ENERGETSKI EFIKASAN SISTEM ZA STERILIZACIJU DRVETA

ENERGY EFFICIENT SISTEM FOR WOOD STERILIZATION

Miloš MARJANOVIĆ*[1], Miša STEVIĆ[2], Miloš MILEŠEVIĆ[3], Žarko ŠEVALJEVIĆ[3], Sanja PETRONIĆ[4], Marta TRNINIĆ[5], Zoran STEVIĆ[6]

[1] VISER, Belgrade, Serbia

[2] Mikroelektronika, Belgrade, Serbia

[3] University of Belgrade, School of electrical engineering, Belgrade, Serbia

[4] Inovation center of Mechanical faculty, Belgrade, Serbia

[5] University of Belgrade, Mechanical faculty, Belgrade, Serbia

[6] University of Belgrade, School of electrical engineering, TF Bor, CIK Belgrade, Serbia

U radu je opisan dizajn energetski efikasnog sistema za sterilizaciju drveta. U zatvorenom sistemu automatskog upravljanja temperaturom primenjen je kontinualni PID regulator sa trofaznim tiristorskim faznim regulatorom na izlazu. Merenje temperatura u 5 zona komore sa drvetom izvedeno je Pt1000 sondama i one su po određenom algoritmu iskorišćene za definisanje referentne temperature PID regulatora koji upravlja snagom grejača generatora vodene pare.

Ključne reči: *energetska efikasnost, sterilizacija drveta, PID regulator, tiristorski fazni regulator, regulacija temperature*

The paper describes the design of an energy efficient wood sterilization system. In a closed automatic temperature control system, a continuous PID controller with a three-phase thyristor phase controller at the output was applied. Temperature measurement in 5 zones of the chamber with wood was performed with Pt1000 probes and they were used according to a certain algorithm to define the reference temperature of the PID controller that controls the power of the steam generator heater.

Key words: *energy efficiency, sterilization of wood, PID regulator, thyristor phase regulator, temperature control*

1 Specific requirements for heat treatment (HT) treatment

Specific requirements for wood heat treatment processes, which are the subject of this paper, are given in Annex 1, IPSM standard 15.

The guidelines given in this appendix apply to the thermal treatment of wood in conventional heat chambers (dry kilns) commonly used for drying wood. Newer treatments involving dielectric heating (eg radio frequency, microwave ovens), hot water baths, etc. are not considered. Although, as mentioned earlier, these treatments can be equally effective in combining temperature and time to destroy pests [1].

Research has confirmed that heating a tree, including its core, to a minimum temperature of 56 ° C for a period of 30 minutes is effective in destroying pests. Recent results have shown that this method of heat treatment also kills many fungal organisms that can be found in wood .

Heat treatment is achieved by regulating the temperature inside the heat chamber. The chamber temperatures required for effective treatment depend on:

- types and conditions of the treatment chamber;
- volume and direction of air flow through beams / piles of trees;
- moisture content in the surrounding air surrounding the trees during treatment;
- initial wood temperatures;
- moisture content in the wood;
- wood density;
- dimensions of the tree;

* Corresponding author, email: milosmarjanovich@gmail.com

- the species of wood to be treated, and
- the amount of heat applied in the chamber, which is determined by the heating system.

The air flow inside the closed chamber depends on:
- capacity of the equipment in the air movement chamber;
- dimensions of the wood being treated;
- size of airspace, and
- the degree of separation between the pieces of wood within the pile .

Given the influence of the above factors, heat treatment is based on the development of a treatment procedure and the definition of procedures that minimize variations in these components during and between treatments.

The NPPO should establish specific heat treatment parameters, including processes to measure treatment efficacy and audit by authorized manufacturers. The guidelines given in this Annex 1 require verification that the treated wood is subjected to sufficient heating as prescribed in ISPM 15. It is not stated to what extent the NPPO may prescribe individual requirements for individual producers or parameters necessary to effectively verify those requirements. This should be determined in relation to the type of facility in which heat treatment is performed and in relation to the degree of specificity of the approach to heat treatment [1].

1.1 Technical elements of thermal treatment

The standard lists some technical elements that should be taken into account in thermal treatment.

Technical requirements relate to:
1. Heat chamber;
2. Filling the heat chamber;
3. Air circulation;
4. Venting;
5. Humidification.

