Systematic Patent-Information Search as a Basis for Synthesis of New Objects of Intellectual Property: Methodology and Findings

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Abstract: ***The articlereveals that systematic patent-information search is a foundation for building the knowledge bases, which are used as a synthesis of new objects of intellectual property patented as results of intellectual activity. The article presents the methodology of building of knowledge bases and their use for the development of patentable solutions in various areas of science and technology. The knowledge bases are built upon the expanded collection and analysis of Russian and foreign scientific and technical information for the specific types of technology and technical equipment. The synthesis of patentable objects of intellectual property is carried out upon functional and technological analysis and brainstorming. The authors developed the methodology with the synthesis of patentable technological solutions from the field of cross-cutting technology that integrates the operations on food raw materials preparation and transportation, production of functional food, mining industry, manufacturing of equipment for spent nuclear fuel handling; exploration works in the field of timber industry and forestry, and low-temperature plasm.***

Keywords: knowledge base, objects of intellectual property, spent nuclear fuel, patent, transportation and storage, transportation and storage container.

I. INTRODUCTION

During the last years, Russian universities with support from Government and Ministry of Education and Science of the Russian Federation (RF) are actively involved in the development of innovations and their commercialization. For this purpose, Government and Ministry of Education and Science of the RF apply a number of instruments, including: grants supported by Russian Government represented by Ministry of Education and Science of the Russian Federation; contests of Russian Science Fund; grants and fellowships of the President of the Russian Federatio[1]n; 5-100 Project aimed at maximum strengthening of the position of a number of leading Russian universities in competition with foreign universities in the global market of educational services and research programs; projects and contests of the Innovation Promotion Fund, including start-up project "START", project "RAZVITIE" ("Development"), "KOOPERATSIYA" ("Cooperation"), Russian and foreign contents, as well as annual contest "UMNIK" ("Clever fellow"), which is quite popular among the youth, its winners along with other tasks have to prove the innovative nature of their developments to the regional and Moscow experts.

At the same time, it is important to support the leading scientific schools, establish scientific laboratories of the European level, support young scientists and their teams, attempts (modest so far), involve large enterprises, including state corporations, in scientific and educational activities. In our opinion, very important was the implementation of grants in accordance with the Decree of the Government of the Russian Federation no. 218, integrating the interaction of universities with industry, and according to these grants, innovative high-tech production or specific samples of technologies and equipment had to be created.

Most of the above-mentioned projects with the participation of universities are aimed at the need to create and protect new objects of intellectual property (protectable results of intellectual activity) that are competitive in Russia and abroad. It seems clear that progressive universities, economy and industry of the country are interested in the formation and patent protection of the results of intellectual activity. Such an approach will allow the patenting of intellectual property and the transfer of the property on a commercial basis (for example, in the form of exclusive or non-exclusive licenses) to industry and the economy.

All this necessitates the intensification of the processes of formation and patenting of the results of intellectual activity in the implementation of grants and search operations. In this regard, this article presents a methodology for the building of knowledge bases and their use for the development of patentable solutions in various areas of science and technology. The methodology is implemented by the authors in the synthesis of patentable technological solutions in the wide areas of knowledge. These consist of agriculture and agro-industrial complex and food industry (cross-cutting technology that integrates the operations on food raw materials preparation and transportation, production of functional food), equipment for the spent nuclear fuel handling; fittings for nuclear power plants and main pipelines; mining industry, forestry and trim industry, low-temperature plasma.

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II. LITERATURE REVIEW

The authors found it necessary to confirm the effectiveness of the work performed in more detail on the example of technologies and equipment for spent nuclear fuel handling. This is attributed to the following reasons: a) the relevance of this problem; b) grant works completed by the authors in the field of spent nuclear fuel containers in 2010-2012 (patent RU2486614) and the subsequent search work that allowed to accumulate serious knowledge base; c) the authors' aspiration to show that the completion of the grant works does not stop the scientific thought, but promotes scientists to actualize the knowledge and competencies accumulated in the process of grants and research performance.

