B&H Electrical Engineering Volume 15 January/December 2021 71-77

sciendo DOI: 10.2478/bhee-2021-0020

Professional paper/Stručni rad

ON-SITE SAFETY-VALVES TESTING IN THERMAL POWER PLANTS

ON-SITE ISPITIVANJE SIGURNOSNIH VENTILA U TERMOENERGETSKIM POSTROJENJIMA

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Abstract: The paper describes the function and importance of safety devices on pressure equipment, legal regulations for the necessary scope and periods of functional inspections of safety valves in thermal power plants. The mode of operation of the apparatus for in-site testing and adjustment of safety valves on pressure vessels is described, as well as a comparative presentation of the obtained test results compared to the results obtained by the conventional method that uses hydraulic pressure of the medium for valve spring load. The on-site method uses a motor drive to load the valve spring, and uses sensitive displacement, force and sound sensors to generate signals, which are processed in a suitable software application to obtain test results. Unlike the conventional method, the on-site method allows testing of safety valves without their disassembly from the installation site. A comparison of the test results obtained by the modern method with the test results by the conventional method was made on several safety valves. It has been shown that in addition to better precision, which is important for valves with lower operating pressures, the application of the on-site method shortens the test time several times.

Keywords: on-site testing, pressure equipment, opening pressure, software tools

Sažetak: U radu je opisana je funkcija i važnost sigurnosnih uređaja na opremi pod pritiskom, zakonska regulativa za neophodnim obimom i periodima funkcionalnih provjera sigurnosnih ventila u termoenergetskim postrojenjima. Opisan je način funkcioniranja aparature za in-site ispitivanje i podešenje sigurnosnih ventila na posudama pod pritiskom, kao i usporedni prikaz dobijenih rezultata testiranja spram rezultata dobijenih konvencionalnom metodom testiranja koja za podešenje koristi hidraulički pritisak medija za opterećenje opruge ventila. On-site metoda koristi motorni pogon za opterećenje opruge ventila, a osjetljive senzore pomaka, sile i zvuka koristi za generisanje signala, čijom se obradom u podesnoj softverskoj aplikaciji dobiju rezultati testa. Za razliku od konvencionalne, on-site metoda omogućuje testiranje sigurnosnih ventila bez njihove demontaže sa mjesta ugradnje. Na nekoliko sigurnosnih ventila napravljena je uporedba rezultata testiranja dobijenih savremenom metodom sa rezultatima ispitivanja konvencionalnom metodom. Pokazalo se da je osim bolje preciznosti, što je važno kod ventila sa nižim radnim pritiscima, primjena on-site metode nekoliko puta skraćuje vrijeme testiranja.

Ključne riječi: on-site ispitivanje, oprema pod pritiskom, pritisak otvaranja, softverski alati

INTRODUCTION

The pressure vessel by definition is a closed space, which is designed and constructed with the intention of being filled with pressurized fluid and is a part of the process equipment system in the plant. These are usually some vessels (tanks), pipelines and devices that are under pressure. Pressure equipment must be equipped with safety devices that will release excess pressure inside the vessel, in order to prevent its damage.

The function of the safety device can be performed by devices for direct pressure relief (safety valves), devices with safety membrane, deformation rods, systems for controlled pressure reduction, pressure limiting devices that activate control, shutdown or blocking elements such as pressure switches, thermostats and pressure level regulators. Safety valves are most often used to protect pressure vessels, which are selected according to the operating parameters of the plant and the type of working medium. As a rule, safety valves are placed high on the pressure vessel and are secured against clogging due to dirt in the medium. If such a position is not achievable due to the construction of the vessel or due to operating conditions, safety valves may be located in the immediate vicinity of the vessel - on a pipeline or a special branch, but so that there is no closing device between the valve and the vessel. The safety valves are adjusted so that they react, i.e. open and relieve the pressure vessel only when the maximum allowable working pressure is exceeded. The maximum allowable pressure is the maximum design pressure of the pressure equipment, and to which, accordingly, it

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Paper submitted: September 2021 Paper accepted: October 2021

may be exposed under operating conditions. When all control devices fail, the safety valve is the last device that must release excess pressure and thus protect the protected equipment, [1], [2]. Therefore, safety valves must be maintained and periodically tested to ensure their reliable operation. Particular attention must be paid to the maintenance of safety valves and parts whose operation may be compromised by dirt in the working medium.

