

MEHAANIKATEADUSKOND
SOOJUSTEHNKA INSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2012

1. Instituudi struktuur

Soojustehnika instituut, Department of Thermal Engineering
Instituudi direktor Aadu Paist

- Soojusenergeetika õppetool, Chair of Thermal Power Engineering, Aadu Paist
- Soojusjõuseadmete õppetool, Chair of Thermal Power Equipment, Andres Siirde
- Tööstusliku soojustehnika õppetool, Chair of Heat Engineering, Ivan Klevtsov

2. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

(NB! punktid 2.1- 2.6 täidab struktuuriüksus)

2.1 struktuuriüksuse koosseisu kuuluvate uurimisgruppide

2.1.1 teadustöö kirjeldus *(inglise keeles)*;

Diagnostics and reliability of high pressure equipment of power plants

95% of electricity in Estonia is produced at thermal power plants by firing of oil shale, low-grade local fuel. Most of the units of Narva power plants were built about 50 years ago and all of them have exceeded their design lifetime. Further operation of these units is allowable only if careful metal condition monitoring of the blocks main elements is carried out. In 2012 the investigation of metal condition of the basic components of units 1, 2 and 8 was carried out by Department of Thermal Engineering. These components were main steam piping, hot reheat steam piping, boiler drums, turbine casings and rotors. The research was performed by NDT methods: hardness measurement, investigation of the metal structure (replication), mechanical properties measurement of the metal using miniature tensile specimens sampled from the components, the measurement of creep deformation of the internal rotor boors. Based on the results of the investigation have been issued permission for a certain period of operation till the next mandatory inspection.

Utilization of biomass and wastes

During 2012 two EU financed INTERREG projects „Waste to Traffic Fuel (W-Fuel, VIR442)“ and „The Bioenergy System Planners Handbook (Bisyplan, VIR499)“ were finished. One INTERREG IVA project „Reed for Bioenergy and Construction (COFREEN, VIR464) is continuous.

W-Fuel have three outputs on paper (From Waste to Traffic Fuel, MTT Report 53, 2012, 93 pp, Biogaasi tootmise ja kasutamise pilootuuring Harjumaal, MTT Report 54, 2012 40 pp, Biogaasi tootmise ja kasutamise pilootuuring Lääne-Virumaal, MTT Report 52, 2012 36 pp) and one in project homepage (WP3 Report – Biogas Production, <http://wfuel.info/julkaisut.php>).

During Bisyplan project Internet based “The Bioenergy System Planners Handbook” was blueprinted and uploaded to project web-page (<http://bisyplan.bioenarea.eu/>). In five chapters and for four types of biomass (lingo-cellulose, herbaceous, putrescible and others) all aspects about properties, resources, supply chains, processes and economy were introduced.

During COFREEN project study tour to UK and France took place, presentations on seminars in Estonia and Finland were made. Different types of reed and wood mixed pellets was made in VTT Finland and combustion tests on small scale boiler with these were carried out.

On Conference Investigation and Usage of Renewable Energy Sources (TEUK IX) was presentation “Motor fuel could be soon produced from grasslands’ and animal farms biomass”. This article was issued in Fourteenth Conference Proceedings (Tartu, Estonia, 2012, 16-27 pp).

In magazine Horisont article “Ü. Kask Energeetika – otsapidi tuleviku biomajanduse küljes – Energy – connected in future to bio-economy“ was issued.

Presentation was made and article “The ash fusion characteristics of the blends of reed and wood ashes” in European Bioenergy Conference proceedings was issued (Milano, Italy June 2012).

Much of consultations to entrepreneurs and planners about bio-energy technology and devices were given.

Air emissions

Investigation and optimization of installed DeSO_x units (NIDs) operation at Eesti PP was proceeded. Installed NID units were upgraded with additional lime injection and hydration possibility for cutting down SO₂ emissions to the acceptable level of 400 mg/Nm³.

Air emissions at oil shale co-firing with biomass and peat were determined at the tests on CFB boiler at Balti PP.

New more reliable and correct air emission inventory methodology based on CEMS and fuel supply data was worked out for Narva Power Plants.

Participation on the meetings and discussions on Narva Power Plants pulverized fired boilers deNO_x units tender terms.

Full scale emission measurements, provided for estimation of the environmental impact of OS PF at different regimes, were performed. Two different fuels – OS from open pit and underground mines – were tested. Specific emission of CO₂ rises if limestone added for sulfur binding. If limestone is added into furnace for sulfur capture, the specific emission of SO₂ will drop. Large scale tests to determine the specific emissions of NO_x, SO₂ and CO₂ on PF units while the retort gas fired were carried out.

