



**SIMTERM
2011**

PROCEEDINGS

**15th Symposium on Thermal Science
and Engineering of Serbia**

Sokobanja, Serbia, October 18-21, 2011

University of Niš, Faculty of Mechanical Engineering Niš
Society of Thermal Engineers of Serbia



**2011
SOKOBANJA
SERBIA**

PROCEEDINGS

**15th Symposium on Thermal Science and
Engineering of Serbia**

Sokobanja, Serbia, October 18–21, 2011

University of Niš, Faculty of Mechanical Engineering Niš
Society of Thermal Engineers of Serbia

ISBN 978-86-6055-018-9

Publisher:
University of Niš, Faculty of Mechanical Engineering Niš

2011



Влада Републике Србије
Министарство просвете и науке

Инжењерска комора Србије



ENERGOPROJEKT
ENTEL a.d.

ENERGOPROJEKT
ENTEL

VIA OCEL
Excellence as standard

Radijator
INZENJERING

TROX® **TECHNIK**
The art of handling air

GasTeh
PRIVREDNO DRUŠTVO ZA PROIZVODNJU GASNE I ENERGETSKE OPREME, INŽENJERING I TRGOVINU

HERZ®

Rading

REHAU®
Unlimited Polymer Solutions

WILO
Pumpen Intelligenz.

ALFA CLIMA

testo
LABORATORIJA
BEOGRAD

PARADISO - LESKOVAC
SRBIJA

KNAUF INSULATION
Vreme je za stedjiti energije!

15th Symposium on Thermal Science and Engineering of Serbia

under title:

“Energy – Ecology –Efficiency”

is organized by:

University of Niš, Faculty of Mechanical Engineering Niš
and
Society of Thermal Engineers of Serbia

Under patronage of the

GOVERNMENT OF THE REPUBLIC OF SERBIA
MINISTRY OF EDUCATION AND SCIENCE

and supported by:

General Sponsor

SERBIAN CHAMBER OF ENGINEERS, Belgrade

Grand Donor

ENERGOPROJEKT ENTEL, Belgrade

Sponsors and Donors

VIA OCEL, Belgrade
RADIJATOR INŽENJERING, Kraljevo
VERSO IL PARADISO, Leskovac
TROX, Belgrade
GASTEH, Indija
HERZ, Belgrade
RADING, Kraljevo
REHAU, Belgrade
WILO, Belgrade
ALFA CLIMA, Knjaževac
LABORATORIJA TESTO, Belgrade
KNAUF INSULATION Belgrade

International Scientific Committee

Prof. Dr Gligor Kanevče	[MKD]
Prof. Dr Petar Novak	[SVN]
Prof. Dr Jordan Hristov	[BGR]
Prof. Dr Neven Duić	[HRV]
Prof. Dr Engin Ture	[TUR]
Prof. Dr Dušan Golubović	[BIH]
Prof. Dr Petar Gvero	[BIH]
Dr Maria Ichim	[ROU]
Dr Vesna Barišić	[FIN]
Prof. Dr Agis M. Papadopoulos	[GRC]
Prof. Dr Nenad Kažić	[MNE]

Program Committee

Prof. Dr Milan Radovanović,	Faculty of Mechanical Engineering Belgrade
Prof. Dr Simeon Oka,	Vinča Institute, Belgrade
Prof. Dr Miroljub Adžić,	Faculty of Mechanical Engineering Belgrade
Prof. Dr Miloš Banjac,	Faculty of Mechanical Engineering Belgrade
Prof. Dr Dragoslava Stojiljković,	Faculty of Mechanical Engineering Belgrade
Prof. Dr Goran Jankeš,	Faculty of Mechanical Engineering Belgrade
Dr Predrag Stefanović,	Vinča Institute, Belgrade
Prof. Dr Dragoslav Šumarac,	Faculty of Civil Engineering Belgrade
Dr Miodrag Mesarović,	Energoprojekt ENTEL, Belgrade
Prof. Dr Dušan Gvozdenac,	Faculty of Technical Sciences Novi Sad
Prof. Dr Milun Babić,	Faculty of Mechanical Engineering Kragujevac
Prof. Dr Vladan Karamarković,	Faculty of Mechanical Engineering Kraljevo
Dr Žarko Stevanović,	Vinča Institute, Belgrade
Prof. Dr Gradimir Ilić,	Faculty of Mechanical Engineering Niš
Prof. Dr Bratislav Blagojević,	Faculty of Mechanical Engineering Niš
Prof. Dr Dragoljub Živković,	Faculty of Mechanical Engineering Niš

Honorary Committee

Prof. Dr Vlastimir Nikolić,	Faculty of Mechanical Engineering Niš
Prof. Dr Kosta Maglić,	Vinča Institute, Belgrade
Prof. Dr Dimitrije Voronjec,	Faculty of Mechanical Engineering Belgrade
Prof. Dr Slobodan Laković,	Faculty of Mechanical Engineering Niš
Prof. Dr Nenad Radojković,	Faculty of Mechanical Engineering Niš
Prof. Dr Zoran Boričić,	Faculty of Mechanical Engineering Niš
Prof. Dr Maja Đurović Petrović,	European University, Belgrade
Jaroslav Urošević,	Energoprojekt ENTEL

Organizing Committee

President: Prof. Dr Mladen Stojiljković,	Faculty of Mechanical Engineering Niš
Vice President: Doc. Dr Mirjana Laković,	Faculty of Mechanical Engineering Niš
Vice President: Doc. Dr Dejan Mitrović,	Faculty of Mechanical Engineering Niš
Prof. Dr Branislav Stojanović,	Faculty of Mechanical Engineering Niš
Prof. Dr Mića Vukić,	Faculty of Mechanical Engineering Niš
Doc. Dr Jelena Janevski,	Faculty of Mechanical Engineering Niš
Prof. Dr Velimir Strefanović,	Faculty of Mechanical Engineering Niš
Doc. Dr Gordana Stefanović,	Faculty of Mechanical Engineering Niš
Mr Goran Vučković,	Faculty of Mechanical Engineering Niš
Dr Predrag Živković,	Faculty of Mechanical Engineering Niš
Mr Dragan Kuštrimović,	Faculty of Mechanical Engineering Niš
Mirko Stojiljković,	Faculty of Mechanical Engineering Niš
Marko Ignjatović,	Faculty of Mechanical Engineering Niš

Disclaimer

The contents of the papers presented in this publication are the sole responsibility of their authors and can in no way be taken to reflect the views of the Organizer.

Contents

1. Plenary Session	1
INTEGRATED RENEWABLE ENERGY SYSTEMS IN BUILDINGS: POTENTIAL AND PERSPECTIVES OF LOW TEMPERATURE SYSTEMS Agis M. Papadopoulos, Christina V. Konstantinidou	2
DEVELOPMENT OF THE MACEDONIAN ENERGY SECTOR IN THE FRAMEWORK OF THE ENERGY COMMUNITY G. H. Kanevce, L. P. Kanevce	10
EXERGY ANALYSIS OF TWO-STAGE WATER TO WATER HEAT PUMP D. Antonijević, N. Rudonja, M. Komatina, D. Manić, S. Uzelac	18
EDUCATION, SCIENCE AND TECHNOLOGY – TRENDS AND ACCIVEMENTS Vojin Grković	28
NEW ENERGY TECHNOLOGIES AS A CHALLENGE FOR THERMAL ENGINEERS Miodrag Mesarović	37
2. Environmental Protection	46
POLLUTANTS DISPERSION MODELING USING CLASSICAL AND MODIFIED GAUSSIAN MODELS Igor B. Andreevski, Gligor H. Kanevče, Ljubica P. Kanevče, Aleksandar P. Markoski, Sevde K. Stavreva	47
THE CONCEPT OF CCS READY PLANTS Sanja B. Petrović Bećirović, Đorđina Lj. Milovanović	56
A METHOD FOR DEFINING STREETS AS SOURCES OF CO ₂ EMISSION AND THEIR CLASSIFICATION IN THE CITY OF NIŠ Mladen Tomić, Predrag Živković, Gradimir Ilić, Mića Vukić, Jelena Milisavljević, Petar Đekić	65
TRAFFIC AND POLLUTION IN THE CITY OF NIŠ Predrag M. Živković, Mladen A. Tomić, Gradimir S. Ilić, Andrijana D. Stojanović	77
INFLUENCE OF TRAFFIC ON THE CITY OF NIŠ AIR QUALITY Predrag M. Živković, Mladen A. Tomić, Gradimir S. Ilić	85
ENVIRONMENTAL BENEFITS OF USING MUNICIPAL SOLID WASTE AS AN ENERGY SOURCE-CASE STUDY: SERBIA Dušan Marković, Gordana Stefanović, Marko Mančić, Mladen Tomić, Goran Vučković, Biljana Milutinović	94