1.1.1 Heat chamber

The heat chamber can be made of different materials. The materials used in the construction should not affect the functioning of the chamber. It can be used through heat sources, including natural gas, oil, electricity, solar energy and biofuels.

Chamber construction can affect the effectiveness of treatment. Some criteria that should be met are:

- the door of the heat chamber must not be damaged and should be sealed in order to prevent heat loss from the chamber;
- the chamber itself should be built in a way that reduces heat loss;
- the air flow must be uninterrupted through a bundle of wood and equipment must be used to direct the air flow, such as baffles;
- fans should be used for air circulation in the chamber;
- fans should meet the requirements of the chamber and work in accordance with the manufacturer's specification. If more than one fan is used, they must all work in such a way as to maximize the air flow in the same direction and direction;
- venting used in the chamber should ensure even temperature distribution;
- temperature sensors, including cables, must be in good condition;
- valves and motors used to reverse or change the air flow should work properly;
- the appearance of moisture on the floors can be an indicator that the measurement of moisture in the building is inadequate, that there is not enough air circulation or other causes that require resolution.

1.1.2 Charging the heat chamber

The way in which the heat chamber is filled affects the flow of air through the wood beam, and therefore care should be taken about the location of "cold spots " (places where the set temperature is reached most slowly) in the chamber and the position of the wood in these positions. To ensure proper airflow through the wood beam, the following should be considered:

- The wooden beam should be lifted off the ground to allow efficient air flow under the tree and to avoid the effects of cooling from the ground.
- The beam must not be overloaded so as to prevent the flow of air over the top of the beam.
- The space should contain enough free space to allow sufficient, uniform air flow through the wood beam.
- The material to be treated should be the same (eg pallets only or slabs only) to ensure a homogeneous heat distribution. Mixing materials such as pallets and boxes can make it difficult to reach the recommended temperature and more temperature sensors may be needed to confirm that the appropriate mode has been achieved.
- Sheaves of sawn wood should be stored with spacers or stickers between the boards. The spacers must be placed parallel to the direction of air flow. Some heat chambers may require the use of special perforated stickers to allow the required airflow.
- In cases when the chamber is not filled along the entire cross-section, it is necessary to install partitions to direct the flow of air through the wood beam. Where bulkheads are not used, air will move through the lowest air resistance (Figure 1, right) [1].

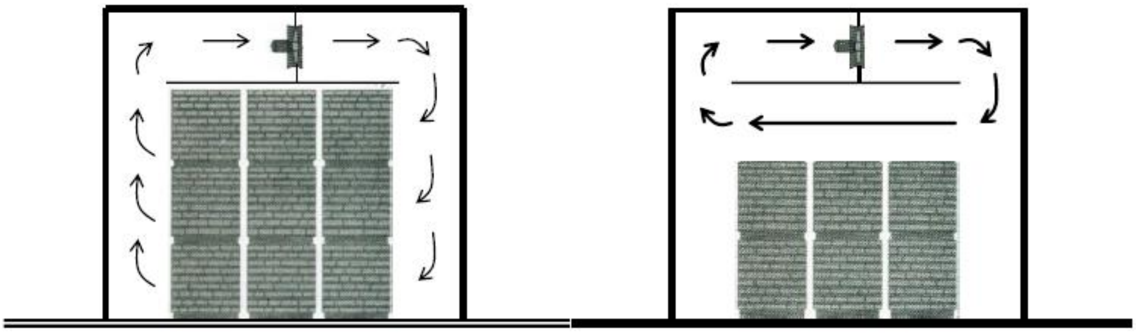

*Figure 1. Schematic cross-section of the chamber, **Left** : Filled chamber; the air circulates through the entire beam, and the heating is more uniform. **Right** : Insufficiently filled chamber , air circulates over the beam of wood, due to which the free space heats up faster than the beam*

1.1.3 Air circulation

Air circulation fans help to ensure the controlled movement of heated air in the chamber. Air flow can be measured using an anemometer. These can be fixed units that perform constant automatic measurements or manual units that periodically record the air flow to determine if the fans are operating within the desired parameters. A minimum air flow of 0.5m / s (100ft / min) is recognized as necessary for normal operation in the chamber [1].

