# United States Patent [19]

**Balevski et al.**

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[54] **APPARATUS FOR CONTINUOUS CASTING OF METALS**


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[ * ] Notice: The portion of the term of this patent subsequent to Mar. 21, 1989, has been disclaimed.

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[21] Appl. No.: **415,752**

**Related U.S. Application Data**

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[30] **Foreign Application Priority Data**

Apr. 7, 1971 Bulgaria ..... 17295

[52] **U.S. Cl.** ..... **164/259;** 164/55; 164/281

[51] **Int. Cl.** ..... **B22d 27/20**

[58] **Field of Search** ..... 164/55, 66, 67, 68, 82, 164/119, 259, 266, 281; 266/34 T



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,650,313 | 3/1972 | Balevski et al. | 164/259 X |
| 3,689,048 | 9/1972 | Foulard et al. | 266/34 T |
| 3,718,175 | 2/1973 | Rinesch | 164/259 X |



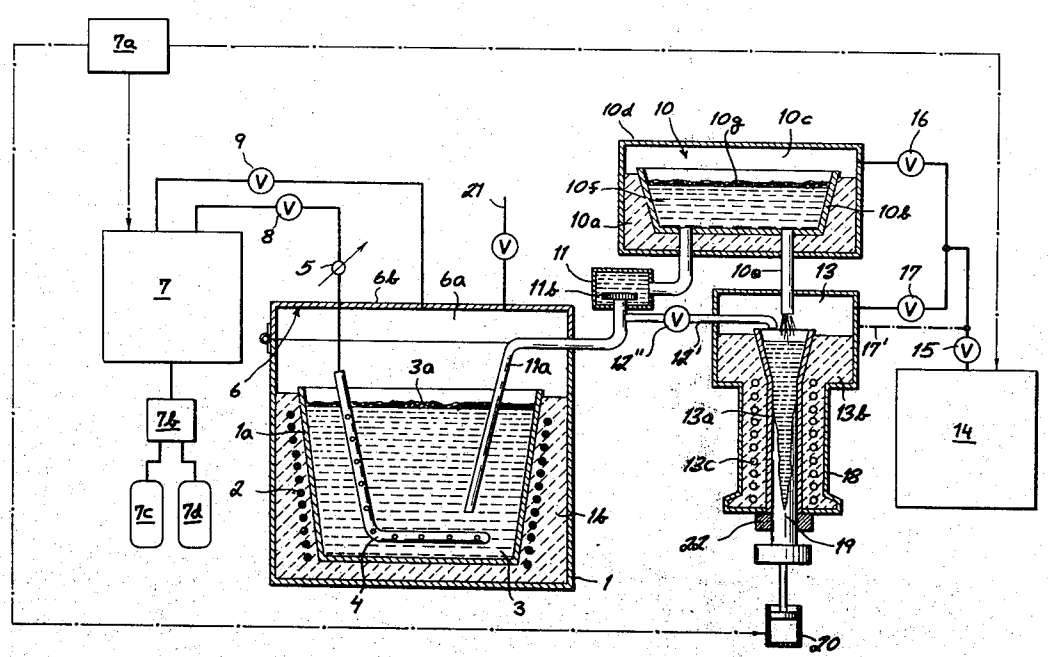
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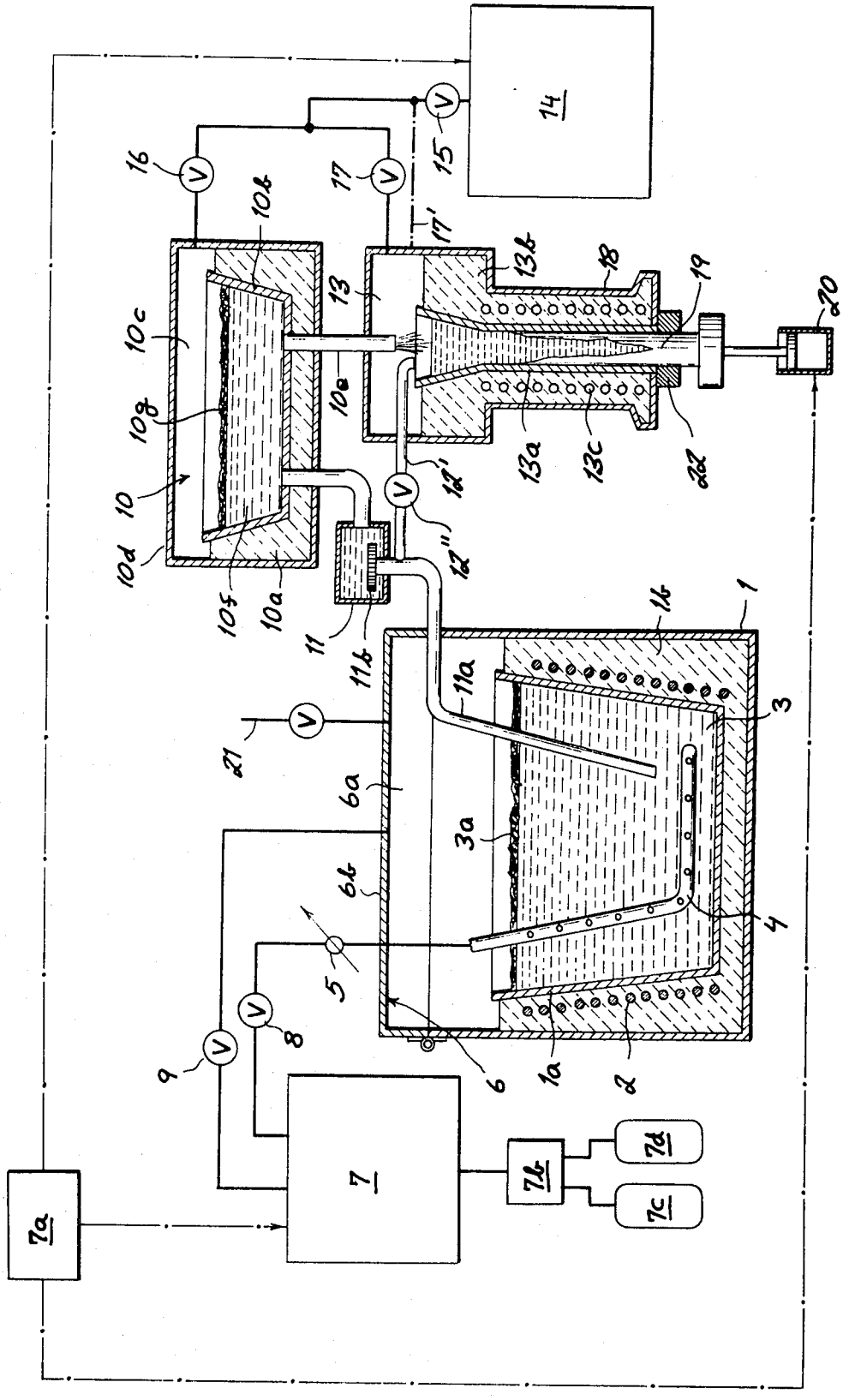


