

[54] **METHOD AND DEVICE FOR MONITORING THE WORKING OF A FURNACE**

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[58] Field of Search178/DIG. 1, DIG. 2, DIG. 14, 178/6.8, DIG. 38

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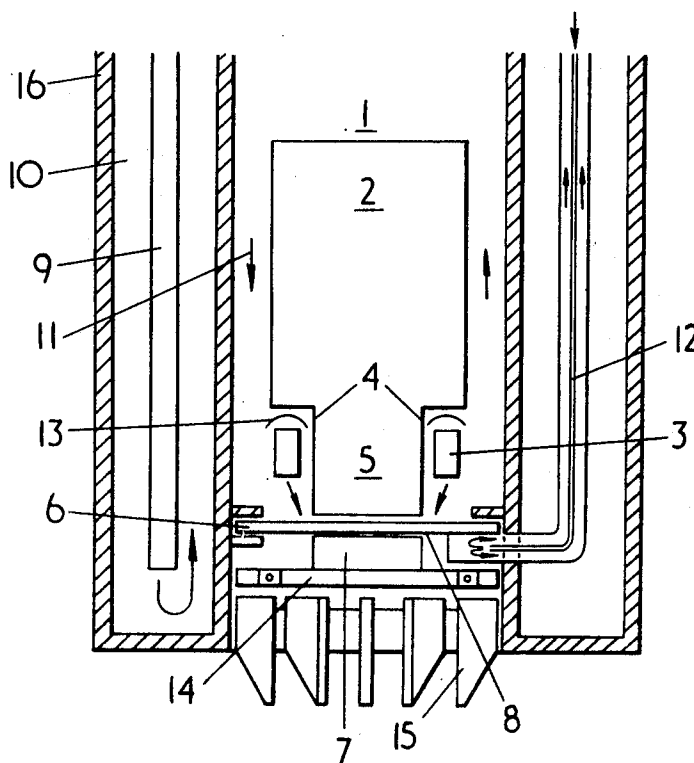
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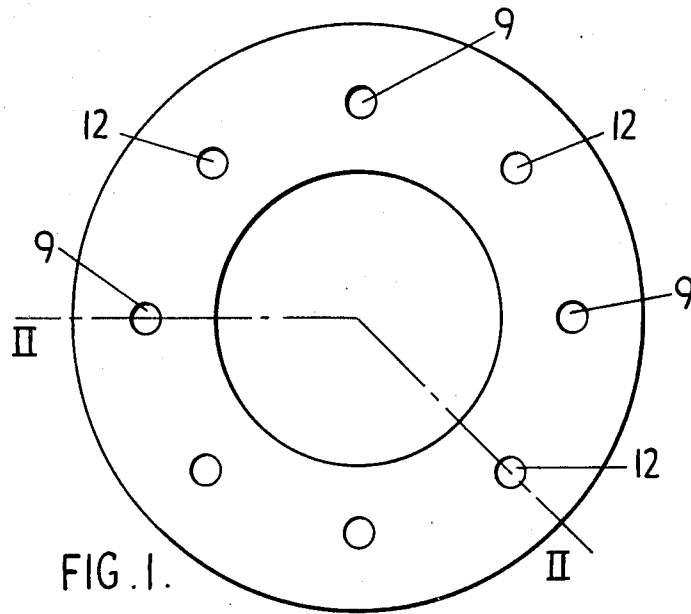
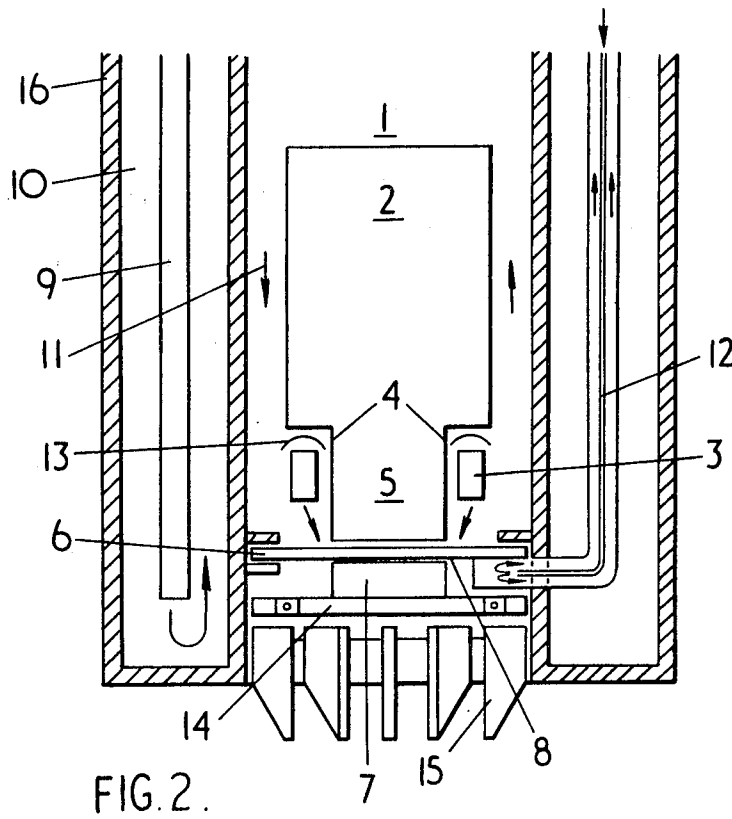
Primary Examiner—Robert L. Griffin
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[57] **ABSTRACT**

