (4)

$$\delta = \Delta\left(1-\sqrt{1+\frac{2gh}{U_1^2}}\right) = \Delta\left(1-\sqrt{1+\frac{2gh\Delta^2 l^2}{Q_{tot}^2}}\right)$$

(5)

where Δ and l are inlet width and length, respectively.

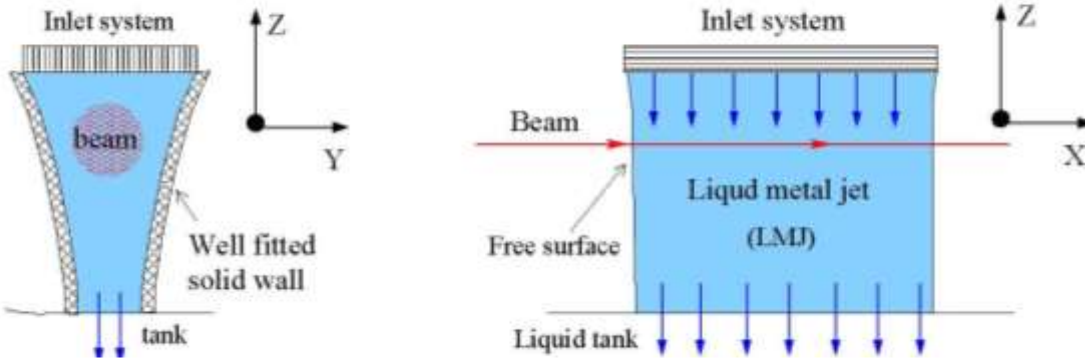

Fig. 3.3. Concept of partially constrained jet as spallation source

Although proposed particularly constrained liquid jet design solves geometric and surface tension related stability problems, it also introduce an additional turbulisation of liquid film due to liquid jet interaction with constraining walls. Turbulent pulsations may affect free surface near beam entrance location, particularly leading to unpredictable local beam entrance angle. The allowed maximum of chaotic free surface pulsations is rather small — below 1mm, which may be limiting factor for use of proposed design for high Re jets, i.e. high velocities or thick injector. Both, numeric and experimental routes are suggested in order to find a maximum acceptable D value for given Hg consumption rates.

EXAMPLE OF ONGOING CFD SIMULATORS

Important note. Results below originate from ongoing simulations, which is work in progress. As such, results are unverified and shown for illustrative purpose only. Boundary conditions as well as domain shape and numeric values of liquid film characteristics in the final report of JES may be different from ones shown in this chapter.

. DOMAIN SHAPE AND BOUNDARY CONDITIONS

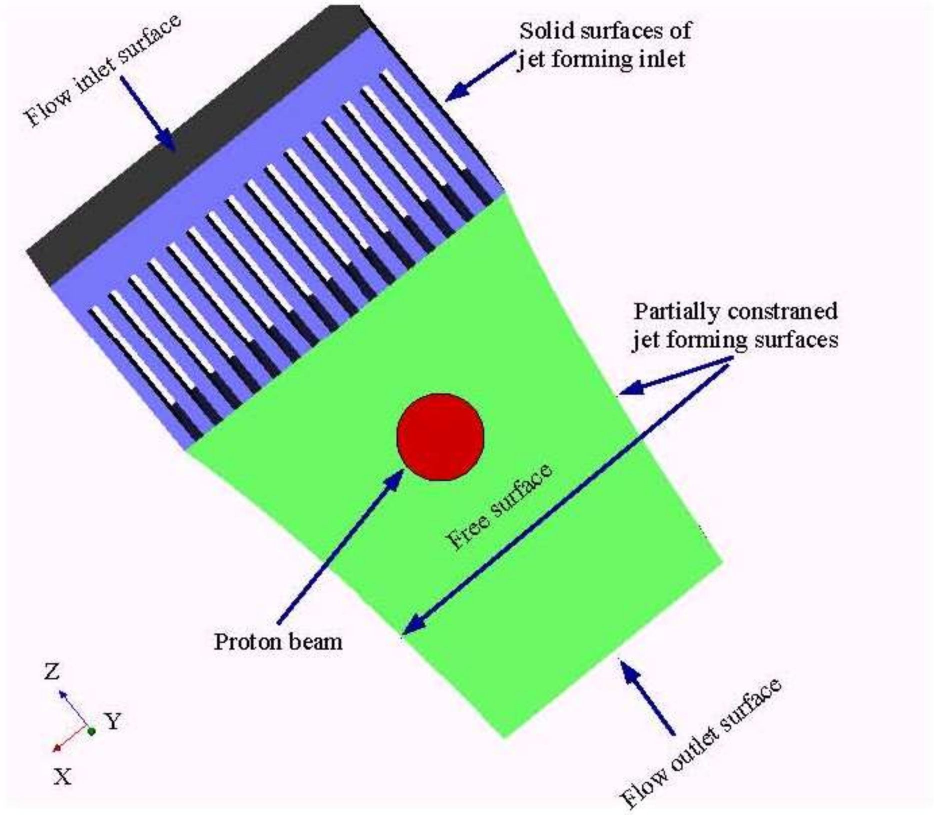

Fig. 3.4. Example of computational 2D domain used in CFD simulations. The red spot marked as “proton beam” is shown for illustrative purpose only.

The shape of inlet is mainly limited by available processing routes. After consultations with IPUL the following dimensions of inlet was selected for next experiment: D = 14.26(mm), l = 107(mm). The thickness of internal separators is 2.5(mm). Corresponding computational domain, designed for average Hg velocity U_1 = 0.5(m/s) in jet cross section directly after the inlet, is shown in Figure 3. 4.

