

[54] METHOD FOR CASTING BLOCKS

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[63] Continuation-in-part of Ser. Nos. 147,646, May 27, 1971, abandoned, and Ser. No. 781,484, Dec. 5, 1968, abandoned.

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[51] Int. Cl. **B22d 5/02, B22d 1/02**

[58] Field of Search 164/4, 133, 154, 155, 156,
164/157

[56] References Cited

FOREIGN PATENTS OR APPLICATIONS

1,300,207	7/1969	Germany	164/154
556,385	4/1958	Canada	164/164

1,045,054	11/1958	Germany
1,064,206	8/1959	Germany
1,217,558	5/1966	Germany
1,231,855	1/1967	Germany

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[57]

ABSTRACT

A tiltable furnace to supply molten metal to a ladle and the ladle is connected to a computing and automatic control system which continuously senses the rate of change of weight of the ladle as liquid is poured from the ladle into a mold. The control system tilts the furnace and the ladle to regulate the flow of liquid into the mold to hold the casting to a predetermined weight. The rate of change of the weight of liquid times the time of the pour will give the weight poured in that time.

8 Claims, 2 Drawing Figures

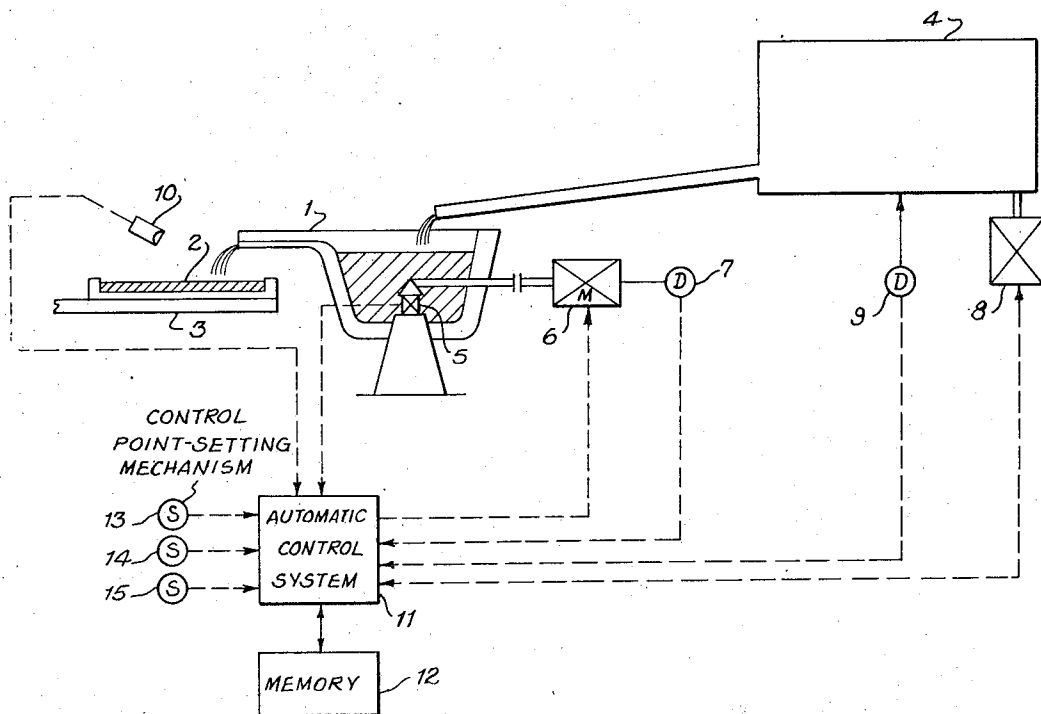


Fig. 1

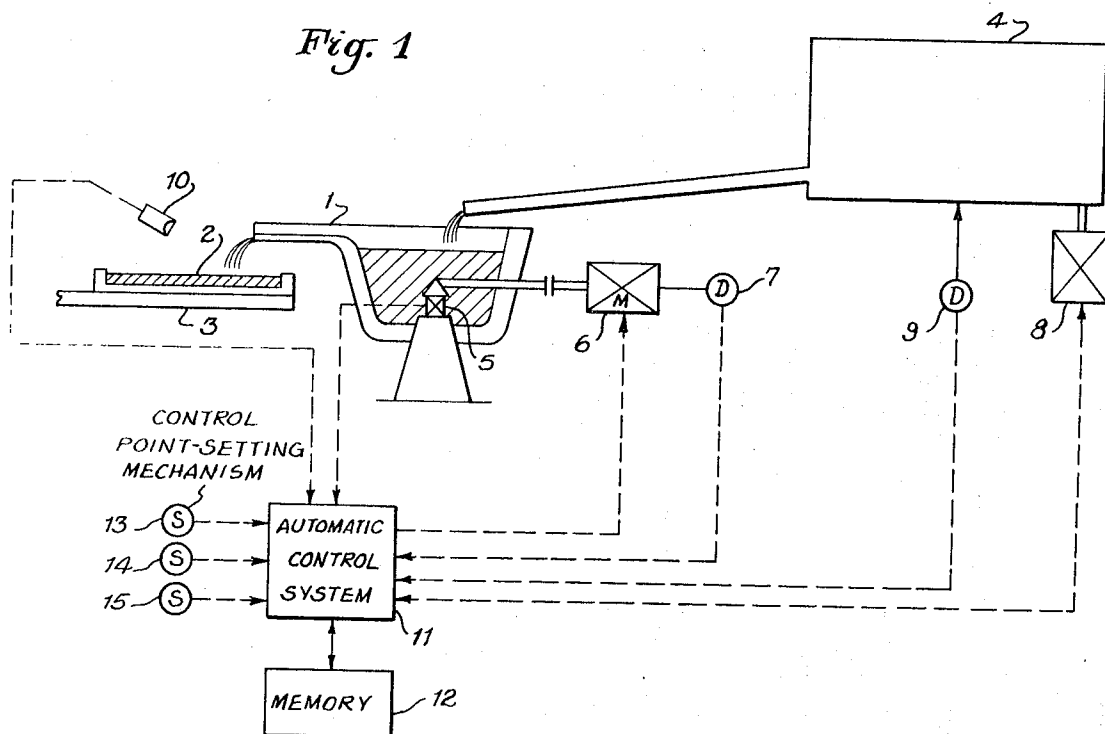
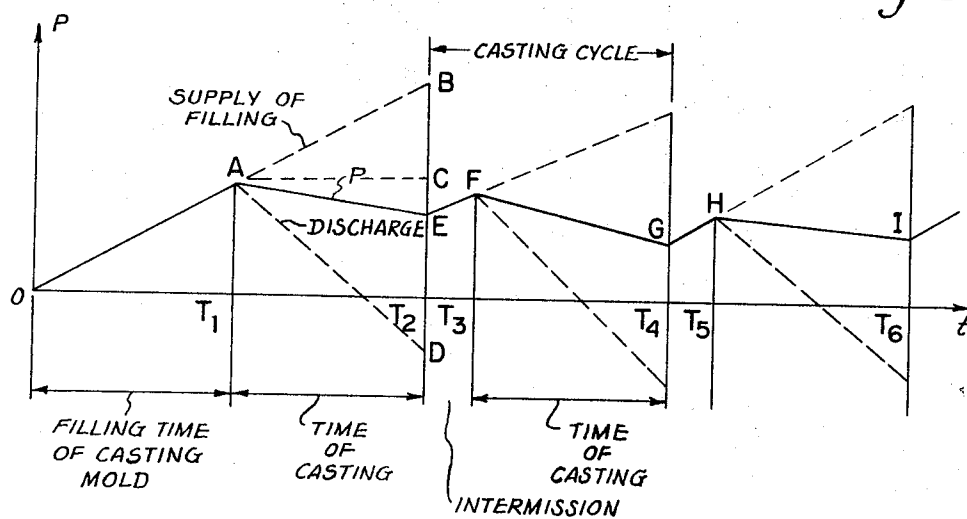


Fig. 2



METHOD FOR CASTING BLOCKS

This is a continuation-in-part of application Ser. No. 147,646, filed 27, May 1971, now abandoned, and of 781,484 filed 5 Dec. 1968, now abandoned.