A method and apparatus for monitoring the operation of a furnace, and more particularly of a blast furnace, by making a visual examination of the charge and/or the walls and internal accessories of the said furnace, in which a mobile probe including equipment to pick up optical rays that may comprise at least one television camera sensitive to the optical rays coming from the charge is inserted into the furnace charge and the rays coming from the said charge are received by means of the said pick-up equipment, giving a representative image of its and enabling the required characteristics to be deduced.

3 Claims, 7 Drawing Figures





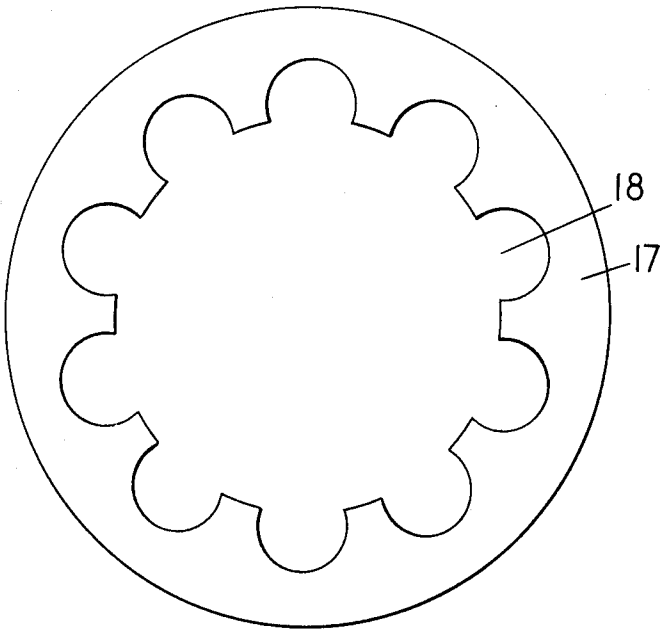


FIG. 3

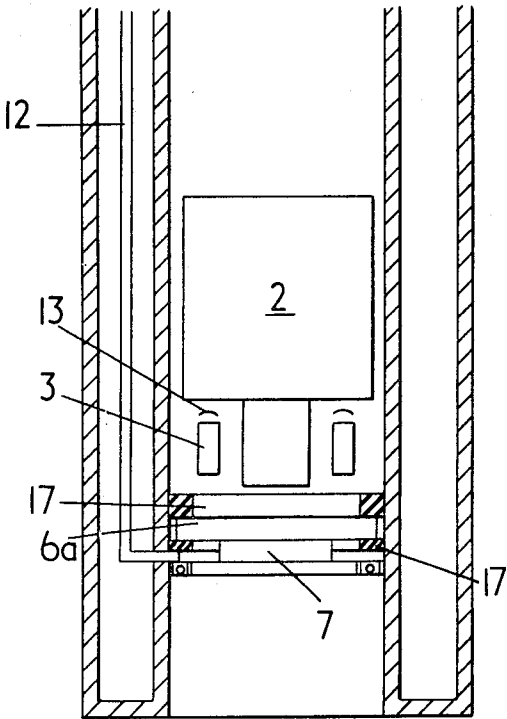


FIG. 4

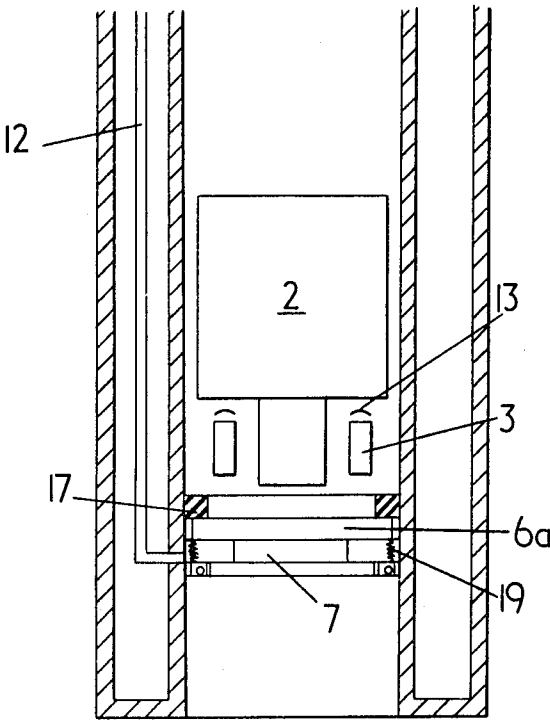


FIG. 5

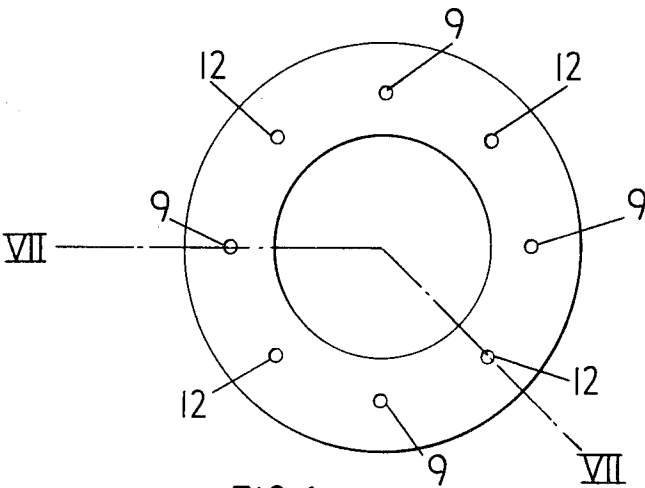


FIG. 6

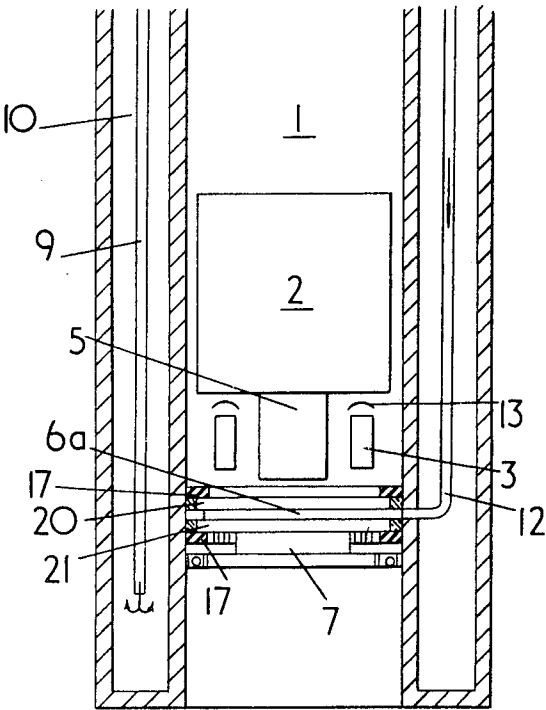


FIG. 7

METHOD AND DEVICE FOR MONITORING THE WORKING OF A FURNACE

The present invention relates to a method and device for monitoring the working of a furnace, particularly advantageous in that they enable a visual inspection to be made of the charge and inside walls of the furnace.

The following description is based on the application of the method and the corresponding device, to a shaft furnace of the blast furnace type, but it should be clearly understood that the considerations expounded below can be applied "mutatis mutandis" to any other type of furnace, whether of the shaft type or not, and the scope of the invention therefore extends to all these types of furnace.

A knowledge of the state of the charge in a blast furnace as it descends after being charged at the top is of increasing importance for controlling the operation of the furnace and ensuring the production of an iron of the specified composition under optimum operating conditions. The concept of automatic control methods for modern blast furnaces is also based on such a knowledge and the more detailed this knowledge, the better the results which may be expected.