Open FOAM CFD package/toolkit, [2], is used for all simulations. Conventional k □ϙ model was chosen for turbulence description. Boundary conditions which during the simulations were applied to the computational domain are also rather standard for CFD. Thus, on all solid surfaces, such as inlet and jet forming walls zero velocity and standard k □ϙ wall functions was set. Uniform velocity was set on domain inlet, while pressure gradient conditions were corrected by taking into account gravitational force. Zero pressure condition and zero normal gradients for velocity take a place on outlet. On free surfaces the slip condition was set.

Since results above are from stationery fluid dynamics models, the initial conditions are not specified.

RESULTS OF SIMULATION

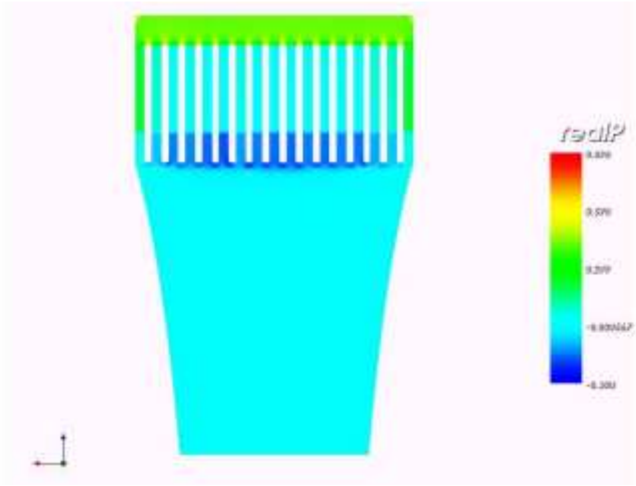

Fig. 3.5 Example of CFD simulations, density normalized pressure $p^* = p/\rho$ (m^2/s^2) on Y-symmetry plane to domain.

It is well known that CFD system of equations in the case of k ΔϘ is rather “stiff”, thus an additional efforts to obtain a stable solution, like massive under relaxation of linear equation systems was performed.
The next, Figure 3.6 shows velocity U (m/s) distribution (modulus and vectorial) in the same region.

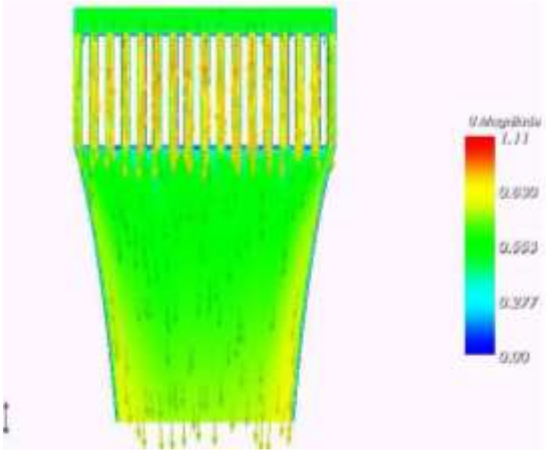

Fig. 3.6 . Example of CFD simulations, velocity *U (m/s)* modulus (color) and it’s vectorial representation in selected points on Y symmetry plane

SOLUTION ON JET FREE SURFACE

In the real setup the shape of free surface will differ from flat, due to requirement of pressure balance in both environments gaseous on liquid metal. However, driven by simplicity considerations (more realistic free surface tracking modeling is still unfinished at the moment of writing) author has used flat jet free surface representation. In this case pressure deviation from atmospheric (in the model $p_{atm} = 0$) indicate direction and approximate value of free surface deviation from flat one. The pressure ($\rho_{normalized}$) distribution on free jet (film) surface (slip condition) is shown in Figure 3.7. The distribution of pressure in this region is slightly asymmetric, due to asymmetrically located inlet separators. As one may notice, the pressure deviation from zero near to location considered for proton beam entrance is □0.01 < p_ < 0.015, or □0.0014(bar) < p < 0.002(bar), by more as on order of magnitude lower as pressure head range in the system. Further shape optimization may decrease the pressure deviation even more, however even recent results seems to be acceptable for max. 1 mm deviation of free surface. Lets use k□ϱ turbulence model for estimation of order of magnitude of free surface pulsations near beam entrance. One may do it by using relationship between turbulent kinetic energy k and turbulent kinetic energy dissipation ϱ which is base of k□ϱ model

$$\varepsilon = \frac{k^{3/2}}{L} \quad \text{or} \quad L = \frac{k^{3/2}}{\varepsilon} \qquad (6)$$

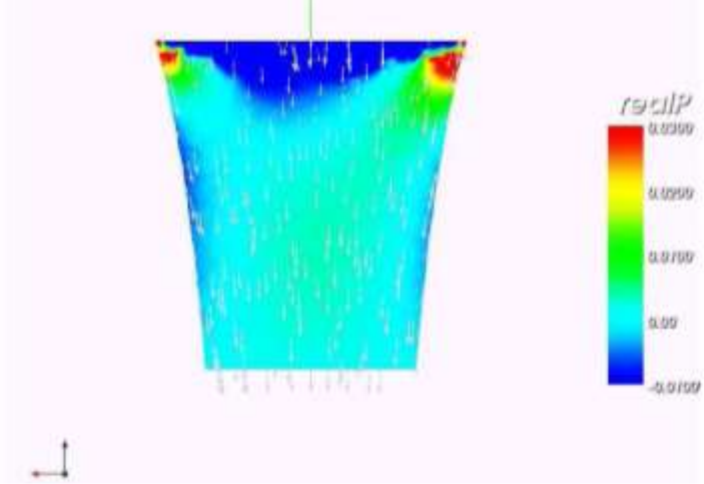

Fig. 3.7. Example of CFD Example of CFD simulations, density normalized pressure $p^* = p/\rho\ (m^2/s^2)$ on free surface of liquid film.

