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Editors

Burhan ÇUHADAROĞLU
Ömer Necati CORA

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Keynote Speakers

Assoc. Prof. Hafiz Muhammad ALI
Topic: "Surface Condenser: Heat Transfer"



Dr. Hafiz Muhammad Ali, an associate professor of Mechanical Engineering at King Fahd University of Petroleum and Minerals, Saudi Arabia, received his Ph.D degree from Mechanical Engineering, Queen Mary, University of London, United Kingdom in 2011. He was a post-doc at Water and Energy Laboratory, University of California at Merced, United States during 2015-16 period. Dr. Ali is a noted faculty member having thermal sciences, heat transfer and solar energy as areas of interest. Over the years, he has supervised several undergraduate and postgraduate students and his work, more than 230 papers (h-index: 40, citations: +5000 according to Google Scholar), have been featured in various reputed international journals. Dr Ali has also represented his institution and Pakistan at several international and national conferences as an invited speaker and delivered numerous keynote talks. His other research interests include electronics cooling, condensation, nanofluids, heat transfer devices, thermal management. He is the recipient of the 'Best Young Research Scholar Award' for 2017 in the Engineering category. He was conferred the honor at the 7th HEC Outstanding Research Award Ceremony held the other day. The award is of immense value to scholars competing for the honor as there is only one award reserved in the Engineering Category for 'Best Young Research Scholar' across all of Pakistan. Dr Ali has also had the honor of receiving HEC's Best Research Paper Award (2013/2014) and Research Productivity Award by Pakistan Council of Science and Technology (2016-17).

Prof. Frede BLAABJERG
Topic: "Wind Power – A Technology Enabled by Power Electronics"



Frede Blaabjerg (S'86–M'88–SM'97–F'03) was with ABB-Scandia, Randers, Denmark, from 1987 to 1988. From 1988 to 1992, he got the PhD degree in Electrical Engineering at Aalborg University in 1995. He became an Assistant Professor in 1992, an Associate Professor in 1996, and a Full Professor of power electronics and drives in 1998. From 2017 he became a Villum Investigator. He is honoris causa at University Politehnica Timisoara (UPT), Romania and Tallinn Technical University (TTU) in Estonia. His current research interests include power electronics and its applications such as in wind turbines, PV systems, reliability, harmonics and adjustable speed drives. He has published more than 600 journal papers in the fields of power electronics and its applications. He is the co-author of four monographs and editor of ten books in power electronics and its applications. He has received 33 IEEE Prize Paper Awards, the IEEE PELS Distinguished Service Award in 2009, the EPE-PEMC Council Award in 2010, the IEEE William E. Newell Power Electronics Award 2014, the Villum Kann Rasmussen Research Award 2014, the Global Energy Prize in 2019 and the 2020 IEEE Edison Medal. He was the Editor-in-Chief of the IEEE TRANSACTIONS ON POWER ELECTRONICS from 2006 to 2012. He has been distinguished Lecturer for the IEEE Power Electronics Society from 2005 to 2007 and for the IEEE Industry Applications Society from 2010 to 2011 as well as 2017 to 2018. In 2019-2020 he served as a President of IEEE Power Electronics Society. He has been Vice-President of the Danish Academy of Technical Sciences. He is nominated in 2014-2020 by Thomson Reuters to be between the most 250 cited researchers in Engineering in the world.

Assoc. Prof. Barbaros ÇETİN
Topic: "Grooved Heat Pipes: Modeling, Experimentation and Applications"



Dr. Barbaros Çetin received his B.S. (2002) and M.S. (2005) in Mechanical Engineering at Middle East Technical University, Ankara, Turkey. He received his PhD (2009) in the Department of Mechanical Engineering at Vanderbilt University where he focused on electrokinetic transport and particle manipulation in lab-on-a-chip devices for biomedical applications. Following his PhD, he became a faculty member in Middle East Technical University-Northern Cyprus Campus Mechanical Engineering Program. In 2011, he became a faculty member in the Mechanical Engineering Department at I.D. Bilkent University, Ankara, Turkey. His current research interests include particle manipulation for microfluidic application, modeling of particle motion using boundary element method, and modeling, fabrication and experimentation of flat-grooved heat pipes. Dr. Çetin is the recipient of the 2015 Bilkent University Distinguished Teacher Award, 2017 Outstanding Young Scientist Award of the Turkish Academy of Sciences (TÜBA-GEBİP), 2017 METU Prof. Dr. Mustafa N. Parlar Research Incentive Award and 2018 Science Academy Distinguished Young Scientist Award (BAGEP).

Prof. Orhan DURGUN
Topic: "Recent Situation of Energy on the World and Turkey and some Solution Proposals"



Professor DURGUN obtained his combined B.Sc. and M.Sc degree from İstanbul Technical University (ITU), Department Mechanical Engineering in 1973. After working as an operation and maintenance engineer at TEK Seydişehir Gas Turbine Power Plant for a year, he had started working as research assistant at the Department of Mechanical Engineering in Karadeniz Technical University (KTU). He completed his Ph.D. study in 1983 at ITU Faculty of Naval Architecture and Marine Sciences. Then, he worked as an assistant professor, associate professor and professor in KTU Mechanical Engineering Department. Since 2014, he is at the Department of Mechanical Engineering of Avrasya University. Prof. Orhan DURGUN served as chairman of the department of KTU Marine Engineering, head of the Energy, Automotive branches of KTU Department of Mechanical Engineering. He is currently the chairman of the Department of Mechanical Engineering at Avrasya University, Trabzon. His research expertise focuses on internal combustion engines, fuels, engine design, combustion modeling, and ship hydrodynamics. Prof. Orhan DURGUN has about 100 scientific articles published in national and international journals, symposium proceedings. He also authored two book on internal combustion engines, and supervised +13 M.Sc. and Ph.D theses. Besides his technical expertise, Prof. Orhan DURGUN is an active folk dancer, trainer and has publications on Trabzon and Turkish Folklore, Trabzon folk dance and music.

Prof. Birol KILKIS
Topic: "Exergy Solutions in Energy and Global Warming Dilemma"



Dr. Kilkis received his Ph.D. degree in Mechanical Engineering with high honors from Middle East Technical University. He graduated in 1972 with honors degree from von Karman Institute for Fluid Dynamics in Belgium. Since then, Kilkis has been working on heat transfer, unified heat transfer theory, high-performance buildings, quantum mechanics, fluid dynamics, heat pumps, energy strategies, aerodynamics, exergy analysis, combined heat and power, tri-generation, hybrid solar PV systems, simulation, and computer aided design of green buildings. He is also active in wind, solar, and geothermal energy, global warming issues and solutions, innovative HVAC systems, low-exergy and waste heat utilization, district energy systems, and energy strategies. He revised Chapter 6 in ASHRAE Handbook on Radiant Panel Heating and Cooling and four other chapters at a capacity of principal reviewer. He is the co-author of a most recent book on cogeneration with renewables. He taught graduate and undergraduate courses at several universities like Gannon University (full time, Director of Computer Graphics), University of Missouri Rolla (adjunct), Middle East Technical University (full time, Assistant Dean, Assistant Director of the Graduate School), Baskent University (full time, Head of Energy Engineering Graduate Program), and Atılım University (Adjunct) between 1972 until 2019. In 1981 he received the Science Encouragement Award from TUBİTAK. He is the author of more than 500 papers in several journals and proceedings. ASHRAE has elevated him to Fellow Grade and has been named distinguished lecturer. In 2008, he received Distinguished Service and Exceptional Service awards from ASHRAE. Kilkis was always charged with the most challenging sustainable building design and radiant projects and has worked on more than 250 unique projects. One of them is the LEED Platinum ESER Building in Ankara Turkey. Kilkis has been appointed to the Executive Committee membership of the European Union Solar Thermal Technologies Platform in 2015. After the commencement of this duty in 2018, he became the Vice Chair of Renewable Heating and Cooling Committee (RHC).

