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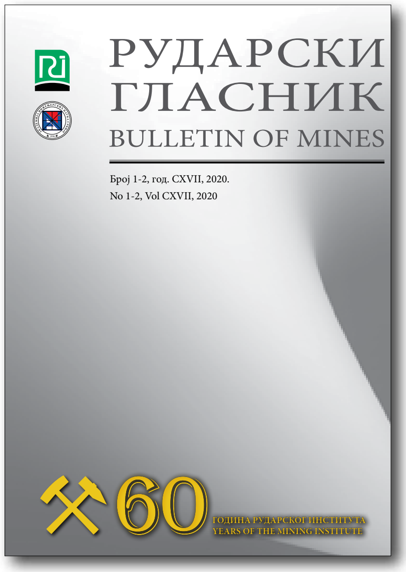

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УВОДНА РЕЧ

Ове 2020. године је шест деценија од оснивања Рударског института Београд. Тим поводом, уз честитке с рударским Срећно! овај број Рударског гласника посвећен је великом јубилеју Рударског института, са жељама усмерним ка новим креативним достигнућима и успесима интегрисања науке и инжењерства на добробит рударства и Србије.

Разумевајући поруке времена и потребе српске и југословенске рударске привреде оснивача Института, генерације истраживача, пројектаната и сарадника шест деценија марљиво је градило Рударски институт подижући га на највиши научни и инжењерски ниво. Ово издање Рударског гласника у тексту Шест деценија креативног стваралаштва пружа читаоцима могућност да сазнају више о значајнијим секвенцама из развоја и рада Рударског института. Истим поводом, али детаљно, систематично, историји развоја и достигнућима Института посвећена је монографија Шест деценија Рударског института Београд.

Ово је година великог јубилеја Горног журнала (Рударског журнала) - данас у свету најстаријег научног и стручног часписа за рударство, у континуитету излази од 1825. У овом броју приложен је пригодан текст поводом *195. рођендан*а Горног журнала. Аутору проф. др Александру Г. Воробиеву, заменику главног уредника, пријатељу и драгом колеги,

INTRODUCTORY SPEECH

This year, 2020, marks six decades since the founding of the Mining Institute Belgrade. On that occasion, with congratulations and the mining Good luck!, this issue of Bulletin of Mines is dedicated to the great jubilee of the Mining Institute, with wishes aimed at new creative achievements and successes of integrating science and engineering for the benefit of mining and Serbia.

Generations of researchers, designers and associates have diligently built the Mining Institute for six decades, raising it to the highest scientific and engineering level, understanding the messages of the time and the needs of the Serbian and Yugoslav mining economy as the founder of the Institute. The text Six decades of creative creation in this issue of the Bulletin of The text Six decades of creative creation in this issue of the Bulletin of Mines provides readers with the opportunity to learn more about significant sequences from the development and work of the Mining Institute. Mines provides readers with the opportunity to learn more about significant sequences from the development and work of the Mining Institute. On the same occasion, but in detail, and systematically, the monograph Six Decades of the Mining Institute Belgrade is dedicated to the history of development and achievements of the Institute.

This is the year of the great jubilee of the Gornyi Zhurnal (Mining Journal) - today the world's oldest scientific and professional journal on mining, which has been published continuously since 1825. This issue includes an appropri-

захваљујемо на прихватању позива и уложеном труду.
Са жељом да се сарадња наших часописа постојано шири и унапређује, уз честитку за 195. рођендан Рударском журналу желимо да своју мисију настави успешно на срећу рударства!

ate text on the occasion of the 195th birthday of The Gornyi Zhurnal.
We thank the author Prof. Dr. Aleksandar G. Vorobiev, Deputy Editor-in-Chief, friend and dear colleague, for accepting the invitation and for the invested effort.
With the desire that the cooperation of our journales is constantly expanding and improving, with congratulations on the 195th birthday of the Gornyi Zhurnal, we wish it to continue its mission successfully and fortunately for the mining!

Slobodan Vujić

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ШЕСТ ДЕЦЕНИЈА КРЕАТИВНОГ СТВАРАЛАШТВА
SIX DECADES OF CREATIVE CREATION

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Сажетак: *Ове 2020. године је 60. рођендан Рударског института Београд. Рад је посвећен овом јубилеју. С обзиром да монографија Шест деценија Рударског института Београд, прпремљена истим поводом, даје исцрпан, садржајно систематизован приказ развоја и резултата Института од оснивања до данас, рационалност је ограничила обим овог текста и садржајно орјентисала ка најважнијим секвенцама из шездест годишњег развоја и рада Рударског института Београд.*

Кључне речи: *Рударски институт Београд, јубилеј, рођендан, шест деценија постојања*

Abstract: *This year, 2020, marks the 60th birthday of the Mining Institute Belgrade. The paper is dedicated to this jubilee. Rationality has limited the scope of this text and focused on the most important sequences from the sixty years of development and work of the Mining Institute Belgrade, given that the monograph Six Decades of the Mining Institute Belgrade, which has been prepared on the same occasion, gives an exhaustive, systematized overview of the development and results of the Institute from its founding until today.*

Key words: *Mining institute Belgrade, jubilee, birthday, six decades of existence*

ОСНИВАЊЕ ИНСТИТУТА

На иницијативу и уз материјалну подршку рударске привреде, 14. јула 1960. године основан је Рударски институт Београд (РИ).
У уредби IV, бр. 452, од 14. 07. 1960. Извршног већа Народне скупштине Народне Републике Србије, о оснивању Рударског института пише: „Извршно веће Народне скупштине

ESTABLISHMENT OF THE INSTITUTE

On the initiative and with the financial help of the mining economy, on July 14, 1960, the Mining Institute Belgrade was founded (MI).
Decree IV, no. 452, dated July 14, 1960 of the Executive Council of the National Assembly of the People's Republic of Serbia (today the Government of the Republic of Serbia), on the es-

Народне Републике Србије, Предузеће Индустријско-енергетски комбинат Костолац, Предузеће површински копови и сушара лигнита Вреоци и Комбинат за прераду и експлоатацију косовских лигнита у Обилићу (у даљем тексту: оснивачи), заједнички оснивају научну установу: Рударски институт.[…]"

Оснивању Института одмах су се придружили: Рударско-геолошки факултет Универзитета у Београду, Рударско-топионичарски басен Бор, Рудник и флотација Трепча, Рударско-металуршки комбинат Зеница, Рударско-индустријски комбинат Алексинац, Ресавско-моравски угљени басен, Рудник и флотација Шупља Стијена, Рудник мрког угља Каменград, Рудник мрког угља Боговина и Рудник антимона Зајача.

Формиран је оснивачки фонд за изградњу, 1,5 милиона долара. Прикупљена средства коришћена су за учешће у добијању банкарских кредита и делом за директно инвестирање у изградњу објеката, уређење институтског комплекса, опремање лабораторија и формирање библиотечког фонда.

ИЗГРАДЊА ИНСТИТУТА

При избору места изградње РИ разматране су две локације: једна у улици Војводе Степе на Вождовцу, а друга у Земуну, на Батајничком путу.
Због полуиндустријског постројења за експериментална испитивања добијања кокса из нискокалоричних угљева, предност је дата локацији на Батајничком путу (садашња локација РИ)
После кратких административних припрема и израде пројектне документације, изградња РИ почела је у новембру 1960. године. У настојању да Институт што пре почне са радом, изабран је монтажни тип градње.
Радове изградње отворио је Михајло Швабић, потпредседник Извршног већа (Владе) Србије. Почетку радова присуствовале су бројне угледне званице, професори универзитета, угледни стручњаци, представници рударске привреде, научних института,

tablishment of the Mining Institute, states: "*The Executive Council of the National Assembly of the People's Republic of Serbia, Industrial and Energy Combine Kostolac, Surface Mines and Lignite Drying Facility Vreoci and Kosovo Lignite Processing and Exploitation Plant in Obilić (hereinafter: the founders), jointly establish a scientific institution: the Mining Institute.* […]"

The foundation of the Institute was immediately joined by: Faculty of Mining and Geology University of Belgrade, Mining and Smelting Basin Bor, Trepča Mine and Flotation, Mining and Metallurgical Combined Company Zenica, Mining and Industrial Complex Aleksinac, Resava-Morava Coal Mine, Šuplja Stijena Mine and Flotation, Brown Coal Mine Kamengrad, Brown Coal Mine Bogovina and Antimony Mine Zajača.

A founding fund for construction was formed, $ 1.5 million. The collected funds were used for participation in obtaining bank loans and partly for direct investment in the construction of facilities, arrangement of the institute complex, equipping laboratories and forming a library fund.

CONSTRUCTION OF THE INSTITUTE

When choosing the MI construction site, two locations were considered: one in Vojvode Stepe Street in Voždovac and the other in Zemun, in Batajnički drum.
Because of the semi-industrial plant for experimental testing of coke production from low-calorie coal, priority was given to the location on Batajnički drum (current MI location).
After short administrative preparations and preparation of project documentation, the construction of MI began in November 1960. In an effort to get the Institute up and running as soon as possible, a prefabricated type of construction was chosen.
The construction works were commenced by Mihajlo Švabić, Vice President of the Executive Council (Government) of Serbia. The beginning of the works was attended by numerous distinguished guests, university professors, renowned experts, representatives of the mining industry, scientific institutes, design company,

пројектантских кућа, друштвене заједнице. Изградња је трајала двеипо године.

СВЕЧАНО ОТВАРАЊЕ ИНСТИТУТА

Рад Института свечано је озваничен 8. маја 1964. У време овог догађаја РИ је имао више од 120 високо образованих стручњака, успостављену пословну сарадњу са више од 100 привредних организација из рударства, металургије, машиноградње и других области, и потпуну опремљеност најсавременијом опремом за полуиндустријска и лабораторијска истраживања, испитивања и мерења. Дакле, Институт је кадровски, организационо и радно био у пуној функцији. Разлог трогодишњег „одлагања“ церемоније отварања је трајање комплетне изградње и опремања Института. Од оснивања 1960. до 1964. Институт је радио на седам локација.
Свечности су присуствовали чланови колектива, представници рударских, металуршких и других привредних организација, представници универзитета, института, Савеза екстрактивне индустрије, бројни угледни стручњаци и високи државни званичници.
После излагања Мирка Перишиће, директора Рударског института, Јаков Блажевић члан Савезног извршног већа (Савезне владе) и председник Савезне привредне коморе отворио је Рударски институт.

КРЕИРАЊЕ И ПОСТАВЉАЊЕ ОСНОВА РАДА ИНСТИТУТА

У креирању и постављању основа развоја РИ најзаслужнији су: проф. др Мирко Перишић, две и по деценије директор РИ (1960–1985), и четири истакнута професора, утемељивача Рударско-геолошког факултета Универзитета у Београду: Милорад Чича Петровић, Бранко Јокановић, Ђура Лешић и Бранко Глушчевић. Бранко Глушчевић, помоћник директора за науку, поставио је организационе основе научноистраживачког рада у РИ. Милорад Чича Петровић, као први управник, допринео је оснивању и организовању рада Завода за експлоатацију

social communities. The construction lasted two and a half years.

OPENING CEREMONY OF THE INSTITUTE

The work of the Institute was ceremonially made official on May 8, 1964. At the time of this event, Mining Institute had more than 120 highly educated experts, established business cooperation with more than 100 economic organizations in mining, metallurgy, mechanical engineering and other fields, and was fully equipped with the most modern equipment for semi-industrial and laboratory research, testing and measurements. Therefore, the Institute was in full function in terms of personnel, organization and work. The reason for the three-year “delay” the opening ceremony of the duration of the complete construction and equipping of the Institute. From its founding in 1960 to 1964, the Institute used seven locations for work.
The ceremony was attended by members of the collective, representatives of mining, metallurgical and other economic organizations, representatives of universities, institutes, the Extractive Industry Association, numerous eminent experts and senior government officials.
After the presentation of Mirko Perišić, director of the Mining Institute, Jakov Blažević, a member of the Federal Executive Council (Federal Government) and the President of the Federal Chamber of Commerce, opened the Mining Institute.

CREATING AND LAYING THE BASIS OF THE WORK OF THE INSTITUTE

In creating and laying the foundations for the development of MI, the most notable are: prof. Mirko Perišić, director of MI for two and a half decades (1960–1985), and four prominent professors, founders of the Faculty of Mining and Geology, University of Belgrade: Milorad Čiča Petrović, Branko Jokanović, Đura Lešić and Branko Gluščević. Branko Gluščević, Assistant Director for Science, laid the organizational foundations of scientific research work at the MI. Milorad Čiča Petrović, as the first manager, contributed to the establishment and organization of the Department for the Exploitation of минералних сировина. Бранко Јокановић, као први управник, допринео је оснивању и организовању рада Лабораторије и Завода за вентилацију рудника. Ђура Леши, као први управник, допринео је оснивању и организовању рада Лабораторије и Завода за припрему минералних сировина, а као први председник Научног већа РИ, допринео је постављању основа његовог функционисања.

Mineral Resources. Branko Jokanović, as the first manager contributed to the establishment and organization of the Laboratory and the Department for Mine Ventilation. Đura Lešić, as the first manager, contributed to the establishment and organization of the work of the Laboratory and the Department for the Preparation of Mineral Processing, and as the first president of the Scientific Council of the MI, contributed to laying the foundations for its functioning.

ОРГАНИЗАЦИЈА ИНСТИТТА

Да би успешно одговорило на постављене задатке, РИ је организован по заводима за пет тематских области, касније је формиран и шести завод:

- Завод за експлоатацију минералних сировина (Завод I, први управник био је проф. Милорад Чича Петровић);
- Завод за припрему минералних сировина (Завод II, први управник био је проф. др Ђура Лешић);
- Завод за вентилацију и техничку заштиту (Завод III, први управник био је проф. Бранко Јокановић);
- Завод за термотехнику (Завод IV, први управник био је проф. др Душан Величковић);
- Завод за пројектовање и конструкције (Завод V, први управник био је Јован Михајловић, дипл. инж.);
- Завод за информатику и економику (Завод VI, касније је формиран а први управник био је др Чедомир Раденковић).

ORGANIZATION OF THE INSTITUTE

In order to successfully respond to the set tasks, MI was organized by departments for five thematic areas, and later a sixth department was formed as well:

- Department of Exploitation of Mineral Resources (Department I, the first manager was prof. Milorad Čiča Petrović);
- Department of Mineral Processing (Department II, the first manager was prof. Đura Lešić);
- Department of Ventilation and Technical Protection (Department III, the first manager was prof. Branko Jokanović);
- Department of Thermotechnics (Department IV, the first manager was prof. Dušan Veličković);
- Department of Design and Construction (Department V, the first manager was Jovan Mihajlović, BCE);
- Department of Informatics and Economics (Department VI, formed later and the first manager was Čedomir Radenković, PhD).

ДЕЛАТНОСТ И РЕЗУЛТАТИ

Пред Институтом се увек налазе високо постављени захтеви у домену науке и пројектовања. Институт предњачи захваљујући оригиналним идејама и решењима. Многи резултати југословенског и српског рударства, било да је реч о пројектима, истраживањима, иновацијама и сл., докази су који говоре томе у прилог. Резултати обавезују да будемо одређенији, а њихову листу започињемо спектром научноистраживачких и пројектантских делатности РИ:

ACTIVITY AND RESULTS

The Institute always has high requirements in the field of science and projects. The Institute is at the forefront thanks to its original ideas and solutions. Many results of Yugoslav and Serbian mining, be it projects, research, innovations, etc. speak in favor thereof.
The results oblige us to be more specific, and we start the list with a range of scientific research and design activities of the MI:

1. Експлоатација минералних сировина (подземна, површинска и подводна);
2. Припрема минералних сировина;
3. Планирање, пројектовање и оптимизација производње рудника;
4. Рудничка геологија;
5. Хидрогеологија и заштита рудника од вода;
6. Вентилација рудника;
7. Технологија бушења и минирања;
8. Физичко-механичка својства стенских масива, механика стена и тла;
9. Заштита животне и радне средине;
10. Рекултивација, ревитализација и уређење деградираних површина;
11. Термотехника и сагоревање енергената;
12. Пројектовање и конструисање рударских објеката и инфраструктуре;
13. Електроенергетско напајање рудничких постројења;
14. Ризици и управљање ризицима у рударству;
15. Рачунарски интегрисане технологије, аутоматизација и управљање процесима;
16. Просторна мерења;
17. Економика индустрије минерала;
18. Стандарди, законска и нормативна регулатива;
19. Издавачка делатност.

РИ је ауторизовао више од 7.300 студија, инвестиционих програма и пројеката за потребе рударске привреде у земљи и иностранству. Нема значајнијег рудника у Југославији и Србији где РИ, својим пројектним решењима није допринео унапређењу производње, технолошкој модернизацији, повећању ефикасности, еколошкој и производној безбедности.

На основу пројеката Рударског института, уведене су нове рудничке технологије.

Били су то успешни пионирски кораци увођења нових технологија у којима није било довољно практичних искустава. Остварени резултати изазивали су велико интересовање светске стручне јавности и скретали пажњу на РИ.
Широм Југославије и у иностранству, на основу пројеката РИ, отворено је више од 70 рудника са комплетном инфраструктуром.

1. Exploitation of mineral raw materials (underground, surface and underwater);
2. Mineral processing;
3. Planning, design and optimization of mine production;
4. Mining geology;
5. Hydrogeology and protection of mines from water;
6. Mine ventilation;
7. Drilling and blasting technology;
8. Physical-mechanical properties of rock massifs, rock and soil mechanics;
9. Environmental and working environment protection;
10. Reclamation, revitalization and arrangement of degraded areas;
11. Thermotechnics and energy combustion;
12. Design and construction of mining facilities and infrastructure;
13. Electric power supply of mining plants;
14. Risks and risk management in mining;
15. Computer integrated technologies, automation and process management;
16. Spatial measurements;
17. Economics of the mineral industry;
18. Standards, legal and normative regulations;
19. Publishing activity.

The MI has authorized more than 7,300 studies, investment programs and projects for the needs of the mining industry in the country and abroad. There is no significant mine in Yugoslavia and Serbia where the MI, with its design solutions, has not contributed to the improvement of production, technological modernization, increasing efficiency, environmental and production safety.

Based on the projects of the Mining Institute, new (at that time) mining technologies were introduced.

These were successful pioneering steps in the introduction of new technologies in which there was not enough practical experience. The achieved results aroused great interest of the world professional public and drew attention to the MI.
Across Yugoslavia and abroad, based on the MI projects, more than 70 mines with complete in-

Пуштено у погон преко 40 постројења за припрему минералних сировина и чишћење угља, изграђено више од 20 јаловишта и депонија пепела и шљаке.
Нема значајнијег рудника у Југославији и Србији, чијем отварању, развоју, реконструкцији, технолошком осавремењавању, реинжењерингу експлоатационог захвата и сл. РИ није допринео.

На светском тржишту РИ је реализовао пројекате за: Мјанмар (Бурма); САД - Агенција за заштиту животне средине; Алжир; Боливија; Египат; Тунис; Јордан; Замбија; Аустралија; Индија; Кина, Мозамбик, Чехословачка.

РИ је реализовао више од 60 научно-истраживачких, развојних и иновационих пројеката под окриљем и финансијском подршком Министарства просвете, науке и технолошког развоја Републике Србије и Савезног министарства за науку и технолошки развој Југославије. Патентирано је 11 технологија и поступака.

У Институту је 1969. године конструисан и направљен аналогни електронски симулатор вентилационих мрежа. Била је то оригинална конструкција аналогног рачунара за симулацију и истраживања вентилационих процеса. То је достигнуће које је нашу научну мисао довело у светски врх, а само још неколико земаља у свету (САД, СССР, В. Британија и Француска) поседовало је сличну лабораторијску опрему.

Међу првима у свету, РИ је опремио лабораторију и овладао техником фотоеластичних испитивања напонско деформационих стања у стенским масивима. Није претерано рећи, био је то велики научни искорак у геостатичким анализама геометрије и конструкције подземних рудничких објеката.

Важан допринос Института српском рударству је у издавачкој делатности, у публиковању књига и периодике из области рударства, рудничке геологије и економике индустрије минерала. То су биле прве стручне публикације на српском језику

frastructure have been opened. Over 40 plants for preparation of mineral raw materials and coal cleaning were put into operation, more than 20 tailings and ash and slag dumps were built. There is no significant mine in Yugoslavia and Serbia whose opening, development, reconstruction, technological modernization, reengineering of the exploitation project, etc. was not contributed by the MI project.

In the world market, MI has implemented projects for: Myanmar (Burma); USA - Environmental protection agency EPA; Algeria; Bolivia; Egypt; Tunisia; Jordan; Zambia; Australia; India; China, Mozambique, Czechoslovakia.

The MI has implemented more than 60 scientific research, development and innovation projects under the auspices and financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia and the Federal Ministry of Science and Technological Development of Yugoslavia. 11 technologies and procedures have been patented.

In 1969, an analog electronic simulator of ventilation networks was constructed and made at the Institute. It was the original construction of an analog computer for simulation and research of ventilation processes. This was an achievement that brought our scientific thought to the top of the world, and only a few other countries in the world (USA, USSR, Great Britain and France) had similar laboratory equipment.

Among the first in the world, the MI equipped the laboratory and mastered the technique of photo-elastic testing of stress-strain states in rock massifs. It is not an exaggeration to say it was a great scientific step forward in geostatic analyzes of the geometry and construction of underground mining facilities.

An important contribution of the Institute to Serbian mining is in publishing, i.e. in publishing books and periodicals in the field of mining, mining geology and economics of the mineral industry. These were the first professional publications in the Serbian language in these fields.

Радови на замени кровног покривача / *Works on replacing the roof covering, 2020*

Адаптација фасаде / *Facade adaptation, 2020* из ових области.Институт је издавач једног од најстаријих научних часописа за рударство у свету – Рударског гласника. Први број часописа штампан је 1903.

The Institute is the publisher of one of the oldest scientific journals for mining in the world – *Bulletin of Mines.* The first issue of the magazine was printed in 1903

НЕВОЉЕ И НОВИ УСПОН

Распадом Југославије 1991. године, распада се и југословенско тржиште истраживачких и креативних инжењерских услуга, а са санкцијама, изолацијом, НАТО агресијом и неолибералном приватизацијом, интензивира се урушавање економије земље и рударске привреде као њеног дела. Све то веома негативно утиче на РИ, те после три деценије успешног рада, почиње да стагнира, долази до пада дохотка, осипања кадрова и других негативних последица. После 2000. године, турбулентни транзициони процеси, приватизациони атак једне групе и несналажење тадашњег руководства, још више погоршавају положај и ситуацију у РИ. Захваљујући одлучности колектива, ова претња која је водила ка нестајању, заустављена је 2004.

Осмишљеним активностима од 2013. до 2019. обављене су захтевне припреме за враћање научног статуса Институту и средином 2019. поднет је захтев за научну акредитацију. Министарство просвете, науке и технолошког развоја Републике Србије, Одбор за акредитацију научноистраживачких организација, оцењује да Институт испуњава све акредитационе услове и одлуком број 660-01-00003/10 од 15. 10. 2019. године, Рударски институт је акредитован као истраживачко-развојни институт у области техничко-технолошких наука – рударства и геологије, за обављање научоистраживачке делатности.

TROUBLES AND A NEW RISE

With the disintegration of Yugoslavia in 1991, the Yugoslav market for research and creative engineering services disintegrated, and with sanctions, isolation, NATO aggression and neoliberal privatization, the collapse of the country's economy and the mining economy as part of it intensified. All this has a very negative effect, and the MI, after three decades of successful work, begins to stagnate, there is a decline in income, staff turnover and other negative consequences. After 2000, turbulent transition processes, the privatization attack of a group and the incompetence of the then leadership, further aggravated the position and situation at the MI. Thanks to the determination of the collective, this threat of disappearance was stopped in 2004.

Designed activities from 2013 to 2019 made demanding preparations for the return of scientific status to the Institute and in mid-2019 a request for scientific accreditation was submitted. The Ministry of Education, Science and Technological Development of the Republic of Serbia, the Board for Accreditation of Scientific and Research Organizations, estimates that the Institute meets all accreditation requirements and by decision number 660-01-00003/10 dated October 15, 2019, the Mining Institute is accredited as a research and development institute in the field of technical and technological sciences - mining and geology, to perform scientific research activities.

ИНСТИТУТ ДАНАС

Као и раније, и данас је капацитет РИ прилагођен потребама рударске привреде Србије. У Институту ради око 90 сарадника. Образовна структура је слична структурама из ранијих периода. Актуелно стање на тржишту, обим, врсте послова и други чиниоци, утицали су и на организацију РИ па постоји шест јединица одговорних за

INSTITUTE TODAY

As before, today the MI capacity is adjusted to the needs of the mining economy of Serbia. There are about 90 associates working at the Institute. The educational structure is similar to the those from earlier periods. The current market situation, volume, types of business and other factors have influenced the organization of the MI, so there are six units respon-

Ентеријер, *пре и после реновирања* / *Interior, before and after renovation, 2020*

успешност организације рада, реализацију послова и финансијске резултате:
- Завод за пројектовање експлоатације лежишта минералних сировина;
- Завод (са лабораторијом) за припрему минералних сировина и пројектовање;
- Лабораторија за заштиту животне и радне средине;
- Лабораторија за геомеханику;
- Лабораторија за чврста горива;
- Менаџмент и заједничке службе.

Према стандарду ISO 45001:2018, Институт је сертификован за пројектовање, консалтинг и примењена испитивања у рударству, геологији, енергетици и заштити животне и радне средине. Лабораторије Института индивидуа-лно су сертификоване акредитацијама Акреди-тационог тела Србије.

Институт је 2019. сопственм средствима реконструисао систем за грејање: дотрајали котлови на угаљ замењени су котловима на гас, адаптиран је објекат котларнице и изведен прикључак на гасну мрежу.

sible for the success of the work organization, realization of works and financial results:
- Department for Designing the Extraction of Mineral Resource Deposits;
- Department (with the Laboratory) for Mineral Processing and Designing;
- Laboratory for the Protection of Living and Working Environments;
- Laboratory for Geomechanics;
- Laboratory for Solid Fuels;
- Management and joint offices.

According to the standard ISO 45001:2018, the Institute is certified for design, consulting and applied testing in the field of mining, geology, energy and environmental protection.
The laboratories of the Institute are individually certified by the accreditations of the Accreditation Body of Serbia.

In 2019, the Institute invested own funds for the reconstruction of the heating system: dilapidated coal-fired boilers were replaced with gas-fired boilers, the boiler room building was reconstructed and a connection to the gas network was built.

Ове јубиларне 2020, изведени су капитални радови на главном објекту: замењен је кровни покривач, електро инсталација реконструисана и обновљена, реновиран је и уређен ентеријер, адаптирана фасада, замењени прозори на фронталном делу зграде, преуређена зелена површина испред главног улаза итд. Циљеви ове велике инвестиције Института су поред стварања хуманијих услова и пријатнијег радног амбијента, рационализација коришћења простора и заштита зграде од даљег пропадања.

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This jubilee 2020, capital works were performed on the main building: the roof covering was replaced, the electrical installation was reconstructed and replaced, the interior was renovated and arranged, according to the main entrance the facade was reconstructed, windows a have been replaced and green areas rearranged, etc. The goals of this large investment of the Institute are in addition to creating more humane conditions and a more pleasant working environment, rationalization of the use of space and protection of the building from further deterioration.

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РУДАРСКИ ГЛАСНИК
BULLETIN OF MINES

1903.

YU ISSN 0035-9637 (CXVII) 1-2

THE GORNYI ZHURNAL JOURNAL AND ITS ROLE IN MINING ENGINEERING AND ITS ADVANCE IN RUSSIA AND IN THE WORLD

DOI: 10.25075/BM.2020.02

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Abstract *This paper familiarizes readers with history of the Gornyi Zhurnal journal—the oldest periodical on engineering in Russia. Within the space of 195 years of its life, the Journal has published a vast number of articles, reviews and essays on various aspects of mining engineering, metallurgy, mining machinery, economy, inventions and discoveries, as well as on higher education in mining. Gornyi Zhurnal is a living chronicle of the research activities of Russian scientists and engineers who made an immense contribution to the science and technology both in Russia aand worldwide. The Journal's publications of different times witness the incontestable headship of the Russian science. Gornyi Zhurnal remains a fundamental educational medium for students of training schools and higher educational institutions. The Journal persistently promotes science and technology to the benefit of the mining industry in Russia.*

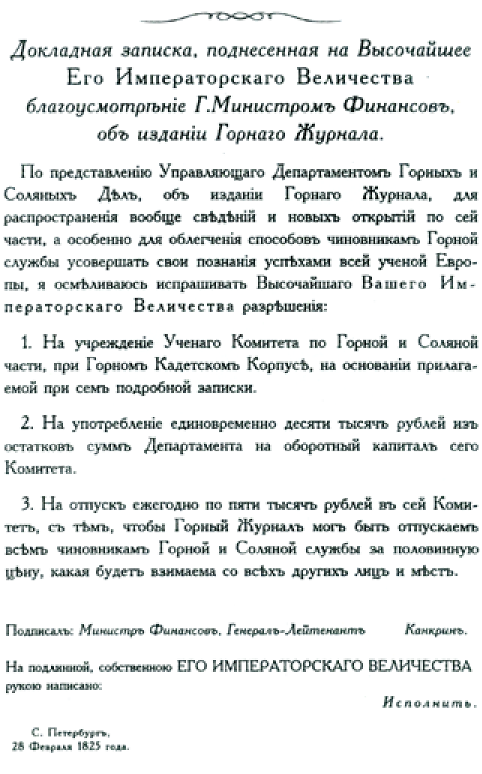
Keywords: *Gornyi Zhurnal, oldest domestic periodical, scope, science and technology achievements, higher education in mining, progress, prospects*

Gornyi Zhurnal (Mining Journal) celebrates its 195th anniversary. Hardly many specialized journals can boast such respectable age and rich history.

The Journal's origin was the Memorandum for the Highest Pleasure of Sir Secretary of the Treasure on Setting Up an Academic Committee for Mineral and Salt Mining, and on the Gornyi Zhurnal Edition prepared by Lieutenant General E. V. Karneev, Director of the Mining Cadet Corps, and signed by Lieutenant General E. F. Kankrin, Secretary of the Treasure. The Memorandum was submitted to Alexander I, and the emperor of Russia approved it right away. The date of birth of Gornyi Zhurnal is assumed July 1, 1825, the publication data of the first issue.

Establishment of the Journal was spotlighted on the front page of Severnaya Pchela (Northern Bee)—one of the most popular newspapers in Petersburg, which read: "Last Saturday of March 21 of this year witnessed the origin and imperial new-establishment of the Academic Committee for Mineral and Salt Mining at the Mining Cadet Corps upon the confirmed report of the Sir Secretary of the Treasure. The Committee is going to be chiefly engaged with edition of a journal under the name Gornyi Zhurnal, or with compilation of information on mineral and salt mining, with aggregation of scientific discoveries concerned herewith" [2].
The first issue of Russia's new journal opened with an editorial address entitled The Review of Sciences and Crafts within Gornyi Zhurnal aimed to give reasons for the transition from the empiricism to academic sciences in the field of mining [3].

Since the early days of activity, publishers of Gornyi Zhurnal defined its orientation towards distribution of information on progress of the mining art and on advance of the mining sciences. The cover page of Gornyi Zhurnal presents the painterly framed Journal's title, the issue and publication data, a picture of a medieval Saint-Petersburg's mining landscape and the publishing office: "Printed in the State Papers Procurement Expedition Printing House." There is also an owl imaged against the crossed primary miner's tools of labor for that time—a mining pick and a hammer. Owl as a symbol of knowledge and wisdom is also known for being a nocturnal bird to symbolize an underground reign as well. In Sumerian–Akkadian mythology, Ereshkigal, the goddess and the ruler of underworld, the "Queen of the Great Below" is depicted with a symbol of an owl. Afterwards, the Journal's emblem was changed and dwarfs appeared there, for gnomes in Western European myths symbolized ghosts indwelled in the Earth's interior to keep the underground wealth [4].



Докладная записка, поднесенная на Высочайшее
Его Императорскаго Величества
благоусмотрѣніе Г.Министромъ Финансовъ,
объ изданіи Горнаго Журнала.

По представленію Управляющаго Департаментомъ Горныхъ и Соляныхъ Дѣлъ, объ изданіи Горнаго Журнала, для распространенія вообще свѣдѣній и новыхъ открытій по сей части, а особенно для облегченія способовъ чиновникамъ Горной службы усовершать свои познанія успѣхами всей ученой Европы, я осмѣливаюсь испрашивать Высочайшаго Вашего Императорскаго Величества разрѣшенія:

1. На учрежденіе Ученаго Комитета по Горной и Соляной части, при Горномъ Кадетскомъ Корпусѣ, на основаніи прилагаемой при семъ подробной записки.

2. На употребленіе единовременно десяти тысячъ рублей изъ остатковъ суммъ Департамента на оборотный капиталъ сего Комитета.

3. На отпускъ ежегодно по пяти тысячъ рублей въ сей Комитетъ, съ тѣмъ, чтобы Горный Журналъ могъ быть отпускаемъ всѣмъ чиновникамъ Горной и Соляной службы за половинную цѣну, какая будетъ взимаема со всѣхъ другихъ лицъ и мѣстъ.

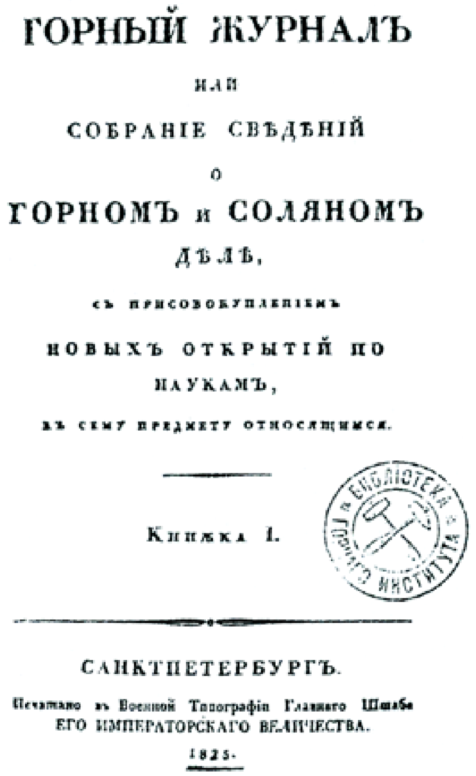
Подписалъ: *Министръ Финансовъ, Генералъ-Лейтенантъ* *Канкринъ.*

На подлинной, собственною ЕГО ИМПЕРАТОРСКАГО ВЕЛИЧЕСТВА рукою написано:

Исполнить.

С. Петербургъ,
28 Февраля 1825 года.

Report note of the finance minister
to his Imperial majest



ГОРНЫЙ ЖУРНАЛЪ
или
СОБРАНІЕ СВѢДѢНІЙ
о
ГОРНОМЪ и СОЛЯНОМЪ
ДѢЛѢ,
съ присовокупленіемъ
НОВЫХЪ ОТКРЫТІЙ ПО
НАУКАМЪ,
къ сему предмету относящимся.

Книжка I.

САНКТПЕТЕРБУРГЪ.
Печатано въ Военной Типографіи Главнаго Штаба
ЕГО ИМПЕРАТОРСКАГО ВЕЛИЧЕСТВА.
1825.

Gornyi Zhurnal 1825

Editors of Gornyi Zhurnal were representatives of the Academic Committee for Mineral and Salt Mining founded at the Mining Cadet Corps, and each section of the Journal had its peculiar editor.

Upon approval, the Journal had 10 sections, namely, Mineralogy, Chemistry, Mining, Processing, Coinage, Salt Mining, General Mineral and Salt Mining Bibliography, Mineral and Salt Mining Laws, Biographical News and Obituary Notices and Miscellaneous [1]. Editorial Board strictly adhered to that structure, though the sections were rotated from issue to issue. The titles of the sections were modified with time, and new sections appeared, but the intrinsic structure of the Journal remained the same for many decades [3].

Six 'books' (issues) of Gornyi Zhurnal were published in the first year. The Journal had 1093 subscribers. It is interesting that for many a decade readers could order printed copies of the Journal's issues, even the very first edition, that is, the copies were reprinted as needed [1].

The very first releases of the Journal kept pursuing its key objective—furnishing the mining society of Russia with update information on advance in mining sciences and on progress in mining which was defined as extraction of minerals, their pretreatment and processing (metallurgy) [1].

