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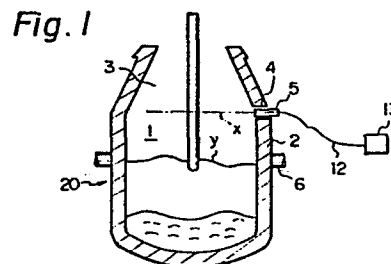
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54 Method and apparatus for measuring slag-forming conditions within converter.

57 A method and apparatus for directly observing the slag-forming conditions in a vessel interior (3).

A device (5) for observing the vessel interior light is disposed in a throughhole (4) extending through the side wall 20 of a top-blowing or top- and bottom-blowing converter to reach the vessel interior (3). The converter operation can be carried out at a high accuracy on the basis of this observation.



METHOD AND APPARATUS FOR MEASURING
SLAG-FORMING CONDITIONS WITHIN CONVERTER

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a method and apparatus for directly observing slag-forming conditions
5 within a converter used for steel refining.

(2) Description of the Prior Art

In refining molten pig iron and steel in a converter, pure oxygen is ejected from a lance inserted through the mouth of the converter into the converter
10 body (below "vessel"). The oxygen is blown onto the molten steel to both effect decarburization and stir the molten steel. In addition, flux is charged into the converter to form molten slag, thereby effecting dephosphorization, desulfurization, or the like due to the reactions
15 between the molten slag and steel.

Slag foaming occurs due to several slag conditions, such as the slag composition, viscosity, the total amount of oxygen in the slag, etc. Too extensive slag foaming causes the slag and even molten steel to overflow
20 the converter mouth, which overflow is referred to as "slopping". Of course, the composition of the molten steel and the steel yield are greatly influenced by slopping. Also, various problems are caused, such as reduction in the operational efficiency and in the
25 calorific content of the recovered gases, impairment of the operational environment, e.g., generation of brown smoke, and damage to the steelmaking devices. Slopping therefore must be suppressed as much as possible.

Various proposals have been made on how to enable
30 prompt prediction of the slag conditions within a converter and hence realize optional converter operation without slopping.

Japanese Unexamined Patent Publication (Kokai)

No. 52-101618 discloses a method for estimating the amount of slag by calculating the oxygen balance based on information on the waste gases during blowing and then estimating the amount of oxides formed in the converter, i.e., the molten slag. In this method, however, there is an unavoidable time delay due to the gas analysis and mathematical analysis. In addition, since slopping is not dependent upon just the amount of molten slag alone, the accuracy of prediction of slopping is not very high.

Various attempts have also been made on detecting the slag level by physical means. These include an acoustic measuring method (Japanese Unexamined Patent Publication No. 54-33790), a vibration measuring method (Japanese Unexamined Patent Publication No. 54-114,414), a method for measuring the inner pressure of a converter (Japanese Unexamined Patent Publication No. 55-104,417), a method using a microwave gauge (Japanese Unexamined Patent Publication No. 57-140812), and a method for measuring the surface temperature of the converter body (Japanese Unexamined Patent Publication No. 58-48615).

In the acoustic measuring method, changes in the frequency and magnitude of the acoustics generated in the converter are monitored to estimate the slag level and to predict slopping.

In the vibration measuring method, changes in the magnitude of lance vibration and the wave transition of the lance vibration are monitored during blowing to estimate the slag level or conditions and then to predict slopping.

In the method for measuring the inner pressure of a converter, variations in the ejecting pressure of the waste gases through the converter mouth are monitored to predict slopping.

In the method using a microwave gauge, a microwave is directly projected into the converter interior to directly measure the slag level based on the FM radar

technique and to predict slopping.

In the method for measuring the surface temperature of a converter body, the energy emission from the upper and lower parts of the converter body is detected as temperature, and the occurrence and magnitude of slopping are predicted based on the temperature magnitude and peak values.

The acoustic measuring method, vibration measuring method, method for measuring the inner pressure of a converter, and method for measuring the surface temperature of the converter body are all indirect measuring methods and suffer from low accuracies of prediction of slopping due to the inability to quantitatively measure the slag level or conditions. The method using a microwave gauge enables direct measurement of the slag level, but suffers from the fact that it is not easy to detect or estimate abnormalities by microwave measurement, since the melt, slag, gases, and the like effect considerably complicated movement in the converter during blowing. In addition, this method requires sophisticated signal processing, which increases the cost of the measuring device.

SUMMARY OF THE INVENTION

The present inventors recognized, as a result of various studies concerning abnormal reactions in a converter, that the occurrence of such abnormal reactions is closely related to the slag-forming conditions, i.e., the foaming behavior of slag. The present inventors studied the foaming behavior of slag and discovered that the light intensity of the gaseous atmosphere and the wavelength characteristics of light emitted from the gaseous atmosphere considerably differ from those of the slag. The present inventors discovered that they could positively utilize such differences to detect the foaming behavior.

The present invention provides a method and apparatus for directly observing slag-forming conditions,

i.e., the slag-foaming conditions, in a converter during blowing, thereby allowing more precise and speedy observation than in the prior art and contributing to a highly accurate converter operation.

5 The method according to the present invention is characterized in that at least one observation device of the vessel-interior light is disposed in at least one throughhole of the side wall of a converter so as to face the vessel interior and observe the slag-forming
10 conditions.

 The apparatus according to the present invention comprises a light-detecting device including a receptor, which receptor is disposed in a throughhole of the side wall of a converter so as to face the vessel interior,
15 and a device for detecting the intensity and/or wavelength of a light signal input from the light-detecting device.

BRIEF DESCRIPTION OF DRAWINGS

 In the drawings, Fig. 1 is a cross-sectional view
20 of a top-blowing converter, schematically showing an embodiment of mounting a device for observing the vessel-interior light on the converter;

 Figs. 2A through 2C are cross-sectional views of a converter, showing non-immersion portions of the
25 converter side wall;

 Figs. 3A through 3C, Fig. 4, and Fig. 5 illustrate the principle of the present invention, Figs. 3A through 3C showing the position of mounting the devices for observing vessel-interior light and Figs. 4 and 5
30 showing time charts on the level of detected light signals;

 Figs. 6 and 7 are partial cross-sectional views of a converter, showing different mounting structures of a device for observing the vessel-interior light;

35 Fig. 8 is a schematic drawing of the arrangement of the device for observing the vessel-interior light, relative to the converter;

Fig. 9 is a partial cross-sectional view of a converter and a cross-sectional view of the device for observing the vessel-interior light, which device is gas-tightly inserted into a throughhole of the converter;

5 Fig. 10A is an overall view of a supporting platform with a displacement mechanism;

Figs. 10B through 10E are partial views of the supporting platform shown in Fig. 10A;

10 Figs. 11 (I), (I'), (II), (II'), (III), and (III') illustrate the blowing conditions of a converter and the operation of the device for observing vessel-interior light according to the present invention;

15 Fig. 12 graphically illustrates the relationship between the wavelength and intensity of light emitted from the slag and gaseous atmosphere above the slag;

Fig. 13 illustrates an example of a vessel-interior display, showing the variation in the surface-area proportion with the lapse of blowing time;

20 Fig. 14 illustrates an example of the piping of purge gas;

Fig. 15 is a partial cross-sectional view of an example of a probe according to the present invention;

Fig. 16 illustrates the relationship between the slag level and blowing time;

25 Fig. 17 is a block diagram of another example of the device for observing the vessel-interior light;

Fig. 18 shows the mounting position of devices for observing the vessel-interior light mounted on a top- and bottom-blowing converter;

30 Fig. 19 is a time chart of light signals detected by the devices shown in Fig. 18 and of the slag level detected by using a substance;

Fig. 20 is a block diagram of method of detecting the slag-forming conditions according to the present invention; and

35 Figs. 21 through 23 illustrate the slag level during blowing and a method for controlling it.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a cross-sectional view of a top-blowing converter, schematically showing an embodiment of mounting a device for observing the vessel-interior light. Referring to Fig. 1, a converter 1 is provided, on its side wall 2, with at least one throughhole 4 opening into the vessel interior 3. At least one vessel-interior observation device 5 is disposed in the throughhole 4 to face the vessel interior 3 and observe the intensity or the wavelength of the light emitted from the slag and gaseous atmosphere within the converter 1. This observation device 5 may be a photometer and is hereinafter referred to as the photometer 5. In Fig. 1, only one throughhole and observation device are shown.

It is possible, based on the measurement of intensity and or wavelength of the light, to monitor whether slag-foaming occurs above or beneath a processing level X of the photometer 5.

Figures 2A to 2C show non-immersion portions 8 of the converter side wall 20, i.e., in the converter upright position, tilting position for tapping, and tilting position for charging the pig iron from the ladle, respectively. In each of the positions shown in Figs. 2A, 2B, and 2C, the portion of the converter wall 20 where a trunnion shaft 6 is rigidly secured and the region around that portion are not immersed within a melt 7. This portion and region, shown by the hatching are the non-immersion portion 8. The throughholes 4 can be formed through the non-immersion portion 8 to prevent the melt 7 from entering the throughholes 4.

As is described below, the photometers 5 can also be removably inserted into the tapping hole. When the molten steel is tapped through the tapping holes, the photometers 5 are removed therefrom.

Figures 3A through 3C, Fig. 4, and Fig. 5 illustrate the principle of the present invention, Figs. 3A

through 3C showing the portions of mounting the devices for observing vessel-interior light and Figs. 4 and 5 showing time charts on the level of detected light signals. Referring to Figs. 3A through 3C, three
5 photometers 5a, 5b, and 5c are arranged as seen in the vertical direction of the converter, so as to measure the vessel-interior light at the levels Xa, Xb, and Xc, respectively. The position of the throughholes 4, i.e., their distance from the bottom or mouth of the
10 converter 1, must be empirically determined by the size and capacity of the converter 1. In the case of a single throughhole 4, the throughhole 4 must be located at the highest target slag level. In the case of plurality of throughholes 4, the highest and lowest
15 throughholes 4 must be located straddling the highest target slag level.

