

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 April 2002 (04.04.2002)

PCT

(10) International Publication Number
WO 02/28084 A2

(51) International Patent Classification⁷: **H04N**

(21) International Application Number: PCT/US01/29660

(22) International Filing Date:
21 September 2001 (21.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/669,199 25 September 2000 (25.09.2000) US

(71) Applicant: **UCAR CARBON COMPANY INC.**
[US/US]; Suite 1100, 3102 West End Avenue, Nashville,
TN 37203 (US).

(72) Inventor: **GERHAN, Ronald, Eric**; 2705 Wakefield
Drive, Clarksville, TN 37043 (US).

(74) Agent: **CARTIGLIA, James, R.**; UCAR Carbon Com-
pany Inc., 3102 West End Avenue, Suite 1100, Nashville,
TN 37203 (US).

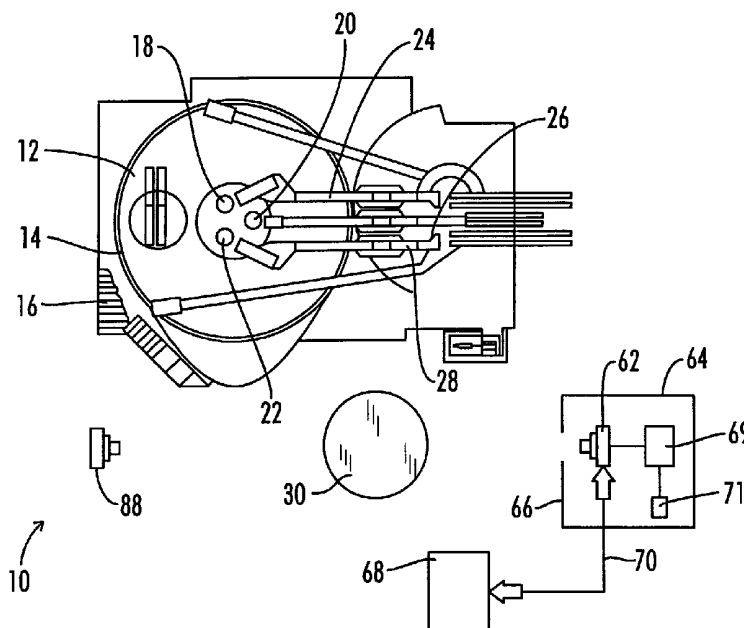
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: DIGITAL ELECTRODE OBSERVATION



(57) Abstract: A system is provided for recording information relating to the condition of electrodes in an electric arc furnace. A digital camera is provided in a consistent position relative to a photographing station. Periodically, the electrode columns are removed from the furnace and moved to a position such that a stub end of the electrode column is placed upon the photographing station. Then the stub end of the electrode column is photographed with a digital camera, and the digital images are stored in a memory of a computer for subsequent analysis.



WO 02/28084 A2



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DIGITAL ELECTRODE OBSERVATION

Be it known that I, Ronald E. Gerhan, a citizen of United States, residing at 2705 Wakefield Drive, Clarksville, TN 37043 have invented a new and useful invention entitled "DIGITAL ELECTRODE OBSERVATION."

BACKGROUND OF THE INVENTION**FIELD OF THE INVENTION**

The present invention relates generally to systems for observing and recording data relating to an article, and more particularly, but not necessarily by way of limitation, to a system for recording digital photographs of a stub end of an electrode utilized in an electric arc furnace in order to record the condition of the electrode.

DESCRIPTION OF THE PRIOR ART

One technique currently used for steel making is the use of an electric arc furnace which operates as a batch melting process producing batches of molten steel known as heats. The electric arc furnace operates on a cycle which includes steps of furnace charging, melting, refining, de-slagging, tapping and furnace turn around. Modern electric arc furnace operations have a tap-to-tap time of approximately 60 minutes or less.

One of the most important elements in the electric circuit which provides the energy to melt the scrap steel in the electric arc furnace, is the

graphite electrode or electrodes. These electrodes deliver the electric power to the furnace in the form of an electric arc between the electrodes and the scrap steel and other materials making up the furnace charge which is to be melted. Electrodes come in two forms: amorphous and graphitic carbon, or graphite. Graphite electrodes are typically used in modern steel making.

The graphite electrodes are continuously consumed during the heating process in the electric arc furnace. Historically, electrode consumption has been as high as 12 to 14 pounds of graphite per ton of steel.

The electrodes are provided in cylindrical sections having threaded connections formed in each end thereof. The threaded sections are joined together to form a column of several electrode sections, which electrode column is adjustably placed within the furnace by a movable electrode holder arm which can raise and lower the electrode column, and can pivot to move the electrode column away from the furnace.

Electrodes are commonly available in sizes from 15 to 30 inches in diameter and in varying lengths up to about 10 feet.

In an AC electric arc furnace, there will be three sets of electrode columns. In a DC electric arc furnace, there are one or two electrode columns.

During the steel making operation, the electrode column or columns are typically removed from the furnace at the end of each heat, and they may also be removed from the furnace during a heat in order to add additional charge materials to the furnace.

Historically, the performance of the electrode columns has been measured only in a gross fashion, such as cumulative monthly totals, so as to provide numbers such as the pounds of graphite required per ton of steel during the long term operation of the steel mill.

The physical condition of the electrode column has been visually observed during those instances when the electrode column is removed from the furnace, and from time to time anecdotal data may be observed and recorded in a manual fashion to describe the observed condition of the electrode column.

Furthermore, no attempt has been made to trace the identity of a given electrode section so that its observed performance can be correlated to various historical data such as operational parameters of the furnace, or manufacturing processes.

Accordingly, there is a need in the art for systems capable of viably monitoring and recording the condition of the electrode column so as to permit subsequent analysis of and optimization of various operating parameters for the furnace and manufacturing processes associated with quality control.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for recording information relating to the condition of electrodes in an electric arc furnace. A digital camera is provided in a consistent position relative to a photographing station, such as a slip stand of the electric arc furnace. Periodically, when the electrode column is removed from the furnace, the stub end of the electrode column is placed upon the slip stand, and the electrode column is photographed with the digital camera. The digital photographs may then be stored for later analysis.

Preferably, the system also includes means by which the identity of a given electrode section, which comprises the stub end shown in a given photograph, can be identified and traced back through both its manufacturing process and its subsequent operational environment, so that the observed condition of the electrode may then be correlated to one or more of those historical events to aid an improved quality control and optimization of both the electrode manufacturing process and the steel making process.

A unique system is provided for defining, and assigning numerical values to, a plurality of recurring defective conditions. The numerical values are preferably assigned in a ranked numerical series which is constructed such that each possible sum value for the conditions present in a given electrode corresponds to a unique combination of defined conditions. The numerical series is preferably a binary series.

It is therefore an object of the present invention to provide improved methods and apparatus for observing and recording data corresponding to the condition of an electrode column in an electric arc furnace.

Another object of the present invention is the provision of unique systems for defining and recording the observed defective conditions utilizing numerical values representative of the observed conditions.