Foreword

The 5th Anatolian Energy Symposium, which has been held in March 24-25, 2021 in Trabzon, is the latest one of the Anatolian Energy Symposium series. Since the first symposium hosted by Fırat University in Elazığ, each one was organized in different parts of Anatolia including Diyarbakır, Muğla and Edirne which each has a great cultural heritage.

With the civilization, the human being is highly motivated by at least two things of elapse of time, and the infinity of space. Although we dare to discover Mars and Titan, we sometimes dismiss the universe's infinite limits. During the last few decades, it has been increasingly important to minimize our footprints on the earth while trying our best in our professions. Specifically, in our opinion, we have to control the post-term of catalyzer and chemical reaction in our universe, which is made of chemical compounds. In other words, "the energy conversion process by burning" is not a contemporary approach for humankind anymore. "Energy conversion without burning" is regarded as an essential indicator in today's civilization.

Fire and its energy have been a close friend of humankind during our journey of civilization. The limit of our knowledge and skills have been increasing, yet chemical reactions through firing have still been an important energy source. The concept of "sustainable development" defined by Gro Harlem Brundtland, one of the former prime ministers of Norway, suggest to replace this conventional energy generation. This new concept has been transformed our world into a new era focusing on sustainability even though we have a lot to do on our way ahead.

Energy, which represents life and health, has a significant role in all economic activities and scientific endeavors. Moreover, developing a financial perspective on energy is an essential issue for governmental politics. International Energy Agency-IEA has provided medium-to long-term energy projections using the World Energy Model. The model is a large-scale simulation model designed to replicate how energy markets function and is the principal tool used to generate detailed sector-by-sector and region-by-region projections for the World Energy Outlook scenarios. The model consists of three main modules: final energy consumption; energy transformation including power generation and heat, refinery and other transformation – such as coal to liquids or hydrogen production; and energy supply [1].

Today, many countries develop different energy policies based on their domestic circumstances with varying natural resources and socioeconomic systems. This diversity of energy sources leads simply to no single golden path for the successful energy transition. Instead, each country will need to determine its unique energy policy pathway considering its situation and priorities. This means that direct comparisons between countries' rankings and scores can be less informative, but instead, it helps to provide a conversation opener. Nevertheless, governments can and should learn from each other by learning which policies work better and why such policies might be successful within some contexts but not in others. The Energy Trilemma Index can help countries and energy stakeholders in an ongoing dialogue to determine which areas of energy policies need to improved and examples from other countries that may help decide which options might be more appropriate [2]. Trilemma Index has the following dimensions of 1) energy security, 2) energy equity, and finally, environmental sustainability. Trilemma scores of countries reveal that scientific and technical infrastructure has a significant role in affordable, abundant energy and environmental harm mitigation.

These are the policies and resulted from increasing energy demand, depletion and lack of conservation of natural resources along with unrestrained greed of human being. We believe that each of us has responsibility and should act accordingly by remembering one single self-check question in our every action "How can we make the world a better place to live?"

We are now carrying out our mission by providing a scientific medium to scientists and energy researchers to exchange ideas and share recent works and applications on various aspects of energy and related technologies. The symposium has a broad perspective from Heat and Mass Transfer to Fluid Mechanics and Thermodynamics, Computational Heat Transfer and Fluid Dynamics, HVAC Systems, Solar Energy, Wind Energy, Fuel Cells, Hydrogen Energy, Energy Technologies, Cooling Technologies, Fuels and Combustion, Heat Insulation, Exergy, Energy Management, Power Plants and Power Generation, Nanofluids, Global Warming and Environmental Pollution, Energy Policies, Occupational Health and Safety in Energy Sector, Energy Transmission Lines, and so on.

The symposium would not be realized without the support and efforts of too many individuals. We would like first to thank Karadeniz Technical University president, Professor Hamdullah ÇUVALCI and our former president, Professor Süleyman BAYKAL, for their sincere support. Thanks to the Trabzon Chamber of Commerce and Industry for their financial support. We express our gratitude to the invited speakers and all participants for their valuable contributions. We especially thank our colleagues Furkan, Ayşe, Aleyna, Mustafa Yavuz, Mehmet, Soner and Cansu, for their devoted efforts.

Karadeniz Technical University, Trabzon, TURKEY

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[1] World Energy Model Documentation, 2020 version (19.02.2021), International Energy Agency, Available at: https://iea.blob.core.windows.net/assets/dd88335f-91ab-4dbd-8de7-d2dc4fee90e0/WEM_Documentation_WEO2020.pdf, Last access date: 29.03.2021.

[2] 2021 World Energy Issues Monitor, World Energy Council, Available at: https://www.worldenergy.org/assets/downloads/Issues_Monitor_2021-final.pdf , Last access date: 29.03.2021.

Symposium Program

24.03.2021 (DAY 1)

Start	End	Welcome Remarks
09:30	09:40	Prof. Burhan ÇUHADAROĞLU (Conference Chairman)
09:40	09:50	Prof. Hamdullah ÇUVALCI (President of KTU)
09:50	10:00	Prof. Gençağa PÜRÇEK (Dean of School of Engineering)
10:00	10:10	Dr. M. Suat HACISALİHOĞLU (Chairman of the Trabzon Chamber of Commerce and Industry)
10:10	10:40	**Keynote Speaker-1 : Professor Frede Blaabjerg | *"Wind Power – A technology enabled by power electronics"***
10:40	10:45	Break

Parallel Session-1

		ROOM 1: Heat and Mass Transfer-I	ROOM 2: Energy Technologies-I	ROOM 3: HVAC Systems
		Session Chair: *M.E. ARICI*	Session Chair: *C. TURHAN*	Session Chair: *A. DALOĞLU*
10:45	11:05	**A comparative Analysis on Heat Pipe Heat Exchangers and Rotary Regenerative Heat Exchangers** *K.ÖZDEMİR, E. BÜYÜK ÖĞÜT*	**Electrochemical Characterization of Temperature Dependence of a Lithium-Ion Battery** *O. B. SABAN, E. GÜZEL, M. F. SERİNCAN, M. A. ARSLAN*	**Effect of Vertical Skirt on Airflow and Particle Distributions in an Operating Room A Numerical Study** *A. AGIRMAN, Y. E. CETIN, M. AVCI, O. AYDIN*
11:05	11:25	**Numerical Investigation of Flow and Heat Transfer in an Open Cavity** *E. ÖZGİRGİN YAPICI, E. AYLİ, A. DENİZ*	**Smart Thermos Design Integrated with Thermoelectric Module** *E. ÖZTÜRK, A. HİNDİSTAN, K.YILDIZLI*	**Investigation of BIM (Building Information Modeling) System in Terms of Pressure Energy Losses in Ventilation Systems** *F. DEMİRTAŞ, C. DEMİRTAŞ*
11:25	11:45	**An Experimental Study on Overall Heat Transfer Coefficient of Some Wall Brick Models** *A. RAHMANPARAST, B. ÇUHADAROĞLU, F. E. KAN*	**Calibration of a Low-Cost Globe Thermometer with Linear Comparative Calibration Method** *M. F. ÖZBEY, C. TURHAN*	**On the Use of Natural Ventilation System for Suction of Inhaled Gases in Production Lines for Improved Indoor Air Quality** *O. KAYAPINAR, O. ARSLAN*
11:45	12:05	**The Effect of the Various Arrangements of the Lithium-ion Battery Pack on the Cooling Performance** *A. AKTÜRK, M. E. ARICI, F. E. KAN*	**Development of a Novel Temperature and Relative Humidity Data Logger** *A.Y. BAYHAN, C. TURHAN*	**Air Conditioning System Design of a Archives Storage Facility in the Warm Climate Region** *M. SUNMAN, Ö. AĞRA*
12:05	12:10	Break		