In recent years in Russia (Popkov, 2016; Shegelman et al., 2013) and abroad (Satoh,Iwai & Aral, 2009; Goff et al., 2005; Hayashi et al., 2014), researchers have been paid an increased attention to issues of research and scientific justification of processes that eliminate environmentally-hazardous risks and are related to handling, storage, involvement in the industrial processing as secondary raw materials (Grishin 2011; Muratov,Stepanov & Tsareva, 2013) and disposal of spent nuclear fuel in the study of radiological situation and radio-ecological hazard (Muratov, Tikhonov & Rylov, 2014; Muratov et al., 2012). The issues of optimization of spent fuel handling (Vavilkin et al., 2011), effective use of metal-concrete containers for its "dry" storage (Kariakin et al., 2012; Kariakin, Nekhozhyn & Pletnev, 2013), improvement of technologies for its management (Ignatov et al., 2010; Ignatov et al., 2016; Uiba et al., 2017; Vasilev, Shegelman & Romanov, 2012) have been studied.

Patent-information research generates special attention in the creation of innovative solutions in general and in the field under consideration. The experience of Petrozavodsk State University has shown that the systematic patent-information search is a basis for the building the knowledge base used for the synthesis of new intellectual property objects.

The importance of the problem of spent nuclear fuel handling is confirmed by numerous patents. In this regard, in association with the development of previous studies, the authors examined technological and technical solutions in the field of spent nuclear fuel handling patented in 2018-2019.

JSC "AKME-engineering" patented a group of inventions (Patent RU2671844). It comprises a method of long-term storage of spent nuclear fuel (SNF), as well as a cooling and storage tank (CST) for the implementation of this method. According to this method, the SNF is first discharged from the reactor completely without core disassembly as part of the portable basket and placed in the CST, previously located in a pool with a cooling system and filled with liquid lead-bismuth eutectic alloy (LBE alloy). In CST, after SNF immersion below the level of LBE alloy, there are provided the conditions of natural circulation, maintaining of the liquid form of the LBE alloy and control over its temperature for SNF decay heat dissipation through the CST body into the pool without exceeding the allowable storage temperature of the LBE alloy until the desired level of SNF decay heat is attained. Then, the CST is extracted from the pool and placed in an in-plant storage container without exceeding the LBE alloy allowable temperature during SNF decay heat dissipation due to the natural circulation of atmospheric air until the LBE alloy hardens in it. CST is reloaded from the in-plant container into the transport and storage container without taking additional steps on the decay heat dissipation. Then CST is transported to the place of long-term storage or SNF processing. SNF is reloaded from the CST into a long-term storage tank at a special landfill or at a spent nuclear fuel processing plant for core disassembly, for this purpose the LBE alloy is preliminarily liquefied by means of a heating system.

The invention of JSC "Atomenergoproekt" (Patent RU2656249) is related to methods for placing of spent nuclear fuel in storage facilities and can be used at nuclear power plants. The method includes well drilling in order to form a spent nuclear fuel pool and placing containers with SNF assemblies therein. The novelty of the invention lies in the fact that the wells are drilled under the building of the NPP reactor; SNF pool is built from the lower part formed from the drilled well and the upper part, which is formed in the NPP reactor building; drilling and construction of the pool of the required depth for SNF placement and storage take place during NPP construction; the upper part of the pool is constructed with the possibility of reloading of SNF assemblies from a reactor; after the reactor shutdown, the assemblies are reloaded from the reactor into the storage pool and placed in the container. Then the container is lowered into the lower part of the pool.

At present, fuel elements bundles of spent fuel assembly (SFA) with hermetically sealed fuel elements loaded into ampoules are transported to the SNF dry storage facility. There was identified a necessity to create the possibility of transportation and storage of off-spec fuel elements bundles with leaking fuel element in a hermetically sealed ampoule. To solve this problem, employees of Federal State Unitary Enterprise "Mining and chemical plant" (Patent RU180654) proposed an innovation protected by the utility model patent in the form of ampoule for SFA thatconsists of a cylindrical body with bottom and lid containing an inner bore with a ring lug, the bottom, which upper part has a conical lug. The novelty of the construction is that the lid is connected to the body by a sealed weld after loading of fuel elements bundles into the body. Above the conical lug and along with it, a stepped lug was made that does not protrude out of cone element. The stepped lug has a cylindrical hole with the formation of a ring-lug-formed seat. In the conical lug, cylindrical and threaded holes are made, wherein a valve is placed to fill the ampoule with a storage medium. This enables to create an ampoule with a sealing barrier for the aerosol and

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gas medium and the possibility of filling it with a storage medium.