Still another object of the present invention is the provision of systems which allow the subsequent analysis of recorded data for use in optimizing manufacturing processes and operational processes associated with the electrodes.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the following disclosure when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan schematic view of an AC electric arc furnace having three electrode columns in place therein. Adjacent the furnace is schematically illustrated a slip stand, an observation pulpit, two digital cameras, and a computer for recording the digital images from the cameras and other associated data.

Fig. 2 is a schematic elevation partially sectioned view of an electric arc furnace and an electrode column in place therein, along with the associated mast and electrode holder arm.

Fig. 3 is a schematic illustration similar to Fig. 2, showing the electrode column having been moved by the electrode holder arm into a photographing position on a slip stand.

Fig. 4 comprises an array of schematic illustrations representative of a plurality of pre-defined failure conditions, and in tabular form associated therewith is a series of assigned numerical values and condition definitions.

Fig. 5 is a photographic illustration of one of the digital photographs of an electrode stub end illustrating a partial collar, a top of socket split, a bottom of socket crack and a top of socket crack.

Fig. 6 is a first photographic illustration of stub end of an electrode section.

Fig. 7 is a second subsequent view of the stub end of the electrode section of Fig. 6, after the stub end has partially eroded during operation.

Fig. 8 is a third sequential view of the stub end of Figs. 6 and 7, after still further erosion.

Fig. 9 is a photographic illustration of Fig. 8 overlaid on Fig. 7 to illustrate the manner in which the volume of electrode consumption between heats can be calculated.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to Fig. 1, the system for creating photographic records of the electrode column of an electric arc furnace is shown and generally designated by the numeral **10**.

An electric arc furnace **12** is shown in plan view. A circular furnace shell **14** is located above a working platform **16**. First, second and third electrode columns **18**, **20** and **22** are supported in place within the furnace shell **14** by first, second and third electrode holder arms or carrier arms **24**, **26** and **28**.

Located adjacent the furnace **12** is a slip stand **30**. As will be understood by those skilled in the art, each of the electrode column holder arms **24**, **26**, and **28** is pivotable relative to the furnace **12** so that the associated electrode can be placed above the slip stand **30** and then lowered onto the slip stand **30** as is best illustrated in Fig. 3.

Referring now to Fig. 3, one example of an electrode holder arm **24** and associated structural apparatus for moving the electrode column **18** is schematically illustrated. The electrode holder arm **24** is supported on a mast **32**. An electric motor **34** drives a rotating drum **36** about which is wound a cable **38** which extends past lower rollers **40** and **42**. As the mast support cable **38** is wound or unwound upon the drum **36**, the mast **32** will be raised or lowered, respectively, relative to the furnace shell **14**, thus raising and lowering the electrode holder arm **24** and the electrode column **18**. The electrode holder arm **24** may also pivot about the mast **32** so that the electrode column **18** can be pivoted to a position as shown in Fig. 3

wherein butt end **44** of the electrode column **18** is in place upon the slip stand **30**. The slip stand **30** is commonly used to support the electrode column **18** when the electrode arm **24** is being repositioned upon the electrode column **18**. As will be understood by those skilled in the art, the electrode arm carries an electrode clamp **46** on its distal end, which can be released from the electrode column **18** and moved to a new position upon the electrode column **18**, so as to subsequently adjust the depth to which the electrode column **18** is inserted into the furnace shell **14**.

Another method of adjusting the position of the electrode column **18**, is to suspend the electrode column **18** from a crane (not shown) attached to its upper end. Then the clamp **46** can be opened and repositioned while the electrode column is held in place by the crane.

Although a cable type mast is illustrated in Figs. 2 and 3, the mast may also be controlled by hydraulic cylinders, or any other suitable mechanism for providing vertical and pivotal motion of the electrode arm **24** in order to control the position of the electrode column **18** within the furnace **12**, and to remove the electrode column **18** from the furnace **12** as needed during the operation of the furnace.

The furnace **12** also includes a roof **48**. During typical removal of the electrode columns between heats, the roof **48** may be removed intact with the electrode columns. Also, from time to time the electrode columns may be completely removed through the roof **48**.

Each of the electrode columns such as column **18** is made up of a plurality of electrode sections, in this case segments **50**, **52** and **54**.

As is illustrated in Fig. 2, each electrode section includes a threaded socket **56** in its lower end and a threaded socket **58** in its upper end. A threaded pin **60** is threaded into both the sockets **56** and **58** provide a secure physical and electrical connection between the adjacent electrode sections.

The electric arc furnace **12**, the slip stand **30**, and the various apparatus supporting the electrode columns **18**, **20** and **22**, described to this point in this specification, are all a part of the prior art and are present in any conventional electric arc furnace operation.

Each of the arms such as electrode arm **24** may be described as being movable through a range between a position like that shown in Fig. 2 wherein the electrode column is in place within the furnace **12** and a position like that shown in Fig. 3 wherein the electrode column is supported upon the slip stand. The slip stand **30** can be described as being located within that range so that the electrode arm **24** can place the electrode column **18** upon the slip stand **30**, which in the system **10** will serve as a photographing station **30**. Similarly, the electrode arm **24** can move the electrode column to the position of the crane (not shown) described above, which also serve as a photographing station.

As shown in Fig. 1, the system **10** includes a first digital camera **62** which is located in a fixed position relative to the photographing station **30**. Preferably the first digital camera **62** is located within an enclosure commonly referred to as a observation pulpit **64** within which the human operator who is observing the furnace operation is typically located. Thus,

the first camera **62** views the photographing station **30** through a transparent window **66** which protects the camera **62** from the heat of the furnace **12**.

By maintaining the first camera **62** in a fixed position relative to the slip stand **30**, and by consistently placing the electrode columns **18**, **20** or **22** which are to be photographed in a consistent position in the center of the slip stand **30**, the digital photographs which are taken of the butt end of each electrode column will be of the same scale, so that measurements of stub end length, stub diameter, and the like can be determined by applying a common scale to measurements taken from the photographs themselves. It will be understood that such a scale can be easily determined by simply placing an article in the photographing station **30**, taking a digital photograph, then measuring the dimensions of the physical article and comparing those to the dimensions on the photograph. Then so long as the camera settings are maintained, subsequent photographs taken with the same camera of objects at the same location can be compared utilizing the same scale.

Although the slip stand **30** has been described herein as the preferred photographing station, it will be appreciated that any other repeatable location of the electrode column could be utilized. The electrode column could be suspended from a crane as described above. Also, if sufficiently precise control of the carrier arms is provided, the electrode columns could be simply withdrawn from the furnace and held at an identifiable location in space. For example, the photographs shown in Figs. 5-9 were taken with the

electrode column raised 18 inches above the slip stand, in order to accommodate the position of camera **68**. The slip stand, the crane or the identifiable location in space can all serve as the photographing station.