Parallel Session-2

		ROOM 1: Heat and Mass Transfer-II	ROOM 2: Energy Technologies-II	ROOM 3: Wind Energy
		Session Chair: *O.AYDIN*	Session Chair: *K. BİLEN*	Session Chair: *M. E. ŞAHİN*
12:10	12:30	**Mixed Convection in a Vertical Parallel-Plate Microchannel with Viscous Dissipation Effect** *A. N. ALTUNKAYA, M. AVCI, O.AYDIN*	**Energy Efficiency Analysis of Turbocharges with Wastegate** *K. BİLEN, T. TOPCU, D.HAYDARGİL*	**Investigation of Vertical Axis Wind Turbines and Their Components Design** *A. BOZTAŞ, O. DEMİRBAŞ, M. E. ŞAHİN*
12:30	12:50	**Artificial Neural Networks For Drying Characteristics Determination An Application In Fluidized Bed Drying** *A. YILDIRIM, H.ERGÖK, Ö. AĞRA*	**Influences of Vanisperse in Negative Active Material on the Performance of Lead-Acid Battery** *Y. ŞİRİN, Y. EYDEMİR, Ç. AYHAN, E. DEMİRYÜREK, E. KOÇ*	**Design of the Deformable Wind Turbine Blade to Keep Efficiency High** *Y. GÜLTEKİN, E. KOÇ, T. YAVUZ*
12:50	13:10	**Experimental Investigation Jet Flow with Different Aluminium Foam Receivers** *B. ÖZŞAHİN, S. ÇALIŞKAN, K. BİLEN, F. GÜLER*	**Turkey's Pumped Hydro Storage Status: Current Scheme and Potential** *S.C. TOKER, G. SOYTÜRK, Ö. KIZILKAN*	**Design and Aerodynamic Performance Analysis of Micro Wind Turbine Blade** *K. KAYA, E. KOÇ*
13:10	13:30	**Experimental Investigation of the Effects of Foam Heat Sinks on Heat Transfer in Cross Flow** *S. ÇALIŞKAN, U. R. ŞAHİN, F. GÜLER, O. ÖZENÇ*	**The Thermal Decomposition of the Liquid Hot Water & Alkali Pretreated Cotton Fiber** *S. ÖZGÜL, G. KOÇAR*	**The State of Energy in World and Turkey – Wind Energy** *K. KAYA, E. KOÇ*
13:30	13:35	Break		

Parallel Session-3

		ROOM 1: Heat and Mass Transfer - Nanofluids	ROOM 2: Comput. Heat Transfer &Fluid Dynamics - I	ROOM 3: Heat Insulation - Power Plants and Power Generation
		Session Chair: *İ. KURTBAŞ*	Session Chair: *T. BALİ*	Session Chair: *H.K. ÖZTÜRK*
13:35	13:55	**Mixed Convection in a Square Cavity Filled with Hybrid Nanofluid** *B. ŞAHİN*	**Numerical Investigation of the Effect of Obstacles Configuration in the Flow Channel on Heat Transfer** *İ. KURTBAŞ, M. SENER, S. KIZILCAOĞLU, H. DURAN*	**Optimization of Insulation Thickness for Pipes in a Low Temperature District Heating Network** *M. TERHAN*
13:55	14:15	**Investigation of Boiling Instability in Rectangular Spiral Mini Channel** *M. SENER,İ. KURTBAŞ, S. KIZILCAOĞLU*	**Effect of Magnetic Field on Flow and Heat Transfer in Hydrodynamically and Thermally Developing Couette-Poiseuille Flow Between Paralel Plates** *E. YAĞCI, O. AYDIN, T. BALİ*	**Thermal Comfort Analysis of Historical Mosques. Case Study: The Ulu Mosque, Manisa, Turkey** *Y. DİLER, C. TURHAN, Z. D. ASLAN, G. G. AKKURT*
14:15	14:35	**A Review of the Effects of Micro Fin Geometry and Alignment on Flow Boiling Characteristics in Microchannel Heat Sinks** *B. MARKAL, B.KUL*	**Numerical Investigation of Naturally Ventilated Facade with PCM Located in Mediterranean Region** *S. BIRINCI, M.SAGLAM, B. SARPER, M. Y. YAZICI, O. AYDIN*	**Auxiliary Power Generation Design for Power Plants with Using Thermoelectric Generators** *Ş. K. YENER, B. AKBOĞA, B. ÇETİN*
14:35	14:55	**Adaptation of the Touhami *et al.* Correlation for Pool Boiling Outside a Horizontal Tube at Subatmospheric Pressures** *T. BAKI, D. NEHARI*	**Numerical Investigation of the Effect of Air Velocity on Heat Transfer to Heat Sink in Thermoelectric Modules** *S. ÖZBEKTAŞ, B. TOPAL, B. SUNGUR*	**Comparative Thermodynamic Analysis of Organic Rankine Cycle with Different Working Fluids** *O. ARSLAN, İ. CEYLAN*
14:55	15:00	Break		
15:00	15:30	**Keynote Speaker-2 : Professor Birol KILKIS | *"Exergy Solutions in Energy and Global Warming Dilemma"***		
15:30	15:35	Break		

Parallel Session-4

		ROOM 1: Thermodynamics-I	ROOM 2: Comput. Heat Transfer and Fluid Dynamics II	ROOM 3: Global Warming and Environmental Pollution
		Session Chair: *A. GÜNGÖR*	Session Chair: *T.YAVUZ*	Session Chair: *B. ÇUHADAROĞLU*
15:35	15:55	**The Performing of Thermodynamic Analysis of R134a Refrigerant and Alternative Refrigerants on Their Application Areas** *Ö. F. SEL, O. HACIHAFIZOĞLU, Ü. AYBEK, A. CİHAN*	**Numerical Analysis of Aerodynamic and Aeroacoustic Characteristics of Subsonic Rectangular Cavity with Different Aspect Ratios** *E. KOCAK, E. AYLİ, H.TURKOGLU*	**Geopolymer Cement Production in the Struggle to Global Warming** *S. OZEN*
15:55	16:15	**Development and Thermodynamic Analysis of a Hybrid Evaporative Evaporator Air Cooling System** *F. ÖZDEMİR, A. GÜNGÖR*	**A New Vortex Preventing Element Design for Francis Turbines and Comparison of Different Geometric Shapes** *D. S. SEMERCİ, T. YAVUZ*	**Sustainable Phytoremediation with Energy Crops in Turkey** *B. BAŞTABAK, E. GÖDEKMERDAN, G. KOÇAR*
16:15	16:35	**Performance Prediction of a Two-Bed Adsorption Chiller Using the Silica Gel Water Working Pair Considering the Effect of Hot and Cold Water Temperatures** *T. Ü. ERKEK, A. M. S. SHAKIR, M. W. K. JABER, A. GÜNGÖR*	**Design and Prototyping of Air-to-Ground Smart Fire Extinguisher Ammunition** *M. TOPTAŞ, M. YILMAZ*	**Türkiye Şartlarında Fitoremediasyon Tekniğinde Kullanılan veya Kullanılma Potansiyeli Olan Bazı Bitkiler** *E. YILMAZ, Ö. KILIÇ, M. ZAFAR, M. AHMAD*
16:35	16:55	**Termodynamic Investigation of Flat Plate Collector** *A. B. GÜNDÜZ ALTIOKKA, A. MAVİ, O. ARSLAN*	**Modelling and Performance of a Thermoelectric Refrigerator** *H. KEPEKÇİ, E. KOSA , C. EZGI*	**Nanoakışkan Kullanılan Parabolik Oluk Tipi Güneş Kolektörlü Organik Rankine Çevriminin Teorik Modellenmesi ve Sistem Parametrelerinin İncelenmesi** E. KIRTEPE, O. E.TURGUT
16:55	17:00	Break		

