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Alberny et al.

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[54] **METHOD FOR THE COOLING OF A CONTINUOUSLY CAST PRODUCT**

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[52] **U.S. Cl.** .... **164/89,** 164/283 S

[51] **Int. Cl.** **B22d 11/12**

[58] **Field of Search** .... 164/89, 283 R, 283 M

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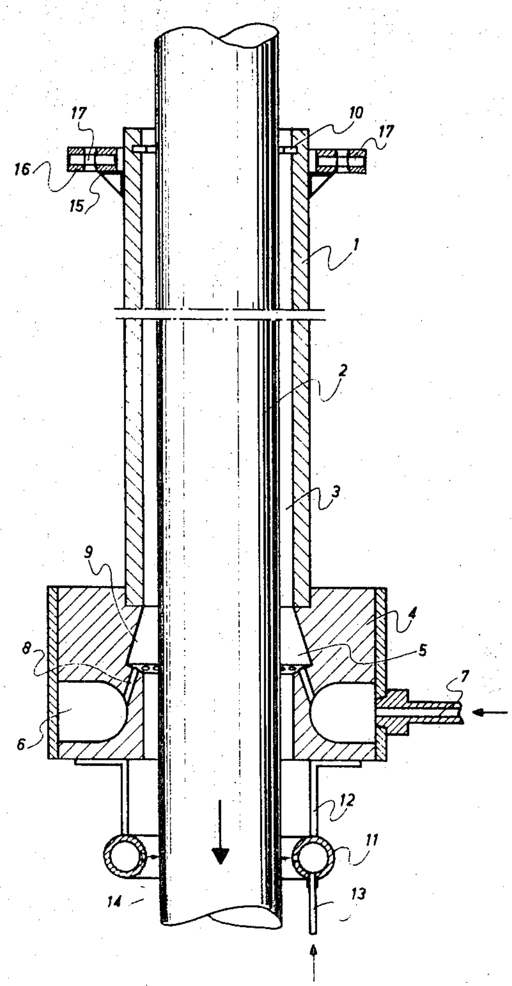
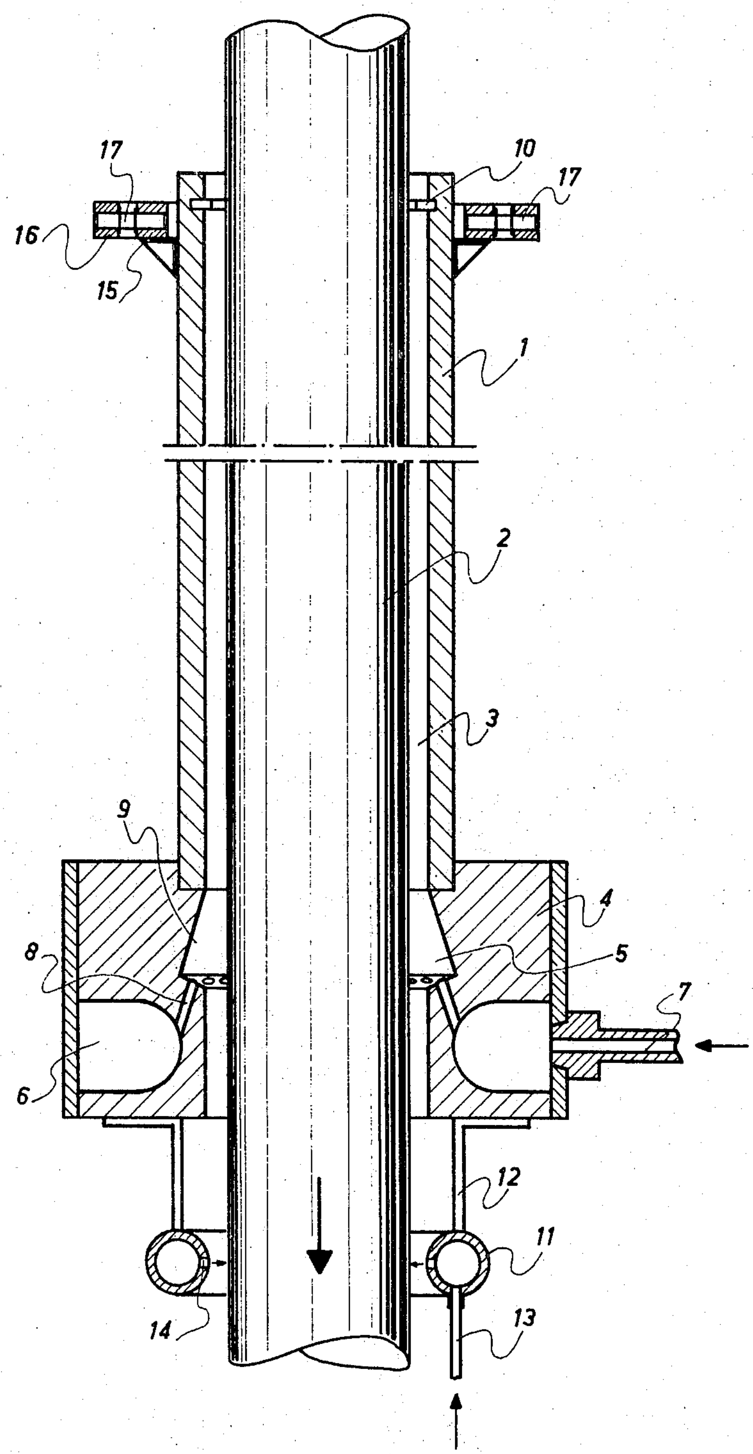
Primary Examiner—R. Spencer Annear