Figure 4 shows the light signal (ordinate) detected by any one of the photometers 5a, 5b, and 5c and then subjected to signal processing with the aid of an
20 appropriate filter. The abscissa of Fig. 4 indicates the blowing time periods, the former period when the gaseous atmosphere is present beneath the level Xa, Xb, or Xc and the latter being when foaming slag is present beneath the levels Xa, Xb, or Xc.

25 Figure 5 illustrates the results of continuous measurement of the vessel-interior light by the photometers 5a through 5c. Under the slag-foaming conditions shown in Fig. 3A, all of the photometers 5a through 5c face or are exposed to the gaseous atmosphere, which
30 indicates that the slag-foaming level y is located beneath the level Xc.

Under the slag-foaming conditions shown in Fig. 3B, the photometers 5a and 5b face or are exposed to the gaseous atmosphere and the photometer 5c faces or is
35 exposed to the foaming slag. The slag-foaming level y is therefore located beneath the level of the converter mouth 9 and between the levels Xb and Xc.

Under the slag-foaming conditions shown in Fig. 3C, all of the photometers 5a through 5c face or are exposed to the slag. The slag-foaming level y is therefore located between the level of the converter mouth 9 and the level Xa of the photometer 5a.

The complicated foaming behavior of slag can therefore be accurately monitored by means of mounting a plurality of the photometers in the vertical direction and continuously measuring the vessel-interior light during the operation of the converter 1. If necessary, photometers may also be mounted along the width of the converter 1.

As described above, the intensity of light of the gaseous atmosphere and the wavelength characteristics of light emitted from the gaseous atmosphere considerably differ from those of the slag. Therefore, by direct observation of the vessel-interior light, it is possible to distinguish, without signal processing of the light, the light upon facing or exposure to the slag from the light upon facing or exposure to the gaseous atmosphere. However, if the vessel-interior light is subjected to signal processing with regard to the intensity or wavelength of the light, a clearer image of the slag-forming conditions can be obtained. Also as is described in detail hereinbelow, the obtained signals can be advantageously utilized for controlling various blowing operations.

Using the slag-foaming behavior, one can preliminarily determine slag-forming criteria specifying the relationship between such behavior and slag-forming conditions. Therefore, according to an embodiment of the present invention, it is possible to compare the detected intensity and/or wavelength of the vessel-interior light with the slag-forming criteria determined for specific slag-forming conditions, such as formation of dephosphorizing and/or non-slopping slag. The slag-forming criteria are determined for each converter

having a specified structure and vessel volume and for each blowing condition. The value detected by the photometers 5a through 5c (Figs. 3A through 3C) is compared with the slag-forming criteria, thereby achieving detection of slag-forming conditions.

An example of the slag-forming criteria is as follows. When the slag-forming level y arrives at the level Xa of the highest photometer 5a, this means there is excessive slag formation and a high possibility of slopping. The level Xa can therefore be established as the slag-forming criterion indicating excessive formation of slag.

The slag-forming criteria are determined for each type of slag formation. That is, dephosphorization requires formation of a dephosphorizing slag having an appropriate total amount of iron-oxide for a normal dephosphorization reaction and also having a sufficient volume. The formation of the dephosphorizing slag can be verified by monitoring the slag-forming level y, e.g., at the lowest level Xc of the photometer 5c. If the level of slag is beneath the lowest level Xc during the dephosphorizing period, abnormality in slag formation occurs.

Although the above explanation was made with reference to a plurality of photometers 5a through 5c arranged in the converter 1, it is possible to satisfactorily observe the slag-forming conditions even by a single photometer, as shown in Fig. 1 and as described hereinbelow.

Figures 6 and 7 are partial cross-sectional views of a converter, showing different mounting structures of a photometer. Referring to Fig. 6, a photometer 5 is mounted in the throughhole 4 via a protective tube 11 having an inner cylinder 110. A cooling-water circulating channel 111 is formed in the protective tube 11. Cooling water w is supplied into the cooling-water circulating channel 111 via one of conduits 112. The water w is withdrawn via the other conduit 112. The

photometer 5 is installed within the inner cylinder 110 in such a manner that its active side faces the vessel interior. Purge gas, such as N_2 , Ar, CO_2 , or another inert gas g, is supplied to and passed through the inner
5 cylinder 110 and then ejected through the aperture 113 into the vessel. During its passage and ejection, the purge gas cools the photometer 5 and prevents gases including dust, slag, or the like from entering the inner cylinder 110.

10 The signal detected by the photometer 5 is input via a cable 12 into a signal processing device 13, such as a transmission filter, a computing device 14, and a display device 15.

The converter operation may be controlled either
15 automatically or by a human operator. In automatic control, the signal detected by the photometer 5 is compared with the slag-forming criteria preliminarily input into the computing device 14 so as to automatically detect the slag-forming conditions. A warning
20 signal or operating command is thereupon generated from the computing device 14 to various controlling devices (not shown). In control by a human operator, the operator watches detected values indicated on the display device 15 and compares them with predetermined
25 slag-forming criteria, to control the converter operation.

Figure 7 shows another examples of the photometer in Fig. 7, the same reference numerals and symbols as those of Fig. 6 indicate identical members. An optical
30 conductor 51, i.e., a body capable of transmitting at a low loss the light emitted from a high temperature body, e.g., a quartz-based optical fiber, is located in the inner cylinder 110 of the protective tube 11. The optical conductor 51 is connected to the body of a
35 photometer 52, which is disposed at an appropriate position outside the converter. The structure shown in Fig. 7 is particularly advantageous, since the body of

photometer 52, which is expensive, can be located a safe distance from the high-temperature wall 2.

The photometer 5 is not limited to any particular form provided that it can measure the intensity and/or wavelength of the vessel-interior light. The photometer 5 includes various assemblies; a MOS or CCD device assembled with an optical filter, and a lens; a spectrometer and a photomultiplier; and an optical thermometer and a detector of the temperature profile.

Figures 8, 9, and 10 show still another structure for mounting a photometer on a displacement mechanism disposed in the neighborhood of the converter and provided with means for retractably inserting the photometer into the throughhole.

Referring to Fig. 8, a supporting stand 21 located at the neighborhood of the converter 1 is equipped with a photometer 22. The photometer 22 includes an optical conductor and a receptor 23 at the front end thereof. The receptor 23 can be retractably advanced into the throughhole 4 by means of the displacement mechanism 24 which is secured to the supporting stand 21. The receptor 23 can therefore be timely inserted into the throughhole 4 when the vessel interior is to be observed and can be kept protected from such detrimental environments as thermal load and dusts during the operation period, e.g., the tapping period, in which the vessel interior is not to be observed. The tapping hole can therefore be utilized as the throughhole 4. The vessel-interior light received by the receptor 23 is transmitted via connector 25 into a photoelectric converter 26 for generating an electric signal. The electric signal is input into an image processor 27 for detecting the intensity and/or wavelength of the vessel-interior light. The detected signal is shown on a display 28 of the vessel-interior conditions or a display 29 of the slag level.

Referring to Fig. 9, showing a detailed structure

of the photometer as well as an example of the seal mechanism of the throughhole 4, an inner brickwork lining 2a and steel mantle 2b have an aperture of, e.g., 500 mm diameter. A cylindrical body 4a has an inner refractory lining for defining the throughhole 4 and is welded to the steel mantle 2b. A flange 4c having an aperture is secured to the cylindrical body 4a. A seal cap 4d is attached to the flange 4c by bolts and has a conical-shaped seal surface spread toward the vessel exterior. A probe 22a provided with a photoconductor therein (not shown) is equipped with a conical seal body 22b, the conical shape of which body allowing gas-tight contact with the seal cap 4d. The length of the probe tip end 23 is adjustable by an adjusting bar 22c and adjusting nut 22d, so that the probe tip end 23 can be positioned at an appropriate position to receive the vessel-interior light. The probe 22a is displaced toward and locked to the seal cap 4d by displacement mechanism 24 (Fig. 8). The spring 22e, which is guided along the spring guide 22f, is not indispensable but is preferable to further displace or and thus compress the probe 22a against the seal cap 4d.

Referring to Figs. 10A, 10B, and 10C, showing an example of the displacement mechanism 24, a supporting platform 30 having wheels 30a and 30b is displaced along a pair of rails 21a. The wheels 30a are attached to the supporting platform 30 so that they are engaged to the upper and lower surfaces of the rails 21a, while the wheels 30b are attached to the supporting platform 30 so that they are engaged to the inner surfaces of the rails 21a. The probe 22a is provided, at its rear end as seen from the throughhole (not shown), metallic fittings 22g and is loosely connected to the displacing platform 30c via the metallic fittings 22g and a bolt 30c. The displacing platform 30c is provided with a probe-supporting base 30d on which the probe 22a is freely placed.

The displacement mechanism 24 described above with reference to Figs. 10A, 10B, and 10C, retractably displaces the receptor included in the probe tip end 23 into the throughhole 4 by means of carrying the displacing platform 30 along the rails 21a. The displacing platform 30 can be an automotive one directly equipped with a driving mechanism or one which is driven via a rod, gear, wire, or the like by means of an electric motor, pneumatic means, or hydraulic means installed separate from the displacing platform 30.

The driven mechanism shown in Figs. 10A through 10C are hydraulic. The hydraulic cylinder 24a is connected via the rod 24b to the metallic fittings 22h, thereby transmitting the force of the hydraulic cylinder 24a to the probe 22a. As shown in Figs. 10D and 10E, the metallic fitting 22h the rod 24b are loosely connected with one another. Since the probe 22a is loosely connected to both the displacement mechanism 30 and the rod 24b as is described above and, further, since a clearance can be formed between the wheels 30b and one of the rails 21a, the probe 22a is somewhat displaceable in any direction, thereby making it possible to realize a further highly gas-tight contact between the conical seal body 22b and the conical seal surface of the seal cap 4d.

The probe 22a, including the photo-conductor therein, is generally a dual tube. Therefore, the annular space between the inner and outer tubes can be used as the passage for an inert gas blown toward the end of the probe so as to cool it or clean the receptor located at its end.

