The Gas Institute of NAS of Ukraine

- **The JRC/NASU Enlargement Workshop «Materials resistant to extreme conditions for future energy systems»**

NANOFLUIDS FOR EMERGENCY COOLING OF OVERHEATED SURFASES OF POWER EQUIPMENT

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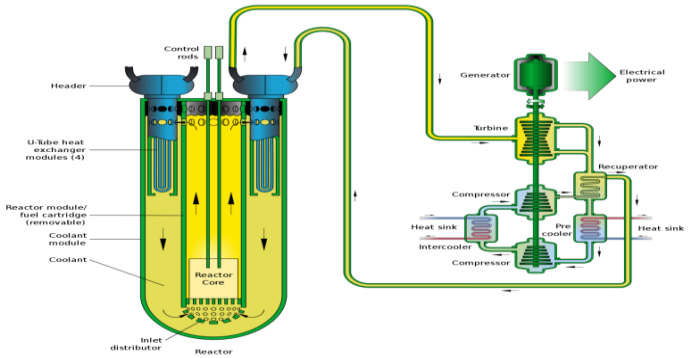
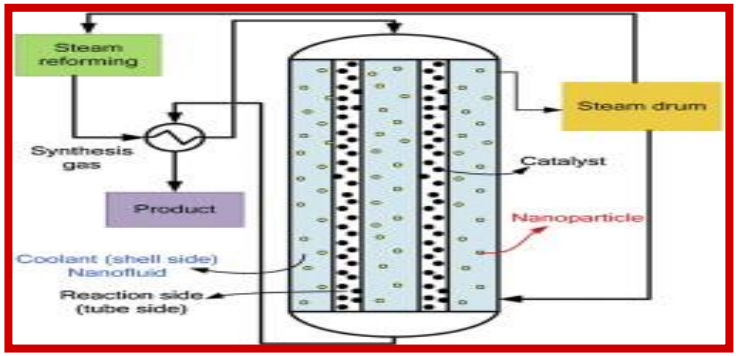
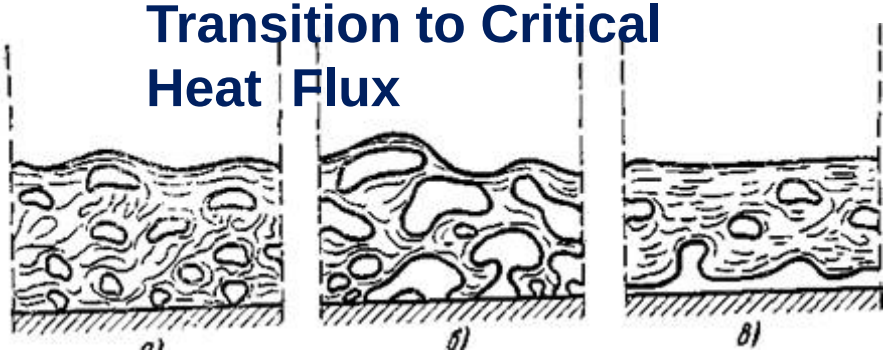
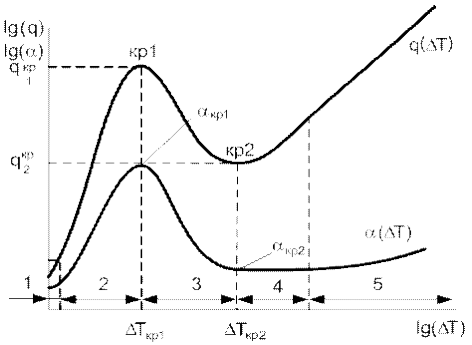
The equipment overheat takes place from time to time in metallurgy, the chemical industry, on transport, in fuel and nuclear power (continuous casting, electronic beam fusion, plasma reactors, Fisher-Tropsh reactors, nuclear reactors, etc)





Transition to Critical Heat Flux





Last two decades in many countries are conducted researches concerning Thermophisical usage of nanofluids (USA, S.Korea, Iran, Egypt, France, Russia, Japan etc.)

Systematic analisis of Thermophisical peculiarities of Nanjfluids were founded by Choi S.U.S. (1995-1999).

Researches of increasing Critical Heat Flux and use this pfenomenon for nuclear reactors cooling are stated in works of prof.J.Bonjorno with co-authors (2005-2016).