For this purpose, a very large number of measurements, analysis and determinations are made, such as the analysis of top gas, the determination and inspection of the upper level of the charge, horizontal samplings to check the distribution of gases at different levels, the combustion at the tuyeres, the analysis of the iron produced, and so forth.

However, it has not hitherto been possible to determine the state of a part of the charge situated at any point below the upper exposed surface of the charge, nor to follow the progress of such a part.

A method according to the present invention consists essentially of the introduction into the furnace charge of a mobile probe including equipment designed to pick up the optical rays coming from the charge and having at least one television camera sensitive to the said optical rays, and the reception of the rays coming from this part of the charge, giving a view of a representative image of it and enabling the required characteristics to be deduced.

According to an advantageous variant of the method according to the invention, the mobile probe inserted into the charge of the blast furnace also includes equipment to transmit optical rays and the optical rays transmitted by this transmitter are directed towards the part of the charge to be examined, then the optical rays retransmitted by the charge are received, again giving a view of a representative image and enabling the required characteristics to be deduced.

It should be noted that the expression "optical rays" refers to rays of a wave length between 0.12 and 40 microns.

For application of this process to a hearth-type furnace, such as an open hearth furnace or a glass making furnace the device described above has to be adapted so as to obtain the furnace a view allowing observation either along the axis of the probe carrying the camera, or obliquely or even at right angles to that axis.

Such a view can advantageously be obtained by equipping the probe carrying the camera with a head that can be pivoted around one or more axes and itself containing the whole of the optical device, so that the direction of observation can be modified as required.

Moreover, if it is desired to obtain either a stereoscopic view or a view in several directions at the same time, the end of the probe can be equipped either with several optical devices each facing a selected direction and possibly able to be pivoted individually, or with optical devices giving a view in several directions at the same time. All these devices, suitable in particular for the application of the method according to the invention to the special cases mentioned above, must be considered as included in the list of equipment used by the said method, in accordance with the content of the characteristic part of its definition above.

According to the invention, the pick-up device is associated with a focal optical system, such as a lens, and the image is focussed in the plane of the sensitive surface of the television camera either by moving the said television camera within the probe or by using a zoom lens.

According to a particularly advantageous variant of the invention, the device to pick up the optical rays has at least one optical fibre and the rays reflected by the part of the charge observed are sent back through the optical fibre or fibres to a receiver placed outside the furnace, which again provides a representative image of the area explored, from which image the required characteristics can be deduced.

The optical fibres, use of which for sampling of the furnace charge is convenient, all well known per se.