Federal State Unitary Enterprise "Mining and chemical plant" patented the design of the shielding plug for the hole of storage cask with spent nuclear fuel (Patent RU2645833). The design includes a body formed by the upper and lower discs and a shell filled with concrete. Its novelty consists in the fact that in the plug body there is a stepped penetration adjacent to the shell with its lower part and connected to the upper and lower discs by welding, equipped with a threaded fitting with a cap nut. In the stepped penetration, a stepped protective rod is placed with the possibility of its extraction, between the steps of which a gasket is installed.

The specialists from JSC "Central Design Bureau of Machine Building" proposed the patented design of the SFA ampoule (Patent RU2670104). The ampoule contains a cylindrical body with a bottom where the fuel elements bundles of SFA is placed, and a lid entering the neck of the body with a gap in the form of a labyrinth seal and made with the possibility of its fixing by means of a locking device in the form of a spring split ring. The novelty of the design is that for the ampoule orientation in the upper part of its body, six vertical grooves are made for positioning the ampoule in the device for lid opening.

It should be mentioned here that the effectiveness of decision-making about the use of ampoules, that are not used in containers and storages abroad, is questioned in the work of Fromzel (2016). The author notes that the ampoules are not used in containers for transportation and storage of SNF, which are developed and manufactured by leading container companies in Germany, France, England, Japan and other countries; as well as they are not used in "dry" SNF storage systems in the United States, where multi-purpose hermetically sealed canisters are used, and their use for the permanent disposal of spent nuclear fuel is intended. In addition, the above author notes that ampoules are not used in containers and storage systems abroad, although the operating light-water reactors such as PWR and BWR use fuel with a much higher initial enrichment in fissile material ≈ 5.0 % than in RBMK reactors, which increases the probability of a self-sustaining fission chain reaction in accidents.

JSC "Atommashexport" invented a useful model of a trolley for transportation of baskets with new or containers with spent nuclear fuel of the reactor facility (Patent RU186881). Trolley consists of wheelpair, retainer and cradle, equipped with trunnions, for placement of containers. The novelty of the design is that the wheelpair is mounted on a frame forming a common platform. Retainers and cradles for containers are presented by a supporting ring surface fixed in the frame under a vertically placed SFAbasket and device for fixing the latter relatively to the platform frame and a support-rotary mechanism for the container. This mechanism includes a cradle with a hole for the top load trunnion of the container and supports with holes for the lower trunnions of the container transported in a horizontal position. At the same time, the safety of NPP operation is increased due to the possibility of passing the trolley through the transport gateway of the reactor block building to transport the basket for new fuel in a vertical position, and the container with spent nuclear fuel – in a horizontal position.

The invention (Patent RU2669197) was patented by Production Association "Mayak" aimed at handling of spent fuel assemblies (SFA) of reactor VVER-1000 in the SNF storage pools by increasing the reliability and radiation safety by means of guaranteed elimination of the possibility of SFA falling to the bottom of the storage pool. Telescopic lifting boom, made of stainless steel, equipped with a drive with brake, the tracking system, with characteristic feature of having square tubes with guiding rollers, load-lifting drum with two wound steel stainless cables, the axle rotation drive and bayonet position monitoring system, and self-braking reducer and shoe-type brake are used as a brake.

To detect and eliminate leaks in spent fuel pools, a patented device (Patent RU2654834) is proposed, wherein the working chamber is equipped with a video camera and a vacuum chamber with nozzles and a seal placed on the end surface.

JSC "Research and Development Institute of Construction Technology – Atomstroy" (OJSC "NIKIMT-Atomstroy") patented the invention for the device for repairing the damaged internal liners of the water-filled NPP SNF pool (Patent RU2661335). At the same time, the liners repair is conducted by applying a patch to the defective place, which makes it possible to repair the pool with spent nuclear fuel without extracting it or without pool draining.

Federal State Unitary Enterprise "Mining and chemical plant" patented a method and device for decladding of SFA fuel elements relating to the reprocessing of SNF by separating the fuel elements into fragments (Patent RU2658295). The proposed method includes cutting the shell with discs (rollers). Its novelty is that the fuel element is inserted in the gap between the rolling and supporting rollers and isrotated then. The rolling roller with the notching disk is placed closely to the fuel element and then a groove is made on the fuel element cladding with its notching. Then, with striking the fuel element fragment below the notched groove, fuel element fragment is separated along the notched section, then it is sent to a high-temperature oxidation treatment.

