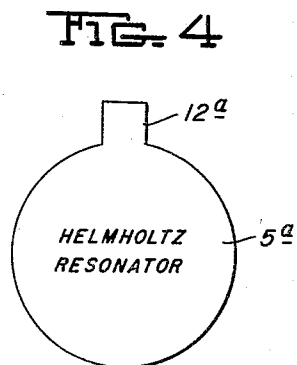
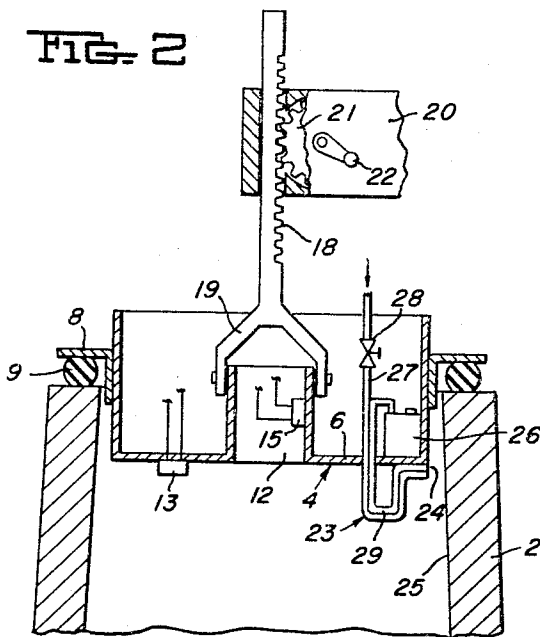
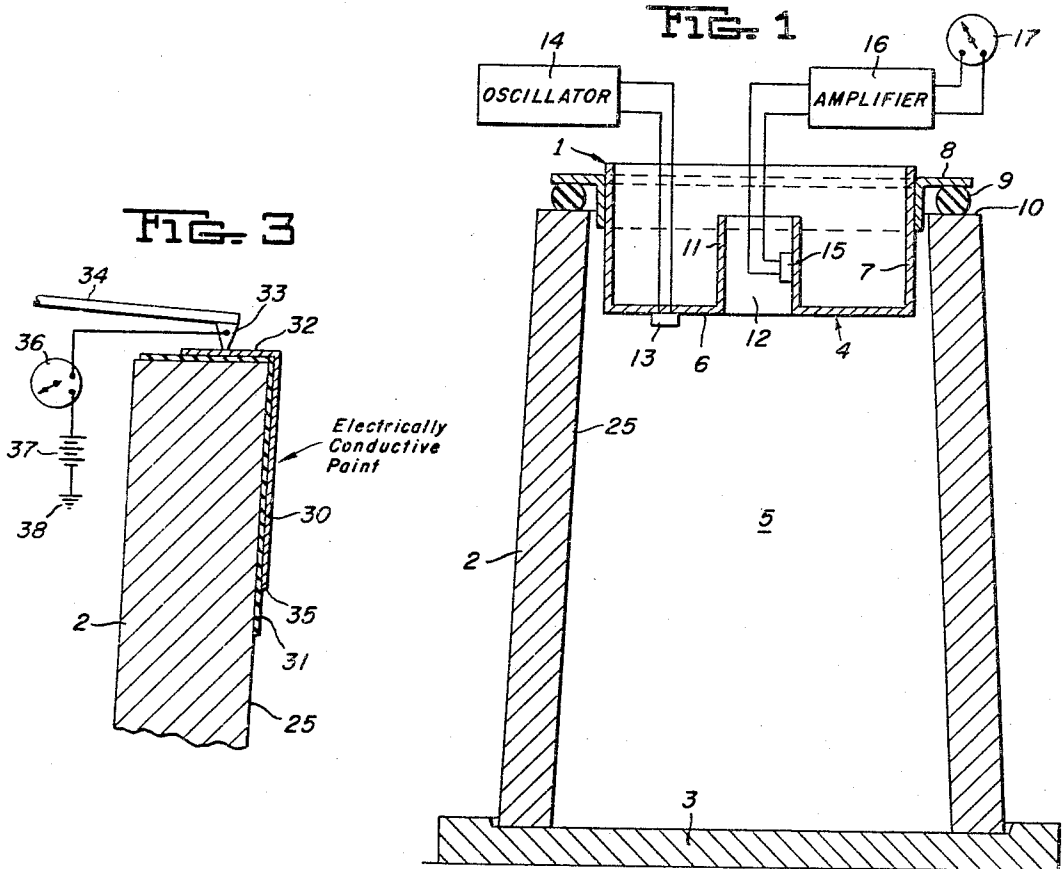