3. Mathematical Modeling and Numerical Simulation	102
NUMERICAL PREDICTION OF OVERFIRE AIR INFLUENCE ON FEGT AND NO _x EMISSION IN 350 MWe PULVERIZED COAL UTILITY BOILER V. B. Beljanski, I. D. Tomanović, S. V. Belošević, M. A. Sijerčić, B. D. Stanković, N. Đ. Crnomarković, A. D. Stojanović	103
REVIEW OF SOFTWARE FOR SIMULATION AND OPTIMIZATION OF ENERGY SYSTEMS Marko M. Mančić, Dragoljub S. Živković, Velimir P. Stefanović, Milan Lj. Đorđević, Saša R. Pavlović	113
MODELING OF SMALL SCALE POLYGENERATION SYSTEMS Marko M. Mančić, Dragoljub S. Živković, Velimir.P. Stefanović, Saša R. Pavlović	127
MODELING OF FLUE GAS TEMPERATURE INFLUENCE ON POLLUTANT PRODUCTS EMISSION DURING THE BIOMASS COMBUSTION B. S. Repić, A. D. Marinković, G. S. Živković, S. Dj. Nemoda, B. D. Grubor	140
SOLAR WATER HEATING SYSTEMS FOR RUSSIAN CLIMATE: EFFECTIVENESS AND PERSPECTIVES OF DIFFERENT UNIT TYPES S. E. Frid, Yu. G. Kolomiets, E. V. Sushnikova	150
USAGE OF METHODS OF OPTIMIZATION FOR SELECTION OF CONSTRUCTIVE CONCEPTION OF FACILITIES OF SMALL HYDRO POWER PLANTS ON PREVIOUSLY SELECTED MACRO LOCATIONS BY METHOD OF MULTY CRITERIA RANKING Zdravko N. Milovanović, Darko Knežević, Aleksandar Milašinović, Svetlana Dumonjčić-Milovanović, Jovan Škundrić	156
MODELING OF POLLUTANTS AT THE LANDFILL WASTE Sonja Stefanov, Rade Biočanin	168
CALCULATION OF FAN OPERATING PARAMETERS FOR DIFFERENT NUMBERS OF REVOLUTIONS, CONSIDERING THE INFLUENCE OF REYNOLDS NUMBER B. P. Bogdanović, J. B. Bogdanović-Jovanović, S. Milanović	177
MONTE CARLO RANDOM WALK METHOD FOR SOLVING LAPLACE EQUATION Mladen Tomić, Predrag Živković, Mića Vukić, Gradimir Ilić, Žarko Stevanović	187
RESIDENTIAL BUILDINGS' SUSTAINABILITY BY NON-LINEAR NORMALIZATION B. Vučićević, M. Stojiljković, N. Afgan, V. Turanjanin, M. Jovanović	197
ABOVE GROUND PIPING UNDER THE INFLUENCE OF RADIATION Marko N. Ilic, Velimir P. Stefanovic, Gradimir S. Ilic, Saša R. Pavlović	207
MATHEMATICAL MODEL AND NUMERICAL SIMULATION OF CPC-2V CONCENTRATING COLAR COLLECTOR Velimir P. Stefanović, Saša R. Pavlović, Marko V. Mančić, Andrijana D. Stojanović, Milan Lj. Đorđević	219
STRUCTURAL ANALYSES OF A GUYED MAST EXPOSED TO DYNAMIC WIND ACTION M. Pezo, V. Bakić, Z. Marković, Ž. Stevanović	233
DYNAMICAL ANALYSIS OF COMBINED WIND-PHOTOVOLTAIC ENERGY SYSTEM V. Bakić, M. Pezo, M. Zivković	242

4. New and Renewable Energy Sources	250
MODERN TECHNOLOGY FOR SUSTAINABLE EXPLOITATION OF GEOTHERMAL ENERGY	
Dragoljub S. Živković, Dragan S. Milčić, Dejan M. Mitrović, Marko V. Mančić	251
THE DEPOSIT DECREASE IN INSTALLATIONS WITH GEOTHERMAL WATER IN SIJARINJSKA SPA	
Dragan T. Stojiljković, Nebojša Č. Mitić, Andrija Šmelcerović, Biljana Kaličanin, Maja Đurović-Petrović	261
GEOTHERMAL ENERGY IN VOJVODINA - POTENTIAL, UTILIZATION, POSSIBILITIES AND LEGAL REGULATIONS	
Milovan M. Medojević, Milana S. Perić	266
POSSIBILITIES FOR USING VINEYARD PRUNNING BIOMASS IN SERBIA	
Ivana Radojević, Gordana Stefanović, Marko V. Mančić, Dušan Marković, Zorica Ranković Vasić, Olivera Milošević	276
SMALL SCALE PLANT FOR COMBINED HEAT AND POWER GENERATION UTILIZING LOCAL BIOMASS	
B. S. Repić, D. V. Dakić, D. M. Đurović, A. M. Erić, M. J. Paprika	283
MODELING OF TRANSPORT PHENOMENA DURING BALED SOYBEAN RESIDUES COMBUSTION	
Aleksandar M. Erić, Stevan Đ. Nemoda, Dragoljub V. Dakić, Mirko S. Komatina, Branislav S. Repić Milica. R. Mladenović	293
SOLAR ORGANIC RANKINE CYCLES	
Milan. Lj. Đorđević, Velimir P. Stefanović, Marko V. Mančić, Saša R. Pavlović	305
APPLICATION OF SOLAR ENERGY IN STREET LIGHTING DESIGNING	
Kristina Zubović	318
WIND ENERGY POTENTIALS ON STARA PLANINA MOUNTAIN	
Predrag M. Živković, Dušan LJ. Petković, Mladen A. Tomić, Gradimir S. Ilić, Žarko M. Stevanović, Andrijana D. Stojanović	326
WOOD CHIPS PRODUCTION - LOCATIONS AND WOOD CHIP PRODUCTION EQUIPMENT	
Dejan Mitrović, Branislav Stojanović, Mladen Stojiljković, Jelena Janevski, Marko Ignjatović	333
THE SUPPLY OF THERMAL ENERGY OBTAINED FROM RENEWABLE ENERGY SOURCES FOR SMALLER URBAN UNITS	
Maja N. Marković; Ana A. Berket Bakota; Milena S. Jovanović; Branislav V. Stojanović; Jelena N. Janevski	344
BIOMASS DISTRICT HEATING SYSTEMS AND CONTROL STRATEGIES	
Marko G. Ignjatović, Bratislav D. Blagojević, Dejan M. Mitrović, Mirko M. Stojiljković	354
POSSIBILITIES OF USING BIOMASS IN THE SLAUGHTER-HOUSE INDUSTRY FOR HEAT PRODUCTION	
D. V. Dakić, B. S. Repić, A. M. Erić, D. M. Đurović, M. R. Mladenović	362
IMPACT OF THE NUMBER AND OF THE TYPES OF THE COVERS ON THE TOP HEAT LOSS OF FLAT PLATE SOLAR COLLECTOR	
Velimir P. Stefanović, Andrijana D. Stojanović, Saša R. Pavlović	369

