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Formation of a Knowledge Base for the Synthesis of New Technological and Technical Solutions in the Field of Wood Drying and Impregnation

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Abstract
The most important technological operations performed by timber enterprises include drying and impregnation of wood. It is precisely at these operations that various types of timber are given the consumer properties necessary for the commercial sale. To date, despite numerous research and development, drying and impregnation of wood remains very energy-intensive, and the equipment used for this requires improvement. The need to improve the drying and impregnation of wood, as well as the equipment used in these processes, has increased the attention of scientists and developers to solve this problem. However, there is a lack of patented intellectual property that provides a spasmodic development of technologies and equipment for drying and impregnating wood. The authors develop patentable intellectual property objects based on the methodology of functional technological analysis and synthesis of new technical solutions using the generated knowledge base on improved/newly created equipment and technologies based on an extended patent information search. As a result of research, a knowledge base was formed in the field of technology objects and equipment for drying and impregnating wood and the effectiveness of its use was proved using the methodology of functional, structural and technological analysis to form a new patentable intellectual property using technologies and equipment for centrifugal drying, and wood impregnation. The formed knowledge base has become the basis for the synthesis of patented technological and technical solutions that provide elementary and high-quality leaps in the development of technologies and equipment for drying and impregnating wood. This allows you to go to the next stage of work - experimental design, the creation of experimental and prototypes of technology and equipment.

Keywords: *knowledge base, timber, intellectual property, patent search, wood impregnation, wood drying.*

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I. Introduction

One of the most important indicators of the level of equipment for drying and impregnating wood is its creation on the basis of fundamentally new competitive technological and technical objects of intellectual property - the results of intellectual activity. Therefore, these objects must be protected by security documents - patented. The formation of patentable intellectual property by the authors is based on the methodology of functional-structural-technological analysis and synthesis of new technological and technical solutions. The most important tool in this case is the formation of knowledge bases about known/improving/newly created objects of engineering and technology based on an extended patent information search. The formed knowledge base has become the basis for the synthesis of patented technological and technical solutions that provide elementary and high-quality leaps in the development of technologies and equipment for drying and impregnating wood. This allows you to go to the next stage of work - experimental design, the creation of experimental and prototypes of technology and equipment.

In this work, the knowledge base is formed in the field of drying and impregnation of wood. By the example of equipment based on the effect of centrifugal drying and wood impregnation, the effectiveness of using the generated knowledge base using functional-structural-technological analysis as tools for the formation of new intellectual property objects protected by patents is shown. This allows you to go to the experimental development, the creation of experimental and prototype technologies and equipment.

II. Literature Review

Drying and impregnation of wood using special physical effects and quality control are important technological operations of through processes of harvesting and production of various types of logging materials commercially sold (Baettig, Remond&Perre, 2006; Billiey, 2002; Patyakin, Tishin&Bazarov, 1990; Peich&Tsarev, 1990; Platonov, 2005; Sokolov, Kharitonov&Dobrynin, 1980; Ross, 2010; Tanaka & Kawai, 2013).

A large-scale analysis of literary sources devoted to the drying of lumber and published between 2005 and 2016 was performed in (Bond & Espinoza, 2016). Most of this work focused on improving the methods used to dry lumber, improving methods for controlling the drying process, and also on the environmental aspects of the drying process. Positive assessment of the quality and level of this work, the authors consider it necessary to note that it does not pay enough attention to the analysis of technological and technical solutions patented in recent years in the field of drying and impregnation of wood. The work does not take into account the fact that these two processes are closely related. In addition, in this work, insufficient attention is paid to the analysis of the work of Russian scientists in this field.

A number of technical solutions in the field of wood drying are devoted to convective drying processes (Gorokhovsky, Shishkina&Chernyshev, 2014; Zaripov, 2013). For example, in a fairly long-known work (Bogdanov, Kozlov, Kuntysh et al., 1990), an installation based on this principle was described that contains the upper and lower circulation channels separated by a false ceiling, a fan, a humidifier, and a heater. In the work of Bratsk State University (Nagovitsyn&Fedyaev, 20.07.2016), among the shortcomings of such an installation, uneven drying of boards in terms of stack volume is noted. NagovitsynD.A. and Fedyaev A.A. (20.07.2016) proposed a technical solution for the uniform drying of boards formed into a stack due to the uniform distribution of the working agent along its height. For this purpose, a convection drying dryer is patented, in which two gases guiding devices are located in the area of rotation of the working agent from the upper

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circulation channel to the lower. One of them is mounted in the upper corner of the unit, the other between the end of the false ceiling and the wall of the drying unit.

The mechanism of moisture transfer in larch wood during convective drying was studied in (Zaripov, 2013). Moisture transfer by a gas-vapor mixture, which is formed with increasing temperature as a result of physicochemical processes in wood, is considered. It is shown in the work that the conductivity of wood depends on the state of aggregation of the extractive substances present in it.

