United States Patent [19]

Vitale et al.

[11] **3,823,243**

[45] **July 9, 1974**

[54] **APPARATUS FOR LIMITING MAST TRAVEL IN ELECTRIC FURNACE SYSTEM**

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[22] Filed: **Oct. 29, 1973**

[21] Appl. No.: **410,567**

[52] **U.S. Cl.** **13/13**

[51] **Int. Cl.** **H05b 7/12**

[58] **Field of Search** ..... 13/9, 13, 13 ES

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[57] **ABSTRACT**

In electric furnace systems, the electrode for supplying current to the furnace is normally moved up and down by a reciprocating mast mounted by upper and lower mast-guiding means fitting closely about the mast, the reciprocating motion being provided by suitable motor means. To prevent dangerous up-and-down extremes of travel of the mast, there is employed a normally-open type of switch means positioned between the upper and lower mast-guiding means so as to be held closed by a surface of the mast during execution by the mast of its desired maximum length of travel. The mast surface is configured to permit the switch means to open when the mast moves beyond the desired maximum length of travel, and this opening of the switch is caused to deactuate the motor means. Preferably the configuring of the mast surface comprises providing a recess therein so positioned that when the switch arm, which normally rides along the exterior of the mast, reaches the recess, it moves into the recess to permit the switch to open and discontinue the motor operation. The position of the switch is preferably on the side of the mast away from the furnace means and within an at-least-partially protected region. Other arrangements employ more than one recess and/or switch, some of which may be used for normal arrest of the extreme motion of the mast and others of which may be used as back-up safety devices in case the normal mast-arresting arrangement does not function.

7 Claims, 8 Drawing Figures

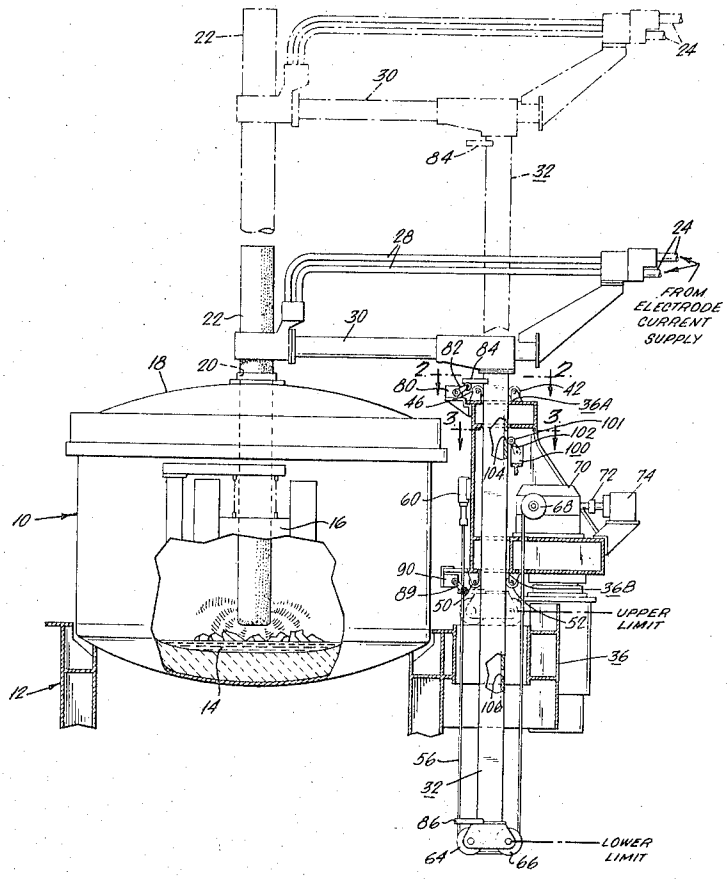


FIG. 1.