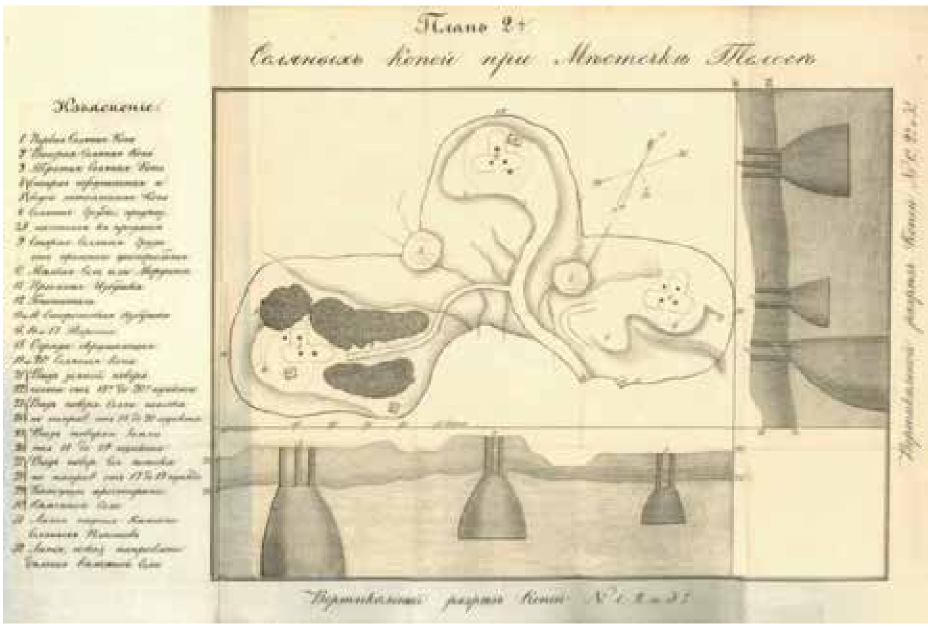
Looking at the articles of Gornyi Zhurnal in its early days with modern eyes, we recognize high professional skills of both authors and publishers. Written in high-quality language and backed up by ample Russian and foreign references, the articles feature simple presentation of intricate mining problems. The publications included drawings to provide thorough understanding of mining projects. An interesting fact—each article had only one author. This approach has nearly been lost as today co-authorship finds higher preference and prevails.

Front cover of Gornyi Zhurnal's Issue 10, 1828, with an owl image

Coverage page of the first Gornyi Zhurnal's Special Issue in celebration of the Saint-Petersburg Mining Institute's 150th anniversary

More recent section Mining Laws in Gornyi Zhurnal elucidated critical governmental decisions on mining. For example, in Book 1, Part I, 1835 edition, this section informed on the Mining Engineers Corps Headquarters staffing authorized by the Sovereign Emperor. The authorized staff number was 16, out of which the Chief of Staff, Field-Officer on Duty and two Principal Aides-de-Camp, and heads of Main Offices were selected from among mining engineers and were appointed at the Imperial Will. Professional engineers were the 'piece-goods' and were highly appreciated in the Russian Empire as mining was thought to be the backbone of the national security and economy. Mining engineering preserves its significance these days, too. Preservation and advancement of the mining engineers corps is both the tradition of the great mineral resources power, which the Russian Empire was, and the practice of critical concern for modern Russia.

During the course of the 19th century, the mining art was improved and evolved in Russia, with discovery of new mineral deposits and novel knowledge on exploitation. Step by step Gornyi Zhurnal not only comprehensively exposed history of mining industry in Russia but also promoted mining engineering in the country through the agency of its numerous publications. Toward the end of that century, the Journal presented color geological maps of Russian territories, advertizing of novel mining equipment, various related industries and companies, new periodicals, data on various-scale education in mining and scientific advancement in Russia and abroad. Gornyi Zhurnal imaged on its pages a powerful mining country steadily developing in diverse areas.
The Journal enjoined great success abroad. Foreign periodicals published translated articles, and in 1840 a selection of Gornyi Zhurnal's papers for the previous five years (1835–1839) was released in French—Annuairedu Journaldes Mines de Russie [3].
It is impossible to overestimate the value of the Gornyi Zhurnal journal. Right down to the late 19th century, it was the only source for a mining engineer in Russia to learn about situation with equipment at the domestic and foreign mines and factories, or to know on the advance in natural and engineering sciences in Russia and abroad. The Journal's authors discussed the challenges of mining, including production of ferrous and nonferrous metal ores, coal, peat and oil, as well as geological exploration, mineral processing and metallurgical conversion. At the turn of the 20th century, other periodicals on similar subjects appeared in Russia though not for a long time. Gornyi Zhurnal yet remained the first and the only one.



An illustration of a mine project drawing to accompany an article [5]

The early 20th century faced turbulent historical events in Russia, which affected the fortune of Gornyi Zhurnal. For instance, during the second half of 1918, Gornyi Zhurnal was named Bulletin of the Mining Department of the Supreme Council of National Economy. The publication was aborted by World War I, and the Journal only saw the light in May 1920. It lacked science but only addressed the problems of concern at the moment, discussed production problems of the Mining Council and offered an ample of various reports from industrial management offices. It was in the year of 1922 that the Gornyi Zhurnal journal retrieved its initial name.

The year of 1923 in mining in Russia was marked by a notable event—the 150th anniversary of the Saint-Petersburg Mining Institute—the brain of the mining industry in Russia. The scientific and technological community, the industry and the government responded keenly to the event. It is worthy of mentioning that despite anxiety of those times, all governmental agencies acknowledged the priority of mining as a framework for the development and improvement of the national economy, finance and security. Gornyi Zhurnal fervently participated in the festive celebration of the Institute's anniversary. Under the auspices of the Supreme Council of National Economy, the Jubilee Committee was set up and presided by Mining Engineer, Honorary Professor of the Mining Institute, Academician and President of the Russian Academy of Sciences A. P. Karpinsky as an appointed honorary chairman. The Jubilee Committee was short of money for the anniversary commemorative publication, and Professor A. A. Skochinsky, Gornyi Zhurnal editorial board member suggested that a special issue of the Journal was dedicated to that remarkable event. The suggestion was taken, and in November 1923 the Gornyi Zhurnal's Special Issue was published [6]. It contained 12 sections illustrating diverse activities of the Mining Institute in the field of mining engineering, including professorship, studentship and graduates. Higher officials and the Jubilee Committee expressed their gratitude to the Editorial Board of Gornyi Zhurnal for the partnership.

The Soviet period pursued the mining traditions of Russia and prosperous history of Gornyi Zhurnal. During those years, the Journal laid a major emphasis on the critical problems existing in mining science and production, labor management and mechanization of operations. The mining industry of the Soviet Republics was in the spotlight, too.

The Soviet Union stoutly developed the mining art. The mining industry was mightily spurred, and its weight in the national economy elevated. Mining was intellectually boosted by the establishment of the Mining Academy in Moscow under authorization of the Council of People's Commissars. Moscow as a new capital of the country attracted distinguished scholars of mining science, who later on became the Gornyi Zurnal's editorial board members. Their

Cars with suspended sidewalls and drop down bottom, 1914

Unloader and winch cable bond, 1914

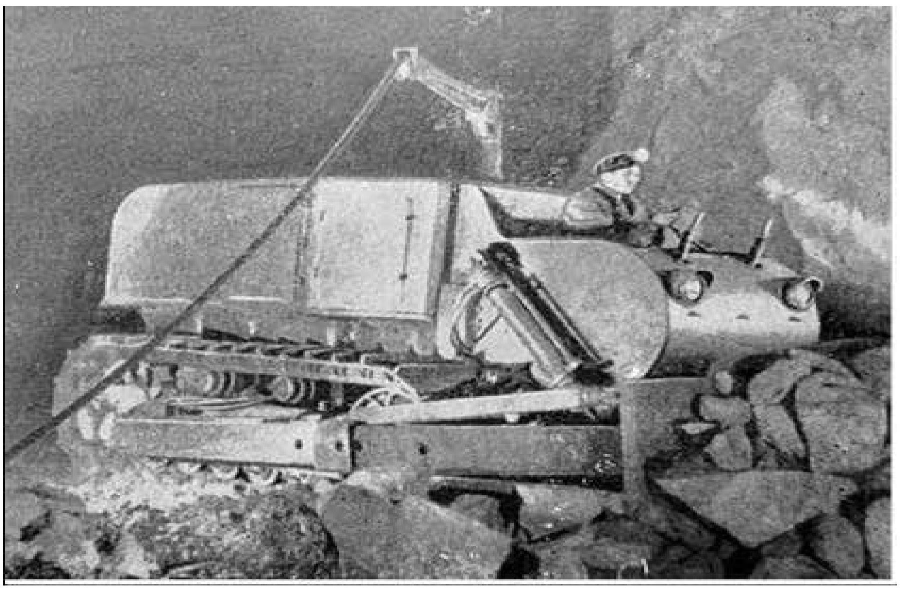
thematic contributions inherited the Journal's general traditions of background knowledge and single authorship. Each author possessed extensive knowledge in certain diverse areas of mining science such as geology, mining technology, mechanization, strata pressure, electrical engineering, mine heading and support installation, water removing, ventilation and mineral processing. The articles of Gornyi Zhurnal discussed generalities of the industry, performed in-depth studies and debated on various geotechnical designs. The new-generation Soviet mining science featured a more comprehensive, compared to the canonic mining art (the term borrowed from European mining engineering), physical and, accordingly, mathematical description of processes and phenomena in mining, as well as developed brand-new methods of mine planning and design on this basis.

The aspiration of theoreticians and practitioners in mining engineering toward technological innovation in those days was amazing and admirable, and was greatly inspired by the overwhelming mineral wealth of Russia. In 1926 Gornyi Zhurnal Issue 12 focused on natural gas production and on construction of gas-fired power plants in the USSR. In 1927 the appointed Chairman of the Editorial Board of the Journal, I. M. Gubkin, Rector of the Moscow Mining Academy zestfully promoted oil and gas extraction within the framework of mining. Oil and gas production became an independent and self-sustained industry afterwards.

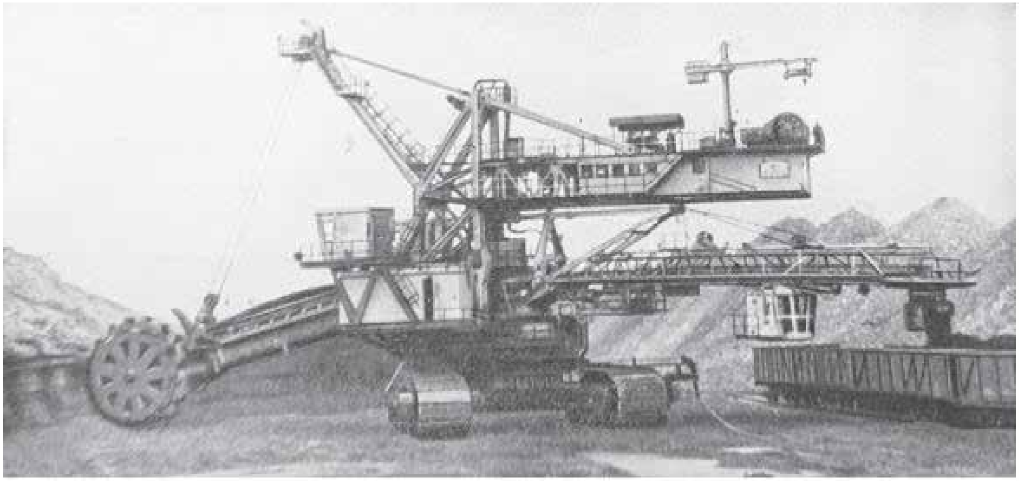
Gornyi Zhurnal is a pioneer in this field and incessantly exposes problems of oil and gas production. At the same time, the Journal provided a platform for the vivid discussion of more than 60 minerals mineable and planned to be produced in the USSR. Such scale of progression could only be comparable with the territorial evolution in of the United States.

In the 1930s the Journal grows concerned with occupational safety of miners. The editorial board draws attention to mine ventilation, accident prevention, mine rescue work, dust control and endogenous fire fighting. The related research findings are introduced into production at once in the form of design guidelines for complex process flows, safety regulations and fitting of miners with individual means of protection.

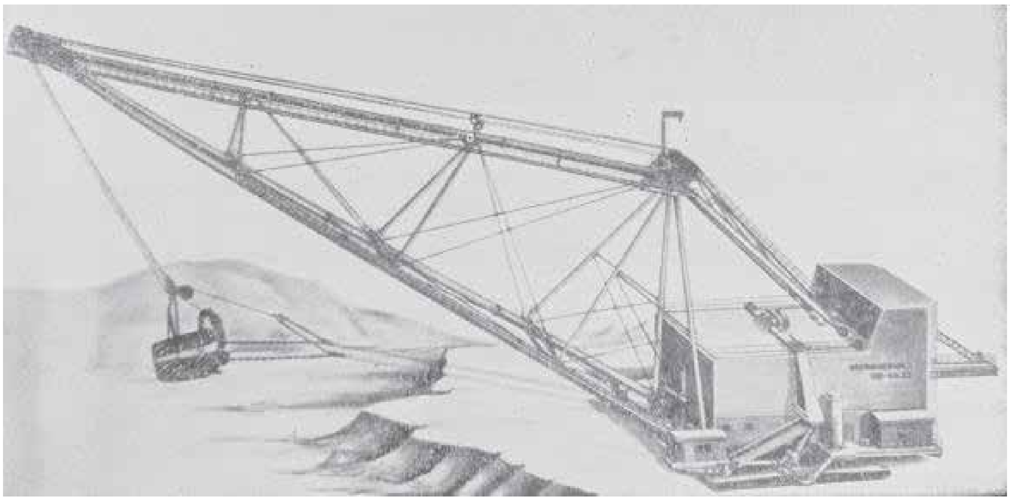
While incessantly encouraging attention of mine engineering community to the productive industry advance, Gornyi Zhurnal energetically participated in organization of numerous professional conferences and symposiums, and published the conference proceedings. The Journal publications allow tracing the whole history of rise, development and improvement of the domestic mining and metallurgy: the



Electrical bulldozer, 1914



Bucket-wheel excavator ER-1250 16/1, 5D, 1975



Walking dragline ESH-40/85, 1975

scientific and technological breakthrough promoted mining engineering as one of the most important industries of the national economy.

In 1939 Gornyi Zhurnal became the governmental publication of the People's Commissariat for the Ferrous and Nonferrous Metallurgy of the USSR and therefore focused on research and production in the field of mining of ferrous and nonferrous metals, nonmetallic and common minerals.

Higher education in mining was thriving, too. The Gornyi Zhurnal Issue 11–12 in 1937 published the article by Engineer G. D. Vesman from the Committee on Higher School Affairs, entitled: "Mining Engineering Personnel Requirements and Training", highlighted that 22 institutes trained mining engineers by that time [7]. By October 1, 1929, the USSR had only 3200 mining engineers. Later on, the educational institutions graduated 7600 mining engineers in 1930–1934 and 7200 in 1935–36. The graduates specialized in 15 areas of expertise, including Oil Field Development and Geological Exploration and Survey. The graduates annually took employment at hundreds mining projects. In this respect, the competent personnel requirements of mines were satisfied in full.

In 1942 to 1943 the publication was stopped because of the Great Patriotic War and was recommenced in 1944. During that period of time, Gornyi Zhurnal engaged itself with raising of funds and mobilizing efforts toward the long-awaited victory, advised on feasible improvement of mining operations and published innovation proposals on various practices. The defense industry of the country was in acute shortage of resources, which called for the industrial stimulation, and Gornyi Zhurnal became a major source of mission-critical information. In the post-war years of accelerated reconstruction of economy annihilated by the war, Gornyi Zhurnal kept in the first flight of technical progress in the primary industry. In the 1950s–80s the scope of problems addressed by Gornyi Zhurnal expanded and became more specific: it embraced geology, ore field development, production mechanization and automation, heading works, blasting, mineral processing, mine support design and installation, hoisting, water drainage, electrical engineering, safety, ventilation, etc. The wide range of topics attracted high readership from the professional mining community. The Journal's articles boosted the iron ore industry, potent mining and processing works and operating efficiency.

Times of the 1960s and 1970s featured a tremendous upgrowth of mineral production, mining sciences and higher education in mining. Initiation of new mines and preps, novel studies, modern research and educational institutions and fresh lines of mining engineer training—everything was reflected on the pages of Gornyi Zhurnal. Latter-day domestic machinery was manufactured in an impressive number. Development of great deposits such as Norilsk nonferrous metals, Yakutsk diamonds, alongside with operation of large mining and processing integrated works for the benefit of the iron industry called for the quality information support, and Gornyi Zhurnal took and dispatched the mission. On July 1, 1975, for the great services in promotion of the mining science and technology, generous contribution to advancement of the national metal mining industry, for the high-qualified scientific and engineering personnel training, in honor of the 15th anniversary, Gornyi Zhurnal was awarded the Order of the Red Banner of Labor.

In the context of technological advance in the mining practice, the innovative science and technology were applied in the field of sciences and higher education in mining. Gornyi Zhurnal provided a core platform for discussion of efficiency of various scientific advances in mining engineering.
The discussions unfolded on the Journal's pages were reflective of the great wish and need for educated mining engineers possessing fundamental knowledge and good grounding in system-wide safety, economy and management, including general and special engineering. These issues remain in the limelight so far.

The social, economic and political changeover in the early 1990s, with the most parlous consequences for the nation, affected Gornyi Zhurnal as well. The Nedra Publishing House cut off funding of the Journal. The size of subscription dropped. The Journal supported by the govern-

View of Tsentralny Mine, Apatit Company

Kimberlite pipe, Yakutia

ment up to then landed on the brink of closure. At that tough date, Gornyi Zhurnal obtained an unvalued support from the industry also suffering from financial straits.

The rugged times of the Journal ended in 1996 when it found itself under the umbrella of the Ore and Metals Publishing House. The new publisher had a clear understanding of the affinity of the mining and metallurgy industries, realized the significance of awareness on state-of-the art advances in science and technology, and recovered the position of Gornyi Zhurnal in the field of information support of the mining industry in the post-Soviet states at the shortest notice and with all the forces and facilities available [8].

The industrial relations were interrupted after the dissolution of the Soviet Union, and mines and factories in the former Soviet Republics functioned in the conditions of total deficit of actual production data. Gornyi Zhurnal immediately and lively responded to the needs and deployed a multi-branch network to receive the actual performance information on mining projects from all CIS countries. This replenished manuscripts at Editor’s hand with digests and topical contributions on the burning issues of mining engineering from Russia and from the CIS countries.

In 2000 on the eve of the Gornyi Zhurnal’s 175th anniversary, the Russian Academy of Natural Sciences awarded the Journal with the Tatishchev Order for the Benefit of the Fatherland.
In 2004 Gornyi Zhurnal became the master publication of the Intergovernmental Subsoil Exploration, Management and Protection Council intended to develop cooperation between the CIS countries toward efficient and multipurpose use of mineral wealth.
Today Gornyi Zhurnal is truly a national endow of Russia, a genuine information center and a reliable conductor of high technologies and innovation in mining both in Russia and abroad.

By the way, another mining journalism patriarch, The Mining Journal was founded in the United Kingdom in 1835, 10 years later than Gornyi Zhurnal. Founded in France in 1794, Annels de Mines, although retained the brand, has lost its mining-related content.
Speaking about a journal, it is absolutely impossible to leave unmentioned its backbone—the editors, editorial board, publisher, and first and foremost, the authors.

Success of a periodical publication totally depends on the value of its content in terms of science and practical application. For example, the first Gornyi Zhurnal issue released the articles of the renowned scientists of the time, lecturers

Pavel P. Anosov

of the Mining Cadet Corps, namely, "Mountain Surveys, or Particular Mineral Hunting" by I. G. Gavelovsky, "Salt Making at Permian Mines" by V. V. Lyubarsky, or "Geodesy Advances" by D. I. Sokolov [1].

One of the most active Gornyi Zhurnal's partners was distinguished Russian metal-maker P. P. Anosov whose contributions enjoyed periodical routine publication in 1826 to 1841. In his very first article entitled "Geognostic Observations of the Ural Mountains", P. P. Anosov as a reporter elect of Zlatoust Mining Community wrote: "The Urals Mountain … have long deserved a full-scale exploration. It is high time to become acquainted with their structure, and to determine intercalation and contact mechanics of rocks to most easily arrive to the chief objective—discovery of particular mineral deposits" [9]. For many years P. P. Anosov was deeply concerned with research connected with high-quality steel-making. In 1837 after he manufactured crucible steel for the first time, Anosov published the article entitled "Crucible Steel Making" in Gornyi Zhurnal. Later on, after lots of experiments, the Ural works commenced the world's first bulk production of the highest grade steel named Bulat. Anosov's research "Bulat" was given the whole Gornyi Zhurnal Issue 2 in 1841 [3].

Naturally, the scope of this article is incapable to embrace each of the prominent men of science who generously shared their research findings with the readers of Gornyi Zhurnal during 195 years of its history. One thing is for sure, one and all the foremost theoreticians and practitioners in mining engineering maintained cooperation with the Journal.
From the very beginning of its life, Gornyi Zhurnal provided a peer review of submitted manuscripts. An ancestor of the present-day editorial board was the Academic Committee which subjected each article to a close discussion at the meetings. Participation at such discussions as well as publication in Gornyi Zhurnal was considered an honor, and neither authors nor editors were remunerated.

The editorial board of the Journal was ever the cream of Russian mining science [11]. More recently, prominent chief officials from the mining industry, well acquainted with the current needs production, joined the Journal's editorial board alongside with the scientists. Such a fusion of theory and hands-on experience allowed Gornyi Zhurnal to keep up-front the scientific-and-technological advance in mining engineering. Up to this day, the editorial board of the Journal represents a team of renowned and reputable scientific and professional men. With deep knowledge from diverse areas of mining science and industry in possession, they perform high-quality expert appraisal of Journal's articles prior to publication.

It is true to say that Gornyi Zhurnal was always lucky with the men at the wheel. Those were the talents and highly skilled professionals. Their minds and vigor made the Journal a true informational hub targeted at development of the mining industry. These experts have laid the firm theoretical and applicative foundation for the Journal to become what it is today—the trade publication intent to elucidate the latest achievements in mining engineering and pointed at meeting the current challenges in the mining industry and at enhancing resource security of Russia.

During all these years, Gornyi Zhurnal has founded its editorial policy on the promotion of the advance research findings and industrial know-how toward further development of mining engineering. The Journal never stopped evolving. Unceasingly it strived for new heights and succeeded and kept in line with the spirit of the times. Both readers and authors of the Journal spread it in Russian-speaking countries and far abroad.

Today Gornyi Zhurnal leads an active and vivid life. Persistent hunting for new sources of information and forms of its presentation, as well as zealous participation in diverse conference and exhibition activities and numerous branch-wide events is reflective of an immense and unexhausted potential of the Journal.

Founded on the firm scientific principles diligently cultivated by the ancestors, well-deserved authority, backing and concern of the editorial board, authors, readers and the whole mining engineering community, Gornyi Zhurnal sets out to handle all challenges of modern times. This includes creativity and management, as well as, first and foremost, elevation of the scholarly status of the Journal, expansion of its scope, enhancement of authors' involvement and strengthening of links with the readers. Such many-sided performance can form a priceless technological potential to be in high demand for many decades or even centuries.

A cultural canon is the collection of values, codes and regulations inherent to the nations having great influence on the world history, the spiritual bonds for many and many generations. For mining industrialists of the Russian Empire as for the Soviet-era and todays miners, this part is taken by Gornyi Zhurnal which has been uniting the mining community in Russia and in foreign countries for as long as 195 years.

Russia and Serbia maintain the long-lived and close-tie of friendship and cooperation. Gornyi Zhurnal strives to facilitate the dialog between researchers and experts from the two countries. The Journal's team highly appreciates the friendly relations with Serbian colleagues represented in the Editorial Board by Professor Slobodan Vujic.

This article has attempted to provide a sort of hindsight and to retrace the growth and activities of Gornyi Zhurnal, from its foundation and up to the present day, with adherence to the traditional Russian school of engineering.

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GEOLOGICAL-ECONOMIC MONITORING IN IMPROVEMENT OF BUSINESS CONDITIONS AND EFFECTS OF MINERAL SECTOR COMPANIES

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Abstract: *Modern conditions of market jobs and competitive functioning of the mineral sector enterprises in the country's mineral economy require a higher degree of geological-economic analysis and economic evaluation of the profitability of mineral reserves in ore deposits. Successful material production of mineral resources in companies in the mineral sector depends on the mineral reserves and the provision of the necessary elements of the production process. Part of the production base with mineral reserves is geologically and economically analyzed, with their starting qualitative-quantitative geological definition, to which the economic analysis of the profitability of their exploitation continues. Such a complex analysis covers a large number of factors and indicators of geological-economic evaluation related to geological, mining, technological, economic and other aspects of the profitability of mineral reserves of the ore deposit. The volatility of market conditions of business, supply and demand, as well as the market price of mineral resources, necessitates the monitoring of influential elements of business. They can most fully be encompassed by continuous geological-economic monitoring, as a permanent expert geological and economic basis for improving the business conditions of the mineral sector enterprises.*

Keywords: *economic geology, geological-economic evaluation, geological-economic monitoring, ore deposit*

INTRODUCTION

The successful functioning of the country's mineral sector enterprises and the production of certain mineral resources in individual enterprises is directly related to the operation of certain: (a) macroeconomic and (b) microeconomic factors. Macroeconomic factors, which, from the point of view of an enterprise as a manufacturing entity, are external factors, primarily relate to general market conditions, and are directly reflected through competition, supply and demand for certain mineral resources. Individual companies in the mineral sector cannot be significantly influenced by them, but through adequate business decisions they have to adapt. Microeconomic factors, on the other hand, are internal-type factors that depend directly on the enterprise itself. The degree and success of engaging and using appropriate production resources of an enterprise is crucial to its production and business success, related to geological exploration, exploitation, preparation, processing and market valorization of mineral resources. Existing transition and economic trends in mineral resource economy and enterprise economics are directed to market-oriented principles and criteria for planning and realization of production of required mineral resources [1]. Accordingly, the need for more intensive introduction and faster application of efficient geo-management [2], then the concept of sustainable development [3], as well as the necessity of comprehensive study, observation and market definition of key geological and economic characteristics of the mineral deposit [4] with the mineral raw materials in question.

Economic evaluation of a deposit, which is the subject of economic activity of enterprises, developed and applied in countries with developed mineral economies, [5-8], has significantly influenced the improvement of domestic economic geology [9] and the contemporary practice of geological-economic evaluation of domestic mineral deposits [10]. The complex geological-economic evaluation of ore deposits in Serbia has been significantly improved and modernized in the recent period, which has, among other things, resulted in the introduction and development of market criteria for geological-economic evaluation of the deposits [4] and treatment of the deposits, not only as geological ones, but primarily economic categories. Through the collection, analysis and presentation of factors and sets of indicators of geological-economic evaluation [1], it is significantly facilitated the systematization, processing, interpretation and final presentation of numerous geological and economic information [11, 12] related to the mineral deposit as the basis of business of the mineral sector enterprises. The main objective of this paper is to highlight the place, role and importance of geological-economic monitoring in monitoring the geological-economic characteristics of the ore deposit, which are significant for improving the conditions and effects of business of the mineral sector of the country.

ECONOMIC EVALUATION OF MINERAL DEPOSITS AND MONITORING

Contemporary evaluation of mineral reserves, in the world practice of mineral economics, includes different types and types of grades, which allow evaluation from different aspects, different degrees of complexity and the final expression of the rating [1]. The most commonly used types are: Geological Assessment, Geological-economic Evaluation, Technical-economic Evaluation, Economic Evaluation, Technological Evaluation, Industrial Evaluation, Affordable Study, Feasibility Study, Mining Report, Geoecological Assessment, etc. In the domestic conditions of decades of development of the mineral economy and functioning of the mineral sector of Serbia, within the well-known Belgrade School of Economic Geology, a complex and comprehensive geological and economic assessment [13, 14] was developed. This type of integral evaluation represents a specific evaluation, which combines the basic geological sphere of knowledge of mineral deposits with the economic sphere, as a market valuation of the mineral resources in question. The final result of integrative integration of various data and information from the first phase of geological exploration, through exploitation, technological preparation and processing, to obtaining the final market product in the form of trench ore, refined concentrate, molten metal or finished mineral product, is obtained as a measure of profit, which can be realized from it [13,14].

The geological-economic evaluation of an individual mineral deposit, in practical terms, is a special type of managerial tool, very important for making the necessary professional and managerial decisions relevant to the operations of the mineral sector enterprises. For the specific application of geological-economic monitoring of certain elements of geological-economic evaluation, the temporary character of the evaluation is essential. It is, in fact, a very important starting principle of evaluation, according to which analytically determined individual values and sizes, as part of a geological-economic evaluation, relate to a certain time cross section of the validity of the defined factors and indicators of the evaluation. With the change of the time section there are certain changes in certain factors and indicators, which is directly reflected in the economic evaluation of mineral reserves and the economic effects of production in the company. In the simplest way, this temporality and volatility can be illustrated through the market price of mineral resources, which can fluctuate significantly depending on market movements. The aforementioned necessitates the monitoring of all significant factors and indicators of the evaluation, in order to monitor the values of the reserves in question and the economic and financial results of its operations at any time during the enterprise's operations. In doing so, we can distinguish: (a) monitoring of economic evaluation factors and (b) monitoring of economic evaluation indicators. The geological and economic character of the monitoring stems from the geological and economic nature of the ore deposit and the fact that the economic value of the reserves and the economic and financial effects of production in the mineral sector enterprise are based on geological and mineral reserves as a basis. Monitoring periods should correspond to weekly, monthly and quarterly levels.

MONITORING OF ECONOMIC EVALUATION FACTORS

The geological-economic evaluation of mineral resources, through a system-analytical approach, can be represented as a hierarchical highest system, consisting of subsystems expressed through concrete factors, namely [4, 9, 14]: (1) Metallogenetic; (2) Geological; (3) Technical exploitation; (4) Technological; (5) Market; (6) Regional; (7) Socio-political-economic-strategic; (8) Geo-ecological and (9) Legislative factors. These factors, by the breadth of the factorial analysis of the underlying mineral data, provide the opportunity to fully analyze the relevant data relevant to the business of the company, which performs the valorisation of mineral resources. Geological-economic monitoring of factors, due to mostly descriptive and extensive factor analysis, is operationally focused on monitoring of individual indicators of economic evaluation.

MONITORING OF ECONOMIC EVALUATION INDICATORS

The initial geological-economic analytical activity, through which the above-mentioned factors of the geological-economic evaluation are addressed, is followed by a second, higher and more explicit analytical step. From the basic expert analysis of each of the specified specific factors, individual rating indicators are derived, as elements important for the completeness of the presentation of these factor subsystems, and comprise the three bases of a set of indicators, namely [4, 9, 14]: (1) Set of natural indicators; (2) Set of value indicators and (3) Set of synthetic indicators. Monitoring of value and synthetic indicators is of particular market importance, both for the mine deposit and for the company. Linking them to natural indicators is crucial to monitoring the possibility of further profitable / profitable exploitation of mineral reserves. This monitoring is important both for the preparation of planning documents related to mineral reserves, as well as for annual and multi-annual production plans and business plans of the mineral sector enterprises. In addition, they are especially important for analyzing the success of planning and for monitoring the movement of production factors related to the mineral reserves and the mineral resources market.

MONITORING OF THE SET OF NATURAL INDICATORS

Natural indicators are expressed in physical or natural units of measure (eg percentages, meters, tons, years, etc.). Two subsets of natural indicators are distinguished, namely [4, 9, 14]: (a) a reminder of natural indicators in the narrow sense and (b) a reminder of natural indicators in a broad sense. The former are simpler, easier to calculate or measure. The latter are more complex and are often calculated by combining natural indicators in the narrow sense and value indicators, and are much more numerous.

Natural indicators in the narrow sense, as the most important individually, include the following: (1) Geological reserves of mineral raw materials (ores and useful components); (2) Mean content of the useful component; (3) Mean content of harmful and undesirable components; (4) Mean thickness of ore body; and (5) Mean thickness of reactive layers.

Natural indicators in the broad sense, as the most important individually, include: (1) The minimum economic content of a useful component; (2) Minimum excavation content (marginal content); (3) Minimum geological reserves in the deposit and individual ore bodies; (4) Minimum thickness of ore bodies and deposits; (5) Minimum thickness of overburden layers and off-balance parts; (6) Optimum and maximum bearing depth; (7) Coefficient of yield; (8) Maximum content of harmful and undesirable components; (9) Minimum content of usable supporting components; (10) Losses from the exploitation, preparation and primary processing of mineral raw materials; (11) Dilution of the useful component during exploitation; (12) Exploitation reserves of mineral raw materials, ie useful components; (13) Capacity of mines, preparation plants and processing plants; (14) A lifetime of bearing exploitation; (15) Content of useful and harmful components in concentrate; (16) Content of useful and harmful components in the primary final product; (17) Utilization rate for ore preparation and ore/concentrate processing; (18) Consumption of ore per 1 ton of concentrate; (19) Consumption of concentrate per 1 ton of primary (final) product; (20) Repayment period of the invested funds; (21) Mean and boundary overlay coefficient; and (22) Rate of profitability relative to the mine, the preparation plant and the primary processing.

Monitoring of these natural indicators is of particular importance for making appropriate business decisions related to mineral reserves, quality of mineral raw materials, production capacity and lifetime of exploitation. In particular, it should be borne in mind that for various metallic, non-metallic and energy mineral resources, the subject indicators have their own specificities and, accordingly, the need to display and monitor the values of individual indicators from the complete set. Based on the monitoring of these natural indicators, the appropriate natural planning elements of production in the business year can be further corrected, planned, monitored and implemented and the necessary business decisions planned and executed.

MONITORING OF THE SET OF VALUE INDICATORS

Value indicators are expressed in terms of value, ie monetary units, and the most important are the following [4, 9, 14]: (1) Costs of geological exploration 1 ton of reserves of certain categories and total costs of exploration; (2) Total investments required and invested in the exploration, construction of mines, preparation plants and primary processing plants; (3) Specific investments per 1 ton of ore, concentrate and final product; (4) Cost of 1 ton of ore, concentrate and final product; (5) Market price of ore, concentrate and final product (current and forecast); (6) Accumulation, ie profit per 1 ton of ore, concentrate or final product; (7) Transportation costs; and (8) Rentability.

Monitoring of these indicators is especially important for cost and investment indicators, as well as a particularly practically significant indicator of the cost of mineral raw materials. It includes a detailed calculation with all the necessary cost elements in the various stages of treatment. Changes in input elements consequently result in a change and cost price. Monitoring the relationship with the market price, can allow correction of the planned economic effect of production and more complete definition of the level of profitability and economy of the subject production of mineral raw materials in the company. Ultimately, it also affects possible adjustments to the financial result of the business, and in extreme cases, a possible fall in the market price below cost, and up to production losses.

MONITORING OF THE SET OF SYNTHETIC INDICATORS

Synthetic indicators are the most complex indicators, often expressed by a system of indicators. They include higher order indicators, the determination of which includes predetermined natural and value indicators, and the most important of which are the following [4, 9, 14]: (1) Value of deposits and reserves without taking into account the time factor; (2) Economic classes of reserves based on potential profits (economic classification of reserves); (3) Bearing value determined by dynamic evaluation methods (with time factor taken into account) - indicators obtained by calculation of NPV and IRR, and derived indicators; and (4) Cost of 1 ton of reserves explored.

Monitoring of these indicators is especially important for planning and investment indicators, especially for the value of the deposits, which is expressed through the amount of net profit that can be achieved in the operations of the company, based on the monitoring of established exploitation mineral reserves. In domestic practice of mineral economy in Serbia, for each mineral reservoir, the value of the deposit is made with and without taking into account the time factor. The value determined by the NPV and IRR method is considered to be particularly economically relevant, especially in the case of longer exploitation of the mineral reserves in question. Monitoring indicators that appear as input budgetary values for NPVs and IRRs may lead to the need to correct them, which has significant consequences in terms of looking at the real economic effects of production and operations of the mineral sector enterprises.

CONCLUSION

The geological-economic evaluation of the mineral deposit is a special type of management tool, very important for making the necessary professional and managerial decisions for the business of the mineral sector enterprise. Starting from the principle of the temporary character of economic evaluation, there is a need to monitor all relevant factors and indicators of the evaluation. It should enable the ongoing monitoring of the value of mineral reserves and in particular the economic and financial results of operations. The following are distinguished: monitoring of (i) economic evaluation factors and (ii) economic evaluation indicators.

The application of geological-economic monitoring in the enterprises of the mineral sector is very important in order to realistically monitor the geological and economic significance of the deposit, then the economic effect of the production and profit from the mineral resources, based on the geological elements of the production process and value indicators related to mineral resources. It is very important for the preparation of planning documents related to mineral reserves, then for annual and multi-year production plans, plans of business success of the companies of the mineral sector and appropriate business decisions. More intensive activity in the application of geological-economic monitoring should be carried out at the level of the individual reservoir, as well as at the level of the mineral sector. The same should provide prerequisites for successful economic operations of enterprises carrying out activities of exploration, exploitation and valorisation of the mineral resources in question as part of the successful functioning of the mineral economy in the forthcoming period of social, economic and economic development of the country.