A patent presenting a method of spent nuclear fuel reprocessing (Patent RU2669197) includes the purification of uranium (VI) from one or more actinides (IV). Purification involves at least one operation of actinide (IV) or actinides (IV) separation step from an organic phase that is immiscible with water and contains tri-n-butyl phosphate as an extractant of uranium (VI) where uranium (VI) and actinide (IV) or actinides (IV) are presented in the specified organic phase by bringing the organic phase into contact with an aqueous phase containing nitric acid and at least one complexing agent that forms stronger complexes with actinides (IV) than with uranium (VI), and then by

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separating the organic phase from the aqueous phase. Diglycol amid is used as at least one complexing agent.

The Institute of High-Temperature Electrochemistry of the Ural Branch of the RAS patented the invention (Patent RU2647125), according to which, during the electrochemical reprocessing of spent nuclear fuel into a molten electrolyte based on a eutectic mixture of lithium and potassium chlorides, after the separation of actinides, lanthanides and alkaline-earth metals, cadmium dichloride is added. The process is performed at temperatures not exceeding 350 °C.

Federal State Unitary Enterprise "Mining and chemical plant" patented the invention (Patent RU2648283), which can be implemented in technologies for spent nuclear fuel reprocessing. According to the patented method, the spent extraction system is regenerated on the basis of an organic solution of tributyl phosphate in hexachlorobutadiene. The method includes spent extraction system treatment with sorption-active solid-phase composition and is characterized in that the organic solution treatment is carried out in two successive stages. The first stage involves the treatment with an aggregate-stable aqueous suspension containing hydrated zirconium dioxide in the dispersed phase. At the second stage, there is treatment containing oxalate-ion solution. The implementation of this method allows to return the organic solutions of tributyl phosphate in hexachlorobutadiene subject to underground storage into repeated cyclic operation by direct re-use in the extraction stage or mixing with fresh extraction system.

OOO "Stalker" has patented a method of producing sorbent matrix materials for immobilization of radionuclides alkaline earth and rare-earth elements from spent nuclear fuel (Patent RU2664893).

A method of producing a radioactive-grown diamonds having β-radiation using spent nuclear fuel was patented by OOO "Synthesis" (Patent RU2660872C1). According to this method, diamonds are grown from iron carbide, formed directly in the growth chamber from barium carbonate, which is a product of spent nuclear fuel reprocessing and contains in its composition 50-70 % of the isotope ^{14}C of the total mass of carbon, and not less than 5-fold excess iron relative to the total mass of barium carbonate.

III. MATERIALS AND METHODS

Among the materials used in this work were the findings of systematic patent-information searches for grants in the field of cross-cutting technologies that integrate the operations on food raw materials preparation and transportation, production of functional food; manufacturing of equipment for spent nuclear fuel handling; creation of solid-state data storage systems using large-scale three-dimensional multichip integrated circuits; timber industry and mining industry.

These materials constituted the basis for the knowledge base building used for the synthesis of new objects of intellectual property in various areas of science and technology. The methodology of functional and technological analysis and synthesis of patentable solutions developed by Professor I. R. Shegelman was used. On the basis of an extensive analysis, there are studied factors characterizing the imperfection of the improved technological (technical) system, its elements or the process of their functioning, undesired effects, loss of time, insufficient parameters (quality of work, productivity, cost-effectiveness, resource saving, energy intensity, power capacity, environmental friendliness, etc.), i.e. "bottlenecks" and reserves for the development of the analyzed objects of equipment and technologies. At the analytical-synthetic stage, technological and technical solutions are developed: dividing (redistributing, combining) operations or technical systems, the object of labor in time (space); changing the principle of operations; introducing (excluding) operations; changing the nature of interaction and connection of the technical system with the external environment; changing the input (output) effects (product type), etc.