POTENTIAL OF BIOMASS AS RENEWABLE ENERGY SOURCE IN SERBIA AND THE WORLD Velimir P. Stefanović, Andrijana D. Stojanović, Saša R. Pavlović	379
ADVANTAGES AND DISADVANTAGES OF INNOVATIVE TECHNOLOGIES FOR THERMAL TREATMENT OF MUNICIPAL SOLID WASTE Velimir P. Stefanović, Andrijana D. Stojanović, Saša R. Pavlović, Predrag Živković	389
MULTI-CRITERIA METHODS FOR RANKING POLYGENERATION SYSTEMS BASED ON RENEWABLE ENERGY SOURCES G. Lj. Janačković, S. M. Savić, M. S. Stanković	399
EFFICIENT USE OF WIND ENERGY USING WIND TURBINES WITH CVT DRIVE TRAIN Vukašin Pavlović, Miloš Milošević, Nenad D. Pavlović, Milan Pavlović, Nataša Jovanović	409
PRODUCTION OF PELLETS AND THEIR USE FOR HEATING PURPOSES Mladen Stojiljković, Mirjana Laković, Branislav Stojanović, Jelena Janevski, Dejan Mitrović	417
THE USE OF AQUIFERS AS SEASONAL THERMAL STORAGE RESERVOIRS Miloš Banjac, Mirjana Laković	429
POTENTIALS AND POSSIBILITIES OF USING WOOD BIOMASS IN SERBIA Jelena N. Janevski, Branislav V. Stojanović, Mirjana S. Laković, Mirko M. Stojiljković	438
5. Fluid Flow and Heat and Mass Transfer	445
THERMOECONOMIC MODELING OF A SIMPLE HEAT PUMP CYCLE: AN ALTERNATIVE APPROACH FOR VALVE ISOLATION A. B. Lourenço, J. J. Santos, J. L. Donatelli	446
ONE DIMENSIONAL MODEL OF COOLING WATER IN COUNTERFLOW COOLING TOWER Dušan Golubović, Dušica Golubović	454
INFLUENCE OF VOLUME INITIALIZATION IN LARGE EDDY SIMULATION OF TURBULENT COMBUSTION INSIDE CLOSED VESSEL L. Perković, M. Tomić, N. Duić	461
THERMAL INSTABILITY IN PERTURBED POISEUILLE FLOW IN PRESENCE OF TIME VARYING TEMPERATURE DIFFERENCE Milos M. Jovanovic, Jelena D. Nikodijevic	470
CHARACTERISTICS OF COMBUSTION CHAMBER FOR COMBUSTION OF PELLETS AND WOODCHIPS Branislav Stojanović, Jelena Janevski, Mladen Stojiljković, Dejan Mitrović	479
VERTICAL TEMPERATURE PROFILE IN THE INSTALLATION FOR THE COMBUSTION OF WASTE FUELS IN THE FLUIDIZED BED FURNACE Milica R. Mladenović, Dragoljub V. Dakić, Stevan Đ. Nemoda, Rastko V. Mladenović, Aleksandar M. Erić, Milijana Paprika, Mirko S. Komatina	490
LOCATION'S ALTITUDE AND ITS INFLUENCE ON THE EVAPORATION RATE OF COOLING WATER AT NATURAL DRAUGHT COOLING TOWER Vladimir I. Mijakovski, Vangelče B. Mitrevski, Nikola I. Mijakovski	500
MHD DYNAMIC AND DIFFUSION BOUNDARY LAYER FLOW OF VARIABLE ELECTRICAL CONDUCTIVITY FLUID PAST A CIRCULAR CILYNDER A. Boričić, Ž. Stamenković, B. Boričić	508

6. Examination of Operating Plants and Experimental Examination of Plants	518
POSSIBILITY OF IMPROVING MAINTENANCE PROCESS IN HEATING PLANTS Peđa Milosavljević, Dragoljub Živković, Dragan Milčić	519
EXPERIMENTAL DETERMINATION AND REVIEW OF HEAT PERFORMANCES OF THREE FLAT COLLECTORS AND A CPC-2V CONCENTRATING COLLECTOR WITH A SMALL CONCENTRATION RATIO Velimir P. Stefanović, Saša R. Pavlović, Andrijana D. Stojanović, Marko V. Mančić, Milan Lj. Đorđević	529
EFFECT OF CARBON DIOXIDE CONTENT IN NATURAL GAS ON EMISSIONS AT LEAN PREMIXED CONDITIONS Marija Živković, Miroljub Adžić, Aleksandar Milivojević, Dejan Ivezić, Vuk Adžić, Vasko Fotev	542
THE IMPACT OF LOAD OF TRANSMISSION LINES AND TRANSFORMERS ON POWER SYSTEM GENERATION Vladan D. Krsman, Ljiljana M. Samardžić	549
THE INFORMATION SYSTEM OF REPORTING AND MONITORING PROCESSES IN A POWER PLANT HEATING PLANT NOVI SAD Slobodan Stevanović, Sladjana Barjaktarović, Nebojša Kaljević, Tatjana Karadjinović,	559
PARTICULATE MATTER EMISSION INVESTIGATION ON THE UPGRADED ELECTROSTATIC PRECIPITATORS AT TPP "NIKOLA TESLA" Milić Erić, Predrag Škobalj, Zoran Marković, Dejan Cvetinović, Rastko Jovanović, Predrag Stefanović	568
MATHEMATICAL MODELLING AND EXPERIMENTAL INVESTIGATION OF THE FURNACE FOR STRAW COMBUSTION D. Djurovic, S. Nemoda, D. Dakic, A. Eric, B. Repic	577
VARIATION OF OPERATION OF LOW-PRESSURE REVERSIBLE AXIAL FAN DRIVEN BY INDUCTION MOTOR FROM START TO THE STEADY-STATE Živan Spasić, Božidar Bogdanović, Milan Radić	586
7. Energy Efficiency and Rational Energy Management	596
ENERGY EFFICIENCY OF TYPICAL SERBIAN RURAL HOUSES D. M. Šumarac, M.N. Todorović, Z.B. Perović, R. D. Roglić	597
THE DIFFERENT ENERGY SOURCE TYPE INFLUENCE ON BUILDING PRIMARY ENERGY NEEDS M. N. Todorović, T. S. Bajc	607
A REVIEW OF BUILDING ENERGY REGULATION, CLASIFICATION AND CERTIFICATION SCHEMES J. Skerlić, D. Gordić	617
APPLICATION OF ENERGY EFFICIENCY AND BIOCLIMATIC PRINCIPLES IN URBAN PLANNING Biljana Rakić, Ljiljana Mihajlović	627
DUOBLE SKIN FAÇADES – DEFINITION AND CONCEPT, HISTORICAL DEVELOPMENT, ADVANTAGES AND DISADVANTAGES Aleksandar S. Anđelković, Damir D. Đaković	638
COMPRESSED AIR SYSTEM STRUCTURE AND ENERGY EFFICIENCY D. D. Šešlija, I. M. Ignjatović, S. M. Dudić	649