In an embodiment of the method according to the present invention, described with reference to Figs. 11, 12, and 13, the photoelectrically conducted signal of the vessel-interior light is divided into a plurality of ranges of wavelength. The proportion of area of the light to the total image area of the receptor is computed

with regard to each wavelength range, and the computed area proportion compared with predetermined slag-forming criteria.

Referring to Figs. 11 (I, I') through (III, III') the melt 7 is charged in the converter 1. A photometer 22 is displaced until it is inserted into the through-hole. Oxygen begins to be blown through a lance 16, and then refining is initiated. The flux materials are charged into the converter 1 and form molten slag.

The amount of slag 31 is still relatively small in Fig. 1 (I), and the circular field of the receptor 22 gives a white image of the high-temperature gaseous atmosphere 32 of converter, as shown in Fig. 11 (I'). When the slag formation further advances, the surface of the slag 31 (Fig. 11 (II)) is vigorously stirred by the oxygen blown through the lance 16 and by the CO gas or the like formed due to the blowing reactions. The slag 31, which is in an emulsion state and which has a lower temperature than the high-temperature gaseous atmosphere 32, is detected by the circular field of the receptor 22 as yellow waves. When the slag 31 (Fig. 11 (III)) overflows the converter mouth and slopping occurs, the circular field of the receptor 22 is entirely yellow. The above changes in the conditions of slag formation can be continuously observed by television with the naked eye or can be recorded as is explained with reference to Figs. 12 and 13.

The intensity-wavelength relationship of slag becomes clearly different from that of the gaseous atmosphere above the slag, as shown in Fig. 12, when the slag forming proceeds to an appreciable extent and the temperature of the gaseous atmosphere is higher than that of the slag. Therefore, the vessel-interior light can be subjected to wavelength separation by means of, for example, a blue-transmitting filter, so as to pass through the filter light having the wavelength range where the intensity of light emitted from the slag is

dominant. The filtered light is subjected to a computing process so as to obtain the proportion of the filtered light to the entire area of the circular field of the receptor. The obtained surface-area proportion is plotted, as shown in Fig. 13, with time.

Referring to Fig. 13, A indicates the pseudo slag signal generated during the blowing start period, in which the temperature of the gaseous atmosphere is low, and B indicates an abrupt increase of the surface-area ratio and thus occurrence of slopping. Prior to the occurrence of slopping, the surface-area ratio intensely varies. The slopping can therefore be predicted on the basis of such intense change.

When a throughhole is exposed to the gaseous atmosphere, the vessel's contents progressively deposit on the throughhole, resulting in clogging. In an embodiment of the method of the present invention, described in with reference to Figs. 14 and 15, observation of the vessel interior is carried out while blowing through the probe an oxygen-containing purge gas to prevent clogging of the throughhole. Clogging of throughhole is one of the most serious problems impeding the observation of the vessel interior. The situation is not so serious when using the tapping hole as the throughhole for observation. Since the tapping hole is brought into contact with molten steel at each tapping, the tapping hole can be maintained at an extremely high temperature even during the blowing period. The deposits on the tapping hole, composed of contents of the vessel, therefore cannot solidify that much and can be blown out even by inert purge gas blown through the probe tip end. Contrary to this, a throughhole formed at the non-immersing portion 8 (Figs. 2A, 2B, and 2C) cools due to non-contact with the molten steel and further cools if the inert purge gas is blown to it through the probe tip end. Still, deposits on the throughhole can be melted due to the latent heat of the slag when the end of the

throughhole is exposed to the foaming slag. In this case, the deposits can be blown out by inert purge gas, thus preventing accumulation of deposits.

Oxygen-containing purge gas is preferred purge gas
5 discovered after various investigations of the assignee of the present application. In this regard, while the coolant gas of the probe can be blown at an almost constant rate to attain the intended cooling, the flow rate of the oxygen-containing purge gas for attaining
10 the intended purge greatly varies depending upon the position of the throughhole, quality and quantity of the vessel's content, temperature, and vessel interior conditions. Control of the flow-rate for the purge is therefore difficult. It is more desirable and convenient
15 to control and to vary the oxygen content of the purge gas.

Referring to Fig. 14, inert gas is fed from a source A and is separately blown into conduit systems 34 and 40. The conduit system 34 includes a stop valve 35
20 and a reducing valve 36, a flow-rate adjusting device 37 with an orifice and flow-control valve, and a stop valve 38 successively arranged in the flow direction. The inert gas blown through the conduit system 34 flows via a flexible hose 39 into an inner cylinder 62
25 (Fig. 15) which is connected via an inlet port 63 (Fig. 15) to the flexible hose 39. The inert gas is further blown through a small aperture 42 of a front tip 41 screwed into a probe 61. The inert gas is then released from a tip aperture 43 into the vessel interior
30 while preventing fogging or contamination of a front glass 67 of the probe 61.

The inert gas flowing through the conduit system 40 is mixed with oxygen fed from a source B into the conduit system 44. The mixture gas flows via a flexible hose 45
35 and inlet port 65 into an outer cylinder 64 to cool the outer surface of the inner cylinder 62 and the front tip 41. The mixture gas is released into the vessel

interior from the outer cylinder 64. The flow rate ratio of oxygen to inert gas is adjusted by a flow-rate controller 33 connected to the conduit systems 40 and 44. The reverse Z (Σ) symbol indicates the check valves located upstream of the joining point of the conduit systems 40 and 44. The probe 61 includes a photo conductor therein. The symbols 26, 27, 28, and 29 indicate a photoelectric converter, image processor, display device of the vessel-interior condition, and slag level-display device, respectively.

In an embodiment of the method according to the present invention, the amount of slag is controlled on the basis of the detected slag-forming conditions so as to maintain the amount of slag within an appropriate range at a high accuracy. This embodiment aims not only to predict the occurrence of slopping but also to enhance operational efficiency and improve the steel quality by means of observing the slag level at a high accuracy, monitoring the variation tendencies in the slag level, and suppressing detrimental tendencies. A typical example of this embodiment is described with reference to Fig. 16.

Referring to Fig. 16, the level of slag at which slopping is likely to occur is denoted by 72. Reference numeral 74 indicates the change of the slag level with time, allowing one to maintain the level of slag lower than the level 72 over the entire blowing period. The level of slag at which the slag formation is poor is denoted by 73. Reference numeral 75 indicates the change of the slag level with time, allowing one to ensure, at a certain initial preparatory blowing period, a slag level higher than 75. In this example, target slag-level control is effected to control the level of slag between the levels 74 and 75 during the entire blowing period. The symbols I, II, and III indicate that slag-level control actions.

In an embodiment of the present invention,

information is extracted from the signal obtained by the photometer so as to monitor the surface-area proportion of yellow base color to the entire color signal and variation in that proportion. The proportion and
5 variation are compared with predetermined color criteria. This embodiment enables very accurate detection of the slag-forming conditions, as described with reference to Fig. 17.

Figure 17 is a block diagram for computing and
10 outputting the proportion described above. The probe 61, more specifically the photo-conductor, is provided with a connector 25 and photoelectric converter 26. The light detected by the probe 61 is electrically converted to an image signal 77 which is transmitted to the
15 wavelength-range divider 78. Analog signals 79, i.e., one (B-blue) having a wavelength range of from approximately 0.3 to 0.4 μm , another (G-green) having a wavelength range of from approximately 0.4 to 0.6 μm , and the other (R-red) having a wavelength range of from
20 approximately 0.6 to 0.8 μm , are generated by the wavelength range-divider 78. The analog signals are converted at an appropriate threshold level to binary signals 80 which are input into an area-computing device 81. In the area-computing device 81, the binary R
25 signal, the binary G signal, and the binary B signal are multiplied by a count pulse of, for example, 0.134 μsec (7 MHz) in a reset cycle of 16.7 msec, and the number of pulses of R·G on and B off is counted. Thus, the area proportion of yellow base color is counted for each
30 16.7 msec cycle and is generated as the output signal of yellow 82, which is observed with a area-proportion display device 91.

In an embodiment of the method according to the present invention, in accordance with the observed
35 slag-forming conditions, at least one of the following control operations: controlling the oxygen-blowing rate; controlling the lance height; charging the

auxiliary raw materials, such as lime or iron ore; and controlling the bottom-blowing gas rate are carried out. This allows stabilization of the slag composition to drastically reduce the occurrence of slopping and to
5 improve the slag quality.

In another embodiment of the method of the present invention, one or more of dolomite powder, quick lime powder, coal powder, and cokes powder is blown, into the vessel preferably through an additional throughhole of
10 the side wall, upon the prediction of occurrence of slopping so as to stabilize the blowing. The present invention will be further clarified by the ensuing examples, which, however, by no means limit the invention.

15 Example 1

Figure 18 shows a 170 ton top- and bottom-blowing converter which has a top lance 16 for blowing O_2 and a bottom nozzle 17 for blowing CO_2 .

Throughholes 4 were formed at levels 1.5 m, 2.5 m,
20 and 3.5 m beneath the converter mouth 9. Protective tubes 11 having an inner cylinder 110 (Fig. 7) were inserted into the throughholes 4. An optical conductor 51, having a diameter of 12 mm, was stationarily located in each inner cylinder 110 and was connected to each
25 body of photometers 52. The photometers 52 were ITV cameras equipped with short wavelength-transmitting filters. Signals from the ITV cameras were transmitted into signal processing units 13 including digital memories to store the signals in the digital memories.
30 The digital information was subjected to signal processing for generating an image. The difference in the intensity of light between the gaseous atmosphere and the foaming slag was more distinct than by conventional photometers.

35 In addition to the observation of the slag-forming conditions as described above, observation using a substance, hitherto for believed to be the most reliable,

was carried out. The temperature of the foaming level of slag was intermittently measured by lowering the substance equipped with a consumable thermometer at the tip end thereof.