The installation of the fan ensures the movement of air in the desired direction. Directing the flow of air during the treatment helps to ensure even heating on all sides of the wood. Changing the air flow ensures that the wood in the chamber is heated to the maximum temperature. As the air moves through the wood beam, it cools due to the evaporation of water from the wood. By directing the air with the fans, the processing time is reduced, reducing the influence of this cooling effect by the constant circulation of warm air. Depending on the position of the air directing fan, the position of the "cold spots " (places where the wood heats up the slowest) is estimated , and temperature sensors should be installed in these places to ensure that the required temperature is reached at all critical points. However, in chambers where fans are not used to direct the air flow, the wood is effectively treated by achieving a higher ambient temperature or compensated by a much longer heating duration [1]. .

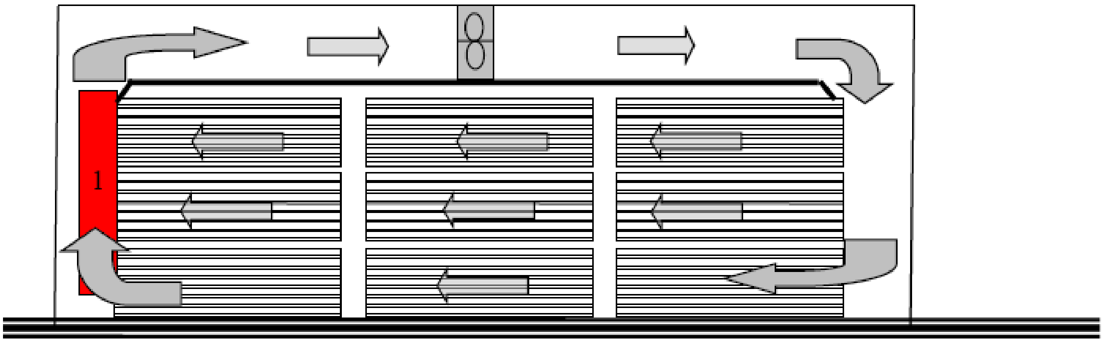

Figure 2. Heating chamber in which the heating pipes are placed with a fan above the wood bundle . The "cold spot " is probably located on the outlet side of the beam, so the temperature sensor should be placed where the air exits the wood beam (marked "1").

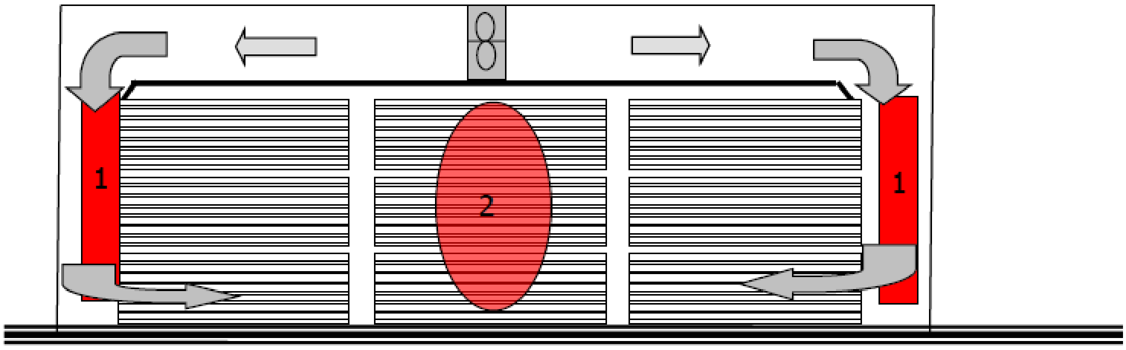

Figure 3. Heating chamber in which the heating is two-way. If the intended treatment is long, the "cold spot " may be on the side outlets of the beam (marked 1). Temperature sensors should be placed along the walls of the chamber. If the intended treatment is shorter, the "cold spots " are probably in the center of the beam (marked "2") and the sensors should be placed there.

Figure 4. Heating chamber in which heating occurs on one side of the floor. The temperature sensor is placed at the air outlets from the wood beam (marked with "1").

2 . System construction

A modern process control system has been upgraded to the existing wood sterilization system in order to increase energy efficiency, reliability, product quality and user comfort. The existing ON / OFF temperature controller has been replaced by a continuous PID controller with a three-phase thyristor phase controller at the output. The existing temperature measurement in the zones of the chamber with wood was retained, but the same signals were introduced in the new system, where they were used according to a certain algorithm to define the reference temperature of the PID controller [2,3].