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INVESTIGATION INTO INTERACTIONS BETWEEN UNCERTAIN VARIABLES IN MINING VENTURES

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Abstract: *Design of experiment (DoE) is a technique that is used to investigate the effects on the dependent variable of the independent variables of a scientific phenomenon. This technique utilized in the applied sciences and humanities widely performs a set of experiments to harvest maximum information about a variable with minimum effort. In this paper, the interactions between uncertain variables used in mining business are set forth through DoE. The main effect and interaction profiles of the uncertain variables (i.e., price, cost, and mine production rate) in a coal mining project in Indonesia is discussed. The net present value (NPV) and internal rate of return (IRR) are response variables. As a result, for both responses (i.e., NPV and IRR), cost, price, and production were the most impactful variables, respectively. Moreover, if NPV was the concern, it is recommended that the cost and production must be paid more attention especially when the coal price is in the high level. On the other hand, if IRR is the concern, the cost must be more observed when the price is in the low level, but the production must be more observed when the price is in the high level.*

Keywords: *design of experiment, discounted cash flow, interaction profiles, main effect estimates, mining*

INTRODUCTION

Mining ventures are characterized by high risk due to the many uncertain variables involved. Among the others, price, production costs, and grade play important role in decision-making in the mining industry. The commodity price is seen as the most crucial variable in the industry and exogenous to a mining company. The mining companies are usually price takers and have no power to set a price. The commodity prices are governed by supply and demand to a large extent. Given that mining operations have very specific characteristics, changing widely in ore and barren rock, operation costs have also wide fluctuation and hard to estimate. Ore within an orebody vary qualitatively and quantitatively. In other words, setting a production rate is not only the function of demand, but also a function of heterogeneity of ore quantity and quality. This heterogeneity bring significant risk to a mining project. Interest rate, expected recovery rate, or geological uncertainties are also important sources of risks in project evaluation.

One of commonly used evaluation technique is discounted cash flow (DCF). All the uncertain variables discussed previously are used in DCF. However, DCF is a static method and does not consider risks associated with the uncertainties. In risk analysis, in addition to reproduction of correlations between uncertain variables, the analysis of the interactions between uncertain variables will be very useful. It will strengthen the performance of risk analysis. Therefore, in this research, the design of experiment (DOE) technique is performed to understand the characteristic of the uncertain variables correspond to the project value. A coal mine project is conducted to see its practicality. In other words, this paper focuses on the propose a way to understand the impact of interactions of uncertain variables on the project value.

METHOD

In this research, the specific methods in the Design of experiment (DOE) were used to quantify the main effect and interaction profiles on the project NPV. The DOE is a technique to observe the main and interaction effects on the response variable. However, the use of time series needs a special attention because the errors (residuals) are independent of each other (no autocorrelation).

DOE performs numerical analysis such that times and costs are saved (Hibbert, 2012). In the DOE, depending on DEO technique selected, a number of scaled experimental values, including exploratory and response variables, factors, levels, and runs are initiated. Additionally, there is "interaction" term in the DOE. The interaction is a variable that represents at least two interacted variables. As a consequence, the more variables and the more values are being tested, the more runs must be conducted. All the combinations are put in a table namely full factorial design (Ryan, 2007).

The responses in this research are NPV and IRR. The profit, NPV, and IRR can be calculated by following Eq. (1), (2), and (3), respectively (Ardian & Kumral, 2018; Hustrulid, Kuchta, & Martin, 2013). Where CT is coal tonnage, rec is the recovery, CWC is coal washing cost, WT is waste tonnage, WSC is waste stripping cost, CMC is coal mining cost, r is the discount rate, and C0 is the capital expenditure at year 0. The profit calculation is simplified by remove the company liabilities (Ardian & Kumral, 2020b; Kumral, 2013). Notice that the profit calculation is modified due to the cost in this paper represents all the cost incurred (i.e., CWC, WSC, and CMC).

$$\text{Profit}=(\text{price} \times \text{CT x rec})-(\text{CWC} \times \text{CT})-(\text{WT-WSC})-(\text{CT} \times \text{CMC}) \quad (1)$$
$$\text{Profit}=(\text{price - cost}) \times \text{CT} \times \text{rec}$$

$$\text{NPV}=\left(\sum_{t=1}^{N}\frac{\text{Profit}_t}{(1+r)^t}\right)-C_0 \quad (2)$$

$$0=\text{NPV}=\left(\sum_{t=1}^{N}\frac{\text{Profit}_t}{(1+\text{IRR})^t}\right)-C_0 \quad (3)$$

In term of a coal mine project evaluation, the factors were coal price, costs (all the costs incurred until coal is ready to be sold), and the production. The levels were the lowest and the highest value of each variables, where are coded as -1 and +1, respectively. After all the factors, levels, and responses are defined, the full factorial design can be constructed. The number of combinations or runs may follow Eq. (4).

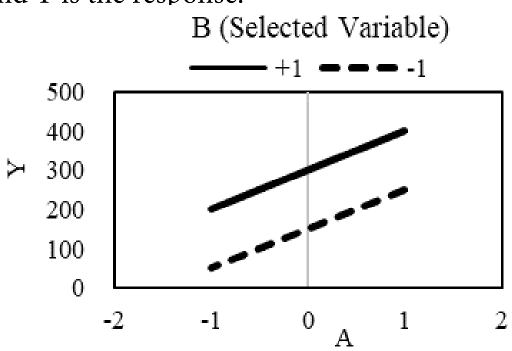
$$\text{run}=L^f \quad (4)$$

Where *L* is the number of levels and *f* is the number of variables. Furthermore, the main effect shows the magnitude of the effect of an independent variable itself on the response variable. The main effect can be estimated by calculating the average gains. The average gains is a response average at the low and high level of the observed factor. Needless to say, all the variables are observed. As a result, two average values are obtained to represent the -1 and +1 level for each variables. The calculation of average gains is a simple responses average for each level of designated factor/interaction that may follow Eq. (5) and (6) for low level and high level, respectively. Where F(−1) and F(+1) are the average gains for low and high level, respectively, Yn−1 is the response value at low level of the designated factor/interaction, and n is the number of calculated responses

$$F(-1)=\frac{Y_1^{-1}+Y_2^{-1}+\cdots+Y_n^{-1}}{n} \tag{5}$$

$$F(+1)=\frac{Y_1^{+1}+Y_2^{+1}+\cdots+Y_n^{+1}}{n} \tag{6}$$

The most impactful variable is the variable that has the highest absolute value of the slope coefficient (Ardian & Kumral 2020a; Ryan, 2007). Then, the variables are ranked accordingly. The next is the interaction profiles analysis. The interaction profiles examine the relationship between the variables. One variable may affect positively or negatively towards the project value. However, in a more detailed analysis, one variable may have different impact when is related to the other variable. Figure 1 shows how one variable may affect the response differently where combined with other variable. Where A and B are the uncertain variables, and Y is the response.



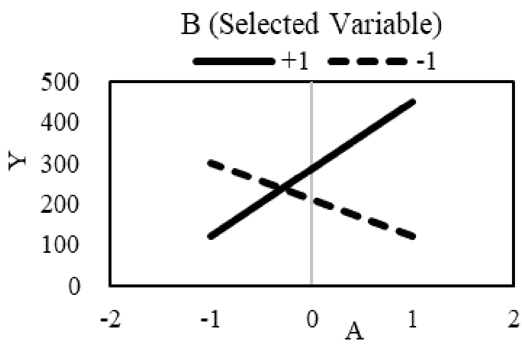


Figure 1. Two different interaction profiles.

Figure 1 (left), the variable A and B has no interaction on response variable, Y because the behaviour of the variable A does not change with varying values of the variable B. To be more precise, the high value of A and high value of B result 400 of Y, but low level of A and high level of B result 200 of Y. The dash line represents the low value of B, where the A at high and low value result 250 and 50 of Y, respectively. It clearly shows that 1 unit changes of A at low or high value of B results the same rate on Y. Figure 1 (right) shows strong interaction between variable A and B. The variable A affects to the Y strongly depends on B at low or high value. Where the B at low value, lower value of A results higher Y.

Eventually, the interaction profiles can be analyzed through generating all interaction profiles for each pair of variables. Comparing with main effect, the interaction profiles are beneficial to see the variables as a whole, not only as individual variable. One variable may have low impact towards responses, but pairing it with other variable may have important role in the evaluation. In the interaction profiles analysis, the variables that have strong interaction and steep slope are highly recommended to be carefully observed over time.

APPLICATION OF THE PROPOSED APPROACH

In this paper, a coal mine project in Indonesia was selected as a case study. The calorific value of the coal was 4,200 kcal/kg. The required monthly data was extracted from January 2019 to June 2019. The input parameters and variables for the analysis are presented in the Table 1.

Table 1, Project evaluation input parameter

Variables	Value	Unit
Price (min)	31.77	US$/tonne
Price (max)	38.62	US$/tonne
Cost (min)	15.38	US$/tonne
Cost (max)	30.24	US$/tonne
Production (min)	615,671	Metric tonne/year
Production (max)	932,680	Metric tonne/year

Variables	Value	Unit
Discount rate	15	%
MARR*	20	%
Recovery	95	%
Investment	3	Billion US$
Mine life time	10	years
Lag time	1	year

*Minimum accepted rate of return.

In this paper, the cost was all costs incurred, which were coal washing, coal mining, and waste stripping cost. The lag time was the pre-production time, it was assumed to be 1 year. The capital expenditure was assumed to be incurred only in year 0. For conducting a project with multiple capital expenditure, the annual profit that was utilized from Eq. (1) should be adjusted.

Firstly, NPV and IRR were calculated for each experimental configuration. Performing Eq. (1), (2) and (3), the price, cost, and production at the lowest level, the NPV and IRR were US$ 1,811,487,038 and 29.6%, respectively.

Secondly, the factorial design was constructed. The classical factorial design with 3 factors and 2 levels, utilized from Eq. (4), resulted 8 runs or combinations. Putting NPV and IRR for each runs, the factorial design table is presented in Table 2, where A, B, and C variables were price, cost, and production, respectively. The AB, AC, BC, and ABC were the interaction between variables A, B, and C.

In Table 2, the grey highlight in the factors represent high level (+1) of the variables. The grey highlight in the responses represent unattractive scenario where the NPV was lower than US$0 and/or the IRR was lower than the minimum accepted rate of return (MARR). Moreover, the negative IRRs emerged when the cumulative cash flow was less than the initial investment in the end of the mine life time (i.e., end of year 10). Negative IRR, in other words, meant the NPV of the project was zero if only the future event was more valuable instead of risky, which rarely happened especially in the extraction industry.

Thirdly, based on Table 2, the main effects and utilized from Eq. (5) and (6), the slope for each uncertain variables were estimated. Table 3 presents the main effect estimation by performing Eq. (5) and (6) for NPV and IRR.

Table 2, Full factorial design table

Run	A	B	C	AB	AC	BC	ABC	NPV (US$)	IRR (%)
1	-1	-1	-1	1	1	1	-1	1,811,487,038	29.6
2	1	-1	-1	-1	-1	1	1	3,823,566,676	44.2
3	-1	1	-1	-1	1	-1	1	-2,551,628,605	-17.6
4	-1	-1	1	1	-1	-1	1	4,288,922,800	47.4
5	1	1	-1	1	-1	-1	-1	-539,548,966	10.1
6	1	-1	1	-1	1	-1	-1	7,337,022,699	68.3
7	-1	1	1	-1	-1	1	-1	-2,320,762,072	-12.4
8	1	1	1	1	1	1	1	727,337,827	21.1

Table 3, The most impactful variables

Rank	NPV		IRR	
	Variables	**Slope (absolute value)**	**Variables**	**Slope (absolute value)**
1	Cost	2,743,200,129	Cost	1.97
2	Price	1,265,044,884	Price	1.58
3	Production	936,080,639	Production	1.26
4	Cost-Production	561,642,307	Cost-Production	1.12
5	Price-Production	259,005,065	Price-Cost	1.00
6	Price-Cost	0	Price-Production	0.88
7	Price-Cost-Production	0	Price-Cost-Production	0.74

Note that the order of the impactful uncertain variables were same for NPV and IRR except the fifth and sixth order (grey highlighted). In NPV oriented, the pair of Price-Production came first then Price-cost, but in IRR oriented, the pair of Price-Cost came first then Price-Production.

Finally, the interaction profiles are provided in Figure 2 and 3 on NPV and IRR, respectively.

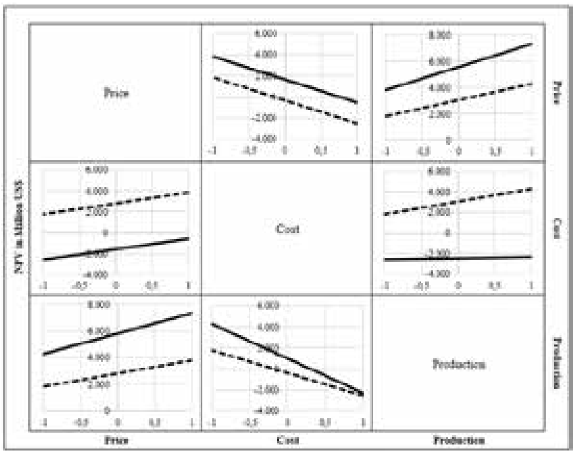


Figure 2, Interaction profiles between uncertain variables toward NPV.

In Figure 2, the price and cost (i.e., Price-Cost and Cost-Price) had no interaction effect toward the NPV because their lines were parallel. It means, the changes happened either in price or cost had the same changes rate. On the other variables that exhibited non-parallel lines, such as Price-Production (second column in the first row) and Cost-Production (third column in the second row) and of course for the inversed pair as well (i.e., Production-Price and Production-Cost). These non-parallel lines indicated interaction effect between them toward the NPV. The more slope-difference between two lines, the more effect they had.

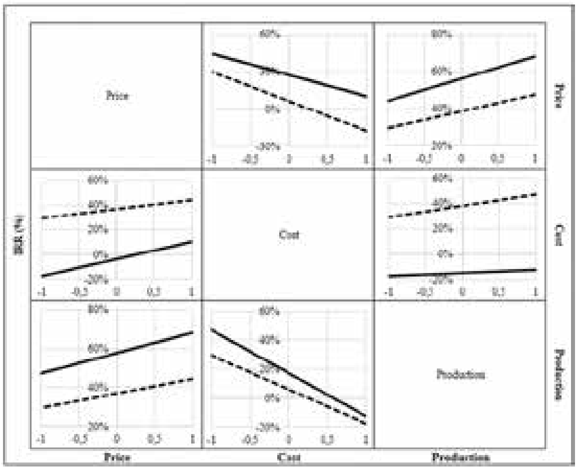


Figure 3, Interaction profiles between uncertain variables toward IRR.

Likewise, in Figure 3, the interaction effect happened between uncertain variables that shows non-parallel line. In Figure 3, all the pairs had interaction effect. Only the pair of Price-Production had the lowest interaction, which was consistent with Table 3 that the Price-Production had relatively low main effect.

CONCLUSION

Design of experiment is a useful technique to quantify important magnitude of exploratory variables on the response variables. It also provides significant information on the nature of interaction between the exploratory variables. Even though the DoE is widely used in experimental works based on controllable variables, we utilized from DoE to understand the effects of the variables in a mine project.

We carried out an application of the proposed approach on a coal mine project. The response variables were NPV and IRR. The results were relatively consistent that either the parameter NPV or IRR, which the importance order was cost, price, and production. Examining the interaction between variables, in NPV, the cost was critical if production was in the high level. The price was critical if production was in the high level. The production was critical if cost in the low level and price in the high level. In IRR, the cost was critical if price was in the low level and production was in the high level. The price was critical if cost and production were in the high level. The production was critical if cost was in the low level and price was in the high level.

Therefore, by observing the interaction profiles and focusing on NPV, the cost and production must be paid more attention when the coal price in the high level. However, by focusing on IRR, the cost must be paid more attention when the coal price in the low level, but if the coal price is in the high level, the production must be paid more attention. This is due to the cost and production are controllable variables.

Finally, as a future work, the more uncertain variables (e.g., discount rate, recovery, and grade) can also be considered in the calculation. The more analysis in the DoE, performing different design, or performing more number of level can also be explored.

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SPECIFICITY OF TECHNICAL – TECHNOLOGICAL SYSTEM OF TAILINGS MINING ON COAL MINE „SUVODOL“

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Abstract: *In order to enable excavation of the overburden, and thereby continuous coal exploitation on the open-pit mine "Suvodol", for a period of five years, it is necessary to find a solution that satisfies given conditions, while also provides fulfillment of required capacities in the specified period. The excavation of the overburden is performed with two BTO systems ("0"BTO system and "I" BTO system). Moving these systems is in function of the given dynamics of the operations performance. If necessary, dragline excavators are also included, in order to transfer tailings material to the planum of the excavator. According to the needs, tailings material is removed by bulldozers, loaders, and then transported by trucks to the disposal area.*

Keywords: *overburden, coal, BTO system, Suvodol*

INTRODUCTION

When making Additional Mining Project of the Open-pit Mine PJS Mining and Energy Combine (MEC) „Bitola“ document, the following restricting factors affected the final solution of excavation technology of the overburden:

- Continuous excavation $3x10^6$ t of coal annually for the period of five years should be provided to the project solutions and necessary amount of coal should be excavated and disposed to the given amount of the overburden;
- The task was to use only available equipment;
- The project had to be harmonized as much as possible with the Main Maining Project (MMP), which was made in 2009.

During designing the project guidelines of the designed task were followed, designing only what was possible to design in the given conditions, that is, what was possible to achieve in the technological terms. It is necessary to say that excavation of the overburden and coal was planned for the limited zone, down to the profile line 72 in the southern part of the mining field, 29 in the eastern part, 46 in the northern part and the western part generally to the profile 59. Profile line 49 is practically a dividing line between defined eastern and western part, for the purpose of designing and understanding operation technology.

In addition to the excavation equipment, as a basic designing factor, geomechanical stability conditions were an important factor to which everything had to be subordinated in order to safely excavate the tailings. The defined, geomechanically stable zones for the assumed pore pressure value of 0.1 are shown by curved lines in Figure 1. The line marked as 1 represents the boundary of the overburden excavation, and the dashed line marked as 2 represents the boundary of coal excavation. According to the available data, the slope of the paleosurface is from 2° to 30° in the zone of the previously projected cut slope opening, in the western part of the field. Figure 1 shows the initial positions of the system drive stations at the beginning of the project activities, letters A, B and C denote the stations on the overburden system, and the letters D, E, F, G and H denote the station on the coal system. During the project development phase, the start

Figure, Condition on the Terrain before the Beginning of the Project.

LEGEND: *A - drive station of the belt conveyor ETJ-2; B - drive station of the belt conveyor ETJ-4; C - turning station of the belt conveyor ETJ-4; D - drive station of the belt conveyor ETU-1; E - drive station of the belt conveyor ETU-0; F - drive station of the belt conveyor ETU-3; G - turning station of the belt conveyor ETU-3;*
H - turning station of the belt conveyor ETU-0; I - border of the overburden for the pore pressure coefficient 0,1,2 - border of the coal mining for the pore pressure coefficient 0,1.

date of the SRs(H) 1050 ×23/2 bucket-wheel excavator was unknown, so the designer in agreement with the investor, assumed that term. Almost all of the abovementioned can be seen in Figure 1, which represents the situation on the terrain before the project begins.

Coal and overburden excavation should be projected for the next five-year period. Only characteristic segments during projecting will be stated in this paper, which will be presented from three mechanization positions, initial condition, third year and final fifth year.

OPERATION TECHNOLOGY IN FIVE-YEAR PERIOD

In the initial project phase, and using existing exploitation systems, the excavation of tailings mass is performed in the western part of the excavation field. The bucket-wheel excavator SRs1300 × 32/5+ VR is operating on the overburden excavation, and its operating zone is within the limits of geomechanically allowed parameters. The excavator operates in the height of the block of twenty meters along the floor conveyor ETJ-4, marked with points B and C, and all the mass above that height dragline excavator EŠ 10/70 excavates and throws it on the planum of the bucket-wheel excavator. One part of the mass is taken by dumpers and the other is taken by the bucket-wheel excavator, and then everything is taken to the disposal area by the belt conveyors. During the first year, floor conveyor of this excavator, ETJ-4, will move once radially with a turning point in the drive station, point B, for a step of 65mpo direction generally looking east-west. With moving, this belt conveyor will also be extended by 98m, allowing tailings to be reached at the far southwestern part of the limited excavation field. After moving the floor conveyor bucket-wheel excavator starts the excavation of the new block from the turning station to the drive station. The excavator will excavate all the way to the ETJ-2 chain conveyor, marked with points A and B. The excavator then turns around and starts the excavation along ETJ-2 belt conveyor, which now becomes floor conveyor and works in high and deep operation with 3%. At the end of the excavation block in the south-north direction, a ramp will be made to connect the levels K + 566m and K + 577m, position south of point A. By constructing a ramp and moving the ETJ-2 conveyor to a new position, a situation is obtained that is approximate to the position of the transporter ITJ1 / N given in the framework of the Main Mining Project of open-pit mine "Suvodol". By excavation of the working block height 160m in length the operation in the zone of the ETJ-2 conveyor is being finished because of the bad geomechanical conditions. The tailings excavation in the western zone of the excavation field is also excavated for some time by the SRs630 (1) bucket-wheel excavator that works on coal (current situation), and then switches to the overburden and operates at the same time with the SRs1300 × 32/5 +VR excavator. The part of the tailings mass is driven away with trucks as well. These two excavators work along different floor conveyors while they have all other conveyors in common. This technical solution is accepted by the investor at the beginning of the project as only possible solution in the given situation. Before the end of the first year, the reconstruction is performed, so that the SRs630 (1) bucket-wheel excavator remained in the western part, until the completion of the mass excavation that could be technologically excavated with the assistance of a dragline excavator, while the SRs1300 × 32/5 +VR bucket-wheel excavator moved to the eastern part of the excavation fields, and began the formation of a working height and depth block by excavating along the ETJ-4 floor conveyor in the east-west direction, while generally the direction of progress is south-north, the orientation position of this conveyor can be seen in Figure 2. At the end of the first year of exploitation, in the production process should also enter bucket-wheel excavator SRs(H) 1050 ×23/2, which is just one of the assumptions the designer was faced with. With this reconstruction of the overburden excavation system, two tailings systems are formed and the overburden excavation is performed by two BTO systems - "0" BTO system consisting of the SRs1300 × 32/5 +VR bucket-wheel excavator, conveyor belt, B = 1.600 (mm) and disposer A 2 RsB-5500 x55 and "I" BTO system consisting of SRs 630 (1) bucket-wheel excavator and SRs (H) 1050 × 23/2 bucket-wheel excavator, belt conveyor B = 1,600 (mm) and A 2 RsB- 5500 x60 disposer. The systems are assisted, if necessary, by dragline excavators, EŠ 6/45 and EŠ 10/70.

Upshot of all of this is although the first year is extremely technologically demanding, floor conveyor often move parallel and semi-parallel with shortening or lengthening, while the chain conveyors of both systems remain in their positions, at the end of the first year, with all restrictions, a total of 5.448.005,80 m3 the overburden is excavated.

During the second year of exploitation at the Open-pit Mine "Suvodol" there is a partial clearing of the situation in terms of forming the fronts on the excavation of the overburden and visually the fronts approach to the settled mine. Operation technology on "0" BTO system will not change significally. Bucket-wheel excavator excavates the height of the block with the sublevel in zones where it is necessary. Where working with the help of a sublevel is not enough, and in terms of height, the dragline excavator EŠ will remove the height difference and throw the material on the excavator planum. Where it is necessary, the tailings material will be removed, by bulldozers and loaders, and then transported to the disposal area by trucks. During the second year, the floor conveyor moves three times radially with a turning point in the drive station, the drive station rises a total of ten meters during the year, with each movement the conveyor extends by 65-75m, and the turning station level remains constant K + 533m . In depth operation excavator excavates along with two sublevels, while in the zone of the drive station it excavates up to level K + 536m. The operation technology on the "I" BTO system is such that the progress of the "0" BTO system is being monitored with the maximum use of technological characteristics of the bucket-wheel excavator. A relatively small block height is being excavated and the focus is on depth operation and excavation as close as possible to the coal roof. The floor conveyor moves once in parallel during the year and then twice radially with the turning point in the turning station. The maximally spread excavator excavates as far as it can reach, although a certain quantity of overburden still needs to be loaded by dragline excavators in the excavator's reach, and one part is driven away by trucks to the disposal area. From the last radial movement of the floor conveyor, the SRs(H) 1050 × 23/ bucket-wheel excavator returns to the western zone, the zone between points B and C in Figure 2, and excavates two depth blocks, which would significantly relieve that zone of native tailings material, creating space for temporary storage of additional quantities of the overburden, which would allow the front of the "0" BTO to be moved. The bucket-wheel excavator then returns in the eastern part of the open-pit mine. Moving the bucket-wheel excavator from the east to the west of the open-pit mine is not a particularly technologically difficult procedure, but it is quite serious enough to require maximum concentration and caution of the personnel. In the second year, a total of 5.814.338,70 m3 of the overburden should be excavated.

Third year of the overburden excavation also requires specific reconstructions of both chain and floor conveyors, in order to keep formed front of the operations. Chain conveyor ETU-1/0, the zone north-eastern from the point D in the Figure 2, moves radially, one part moves to the east with a turning point in the drive station. On this occasion, this conveyor is extended. The floor conveyor ETJ-4/0 is attached and extended to it, and the last positions of these conveyors are shown in Figure 2. The bucket-wheel excavator will operate to a lesser extent with a height ramp, but it will not operate in the block depth. On the first tailings system, chain conveyor moves radially in the eastern direction, with the turning point in the drive station. For the new position of the chain conveyor the ramp is built by the bulldozers. On such a displaced chain conveyor the level conveyor ETU 3/I is connected, and both conveyors are extended during the year depending on necessity. On this system, the bucket-wheel excavator excavates the working block height as well as depth block lowering two transports in depth and then only the large transport to excavate to the overlying soil. Cleaning the coal overlying is done with auxiliary mechanization. The condition at the end of the third year is given in Figure 2. During the third year 6.402.625,50 m3 of the overburden is being excavated.

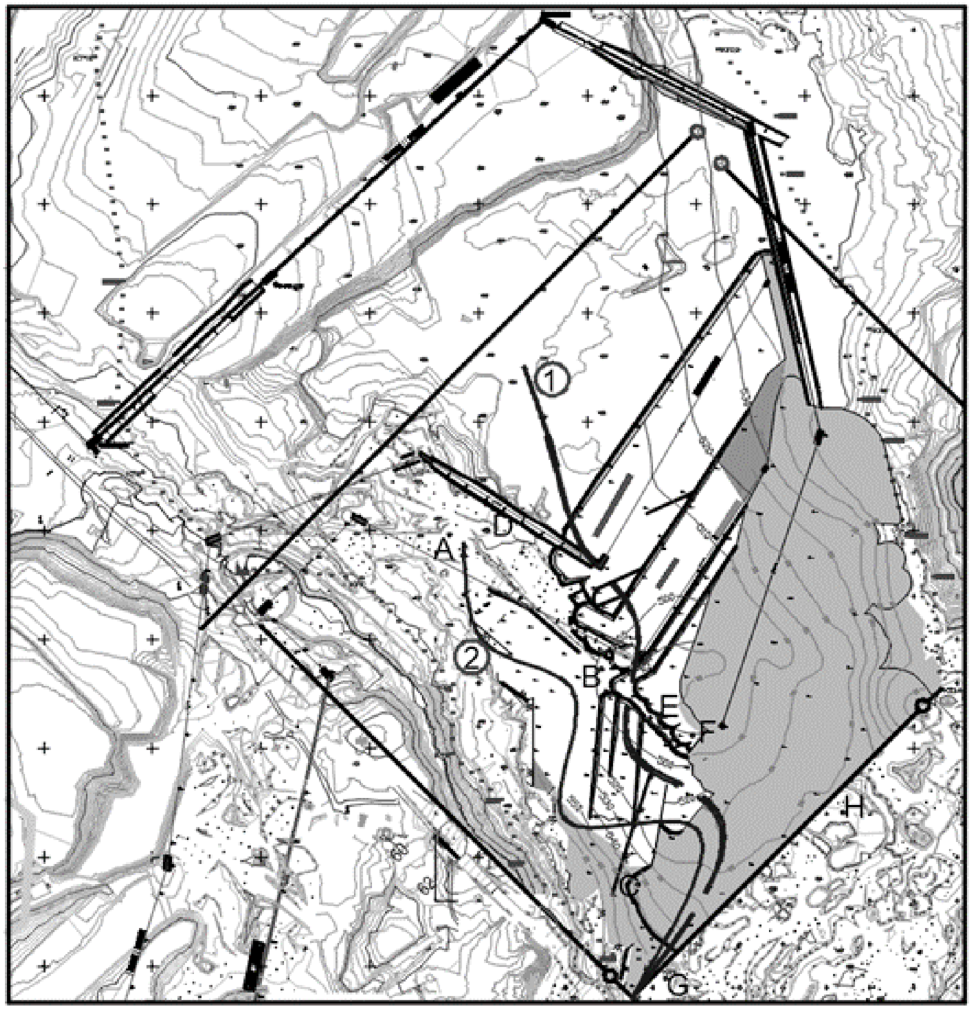

Figure 2, Condition of the Operations at the End of the Third Year of Exploitation.

The fourth year of the overburden excavation implies excavation continuation with both tailings systems. The front of the progression is maintained in the south-north direction, and is generally excavated in the east-west direction. The floor conveyors of both systems move radially with the turning points in the drive stations, and, if necessary, they are extended or shortened. Before the end of the fourth year of the exploitation on "0" BTO system reconstruction will be performed. On existing chain conveyor another chain conveyor is attached, and then another one is attached on it at almost right angle. The last one is set at ramp formed by bulldozer operations in the far east of the excavated field. On the last chain conveyor ETU-1/0 the chain conveyor ETJ-4/0 is attached by its drive station, whereby that point will be the rotation turning point of the floor conveyor till the end of the fourth year and the whole fifth year of exploitation. The floor conveyor in further operation and during the fourth year from this position moves once radially. Excavator excavates only in the height of the block. There are no technological changes in the "I" BTO system during the fourth year of excavation. The ETU-3/I chain conveyor moves radially with a turning point in the newly formed deposit point. When moving, the floor conveyor is extending in the turning station zone, which creates the condition for the excavator to reach and excavate all planned tailings mass. The bucket-wheel excavator excavates both the height and depth blocks, lowering both transports first and then only the large one. This is necessary in order to collect all the tailings mass to the overlying soil. Tailings mass that cannot be removed from the coal overlying are being transferred within reach of the excavator by the operation of the dragline excavator, and one part is driven away by trucks. In this year, total of 5.098.362,50m3 the overburden is excavated.

The fifth year of the overburden excavation is by the project the final year of exploitation. On "0" BTO system there are neither technological changes nor reconstructions. The floor conveyor still moves radially, with a turning point in the drive station. The moving step is 80m, then the conveyor is shortened by approximately 75m and moved radially, and after another movement and shortening it comes to its last position in the fifth year. The shortening of the floor conveyor and the radial movements are directly related to the appearance of the terrain behind the turning station. At the end of the fifth year of the exploitation, the floor conveyor of this system, ETJ-4/0, is 590m long, the drive station level is K + 528m, and the turning station level is K + 540m. During the 5th year, on the "I" BTO the ETJ-2 / I chain conveyor is removed, as it is no longer possible to reach the chain and floor outflow, taking into account the direction of progress and the angle these two transporters occupy in relation to one another. This is the reason why the chain conveyor of the "0" BTO system, ETU-1/0 is extended by 145m, position 3 in Figure 3, and the floor conveyor ETU-3 / I is attached on it, so we have a situation that both tailings systems are excavating the overburden along two different floor conveyors with all the other conveyors in common. The overburden from these two systems is disposed on the same disposal area. The positions of the conveyors of these two tailings systems as well as the levels of the drive and turning stations can generally

Figure 3, Finishing Condition of the Operations.

be seen in Figure 3. During this year, a total of 6,847,339.20 m3 of the overburden is excavated.

CONCLUSION

The designed operation technology is subordinated to the open-pit mine condition at the beginning of the designing, available documentation and mechanization, rationalization of the excavation process, geomechanical stability conditions, the required coal production, as well as certain dilemmas that were difficult to resolve in a short period of time. Working in the period of projected five years will be extremely complicated in technological terms. The designer is not sure that despite the finished and technologically achievable project, the investor will be able to follow the ideas of the designer. It is important to note that this technological solution of the overburden excavation was given for a period of five years, and it is important to define the continuation of the overburden and coal excavation in a period after the given 5 years. The current working technology both on the overburden and on the coal is a consequence of a number of negative factors that occur at this highly demanding mining facility. The designer has managed to introduce very little of this project into the solutions provided according to the document Additional Mining Project of the Open-pit Mine "Suvodol", since there were no realistic conditions for this.

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HYDRODYNAMIC MODEL OF THE COAL MINE SUVODOL

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Abstract: *The designed open-pit mine of the Underlying Coal Series (UCS) is specific for the method of tailings excavation, which is performed in very complex geological and technical conditions, since the tailings material above the coal does not have a constant height, and therefore the technological parameters of the excavation are changing by the phases of exploitation. The current way of defense from surface water at open-pit mine UCS has included the drainage of water with perimeter canals, and from the working areas in the mines by level, connecting or transverse canals connected to watercollectors located at the lowest levels of tailings, coal levels and underlying soil. Water from watercollectors is pumped by suitable centrifugal pumps and pipelines to the existing recipients. When talking about the protection of mines from groundwater, in order to provide favorable conditions for the coal exploitation, it was necessary to build drainage facilities to achieve this (drainage wells, drainage ditches, drainage of operation levels).*

Keywords: *underlying coal series, wells, watercollector, canals*

INTRODUCTION

Tailings excavation on the open-pit mine Suvodol will be performed in a very complex geological-technical conditions (narrow space for excavator maneuvering, taking into account the dimensions of the backet-wheel excavator, the height of the excavator reach due to the geomechanical stability conditions on one side and the technical and technological capabilities of the excavator itself, the height of the excavated area, the proximity of the belt conveyor and the time period in which it operates) [3]. Due to the irregularity of the coal layer dip, the tailings material above the coal does not have a constant height, which is why the technological parameters of the excavation are changing by the phases of exploitation.

HYDROGEOLOGICAL COLLECTORS

In the current area, four hydrogeological colecotrs have been isolated in which the overlying (O), interlying (I_1 and I_2) and underlying (U) aquifer were formed [1].

Overlying aquifer (O) is formed in silty sand of heterogeneous granulation and sandy silt with a general decline from south to north, consistent with a general decline of the coal series. Within the complex lens-like sand of the larger granulation appear. The value of the filtration coefficient of these sand series is approximately 5x10^{-4}m/s [1].

Replenishing of the complex is along the perimeter of the neogene basin at the contact of the base rock made of gneiss, and atmospheric precipitation in the open part of the open-pit mine. In natural conditions the complex is being emptied in the middle, which is hypsometrically lowest and is located north of the observed area. The artificial emptying conditions are performed at the mining facilities at open-pit mine UCS.

Interlying aquifer (I_2) is formed in silty sand of different granulation and sandy silt. The filtration coefficient is approximately 2x10^{-5}m/s [1]. This complex is an extension of the overlying aquifer.

Interlying aquifer (I_1) is formed in sandy silt and in silty sand of different granulation. The thickness of this complex is up to 5 m, while going north increases and expands. A complex of sandy sediments "lies" within the underlying series in the form of intercalations. At the perimeter of the basin, this aquifer is in hydraulic connection with other neogene sediments. The value of the filtration coefficient of these sand series is approximately 1x10^{-5}m/s [2].

Underlying aquifer (O) is formed in gneiss and in silty sand which are located in the immediate overlying coal series. Immediate coal overlying are coal clay, gneiss and silty sand. The surface of direct contact of silty sand and coal is increasing in the north direction. The value of the silty sand filtration coefficient is of the order of magnitude 1x10^{-5}m/s, and grus of gneiss filtration coefficient, obtained on the basis of granulation is of the order of magnitude 1x10^{-4}m/s [1]. The groundwater level at the beginning of making the technical documentation is shown in Figure 1.

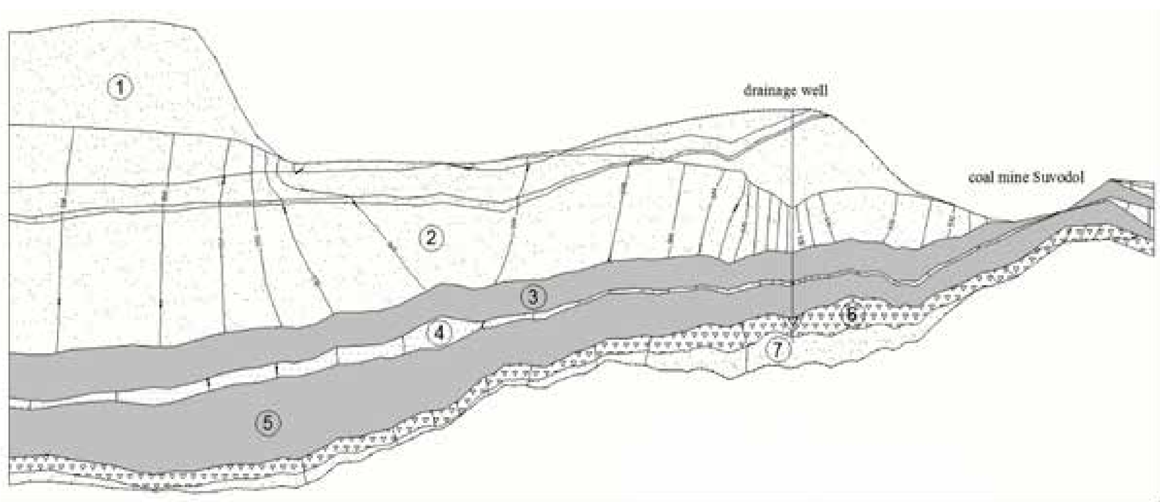

Figure 1, Profile with Initial Groundwater Level for All Three Aquifers [2].