where L is characteristic size of turbulence. Values of L (in meters) calculated from CFD results are shown if Figure 3.7

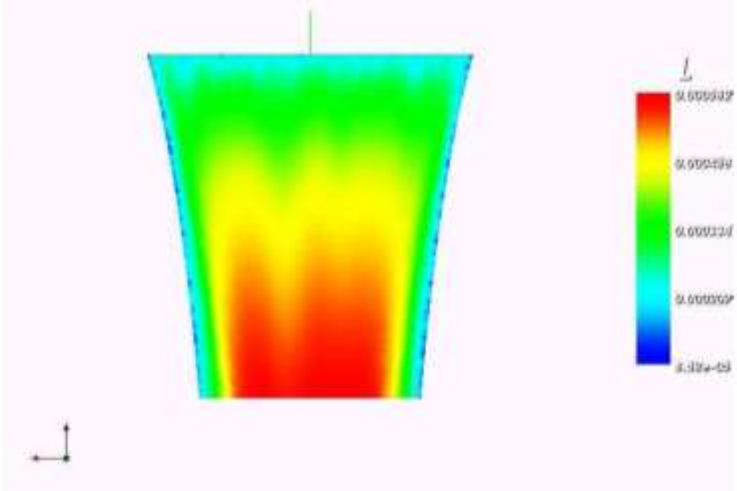

Fig. 3.8 Example of CFD simulations, characteristic size of turbulent pulsations (in meters) on free surface of liquid film.

Figure 3.8 shows rather small amplitude of turbulent pulsations, which would be quite acceptable for use with proton beam. However, this result is unverified as well as it depends on approximate k □ϱ model, thus experimental verification is required.

IV Hg- LOOP DN-60

As theoretical estimations showed the possible solution could be partly to constrain a liquid metal film in the beam direction with definitely shaped solid walls. The appropriate shape of walls must ensure almost flat free surface in the transverse plane.

Fig. 4.1 Mercury loop DN- 60

On the basis of theoretical estimations injector of transverse flow film target with definite shape of side walls have been developed and installed on the Hg – loop DN-60, fig. fig. 4.1

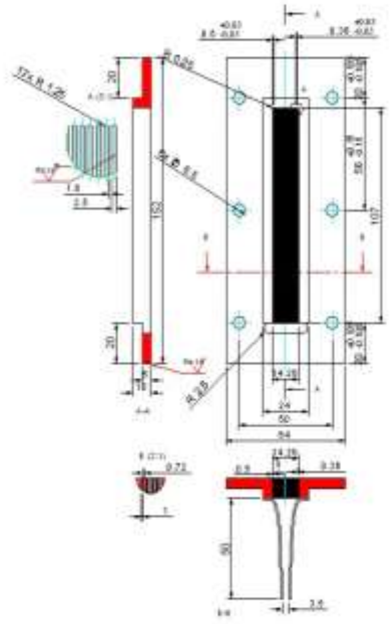

Fig. 4.2 Injector of mercury film

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Received experimental results are rather perspective – film in 100mm in width and 9mm in thickness is stable and homogeneous.

Windowless transverse flow film target formation seems rather perspective. Injector in scale 1:1 has been designed and developed for installation on Hg-loop, fig.

Fig. 4. 3. Film of mercury

Windowless transverse flow film target formation seems rather perspective. Injector in scale 1:1 has been designed and developed for installation on Hg-loop, fig. 4.4

