

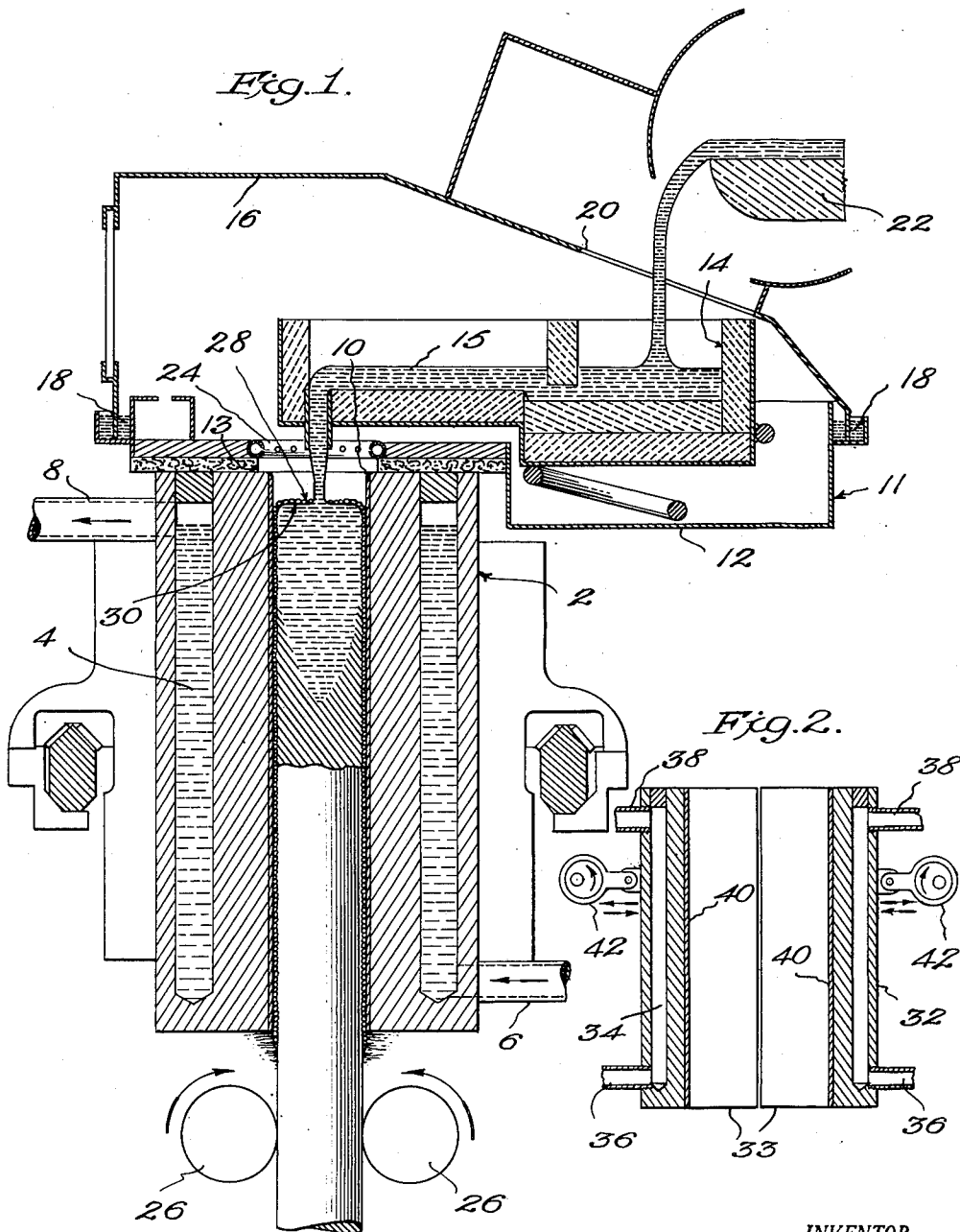
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N. S. SPENCE

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METHOD OF CASTING METAL

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METHOD OF CASTING METALS

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14 Claims. (Cl. 22—200.1)

The present invention relates to a method of casting metals and more particularly to a method of autogenously forming a mold dressing or lubricating layer between the mold walls and the metal being cast and solidified in a mold by the continuous casting process.