The widely used convective drying method uses the circulation of heated air or flue gases, or superheated steam - drying agents as a physical effect. As shown in (Oti Moto Paul Maxim, 2008) when drying in large sections of saw and round timber, the creation of a large moisture gradient causes cracking. Experts note the use of large-sized drying chambers, high energy intensity and duration of wood drying, the complexity of high-quality drying of large timber materials as disadvantages of this method.

The Fund for Assistance to the Development of Russian Technologies in one patent has patented technological and technical solutions for wood drying (Serkov, 27.09.2008). According to the technological solution, the wood is heated at a temperature of 80 to 140 ° C. The drying agent is supplied at a speed of 3.5 to 4.0 m/s. The vapor-air mixture from the chambers and moisture is removed at a pressure in the vacuum chamber of 2 to 60 mmHg. Depression in the working chamber is created within 80 to 120 and 30 to100 mm of mercury. To measure humidity, electrodes with spear-shaped ends are used, which are introduced into the wood to a depth of 10 to 15 mm from the surface and the middle of the cross section of assortments.

The wood drying method according to the patent (Golitsyn&Plotnikov, 19.03.19) is aimed at increasing the drying efficiency and quality of dried wood, reducing the drying time of wood and reducing energy costs. This method combines well-known and new distinctive features. The heating of the drying agent and wood in the drying chamber, the movement and distribution of the drying agent are carried out by a fan. The vapor-air mixture and condensed moisture from the drying chamber are removed to the receiver and then to the condensate collecting tank. According to the method, wood is exposed to three periods by vacuum pulses, displacing moisture from the wood and deepening the vacuum with each subsequent pulse. In the first two periods, free moisture is removed, in the third - bound moisture. New features are added to the well-known signs: a) after the vacuum action of the first period, the moisture is removed by draining or forced pumping of moisture accumulated in the drying chamber; b) in the second and third periods, cool the condensate to a temperature of 15 to 45 ° C; in the third period, when displacing the associated moisture, at least one steaming of the wood is carried out. A feature of the device for implementing this method is that its chambers are equipped with a means for draining moisture from the chamber. The displaced moisture is cooled in a heat exchanger-cooler. Means for steaming wood associated with the drying chambers and made in the form of containers with heating elements and pipelines.

A method has been patented (Kuryshov, Raseva&Kosarin, 11.04.2017) which provides pulsed drying of lumber. The method includes sub-operations of preheating and cyclic drying, alternating modes of supplying fresh air to the dryer and energy carrier into the air heater during the circulation of heated air in the dryer. These sub-operations are included in the operation “work”. Operation "pause" includes a complete cessation of the supply of fresh air, energy to the heater and the circulation of heated air in the drying volume. Then produce exposure of wood. The novelty of the method lies in the fact that after

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the operation "work" at the end of the operation "pause" in the dried wood determine the drying stress and residual deformation. In this case, the duration of operations of operations “work” and “pause” is selected according to the established data on drying stresses and residual deformations.

According to the drying method patented by Moscow State University of Forests (Kuryshov, Raseva&Kosarin, 11.04.2017) during the “pause” operation, the temperature will be determined using a dry thermometer and the relative humidity of the drying agent. With this in mind, the equilibrium moisture content of the wood is calculated, and its average current moisture content is determined by the equilibrium moisture content at the end of the “pause” operation.

In yet another method, wood is exposed to wood in a preliminary drying oven with heated steam (Mülbeck, 27.11.2015). In the main drying chamber, it is affected by circulating air entering through the heating element. A partial stream of exhaust air is separated and replaced with heated supply air. The novelty of the method is as follows: a) the exhaust air separated from the circulation air is supplied to a heat exchanger located in front of the preliminary and main drying chambers; b) pre-drying is carried out by a stream of heated supply air in the pre-drying chamber and the circulating air discharged from the main drying chamber is replenished.

A number of experts note the disadvantages of traditional installations for chamber drying of wood in plants containing a fan heater. Among these shortcomings: a) a long drying process (5 - 45 days) depending on the breed, thickness and initial moisture content of the dried wood; b) significant energy costs for drying timber; c) the facts of occurrence in dried wood that reduce the quality of internal stresses as a result of microcracks and warping.

Among the technologies of wood drying, a certain place is occupied by various methods of preliminary drying of round timber, including cylindrical ones, to the equilibrium humidity that they will acquire during operation. This allows you to abandon the long exposure and allows immediately after construction to proceed to the fine finish in wooden housing construction.

The convective method considered in the work (Artemenkov&Akishenkov, 2003) provides for drying of round timber in chambers equipped with heat exchangers, fans and air exchange pipes. Given the simplicity of the structures implementing this method, it is difficult to exclude the occurrence of radial drying cracks that reduce the commercial value of the final product.