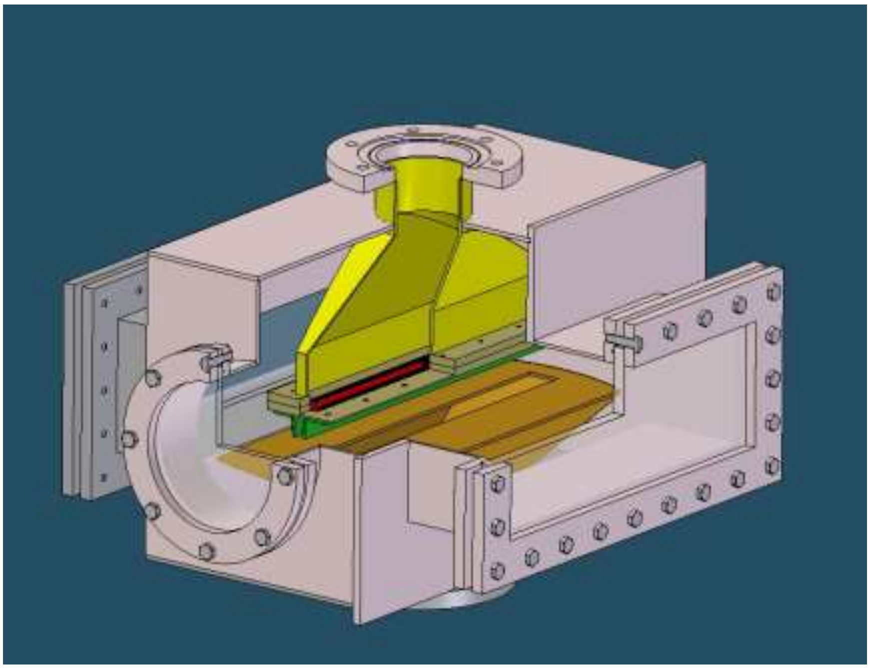

Fig. 4.4 Principle scheme of injector

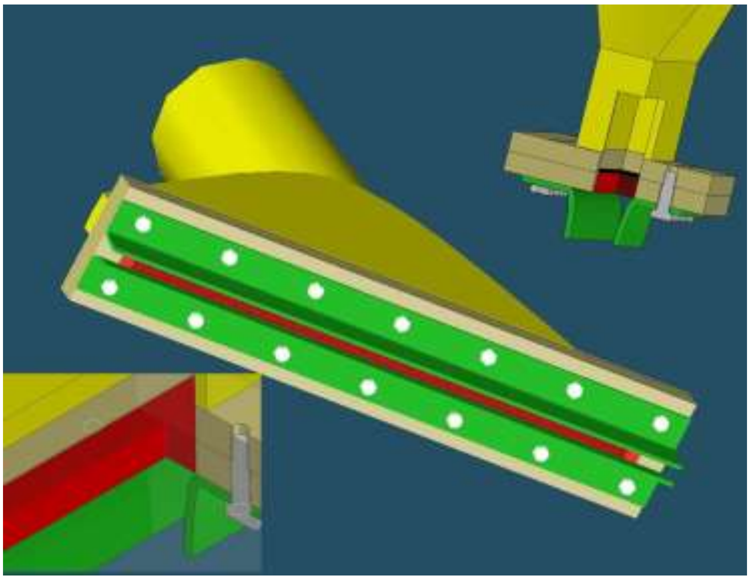

Fig. 4.5

CONCLUSIONS

- Hg – loop is designed and assembled. Practically it is prepared for thermo - hydrodynamics tests of EURISOL Target mock-ups at parameters closed to real ones.

- proposed transverse film target is with good prospects - operating pressure in the mercury loop is only some bars, film is rather stable. Besides depending on the beam power and heat regime /distribution/ in the target the flow rate of mercury is easy to adjust in the loop:
- experimentally observed free liquid metal film shape changes (shrinkage) may be explained with simple application of Bernoulli's theorem;
- performed CFD simulations do not contradict with partially constrained jet design applicability;
- on the basis of experimental results received on InGaSn- and Hg-loops as well theoretical simulations injector of transverse flow film target is designed and developed for installation on functional mercury loop and realization tests in scale one to one.

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2. Engineering design and construction of a function Hg – loop; Preliminary Report, IPUL, Salaspils 2007.
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Preparation of a gallium multi-jet limiter for installation on Tokamak ISTTOK

Initial conditions for the development of a multi-jet limiter for ISTTOK

The idea of the transfer to a multi-jet limiter is clear – to organize an aprox. 1 cm wide opaque obstacle able to "scrape of" a real outer layer of plasma. Under such conditions, compared with the single jet case, a detectable already influence of the limiter on the parameters of discharge could be expected. To make the transfer as easy as possible it was decided to keep the main parameters of the stands (both on ISTTOK and at IPUL) unchanged and concentrate all the introductions on the injecting part, starting with the outlet flange of the upper reservoir and down to the nozzles (Fig.1). On the left side of the picture the new developed unit is shown with the nozzles shifted close to the wall of the inlet opening. The proposal about a shifted injector must be considered as typical directly to multi-jet systems. In the single jet version the nozzle was placed directly above the center of the d=38 mm outlet port of the chamber. If the single jet (d order 2.5mm) would be directly replaced by a multi-jet screen (d order 10mm) we would be at risk that for regular discharges the cross section is to strong limited. Therefore it was proposed to shift the nozzle section of the injector as close as possible to outer edge of the d=38mm inlet port and then step by step bring it deeper in the volume, using a similar positioning mechanism as in the case of the single jet. But at such a disposition trouble is invited that the jets can be targeted against the outer edge of the outlet port.

The next consequences are connected with the fact that at the same acting pressure Δh= 1.3 m the flow-rate must be increased three, four or even five times (depending on the number of jets in the multi-jet system) compared with the initial single-jet version. To reach the same breakup length for the multi-jet system the velocity in each of the jets must remain unchanged, equal to the velocity in the single-jet version. The first and simplest pressure consumer, these are hydraulic losses in the connecting tubes. There were no questions with their minimization, the diameter of the tubes was simply increased from d=5mm to d=10 mm. Next component, these are local losses in the "on/off" shutting valve. Here unexpected problems appeared. It turned out that the choice at selection of bellows sealed valves is very limited, at least at the *Swagelok Company.* Additionally, at the transfer to lower hydraulic resistances the valves are critically increasing in size (Fig.2). The ratio between the flow-rate and pressure drop in the valve is characterized by the flow coefficient c_v: $q = c_v \Delta p^{1/2}$. The numerical values of c_v presented in Fig.2 correspond to q measured in "gal/min" and Δp measured in "psi". In the single jet version it was enough to use a small valve with c_v=0.36. Approximately the same dimensions (height order 100 mm) are characteristic also for the valve with c_v=0.7 (Fig.2) and the intension was to build the multi-jet injector on the base of this BN8 size valve. But in such a case only a three jet version can be proposed (see later). Four jets are requiring already a 8UW series valve with c_v= 1.2 . The dimensions of this valve remain acceptable, the height = 290 mm. It should be remembered, that the valve must be mounted on a d=12 mm tube. Exactly a four jet version with such a valve was taken as a base for further development. But initially it was proposed to install on ISTTOK a limiter with a higher number of jets. In direct measurements it was stated that in such a case a valve with a higher flow coefficient is required. Next after series 8UW follows series 12UW, and these "machines" are huge indeed, reaching in height 465 mm. Also such a valve was acquired (see Fig.2) but considered as unacceptable for installation on a d=12 mm tube, at least on this first phase of investigation. In the same time it should be remembered that this valve is design with 16 mm in/out joints, it means, not so big.

