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Colinet

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[54] **ELECTROSLAG MELTING PROCESS**

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[52] **U.S. Cl.** **219/73,** 219/74, 219/137, 219/146

[51] **Int. Cl.** **B23k 9/18**

[58] **Field of Search** 219/73, 74, 126, 137, 145, 219/146; 164/52, 252; 13/18, 9

[56] **References Cited**

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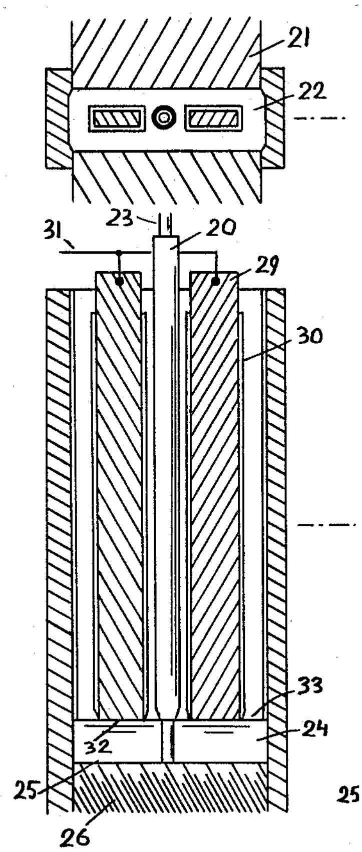
Primary Examiner—Bruce A. Reynolds

[57] **ABSTRACT**

Modified electroslag metal melting process for welding, refining, ingot making, where metal from bars or wires (thereafter called "bars") is added to molten pools by the method of dropping said bars into said pools by free or controlled gravity action, without any such bar conducting electric current, until said bar comes to rest temporarily on the solidified bottom of the lower metal pool. Heating of the upper slag pool, needed to melt such bar, is obtained from stationary fusible metallic electrode or electrodes connected at their tops to one or more sources of high intensity electric current, said electrodes being devoid of any function of guiding said dropping bar.