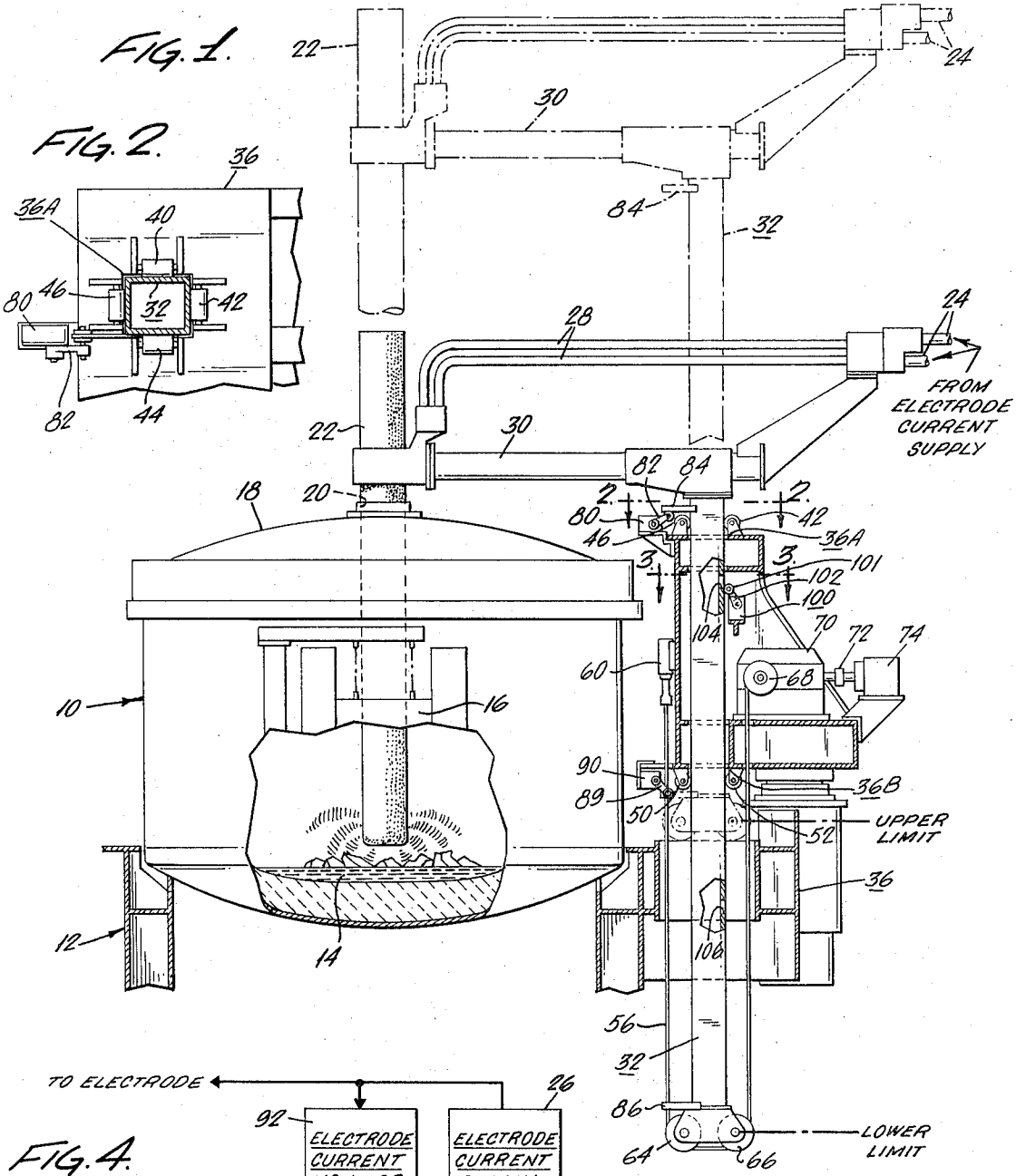


FIG. 2.

FIG. 4.

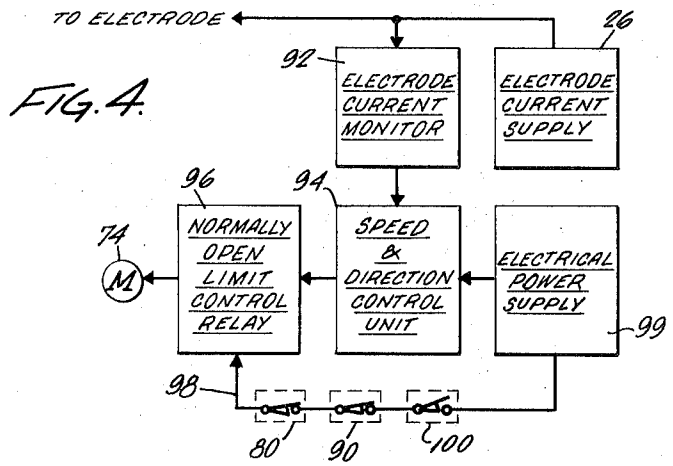


FIG. 3.

