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(54) METHOD FOR LINING METALLURGICAL UNITS, AND APPARATUS FOR CARRYING OUT SAME

(57) The group of inventions relates to the field of metallurgy, and more specifically to methods of lining metallurgical units and other thermal units by gunning, and to gunning device design. The method for lining metallurgical units includes applying a stream of a prepared, saturated with air composition based on a refractory mixture moistened with water, on their internal surfaces by means of a nozzle, while the composition is prepared by wetting a dry refractory mixture with water in a turbulent flow of compressed air. The composition stream is then rarefied and impregnated with a hardener in an additional stream of compressed air. Before the prepared composition is applied to the internal surfaces of the units, the composition is condensed. The device for lining metallurgical units includes a nozzle with a housing. At the inlet end of the housing, there is a branch pipe for supplying a dry refractory mixture in a compressed air stream and a branch pipe for supplying water. A nozzle housing comprises a rarefaction chamber fitted with a branch pipe for a mixture of a hardener and compressed air. The outlet end of the nozzle is tapered. As a result, the quality of preparation, the homogeneity and stability of the composition of the lining mixture were improved, density, porosity and strength of which approached in properties to poured refractory concrete, the design of the lining device was simplified and its dimensions decreased, besides, the time for installation of the lining was significantly reduced. 2 primary claims and 7 subclaims, 4 figures, 6 examples.

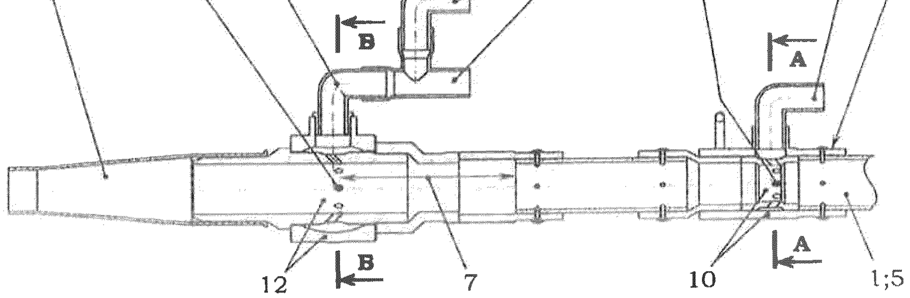

Fig. 2

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Description

[0001] The group of inventions relates to the field of metallurgy, and more specifically, to methods of lining metallurgical units and other thermal units by gunning, and to gunning device design.

[0002] For general information on gunning lining of various metallurgical units and devices for carrying out the same see the reference literature [Stepanov Yu. A., F.S. Demyanyuk, A.A. Znamenskiy et al. (edited by) Concise Polytechnical Dictionary, Moscow, Gosudarstvennoye izdatelstvo tekhniko-teoreticheskoy literatury, 1956, p. 954]. The method includes the application of a refractory concrete (for metallurgical units - a refractory mixture) carried in a stream of compressed air through a gunning machine. Dry mixture is loaded into the gunning machine and introduced under air pressure into a hose ending with a nozzle. Before entering the nozzle, the mixture is moistened automatically. The resulting shotcrete has a high strength, density, water, and air tightness.

[0003] The prior art in the field of non-flame gunning of refractory materials and its analysis are most completely described in the Russian Federation Patent "An apparatus for Gunning Refractory Material and a Nozzle for Gunning" [Specification to RU patent No. 2363543 of 22.01.2004, IPC B05B 7/14, B05B 13/00, published on 10.08.2009 Bull. No. 22]: Two widely used gunning methods to build and repair refractory linings are known: nozzle gunning and gunning of dense concrete (density higher than 2.4 kg/cm^3) by means of a pump. Unlike other refractory casting methods, these gunning methods do not require mold to build refractory linings and they provide easy application of linings even to irregular shapes or in cases where mold is difficult to design. Accordingly, gunning methods have become widely used in the constructing and repairing of refractory lining, especially in furnaces such as blast furnaces, hot-blast stoves, electric furnaces, casting ladles, pouring spouts, basic oxygen converters, reheating furnaces, etc.

[0004] In nozzle gunning (dry gunning method) a dry powder material to be gunned is pneumatically fed through a conveying hose to a nozzle assembly where water is added to form a wet, highly viscous gun mixture with good adhesive properties. The gun mixture is ejected out of the nozzle, so that it adheres to and hardens on a unit wall section, thus building or repairing a unit refractory lining.

[0005] Gunning with a nozzle does not require preliminary mixing of the material with water, and consequently work can be carried out quickly and shortly after notification, with minimal device cleaning required. Besides, mold for casting of lining is not required, which ensures work cost reduction and labor efficiency improvement, as well as the possibility of, for example, repairing both hot and cold unit linings.

[0006] However, when using the nozzle gunning method, it is difficult to completely wet and thoroughly mix the material with the water jet while being conveyed in a pipe or nozzle. This is especially true when using gunning pipes shorter than 1.5 m. In these cases, the disadvantage related to thorough mixing leads to a lesser than optimal or desired homogeneity of the applied mixture, its lower density and increased effective porosity, as well to an increase in material waste due to bounce-off of aggregated particles, poor adhesion of the mixture and to excessive material dripping from the pipe. The problem with a high dryness or poor wettability of the gunned material applied to a desired location is that some of the material does not adhere to the surface, which leads to loss of deflected particles (rebound), hence a decrease in the percentage of the material adhered to a unit wall causing a lower quality and a shorter life of refractory lining. In practice, density of such lining does not exceed 1.8-2.3 kg/cm^3.