They consist of elongated rods of glass, composed of a core and a sheath of glasses with different refraction indices so that the light entering such a fibre at one end can only emerge at the other end. Such optical fibres can describe various curves and deliver the light in a direction different from the direction in which it enters them. Therefore they make it possible to pick up images at points difficult of access to transmit them to a receiving station where access is easier.

It is also known that to retransmit a given image it is necessary to use a bundle of fibres in which the arrangement of the fibres at the entrance and exit is identical.

Although the use of such optical fibres is a particularly advantageous way of implementing the method according to the present invention, the invention also includes methods of monitoring the working of a blast or other furnace in which a set of prisms and/or mirrors bringing the image picked up into the focal plane of the optical ray receiving equipment is used as the device to pick up and send back the optical rays.

According to an advantageous form of the invention, a wide angle lens device is used when a large area is to be examined.

According to another advantageous form of the invention, a telephoto lens device is used to examine a very small area and follow its movement.

The optical rays sent out may consist of visible light or of infra-red rays, the latter being particularly advantageous for temperature measurement. In addition to temperature measurement, the method enables gas analyses and pressure measurements to be made.

Also according to the invention, it is advantageous to send out periodically modulated infra-red or visible light rays in order to enable the receiving equipment to distinguish between the rays originating from the charge and those emanating from the transmitting device.

According to a variant of the invention, the radiations transmitted are of the laser or maser type because of their high intensity and coherence, which enables them to be clearly distinguished from the other rays and facilitates their focussing

To allow the largest possible number of observations, the probe is designed so that it can be arranged vertically or horizontally or inclined between these two extreme positions, to examine for example: the coke, the core and the fluxes. Likewise, it can be inserted along the furnace axis, or eccentrically or along the walls, depending on the purpose for which it is used, for example to inspect the refractory lining or to examine the tuyeres.

In order to protect the outside wall of the probe from the heat, a cooling water circuit may be established inside the said wall.

Likewise, to protect the transmitting and receiving equipment from the heat, a cooling air circuit may be established in a central conduit of the probe in which they are housed.

Finally, to protect the focal optical system associated with the pick-up equipment from the heat and also to provide at least partial cleaning of it, inert gas, such as nitrogen, may be blown in a direction substantially tangential to the outside surface of said optical system.

To ensure transparency of the focal optical system associated with the pick-up equipment, the surface of the said optical system facing the charge is swept by means of a scraper driven in a rotating or reciprocating movement.

The rotating or reciprocating movement imparted to be scraper to clean the focal optical system associated with the receiving equipment is advantageously of a speed such that the said component cannot disturb the image received, i.e., the frequency of rotation or reciprocation is equal to or greater than 30 movements per second.

The insertion of the probe and its movement in the charge can advantageously be facilitated and the focal optical system and its cleaning mechanism protected at the same time, if the end of the probe that penetrates the charge is fitted with suitable fins.

It has been found advantageous to use a transparent element to protect the focal optical system, which element is preferably supported on at least one annular support, the internal part of which is equipped with recesses to let through the optical rays sent out by the transmitting system and directed towards the part of the furnace to be examined.

During testing, it has been found that the use of an annular support of a relatively small inside diameter but having internal recesses gave better results than the use of an ordinary ring with a larger inside diameter. The support may be housed in the central conduit of the probe in which it is held either by screwing or by wedging against stops or by any other suitable means.

According to an advantageous variant, the transparent protective element may consist of two parallel sheets placed at a certain distance from each other, between which a cooling fluid circulates, with the outside face of the said element being cleaned in a fashion known per se, for example by a scraper device moved by any suitable means, preferably mechanical or electrical. This variant eliminates the need for blowing in

gas and the resultant disturbances in the measuring area. Elimination of the blowing in of compressed gas involves the disappearance of the fluid driving the scraper device, so that this cannot be pneumatically driven, and therefore this device must be provided with a mechanical or electrical drive.

An advantageous method of implementing this variant consists of using two quartz sheets between which a cooling liquid, preferably pure water, is circulated.