5 The results are shown in Fig. 9. As is apparent from Fig. 9, there is no appreciable difference between the value measured by the substance method and the value detected by the method according to the present invention. Thus, the present invention attains measurement
10 of the slag level y at a high accuracy. The present invention attains, furthermore, continuous measurement, which makes it possible to successfully detect or predict the dynamic slag-foaming behavior within the converter.

15 Table 1 shows the relationship between the total number of heats in which the foaming level of slag y arrived at the respective levels of the photometers and the occurrence of slopping, the relationship being determined by investigations of the assignee.

Table 1

Level of photometers	Total number of heats	Occurrence of slopping	
		Times	Percentage
1.5 m (5a)	28	15	54%
2.5 m (5b)	35	6	17%
3.5 m (5c)	52	0	0%

In the present example, the slag-forming criterion was defined as the time when the photometer 5a detected
35 the foaming slag, i.e., the slag-foaming criterion indicated abnormal or excessive formation of slag. The intensity of vessel-interior light was continuously

measured during blowing by the photometers 5a, 5b,
and 5c. When the photometers 5a, 5b, and 5c detected
the above-mentioned slag-forming criterion, the warning
signal shown by Z in Fig. 19 was generated to warn of
5 abnormal or excessive formation of slag. On the basis
of the warning signal, control actions, such as reduction
in the O_2 -flow rate, through the top-blowing lance 16,
and charging of unburnt dolomite into the converter 1,
were carried out. Due to such control actions, the
10 occurrence of slopping could be reduced to as low as
0.5% or less.

Example 2

A converter having an outer diameter of approxi-
mately 7 m and a height from the bottom to mouth of 8 m
15 was pierced by a throughhole 150 mm in diameter through
the side wall. A probe having an outer diameter of
80 mm and a photoconductor having an outer diameter of
40 mm were used.

The type of probe and also the type of purge-gas
20 blowing conduit systems were as described with reference
to Figs. 14 and 15. As the inert gas, CO_2 was used.

By means of varying the flow rate ratio of the
oxygen to inert gas, the influence of oxygen upon the
burning out of deposits was investigated. The results
25 are shown in Table 2.

Table 2

Gas rate (Nm ³ /Hr)			O ₂ Vol%	Ejecting rate (Nm ³ /s)	State of Throughholes	Evaluation
*	**					
CO ₂	CO ₂	O ₂				
100	100	0	0	11	Clogging, 3 minutes after blowing initiation	x
100	200	0	0	17	Clogging, 7 minutes after blowing initiation	x
100	300	0	0	22	Clogging, 15 minutes after blowing initiation	x
100	250	50	12.5	22	Clogging at 4 heats	x
100	100	70	25.9	15	Clogging at 4 heats	x
100	200	140	31.8	24.2	No clogging	o
100	150	150	37.5	22	No clogging	o
100	70	110	39.3	15.4	No clogging	o
100	100	200	50.0	22	Bricks of vessel eroded greatly	x

* Conduit system 34

** Conduit system 40

As understood from Table 2, when the purge gas is free of oxygen, clogging of the throughhole cannot be sometimes prevented even by blowing a large amount of inert gas. In addition, when the purge gas contains too high a concentration of oxygen, the bricks around the throughhole greatly erode due to oxidizing. An appropriate oxygen concentration is from 30 to 45% by volume. In this case, repeated observation of the vessel interior is possible without trouble such as clogging of the throughhole and erosion of the bricks.

The purge gas blowing exerted no detrimental influence upon the blowing operation and quality of tapped steels.

Example 3

5 A 170 ton top- and bottom-blowing converter 8 m in height was charged with melt 1.5 m in depth. A through-hole was formed at the converter wall 2.5 m perpendicu-
10 larly under the mouth. An optical fiber 12 mm in diameter was used as a photoconductor and inserted into a cooling protective tube. A CCD color-camera was used as a photoelectric converter. The slag level was detected by the method as described with reference to Fig. 17 of computing the area ratio of yellow base color. The relationship between the area ratio of yellow base
15 color and the position of the optical fiber was so established that the area ratio was 50% when the slag level coincided at the center of field of the optical fiber. The area ratio 100% and 0% corresponded to the slag levels above and below the throughhole, respec-
20 tively. The threshold levels in the binary circuit were K 35%, G 35%, and B 25%.

 Slopping was detected by the following method, described in reference to Fig. 20. The area ratio signal of yellow base color 82 from a circuit 81 was
25 divided and transmitted into two circuits. In one of the circuits, the area ratio signal was converted in the binary circuit 83 having appropriate threshold level (10%), into a binary signal 84. In the other circuit, the area-ratio signal of yellow base color 82 was passed
30 through a high-pass filter 85 (cut frequency of 5 Hz) and then converted to a positive value at a circuit 86. The positive signal was converted to a binary signal 88 in the binary circuit 87 having an appropriate threshold level (50%), which binary signal 88 indicated the changes
35 in the area ratio. The two binary signals 84 and 88 were input into a decision circuit 89. The possibility of occurrence of slopping was decided as shown in Table 3.

Table 3

Possibility of occurrence of slopping	Yes	No	No	No
Binary signal 84 (Area ratio of yellow base color)	1	1	0	0
Binary signal 88 (Change in the area ratio of yellow base color)	1	0	1	0

The control actions to attain the target slag level were as shown in Table 4.

Table 4

Operating object		Controlling method or amount	
		Suppression of foaming	Promotion of foaming
No. 1	Bottom-blowing flow rate (CO ₂)	increase by 50 Nm ³ /H	decrease by 50 Nm ³ /H
No. 2	Lance height	decrease by 100 mm	increase by 100 mm
No. 3	Top blowing flow rate	increase by 1000 Nm ³ /H	decrease by 1000 Nm ³ /H
No. 4	Auxiliary raw materials	Continuous charging of coolant	Charging of agent (fluorite) to promote slag formation

One or more of the operating objects were manipulated as described with reference to Figs. 21 through 23. Referring to Fig. 21, when the slag level varies during operation as shown by a curve 71 and exceeds the target

slag level 76 at the points 92 and 93 and when there is no possibility of occurrence of slopping, an increase in the bottom-blowing flow rate (No. 1) is effective to attain the target slag level 76.

5 Referring to Fig. 22, when the slag level varies during operation as shown by the curve 71 and falls under the target slag level 76 at the points 94 and 95, a decrease in the bottom-blowing flow rate (No. 1) is first employed. If the slag level seemingly will not
10 reach the target level 76 approximately 2 minutes after than the decrease in bottom-blowing flow rate, the lance is lifted (No. 2) or the oxygen-flow rate is decreased (No. 3) to promote the foaming of slag.

Referring to Fig. 23, when the slag level varies
15 during operation as shown by the curve 71 and exceeds the target slag level 76 at the point 97 and when there is a possibility of occurrence of slopping, continuous addition of ore and dolomite is effective to attain the target slag level 76 and to prevent slopping.

20 It was found that the operations are preferably carried out in the order of Nos. 1, 2, 3, and 4. It was also found that, for action I in Fig. 16, increasing the bottom blowing rate was effective and, for action II, either decreasing the bottom blowing rate or lifting the
25 lance (increasing the lance height) was effective.

The operations as described above were carried out for 50 heats. The results are shown in Table 5.

Table 5

	(T-Fe)%		[P] ($\times 10^{-3}\%$) at blowing end		Blown heats with slopping (%)	Failure in [P] outside standard (%)	Remarks
	$\bar{X}$	σ	$\bar{X}$	σ			
Inven- tion	15	1.1	20	2.2	2	0.5	Low-carbon steel
Conven- tional	16	2.3	17	5.3	28	4.2	[P] $\leq 25 \times 10^{-3}\%$

Example 4

Blowing was carried out as in Example 3 except for the following: In addition to the throughhole (for observing the vessel interior), another throughhole was formed in a non-immersing portion of the side wall of the converter to charge the auxiliary raw materials therethrough. The additional throughhole was equipped with a nozzle for blowing auxiliary raw materials, purge gas and carrier gas. Purge gas consisting of 75% CO₂ and 25% O₂ was blown without interruption at a rate of 120 Nm³/hr to prevent clogging of the additional aperture. When the occurrence of slopping was predicted, the CO₂ gas was blown with flow rate by 500 Nm³/hr as carrier gas, and coke powder (5 mm or less) was blown into the vessel interior. Alternatively, instead of the coke-powder injection, lump dolomite was charged.

The results of blowing were as shown in Table 6.

Table 6

<u>Auxiliary raw materials</u>	<u>Total number of heats</u>	<u>Successful heats</u>	<u>Success percentage</u>
Lump dolomite	32	11	34%
Powder coke	43	42	98%

When the prediction signal of slopping disappeared 1 minute or less after the blowing of the auxiliary materials to suppress the slopping, the heats were deemed to be successfully blown. This was used as the
 15 criterion for effective suppression of slopping.

As is understood from Table 6, the coke-powder injection is more effective than the lump dolomite charging.

Since the auxiliary material was directly injected
 20 through the additional throughhole into the foaming slag, blowing could be initiated immediately after the prediction of occurrence of slopping.

Example 5

Blowing was carried out as in Example 4 except
 25 for the following: Instead of addition of another throughhole for injection of pulverized auxiliary raw materials using purge gas to the throughhole for observation of the vessel interior, an assembled probe was equipped, which had an observation device and
 30 injection mechanism. This kind of probe is a modified one shown in Fig. 15 in the following points. Inlet port 65 into an outer cylinder 64 is connected to the powder injection unit. The injected powder in carrier gas is released into the vessel interior from the outer
 35 cylinder 64. The probe 61 includes a photoconductor therein. The purge gas is released from an inlet port 63 and blown through a small aperture 42 of a front tip 41

screwed into a probe 61. The purge gas is mixed with oxygen concentration with 30 to 40% by volume.

CLAIMS

1. A method for observing the slag-forming conditions in a vessel of a converter, characterized in that at least one observation device (5) of the vessel-interior light is disposed in at least one throughhole
5 (4) of the side wall (20) of a converter (1) facing the vessel interior and in that the slag-forming conditions are observed by said at least one observation device (5).