Finally, the jets are pulled out with a definite non-zero velocity and the corresponding accelerating energy, again generated by the same pressure, is lost for the system. Such outlet pressure loses are present in all "open" hydraulic systems, but their relative role can be very different.

On Fig.3 a concrete case is consider, it shows that our configuration is rather "open", the pressure losses in all the three mentioned elements (connections-valve-outlet) are practically equal. Curve 1 represents losses in an "empty" connection, without flow meter and valve. At the acting value of the hydraulic height Δh = 130 cm (see Fig.1) the corresponding flow-rate Q was directly measured and the curve was drawn through this point. Curve 2 corresponds to the situation when the mentioned Δvalve with c_v=1.2 was included in the hydraulic chain. Losses calculated from the relation $Q = c_v (\Delta p)^{1/2}$ were simply added to curve 1. To determine the outlet losses it is necessary to known the outlet velocity. A case with four d=2.5 mm jets was considered, the value of velocity in each of such jets is also represented on the x-coordinate. The outlet losses were determined by means of relation $\Delta h= v^2/2g$. To construct the curve 3 these outlet losses were added to curve 2. For the system "connections+ valve" at the acting pressure the flow- rate was also directly measured, Q= 60 cm^3/s was reached. Probably by accident for such a simplified scheme, but this point matches excellent to the independently constructed curve 3. A similar approach can be applied also in cases with different number of jets, their diameters as well as with different characteristics of the valve. Let us take an example. Considering the potential application to FTU because of space limitations only the small valve with c_v=0.7 can be proposed. At ΔH=130cm for a single d=3mm jet estimates were predicting velocity v=3.8 m/s, in an experiment v=4.4 m/s was reached. In this case the most complicated, the outlet losses were clearly prevailing making up 75% of the total pressure losses.

Behavior of individual jets in multi-jet injectors.

The upper chapter leads to the conclusion that in systems under consideration the main working parameter - the velocity of the jets - can be estimated/predicted with a good enough accuracy. And this accuracy can be increased, first of all, by using more precise expressions for the mentioned losses. In the case of a single jet it would be o.k. also with the determination of the second main parameter, the breakup length. But it turns out, that at a real design of a multi-jet injector the individual jets do not behave so nice as initially expected. Initial were the made in 2006 experiments confirming that all the jets in a three jet system break up according the rules established for an individual jet (Fig.4). But in this case the nozzles were placed in line with enough spacing, determined in special measurements. By a precise mechanism two jets were brought closer and closer and it was stated that 13 cm long jets behave as fully individual down to a distance of approx. 2.5 mm. But at a real design it is difficult to take all these requirements fully into account. For example, spacing becomes strongly limited because of the necessity to bring the nozzles a close as possible to the outer wall of the inlet opening (see Fig.1). All the nozzles must be squeezed in outer d ≈1 cm housing. In reality the breakup length in a multi-jet system can differ, and essentially, from the ideal “single jet” predictions. An example is presented on Fig.5 where the breakup length in a system of four jets can be seen (d=2.6mm; v=2.8 m/s). According to the “single jet” predictions BUL= 21 cm should be expected, in reality BUL order 11 cm was reached, it means, close to two times lower.

Water as modeling liquid for investigation of Rayleigh instability in liquid metals.

In the proposal under consideration the MHD interaction (generation of induced currents) should be avoided by the Rayleigh instability – breakup of liquid jets in shorter/smaller fractions. This process is governed by the Weber number *Wb* and the breakup length *L* for a jet of the diameter *d* can be determined by a rather simple expression

$$L/d = coef.\ (Wb)^{1/2} = coef.\ (\rho v^2 d/\sigma)^{1/2}$$

where ρ stays for density, σ – for surfice tension and ν – for velocity.
For a rather wide range of quasi-similar conditions the *coef.* remains practically constant, with a weak dependence on the Reynolds number *Re*. In the reference period a physically interesting and practically important result was achieved, namely, the initially formal assumptions that ordinary water can be used for modeling of the breakup process in interesting us liquid metals were experimentally confirmed. These ideas are based on the circumstance that for water and such materials as InGaSn and Ga at given velocity *v* and diameter *d* the values of the Weber number (and also of Reynolds number) differ very little:

$Wb(InGaSn) / Wb(H_2O) = 1.28$; $Re(InGaSn) / Re(H_2O) = 2.5$
$Wb(Ga) / Wb(H_2O) = 0.66$; $Re(Ga) / Re(H_2O) = 3.3$
at parameters
InGaSn (ρ = 6400 kg/m^3; σ = 0.353 N/m; $\nu = 4.10^{-7}$ m^2/s)
. Ga (ρ = 6093 kg/m^3; σ = 0.723 N/m; $\nu = 3.10^{-7}$ m^2/s)
H_2O (ρ= 1000 kg/m^3; σ = 0.072 N/m; $\nu = 10.10^{-7}$ m^2/s)