Parallel Session-5

		ROOM 1: Thermodynamics-II	ROOM 2: Comput. Heat Transfer & Fluid Dynamics-III	ROOM 3: Cooling Technologies
		Session Chair: *Z. YUMURTACI*	Session Chair: *E. BUYRUK*	Session Chair: *M. AVCI*
17:00	17:20	**Performance Analysis of Solar and Geothermal Energy Powered Kalina Cycle** *M. Ş. ACAR, O. ARSLAN*	**Effects of Injection and Suction Through a Perforated Circular Cylinder on Some Thermo-Fluid Parameters** *M. E. VAKHSHOURI, B. ÇUHADAROĞLU*	**Experimental Investigation of the Pulsating Heat Pipes Having Larger Flow Sections in the Evaporator Region** *A. CANDERE, B. MARKAL, O. AYDIN, M. AVCI*
17:20	17:40	**Comparative Techno-economic-environmental Assessment of Biomass Fuelled Integrated Energy Systems** *P. HEIDARNEJAD, H. GENCELİ, Z. YUMURTACİ*	**A Numerical Study on Phase Change Material Integrated Borehole Heat Exchanger** *N. Y. ÇAM, M. A. EZAN, L. BİLİR*	**Heat Transfer and Thermal Management of Lithium-Ion Battery Pack System with Forced Air Convection** *İ. HOŞ, G. TÜRKAKAR*
17:40	18:00	**Thermodynamic Analysis of Automobile Brake System** *A. MAVİ, A. B. GÜNDÜZ ALTIOKKA, O. ARSLAN*	**Validaton Study of a Naturally Ventilated Solar Facade** *B. SARPER, S. BIRINCI, M. SAGLAM,O. AYDIN*	**Superelastic Properties of NiTi for new generation cooling technologies** *S. ÖZKAN, E. DEMİRTAŞ, G. DURAK YÜZÜAK, E. YÜZÜAK*
18:00	18:20	**ORC Sistemlerinde Kullanılan n-Pentane Akışkanının Pompada Sıkıştırma Oranının Termodinamik Verimlere ve Ekserji Yıkımına Etkisi** *M. ALTINKAYNAK*	**CFD Analysis of Fluid Passing Through Venturimeter** *C. KISTAK, F. ÖZGEN*	**Elastocaloric Properties of the Optimized Ni-Ti Alloy** *G. DURAK YÜZÜAK, E. YÜZÜAK*

End of Day 1

Symposium Program

25.03.2021 (DAY 2)

Start	End			
09:00	09:10	**Second Day Welcome** | *Assoc. Prof. Ömer Necati CORA (Co-Chairman)*		
09:10	09:40	**Keynote Speaker-3 : Professor Orhan DURGUN | *"Dünya'da ve Türkiye'de Enerji Üretiminin Güncel Durumu ve Türkiye için Çözüm Önerileri"***		
09:40	09:45	Break		
		Parallel Session-6		
		ROOM 1: Fuels and Combustion - Exergy	**ROOM 2: Solar Energy-I**	**ROOM 3: Fuel Cells - Wind Energy - Solar Energy**
		Session Chair: *Z. ŞAHİN*	Session Chair: *N. ÇELİK*	Session Chair: *M. ÖZBEY*
09:45	10:05	**Second Law Analysis of Novel Fractal Structure Heat Exchanger** *A. B. ÇOLAK , İ. KOTCİOĞLU, O. ARSLAN*	**Dynamic Simulation of a Flat Plate Solar Collector System under Hot and Humid Climatic Conditions** A. YUMUŞAK, H. GENCELİ, M. ASKER	**Development of a Dynamic System-Level Thermodynamic Model of Solid Oxide Fuel Cell (Sofc) Integrated Gas Turbine (Gt) Power Plant** *M. B. KAYA , A. C. İNCE, F. BEDİR, M. F. SERİNCAN*
10:05	10:25	**Engine Performance and Exhaust Emissions of a Spark Ignition Engine Operating on 2.5 % N-Butanol/Gasoline Blend and 2.5 % N-Butanol/Gasoline Blend with 9 % Water Injection to Intake Air** *Z. ŞAHİN, O. N. AKSU, C. BAYRAM*	**Exergy Analysis of a Solar Power Plant and Comparison of Production Values with Software** *B. GÜLMEZ, R. KÖSE, O. O. YOLCAN*	**Thermal Expansion, Porosity, and Microhardness Properties of Solid Oxide Fuel Cell Metallic Interconnects Manufactured by Powder Metallurgy Approach** *A. TOPCU , Ö. F. YALÇIN, B. ÖZTÜRK, Ö. N.CORA*
10:25	10:45	**Theoretical Investigation of Engine Performance and Exhaust Emissions in Ethanol-fueled Dual-plug SI Engine** *İ. ALTIN , A. BİLGİN, İ. SEZER*		**Wind Energy Potential Assessment of Susurluk Region in Balıkesir** *A. DÜZCAN , Y. A. KARA*
10:45	11:05	**Sesame Harvesting Waste: Thermal Characterization and Conversion for Biofuel and Biochar Production** *E. GÖDEKMERDAN , B. BAŞTABAK, G. KOÇAR*		**Potential for the Use of Solar Energy in the Food Industry** *D. BAYANA , F. İÇİER*
11:05	11:10	Break		
11:10	11:40	**Keynote speaker-4 : Assoc. Prof. Barbaros ÇETİN | *"Grooved Heat Pipes: Modeling, Experimentation and Applications"***		
11:40	11:45	Break		
		Parallel Session-7		
		ROOM 1: Solar Energy-II	**ROOM 2: Energy Management - Occupational Health and Safety in Energy Sector**	**ROOM 3: Fluid Mechanics-I - Cooling Technologies**
		Session Chair: *K. KAYGUSUZ*	Session Chair: *M. YILMAZ*	Session Chair: *O.TURAN*
11:45	12:05	**Artificial Neural Network Modeling of Parabolic Trough Type Solar Thermal Power Plant** *D. KILIÇ, O. ARSLAN*	**Effect of Collection Tank Level on Energy Consumption of Lifting Pumps in Drinking Water Distribution Systems** *U. SEKMEN , M. YILMAZ, Ö. ÖZDEMİR, A. İNCE*	**Numerical and Experimental Investigation of Air Injection Process with Venturi Pipe Part** *Ö. F. CAN, T. BAĞATUR, N. ÇELİK*
12:05	12:25	**Analysis and Design of a Cooling Channel for a Photovoltaic Panel** *Z.ÖZCAN , M.GÜLGÜN , E. ŞEN, N. Y. ÇAM, L. BİLİR*	**Lead Acid Batteries for Micro Hybrid Electrical Vehicles – Influence of Different Type Expanders on the Performance of the Negative Plates** *Y. ŞİRİN , Y. EYDEMİR, Ç. AYHAN, E. DEMİRYÜREK, E. KOÇ*	**An Energy Efficient Mixed Flow Submersible Pump Design and Computational Fluid Dynamic Processes in a Case Study 7" 110 m3h** *M. AKDEMİR , M. C. ÇAKMUR*
12:25	12:45	**Collaborating Sharing Decentralized Solar EnergySystem in Pakistan** *S. M. K. SHAH , R. TANZEEL*	**Ship Energy Efficiency Analysing Approaches: A Case Study** *O. YILMAZ , T. UYANIK, Y. ARSLANGOĞLU*	**Analysis and Design of an Air to Air Heat Exchanger Used in Energy Recovery Systems** *H. Ü. ELMACIOĞLU , İ. ÖZSEVGİ, C. KOCABIYIK, N. Y. ÇAM, L. BİLİR*
12:45	13:05	**Design and Analysis of Evacuated Tube Solar Collector Integrated Supercritical Brayton Cycle for Low-Temperature Applications** *G. SOYTÜRK , S.Ç. TOKER, Ö. KIZILKAN*	**Rüzgar Enerji Santrallerinde İş Sağlığı ve Güvenliği** *S. ŞİMŞEK, F. DOĞAN*	**Magnetic Refrigeration Technology and Applications** *A. ZAİM , H. ARAS*
13:05	13:10	Break		
		Parallel Session-8		
		ROOM 1: Solar Energy-III	**ROOM 2: Energy Management - Hydrogen Energy**	**ROOM 3: Fluid Mechanics-II - Comp. Heat and Mass Trans.**
		Session Chair: *Y. ARSLANOĞLU*	Session Chair: *E. F. KENT*	Session Chair: *L. NAMLI*
13:10	13:30	**Experimental Investigation of Thermal Gain in PV Panels** *H. DUMRUL , S.YILMAZ*	**Parametric Analysis of a Plate, Finned and Cross Flow Heat Exchanger for Heat Recovery in Buildings** *S. TEKİN, G. TÜRKAKAR*	**Investigation of Flow Field Characteristics of Synthetic Jet Driven by Half Sinusoidal Signal** *M. Y. BAYAT , M. SARIOĞLU, Y. E. AKANSU*
13:30	13:50	**Following the Balloon Temperature of a Solar Water Heater Installed in Oran, Algeria** *T. BAKI , M. TEBBAL, H. BERREBAH*	**An Ore Enrichment Plant, The Effect of Operation Optimization of Operators on Production and Energy Efficiency** *E. BULAT , C. AYGÜN*	**Bubble Pump Design and Performance Analysis** *A. DALLOUL , M. ÖZBEY*
13:50	14:10	**Bidirectional Flyback Based Differential Power Processing Converter for Photovoltaic Applications** *E. KARAKAŞ , Y. ÖNER, S. KESLER*	**Exergy and Thermoeconomic Analyses of Solar Hydrogen Production and Liquefaction Process** *T. KOYUN, E. F. KENT*	**Numerical Investigation and Optimization of the Effect of Heat Transfer and Pressure Drop on the Circuit in Finned Tube Heat Exchangers** *A. YILDIRIM , Ş.Ö. ATAYILMAZ*
14:10	14:30	**A Machine Learning Approach for Solar Power Plant Electrical Power Estimation** *T.UYANIK, O. YILMAZ , Y. ARSLANOĞLU*	**Hidrojen Tedarik Zinciri ve Türkiye Örneği** **A. ERDOĞAN, E. GEÇİCİ, M. G. GÜLER**	**Investigation of Air Flow Inside an Airplane Passenger Cabin** *L. BİLİR , H. ÇELİK, M. B. ÖZERDEM*
14:30	14:35	Break		
14:35	15:05	**Keynote speaker-5 : Assoc. Prof. Hafız Ali | *"Surface condenser: Heat transfer"***		
15:05	15:10	Break		
		Parallel Session-9		
		ROOM 1: Solar Energy-VI	**ROOM 2: POSTER SESSION**	**ROOM 3: Energy Technologies-III**
		Session Chair: *C. DEMİRTAŞ*	Session Chair: *F.E. KAN*	Session Chair: *Ö.N. CORA*
15:10	15:30	**State of the Art Review on the Cu(InGa)Se2 Thin-film Solar Cells** *M. A.OMID , Ö. N. CORA*		**Thermoelectric Thin Film Modules** *S. ÖZKAN , G. DURAK YÜZÜAK, E. YÜZÜAK*
15:30	15:50	**A Study of the Effect of Baffles Inside Solar Collector** *B. GÜLMEZ , A. B. AKSOY*	**Sensorless Flow Rate and Total Head Measurement of Centrifugal Pumps Operating with Variable Frequency Drive** *E. KARAKAŞ , Y. ÖNER, S. KESLER*	**Indigenous Oil Yielding Plants as Energy Sources in Pakistan** *M. ZAFAR, M. AHMAD, Ö. KILIÇ , S. SULTANA, J. ZAHOOR, E. YILMAZ*
15:50	16:10	**Analysis of 100 kW Solar Photovoltaic Power Plant Which Can Be Installed In Trabzon** R. KÖSE, A. B. AKSOY, B. GÜLMEZ, O. O. YOLCAN	**Thermal Power Plant Emissions and Emission Prevention Studies in Turkey** *H. ERGÖK , A. YILDIRIM*	**RF Sputtered TiO2 Thin Films with Various Deposition Conditions for Triboelectric Friction Layer** *G. DURAK YÜZÜAK , S. ÖZKAN, E. YÜZÜAK*
16:10	16:30	**Important Parameters in Solar Power Plant Installation and Analytical Hierarchy Process** B. GÜLMEZ, R.KÖSE, O. O. YOLCAN	**Solar Powered Cooler Design** *H. KORKMAZ , M. E. GAZI, Ö. N. CORA*	**Comparative Environmental Sustainability of Two Different Sizes of Wind Turbines** *B. A. TÜRKMEN*
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ABSTRACT