Regular emission measurements at different boilers and industrial facilities were carried through.

Processes at pulverized (PF) and circulated fluidized bed (CFB) fired boilers

Co-firing of oil shale and peat up to 40% by heat in large CFB boilers was investigated. Changes of heat and mass transfer in fluidizing bed were noted. Relatively short time co-firing experiment does not show big changes in ash composition and properties. Coal and semi-coke co-firing with oil shale is in preparation stage. The relevant tests are arranged on CFB unit of Balti Power Plant in 2013.

The basis of heat and mass transfer

The long-term on-going full scale experiments using heat transfer enhancement techniques developed in TED of TUT were performed in tubular air preheater of 200MW oil shale power unit. The aim of the work is to increase the thermal efficiency of the boilers up to 2% by means of increasing the heat transfer coefficient in gas side. It was found that using compound heat transfer enhancement technique the overall heat transfer coefficient was enhanced up to 70% as compared with the smooth tube. The friction characteristics of the considered inserts were studied in laboratory condition on specially constructed for that purposes test facility.

Power unit performance during load change

The experimental method for determination of the fuel flow rate and corresponding oil shale power unit characteristics during it load change was proposed and experimentally tested. The method is based on the fact that pressure drop of flowing flue gas through convective heat transfer surfaces (HTS) of boiler is proportional to velocity, which is, in turn, proportional to mass fuel rate. Therefore measuring during steady state regime pressure drop, for example, in tubular air pre heater as the HTS which is less susceptible to contamination from particle laden gas flow, and at the same performing and calculating the mass flow rate through indirect heat balance, these two parameters can be interrelated. Obtained in this way semi empirical relation can be then used for determination mass fuel rate during transient regime.

Proposed method was used to determine the technical and economical characteristics of pulverized firing power unit at Eesti Power Plant. For this purpose the large scale experiments were performed.

Oil shale ash properties, ash fields technological problems and environmental impact

Different mixes of ashes from PF, CFB, DeSO_x and ENEFIT are stored in Eesti Power Plant ash field. Mineralogical properties of these ashes are investigated. The samples of petrified ash material

from ash fields were sampled and analysed. Chemical analyses, XRD and CEM were used for determination of ash material properties.

2.1.2 aruandeaastal saadud tähtsamad teadustulemused (*inglise keeles*).

- Empirical methodology for the determination of fuel consumption during transient regime of large oil shale PF boiler
- Meetod plastjäätmete ja põlevkivi koosutmiseks (Method for copyrolysis of plastic wastes and oil shale), 15.08.2012, patent, Arvi Poobus, Laine Tiikma, Allan Vrager, Tõnu Pihu, Siim Link
- Specific air emissions on oil shale co-firing with other fuels (biomass, peat, oil shale processing gas)
- Experimental results of oil shale and peat co-firing are showing, that using the peat up to 40% does not cause any operational problems to boiler availability and efficiency.

2.2 Uurimisgrupi kuni 5 olulisemat publikatsiooni läinud aastal.

- Link, S.; Arvelakis, S.; Paist, A.; Martin, A.; Liliedahl, T.; Sjöström, K. (2012). Atmospheric fluidized bed gasification of untreated and leached olive residue, and co-gasification of olive residue, reed, pine pellets and Douglas fir wood chips. *Applied Energy*, 94, 89 - 97.
- Pihu, T.; Arro, H.; Prikk, A.; Rootamm, R.; Konist, A.; Kirsimäe, K.; Liira, M.; Mõtsep, R. (2012). Oil shale CFBC ash cementation properties in ash fields. *Fuel*, 93, 172 - 180.
- Pihu, T.; Konist, A.; Neshumayev, D.; Loosaar, J.; Siirde, A.; Parve, T.; Molodtsov, A. (2012). Short-term tests on firing oil shale fuel applying low-temperature vortex technology. *Oil Shale*, 29(1), 3 - 17.

2.4 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

Arvo Ots

Ameerika Mehaanikainseneride Assotsiatsiooni liige

Soome Tehnikateaduste Akadeemia Välisliige

Inge Roos

ÜRO Kliimasekretariaadi (UN FCCC, Climate Secretariat) /mittekoosseisuline ekspert kasvuhooonegaaside inventuuri alal

Andres Siirde

Euroopa Komisjoni Sõe Nõuandva töögupi /liige

Maailma Energeetikanõukogu Eesti Rahvuskomitee (WEC-Estonia) juhatuse liige

Alar Konist

Eesti esindaja IEA-s

Sulev Soosaar

Eesti esindaja Euroopa Komisjoni Energeetika ja Transpordi Peadirektoraadi (DG TREN) nõuandvas energiamajanduse analüütikute (*Energy economic analysts*) töögrupis (alates 2009. aastast)/liige