[57] **ABSTRACT**

A method and apparatus for cooling a product emerging from a mold, in which a coolant is directed upwardly through a casing surrounding the product as the product moves downwardly through the casing from the mold. The casing has an internal cross section similar in shape to but larger than the cross section of the product.

3 Claims, 1 Drawing Figure

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METHOD FOR THE COOLING OF A CONTINUOUSLY CAST PRODUCT

The present invention relates to a method and apparatus for directly cooling a product emerging from a mold for the continuous casting of molten metals, and especially metals having a high melting point such as steel.

The procedure for cooling an ingot-forming mass in a continuous casting process is generally performed in two successive steps. During the first step, or the primary cooling step, the metal is maintained in a continuous flow inside a chilled open-ended mold, the inner walls of said mold being cooled by means of a cooling medium such as water. During the primary cooling step, the removal of heat from the product occurs through conduction by direct contact of the product with the inner mold walls. As the ingot-forming mass is displaced downwardly, a solid outer surface is formed which tends to shrink away from the mold walls, thus impeding the transfer of heat from the product to said walls.

In order to increase the output of a continuous casting plant, the ingot forming mass must be preferably subjected to a rapid cooling action as it emerges from the mold, said rapid cooling allowing for an increase of the casting rate. The ingot-forming mass is therefore usually subjected to a second cooling operation, or secondary cooling, consisting of a direct action of a cooling medium such as water on the ingot surface.

It has already been proposed to perform the operation of secondary cooling by means of water sprays directed at the product. Since the surface temperature of the product is very high, a barrier of steam builds up at the surface of the product, said barrier greatly impeding the cooling effect of the water sprays. It is moreover difficult by this technique to insure evenness of the cooling effect at each point of the product surface.

French Pat. No. 903,950 describes a means for cooling a product in which the product is cooled by directly contacting said product by a flow of coolant at atmospheric pressure moving upwardly around the product. This patent does not disclose the provision of any means for preventing the possible lack of contact between the cooling medium and the product resulting in the minimizing of the cooling action of the cooling medium.

French Pat. No. 1,280,293 describes a method including the step of cooling a product by establishing a jacket of cooling medium continuously flowing downwardly, said cooling medium being laterally confined in a hollow open ended casing surrounding the product. The casing bears a plurality of apertures oriented in the direction of displacement of the flow substantially along its entire length for supplying water to the gap between the casing and the product surface. This method of cooling provides for circulating a sheet of water in rapidly flowing state at the surface of the product and has the benefit of the high value of the heat transfer coefficient thus obtained between the product and the water. The speed imparted to the water sheet theoretically permits flushing away of the steam which is likely to form by local vaporization of the water contacting the product surface. It is however difficult to insure homogeneity in a downwardly circulating sheet of water freely escaping at the atmosphere. Consequently, this method does not prevent the undesirable reduction in contact between the liquid cooling medium and the product surface.