In all continuous casting processes using a mold chamber to shape and congeal molten metal there exists a certain amount of frictional resistance between the walls of the mold chamber and the congealing metal form which is being both solidified and withdrawn at one and the same time. This frictional resistance may be due to a variety of causes, all of which are fundamentally the same, in that there is a common bond at one, several, or all points where contact between the solidified casting and the mold chamber exists. This bonding will inevitably result in rupturing of the surface, which may or may not interfere with the production of a commercially acceptable surface on the solidified casting, depending upon whether the ruptures become healed or not. In any case such rupturing is a most undesirable condition and it must be prevented for satisfactory, truly continuous casting results.

A major step in the reduction of the frictional resistance between the walls of the mold chamber and the congealing metal form has been achieved through the use of a split mold whose sections are vibrated transversely to the direction of movement of the congealing metal form through the mold. In this vibrating mold the walls of the mold chamber are in contact with the congealing casting only a very small percentage of the time, viz., at the time when the mold sections are in the position of minimum cross section for each complete vibration cycle. In order to operate such a mold in a truly continuous manner, it is necessary to keep the mold walls free from foreign materials which would interfere with the free movement of the congealing casting through the mold. When the metal walls of the mold are wetted by the metal being cast, or where there is a residual film of material left by the casting on the mold walls, or where slag, dross and the like get into the mold chamber either by entrapment with the metal being poured or by reason of the reaction between the metal and the gases in the mold, which dross, slag, and the like adhere tenaciously to the mold wall, it has been found necessary even with the split mold to interrupt the casting operation after an interval of time to clean the mold walls. While this interval of time in the case of the split molds

is much longer than in the casting operations employing molds which do not vibrate transversely, it would still be desirable to avoid all interruptions in the continuous casting operation traceable to frictional resistance between the mold walls and the casting.

I have invented a process of providing a lubricating dressing between the mold walls and the congealing metal which satisfactorily overcomes the difficulties of the prior art arising from the adherence of the congealing metal to the mold walls.

It is an object of the present invention to reduce the friction between the mold walls and the congealing metal form in continuous casting operations.

It is another object of the present invention to provide a process of continuously forming a lubricating dressing between the mold walls and the congealing metal of a casting produced by a continuous casting process.

It is a further object of the present invention to lengthen the time during which the continuous process of casting metal may be carried out without interruption due to adherence of the solidifying metal to the mold walls.

The invention also contemplates a process of producing continuously cast shapes of metal having superior surface finish.

The foregoing and other objects and advantages of the present invention will become apparent from the following description thereof taken in connection with the accompanying drawing in which:

Fig. 1 is a somewhat fragmentary diagrammatic sectional elevation of an apparatus in which the process embodying my invention may be carried out, and

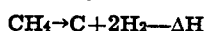
Fig. 2 is a diagrammatic sectional elevation of a split mold whose sections are capable of transverse vibration during the casting operation embodying my invention.

Generally speaking, the process embodying my invention comprises pouring molten metal into a mold, decomposing a hydrocarbon to produce finely divided free carbon in the mold whereby carbon particles thus formed deposit on the meniscus at the top of the column of metal in the mold, solidifying the metal, and withdrawing the solidified metal shape from the mold.

When a column of liquid is enclosed by a confining surface the meniscus at the top of the column is concave if the liquid wets the surface and is convex when the surface is not wetted by the liquid. I have found that it is preferable in suc-

cessfully carrying out the process embodying my invention to have a convex meniscus at the top of the column of metal in the mold. This convex meniscus is readily obtained by providing a mold surface which will not be wetted by the metal being cast. For example, if copper is to be cast, the mold surface may be made of chromium which is not wetted to any substantial extent by molten copper. The entire mold need not be and preferably is not made of chromium. It is sufficient, for example, to electrodeposit chromium in a relatively thin layer on the inner surface of a mold made of a base metal such as copper. This has the advantage of providing a mold material of high thermal conductivity whereby heat can be withdrawn from the molten metal at a more rapid rate than if the entire mold were made of chromium which has a much lower thermal conductivity than copper.