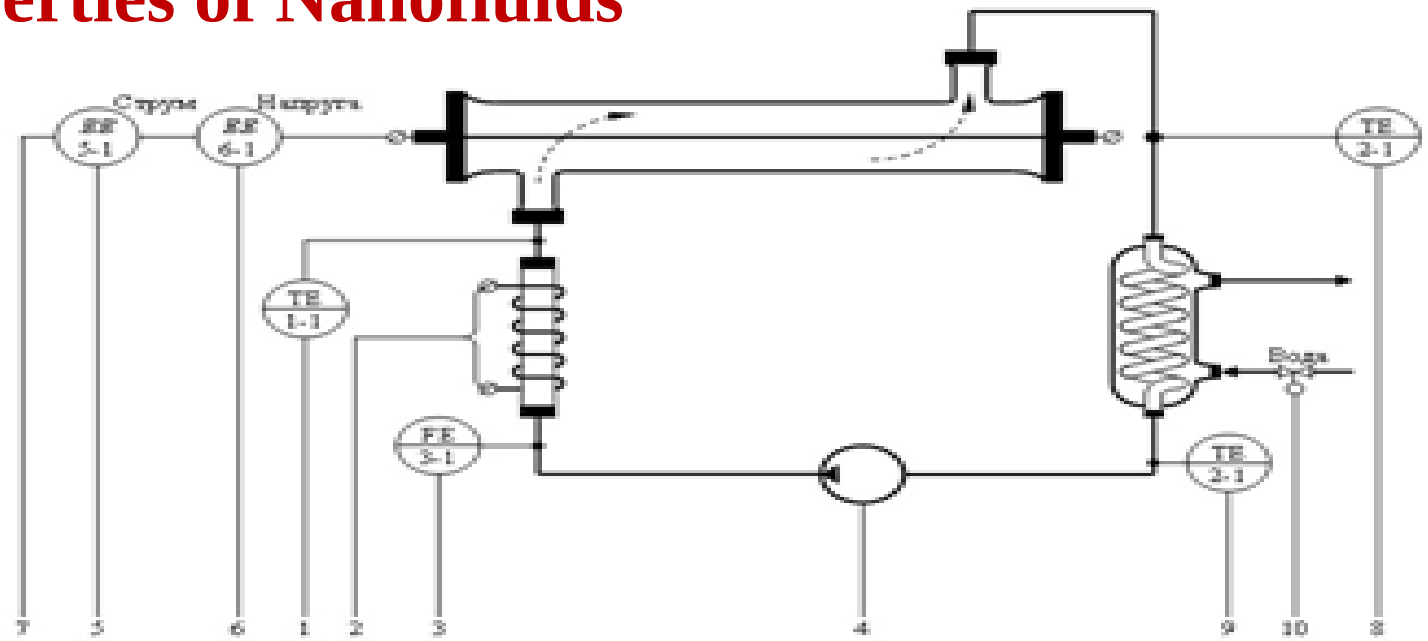
Nanofluid (NF) is the liquid containing particles and agglomerates of particles with the characteristic size of 0,1-100 nanometers. Such liquids represent colloidal solutions of nanoparticles in liquid solvent

We develop a series stable Nanofluids (NF) on a basis metals oxides, natural aluminium silicates, nanodiamods, gas soot, the thermoexpanded graphite and carbon nanotubes (Last two are received by us on our manufacture own pilot manufacture)

Phisico-chemical characteristics of some NF

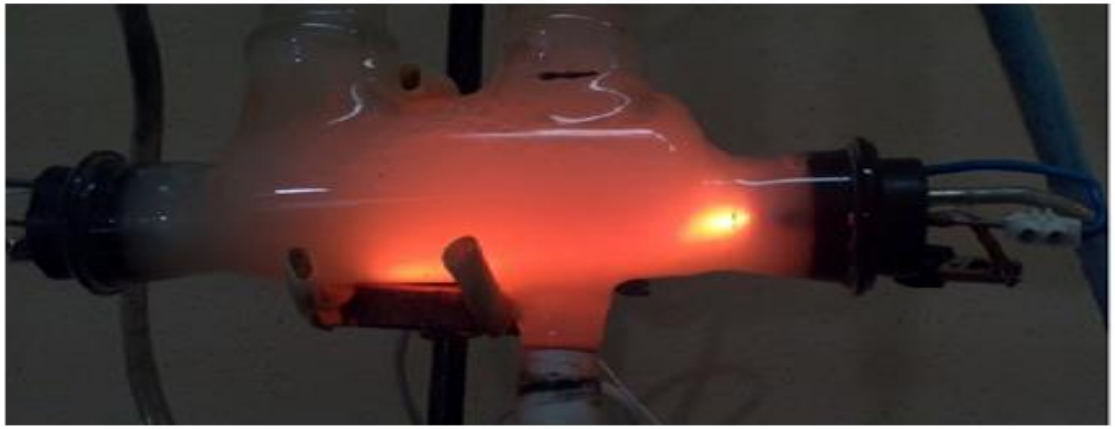
NF	Middle sise, nm	Concentration(vol. %)	Middle coefficient of anysometry (l/d)	Surface tensions under 20^0C σ (mN/m)	pH	Electrocinetics potencial ζ (mV)	Heith of electrocinttics barier, (U/kT)	q_{cr} x10^{-6} (W/ m^2)
Дистильована вода	-	0	-	72.50	6.0	-	-	0.7
AlSi-5	150-500	0.30	200-400	72.5	5.5	-19.8	13	1.7-2.03
AlSi-5dis	50-150	0.30	300-500	65.8	6.7	-57.0	≥50	1.6-2.24
AlSi-6	100-300	0.23	30-100	72.6	5.4	-25.5	14	1.63-2.15
AlSi-6dis	50-150	0.23	30-100	72.2	6.75	-48.0	45	1.35-1.5
AlSi-7a	150-500	0.25	200-500	72.7	5.5	-19.7	12	2.50
AlSi-7dis	50-150	0.25	400-500	71.9	6.75	-57.0	≥50	2.25
NF-8 (TiO_2)	50-100	0.10	1-3	71.8	10.3	-52.5	48	1.35-1.68
ВНТ+стаб.	100-700	0.06	200-700	31.0	5.9	-	-	1.6

The scheme of the laboratory installation for research properties of Nanofluids



Технічні засоби автоматизації місцеві		1 101.5°C ТТ 1-2	2 0÷200 В ЖУ 1-3	3 0÷30 мА/см² РТ 3-2	4 0÷12 В ЖУ 3-3	5 0÷30В ВТ 5-2	6 0÷10 А ВТ 6-2	7 0÷30В ЖУ 7-2	8 200°C ТТ 6-2	9 200°C ТТ 7-2	10 0÷12 В ЖУ 8-2
Функції цифрового приладу	Системна шина	•		•		•		•	•	•	•
	Фільтрація	•		•		•		•	•	•	•
	Нормалізація	•		•		•		•	•	•	•
	Згладжування	•		•		•		•	•	•	•
	Вимірювання	•		•		•		•	•	•	•
	Індикація	•		•		•		•	•	•	•
Функції програмного забезпечення	Реєстрація	•		•		•		•	•	•	•
	Обробка	•		•		•		•	•	•	•
	Корегування										