The system **10** further includes a computer **68** which includes a memory section in which a database including digital copies of the various photographs are stored. The digital data representing the images recorded by the camera **62** may be transferred from the camera **62** to the computer **68** in a variety of ways which are schematically illustrated by the connection **70**. The images may in fact be transmitted over a communication cable as represented by **70**. This transmission of data can be via any standard video transmission format, including composite video, S video, RGB or any other available format. The video signal is carried via cable **70** to an internal frame grabber card in computer **68**, which converts the video signal and stores it as a digital image in the computer memory. The frame grabber card may, for example, be a Flashbus MVPro, available from Integral Technologies of Indianapolis, Indiana. In a more rudimentary form of the invention, the images may be recorded on a memory device such as a floppy disc or CD, or other such device, which device can then be physically moved to an input device associated with computer **68**. For example, the floppy disc may be placed within a floppy disc drive of the computer **68** and the data read therefrom into the computer memory. It will be appreciated that in its broadest sense the present invention involves any transfer of the recorded digital data from the camera **62** to the computer **68** whether the same be

completely automated, or whether human steps are involved in transferring the data.

The system **10** preferably will include a means for automatically triggering the camera **68** to take the photograph once the electrode column **18** is properly positioned at the photographing station. For example, for the photographs shown in Figs. 5-9, the camera **68** was triggered by a signal from a programmable logic controller **69** which was connected to sensors, such as **71**, monitoring mast position and the open/closed status of the clamp **46**. When the programmable logic controller determined that the clamp had been opened, the mast had been moved, the clamp had been closed, and the mast had then been raised 18 inches, the trigger signal was generated and sent to camera **68**.

Alternatively, the programmable logic controller **69** can be replaced by a software program in computer **68**, plus input devices to provide the clamp open/closed and mast position signals to the computer.

Although the system **10** has been described utilizing a single camera **62**, it will be appreciated that an improvement and more complete data can be provided by including at least one additional camera **88** positioned such that the view of the combined cameras encompasses 360° around the photographing station **30**, so that the electrode can be viewed from all angles to record all defects present therein. An even further improved system would include three or more cameras spaced around the circumference of the photographing station **30**.

Although the system **10** has been described in the context of a digital camera, it will be appreciated that in its broadest context, the invention can be implemented through the use of a non-digital camera from which printed conventional photographs are produced, so long as the camera is maintained in a consistent position relative to the photographing station **30**, so that the resulting photographs are of common scale. When utilizing a conventional camera, the printed paper photographs can be stored in physical paper files, and can be examined using a common scale by various mechanical measurement means.

DEFECT CLASSIFICATION SYSTEM

I have also developed a unique system of analyzing and cataloging the defects observed when examining the photographs taken by the system **10**. As will be appreciated by those skilled in the art, there are many different types of defective conditions which recur on a regular basis in electrodes. Fig. 4 comprises a series of schematic illustrations of the types of defects which commonly occur. Located below each schematic illustration is a numerical value which I have assigned to that type of defect. Located below the numerical value is a brief description of the condition or type of defect illustrated.

Furthermore, I have arranged the defects from left to right in Fig. 4 in order of the severity of the defect, with the most severe defect being on the right hand end. The numerical values which I have assigned are in a binary series such that the first condition is assigned the number 1, the second

condition is assigned the number 2 which is twice the first value, the third condition is assigned the number 4 which is twice the second value, the fourth condition is assigned the number 8 which is twice the third value, etc.

Starting at the left hand end, the electrode column designated **18A** is a clean column with no defects to which I have assigned the numerical value 1.

The next condition illustrated by electrode column **18B** is a partial collar to which I have assigned the numerical value 2.

The next example **18C** illustrates a split tip as denoted by the vertical crack **70** which runs from the butt end of the electrode. I have assigned the numerical value 4 to this condition.

The next example **18D** illustrates a converging branch crack, to which I have assigned the numerical value 8.

The next example **18E** illustrates a diverging branch crack to which I have assigned the numerical value **16**.

The next example **18F** illustrates a bottom of socket split to which I have assigned the numerical value 32.

The next example **18G** illustrates a top of socket split to which I have assigned the numerical value 64.

The next example **18H** illustrates a bottom crack to which I have assigned the numerical value 128.

The next example **18I** illustrates a bottom of socket crack to which I have assigned the numerical value 256.

The next example **18J** illustrates a top of socket crack to which I have assigned the numerical value 512.

The next example **18K** illustrates a top crack to which I have assigned the numerical value 1024.

When analyzing the condition of a particular electrode stub as shown in one of the digital photographs taken by the system **10**, that condition can be represented as a combination of one or more of the conditions illustrated in Fig. 4.

For example, Fig. 5 is a photograph illustrating an electrode stub having the characteristics of a partial collar **72**, a top of socket split **74**, a bottom of socket crack **76**, and a top of socket crack **78**. These characteristics have respective values of 2, 64, 256, and 512 according to my rating system. A rating that would capture the characteristics of this stub would be 834, or simply the sum of the individual characteristic values. It is significant to note, that the intent of this rating is not to infer that a top of socket crack is twice as bad as a bottom of socket crack, but to rather provide for unique characteristic identification while still indicating a relative measurement of severity.

It is noted that this sum 834 is unique to the combination of partial collar, top of socket splitting, bottom of socket cracking and top of socket cracking. There is no other combination of defects which will result in a sum of characteristic values equal to 834. Thus, with my unique defect identification system, each possible sum value corresponds to a unique combination of defined defective conditions.

The system illustrated above utilizes a binary series. Other examples would include any numerical base where successive assigned values were

incremental increases in exponential value, for example 3^0 , 3^1 , 3^2 , 3^3 , etc. or 4^0 , 4^1 , 4^2 , 4^3 , etc.

Additionally, since I have ranked the defects in order of severity, the sum of the assigned values is representative of the overall severity of the damage which has occurred to the sample being observed.

Thus, one mode of analysis of the digital photographs taken by the system **10** is to examine each of the photographs to determine whether or not each of the predefined conditions illustrated in Fig. 4 is present, and to then record that data and to determine a sum of the assigned values which is indicative of both the overall degree of damage to the electrode, and which is representative of a unique combination of previously defined defects.

This process may be performed by human observation of the digital photographs and entry of the presence or absence of each of the pre-defined defective conditions into a database, from which the assigned values can be determined and the summation thereof calculated and again stored in the database of the computer **68** in association with other data corresponding to the electrode section in question.

It is also anticipated that the process can be implemented either partially or completely by machine observations.

Thus, the computer **68** will have a plurality of condition data files stored therein, each condition data file corresponding to an observed physical condition of the electrode column shown in one of the digital photographs. Each condition data file will include data indicating the observation of one or more of the plurality of defined recurring defective conditions in the

associated digital photograph. Each of the condition data files will also include data representative of the sum of assigned values for all of the observed defined recurring defective conditions.

In its broadest embodiment, the use of the unique numeric value assignment system can be described as a method of tracking a combination of characteristics relating to one of a plurality of articles. The method includes defining a plurality of recurring characteristics for such articles. Then assigning to each of the recurring characteristics a unique assigned numerical value, the values comprising a series constructed such that each possible sum of assigned numerical values corresponds to a unique combination of defined characteristics. Then determining whether each of the plurality of recurring characteristics is present for one of the articles. Then summing the assigned numerical values of the characteristics present for said one article to obtain a sum corresponding to said one article.

While this system has been specifically disclosed in the context of a method for tracking a combination of defective conditions in one of a plurality of electrodes of a furnace, similar systems could be utilized in many other processes.