LEGEND: *1-Silty and clay sediments; 2-Silty sediments; 3-The first coal layer; 4-Fine grain sand; 5- The second coal layer; 6-Coal clay; 7-Underlying sand; —-Equipotential groundwater level lines.*

The method used before for defending mine from surface water has consisted of collecting waters from working areas, perimeter, connecting and transverse canals connected to water-collectors. Water is pumped from the watercollectors, with appropriate centrifugal pumps, to the existing recipient.

HYDRODYNAMIC MODEL

Hydrodynamic model of the open-pit mine Suvodol was designed and constructed as a multi-layer model, with a total of ten layers, observed in a vertical profile. Each of these layers corresponds to a specific realistic layer, schematized and separated based on the terrain knowledge and the results of the condacted analysis of extensive field exploration operations.

Observed from the surface of the terrain, the corresponding layers of the model and terrain are:

1. The first model layer – silty and clay sediments that form disposal area;
2. The second model layer – silty sand widespread on terrain surface;
3. The third model layer – clay sediments;
4. The forth model layer – silty sand with poor filtration characteristics;
5. The fifth model layer – silty sand in which free level aquifer is formed;
6. The sixth model layer – the first coal layer;
7. The seventh model layer – fine grain sand, silty;
8. The eighth model layer – the second coal layer;
9. The ninth model layer – coal clay;
10. The tenth model layer – underlying sand.

Of particular interest are the fifth, seventh and tenth model layers so that they are dedicated the greatest attention.

Based on the existing results of the geological and hydrogeological structure of the subject area, a hydrodynamic model was developed to analyze the operation of the projected open-pit mine drainage facilities. The mathematical model was made using the finite element method, and the SPRING package was used as software [2]. The basic dimensions of the model are 3000x1500 m, or about 4.5km^2. The discretization of the stream field in the plan was performed by a non-homogeneous series of elements of size from 50 m to 5 m. The time step is one year (Figure 2).

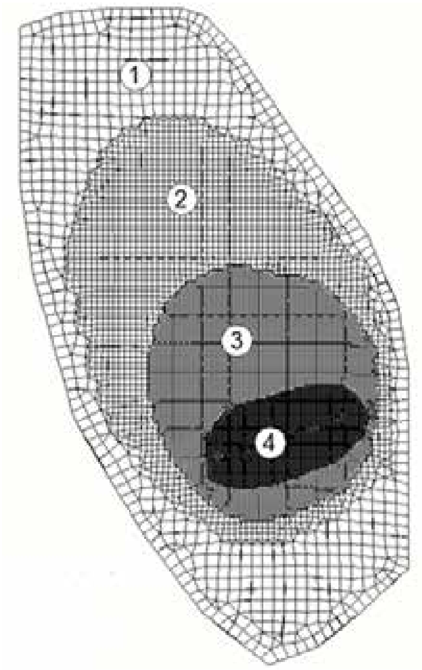

Figure 2, Discretization View of the Hydrodynamic Model [2].

LEGEND:
1 – Elements of size 50m x 50m;
2 – Elements of size 25m x 25m;
3 – Elements of size 12m x 12m;
4 – Elements of size 5m x 5m.

The mathematical-hydrodynamic model was set up as a water-bearing multilayer porous environment, with representative filtration parameters and given boundary conditions. Groundwater flow was calculated as stationary, under pressure and free-flowing, where appropriate conditions were fulfilled over time. The area of the model is defined by the boundaries of the spreading of the underlying aquifer. As boundary conditions, the model hydrodynamic conditions of the replenish zones are given, as contours with a given potential, in the field wells, or horizontal drainages, canals, are specified as drainage facilities, as needed.

Hydrodynamic model of the open-pit mine Suvodol was designed and constructed as a multi-layer model, with a total of ten layers, observed in a vertical profile. Each of these layers corresponds to a specific realistic layer, schematized and separated based on the terrain knowledge and the results of the condacted analysis of extensive field exploration operations.

The underlying aquifer is formed in the underlying sand and, although small in thickness, represents a complex problem, primarily because of good filtration characteristics of the underlying sands, but also due to the spread of the layer which allows high piezometer level in the aquifer. On the model are set "windows" (Figure 3), the zones of direct contact of the underlying aquifer with coal series.

Through this „windows"ground water passage on the terrain surface during coal exploitation is enabled. The moment of opening the "window" is a critical moment, given the high pressures prevailing in the underlying aquifer and it is therefore necessary to ensure acceptable, normal conditions of coal exploitation. A favorable circumstance is that the moment of the opening of the underlying aquifer occurs in two to three years, which gives enough time to reduce the pressure.

Whereas the concept of drainage of the underlying aquifer was adopted, representing the use of wells in the front and at the rear of the operations. The goal is to bring down the groundwater level of the overlying aquifer below the future level of the operations. In accordance with the adopted concept of drainage, and testing in the model, the number, layout and dynamics of construction of drainage facilities - wells were defined. Following the dynamics of mining operations, it was necessary to ensure favorable conditions for excavation at all times.

On the model the given dynamic levels are set as input data, while pumping capacities were used for verification in the model calibration process. Groundwater level condition at the end of the fifth year of exploitation is shown in Figure 4.

CONCEPTION OF MINE PROTECTION FROM SURFACE AND GROUND WATER

The basic protection concept of open-pit mine UCS from surface water involves collecting water from working areas, perimeter, connecting and transverse canals connected to watercollectors. Water is pumped from watercollectors, with appropriate centrifugal pumps, to existing recipients. [2].

The perimeter canals accept water that gravitate into the work area, as well as atmospheric water that fall into the work area of the mine. They

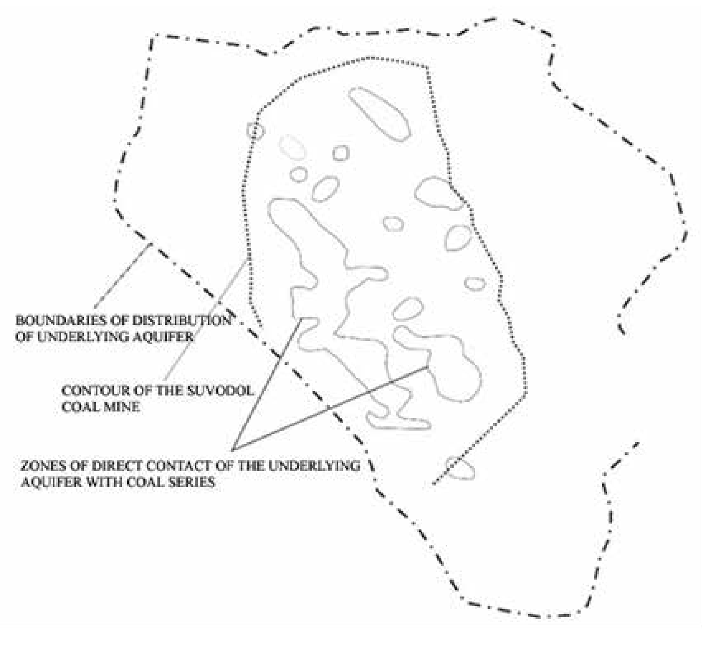

Figure 3, Spreading Contours of the Underlying Aquifer [2.].

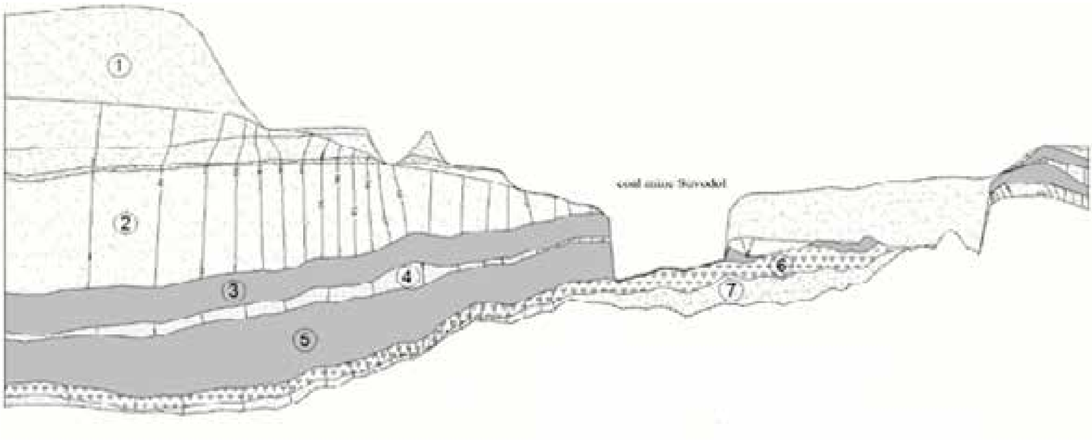

Figure 4, Profile Showing Equipotential Groundwater Level Lines for All Three Aquifers in the Fifth Year of Exploitation [2].

LEGEND: *1-Silty and clay sediments; 2-Silty sediments; 3-The first coal layer; 4-Fine grain sand; 5- The second coal layer; 6-Coal clay; 7-Underlying sand; —-Equipotential groundwater level lines.*

are directed to the watercollectors from where they are taken out of the mine by the pump aggregates.

Level canals are made on tailings and coal levels in order to collect atmospheric water and water that gravitationally exits from level slopes, and then by the shortest way is gravitationally conducted to the temporary and main watercollectors. The production of level canals is directly dependent on the dynamics of mining operations progress.

The technical solution of the mine protection from ground water foresees construction of [2]:
- Drainage wells;
- Drainage ditches and;
- Temporary canals.

Drainage wells are in the function of protecting the working figure of the mine during exploitation and their construction must take precedence over the advancement of the mining operations front.

Drainage ditches are made at the underlying soil of the mine, behind the mining operations, parallel to the toe of the lowest coal level and allow groundwater from the gneisses to be received. At the same time they can be used as collecting canals for protection from surface water.

Temporary canals collect ground water that run out from level slopes and direct it to the level canals, and then to the nearest watercollector.

In order to obtain data on the groundwater regime and the effects of the drainage system operation, it is necessary to perform monitoring, which includes:
- Mine level and disposal mapping;
- Making piezometer network and measuring level of ground water;
- Measuring well flow;
- Collecting data on rainfall and processing the obtained data.

With this technical solution of mine protection from water, it is possible to provide optimal conditions for the operation of basic mining machinery for the excavation and transportation of coal and tailings mass.

CONCLUSION

Available geological and hydrogeological data show an uneven exploration picture and insufficient information on the working environment and environment of open-pit mine UCS. Regardless of the level, quality of processing and interpretation of the available hydrogeological data, it is not possible to provide a reliable determination of the hydrodynamic model of the working environment and of the system for protection of the open-pit mine from water. It is necessary to establish high-quality, continuous hydrogeological monitoring of the working environment and surroundings, and in harmony with the development of exploitation operations on the open-pit mine, to continue with hydrogeological exploration in order to possibly adapt the project solutions of the system for the protection of the mine from water.

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GEOMECHNICAL RESEARCH FOR THE NEW BUCKET WHEEL EXCAVATOR TESTING AT OPEN PIT "FILIJALA"

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Abstract: *Since 1976 cement marl excavation at open-pit mine „Filijala" is carried out by continuous exploitation technology using bucket wheel excavator SH 400 manufactured by Orenstein und Koppel (O & K) company. Due to the bucket wheel excavator time-worn and high operating cost it was necessary to replace it with new one. In order to test the new bucket wheel excavator and prove its capacity a testing zone was defined as test block for excavation, in which the bucket wheel excavator testing will be conducted. In the test block area detailed investigations were carried out which included laboratory testing in order to determine the value of material cutting resistance.*

Keywords: *cutting resistance, marl, bucket wheel excavator*

INTRODUCTION

The cement marls deposit „Filijala" is the main source of the basic raw material for the cement factory today. It has been known since 1838, and its exploitation works began in 1869 where the open-pit mine „Filijala" was developed. This deposit consists of three mining areas of unequal size and degree of exploitation called: „Severno polje", „Srednje polje" or „Međupolje" i „Južno polje"(Ganić M. et al., 2012).

The cement marl basic technology of exploatation is continuous with the use of a bucket wheel excavator. Due to the conditions in the deposit, especially due to the quality of marl, it is not possible to apply exclusively continuous technology, so the discountinuous exploitation technology is used as well. Discontinuous technology is used for the exploitation in parts of deposits where the bucket wheel excavator can't operate, as well as for simultaneous excavation from both technologies in order to homogenize the quality of the cement marl. Marl continuous exploitation technology is carried out by a bucket wheel excavator model SH 400, which was produced by the company Orenstein und Koppel (O & K) and has been in operation since 1976. Picture of this excavator in operation at open-pit mine is given in Figure 1.

Lafarge Beočin cement factory management decided to purchase a new bucket wheel excavator, due to the time-worn of the existing rotor excavator. Based on the technical specifications provided by LBFC mining engineers and technicians, a bucket wheel excavator with a working name „new bucket wheel excavator" has been designed, built and delivered. After completing the installation of a new bucket wheel excavator, it is necessary to carry out its testing, which, among other things, includes the proving of the exploitation capacity. For the purpose of testing a new bucket wheel excavator and proving its capacity, a digging test block is defined, in which the testing will be carried out.

At the open-pit mine „Filijala" test block location an detailed research program was carried out which covered both field investigations and geomechanical laboratory tests. Results of this research will serve as a basis for new bucket wheel excavator testing and proving its exploitation capacity.

FIELD INVESTIGATIONS

Field investigation included the exploratory borehole drilling from which core was collected and mapped. A total of sixteen boreholes were drilled at the open-pit mine „Filijala" test block zone. The spatial positions of the exploratory boreholes are shown at the map in Figure 1.

Figure 1, The "old" bucket wheel excavator SH 400.

Figure 2, The "new" bucket wheel excavator.

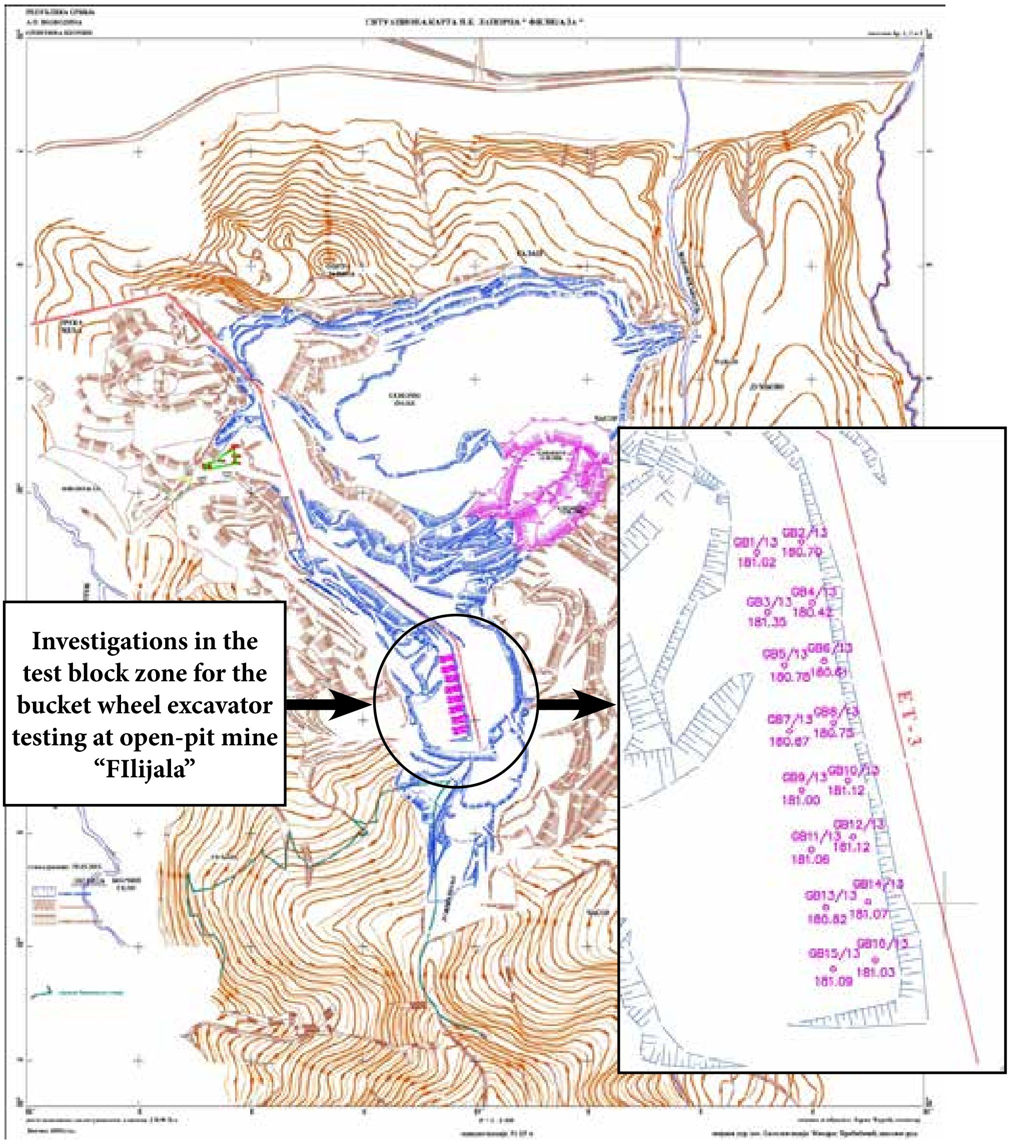


Figure 3, Disposition of investigations in the test block zone at open-pit mine "Filijala".

Exploratory drilling is performed by rotary drilling machine with continuous coring. For these purposes, GAK-300 drilling rig with all associated equipment was used. During the drilling itself, detailed geoengineering and hydrogeological mapping of the collected core was carried out. The results of the core mapping allowed the selection of rock material representative samples, after that the representative samples were labeled and packed for geomechanical laboratory testing. The aim of the conducted field research was to determine the geological structure of the micro-location of the zone and to select and collect the rock material samples for laboratory testing. Boreholes and samples basic data are given in Table 1 (Gojković N. et al., 2013).

LABORATORY TESTING OF PHYSICAL AND TECHNICAL PROPERTIES OF ROCK MATERIAL

Total of 23 rock material samples were collected from open-pit mine „Filijala" test block zone and delivered to Laboratory for rock mechanics at Faculty of Mining and Geology. All samples belong to a group of gray marl. On these samples the laboratory testing was carried out in order to determine the physical and technical properties, such as: the unit weight γ, the water

Table 1, Basic data on exploratory boreholes

Borehole				***Samples***		
Label	***Coordinates***			***No.***	***Depth***	
	Y (m)	***X (m)***	***Z (m)***		***From***	***To***
BGF-01/13	7400928.87	50066333.1	181.02	2	1.30	2.50
					5.35	6.60
BGF-02/13	7400945.80	5006637.10	180.70	2	1.30	2.60
					5.40	6.50
BGF-03/13	7400932.97	5006610.38	181.35	1	3.40	4.60
BGF-04/13	7400949.93	5006614.09	180.42	1	3.40	4.60
BGF-05/13	7400939.38	5006590.47	180.88	2	1.50	2.55
					5.40	6.60
BGF-06/13	7400954.49	5006592.07	180.61	2	1.40	2.60
					5.40	6.60
BGF-07/13	7400941.30	5006565.33	180.87	1	1.80	6.20
BGF-08/13	7400958.09	5006568.56	180.75	1	3.20	4.60
BGF-09/13	7400945.93	5006543.00	181.00	2	1.50	2.60
					5.40	6.60
BGF-10/13	7400963.43	5006546.72	181.12	2	1.40	2.60
					5.45	6.65
BGF-11/13	7400949.60	5006520.46	181.06	1	3.40	4.70
BGF-12/13	7400965.44	5006525.28	181.12	1	3.40	4.60
BGF-13/13	7400955.14	5006498.53	180.82	1	1.90	6.25
BGF-14/13	7400971.16	5006500.67	181.06	2	1.45	2.70
					5.40	6.60
BGF-15/13	7400957.86	5006475.17	181.08	1	3.40	4.60
BGF-16/13	7400973.83	5006478.51	181.02	1	3.40	4.55

content ω, the cutting resistance per unit of cutting edge length engaged K_L and the cutting resistance per unit of slice cross-sectional area K_F.

Physical and technical properties laboratory testing was performed in total of: 111 unit weight tests with paraffin (SRPS U.B1.017), 111 water content tests (SRPS U.B1.012) and 111 tests for determining the cutting resistance per unit of cutting edge length engaged and per unit of slice cross-sectional area. Marl cutting resistance testing of the was performed according to wedge test method proposed by Orenstein und Koppel (Durst W., Vogt W, 1988, Raaz V., 1999). The borehole labels and the number of samples from each borehole for laboratory testing are shown in Table 2.

CUTTING RESISTANCE

Gray marl cutting resistance was determined according the wedge test method proposed by Orenstein und Koppel. For this purpose, a specially constructed wedge was used for the breaking of marl test bodies. This wedge has angle of 34^o, the glossy top of b = 5 mm with blade length of l = 65 mm and its schematic representation and appearance is given in Figures 4 and 5 (Radojević J., 1979, Radojević J., 1992).

According to the original test method the wedge is installed into a suitable hydraulic press which is used for vertical force applying. The vertical force increases constantly until the specimen fracture. During the tests, the force value which led to specimen fracture and wedge penetration depth into the specimen were determined.

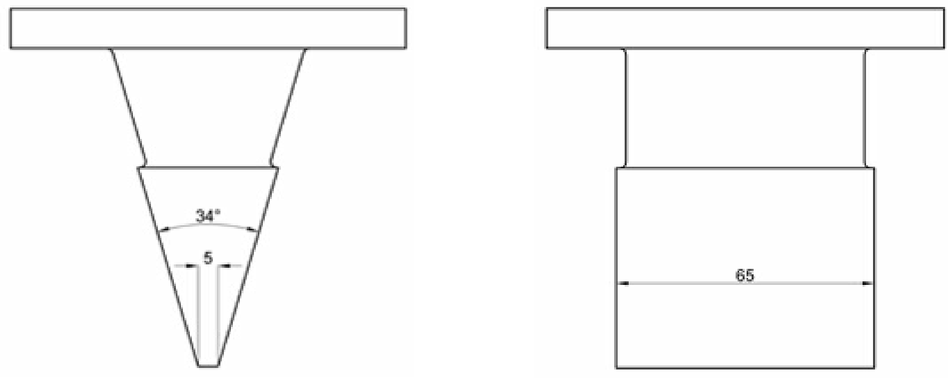


Figure 4, Schematic representation of wedge that was used for cutting resistance testing.

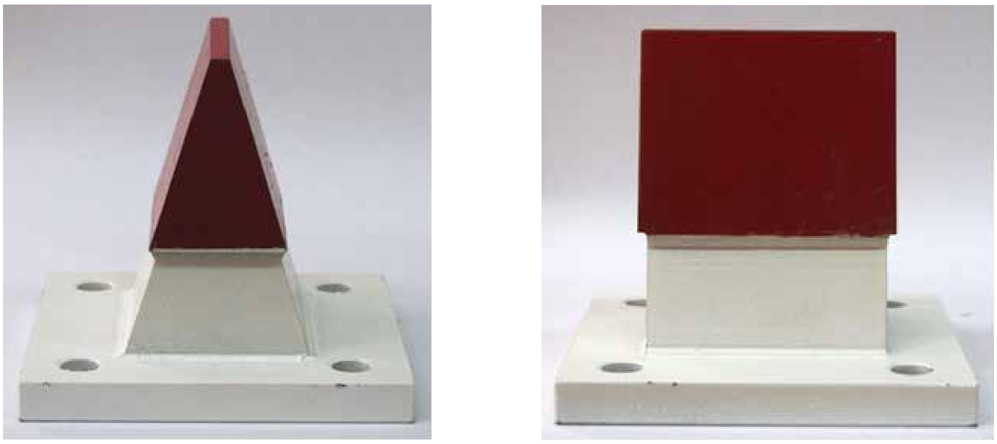
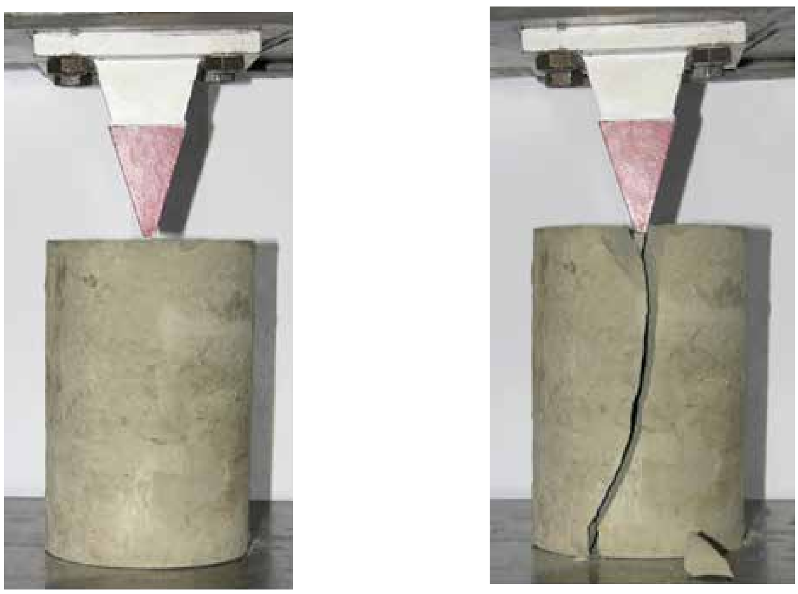


Figure 5, Appearance of wedge that was used for cutting resistance testing.



Before testing *After testing*

Figure 6, Testing body appearance before and after cutting resistance testing.

After testing, the rock material water content for each test specimen was determined. The water content tests were carried out according to the standard testing procedure using an electric dryer (SRPS U.B1.012).

Specific cutting resistance per unit of cutting edge length engaged K_L and the cutting resistance per unit of slice cross-sectional area K_F values are calculated according to the following equations:

$$K_L = \frac{P}{d} \quad (\mathrm{N/cm`}) \quad \& \quad K_F = \frac{P}{F} \quad (\mathrm{N/cm^2}),$$

where: P – breaking force (N),
d – diameter of sample (cm`),
F – specimens cross-section area (cm²).

ANALYSIS OF THE LABORATORY TESTS RESULTS

A total of 23 gray marl samples were collected from exploratory boreholes for laboratory testing of cutting resistance. Overview of tested rock material (gray marl) samples physical and technical properties mean values is given in Table 2.

The text that follows provides an detailed statistical analyses of rock material (marl) physical and technical properties testing result. The results of statistical analyses are given in the form of overview, tables and corresponding graphic representations.

Table 2, Overview of the rock material samples physical and technical properties mean values

Sample label	*No. of testing bobies*	*Unit weigth γ (kN/m³)*	*Water content w (%)*	*Mean value of digging force K_L (N/cm`)*	*Mean value of digging force K_F (N/cm²)*
BGF - 1/13(1.30 – 2.50)	5	19.32	27.15	649.49	28.70
BGF - 1/13(5.35 – 6.60)	5	19.23	26.49	639.29	28.37
BGF - 2/13(1.30 – 2.60)	5	18.55	23.88	667.84	29.62
BGF - 2/13(5.40 – 6.50)	5	17.65	26.36	650.50	28.35
BGF - 3/13(3.40 – 4.60)	5	18.32	26.19	651.52	28.30
BGF - 4/13(3.40 – 4.60)	5	18.06	26.17	650.50	28.45
BGF - 5/13(1.50 – 2.55)	5	19.48	26.01	652.54	29.78
BGF - 5/13(5.40 – 6.60)	5	18.94	26.07	653.56	28.24
BGF - 6/13(1.40 – 2.60)	5	18.97	25.76	655.60	29.72
BGF - 6/13(5.40 – 6.60)	5	18.96	25.83	654.58	28.13
BGF – 7/13 (1.80 – 6.20)	3	18.58	25.18	655.94	27.27
BGF - 8/13(3.20 – 4.60)	5	19.35	25.56	652.54	28.54
BGF - 9/13(1.50 – 2.60)	5	18.00	25.52	656.62	28.12
BGF - 9/13(5.40 – 6.60)	5	17.80	25.65	655.60	28.05
BGF - 10/13(1.40 – 2.60)	5	18.93	25.24	658.66	29.80
BGF - 10/13(5.45 – 6.65)	5	18.48	25.49	654.58	28.41
BGF - 11/13(3.40 – 4.70)	5	18.08	25.04	657.64	29.29
BGF - 12/13(3.40 – 4.60)	5	18.65	24.96	656.62	29.35
BGF – 13/13 (1.90 – 6.25)	3	18.08	24.70	659.34	27.73
BGF - 14/13(1.45 – 2.70)	5	17.84	24.64	661.72	29.59
BGF - 14/13(5.40 – 6.70)	5	18.32	24.70	662.74	28.37
BGF - 15/13(3.40 – 4.60)	5	18.02	24.61	660.70	29.11
BGF - 16/13(3.40 – 4.55)	5	17.89	24.53	663.76	29.82

UNIT WEIGTH

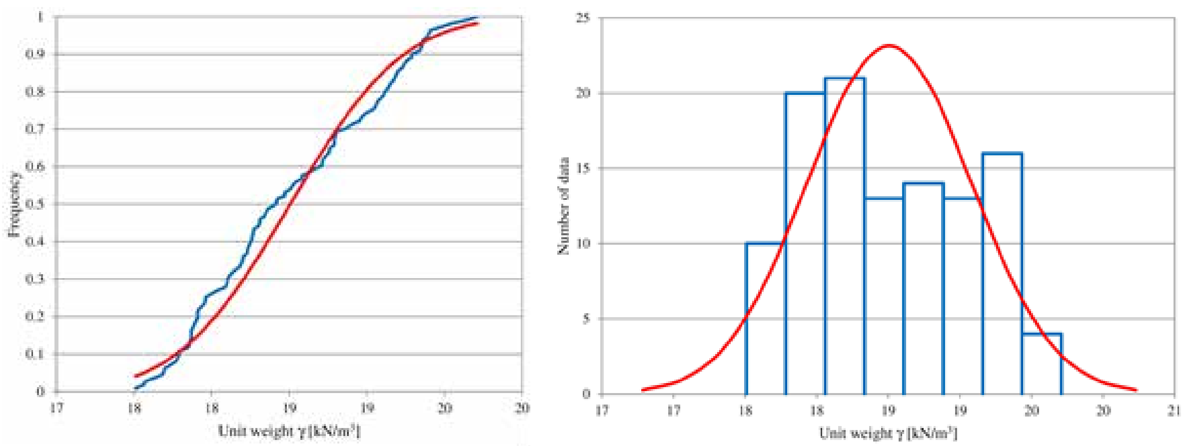
The unit weigth γ was determined on five test body from each cutting resistance laboratory testing specimen. The results of unit weigth testing were statistically analyzed. Total of 111 data were analyzed and statistical parameters are shown in Table 3 and Figures 7a and 7b.

WATER CONTENT

The water content w was determined on five test bodies from each cutting resistance laboratory testing specimen. The results of water content testing were statistically analyzed. Total of 111 data were analyzed and statistical parameters are shown in Table 4 and Figures 8a and 8b.

Table 3, Overview of statistical parameters of the rock material unit weigth testing results

Statistical parameters	***Value***
Number of data	111
Minimum value	17.51
Maximum value	19.71
Value interval	2.200
Sum of all values	2054.16
Average	18.506
Variance	0.329
Mean square deviation	0.574
Standard error	0.054

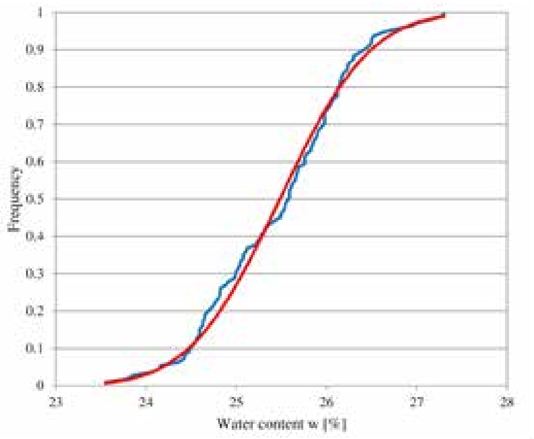


a) *b)*

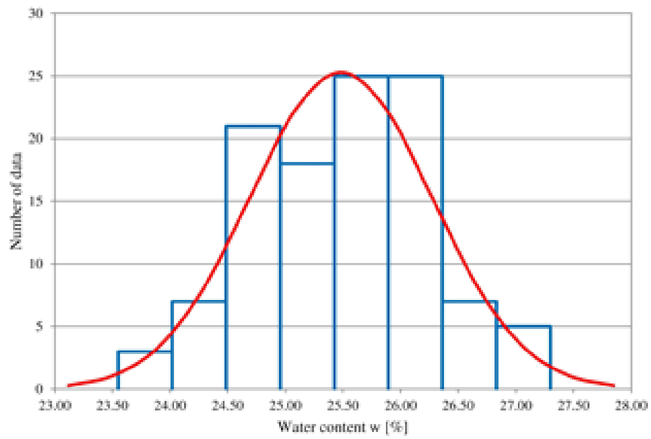
Figure 7, Cumulative curve (a) histogram and normal distribution, (b) of the unit weigth γ testing results.

Table 4, Overview of statistical parameters of the rock material water content w testing results

Statistical parameters	Value
Number of data	111
Minimum value	23.55
Maximum value	27.30
Value interval	3.750
Sum of all values	2828.610
Average	25.483
Variance	0.621
Mean square deviation	0.788
Standard error	0.075



a)



b)

Figure 8, Cumulative curve (a) histogram and normal distribution, (b) of the water content ω testing results.

CUTTING RESISTANCE

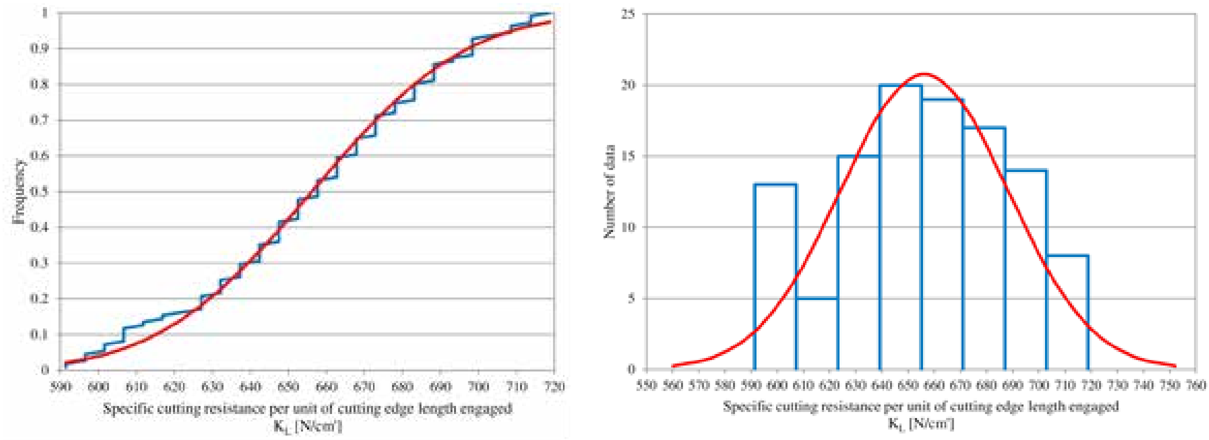
The laboratory testing of cutting resistance was carried out on five test bodies from each testing specimen. The results of samples cutting resistance testing (cutting edge K_L i cross-sectional K_f) were statistically analyzed. Total of 111 data were analyzed and all important statistical parameters are shown in Table 5.

The cutting resistance per unit of cutting edge length engaged values ranged from K_L = 591.37 to 718.82 N/cm, while the average values of this parameter ranged from K_L = 639.29 to 667.84 N/cm and are shown in Table 2 - overview of the samples physical and technical properties. The results of testing the cutting resistance per unit of cutting edge length engaged K_L (111 data) were statistically analyzed and statistical parameters are shown in Table 5. The graphic interpretation of the results of this analysis is shown in Figures 9a and 9b.