Measuring cells of computerised installations for research Critical Heat Flux



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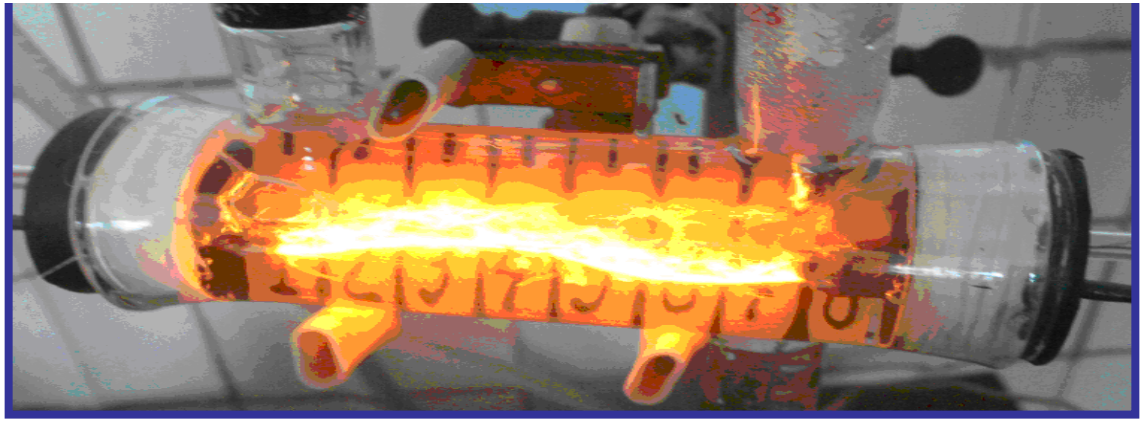
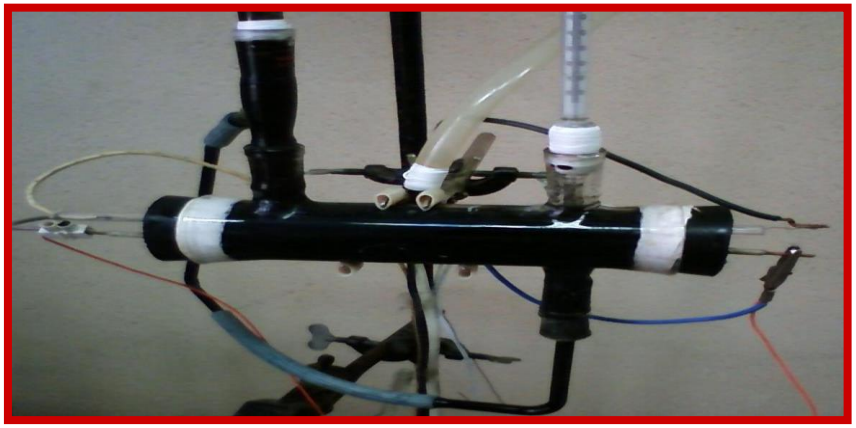
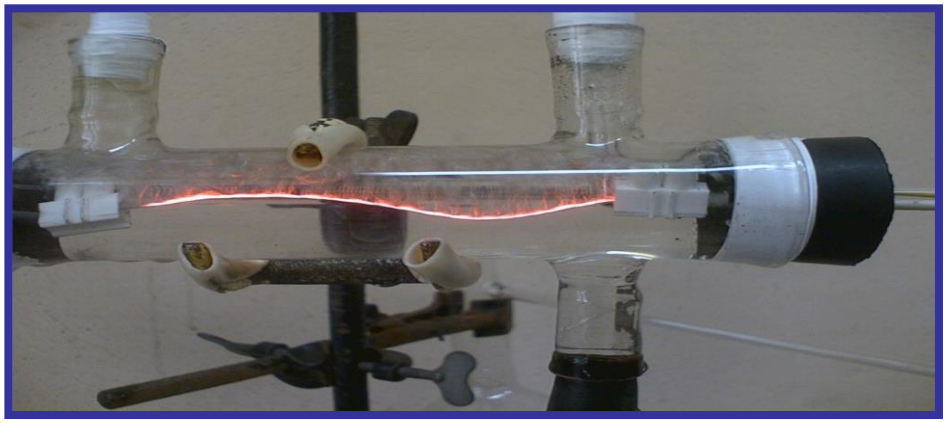
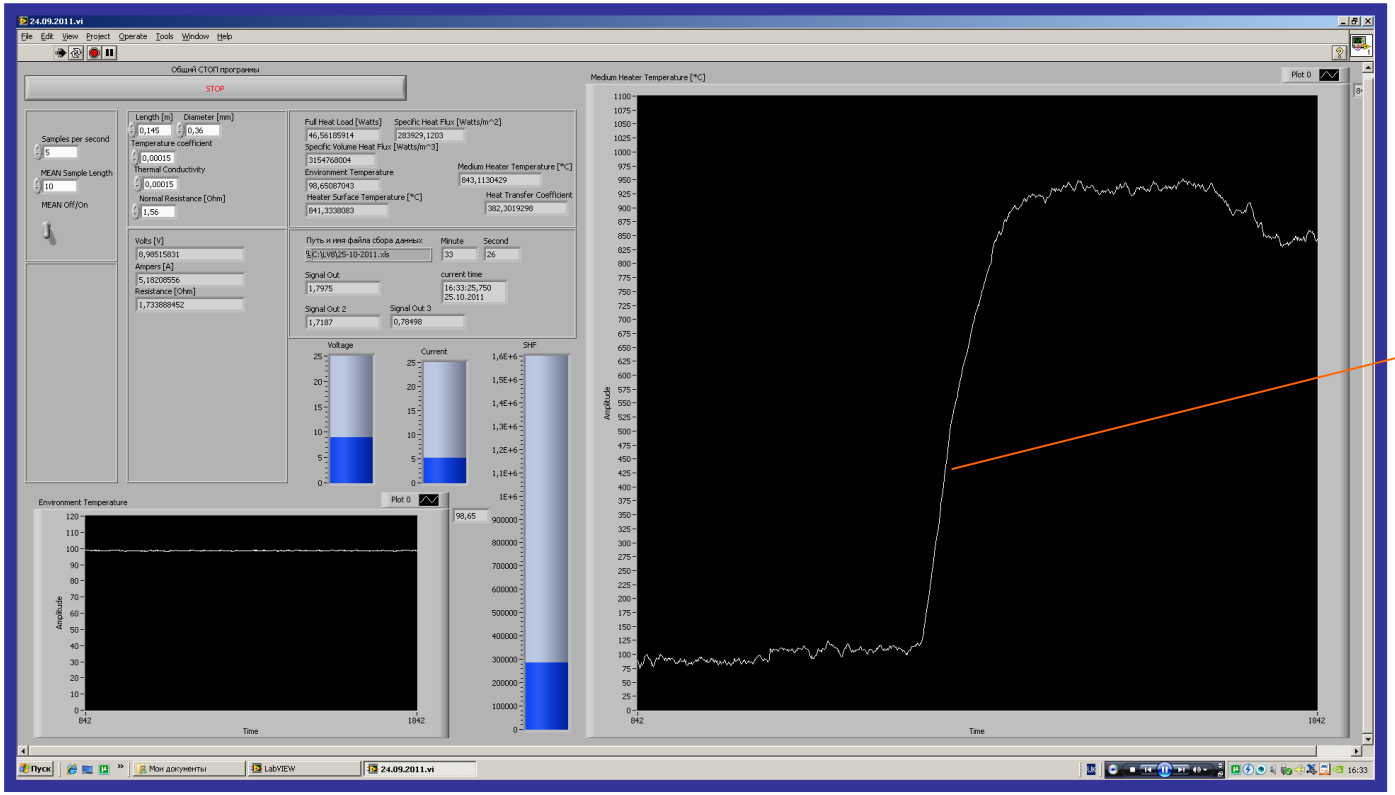