For example, such a system could be utilized to track the manufacturing process for the electrodes where the electrode passes through a plurality of steps, some of which are variable, and each variable step of which has a unique assigned numerical value according to the system described above. Thus, the resulting numerical sum of the manufacturing

process is encountered by the electrode would be representative of the unique series of process stubs encountered by that particular electrode.

OTHER MODES OF OBSERVATION

Another physical parameter of the electrode column which is desirable to record is the stub length **80**, which is defined as distance from the butt end **44** to the joint **82** between the intermediate electrode section **52** and the lowermost electrode section **54** as shown in Fig. 3.

If the scale of the digital photograph is known, this length **80** can easily be measured by measuring the length on the photograph and applying the known scale. The means of accomplishing this is through the use of a software program such as the ImagePro program, available from Media Cybermedics of Silver Springs, MD, which can automatically measure the distance between two identifiable points on a digital drawing or photograph. Thus, the human operator of the program identifies the lowermost point on the butt end **44** and identifies a point on the joint **82** immediately above the lowermost point, and the software program can immediately determine the distance between those two points which corresponds to the stub end length **80**. This data can then be stored in the memory of the computer **68** and associated with the other data corresponding to the lowermost electrode section **54**.

Another manner in which the digital photographs may be utilized to obtain useful data corresponding to the performance of the electrode is through the comparison of consecutive photographs of a given stub end,

which consecutive photographs are taken at the end of a series of heats or other events. For example, Figs. 6, 7 and 8 comprise three consecutive photographs of a stub end electrode section **54**.

Fig. 6 represents the condition of the stub end section **54** after the next lower electrode segment has broken away, and the stub end section **54** is substantially undamaged.

Fig. 7 is a photograph of the same stub end section **54** after one heat has been performed.

Fig. 8 is a photograph of the same stub end after a second heat has been performed. It is apparent in comparing Fig. 6, 7 and 8, that the stub end electrode section **54** is slowly being consumed in use.

As is apparent in Figs. 6, 7 and 8, there is a tip split **84** present in the electrode section **54**.

Fig. 9 illustrates a technique by which the two consecutive photographs such as Figs. 7 and 8 may be utilized to calculate the actual volume and poundage of the electrode which is consumed during the single heat of the electrical arc furnace, which occurred between photographs 7 and 8.

In Fig. 9, the image of Fig. 8 has been overlaid upon the image of Fig. 7, and the common portions of the split **84** have been aligned. In Fig. 9, the butt end of the electrode as shown in Fig. 7 is designated by **44A**, and the butt end as shown in Fig. 8 is designated as **44B**.

The volume of the electrode **54** at the time of Fig. 7 can be calculated by measuring the stub length **80**, and measuring the diameter at one or

more locations and calculating the volume therefrom. The volume of the stub end electrode **54** in Fig. 8 can be calculated in a similar manner, and the volume of electrode consumed between the two photographs is simply the difference between the two calculated volumes.

Another method of determining consumption during a heat is to determine consumption by length of the electrode column. This can be done using two auxiliary furnace inputs, namely the mast position in inches, and the electrode clamp position, either open or closed. A mast position reading can be recorded both before and after a heat and the consumption then calculated from the difference. This method of determining linear consumption requires an operational procedure of placing the electrode on the slip stand, and the clamp be open prior to each heat, and also before and after swapping electrode columns.

Thus, with the data which is available from the digital photographs, and with analysis techniques such as those described above, very accurate determinations can be made of the exact poundage of electrode consumed during a single heat of the electric arc furnace **12**. Thus, a much more accurate measurement of electrode performance is provided than with the gross techniques of the prior art, and more significantly this data is correlated to a specific electrode section, and can in turn be correlated to other data which has been recorded relevant to that electrode section, such as manufacturing conditions when the electrode was manufactured and such as operating conditions when the electrode was present in the furnace **12**.

It will be apparent that through the techniques described above, a great detail of very specific information on the performance of each electrode can be obtained, and it can then be correlated with any other historical parameters of the electrode section.

For example, various operating parameters relating to the operating conditions in the furnace **12** when the electrode is present, may be measured and recorded with a system like that shown in U.S. Patent No. 5,099,438 to Gulden, Jr., et al., and assigned to the assignee of the present invention, which disclosure is incorporated herein by reference. The computer will have a plurality of historical operational data files stored therein corresponding to the furnace operating conditions experienced by the electrode column.

Other historical data, such as data relating to the process by which the particular electrode section was manufactured can be recorded and stored in association with all of the other data corresponding to a given electrode section, to allow analysis collectively of all of the data to determine what correlations might be present between electrode performance and historical manufacturing and/or operating conditions. It will be apparent that by studying such correlations, both the manufacturing process and the operation of the electric arc furnace can be improved and optimized.

One factor which is important to the optimum usage of the system **10** is to provide reliable means for identifying each individual electrode section. This can be accomplished in several ways.

Fig. 3 schematically illustrates the use of visual identification indicia **84** and/or a machine detectable identification tracer **86**, such as a radio

frequency identification tag, embedded in the electrode section. By either system, the upper electrode section **50** can be specifically identified at the time it is added to the upper end of the electrode column **50**. Then, due to deterioration or destruction of the identifying marker as the electrode section progresses downward toward the end of the electrode column, it is desirable to visually track the electrode section, such as by recording through photographs each subsequent change made to the electrode column. This could for example be accomplished through the use of an additional camera (not shown) to monitor mast arm position and slipping distances when the position of the electrode column is adjusted on the slip stand. Also, if an embedded tracer is capable of withstanding the extreme heat conditions present in the furnace, it could also be possible to continue to directly identify the electrode section as it moved downward through the electrode column.

Alternatively, if each individual electrode section is not specifically identified, it is also possible to identify groups of electrode sections, such as a group that is of common manufacture and origin, and to collectively record the data for all members of that group and analyze the data for the group.

SUMMARY OF METHODS OF OPERATION

The methods of recording information utilizing the system **10** include generally the following steps. The digital camera **62** is provided in a consistent position relative to the photographing station **30** defined by the slipping station. Periodically, when the electrode column **18**, **20** or **22** is removed from the furnace, such as at the end of a heat, or when adding additional charge during a heat, the electrode column is moved by its associated electrode holder arm to the photographing station **30** and the stub end of the electrode column is placed on the photographing station **30**. Then a trigger signal is sent to camera **68** and the stub end of the electrode column is photographed with the digital camera **62**, and the digital photograph is stored in the memory of the computer **68**.

Then the stored digital photographs can be analyzed in the various ways described above to determine the physical condition of the stub end of the electrode column. This data can be correlated to various historical data for the electrode section in question, including both manufacturing data and operational performance data in the furnace.

The resulting data can be analyzed in many ways.

The data can be grouped to identify recurring failure patterns in the electrode assemblies, and to correlate those failure patterns to either manufacturing processes and/or operational parameters encountered in the furnace. Stub end lengths and volumes can be measured and translated into measurements of electrode consumption by the furnace.