COMPARATIVE REVIEW OF THE ENERGY EFFICIENCY OF THERMAL POWER PLANTS WITH THE OPEN AND CLOSED-CYCLE COOLING SYSTEM Mirjana Laković, Slobodan Laković, Miloš Banjac, Mladen Stojiljković	659
DESIGN OF SYSTEM FOR CENTRAL ASPIRATION OF WOOD DUST Vladimir Vukašinović, Dušan Gorgić, Milun Babić	668
APPLICATION OF AHP AND QFD METHOD IN THE ANALYSIS OF ENERGY EFFICIENCY Slađana Živadinović, Ivan Savić	677
A STRATEGIC APPROACH TO ENERGY AND ENVIRONMENTAL MANAGEMENT Slađana Živadinović, Marija Milicević, Nada Živanović	685
STUDY OF USAGE OF RECYCLED RUBBER CRUMBS (RRC) FOR PRODUCTION OF THERMAL INSULATION PANELS Petar Đekić, Anica Milošević, Boban Cvetanović	692
USING INDUSTRIAL WASTE HEAT TO COVER DOMESTIC HEAT DEMAND - ANALYZING POTENTIAL AND DEMAND S. Brückner, H. Schäfers, I. Peters	699
EVALUATION OF THERMAL AND ELECTRICAL ENERGY CONSUMPTIONS IN SCHOOLS OF ČAČAK REGION S. M. Dragičević, S. M. Stojković, S. G. Vasović	707
REVIEW OF THE CURRENT ENERGY POLICY IN THE REPUBLIC OF SERBIA WITH THE DEVELOPMENT PERSPECTIVES Mirjana Laković, Branislav Stojanović, Mladen Stojiljković, Marko Ignjatović	716
THE ROLE OF THE INTELLIGENT BUILDING SKIN IN INCREASING ENERGY EFFICIENCY IN BUILDINGS Milica Stojanović, Nataša Petković, Petar Mitković	728
ESTIMATION OF ENERGETIC CHARACTERISTICS OF SETTLEMENTS IN NIŠ REGION, SERBIA Branislav V. Stojanović, Mirko M. Stojiljković, Marko G. Ignjatović, Goran D. Vučković, Mladen M. Stojiljković, Jelena N. Janevski	735
8. Energy and Environmental Aspects of Transportation	741
ONE APPROACH FOR IMPROVEMENT OF SPARK IGNITION ENGINE EFFICIENCY Jovan Ž. Dorić, Zoran M. Čepić, Ivan J. Klinar	742
HYDRAULIC HYBRID TECHNOLOGY REVIEW – PERSPECTIVES AND BENEFITS OF ITS IMPLEMENTATION ON PUBLIC TRANSPORTATION VEHICLES M. Kitanović, S. J. Popović, N. Miljić, M. Cvetić, M. Tomić, P. Mrđa	752
THE EFFECT OF BIODIESEL AND BLENDED DIESEL FUEL ON EXHAUST EMISSIONS R. Gligorijević, J. Jevtić, Đ. Borak	761
ECOLOGICAL AND ENERGETIC DIESEL ENGINE CHARACTERISTICS WITH BIODIESEL Aleksandar Lj. Davinić, Radivoje B. Pešić, Stevan P. Veinović, Stojan V. Petrović	766
THE COMBUSTION CHAMBER APPRAISAL ON THE BASIS OF ITS FLUID FLOW CHARACTERISTICS Zoran S. Jovanović, Zlatimir M. Živanović, Željko B. Šakota, Zoran M. Masonicic	774

USAGE OF SMALLER VEHICLES IN URBAN ENVIRONMENT IN ORDER TO DECREASE CO ₂ EMISSIONS V. Momčilović, A. Manojlović, D. Vujanović, S. Bunčić, V. Papić	784
AUTOMOTIVE MECHATRONIC SYSTEMS – ECONOMY AND ECOLOGY Milan Pavlović, Miloš Milošević, Dušan Stamenković, Aleksandar Stefanović, Vukašin Pavlović	792
9. Technologies and Plants	802
ENERGY EFFICIENCY IMPROVING OF COMBINED CYCLE GAS POWER PLANTS (CCGPP) AND ENVIRONMENT BENEFITS WITH TRIGENERATION AND TRIGENERATION POWER PLANTS (TPP) USED Marijan Gacevski	803
CALCULATION ANALYSIS OF WAVED EXPANSION JOINT Jelena Nikolić, Aleksandra Đerić, Aleksandar Petrović	810
EFFICIENCY ASSESSMENT OF DIFFERENT CAB AIR DISTRIBUTION SYSTEM LAYOUTS Dragan Ružić, Ferenc Časnji, Aleksandar Poznić	819
HOW TO DETERMINE WHEN DRYING INTERVALS START AND FINISH DURING GRAIN DRYING Damir D. Đaković, Aleksandar S. Anđelković	829
COMBINED HEAT AND POWER TECHNOLOGIES - AN OVERVIEW Dejan Mitrović, Dragoljub Živković, Velimir Stefanović, Mirjana Laković-Paunović	834
ROTATING STALL IN CENTRIFUGAL PUMP RADIAL IMPELLERS Ž. M. Stamenković, J. B. Bogdanović-Jovanović	846
CONVENTIONAL AND ADVANCED EXERGETIC ANALYSES APPLIED TO AN INDUSTRIAL PLANT Goran Vučković, Gradimir Ilić, Mića Vukić, Mirko M. Stojiljković	856
10. Automatics, Process Control and Expert Systems	866
ABOUT THE DYNAMIC BEHAVIOR AND THE REGULATION OF NEW TYPE OF WIND TURBINE GEARBOX BASED ON CVT Boban Andjelković, Dragan Milčić, Jelena Stefanović Marinović, Aca Micić, Biljana Djordjević	867
SYSTEM MODERNIZATION OF THE STEAM BLOCK AUTOMATIC CONTROL USING DCS AND SCADA SYSTEMS AND PLC CONTROLLERS Milena Todorović, Dragoljub Živković	875
DETECTION OF THE POSITION AND ESTIMATION OF DIMENSIONS OF THE MOVING OBJECT IN THE LOW VISIBILITY CONDITIONS BY APPLYING THE TECHNIQUE OF DIGITAL IMAGE PROCESSING Aca Micić, Biljana Djordjević, Boban Andjelković, Dragan Radenković	884
A TRACEABLE RELATIVE HUMIDITY CALIBRATION IN THE INSTITUTE “VINČA” N.D. Milošević, N.M. Stepanić	890
APPLICATION OF LIQUID COOLING IN DATACOM EQUIPMENT Sevde Stavreva, Marko Serafimov	900

EXPLOITATION RESEARCHES OF THE THERMO-ENERGETIC SYSTEM'S AVAILABILITY	
Dragan Milčić, Dragan Kalaba, Dragoljub Živković, Miroslav Mijajlović	905
CONTROL SYSTEMS FOR MICRO AND MINI HYDROPOWER PLANTS	
Vladislav. A. Blagojević, Jasmina B. Bogdanović-Jovanović, Miodrag M. Stojiljković	918
CONTROL PRINCIPLES OF BOILERS FOR CHOPPED STRAW BALES COMBUSTION	
Dragan Mitić, Milan Protić, Velimir Stefanović	928



EXPLOITATION RESEARCHES OF THE THERMO-ENERGETIC SYSTEM'S AVAILABILITY

Dragan Milčić*, **Dragan Kalaba****, **Dragoljub Živković***, **Miroslav Mijajlović***

*University of Nis, Faculty of Mechanical Engineering, Aleksandra Medvedeva 14, 18000 Nis**

*University of Pristina, Faculty of Technical Sciences Kosovska Mitrovica, Kneza Miloša 7, 38220
Kosovska Mitrovica***

Abstract: Thermo-energetic system, consisting of boiler, steam turbine and three-phase synchronous generator, represents a major power plant component, so delays in the working process of such a systems directly cause delays in work of the power system, or furthermore of complete electro-energetic system of a country. This implies that power plants must have technical solutions that will work give maximum availability and reliability during the process of working. The paper presents the determination of availability and reliability of a thermo-energetic system based on exploitation researches.

Key words: *Thermo-energetic system, Reliability, Maintainability, Availability*

2. INSTRUCTION

Development of the industrial and the nonindustrial complex, as well as development of living standards are in high mutual dependence with the development of energy production and energy consumption. Therefore, any disruption in energy supply has negative consequences in social reproduction.

In a very complex economic and energetic situation in the world as well in Serbia, there is as great a problem finding alternative solutions for providing long-term stable energy supply of any kind, especially electricity. Therefore almost all countries around the globe try to achieve this goal and direct its activities on finding energy reserves, or procedures for the use of new forms of energy and above all - rationalization of energy consumption.

Accordingly the question being asked is: how the availability of the thermo-energetic system can contribute to achieving the tasks being set; giving rise to the importance of availability, exploitation, production planning, design and construction of new thermo-energetic systems as well as the whole powerplant.

3. AVAILABILITY OF THE THERMO-ENERGETIC SYSTEMS

The availability is defined as:

The probability that an item is in state of functioning at a given point in time (point availability) or over a stated period of time (interval availability) when operated, maintained and supported in a prescribed manner.

It is clear from the above definition that availability is a function of reliability, maintainability and supportability factors (Figure 1).