2. A method according to claim 1, characterized in that the intensity and/or wavelength of the vessel-
10 interior light is detected by said at least one observation device (5).

3. A method according to claim 2, characterized in that the detected intensity and/or wavelength of the vessel-interior light is compared with a slag-forming
15 criterion determined for a specific slag-forming condition, such as formation of dephosphorizing and/or non-slopping slag.

4. A method according to claim 2, characterized in that the vessel-interior light is photoelectrically
20 converted into a signal; the signal is divided into a plurality of ranges of wavelength; an area proportion of the light to a total image area of the observation device is computed with regard to each wavelength range; and the computed area proportion is compared with a
25 predetermined slag-forming criterion.

5. A method according to claim 2, wherein information is extracted from a signal obtained by the observation device (5) so as to monitor a proportion of yellow base color to all color signals and variation in
30 said proportion, and said proportion and variation are compared with a predetermined color criterion.

6. A method according to claim 1, characterized in that observation is carried out while blowing through a probe an oxygen-containing purge gas to prevent
35 clogging of the at least one throughhole (4).

7. A method for carrying out blowing in a top-

and bottom-blowing converter using any one of the methods according to claims 1 through 6, characterized in that at least one of the following control operations is carried out in accordance with the observed slag-forming conditions: controlling an oxygen-blowing rate; controlling lance height; charging auxiliary raw materials, such as lime or iron ore; and controlling a bottom gas blowing-rate.

8. A method for carrying out blowing in a converter using any one of the methods according to claims 1 through 6, characterized in that at least one of dolomite powder, quick lime powder, coal powder, and coke powder is blown, preferably through a throughhole of the side wall, into the vessel upon the prediction of occurrence of slopping so as to stabilize the blowing.

9. An apparatus for observing slag-forming conditions in a vessel of a converter, characterized by comprising a light-detecting device including receptor, which receptor is disposed in a throughhole of the side wall of the converter and faces the vessel interior, and a detector device of intensity and/or wavelength of a light signal input from said light-detecting device thereinto.

10. An apparatus according to claim 9, characterized in that the light-detecting device is mounted on a displacement mechanism disposed in the neighborhood of the converter and provided with means for retractably inserting the receptor into the throughhole.

Fig. 1

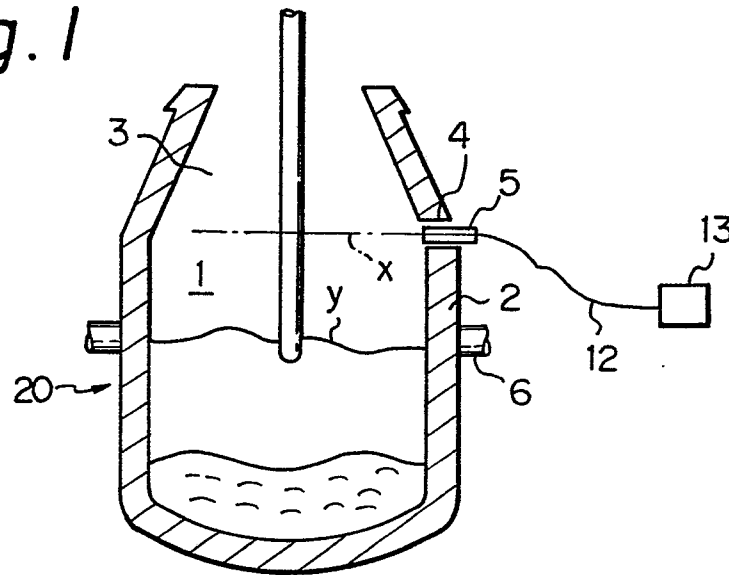


Fig. 2A

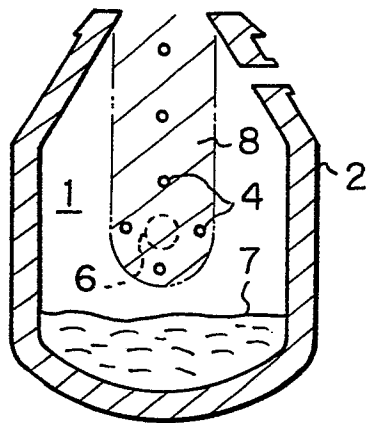


Fig. 2B

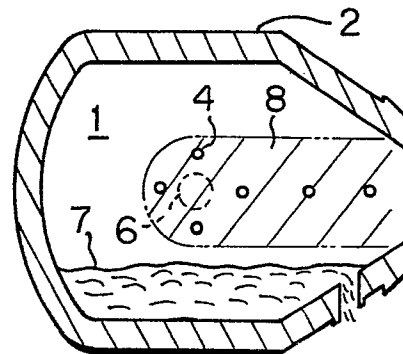
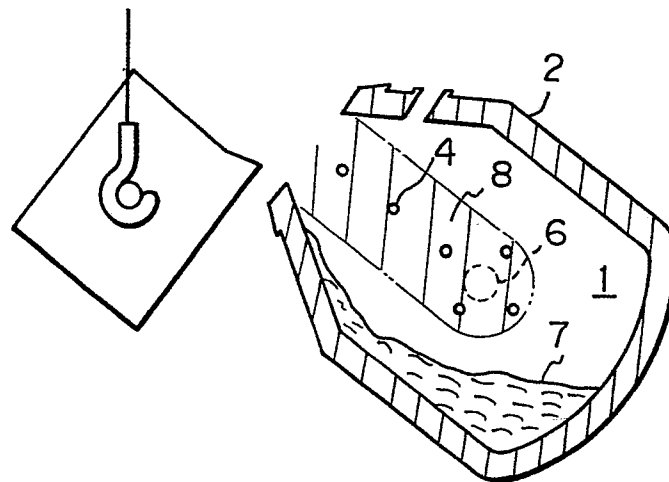


Fig. 2C



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Fig. 3A

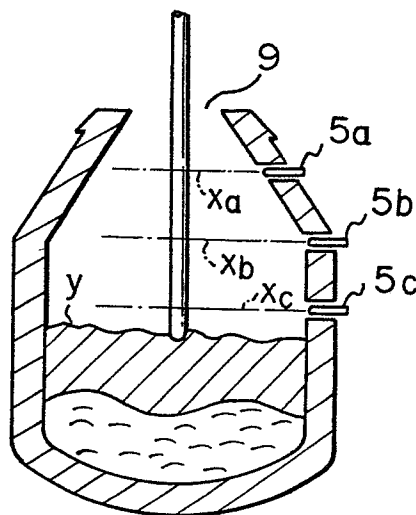


Fig. 3B

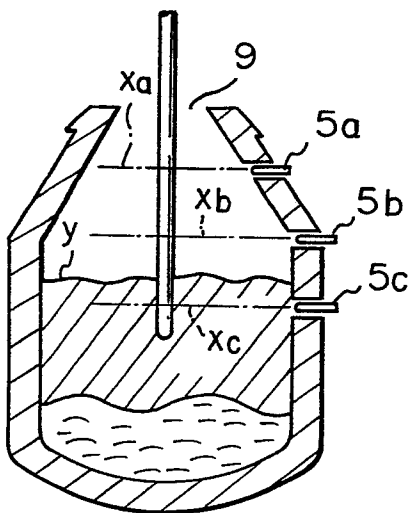
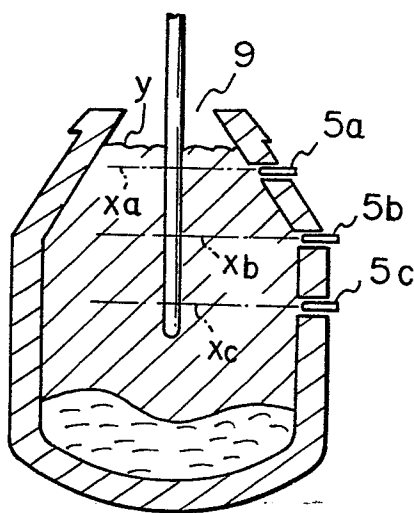