Thus, it is seen that the apparatus and methods of the present invention readily achieve the ends and advantages mentioned as well as those inherent therein. While certain preferred embodiments of the invention have been illustrated and described for purposes of the present disclosure, numerous changes in the arrangement and construction of parts and steps may be made by those skilled in the art, which changes are encompassed within the scope and spirit of the present invention as defined by the appended claims.

What is claimed is:

CLAIMS

1. A method of recording information relating to the condition of electrodes in an electric arc furnace, the method comprising:
 - (a) providing a camera in a consistent position relative to a photographing station;
 - (b) periodically removing an electrode column from the furnace, and moving the electrode column to the photographing station;
 - (c) photographing the electrode column with the camera when the electrode column is located at the photographing station; and
 - (d) storing the photographs of the electrode column.
2. The method of claim 1, wherein:
 - in step (a), the camera is a digital camera; and
 - in step (d), the storing step includes storing an electronic digital copy of the photograph in a digital memory.
3. The method of claim 1, wherein:
 - in step (a), the camera is a non-digital camera from which printed photographs can be produced; and
 - in step (d), the storing step includes storing the printed photographs in physical paper files.

4. The method of claim 1, wherein:
in step (a), the photographing station is a slip stand; and
in step (b), a stub end of the electrode column is placed on the slip stand.
5. The method of claim 1, further comprising:
analyzing the stored photographs to determine the physical condition of the electrode column shown in each photograph.
6. The method of claim 5, wherein:
the analyzing step includes measuring a stub length in each photograph, using a common scale applied to all of the photographs, thereby eliminating observer subjectivity in determining stub length.
7. The method of claim 6, wherein:
in step (a), the camera is a digital camera;
in step (d), the storing step includes storing an electronic digital copy of the photograph in a digital memory; and
the step of measuring the stub length includes using a software program to automatically measure a distance between identifiable points associated with the ends of the stub.
8. The method of claim 5, wherein the analyzing step includes:
defining a plurality of recurring defective conditions;

examining the stored photographs to identify whether each of the defined conditions is present; and

recording data indicating whether each of the defined conditions is present in each photograph.

9. The method of claim 8, wherein the analyzing step further includes:
assigning to each of the defined conditions a unique numerical value;
and

for each photograph, summing the numerical values corresponding to the defined conditions which are present, to provide a numerical indication of overall condition of the electrode column as shown in each photograph.

10. The method of claim 9, wherein:

the assigned numerical values comprise a binary series ranking the defined conditions in order of severity, so that the sum value for each photograph provides a relative measurement of severity of physical damage depicted in the photograph.

11. The method of claim 9, wherein:

the assigned numerical values comprise a numerical series constructed such that each possible sum value corresponds to a unique combination of defined conditions.

12. The method of claim 11, wherein:

the numerical series is a binary series wherein each numerical value, other than the smallest value, is twice the immediately preceding value.

13. The method of claim 8, wherein the analyzing step includes:

grouping the data to identify recurring failure patterns in the electrode column.

14. The method of claim 5, further comprising:

identifying a stub end electrode section of the electrode column and correlating the observed physical condition to the identification of the stub end electrode section.

15. The method of claim 14, further comprising:

recording at least one historical operating parameter for the stub end electrode section; and

correlating the observed physical condition to the historical operating parameter.

16. The method of claim 14, wherein:

the step of identifying a stub end electrode section includes providing an identifiable tracer embedded in the electrode section and identifying the tracer.

17. The method of claim 14, wherein:

the step of identifying a stub end electrode section includes providing a visual identification indicia on each electrode section, identifying each electrode section by the visual identification indicia when the electrode section is added to an upper end of the electrode column, and tracking the electrode section identity as it moves downward to become the stub end electrode section.

18. The method of claim 5, wherein:

the analyzing step includes comparing consecutive photographs of the electrode column and thereby measuring electrode consumption.

19. The method of claim 5, wherein:

the analyzing step includes calculating a volume of a stub end electrode section of the electrode column.

20. The method of claim 1, wherein:

step (a) includes providing at least one additional camera positioned such that the view of the combined cameras encompasses 360° around the photographing station.

21. The method of claim 1, wherein:

step (c) includes a step of automatically triggering the camera when the electrode column is located at the photographing station.

22. A system for creating photographic records of an electrode column of an electric arc furnace to document the condition of the electrode column, comprising:

an electric arc furnace, including an electrode column carried by an electrode carrier arm, the arm being movable through a range;

a photographing station located within the range of the arm, so that the arm can place the electrode column at the photographing station; and

a digital camera, located in a fixed position relative to the photographing station, so that a plurality of digital photographs taken of the electrode column at the photographing station by the digital camera are of the same scale.

23. The system of claim 22, wherein:

the photographing station is a slip stand for supporting a stub end of the electrode column.

24. The system of claim 22, further comprising:

a computer including a database in which digital copies of the photographs are stored.

25. The system of claim 24, wherein:

the computer has a plurality of condition data files stored therein, each condition data file corresponding to an observable physical condition

of the electrode column shown in one of the digital photographs, each condition data file including data indicating the observation of one or more of a plurality of defined recurring defective conditions in the associated digital photograph.

26. The system of claim 25, wherein:

each of the condition data files includes data representative of a sum of assigned values for all of the observed defined recurring defective conditions.

27. The system of claim 26, wherein:

the assigned values for each of the defined recurring defective conditions are ranked according to severity, so that the sum is indicative of overall condition of the electrode column.

28. The system of claim 27, wherein:

the assigned values comprise a series constructed such that each possible sum corresponds to a unique combination of defined conditions.

29. The system of claim 28, wherein:

the series is a binary series.

30. The system of claim 26, wherein:

the assigned values comprise a series constructed such that each possible sum corresponds to a unique combination of defined conditions.

31. The system of claim 30, wherein:

the series is a binary series.

32. The system of claim 24, wherein:

the computer includes a software program for determining a stub end length of the electrode column shown in the digital photograph.

33. The system of claim 32, wherein:

the software program requires manual identification of the end points of the stub end shown in the digital photograph.

34. The system of claim 24, wherein:

the computer has a plurality of historical operational data files stored therein corresponding to furnace operating parameters experienced by the electrode column.

35. The system of claim 34, wherein:

the historical operational data files and the digital copies of the photographs are associated with each other via a recorded identify of each electrode section located at the stub end of the electrode column.

36. The system of claim 22, wherein:

each electrode section of the electrode column carries a unique visually observable indicia when the electrode section is first placed on the upper end of the electrode column.

37. The system of claim 22, wherein:

each electrode section carries a unique machine detectable identification tracer.

38. The system of claim 22, further comprising:

at least one additional digital camera located circumferentially about the photographing station from the first digital camera, so that the entire circumference of the electrode column can be photographed.

39. The system of claim 22, further comprising:

an automatic triggering device, including a sensor for sensing electrode column position, and a signal generator for generating a trigger signal to operate the camera when the electrode column is in place at the photographing station.

40. A method of tracking a combination of characteristics relating to one of a plurality of articles, comprising:

- (a) defining a plurality of recurring characteristics for such articles;
- (b) assigning to each of the recurring characteristics a unique assigned numerical value, the values comprising a series constructed such that each possible sum of assigned numerical values corresponds to a unique combination of defined characteristics;
- (c) determining whether each of the plurality of recurring characteristics is present for said one article; and
- (d) summing the assigned numerical values of the characteristics present for said one article to obtain a sum corresponding to said one article.