2.1 Three-phase phase controller SCR -380 D 100 P

SCR -380 D 100 P, from LeiChuang TEC , is an integrated module for phase voltage regulation. It consists of three anti-parallel connections of two thyristors and one chip that serves to generate the ignition signal. It has good output voltage symmetry, precise control and high operating stability. This module has the following parameters:

- Rated voltage (U_n) : 400 V AC ;
- Rated frequency: 50Hz / 60Hz;
- Rated current: 100A,
- Output voltage asymmetry: ≤ 5%;

There is a built-in power supply for the steering wheel that is powered by 230V AC. In Figure 5 is a schematic of internal connections, and in Figure 6 the wiring diagram of this module is given.

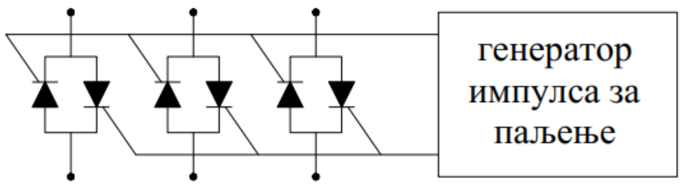

Figure 5. Scheme of internal connections of the module

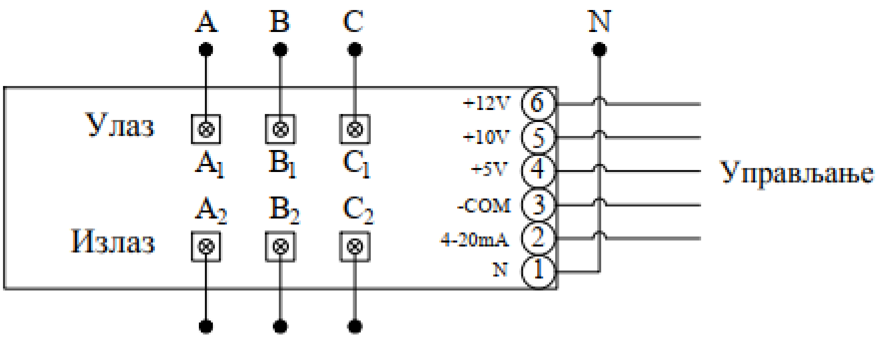

Figure 6. Module connection diagram

This inverter can be operated in five different ways (Figure 7). Control methods 1, 2, 3 and 4 use an internal power source, and method 5 an external one. Method 4 involves manual control, via a potentiometer [4].

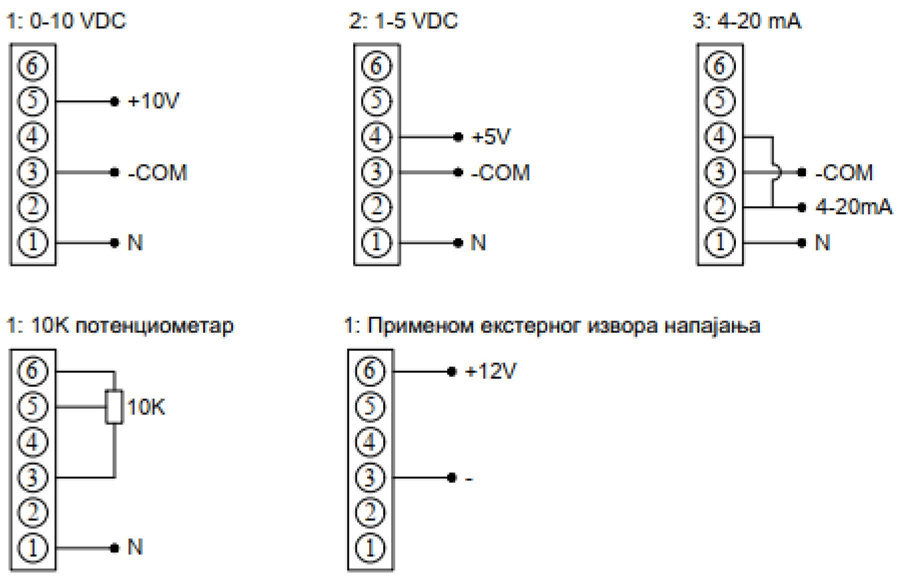

Figure 7. Module management methods

Given the output voltage range of the NI USB -6001 card [5], the module will be controlled by a voltage signal in the range of 0 to 10 V and the control inputs will be connected as in Figure 7 for the specified range.

In Figure 8 the scheme of the control - energy part of the system with the phase regulation of the power of the steam generator heater is shown .