June 13, 1967

W. L. ROBERTS
METHOD AND APPARATUS FOR ACOUSTICALLY DETERMINING
THE SIZE OF CAST INGOTS
Filed Dec. 12, 1963

3,324,716



INVENTOR
WILLIAM L. ROBERTS
By *Donald G. Dalton*
Attorney

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3,324,716

METHOD AND APPARATUS FOR ACOUSTICALLY DETERMINING THE SIZE OF CAST INGOTS

William L. Roberts, Murrysville, Pa., assignor to United States Steel Corporation, a corporation of Delaware

Filed Dec. 12, 1963, Ser. No. 330,034

6 Claims. (Cl. 73-149)

This invention relates to steel ingots and, more specifically, to a method and apparatus for determining the vertical level to which a mold should be filled with molten metal in order to obtain an ingot of a predetermined size.

The invention, generally stated, is directed to the problem of reducing scrap losses that are caused by ingots being teemed to sizes that are either too large or too small. To produce ingots of the desired size, the practice of marking the side of the ingot mold with chalk to indicate the level to which the mold should be filled with molten metal is commonly employed. This practice assumes that the interior dimensions of molds of a given size are the same and that the desired size of ingot can be obtained by calculating the vertical level to which the mold must be filled. However, the interior dimensions of molds are subject to change in use as the result of warping, washing, accumulation of scale on the inner mold surfaces, etc. and, since the practice of calculating the height of the ingot does not take dimensional changes of this character into consideration, such practice does not always result in the production of ingots of the desired size, and excessive scrap losses frequently result. For the purpose of obtaining ingots of the correct size and reducing losses of this character, different arrangements for weighing the ingot metal as it is teemed into a mold have been proposed. Such proposals, however, have not proved effective and the practice of pouring ingots to vertical levels calculated in accordance with mold dimensions has continued.

This invention is directed to the problem of obtaining greater accuracy in the casting of ingots to a predetermined size and consequent reduction in scrap losses. To this end the vertical level to which molten metal is to be teemed into a mold is determined in accordance with the actual space or volume within the mold without regard to the physical dimensions of the mold. In a manner to be described this is accomplished by measuring the interior of the mold acoustically and from the information thus obtained determining the vertical level to which the mold is to be filled. More specifically, the invention contemplates an apparatus that uses the principles of a Helmholtz resonator and includes a closure member that is adjustably mounted for vertical movement in an ingot mold to define an underlying gas-filled space of variable volume which is subjected to sonic vibrations while the closure member is moved vertically until a resonant relation is established. The vertical position of the closure member when such resonant relation is established determines the vertical level to which the ingot mold must be filled with molten metal to obtain the desired size of ingot.

Other objects and advantages of the invention will become apparent from the following description and accompanying drawings in which:

FIGURE 1 is a vertical sectional view showing somewhat diagrammatically the apparatus of this invention in its assembled position on a conventional ingot mold;

FIGURE 2 is a fragmentary view similar to FIGURE

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1 but showing a mechanism for adjusting the vertical position of the apparatus and a device for marking the side of the ingot mold;

FIGURE 3 is a fragmentary showing of a control circuit that includes a painted circuit formed by the marking device shown in FIGURE 2; and

FIGURE 4 is a sketch illustrating the principles of a Helmholtz resonator.

The drawings show diagrammatically the manner in which the apparatus 1 of this invention is applied to a conventional ingot mold 2 and its supporting stool 3. In a manner to be described, the apparatus 1, mold 2 and stool 3 cooperate to form an acoustic resonant system and, more particularly, a Helmholtz resonator, for determining the level to which the mold 2 must be filled with molten metal to produce an ingot of a predetermined size.

The apparatus 1 comprises a closure member 4 that has an adjustable mounting for vertical movement in the upper end of the mold 2 and cooperates therewith to define an underlying chamber or enclosure 5, the volume of which varies with the vertical position of the member 4. The member 4 is in the form of a flat horizontal plate 6 that has a peripheral flange 7 projecting upwardly about its outer edge. The flange 7 has a telescopic or slide fit for guided vertical movement in a mounting collar 8 that is supported by a rubber gasket 9 or other sealing member on the upper end 10 of the mold 2. The volume of the enclosure 5 may be varied by adjusting the vertical position of the closure member 4 relative to the mounting collar 8. A vertically extending neck or tube 11 is arranged centrally of the plate 6 and provides a restricted passage 12 that opens into the enclosure 5. Sonic vibrations are applied to the air in the enclosure 5 by a transducer 13, in the form of a permanent-magnet loud-speaker, coupled to an oscillator 14, which has conventional provisions (not shown) for varying the oscillations produced thereby and the sonic vibrations applied by the transducer 13 to the enclosure 5. A second transducer 15, which may be a conventional microphone, such as a crystal type of instrument, is coupled to an amplifier 16 and an A.-C. voltmeter 17 for measuring the force or amplitude of the acoustic vibrations in the passage 12.