41. The method of claim 40, wherein:

in step (a), each of the plurality of recurring characteristics is a defective condition of the article.

42. The method of claim 41, wherein:

in step (b), the assigned numerical values are ranked in order of severity of the associated defective conditions; and

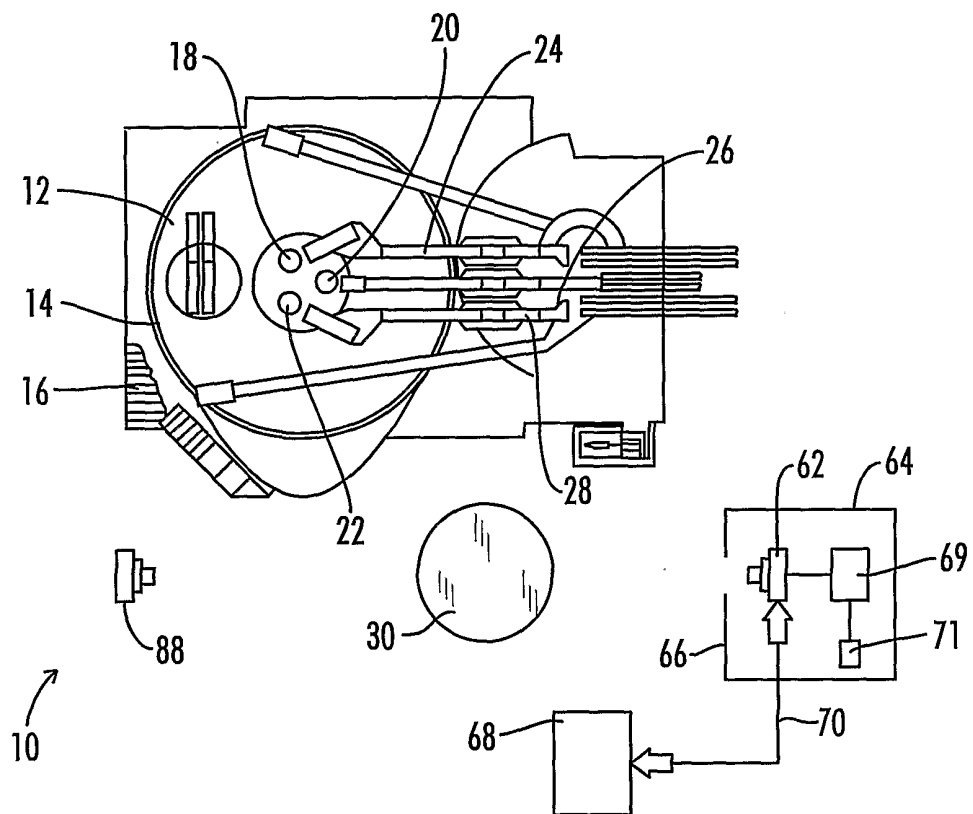
in step (d), the sum is indicative of the condition of the article.

43. The method of claim 40, wherein:

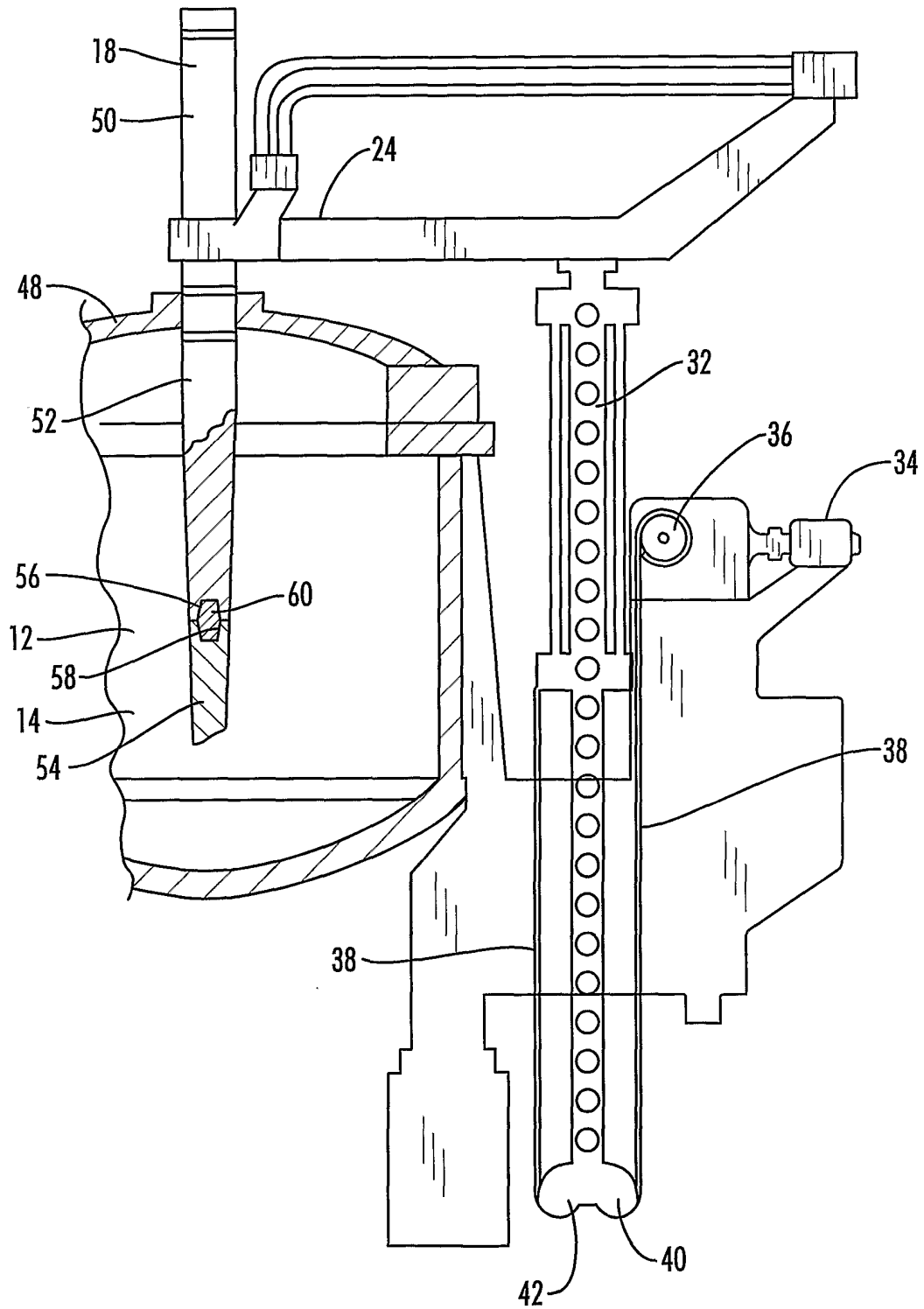
in step (b) the series is a binary series.