[0007] These disadvantages are not present in gunning methods using a pump ("wet" gunning methods), which build refractory linings with a greater uniformity of properties and better physical properties than those created by the nozzle gunning method. They are usually used to build monolithic high-density structures. When using the method of gunning by a pump, the gunned mixture is obtained by premixing dry material with water in a separate mixer before being fed to the gunning device. The dry powdery material is premixed with water in a mixer and then pumped through a supply hose to a gunning device (pump), which projects the gunning mixture onto a surface. Usually, a reagent is added to a gunned mixture (for a better setting while still in the nozzle) before the gunned material is applied to a unit wall surface. This method is used to apply dense refractory mixtures with a high strength. This type of mixtures cannot be applied using dry gunning device.

[0008] The disadvantages of this method relate to the necessity of mixing dry material with water in a separate mixer to reach needed consistence. Thus, the material to be gunned is mixed before being fed into the gunning device. This requires additional device, such as a mixer, expensive feeding appliances, as well as a considerable labor effort when compared to the nozzle gunning method. Furthermore, when using the pump method, it is important to accurately control the quantity of water added to the gunned material to maintain needed consistence. An operator well qualified in pump gunning of linings is required to maintain a quantity of water needed to get desired composition. If too little water is used, the gunned material can set or harden too soon in the pump or feeding hose. If too much water is used, particles and fine powder may segregate in the gunned material, which would lead to formation of non-uniform refractory layers of poor quality.

[0009] The additional disadvantage of the pump method is the mixer-pump interaction. A part of gunned material is retained in the feeding hose and the nozzle, which leads to material waste and additional cost of labor effort for device operation and cleaning. The device for this method is large and heavy and requires a large number of operating personnel.

[0010] While the nozzle gunning method can be used to repair unit walls at more than 1000°C, using the pump method to repair refractory linings at high temperatures has been estimated to be ineffective.

[0011] To eliminate the abovementioned disadvantages, appropriate device have been designed, see the specification of the invention to the patent of the Russian Federation No. 2363543.

[0012] The first version of the device for gunning of refractory material comprises a nozzle with an internal channel having an inlet end into which the wetted material is fed and an outlet end from which the material is projected. The inner tubular element comprises one through hole and a few through grooves positioned circumferentially. The outer channel is located around and connected to the inner channel and has an inlet end for feeding in compressed air that is passed through the outer channel and pushes out the wetted material passing through the inner channel.

[0013] The second version of the device comprises a material supply hose, into which water for material wetting is fed through a special inlet. An inlet branch pipe connects the hollow flange to the inlet end of the outer tubular member. Wetted material is pushed out through a nozzle, while the mixing chamber is in an intermediate position with a connection to the material supplying hose and comprises an inlet for feeding in compressed air.

[0014] One noteworthy disadvantage of the versions described above is that they can only be operated with a "wet" composition fully prepared for gunning, of which a jet is formed for applying quality lining layers on surfaces of various units. Hence a larger nozzle with a more complicated design, which makes it difficult to work in confined spaces and cramped conditions. In addition, when working with discharge pumping device, all characteristic disadvantages of this gunning method, though to a lesser extent, remain: a part of gunned material still remains in the feeding hose and nozzle, which leads to material waste and additional cost of labor effort for device operation and cleaning.

[0015] Among other gunning technologies is the method of vortex (flame) gunning of cylindrical linings and an device for carrying out the same [Specification of the invention to RF patent No. 2108397 dated 08.28.1995, IPC C21C 5/44, F27D 1/16, published on 10.04.1998]. The method includes supply of gunning components through channels installed along the axis of the gunning lance and out of the gunning lance nozzle in the form of a single swirling vortex stream, adhesion of the supplied gunning mixture particles simultaneously over the entire cylindrical surface of the gunned area and formation of a lining layer on the surface, while the gunning mixture components are projected from the end nozzle of the gunning lance, which has an outer round edge, and are twisted into a single vortex stream in the form of a hollow cone with an external opening angle of at least 45°, and the simultaneous adhesion of gunning mixture particles to the entire cylindrical surface of the gunned area is provided through required values of the radial and tangential velocity components of the mixture particles by regulating the twisting degree of the single vortex stream or its components in one direction or another.

[0016] The device for implementing this method comprises the following interconnected units: a container with gunning mixture, a pneumatic conveyer, pipelines for supplying gunning components connected to the corresponding channels of the gunning lance fitted with a nozzle, a swirler for at least one component fed through the channels of the gunning lance. The gunning lance is fitted with an end nozzle with an outer circular edge and capable of projecting gunning components in the form of a single swirling vortex stream. The lance is also fitted with a vertical travel mechanism installed on a mobile frame and a protective screen. The swirler is connected to at least one gunning lance channel.

[0017] The disadvantages of this method include the large dimensions of the device hampering its use. In addition, creation of a single swirling vortex stream is useful and possible only in a case of mixing of gunning components. The swirling ends at the point of ejection from the nozzle where direct inertial forces act. Large external opening angles of the mixture stream provide a high quality of application for repair of cylindrical (horizontal) surfaces of small diameter units. However, in the vertical plane, the large angles lead to traditional mixture losses due to its bounce-off. As a result, the method and device are not universally applicable for the lining of many metallurgical units and their elements, except for those including spherical and cylindrical surfaces. It should also be noted that the flame application of the mixture is mainly used for hot repair of metallurgical units and is rarely used in production of linings for newly built units, as well as of large-volume linings.