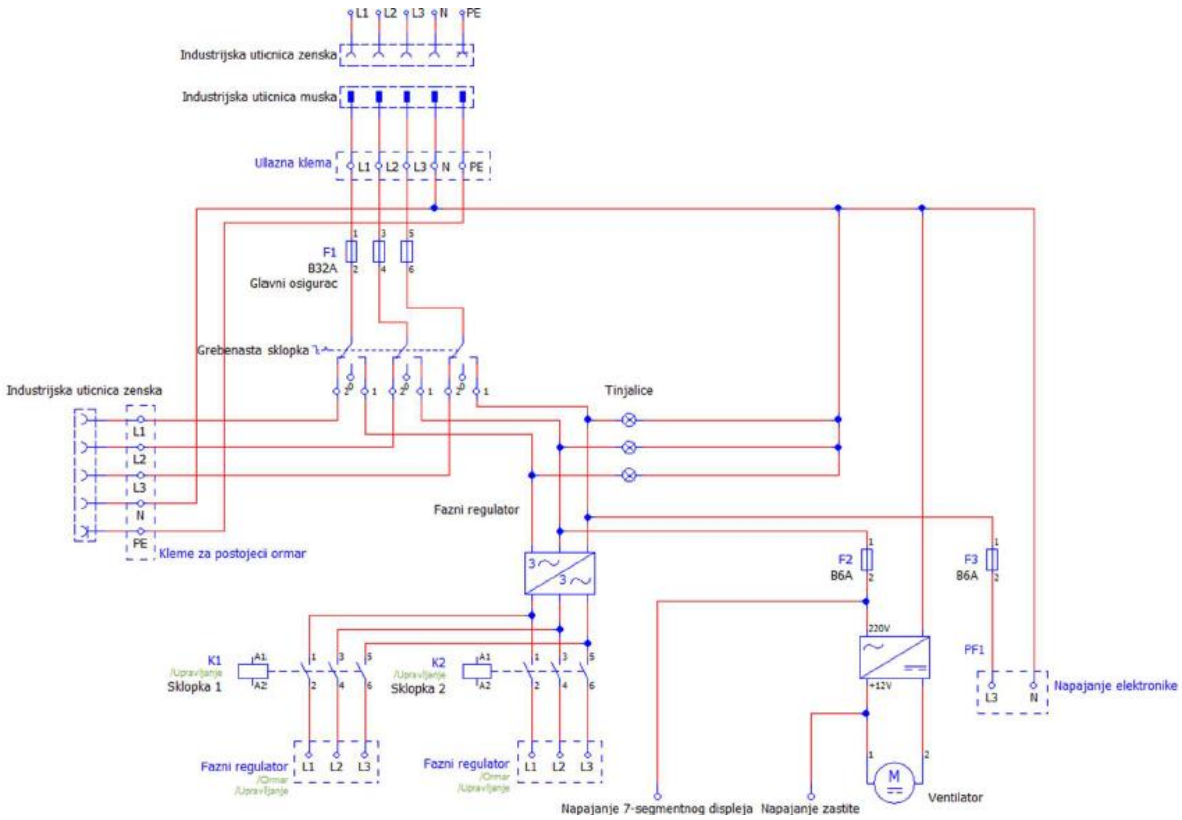

Figure 8. Scheme of control cabinet

3 Acknowledgement

The authors gratefully acknowledge financial support from the Ministry of Education and Science, Government of the Republic of Serbia.

4 References

[1] **Sela, S., et al.** Explanatory document for ISPM 15 (Regulation of wood packaging material in international trade). [ed.] IPPC Secretariat. s.l. : FAO, Approved in 2014, published in 2017..

[2] **Marjanović M.**, Optimization of electrical installations in the technological process of wood thermal treatment in small dryers, Master Thesis, School of Electrical and Computer Engineering of Applied Studies, Belgrade, 2020

[3] **Радовановић, И., Стевић, З.** Завршни извештај пројекта унапређења процеса термотретирања дрвета са становишта поузданости и енергетске ефикасности. Београд : Иновациони центар електротехничког факултета, 2019.***, Standard title, Publisher, year

[4] ***, SCR-380D100P thyristor power controller product manual. https://chinese.alibaba.com/product-detail/100A-SCR-power-controller-three-phase-62248833692.html. [Online]

[5] USER GUIDE: N1 USB-6001/6002/6003 Low-Cost DAQ USB device. http://www.ni.com/pdf/manuals/ 374259a.pdf. [Online]