This invention relates to a method and apparatus for the automatic control of the desired weight of cast blocks or plates, particularly of metal, in such a manner that the differential quotient of the change (i.e., rate of change or slope of a line on a graphical representation) in weight of the ladle during the casting cycle is continuously sensed and is used to control the desired weight of the cast blocks or plates.

In numerous foundry operations, castings are made in a rapid sequence by a pouring of molten material. It is particularly important to maintain exactly the desired weight of the castings because even small deviations from the desired weight involve great disadvantages in cost and processing technology during the further processing.

For instance, an extra weight of 2 percent above the desired weight of copper anodes results in short circuits between the anodes and cathodes so as to reduce the current efficiency during electrolysis by 0.4 percent.

If the initial weight of the copper anode is below the desired value, the residual weight of the anode at the end of the life of the anode will be much less than that of the anodes having the desired weight. Owing to the small residual weight of the anodes which had an initial weight below the desired value, the strength of such anodes is reduced so that they collapse, fall into the bath and are distorted. This results in short circuits, damage to the lining of the bath and a premature termination of the life of the anode in entire groups of baths.

In the manufacture of wire, deviations of the weight of the castings from the desired value due to different dimensions of the casting will result in irregular annealing and forming conditions, wire lengths and cycles of operation. This involves trouble in operation, particularly in highly automatic plants.

In order to avoid these disadvantages, Printed German application No. 1,186,175 discloses sensing the change in weight of the ladle during the pouring operation with the aid of a scale or a pressure gauge. The output signals of such sensing devices serve to control the ladle, which pours metal until the load which acts on the sensing devices has reached a predetermined value.

Printed German application No. 1,217,558 discloses controlling the desired or average weight of cast blocks or plates made in large quantities depending upon the actual weight of the cast blocks or plates in the molds at the end of the pouring operation. The deviation of the actual weight from the desired weight is used to control the pouring of the following blocks or plates. This process had the disadvantage that weight deviations can not be detected until the pouring operation has been completed.

To improve the accuracy of the measurement, Printed Germany application No. 1,064,206 discloses weighing a certain amount of metal and then to cast said amount, program control being used to ensure automatically the charging of the desired weight. These processes have the great disadvantage of requiring a subsequent sorting of the cast blocks or plates because there are numerous cast blocks or plates which differ in weight from the desired value.

For this reason, Printed German application No. 1,045,054 discloses controlling the desired weight from the mold. In this case, a certain amount of metal is poured continuously depending upon the level of metal in the mold. Heat-sensitive elements are placed in the wall of the mold and are connected to a bridge circuit and a control circuit for controlling the amount to be poured.

Printed German application No. 1,231,855 discloses lifting the mold into a weighing position, in which the mold rests on a pressure gauge, and to use the emitted signals to control the ladle in such a manner that it discharges metal until the load action on the pressure gauge has a predetermined value and the casting operation is completed. This process had the disadvantage that the indication is considerably biased owing to the dynamic force of the pouring stream flowing into the mold, particularly when relatively small molds are used which have no tubular gate.

It is an object of this invention to ensure a high consistency of the dimensions of the several cast blocks or plates in the casting of blocks or plates in large quantities and in rapid sequence.

The means by which the objects of this invention are obtained are described more fully with reference to the accompanying drawings in which:

FIG. 1 is a schematic view of the apparatus used in this invention; and

FIG. 2 is a chart showing the change in ladle weight depending upon the time in several casting cycles.

According to this invention, this object is accomplished in that the differential quotient of the change in weight P of the ladle due to the flow of liquid from the supply furnace into the ladle in the interval t between two pouring periods is stored as a specific function, e.g., in kilograms per second $\Delta P/\Delta t$ in the memory of a computing and automatic control system and is utilized during the pouring time together with the value $\Delta P/\Delta t$ derived from the change in weight of the ladle during the pouring operation for determining the actual weight of the liquid which is poured from the ladle.