As described in greater detail in the text book by Theodor F. Heuter and Richard H. Bolt, entitled, "Sonics-Techniques for the Use of Sound and Ultra-Sound in Engineering and Science," pages 325-327, and as shown for example in FIGURE 4, a Helmholtz resonator consists of a gas-filled cavity 5a with a constricted neck or opening 12a. The gas inside the cavity 5a acts like a spring, whereas the gas in the neck or constriction 12a acts like a mass. Thus, the gas in the neck 12a may be set in oscillatory motion in much the same way that a body attached to the end of a spring may be made to oscillate. If the volume of the cavity 5a is V, the cross-sectional area of the neck 12a is S, the effective length of the neck 12a is l_e , and the velocity of sound is c, then the resonant frequency v_0 of the system in cycles per second is given by the formula:

$$v_0 = \frac{1}{2\pi} \sqrt{\frac{c^2 S}{l_e V}}$$

In this sketch, the cavity 5a and restricted neck 12a respectively correspond to the air or gas-filled chamber

5 and the restricted neck opening 12 thereto in the apparatus shown in FIGURE 1 which as indicated above cooperates with the mold 2 to form a Helmholtz resonator.

In operation, the volume of molten metal required to produce an ingot of predetermined size is calculated, and the oscillator 14 is adjusted to actuate the transducer 13 to apply sonic vibrations to the chamber at a frequency ν_0 according to the above formula that is resonant for such volume. The vertical position of the member 4 is then adjusted until resonance occurs. This is detected by the transducer 15 and the output voltmeter 17 which registers a maximum output from the amplifier 16 when the volume of the enclosure 5 has a resonant relation to the frequency output of the oscillator 14. When this condition takes place, enclosure 5 has a volume which will produce an ingot of the predetermined size when filled with molten metal, and the vertical position of the horizontal closure plate 6 furnishes an indication of the vertical level to which the mold 2 must be filled with molten metal to produce this ingot. This level may be marked on the side of the mold by measuring the vertical distance of the plate 6 below the mounting collar 8 or the upper end of the mold 2.

FIGURE 2 discloses an apparatus for adjusting the vertical position of the closure member 4 and for marking the inner surface of the mold 2 to indicate the level to which it should be filled with molten metal. The mechanism for adjusting the vertical position of the closure member 4 comprises a gear rack 18 which has its lower end 19 connected with the closure member 4 and is guided for vertical movement in a supporting frame 20. The supporting frame 20 occupies a stationary position relative to the mold 2 and may be either temporarily supported on the mold 2 or on the support for the mold stool 3. Vertical movement is imparted to the rack 18 by rotation of a rack pinion 21 that is manually rotated by a handle 22. In this showing, marking is effected by a spray gun 23 having a spray nozzle 24 for applying a level indicating mark on the inside wall 25 of the mold 2. The position of the nozzle 24 corresponds to the vertical position of the closure member 4 so that when it is operated the mark applied to the mold wall surface 25 indicates the vertical position of the member 4 at the time of such operation. A paint reservoir 26 for the gun 23 is mounted on the plate 6 and compressed air is supplied to the nozzle 24 through a pipe 27 under the control of a valve 28. Paint is delivered from the reservoir 26 to the nozzle 24 through a supply pipe 29 by the aspirating effect of the air flowing through the conduit 27.