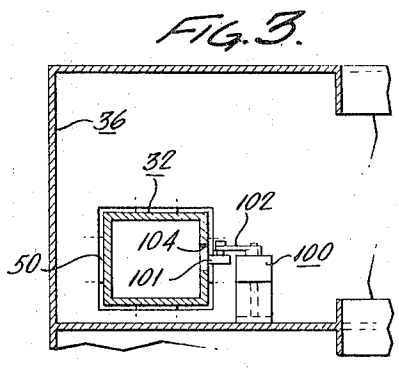


FIG. 6

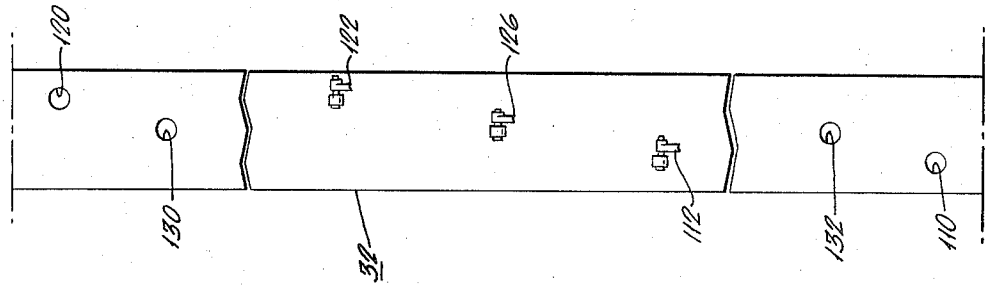


FIG. 5C

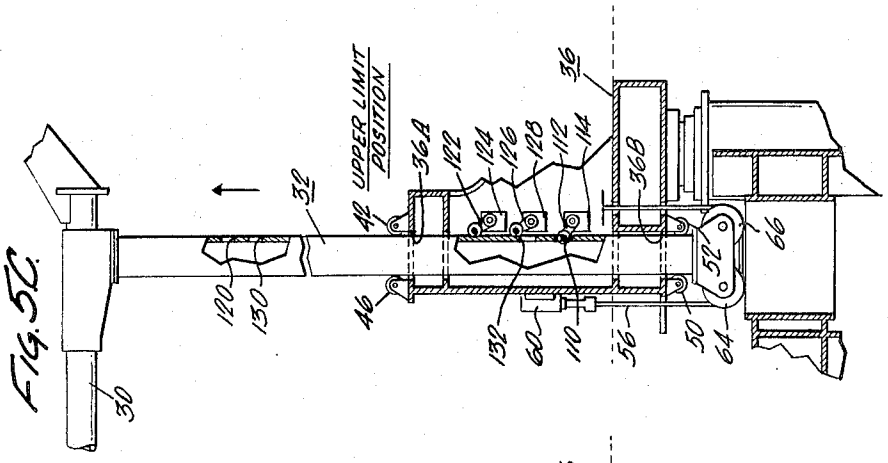


FIG. 5B

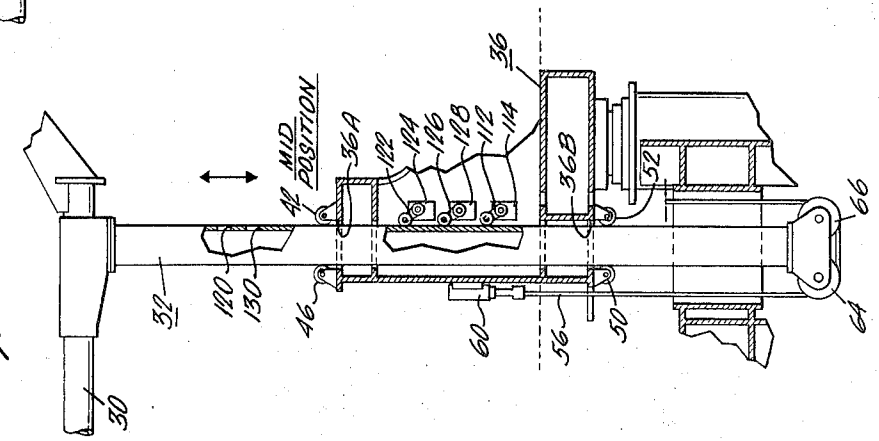
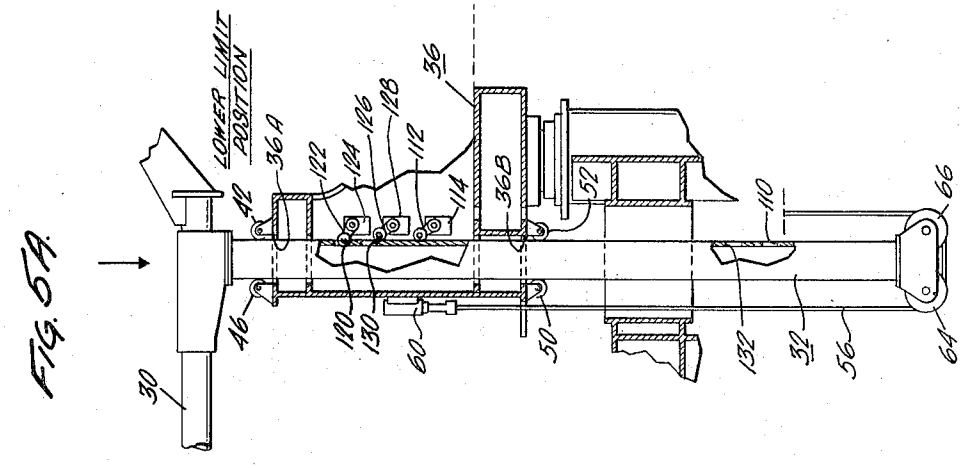