The hydrocarbon which is decomposed to produce finely divided free carbon preferably is one of the lower molecular weight hydrocarbons of the alkane, alkene or alkyne series. It is well known that the decomposition of such hydrocarbons may be carried out under such conditions as to produce free carbon in the form of very finely divided soot-like particles. The liberation of carbon from hydrocarbons is a chemical process which follows the thermo-dynamic laws applicable to such reactions and it can therefore be controlled to the desired degree by suitable adjustments of the physical and chemical conditions covering the reaction. For example, the simple hydrocarbon gas methane CH_4 , the lowest member of the alkane series, has a definite tendency to decompose into carbon and hydrogen above a critical temperature. The degree of dissociation depends upon the amount by which the critical temperature is exceeded, and certain other conditions. The reaction may be represented by the following formula:



Up to about 490°C . the free energy of formation of methane is negative; above this temperature it is positive. In other words, above 490°C . the hotter the system the greater the tendency of methane to dissociate into C and H_2 . This can be expressed in terms of the dissociation constant which is defined as

$$K = \frac{P_{\text{H}_2}^2}{P_{\text{CH}_4}}$$

The dissociation constant is the ratio between the square of the hydrogen pressure and the pressure of undecomposed methane. The dissociation constant at various temperatures is indicated in the following table:

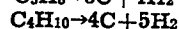
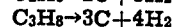
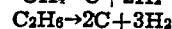
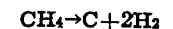
Temp., ° C.	$K = \frac{P_{\text{H}_2}^2}{P_{\text{CH}_4}}$
400.....	0.071
500.....	0.427
600.....	2.14
700.....	7.24
800.....	20.0
900.....	47.9
1,000.....	105
1,100.....	190

It is evident from the foregoing table that the higher the temperature above a critical minimum temperature the greater is the tendency of the compound gas to dissociate to produce more C and H_2 .

Since one product of dissociation is H_2 , the concentration of this gas in the system will have

a decided effect on the dissociation of the CH_4 , and it can be calculated that for any temperature and gas analysis there is a critical H_2 content, which if exceeded, will prevent the further dissociation of CH_4 since the system is "satisfied" with regard to H_2 and will tend to suppress any reaction which will produce more H_2 . This is pronounced in effect due to the fact that one molecule of CH_4 produces two molecules of H_2 on dissociation, and hence the H_2 concentration is built up rapidly. This can be seen from the equilibrium constant, which takes this fact into account and includes the square of the hydrogen concentration.

Other gases of the paraffin series act in a similar way to CH_4 under heat, dissociating to carbon and hydrogen. In fact no other analogous gas is as stable as CH_4 , and consequently the production of carbon from them can be more readily accomplished under the proper conditions. However, there is a very important consideration to be borne in mind—and that is the critical concentration of H_2 which (as has previously been explained) affects the dissociation of the hydrocarbon gas. Theoretically the first four members of the alkane series dissociate as follows:



One molecule of hydrocarbon gas of the paraffin series on dissociation liberates, at a minimum (methane), two molecules of H_2 but the higher members of the series liberate greater amounts of H_2 and would appear as a consequence to be increasingly sensitive to the concentration of H_2 in the gas atmosphere. The higher members, however, will release more C and therefore will not have to dissociate to the same extent to produce an equivalent soot effect. Thus propane, C_3H_8 , while it produces twice as much H_2 as CH_4 does on dissociation and might therefore be expected to be four times as sensitive to effects of H_2 concentration, also liberates three times as much C. The two effects are compensating to a fairly good degree.

The finely divided soot particles liberated by the dissociation of the hydrocarbon are believed to be essentially pure carbon. I do not exclude the possibility, however, that they may be covered by or impregnated with higher hydrocarbons which may be formed by polymerization of the gas or other complex reactions taking place during the decomposition process. It will be understood that the terms "carbon" or "soot" as applied to the particles formed by dissociation of hydrocarbon gas, as used herein define and cover these particles whatever their chemical composition may be.

The process of the present invention is particularly useful in casting metals or alloys, e. g., copper and copper alloys, which do not have an appreciable affinity for carbon. Hydrogen, however, is soluble in molten copper and for this reason the concentration of hydrogen in the atmosphere contracting the molten copper or copper alloys should be kept low, preferably under 8%. This is readily accomplished by flowing a protective atmosphere low in hydrogen, e. g., producer gas over the molten metal.

Referring now more particularly to the drawing, Fig. 1 illustrates somewhat diagrammatically a vertical section of an apparatus suitable for carrying out the process of the present invention.

Reference character 2 designates an open ended mold provided with a water jacket 4 having an inlet pipe 6 and an outlet pipe 8. The walls of the mold which will come in contact with the molten metal that is poured into the mold preferably are provided with a layer 10 of a material which will not be wetted by the molten metal. This layer 10, for example, may be electrodeposited chromium when copper is the metal being cast.