Periodic control of correctness and adjustment of safety valves is performed at intervals specified in the technical instructions of the manufacturer or recommendations of technical regulations, depending on the type, class and purpose of the pressure vessel, at least once a year, which is recorded, [3], [4].

1. CONVENTIONAL METHOD OF TESTING SAFETY VALVES

The process industry is characterized by a large number of pressure equipment. Thus, thermal power plants are also equipped with dozens of vessels of different working pressure. Each of the pressure vessels is protected by a safety valve, so a large number of tests are required each year.

Conventional test bench methods that require valve disassembly are still used to test safety valves in some conditions. The results of these methods are also recognized and acceptable as inspection data sheets. Conventional methods for testing safety valves have been developed and improved, from those devices with manual hydraulic pressure generation of the test medium, to semi-automatic test benches.

A schematic representation of the conventional method is shown in Figure 1. By raising the pressure inside the tested vessel, it is monitored with an analogue manometer and/or digital instrument via a measuring transmitter, the pressure of opening the safety valve is read.

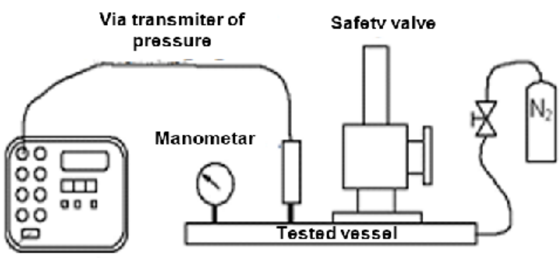

Figure 1: Conventional method of testing safety valves

2. ON-SITE METHOD OF TESTING SAFETY VALVES

Today, the on-site method of testing safety valves, which is based on the application of software tools and sensitive electronic measuring sensors, is increasingly in use. This method is applicable directly to the installation position of the valve, without its disassembly and interruption of the plant, which is the main advantage over the conventional method. The components of the device for such tests can function smoothly and safely in the working conditions of the test facility, i.e. withstand the temperature of the medium and temperature of the environment, maintain the circulation of the medium through the test valve and work in noisy and dusty conditions.

On-site method of testing safety valves used worldwide in different industries, schematic is shown in Figure 2. The development of the on-site method of testing safety valves has just emerged from the practice of applying the conventional method, and after recognizing the disadvantages, its improvement by applying software tools. [5].

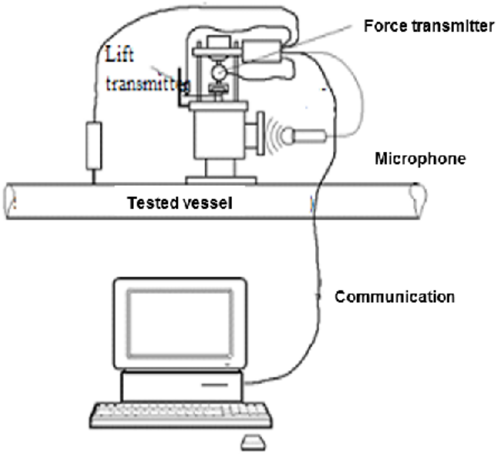

Figure 2: On-site method of testing safety valves

The test device uses a motor drive to open the valve by pulling the spindle. Force, pressure, lift and acoustic sensors send a signal to the data acquisition unit. The main difference between these methods, the on-site safety testing method allows testing of safety valves at their location in the plant without dismantling or removing from their system. Also, in this case, the difference is that the on-site method uses a motor drive to move the spindle of the tested valve as opposed to the conventional method which is based on hydraulic pressure, which makes it more accurate.

The principle of operation of the test device is based on the fact that the spindle of the tested safety valve is gradually raised by means of a motor jack, and in order to determine the set pressure - shown in Figure 3 as the value L. The force sensor measures the force required to lift the safety valve spindle, [6].