Fig. 3C



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Fig. 4

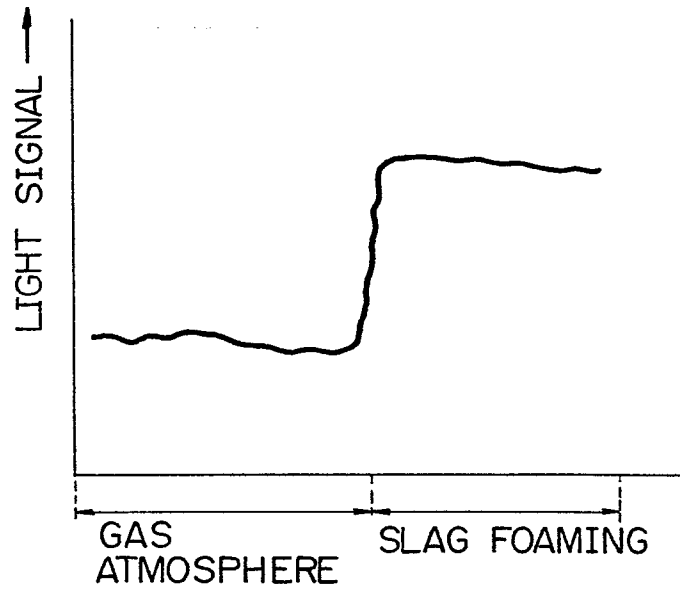


Fig. 5

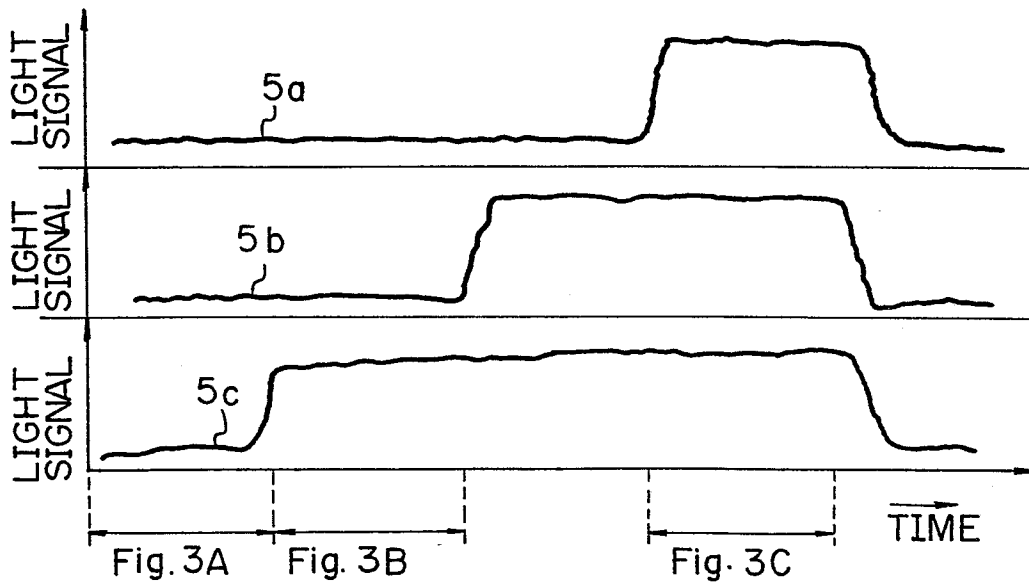


Fig. 6

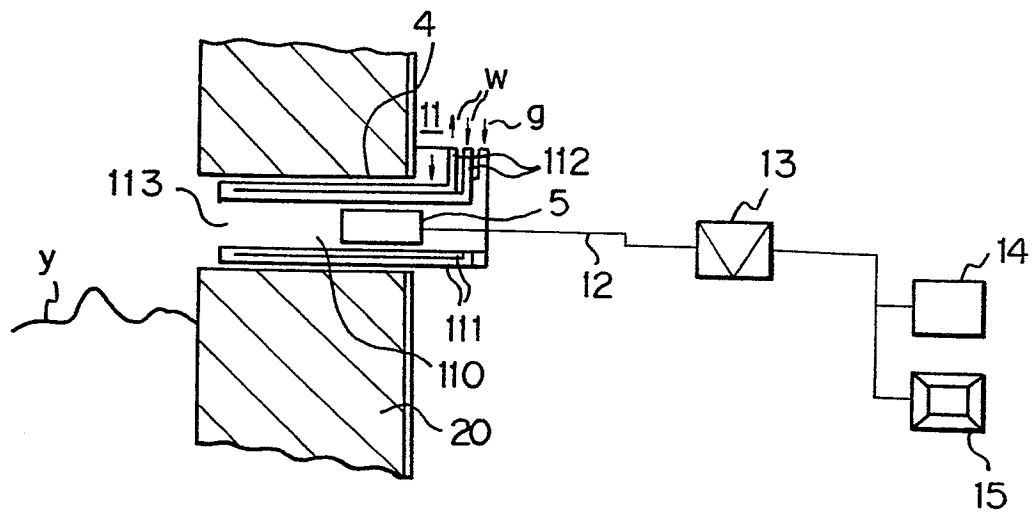


Fig. 7

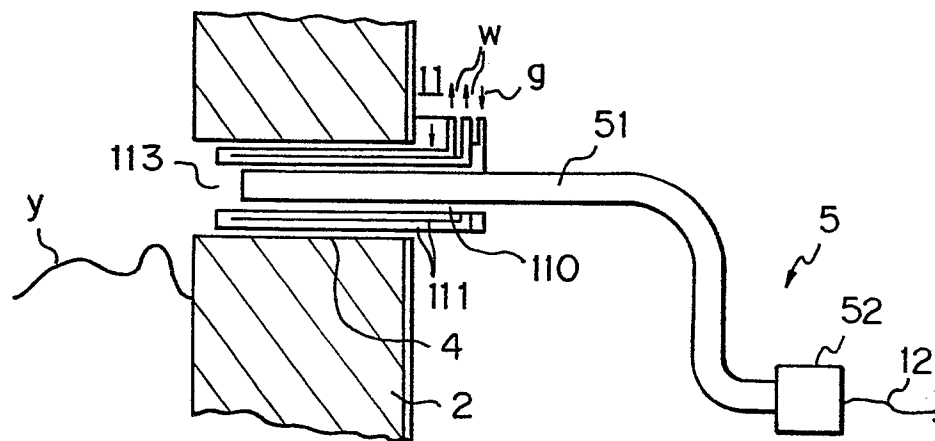
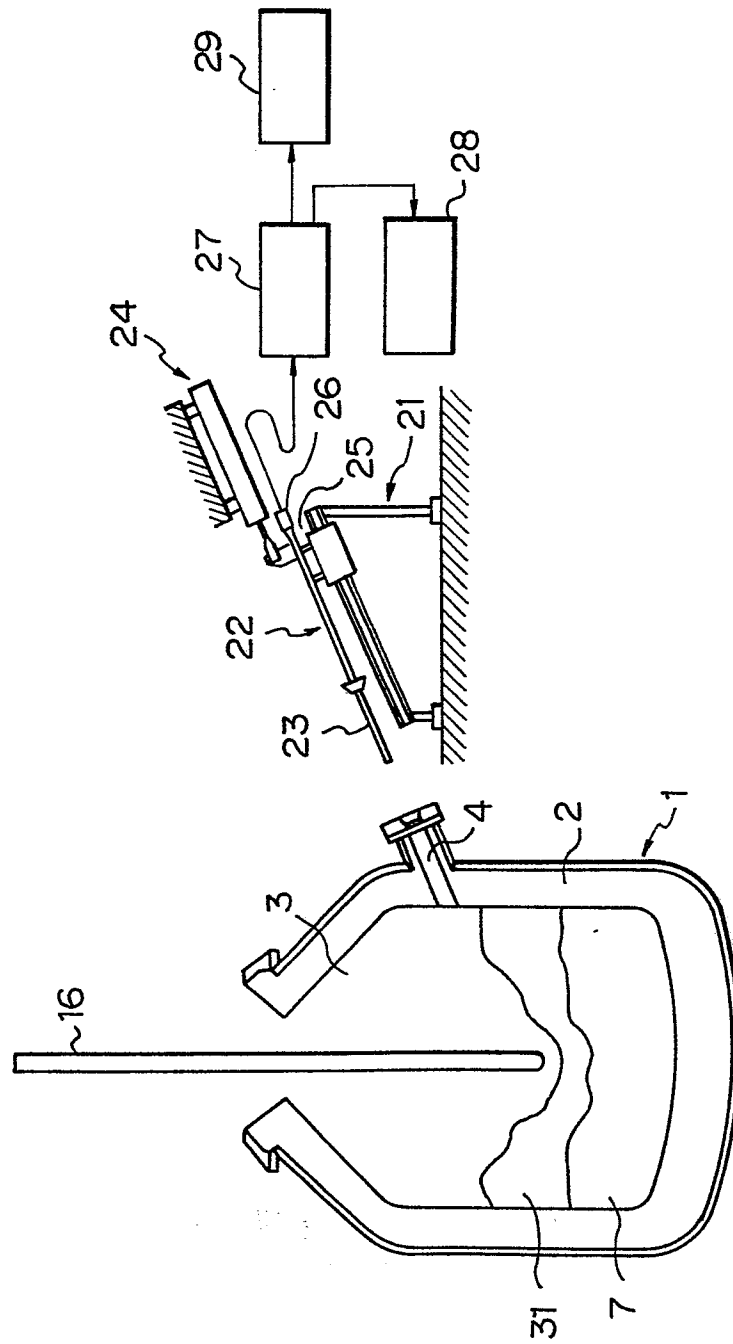