The object of the present invention is to obviate or mitigate the above-mentioned difficulties particularly with regard to the maintaining of contact of a circulating sheet of water with a product surface at high temperature to allow for a rapid and even cooling of an ingot-forming mass being cast in a vertically operating continuous casting apparatus.

To this end, the invention provides a method for cooling a moving product at the emergence of said product from a vertical continuous casting mold through direct action of a continuously moving sheet of a cooling medium displaced at high speed at the surface of the product in a direction parallel to the direction of displacement of the product. The cooling medium is laterally confined in an annular space surrounding the product and the cooling medium is continuously admitted in the lowest region of the annular space and is displaced upwardly in said annular space.

The invention also provides an apparatus for the performance of the method, said apparatus comprising a hollow vertical casing having an inner cross sectional area which is similar to the cross sectional area of the cast product and larger than said cross sectional area of said product. The casing extends substantially coaxially with the product; and a supply head is arranged in fixed coaxial relationship with the lowest extremity of the casing. The supply head has an annular chamber connected to a source of a liquid medium under pressure and comprises a plurality of upwardly oriented apertures for communicating said chamber with an axial opening of the supply head of substantially the same cross sectional area as the inner cross sectional area of the casing. The apertures are oriented to conduct the cooling medium to said axial opening along an upwardly directed path which forms an angle at least equal to 135° with the vertical direction.

An apparatus according to the present invention may further comprise centering means consisting of a set of sprays of a fluid medium showering from a centering device attached to the supply head, said fluid sprays being directed at the product substantially perpendicularly to the outer surface of said product.

The apparatus according to the present invention may further comprise loss of head means located near the upper end of the casing, said means being adapted to generate a loss of head in the cooling medium flow escaping through said upper end.

According to the method of the invention, the direct cooling of a vertically cast ingot-forming mass is achieved by contacting the surface of said product with a homogeneous flow of a cooling medium displacing upwardly at high speed in a confined space surrounding the product. The speed value for the cooling medium may be determined through a calculation well known in the art, said speed value being such that ebullition of the cooling medium under such conditions as to give rise to calefaction is prevented at every point of the upwardly displacing flow. The minimum value of the speed of the cooling medium for given conditions of casting depends from the initial feed temperature of the cooling medium, the geometry of the apparatus, particularly the actual length of the casing surrounding the product, and the degree of solidification of the product at the beginning of the procedure of direct cooling.

The use of an ascending direction of displacement of the cooling medium according to the method greatly fosters the maintenance of a homogeneous flow inside the casing by preventing local discontinuance of contact between the cooling medium and the surface of the product, and further allows for a rapid suppression of the harmful consequences, as regards the efficiency and evenness of cooling, and of the occurrence of local calefaction likely to result from possible momentary changes in the conditions of casting or from any other variation in the cooling procedure.

Further features and advantages will appear from the following description, given by way of example only and with reference to the single attached drawing which represents a cross-sectional view of an apparatus according to the present invention for the so-called secondary cooling of a cylindrical billet of circular shape in the course of being formed in a vertical continuous casting machine.

The FIGURE is a section view of the device.

Referring now to the FIGURE, an apparatus according to the invention comprises a tubular open-ended casing **1** coaxially arranged around a billet **2** over a given vertical length, an annular space **3** being formed between said tubular casing and the surface of the billet. The billet extends inside and below a suitable vertical continuous casting mold (not shown) of conventional design. The vertical distance between the upper end of the tubular casing **1** and the lower end of the mold may vary according to specific embodiments provided there remains substantial clearance between the casing extremity and the mold. The tubular casing **1** may be arranged, for example, below the contact rolls generally provided below the mold in the technique of continuous casting. It should however be understood that the casing **1** is arranged in a region where the billet-forming mass still has an internal molten portion, or in other words, that the casing **1** extends vertically in the so-called secondary cooling zone.

During the process of casting, the billet is axially subjected to a continuous downward displacement and may also be subjected to rotation around its own axis.