In Fig.1 results are compared when the relative breakup length *L/d* has been measured both for liquid metals and water. The „old” points that appear black where used to establish the very handy for liquid metals dependence

$$L/d = 4.2\ (Wb)^{1/2}$$

The light points relate to measurements with water. Both sets of measurements coincide surprisingly good. It shows that in general we

have to do with a clearly expressed physical mechanism practically governed only by one non-dimensional parameter, the Weber number.
The results of the essentially more convenient measurements with water can be used also at the discussion about the reasons for the “strange” behavior of individual jets in liquid metal multi-jet systems. Measurements with water confirm that breakup length for individual jets in a multi-jet system can remain practically unchanged compared with the single jet case. Both for individual jets (1x), as well as for ansambles of three (3x) and five (5x) jets the breakup length depends on the Weber number in the same way. It should be underlined that the geometry of the nozzle units in both cases was kept practically similar, both for H_2O and InGaSn.

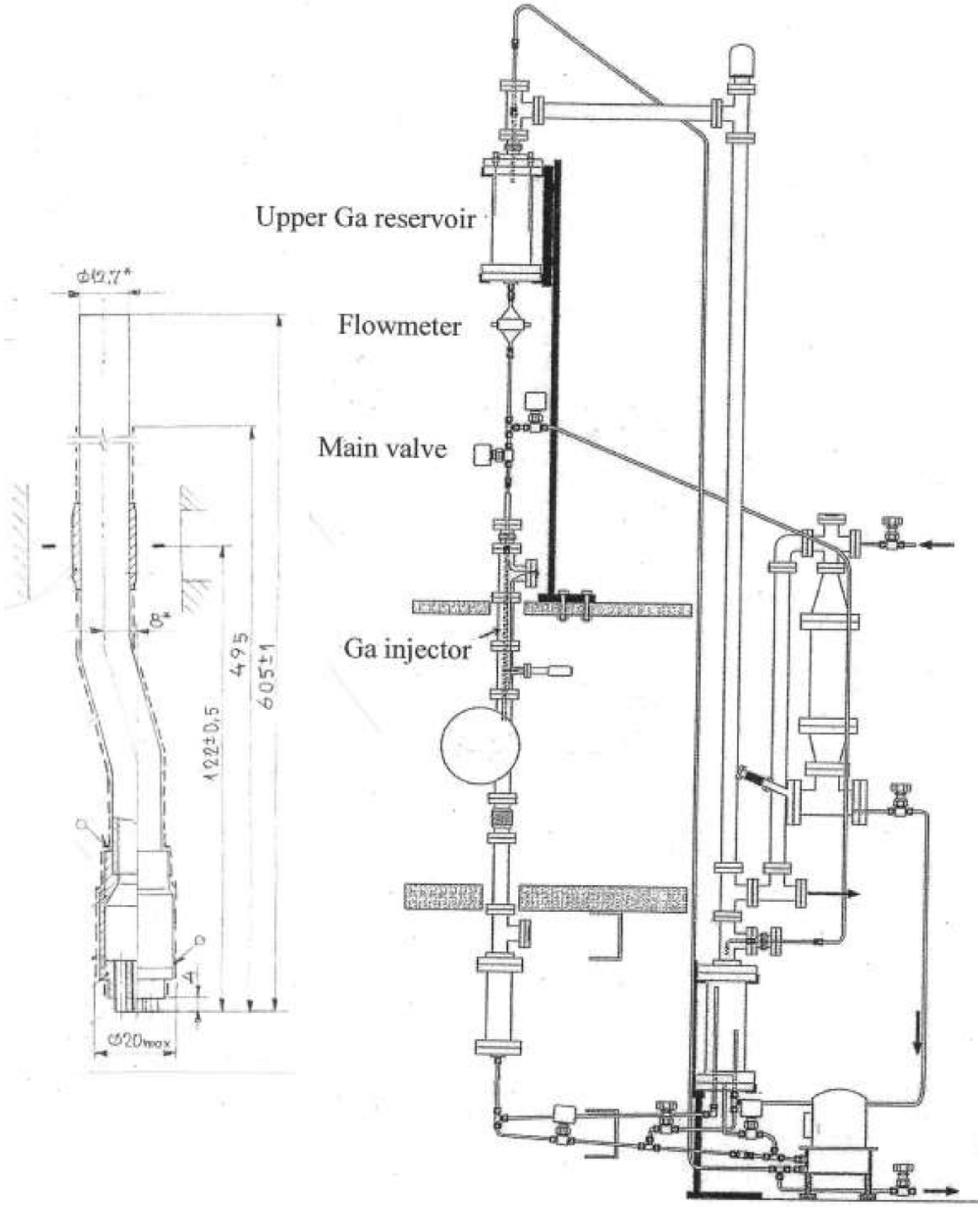

Figure 1. Scheme of Ga limiter installed on ISTTOK and of the new designed multi-jet injector