2.5 Aruandeaasta tähtsamad T&A finantseerimise allikad.

1. T024, Energiaressursside säästlik kasutamine ja protsesside täiustamine põletusseadmetes, Ots Arvo
2. AR12003, CO2 heitme vähendamine põlemisõhu hapnikurikkamaks muutmisega keevkihtkatlas, Pihu Tõnu
3. Lep12018, Põlevkivielektrijaamade käiduga seotud soojustehnilised ja keskkonnavalased probleemid, Pihu Tõnu
4. Lep12064, AS Narva elektrijaamade surveeadmete ohutu käitamise tagamise uuringud, Klevtsov Ivan

2.6 Soovi korral lisada aruandeaastal saadud T&A-ga seotud tunnustusi (va punktis 2.3 toodud tunnustused), ülevaate teaduskorralduslikust tegevusest, teadlasmobiilsusest ning anda hinnang oma teadustulemustele.

2.7 Instituudi teadus- ja arendustegevuse teemade ja projektide nimetused (*Eesti Teadusinfosüsteemi, edaspidi ETIS, andmetel*)

- Haridus- ja Teadusministeerium
 - sihtfinantseeritavad teemad:
T024, Energiaressursside säästlik kasutamine ja protsesside täiustamine põletusseadmetes, Ots Arvo (2007 – 2012)
 - baasfinantseerimise toetusfondist rahastatud projektid (sh TTÜ tippkeskused):
B15, Vanemteadur Tõnu Pihu uurimisgrupi toetamine (2012)
- SA Eesti Teadusfond/Eesti Teadusagentuur
 - grandid:
 1. ETF8633, Soojusjõuseadmete metalli seisundi uuringud, Dedov Andrei (2011 – 2014)
 2. ETF9370, Ammooniumi anaeroobse oksüdatsiooniprotsessi alternatiivsed teed ja kasutusvõimalused, Menert Anne (2012 – 2015)
 3. ETF8782, Põlevkiviõli ja elektrienergia koostootmise mudelleerimine, Ots Arvo (2011 – 2014)
 - ühisgrandid välisriigiga:
 - järel doktorite grandid (SA ETF ja Mobilitas):
 1. MJD10, Volkova Anna, Small-scale cogeneration plants in Estonian towns (1.08.2009 - 31.07.2012)
 2. MJD455, Gusca Julija, Integrated Assessment Analysis of Greenhouse Gases Emissions of Estonian Energy Production Sector (1.10.2012 - 31.07.2015)
- SA Archimedesega sõlmitud lepingud
Energiatehnoloogia programm:
 1. AR12003, CO2 heitme vähendamine põlemisõhu hapnikurikkamaks muutmisega keevkihtkatlas, Pihu Tõnu, (2012-2014)

2. AR10126, Energiasüsteemi talitluse optimeerimine muutuvkoormuste tasakaalustamiseks, Arvo Ots, (2011 – 2013)

– muud T&A lepingud:

• Siseriiklikud lepingud:

1. Lep10011, Katla küttepindade saastumise põhjuste väljaselgitamine ja meetmete kavandamine saastumise vähendamiseks Tallinna Elektri jaamas, Konist Alar (1.02.2010 - 31.07.2013)
2. Lep11011, Osalemine Euroopa Komisjoni IEE programmi projektis "Monitoring of the EU and national energy efficiency targets" (akronüüm ODYSSEE-MURE 2010), Soosaar Sulev (8.02.2011 - 1.07.2012)
3. Lep11003, AS Tallinna Küte kaugküttevõrkude olemasoleva olukorra hinnang ja renoveerimise arengukava aastani 2020, Kask Ülo (6.01.2011 – 30.06.2012)
4. Lep12018, Põlevkivielektri jaamade käiduga seotud soojustehniliste ja keskkonnaalaste pürobleemide lahendamine, Pihu Tõnu (1.01.2012 - 31.12.2012)
5. Lep12032, Tehniline ja majanduslik hinnang vedelkütusel töötavate katlamajade üleviimiseks veeldatud maagaasi kasutamisele, Siirde Andres (10.02.2012 - 15.06.2012)
6. Lep12037, Puidu gaasistamise seadme eeluuring, Kask Ülo (29.02.2012 - 31.12.2012)
7. Lep12064, Eesti Energia Narva Elektri jaamade AS surveseadmete ohutu käitamise tagamise uuringud, Klevtsov Ivan (1.04.2012 - 31.03.2013)
8. Lep 12072, Balti EJ juurde soojuse akumulatsioonipaagi ehitamine ja ühendamine kaugküttevõrguga, Hlebnikov Aleksandr (09.04.2012 – 29.06.2012)
9. Lep12081, Turbulaatorite kasutamine soojusülekanne intensiivistamiseks põlevkivikatelde õhuelsoojendis II, Nešumajev Dmitri; Ots, Arvo; Poobus, Arvi (2.05.2012 - 31.03.2013)
10. Lep12142, Raamatu "Tahkekütuse keevkihtpõletustehnika" koostamine, Arvo Ots (3.09.2012 - 31.10.2014)
11. Lep 12143, Uuring arendustegevusena energiamajanduse arengukava koostamiseks kaugküttepiirkonnale, et kasutada koostatud energiakava kohaliku omavalitsuse ametnikele ja töötajatele koolituse alusmaterjalina, Kask Ülo (07.09.2012-01.05.2013)
12. Lep 12176, Pakri Energiavõrk energia ressursside, salvestustehnoloogia ja tasuvuse uuring, etapp nr.1, Kask Ülo (10.2012-01.04.2013)
13. Lep 12185, Vaivara valla kaugküttele põhineva soojusmajanduse arengukava aastateks 2013-2022, Hlebnikov Aleksandr (01.11.2012-15.02.2013)
14. Lep12192, Lubja sisseande süsteemi vastuvõtu katsed plokkidel 3, 4, 5 ja 6, Loosaar Jüri (17.12.2012 – 30.03.2013)
15. Lep7015, AS Narva elektri jaamade surveseadmete ohutu käitamise tagamise uuringud, Klevtsov Ivan (1.04.2007 - 31.03.2012)

• Välisriiklikud lepingud:

1. VIR417, Bioenergia kasutamise edendamine Balti mere äärses riikides, Roos Inge (2.03.2009 - 24.01.2012)
2. VIR442, Waste to Traffic Fuel, Kask Ülo (01.09.2009 – 30.04.2012)

3. VIR464, Pilliroo kui kohaliku ehitusmaterjali ja bioenergia allika kasutamise kontseptsioon, Kask Ülo (1.05.2010 - 30.04.2013)
4. VIR499, Bioenergiasüsteemide planeerijate käsiraamat, Kask Ülo (1.01.2011 - 30.09.2012)

2.8 Struktuuriüksuse töötajate poolt avaldatud eelretsenseeritavad teaduspublikatsioonid (*ETIS klassifikaatori alusel 1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1 ja 5.1*).

1.1

1. Link, S.; Arvelakis, S.; Paist, A.; Martin, A.; Liliedahl, T.; Sjöström, K. (2012). Atmospheric fluidized bed gasification of untreated and leached olive residue, and co-gasification of olive residue, reed, pine pellets and Douglas fir wood chips. *Applied Energy*, 94, 89 - 97.
2. Roos, I.; Soosaar, S.; Volkova, A.; Streimikene, D. (2012). Greenhouse gas emission reduction perspectives in the Baltic States in frames of EU energy and climate policy. *Renewable & Sustainable Energy Reviews*, 16(4), 2133 - 2146.
3. Raukas, Anto; Siirde, Andres. (2012). New trends in Estonian oil shale industry. *Oil Shale*, 29(3), 203 - 205.
4. Pihu, T.; Arro, H.; Prikk, A.; Rootamm, R.; Konist, A.; Kirsimäe, K.; Liira, M.; Mõtlep, R. (2012). Oil shale CFBC ash cementation properties in ash fields. *Fuel*, 93, 172 - 180.
5. Pihu, T.; Konist, A.; Neshumayev, D.; Loosaar, J.; Siirde, A.; Parve, T.; Molodtsov, A. (2012). Short-term tests on firing oil shale fuel applying low-temperature vortex technology. *Oil Shale*, 29(1), 3 - 17.

1.2

6. Ots, A. (2012). Fusibility and sintering characteristics of ash. *Power Technology and Engineering*, 45(6), 460 - 465.