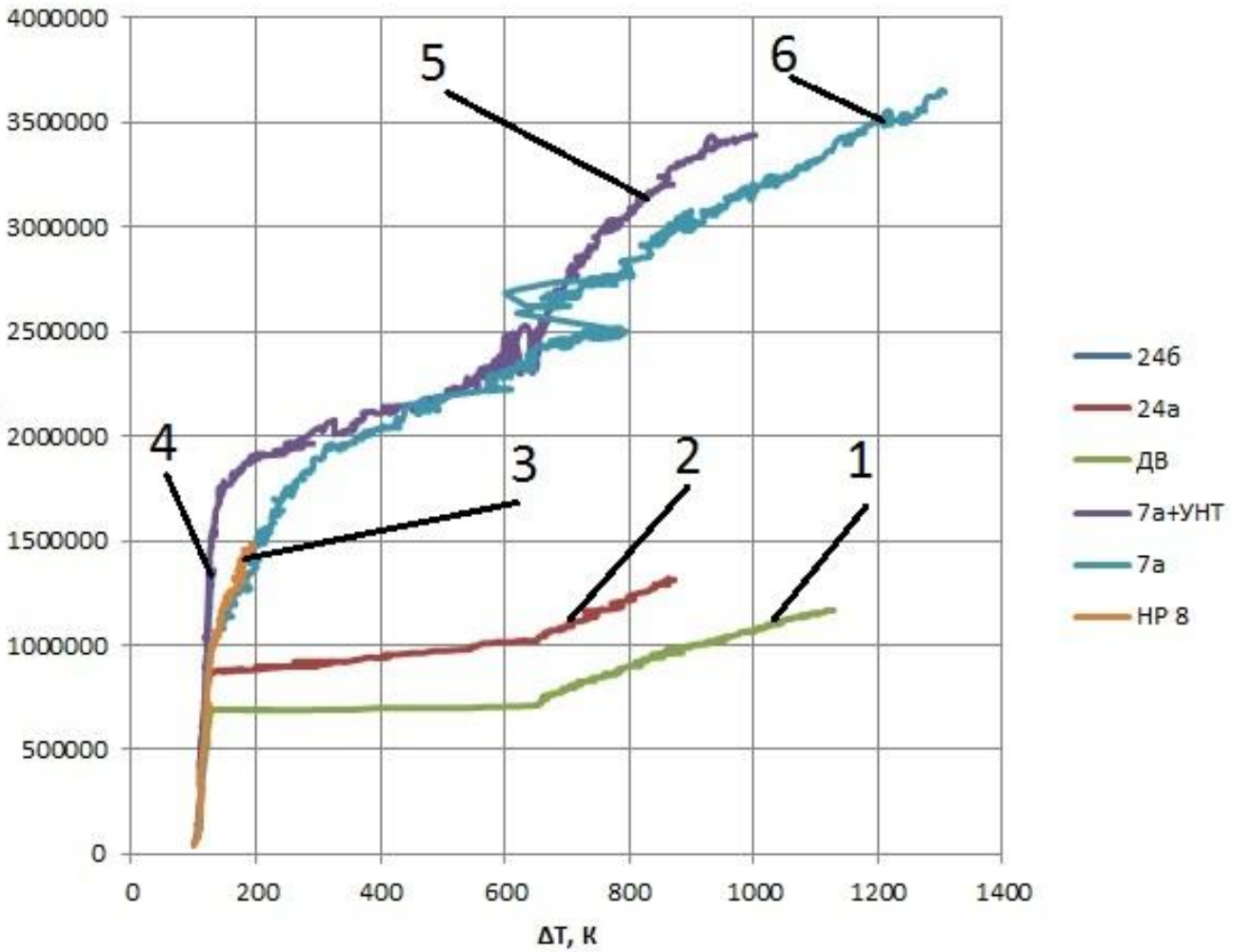
Real Time computerised measurement



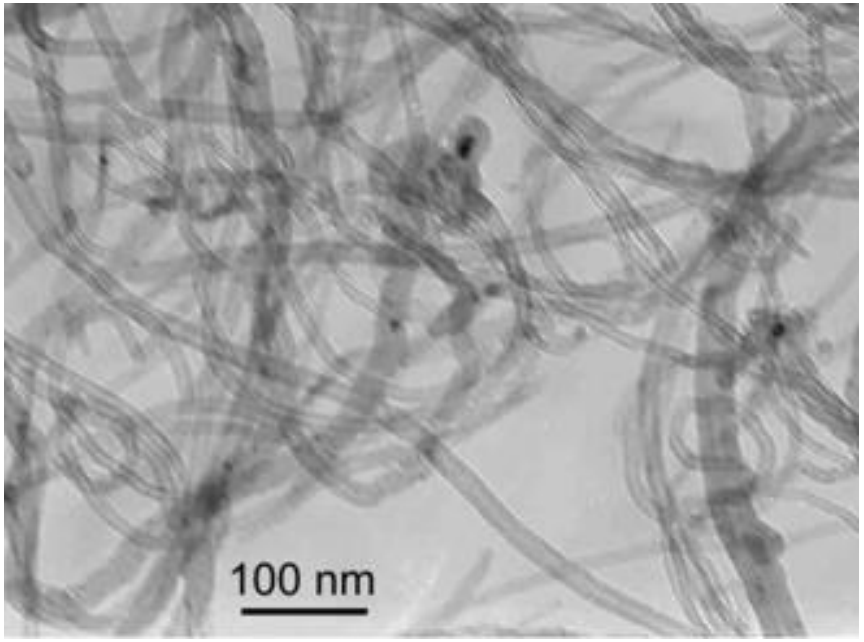
Temperature
Of HEATER