[57] **ABSTRACT**

A system for the continuous casting of a molten metal containing gas in solution wherein the molten metal is treated with gas under pressure in a first chamber containing the soluble gas together with an inert gas which may or may not dissolve in the melt, and is delivered to a second chamber and thereafter to a final chamber provided with the continuous-casting mold, the latter two chambers being maintained under super atmospheric pressure by the soluble gas.


**5 Claims, 1 Drawing Figure**




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17'
10b
13b
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19
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10c
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10e
10g
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10d
12'
13a
13c
22
12''
10f
10a
11
11b
1
1b
11a
3
21
6a
3a
6b
4
5
8
9
6
1a
2
7
7a
7b
7d
7c

# APPARATUS FOR CONTINUOUS CASTING OF METALS

This is a division of application Ser. No. **241,251**, filed Apr. **5, 1972.**

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is related to our copending application Ser. No. **811,450** filed Mar. **28, 1969** and extending the principles set forth in then-pending application Ser. No. **667,409** of Sept. **13, 1967.** That application, in turn, represented a further development of the system described in an application Ser. No. **173,052** issued as U.S. Pat. No. **3,196,501,** and itself has issued as U.S. Pat. No. **3,532,154.**

## FIELD OF THE INVENTION

Our present invention relates to a method of and an apparatus for the continuous casting of metal bodies and, more particularly, to the continuous or semicontinuous casting of elongated metal bodies from a melt containing a dissolved gas affecting the properties of the metals.

## BACKGROUND OF THE INVENTION

The aforementioned applications and patents describe our prior developments in the field of intermittent casting wherein a melt of metal or some other material such as a synthetic resin, is maintained under pressure to avoid evaporation (volatilization) and spontaneous decomposition which may occur with heating at low pressures. The melt is generally induced to flow from the superatmospheric melt chamber to a superatmosheric mold chamber, e.g. through a syphon or by gravity, and is thus maintained under pressure in both chambers while a pressure differential is applied between the mold and the melt to induce the metal to flow. Such systems are generally directed to the production of individual casting in a mold cavity of predetermined volume and configuration.