The valve spindle is, in order to determine the set pressure, raised minimally with a motor lifting rig. The installed force sensor is, together with the travel and/or acoustic sensor (microphone), recording the force required to lift the valve. The movement of the valve spindle is simultaneously measured parallel to the force, along with the progress of the process pressure and the acoustic level at the safety valves.

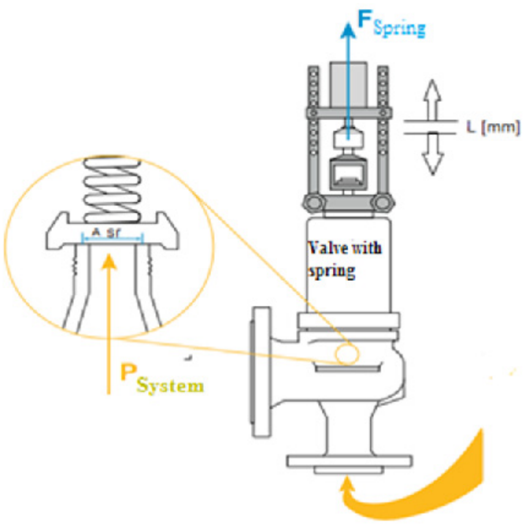

Figure 3: Illustration of the operation

Calculates the set pressure using the following formula:

$$P_{set} = \frac{F}{A_S} + P_{sys}$$

where is:

P_{set} - Safety valve set pressure (Pa)
F - Hydraulic force at set pressure point (N)
A_S - Active valve seat area (m^2)
P_{sys} - System pressure at set pressure point (Pa)

Considering the formula, the safety valves seat diameter and seat geometry will influence the on-site test result accuracy as much as the system pressure during the test.

Graphic evaluation of the force, pressure, lift and acoustic signal characteristic curve enables one to unequivocally identify the set point (i.e. the moment in which the valve disk commences to lift). Figure 4 is an example of a diagram showing the test values of a safety valve.

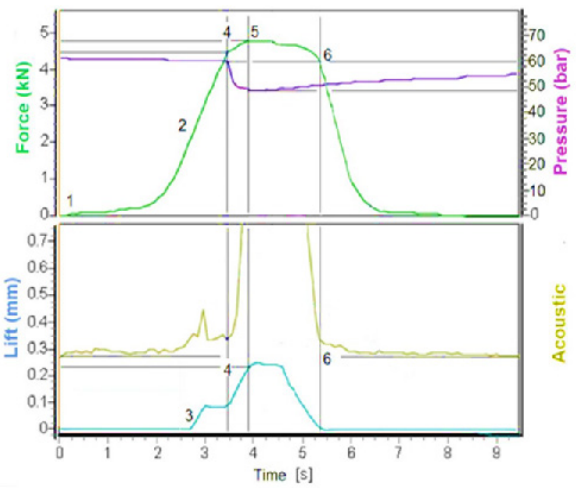

Figure 4: Test diagram of on site tested valve

This diagram shows four curves in different colours that represent sensor signals:

Green = spring compression force
Purple = system pressure
Blue = lift spindle
Yellow = acoustic signal

On the curves of the graphical display of the results generated in the software tool, the following characteristic points of certain phases of events in the valve during the test are recognized:

1 – Start of test
2 – Valve spring compression phase
3 – Spindle displacement due to the influence of valve spring operation
4 – Valve opening point: the moment at which the valve disc begins to rise (displacement is also visible on the displacement diagram - 'Lift'), the valve opens and the medium begins to circulate, and the level of acoustic signal generated by vibrations in the spring begins to decline.
5 – Maximum spindle displacement: the point at which the test drive motor rotates the valve spindle and it begins to lower the disc
6 – Valve closing point (relevant only in the case of hot test). The valve disk sits on the valve seat.
Points like the set pressure point are picked from the diagram by using markers operated, [7].

The on-site method for testing safety valve meets the requirements of international standards (ISO, EN) used to test pressure equipment. Also, the method and test equipment meets the requirements for testing and calibration specified in PED 97/23 EC - Pressure Equipment Directive and reference European standards, defining requirements for test equipment and requirements for test methods in the field of safety equipment [8].