FIG. 5A



APPARATUS FOR LIMITING MAST TRAVEL IN ELECTRIC FURNACE SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to safety apparatus for preventing dangerous over-travel of a reciprocating member, and particularly to such safety apparatus for limiting to safe values the extremes of travel of the electrode-supporting mast in an electric furnace system.

In a typical electric furnace system, such as for the production of steel, a massive electrode is positioned vertically in the furnace and serves to deliver very high electrical currents to the melt. Provision must be made for the controlled vertical adjustment of the position of the electrode, for example to lift it during recharging or pouring off of slag or molten steel and then to replace it into operating position adjacent the melt; also, since the electrode is consumed during the process, it is normally moved controlledly downward during operation, so as to maintain its lower end in the proper position with respect to the top of the melt.

To provide for this up-and-down motion of the electrode, the electrode is normally supported on a horizontal supporting arm which in turn is carried by an adjacent vertically reciprocable mast, positioned adjacent the furnace. The mast is held in suitable supporting means so that it may be driven up and down by an appropriate motor driven arrangement. Operation of the motor is normally controlled by a relatively complex electronic system which, during furnace operation, typically senses the current being supplied through the electrode to the melt, and automatically operates the motor to maintain the lower end of the electrode at the proper position for which the desired current is obtained. In addition, normally there are operator overrides for this automatic system so that the operator may, when he wishes, raise the electrode from operating position and replace it when desired.

It will be appreciated that the size and weight of all this apparatus is very great. For example, the mast may be 20 or 30 feet long, and it together with the parts supported on it may weigh many tons. In one form of arrangement for mounting the mast, the mast is held vertical in a supporting frame comprising upper and lower guide-means, each closely surrounding the mast and typically including roller means bearing against the periphery of the mast to guide it while permitting it to move freely through the closely-surrounding support structure. Motion of the mast may be provided, for example, by a cable fixed at one end and passing around sheaves secured to the lower end of the mast, and thence upward to a motor-driven winch arrangement. By operating the motor so as to tighten the cable, the mast is forced to move upwardly, and when the cable is unwound the mast moves downwardly under its own weight.

Important practical difficulties have been encountered in the past in the operation of such systems as a result of unintended over-travel of the mast in either of its two extreme directions. Excessive upward drive may cause damage to components of the system when the sheave arrangement at the bottom is forced upwardly into contact with them, and it is also possible under these conditions for the cable to snap, allowing the mast to fall downwardly in its supporting frame and cause serious damage to the equipment.

Such over-travel of course, is not intended to occur, but in fact sometimes does occur either because of malfunction of the control equipment or in some cases due to operator in attendance or error.

To reduce the chances for such dangerous over-travel, it has been known in the prior art to employ projections placed on the outer surfaces of the mast near its opposite ends, and to mount a pair of electrical limit switches so that one of the limit switches is operated by one of the projections when the mast reaches its maximum desired downward position and so that the other limit switch is operated by the other projection when the mast reaches its desired maximum upward position. These switches can then be connected in series in the motor control circuit, so that if either switch is opened it cuts off current to the motor and prevents any further motion of the mast.

We have found that even with such a limit switch arrangement, serious and expensive damage and down-time due to mast over-travel may still occur upon occasions. This unreliability has been found to result from certain conditions existing in the environment of an electrical furnace of the type described.