Specialists of the Siberian State Technological University have proposed improving the convective method (Ermolin&Namyatov, 20.05.2015) to eliminate the risks of cracking in round timber and to ensure stable wood sizes during operation. To implement the method, the value of the equilibrium moisture content of wood is increased by 8 to 10% of the initial moisture content. Before convective chamber drying, round timber is autoclaved with 16 to 18% aqueous solution of a mixture of substances ammonium nitrate and urea or ammonium nitrate and calcium nitrate, taken in a ratio of 1:1. The proposed method is characterized in that the substances introduced into the wood during the impregnation lower the value of the partial pressure of the vapor. Therefore, equilibrium with the surrounding air occurs at higher wood moisture. At the same time, the impregnated round timber is provided with constant dimensions during operation at higher humidity than that of the non-impregnated ones and eliminates crack formation.

In the works (Belyakova&Bodylevskaya, 2012; Kainov,Khasanshina, &Shulaev, 2014; Bykova, 2013), the advantages of vacuum wood dryers over convective ones are proved by shortening the drying time at lower temperatures. According to research data (Brenes-Angulo, Bond, Kline et al. 2015), performed on the example of hardwood, the vacuum drying cycle time was 90% less than

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with conventional drying. Lower storage costs, faster drying speeds and shorter cycle times show that vacuum drying can significantly increase the competitiveness of hardwood flooring manufacturers.

In (He,Yang, Peng & Yi, 2013), ultrasonic energy was used to intensify the process of vacuum drying of wood. At a drying temperature of 60 ° C, the absolute pressure was 0.05 or 0.08 MPa, and the power and frequency of the ultrasound were 100 W and 28 kHz, respectively. Studies have shown that the effective diffusion of water in samples dried by ultrasonic vacuum drying at 0.05 MPa or 0.08 MPa was faster than at a pressure of 0.08 MPa. Drying with ultrasound proved to be especially useful when removing free water. The authors conclude that the use of the effect of ultrasonic vacuum drying can be applied in the woodworking industry as a means of saving energy and minimizing damage to product quality.

For drying stacks of lumber using vacuum, the Scientific-Technical Center for the Development of Technologies and Equipment for Wood Drying patented a vacuum-type plant. The upper and side sections of such an installation are made of elastic material in the form of impermeable membranes, and the lower one has longitudinal slots through which the cargo trolley is introduced into the drying chamber.

The drying quality of lumber increases in vacuum under reduced pressure, at which the drying time is 4 - 6 times less than with convective drying. The works (Safin,Khasanshin, Safin et al., 2005; Khasanshin, 2007) proposed new approaches to improving vacuum convection drying, studied the kinetics and dynamics of the process of moisture removal. The development of these studies in relation to shredded wood was performed in (Safin,Khasanshin, Garaeva et al., 2016).

In (Naumov, 2012), an experimental setup for studying oscillating drying-impregnation of rounded logs in a solution of sodium chloride was considered. A circulation pump is used to circulate the hot fluid between the heating tank and the vacuum dryer. The inside of the unit is in communication with a vacuum pump with a nozzle and a reservoir for hydrophilic liquid. During operation, a rounded log is placed in the chamber and sealed. A drying agent is fed into the chamber - a solution of sodium chloride, the heated hydrophilic liquid from the chamber is drained by gravity and evacuation begins, which reduces the temperature in the center of the log. The cycle "heating - evacuation" is repeated until a constant moisture content of the wood is achieved.

A drying method has been patented, including treating wood with air pressure and heating (Sukhov, 20.11.2015). Its novelty lies in the fact that the wood is treated with an air pressure of 10-40 atmospheres with heating by microwave energy followed by pressure relief after exposure to wood.

Another method of drying round timber in chambers uses the microwave energy effect (Gareev, 20.04.2005). It should be noted that the use of microwave drying has been considered in a whole series of studies (Bombin&Mordvinov, 2010; Vrublevskaya, Matusevich&Nevzorova, 2013; Galkin,Melekhov, Shulgin et al., 16.07.2015; Omarov,Tsekhmistro&Khatnyuk, 2008; Tsvetkov, 2013). The work (Melekhov et al., 2016) noted the need for automatically operating high-tech devices for drying wood in a microwave field. This requires systems for monitoring and controlling the drying process with specialized software. However, with the advantages of this drying method, it should be noted that it does not exclude surface cracking, and the technology itself requires significant costs for electricity, acquisition and maintenance of microwave equipment.

When drying using the energy of an electromagnetic field, an effective range of ultra-high frequencies is effective. The drying process in resonator-type chambers using microwave

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frequencies is characterized by resonant electrophysical phenomena. The work (Melekhov& Shulgin, 2015) examined these phenomena that occur during drying of wood at ultrahigh frequencies and offers suggestions for optimizing the regime of such drying.