[0018] Full process automation for application of gunning mixture to an uncooled, unprepared surface of a unit ("hot" repair) often leads to an unpredictable result.

[0019] The problem solved by the group of the claimed inventions and the achieved technical result is the creation of a new method of lining of metallurgical and other thermal units and its implementation into design allowing improvement of preparation quality, homogeneity and stability of the lining mixture composition, with its density, porosity and strength getting close to those of poured refractory concrete with a density higher than 2.4 kg/cm^3, while simplifying the design of the lining device and reducing its dimensions. Besides, the time for installation of lining is significantly reduced (up to 1.5-2.0 times).

[0020] To solve the problem and achieve the claimed technical result by the method of lining metallurgical units, including application of a prepared composition based on a refractory mixture moistened with water and saturated with compressed air on the inner surfaces of such metallurgical units using a nozzle, while the composition is prepared by wetting a dry refractory mixture with water in a turbulent compressed air stream, after which the composition stream is rarefied and impregnated with a hardener in an additional compressed air stream and then condensed before application of the composition to the inner surfaces of units.

[0021] Besides:

- saturation of refractory mixture in the air stream with water and its subsequent impregnation with a hardener is carried out evenly over the cross section of the stream;
- the stream of prepared composition is applied to inner surfaces of metallurgical units from a distance of 0.2-4.0 m and at an angle to the normal not exceeding 60°;
- the prepared composition is applied to the inner surfaces of metallurgical units sequentially in several layers, while the chemical composition may be the same or different for each layer.

[0022] Also, to solve the problem and achieve the claimed technical result an device for lining metallurgical units is proposed, including a nozzle with a housing, to the inlet end of which a branch pipe for supplying a dry refractory mixture in a compressed air stream and a branch pipe for supplying water are connected, while the nozzle housing comprises a rarefaction chamber, fitted with a branch pipe for supplying a hardener mixture by compressed air, and the outlet end of the nozzle is tapered.

[0023] Besides:

- a branch pipe for supplying a dry refractory mixture in a compressed air stream is installed coaxially with the nozzle housing;
- a branch pipe for supplying water to the nozzle housing includes a manifold perpendicular to the branch pipe with several holes evenly distributed along the housing perimeter;
- the branch pipe for supplying a hardener mixture by compressed air to the rarefaction chamber of the nozzle housing includes a manifold perpendicular to the branch pipe with several holes evenly distributed along the housing perimeter;
- the branch pipe for supplying the hardener mixture by compressed air includes a channel for supply of the compressed air perpendicular to the channel for supplying the hardener.

[0024] The group of inventions is illustrated by drawings, where:

- Fig. 1 shows a general view of the most important design element of the device for lining metallurgical and other thermal units - the nozzle with the housing, - in axonometric projection;
- Fig. 2 shows a longitudinal section of the lining device in Fig. 1;
- Fig. 3 shows section A-A of Fig. 2 - the design of the manifold for supplying water and its even distribution in the stream of a dry mixture saturated with compressed air based on a refractory composition;
- Fig. 4 shows section B-B of Fig. 2 - the design of the manifold for supplying a hardener mixture by compressed air into the stream of wetted refractory composition.

[0025] The device for lining of metallurgical units includes a traditional and rather widespread (series-produced) set of device, which comprises, for example, most of the device of a typical dry gunning unit (not shown), the function of which is reduced to feeding into the transport pipeline 1 of a dry refractory mixture under the action of compressed air, and nozzle 2 with housing 3, to inlet end 4 of which and coaxially with it branch pipe 5 for supplying a dry refractory mixture in a compressed air stream and branch pipe 6 for supplying water are connected, while nozzle housing 3 comprises a rarefaction chamber 7 equipped with branch pipe 8 for supplying a hardener mixture by compressed air. Outlet end 9 of nozzle 2 is tapered. Since outlet end 9 is a separate piece made of special wear-resistant materials such as polyamide, it is called "head piece".

[0026] Branch pipe 6 for supplying water to housing 3 of nozzle 2 includes a manifold perpendicular to branch pipe 10 with several holes 11 evenly distributed along housing 3 perimeter.

[0027] Branch pipe 8 for supplying the mixture of hardener with compressed air to rarefaction chamber 7 of housing 3 of nozzle 2 includes a manifold perpendicular to branch pipe 12 with a number of holes 13 evenly distributed along the housing perimeter, perpendicular to which hardener supply channel 15 is located. Branch pipe 8 for supplying the mixture of hardener with compressed air is made in the form of channel 14 for supplying compressed air, perpendicular to which channel 15 for supplying the hardener is located.

[0028] The method implemented by this device for lining metallurgical units includes application of a prepared composition based on a refractory mixture moistened with water and saturated with compressed air to their inner surfaces through outlet end 9 of nozzle 2, while the composition is prepared by wetting a dry refractory mixture with water in a turbulent compressed air stream, after which the composition stream is rarefied, impregnated with a hardener in an additional compressed air stream and then condensed before application of the composition to the inner surfaces of units by reduction of its cross section through the use of tapered outlet end 9 of nozzle 2.

[0029] Saturation of refractory mixture in the air stream with water and its subsequent impregnation with a hardener is carried out evenly over the cross section of the stream, while the stream of prepared composition is applied to the inner surfaces of metallurgical units sequentially in several layers from a distance of 0.2-4.0 m and at an angle to the normal not exceeding 60°, while the chemical composition may be the same or different for each layer depending on process requirements to the quality of lining.

[0030] Let us analyze the essential features of the group of inventions.