One basic difficulty is that the special environmental conditions existing around an electric furnace system can cause the limit switch and projecting trip to malfunction, in which event the motor power will continue to be applied and the above-described dangerous or catastrophic mast-over-travel will occur; when the limit switch arrangement fails, it fails in a manner which permits dangerous over-travel to occur. Another basic problem is that since the limit switch arrangement utilizes a projection on the mast to trip the switch, the trip (and switch) must be located outside the protected region between the upper and lower mast-guiding means since, due to their projecting configuration, they cannot move through the mast-guiding means which surround the mast closely on all sides. The limit switch arrangement is therefore exposed to atmospheric and physical damage of a severe nature in the environment involved, which, as set forth hereinafter in detail, is often such as to cause malfunction in the limit switch arrangement and consequent catastrophic over-travel by the mast.

SUMMARY OF THE INVENTION

In accordance with the invention, in a system comprising an electric furnace, an electrode for supplying current to the furnace, a mast supporting electrode, means mounting the mast for reciprocatory motion adjacent the furnace to control the position of the electrode with respect to the furnace, the mounting means including upper and lower mast-guiding means fitting closely about the mast, and motor means for effecting said reciprocatory motion of the mast, there is provided an improvement comprising a normally open type of switch means positioned between the upper and lower mast-guiding means to be held closed by a surface of the mast during execution by the mast of its desired maximum length of travel, the mast surface being configured to permit the switch means to open when the mast moves beyond the desired maximum length of travel in a predetermined direction, and means for preventing the motor means for moving the mast further when the switch means opens. Preferably the swtich means comprises a switch arm normally riding along the surface of the mast, and the mast is configured to

define a recess in its surface into which the switch arm moves to open the switch means when the mast has executed its desired maximum length of travel in one direction. In a preferred form, the mast is configured also to define another recess in its surface into which the switch arm moves to open the switch means when the mast has executed its desired maximum length of travel in the opposite direction. Advantageously the switch arm is located on the opposite side of the mast from the furnace and is at least partially shielded from above and from the sides, and preferably the motor means is an electric motor the current to which is cut off by the closing of said switch means to prevent further motion of the mast.

The term "recess" as utilized herein includes either end of the mast, which will permit the switch arm to move inwardly with respect to the mast surface when it passes beyond an end of the mast.

Various combinations of plural switches and recesses may be employed where desired, for example so as to provide a first normally operating limit switch arrangement and an additional back-up limit switch arrangement if desired.

Because recesses, rather than projections, are utilized to operate the limit switch means, they may be provided in the mast without interfering with the motion of the mast through the upper and lower mast-guiding means. The recesses are also substantially impervious to damage which would prevent their proper cooperation with the limit switch or switches, and the limit switch or switches themselves may be located in a protected position between the upper and lower guiding-means and on the opposite side of the mast from the furnace. In addition, even if damage, or misalignment or misorientation, of the limit switch arrangement should occur (for example should a switch arm break off, or its higher-potential contact become grounded, or too great a separation occur between the mast and the switch arm), the limit switch will nevertheless operate to shut the motor off and prevent further mast motion. In this sense a limit switch of the normally open type, held closed by riding on the mast surface, constitutes a "fail-safe" arrangement important in assuring prevention of catastrophic damage.

BRIEF DESCRIPTION OF THE FIGURES

These and other objects and features of the invention will be more readily appreciated from a consideration of the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 is an elevational view, partly in section, of electric furnace apparatus embodying the safety arrangement of the invention in one of its preferred forms;

FIG. 2 is a fragmentary sectional view taken along lines 2—2 of FIG. 1;

FIG. 3 is a fragmentary sectional view, with parts omitted, taken along lines 3—3 of FIG. 1;

FIG. 4 is a functional block diagram illustrating one manner of connection of the electrical components for the system of FIG. 1;

FIGS. 5A through 5C are elevational views, with parts broken away, showing another alternative embodiment of the invention in three different operating positions thereof; and

FIG. 6 is a fragmentary side view of a portion of a mast in the embodiments of FIGS. 5A through 5C, showing the location of the recesses and switch arms.