The values of the cutting resistance per unit of slice cross-sectional area ranged from K_F = 24.86 to 32.89 N/cm^2, while the average values of this parameter ranged from K_F = 28.05 to 29.82 N/cm^2 for tested samples and are shown in a in Table 2 - overview of the samples physical and technical properties. The results of testing the cutting resistance per unit of slice cross-sectional area K_F (111 data) were statistically analyzed and statistical parameters are shown in Table 5. The graphic interpretation of the results of this analysis is shown in Figures 10a and 10b.

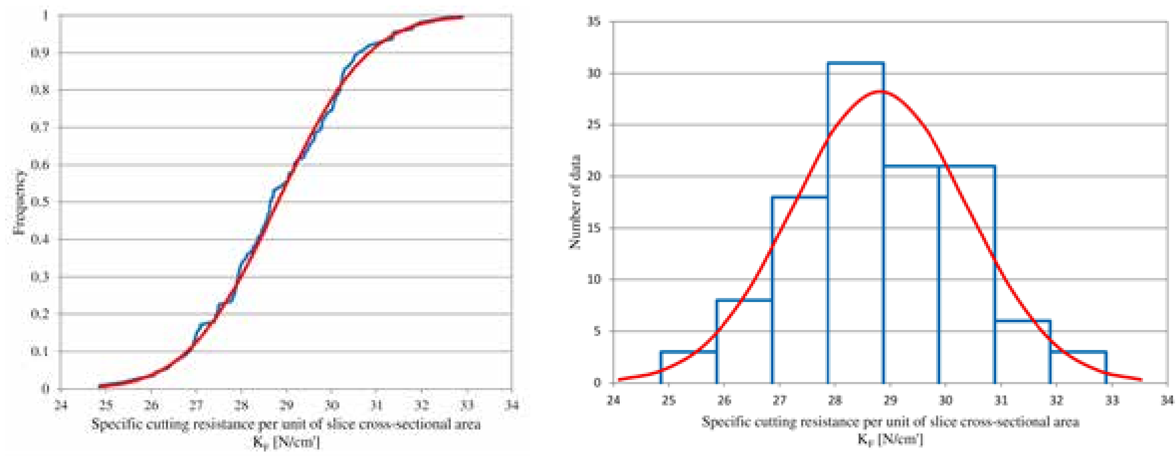
Table 5, Overview of statistical parameters of the rock material cutting resistance testing results

Statistical parameters	***Specific cutting resistance per unit of cutting edge length engaged K_L***	***Specific cutting resistance per unit of slice cross-sectional area K_F***
Number of data	111	111
Minimum value	591.37	24.86
Maximum value	718.82	32.89
Value interval	127.450	8.030
Sum of all values	72835.130	3198.180
Average	656.172	28.812
Variance	1023.248	2.467
Mean square deviation	31.988	1.571
Standard error	3.036	0.149



a) *b)*

Figure 9, Cumulative curve (a) histogram and normal distribution,
(b) of the cutting resistance per unit of cutting edge length engaged K_L testing results.



a) *b)*

Figure 10, Cumulative curve (a) histogram and normal distribution,
(b) of the cutting resistance per unit of slice cross-sectional area K_F testing results.

CONCLUSION

Purpose of the research presented in this paper is to carry out cutting resistance laboratory testing on rock material (gray marl) samples. Samples were collected from boreholes at open-pit »Filijala« site. Laboratory testing results should serve to evaluate bucket wheel excavator cutting resistance at the moment of testing and proving its explotation capacity.

In order to prove the excavator exploitation capacity, a test block zone is determined where the new bucket wheel excavator tesing will be carried out. Detailed research of the test block micro-location at open-pit mine „Filjala" was carried out with the aim to determine the geological structure at test block zone and select rock material representative samples for cutting resistance laboratory testing. In this area at open-pit mine „Filijala", a total of 16 exploratory boreholes were dilled, out of which 23 gray marl samples were collected. On the above-mentioned rock material (marl) samples, physical and technical properties were tested such as: unit weight γ, water content w, specific cutting resistance per unit of cutting edge length engaged K_L and specific cutting resistance per unit of slice cross-sectional area K_F. Laboratory tests covered a total of: 111 unit weight tests with paraffin (SRPS U.B1.017), 111 water content tests (SRPS U.B1.012) and 111 tests for determining specific cutting edge i cross-sectional cutting resistance (Orenstein und Koppel method).

The values of the rock material (gray marl) specific cutting resistance per unit of cutting edge length engaged K_L ranged from K_L = 591.37 to 718.82 N/cm, while the values of specific cutting resistance per unit of slice cross-sectional area K_F ranged from K_F = 24.86 to 32.89 N/cm^2. The technical documentation for the purchase of a bucket wheel excavator required the specific line-cut digging force K_L of 715.00 N/cm. By analyzing the laboratory tests results it can be noticed that only one specific cutting resistance (K_L = 718.82 N/cm) test has a higher value than the defined value of 715 N/cm. According to the previous one, it can be concluded that the defined test block zone fully meets the conditions for testing the bucket wheel excavator in order to prove its capacity.

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NEW METHOD FOR DETERMINING THE EFFICIENCY OF THE VENTILATION NETWORKS

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Abstract: *The first measure for ensuring optimal occupational health and safety conditions in underground minerals exploitation is the achievement of proper ventilation (Teodorescu C., et all, 1980). For ensuring proper ventilation of each mine working, there is imposed the optimization of air flow repartition in each branch of the network, fact which involves the mine's entire ventilation network solving. In hard coal exploitation, opening, preparation and exploitation works undergo a nonlinear continuously and differentiated process of specific aerodynamic parameters degradation. Following the changes in time of aerodynamic parameters of mine workings, specific ventilation parameters also change, leading to the ventilation network's deviation from the aerodynamic point of view, compared to the standard situation (Patterson A. M., 1992). The ventilation network's deviation is directly proportional to costs required for air circulation and inversely proportional to the efficiency of the ventilation network's ventilation. In order to assess the efficiency of ventilation networks, a new parameter has been introduced, namely the ventilation network's standard deviation. In this paper is presented the theoretical basis, solving the ventilation network in normal conditions and in standard conditions and also the determination of the efficiency of ventilation networks applied for Lupeni mine unit ventilation network.*

Keywords: *efficiency, modelling, software, solving, ventilation networks*

LUPENI MINE UNIT VENTILATION NETWORK

Lupeni mine unit is equipped with two main ventilation stations: Shaft 1 East and Central Rising. Underground mine workings are ventilated under the depression of the Main ventilation station Central Rising, fitted with two axial fans type VOKD 1.8. Underground mine workings which are ventilated under the depression of the Main ventilation station Shaft 1 East is equipped with two axial fans type VOD

3.0. Fresh air entrance in underground is performed through 5 mine workings: Stefan shaft, shaft no. 12, shaft with skip, coast gallery horizon 650 and auxiliary shaft south. Central Rising and Shaft 1 East circuits are extended over 5 horizons: horizon 300, horizon 360, horizon 400, horizon 480, horizon 650.

CLASSICAL METHODS FOR DETERMINING THE VENTILATION'S EFFICIENCY

For the classification of ventilation networks in terms of efficiency (Cheng J., et all, 2010; Cheng J., et all, 2012) are used several methods, namely: Equivalent orifice method, Ratios method, Temperament method.

EQUIVALENT ORIFICE METHOD

The equivalent orifice of a mine is a ventilation parameters using which there may be characterized the ventilation capacity and it represents a fictional orifice A, performed into a thin wall, through which at a pressure difference on the two sides of the wall equal with the mines depression "h", will be circulated the same amount of air Q as the one circulated through the mine.

RATIOS METHOD

This method is characterized by the efficiency of the mine's general ventilation and takes into account the size of ratios:

$$\frac{Q_{sc}}{Q_{ef}} \text{ and } \frac{h_{ef}}{h_t} \qquad (1)$$

in which:
Q_{sc} - Air flow short-circuited in underground, m³/s;
Q_{ef} - Air flow which ventilates the work fronts, m³/s;
h_{ef} - Depression of the mine, determined by measurements, N/m²;
h_t - Theoretical depression of the mine, determined by calculation, N/m².

TEMPERAMENT METHOD

In order to classify the manner in which a mine working's ventilation is achieved is used the T temperament term. Temperament represents the easiness with which the fluid passes the mine working.

NEW METHODS FOR DETERMINING THE VENTILATION'S EFFICIENCY - STANDARD DEVIATION

Underground hard coal exploitation involves the performance of a complex of opening, preparation and exploitation workings in order to extract and transport the useful minerals to the surface.

Mine workings are executed by conventional and unconventional methods. The most used method is the one by blasting using industrial explosives.

After their execution, mine workings are supported and fitted depending on their destination.

The execution and fitting of mine workings is achieved in accordance with technical projects. Also, when entering into operation they have certain distinct characteristics. The most relevant group of parameters which defines the state of the mine working at a certain moment, from the ventilation point of view, is represented by the specific aerodynamic parameters.

Once with the increase of the mine workings usage, their aerodynamic parameters negatively change, having severe consequences from the point of view of air flowing on their alignment.

The degradation in time of aerodynamic parameters of mine workings leads to the change of the ventilation network's aerodynamic parameters. The change of aerodynamic parameters of mine workings in relation with the initial value represents the ventilation network's deviation (Cioclea D., 2015).

STANDARD DEVIATION OF A VENTILATION NETWORK

The standard deviation of a ventilation network is defined as the change in time of aerodynamic parameters specific for a ventilation network in relation with the aerodynamic parameters specific for the same ventilation network in standard conditions.

Mine workings are executed in a well-established order, starting with opening, preparation and exploitation works, special mine workings etc. Due to this aspect, certain types of mine workings enter into exploitation differently. In addition, while carrying out exploitation works, within the mine units occur moments when it is required to extend or restrict the network of mine workings.

For determining the parameters which are applicable for any ventilation network, regardless of its' structure and complexity, there has been used the term of ventilation network in standard conditions. The ventilation network in standard conditions represents the structure of a ventilation network evolving at a certain time, which is characterized by the fact that all active mine workings have associated the aerodynamic parameters specific for the moment of entrance into exploitation.

Aerodynamic parameters specific for the entrance into exploitation of a mine working and the ones established through the technical project. Aerodynamic parameters specific for a mine working at a certain time during exploitation air determined through flow and pressure measurements performed on site.

There fore, Atkinson's equation in this conditions may be written as follows:

$$h = R\,Q^2 \qquad (2)$$

in which:
h - Required value for depression/pressure in order to circulate a Q airflow over a pathway with the resistance R (Pa);
Q - Airflow established to be circulated over the mine working (m^3/s);
R - Aerodynamic resistance of the analysed mine working (Ns^2/m^8).

The value of the aerodynamic resistance of a mine working is determined using the formula:

$$R = \frac{\alpha\, L\, P}{S^3} \ (Ns^2/m^8) \qquad (3)$$

in which:
α - Aerodynamic coefficient specific for the type of mine working (Ns^2/m^4);
L - Length of the mine working (m);
P - Perimeter of the mine working, specific to its' profile (m);
S - Section of the established mine working (m^2).

After establishing the calculation manner, aerodynamic parameters specific for all branches are determined. Solving the ventilation network in standard conditions involves the use of special software, in this case VENTSIM Visual Advanced.

After solving the ventilation network in standard conditions are obtained the specific parameters for the main ventilation station (s).

ESTABLISHING THE STANDARD DEVIATION OF A VENTILATION NETWORK

For assessing the ventilations efficiency at a certain moment is used the A_s parameter which represents its' standard deviation. The standard deviation of a ventilation network is defined by the ratio between the equivalent orifice of the ventilation network at a certain moment A and the equivalent orifice of the ventilation network in standard conditions A_0:

$$A_s = \frac{A}{A_0} \cdot 100 \qquad (4)$$

in which:
A - Equivalent orifice of the ventilation network at a certain moment (m^2);
A_0 - Equivalent orifice of the ventilation network in standard conditions (m^2).

Equivalent orifice of the ventilation network at a certain moment A is determined using the approximate Eq. 5:

$$A \cong \frac{1.2}{\sqrt{R}} \ (m^2) \qquad (5)$$

Equivalent orifice in normal conditions may be calculated using the exact Eq. 6 (i.e. for two ventilation stations):

$$A = 1.2\sqrt{\frac{Q_m^3}{Q_{s1}\, h_{s1} + Q_{s2}\, h_{s2}}} \ (m^2) \qquad (6)$$

Equivalent orifice of the ventilation network in standard conditions A_0 is determined using the approximate Eq. 7:

$$A_0 \cong \frac{1.2}{\sqrt{R_0}} \ (m^2) \qquad (7)$$

Equivalent orifice of the ventilation network in standard conditions (i.e. for two ventilation stations) may be also calculated using the exact Eq. 8:

$$A_0 = 1.2\sqrt{\frac{Q^3_{0m}}{Q_{s01}\,h_{s01} + Q_{s02}\,h_{s02}}} \ (m^2) \qquad (8)$$

In these conditions, the standard deviation of the ventilation network A_S is:

$$A_s = \sqrt{\frac{R_0}{R}} \cdot 100\,;\ A_s = \sqrt{\frac{Q^3_m\,(Q_{s01}\,h_{s01} + Q_{s02}\,h_{s02})}{Q^3_{0m}\,(Q_{s1}\,h_{s1} + Q_{s2}\,h_{s2})}} \times 100 \qquad (9)$$

CHARACTERIZATION OF VENTILATION NETWORKS DEPENDING ON THE STANDARD DEVIATION

The standard deviation of a ventilation network is a non-dimensional parameter which establishes the level of deviation from standard conditions. In order to characterize ventilation networks in relation with the standard deviation is required the establishment of periods defining concrete states specific for the ventilation network.

There fore, ventilation network may be split into three categories:

a) Ventilation network with optimal standard deviation characterized by

$$A_s > \frac{2}{A_0} \cdot 100;$$

b) Ventilation network with acceptable standard deviation characterized by

$$A_s = \frac{1}{A_0} \cdot 100 \div \frac{2}{A_0} \cdot 100;$$

c) Ventilation network with unacceptable standard deviation characterized by

$$A_s = 0 \div \frac{1}{A_0} \cdot 100.$$

If the ventilation network is assessed from the standard deviation point of view in different categories, then is chosen the assessment which takes into account the exactly calculated equivalent orifice.

LUPENI MINE UNIT VENTILATION NETWORK SOLVING IN NORMAL CONDITIONS

For solving the ventilation network of Lupeni mine unit was used VENTSIM Visual Advanced software, (Hargreaves D.M., et all, 2007), (User Guide, 2014), (Wei G., 2011) designed and developed in Australia. A number of 386 junctions and 481 branches have been inserted into the software's database. Figure 1 presents the 3D spatial ventilation network of Lupeni mine unit.

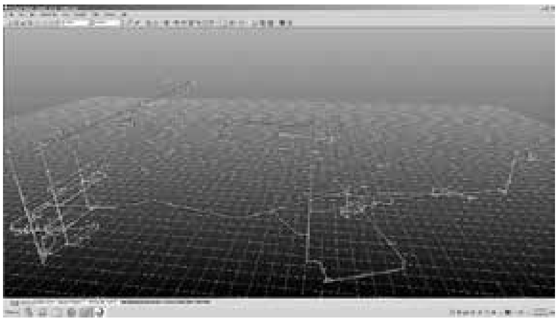

Figure 1, Lupeni mine unit ventilation network in 3D system.

Figures 2 to 6 present details from the ventilation network of Lupeni mine unit, representing the areas of active longwalls with undermined coal bed Panel 1/3/II Sublevel II, Panel 1/3/II Sublevel III, Panel 11/3/V, Panel 3/3/V and the longwall with mechanized complex Panel 2C/3/V.

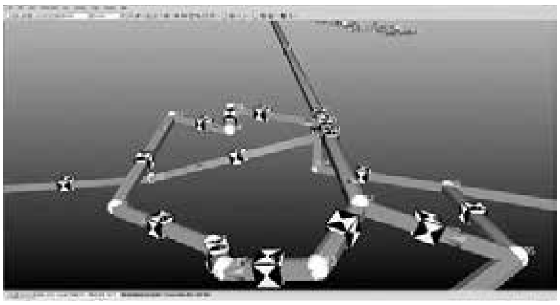

Figure 2, Longwall with undermined coal bed Panel 1/3/II Sublevel II.

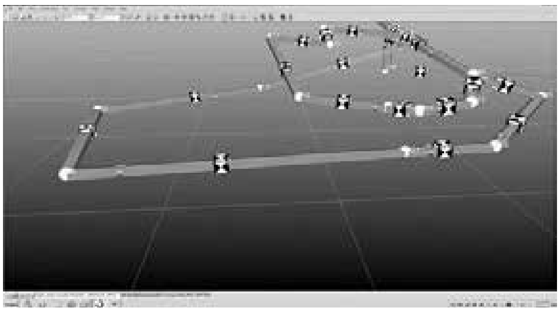

Figure 3, Longwall with undermined coal bed Panel 1/3/II Sublevel III.

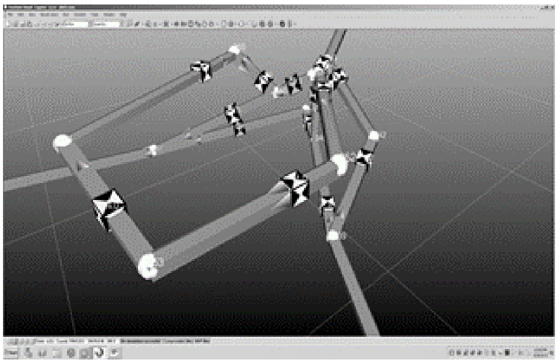

Figure 4, Longwall with under-mined coal bed Panel 11/3/V.

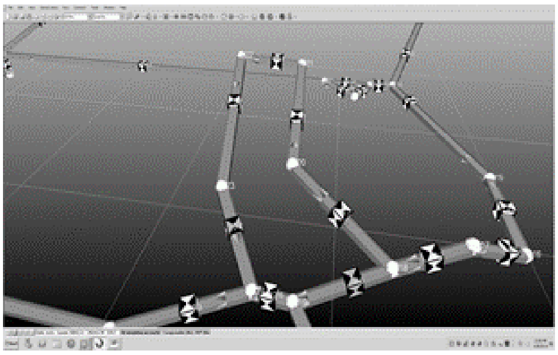

Figure 5, Longwall with under- mined coal bed Panel 3/3/V.

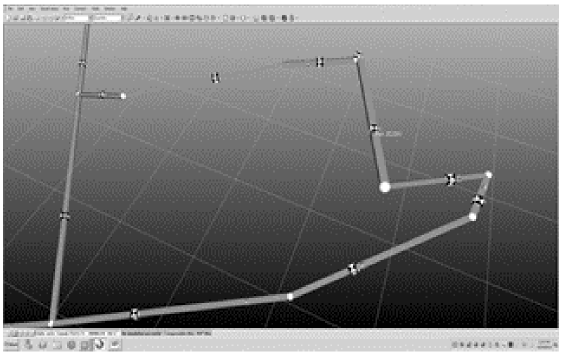

Figure 6, Longwall with Panel mechanized complex 2C/3/V.

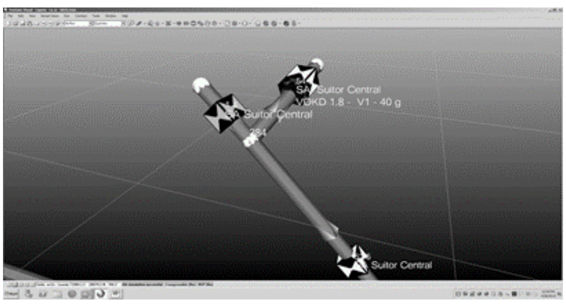

Figure 7. Central rising main ventilation station.

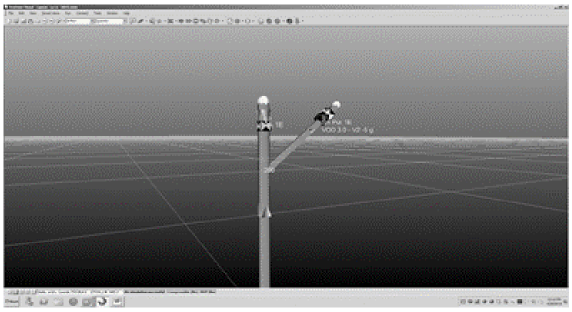

Figure 8. Shaft 1 East main ventilation station.

Figure 7 and 8 present the main ventilation stations Shaft 1 East and Central rising.

After the ventilation network's solving (Cioclea D, et all, 2012; Cioclea D, et all, 2014; Gherghe I., 2004), the following results have been obtained:

- Air flow on the fresh air supply circuit at horizons 650, 480, 400, 300, branches with unique number 587, 267, 481, 410, 343, 115, 288, was of 85,4 m^3/s.
- Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, bl. II Sublevel II, with unique number 742 was of 3,2 m^3/s.
- Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, bl. II Sublevel III, with unique number 732 was of 3.2 m^3 / s.
- Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, bl. V, with unique number 663 was of 4.0 m^3 / s.
- Air flow at the level of the longwall with undermined coal bed no. 3, seam 3, bl. V, with unique number 634 was of 3.7 m^3 / s.
- Air flow at the level of the longwall with undermined coal bed no. 2C, seam 3, bl. V, with unique number 623 was of 6.6 m^3 / s.
- On the return air exhausting circuit related to longwall no. 1 seam 3, bl. II, Sublevel II, with unique number 753, air flow was 8.7 m^3 / s.
- On the return air exhausting circuit related to longwall no. 11 seam 3, bl. V, with unique number 386, air flow was 8.1 m^3 / s.
- On the return air exhausting circuit related to longwall no. 3 seam 3, bl. V, with unique number 645, air flow was 16.3 m^3 / s.
- On the return air exhausting circuit related to longwall no. 2C seam 3, bl. V, with unique number 629, air flow was 10.1 m^3 / s.
- At mine level, branches with unique number 216 and 568 it was of 83.7 m^3 / s.

- At ventilation network station level, with unique number 569 and 593 was of 85.4 m^3/s.

LUPENI VENTILATION NETWORK SOLVING IN STANDARD CONDITIONS

For solving Lupeni ventilation network in standard conditions was used the database of VENTSIM Visual Advanced (User Guide, 2014) for solving the ventilation network in normal conditions.

For solving Lupeni ventilation network in standard conditions was used the database of VENTSIM Visual Advanced for solving the ventilation network in normal conditions.

After the input of geodesic coordinates into the database of Ventsim Visual Advanced, it calculates automatically the spatial distance between two consecutive junctions and instantly draws up the specific branch.After modelling the ventilation network in 3D there are inserted for each branch the technical data, respectively profile and shape of mine workings and ventilation constructions.Technical data for each branch represent their specific aerodynamic parameters calculated for their standard conditions.

The aerodynamic coefficient α is a parameters which is specific for each type of mine working, in relation with the improvement executed on its' alignment. In this regard are identified 481 aerodynamic coefficients specific for each branch.

The length of the mine working L is calculated automatically by VENTSIM Visual Advanced, based on geodesic coordinates (x;y;z) specific for each of the 381 junctions. The length of a branch means the distance between two consecutive junctions and is calculated using the following Equation:

$$L_{branch} = \sqrt{(X_{nod1} - X_{nod2})^2 + (Y_{nod1} - Y_{nod2})^2 + (Z_{nod1} - Z_{nod2})^2} \quad (10)$$

The perimeter of the mine working P is specific for the shape of each mine working, respectively of each branch. For establishing the perimeter, there may be consulted the Typical Mine Workings Album, in which are specified all geometric parameters specific for the mine workings profile. The section of the mine working S is specific for the shape of each mine working, respectively of each branch. For establishing the section, there may be consulted the Typical Mine Workings Album, in which are specified all geometric parameters specific for the mine workings profile.

The ventilation network in standard conditions will used characteristic operation curves for the fans within main ventilation stations, which have been determined for normal operation conditions. The parameters of the fans from the main ventilation stations will be modified in case of applying characteristic curves to the ventilation network in normal conditions.

The operation point will be displaced descendant and towards the right, due to the fact that the resistance of the network is considerably greater at a certain time compared to the resistance of the network in standard conditions.

After performing the previously mentioned step, the ventilation network is balanced and solved for standard conditions, and the movements of air currents specific for each branch and for the fans from the main ventilation station are activated. In this phase are available information which are specific for each branch of the ventilation network modelled and solved for standard conditions. Figure 9 presents the 3D ventilation network of Lupeni mine unit solved for standard conditions.

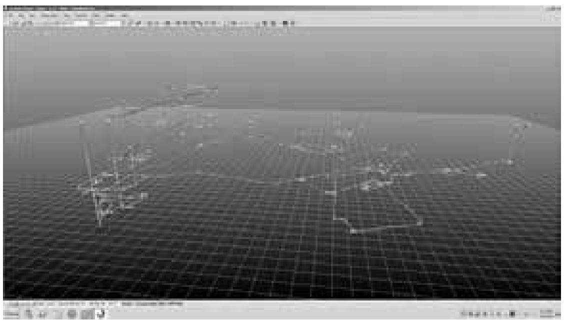

Figure 9, Lupeni mine unit ventilation network in 3D system.

A number of 386 junctions and 481 branches have been inserted into the software's database, which are specific for the ventilation network solved in standard conditions.
Figures 10 to 14 present details from the ventilation network of Lupeni mine unit, representing the areas of active longwalls with undermined coal bed Panel 1/3/II Sublevel II, Panel 1/3/II Sublev-

el III, Panel 11/3/V, Panel 3/3/V and the longwall with mechanized complex Panel 2C/3/V.

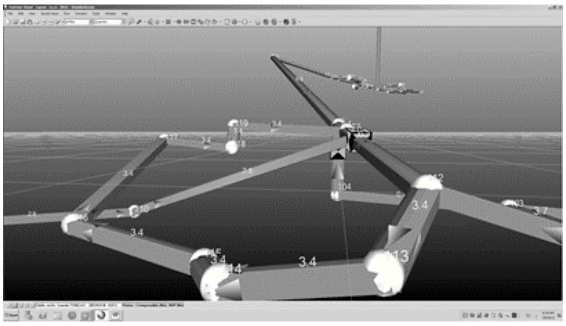

Figure 10, Detail-longwall with undermined coal bed Panel 1/3/II Sublevel II.

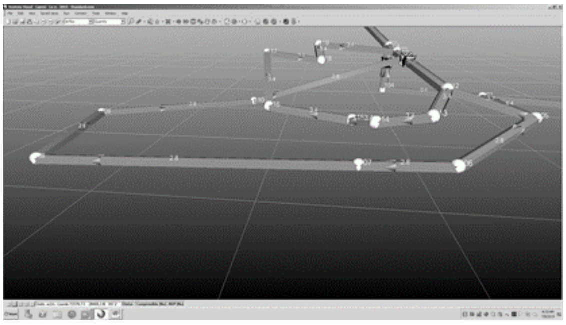

Figure 11, Detail-longwall with undermined coal bed Panel 1/3/II Sublevel III.

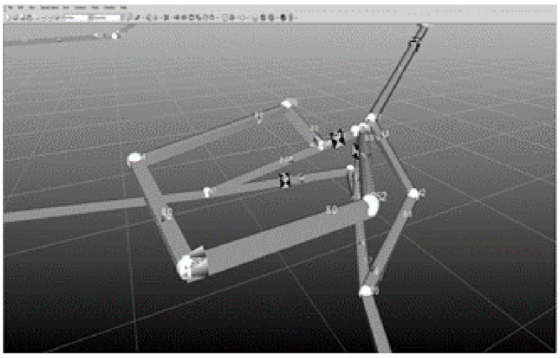

Figure 12, Detail-longwall with undermined coal bed Panel 11/3/V.

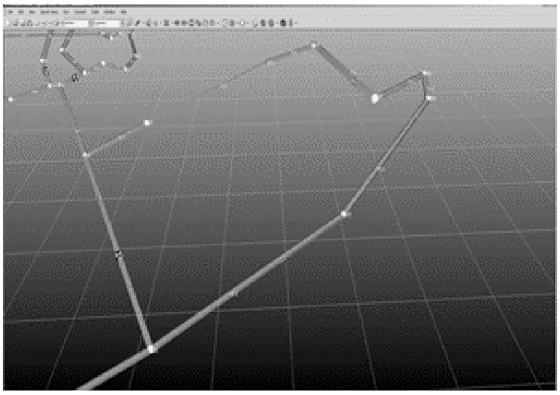

Figure 13, Detail-longwall with undermined coal bed Panel 3/3/V.

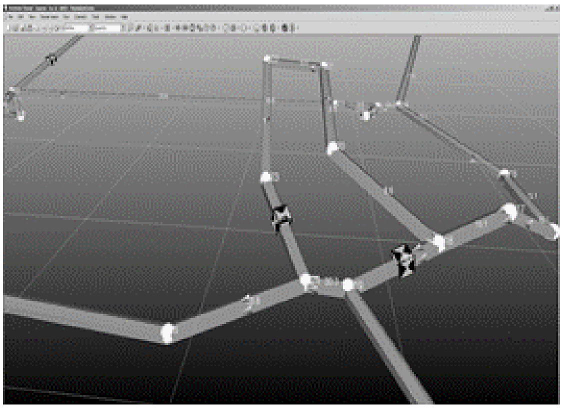

Figure 14, Detail-longwall with mechanized complex Panel 2C/3/V.

Figure 15 and 16 present the main ventilation stations Shaft 1 East and Central rising.

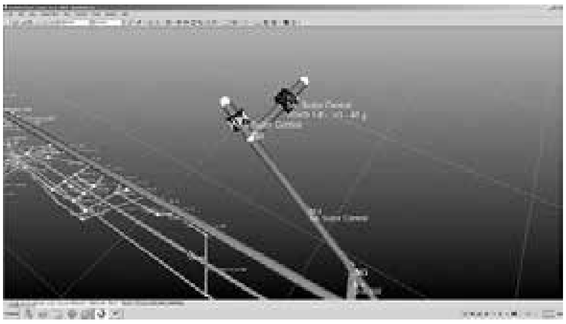

Figure 15, Central rising main ventilation station.

Figure 16, Shaft 1 East main ventilation station.

Following the ventilation network's solving resulted the following:

- Air flow on the fresh air supply circuit at horizons 650, 480, 400, 300, branches with unique number 587, 267, 481, 410, 343, 115, 288, was of 108,6 m^3/s.
- Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, bl. II Sublevel II, with unique number 742 was of 3,4 m^3/s.
- Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, bl. II Sublevel III, with unique number 732 was of 2.8 m^3/ s.

- Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, bl. V, with unique number 663 was of 8.0 m^3 / s.
- Air flow at the level of the longwall with undermined coal bed no. 3, seam 3, bl. V, with unique number 634 was of 8.6 m^3 / s.
- Air flow at the level of the longwall with undermined coal bed no. 2C, seam 3, bl. V, with unique number 623 was of 15.3 m^3 / s.
- On the return air exhausting circuit related to longwall no. 1 seam 3, bl. II, Sublevel II, with unique number 753, air flow was 6.8 m^3 / s.
- On the return air exhausting circuit related to longwall no. 1 seam 3, bl. II, Sublevel III, with unique number 753, air flow was 6.8 m^3 / s.
- On the return air exhausting circuit related to longwall no. 11 seam 3, bl. V, with unique number 386, air flow was 9.1 m^3 / s.
- On the return air exhausting circuit related to longwall no. 3 seam 3, bl. V, with unique number 645, air flow was 38.8 m^3 / s.
- On the return air exhausting circuit related to longwall no. 2C seam 3, bl. V, with unique number 629, air flow was 23.7 m^3 / s.
- At mine level, branches with unique number 216 and 568 it was of 107.6 m^3 / s.
- At ventilation network station level, with unique number 569 and 593 was of 108.6 m^3/s.

DETERMINING THE STANDARD DEVIATION FOR VENTILATION NETWORK OF LUPENI MINE UNIT

For determining the standard deviation of a mine is required the knowledge of aerodynamic parameters specific for the ventilation network, respectively of operational parameters of active fans. The aerodynamic and operational parameters are required both for the ventilation network solved in normal conditions, as well as for the ventilation network brought to its' standard condition.

STANDARD DEVIATION CALCULATION

For calculating the standard deviation is determined the equivalent resistance of the ventilation network in normal conditions:

$$R = \frac{R_1 \ \ R_2}{(R_1 + R_2 + 2\sqrt{R_1 \ \ R_2})} \ (Ns^2/m^8) \qquad (11)$$

Particularly for Lupeni mine unit ventilation network we have the following: R= 0.26753 (Ns^2/m^8).

The equivalent resistance of the ventilation network in standard conditions is calculated using Eq. 12:

$$R_0 = \frac{R_1 \ \ R_2}{(R_{01} + R_{02} + 2\sqrt{R_{01} \ \ R_{02}})} \ (Ns^2/m^8) \qquad (12)$$

Particularly for Lupeni mine unit ventilation network we have the following: R_0 = 0.05846 (Ns^2/m^8).

Based on previous results is determined the ventilation network's equivalent orifice in normal conditions:

$$A \cong \frac{1.2}{\sqrt{R}} \ (m2); \ A \cong 2.32004 \ (m2) \qquad (13)$$

The equivalent orifice in normal conditions is exactly calculated using Eq. 14:

$$A = \sqrt{\frac{Q^3_m}{(Q_{S1} \ \ h_{S1} + Q_{S2} \ \ h_{S1})}} \ (m^2); \ A = 1.93973 \ (m^2) \qquad (14)$$

The equivalent orifice of the ventilation network in standard conditions is calculated using the approximate Eq. 15:

$$A_0 \cong \frac{1.2}{\sqrt{R_0}} \ (m^2); \ A_0 \cong 4.96308 \ (m^2) \qquad (15)$$

The equivalent orifice in standard conditions is exactly calculated using Eq. 16:

$$A_0 = 1.2\sqrt{\frac{Q^3_{0m}}{Q_{s01} \ h_{s01} + Q_{s02} \ h_{s02}}} \ (m^2); \ A_0 = 3.78194 \ (m^2) \qquad (16)$$

Based on the previous results is determined the ventilation network's standard deviation.

Thus, there may be determined the standard deviation based on the approximate mathematical Eq. 17:

$$A_s \cong \sqrt{\frac{R_0}{R}} \cdot 100; \ A_s \cong 46.75 \qquad (17)$$

Also, by using Eq. 18 which uses the values of exactly calculated equivalent orifices for the situation of normal and standard conditions ventilation networks.

$$A_s = \frac{A}{A_0} \cdot 100 \quad \text{or } A_s = 51.29 \qquad (18)$$

VENTILATION NETWORK CHARACTERIZATION IN RELATION WITH THE STANDARD DEVIATION

In order to characterize the ventilation network in relation with the standard deviation, there are firstly calculated the ratios $\frac{A}{A_0}$x100 and $\frac{2}{A_0}$ x100, using the equivalent orifice in standard conditions with approximate value:

$$\frac{1}{A_0}\text{x}100 = 20.149; \quad \frac{2}{A_0}\text{x}100 = 40.297 \qquad (19)$$

or by using the equivalent orifice in standard conditions with exact value:

$$\frac{1}{A_0}\text{x}100 = 26.44; \quad \frac{2}{A_0}\text{x}100 = 52.883 \qquad (20)$$

For the value of the standard deviation A_s= 46.75, calculated using the value of the approximate equivalent orifice, results that Lupeni mine unit ventilation network frames into category a) “Ventilation network with optimal standard deviation”.

Also, for values of the standard deviation A_s= 51.29, calculated using the value of the exact equivalent orifice, results that Lupeni mine unit ventilation network frames at the upper limit of category b) “Ventilation network with acceptable standard deviation”.

If the ventilation network is assessed in terms of standard deviation into different categories, then is chosen the ventilation network assessment which takes into account the exactly calculated equivalent orifice.

Therefore, the final assessment of Lupeni mine unit ventilation network in terms of standard deviation is: The ventilation network frames into category b) “Ventilation network with acceptable standard deviation”.

CONCLUSIONS

The main measure for ensuring optimal occupational health and safety conditions in underground hard coal mining is the achievement of proper ventilation.

In order to assess the efficiency of the ventilation network was inserted the A_S parameter, representing its’ standard deviation.

For modelling and solving the very complex ventilation network of Lupeni mine unit, reason for which it was chosen in order to determine the standard deviation, was used VENTSIM Visual Advanced software.

For solving the ventilation network of Lupeni mine were inserted 386 junctions and 481 branches.

Results obtained after solving Lupeni mine unit ventilation network in normal exploitation and in standard conditions highlight the fact that a total flow of 85.4 m^3/s respectively 108.6 m^3/s is circulated in the ventilation network, through the two main ventilation stations: Central Rising and Shaft 1 East.

The assessment of Lupeni mine unit ventilation network in terms of standard deviation highlights the fact that the ventilation network frames into category b) “Ventilation network with acceptable standard deviation”.