The primary differences between the methodology used and the known methodologies are as follows: technical system to be replaced (improved) is analyzed not in the manufacturing process, but in the process of its functioning (consumption); the process of analysis of equipment and technologies includes the known method of building a "goal tree"; the most rational iterative sequence of stages of analysis and synthesis of systems is used; the combination of analysis and building of the "goal tree" activates the mental activity potential, changes the thought orientation, causing new associations and mental generation of technological and technical solutions. The methodology performs heuristic functions, while remaining slightly bound by the set of cognitive actions and principles guiding a particular study and enabling to assess traditional technological processes and machinery system for the formulation and solution of new tasks.

In the course of the studies, there was implemented authors' methodology of analysis of knowledge bases and formation of protectable results of intellectual activity. The given methodology involves the sequential implementation of the following stages underlying the solution of scientific and technological application tasks:

- supervisor's (leader) formulation of the problem or its suggesting by the creative research team member (research scientists, postgraduate student, doctoral student);
- formation of the research participants list from among the creative team members;
- building the knowledge base and its use for the solution of scientific and technical problems basing on the expanded collection and analysis of Russian and foreign scientific and technical information for specific types of technologies and technical equipment;
- during the knowledge base building, special attention is paid to the extended patent-information search, which requires certain knowledge and skills;
- discussion of the knowledge base in the creative team for a clear understanding by all team members of the state and trends of

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technology and technical equipment development in the study area;

- synthesis of ideas for new patentable objects of intellectual property using functional-structural-technological analysis and brainstorming;

- selection and formulation of ideas as applications for patents of inventions and utility models. The close interaction of the team members is important, as the solutions developed by brainstorming are of collective nature.

Implementation of the methodology is demonstrated in the article on the example of creating technologies and technical equipment for spent nuclear fuel. At the same time, it is taken into account that the containers for storage and transportation of spent nuclear fuel – transport package – must withstand difficult conditions, both environmental and internal aggressive effects occurring during long-term operation.

IV. RESULTS AND DISCUSSION

The analysis revealed that the most serious attention in recent years is paid to the complex state of nuclear engineering and of the consumption related to the containers for spent nuclear fuel form power reactors.

Candidates of Technical Sciences, Fromzel and Shleifer (2016), consider that the choice of solutions for the current situation should be founded on the use of reliable information on the projects of containers developed by leading foreign companies, its critical analysis and application with respect to the fact that the country should immediately create new heavy-load containers for spent nuclear fuel of the VVER-1000 fuel assembly with increased initial enrichment and greater depth of fuel burn-up. As they note, the absence of the project of modern transport package for VVER-1000 SFA is unacceptable, since with the gradual final closure of 11 units of RBMK-1000 at the Leningrad, Kursk and Smolensk NPP and their replacement with VVER-1000 units, NPPs with such types of reactor will become the main ones in the Russian nuclear power industry. At the same time, a successful solution to the problem can be expected only if the design of new transport package eliminates the shortcomings of the previously developed transport package with steel forged-welded bodies for the VVER-1000 SFA and VVER-440 SFA. The authors of the analyzed work predict that the metal bodies of the newly created containers made in Russia will be casted from domestic high-strength cast iron with spheroidal graphite (HSCISG). Such cast iron, which is abroad called “malleable iron”, has been used for decades in Germany for the manufacture of “CASTOR” container body developed by “GNS” company and its subsidiary “GNB”. In subsequent work of Fromzel (2016) it was noted that a large number of “CASTOR” containers were manufactured from cast iron with spheroidal graphite GGG40 in Germany, and “CASTOR Ic DIORIT” has been loaded with spent nuclear fuel as early as in 1989.

A whole group of patented technical solutions is related to transport package for the transportation and storage of spent nuclear fuel. In this regard, special attention is paid to patents in the field of manufacture of SNF transport package.

Krylov State Research Center patented arctic marine vessel for transportation of break-bulk cargo and SNF of nuclear power plants (Patent RU2649561). The vessel is universal and of INF-2 class. Its hull and powerplant meet the requirements for vessels of Arc 6 ice class. The vessel contains additional ballast tanks for increased draught, as well as holds to accommodate 20-foot containers, including SNF transport package.