When comparing energy costs between conventional, electric and hybrid drying, the reduction in energy consumption for all electric and hybrid drying cycles was 42-48% compared to the energy consumption during conventional drying (Minea, 2012).

The Bashkir State Agrarian University has patented the installation of a chamber type for drying wood (Aipov&Tukhvatullin, 04.07.2019). Microns of microwave radiation are staggered on the lateral opposite walls of the drying chamber. The air circulation system of the device eliminates the penetration of microwave radiation outside the chamber. In the duct, temperature sensors and an electric moisture meter and a fresh air intake hatch are mounted. Protection of magnetrons from moisture and thermal insulation of a stack of wood provide vertical partitions made of polyethylene. The choice of drying modes is provided by turning on/off the magnetrons and adjusting the speed of rotation of the wood in the chamber. The installation reduces the duration and improves the quality of drying due to the rotation of lumber in an electromagnetic field. This ensures a uniform distribution of the electromagnetic field interacting on the wood and increases the effect of forced air exchange in the chamber and reuse that heats the wood with hot air.

According to the method patented by Novosibirsk State Technical University, the wood is stacked in a drying chamber, electrodes are installed, an electric field of 200 to 260 V/m is formed on the stack and a drying agent is supplied (Nikandrov&Porsev, 28.06.2019). The electrodes are installed at the ends of the timber; an electric field with a constant component is directed along the wood fibers. The novelty of the method lies in the fact that the polarity of the pulsed electric field is reversed after 50 ... 90 hours with duration of application of power supply of reverse polarity of 8 ... 10 hours.

In the modern literature, studies of the state and prospects of the development of wood drying in a vacuum medium are rather widely represented (Safin,Ziatdinov, Safina et al., 2014). A method of vacuum drying lumber has been patented (Mashkovtsev, 24.04.2017), in which a reduced pressure is created in the area where the sawn timber is located within 5 -150 mm Hg and the temperature is 5 -25 ° C higher than the boiling point of moisture at a given reduced pressure . Before drying, the lumber materials are placed in a sealed elongated shell, the inner cavity of which is connected to a vacuum pump. Then the lumber in the shell is placed in a heat chamber. The heat chamber provides drying both on microwave radiation, and according to the convection principle.

The issues of electro kinematic dehydration of wood were considered in the work (Patyakin&Sokolova, 2009). The issues of optimizing the drying of timber in a liquid hydrophobic medium using ultrasound were considered in (Fayzrakhmanov,Smagin, &Baykov, 2014).The study of protective wood impregnation modes in autoclaves was performed in (Varfolomeev&Badanina, 2002), the author proposed dependencies for optimizing deep impregnation modes.

Northern (Arctic) Federal University named after M.V. Lomonosov patented a plant with a hermetic container for wood impregnation (Melekhov&Sazanova, 28.08.2016). The novelty of the installation lies in the fact that it is equipped with a hydrostatic thermo-hydraulic pressure generator in the form of a sealed elastic thermally insulated shell. Heat exchangers are installed inside the shell. The working fluid of a hydrostatic pressure generator contains a 6-block granular polyamide. The action of the generator is based on

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the properties of thermal expansion of the liquid. When the heat exchanger is turned on, the working fluid with the polyamide granules begins to heat up and expand, and the coefficient of volume expansion of the polyamide is much higher than that of the liquid. With an increase in the volume and pressure of the working fluid, the elastic shell increases in volume, the pressure of the working fluid is transferred through the elastic shell to the volume of the impregnating liquid in the container and, since the liquid is practically not compressed, the pressure of the impregnating liquid in the container increases. The pressure of the impregnating liquid reaches the required level and is maintained so during the period of impregnation of the material.

The process of wood impregnation in a piezoperiodic field was simulated in (Kunitskaya,Burmistrova, Khitrov et al. 2018). It shows that the impregnation rate is higher than that of other known methods, since the work pieces are additionally exposed to pulsed pressure increase. During the implementation of the developed mathematical model, it was found that for 25 cycles of pressure increase, the sample is impregnated by 25 to 30 cm depending on the wood species, which, taking into account the cycle time of 60 s, indicates that the proposed design of wood impregnation plants at water hammer, as well as the principle of pressure-relief-pressure surpass the already known installations.

In the work (Shamaev,Kunitskaya, Grigoryev, et al., 2018), the operating principle of an innovative installation for impregnation using the butt end method under pressure was proposed, which allows through impregnation of logs three meters long of hard-to-absorb wood species. There is a pilot installation in LLC Modification (Voronezh). The advantage of this device is that the through impregnation of moderately impregnated wood in time is 2-3 hours, and the impregnation of spruce and larch wood, which are considered impregnated, has duration of 12-20 hours with both an aqueous and oily solution.