In the study, a thermo-economic analysis has investigated using Equivalent Annual Worth (EAW) Analysis Method to determine the optimum insulation thickness of pipes such as supply and return water pipes; hot water and circulation pipes existed in a low-temperature district heating network. In the analysis, energy savings over a lifetime and payback periods of the pipe insulation material (glass wool) have calculated depending on the different nominal pipe sizes (20-150 mm). The results show that the optimum insulation thicknesses found between 30 mm and 40 mm. The investment cost of the pipe insulation material changes over the range 0.53-11.78 $/m, while total energy savings of the insulation material wave to 102.17 $/m from 19.24 $/m according to the variable pipe insulation thickness like 25-100 mm. The payback periods of the different insulation thicknesses have calculated between 0.06 and 2.53 years.

Keywords: low-temperature district heating network, pipes, optimum insulation thickness, energy savings, equivalent annual worth (EAW) analysis

Symbol List

β	Volume expansion coefficient (1/K)
C_f	Fuel cost ($/m^3)
C_{fl}	Annual fuel consumption cost occurred heat losses from pipes ($/year)
C_i	Cost of insulation material per unit volume ($/m^3)
C_{ins}	Insulation cost ($)
C_m	Maintenance and operation cost ($)
C_{tot}	Total cost ($)
d	Inflation rate (%)
D_t	Diameter of insulation pipe (m)
E_s	Energy savings ($/m)
g	Gravitational acceleration (m/s^2)
h	Heat convection coefficient (W/m^2.K)
H_u	Lower heating value of the fuel (kJ/m^3)
i	Interest rate (%)
k	Thermal conductivity coefficient (W/m.K)
L	Length (m)
N	Lifetime years
N_u	Nusselt number
Pr	Prandtl number
r_v	Ratio of resale value to the first cost
R	Thermal resistance (m^2.K/W)
Ra	Rayleigh number
Q	Heat transfer rate (kJ/s)
Q_f	Annual fuel energy consumed from the heating system (kJ/year)
t_c	Canal thickness (m)
T	Temperature (°C)
T_b	Base temperature (°C)

T_{sa}	Solar-air temperature (°C)
ύ	Volumetric flow rate (m^3/s)
V	Volume (m^3)
V_f	Annual fuel consumption of heating system (m^3/year)
V_{pl}	Annual fuel consumption occurred heat losses from pipes (m^3/year)
x_{cp}	Canal perimeter (m)
x_c	Canal deepness (m)
α	Heat diffusion coefficient (m^2/s)
η_s	Efficiency of heating system (%)
υ	Kinematic viscosity (m^2/s)

1. INTRODUCTION

Energy plays an essential role in increasing economic development and welfare level. Energy consumption has been quickly increased depending on life standard improvement, rising population, and urbanization because of migration to big cities. Besides, environmental pollution related to fossil fuels has become a severe threat to human wealth and the ecosystem. Thus, the main idea is to maximize energy savings and minimize energy consumption in the design stage of the power and heating systems with fossil fuel. The building sector is numerous remarked on energy consumption because of high heat losses. In the world, the most significant part of global energy demand consists of the building sector with a percent of 40% [1-6]. Used to cover space heating and domestic hot water needs, heat produced in a plant is transferred to the buildings in a campus or region in the district heating systems (DHS) [7]. The district heating systems are provided solutions for the increasing energy problems in high population cities such as remediation of air quality because of reducing CO_2 emissions, increasing renewable energy sources share, reducing energy export owing to control of energy demands [8]. The advantages of DHS can be sorted as high efficiency in heat generation, fuel used diversity, and low interaction on the environment [9]. The first investment cost, operation cost, and total energy cost go up depending on increasing heat loss in DHS's distribution network. Thus there is a needs decreasing of heat losses from pipes in the network. Heat loss from the network corresponds percent of 5-20% transferred energy, and this loss is higher than the other losses in the heating system. Heat losses from the network depend on many factors such as outdoor conditions, insulation of pipes, and length of distribution network [7-11].