3 Claims, 5 Drawing Figures



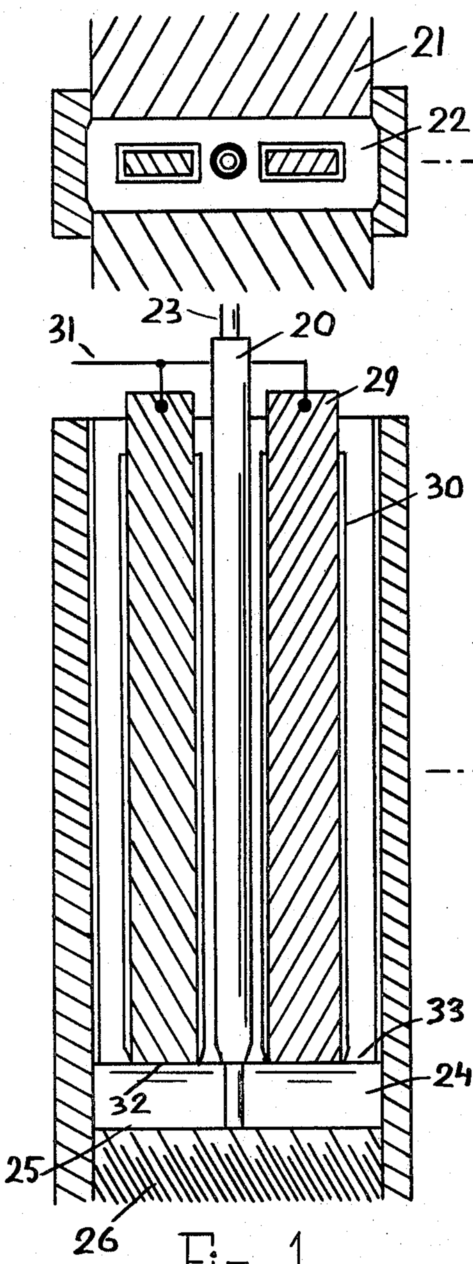

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Fig. 1

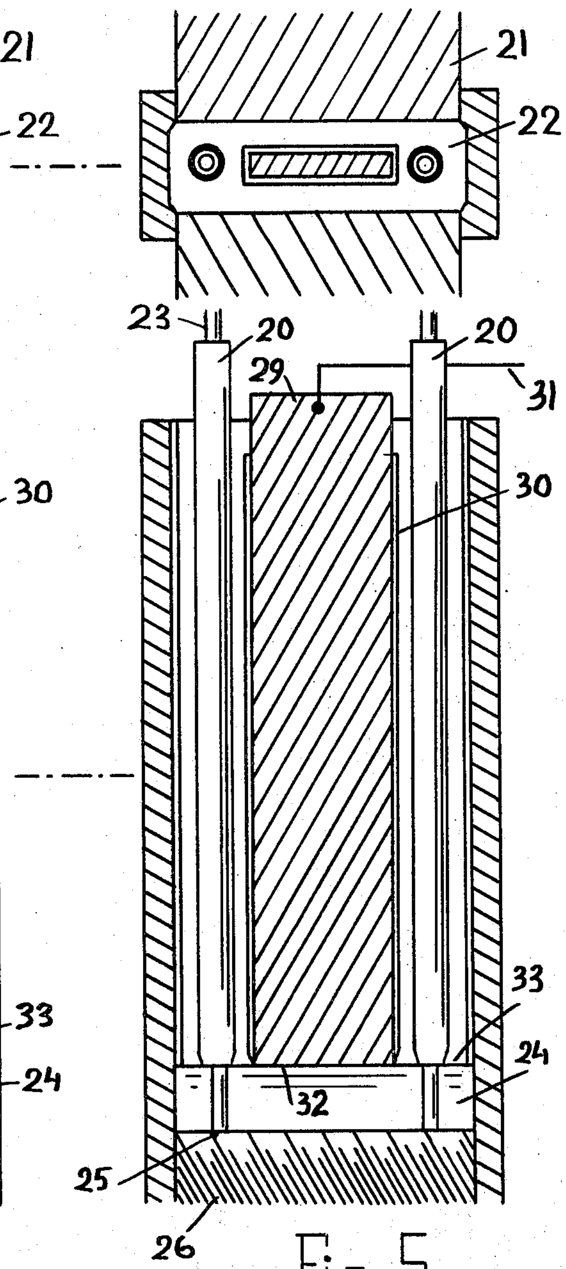
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Fig. 5

Fig. 4

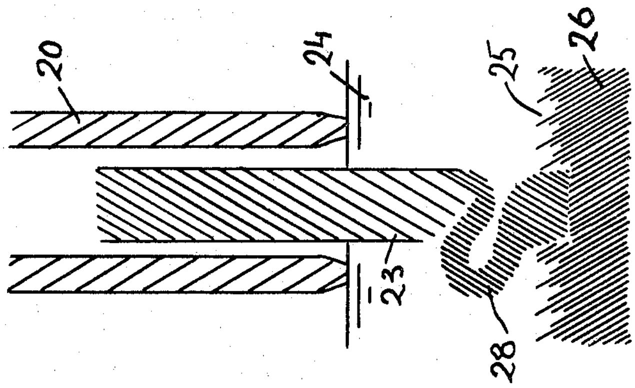


Fig. 3

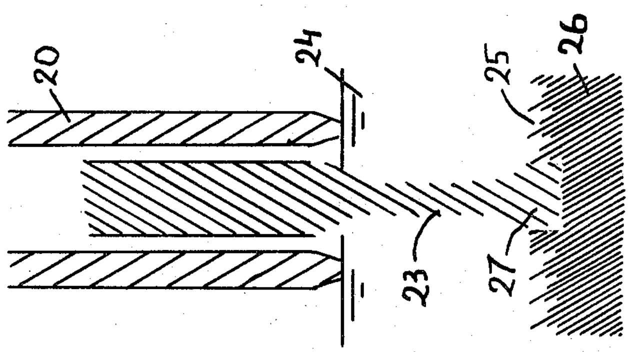
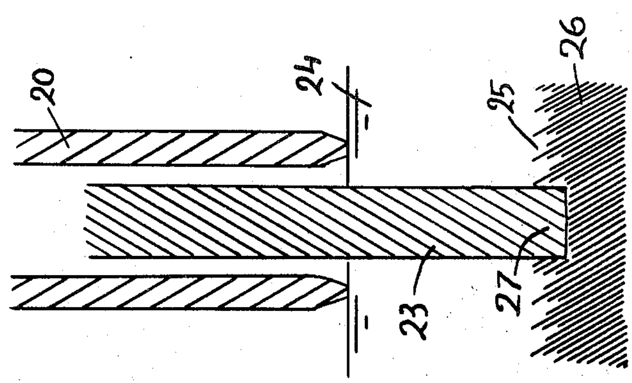


Fig. 2



ELECTROSLAG MELTING PROCESS

SUMMARY OF THE INVENTION

This invention relates to means to increase the productivity of conventional electroslag melting process, and also to reduce the cost of equipment and consumable materials therefor.