(Crisis of boiling)

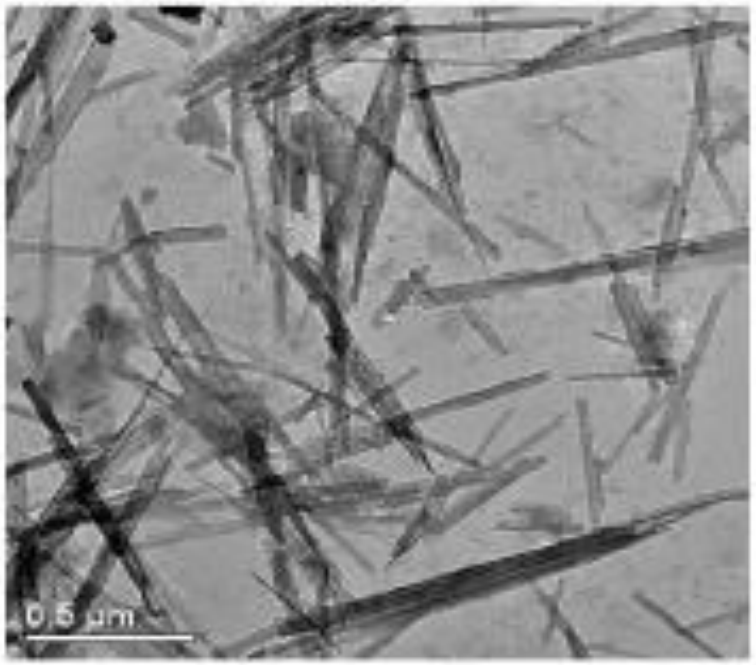
Temerature of boiling
NF

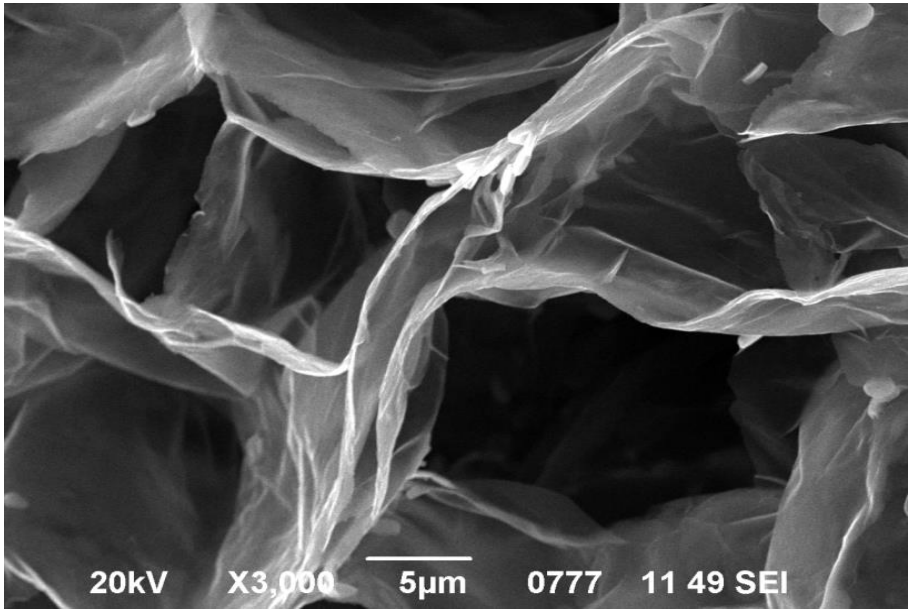
Criical Heat Flux (Vt/sq.m)