Flow coefficient c_v

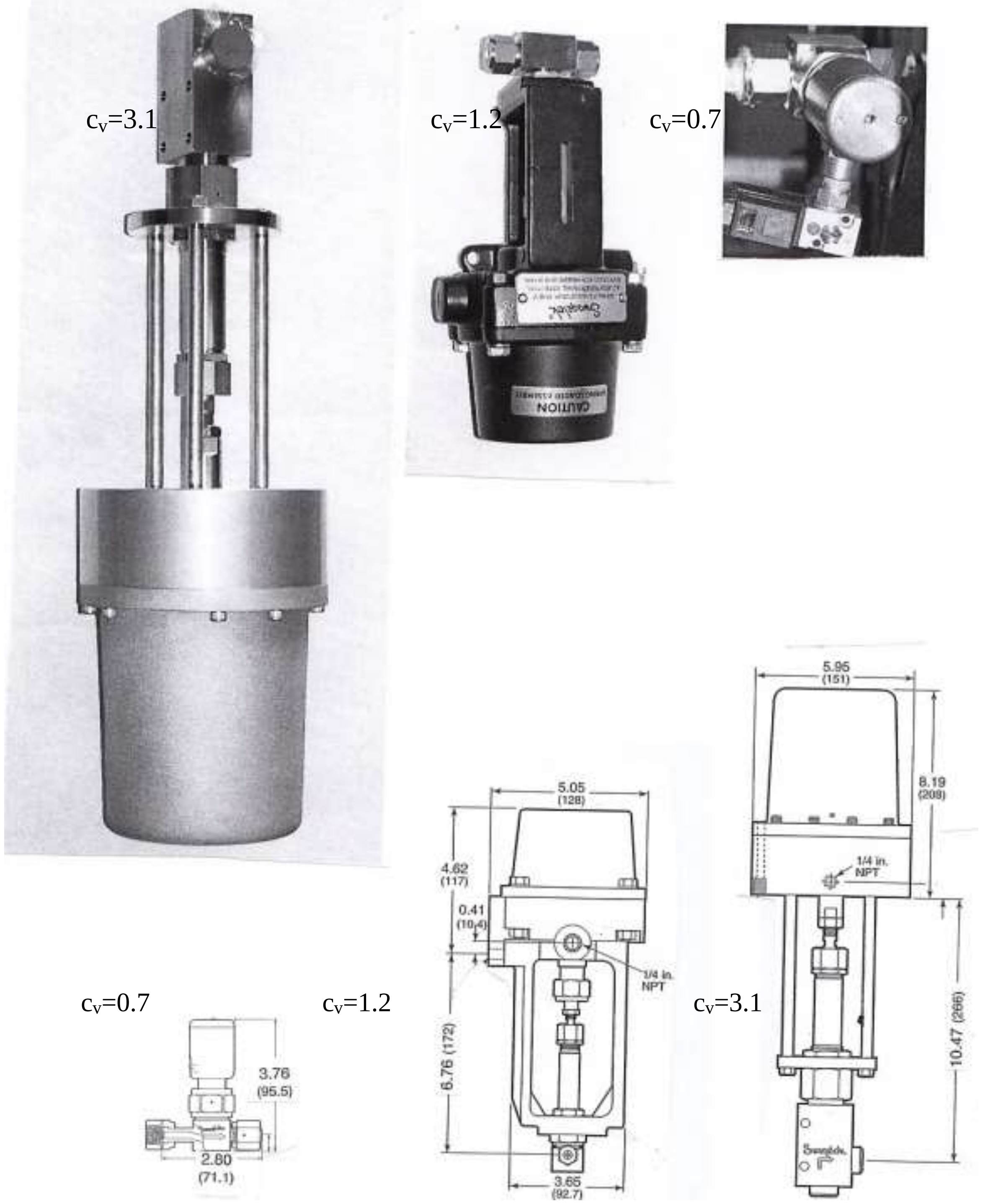

Figure 2. Bellow sealed valves

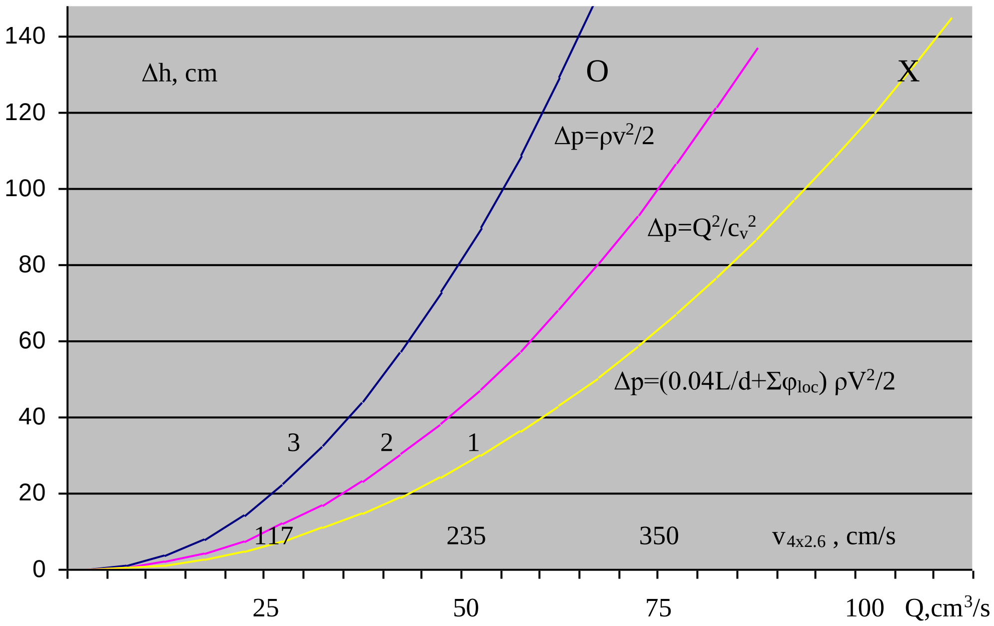

Figure 3. Hydraulic scheme for determination of jets velocity

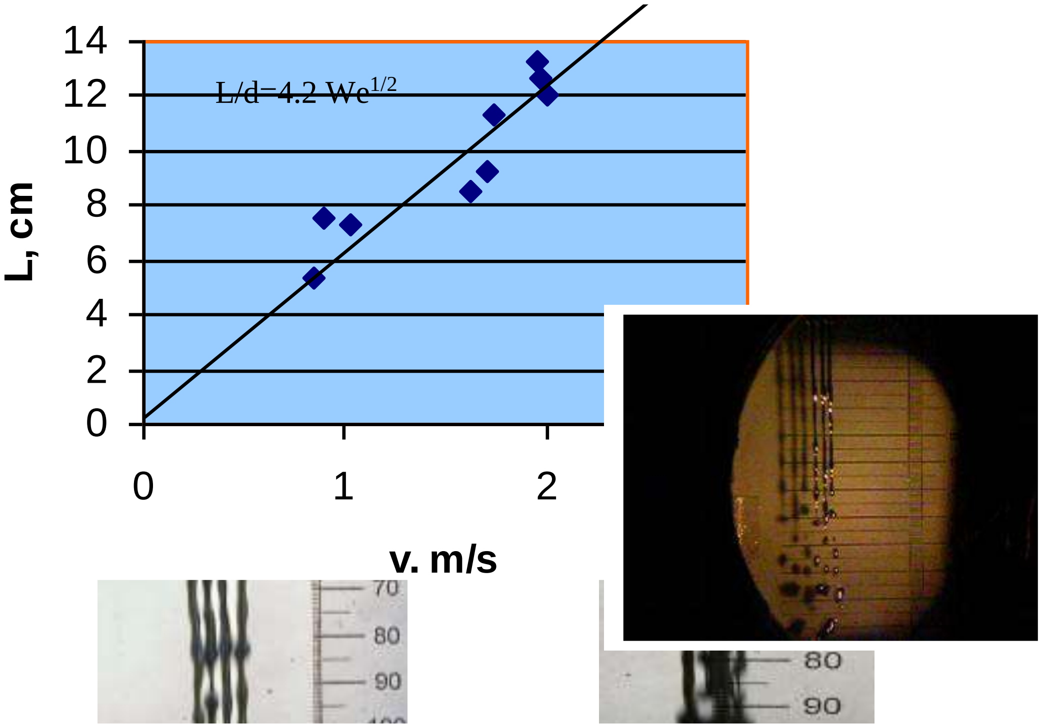

Figure 4. Break-up length in the system of three d=2.5 mm InGaSn jets