Also according to this variant, the cooling fluid may contain a substance such that the mixture acts as an optical filter.

In particular, two types of such organic substances are known which, in solution in a solvent, absorb all of the optical rays to which they are exposed.

Substances of the first type have a very great absorption power in that they absorb all optical radiations, whatever the wave length of these radiations. However, the absorption rate of the said radiations depends on the concentration of the said substance in the solvent.

Substances of the second type have a selective absorption power in that they absorb only radiations of specific wave lengths. Here again, the rate of absorption of these radiations depends on the concentration of the said substance in the solvent.

Still according to this variant, it is particularly advantageous to add to the fluid cooling the element protecting the blast furnace probe at least one coloring substance with a wide absorption and/or at least one substance with a selective absorption.

These absorbing substances are preferably organic compounds, but it is possible to use inorganic substances, such as copper sulphate, for this purpose.

The use of a filter of this kind makes it possible to focus on areas with very high temperatures and to obtain a satisfactory image of them, as a result of the elimination of disturbing radiation by the filter.

To retain a very clear image when the blowing of inert gas against the protective element is avoided, it is proposed to use, during the actual observations, discontinuous blowing of a gas, for example an inert gas, in the direction of the specific part of the charge or of the furnace under observation. For this purpose, a special pipe is used, delivering the gas below the cleaning element, preferably between the protective fins.

It has been found that intermittent blowing of inert gas during the observations improved the clarity of the image obtained and clarified the objects observed. It is important to note that the intermittent blowing of small volumes of gas does not significantly disturb the observations.

The invention further includes a probe for putting the invention into effect the probe comprising a means of monitoring the operation of a furnace, and more particularly of a blast furnace, by making a visual examination of the charge and/or the walls and internal accessories of the said furnace in which a mobile probe including equipment to pick up optical rays is inserted into the furnace charge and the rays coming from the said charge are received by means of the said pick-up equipment, giving a representative image of it and enabling the required characteristics to be deduced.

The invention will be further described with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic plan view of one form of probe for putting the method of the invention into effect;

FIG. 2 is a section of the lower part of a probe taken on the line II—II of FIG. 1;

FIG. 3 is a plan view of a form of annular support for the optical system;

FIGS. 4 and 5 are views similar to FIG. 2, illustrating alternative forms of embodiment; and

FIGS. 6 and 7 are views similar to FIGS. 1 and 2 illustrating further forms of embodiment.

The probe illustrated in FIGS. 1 and 2 consists of a hollow body containing at least one movable television camera 2 mounted in a central conduit 1 of the said hollow body, where appropriate, at least one optical ray transmitting device 3 also mounted inside the central conduit 1 and preferably in a recess 4 in a head 5 of the camera 2.

A focal optical system 6 is also mounted inside the central conduit 1 and lies between the above-mentioned transmitting devices 3 and the camera 2 from the material to be examined.

FIG. 2 also illustrates means 7 for cleaning the surface 8 of the said focal optical system 6 facing the material to be examined. Cooling water is circulated in a space 10 within the outside wall 16 of the probe by means of pipes 9. Air is circulated as shown by the arrows 11 in the central conduit 1 around the television camera 2 and the transmitter devices 3. Inert gas is blown through pipes 12 onto the focal optical system 6 to cool it, the said pipes 12 being mounted in the cavity 10.

The transmitting device 3 may consist of four filament or gas discharge lamps situated around the vision head 5 of the television camera 2.

Alternatively the transmitting device 3 may consist of at least one laser.

The transmitting device 3 is shown as equipped with at least one reflector 13 intended to concentrate the optical rays on the material to be examined.

The focal optical system 6 associated with the receiving device is indicated as a lens.

The means 7 for cleaning the surface 8 of the focal system 6 facing the material to be examined is advantageously constituted by a copper scraper with a rotating or reciprocating movement imparted by means of a suitable motor, for example electric, pneumatic, etc., and mounted on bearings 14 such as ball bearings.