Dependence of density of a Heat Flux (vt/sq.m.) from a temperature difference (T=Tw-Tnl): 1-distilled water; 2-NF with Nanodiamond without dispersant; 3-NF on the basis of TiO2; 4 NF with Nanodiamond and dispersant; 5-NF with aluminium silicate and CNT; 6 NF on the basisof aluminium silicate

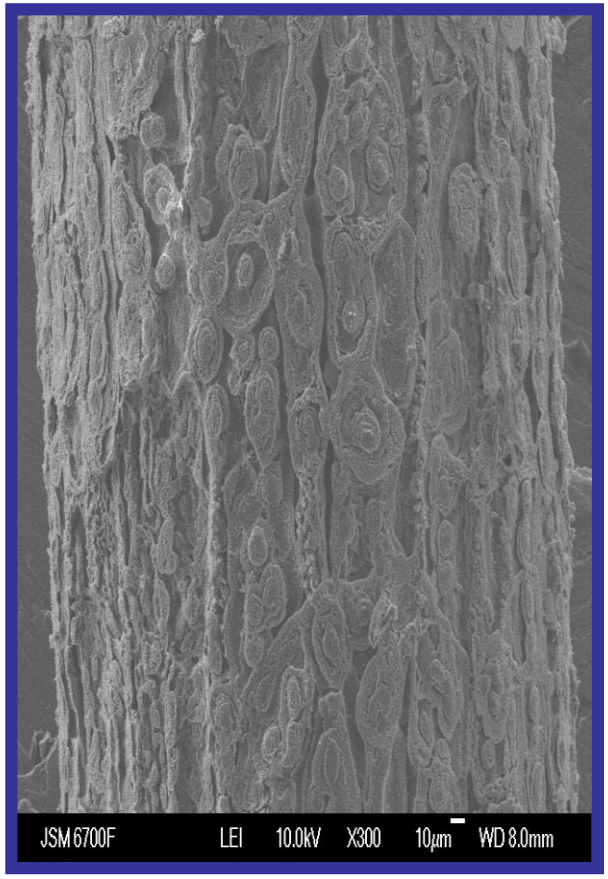


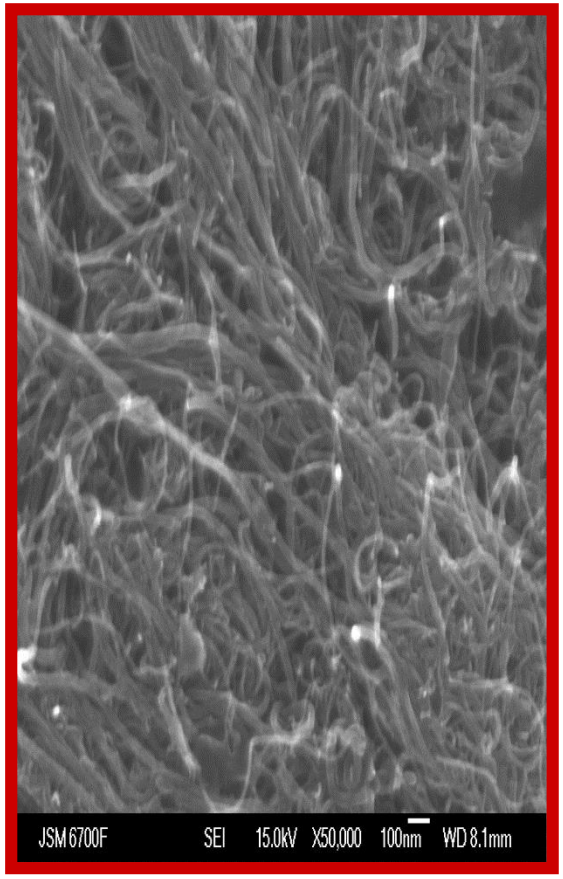


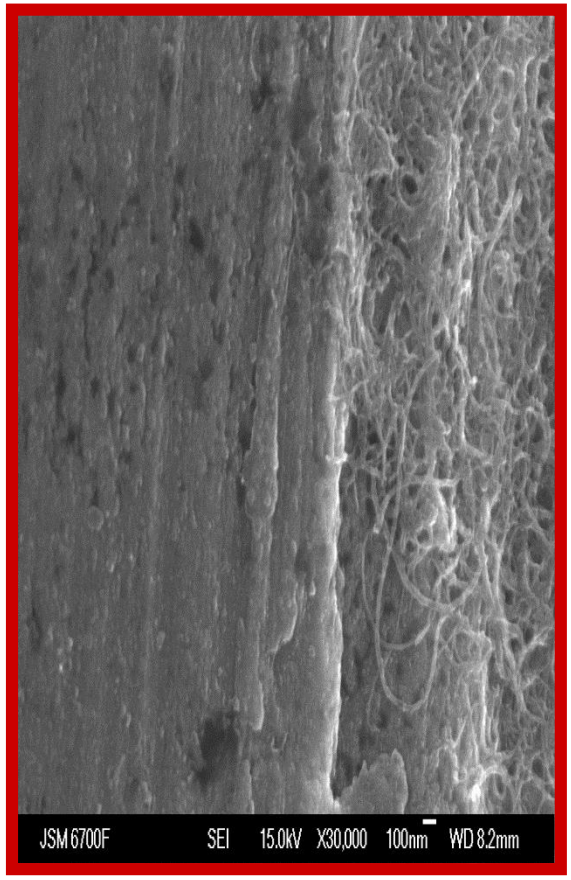


Electron Microscope Imagines of Carbon Nanotubes , Attapulgitte and FLG (Few Layers Graphen)