[0031] Wetting a dry refractory mixture with water in a turbulent stream of compressed air is known from the "dry" gunning method. However, in the claimed method the stream of the resulting mixture is not applied to the surfaces of metallurgical units, but is rarefied in a conditionally closed volume (chamber 7) of housing 3, which results in a more complete and uniform wetting of the dry refractory mixture. A similar, but more pronounced rarefaction of the wetted mixture can be observed in the "dry" method of gunning at the nozzle outlet, but this process goes along with unregulated redistribution of water amount over the cross section of the wetted stream, which results, in particular, in fluidity of lining local fragments, which is not intended by the technology. After the rarefaction in the closed volume of housing 3 of the refractory mixture stream moistened with water and saturated with air, the hardener is introduced into it in the form of an independent stream of mixture saturated with air bubbles. Unlike the final stage of the "wet" method of gunning - saturation of a dense airless stream of a moist refractory mixture with air bubbles - a turbulent stream of dry refractory mixture moistened with water does not require additional preparation, it is naturally impregnated with the hardener. Then required chemical composition and physical properties are obtained, and the composition is ready for application on the surface of metallurgical units. The stream of the prepared composition is condensed by moving it towards tapered outlet end 9 of nozzle 2. As a result, flow rate increases and at the outlet of nozzle 2 a compact jet is formed from a uniformly mixed composition of refractory mixture, water, and hardener, saturated with small air bubbles. The rarefaction of the stream at the outlet condenses the composition, and presses out air bubbles, which are now useless. Hence on the surface of the unit a layer of composition with properties similar to those of poured concrete.

[0032] Obtaining such a result becomes possible through sequential saturation of the air stream of the refractory mixture with water and its subsequent impregnation with the hardener evenly over the cross section of the stream, which is facilitated by its forced turbulence.

[0033] It is recommended to apply the stream of the prepared composition to the inner surfaces of metallurgical units from a distance of 0.2-4.0 m and at an angle to the normal not exceeding 60°. Distances less than 0.2 m do not allow complete removal of air bubbles, the lining is more porous, which degrades its performance. Distances of more than 4.0 m promote formation of excessively large conglomerates during the flight of composition particles, which create irregularities on surfaces of the unit: unwanted protrusions (ripples) and, as a result, beads and streaks that require subsequent cleaning and/or calibration. These are also promoted by the application of the prepared composition to inner surfaces of metallurgical units at an angle to the normal exceeding 60°. Angles of attack considerably larger than 60° contribute to bounce-off of a part of the composition and it is going to waste.

[0034] The prepared composition is applied to inner surfaces of metallurgical units in one layer or sequentially in several layers, while the chemical composition may be the same or different for each layer. Obviously, depending on the type of metallurgical device - blast furnaces, hot-blast stoves, electric furnaces, casting ladles, pouring spouts, basic oxygen converters, reheating furnaces, etc. - lining thickness, number of layers and composition, including for each layer, are determined. For example, in a blast furnace, the outer lining layer should have a higher wear resistance than inner layers, which is ensured by an appropriate composition of the applied refractory mixture.

[0035] As a result, the claimed method of lining provides the ability to work with a wide range of geometric dimensions of metallurgical units, similar to the method of "dry" gunning, but with a quality of the resulting lining characteristic of the "wet" method and, as can be seen from the information given, with significantly lower costs of implementation and a simpler design.

[0036] A typical device for lining metallurgical units includes a nozzle 2 with housing 3, to inlet end 4 of which a branch pipe 5 for supplying a dry refractory mixture in a compressed air stream and a branch pipe 6 for supplying water are connected. However, in the claimed device, housing 3 of nozzle 2 comprises the rarefaction chamber 7, i.e., a guaranteed cavity, the length of which conditionally reaches the outlet of holes 13 of manifold 12 inside housing 3), which contributes to additional turbulation of the stream of wetted refractory mixture and creates favorable conditions for its additional mixing and impregnation with a hardener. After holes 13 the streams are summed up, and turbulence is reduced and maintained due to the forced mixing of the mixtures through holes 13 evenly distributed around the circumference, similar to the supply of water through holes 11 of manifold 10.

[0037] It should be noted that the hardener is introduced into the wet mixture stream after premixing of hardener with air. For this purpose, branch pipe 8 on housing 3 is used, which includes compressed air supply channel 14, perpendicular to which hardener supply channel 15 is located. The preliminary preparation of a mixture of air with a mainly liquid hardener is ensured by supply of the hardener stream to the air stream perpendicularly or close to it, and due to, among other things, the ejection conditions, they are premixed. The thoroughly mixed air mixture of the refractory composition, water and hardener is fed along housing 3 to nozzle 2, outlet end 9 of which is made tapered. The tapering of nozzle 2 smoothly condenses the flow of the prepared composition and increases its rate, which is formed into a compact jet at the outlet. Thus, the implementation of the claimed method is provided by rather simple design means.

[0038] Additional design solutions of the device for lining metallurgical units enhance the effect obtained. These solutions include the technologically advanced coaxial arrangement of branch pipe 5 for supplying of dry refractory mixture in the compressed air stream to housing 3 of nozzle 2 and the presence on housing 3 and in its rarefaction chamber 7 of, preferably, two manifolds perpendicular to branch pipes 10 and 12, one of which is an element of branch pipe 6 for supplying water, and the other - an element of branch pipe 8 for supplying the hardener mixed with compressed air. Both manifolds 10 and 12 are provided with holes 11 and 13 evenly distributed around the housing perimeter. These design features contribute to obtaining a working composition in a much shorter length of housing 3 of nozzle 2, in contrast to designs without manifolds. This is also promoted by the design of branch pipe 8 for supplying the mixture of the hardener with compressed air in the form of compressed air supply channel 14, perpendicular to which hardener supply channel 15 is located, although this is not necessary. However, the best effect and maximum flexibility of the device can be obtained by using all its the design features.