3. COMPARISON OF METHODS

Thermal Power Plant (TPP) Kakanj procured equipment for on-site testing safety valve and trained its employees, so now the testing of all safety valves is carried out by the on-site method.

To compare the test costs and the number of staff involved in the application of these methods, tests of 30 safety valves, of different dimensions and pressures, were taken as a sample. A comparison is given in Table I.

It is important to note that the same valves were tested by different methods, in order for the analysis to give more reliable and accurate results. The conventional test method has lower accuracy of measuring test quantities and lower control of the test process. This requires the need to correct the set pressure in order to meet the regulations and tolerances according to the standard on Safety devices for protection against excessive pressure BAS EN ISO 4126-1: 2014, [9].

Table I: Comparison of test costs and the number of staff involved for testing safety valves

	CONVENTIONAL METHOD	ON-SITE METHOD
Testing device	Assembled hand-held devices adapted for the purpose of testing safety valves in the workshop, with manual pressure measurement, were used. A device for measuring hydraulic pressure on the principle of a water pump is used for valves of lower test pressure, and a device with a motor pump is used for valves of higher pressure.	Testing of safety valves was done at the installation site with apparatuses for on-site testing, and two modes tests were performed: without system pressure - cold test, and with system pressure - hot test.
Testing activities	✓ Cutting of welded valves or disassembly of flange bolts, ✓ Cleaning of connecting surfaces, ✓ Mounting the valve on the test bench, ✓ Testing safety valves, ✓ Disassembly of the valve from the test bench, adjustment of the valve, reassembly and testing (activity as required), ✓ Preparation and replacement of sealing material, ✓ Reassembly (welding with frequent need for additional time due to thermal preparation, welding material and other material or clamping flanges with screws).	✓ Mounting test device on the valve, ✓ On site testing safety valve, ✓ Disassembly of the test device from the valve.
Working time	Testing 30 valves: 3 worker x 20 WH.	Testing 30 valves: 3 worker x 4 WH.
Additional costs	Additional costs were: sealing material and welding material.	There were no additional costs.
Accuracy of testing	This method is characterized by lower accuracy, control and protection of the testing process. The lower accuracy results from the manual monitoring of the set (opening) pressure, i.e. the physical reading of the working staff from the manometers, where the hydraulic drive in particular has no control and protection against system overload.	The motor drive has better dynamic properties that allow good control of traction and there is no possibility of error in determining the set pressure of the safety valve. Also, the use of a motor drive provides protection of the system from overload in such a way that the maximum traction force of the motor is limited by the regulation of the load current.

In Table II a comparative presentation of test results for six valves on Unit 7 (230 MW) in TPP Kakanj is given. The results are presented for the 3 mentioned valves, in which the need for correction of the set pressure after the application of the online method was indicated, and 3 valves in which the adjustment of the set pressure by the conventional method gave a result in the allowed adjustment interval.

For the analysis and argumentation of the accuracy and more reliable control of the safety valve testing process when comparing these test methods, one of the three valves listed in Table II was analysed, which indicated the need to correct the set pressure.

The safety spring valve (the valve manufacturer is Severočeška armaturka - SČA) which is on a Low Pressure Heater 3 (LPH3) on Unit 7, was analysed, where the set pressure was corrected according to the on-site method. According to the manufacturer's documentation, the working pressure of the vessel is 4 bar (400 kPa) and the test pressure of the safety valve is 4.6 bar (460 kPa). According to the standard for safety devices for overpressure protection, the tolerance for setting the opening pressure is ± 0.138 bar, [9].

This safety valve was first tested by the conventional method. A test bench with a hand pump was used, where the pressure was adjusted to 4.6 bar. Subsequent verification of this test, using the software