Novosibirsk State Agrarian University has patented a method (Pichugin, Denisov, Batinet al.,27.12.2016), which includes preliminary drying of wood, evacuation, impregnation of blanks, subsequent drying and heat treatment. The impregnation is carried out with an aqueous composition, which includes: phenol alcohol; 30% dispersion of silica sol; 3% aqueous solution of carbon nanotubes. The positive effect of nanosized additives of silica sol and nanotubes on the properties of the material and its resistance to external influences is noted. Carbon nanotubes are centers of formation of a new, more durable polymer phase, which contributes to long-term resistance to influencing factors. In addition, they are a sorbent that reduces the amount of free phenol and formaldehyde. The introduction of a complex additive of silica sol and carbon nanotubes contributes to the production of modified wood for floors of livestock buildings, capable of resisting biological, chemical, thermal and mechanical influences for a long time.

Compositions for impregnating wood against fire may contain components, such as finely divided solid material, which have flame retardant properties, or intumescent compounds that form an insulating carbonized layer on a coated product at high temperature, or compounds that impregnate the wood to form, for example, water vapor in case of fire. The Finnish company EPP WOOD OI patented an invention (Kimmo, 20.10.2015), which provides an aqueous flame retardant composition containing ammonium, phosphoric acid, diammonium phosphate, ammonium sulfate, urea and a complexing agent, and methods for impregnating wood in which wood impregnated with the specified composition. One advantage of the present invention is that it forms a protective layer and/or foam on the impregnated wood, which acts as an effective flame retardant. The specified insulating

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protective layer prevents the penetration of fire into the wood, thus keeping the wood fabric intact. Northeast Federal University named after M.K. Ammosov patented a method for increasing the stability, strength, and fire resistance of wood (Pakhomov,Ilarova, Gaenkova, et al., 20.11.2015). The method involves evacuation and impregnation of wood blanks. The impregnating solution is the liquid phase of natural cattle waste. Preliminary evacuation of wood blanks is carried out in a measure at a pressure of 60 to 62 mm Hg, a temperature of 70 to 80 ° C for 18 - 20 min. After depressurization of the chamber, the wood is impregnated without external pressure for 15 - 20 minutes. After processing the wood according to the claimed method, the density increases to 30 - 35% mainly due to a decrease in porosity as a result of salting of the impregnating substance in the pores of the wood; increase in strength properties up to 10 - 15% as a result of wood compaction. At the same time, the wood's resistance to temperature and humidity is improved, stability is ensured by the shape and linear dimensions of timber, water and gas permeability and water absorption are significantly reduced; fire resistance increases due to the prevention of the free flow of oxygen into the internal cavities of wood.

Known multifunctional equipment, providing a range of operations for drying and impregnation of wood. The Scientific and Technical Center for the Development of Advanced Equipment has patented a method of drying and impregnating wood (Safin, Safin, Galyaveddinov, et al., 20.04.2010) by alternating the stage of heating wood at a temperature of 80 - 90 ° C with simultaneous moistening and impregnation and the stage of evacuation.

For drying and impregnation of wood, an installation was proposed (Komaritsky&Minakov, 10.09.2007), the drying chamber of which is equipped with water/steam and impregnation systems, as well as a vacuum pump. The novelty of the installation is as follows: a) a droplet separator is placed on the receiver vacuum line; b) periodic chamber depressurization is carried out automatically when the wood is heated after evacuation; c) heaters are installed in the chamber in the zone of maximum temperatures; d) a receiver for collecting condensate, periodically disconnected from the receiver unit to drain it. The installation provides periodic conditioning of wood when heated due to the process in an isolated chamber with multiple steaming. This makes it possible to obtain fire-resistant and bio-resistant wood of various shades and colors by impregnating wood with anti-pyrenes and antiseptic compounds.

The formed knowledge base showed that among the various methods of drying and impregnating wood, centrifugal drying and impregnation technology occupies a special place (Vasiliev, 2012;Kozhin, 2012; Kunitskaya,Kostin&Burmistrova, 2012; Kucher,Grigoryev, & Ivanov, 2018 ; Oti Moto Paul Maxim, 2008). However, despite the advantages of this technology, to date, developments in the field of centrifugal drying and wood impregnation are at the stage of prospecting. As a result, there are practically no effective solutions for its commercial implementation, which determines the need for additional research aimed at developing new technological and technical solutions in this area. In this regard, as an object for in-depth research with the synthesis of new solutions, the authors adopted technologies and equipment for centrifugal drying and wood impregnation.

III. Materials and Methods

As an object of research, technologies and equipment used for drying and impregnating wood were selected. The purpose of the work is to form a knowledge base in the field of technology objects and equipment for drying and impregnating wood and to prove the effectiveness

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of using the knowledge base using the methodology of functional, structural and technological analysis to form a new patentable intellectual property.