[0039] Of course, setting up such a device requires special knowledge and practical experience, adequate to the task of setting up a well-known series-produced gunning device.

[0040] It should be noted that the result of implementation of the group of inventions is creation of a new class of special device - units for shotcreting. The etymology of the new term comes from the English words "gunning" ("dry" lining application) and "shot" - shotcreting ("wet" gunning). The result is "shotgun" - the technology and device, consisting mainly of elements of device for "dry" gunning with properties and resulting performance of device for "wet" gunning.

[0041] The implementation of the group of inventions can be illustrated by the following examples:

<u>Example 1.</u> Building of an original device for lining metallurgical units.

[0042] It should be noted that for manufacturing of the device elements of typical lining device, mainly for "dry" gunning, can be used. Thus, a shotgun unit includes, for example, a part of the device of a typical gunning machine (not shown) with a receiving hopper for dry refractory mixture, a revolving rotor fitted with several batch chambers, a module for their sequential unloading with air supply for unloading, an outlet chamber with air supply for transportation and a main pipeline. Additionally, a compressor (in case there is no pneumatic transport supply) and a container for a hardener are installed.

[0043] Transport pipeline (main line) 1 ends with branch pipe 5 for supplying a dry refractory mixture in a compressed air stream. This branch pipe 5 is connected to housing 3 of nozzle 2 through its inlet end 4.

[0044] In addition, the shotgun unit is equipped with a set of supply pipes and hoses for the refractory mixture, hardening additive, air and water.

[0045] To the main pipeline a working member is connected, which is made according to the invention and includes, in particular, nozzle 2 with housing 3, to inlet end 4 of which branch pipe 5 for supplying a dry refractory mixture in a compressed air stream and branch pipe 6 for supplying water are connected, while housing 3 of nozzle 2 comprises rarefaction chamber 7 fitted with branch pipe 8 for supplying the hardener mixed with compressed air. Outlet end 9 of nozzle 2 is tapered.

[0046] To produce the best technical result, nozzle 2 with housing 3 is provided with all or some of the essential design features:

- branch pipe 5 for supplying a dry refractory mixture in a compressed air stream is installed coaxially with housing 3 of nozzle 2;
- branch pipe 6 for supplying water to housing 3 of nozzle 2 includes a manifold perpendicular to branch pipe 10 with a number of holes 11 evenly distributed along the perimeter (perpendicular to the longitudinal axis) of housing 3, the axes of which holes, for example, are inclined to the axis of housing 3 of nozzle 2 and away from it (although not necessarily);
- branch pipe 8 for supplying the mixture of hardener with compressed air to chamber 7 of housing 3 of nozzle 2 includes a manifold perpendicular to branch pipe 12 with a number of holes 13 evenly distributed along the perimeter of housing 3, the axes of which, for example, are also inclined to the axis of housing 3 of nozzle 2 and away from it (although also not necessarily);
- branch pipe 8 for supplying the hardener mixed with compressed air is made in the form of channel 14 for supplying compressed air, perpendicular to which channel 15 for the supply of the hardener is located, which makes it possible to regulate its ejection, and, thus, to obtain a finely dispersed air-hardener mixture of a better quality.

[0047] An assembled shotgun unit is additionally equipped with a control system, tested, marked accordingly and delivered in this form to the customer.

[0048] The unit functions as follows.

[0049] Through the receiving hopper (hereinafter, the function of typical technological conversions is not illustrated), the gunning mixture enters the revolving rotor chambers. Due to the rotation of the rotor, a chamber with material comes to its unloading point. Compressed air is used to unload the material out of the chamber. Through the outlet chamber, the mixture enters the initial section of the main line and then by means of compressed air, i.e., in the air stream (the so-called pneumatic supply), the mixture is transported at a high speed to its final section - branch pipe 5 for supplying the dry refractory mixture to housing 3 of nozzle 2.

[0050] Through manifold 10 of branch pipe 6, the refractory mixture is wetted with water and in this form enters rarefaction chamber 7 on housing 3, where through manifold 12 of branch pipe 8 the wetted mixture is mixed with the hardener. The prepared composition is condensed due to the tapering of nozzle 2 and flows out towards the lined surface of a metallurgical unit.

[0051] The composition is applied to the lined surface in one or several layers.

Example 2. Upgrade of a series-produced unit for "dry" gunning.

[0052] A company or its specialized service, that deals professionally with lining of metallurgical units, has a functioning gunning machine, for instance, AC1-AC6 series, SSB series (SSB 02, 05, 14 and 24), MPCS 4 or other units.

[0053] To expand the process capabilities of the device it has been decided to upgrade it and bring it to the level of specialized shotgun units.

[0054] The upgrade is limited to dismantling of the working member (nozzle) and fitting the machine with a working member made according to Example 1. If necessary, appropriate changes are made to the control system.

Example 3. Lining of a blast furnace under construction.

[0055] On the site the furnace mantle has been built, on the inner surface of which tubular heat exchangers have been mounted, the hearth and boshes erected. The latter are covered with a process apron. There is a power supply -380 V mains; compressed air supply of 0.64 MPa and a water supply system. Depending on the design, distance from the machine to the gunned surface and length of the material hoses, the working pressure in the gunning machine should be in the range from 0.2 to 0.6 MPa. The pressure in the water tank should be 0.05-0.1 MPa higher than the working pressure in the gunning machine. When gunning, the air pressure in the gunning machine and the water pressure in the water tank must be constant.