A hood designated by reference character 11 is adapted to be placed over the upper end of the mold 2. The hood 11 comprises a lower section 12 having an outlet opening 13 adapted to register with the mouth of the mold cavity. A ladle 14 is mounted in the lower section 12 in such position that its spout 15 will direct a stream of metal substantially through the center of the opening 13 into the mold 2. An upper section or cover 16 rests down over the lower section of the hood and the joint between them is made substantially gas tight by means of a liquid seal 18. An inlet opening 20 is located in the cover 16 immediately above the ladle through which molten metal may be introduced into the ladle 14 within the hood 12 from a furnace 22 or the like which is shown only fragmentarily in the drawing. A perforated ring 24 is located within the hood 12 surrounding the outlet opening 13 and when the apparatus is in operation the ring 24 will be connected with a suitable source of hydrocarbon gas. Below the mold is a device designated by reference character 26 for withdrawing and supporting the solidified metal.

The process of the present invention may be carried out in this apparatus as follows: At the beginning of a continuous casting operation mold 2 and hood 11 are filled with a non-oxidizing or reducing gas which preferably is practically insoluble in the metal to be cast and a dummy bar is inserted into the bottom of the mold where it is supported by the withdrawal device 26. Molten metal is then poured into the mold from the furnace 22 through the ladle 14. The molten metal first poured into the mold freezes against the dummy bar which is lowered as the metal progressively solidifies and becomes self sustaining to bring the ingot into the withdrawal device 26. The dummy bar can then be severed from the ingot and set aside for reuse at the beginning of another run.

At the same time hydrocarbon gas is introduced through the ring 24 into the hood where it is dissociated to produce quantities of finely divided free carbon particles. This dissociation may be caused by incomplete combustion of the gas or, by choice of a suitable gas, by the heat of the molten metal. Most of the particles of the soot, represented by reference character 28, deposit on the meniscus 30 at the upper end of the column of metal in the mold. These particles 28 form a substantially continuous film of lubricating carbon particles over the entire meniscus.

While I do not desire to be bound by any particular theory as to what happens thereafter, careful observations seem to indicate that during the casting operation the surface of the meniscus moves from the incoming stream outwardly to the mold walls where it congeals to form the outer skin of the solidifying casting practically as soon as it contacts the cold mold wall. The finely divided carbon particles that have deposited on the meniscus appear to be carried along by the surface of the metal not only as it moves outwardly toward the mold but also after it solidifies

to form the skin of the casting, resulting in the presence of a blanket or layer of very fine carbon particles between the mold walls and the casting. This layer or blanket of finely divided particles of free carbon is formed continuously or progressively and may be described as an autogenous mold dressing which lubricates the adjacent surfaces of the mold and casting so that frictional resistance between these surfaces is reduced to an extremely low value. As the column of metal moves downwardly through the mold it solidifies more and more toward the center until it becomes self-sustaining and can safely be withdrawn from the mold which has given the casting lateral support. The metal, however, is still at a very high temperature when it is withdrawn from the mold and the layer of carbon which has now served its purpose may, if desired, be permitted to burn in the air. The casting may be severed into convenient lengths for further processing without interrupting the continuity of the casting operation.

In Fig. 2 is illustrated somewhat diagrammatically a preferred type of mold for use in carrying out the process of the present invention. The structure of the mold and the apparatus used therewith are more particularly described and claimed in the copending application of Albert Welblund and Fred Benard, Serial No. 211,116, filed June 1, 1938. In this form of the apparatus, reference numeral 32 designates a mold formed of mating sections 33 each of which is provided with a water jacket 34 having suitable inlet and outlet pipes 36 and 38, respectively. The mold walls which will contact the molten metal are provided with a layer of material 40 which will not be wetted by the molten metal. Means designated generally by reference character 42 are provided for vibrating the mold sections 33 transversely with respect to the longitudinal axis of the casting formed in the mold. By vibrating the mold walls rapidly, the metal which has been poured into the mold is given intermittent lateral support at a sufficient rate to maintain the molten metal as an upright column which does not run down between the solidified metal and the mold walls or out of the joints between the mold sections.

The operation of the apparatus illustrated in Fig. 2 differs from the operation of the apparatus depicted in Fig. 1, and as already described hereinabove, in that the mold sections are vibrated at a rapid rate during the casting process.