Table II. Pressure test results of different safety valve testing methods

Installation position	Test pressure and limits according to EN ISO 4126-1:2013		Pressure test results (bar)		Evaluation of results
			Conventional method	**On-site method**	
Low pressure heater LPH2	**1.5 bar**		**1.55**	**1.55**	Correctly set with both methods
	Upper limit	1.6			
	Lower limit	1.4			
Low pressure heater LPH3	**4.6 bar**		**4.82**	**4.65**	Correction of valve set pressure according to on site method
	Upper limit	4.738			
	Lower limit	4.462			
Low pressure heater LPH4	**6.6 bar**		**6.50**	**6.55**	Correctly set with both methods
	Upper limit	6.798			
	Lower limit	6.402			
Feed-water heater	**7.9 bar**		**8.20**	**8.10**	Correction of valve set pressure according to on site method
	Upper limit	8.137			
	Lower limit	7.663			
High pressure heater HPH1	**17.6 bar**		**17.00**	**18.00**	Correction of valve set pressure according to on site method
	Upper limit	18.128			
	Lower limit	17.072			
High pressure heater HPH2	**44.0 bar**		**44.50**	**44.50**	Correctly set with both methods
	Upper limit	45.32			
	Lower limit	42.68			

of the on-site method, found that the valve was set at a pressure of 4.82 bar. The same valve was tested by the on-site method, which, using software that has an integrated and tolerant interval for each value, does not allow the occurrence of an error that occurred with the conventional method, or warns that the test is not performed correctly. From the test report (Figure 5), it can be seen that the actual value of the setting pressure is 4.65 bar. A very similar situation was found and adjustment was made to two more valves, with the results marked in red in Table II. In this case, the pressure setting error made is + 0.170 bar and is higher than the allowed tolerance. There is a real possibility that in the same way a significantly larger pressure deviation

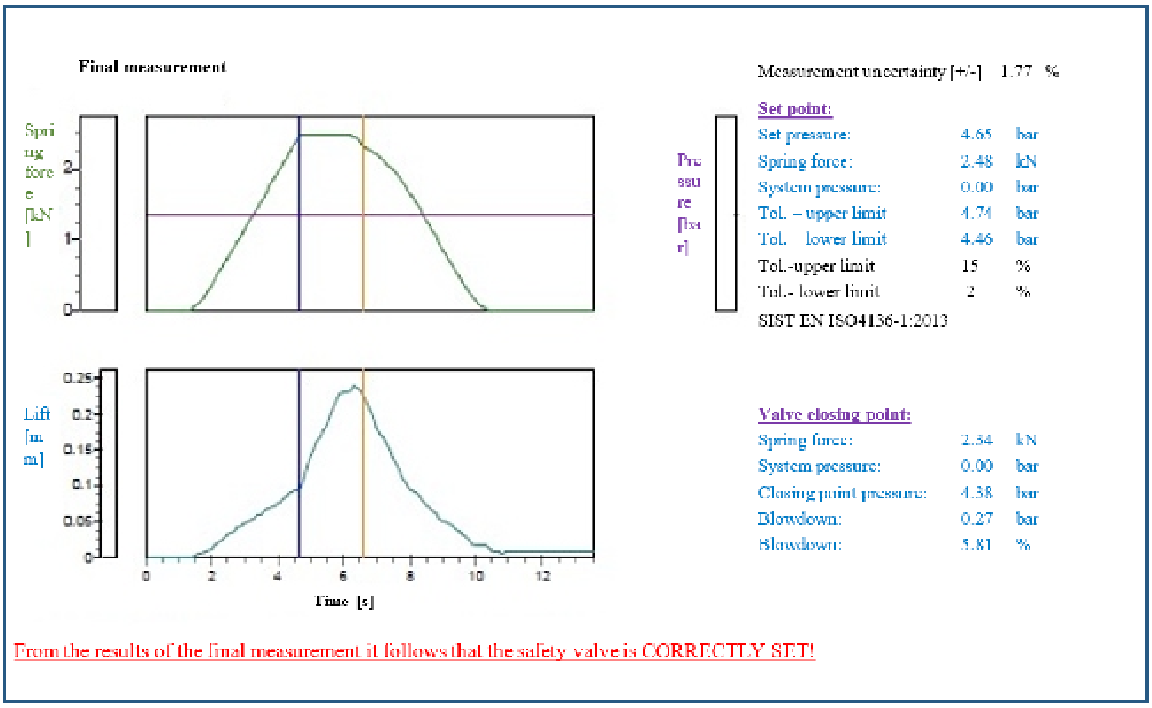

Figure 5. Test-report of on-site testing safety valve at position LPH3

will be made and thus endanger the equipment and the course of the technological process.