The standard electroslag metal welding or melting process as known in the art, a vertical joint comprising the steps of forming a vertical gap between spaced metallic plates, closing the space between said plates by placing cooling shoes on each side of said plates along said gap, feeding in electroslag flux to said gap, establishing a pool of molten metal by feeding current through at least one consumable electrode and said flux to initiate electroslag melting of the electrode and plates, and retaining the molten pool between said shoes while raising the pool along said gap to provide an electroslag weld between said plates, as described for instance in U.S. Pat. Nos. 3,344,839 and 3,511,303, generally using one or more electrodes consisting of metallic bars or wires, moved mechanically inside non-consumed copper tubular guides, to plunge steadily into a pool of molten slag which floats upon another pool of molten metal, which in turn is supported itself by the solidifying subjacent metal as it cools off gradually. Electric current conducted by said electrodes crosses the slag pool and heats it by electrical resistance (I^2R effect) to return toward the current source by the parts being welded or by a copper mold, to close the electric circuit.

This continuous supply of heat by the electrodes is made possible by the constant penetrating motion of said electrodes into the slag pool, with transfer of said current from the electrode to the pool through solid-to-liquid contact. The penetration of the wire in the slag must be short of reaching the subjacent metal pool, to avoid short-circuiting the electrode. Conversely, said penetration must not be so short as to permit insufficient or no contact between electrode and slag, resulting in striking an electric arc unwanted in the electroslag process.

In a known variation of the standard electroslag process (U.S. Pat. No. 3,558,845) the wire-electrode is fed through and guided by a consumable fusible stationary tube attached at its top to a fixed support, said tube hanging loosely in the vertical gap between the two plates being butt-welded. Even though this tube does not move down, its lower end is gradually melted away by the rise of the slag and metal pools, said pools being contained laterally by the plates and by water-cooled copper shoes. Their rise results from the steady addition of new metal to the pools, mainly from the electrode itself and also from the lower end of the wire-guide reached by the rising slag pool.

Such a consumable wire-guide can be merely tubular, or it can be provided with lateral metallic wings filling the gap between the plates. The wings increase the cross section of the guide, therefore also the contact between guide and slag to distribute and enlarge the melting rate across the width of the plates. Wire-guides with or without wings are usually protected against any lateral contact with the plates and the resultant short-circuit, either by a non-conductive but fusible coating, or by insulating rings set at regular intervals along the guide. The coating or the rings provide also, through

progressive melting, a small and steady addition of slag-producing flux materials which compensates for a constant loss of slag adhering to the copper shoe/weld interface.

The standard electroslag process, first conceived for vertical welding between plates, and later adapted for ingot making, recently received application for metal refining as well, through progressive fusion and appropriate slag purification of the electrode metal. In the ingot and refining applications, both pools are usually contained in stationary sleeve-type copper molds, with the liquid levels of the slag and metal remaining substantially unchanged through the entire operation.

It is obvious that the wire-guides just described remain applicable to such types of stationary molds through which the ingot moves gradually downward under mechanical controls. But then it becomes necessary to move the wire-guides slowly down, at much lesser speed than the electrode wires. In other words, the relative positions of the pools, electrode wires and wire-guides must remain unchanged, while the entire installation receives a whole displacement which is absent in the welding of plates.

It is clear that the rising speed of a welding pool depends on the rate of addition of new metal from the electrode with or without the contribution of slow-melting wire-guides, and it would appear at first glance advantageous to increase the current intensity as much as possible in order to speed up the welding operation. Unfortunately, there are two serious limitations.

1. the electrode must remain stiff and straight when entering into the slag pool. This imposes a limitation to the current density in the free portion of the wire between the non-consumable guide and the pool.

2. the wire must not possess an excessive speed of descent through the slag, such that the wire would reach the molten metal and cause a short-circuit. The heating of the slag pool would then be drastically reduced.