The Russian Federal Nuclear Center - All-Russian Research Institute of Experimental Physics (RFNC-VNIIEF) patented the basket for transport package (Patent RU2642853). Inventers noted that to date, the problem of basket materials corrosion and nuclear safety in case of accidents, during storage and transportation of the maximum possible quantity of VVER-1000/1200 SFA, has not been resolved. In the mentioned patent, the basket of the SNF transport package contains a central supporting tube made of corrosion-resistant steel, whereon there are fastened together sections. Each section is made of two stainless steel spacer grids. Between them there are hexagonal tubes for placing FA, having neutron shield and installed relatively to the axis of the central supporting tube in two circular rows. Sections are installed on the foundation of the support spacer with holes, along with which axes there are tightening devices on the outer side. The central supporting tube has an adapter for the load gripper. The novelty of the design is that between the spacer grids there are heat absorbent discs installed parallel to them; steel racks, forming together with the grids the load-bearing frame, are installed parallel to the hexagonal tubes. In this case, the neutron shield is installed inside each tube face in the form of a plate made of boron-containing composite; from the axis of the supporting tube in the first circular row there are six, and in the second – twelve tubes.

Guided by the researches of nuclear engineering specialists, the prospects of manufacture of HSCISG-casted containers were discussed. We believe it is necessary to focus on patents in the field of manufacturing and design of SNF transport package with the use of HSCISG. Their prospectivity is shown in the works of specialists of JSC NPO “Central Scientific-Research Institute of Technology and Mechanical Engineering” and JSC “Engineering Center of Nuclear Containers” (Aleksandrov,Radchenko & Zubkov, 2011), OOO “Foundry ‘Petrozavodskmash’” (“Liteyny zavod “Petrozavodskmash”) (Andreev et al., 2018; Kapilevich, Triapichkin et al., 2018), etc.

Technological and technical solutions in the field of manufacture of SNF transport package with the use of HSCISG patented and created with the participation of the authors are provided below.

Containers for transportation and storage of spent nuclear fuel, made of

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high-strength cast iron, are usually cylindrical, while their dimensions, such as the outer diameter and height, are of several meters, the thickness of the walls of the container can reach several hundred millimeters and they have a significant weight reaching 100 tons or more. These design features require increasing the maintainability of containers to reduce the complexity of work in their manufacture and assembly. As a rule, the container consists of internal and external shells, between which a neutron shield is placed, to protect the environment and operation staff from radioactive radiation, as well as heat absorbent elements to prevent overheating of the container contents.

Petrozavodsk State University has patented a method of manufacturing a device for transporting and storing spent nuclear fuel (Patent RU2486614). The method is carried out by installing the outer and additional shells on the hollow inner sleeve. First, on the outer surface of the hollow inner sleeve additional shell is overmoulded, which inner and outer surfaces are made respectively to the shape of the outer surface of the hollow inner sleeve and the inner surface of the outer shell, and provided with longitudinal channels. Then, on the outer surface of the additional shell, the outer shell is overmoulded. Further, from the side of the base, longitudinal channels, made on the outer and inner surfaces of the additional shell, are filled with neutron-poisoning material and the bottom on the outer shell is installed. The proposed method will help to increase the maintainability of the container by simplifying its design and reducing the cost of labor, time and money for its assembly. This is achieved by making the additional shell of solid, not of constituent parts, while it has a fairly simple geometric shape, which simplifies its mechanical operation and container assembly process. With the proposed method of assembling the device for SNF transporting and storing, the connection of an additional shell with a hollow inner sleeve and an additional shell with an external shell is performed by a simple method – press fit. This does not require the use of any special additional fasteners and provides good centering of the connected hollow inner sleeve, additional shell and outer shell. These structural elements are securely fixed relatively to each other in the required position. Due to the novelty of the proposed method, the technology of assembling the device for SNF transporting and storing is simplified and the labor and financial costs for its manufacture are reduced.