The materials used are the results of the collection and subsequent analysis of the results of research and development of domestic and foreign scientists and developers, as well as inventors. The collection of materials was based on the fact that an active search for ways of technical re-equipment of the basic operations of the forest complex is actively conducted in many countries of the world. When conducting a patent search, the information retrieval system of the Federal Institute of Industrial Property was used. Data on foreign developments in the field under study has been collected. When collecting information, the knowledge base of the Russian Science Citation Index and search engines were actively used.

According to the research methodology, the following tasks were solved: a) the formation of a knowledge base in the field of technology and technology objects for wood-cutting and technological preparation of cutting areas; b) the allocation of specific objects of technology and equipment for the application of functional, structural and technological analysis. Among these technologies, the technology of drying and impregnation of wood, based on centrifugal drying and impregnation of timber and the equipment used for this, was singled out; c) an in-depth analysis of the allocated technology and equipment with the identification of reserves for their improvement; d) synthesis of new patentable intellectual property objects; e) registration of applications with Rospatent for obtaining security documents.

In the synthesis of new intellectual property, the authors formed two groups of patentable solutions: a) aimed at the evolutionary development of technologies and equipment for drying and impregnating wood; b) aimed at elementary and qualitative leaps in their development.

When using the methodology of functional-structural-technological analysis, the object of technology was considered both in the process of its functioning, and in the process of its manufacture. This method involves structuring the information collected in relation to the object in question. After selecting the object of study, in relation to which it was planned to find a new technical solution for its improvement, a patent information search was carried out to identify similar competitive constructions or technologies depending on the characteristics of the object of study. The formation of a knowledge base is based on an expanded collection and analysis of scientific and technical information.

The synthesis of ideas for new patentable solutions - objects of intellectual property is made using functional-structural-technological analysis and brain attack. Registration of the most promising technical solutions is carried out by preparing patent applications for inventions and utility models.

IV. Results and Discussion

The analysis showed that among the known patented solutions (Birman & Nguyen, 29.03.2017; Galkin,Melekhov, Shulgin, et al., 16.07.2018; Melekhov,Melekhov, &Spirin, et al., 17.05.2019, Hellberg&Jorn, 27.02./2016) is not enough. Attention was paid to the use of centrifugal effect for drying and impregnating wood. Therefore, technologies and equipment based on the effect of centrifugal drying and wood impregnation were considered as specific objects of equipment for the synthesis of new intellectual property objects. This section shows that the knowledge base generated by the authors is effectively used to synthesize patented solutions in the field under study.

The issues of centrifugal drying and impregnation of wood, including wood chips, have been

repeatedly considered in the scientific literature (Grigoryev,Kunitskaya, Grigoriev, et al., 2013; Katsadze&Vinogradov, 2007; Kunitskaya, 2011; Kucher,Grigoryev& Ivanov, 2018). In the well-known literature, the issues of centrifugal drying of chopped wood are rather widely considered (Lokshtanov,Orlov, Bacherikov, et al., 2015; Lokshtanov, Orlov, Sokolova et al., 2018; Petrovsky& Safonov, 2002).

However, the analysis showed the need to develop effective technological and technical solutions in the field of centrifugal drying and impregnation of wood for sale in production. This determined the need for additional research aimed at developing new technological and technical solutions in this area. In this regard, the authors adopted technologies and equipment for centrifugal drying and impregnation of wood as an object for in-depth research with a synthesis of new intellectual property objects.

At the first stage of research in the field of drying and impregnation of wood with the participation of the authors, a number of technical solutions for utility models were patented by Petrozavodsk State University. Among them are patents (Shegelman&Vasiliev, 20.03.2012; Shegelman, Demchuk, Vasiliev et al., 10.01. 2013; Shegelman, Vasiliev, Demchuk et al., 27.06.2013;Shegelman, Vasiliev, Demchuk et al., 10.09. 2013), which were aimed at the evolutionary development of well-known technical systems.

At the second stage, the authors proceeded to the formation and patent protection of fundamentally new technological and technical solutions that provide elementary and high-quality leaps in the development of technologies and equipment for drying and impregnating wood. Here are the main of these patentable solutions.

The method of centrifugal drying of lumber has been patented by Petrozavodsk State University (Shegelman, Demchuk,Vasiliev, 20.06.2014). The method includes forming a bag on the outer surface of the drum body. Lumber is laid on a flexible tape, and then wound it with lumber on the outer surface of the drum. At the same time, it drastically reduces the period of time spent on the formation of a package of lumber.