For the purpose of giving those skilled in the art a better understanding of the process and advantages of the present invention, the following illustrative example is given:

Casting phosphorized copper

5000 lbs. of copper cathodes were melted in an induction heated furnace to produce a bath of molten copper. The melt was deoxidized by the addition of 11.5 lbs. of phosphor copper containing about 15% phosphorus. When the deoxidation was complete the heat was cast in an apparatus having a vibrating mold of the type illustrated in Fig. 2 hereof and described in greater detail in the Welblund-Benard application referred to hereinabove.

The heat was cast in about an hour and a quarter in a circular mold of about 3 inch diameter. During the casting operation a flow of charcoal producer gas at the rate of about 2300 cubic feet per hour was maintained through the hooded chamber protecting the molten metal. The producer gas contained about 30% CO, 0.5% CO₂, 4% H₂, a trace of CH₄, and the balance

largely nitrogen. At the same time a hydrocarbon gas which is sold under the trade-mark "Pyrofax" was fed through the perforated ring 24 into the hood at the rate of about 3.7 cubic feet per hour. The Pyrofax gas was essentially propane C_3H_8 . The metal was poured from the furnace at a temperature of about 2175° F. and under these conditions the correct amount of carbon was deposited on the molten copper meniscus. The temperature of the Pyrofax gas at the immediate zone of decomposition (i. e., at the metal surface) was approximately 2050° F.

During the continuous casting operation the solidified ingot which was withdrawn from the bottom of the mold was severed into 4 foot copper billets and 42 such billets were produced from this melt. The surface of the castings was excellent and the metal was sound, dense, and free from porosity. Chemical analysis showed that the quantity of phosphor copper alloy added as a deoxidizer was sufficient to deoxidize the melt and leave a residual phosphorus content of 0.018%. The density of the metal was found to be 8.95.

Although I have described my invention in connection with two specific embodiments of suitable apparatus, the process of the present invention is applicable to all continuous casting processes in which a mold is used to shape and solidify the molten metal. It will be apparent to those skilled in the art that modifications and variations of the process as described hereinabove can be made without departing from the spirit and scope of the present invention as defined in the following claims.

I claim:

1. A process of continuous casting comprising pouring molten metal into a mold, supporting the metal in the mold, depositing soot-like particles of free carbon on the meniscus at the upper end of the metal in the mold, cooling the metal to cause it progressively to solidify, causing the deposited soot-like particles to form a layer of lubricating material between the solidifying metal and the mold walls, and withdrawing the solidified metal from the mold.

2. The process of continuous casting comprising pouring molten metal into the upper end of a vertical open ended mold, progressively solidifying the metal, withdrawing the solidified metal from the bottom of the mold at a rate correlated with the rate of solidification, dissociating a hydrocarbon adjacent to the upper end of the mold under such conditions as to deposit quantities of soot-like particles on the meniscus of the molten metal in the mold, and causing the soot-like particles to progressively form a layer of lubricating material between the mold walls and the solidifying metal.

3. The process of continuous casting comprising introducing molten metal into one end of a cooling and shaping chamber, progressively solidifying the metal, withdrawing the solidified metal from the other end of the chamber at a rate correlated with the rate of solidification, dissociating a hydrocarbon gas adjacent to the first-mentioned end under such conditions as to deposit soot-like particles on the molten metal, and vibrating the walls of the chamber rapidly to increase and decrease the cross section thereof during the casting operation.

4. The process of continuously casting metals and alloys having no appreciable affinity for carbon comprising continuously introducing molten metal into the upper end of a vertical open ended

mold, progressively solidifying the metal, withdrawing the solidified metal from the bottom of the mold at a rate correlated with the rate of solidification, protecting the molten metal during pouring with a non-oxidizing atmosphere having low solubility in the molten metal, and dissociating a hydrocarbon gas adjacent to the upper end of the mold whereby soot-like particles deposit on the meniscus of the molten metal in the mold and are carried thereby to the mold wall to form a lubricating blanket between the mold wall and the metal in the mold.

5. The process of continuously casting copper and copper alloys comprising directing a stream of the molten metal through a producer gas atmosphere into an open ended mold, progressively solidifying the metal into an elongated shape, withdrawing said shape at a rate correlated with the rate of solidification, dissociating hydrocarbon gas in the vicinity of said molten metal, causing carbon particles liberated by said dissociation progressively to form a lubricating layer between the metal and the mold, and changing the producer gas atmosphere to maintain the hydrogen concentration under about 8%.