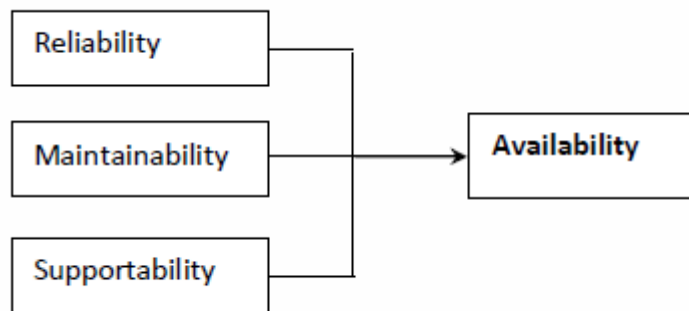


Figure 1 Availability as a function of reliability, maintainability and supportability

Point availability is defined as the probability that the system is in the state of functioning (SoFu) at the given instant of time t . We use the notation $A(t)$ to represent the point availability. Availability expressions for systems can be obtained by using stochastic processes. Depending on the time to failure and time to repair distributions, one can use Markov chain, renewal process, regenerative process, semi-Markov process and semi-regenerative process models to derive the expression for point availability. For example, consider an item with constant failure rate λ and constant repair rate μ . At any instant of time, the item can be in either the state of functioning (say, state 1) or in the state of failure (say, state 2). As both failure and repair rates are constant (and thus follow exponential distribution), we can use a Markov chain to model the system to derive the availability expression.

Despite the intensive development of the theory of the availability by various authors still there are some differences in interpretation and definitions of basic concepts and laws of this branch of science. However, definition of the availability is as follows:

Availability is the probability that a particular system or device will be able to work during the time regarding to the functioning of the system or device that is properly or part of a system that was repaired in time equal to or less than the total set maintenance time.

The point availability $A(t)$ is given by:

$$A(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} \cdot e^{-(\lambda + \mu)t} \quad (1)$$

Substituting $\lambda = 1/MTTF$ and $\mu = 1/MTTR$ in the previous equation, we get:

$$A(t) = \frac{MTTF}{MTTF + MTTR} + \frac{MTTR}{MTTF + MTTR} \cdot e^{-(\lambda + \mu)t} \quad (2)$$

Since the working capacity of the system is a variable value, at the beginning of the availability analysis of any technical system, basic conditions and delays are defined. There are three types of the availability characteristic for the thermo-energetic systems:

- availability of time,
- availability of power and
- availability of energy.

The basic system's status, condition and state of the work to a standstill, are influenced with drive, work, and external control mechanisms of the system, whereby the state of work is resulting in the work of the criteria function within the limits of permissible deviations - the stalemate in the state of partial or complete loss of working ability system, or the inability of the system to perform the functions set criteria within the permissible deviations. Occurrence of delays in the system are caused by the effects of different types and their distribution.

Delays in work of the system appear because of:

- standstill of the part of the system or
- standstill because of the external influences.

Both of them can be:

- planned delays and they relate to those delays that occurred at the previously established plan for a certain period of time and
- unplanned, which apply to all delays that occurred unexpectedly in a period of time. Unplanned outages can be enforced and refer to those that are involuntary delays, current and as such can not be delayable and undelayable or delays may arise because they appeared minimal causes giving rise to deadlock.

Planned or unplanned delays as well as complete failure, and failure that cause the reduction of capacity (the parts of the system) are planned or unplanned interventions on the system appearing as:

- Revision or care, which provides timely halt to the detailed list of works to be performed. It usually provides for the performance of control and diagnostic operations.
- Preventive testing to determine the required characteristics.
- Forced repair or repairs, with repairs made on assemblies and parts or replacing equipment, for which there was an immediate switch off the system or elements.

Also, the delays caused by outside influences can cause a complete failure or a capacity reduction. Delays caused by external influences are caused by:

- standstill of other system in the power plant, which is in connection with our system (the causes of these delays are identical causes of system downtime).
- lack of fuel.
- by the request of the power system, due to the inability of the sale of electricity and hydrology benefits.
- other delays caused by external influences such as the collapse of the system, electrical discharge, work stoppages, natural disasters etc.

3 AVAILABILITY FACTORS

Value of the time availability is determined by 2 factors:

- reliability and
- maintainability.

3.1. Reliability

Today it is generally accepted that the theory of reliability, as a new scientific discipline, examines the legality of occurrence of technical failure of the system.

The technical system is considered as a set of elements, which represent a system performing a single function. In reliability theory, the concept elements (components) of the system refers to parts of the system, whose reliability is calculated integral, and therefore they do not have to be inseparable parts. In determining the reliability of a system, it is necessary to first define the reliability of its elements, and then the whole system.

The term reliability represents the probability of failure-free operation at certain times and certain environmental conditions, ie. probability that the manufacturing process for technical systems take place without interruption and downtime by providing the required deadlines in the implementation of the required production volume, product range and quality (function criteria) with the planned standards of materials, labor and cost for a specific time period and predetermined conditions. As the moments of downtime and the length of the work without delay random variables to be reliable based on the application of probability theory and mathematical statistics, but also has applied information theory, queuing theory, linear and dynamic programming.

To determine the reliability of technical systems its basic indicators are mainly used:

- Cumulative distribution function,
- Probability density function,
- Reliability,
- Failure rate function.

3.2 Maintainability

Maintainability can be expressed as the probability that the system will be retained or returned to the state of functionality under the prescribed conditions in a given period of time if the maintenance is in accordance with prescribed procedures. Maintainability is related to:

- principle of simplicity and convenience of the system structure of its composition (assembly, disassembly, easy replace ability, availability, etc.);
- quality of building;
- maintenance conditions;
- integrated system support levels (or degree of organization of functions between the system-environment).

Maintainability is based on the following facts:

- Maintainability is the result of coordination of the design (construction) and operation (operation and maintenance) systems.
- Maintainability must analyze the entire system, not its individual parts.
- Maintainability is determined, predicted, measured and incorporated into the design process and during operation of the system.
- Maintainability is very closely related to the components of effectiveness (reliability, availability).
- Maintainability is a requirement for setting up an efficient system maintenance.
- Requirements that affect maintainability increase productivity (machining-assembly properties of structural systems) and ensure improvement of conditions of exploitation.
- Requests of maintainability influence to apply the innovation system.
- Requests of maintainability also include the maintenance of proper education of employees and others.

To determine the benefits of maintaining the technical systems the following indicators are mainly used:

- Probability density function of minimal maintenance intervals.
- Machinability and non-machinability functions.
- Failure rate function.

Maintenance tasks can be classified into the following three categories:

1. corrective maintenance task,
2. preventive (predictive) maintenance task,
3. conditional maintenance task.

Corrective Maintenance Task

Corrective maintenance task, CRT, is a set of activities, which is performed with the intention of restoring the functionality of the item or system, after the loss of the functionality or performance (i.e. after failure). Figure 2 illustrates typical corrective maintenance task activities. The duration of corrective maintenance task, DMT_c , represents the elapsed time needed for the successful completion of the task. Corrective maintenance task is also referred to as an unscheduled or unplanned maintenance task.

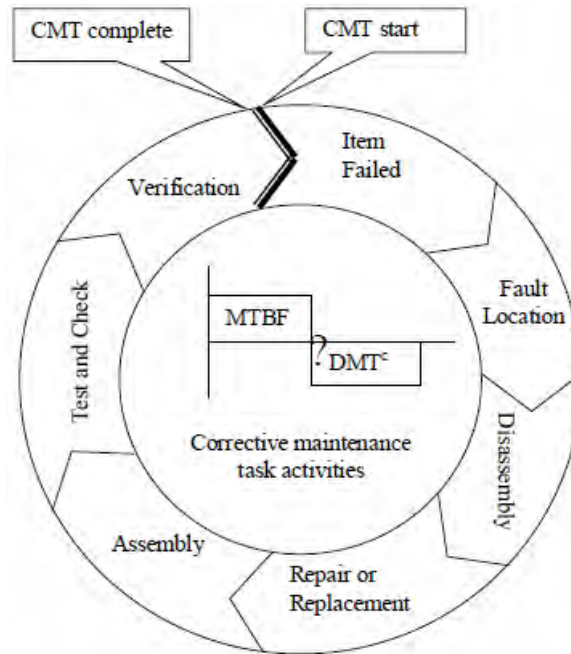


Figure 2 Activities of typical corrective maintenance task

Preventive Maintenance Task

Preventive maintenance task, PMT , is a maintenance activity that is performed in order to reduce the probability of failure of an item/system or to maximise the operational benefit. Figure 3 illustrates the activities of a typical preventive maintenance task. The duration of the preventive maintenance task, DMT_p , represents the elapsed time needed for the successful completion of the task.