If desired, the spray gun 23 may be used to apply a painted conductor 30 on the upper end of the mold 2 as shown in FIGURE 3 of the application drawings. In such case, the reservoir 26 is filled with metallic conducting paint and the upper portion of the inner wall surface 25 of the mold 2 is provided with a coating of electrical insulation 31. After the closure member 4 has had its vertical position adjusted as described above, the painted conductor 30 is formed on the insulated coating 31 by operating the valve 28 to spray conducting paint through the nozzle 24 against the mold 2. The closure member 4 is then moved upwardly to form the painted conductor 30, which is extended horizontally as at 32 over the upper end of the mold wall. After removal of the apparatus 1 and before steel is teemed in the mold 2, a contact 33 carried by a rod 34 of insulating material is placed in electrical contact with the horizontally extended portion 32 of the painted conductor 30. The contact 32 is electrically connected through a meter 36 and a battery 37 to ground 38. After forming a control circuit for the meter 36 in this manner, the stopper rod on a pour ladle may be operated to teem molten steel into the mold 2. When the level of the steel reaches the lower end 35 of the painted conductor 30, deflection of

the meter 36 will indicate that the mold 2 has been filled to the desired level and that the metal teeming operation should be discontinued. Alternatively, the circuit for operating the meter 36 may be used for operating the ladle stopper rod to a closed position.

From the foregoing, it will be apparent that the apparatus 1 of this invention operates to convert a conventional ingot mold into an acoustical resonator. In addition, the provision for adjusting the volume of the resonator by moving the closure member 4 vertically in the upper end of the mold 2 to a resonant position for the frequency of the sonic vibrations applied by the transducer 13 enables a determination of the vertical level to which the mold 2 should be filled with molten steel. Attention is particularly directed to the fact that this determination of the level to which the mold 2 is to be filled with molten steel is made solely in conformance with the volume of the enclosure 5, and that the accuracy of such determination is not affected in any manner by variations in the physical dimensions of the enclosure 5, which may result from warpage or washing of the mold walls 2 in use, accumulations of scale or slag deposits on the inner mold surfaces, or from other factors which affect the physical dimensions of the enclosure 5. In this manner, the apparatus of this invention enables the casting of ingots more accurately to a predetermined size with a corresponding reduction in scrap losses.

While one embodiment of my invention has been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. An apparatus in the form of a sonic cavitometer for determining the size of an ingot to be cast in a mold comprising, the combination with an upwardly open ingot mold, of a closure member supported for adjustable vertical movement in the upper end of said mold, said member and said mold cooperating to form a gas-filled enclosure having a volume varying with the vertical position of said member in said mold, means providing a restricted passage extending outwardly from said enclosure, means for sonically vibrating the gas in said enclosure at a predetermined frequency, said closure member being vertically adjustable to a position in which the volume of said chamber and the frequency of said vibrations have a resonant relation, and transducer means in said passage for determining when said closure member is in a vertical position providing said resonant relation and thereby the vertical level to which molten metal must be teemed into said mold to produce an ingot of predetermined size.

2. Apparatus as defined in claim 1 characterized by means for adjusting the vertical position of said closure member relative to said mold.

3. Apparatus as defined in claim 2 characterized by the provision of means carried by said member for marking the wall of said mold, and means for actuating said marking means to indicate the said vertical level to which said mold must be filled with molten metal.

4. An apparatus as defined in claim 3 characterized by said mold having a lining of electrical insulation on its inner surface, and by said marking means comprising means for painting an electrical conductor on said lining, said conductor forming part of a circuit means for determining the level to which molten metal has been teemed in said mold.

5. In a method of casting an ingot of a predetermined size, the steps which comprise forming a gas-filled cavity of variable volume in the lower portion of an ingot mold, vibrating the gas in said cavity at a frequency which has a resonant relation to a volume which when filled with molten metal will produce an ingot of said predetermined size, and varying the volume of said cavity to produce said resonant relation and thereby determine the vertical

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level to which said mold must be filled with molten metal to produce said ingot.

6. In a method of casting an ingot of a predetermined size, the steps which comprise placing a vertically movable closure member in the upper end of an ingot mold to form a gas-filled cavity in the lower portion of said mold, vibrating the gas in said cavity at a frequency which has a resonant relation to a volume which when filled with molten metal will produce an ingot of said predetermined size, and adjusting the vertical position of said closure member to a level such that the volume of said cavity and said frequency have said resonant relation, and marking the side of said mold according to the vertical position of said member at which said resonant

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relation is produced to thereby determine the vertical level to which said mold must be filled with molten metal.

References Cited

UNITED STATES PATENTS

2,285,151	6/1942	Firestone	73—149
3,060,724	10/1962	Smith et al.	73—149 X
3,075,382	1/1963	Mathias	73—149
3,129,585	4/1964	Hamilton	73—149
3,237,451	3/1966	Haefl	73—149

RICHARD C. QUEISSER, *Primary Examiner.*

J. C. GOLDSTEIN, *Assistant Examiner.*