Fig. 8



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Fig. 10A

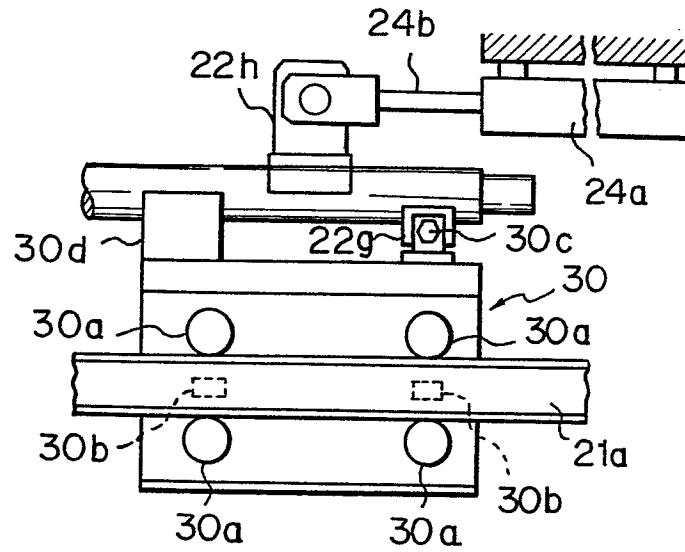


Fig. 10B

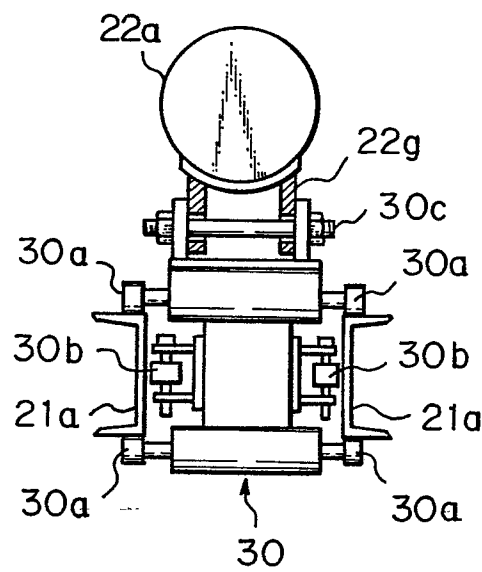


Fig. 10C

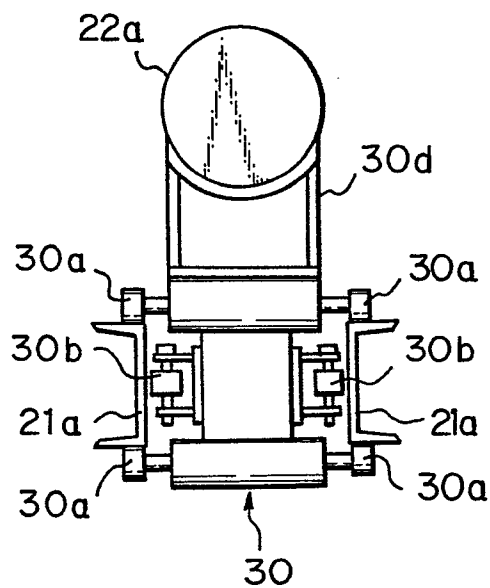


Fig. 10D

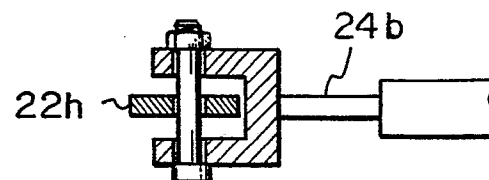
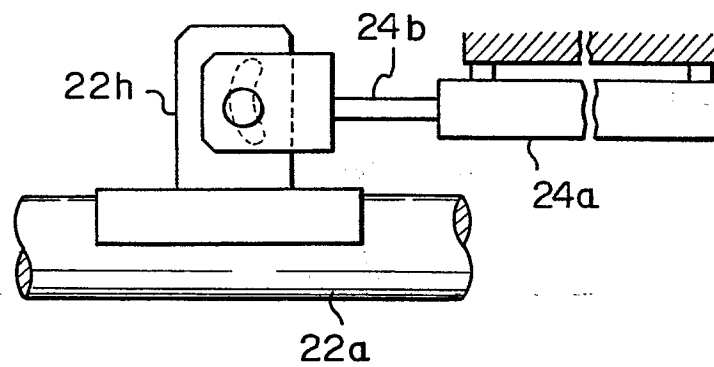


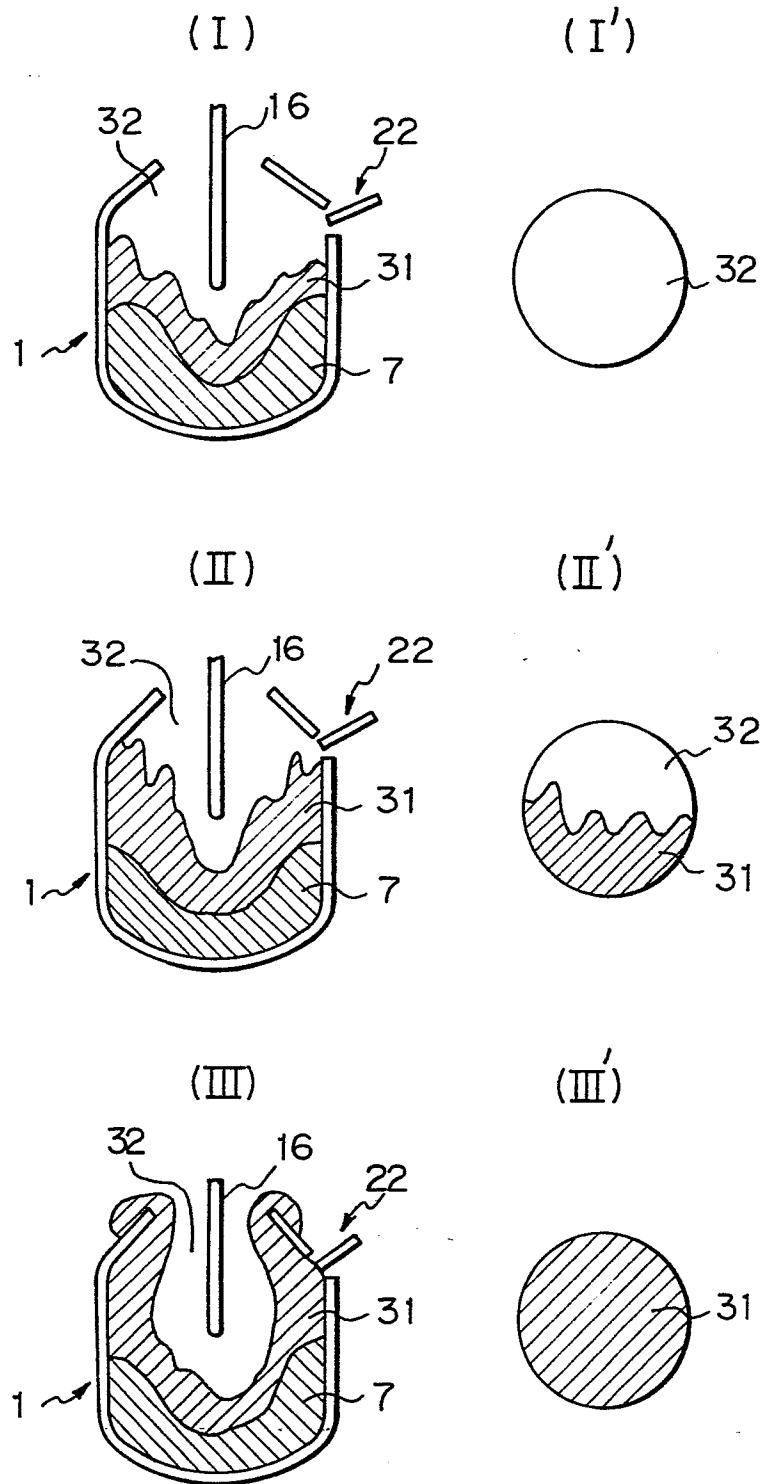
Fig. 10E



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Fig. 11



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Fig. 12

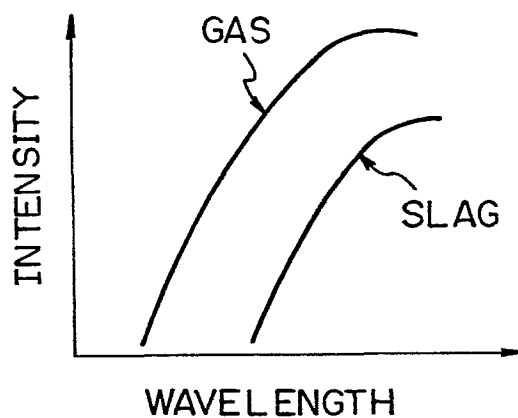
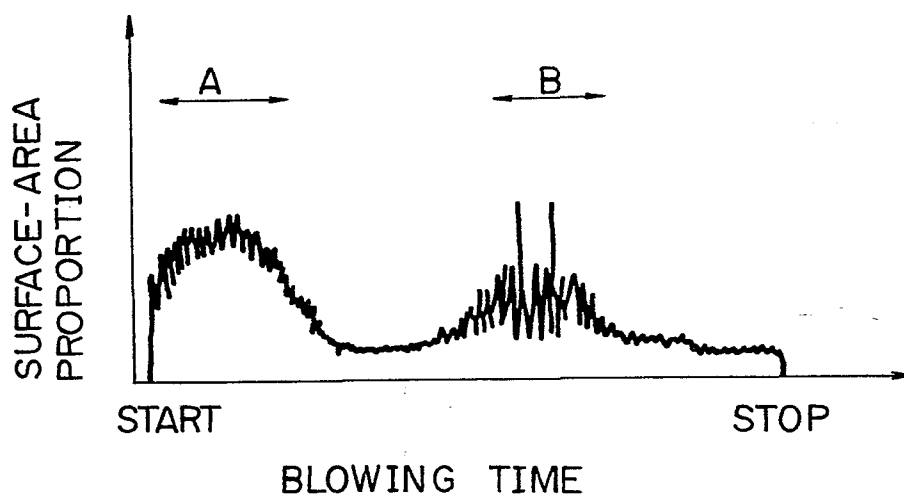


Fig. 13



The schematic diagram illustrates a plasma processing system. At the top, a horizontal substrate 24 is mounted on a support structure 27. A gas inlet assembly 26 is positioned above the substrate, connected to a main gas supply line 22. This line includes a valve 21 and a flow control mechanism 25. The substrate 24 is electrically connected to a power source 28, 29 via a cable 39. Below the substrate, a complex network of valves and switches controls the gas flow and electrical connections. Key components include a central valve 40, two side branches 44 and 45, and several smaller valves labeled 33, 34, 35, 36, 37, 38, and 41. The system is powered by a main supply B and a secondary supply A.