Preventive maintenance task is performed before the transition to the state of failure occurs with the main objective of reducing:

- The probability of the occurrence of a failure
- The consequences of failure

Common preventive maintenance tasks are replacements, renewal and overhaul. These tasks are performed, at fixed intervals based on operating time (e.g. hours), distance (e.g. miles) or number of actions (e.g. landings), regardless of the actual condition of the items/systems.

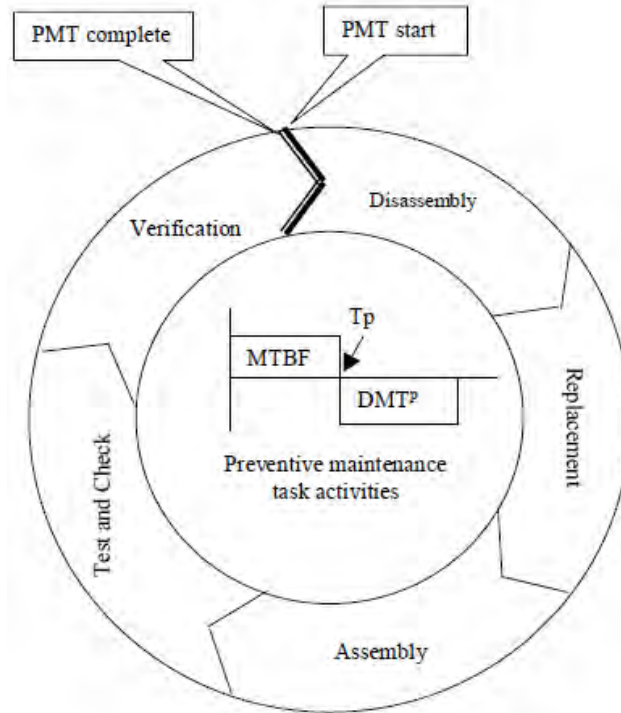


Figure 3 Activities of a typical preventive maintenance task

Conditional (Predictive) Maintenance Task

Conditional maintenance task, *COT*, recognises that a change in condition and/or performance is likely to precede a failure so the maintenance task should be based on the actual condition of the item/system. *COT* does not normally involve an intrusion into the system and actual preventive action is taken only when it is believed that an incipient failure has been detected.

Thus, through monitoring of some condition parameter(s) it would be possible to identify the most suitable instant of time at which preventive maintenance tasks should take place.

Figure 4 illustrates the activities of a typical conditional maintenance. The duration of conditional maintenance task, DMT_m , represents the elapsed time needed for the successful completion of the task. In the past, corrective maintenance and preventive maintenance tasks have been popular among maintenance managers. However, in recent years, the disadvantages of these tasks have been recognised by many maintenance management organisations. The need for the provision of safety, and reduction of the maintenance cost have led to an increasing interest in using conditional maintenance task. Waiting until a component fails may maximise the life obtained from that component but, its failure may cause significant damage to other parts of the system and will often occur at inopportune times causing a disruption to the operation and inconvenience to the users. Routine or scheduled preventive maintenance, on the other hand, may be very convenient but

is likely to result in an increase in the amount of maintenance needed because parts will be replaced when they have achieved a fraction of their expected life.

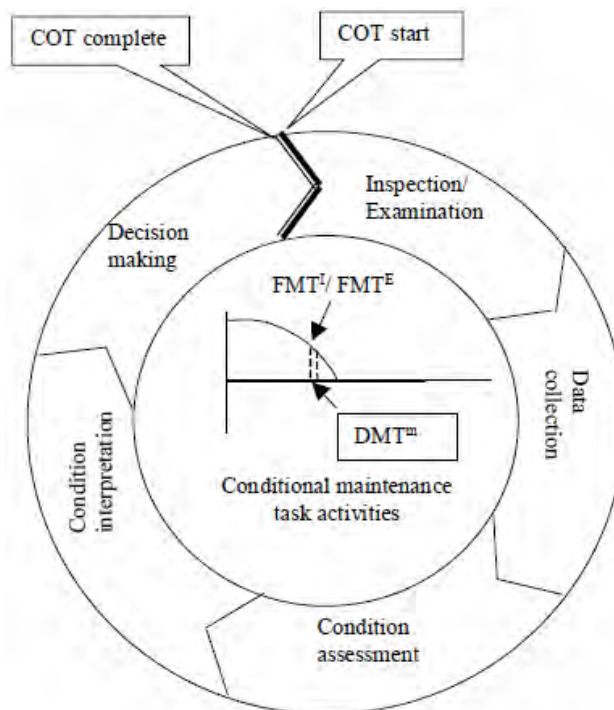


Figure 4. Activities of a typical conditional maintenance task

4. ANALYSIS OF RESULTS AND EXPERIMENTAL RESEARCHES ON THE THERMO-ENERGETIC POWER PLANT NIKOLA TESLA A TPP IN OBRENOVAC

Properties and behavior of all technical systems, as well as TPP Nikola Tesla "A" Obrenovac, by their nature are highly stochastic processes and values. This is, as pointed out, one of the essential features of the concept of reliability. It just explains that all information relating to the reliability of thermal power plant at TPP Nikola Tesla "A" Obrenovac and its main components of random size, subject to certain laws of probability. Because of this, the processing of this information may be performed only with the help of mathematical statistics and probability. Exploiting the thermal power plant operation data of TPP Nikola Tesla A in Obrenovac, and the paper gives the results of these related to the turbine sub-system (Table 1).

Time intervals of work in which are recorded all the data required for processing the reliability and reliability indicators of systems and subsystems are determined by the duration of one year or 8760 hours of work for the period since 1996. year until 2008. year.

Table 1 Experimental results

i	1	2	3	4	5	6	7	8	9	10	11	12	13
T_{ki} [year]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
T_{i-1} [h]	0	8760	17520	26280	35040	43800	52560	61320	70080	78840	87600	96360	105120
T_i [h]	8760	17520	26280	35040	43800	52560	61320	70080	78840	87600	96360	105120	113880
ΔT_i [h]	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
T_{ai} [h]	5456	6962	6756	5894	6584	6533	7176	7234	7035	7172	7113	1878	8443
T_{pzi} [h]	2199.25	1078.38	1062.25	2126.36	1345.1	733.54	746.01	862.17	1169.57	908.45	508.39	6430.39	0
T_{nzi} [h]	23.06	4.39	2.09	0.59	112.03	67.51	0	19.36	1	1.07	0	68.48	1.05
T_{rezi} [h]	1081.69	715.23	939.66	739.05	718.87	1425.95	837.99	644.47	554.43	678.48	1138.61	383.13	315.95
T_{ri} [h]	6537.69	7677.23	7695.66	6633.05	7302.87	7958.95	8013.99	7878.47	7589.43	7850.48	8251.61	2261.13	8758.95
$N(\Delta T)_i$	1	1	1	1	3	1	0	3	1	2	0	4	1
$N(T)_i$	1	2	3	4	7	8	8	11	12	14	14	18	19
$n(T)_i$	18	17	16	15	12	11	11	8	7	5	5	1	0
f_i	0.052632	0.052632	0.052632	0.052632	0.157895	0.052632	0	0.157895	0.052632	0.105263	0	0.210526	0.052632
F_i	0.052632	0.105263	0.157895	0.210526	0.368421	0.421053	0.421053	0.578947	0.631579	0.736842	0.736842	0.947368	1
R_i	0.947368	0.894737	0.842105	0.789474	0.631579	0.578947	0.578947	0.421053	0.368421	0.263158	0.263158	0.052632	0
λ_i	0.055556	0.058824	0.0625	0.066667	0.25	0.090909	0	0.375	0.142857	0.4	0	4	$+\infty$
t_{osi} [h]	23.06	4.39	2.09	0.59	37.34333	67.51	0	6.453333	1	0.535	0	17.12	1.05
Σt_{osi} [h]	23.06	27.45	29.54	30.13	67.47333	134.9833	134.9833	141.4367	142.4367	142.9717	142.9717	160.0917	161.1417
$f(t_0)_i$	0.143104	0.027243	0.01297	0.003661	0.231742	0.418948	0	0.040048	0.006206	0.00332	0	0.106242	0.006516
$PO(t_0)_{empirical}$	0.143104	0.170347	0.183317	0.186978	0.418721	0.837669	0.837669	0.877716	0.883922	0.887242	0.887242	0.993484	1
MR %	3.6082	8.7629	13.9175	19.0722	34.5361	39.6907	39.6907	55.1546	60.3093	70.6186	70.6186	91.2371	96.3918
$PO(t_0)_{theoretical}$	0	0.76812	0.94623	0.98753	0.99711	0.99933	0.99984	0.99996	1	1	1	1	1