CNT on Heater after boiling

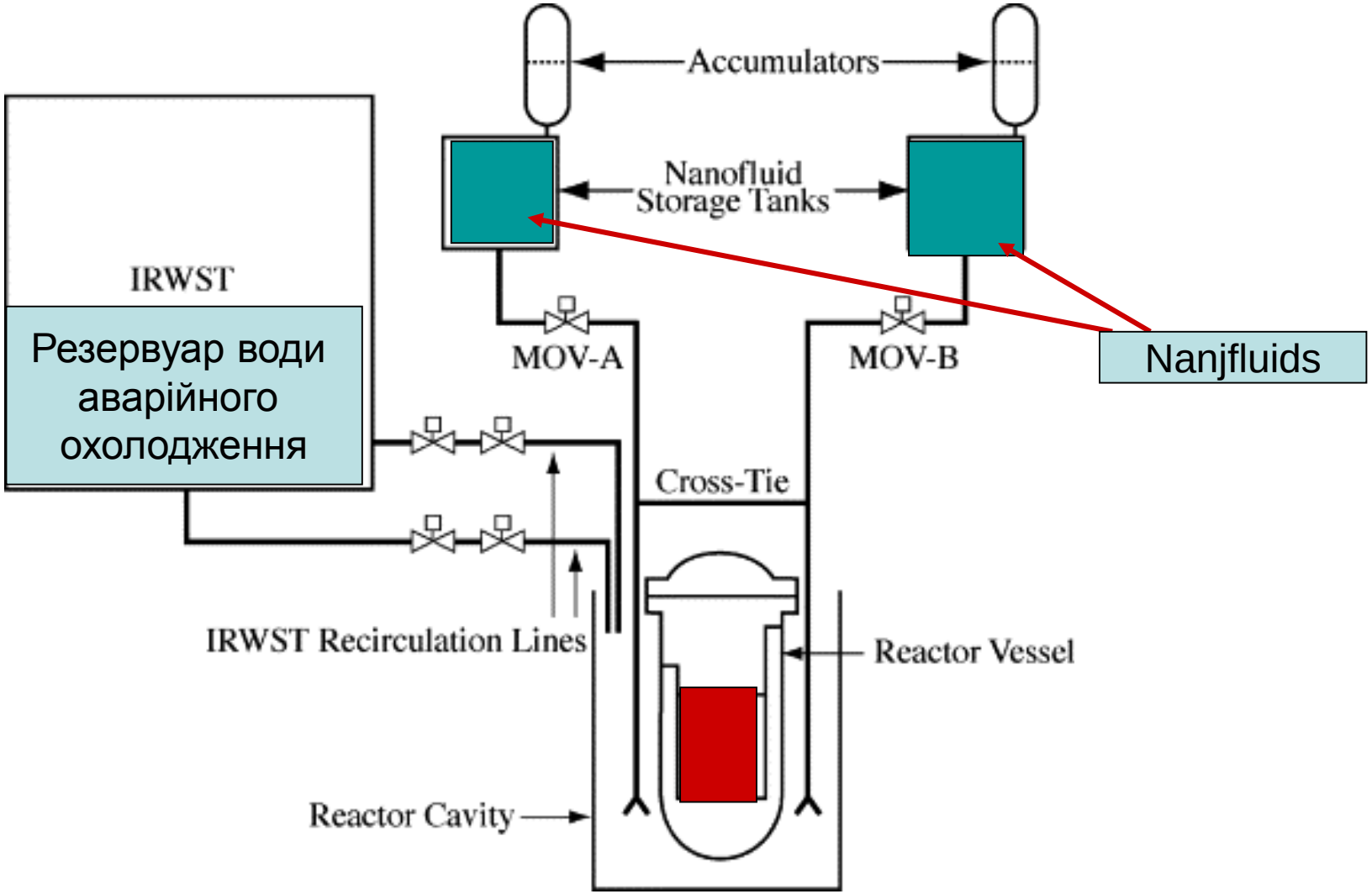




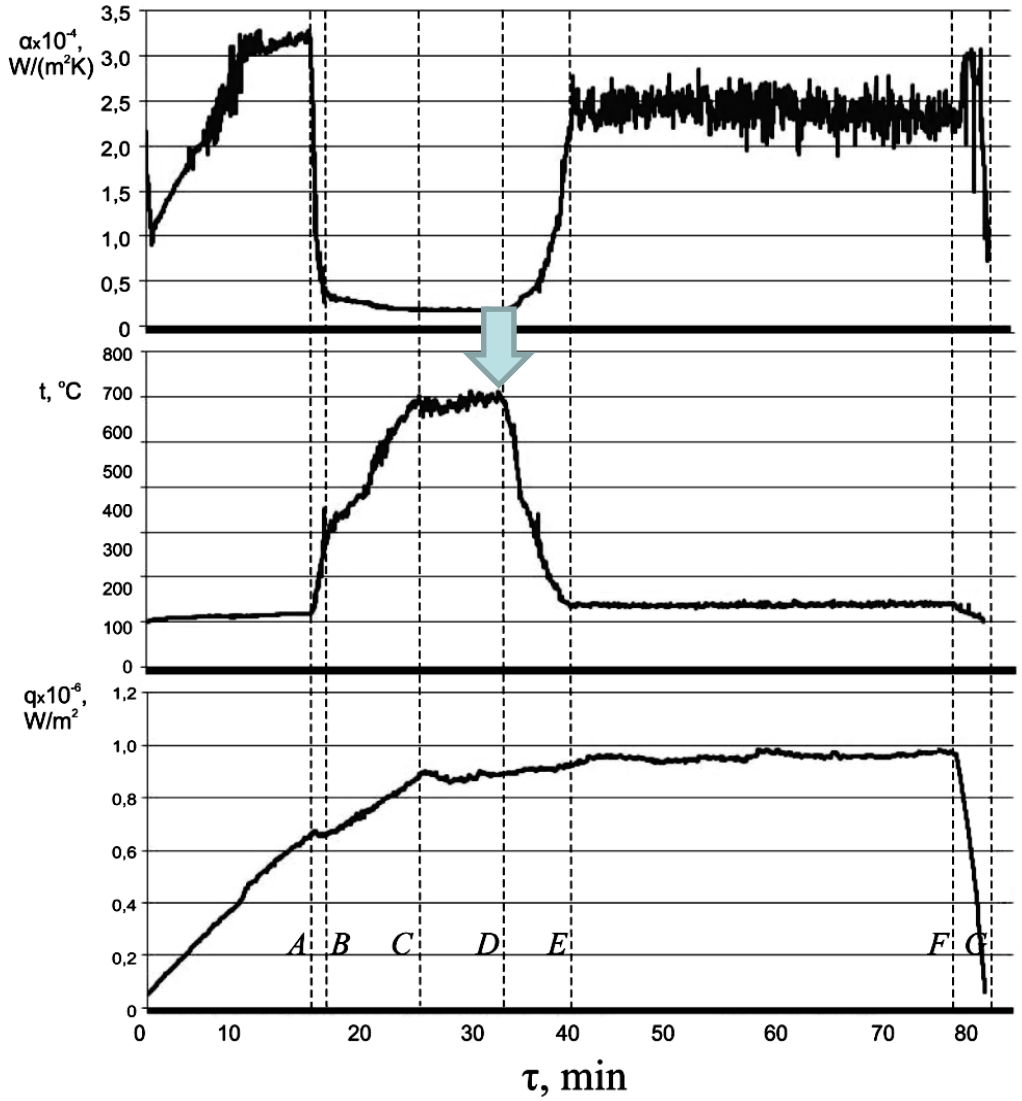


Nano TiO2 on Heater

Nuclear Engineering and Design
Volume 239, Issue 5, May 2009, Pages 941–94



AREVA's Patent: Use of Nanofluids to prevent from Reactor's body meltin



Designations:A- occurrence of crisis of boiling;A-B- a short transitive mode of boiling at which there is a prompt growth of temperature of a surface; D - a heat exchange zone in a film mode of boiling;D – is also a point of addition NF; D - E - decrease temperature of a heater surface and returning to a bubble boiling mode; E - F – stationary bubble boiling mode.F - G - stoppage of experimental installation.

Heat exchange key parametres at boiling of the distilled water and the subsequent addition НЖ-AlSi-7

PUBLICATIONS

- [1] Bondarenko B., Moraru V.*, Sydorenko S., Komysh D., Khovavko A., Snigur A. (2012). Some peculiarities of heat exchange at pool boiling of aluminosilicates-water based nanofluids. Proceedings of the 8th International Symposium on Heat Transfer ISHT-8 October 21-24, 2012, Beijing, China, ISHT8-04-05, pp.181-190.
- [2] Bondarenko B.I, Moraru V.N*., Sydorenko S.V., Komysh D.V., Khovavko A.I. (2012). Nanofluids for Power Engineering: Effect of stabilization on the critical heat flux at boiling. Technical Physics Letters, Vol. 38, No. 9, pp. 853–857.
- [3] Bondarenko B.I., Moraru V.N.*, Ilyenko B.K., Khovavko A.I., Komysh D.V., Panov E.M., Sydorenko S.V., Snigur A.V. (2013). Study of a heat transfer mechanism and critical heat flux at nanofluids boiling. International Journal of Energy for a Clean Environment, 14(2–3), 151–168.