Using suitable insulation material reduces significantly energy consumption in space heating thus decreasing fossil fuel consumption and pollution effect on the environment. Especially, district heating systems have confused and expensive pipe configurations. Un-insulation supply and return pipes of the heating system are essential sources of waste energy. Applications of insulation on pipe systems for energy savings not only decrease heat losses from the pipes but also reduce environmental pollution due to fuel savings. Thermal insulation material used is an effective method for thermal impact protection in buildings and pipes. For these reasons, the selection of suitable insulation material and determination of optimum insulation thickness is quite essential [4-12]. Using suitable insulation material is one of the effective ways for energy savings on pipe networks in the district heating system. The insulation decreases fuel consumption and undesirable carbon emissions from fossil fuel combustion in the system [3]. The insulation material thickness must determine considering the factors such as thermal conductivity and cost of insulation material, and outdoor temperature of the region. Increase the insulation thickness not only energy savings but also contributes to the decrease of environmental pollution. However, the insulation thickness supplied no heat losses is neither practical nor economical. Thus, a balance point must determine between the insulation material cost with energy savings obtained, and this point shows the optimum insulation thickness [1-13].

There are many studies related to the optimum thickness of distribution networks in the district heating system. Comakli et al. [14] investigated the energy and exergy losses of heat distribution networks consisted of 11988 m length and 65-250 mm nominal size pipes of Ataturk University. The heat loss of the district heating networks pipes found as 8.62%. As a result of the study, the insulation material thickness is the most influential factor because of decreasing heat losses from the pipes. In case the insulation thickness of 20 cm uses instead of 8 cm on the pipes, the heat losses from the pipes decreases percent by 25. Keçebaş et al. [1] calculated the optimum insulation thickness, energy savings, and payback periods of pipes used district heating network existed

Afyonkarahisar Province in Turkey for five different nominal sizes of pipes and four fuel types during ten years of economic life. In the study, an optimum model developed based on Life Cycle Cost Analysis Method. Rockwool considered insulation material, and the network consisted of network 50-200 mm nominal size pipes. According to the study results, the optimum insulation thickness, energy-saving, and payback period were shown a change respectively between 0.085-0.228 m, 10.041 $/m-175.171 $/m, and 0.442-0.808 years depending on different pipe diameters. Rosti et al. [2] proposed the determination of optimum insulation thickness by first investment cost of insulation and payback period all climatic zones in Iran. In the study, the optimization carried out by using the Life Cycle Cost Analysis method with a numeric solution. Kayfeci [3] determined energy saving significantly can be obtained by insulating pipe networks, and the incredible number of heat losses stem from the network of heat losses in the district heating system. In the study, the optimum insulation thickness, energy-saving, annual operation cost, and payback period calculated using the Life Cycle Cost Analysis method for different nominal pipe sizes, various insulation materials, and heating degree days (HDD). In the study results, the optimum insulation thickness showed a change between 0.048-0.134 m; while energy-saving and payback period were found respectively between 10.84 $/m-49.78 $/m and 0.74-1.29 years. Zhang et al. [13] calculated the optimum insulation thickness, energy-saving, and payback period of direct-buried pipes used district heating network for various pipe diameters, different soil deepness for Xion Province in China by using the Life Cycle Cost Analysis method in this study. According to the study results, the optimum insulation thickness, energy-saving, and payback period respectively changed between 0.060-0.121 m, 36.395 $/m-194.682 $/m, and 0.445-1.691 years.

In this study, optimum insulation thicknesses, energy savings, first investment costs and payback periods of the pipes in the network of a low-temperature district heating system investigated using Equivalent Annual Worth (EAW) Analysis method for natural gas. The total length of the district heating system's network is 1470 m; and supply-return pipes for space heating, hot water pipes, and circulation pipes locate in the heat canals under the soil. Optimum insulation thicknesses calculated for different nominal sizes pipes (Ø20mm-Ø150 mm) for the fourth climatic zone (the coldest zone) and glass wool.

2. METHOD

2.1 Heat losses from the pipes in the network (heat canals under the soil)

A resistance model is shown in Figure 1for calculating heat losses from the pipes in the canals under soil per unit length [14].

Insulation material resistance;

$$R_i = \frac{1}{2 \times \pi \times k_i} \times In\left(\frac{r_2}{r_1}\right) \quad (1)$$

Canal resistance;

$$r_c = \frac{x_{cp}}{2 \times \pi} \quad (2)$$

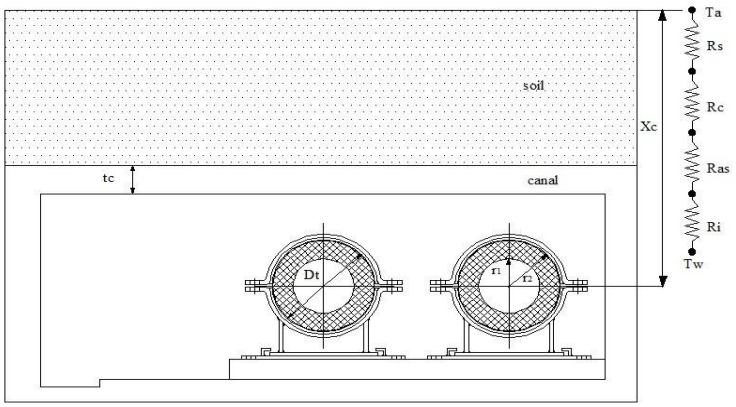

Figure 1. The sectional view of heat canal and the resistance model

$$R_c = \frac{1}{2 \times \pi \times k_c} \times In\left(\frac{r_c + t_c}{t_c}\right) \tag{3}$$

The convection resistance of the air in the canal;

$$R_a = \frac{1}{2 \times \pi \times h_{a\times} r_i} \tag{4}$$

The air convection coefficient can found by the following formula [14].

$$h_a = \frac{k_a}{D} \times Nu_D \tag{5}$$

The following formula can be used for calculating the local Nusselt number at constant temperature and around a cylinder.

$$Nu_D = \left[0.6 + \frac{0.387 \times Ra_D^{1/6}}{\left[\left(1 + (0.559/Pr^{9/16})\right)\right]^{8/27}}\right]^2 \tag{6}$$

$$Ra_D = \frac{g \times \beta \times (T_s - T_\infty) \times D}{\vartheta \times \alpha} \tag{7}$$

Soil resistance;

$$R_s = \frac{1}{2 \times \pi \times k_s} \times In\left[\frac{x_c}{r_c} \times \left(1 + \sqrt{1 - (D_t/x_c)^2}\right)\right] \tag{8}$$

Heat losses from the pipes in the heat canals per unit length calculate with the following formula.

$$\dot{Q_{pl}} = \left[\frac{T_w - T_a}{R_i + R_a + R_c + R_s}\right] \tag{9}$$

Annual fuel consumption corresponding heat losses from the pipes,

$$\dot{V_{pl}} = \frac{\dot{V_f} \times \dot{Q_{pl}}}{\dot{Q_f} \times \eta_s} \tag{10}$$

Annual total fuel energy consumed of the heating system,

$$\dot{Q}_f = \dot{V}_f x H_u \tag{11}$$

Annual fuel consumption cost corresponding heat losses from the pipes,

$$C_{fl} = \dot{V}_{pl} x C_f \tag{12}$$

The volume and cost of insulation material,

$$V_i = \pi \times (r_2^2 - r_1^2) \times L \tag{13}$$

$$C_{ins} = \mathrm{V}_i x C_i \tag{14}$$

Energy savings can calculate as follows:

$$\dot{Q_{es}} = \dot{Q}_{un-ins} - \dot{Q}_{ins} = \left[\left(\frac{1}{R_a + R_c + R_s}\right) - \left(\frac{1}{R_i + R_a + R_c + R_s}\right)\right] \times (T_w - T_a) \tag{15}$$