1.3

2.1

2.2

7. Kallaste, T.; Laur, A.; Menert, A.; Pädam, S.; Kask, Ü.; Andrijevskaja, J.; Kask, L.; Heinla, P. (2012). Biogaasi tootmise ja kasutamise pilootuuring Harjumaal. Jäätmed mootorikütuseks, projekt „From Waste to Traffic Fuel“ (W-Fuel) . MTT Agrifood Research
8. Kask, Ü.; Andrijevskaja, J.; Kask, L.; Heinla, P.; Kallaste, T.; Laur, A.; Menert, A.; Pädam, S. (2012). Biogaasi tootmise ja kasutamise pilootuuring Lääne-Virumaal. Jäätmed mootorikütuseks, projekt „From Waste to Traffic Fuel“ (W-Fuel) . MTT Agrifood Research
9. Kask, Ü.; Andrijevskaja, J.; Kask, L.; Heinla, P.; Hüüs, M.; Kallaste, T.; Laur, A.; Menert, A.; Pädam, S.; Rasi, S.; Heino, E.; Ahonen, S.; Martinen, S.; Heinilä, E.-A.; Teerioja, N. (2012). From Waste to Traffic Fuel (W-Fuel). MTT Agrifood Research

3.1

10. Volkova, A.; Hlebnikov, A.; Siirde, A. (2012). Simulation of the Accumulator Tank Coupled with the Power Unit of Power Plant under the Conditions of Open Electricity Market. In: *Chemical Engineering Transactions: 15th Conference "Process integration, modelling and optimisation for energy saving and pollution reduction"*. (Toim.) P. S. Varbanov, H. L. Lam, J. J. Klemeš. AIDIC, 2012. [ilmumas]

3.2

11. Dedov, A.; Klevtsov, I. (2012). Comparison of direct and indirect methods of tensile properties determination for post-exposed power plant steels. Proceedings of the 23rd International DAAAM Symposium, Volume 23, No.1, 24-27 October, Zadar, Croatia (95 - 98).DAAAM International
12. Klevtsov, I.; Dedov, A.; Bogolyubova, E. (2012). Impact of small specimens sampling on durability of in-service power plant components. Proceedings of 2nd International Conference SSTT, October 2-4, 2012, Ostrava, Czech Republic (373 - 378).OCELOT s.r.o.
13. Link, S.; Kask, Ü.; Lausmaa, T.; Paist, A.; Kask, L.; Arvelakis, S. (2012). Ash Fusion Characteristics of the Blends of Reed and Wood Ashes. In: Proceedings of the 20th European Biomass Conference and Exhibition: 20th European Biomass Conference and Exhibition, Milan, Italy, 18-22 June 2012. ETA-Florence Renewable Energies, 2012, 1316 - 1319.
14. Volkova, A.; Mašatin, V.; Hlebnikov, A.; Siirde, A. (2012). Methodology for the Improvement of Large District Heating Networks. In: Proceedings of ECOS 2012: The 25th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, June 26-29, 2012, Perugia, Italy. Firenze University:, 2012, 46-1 - 46-13.

3.3

4.1

5.1

2.9 Struktuuriüksuses kaitstud doktoriväitekirjade loetelu (*NB! struktuuriüksus lisab struktuuriüksuse töötaja juhendamisel mujal kaitstud doktoriväitekirjade loetelu*)

Kristjan Plamus, soojustehnika instituut

Teema: *The Impact of Oil Shale Calorific Value on CFB Boiler Thermal Efficiency and Environment* (Põlevkivi kütteväärtuse mõju keevkihtkatla efektiivsusele ja keskkonnale)

Juhendajad: vanemteadur Tõnu Pihu ja vanemteadur Dmitri Nešumajev

Kaitses: 28.06.2012

Omistatud kraad: filosoofiadoktor (soojusenergeetika)

2.10 Struktuuriüksuses järel doktorina T&A-s osalenud isikute loetelu (*ETIS-e kaudu esitatud taotluste alusel*)

1. **Volkova Anna**, Small-scale cogeneration plants in Estonian towns (1.08.2009 - 31.07.2012)
2. **Gusca Julija**, Integrated Assessment Analysis of Greenhouse Gases Emissions of Estonian Energy Production Sector (1.10.2012 - 31.07.2015)

2.11 Struktuuriüksuses loodud tööstusomandi loetelu

EE05564B1

Meetod plastjäätmete ja põlevkivi koosutmiseks

Patent välja antud: 15.08.2012

Autorid: Arvi Poobus, Laine Tiikma, Allan Vragar, Tõnu Pihu, Siim Link.

Omanik: TTÜ

3. Struktuuriüksuse infrastruktuuri uuendamise loetelu (*summa eurodes*)

PV007282, Hapniku andur 18.01.2012, (5 996,00)

PV007283, Hapniku andur , 18.01.2012 (5 996,00)

PV007331, Seade turbiini rootori, 7.03.2012 (16 189,00)

PV007356, Termokaamera FLIR E40, 25.04.2012 (3 150,00)

PV007439, Fritsch ettevalmistamise kompl, 28.08.2012 (39 353,00)

Kokkuvõtteks võib instituudi T&A tegevust 2012 aastal hinnata heaks.