ACKNOWLEDGEMENTS

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NEW TECHNICAL MEANS FOR CONTROL OF GRINDING PROCESS

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Abstract: *As a result of the research and experimental studies the specialists of innovative company TRAPEN modernized and developed new technical means for monitoring and control of the grinding process. The short description of the sensors for measuring of impact pulses provoked at the grinding as well as modernized microprocessor modules MILLCONT 2A and VIBROCONT for control of mill loading and microprocessor floating DENSICONT is given in the paper. The economic results of the grinding control system working in semiautogenous (SAG) mill with new technical means are given in the paper as well.*

Keywords: *sensors, microprocessor modules, float densimeter, control system, sag mill*

INTRODUCTION

Aa a result of resent scientific and experimental studies of the specialists of firm TRAPEN new technical means of the grinding process control systems have been developed.The short description of two kind of sensors for measuring of impact pulses provoked at the grinding as well as modernized modules MILLCONT2A, VIBROCONT and microprocessor floating DENSICONT is given here bellow.The structure of automatic system for optimisation of the process in semiautogenous(SAG) mill with above mension technical means and the loops for measuring and control of the basic technological parameters are presented in the paper. The aim is to be increased productivity of the grinding aggregate as well as to impruve the quality characteristics of the ready pulp at minimal inerference of the operator. The nowadays achived economical results from explotation of the control system implemented on SAG mill in ore-dressing factory of Dundee Precious Metals Inc(Bulgaria) are given as well.

TECHNICAL MEANS FOR MEASURING AND CONTROL OF GRINDING PROCESS IMPACT PULSE SENSORS

The sensibility of the developed new remote pulse sensor SRIP (Figure 1) and direct pulse sensor SDIP (Figure 2) is increased in comparison with acoustic sensor [1] and nowadays used magneto-electric sensor [2] for measuring of the mill loading.

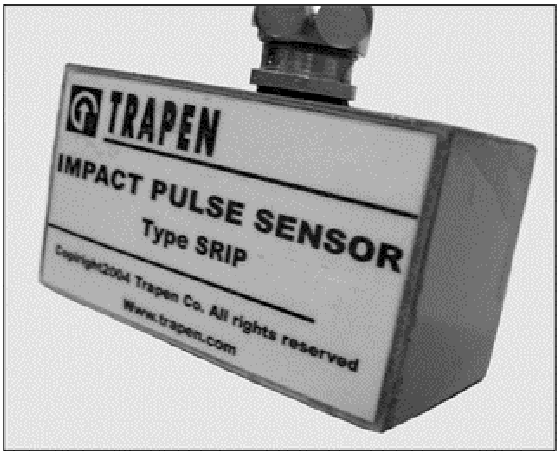

Figure 1, Remote sensor SRIP.

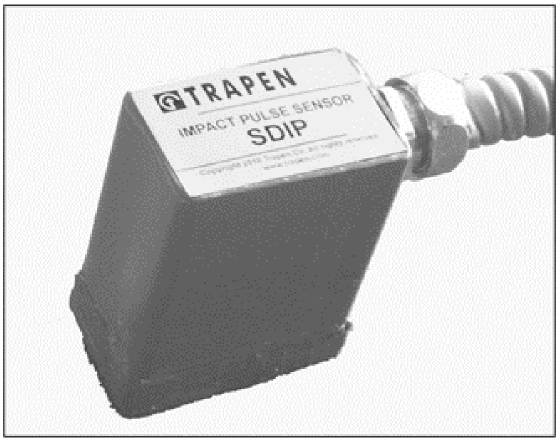

Figure 2, Direct sensor SDIP.

The sensor SRIP consist of two sensitive elements differentially connected for elimination of parasitic signals. They are generator type and do not need additional power supply. Output voltage signal FG from the sensors is up to 1V with amplitudes proportional to impact pulse slope, i.e. the sensors differentiate the impact pulses without distortion. The sensors are covered with special compound reducing the parasitic signals and protecting against outside influences: spattering water, dust, explosion-hazardous mixtures, etc. They are resistant to impact and rough handing as the sensors have not driving parts and do not need maintenance as well as they are in practice everlasting. The sensors resist to temperature from -40° to +100° C. FG isn't influence from the work of near-by mills and other aggregates; The sensor SRIP is installed on the stand hardly connected to the foundation or other stationary body as its adopt part is directed from 15 - 30mm against the waterfall side of the mill under 30 - 40°. The sensor SDIP constructively is similar to SRIP as additionally are built-in fixing elastic elements and magnets for fastening to the casing of the stationary mill.

MICROPROCESSOR CONTROL MODULES

The developed single-loop microprocessor module VIBROCONT (Figure3) converts the signal of the sensor for the mill loading. The treatment of the signal FG is processed by digital filter.

The programmable parameters of the filter are following [2]:
- Fr – Cutting frequency of digital high frequency filter (1 – 1600Hz);
- FO – Order of the digital filter (2^{nd}, 3^{rd} or 4^{th});
- CA – Programmable gain coefficient (1, 2, 4 or 8);
- CF – Coefficient of FG (50 – 9999);
- tA – Average interval of FG (1 – 60s);
- LF – Low value of FG (0 – 1999);
- HF – High value of FG (0 – 1999);
- AL – Low value of alarm (in the range of FG);
- AH – High value of alarm (in the range of FG);
- iF – Type of FG on the display (F or FPrO);
- rO – Range of analog FG output (4 – 20 or 0 -20mA);
- tO – Type of analog FG output, normal or inverse (nor or inv).

The unified signal of FG is sent to PLC where is formed the regulator for grinding process control. The module has standard current output and serial communication channel RS485. It is inserted into aluminum box with dimensions 149 x 168 x 80mm.

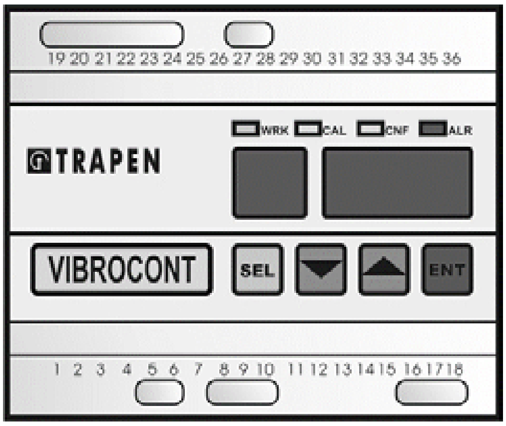

Figure 3, Front panel of VIBROCONT.

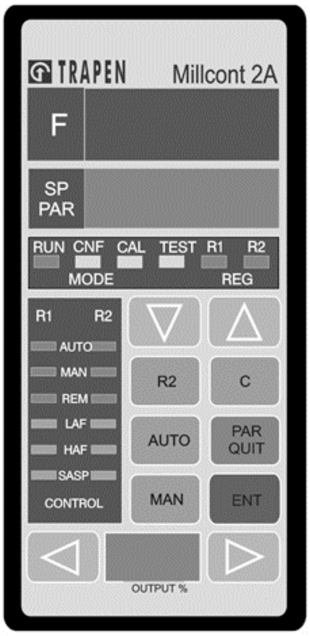

Figure 4, Front panel of MILLCONT 2A.

The microprocessor module MILLCONT 2A (Figure 4) consist of two solo control loops [4]. Each loop has analogue differential amplifier with controlled amplification factor, digital filter with adjustable parameters as of VIBROCONT, special PID - regulator, which can be adjusted to work in different mode at mill loading and discharging. The module is with standard current inputs and outputs, which can be programmed as normal or inverse and also with serial communication channel RS485 programmed to MODBUS.

The module is built - in PVC box with dimensions 65 x 135 x 165mm, inserted in aperture with dimension 67 x 137mm.

MICROPROCESSOR FLOATING DENSICONT

The developed microprocessor floating DENSICONT is purposed for measuring of the pulp density in ore-dressing industry and other related branches[5]. The measuring elevating power by the float with negative floatability is proportional to the density (law of Archimed). The signal from the sensor is sent to the microprocessor module where is performed calibration, calculation of the density, visualization and take out of the information.

The density of the fluid is calculated by the formula:

$$D = (-Ff + CA)\,Cn$$

where: D – Density of the fluid g/l;
Ff – The weight measured from weightmeasuring sensor is equal to the difference between deadweight of the float and elevating power;
CA – Coefficient which is equal to the deadweight of the float plus eventual settling;
Cn – Coefficient for normalizing of the density if the volume of the float is different from a liter.

The adjusted error of measuring is under 0,5%. In order to escape the influence of the technological flow on the measuring the float of DENSICONT is installed into calm media.

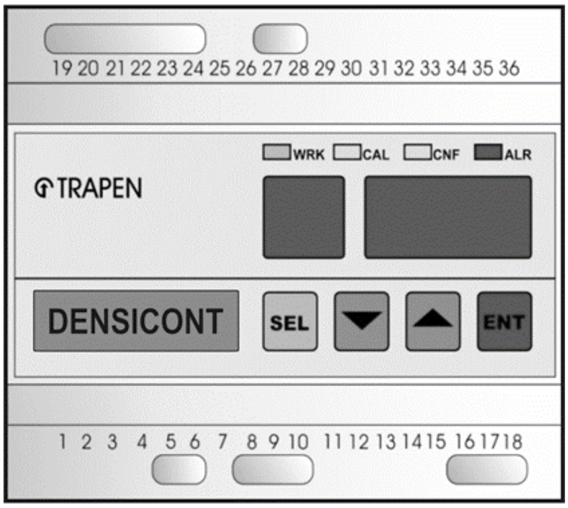

Figure 5, Front panel of DENSICONT.

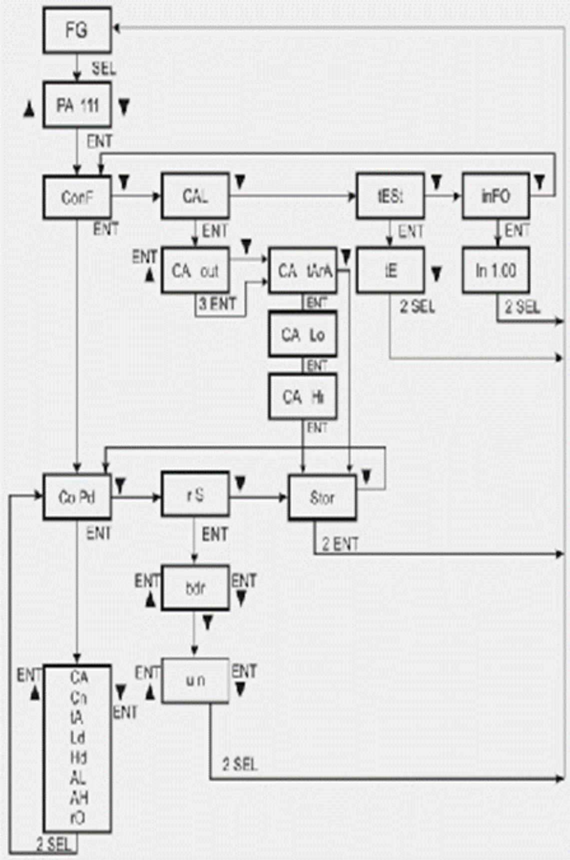

Figure 6, Algorithm for adjustment of DENSICONT.

For the programming of DENSIMETER is developed menu with a shape of reversed tree containing up to 3 levels for a diverge and one level for a programming (Figure 6). After programming the changes are remembered in RAM memory and then are recorded in FLASH memory.

INFORMATION CONTROL STRUCTURE OF THE GRINDING CONTROL SYSTEM OF SEMI-AUTOGENOUS MILL

The automatic system for ore grinding control in semi-autogenous (SAG) mill with above described technical means has the structure diagram given in Figure7. The aim is to be increased productivity of the SAG mill as well to be improved the quality characteristics of the ready pulp at minimal interference of the exploitation personnel. The control system stabilizes the outlet parameters (fineness of grinding and density) of the ready product and provides optimal throughput of the grinding aggregate. The system realizes the following control loops:

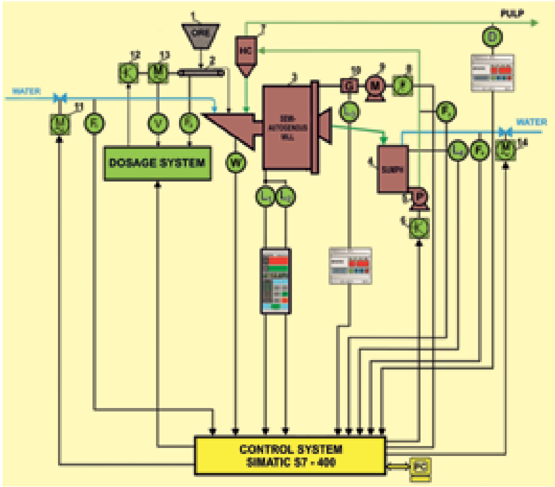

Figure 7, Schematic diagram of the control system.

- The weight flow rate of the ore sent to the mill by the weight feeder (signal V, F_2), with effect on the transistor frequency inverter 12, changing the revs of the band feeder 2;
- The flow rate of the water F_1 sent to the mill in set ratio with the weight flow rate of the ore with effect on the actuator 11 of the water tap;
- The weight of the mill. The loop includes the sensor W and regulator configured from control system SIMATIC S7-400 and connected in cascade with the loop for weight flow rate of the ore;
- The loading (filling level) of the mill. The loop includes the sensors L_1 and L_2 connected by weight coefficients to the microprocessor module MILLCONT 2A. The sensors are remote sensor SRIP installed on stand against the waterfall side of the mill. The sensor L_3 is direct sensor SDIP installed on the casing of the gear 10. The regulator of MILLCONT 2A acts by the control system on the frequency inverter 8 corrected the revs of driver motor of the mill 9;
- The pulp level of the sump by the signal L_4 with effect on the transistor frequency inverter 6, changing the revs of the pump 5. The signal for flow rate of the pulp F3 is sent as a position feedback to the regulator of the loop configured from the control system;
- The density of the pulp for floatation. The loop

contains DENSiCONT D, the regulator configured from the control system and the actuator 14 of the water tap. The flow rate of the water F_4 is sent as a position feedback to the regulator of this loop. Also the signal of the density is used for correction of the water flow rate sent to the mill.

The obtained parameters at the identification of the SAG mill as a object of automation (gain coefficient K_0, transport delay τ_0 , time constant T_0) are used in the developed algorithm for the choice of the type of regulator and the optimal adjustment of its parameters.

CONCLUSION

The experience in grinding process automation of semiautogenous mill shows the following economic results in comparison with manually controlled mill:

- The mill productivity increased with 15 percent;
- The specific power consumption decrease approximately by up to the same percent;
- The durability of the lining and grinding bodies is increased with 3-4 months;
- The average square deviations of the ready product by grinding fineness are 1,3 times less;
- The term of payback of the system is less than 6 months.

In addition, control of grinding process is no longer open to subjective interpretation and the control system reduces manual intervention by grinding personnel.

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UNDERWATER ROCK REMOVAL ACTIVITIES

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Abstract: *Nowadays blasting is used in many other fields of activity, not being limited only to the mining industry. Due to a large range of conditions in which the blasting operation is carried out, it takes the form of a special blasting works. They belong usually to the less polluting, economical and interesting from a professional standpoint blasting procedures. There follows a presentation of the underwater blasting, one of these special types of blasting. When deepening the old harbour basin to allow access for the ships with a larger weight, as well to build new quay structures, it is necessary to remove the bedrock in front of quays. The removal of the compact rock is carried out through a bottom dragging ship, only after a crushing of the rock with the help of underwater blasting technique. The technical challenge when perform underwater blasting works it is that the blast has to be efficient both from the point of view of rock crushing and the seismic protection of the neighbouring harbour structures.*

Keywords: *underwater blast, drilling platform, explosives, shock wave, harbour constructions*

INTRODUCTION

The blasting techniques today experience new areas of applicability, exceeding the field of the mining industry. Due to the diversity of the conditions in which they are executed, they often acquire the character of specialized blasting works.

Underwater blasting works with the help of explosive energy are one of the solutions used to excavate hard rocks in areas where this is not possible with the help of dredging ships or grapples. The underwater operation requires greater care and more thorough planning than similar operations above water.

Both drilling and charging become more difficult and some factors which have to be considerate for the successful underwater blasting operation are:

- Special operations method and drilling equipment;

- Different charging methods;
- Higher powder factor to displace rock, overburden and water;
- Use of explosives with good underwater resistance and performance properties;
- Keep vibrations and water shock waves under control.

Having over 30 years of experience in the field of underwater blasting, INSEMEX has developed the blasting technologies within numerous projects carried out in the Romanian harbors and seaside area and as well in the Beirut harbor.

In the following, the paper present theoretical features and examples of practical applications specific to the underwater rock removal with the help of blasting works.

EXPLOSIVES

Generally, the explosives that can be used for underwater blasting must be substantially water resistant. The explosive must give full detonation even when it has been stored under water for a long time as it must be taken into account that more often than not, unpredictable circumstances in underwater blasting, add time to the operation.

Therefor gelatine explosives of dynamite type are commonly using, either as prefabricated cardboard pipe charges or cartridges. Water resistance also related directly to the explosion propagation of an explosive (dynamites).

The explosion propagation in water is considerably greater than in the air (for instance for a dynamite with a charging density of 2,0 - 3,0 kg/m it is 1,5 - 2,0 meters). The water resistance of explosives used for underwater blasting varies to a great extent, depending on the conditions in each individual case. The periods of time guaranteed by explosives manufacturers are considered to apply to the most disadvantageous conditions that could occur.

Recent developments in slurry - emulsion technology have proved that this type of explosive may offer some advantages in comparation to dynamite explosives.

Their main features are improved performance, safety and reduced vibration hazards associated with hole-to-hole propagation, which ensures maximum fragmentation and vibration control, benefits from delay blasting.

In the case of explosives that are not water resistant the loads must be isolated from the water by placing them in sealed containers.

INITIATION

It is imperative that a safe and reliable initiation system is used in underwater blasting. Since the blasting procedure requires millisecond delay blasting for proper breakage and displacement, electric or NONEL type detonators are preferred to use.

In underwater blasting, water must be considered on electrolytic solution current leakage as a hazard to successful operation. Thus, only detonators with good insulation should be used. If possible, all connections work should be carried out above water surface. It is advisable to make the detonator wires/tube long enough to allow for a number of detonators to be connected at one point.

The major advantage of electric initiations is, however, that it is possible to check for continuity of the circuit at several points before firing. The disadvantages of electric initiations include susceptibility to lighting strike and the necessity of conducting technical evaluations when electric blasting caps are used and there is a possibility of extraneous current.

Thorough evaluations concerning extraneous electricity should be made at blasting sites before any explosives are brought into the area, as unwanted electrical energy may cause accidents, injuring blasting staff and damaging materials.

The non-electric detonator is a NPED-detonator (Non-Primary Explosives Detonator) without the sensitive primary explosive (lead aside). The conventional detonator has a number of safety weaknesses. There are result of primary explosive′s high sensitivity to friction, heat and blows. A conventional detonator as detonate if it is accidentally bent or subjected to a blow on the part that contains primary explosive. It is also sensitive to heat transferred in a fire. The NPED detonator is much less sensitive in situations of this kind.

A good measure of a detonator's sensitivity is what is called the flash-over distance. With the NPED - detonator, the risk of flash-over ceases at just 2 cm. Detonators containing a primary explosive can flash-over at distances up to 20 cm.

In conclusion, the use of electric detonators connected by wiring entails risks due to short circuits in wet conditions, or due to damage to the wires, or when long lengths of vulnerable wiring are required, non-electrical blasting methods may be preferred. This may be also be the case when there are special hazards from stray electric currents or static charges.

SAFETY IN UNDERWATER BLASTING

In underwater blasting is important to control:
- Water borne shock wave;
- Ground vibration;
- Rock throw and scattering.

The two first factors are especially important it there are structures close to the site. Ground vibrations from underwater blast can generally be calculated in the same way as for blasting elsewhere. The risk of flash - over in the case of clay or water fissured rock underlines the importance of recording observations made during the drill work and using the information in preparing the charge for the blast.

WATER BORNE SHOCK WAVE

The detonation of explosives in water naturally causes underwater shock. The pressure of the shock waves is considerably higher if the explosive is detonated freely in the water then if it is confined in a drill hole in the rock.

One of the problems during the underwater blasting is the effect of the generated shock waves on submerged constructions.
- The duration of the water shock wave is so short that is has dropped from its peak wave to half that pressure in a fraction of millisecond;
- This means in practice that cooperation does not occur between charges ignited at different intervals, not even for different charges ignited with the same interval number in which the interval time has a spread of approx. ± 5 ms.;
- I.e. the maximum pressure on a submerged structure is of the same order of magnitude as generated by the charge in one drill hole.

Due to the reduced compressibility of the water, from a detonation the shock propagates unamortized. Because the water is homogeneous and does not have discontinuous surfaces (such as rock), the shock wave does not decrease due to refraction or dispersion. In this situation the water shock wave generated by an underwater detonation can influence with a slightly diminished intensity, over long distances, with dangerous effects on the different objectives.

EVALUATION OF MAXIMUM PRESSURE

To evaluate the maximum shockwave pressure the most common method is using the „Enhamre Graph". The graph shows the relations between the „Scaled Distance" and the maximum pressure generated by the water shock wave.

With a charge of Q = 1 kg the scaled distance Z equal R = the actual distance $\Rightarrow Z = R / Q^{1/3}$

The maximum pressure of the shockwave from an enclosed charge is only 10 to 14 % of maximum pressure of a shockwave from an explosive hanging free in the water.

As a rule of thumb, it is generally accepted that pressure less than 1 MPA is not at all harmful to the existing marine structures. If maximum expected charge in one drill hole is 17 kg, minimum safe distance would be $Z = 5{,}5 \Rightarrow R = Z (Q)^{1/3} = 5{,}5\ (17)^{1/3} = 14$ m, which indicates that there is no risk damage to existing structures in the harbour.

Floating vehicles

The Danish Navy stipulated the following criteria for safe distances from detonating charges under water.

Charges suspended freely in water:

Warships	$R = 12 (Q)^{1/2}$
Merchant ships	$R = 24 (Q)^{1/2}$
Bulk carriers	$R = 48 (Q)^{1/2}$
R = safe distance in m	Q = charge in kg

Charges confined in blast holes:

Warships	$R = 1{,}7 (Q)^{1/2}$
Merchant ships	$R = 3{,}4 (Q)^{1/2}$
Bulk carriers	$R = 6{,}8 (Q)^{1/2}$
R = safe distance in m	Q = total charge per round in kg

Assuming a max. probable charge per round as 17 kg x 48 holes = 816 kg, a safe distance for all floating vehicles would be: $\Rightarrow R = 6{,}8 (816)^{1/2} =$ 194 m say 200 m.

People in water

As regards effects of underwater blasting on human being immersed in water adjacent to blasting sites, it has been established that a shock wave pressure exceeding 400 - 500 Kpa is immediately lethal. A moderate shock wave of 25 to 50 KPa can even result in moderate psychological damages such as bursting of ear drums, etc.

Water shock waves are especially dangerous for divers who are too close to a blasting site. The radius of the dangerous area can be calculated with the equation: $R = 268\ Q^{0,33}$, where R = radius of dangerous area, in m, and Q = size of charge, in kg.

Assuming max. cooperating round to consists of 816 kg explosives and minimum cooperating round to consist of 17 kg explosives, the safety distances for unprotected immersed human beings would be 1000 m for a delayed blast and 2000 m for a full location blasted instantaneously.

PRACTICAL WAYS TO REDUCE THE WATER SHOCK WAVE

Reducing the pressure in front of the shock wave can be done by:

a) Stemming the holes; reduces the pressure by 7-10 times compared to unstemmed loads;
b) Using air bubbles curtains.

When a shock wave hits such a curtain, some of its energy is absorbed by bubbles, the pressure in front of the shock wave being reduced depending on the air pressure and flow (Figure 1).

The practice showed that it is indicated that the curtain be put into operation with 5 minutes before blasting and the distance between the place of the blast and the curtain should be between 15 and 18 m.

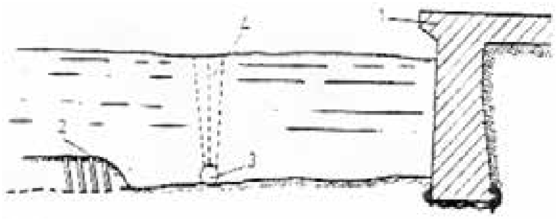


Figure 1, Protecting a construction with bubble curtain.

LEGEND:
1 - Objective to protect;
2 - Explosive charges;
3 - Perforated pipe through compressed air passes;
4 - Air bubble curtain.

GROUND VIBRATION

All blasting works generate ground vibration which in severe cases can result in damages to constructions adjacent to blasting sites. It has been established that the ground vibration velocity is a reliable value to use as a damage criterion. There are many formulas that combine the size of a single explosive charge, the distance of a structure from the site and the maximum oscillation velocity. The most commonly used is the one produced by Langefors and Kihlstrom:

$$V = K (Q / R^{3/2})^{1/2}$$

where: V = Particle vibration velocity, in mm/s;
K = Transmission factor, constant depending on the homogeneity of the rock and the presence of faults and cracks;
K = 400 for hard rock; K = 200 for soft rock; K = 100 for overburden;
Q = Instantaneously detonating charge in kg;
R = Distance from explosion site in m.

Example 1 V = 50 mm/s, K = 400, R = 10 m
$\Rightarrow$ Q = 0,49 kg
Example 2 V = 45 mm/s (measured), Q =1kg,

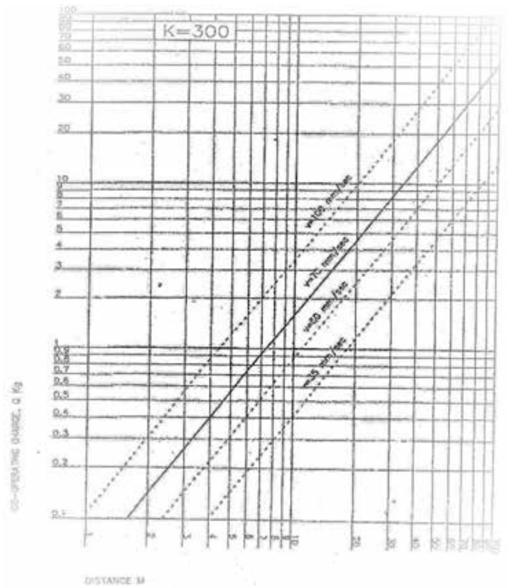
R = 10 m ⇒ K = 253
Example 3 V = 60 mm/s, K = 300, Q = 0,7 kg
⇒ R = 6,7 m
Example 4 Q = 0,4 kg, K = 250, R = 14 m
⇒ V = 22 mm/s

Usually the nearest structure to the dredging areas are the quays, mainly the block quay structure. For such heavy concrete structure, a basic vibration velocity value is 70 - 100 mm/s.

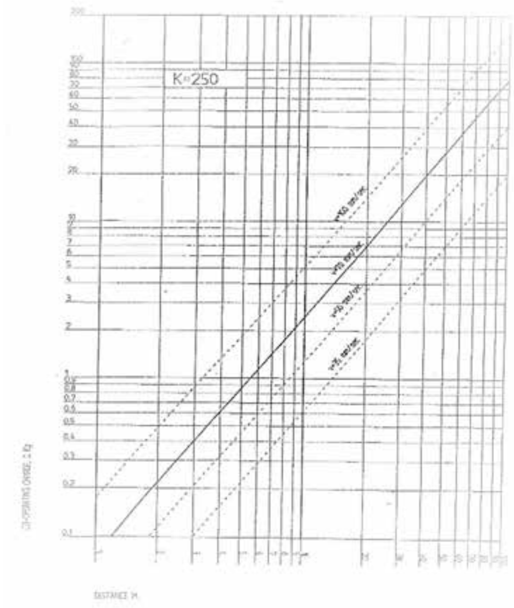
By using an established correction factors (building class factor, type of operation, type of initiation etc.) the final permissible value of peak particle velocity could be between 40 - 70 mm/s.

Transmission factor K is estimated to be 200 - 300. The relationship between charge - distance and ground vibration can be used to make a graph which may serve as ready-reckoner for the planning of blasting operations (Figure 2). The actual K factor shall be established by test blasts and vibration measurements at the structure. The first rounds blasted at the work site must be considered as test blast and the vibration measurements should be used as a guidance for the planning of an optimum blasting operation.

When the rock transmission factor K is determined, the graph may be adjusted accordingly and the realistic relationship between charge - distance and vibration velocity adapted to the local conditions.



Transmission factor K = 300



Transmission factor K = 250

Figure 2, Charge Distance graph for different vibration velocities.

Delay blasting should be considered, particularly millisecond delays, a method came into play by which a large explosive charge could be detonated as a series of small charges, rather than one large one. Obviously, the reduction in charge size can be made by the use of multiple delays. For example, the use of ten delays would reduce the effective vibration generated by charge to one tenth the original charge.

As was mentioned, most used way to reduce ground vibrations from underwater blasting is to reduce the total charge. As a result, instantaneous explosions will be avoided, the loads being distributed over delay stages, thus reducing the amount of explosive that detonates at once. In the case of large rounds, the time needed for the vibrations to reach vibrations sensitive structures can cause interference and result in a lower vibrations level than the cooperating charge alone would have caused.

Reducing the level of ground vibration can be done also by:

a) The use of air cushion technology to protect the objectives if the detonation wave is transmitted mainly through the ground;

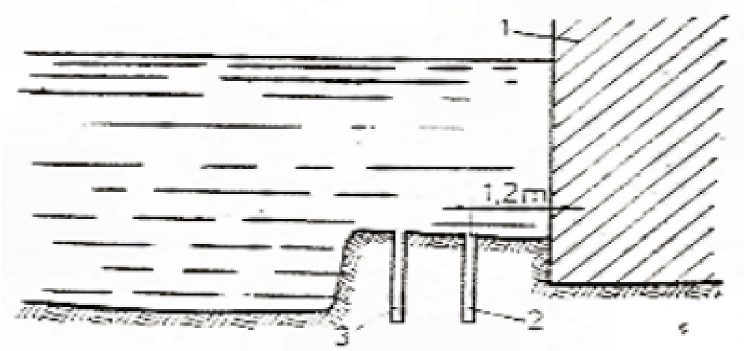
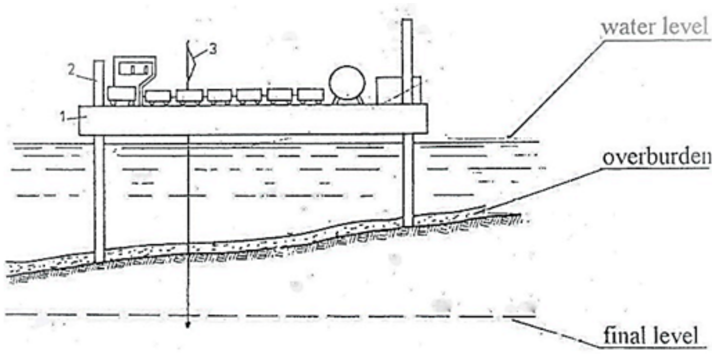


Figure 3, The principle of air damping technology.

LEGEND:
1 - Objective to protect;
2 - Row of holes for protection;
3 - Row of holes for rock blasting.



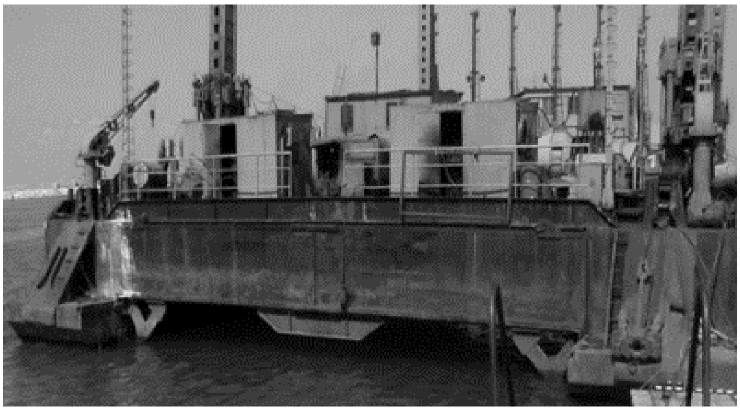


Figure 4, Drill rigs placed on the floating platform.

LEGEND:
1 - Platform;
2 - Legs;
3- Drilling equipment.

This consists in drilling in front of the objective to be protected a row of holes (φ 100 - 500 mm) at a distance of 0.5 m between holes and loading them on full length with sealed containers made from metal shell. The shockwave generated by the explosion will destroy the containers and the rock will detach along the holes line, protecting the target (Figure 3).

a) Creation of a cracked rock screen between the area where the blast is executed and the objective to be protected by blasting small amounts of explosive. This screen will also decrease the shock wave energy.

DRILLING AND BLASTING

The method of rock removing that ensures a uniform distribution of the energy of the explosion in the rock mass, respectively a crushing with a homogeneous granulometry, is the one with drilled holes. For this purpose, technologies have been developed that use floating platforms, supported above water with legs that can be extended down to the bottom and is used for the drilling and charging operations (Figure 4). The platform is equipped with six drilling machines, fixed on a mobile bridge at 2,2 - 2,3 m distance (spacing) between rigs.

Working area, it's gridded into location of 14 x 16 m each one. They are arranged in the order of achievement of every location according to the fulfilment necessity imposed by the design, as well.

The drilling platform is settled above the working surface by GPS equipment. The drilling platform is fixed on the first location and the bridge equipped with the drilling equipment is put in place for the first row of holes.

The overburden drilling method is carried out by using a set of steel tubes with ring bits having 102 mm diameter (Figure 5, a). This is used to drill through the overburden and a few decimeters into the bedrock (Figure 5, b). Drilling is then carried out through the tube with extension rods and a drill bit with 70 mm diameter (Figure 5, c).

The drilling will be performed 1,5 - 2 m deeper than the designed drilling level, so that by interfering of the blasting cones, the whole material will be blasted and excavated at the designed level. On the other hand, it's needs to take in consideration that the final hole length will include 0,5 m length from the bottom filled with different underwater deposits and drill fines and 0,7 - 1 m uncharged length from the top part of the hole.

When the hole is completed and cleaned, the set of drill rods is withdrawn (Figure 5, d) and the plastic tube - container with 60 mm OD and length equal with the length of explosives column charge plus the uncharged part of 0,7 - 1 m (Figure 5, e), is inserted through the steel tube into the collar of the drill hole. After that, the drilling tube is totally withdrawn and the plastic tube/container remains in the blast hole (Figure 5, f).

Preparation of containers is done on shore within the explosive storage place. It consists in the filling of a plastic container with explosives, initiation system and sand. The construction of a container is presented in Figure 6.

4.1 CHARGE CALCULATION

The most important point in underwater blasting are to ensure good fragmentation and avoid stumps above the stipulated bottom.

In underwater blasting, the rock movement is obstructed by the water pressure, the weight of the overburden and the weight of the rock itself. To ensure good breakage and displacement of the rock, the specific charge is increased to compensate for these conditions.

The water pressure is compensated for by increasing the specific charge by 0.01 kg/cu.m. per meter of water depth. For rock covered with overburden, the specific charge should be increased by 0.02 kg/cu.m. per meter of overburden.

For the rock section, the compensation is 0.03 kg/cu.m. per meter of the bench height. In underwater blasting, the nominal specific charge can be expressed as:

$$q = q_b + 0{,}01\ k_w + 0{,}02\ k_{ob} + 0{,}03\ k_{rock},\ \mathrm{kg/m^3}$$

where: q_b = Basic charge in kg;
k_w = Water depth in m;
k_{ob} = Thickness of overburden in m;
k_{rock} = Rock bench height in m.

Further the following terminology will be used:

l_b = Weight of charge in kg/m; B = Burden in m;
S = Spacing in m;
A = Area per hole in m^2, (B x S) = l_b / Q; U = Subdriling in m, U = B;
H = k_{rock} + U = Hole depth; h_0 = B / 3 = Uncharged section of hole

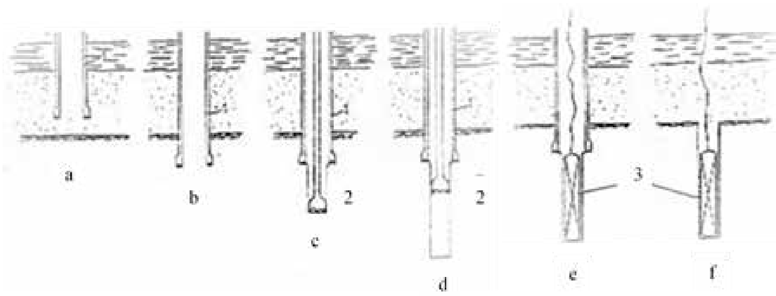


Figure 5, Principle of overburden drilling.

LEGEND:
1 - Steel tube;
2 - Drill bit in the second stage of drilling;
3 - Container with explosives.

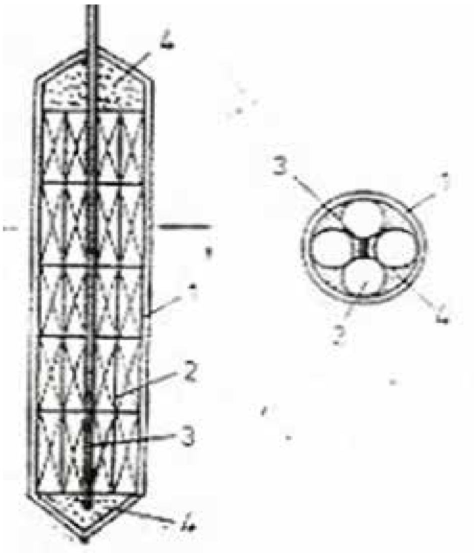


Figure 6, Container construction.