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Fig. 16

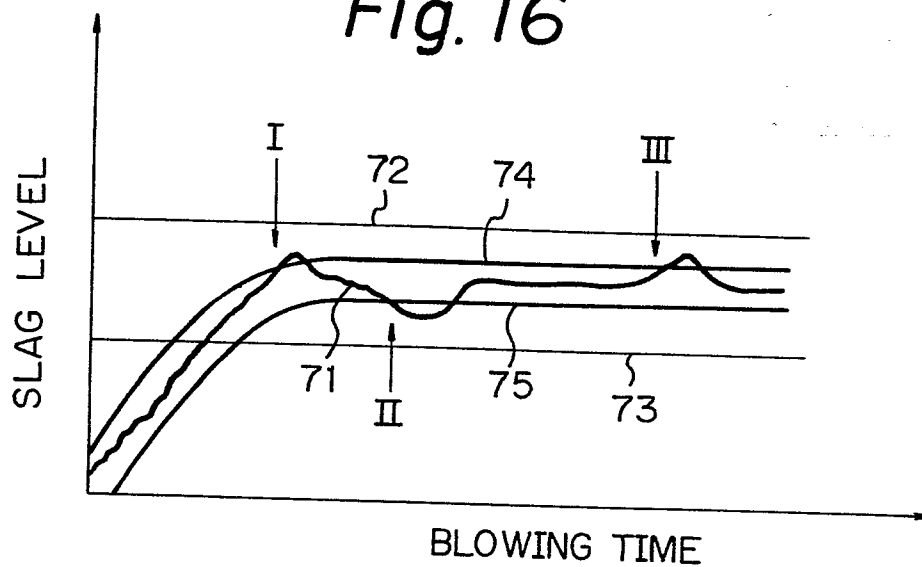


Fig. 17

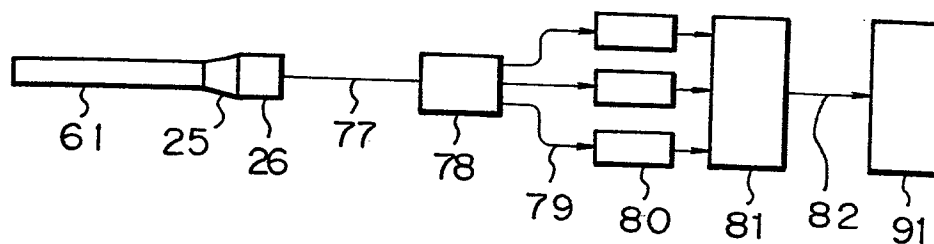
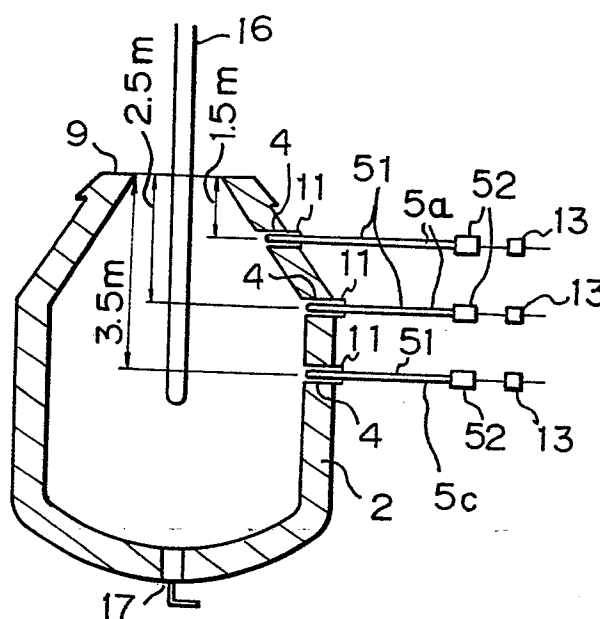


Fig. 18



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Fig.19

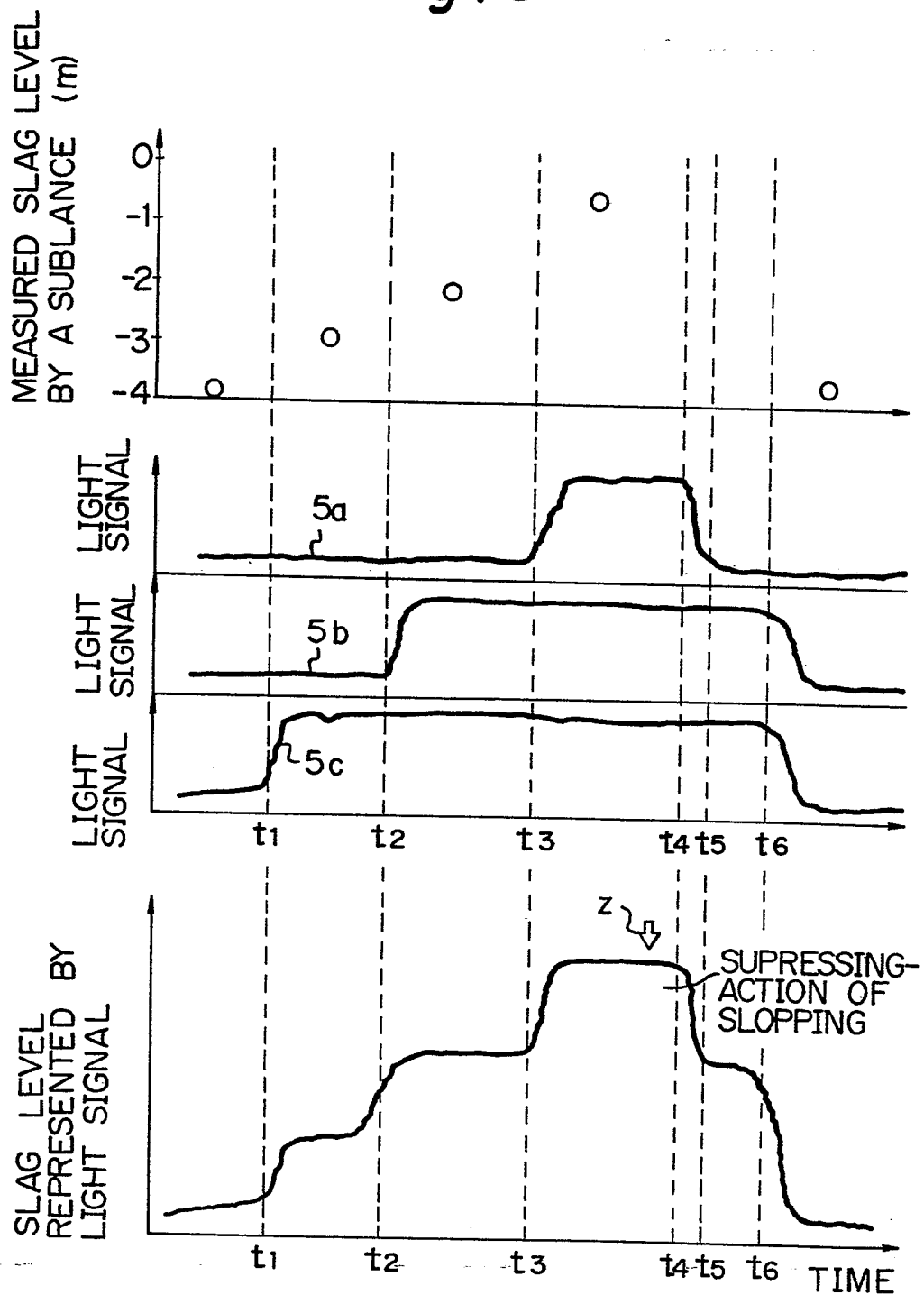


Fig. 20

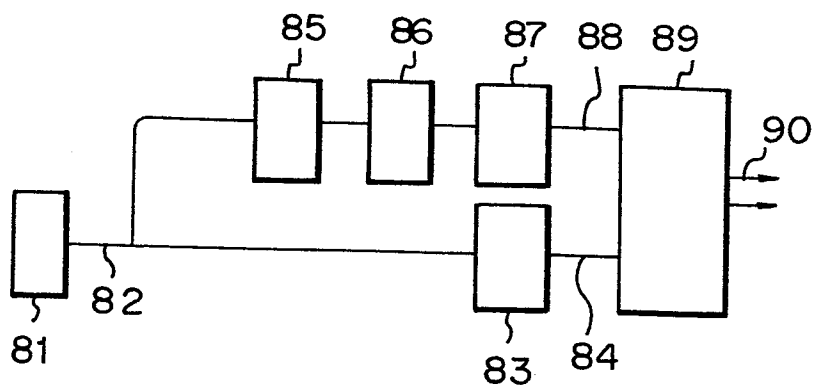


Fig. 21

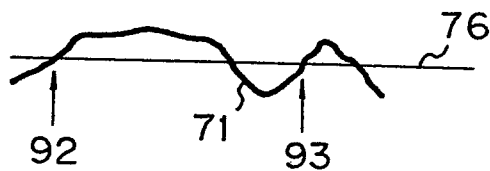


Fig. 22

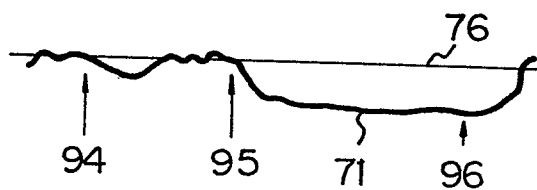
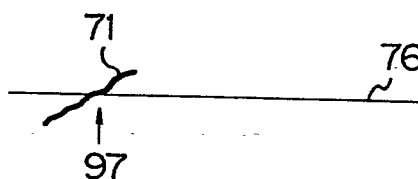


Fig. 23





European Patent
Office

EUROPEAN SEARCH REPORT

0162949

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 84110571.1
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	US - A - 4 345 746 (SCHLEIMER) * Totality *	1	C 21 C 5/30
A	DE - A1 - 2 812 871 (SUMITOMO) * Claims; fig. 1 *	1	
A	DE - A - 1 408 873 (MAX PLANCK INSTITUT) * Claims; fig. *	1	
A	GB - A - 1 411 790 (MONSANTO) * Page 1, line 11 - page 2, line 17; claims 1,15,16 *	2,4	
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, section C, vol. 1, no. 157, December 14, 1977 THE PATENT OFFICE JAPANESE GOVERNMENT page 3497 C 77	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 4) C 21 C G 01 J
D,A	* Kokai-no. 52-101 618 (SHIN NIPPON) *		
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, field C, vol. 4, no. 159, November 6, 1980 THE PATENT OFFICE JAPANESE GOVERNMENT page 73 C 30	1	
D,A	* Kokai-no. 55-104 417 (KAWASAKI) *		
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 30-06-1985	Examiner SCHÜTZ
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



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EUROPEAN SEARCH REPORT

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0162949

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 84110571.1
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, field C, vol. 6, no. 239, November 26, 1982 THE PATENT OFFICE JAPANESE GOVERNMENT page 77 C 137	1	
D,A	* Kokai-no. 57-140 812 (SUMITOMO) *		
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A	PATENT ABSTRACTS OF JAPAN, unexamined applications, field C, vol. 7, no. 135, June 11, 1983 THE PATENT OFFICE JAPANESE GOVERNMENT page 50 C 170	1	
D,A	* Kokai-no. 58-48 615 (KAWASAKI) *		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 30-06-1985	Examiner SCHÜTZ
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			