A supply head **4** is attached to the lower end of the tubular casing **1.** The supply head is provided with a central axial circular opening **5** forming a passage of substantially the same shape and dimension as the tubular casing. The supply head comprises an annular chamber **6** adapted to communicate with a source of water under pressure through a flexible inlet tube **7.** The chamber **6** further communicates with the axial opening **5** through a plurality of regularly angularly spaced apertures **8,** the apertures being directed upwardly from the chamber **6** so as to form a 165° angle with the vertical direction. The opening **5** of the supply head may have a conical recess **9** arranged in the outlet region of apertures **8,** the generatrix of said conical recess being substantially parallel to the axis of the apertures. The upper end of the tubular casing **1** may open freely to the outside or may preferably be associated with the loss of head means consisting of a ring **10** coaxially arranged with the casing near the upper extremity of said casing. The upper end of the casing is centered coaxially with the billet and is suitably attached to a supporting structure not shown. An advantageous embodiment for supporting and centering the casing comprises means for coupling the upper end of said casing to the supporting structure in such a fashion that the casing and the supply head attached thereto may freely swing relatively to a vertical direction, for example, by hanging said casing to a so-called universal joint of conventional design comprising an inner ring **15** attached to the upper end of casing **1** and adapted to rotate around two horizontal spindles **17** having a common axis. The spindles **17** journal in an outer ring **16,** said outer ring being rotatably connected to the supporting structure by means of two spindles (not shown) having a common horizontal axis lying at 90° of the axis of the spindles **17.** Self-acting centering means may be advantageously attached to the supply head. The self-acting centering means comprises a hollow annular member **11** the inner diameter of which is slightly greater than the diameter of the billet. The annular member **11** is arranged underneath said supply head and is attached thereto by means of flanges **12.** The hollow annular member **11** communicates with a source of a fluid medium under pressure through flexible tube **13** and is provided with a plurality of regularly angularly spaced apertures **14.** The axes of said apertures are oriented perpendicularly to the axis of the annular member **11,** said apertures being adapted to direct the fluid medium at the surface of the billet. The fluid medium may be a liquid medium such as water, or a gas such as air.

The process of the present invention is carried out as described hereinbelow.

A cooling medium such as water is introduced under pressure to the chamber **6** of the supply head, said cooling medium entering the passage **5** through oriented apertures **8.** The cooling medium flow separates into two streams at the outlet of said apertures, the general direction of the first stream corresponding to a vertical upwardly oriented flow. The cooling medium enters the annular space **3,** the directional change imparted to said first stream at the outlet of apertures **8** being progressive and thus inducing in the corresponding flow, a substantially small loss of head. The general direction of the second stream corresponds to a vertical downwardly oriented flow, the directional change imparted to said second stream at the outlet of apertures **8** is abrupt and thus induces a substantially large loss of head in the corresponding flow.

The distribution of the total flow conveyed through apertures **8** of the supply head between the two previously mentioned streams depends, for a given orientation of apertures **8,** on the amount of kinetic energy imparted to the cooling medium. The kinetic energy depends on the value of the total flow and the design of the apertures. These parameters are obviously so determined in relation to the actual length of the casing as to allow for the building up of an ascending stream of water rising at least up to the upper extremity of the casing and further flowing at the outside of said casing through said extremity, the actual operation of cooling of the billet being accomplished by said ascending stream of water. The minimum total flow entering the chamber **6** of the supply head and corresponding to the requirement set forth can be readily determined through calculation or experimentation for each specific case. Although said requirement should be stressed as essential to the carrying out of the process, the corresponding minimum total flow value need not be critical since the actual minimum value is imposed by heat transfer requirements to be met between the product to be cooled and the cooling medium, as will be further developed hereinbelow.

One may evaluate the efficiency of the operation of secondary cooling for a given product in the course of being cast in a continuous casting machine by determining the depth of the downwardly decreasing internal molten portion or liquid pool of metal maintained inside the product. It is already known that said depth may be substantially diminished, and therefore the cooling effect accelerated through cooling the product by means of a sheet of a cooling medium displacing at high speed at the surface of said product, the heat transfer coefficient between the product and the cooling medium actually increasing with the speed imparted to the cooling medium. The minimum value of said speed may be evaluated through calculation for a given product in order to meet the requirement according to which the surface temperature of said product should be permanently maintained during the cooling action of the sheet of cooling medium at a value which is kept below the temperature value which causes ebullition of the cooling medium flowing along said surface under such conditions that the ebullition gives rise to calefaction, said calefaction resulting in the localized drying up of the product surface. The principles of this calculation may be found in the book of W. H. McAdams "Heat Transmission," McGraw Hill Publishing Company Ltd., New York. The corresponding minimum total flow for the cooling medium is derived from said minimum speed value for a given geometrical configuration of the apparatus.