The method of manufacturing the SNF transport package body is patented by Petrozavodsk State University (Patent RU2670103). Method includes manufacturing of shells, the installation of the core rod on the pallet, the installation of shell outside on the core rod, the installation of mold coaxially to the core rod, installation of the lid on the upper end of the mold, filling the liquid ferritic spheroidal graphite cast irons in the cavity between the mold and the core rod through the gating system. The novelty of the invention is that atube is coaxially installed into the core rod, forming a cavity. The internal space of a rod, limited by the shell and tube, is filled with a metal shot. On the top end of the core rod the refrigerator is installed, on the upper end of the mold the foundry rod is installed and above it there is a top plate and then cargo is placed. Then through the gating system the cavity between the mold and the core rod is filled with liquid high-strength ferritic cast iron with spheroidal graphite (HSCISG). After HSCISG solidification, the casting mold is dismantled, then the casting mechanical processing is conducted, in the casting blind hole the bottom is installed, afterwards it is welded to the shell. Then, the mounting surfaces are lined with a nickel-containing material resistant to the decontamination solution effects for the installation of internal and external lids. Due to the fact that the shell, after disassembly of casting mold, as a result of shrinkage occurring after HSCISG solidification, has merged into the casting, there is the adaptation of the inner surface of the transport package body to multiple effects of decontamination solutions, which eliminates labor and financial costs for the application of nickel coating on the inner surface of the transport package body, which greatly simplifies and reduces the cost of its manufacturing technology and leads to lower production cost. Using the proposed method enables to obtain finer grain in HSCISG, reduced probability of casting defects and its improved mechanical properties, which will significantly improve the strength characteristics of the transport package body.

Petrozavodsk State University patented a method of manufacturing the transport-package container body with basket made from HSCISG (Patent RU2642449). The method is characterized in that the metal tubes are installed in basket casting mold as the casting rods, then the basket casting mold is filled with the molten high-strength cast iron with spheroidal graphite, and, after the cooling, the basket casting mold is dismantled. Then the basket casting is trimmed for required size and attached to the fixed supportive and solid bottom, cladded with material resistant to decontamination solutions. In the body casting mold, as a casting rod, the basket casting with attached thereto fixed mechanical joint of supportive and solid bottoms is installed. The body casting mold is filled with molten HSCISG. After the cooling, the casting body is dismantled with subsequent mechanical treatment of body casting. Then, in the lower part of the body casting, the through hole is made that is passing through the body wall and the wall of the basket casting bottom part. The through hole is closed with a plug. The upper end of the basket casting, the inner surface of the body casting in its upper part, which is not adjacent with the basket casting outer surface, as well as a stepped-shaped upper end of the body casting is covered with protective coating resistant to decontamination solutions. Then, an additional bottom is attached to the lower end of the body casting, while the inner space between the additional bottom and the lower-end surface of the body casting is filled with a neutron shield material.

The casting mold of the SNF transport package body was patented (Patent RU2660143), according to which the core rod of the

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casting mold is framed by a ferrite steel shell (part of the body casting), and a tube coaxially to the shell is installed inside (its outer diameter is fewer than the inner diameter of the shell). The space between the shell and the tube is filled with metal shot, and a refrigerator is installed on the upper end of the rod.

Petrozavodsk State University patented transport-package container with basket made from HSCISG (Patent RU2642449). The container consists of a body made from HSCISG, internal and external lids and a basket with channels for fuel assemblies installation. The basket is composite, made with a cast body, where the channels for the placement of fuel assemblies designed as tubes of boron-containing metal, fixed by shrinkage of the molten HSCISG occurring during the manufacture of basket casting, and attached to a fixed mechanical joint of the supporting bottom with holes located opposite to the channels for SFA placement. The cross-section area of each channel is from 0.1 to 0.9 of the cross-section area of the channel for SFA placement, and solid bottom attached by a fixed mechanical joint. At the same time, between the solid and supporting bottom, there is free internal space, the basket is fixed in the body due to shrinkage occurring as a result of molten HSCISG solidification during the manufacture of the body casting. In the lower part of the container body there is a channel connecting the basket inner space, located between the solid and supporting bottom, with the environment; the channel is equipped with a plug. The upper end of the basket, its supporting and solid bottom are covered with a protective coating resistant to decontamination solutions.