[0056] It is necessary to line the belly, shaft and mouth of a blast furnace. For this purpose, a standard operating procedure for the work to be performed is developed and released.

[0057] Materials for shotgunning are available - a dry refractory mixture based, for example, on silicon carbide (for application of the first layer) and aluminosilicate composition (for application of subsequent layers); potable water and a hardening additive based, for example, on water glass.

[0058] The shotgunning machine is placed inside of the furnace mantle on the process apron, connected to the power supply system and filled with appropriate materials for application of the first layer. The machine is started and using a special stand is brought to the specified operating mode.

[0059] In accordance with the operating procedure, the machine operator starts the process of application of the first layer of the prepared lining composition onto the inner surface of the furnace mantle by means of nozzle 2. In one or several passes, the first layer of lining is built to the level of the operator's stature (the so-called lining step) along the perimeter of the inner surface of the mantle, which is also used to embed tubular heat exchangers. After raising the apron to the next step, the process of lining is repeated and so on to the entire height of the mantle.

[0060] At the end of the first layer application the apron is lowered to the level of the boshes. The device is washed and filled with materials for the next layer application. The machine is started again and, using a special stand, is brought to the specified operating mode.

[0061] Also in accordance with the operation procedure, the operator starts the process of application of the next layer of the prepared lining composition onto the first layer, naturally or forcedly dried, using nozzle 2. In one or several passes, another layer of lining is applied to the level of the operator's stature along the perimeter of the inner surface of the mantle lined with the first layer, the second layer having, for example, performance properties different from the properties of the first layer. It may be stronger, denser, heat-resistant, etc., and have a corresponding thickness. After raising the apron to the next step, the lining process is continued. If necessary, in accordance with the procedure, the refractory mixture is changed to a mixture with other properties - intended, for instance, for the belly, shaft and mouth of the blast furnace.

[0062] After the lining is applied to the walls of a metallurgical unit, it is cured until completely dry, the formed surface is cleaned (calibrated) and, if necessary, grinded.

[0063] This technology makes it possible to reduce lining installation time by 1.5-2.0 times in comparison with the "wet" gunning method. As a result, construction costs have been significantly reduced.

[0064] After the work is finished, the device is washed, purged with air and left in this condition for later use.

Example 4. Recovery installation of refractory lining of the main trough and blast furnace transport runners (midlife repair).

[0065] A process flow-chart for the upcoming repair work is released.

[0066] The installation of the lining starts with the preparation of the surface to be lined with concrete. The surface must be cleaned of residues of melting products (slag, cast iron), oxidized concrete must also be removed. All unbound, poorly adhered concrete must also be removed.

[0067] The required amount of refractory material has been prepared on the site.

[0068] The device is connected to the utilities (air, water, electrical power) and tested in idle mode (no load).

[0069] The working surface is blown with compressed air to remove dust and small debris.

[0070] Depending on the area of work, refractory materials of various densities and purposes can be used (from the installation of insulating materials to dense working materials with a density higher than 2.4 kg/cm^3, containing as base material Al_2O_3, SiC).

[0071] According to the statement of work, the operator starts application (restoration) of the refractory lining to the geometric dimensions described in the statement of work, using the lining device, namely nozzle 2 with housing 3.

[0072] This technology makes it possible to apply concrete more than 100 mm thick in one pass, since a binder is used. In dry gunning, concrete of this thickness must be applied in layers, which creates a certain undesirable stratification of the lining.

[0073] Today, the basic method to repair working lining of a main spout is exclusively the dry gunning method.

[0074] When using the SHOTGUN method for refractory lining installation, the durability (capacity of the main spout) is increased by 25-30%.

Example 5. Lining of a blast furnace during an overhaul maintenance.

[0075] There is a need for scheduled repairs of a blast furnace, the lining of which is built of partially worn-out refractory bricks, and its useful life is not over yet.

[0076] The furnace is stopped and the inner surface is blown out to reduce the temperature to the level suitable for repair work, including removal of poisonous gases. The boshes and the hearth with the remains of liquid metal and slag are covered with a heat-insulating cover.

[0077] The inner surface of the blast furnace is prepared for repair - potentially hazardous sections of brickwork are removed and surfaces cleaned. The composition of the materials for the lining has been selected. A flow chart of the upcoming repair work has been released.

[0078] The shotgunning machine has been delivered and connected to the utilities. Materials for the lining have been delivered and filled into the machine. The machine is started and, using a special stand, brought to the specified operating mode.

[0079] In accordance with the repair flow chart, the operator starts the process of application of the refractory composition, using nozzle 2, to the inner surface of the furnace or its individual sections, while the composition firmly adheres to the brickwork or its previous layer. The work is carried out until the intended lining thickness is reached. Due to the heated walls, drying of the composition is accelerated.

[0080] After restoring the furnace lining, its inner surface, if necessary, is cleaned (calibrated). Then all devices and materials are removed from the inner space of the furnace. The heat-insulating cover is removed. Routine work is carried out to start the blast furnace, the lining is dried and heated to 700 - 800°C.

[0081] After the work is finished, the device for lining is washed, purged with air and left in this condition for later use.

[0082] Due to the use of the shotgunning technology, the process of blast furnace repair has been significantly accelerated and its cost has been reduced.

Example 6. Lining of a small metallurgical unit - a typical 50-ton steel ladle.