During the filling time the change in weight of the ladle due to the flow of liquid from supply furnace is measured by the pressure gauge per time unit and determined as differential quotient $\Delta P/\Delta t$. The differential quotient is stored as function in the memory of the computing and automatic control system. The curve OA (FIG. 2) defines the value (P) of the differential quotient $\Delta P/\Delta t$ at any time between 0 and t_1 . At the time t_1 the value P corresponds to point A (line t_1A in the dimension of P).

The value of the stored function gives the projected weight of liquid supplied to the ladle during the casting time. The weight added to the ladle during the pouring time is indicated by curve AB for any time between t_1 and t_2 if no liquid were being poured.

Curve AD shows the outflow from the ladle which would take place if no liquid were supplied to the ladle during the casting time.

The actual value derived from the measured change ($\Delta P/\Delta t$) in weight of the ladle during the casting time is shown by a position curve AE at any time between t_1 and t_2 . From the projected inflow AB and the curve AE the weight of liquid poured from the ladle during the casting time is determined. These weights are shown by the length of vertical lines between the curves AB and AE for the respective times between t_1 and t_2 .

At t_2 the weight of liquid that has been poured out from the ladle is shown by the vertical distance BE. This is the desired weight of liquid to be poured into the mold in the desired casting time. Both AB and AE are set on the control pointsetting mechanism. AB from the "memory" and AE by computation in the control system to give, in the time t_1 to t_2 the required weight of liquid BE.

The values corresponding to lines AB and AE are continuously compared in the computing and automatic control system and the tilting of the ladle is controlled and regulated in such a way that the desired weight is poured into the mold in the desired time. A is the weight of the ladle and contents at the beginning of the first casting cycle and E at the end.

In the time between t_2 and t_3 (Intermission) the change in weight of the ladle due to the flow of liquid from the supply furnace 4 into the ladle is measured again per time unit and is determined as a new differential quotient for the next casting cycle. As shown in the table below, the differential quotient can change between the several casting cycles and therefore has to be determined each cycle.

slope $\Delta P/\Delta t$ of line AE and the ladle tilting motor 6 is then operated to give such a pour rate. At the end of each pour, the ladle 1 continues to receive copper from furnace 4 at a rate determined successively by load cell 5 as shown by line EF before the pour FG, and by line GH before pour HI, and so forth.

An indicator, e.g., a photodetector or a radiation pyrometer 10, is positioned close to the ladle lip and serves to indicate the exact beginning and ending of the pouring operation; these times are indicated in the computing and automatic control system.

The desired amount of liquid to be poured from the ladle and consequently the desired weight of the blocks or plates is suitably obtained by controlling the inclination of the ladle, e.g., by means of tilting motor 6.

In this case, a position control element may be used to move the ladle depending upon the weight of its contents to such an initial inclined position that the pouring can be initiated virtually without initial delay.

To prevent spilling of the liquid over the rim of the mold at the beginning of the pouring time, and to enable at the end of the pouring time a fine metering of the liquid which flows from the ladle into the mold so