According to the utility model patented by Petrozavodsk State University, the design of SNF transport package (Patent RU187096) includes the basket with channels for SFA installation, cast body made of HSCISG with channels for neutron shield, arranged in two staggered rows with centers on concentric diameters. Its novelty lies in the fact that the channels for placing neutron shield are made in the form of metal tubes, from one end metal tubes are closed with lids by means of a fixed joint. During the body casting manufacture, metal tubes are fixed due to the shrinkage of the molten HSCISG. During the operation of the SNF transport and storage container, the heat radiated by the SFA is transferred to the inner surface of the container under the basket and to the body outer surface through the neutron-shield inserts and then carried to the environment. In this case, the neutron radiation emitted by the spent fuel assemblies will be suppressed in addition to the neutron shield placed in metal tubes, by means of inserts forming an additional solid wall that prevents the free passage of neutrons in radial directions. Due to the fact that the channels for placing the neutron-shield material in the body are formed by tubes fixed in the body casting as a result of shrinkage of the molten HSCISG occurring during its cooling, an expensive and labor-consuming operation of deep drilling of the casting is excluded. This increases the manufacturability of the container body for SNF transportation and storage. Due to the fact that the space between the side surfaces of the tubes, forming the channels for neutron shield placement, is filled with inserts of neutron-shield material, neutron-shield properties and thermal conductivity of the SNF transportation and storage container are increased.

The cast body with interior for the basket and neutron shield is designed for SNF transportation and storage (Patent RU2686457). The novelty of the new technical solution is that, in the cast body wall, there is casted a neutron-shield barrier of the material with a melting temperature higher than that of the body material and a thermal-conductivity coefficient not less than that of the body material, forming a solid wall that prevents the free passage of neutrons in radial directions. Graphitecan be used as a neutron-shield material; this material is widely used in thermal neutron reactors as a neutron moderator. Boron-containing graphite, gadolinium-containing graphite, and graphite with boron and gadolinium in its composition 0-10 % of total volume. Due to the fact that there is a neutron-shield barrier, made of a material with a thermal-conductivity coefficient higher than that of the body material, in the body casting for SNF transportation and storage container, improved heat dissipation from the inner mounting surface to under the basket to its outer surface is provided. This reduces the risk of uncontrolled nuclear reactions resulting from overheating of fuel assemblies loaded into the container basket. High manufacturability is provided by the installing neutron-shield barrier during the manufacture of body casting and eliminates the labor-consuming operation of drilling of deep (up to 6 m) holes in the body wall to place the neutron shield. Owing to that the neutron-shield barrier is made of a material with a melting point higher than that of the body material, there is a possibility to cast the neutron-shield barrier with molten metal during the manufacture of container body casting and thereby placing it in the cast body wall at the casting stage.

V. CONCLUSION

Studies have shown the effectiveness of the methodology on synthesis of patentable technological and technical equipment which implies expanded patent search, functional-technological analysis, brainstorming, and building the knowledge bases.

The authors implemented the methodology along with synthesis of patentable technological solutions related not only to the area of spent nuclear fuel handling, but also to the broad scope of knowledge. This includes agriculture, agro-industrial sector and food industry (cross-cutting technologies that integrate the operations on food raw materials preparation and transportation, production of functional food) (Patent RU2681676); solid-state data storage systems using large-scale three-dimensional multichip integrated circuits; (Patent RU2680548);fittings for nuclear power plants and main pipelines (Patent RU2684460); technical equipment for forestry and trim industry (Patent RU171706), and for mining

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industry (Patent RU2653874), etc.

In the course of the study it was demonstrated that patent-information search is an effective foundation for synthesis of new objects of intellectual property applying the methods of functional-technological analysis and brainstorming.

There are following patents of technological and technical solutions that the authors obtained applying the developed methodology: RU171706, RU187096, RU2686457, RU2660143, RU2642449, RU2684460, RU2681676 and many others. In total, for 2017-2019 the authors of this article have obtained 52 patents in the above areas of knowledge.

It is important to note, that the built knowledge base and application of the methodology described in the article promote the further synthesis of new technological and technical solutions. For example, with the participation of A. N. Kapilevich and D. M. Bogdanov, a new technical solution was developed as a continuation to previous patents. It pertains to the modernization of transport-package container body casted from high-strength cast iron with spheroidal graphite, which at the stage of container body casting involves an installment of neutron-shield barrier, that forms a solid wall and contains graphite with neutron poison (boron or gadolinium, for example). The above technical solution not only facilitates manufacturability of container but also increases the level of container's radiological protection and improves the heat dissipation from the SFA transported in a container without increasing the dimensional specifications which are regulated as technological equipment used for transport package handling.

The studies have shown that completed research into the grants and exploration works allows accumulation of a serious knowledge base, obtaining new skills and competences. The completion of the grant and exploration works does not stop the scientific thought, but promotes scientists to actualize the knowledge and competencies accumulated in the process of grants and research performance.

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