Marks in table 1:

1. i – the ordinal number of period during system operation
2. T_{ki} – calendar time of the i – th interval $i = 1, 2, \dots, n$ ($n = 13$)
3. T_{i-1} – start time of the i – th interval
4. T_i – end time of the i – th interval
5. T_a – engaged time
6. T_{pzi} – sum of the planned standstills
7. T_{nzi} – total sum of the planned standstills
8. T_{rezi} – total time in reserve $T_{rezi} = \Delta T_i - (T_{ai} + T_{pzi} + T_{nzi})$
9. T_{ri} – medium available time $T_{ri} = T_{ai} + T_{rezi}$
10. $N(\Delta T)_i$ – number of delays in the i -th interval

11. $N(T)_i$ – cumulative sum of the delays by the end of the i -th interval
12. $n(T)_i$ – number of usable states at the end of the i -th interval
13. f_i – probabilistic density of downtimes $f_i = N(\Delta T)_i / \sum_1^n N(\Delta T)_i$
14. F_i – unreliability $F_i = \sum_{i=1}^n f_i$
15. R_i – reliability $R_i = 1 - F_i$
16. λ_i – failure rate $\lambda_i = N(\Delta T)_i / n(T)_i$
17. $t_{0si} = \frac{T_{nzi}}{N(\Delta T)_i}$ – mean duration of maintenance intervention
18. $t_{0sn} = \sum_{i=1}^n t_{0si}$ – total sum of medium duration of maintenance interventions
19. $f(t_0)_i = \frac{t_{0si}}{t_{0sn}}$ – density of minimum maintenance interventions
20. $P(t_0)_i = \sum_{i=1}^n f(t_0)_i$ – empirical maintainability,
24. $t_{0s} = \frac{1}{n} \sum_{i=1}^n t_{0si}$ – median intensity duration of maintenance interventions
24. $\mu_s = \frac{1}{t_{0s}}$ – median intensity of maintenance interventions
23. $P(t_0)_{theoretical} = 1 - e^{-\mu_s \cdot t_0}$ - theoretical maintainability.

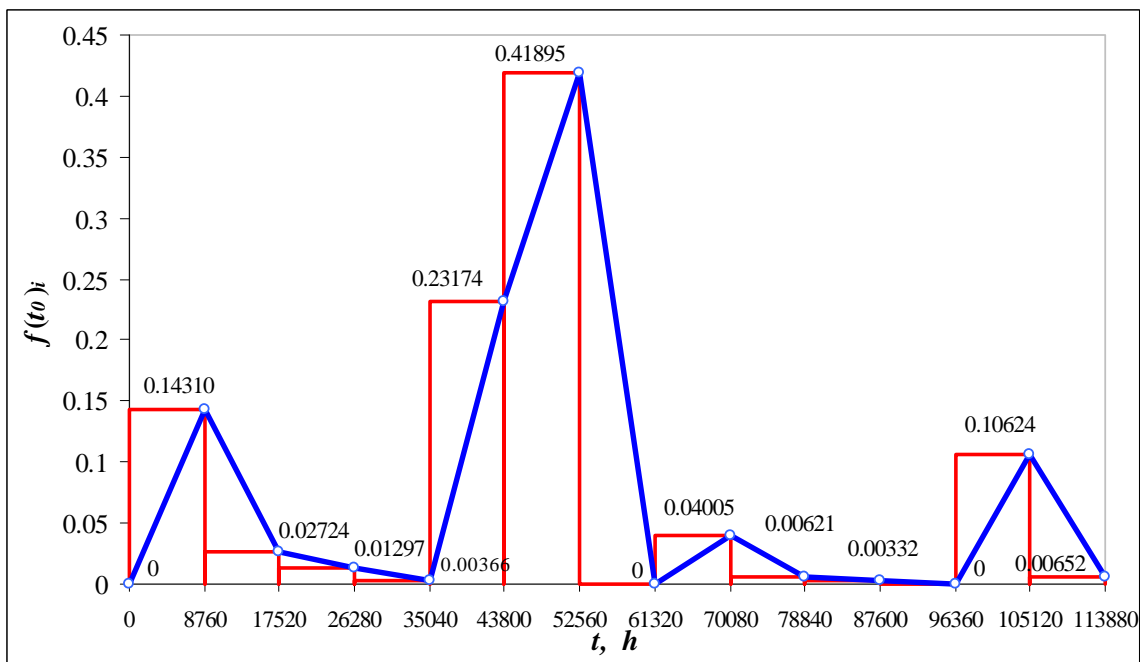


Figure 5 Density of minimum maintenance interventions

$$t_{0s} = \frac{1}{n} \sum_{i=1}^n t_{osi} = \frac{1}{13} \cdot 161,1417 = 12,39 h$$

$$\mu_s = \frac{1}{t_{0s}} = \frac{1}{12,39} = 0,0807 h^{-1}$$

Theoretical maintainability:

$$P(t_0)_{theoretical} = 1 - e^{-0,0807 \cdot t_0}$$

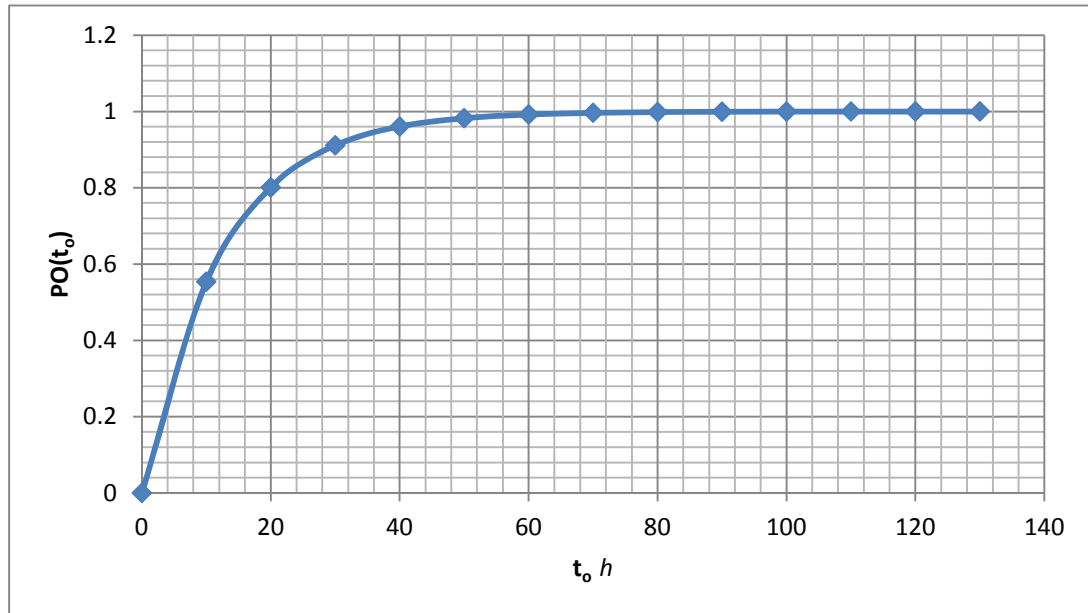


Figure 6 Theoretical maintainability

Function of availability of turbine:

$$A(T)_s = \frac{\mu_s}{\mu_s + \lambda_s} + \frac{\lambda_s}{\mu_s + \lambda_s} e^{-T(\mu_s + \lambda_s)} = \frac{0,08068}{0,08068 + 1,5432 \cdot 10^{-4}} + \frac{1,5432 \cdot 10^{-4}}{0,08068 + 1,5432 \cdot 10^{-4}} e^{-T(0,08068 + 1,5432 \cdot 10^{-4})} = 0,998 + 0,001909 \cdot e^{-T \cdot 0,080834}$$