Time		Working phase	Function of supply, kg./sec.			Actual weight of anodes, kg.
Min.	Sec.		Gross weight of the ladle, kg.	Storage value	During pouring time	
00	00	Measuring of supply.....	2000.0	15.00		
	10		2150.0			
	11	Pouring.....	2165.0	15.00	15.00	302
	21		2013.0			
	22	Measuring of supply.....	2027.9			
	32		2176.9			
	33	Pouring.....	2191.8	14.90	14.9	301
	43		2039.8			
	44	Measuring of supply.....	2054.6			
	54		2201.6			
01	55	Pouring.....	2216.3	14.70	14.6	300
	05		2062.3			
	06	Measuring of supply.....	2076.6			
	16		2220.1			
	17	Pouring.....	2234.4	14.35	14.20	301.5
	27		2074.9			
	28	Measuring of supply.....	2089.1			
	38		2226.1			
	39	Pouring.....	2239.8	13.70	13.60	299
	49		2076.8			
02	50	Measuring of supply.....	2090.4			
	00		2219.9	12.95	12.80	300.5
	01	Pouring.....	2232.8			
	11		2060.3			
	12	Measuring of supply.....	2073.1	11.95	11.75	298.5
	22		2192.6			
	23	Pouring.....	2204.5			
	33		2023.5			
	34	Measuring of supply.....	2035.2	10.65	10.40	299
	44		2141.7			
	45	Pouring.....	2152.3			
03	55		1957.3	9.00	8.70	298
	56	Measuring of supply.....	1967.7			
	06		2057.7			
	07	Pouring.....	2066.7			
	17		1955.7	15.5		
	18	Interruption of casting for altering supply from furnace	2144.7			
	48	Measuring of supply.....	2299.7			
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Referring to FIG. 2 of the drawing taken with the table supra, the slope of the line OA indicates that in 10 seconds 150 kg will flow into the ladle 1 from furnace 4. This is recorded in the "memory" 12 (see under "time" 00 to 10 seconds in table). The weight of copper to be poured from time 11 seconds to 21 seconds, however, is 300 kg (line AD) so the automatic control system 11 computes the weight the ladle will have at the end of a 10 second pour the weight flowing in from furnace 4 being 150 kg during the pour and 300 kg being poured out. This computation establishes the

as to obtain the desired weight with high accuracy, the movements of the ladle are controlled depending upon a predetermined function, and the time in which this function is performed is adjustable depending upon the operating conditions.

In a special embodiment of this invention, the gross weight of the ladle is compared at a given time with the gross weight of the ladle at the corresponding time of the preceding casting cycle. The resulting difference is used as a control signal for changing the desired value of the inclination of the supply furnace and conse-

quently for changing the amount of liquid which flows into the ladle.

The control signal can be used in pouring anode starting blanks which have a weight that exceeds the weight of the normal castings by 10-15 percent, provided that there is a sufficient amount of liquid in the ladle and a starting blank mold is disposed in receiving position under the ladle.

The axle shaft of the ladle 1 is mounted on a load cell 5, which continuously senses the change in weight of the ladle 1 during the interval between the pouring times as well as during the pouring time. The output of the load cell 5 is transmitted to a computing and automatic control system 11. The change in weight of the ladle 1 in the interval between each two pouring periods is stored as a specific function in the memory 12 of the computing and automatic control system 11. The integral of the stored specific function and the integral of the change in weight of the ladle during the pouring period are used together to ascertain the actual weight of the liquid which has been poured from the ladle 1 into the mold 2, which is supported on the mold turntable 3.

The actual weight is continuously compared with a desired weight, which is present on a control point-setting mechanism 13. In response to this comparison, the computing and automatic control system 11 control the inclination of the ladle with the aid of the tilting motor 6. The time for casing one anode can be set at the control point-setting mechanism 15.

The rotation imparted to the axle shaft of the tilting motor 6 in response to the correction signal is fed back without change in angle and without slip to the computing and automatic control system 11 by inclination synchro 7. The feedback current is a measure of the deviation of the actual value from the desired value and is used as a control signal for the re-adjustment of the inclination of the ladle.

At a predetermined time during the casting cycle, the gross weight of the ladle 1 is compared with the gross weight of the ladle at the corresponding time in the preceding casting cycle. The resulting difference is used as a control signal for changing the desired inclination of the supply furnace, which desired inclination is preset on a control point-setting mechanism, not shown, or as a control signal for the casting of anode starting blanks, for which the desired weight is preset on the control point-setting mechanism 14. The inclination of the supply furnace 4 is changed with the aid of the tilting motor 8, and the rotation of the shaft is transmitted without change in angle and without slip by an inclination synchro 9 to the computing and automatic control system 11.

A photoelectric cell 10 is positioned in front of the lip of the ladle. The output signals of said photoelectric cell indicate in the computing and automatic control system 11 the exact times when the pouring begins and ends, respectively.

The advantages afforded by this invention reside particularly in that pouring can be effected directly from the ladle into the mold without use of an intermediate vessel.