44. The method of claim 40, wherein the articles are electrodes for an electric arc furnace.

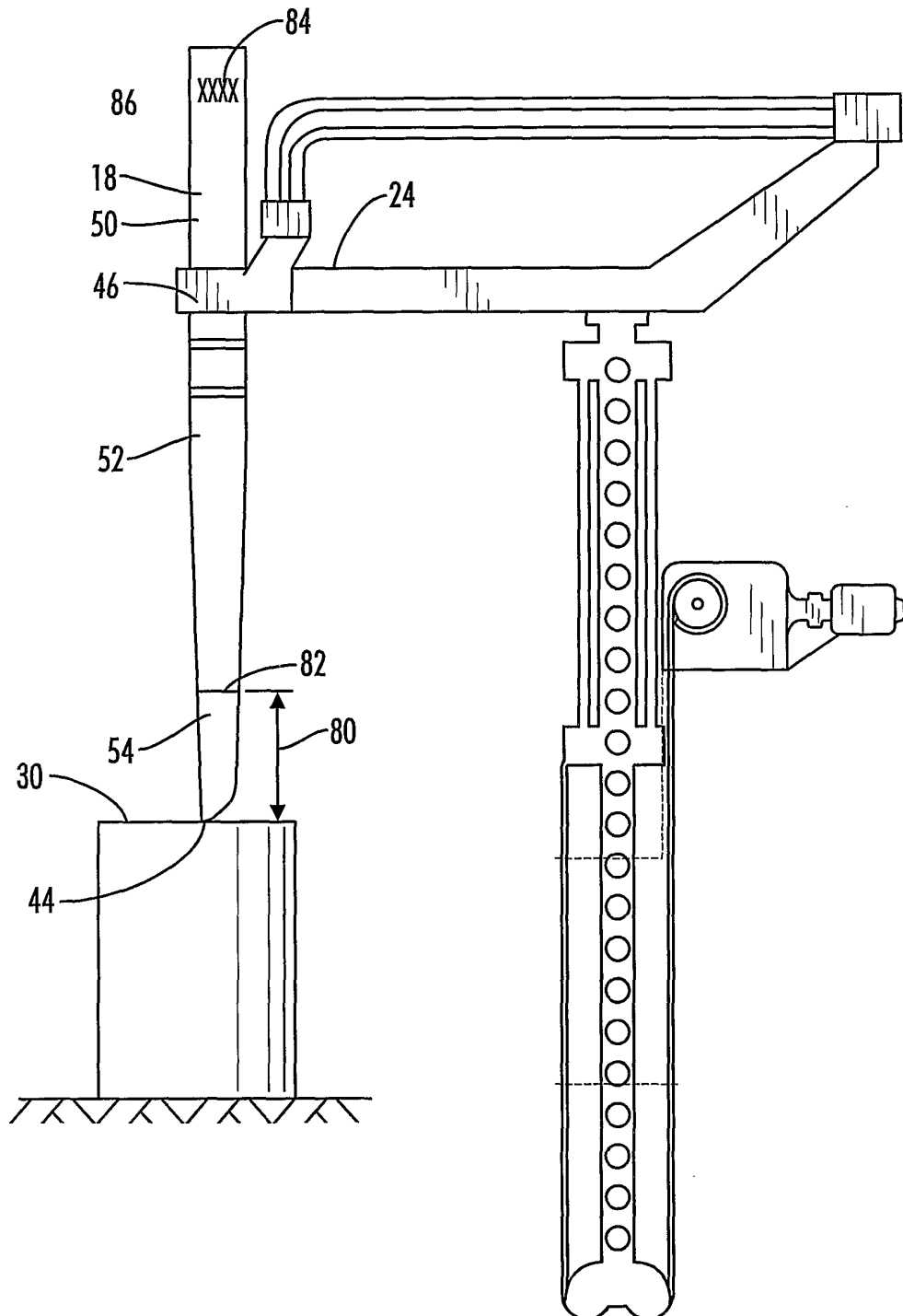
1/6

*FIG. 1*

2/6

*FIG. 2*

3/6

*FIG. 3*

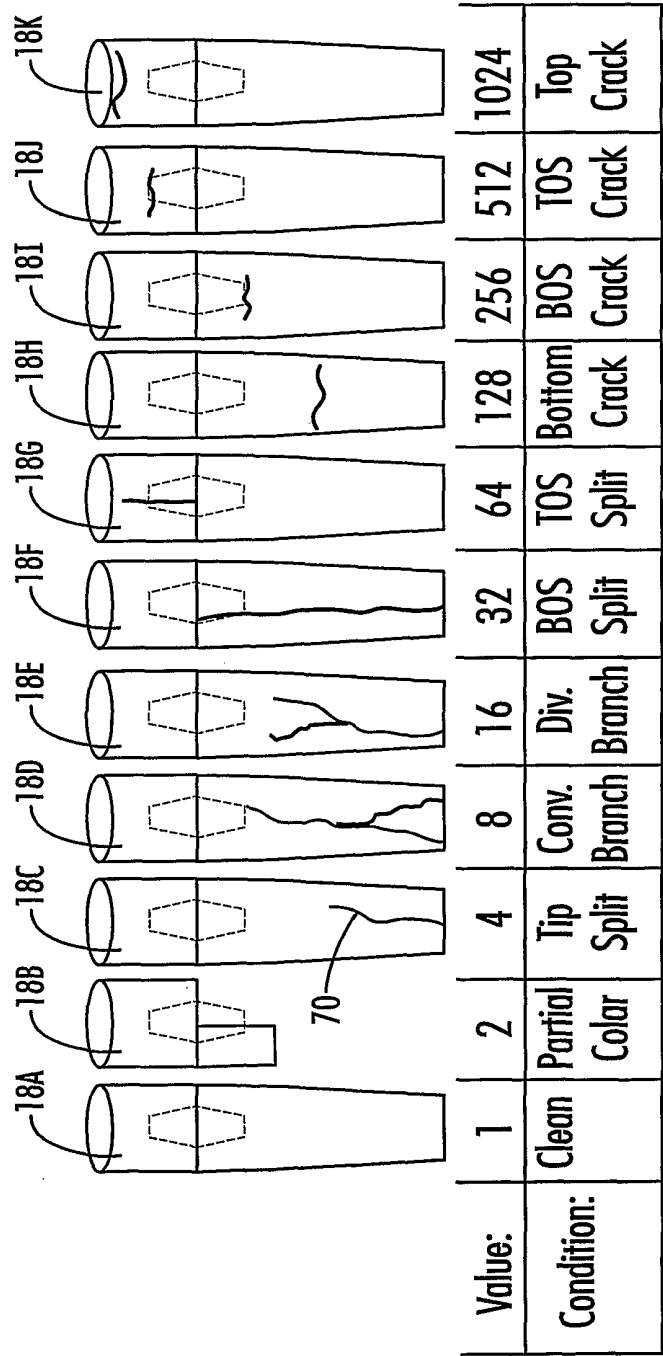


FIG. 4

5/6