Both limitations in current and wire speed render any increase of welding speed difficult.

One purpose of the present invention is to suppress said limitations with the further desirable elimination of any wire-pushing device. Both results are obtained merely by giving no electrical function at all to the moving wire, but to retain its function of providing the necessary continued metal addition to the pools. The heating of the slag pool is now obtained entirely from electric current conducted by independent and stationary electrodes firmly held at their tops by fixed supports in the manner mentioned hereabove for consumable wire-guides.

Another purpose of the invention is to provide a large increase in the current intensity, hence in the melting speed of added metal, and such increases are made possible by the greater cross-section which can be given to the stationary electrodes and by their extended contact with the slag pool.

Another purpose of the invention is to eliminate any sliding electrical contact between the cables feeding current to the electrodes, always a difficult wear and maintenance problem for large currents. Instead, the fixed electrodes can be secured rigidly to the fixed cables by high-pressure bolts and nuts since the connection is itself stationary in all its parts.

Another purpose of the invention is the possibility of reducing the number of electrode-wires needed for thick plates, such as 4 to 10 inches and more, to be welded in a single pass by the electroslag process. Cold zones must be avoided close to the copper shoes, while excessive penetration at mid-thickness may result from overheating the slag in the center region. A smaller number of wide stationary electrodes can solve the distribution problem without any motorized wire-pushers. The addition of new metal is obtained by dropping under their own weight non-electrified bars anywhere in the pools, between the electrodes.

The means to obtain such new advantages and speedier welding operation, as per the invention, will be better understood by examining the illustrations and their explanations hereafter. They are given as non-limitative examples of various forms of execution of the process of this application.

FIG. 1 shows in plan view and in vertical cross-section the arrangement of a central dropping bar in its stationary guide, set between two stationary electrified heating electrodes.

FIG. 2 is a vertical cross-section in the bar of FIG. 1, after it has fallen through both slag and metal pools to rest on the solid bottom of the latter.

FIG. 3 shows the reduction by superficial fusion of the bar of FIG. 2 by exposure and contact with the slag.

FIG. 4 shows the crashing by buckling of the weakened portion of the bar of FIG. 3, resulting in a new fall into the slag and the melting of a new cool portion.

FIG. 5 is a variation of FIG. 1 in which penetration of the weld at mid-thickness of the plate can be increased if so desired.

In the form of execution of FIG. 1, which is preferred for thick plates, the arrangement comprises:

1. one or several consumable and stationary bar guides **20** having no external insulation whatever and suspended at their tops by the plates being welded **21**, hanging freely in the gap **22** between said plates **21**. Contrary to the usual practice, said guides **20** have no electrical connections. Their purpose is merely to prevent the falling bars **23** (see below) which are guided by said tubes **20**, from entering into the slag pool too close to the soft walls of said pools where they might stick and block further descent.

2. the same number of solid bars **23** falling freely through the guides **20** and being preferably straight and several meters long. The bars **23** pass through the slag pool **24** and reach without excessive impact speed the solid bottom **25** of the metal pool **26**. Said bars **23** have no electrical connections either. Their bottom ends **27** (FIG. 2 and FIG. 3) melt by contact with superheated liquid slag and metal, with a pulsating rhythm, as follows:

a. a rapid fall of the cold portion of the bar **23** (FIG. 2) without appreciable melting of said bar.
b. the stop of said fall permitting a fast superficial melting of said immersed portion **27** of the bar **23**, reducing its compression strength (FIG. 3).
c. the remaining unmelted core of this immersed portion **27** of bar **23** suddenly buckles and crashed on the bottom **25** of the metal pool **26**, where it completes melting, while a new cold portion **27** begins to weaken in the pools.

The cycle a) b) c) repeats itself in regular sequence of time without needing any assistance or control from mechanical devices, the rhythm being solely governed by heat action in the same way a car blinking light operates.

The introduction of a new metal-adding bar **23** is done manually as soon as the top end of the previous bar has gone out of sight into guide **20**. It would be easy to provide an alarm system signaling the operator to add a new bar, but even if he should fail to do so, no welding interruption would result for a long time, since the current has not been interrupted or reduced by his failure to act. In conventional electroslag welding, any stoppage in feeding the wire also cuts the heating current off immediately, with the pools cooling rapidly.