Because the pouring operation is controlled depending upon an optimum function, the number of blocks or plates which can be cast per unit of time can be much increased as compared to heretofore used processes. At the same time, the resulting cast blocks or

plates and the anode starting blanks have a constant weight so that there is no need for sorting operations when the cast blocks or plates have been removed from the casting machine.

Another advantage is obtained in that the flow into the ladle can be intermittently quasi-continuously corrected so that a sufficient amount of liquid to be poured is always available in the ladle.

A special advantage is obtained in that the apparatus of this invention can be incorporation into existing casting machines without need to make substantial alterations therein.

The process according to the invention is described with particular reference to the following example:

Ladle 1 was by means of the tilting motor 6 supported on load cell 5 to avoid weight deviations caused by tilting.

At the beginning of a casting cycle, ladle 1 had a total weight of 2,000 kilograms (see table). The interval between pouring times, i.e., the time necessary for rotating the next mold in casting position after the preceding mold had been filled, was 10 seconds. During this time, the function of supply of copper from furnace 4 to ladle 1 was found to have a value $\Delta P/\Delta t$ of 15 kilograms per second by means of load cell 5. This value was transmitted to and stored in the memory of computing and automatic control system 11. After said next mold had reached the casting position, an impulse was given by control system 11 which caused the next pouring action. The pouring time was chosen of about 10 seconds (see table) for each mold. The desired weight of the anodes was 300 kilograms.

If ladle 1 were not tilted and remained in a horizontal position, ladle 1 would be filled with liquid copper. After filling, copper at the same weight of copper per second would flow over the lip of ladle 1 as copper flowed out of supply furnace 4 into ladle 1, i.e., during a pouring time of 10 seconds, $10 \text{ seconds} \times 15 \text{ kilograms per second} = 150 \text{ kilograms}$ copper would flow into the mold. Under these conditions, load cell 5 would indicate no change in weight.

The desired weight of the anodes, however, was 300 kilograms so ladle 1 was tilted during the pouring time by command of the computing and control system 11 in such a way that 150 kilograms of the copper content of ladle 1 were cast into the mold as well as the 150 kilograms from furnace 4. This change in weight of ladle 1 was sensed by load cell 5. Storage value and value of change sensed by load cell 5 during pouring time were cumulated in computer system 11 and used as actual value for regulating the tilting of ladle 1.

The above table shows the values of a number of casting cycles.

Having now described how the objects of this invention are obtained:

I claim:

1. In the method for automatically controlling the desired weight of cast blocks or plates particularly composed of metal comprising the steps of continuously sensing the differential quotient of the change in weight of the ladle used in the casting cycle, and controlling the pouring of liquid from the ladle into a mold by use of said differential quotient in a computing and control system, the improvement in which the differential quotient of the change in weight of the ladle per time unit due to the flow of liquid from a supply furnace into the ladle during the intervals between two pouring periods

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of the ladle is stored as a function in the memory of the computing and control system, and then using said stored function during the pouring period of the ladle as an integrated value together with the integrated value derived from the measured change in weight of the ladle during said pouring period for determining the actual weight of liquid which is poured from the ladle and for obtaining the desired weight of the blocks or plates.

2. In a method as in claim 1, further comprising measuring the beginning and ending of the pouring time by an indicator positioned adjacent pouring lip of the ladle, and sending said time into the computing and automatic control system.

3. In a method as in claim 2, further comprising adjusting the inclination of the ladle by said control system to obtain the desired weight of poured metal.

4. In a method as in claim 3, further comprising ini-

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tially inclining said ladle in accordance with its weight to begin pouring liquid from said ladle without delay.

5. In a method as in claim 4, further comprising pouring from said ladle in accordance with a function having an adjustable time base.

6. In a method as in claim 5, further comprising comparing the gross weight of the ladle at a given time with the gross weight of the ladle at the corresponding time during the preceding casting cycle.

10 7. In a method as in claim 6, further comprising sending the difference in weight at said given time into the computing and automatic control system for changing the flow of liquid from a supply furnace into said ladle.

15 8. In a method as in claim 7, further comprising using the difference in weight at said given time as a control signal for casting starting blanks.

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