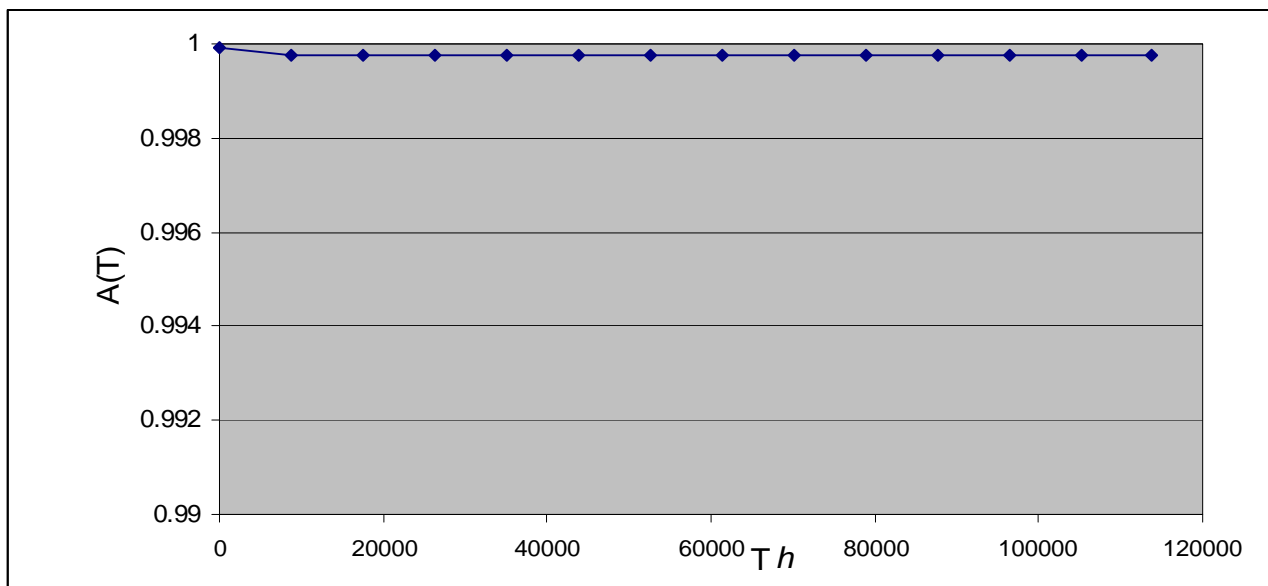


Figure 7 Function of availability

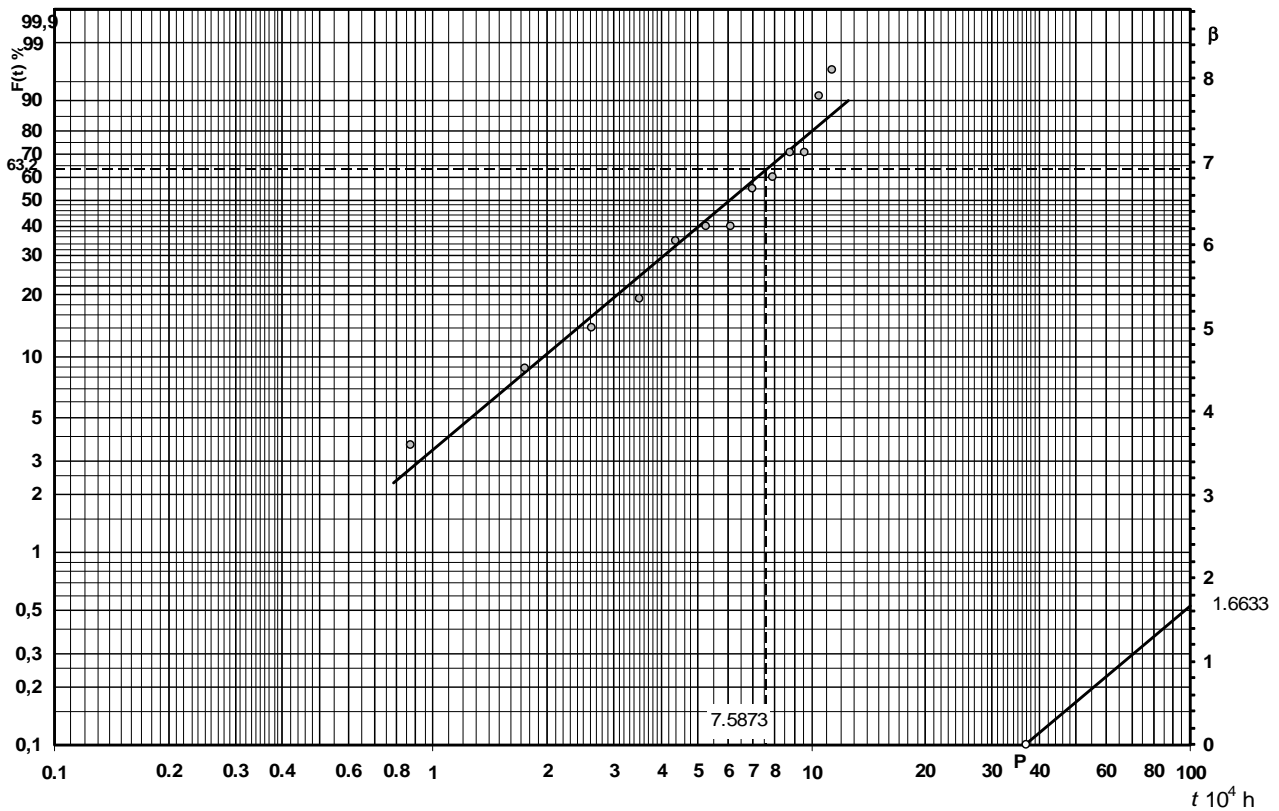


Figure 8 Weibull probability plotting paper

Function of reliability:

$$R(t) = e^{-\left(\frac{t}{75873}\right)^{1.663}}$$

CONCLUSION

Thermo-energetic system, consisting of boiler, steam turbine and three-phase synchronous generator, represents a major power plant component, so delays in the working process of such a systems directly cause delays in work of the power system, or furthermore of complete electro-energetic system of a country.

In paper is give analysis of results and experimental researches on the sub-system turbine of thermo-energetic power plant Nikola Tesla A in Obrenovac.

Data processing functions is determined by the availability, maintainability and reliability of turbine power plant Nikola Tesla A in Obrenovac.

Data processing software was used for reliability analysis, developed at the Mechanical Engineering Faculty in Nis.

REFERENCES

Books

- [1] Kalaba, D., Raspoloživost termoenergetskih sistema, Univerzitet u Prištini, Fakultet tehničkih nauka Kosovska Mitrovica, 2011., s. 149.
- [2] Milčić, D.: Pouzdanost mašinskih sistema, Mašinski fakultet Univerziteta u Niš, 2005., s.200.
- [3] Milčić, D., Mijajlović, M.: Pouzdanost mašinskih sistema – Zbirka rešenih zadataka, Mašinski fakultet Univerziteta u Nišu, 2008., s.215.

Conference or symposium proceedings

- [4] Milčić, D., Mijajlović, M., Metode konstruisanja termoenergetskih sistema na osnovu pouzdanosti, 13. Simpozijum termičara SCG SIMTERM 07, Zbornik apstrakata, Sokobanja, 2007, CD.

ISBN 978-86-6055-018-9



9 788660 550189