In order to meet the conditions of the heat transfer hereinabove mentioned, it is required that the flow of the cooling medium should remain homogeneous at least in a region adjacent to the surface of the product to be cooled, or in other words, and this defines what is meant herein by the expression "homogeneous flow," that the surface of the product is permanently kept in contact with a continuous sheet of a cooling medium moving at said surface. The lack of contact or if there is no contact, would actually cause a disturbance of the cooling action which would likely result in at least local calefaction in the flow and further disturbance of said cooling action. The use of an ascending direction of displacement of the flow of the cooling medium inside the casing, according to the process of the invention, substantially insures the maintenance of permanent contact between the cooling medium and the surface of the product in the confined region delimited by the casing, since downwardly acting gravity forces developing in the flow inside said confined region in opposite direction to the direction of the speed of the cooling medium substantially foster the maintenance of said contact because the static pressure at each point of said confined region is permanently maintained at a greater value than the value of the atmospheric pressure.

The loss of head created by ring **10** in the upper region of the casing and corresponding to a throttling of the flow in said region allows for an amelioration of the homogeneousness in the flow particularly in said upper region. The provision of said loss of head creating means forms an advantageous embodiment of the apparatus although this provision is in no way necessary for the performance of the process according to the present invention.

The downwardly flowing liquid stream represents but a small percentage of the value of the total flow entering chamber **6** for the high value taken by said total flow for meeting the cooling requirements. The downwardly flowing stream corresponds to a highly heterogeneous flow of liquid because of the abrupt directional change imparted to said stream at the outlet of the apertures of the supply head and the presence of gravity forces acting in the same direction as the stream direction to lower the actual static pressure in said stream. The downwardly flowing stream tends to oppose the entry of air in the region located between the surface of the product and the supply head.

At the occurrence of local calefaction resulting from temporary variation of one of the factors from which depends the heat transfer procedure between the product and the cooling medium, the steam which may form is upwardly flushed away through the combined action of the speed of the upwardly flowing stream and the lifting power resulting from the difference in density; consequently, said steam does not disturb the homogeneousness of the ascending stream of liquid for any extent of time. The same applies in case of air which may enter the casing from below through the annular opening between the supply head and the product.

The actual thickness of the sheet of water provided in the space **3** is determined as a compromise. Too small a clearance between the product surface and the casing may be prejudicial to the cooling action, because scale may loosen from the product surface and block the gap between said surface and the casing, and limited displacement of the product relative to the casing may locally hinder the passage of the cooling medium. On the other hand the clearance should be small enough that the total flow output remains reasonably small. Said thickness value is preferably chosen between **3** and **10** mm depending on the type of product being cast.

The centering means comprising member **11** is adapted to prevent the supply head from contacting the product surface in the event of the displacing of the product during the passage of said product inside the apparatus, the position of the product at the entrance of said apparatus being itself determined by the contact rolls generally provided below the mold along the path of said product. The fluid sprays forced through apertures **14** of member **11** permit a limited lateral displacement of the product for correctively displacing member **11** and the supply head and casing attached thereto. The displacement results from the changes in reaction of said sprays upon said member. The centering of the apparatus relatively to the product is thus permanently and automatically obtained.

Experiments which have been conducted on the process have shown that the efficiency of the operation of cooling a product, according to the method, was surprising to such an extent that it has been at times necessary to mitigate the corresponding cooling action, for example, through judiciously selecting the length of the casing and the emplacement of the casing relative to the mold, said emplacement determining the actual lateral extent of the liquid pool at the beginning of said cooling action, in order to prevent, for a given product and a given rate of casting, such an efficiency in the cooling process that it may be harmful to the product. As far it has been known, such a result has not been controllably obtained thus far by known methods for the so-called secondary cooling of an ingot-forming mass of a metal having a high melting point such as steel in the course of being cast in a continuous casting machine.