Figure 5. a) Version proposed for installation on ISTTOK: four d=2.6 mm jets; BUL ~11 cm; v -2.80 m/s; b) version with five d=2.6 mm jets; BUL -9 cm; v-2.3 m/s

Photo under angle when all the jets can be most transparent seen, scales both for break-up length and side deviation.

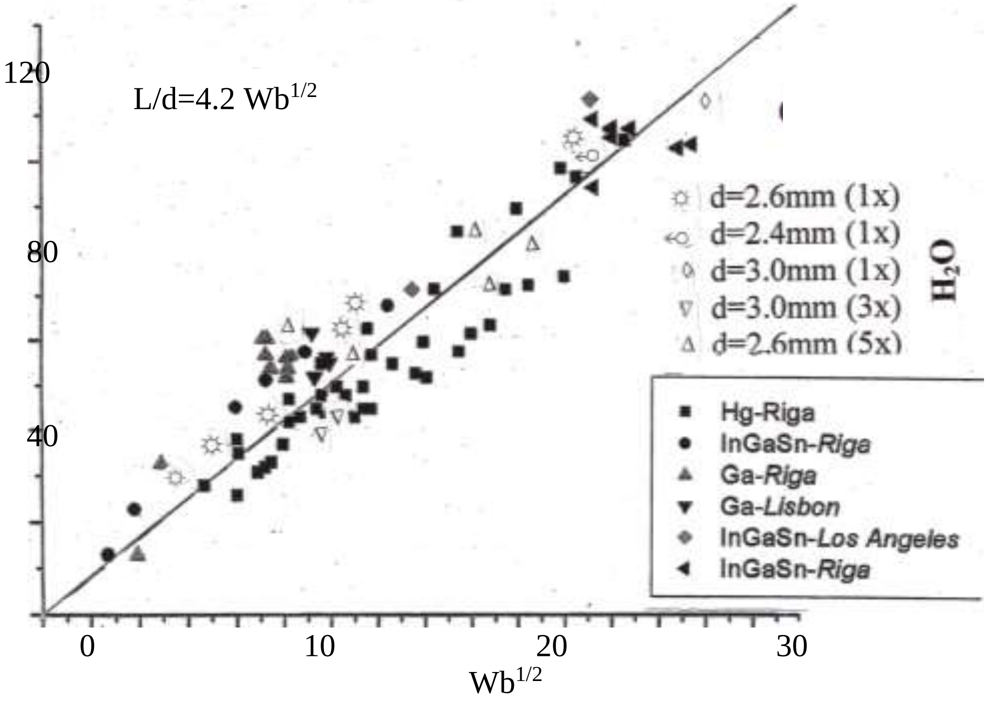

Figure 6. Break-up length of liquid metal and water