DETAILED DESCRIPTION OF EMBODIMENTS

Without thereby in any way limiting the generality of the invention, FIGS. 1–4 illustrate one manner of its application to an electric furnace. Referring to these figures, in which corresponding numerals indicate corresponding parts, there is shown a conventional electric furnace **10** rotatively mounted on its supporting structure **12** so that it can be tilted for pouring purposes, and containing in the bottom a suitable melt **14** to be used in producing steel. The furnace has a slag door **16** and a top **18** including opening **20** thorugh which passes the consumable electrode **22.** Current for the electrode is supplied over buses **24** from an electrode current supply **26** (FIG. **4**) by way of supply buses **28.** Electrode **22** is held by transverse electrode-supporting arm **30,** which in turn is mounted on the top of a vertical mast **32.** Mast **32** is in turn mounted for vertical reciprocatory motion in a support casing **36.**

Support casing **36** surrounds the rectangularly cross-sectioned mast closely on all four sides as at **36**A, normally without touching the mast, and four rollers **40, 42, 44** and **46** each extends across and bear against a different one of the four side surfaces of the mast. The closely fitting casing at **36**A and the rollers **40, 42, 44** and **46** comprise upper mast-guiding means for mast **32.** Lower mast-guiding means are provided by the surrounding support casing at **36**B and by the additional set of four rollers, only two of which are shown and designated as **50** and **52,** it being understood that similar rollers appear on the other two sides of the mast at the lower mast-guiding position.

To raise and lower the mast, there is provided a cable **56** held to the support casing at one end by a cable terminal **60,** extending downwardly around a pair of sheaves **64** and **66** secured to the bottom of the mast, and thence upwardly to a winch **68.** Winch **68** is mounted on a mast-hoist drive arrangement **70** and driven through a clutch **72** by an electrical motor **74.**

Mounted to the support casing **36** near the top thereof is a normally closed limit switch **80,** the arm **82** of which is positioned so that the switch is changed from its normally closed position to its open position when the mast moves so far downwardly that the upper trip projection **84** on the mast strikes the switch arm. In FIG. **1** the full-line portion of the drawing shows the mast in its substantially lowermost position for which projection **84** is about to open switch **80.** A similar lower trip projection **86** is provided on the lower end of the mast and, when the mast is near the uppermost desired position as shown in broken line in FIG. **1,** the latter trip projection contacts and actuates the arm **89** of a lower normally closed limit switch **90,** to move it from its normally-closed to its open position.

As shown in FIG. **4,** the electrical portion of the apparatus in this example includes not only the electrode current supply **26,** but also an electrode current monitor **92** which senses the magnitude of the current being supplied to the electrode **22** and delivers a control signal to the speed and direction control unit **94.** The latter unit contains electronic circuitry for supplying current of the appropriate direction and magnitude to motor **74** for maintaining electrode **22** in the proper desired position with respect to the melt **14** during normal

operation. Between unit 94 and motor 74 there is connected a normally open limit control relay 96 which is held closed so as to supply current to the motor when a control current is supplied thereto over input control lead 98 thereof. A suitable electrical power supply 99 is connected to the unit 94 to provide the necessary electronic supply currents, and also supplies control current to lead 98 upon the closure of all of the switches connected in series with lead 98, namely limit switches 80 and 90, and the additional safety limit switch 100, provided in accordance with the invention and to be described presently. If any of these three switches is open, the motor will stop. In previously known arrangements, only the switches 80 and 90 were utilized, both of which are normally-closed but are intended to be opened by their corresponding trip projections 84 and 86 if the mast tends to overtravel in either direction.

It is noted that both of the switches 80 and 90 and the corresponding trip projections 84 and 86 are exterior to the support casing 36 and to the region between the upper and lower mast-guiding means, hence are in exposed positions with respect to the environment adjacent the furnace. In this environment, dirt and dust laden air can readily damage the limit switch contacts of switches 80 and 90, or can jam the limit switch arms of these two switches. Also, in this environment extremely high ambient temperatures can occur during operation of the furnace, and when the furnace is not operating, extremely cold temperatures occur; this can cause breakdown of insulation in the switches and on the wires connected thereto, can damage the limit switch contacts, and can shorten the effective useful life of the springs which restrain the switch arms. Furthermore, when the furnace is operating the extreme radiant heat from the electrode, refractories, molten metal and slag can also damage the limit switch contacts, the insulation and wiring and the springs in the switches; it can also damage or warp the trip projections so that they do not operate the switch arms in the desired mast positions. In the typical electric furnace environment, moisture from broken water lines and/or high atmospheric humidity are also often present, which can cause corrosion of the limit switch contacts and their internal linkages, and can damage wiring or insulation.