6. The process of continuously casting copper and copper alloys comprising directing a stream of the molten metal through a producer gas atmosphere into a mold chamber, progressively solidifying the metal into an elongated shape, increasing and decreasing the cross sectional area of said mold chamber, withdrawing said shape at a rate correlated with the rate of solidification, dissociating hydrocarbon gas in the vicinity of said molten metal, causing carbon particles liberated by said dissociation progressively to form a lubricating layer between the metal and the mold, and changing the producer gas atmosphere to maintain the hydrogen concentration in the vicinity of the molten metal under about 8%.

7. The process of continuously casting copper and copper alloys comprising directing a stream of the molten metal through a producer gas atmosphere into a vertical mold having a surface that is non-wettable by the molten metal, progressively solidifying the metal into an elongated shape, withdrawing said shape at a rate correlated with the rate of solidification, dissociating hydrocarbon gas in the vicinity of said molten metal, causing carbon particles liberated by said dissociation progressively to form a lubricating layer between the metal and the mold, and changing the producer gas atmosphere to maintain the hydrogen concentration under about 8%.

8. The process of continuously casting copper and copper alloys comprising introducing a stream of the molten metal through a producer gas atmosphere into a confining space having a surface that is non-wettable by the molten metal, varying the cross sectional area of said space, progressively solidifying the metal into an elongating shape, withdrawing said shape at a rate correlated with the rate of solidification, dissociating hydrocarbon gas in the vicinity of said molten metal, causing carbon particles liberated by said dissociation progressively to form a lubricating layer between the metal and the non-wettable surface, and changing the producer gas atmosphere to maintain the hydrogen concentration in the vicinity of the molten metal under about 8%.

9. In the continuous casting of copper and copper alloys in a vertical mold in which the metal is introduced in molten condition at the upper end,

progressively solidified to become self-sustaining and then withdrawn from the lower end, the improved method of lubricating the walls of the mold comprising decomposing hydrocarbon material adjacent to the upper end of the mold, causing the liberated carbon particles to form a lubricating layer between the metal and the mold, and flowing a non-oxidizing atmosphere low in hydrogen over the upper end of the mold at such a rate that the hydrogen concentration adjacent to the molten metal does not exceed about 8%.

10. In the continuous casting of copper and copper alloys in a vertical mold in which the metal is introduced in molten condition at the upper end, progressively solidified to become self-sustaining and then withdrawn from the lower end, the improved method of lubricating the walls of the mold comprising decomposing hydrocarbon material adjacent to the upper end of the mold whereby particles of carbon are set free and deposit on the metal in the mold; vibrating the mold walls toward and away from the metal confined thereby, the particles of carbon moving into the space between the metal and the mold walls progressively to form a lubricating layer therebetween; and flowing a non-oxidizing atmosphere low in hydrogen over the upper end of the mold at such a rate that the hydrogen concentration adjacent to the molten metal does not exceed about 8%.

11. In the process of continuously casting metal in a vertical mold in which metal is introduced in molten condition at the upper end, progressively solidified to become self-sustaining and then withdrawn from the lower end, the improved method of autogenously lubricating the walls of the mold comprising decomposing hydrocarbon material in contact with the molten metal whereby particles of carbon are set free and deposit on the

meniscus of the molten metal in the mold; and rapidly moving the mold walls into and out of contact with the metal confined thereby, the particles of carbon moving into the space between the metal and the mold walls and progressively forming an autogenous lubricating layer therebetween.

12. The method comprising moving a body of molten metal along a shaping surface, rapidly moving said surface into and out of contact with said metal, and introducing soot-like particles between said surface and the metal to lubricate its movement therealong.

13. The method comprising moving a column of molten metal downwardly, laterally supporting the molten metal only intermittently, dissociating hydrocarbon material adjacent to the top of said column, causing liberated carbon particles to form a lubricating layer between the metal and the surface which gives it intermittent lateral support, and abstracting heat during the downward movement of the column progressively to solidify the molten metal.

14. The method comprising introducing a stream of molten metal into a mold to form and maintain a column of molten metal in said mold, abstracting heat from said metal progressively to solidify it into an elongating metal shape, moving the mold walls rapidly into and out of contact with the column of molten metal, whereby it is given only intermittent lateral support, dissociating a hydrocarbon gas in the vicinity of the upper end of the column of metal to form a lubricating layer of the liberated carbon particles between the metal and the mold walls, and withdrawing the elongating metal shape from the mold.

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