The on-site method has integrated specific protection mechanisms that monitor and evaluate the safety valve testing process procedures. On the test report of the valve at position LPH3, an assessment of the performed test is given, where the device ascertains whether the test was performed correctly or the need to correct the test process is required.

The diagram of the test and the curve of the operating sizes of the valves at position LPH3 is shown in Figure 5.

4. ADVANTAGES OF ON-SITE METHOD

As already mentioned, disassembly of the valve is necessary for the application of the conventional method of testing safety valves. This also means a temporary inability to use the equipment, and sometimes the suspension of the plant where the valve is located. This major drawback has been overcome by the use of an on-site method, which offers the possibility of testing at the installation site and during the operation of the plant with the process pressure (system pressure) present. This type of test, with process pressure, is often called a hot- test. The online method of course also offers the possibility of testing without process pressure, when the valve is tested while mounted in position or dismantled as with conventional methods. Testing of safety valves by an on-site method has been shown to be more accurate and reliable than setting by conventional method.

On site testing of safety valves, in addition to not requiring shutdown of the valve being tested, has some other advantages, such as:

- Smaller plant downtime due to testing means lower losses in the production process.
- Reduces energy losses to stabilize the pressure in the system that occurred during testing.
- Pressure relief in the atmosphere is avoided and unpleasant occurrences of noise at the location are prevented.
- The service life of the equipment is extended, as there are lower overpressure loads, and thus potential damage due to erosion of the valve seat or the appearance of deposits on the pipelines.
- Avoiding the dismantling of safety valves saves time and maintenance costs.
- Safety valves are often welded, their disassembly is complicated and requires longer downtimes and higher costs.

Because on-site methods are based on sensitive and precise sensors and software displays of values of all valve sizes, such tests provide greater accuracy and precision of adjustment compared to the conventional method based on visual readings on analogy instruments and measurements of individual quantities in an environment different from real operating conditions. The components of the on-site method device are made of components that withstand the conditions of the working environment, primarily temperature, which is a prerequisite for the accuracy of the results in different ambient conditions.

The application software enables the collection and acquisition of data and can generate a database for each valve, so it is possible to monitor trends by individual valve. The data of individual valves from the formed database, which are needed for testing the valve, the software recognizes and pulls them when starting the test. This shortens the time of test preparation and implementation. This is especially convenient in large industrial systems, where a large number of safety valves need to be tested.

The advantage of the method of on-site testing of safety valves is the use of a motor drive to act on the spindle compared to the hydraulic used in the conventional. The motor drive enables more precise control of the traction force and has no negative effect on the test object, so the pressure can be precisely adjusted. The use of the motor drive also provides protection of the system against overload because the maximum traction force of the motor drive is regulated by the feedback in the function of overload protection, so that the overpressure values of the protected equipment will not be exceeded.

Additionally, the performance of the battery-powered motor drive allows the control and monitoring of the test process from long distances, which can be crucial in some situations because some valves can be located in inaccessible places in the plant.

The use of the on-site method allows subsequent analysis of the obtained diagrams of working quantities. Testing of safety valves, in addition to testing and correction of opening pressure, may also indicate its condition. Some effects that can be recognized through the analysis of the display of the curves of the working quantities are: the action of the sealing elements, leakage after the operation of the valve, the condition of the spring and other internal parts of the valve.

5. CONCLUSION

The paper explains the working principle of the on-site method of testing safety valves, which has been used for two years in the TPP Kakanj. A comparison of the obtained results and the scope of activities undertaken in conducting testing of safety valves is given and the advantages of the on-site method are indicated. The main advantages of the on-site method are:

- The possibility of testing the valve in the operation of the plant without the need to dismantle it.
- More precise adjustment of the opening pressure,
- Shortening the time and reducing the cost of performing the test.

This difference is even more pronounced when one keeps in mind the obligation to test safety valves every year.