In addition to the above types of environmental effects, there are mechanical effects commonly present in such an electric furnace operation which make the usual limit switch arrangements unreliable. For example, the furnace and the supporting arm often vibrate severely, which can cause motion of the limit switch arm or trip projection away from the desired position required for proper operation. In addition, the internal elements of the limit switches can become damaged and disengaged, and wiring connections can also loosen.

Also, scrap falls or catches can occur in the system, in which event one or both of the limit switch arms may jam and become inoperative, or be pulled off or away from its corresponding trip projection. Due to this same cause, the trip projections themselves can be broken or bent away from their corresponding limit switch arms; the wiring can also be crushed, bent, broken or otherwise damaged due to this effect. Explosions from furnace charge can also break or bend the trip projections, or damage the wiring or limit switch arms.

If any of these effects occurs, one or both limit switches may fail to operate properly, with possible catastrophic results due to mast over-travel.

The invention overcomes this difficulty by providing a reliable back-up safety switch arrangement comprising, in the embodiment of FIG. 1, a normally open type of limit switch 100 supported on casing 36 and having an arm 102 positioned to ride along the adjacent surface of the mast as it moves, the mast surface on which it rides holding the switch contacts closed. Preferably the switch arm includes a roller 101 which rolls along the mast surface, to minimize wear. Also provided are an upper recess 104 and a lower recess 106 in the surface of the mast traversed by switch arm 102. Recess 104 is so positioned that if the mast should move slightly below the maximum downward position which it is intended to attain (as due to failure of the intended operation of the limit switch 80), the switch arm 102 will move to a position in which it is spring-urged into the depression 104, permitting its switch arm to turn sufficiently to open the contacts of switch 100. Similarly, if the mast should be raised slightly beyond the most upward desired position for which limit switch 90 is intended to be operated (due to failure of the latter arrangement), then the swtich arm 102 will be spring-urged into the recess 106, and causing switch 100 to open. Switch 100 is connected, as shown in FIG. 4, in series with the limit switches 80 and 90 and, as above noted, it is normally held closed by the mast surface. Thus, under normal operating conditions it will remain closed and current will be supplied over control lead 98 to maintain relay 96 closed and permit operation of the motor as determined by unit 94. However, should either of switches 80 or 90 fail and remain closed despite the fact that the mast has traveled beyond the desired extreme position, then the urging of the arm 102 of switch 100 into one of the two recesses 104 and 106 by its internal spring will open switch 100, cutting off control current over lead 98 and causing normally open relay 96 to open and immediately terminate current to the motor so that no further mast travel occurs. Switch 100 in this application therefor serves as a back-up to the usual external limit switches, which are subject to the failure conditions described briefly above.

It is noted that because the recesses 104 and 106 can readily pass throuh the upper and lower mast-guiding means without adversely affecting operation, the limit switch 100 can be placed between the upper and lower mast-guiding means in a position protected and shielded from the furnace and much of the adverse environment. Thus as shown it is mounted on the side of the mast away from the furnace, and within a relatively sheltered area beneath an overhanging portion of the support casing and at least partially protected from the sides by other elements of the casing. In this position it is provided with a substantial degree of protection from extreme radiant heat, ambient heat, falling scrap, molten metal or slag, etc.

It is also noted that the arrangement of switch 100 is "fail safe" in that it operates to stop the motor upon the occurrence of any of the normally encountered adverse mechanical conditions, such as breaking off or falling off of the limit switch arm, motion of the limit switch arm away from the surface which normally holds it closed, scrap metal lying on the limit switch arm, accidental grounding of the high potential contact of the limit switch, and so forth.

The back-up safety limit switch arrangement of the invention is easily installed on existing masts of electric furnaces, and is easily tested for proper operation after installation by simply loosening the limit switch arm or moving the limit switch away from mechanical contact with the mast to observe that this stops the motor, and replacing it so that the motor starts again. It will be understood that there are various combinations of recesses and switch arrangements which can be used to obtain similar effects. For example, the arrangement in FIG. 1 one can use two normally open limit switches spaced from each other appropriately along the mast surface, and one recess positioned so that the recess causes opening of one normally-open switch when the mast is at its upper extreme of travel and opens the other limit switch when the mast is at its lower extreme of travel.