In the economic analysis, it is necessary determining some parameters such as first investment cost, lifetime period, annual maintenance and operation costs, annual savings, and interest rate. Equivalent Annual Worth analysis is used as the economic analysis method. In the annual equivalent worth analysis, the aim is to transform money into an equivalent uniform annual cost or savings [15]. Equivalent Annual Worth (EAW) and payback period calculate in the following equations. F, C, and IC in the equations show respectively income, cost, and first investment cost.

$$EAW = \left[\sum_{n=1}^{t} \frac{F_n}{(1+i)^n} - \sum_{n=1}^{t} \frac{C_n}{(1+i)^n}\right] \times \frac{(1+i)^n \times i}{(1+i)^n - 1} \tag{16}$$

$$PP = \frac{IC}{EAW} \tag{17}$$

2.2 System description

Space heating and hot water need of buildings in the 18. Regional Directorate of Highway's campus, located in Kars city of Turkey, is satisfied by 4th Generation a low-temperature heating system (LTDH). Kars is the coldest city, situated in the fourth climatic zone of Turkey. Annual fuel (natural gas) consumption of district heating system is on average 809,793.50 Nm^3. Supply and return water temperatures of the district heating networks vary between 60°C/50°C. The heat distribution network's length is 1470 m, and the diameters of the pipes in the heat canals are varied from Ø20 mm to Ø150 mm. The layout plan of the district heating network gives in Figure 2.

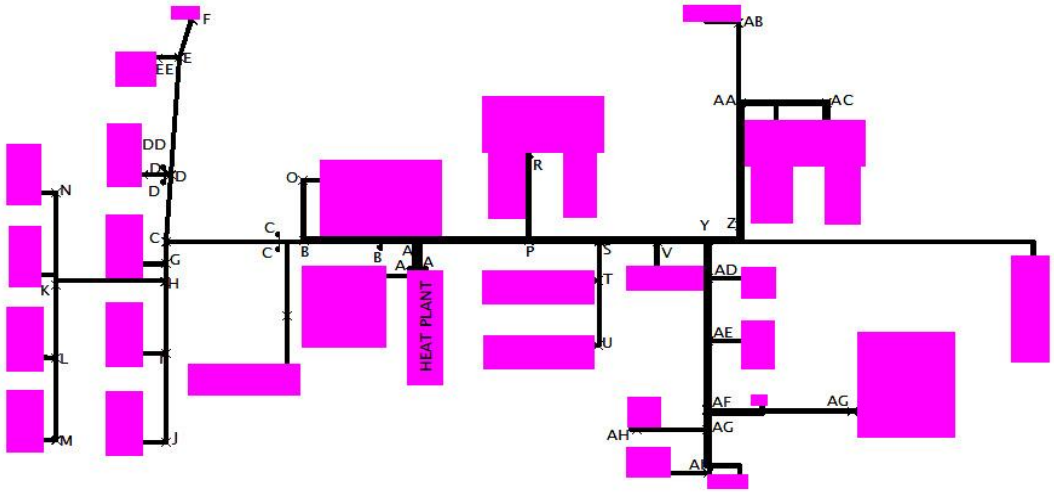

Figure 2. The layout plan of the district heating network

Equivalent Annual Worth (EAW) Analysis method is used to investigate optimum insulation thicknesses of the pipes in heat canals. For the analysis of the heating system, annual fuel consumption values were taken from the regional natural gas company. Supply and return water temperature values of the system measured by the system's thermometers.

3. RESULTS

There are different diameters of heating pipes (supply and return pipes) between Ø25-Ø150 mm, and the total length of 1760 m in the network consists of heat canals. Besides, while a total of 1500 m length of hot water pipes has existed the different diameters Ø25-Ø110 mm, there is a total of 1498 m length of the circulation pipes (Ø20-Ø76 mm). The total length of the pipes in the canals is 4758 m, and supply and return water temperatures of the network vary between 60° and 50°C. At the under soil, the deepness of the canal is an average of 1.2 m. In the system's network in four different sizes, heat canals exist, and the values of the canal resistance change to 0.4403 from 0.3763.

Table 1. Results of the resistant model

Parameter	Value
Canal material	Concrete
k_c	2.1 W/m.K
R_c	0.376-0.441 W/m^2.K
t_c	20 cm
Insulation material	Glass wool
k_i	0.035 W/m.K
R_i	2.679-5.697 W/m^2.K
Deepness of soil x_c	1.2 m
k_s	2 W/m.K
R_s	1.378-1.413 W/m.K
h_a	6.902-7.897 W/m^2.K
Ra_D	$1.25x10^6$-$7.18x10^7$
Nu_D	20.48-69.05

Supply and return heating pipes, hot water pipes, and circulation pipes in heat canals are insulated with glass wool to decrease heat losses. The thermal conductivity coefficient of insulation material has been taken as k=0.035 W/m.K, and soil resistance values have been found between 1.3781-1.4130. Parameters and values used in resistance calculations show in Table 1.

Heat loss from the pipes in the district heating network has been calculated as 46.48 kW, and 31.07 kW of this loss stems from supply and return pipes and 15.41 kW of this loss from hot water and circulation pipes. Considering all district heating system annual heat loss value and heat loss ratio from all pipes in the network has been found respectively as $14.45x10^8$ kJ and 5.44%.

To minimize this high amount of heat loss and save fuel, the pipes should investigate in terms of optimum insulation thickness. Parameters and values used in the economic analysis show in Table 2.

Table 2. Parameters used in the economic analysis

Parameter	Value
Heating degree-days (HDD)	3860°C days
Insulation material	Glass wool
k_i	0.035 W/m^2.K
Fuel	Natural gas
Price, C_f	0.3601 \$/m^3
H_u	8250 kcal/m^3
The efficiency of heating system	95%
Annual fuel consumption, V_f	809,793.50 Nm^3
The interest rate, i	15%
Inflation rate, d	13%
Lifetime, N	Ten years

Total costs, insulation costs and energy, and fuel savings have been calculated for the different pipe diameters and glass wool insulation material according to the different insulation thicknesses in the district heating networks. Change of annual fuel cost, insulation, and total costs according to the insulation thicknesses for a pipe (Ø 90 mm) shows in Figure 3. While depending on different insulation thicknesses, the insulation costs of supply and return pipes (Ø150 mm-Ø20 mm) are changed between 11.78\$/m-0.53\$/m; the insulation costs of hot water pipes (Ø110mm-Ø25 mm) and circulation pipes (Ø76 mm-Ø20 mm) are respectively between 4.94\$/m-0.29\$/m and 2.94\$/m-0.27\$/m.

Insulation thickness, where minimizes total cost, is shown the optimum insulation thickness. The optimum insulation thickness has been investigated for all pipes in the network and compared to the current insulation thickness of the pipes. Optimum and current insulation thicknesses are given for supply and return water pipes in Figure 4. Optimum insulation thicknesses change between 30-40 mm for all pipes.