LEGEND:
1 - Container;
2 - Explosive;
3 - NONEL;
4 - Sand.

According to INSEMEX experience from conducting several blasting underwater blasting operations in limestone formations, the basic charge -q_b- can be set at 0,45 kg/m^3.

As the prefabricated charges are confined in a plastic tube (container) of ID=60 mm, the maximum weight per meter of hard-tamped emulsion explosive type will be $\mathbf{l_{b=}}$3,38 kg/m.

Calculation examples

k_w = 17 m
    k_w = 17 m
k_{ob}= 0 m
    k_{ob}= 2,4 m
k_{rock} = 3,5 m
    k_{rock} = 0,5 m
l_b = 3,38 kg/m
    l_b = 3,13 kg/m
q=0,45+0,01x17+0,02x0+0,03x3,5=0,725kg/m^3
q=0,45+0,01x17+0,02x2,4+0,03x0,5=0,68kg/m^3
A = 3,38 / 0,725 = 4,66 m^2
    A = 3,13 / 0,68 = 4,60 m^2
B = 2 m (variable)
    B = 2 m (variable)
S = 2,3 m (fixed)
    S = 2,3 m (fixed)
U = 2,15 m
    U = 2,15 m
h_0 = 0,7 m
    h_0 = 0,7 m
q = (3,5 + 2,15 - 0,7) x 3,38 = 16,7 kg
q = (0,5 + 2,15 - 0,7) x 3,13 = 6,10 kg
q_{spec} = 16,7 / 2 x 2,3 x 3,5 = 1,04 kg/m^3
q_{spec} = 6,10 / 2 x 2,3 x 0,5 = 2,65 kg/m^3

In accordance with the distance between the quay construction and explosion point and the level of permitted charge per delay we have the following situations:

1) Short distance between quay construction and explosion point (20 - 80 m) and low permitted charge per delay.

In this case, to be able to blast a full location with 48 holes or more (2,3 m spacing and 2 m burden), is need to have a hole by hole delayed blast. In each row it is used the last six period numbers of NONEL MS type (no. 20, 19, 18,17,16,15) and connected between them with connectors having 0 delay time. The connection between rows (at the end of the rows) it is made with connectors having 42 ms delay time.

Using the last six period numbers of NONEL MS type (375 ms, 400 ms, 425 ms, 450 ms, 475 ms, 500 ms, basic in hole delay time for the each row) combined with 42 ms surface delays (starting with the second row, will be added to the basic inhole delay from each row, the surface delay) this will help to avoid the risk of tube cut-offs and to be sure full surface initiation will take place before the rock displacement begins.

2) Longer distance from the quay construction – over 200 m.

The permitted charge per delay and the number of holes fired with the same delay can be increased. In this case, the connections between rows will be made with connector having 0 delay time.

In accordance with the distance and the permitted charge per delay we can to have the following situations:
- To blast instantaneously the full location (48 holes) using a simple firing network;
- To blast three rows per delay;
- To blast two rows per delay;
- To blast row by row.

PRACTICAL APPLICATIONS

INSEMEX has a rich experience in the field of underwater blasting, establishing the blasting technologies with the seismic protection of the port objectives in case of projects of construction or deepening of the docks in the harbours of the Black Sea - Mangalia, Agigea and Constanta as well as Beirut harbour, Lebanon.

Constanta harbour

A special application was the removal from the bottom of the sea of petrified deposits of cement and iron ore, resulting from the operations of unloading - loading of vessels, in front of the docks 65-66-67-68 from Constanta Port. These deposits prevented anchoring and loading transport vessels to their maximum capacity. Since none of the classical variants approached has failed, the attempt was made to remove the deposits by drilling - blasting operations.

In order to carry out the drilling - blasting works, it was arranged a mini floating platform, with a single drill rig, having the possibility of drilling holes starting from 0.5 m distance from the dock face.
The maximum amount of explosive possible to be detonated depending on the distance between the quay walls and the epicenter of the explosion, was established based on the results of the seismic measurements made on the quay, using different amounts of explosive (0.2 - 0.3 kg dynamite) at different distances from quay face (1 - 4 m).Thus it was established that for:

R = 1- 2 m $\quad Q_h$ = 0,1 kg dynamite / hole
R > 2 m $\quad Q_h$ = 0,2 kg dynamite / hole

where: R - Horizontal distance between the epicenter of the explosion and the base of the quay in m.
With increasing distance from the face of the quay, the thickness of the petrified deposits is reduced (from 2 m to 0.2 m). As a result, starting at a distance of 2-3 m from the quay face, the use of a maximum load of 0.2 kg of dynamite per hole was sufficient.

The order of drilling and firing of the holes was one by one from the sea side to the quay face, at a distance of 1.5 - 2 m between the holes. It was also tried to blast the holes by replacing the dynamite with a load made by folding a certain length of detonating cord.

For holes located at distances greater than 1,0 m from the front of the quay, the length of the detonating wire (with loads of 12, 16, 20 gr./ml.) necessary to make a bundle with a length of 0.3 -0.4 m, can be calculated with the relation:

$$L_b = 24/G \text{ (m)},$$

where: G - The weight of the load specific to the type of detonating cord used, (g/m);
L_b - The length of the detonating wick for the formation of a bundle, (m).

The advantages of using an explosive charge made of detonating cord are:
- By folding the detonating cord in a bundle with a length of 300 - 350 mm, it ensures a better distribution of the explosive load along the length of the drilled hole (compared to only 100 mm in the case of dynamite), respectively a more advanced degree of crushing of the blasted mass;
- In the case of a failure, the hole loaded with detonating cord, in the absence of the cartridge explosive, cannot create damage to the ships or dredges that are to clean the area.

The results obtained satisfied both from the point of view of the crushing of the cemented material and of the seismic protection of the adjacent harbour constructions.

Beirut harbour

The extension of the Quay 16 from Beirut harbour involved the excavation of a volume of over 100 000 cubic meters of rock, on a thickness of 0.5 - 3.0 m and at a depth of 14 - 17 m under water. Due to the density and the strength of the limestone about 55 000 cubic meters had to be excavated through drilling - shooting - dredging.

Drilling the holes to a diameter of 70 mm was done from a floating platform, using the drilling method inside a metallic tube with a diameter of 110 mm (OD method). The explosive charges made of gelatinous dynamite and initiated with elements of the NONEL MS type system, were prepared in plastic containers with a diameter of 60 mm and inserted into holes on the platform, through the steel tubes.

Considering that in the vicinity of the blasting area there were objectives that had to be protected from the seismic point of view, it was necessary to determine the vibration level, in order to determine the non-dangerous amounts of explosive.For this purpose, over 10 test explosions were performed, using different amounts of explosive on the hole and on the delay stage as well as different initiation schemes.

Based on the results of the experimental blasting, the optimal execution variants of the underwater rock removal works could be established.

CONCLUSIONS

In the case of the deepening of the old port basins for the access of the ships with greater displacement as well as in the case of the construction of new docks, whose commissioning is urgent, it is necessary to remove the rocks in front of the docks.

Removal of massive, compact rocks can be done by dredging, only after a prior crushing, by underwater blasting works.
Underwater rock removal works with the help of explosive energy are one of the solutions used to excavate hard rocks, and the experience gained in recent years has led to the development of drilling-blasting technologies executed on floating platforms.

The obtained results have satisfied both from the point of view of performing the rock removal work at the estimated parameters as well as of ensuring the protection against the seismic action and of the shock wave transmitted through the water, when carrying out the blasting works.

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РУДАРСКИ ГЛАСНИК
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SHAFT CONSTRUCTION IN SERBIA: THE FIRST RAISE BORING PROJECT IN THE COUNTRY

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Abstract: *In May 2019 the Thyssen Schachtbau GmbH was commissioned to construct two shafts (DN = 3.50 m, depth = 122 m and 106 m) in a limestone quarry for a TITAN Cement Group in Serbia. The raise-boring method was used for shaft construction, excavated material removed by LHD. After completion of the excavation, a hoisting system was installed, consisting of a shaft frame, main winch for the working platform and an emergency winch with emergency cage. In the first step the hoisting system was required to install the temporary rock support (top down), later to install the final shaft lining (bottom up) in form of steel tube lining in the lower, concrete lining in the upper part. A base ring in the tunnel provided a foundation for the shaft lining. The hoisting equipment was certified on the basis of the Serbian regulations in line with the German and European regulations. The Serbian HSEQ requirements, specifications of the international client and internal guidelines had to be taken into account in order to implement the project in a solution-oriented and thus successful manner. Training of Serbian specialist personnel and local subcontractors for working in the shaft was an additional success for the project.*

Keywords: *shaft construction, raise-boring, shaft hoisting system, certification, legislation*

INTRODUCTION

In January 2019 the Thyssen Schachtbau GmbH was commissioned to construct two shafts in Serbia, at a quarry located close to the small town of Kosjeric. The exploitation of the lime stone deposit called Suvo Vrelo had started 1976, for the purposes of the nearby cement plant that is today held by the TITAN Cement Group.

The current transport method – pushing the excavated material from higher to lower levels over the bench using loaders and bulldozers limits the economic efficiency as well as environmental compatibility and occupational safety, TITAN decided to invent a new transport system. The new transport ways shall be mainly underground to reduce emissions, minimize risks and shorten actual transport ways.

PLANNING PROCESS AND PREPARATION

TITAN started the project development in 2006. In 2013 representatives of TITAN Cementara Kosjeric made a first visit to one of Thyssen Schachtbau GmbH´s Raise Boring projects in Austria – and the impressions from that visit should influence the further planning sustainably. TITAN became the first company in Serbia to pick the raise boring method for shaft excavation.

The new design comprises stationary crushers at the surface that shall load the raw material into gravity shafts. The shafts lead into a transport tunnel. Conveyor belts shall transport the material to a truck loading station. Finally trucks shall transport the crushed lime stone to the cement plant.

After two years of construction works the tunnel below the planned shafts S1 and S2 (see figure 1) was fished in November 2017.

The tunnel itself was a precondition to make raise boring applicable. With its length of about 210 m and 5.7° inclination it also secured natural ventilation during works within the shafts. The shafts are of different length, for their starting points are on different levels of the quarry: S#1 121 m, S#2 106 m.

RAISE SHAFT CONSTRUCTION

A raise shaft is defined as a vertical or steeply inclined opening excavated from a lower level to a higher level.[2]

Commonly raise shafts are constructed in mining for ventilation shafts, ore passes or access shafts; in civil construction for underground tunneling and in hydro-power plants for pressure shafts. In the past, raise shafts were often constructed by conventional raising methods, e.g manually or using raise climber (Alimak method, see Figure 2). These variants are rare-

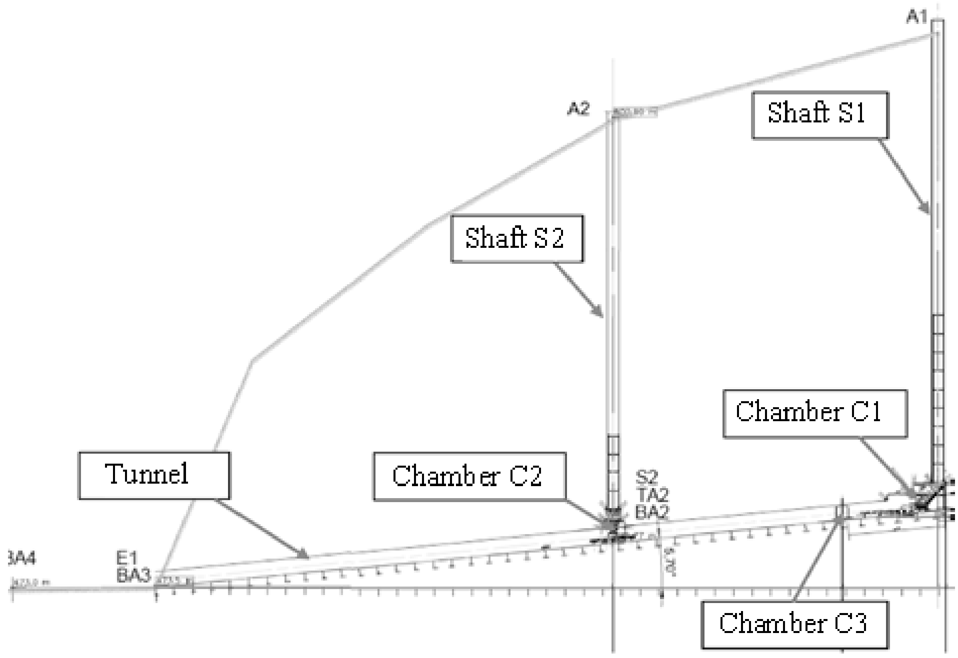

Figure 1, Shaft and tunnel system, longitudinal section.[1]

[1] TITAN

[2] SME Mining Engineering Handbook, Peter Darling (2011), P 1192.

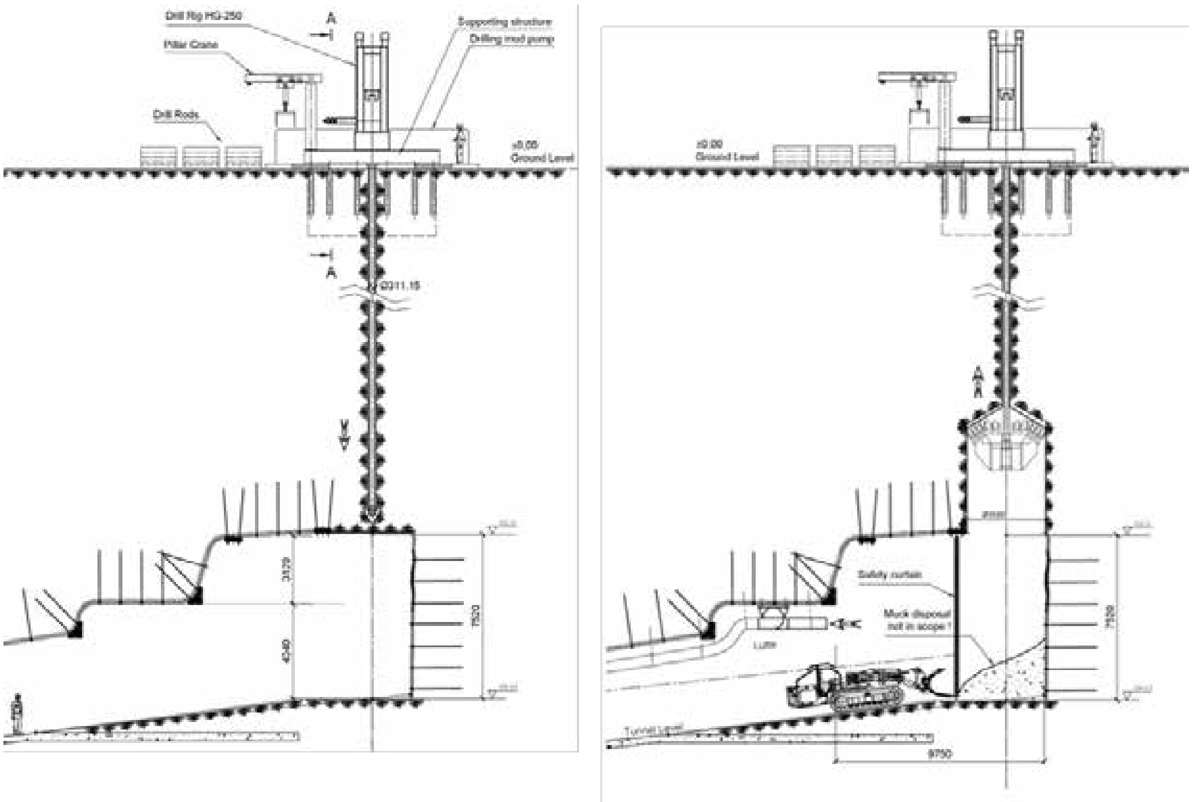

Figure 2, Pilot hole (top down) and reaming (bottom up).[6]

ly used anymore due to the low occupational health and safety standard.

Considering this and also based on the geological exploration, TITAN and the design team selected the raise boring method as the most appropriate at Suvo Vrelo. The excavation is fully mechanized, no persons need to be in the shaft without rock support during this risky first phase of shaft construction.

RAISE BORING – THE METHOD

The raise boring method operates on the principle of first drilling a small pilot hole down and then reaming the hole upward, in one or more stages, to the needed size. A basic requirement is a drift on the lower level (see Figure 3). Furthermore, stable rock behavior with medium to hard rock strength is required. After the pilot hole has been finished, the reamer head replaces the drill bit and reaming operation can begin.

The method was developed in Northern American ore mines in the 1950s. Nowadays, rigs are bigger and so are their technical capacities. Specialist texts from 2007 give 1.0 - 6.0 m diameter and depths of 50 - 1,200 m as maximum parameters,[3] but machine manufacturers of raise boring rigs claim already over 8 m diameter, 2.000 in depth[4] and an inclination up to 45° as possible. Using special constructions even 90° can be bored.[5]

The pilot hole is drilled from top to bottom using the rotary drilling method with minor diameters up to 350 mm., A flushing flow (e.g. water and additives) needs to be pumped downwards through the drill pipe cool the drill bit remove the cuttings rising in the annular space between the drill pipe and the wall of the drill hole.

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[3] Peter Schmäh, Benjamin Künstle, Nobert Handke, Erhard Berger: Weiterentwicklung und Perspektiven mechanisierter Schachtteuftechnik. In: Glückauf 143, Fachzeitschrift für Rohstoff, Bergbau und Energie. Nr. 4, VGE Verlag Essen, Essen 2007, ISSN 0340-7896, S. 161–172)

[4] Herrenknecht, Raise Boring Rig RBR 900VF

[5] https://www.miningweekly.com/article/boring-to-depth-2017-06-08

[6] Thyssen Schachtbau GmbH (2019)

Accuracy can be increased with a stabilized drill string that reduces the deviation of the pilot hole or with the help of a directional drilling system (e.g. drilling motor with MWD-tool). This may access restriction during the drilling work. After completion of the reaming operation, the reamer head is either dismantled above ground or lowered back into the drift for dismantling.

Table 1, Technical data of the raise boring rig Wirth - HG 250

Manufacturer	Wirth
Typ	HG250
Power	250 kW (at 1500 RPM)
Max. torque	15000 mkp / 147 kNm
Max. break torque	16000 mkp / 157 kNm
Max. pulling force	270 000 kp / 2648 kN
Raise bore rods	10" diameter, 60" length, 7 3/4" H-290 connection
Total weight (installed)	Approx. 25 t

Table 2, Range of application HG 250

be necessary due to the client's specifications and in case of drilling inclined or long shafts.
After finishing the pilot hole, the reamer head is mounted underground to replace the drill bit.

The reamer usually consists of the following components:
- base body with extension parts (if necessary) to adapt the diameter,
- tie rod and,
- saddles for bearing the cutting tools.

The excavated material (cuttings) falls downwards and is removed by LHD. In the loading area underneath the open shaft there is a strict

RAISE BORING AT SUVO VRELO

At TITAN´s Suvo Vrelo quarry two shafts with lengths of 106 m and 121 m with excavation diameter of 3.50 m were constructed. While planning the construction, special consideration had to be given to the narrow and steep roads of the quarry and the limited space available at the drilling site. So the modular design of the raise-boring system type Wirth - HG250 (see table below) was an advantage.
The drilling diameter of the vertical pilot hole was 12 ¼", using an insert bit according to the forecasted geology. With up to 3 stabilizers, whose positions were adjusted during the drilling pro-

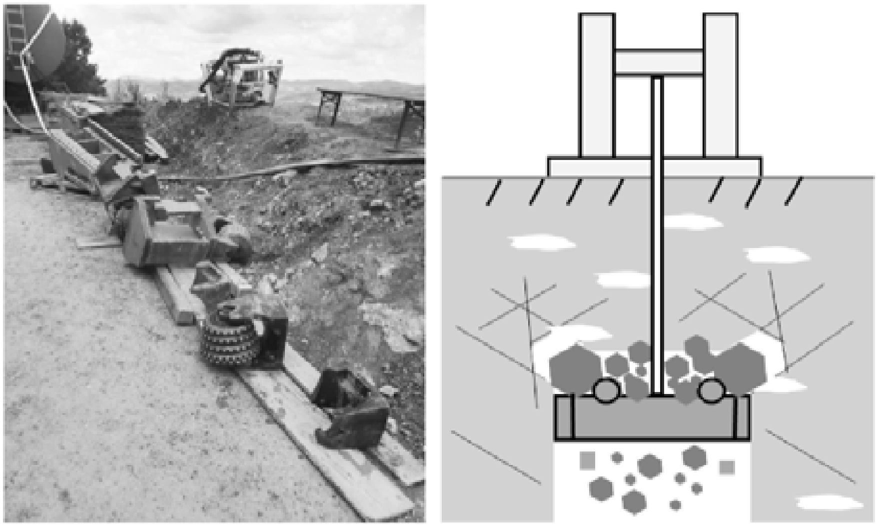

Figure 3, Photo of the damaged plant components at the location of shaft 1. Schematic illustration (right) of the processes during the raising shows the slippage of non-demountable cubatures of > 1 m.

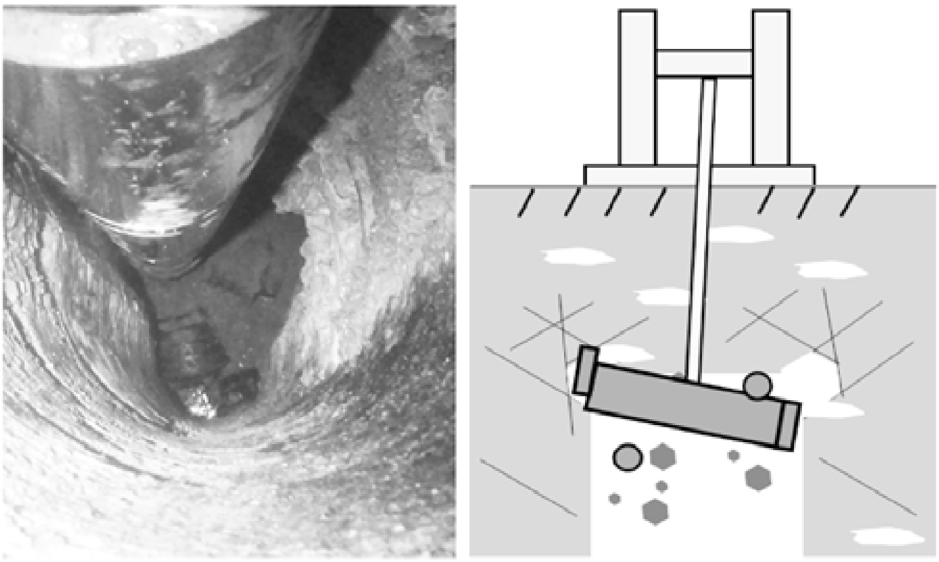

Figure 4, Left - Photo of the inclination of the reamer as a result of the exposed cavities in the excavation area of shaft 1. Right - Schematic illustration showing the tilting of the reamer as a result of the exposed cavities.

gress, the planned accuracy of max 30 cm deviation could be realized. Unexpected massive mud losses could be handled by using polymer-based additives and borehole cementations. Despite the geologically caused difficulties daily performance rates of 30-40 m/d could be reached. The maximum performance was 55 m/d.

During the raising, various adverse geological conditions were encountered. Large boulders fell onto and underneath the reamer, especially in the upper part of the shafts. The average size of the boulders was in the range of 1- 2 cubic meters. The karstic features encountered led to global (complete perimeter of the raise boring

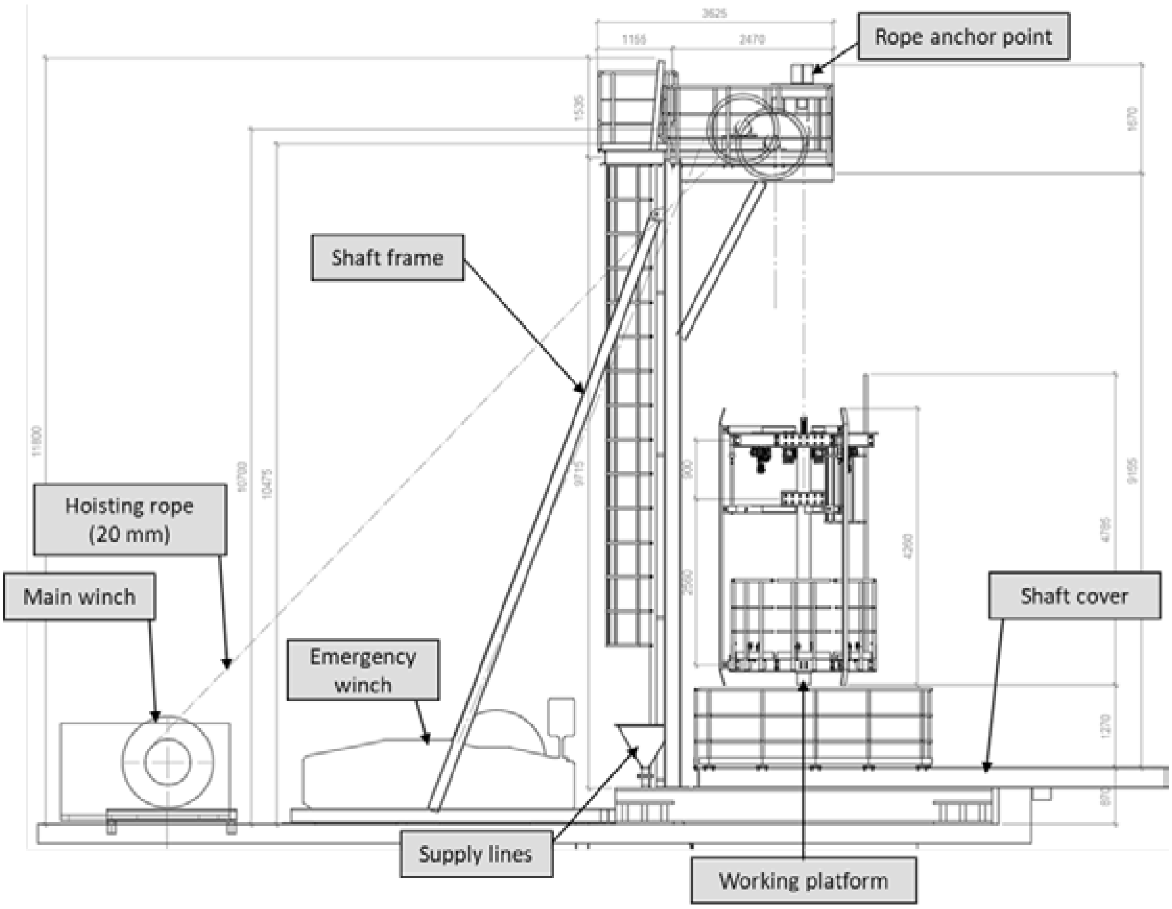

Figure 5, Hoisting system.

operation) instabilities above the reamer head. The large loose blocks lying on the reamer could not be fragmented, which resulted in considerable damage of the cutting tools.

The increased sliding of the large blocks exposed larger cavities. This process was facilitated by the unexpectedly high karstification of the rock mass at the shaft location. The result was an uneven side wall of the shaft with larger lateral dilution. It was hardly possible to induce an even contact pressure between the reamer and the rock mass in the shaft area.

The geological difficulties led to a slackened reaming process. Nevertheless, daily average performances of approx. 14m/d could be achieved. The maximum performance in the lower area of the shafts was 20 m/d. Due to the increasing instability in the upper shaft area, it was decided together with the client to stop the raise-boring works. The simplest and most flexible solution for this issue was to excavate the remaining meters (approx. 10 m) conventionally – by drilling and blasting. For this purpose, the shaft hoisting system described in the following chapter was installed ahead of schedule. The excavated material was removed via the pilot borehole. Finally, the first phase could be successfully finished.

THE HOISTING SYSTEM

After dismantling of the drilling rig, the hoisting system was installed, consisting of shaft frame and shaft cover, main winch for the working platform, emergency winch with emergency cage and communication system (see Figure 5). The hoisting system is specially designed for installation of rock support and lining in raise-bore shafts.

All components were imported either from Germany or Austria, designed and constructed according to German/European modern standards brought in line with the Serbian regulations. These regulations surely need an up-date just as the mining law itself experienced in 2015.

Due to the fact that all installations are based on the former foundation of the drill rig, the time needed from mantling to certification of the hoisting system is approximately 1 week.

TEMPORARY ROCK SUPPORT AND FINAL LINING

In the first step the hoisting system was required to install the temporary rock support (top-down). From the working platform, all works were carried out in the shaft. The work in the shaft mainly comprised: Extending or removing supply lines (water, concrete, compressed air, electricity, etc.) and installation of rock support

The following types of rock support was applied:
- Systematic rock bolting (resin bolts, F = 180 kN, L = 2 m);
  The drilling of the boreholes was done by using hand-guided pneumatic hammer drills. Pneumatic holders were used for support horizontal or upward drilling. Compressed air was supplied via a pipeline.
- Wire netting;

After completion of the rock support, the final shaft lining was installed: 15 m steel tube lining in the lower part and reinforced concrete lining reinforced with steel fibres (40 kg/m^3) in the upper. The final inner diameter of the shaft was 2.9 m.

A base ring in the tunnel serves as a foundation for the shaft lining. Steel tube segments (W = 18 mm, H = 2.5 m) were lifted into the shaft from surface and backfilled with concrete.

Following the lower steel lining, a reinforced concrete lining (W = 30 cm) was implemented in the remaining shaft by using a climbing formwork. The climbing formwork consists of 3-4 formwork rings, each consisting of 4 foldable segments (H = 1.5 m). The daily average performance was approx. 6 m/d.

CONCLUSION

Thanks to a highly motivated team the project could be finished successfully. The cooperation with the client and Serbian specialists was fruitful, bridging biases that showed up during the project, struggling to find solutions for every unexpected difficulty, and inventing precious links. Sustainability was the driving force to start it, and hopefully the results will also show as sustainable in every meaning the word can have: environmentally by decreasing noise and other emissions; regarding safety and occupational health; economically for the shafts and system are expected to have a long operational life. And because as much material as possible stemmed from Serbian factories. Local workers got trainings and additional qualification so the benefits from the German-Serbian cooperation in Kosjeric shall continue in the future. Moreover in this sense, we had the honor to welcome groups from both Serbian Mining faculties at the site to give them impressions from what is waiting for them and incentives to have a look beyond one´s own nose. Thyssen Schachtbau GmbH raised the first shafts in country using the raise boring method. Hopefully, there shall be more projects alike in the modernizing Serbian mining sector.

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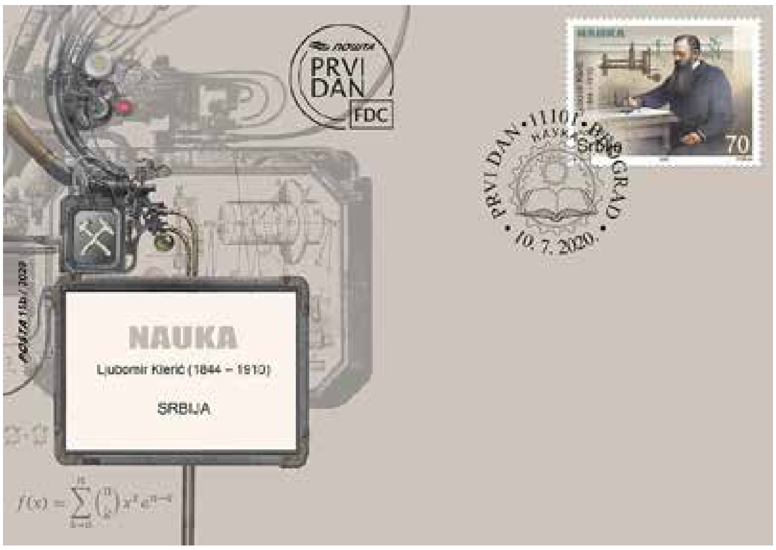
ЗНАЧАЈНИЈИ ДОГАЂАЈИ

SIGNIFICANT EVENTS

ПОШТА СРБИЈЕ штампала пригодну марку и коверат поводом 175 година од рођења академика Љубомира Клерића / POST OF SERBIA printed a commemorative stamp and envelope on the occasion of the 175th anniversary of the birth of Academician Ljubomir Klerić.



ЛАУРЕАТИ ПОВЕЉЕ АКАДЕМИК ЉУБОМИР КЛЕРИЋ И ПРОФ. ДР ДИМИТРИЈЕ АНТУЛА У 2020.

LAUREATES OF THE CHARTERS ACADEMICIAN LJUBOMIR KLERIĆ AND PROF. DR. DIMITRIJE ANTULA IN 2020

Академија инжењерских наука Србије, Одељење рударских, геолошких и системских наука, од 2012. године, додељује признања у виду повеље за нарочите научне и инжењерске доприносе. Повеља Академик Љубомир Клерић додељује се појединцима за животно дело - изузетне резултате постигнуте у научно-истраживачком раду у дугогодишњем периоду, *а Повеља Проф*. др Димитрије Антула за врхунска инжењерска остварења, реализована и у пракси потврђена. *Повеље се* додељују за области рударских, геолошких и системских наука.

Academy of Engineering Sciences of Serbia Department from Mining, Geological and Systems Sciences, since 2012, it has been awarding recognitions in the form of a charter for special scientific and engineering contributions. The Charter Academician Ljubomir Klerić is awarded for exceptional scientific and research results achieved over a long period, and the Charter Prof. Dr Dimitrije Antula is awarded for top engineering achievements, realized and confirmed in practice. The Charters are awarded for the fields of mining, geology and systems sciences.

ДОБИТНИЦИ ПОВЕЉЕ АКАДЕМИК ЉУБОМИР КЛЕРИЋ:

THE WINNERS OF THE CHARTER ACADEMICIAN LJUBOMIR KLERIĆ

Рударски институт Београд - рударство

Поводом шест деценија стваралаштва, за резултате и доприносе у рударству, науци, инжењерству, школовању врхунских инжењерских кадрова, издавачкој делатности,

Mining Institute Belgrade - mining

On the occasion of six decades of creativity, for results and contributions in mining, science, engineering, education of top engineering personnel, publishing, establishment and improvement *успостављању и унапређе-њу међународне научне и стручне сарадње и међународне афирмације наше научне и стручне мисли*

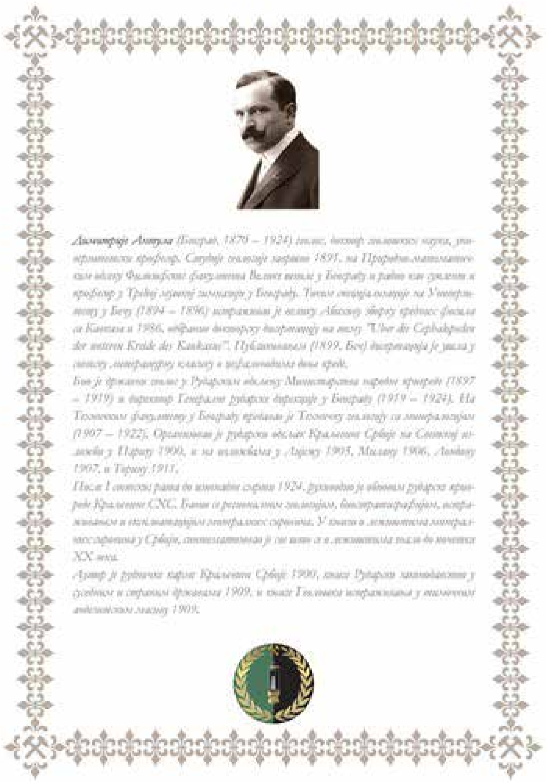
Др Радуле Поповић - геологија

За дугогодишње резултате у научноис-тра-живачком раду и руковођењу истраживањима у геологији, за руковођење Геоинститутом и ауторски допринос унапређењу литературног фонда из геологије.

Проф. др Катица (Стевановић) Хедрик - системске науке

За дугогодишњи истраживачки рад и допринос историографији српског рударства друге половине XIX и почетка XX века - истраживањем живота и дела једног од најзначајнијих српских рударских инжењера академика Љубомира Клерића.

ДОБИТНИЦИ ПОВЕЉЕ
ПРОФ. ДР ДИМИТРИЈЕ АНТУЛА:



Емеритус проф. Надежда Ћалић - рударство

За инжењерско дело и научне доприносе у припреми минералних сировина, школовање гене-

of international scientific and professional co-operation and international affirmation of our scientific and professional thought

Dr. Radule Popović - geology

For long-term results in scientific research and management of research in geology, for managing the Geoinstitute and author's contribution to the improvement of the literary fund in geology.

Prof. Dr. Katica (Stevanović) Hedrik - systems sciences

For many years of research work and contribution to the historiography of Serbian mining in the second half of the XIX and the beginning of the XX century - by researching the life and work of one of the most important Serbian mining engineers, academician Ljubomir Klerić.