FIGS. 5A through 5C and FIG. 6 show a variation of the arrangement of FIG. 1 in which the conventional upper and lower limit switches 80 and 90 are eliminated, as are the corresponding trip projections 84 and 86. Instead, the functions of the latter switches and trip projections are provided by additional recesses and additional normally open limit switches within the support casing. More particularly as shown especially clearly in FIG. 6, the surface of mast 32 is provided with a lowermost recess 110 aligned along the vertical direction with the swtich arm 112 of normally-open limit switch 114; 112 rides on the mast surface, so that when the mast is in its uppermost position, arm 112 will be urged into recess 110 and the motor arrested. The switch 114 and recess 110 therefore takes the place of switch 90 and trip projection 86. Also provided is an uppermost recess 120, laterally displaced with respect to recess 110 and in vertical alignment with the switch arm 122 of normally-open limit switch 124, the arm of which rides on the mast surface; when themast is in its intended lower-most position, switch arm 122 falls into recess 120, and the motor is again stopped. This arrangement therefore takes the place of the switch 80 and trip projection 84 in FIG. 1. In addition there is employed a third normally-open limit switch 128, the switch arm 126 of which rides on the mast surface, is aligned with upper and lower recesses 130 and 132 respectively, and is laterally displaced with respect to each of the other two switch arms 112 and 122. Switch 128 and recesses 130 and 132 are so positioned that if for any reason recess 110 should fail to arrest upward motion of the mast, then switch arm 126 will almost immediately fall into recess 132, stopping the motor; and if for any reason recess 122 should fail to arrest downward motion of the mast when desired, immediately thereafter switch arm 126 will fall into recess 130 and arrest the motor. It will be understood that allof the switches shown in FIG. 6 are connected in series with each other and with the control lead 98 analogously to the connection of the three switches shown in FIG. 4.

FIG. 5A illustrates the condition wherein the switch arm of the upper switch 124 has fallen into the uppermost recess 120 to arrest the mast substantially at its desired lower-most position.

It will be observed from FIG. 5A that should the mast move slightly farther downward, due to any failure of switch 124, then the middle switch arm 126 will fall into recess 130 to stop the motor, thereby providing an additional safety feature. In midpositions of travel, as shown in FIG. 5B, all three of the switch arms ride along the surface of the mast on their respective rollers. FIG. 5C illustrates the condition in which the mast has reached substantially its desired uppermost position, and the lower-most switch arm 112 has fallen into its corresponding recess 110 to terminate operation of the motor. FIG. 5C shows again that should switch 114 fail so that termination of motor operation does not occur as desired, then a slight additional elevation of the mast will cause the middle switch arm 126 to fall into recess 132, providing the desired back-up operation for arresting the mast.

Accordingly, while the invention has been described with particular reference to specific embodiments thereof in the interest of complete definiteness, it will be understood that it may be embodied in a variety of forms diverse from those specifically shown and described, without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. In apparatus comprising an electric furnace, an electrode for supplying current to said furnace, a mast supporting said electrode, means mounting said mast for reciprocatory motion adjacent said furnace to control the position of said electrode with respect to said furnace, said mounting means including upper and lower mast-guiding means fitting closely about said mast, and motor means for effecting said reciprocatory motion of said mast, the improvement comprising:

a normally-open type of switch means positioned between said upper and lower mast-guiding means to be held closed by a surface of said mast during execution by said mast of its desired maximum length of travel, said mast surface being configured to permit said switch means to open when said mast moves beyond said desired maximum length of travel in a predetermined direction; and

means for preventing said motor means from moving said mast further when said switch means opens.

2. The apparatus of claim 1, in which said switch means comprises a switch arm normally riding along said surface of said mast, and said mast is configured to define a recess in said surface into which said switch arm moves to open said switch means when said mast has executed its desired maximum length of travel in said direction.

3. The apparatus of claim 2, in which said mast is configured to define another recess in said surface into which said switch arm moves to open said switch means when said mast has executed its desired maximum length of travel in the opposite direction.

4. The apparatus of claim 1, in which said switch arm is on the opposite side of said mast from said furnace and at least partially shielded from above and from the sides.

5. The apparatus of claim 1, in which said motor means is an electric motor and said means for preventing said motor means from moving said mast further comprises means responsive to said opening of said switch to cut off current to said electric motor.

6. The apparatus of claim 1, comprising limit switch means external to the region between said upper and lower mast-guiding means, and trip-projection means also external to said region, said limit switch means being normally closed but opened by said trip-projection means when said mast approaches closely

the position corresponding to said desired maximum length of travel.

7. The apparatus of claim 6, in which said motor means is an electric motor, and said normally-closed type of switch means and said limit switch means are connected in series with each other to arrest said motor when either is open.

* * * * *