[0083] The usual disadvantage of lining application to the inner surface of such a ladle is the extremely constrained conditions for work - a cone with a height of 2800 mm and the diameters of 2620 mm and 2340 mm, respectively.

[0084] As is known, MgO-C bricks, as well as ramming or casting refractory materials, are widely used for lining newly built or repaired steel ladles. Their installation is a labor-intensive and time-consuming process. The lining life of steel ladles is, as a rule, 7-15 heats.

[0085] It is known that midlife repairs by gunning can increase lining durability by 30-50%.

[0086] A high-quality and fast lining of the abovementioned steel ladle is carried out using a suitable lining device designed according to the invention. Unlike device for "wet" gunning, the size of the working member of this device - nozzle 2 with housing 3 and branch pipe 5 for supplying a dry refractory mixture - is approximately 1 m. With a correction for the jet length of the prepared refractory composition and the bending radius of the supply hoses, about 1.5 m of free space is required. The main working device is located outside of the ladle.

[0087] For a lining of the interior of a new steel ladle all the actions according to Example 3 are performed by, for example, one operator.

[0088] To restore the lining of a steel ladle during scheduled repairs, the actions according to Example 5 are performed, with a correction for significantly smaller ladle dimensions and the absence of a bath with molten metal and slag - also by one operator.

[0089] After the work is finished, the device for lining is washed, purged with air and left in this condition for later use.

[0090] The newly lined or repaired steel ladle is dried, heated to 700-800° and put into operation.

[0091] The durability of a steel ladle lining installed using the shotgunning technology before a midlife repair is comparable to a lining service life, including its refurbishment carried out using a traditional technology, which is at least 20 heats. Midlife repairs using the shotgunning technology allow extending ladle life to 30 heats or more.

[0092] The above Examples 1-6 do not exhaust the opportunities to use the claimed group of inventions. Other options are possible that use the essential features of the inventions in various combinations and on various metallurgical and thermal units.

[0093] The solution of the set problem gave birth to a new method of lining of metallurgical and other thermal units and to the design of a device for carrying out the same. The quality of preparation, homogeneity and stability of the lining mixture composition were improved and the density, porosity and strength of the lining mixture composition approached those of a poured refractory concrete with a density higher than 2.4 kg/cm^3. The design of the lining device was simplified, and its size reduced. In addition, the time for installation of the lining was significantly reduced (up to 1.5-2.0 times).

Claims

1. Method of lining metallurgical units, including the application of a prepared composition based on a refractory mixture moistened with water and saturated with compressed air on their inner surfaces using a nozzle, **characterized in that** the composition is prepared by wetting a dry refractory mixture with water in a turbulent compressed air stream, after which the composition stream is rarefied and impregnated with a hardener in an additional compressed air stream with subsequent condensing of the stream before application of the prepared composition to the inner surfaces of the units.

2. Method of Claim 1 **characterized in that** the saturation of the air stream of the refractory mixture with water and its subsequent impregnation with a hardener is carried out evenly over the cross section of the stream.

3. Method of Claim 1 **characterized in that** the stream of the prepared composition is applied to the inner surfaces of metallurgical units from a distance of 0.2 to 4.0 m and at an angle to the normal not exceeding 60°.

4. Method of Claim 1 **characterized in that** the prepared composition is applied to the inner surfaces of metallurgical units sequentially in several layers, while the chemical composition may be the same or different for each layer.

5. A device for lining metallurgical units, including a nozzle with a housing, to the inlet end of which a branch pipe for supplying a dry refractory mixture in a compressed air stream and a branch pipe for supplying water are connected, **characterized in that** the nozzle housing comprises a rarefaction chamber fitted with a branch pipe for supplying the mixture of hardener with compressed air, and the outlet end of the nozzle is tapered.

6. The device of Claim 5 **characterized in that** the branch pipe for supplying a dry refractory mixture in a compressed air stream is installed coaxially with the nozzle housing.

7. The device of Claim 5 **characterized in that** the branch pipe for supplying water to the nozzle housing includes a manifold perpendicular to the branch pipe with several holes evenly distributed along the housing perimeter.

8. The device of Claim 5 **characterized in that** the branch pipe for supplying the mixture of hardener with compressed air to the rarefaction chamber of the nozzle housing includes a manifold perpendicular to the branch pipe with several holes evenly distributed along the housing perimeter.

9. The device of Claim 5 **characterized in that** the branch pipe for supplying the mixture of the hardener with compressed air is made in the form of a compressed air supply channel, perpendicular to which the hardener supply channel is located.