Centrifugal drying of frozen lumber, reduction of energy costs and time spent on drying are provided by the installation (Pyaskin,Shegelman, Budnik, 27.07.2016). The installation comprises a rotating hollow drum with a drive mounted on the base and a lumber fixing mechanism. At the ends of the drum, heating elements and fans supplying a heated drying agent are installed. A method for centrifugal drying of sawn timber at a negative temperature has also been patented (ShegelmanBudnik, Pyaskin, 11.10.2017). The method includes forming a package of lumber on the outer surface of the drum. The novelty of the method lies in the fact that the heated drying agent is fed into the cavity of the rotating drum body and blown through a packet of lumber. This contributes to the heating of wood and the transition of water from solid to liquid. It is also important to note that when blowing a heated drying agent through a lumber package, the centrifugal drying time is reduced and energy costs for its implementation are reduced, since due to the thermal effect on the lumber package, the process of water evaporation is intensified, as well as its movement inside the wood. Moisture transfer is caused by the temperature difference inside the material (the side of the lumber, on which the heated drying agent is fed, will have a temperature greater than the opposite). The temperature difference leads to the movement of moisture inside the lumber. This movement will go towards a lower temperature. This movement, together with centrifugal forces, increases the efficiency of centrifugal drying of sawn materials (reducing drying time and energy consumption).

However, the analysis showed the need to develop effective technological and technical solutions in the field of centrifugal drying and impregnation of

wood for sale in production. This determined the need for additional research aimed at developing new technological and technical solutions in this area. In this regard, the authors adopted technologies and equipment for centrifugal drying and impregnation of wood as an object for in-depth research with a synthesis of new intellectual property objects.

At the first stage of research in the field of drying and impregnation of wood with the participation of the authors, a number of technical solutions for utility models were patented by Petrozavodsk State University. Among them are patents (Shegelman&Vasiliev, 20.03.2012; Shegelman, Demchuk, Vasiliev et al., 10.01. 2013; Shegelman, Vasiliev, Demchuk et al., 27.06.2013;Shegelman, Vasiliev, Demchuk et al., 10.09. 2013),which were aimed at the evolutionary development of well-known technical systems.

At the second stage, the authors proceeded to the formation and patent protection of fundamentally new technological and technical solutions that provide elementary and high-quality leaps in the development of technologies and equipment for drying and impregnating wood. Here are the main of these patentable solutions.

The method of centrifugal drying of lumber has been patented by Petrozavodsk State University (Shegelman,Demchuk, Vasiliev, 20.06.2014). The method includes forming a bag on the outer surface of the drum body. Lumber is laid on a flexible tape, and then wound it with lumber on the outer surface of the drum. At the same time, it drastically reduces the period of time spent on the formation of a package of lumber.

Centrifugal drying of frozen lumber, reduction of energy costs and time spent on drying are provided by the installation (Pyaskin, Shegelman, Budnik, 27.07.2016). The installation comprises a rotating hollow drum with a drive mounted on the base and a lumber fixing mechanism. At the ends of the drum, heating elements and fans supplying a heated drying agent are installed. A method for centrifugal drying of sawn timber at a negative temperature has also been patented (Shegelman,Budnik, Pyaskin, 11.10.2017). The method includes forming a package of lumber on the outer surface of the drum. The novelty of the method lies in the fact that the heated drying agent is fed into the cavity of the rotating drum body and blown through a packet of lumber. This contributes to the heating of wood and the transition of water from solid to liquid. It is also important to note that when blowing a heated drying agent through a lumber package, the centrifugal drying time is reduced and energy costs for its implementation are reduced, since due to the thermal effect on the lumber package, the process of water evaporation is intensified, as well as its movement inside the wood. Moisture transfer is caused by the temperature difference inside the material (the side of the lumber, on which the heated drying agent is fed, will have a temperature greater than the opposite). The temperature difference leads to the movement of moisture inside the lumber. This movement will go towards a lower temperature. This movement, together with centrifugal forces, increases the efficiency of centrifugal drying of sawn materials (reducing drying time and energy consumption).

It should be noted the advantages of a patented laboratory unit for centrifugal impregnation and drying of lumber, which provides research on the regimes and parameters of the solution mentioned above (Shegelman,Vasiliev, A.S., Bogdanov, 11.10.2017). In this installation, the canisters on the outer surface of the rotating rotor are made rotatable. This allows you to experimentally select the rational parameters of drying and dehydration of timber of various species and thicknesses.

The authors also patented a device for centrifugal impregnation of lumber, including a rotor with an axis of rotation, a container for impregnating liquid, and devices for placing lumber mounted on the rotor surface (VasilievBogdanov, Shegelman,

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09.02.2017). Inside the devices for placing lumber from the sides farthest from the axis of rotation of the rotor of the surfaces, mesh-like spacing elements are installed. The surfaces of the devices for placing lumber adjacent to the axis of rotation of the rotor are made with perforated holes and are elements of the outer surface of the container for impregnating liquid. This container is mounted on the rotor between the devices for placing lumber and rotates with it. During operation of the device for centrifugal impregnation of lumber, a tank filled with an impregnating liquid will perform two very significant functions: a) play the role of a reservoir for impregnating liquid; b) provide self-balancing of the rotor with the devices installed on it, in which impregnated lumber is placed.