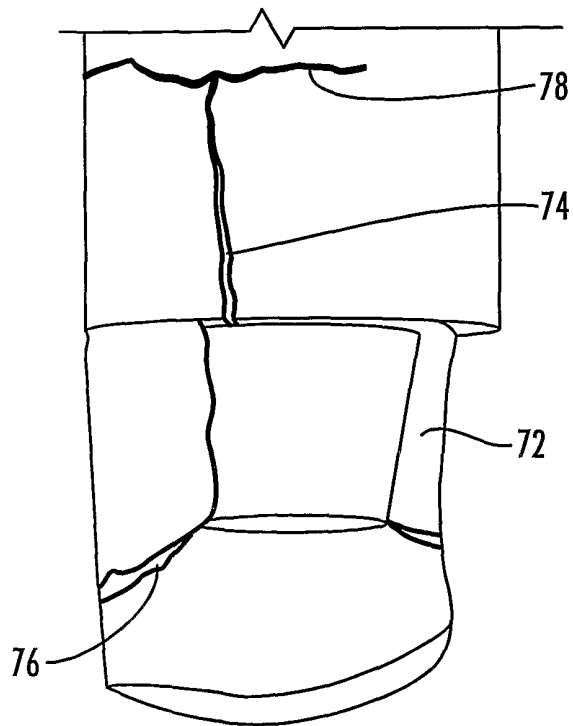


FIG. 5

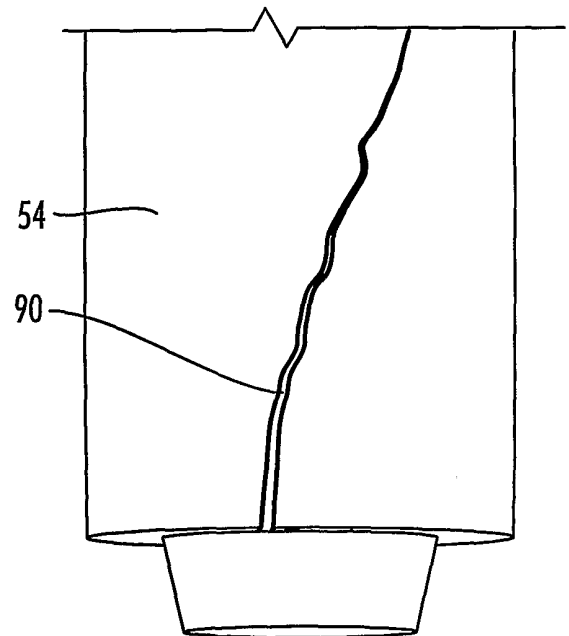


FIG. 6

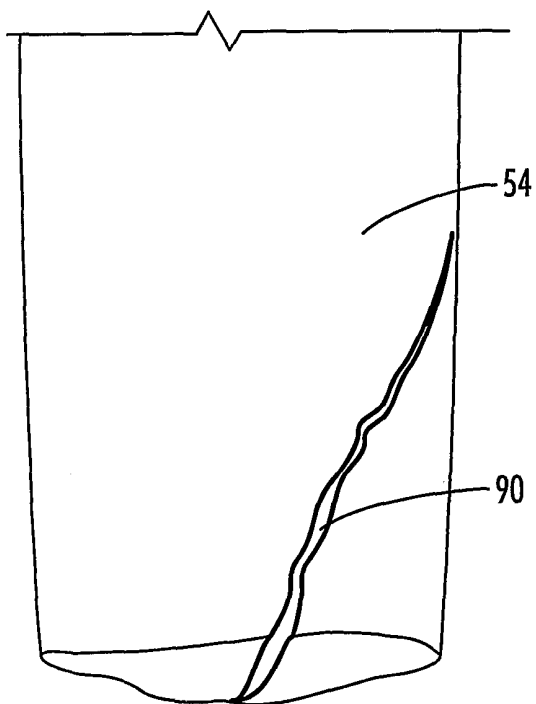


FIG. 7

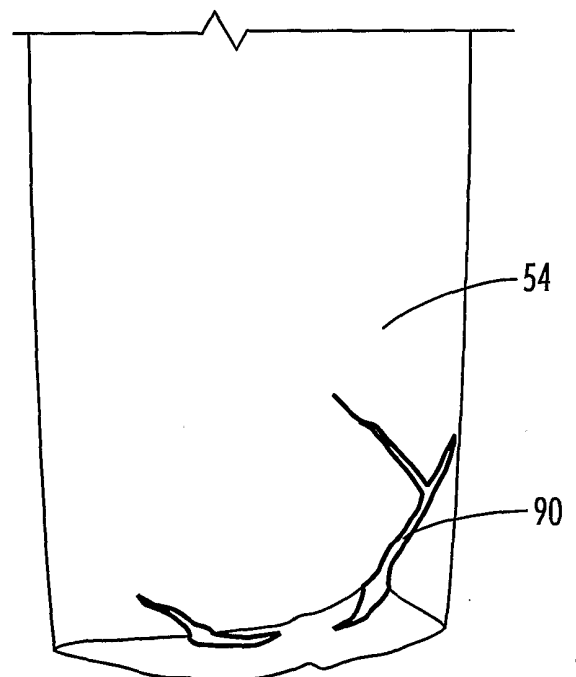


FIG. 8

6/6

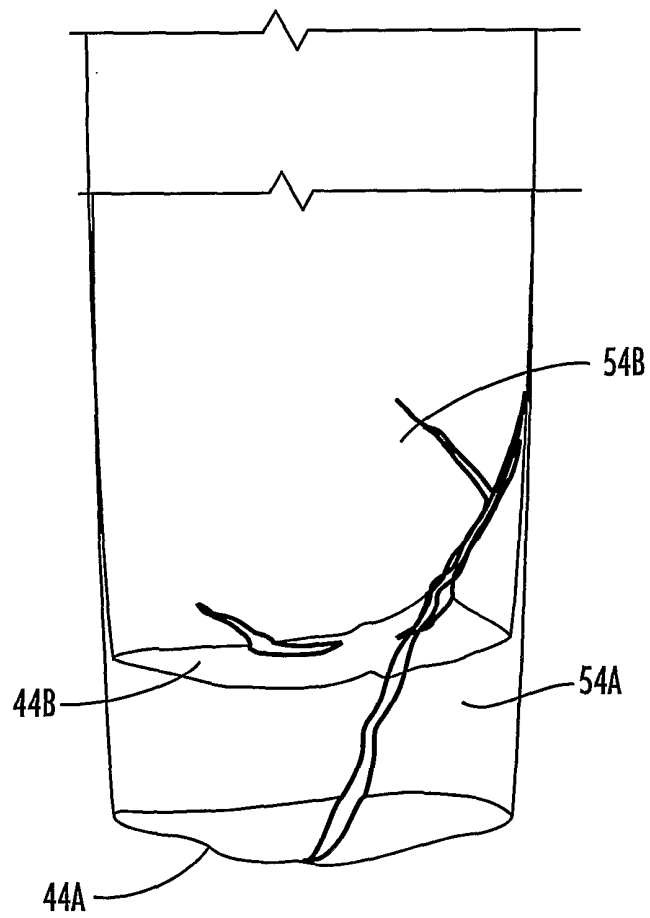


FIG. 9