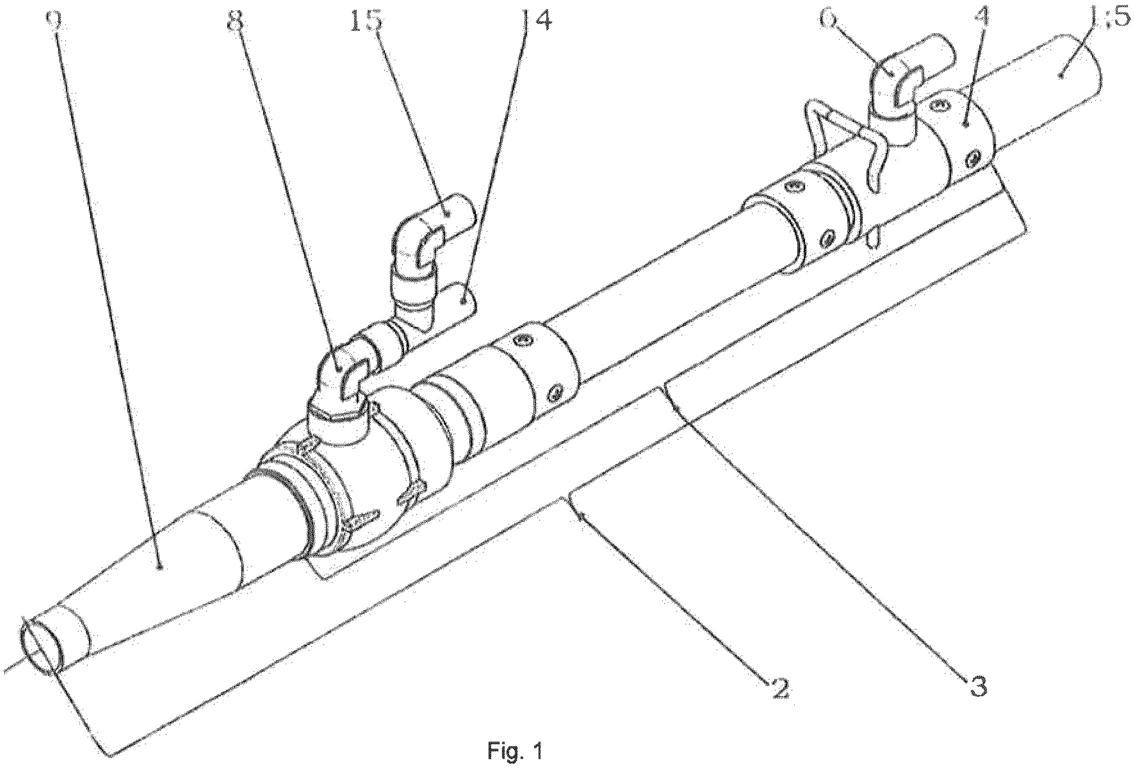

Fig. 1

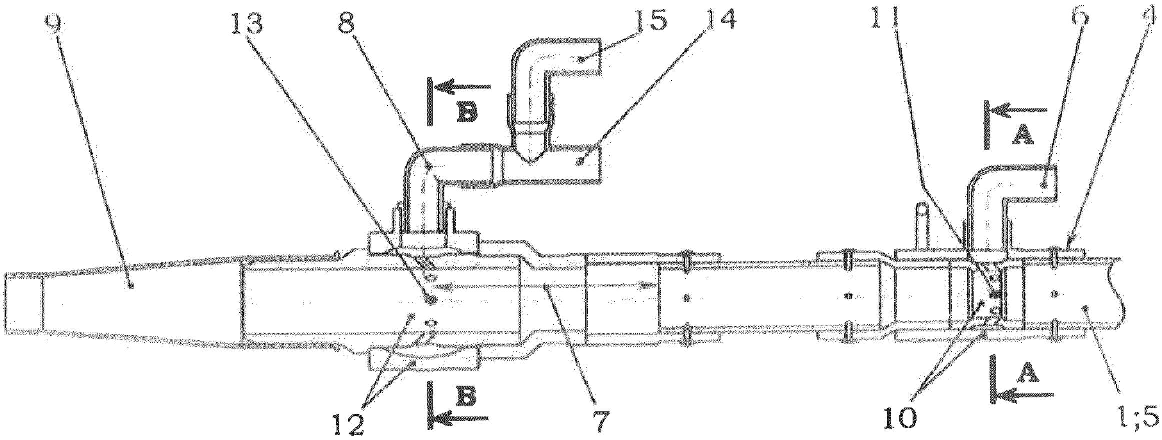

Fig. 2

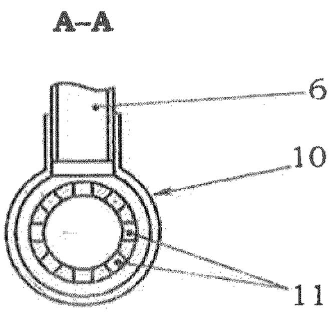

Fig. 3

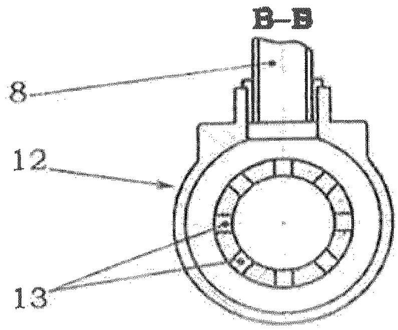

Fig.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2019/000580

A. CLASSIFICATION OF SUBJECT MATTER
B05B 7/14 (2006.01); B05B 13/00 (2006.01); C21C 5/44 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B05B 7/00-7/14, B05B 13/00-13/06, C21C 5/00-5/44, E04B1/00-1/76

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Espacenet, CIPO, USPTO, PatSearch (RUPTO Internal)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
D, A	RU 2363543 C2 (SPESHIALTI MINERALIZ (MICHIGAN) INK.) 10.08.2009	1-19
D, A	RU 2108397 C1 (AKTSIONERNOE OBSCHESTVO «SANKT-PETERBURGSKY INSTITUT OGNEUPOROV» et al.) 10.04.1998	1-19
A	SU 670705 A2 (KISHINEVSKY POLITEKHNICHESKY INSTITUT IM. S. LAZO) 30.06.1979	1-19
A	US 597662 A (NORTH AMERICAN REFRACTORIES SO.) 02.11.1999	1-19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 2019 (11.12.2019)	09 January 2020 (09.01.2020)
Name and mailing address of the ISA/ RU	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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