- [4] Bondarenko B.I., Moraru V.N.*, Sydorenko S.V., Komysh D.V. (2015). Nanofluids for Energetics: Role of Some Colloid-Chemical Factors in Pool Boiling Heat Transfer. The 5th International Conference for Colloid and Interface | 21-24 June 2015, Amsterdam, the Netherlands, Abstract Reference Number: COLL2015_0386.
- [5] Bondarenko B.I., Moraru V.N.*, Sydorenko S.V., Komysh D.V., Khovavko A.I. (2016). Nanostructured Architectures on the Heater Surface at Nanofluids Boiling and Their Role in the Intensification of Heat Transfer. Nanoscience and Nanoengineering, Vol.4(1), pp.12-22.
- [6] Bondarenko B.I., Moraru V.N.*, Sydorenko S.V., and Komysh D.V. (2016). Nanofluids for Power Engineering: Emergency Cooling of Overheated Heat Transfer Surfaces. Technical Physics Letters, Vol. 42, No. 7, pp. 675–679.
- [7] Bondarenko B.I., Moraru V.N*., Sydorenko S.V., and Komysh D.V. (2016). Nanofluids for Power Engineering: Emergency Cooling of Overheated Heat Transfer Surfaces. SpringerLink page Nano&SpringerMaterials http://link.springer.com /article/10.1134/S106378501607004X) DOI 10.1134/S106378501607004X.

Summary

System researches are carried out concerning obtaining stable NF on a basis metal oxides, aluminium silicates, MWCNT, FLG-graphene etc.

Are developed and investigated new composite NF allowing to exceed CHF distilled water in 3-4 times.

Carrying out of joint researches of possible application NF in nuclear power and metallurgy is planned.

Thank you for your kind attention