The bars **23** as per the invention are preferably low carbon steel straight bars, hot rolled type with their scale still present. The bar size should be about one-fourth inch to 1 inch or more, with a normal length of 6 to 10 ft, for example. The bar-guide **20** should have an inner passage at least 25 percent larger than the bar diameter, but no more than 50 percent to avoid jamming two successive bars by mutual overlapping inside the guide **20**.

3. heavy, thick and broad metal bars or strips **29**, hereafter called "electrodes" are held stationary at their tops in the same manner as the bar-guides **20**, and they are provided with individual coatings **30** made of non-conductive slag-forming bound powdery materials, of the same composition as required in conventional electroslag welding to supply a molten slag of properly reduced resistivity needed to generate high heat from the traversing current (high I^2R factor).

The electrodes **29** are connected at their tops by permanent bolting or clamping to lugs of electric cables bringing high amperage current from the power sources. Said electrodes **29** hang freely in the gap between the plates **21** and they transfer their cureent to the slag pool **24** by shallow penetration of their lower ends **32** into the liquid slag or, occasionally, by a flashing arc striking between the electrode **29** and the slag pool **24**, but in both cases the contact is soon re-established by the continuous rise of the slag **24**. Said contact **32** tends to jump from one location to another along the lower edge of the electrode **29**, often running back and forth along its entire width, thereby providing uniform heat to the full thickness of the plates **21** being welded.

There is therefore, in the present invention, a complete separation of functions which are combined in conventional electroslag processes:

a. The electric energy is carried only by fusible consumable stationary electrodes.
b. The new metal is added nearly entirely first by the melting of falling bars and second by the progressive fusion of the bar-guides. Neither of them is insulated, descaled or electrified.

In a variation of the form of execution shown in FIG. 1, a possibly excessive rate of melting of the falling bar **23** could easily be controlled and reduced by a clock mechanism or other known governor connected to feed rolls on the bar at the top. Or else, conventional wire-feeders might operate as retainer instead of as pushers.

Other variations of FIG. 1 are possible, for instance as shown in FIG. 5 which comprises a central electrode **29** and two lateral falling bars **23**. This arrangement might be desirable in special cases where heavy central weld penetration would be called for.

Another variation, for very thick plates, might be the use of three electrodes and of two falling bars between them, or even a larger number of electrodes and bars might be preferred, when required. The process of the invention offers an additional economic advantage: the electrodes can be made of solid bars of commercial cross-section as received, and this is the cheapest form of steel available in the trade. Likewise, the bar guides could be made of plain water or gas pipe with the usual scale and rust inside and outside left untouched. They could not be used in conventional electroslag welding for lack of good contact with the wire as it emerges at the bottom.

Other advantages will no doubt come to light by repeated use of the process of the invention, although they are not mentioned here, but they will fall under the scope of this invention if their arrangement is covered by the claims. The same applies for other forms of execution not explicitly described in this application

Having thus described my invention, what I claim as novel and desire to secure by Letter Patent is:

1. In a process of electroslag welding a vertical joint comprising the steps of forming a vertical gap between spaced metallic plates, closing the space between said plates by placing cooling shoes on each side of said plates along said gap, feeding in electroslag flux to said gap, establishing a pool of molten metal by feeding current through at least one consumable electrode and said flux to initiate electroslag melting of the electrode and plates, and retaining the molten pool between said shoes while raising the pool along said gap to provide an electroslag weld between said plates, the improvement comprising, forming said at least one electrode as a stationary electrode, inserting at least one tubular guide into the space between the plates along the length of the gap, which guide is melted by the rising molten pool, feeding at least one metallic bar through said tubular guide such that the bar falls solely by its own weight through said guide to contact the bottom of the molten pool and continues to fall through said guide by repeated dropping and melting in the molten pool, and electrically insulating said tubular guide and bar such that no electrical current is conducted to the pool through the unmelted portion of said guide or bar.

2. The process of claim **1** wherein the step of electrically insulating the guide and bar comprises providing said at least one consumable electrode with an electrically insulating coating to prevent shorting between the electrode and guide.

3. The process of claim **1** wherein said at least one electrode comprises plural electrodes positioned along said gap with at least one adjacent each said shoe, and positioning said tubular guide between said plural electrodes in said gap.

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