An example of the operation of an apparatus for the carrying out of the method will now be given, said example pertaining to the cooling of a billet of **120** mm diameter at the emergence of a vertically arranged continuous casting mold of conventional design. The cooling apparatus comprised a 1.40 m length casing with an inner diameter of 130 mm and the attached supply head was provided with 108 apertures each of a diameter of 2.8 mm, the axis of said apertures being upwardly oriented at 170°. The emplacement of the upper end of the casing was located 2.7 m below the lower extremity of the mold, the average diameter of the liquid pool at the level of said upper end of the casing being 70 mm, the billet having been subjected to conventional cooling by means of sprays at the immediate emergence of the mold. The minimum value of the total flow supposed to enter the supply head and corresponding to a zero speed in the casing, or in other words, the minimum value of the total flow for which an ascending stream of water forms in said casing was 14 m^3/h. The temperature of casting of the metal was 1,540° ± 5°C and the cast metal was a carbon steel with 0.18° C, the casting rate being 2.3 m/mn. For these values, the heat flux to be extracted by the cooling medium with an imposed value of the temperature of the product surface of 100°C was computed to be 630 W/CM^2 at the level of the upper end of the casing, e.g., at the beginning of the cooling process, the heat flux to be extracted at the level of the apertures of the supply head being 200 W/CM^2, the evolution of the extracted heat flux between these two values rapidly decreasing to 310 W/CM^2 from said level of the upper end of the casing to a level located 20 cm below said upper end level and further progressively decreasing to the 200 W/CM^2 value.

These flux values allow for a trial and error calculation of the speed to be imparted to the sheet of water and taking into account the relationship between the heat transfer coefficient between the cooling medium and the product and the speed imparted to the cooling medium, with the requirement of preventing the building up of calefaction during the cooling action. This requirement was found to be met at the upper end of the casing, where the cooling action is most critical, for a speed value of 3.5 m/sec., corresponding to a flow of the ascending stream of 25 m^3/h. The value of the total flow input to the supply head corresponding to said value of the upwardly displaced flow was computed to be 32 m^3/h for the geometrical configuration of the apparatus set forth. The actual flow imput was therefore set at 32 m^3/h.

The actual depth of the liquid pool for a conventional procedure of cooling by means of water sprays acting on the product surface for substantially the whole length of said product was 8 m. The actual depth of the liquid pool with the use of the apparatus hereinbefore and with a total flow input of 32 m^3/h was observed to be set around 4 m, which means that the product was completely solidified at the emergence of the apparatus. Although this complete solidication need not be a result to aimi at for all specific applications, this experimental result provides evidence that the efficiency of the method is surprisingly high.

The carrying out of the process according to the present invention therefore allows for substantially increasing the rate of casting of a product being formed in a continuous casting machine provided in the secondary cooling zone with an apparatus of the art described, since the depth of the liquid pool is related to said rate of casting. The output of the casting machine may thus be substantially increased while insuring evenness of the cooling action over the product.

We claim:

1. A method for cooling an ingot-forming mass as it emerges downwardly from a vertical continuous casting mold, comprising establishing a confined region surrounding said ingot-forming mass as it emerges from said mold, continuously admitting a liquid cooling medium in the lower region of said confined region to establish a jacket of said cooling medium contacting the surface of said ingot-forming mass, displacing said cooling medium upwardly in said confined region with a velocity whereby calefaction of said liquid cooling medium is prevented in said confined region, and discharging said liquid cooling medium to the outside from the upper end of said confined region.

2. The method of claim **1** further comprising directing a fluid at said mass at a plurality of regularly angularly spaced points below said confined region for centering said mass within said confined region.

3. The method of claim **1** wherein said step of upwardly displacing said liquid cooling medium comprises directing said liquid cooling medium into said confined region at an angle of at least 135° with respect to the downward vertical movement of said mass.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,820,584 Dated June 28, 1974

Inventor(s) Robert Alberney, et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The name of the Assignee should read:

INSTITUT de RECHERCHES de la SIDERURGIE FRANCAISE

Column 8, Line 15: "aimi" should be --aim--

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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