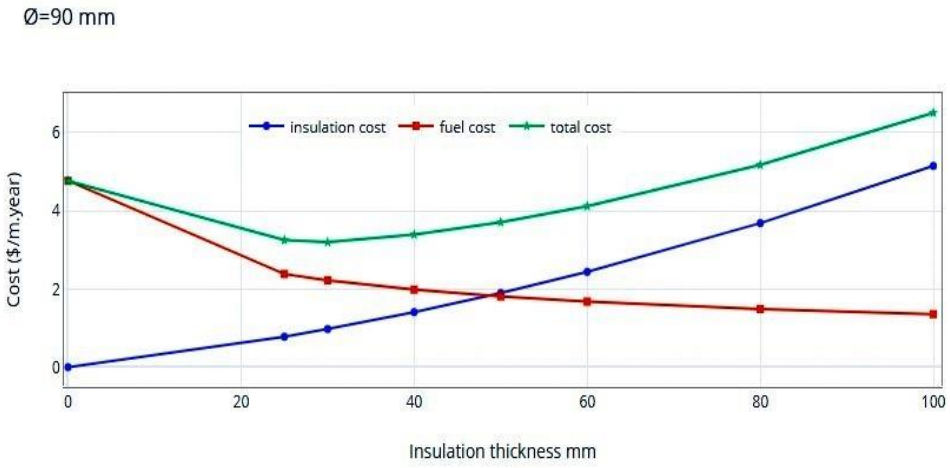

Figure 3. Change of annual costs depending on different insulation thicknesses

The heat loss from the pipes decreases together with the increasing insulation thickness, and fuel savings provides. The chancing of energy savings shows in Figure 5 depending on the increasing insulation thickness for circulation pipes with different nominal sizes. Energy savings are reached a maximum point at the insulation thickness between 25-40 mm and observed no change hardly ever at values between 50-80 mm. Though the insulation costs increase, energy savings is no change at the insulation thickness of 50 mm and over. Therefore, this value and over are not economical.

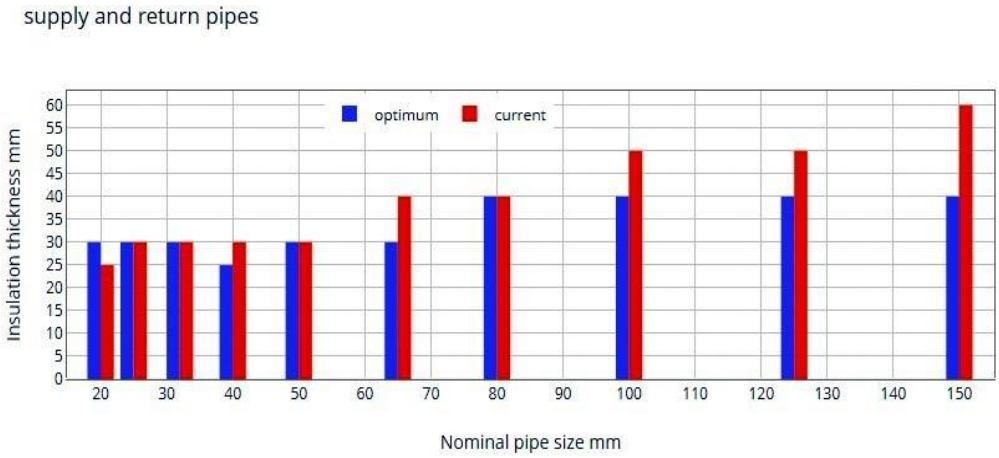

Figure 4. Current and optimum insulation thicknesses of supply and return pipes

Energy savings are respectively changed between 61.60 $/m-102.127 $/m for supply and return pipes depending on the different pipe diameters (Ø150mm-Ø20 mm) during the economic life of 10 years. While energy savings during economic life are obtained as 19.25$/m-29.07$/m for hot water pipes (Ø110mm-Ø25 mm), they are between 20.71$/m-29.91$/m for circulation pipes (Ø76 mm-Ø20 mm).

Payback periods, which to be compensated first investment cost with the energy savings provided, are calculated for various diameters of all pipes in the network. The change of payback periods by different insulation thickness for the supply and return pipes gives in Figure 6.

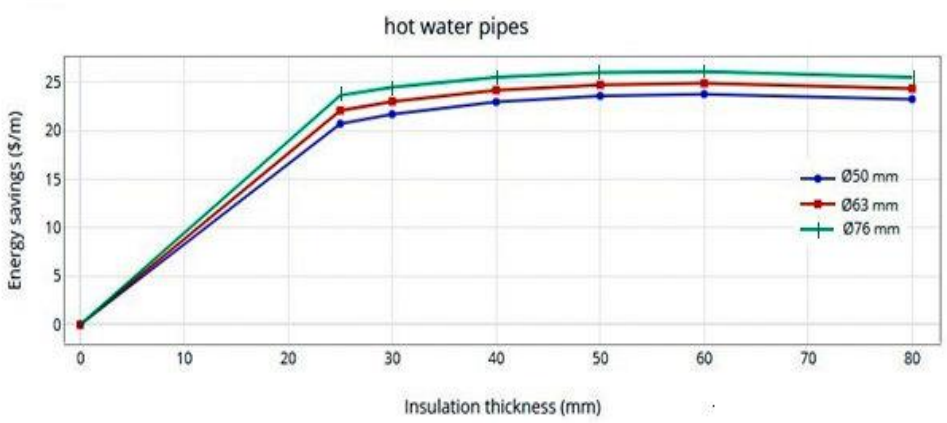

Figure 5. Energy savings of hot water pipes depending on various pipe diameters

Payback periods for supply and return pipes, hot water pipes, and circulation pipes have been respectively found as 1.59-0.06 years, 2.53-0.11 years, and 1.26-0.09 years.

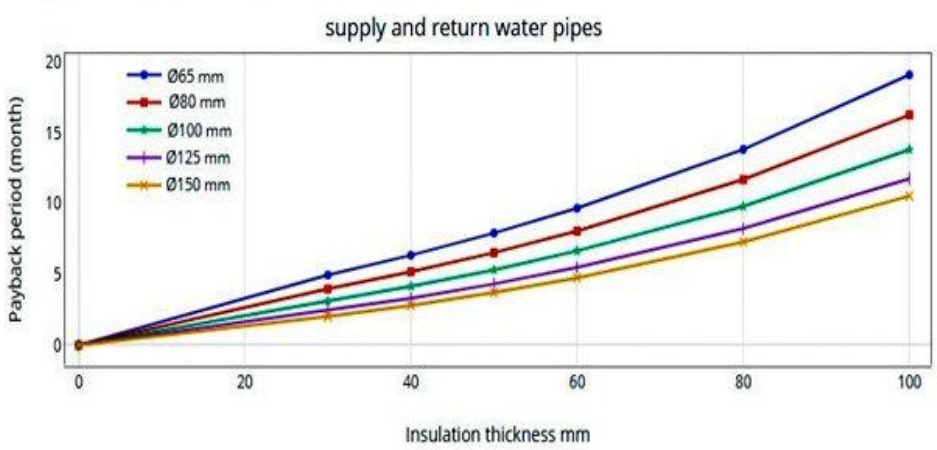

Figure 6. Changing of payback period according to different insulation thickness

4. CONCLUSIONS

The results of the study summarize as:

✓ According to the results, heat loss values from the pipes in the district heating network is as 46.48 kW, and 31.07 kW of this loss stems from supply and return pipes and 15.41 kW of this loss from hot water and circulation pipes.

✓ Annual heat loss value and heat loss ratio from all pipes in the network is respectively as 14.45×10^8 kJ and 5.44% considering all district heating system.

✓ Energy and fuel savings obtained by decreasing of heat loss thanks to insulation have been found for the different pipe diameters in the network used glass wool as insulation material according to the different insulation thicknesses.

✓ Optimum insulation thicknesses vary between 30-40 mm for all pipes and glass wool insulation material.

✓ While depending on different insulation thicknesses, the insulation costs of supply and return pipes (Ø150 mm-Ø20 mm) are changed between 11.78$/m-0.53$/m; the insulation costs of hot water pipes (Ø110mm-Ø25 mm) and circulation pipes (Ø76 mm-Ø20 mm) are between 4.94$/m-0.29$/m and 2.94$/m-0.27$/m.

✓ Energy savings are changed between 19.25$/m-102.127$/m for the supply and return water pipes, hot water, and circulation pipes by various pipe diameters during the economic life of 10 years.
✓ Payback periods vary between 2.53-0.06 years for all pipes.

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