REFERENCES

[1] M. Hellemans: The safety relief valve, handbook, Amsterdam: Elsevier Science, pp. 207–248, 2009

[2] J. P. Boye: Pressure Safety Valves Some considerations on their use & sizing, In: Dynaflow research group lectures, 9 July 2009, https://www.scribd.com/document/271517266/Anderson-Greenwood-Crosby-Pressure-Safety-Valves-Considerations-on-Their-Use-Sizing-Juli-2009

[3] M-S. Hu: Design and development of a high-precision automatic safety valve testing system, Advances in Mechanical Engineering 12, 2020. DOI: 10.1177/1687814020914733

[4] BAS EN 764-5:2003: Pressure equipment - Part 5: Inspection documentation of metallic materials and compliance with the material specification

[5] B. C. R. Ewan, C. Weil, M. Scanlon: A study of pressure safety valve response times under transient overpressures, Symposium series no. 159, 2014, HAZARDS 24, https://www.icheme.org/media/8948/xxiv-paper-53.pdf

[6] J. Johannes: Online safety valve testing, Metrus GmbH, 2020

[7] Safety valves testing procedure, document by L-plan Slovenia, www.l-plan.si/en/products

[8] Directive 97/23/EC of the European Parliament and of the Council on the approximation of the laws of the Member States concerning pressure equipment

[9] BAS EN ISO 4126-1:2014 Safety devices for protection against excessive pressure - Part 1: Safety valves

BIOGRAPHY

Kenan Kadić was born in 1990 in Zenica, Bosnia and Herzegovina. He graduated in 2014 from the University of Sarajevo - Faculty of Mechanical Engineering, Department of Energy. He is currently a PhD student in the course Renewable Energy Resources and Environmental Technologies. He researches the explanations of Clean Coal Technology, Carbon Capture and Storage Technology and New Energy Technologies. In addition to active scientific research, he works full time at the Kakanj, Thermal Power Plant, as a mechanical engineer for the maintenance of mechanical equipment. He is the author and co-author of several scientific and professional papers, as well as a participant in several international conferences. In addition, he participated in the implementation of several professional projects, and several scientific research projects.

Adem Lujnović was born in 1961 in Kakanj. After graduating from the High School of Electrical Engineering in Sarajevo, he graduated from the Faculty of Electrical Engineering in Sarajevo, Department of Electrical Power Engineering. Since graduating, he has been employed at TPP Kakanj. He has extensive experience in the maintenance and modernization of plants and machines, and now performs the duties of the head of the Sector for Development and Investment. He was the leader or participant in the implementation of numerous projects for the modernization in the power plant. He is the author or co-author of several published professional papers.

Nihad Hodžić was born in 1970 in Kakanj, Bosnia and Herzegovina. He is a Doctor of Technical Sciences, and Associate Professor at the University of Sarajevo - Faculty of Mechanical Engineering. So far, he has published more than 50 scientific papers, 15 of which are in journals and over 30 at international peer-reviewed conferences. He was a member or principal researcher in 5 international projects, one of which he was a leader, and 13 domestic scientific research projects, of which he was a leader in 6. Of the over 20 professional projects and studies in which he participated, 10 were is the leader. He is the teacher in charge of the following subjects: Boilers and Furnaces and Introduction to Thermal Turbomachines (Bachelor studies), Introduction to Energy Technologies, Thermal Turbomachines and Energy Steam Generators and Processes (Master studies) and Combustion and Reactive Flows (PhD studies). So far, he has been a mentor or commentator on more than 15 final papers in the second cycle of studies - master studies. He is the current supervisor / mentor on the preparation of a doctoral dissertation and a mentor on the preparation of a master's thesis. The person in charge is for 3 laboratories within the Department of Energy: Laboratory for coal and biomass combustion, Pulsed Combustion Laboratory, and Laboratory for thermal turbomachines.

Anes Kazagić was born in 1973. He is a Doctor of Technical Sciences. He is employed in JP Elektroprivreda BiH d.d.-Sarajevo (EPBiH) – Power utility for generation and supply of electricity and heat energy, with high expertise in energy engineering and power production: over 20 years of industrial experience. Participant and leader R&D projects, partly performed in Germany, Japan, Nederland, Denmark, Croatia, Serbia, Austria and other. Author and co-author over 100 scientific and professional energy-related papers published in CC/SCI energy journals or presented at the prestigious international energy conferences held worldwide. He has won several awards at international conferences.