The end of the central conduit of the probe designed to enter the blast furnace is shown as provided with fins 15 in order to protect all the devices mounted in the central conduit 1 of the said probe and in particular the focal optical system 6 and the means 7 for cleaning its outside surface 8.

FIG. 3 shows an example, which is in no way limiting, of an annular support 17 for the optical system, which support is provided with internal recesses 18.

In FIGS. 4 and 5 the same elements of the device are denoted by the same reference numerals as in FIGS. 1 and 3.

FIG. 4 shows an embodiment of the probe in which a protective element 6a for the focal optical system (omitted for clarity) is held between two supports 17. It is to be understood that the supports 17 are arranged so that their recesses are aligned to ensure a free light path towards and away from the parts to the examined.

FIG. 5 shows a form in which the protective element 6a is supported between one support 17 and an elastic system, shown diagrammatically by springs 19, itself supported on the body of the probe.

FIGS. 6 and 7 show an embodiment in which the protective element 6a is composed of two transparent sheets 20, 21, preferably of quartz, between which pure water is circulated. The water is supplied and removed by the tubes 12 mounted in the other casing 10 of the probe. The outer casing of the probe also has the cooling water supplied by the tubes 9 running through it.

The double transparent sheet 20, 21, can be retained by means of annular supports with recesses, similar to those already described. The accurate spacing of the sheets is also maintained by these supports.

We claim:

1. A mobile probe for monitoring the operation of a furnace by making selective visual examination of the walls, internal accessories and the charge of the furnace, comprising a hollow body containing:

- a. a receiving device to pick up the rays retransmitted by the part of the charge or furnace to be examined, this device comprising least one movable television camera having a head, said device being mounted in a central conduit of the said hollow body;
- b. at least one optical ray transmitting device also mounted inside the central conduit in a recess made in the head of said camera;
- c. a focal optical system also mounted inside the central conduit between the transmitting and receiving devices and the material to be examined; a protective element for said focal optical system, said element being supported on at least one annular support having a plurality of recesses uniformly spaced along the inner periphery thereof said recesses being provided to let through optical rays sent out by said transmitting device and direct towards the charge or a part of the furnace to be examined;
- d. means for cleaning the surface of said focal optical system facing the material to be examined;
- e. means for providing cooling water circulation through hollow outside walls of the probe;
- f. means for providing cooling air circulation in the central conduit around the television camera and the optical ray transmitting device; and
- g. means for blowing cooling inert gas on to the focal optical system associated with the receiving device, which means is mounted inside the outside walls of the probe.

2. A mobile probe for monitoring the operation of a furnace by making selective visual examination of the walls, internal accessories and the charge of the furnace, comprising a hollow body containing:

- a. a receiving device to pick up the rays retransmitted by the part of the charge or furnace to be examined, this device comprising at least one movable television camera having a head, said device being mounted in a central conduit of the said hollow body;
- b. at least one optical ray transmitting device also mounted inside the central conduit in a recess formed in the head of said camera;
- c. a focal optical system also mounted inside the central conduit between the transmitting and receiving

ing devices and the material to be examined; a transparent protective element for said focal optical system, said transparent protective element comprising at least two parallel sheets placed a certain distance apart and having a circulating cooling fluid between said two parallel sheets;

- d. automated means for cleaning the outside surface of said transparent protective element, which outside surface faces the material to be examined;
- e. means for providing cooling water circulation through hollow outside walls of the probe;
- f. means for providing cooling air circulation in the central conduit around the television camera and

- the optical ray transmitting device; and
- g. means for blowing cooling inert gas on to the focal optical system associated with the receiving device, which means is mounted inside the outside walls of the probe.

3. A probe as claimed in claim 2, which further includes at least one pipe for blowing in gas mounted inside the hollow outside walls of the probe, with an outlet end of the said pipe being arranged inside the central conduit of the probe, beyond the transparent protective element and separating the optical system of the probe from the atmosphere in the furnace.

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