Thus, the result of research was the formation of a knowledge base in the field of technology objects and equipment for drying and impregnating wood and the proof of the effectiveness of its use using the methodology of functional, structural and technological analysis to form a new patentable intellectual property using technology and equipment as an example centrifugal drying, and wood impregnation. The formed knowledge base has become the basis for the formation of patented technological and technical solutions that ensure evolutionary development, elementary and qualitative leaps in the development of technologies and equipment for drying and impregnating wood. This allows you to go to the next stage of work - experimental design, the creation of experimental and prototypes of technology and equipment.

V. Conclusion

Among the most important operations carried out by timber enterprises is the drying and impregnation of wood. At these operations various types of timber are given the consumer properties necessary for the commercial sale. To date, despite numerous studies and developments, the drying and impregnation of wood remains very energy-intensive, and the equipment used for this requires improvement. The need to improve the drying and impregnation of wood, as well as the equipment used in these processes, has increased the attention of scientists and developers to solve this problem.

One of the most important indicators of the level of equipment for drying and impregnating wood is its creation on the basis of fundamentally new competitive technological and technical objects of intellectual property - the results of intellectual activity. Therefore, these objects must be protected by security documents - patented. The formation of patentable intellectual property by the authors is based on the methodology of functional-structural-technological analysis and synthesis of new technological and technical solutions. The most important tool in this case is the formation of knowledge bases about known/improving/newly created objects of engineering and technology based on an extended patent information search.

The authors positively assess the quality and level of work of many researchers in the industry under study, their contribution to the development of well-known technologies and equipment for drying and wood impregnation. The authors consider it necessary to note that well-known studies primarily investigate the functioning processes of known technological and technical solutions. However, they do not pay enough attention to the analysis of technological and technical solutions patented in recent years in the field of drying and impregnation of wood, as well as the synthesis and patenting of new solutions in this area.

The formed knowledge base has shown that among the various methods of drying and impregnating wood, centrifugal drying and pro-impregnation technology occupies a special place. However, despite the advantages of this technology, to date, developments in the field of centrifugal drying and wood impregnation are at

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the stage of prospecting. As a result, there are practically no effective solutions for its commercial implementation, which determines the need for additional research aimed at developing new technological and technical solutions in this area.

In this regard, as an object for in-depth research with the synthesis of new solutions, the authors adopted technologies and equipment for centrifugal drying and wood impregnation.

According to the research methodology, the following tasks were solved: a) the formation of a knowledge base in the field of technology and technology objects for drying and impregnation of wood; b) the allocation of specific objects of technologies and equipment for the application of functional, structural and technological analysis (among these technologies, technologies and equipment based on centrifugal drying and impregnation of timber) have been identified; c) an in-depth analysis of the allocated technology and equipment with the identification of reserves for their improvement; d) synthesis of new patentable intellectual property objects; e) registration of applications with Rospatent for obtaining security documents.

In the synthesis of new intellectual property, the authors formed two groups of patentable solutions: a) aimed at the evolutionary development of technologies and equipment for drying and impregnating wood; b) aimed at elementary and qualitative leaps in their development.

At the first stage of research in the field of drying and impregnation of wood with the participation of the authors, the Petrozavodsk State University patented a number of technical solutions for utility models, including patents (Shegelman&Vasiliev, 20.03.2012; Shegelman, Demchuk, Vasiliev et al., 10.01. 2013; Shegelman, Vasiliev, Demchuk et al., 27.06.2013;Shegelman, Vasiliev, Demchuk et al., 10.09. 2013).These decisions were aimed at the evolutionary development of well-known technical systems.

At the second stage of the work, the authors proceeded to the formation and patent protection of fundamental new technological and technical solutions providing elementary and qualitative leaps in the development of technologies and equipment for drying and impregnating wood. The solutions patented at the second stage of work are presented in the works (Bogdanov,Vasiliev&Shegelman, 19.06.2017; Pyaskin et al., 27.06.2016; Shegelman et al., 20.06.2014; 13.04.2017) .

As a result of the research, a knowledge base was created in the field of technology objects and equipment for drying and impregnating wood and the effectiveness of its use was proved using the methodology of functional, structural and technological analysis to form a new patentable intellectual property using technologies and equipment for centrifugal drying, and wood impregnation. The formed knowledge base has become the basis for the formation of patented technological and technical solutions that provide evolutionary development, elementary and qualitative leaps in the development of technologies and equipment for drying and impregnating wood. This allows you to go to the next stage of work - experimental design, the creation of experimental and prototypes of technology and equipment.

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