THE WINNERS OF THE CHARTER
PROF. DR. DIMITRIJE ANTULA

Emeritus prof. Nadežda Ćalić - mining

For engineering work and scientific contributions in the preparation of mineral processing, *рација руда-рских инжењера и доприносе унапређењу Рударског факултета у Приједору.*

Проф. др Раде Јеленковић - геологија

За инжењерско дело и доприносе у геологији лежишта минералних сировина, школовање и образовање инжењера геологије, руковођење и доприносе унапређењу рада матичне Катедре на Рударско-геолошком факултету у Београду.

Др Владан Батановић - системске науке

За инжењерско дело и доприносе у аутоматизацији и управљању саобраћајем, за руковођење и унапређење рада Одељења за управљање саобраћајем Лабораторије за аутоматику и Институтом Михајло Пупин у Београду.

education of generations of mining engineers and contributions to the improvement of the Faculty of Mining in Prijedor.

Prof. Dr. Rade Jelenković - geology

For engineering work and contributions in the geology of mineral deposits, education and training of geological engineers, management and contributions to the improvement of the work of the main Department at the Faculty of Mining and Geology in Belgrade.

Dr. Vladan Batanović - systems sciences

For engineering work and contributions in automation and traffic management, for managing and improving the work of the Traffic Management Department of the Automation Laboratory and the Mihajlo Pupin Institute in Belgrade.

ИЗЛОЖБА У КАМЕНУ СВЕТЛОСТИ ТРАГ
Поводом 150 година сарадње српских и аустријских геолога

EXHIBITION ILLUMINATING STONE
Dedicated to 150 years of collaboration between Serbian and Austrian geologists

Изложба у Музеју науке и технике у Београду од 31.10. до 17.11.2020, планирана поново у Београду у априлу 2021. Биће приказана и у више градова Србије. Аутор изложбе је проф. др Кристина Шарић Универзитет у Београду - Рударско-геолошки факултет са сарадницима др Адријаном Фајксом Аустријски културни форум Београд и проф. Ханс-Јирген Гавликом Универзитет у Леобену). Огаанизатори су Универзитет у Београду Рударско-геолошки факултет и Аустријски културни форум Београд.

The exhibition at the Museum of Science and Technology in Belgrade from October 31st to November 17th 2020, and will be held again in Belgrade in April 2021. In the following period, the exhibition will be shown in several cities in Serbia as well. The author is Prof. Dr. Kristina Šarić University of Belgrade Faculty of Mining and Geology, with the assistance of Dr. Adrien Feix Austrian Cultural Forum Belgrade and Prof. Dr. Hans-Jürgen Gawlick University of Leoben. Organisers are University of Belgrade Faculty of Mining and Geology and Austrian Cultural Forum Belgrade.

Идеја за изложбу „У камену светлости траг” **родила се још** 2002., када је **кроз Програм** *WUS Austria* Савезног министарства иностраних послова Републике

The idea for the exhibition “Illuminating stone” was born in 2002, when a polarization transmitted light microscope was donated to the Faculty

Аустрије Рударско-геолошком факултету у Београду дониран поларизациони микроскоп за пропуштену светлост. Изложбу чине две паралелне тематске целине. Једна је присећање на сарадњу аустријских и српских геолога дугу 150 година коју су потицали континуирани заједнички геолошки изазови у проучавању Алпа и Динарида и жеља за усавршавањем студената и наставника из ова два геолошка центра.

of Mining and Geology in Belgrade through the WUS Austria Program of the Federal Ministry of Foreign Affairs of the Republic of Austria. The exhibition consists of two parallel thematic units. The first is the recollection of the cooperation of Austrian and Serbian geologists that lasts for 150 years, which was encouraged by the continuous joint geological challenges in the study of the Alps and the Dinarides and by the desire to increase the mobility of the students and teachers from both sides.

Друга целина изложбе показује шта се дешава када завиримо у микросвет камена и откријемо његову скривену лепоту. Читање камена виђеног под микроскопом, не само кроз његов састав, структуру и текстуру, већ и кроз естетски моменат заробљен у специфично кадрираним фотомикрографијама и несвакидашњим насловима слика, даје посебну ноту овој изложби која, осим што задржава едукативан карактер, чини и мали искорак ка уметничком.

Приредила
Кристина Шарић

The second part of the exhibition shows the hidden beauty of the micro-world of stone. Reading from the stone seen under a microscope includes not only its mineral composition, structure and texture, but also gives the opportunity of enjoying in colours and morphological phenomena as well as in aesthetic moments. The frozen scenes captured in specifically framed photomicrographs and their unusual explanatory titles, give a special note to this exhibition that, in addition to its educational character, represents a small but brave step towards genuine art.

Prepared by
Kristina Šarič

НАУЧНИ И СТРУЧНИ СКУПОВИ
SCIENTIFIC AND PROFESSIONAL MEETINGS
Најава / Announce

VIII БАЛКАНСКИ РУДАРСКИ КОНГРЕС
8th BALKAN MINING CONGRESS

Београд Србија / Belgrade Serbia
НОВИ ТЕРМИН / NEW DATE
25-27. 05. 2021.

ОРГАНИЗАТОР / ORGANIZER

РУДАРСКИ ИНСТИТУТ БЕОГРАД
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Одељење рударских, геолошких и системских наука Академије инжењерских наука Србије
Department of Mining, Geological and Systems Sciences of the Academy of Engineering Sciences of Serbia

Балканска академија рударских наука
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СЕЋАЊА / IN MEMORIAM

Драгољуб Јујић (Охрид, 03. 02. 1938 – Београд, 02. 05. 2020), дипл. инж. рударства, магистар и доктор техничких наука, директор Рударског института Београд у два мандата. Средњошколско образовање стекао је у Смедереву. Студије рударства завршио на Рударско-геолошком факултету Универзитета у Београду 1961, а магистарске 1974. Докторску дисертацију одбарнио је 1985. на Рударско-геолошко-нафтном факултету Свеучилишта у Загребу на теми масовног минирања на површинским коповима рудника метала.

Радну каријеру започео је 1961. инжењерским ангажовањем на подграђивању и стабилизацији истражне јаме руде гвожђа „Мокра Гора". У Руднике жељезне руде Љубија прелази 1963. и ради на и руководним задацима управника Рудника „Томашица" и главног инжењера предузећа. Од 1970. ради у Рударском институту Београд. Почео је на радном месту овлашћени пројектан, после две године постављен је на место шефа за пројектовање површинских копова метала и неметала. За директора Рударског инсти-

Dragoljub Jujić (Ohrid, February 3, 1938 – Belgrade, 02 May 2020), graduated mining engineer, magister and doctor of technical sciences, director of the Mining Institute Belgrade for two terms. He acquired his high-school education in Smederevo. He completed his studies of mining at the Faculty of Mining and Geology, University of Belgrade in 1961, and his master's degree studies in 1974. He defended his doctoral dissertation in 1985 at the Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb with the topic of mass blasting in the open-pit mines of metal mines.

He began his working career in 1961 with an engineering engagement in the sub-structuring and stabilization of the "Mokra Gora" iron ore exploration pit. He moved to the Iron Ore Mines "Ljubija" in 1963 and worked on the managerial tasks as the manager of the "Tomašica" Mine and the chief engineer of the company. He worked at the Mining Institute Belgrade since 1970. He started working as an authorized designer, and after two years he was appointed head of the designing of open-pit mines of metals and non-metals. He was elected diтута изабран је 1. јануара 1980. У „Инвест-Инпорт“ прелази 1988. на место помоћника директора инжењеринга. Од 1993. ради за рударска предузећа самостално послове ревизија, консалтинга, експертиза и сл. Од 1996. директор је у борду канадске компаније „ERIN VENTURES“ из Едмонтона, а од 1998. директор мешовитог предузећа „RAS-BORATI“ које је формирала ова канадска компанија са Електропривредом Србије ради истраживања и експлоатације руде бора у региону Баљевца на Ибру.

Као експерт био је ангажован на решавању проблема : Рударско-топионичарског басена Бор, Гоше, Трепче, Енергопројекта Београд због експлоатације руде гвожђа у Замбији и Анголи, Инвест-Инпорта због експлоатација злата у Бурми, коксног угља и магнезијума у Аустралији, итд.

Аутор или коаутор је 31 научног и стручног рада, руководио је израдом 35 студија и индустријских пројеката, учествовао у истраживањима више научних пројеката, у стручним оценама (ревизијама) инвестиционе и пројектне документације. Друштвено и политички био је ангажован, обављао је функције секретара Основне организације Савеза комуниста Рударског института и Општинског комитета Савеза комуниста Земуна, био је члан Градског комитета итд. За друштвено ангажовање и остварене радне резултате носилац је више признања.

Приредио
Милинко Радосављевић

rector of the Mining Institute on January 1, 1980. He transferred to “Invest-Import” in 1988 as assistant director of engineering. Since 1993, he worked independently for mining companies in auditing, consulting, expertise, etc. Since 1996 he was a director of the board of the Canadian company “ERIN VENTURES” from Edmonton, and since 1998 he was the director of the mixed company “RAS-BORATI” formed by this Canadian company with Elektroprivreda Srbije for exploration and exploitation of pine ore in the region of Baljevac na Ibru.

As an expert, he was engaged in solving the problems of the Mining and Smelting Basin Bor, Goša, Trepča, Energoprojekt Belgrade due to the exploitation of iron ore in Zambia and Angola, Invest-Import due to the exploitation of gold in Burma, coke coal and magnesium in Australia, etc.

He is the author or co-author of 31 scientific and professional papers, he managed the preparation of 35 studies and industrial projects, participated in research of several scientific projects, in professional evaluations (audits) of investment and project documentation. He was very engaged socio-politically - he performed the functions of the secretary of the Basic Organization of the League of Communists of the Mining Institute and the Municipal Committee of the League of Communists of Zemun, he was a member of the City Committee, etc. He is the holder of several awards for social engagement and achieved work results.

Prepared by
Milinko Radosavljević

Надежда (Нада) Крстић (Ниш, 28. 02. 1934 – Београд, 18. 12. 2019), дипл. инж. геологије, магистар и доктор геолошких наука, научни саветник, палеонтолог међународног угледа. Школовала се у Нишу, Ваљеву и Обреновцу. На Групи за геологију и палеонтологију Природно-математичког факултета Универзитета у Београду дипломирала је 1957. На Рударско-геолошком факултету Универзитета у Београду одбранила је магистарску тезу 1959. а докторску дисертацију 1968. са темом *Биостратиграфија, таксономија и филогенија ципридида (остракода) из конгеријских слојева околине Београда.* Две године провела је на специјализацији и студијском усавршавању у Хамбургу, као стипендиста Фондације Александар фон Хумболт Немачке владе. Радни век провела је у Геоинституту у Београду, пензионисала се 1999.

Изузетно богата научна активност др Н. Крстић доминантно је била орјентисана на истраживања остракода. Одредила је око 250 нових врста, 20 породица и три нова рода. Аутор је више од 300 научних и стручних радова на тему остракода. Међу њеним бројним публикацијама, издајају се две монографије: *Род Цандона (Острацода) из конгеријских слојева јужног дела Панонског басена* (Српска академија наука и уметности,1972) и *Pliocene ostracods of the Paludinian beds in the Pannonian plain, Serbian par* (Природњачки музеј Београд, 2006).

Теренским истраживањима по Србији, Југославији, ев-

Nadežda (Nada) Krstić (Niš, February 28, 1934 - Belgrade, December 18, 2019), graduated geological engineer, magister and doctor of geological sciences, science advisor, a paleontologist of international repute. She attended school in Niš, Valjevo and Obrenovac. At the Group for Geology and Paleontology of the Faculty of Natural and Mathematics Sciences, University of Belgrade, she graduated in 1957. At the Faculty of Mining and Geology, University of Belgrade, she defended her magister's thesis in 1959 and her doctoral dissertation in 1968 on the topic *Biostratigraphy, Taxonomy and Phylogeny of Cypridida (Ostracoda) from Congeria beds in the vicinity of Belgrade*. She spent two years specializing and studying in Hamburg, as a scholarship holder of the Alexander von Humboldt Foundation of the German government. She spent her working life at the Geoinstitut in Belgrade, she retired in 1999.

Dr. N. Krstić's extremely rich scientific activity was predominantly oriented towards the research of ostracods. She identified about 250 new species, 20 families and three new genera. She is the author of more than 300 scientific and professional papers on the subject of ostracods. Among her numerous publications, two monographs stand out: *Candona Genus (Ostracods) from the Conger strata of the southern part of the Pannonian Basin* (Serbian Academy of Sciences and Arts, 1972) and *Pliocene ostracods of the Paludinian beds in the Pannonian plain, Serbian part* (Natural History Museum Belgrade, 2006).

She gained extremely extensive

ропским земљама, Ирану и Либији стекла је изузетно велико и богато практично искуство. Ово је значајно утицало на ширење хоризонта њеног научног и стручног интерсовања на поље палеогеографије и геотектонике Балканског полуострва.

Имала је плодну дугогодишњу сарадњу са Природњачким музејом у Београду, коме је поклонила своју палеонтолошку збирку остракода из периода Терцијера, прикупљену на подручју Балканског полуострва, централне и јужне Европе. У колекцији је преко три милиона примерака остракода. Бројним остракодама дала је научно име у част истакнутих српских научника Николе Тесле (*Cypria teslae)*, Михајла Пупина (*Qinghaicypris pupini)*, Јосифа Панчића (*Reticulocandona pancici)*, Михајла Петровића Аласа (*Caspiola alasi)* или по месту проналаска Београд (*Cyprideis singiduni)*, Беочин *(Caspiola beocini)* итд.

Активно је учествовала у раду Српског геолошког друштва (СГД), била је члан Управног одбора, а својим бројним саопштењима и публиковањем резултата истраживања у Записницима СГД-а пружала је подршку чувању традиције и угледу СГД. Учествовала је у припремама и организацији бројнх научних и стручних скупова, геолошких конгреса и других стручних манифестација. Под окриљем САНУ 1979. организовала је 7. Међународни симпозијум о остракодама и уредила Зборника радова са овог научног скупа у издању СГД.

and rich practical experience through field research in Serbia, Yugoslavia, European countries, Iran and Libya. This significantly influenced the expansion of the horizon of her scientific and professional interest in the field of paleogeography and geotectonics of the Balkan Peninsula.

She had a fruitful long-term cooperation with the Natural History Museum in Belgrade, to which she donated her paleontological collection of ostracods from the Tertiary period, collected in the Balkans, Central and Southern Europe. Over three million specimens of Tertiary ostracods are kept within the collection. She gave a scientific name to numerous ostracods in honor of prominent Serbian scientists Nikola Tesla (*Cypria teslae*), Mihajlo Pupin (*Qinghaicypris pupini*), Josif Pančić (*Reticulocandona pancici*), Mihajlo Petrović Alas (*Caspiola alasi*) or by the location of the invention Belgrade (*Cyprideis singiduni*), Beočin (*Caspiola beocini*), etc.

She actively participated in the work of the Serbian Geological Society (SGS), she was a member of the Board of Directors, and she supported the preservation of the tradition and reputation of SGS with her numerous announcements and publication of research results in the SGS's Minutes. She participated in the preparations and organization of numerous scientific and professional conferences, geological congresses and other professional events. She organized the 7th International Symposium on Ostracods in 1979 under the auspices of Serbian Academy of Sciences and Arts and edited the Proceedings from this scientific conference, which was published by SGS.

Запаженим ангажовањем и иступањима на међународним научним скуповима као што је нпр. UNESCO International Geological Correlation Program, у оквиру кога је руководила Пројектом 329 Neogene of Paratethys и уредила монографију *Neogene of Central Serbia* (Геоинститут, Београд, 1996), афирмативно је утицала и допринела ширењу међународног угледа српске геолошке школе и науке.

Носилац је бројних признања за доприносе и резултате у науци, међу којима је и Повеља Српског геолошког друштва 2015. Према WorldCat Identities њена 32 рада у 44 публикације на 4 језика чува се у 77 библиотечких фондова.

Приредила
Светлана Полавдер

She affirmatively influenced and contributed to the spread of international reputation of Serbian geological school and science through her notable engagement and appearances at international scientific conferences such as the UNESCO International Geological Correlation Program, within which she led the Project 329, Neogene of Paratethys, and edited the monograph *Neogene of Central Serbia* (Geoinstitut, Belgrade, 1996).

She is the holder of numerous awards for scientific contributions and results, among which is the Charter of the Serbian Geological Society in 2015. According to WorldCat Identities, her 32 papers, in 44 publications, in 4 languages, are kept in 77 library funds.

Prepared by
Svetlana Polavder

Радомир Митић (Блендија, Сокобања, 02. 03. 1930 – Београд, 27. 05. 2020), дипл. инж. рударства, магистар и доктор техничких наука, истакнути рударски стручњак, редовни члан Инжењерске академије Србије. Студије рударства завршио је 1955. на Рударско – гелошком факултету Универзитета у Београду. На матичном факултету магистарске студије завршио је 1978. а докторску дисертацију одбранио 1981. Специјализирао је израду подземних рударских и других објеката у Великој Британији у компанији Cementation Mining Ltd.

Радио је на оперативним и руководним инжењерским пословима у Руднику мрког угља Соко, Читлук, у Тимоч-

Radomir Mitić (Blendija, Sokobanja, March 2, 1930 - Belgrade, May 27, 2020), graduated mining engineer, magister and doctor of technical sciences, prominent mining expert, regular member of the Engineering Academy of Serbia. He completed his studies of mining in 1955 at the Faculty of Mining and Geology, University of Belgrade. He completed his magister's degree studies at the home faculty in 1978, and defended his doctoral dissertation in 1981. He specialized in the construction of underground mining and other facilities in the UK at Cementation Mining Ltd.

He performed operational and managerial engineering jobs at the Brown Coal Mine Soko, Čitluk, at the Timok Coal Mines, at the 14 October Industry in ким рудницима угља, Индустрији 14. октобар у Крушевцу, у Пословном удружењу Румаг, у предузећу Југофунд, извесно време у британској компанији Cementation Mining Ltd., у Словеначкој пословној заједници Рудис - Трбовље (представништво у Београду) и у Ирану као директор тамошње компаније. Учествовао је у планирању, пројектовању, отварању и изградњи више рудника, подземних рударских и других објеката широм и ван земље. За доцента у хонорарном односу за предмет Организација градилишта у рударству биран је 1981. на Рударско - геолошком факултету Универзитета у Београду. Пензионисан је на лични захтев 1991.

Аутор или коаутор је бројних научних и стручних радова, претежно на теме конструкције и изградње подземних рудничких и других објеката. Као члан уредничког колегијума задужен за рударске радове и рудничке несреће, значајан допринос дао је вишегодишњем прикупљању грађе, припреми и писању монографије *Српско рударство и геологија у другој половини XX века* (Београд, 2014).

За научне и стручне доприносе носилац је више признања, међу којим се истиче Повеља проф. др Димитрије Антула за врхунска инжењерска остварења у рударству Академије инжењерских наука Србије, 2015. Био је редовни члан и секретар Одељења за рударство и геологију Инжењерске академије Србије и члан више стручних асоцијација и удржења.

Приредио
Слободан Вујић

Kruševac, at the Business Association Rumag, at the Jugofund company Belgrade, at the British company Cementation Mining Ltd. for some time, at the Slovenian business community Rudis - Trbovlje (branch office in Belgrade) and in Iran as a director of the company. He participated in the planning, designing, opening and construction of several mines, underground mining and other facilities across and outside the country.

He was elected a part-time docent for the subject *Organization of construction sites in mining* in 1981 at the Faculty of Mining and Geology, University of Belgrade. He retired at his own request in 1991.

He is the author or co-author of numerous scientific and professional papers, mainly on the topics of construction and building of underground mining and other facilities. As a member of the editorial board in charge of mining works and mining accidents, he made a significant contribution to the long-term collection of material, preparation and writing of the monograph *Serbian mining and geology in the second half of the twentieth century* (Belgrade, 2014).

He is the holder of several awards for scientific and professional contributions, among which the Charter of Prof. Dr. Dimitrije Antula for top engineering achievements in mining of the Academy of Engineering Sciences of Serbia in 2015 stands out. He was a regular member and secretary of the Department of Mining and Geology of the Engineering Academy of Serbia and a member of several professional associations and organizations.

Prepared by
Slobodan Vujić

Светозар Ковачевић (Призрен, 24. 02. 1939 – Београд, 12. 06. 2009), дипл. инж. рударства, доктор техничких наука, универзитетски професор, истакнути рударски стручњак, почасни члан Инжењерске академије наука Србије и Црне Горе. Основно и средњошколско образовање стекао је у Бачком Брестовцу и Сомбору. Студије рударства завршио је на Рударско-геолошком факултету Универзитета у Београду 1962. Докторску дисертацију на тему *Допринос теорији прорачуна капацитета површинских копова лигнита у зависности од геолошких, рударско-технолошких и економских услова* одбранио је на матичном факултету 1989. Студијски је боравио у рудницима Немачке, Пољске, Грчке, Русије, Украјине, Турске и Бугарске.

На Рударско-металуршком факултету у Косовској Митровици Универзитета у Приштини, 1998. изабран је за редовног професора за предмет *Организација и економика производње у рударству.*

Инжењерско искуство почео је да стиче у рудницима угља са подземном експлоатацијом у Костолцу и Бановићима, наставио у рудницим магнезита Магнохрома из Краљева. Пуну стручну афирмацију стекао је у Рударском басену Колубара на пословима: управник рудника, главни инжењер рудника, директор Колубаре пројект, технички директор Комбината, помоћник генералног директора за развој Комбината и заменик директора Дирекције за производњу угља Електропривреде Србије. Припада

Svetozar Kovačević (Prizren, February 24, 1939 - Belgrade, June 12, 2009), graduated mining engineer, doctor of technical sciences, university professor, prominent mining expert, honorary member of the Engineering Academy of Sciences of Serbia and Montenegro. He acquired his elementary and high-school education in Bački Brestovac and Sombor. He completed his studies of mining at the Faculty of Mining and Geology, University of Belgrade in 1962. He defended his doctoral dissertation at the home faculty in 1989, with the topic *Contribution to the theory of capacity calculation of open-pit lignite mines depending on geological, mining-technological and economic conditions*. He spent time on studying basis in the mines of Germany, Poland, Greece, Russia, Ukraine, Turkey and Bulgaria.

He was elected full professor at the Faculty of Mining and Metallurgy in Kosovska Mitrovica, University of Priština, in 1998 for the subject *Organization and Economics of Production in Mining*.

He began to gain engineering experience in coal mines with underground exploitation in Kostolac and Banovići, and continued in the magnesite mines of Magnohrom from Kraljevo. He gained full professional affirmation in the Kolubara Mining Basin in the following jobs: mine manager, chief mine engineer, director of the Kolubara project, technical director of the Combine, assistant general director for development of the Combine and deputy director of the Coal Production Directorate of Elektroprivreda Srbije. He belonged to a pioneering group of mining engineers who laid the foundations for the development of the пионирској групи рударских инжењера који су поставили основе развоја Рударско-енергетског комбината Колубара. Учествовао је или руководио израдом пројеката различитих нивоа површинске експлоатације угља у Колубарском, Костолачком, Косовском, Пљеваљском, Угљевичком, Гатачком и Битољском басену. Руководио је израдом инвестиционих програма за површинске копове Поље Д и Тамнава западно поље Колубаре.

У време НАТО агресије и ратних дејстава 1999, искуством, знањем и храброшћу, у изузетно сложеним и тешким условима, успешно је организовао и руководио производњом угља на површинским коповима Белаћевац и Добро Село Косовског басена.

Аутор или коаутор је бројних научних и стручних радова, најбројније из површинске експлоатације угља. Коаутор је универзитетског уџбеника *Организација производње у рударству* (Рударско-геолошки факултет Београд, 1994). Запажена излагања имао је на Светском рударском конгресу у Стокхолму и на међународној конференцији о угљу у Питсбургу. Учествовао је у организацији бројних научних и стручних скупова.

За научне и стручне доприносе лауреат је више признања и награда: Орден рада са сребрним венцем СФРЈ, Повеља Проф. др Бранислав Миловановић – за научни рад, Плакета Комбината Колубара - за доприносе и изузетно залагање на изградњи Комбината итд.

Заслужни је члан Савеза инжењера рударске, геолошке и металуршке струке Југосла-

Kolubara Mining and Energy Combine. He participated in or led the development of projects of different levels of surface coal exploitation in the Kolubara, Kostolac, Kosovo, Pljevlja, Ugljevik, Gacko and Bitola basins. He led the development of investment programs for the open-pit mines Polje D and Tamnava west field of Kolubara.

He successfully organized and managed the production of coal at the open-pit mines Belaćevac and Dobro Selo in the Kosovo basin, with his experience, knowledge and courage, in extremely complex and difficult conditions during the NATO aggression and war actions in 1999. He is the author or co-author of numerous scientific and professional papers, most of them in the field of surface coal mining. He is the co-author of the university textbook titled *Organization of Production in Mining* (Faculty of Mining and Geology, Belgrade, 1994). He had notable presentations at the World Mining Congress in Stockholm and at the International Coal Conference in Pittsburgh. He participated in the organization of numerous scientific and professional conferences.

He was a laureate of several recognitions and awards for scientific and professional contributions: Order of Labour with a Silver Wreath of the SFRY, Charter of Prof. Dr. Branislav Milovanović - for scientific work, Plaque of the Kolubara Combine - for contributions and exceptional commitment in the construction of the Combine, etc. He was an honorary member of the Association of Engineers of Mining, Geological and Metallurgical Professions of Yugoslavia, a regular member вије, редовни члан Међународне академије наука о екологији и заштити животне средине и почасни члан Академије инжењерских наука Србије и Црне Горе.

Приредио
Слободан Вујић

of the International Academy of Sciences on Ecology and Environmental Protection and an honorary member of the Academy of Engineering Sciences of Serbia and Montenegro.

Prepared by
Slobodan Vujić

Драгомир Коцић (Ниш, 18. 07. 1938 - Београд, 18. 06. 1994) дипломирани машински инжењер, магистар и доктор техничких наука, редовни професор Универзитета у Београду, један од иницијатора аутоматизације рудника са подземном експлоатацијом у Југославији. Школовао се у родном граду. Дипломирао је на Машинском факултету (МФ) 1965. а магистрирао 1973. на Електротехничком факултету Универзитета у Београду. Докторску дисертацију са темом из области аутоматизације вентилационих процеса у рудницима, одбранио је на Рударско-геолошком факултету (РГФ) Универзитета у Београду 1975. Стручно се усавршавао и специјализирао у САД, Канади, Француској и Пољској.

Радну каријеру започео је у Машинској индустрији у Нишу, наставио у конструкционом бироу овог предузећа у Београду. За асистента за предмет *Аутоматизација у рударству* на РГФ-у изабран је 1966, а за редовног професора 1988. На редовним студијама држао је наставу и из предмета *Машински елементи, Основи конструисања и Клипни компресори*, а на последипломским студијама *Аутоматизацију и управљање процесима*

Dragomir Kocić (Niš, July 18, 1938 - Belgrade, June 18, 1994) graduated mechanical engineering, magister and doctor of technical sciences, full professor at the University of Belgrade, one of the initiators of the automation of mines with underground exploitation in Yugoslavia. He was educated in his hometown. He graduated from the Faculty of Mechanical Engineering (FME) in 1965 and acquired his master's degree in 1973 from the Faculty of Electrical Engineering, University of Belgrade. He defended his doctoral dissertation on the topic of automation of ventilation processes in mines at the Faculty of Mining and Geology (FMG), University of Belgrade in 1975. He perfected and specialized in the USA, Canada, France and Poland.

He started his working career in the Mechanical Industry in Niš, and continued in the construction bureau of this company in Belgrade. He was elected an assistant for the subject *Automation in Mining* at FMG in 1966, and a full professor in 1988. In full-time studies, he also taught *Mechanical Elements, Fundamentals of Construction* and *Reciprocating Compressors*, and in postgraduate studies he taught *Automation and Process Management* and *Automation*. He taught at the FME in Belgrade and

и *Аутоматизацију*. Држао је наставу на МФ у Београду и на Рударском факултету у Тузли на последипломским студијама, за те потребе написао је уџбеник. Био је дугогодишњи сарадник Рударског института Београд, Института Електронске индустрије у Нишу и Угаљпројекта у Београду.
Аутор или коаутор је 50 научних и стручних радова. Учествовао је или руководио истраживањима на научним пројектима и у изради и ревизијама инвестиционо-пројектне докуметације. Аутор је више студија и пројеката из области даљинске контроле вентилационих, гасних и пожарних параметара у рудницима са подземном експлоатацијом угља. Заједно са Весном Јовичић, Вуком Радевићем и Слободаном Вујићем утицао је и допринео великом искораку у опремању и унапређењу наставе и научног рад на Рударском одсеку РГФ-а, овладавањем и увођењем у примену 1970. аналогне рачунарске технике, односно аналогног рачунара ТАРА-50.
Несебичним ангажовањем и конструктивним креативним односом активно је доприносио унапређењу рада РГФ-а и шире. Био је шеф Катедре за опште машинство и термодинамику, заменик руководиоца Рударског одсека, продекан факултета, члан Већа и Савета факултета, члан комисија и радних тела на Факултету и Универзитету. Био је секретар Стамбене задруге Универзитета у Београду, председник Секције за аутоматско управљање у рударству САУМ-а, итд. Организатор и учесник је бројних научних и стручних

at the Faculty of Mining in Tuzla in postgraduate studies, for which purpose he wrote a textbook. He was a long-term associate of the Mining Institute Belgrade, the Institute of Electronics Industry in Niš and Ugaljprojekt in Belgrade.
He is the author or co-author of 50 scientific and professional papers. He participated in, or led research on scientific projects, and in the preparation and revision of investment and project documentation. He is the author of several studies and projects in the field of remote control of ventilation, gas and fire parameters in mines with underground coal exploitation. Together with Vesna Jovičić, Vuk Radević and Slobodan Vujić, he influenced and contributed to a great step forward in equipping and improving teaching and scientific work at the Mining Department FMG , by mastering and introducing in 1970 the application of analogue computer technology, that is, the analogue computer TARA-50.
He actively contributed to the improvement of the work of the FMG and beyond with his selfless engagement and constructive creative attitude. He was the head of the Department of General Mechanical Engineering and Thermodynamics, deputy head of the Mining Department, vice dean of the faculty, member of the Faculty Assembly and Council, member of commissions and working bodies at the Faculty and the University. He was the secretary of the Housing Cooperative of the University of Belgrade, the president of the Section for Automatic Management in Mining of SAUM, etc. He is the organizer and partici-

скупова и семинара.
За резултате у науци и инжењерству лауреат је Октобарске награде града Ниша 1985. и Првомајске награде Рударског института Београд - два пута.

Приредио
Милош Танасијевић

pant of numerous scientific and professional conferences and seminars.
For results in science and engineering, he was a laureate of the October Award of the City of Niš in 1985 and twice of the First of May Award of the Mining Institute Belgrade.

Prepared by
Miloš Tanasijević

Драган Половина (Ниш, 02. 04. 1956 – Београд, 07. 05. 2019), дипл. инж. рударства, магистар и доктор техничких наука, научни сарадник. Школовао се у родном граду. Студије рударства завршио је 1981. на Рударско - геолошком факултету Универзитета у Београду на Смеру за механизацију. На матичном факултету магистарску тезу одбранио је 1999. а докторску дисертацију 2011. Научно звање научни сарадник стекао је 2013. Радну каријеру започео је у Руднику мрког угља РЕМБАС Ресавица. После извесног времена прешао је да ради у Рударски басен Колубара, на пословима: руководилац одржавања тракчних транспортера, 1984-1990. и управник машинске службе одржавања. У дирекцију Електропривреде Србије (ЕПС) у Београду прелази 1997. где је радио на аналитичким, оперативним и руководним задацима до позиције директора Сектора за одржавање и накнадна улагања у рударске капацитете ЕПС-а. Аутор или коаутор је 25 научних и стручних радова, сарађивао је у изради бројне студијске, пројектне, инвестиционе и друге техничко-технолошке

Dragan Polovina (Niš, April 2, 1956 - Belgrade, May 7, 2019), graduated mining engineer, magister and doctor of technical sciences, research associate. He was educated in his hometown. He completed his studies of mining in 1981 at the Faculty of Mining and Geology, University of Belgrade, Department of Mechanization. He defended his magister's thesis at his home faculty in 1999, and his doctoral dissertation in 2011. He gained the scientific title of Research Associate in 2013. He started his working career at the brown coal mine REMBAS in Resavica. After some time, he moved to work at the Kolubara Mining Basin, on the following jobs: head of maintenance of belt conveyors 1984-1990, and manager of the machine maintenance service. He transferred to the Directorate of Electric Power Industry of Serbia (EPS) in Belgrade in 1997, where he performed analytical, operational and managerial tasks until he gained the position of Director of the Sector for Maintenance and Subsequent Investments in Mining Capacities of EPS. He is the author or co-author of 25 scientific and professional papers, he has collaborated in the preparation of numerous study, project, investment and документације и у истраживањима више иновативних и развојних пројеката. Допринео је међународној сарадњи ЕПС-а радећи на пројектима донација ЕУ, уговарања рударске опреме и машина са Пољском, на пројектима KFB и EBRD итд. Био је ангажован у изради прописа за рударство, а као члан радне групе Привредне коморе Србије учествовао је у анализи и оцени могућности супституције рудничке опреме иностраних произвођача опремом домаће производње. Био је члан организационих тела више домаћих и међународних научних и стручних скупова.

Родољубље, енергију, стручност, достојанство и храброст испољио је као члан инжењерског тима Дирекције за производњу угља ЕПС-а у време изолације, санкција и других бројних проблема наметнутих Србији. Захваљујући инжењерском тиму, делу запослених у Косовским рудницима, оперативном особљу из Колубаре, Костолца, Гоше и других предузећа, рударско – електроенергетски систем Косова одржан је у функцији све до НАТО агресије и окупације Косова и Метохије.

Приредио
Светомир Максимовић

other technical and technological documentation and in the research of several innovative and development projects. He contributed to the international cooperation of EPS by working on the EU donation projects, by contracting of mining equipment and machines with Poland, by working on projects of KFB and EBRD, etc. He was engaged in drafting regulations for mining, and as a member of the working group of the Serbian Chamber of Commerce, he participated in the analysis and evaluation of the possibility of substituting mining equipment of foreign manufacturers with equipment of domestic production. He was a member of the organizational bodies of several domestic and international scientific and professional conferences.

He showed patriotism, energy, expertise, dignity and courage as a member of the engineering team of the Coal Production Directorate of EPS during the isolation, sanctions and other numerous problems imposed on Serbia. Thanks to the engineering team, part of the employees in the Kosovo mines, operational staff from Kolubara, Kostolac, Goša and other companies, the mining and electric power system of Kosovo was maintained in function until the NATO aggression and occupation of Kosovo and Metohija.

Prepared by
Svetomir Maksimović

Саша Митић (Београд, 07. 05. 1967 – 11. 09. 2020), дипл. инж. рударства, магистар техничких наука, виши стручни сарадник Рударског института. Школовао се у родном граду. На Смеру за подземну експлоатацију Рударско-геолошком факултету Универзитета у Београду дипломирао је 1996. Последипломске студије завршио је 2007. на Катедри за рударске радове и израду подземних просторија матичног факултета са темом тезе „Оптимизација појединих циклуса рада код израде подземних просторија у чврстој радној средини". Од 1996. радио је у Рударском институту Београд у Заводу за пројектовање експлоатације лежишта као пројектант за подземну експлоатацију и подземне радове.

Аутор или коаутор је 22 публикована научна и стручна рада. Учествовао је у реализацији три научна пројекта Министарства просвете, науке и технолошког развоја. Био је сарадник, одговорни или главни пројектант на изради више десетина привредних пројеката, инвестиционих програма, студија, експертиза и ревизија пре свега из подземне експлоатације металичних минералних сировина и подземних радова.

Приредили
Ненад Макар
и Светлана Шакић

Saša Mitić (Belgrade, May 7, 1967 - September 11, 2020), graduated mining engineer, magister of technical sciences, senior expert associate of the Mining Institute. He was educated in his hometown. He graduated from the Department of Underground Exploitation at the Faculty of Mining and Geology, University of Belgrade in 1996. He completed his magister's studies in 2007 at the Department of Mining and Construction of Underground Premises at the home faculty with the thesis titled "Optimization of individual work cycles in the construction of underground premises in a solid working environment". Since 1996, he has worked at the Mining Institute Belgrade in the Institute for the Design of Reserve Exploitation as a designer for underground exploitation and underground works.

He is the author or co-author of 22 published scientific and professional papers. He participated in the realization of three scientific projects of the Ministry of Education, Science and Technological Development. He was an associate, responsible or chief designer in the development of dozens of economic projects, investment programs, studies, expertise and audits, primarily in the field of the underground exploitation of metallic mineral raw materials and underground works.

Prepared by
Nenad Makar
and Svetlana Šakić

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