It is also known to provide continuous casting systems in which an open-ended mold is charged from one extremity with the molten metal and a solidified or semisolidified elongated bady is drawn out of the other end. Continuouscast ingots may be rolled, forged, drawn or otherwise shaped to produce rod, tube, wire, strip and like elongated articles and such articles of a well-defined cross-section may be made without subsequent handling by the continuous-casting method. It should be noted that the term "continuous casting" is not used to suggest that the casting operation is never interrupted or that molten metal is poured into the receiving end of the mold without cessation. The term is one of convenience used, as is known in the art, to indicate the formation of an ingot, bar, bloom, billet or the like which is elongated and generally is of greater length than the mold in which it is formed. Hence the production of any solidifying metal body which emerges from a mold as additionally metal is cast into it, will be defined hereinafter as a "continuously cast ingot."

In the continuous casting of molten metals, attempts have been made to use metal melts which are solutions containing, in addition to a pure metal and an alloy, soluble gases which in some way affect the sharacteristics of the solidified metal. For example, it is known that steel can be modified to improve some of its characteristics by treating it with nitrogen to the point that at least some of the nitrogen is solubilized in the steel.



Efforts to apply gas-solubilizing techniques to continuous casting has generally proved ineffective and it has heretofore been the practice to confine solubilization approaches to interrupted casting operations while avoiding any use of gas in association with continuous casting. The latter avoidance derives, it is believed, from the experience of many workers in the field that the association of gas with continuously-cast molten metal results in gas inclusions and the formation of large gas-filled pockets in the molten metal.

## OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide an improved method of and apparatus for the continuous casting of molten metals.

It is another object of the invention to provide a method of continuously casting rod, tube, wire, strip and like elongated articles or a precursor therefor (ingot or bar) which will avoid the above-mentioned disadvantages and can be constituted from a metal containing dissolved gas which remains dissolved even in the solidified state of the metal.

Still another object of the invention is the provision of a system for the continuous casting of a molten metal containing dissolved gas in such manner as to avoid intercrystalline gas evolution, separation or porosity as has resulted in the past with metals containing gas as a result of the sharp decrease in solubility during the solidification process.

## SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, in a system for the continuous casting of a molten metal containing a dissolved gas capable of modifying the metallurgical properties of the cast (solidified product) wherein the melt is treated under a gas pressure produced by a mixture of the soluble metallurgically effective gas and a gas inert with respect to metallurgical properties. Subsequent to this treatment and preferably at a location spatially removed from the treatment location, the melt is solidified under gas containing a higher partial pressure of the soluble gas. The apparatus for carrying out the method of the present invention thus may comprise a first chamber wherein the molten metal is treated with gas under pressure (i.e., the mixture of the soluble gas having metallurgical properties at a first partial pressure) and the inert gas, and a second chamber connected to the first and receiving the melt therefrom. A third or final chamber provided with or communicating with the continuous-casting mold is connected to the second or intermediate chamber and means is provided for maintaining the second and third chambers under a superatmospheric pressure of the soluble or dissolving gas so that the latter has a higher partial pressure in these chambers than in the first chamber.

According to a more specific feature of the invention, the first or treatment chamber comprises a housing above a ladle for the melt which may be pressurized and is connected by a syphon tube reaching into the melt to a second vessel also maintained under pressure via a housing above this ladle or pan. The pressure differential between the chambers above the melts in

these vessels serves to displace the molten metal from the first chamber to the second through the syphon tube in accordance with principles discussed in the prior applications and patents mentioned above. The third chamber, preferably located below the second vessel is provided with a continuous casting mold which, advantageously, is elongated and is provided with cooling means along the mold wall to solidify the mold cast therein. The chamber above the mold is advantageously connected with the chamber above the second vessel for control of a pressure differential therebetween to regulate the rate at which the molten metal is introduced into the mold. It has been found to be advantageous, moreover, to provide in the syphon tube a one-way valve system for mechanically blocking molten-metal communicating between the first and second vessels. Furthermore, we may provide a direct connection between the first vessel (e.g. via the syphon tube) and the mold chamber as will become apparent hereinafter.

## DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description reference being made to the accompanying drawing in which the sole FIGURE is a diagram of an apparatus embodying the principles of the invention.

## SPECIFIC DESCRIPTION AND EXAMPLE

In the drawing, we show an apparatus for carrying out the method of the present invention, the apparatus comprising a ladle **1***a* received in a mass of insulating material **1***b* of the treatment vessel **1**, the ladle being heated by a coil **2** surrounding it within the insulating mass and preferably constituting an induction coil of conventional construction. The vessel **1** is closed by a cover **6** defining a gas space **6***a* above the melt **3** therein and having a flap **6***b* openable to afford access to the ladle. A perforated pipe **4** reaches downwardly into the melt and is connected via a throttle or pressure-reducing valve **5** and a cut-off valve **8** with a source **7** of gas under pressure. The gas may thus be bubbled through the melt which may have a layer **3***a* of slag thereabove. For venting the space **6***a*, a further valve and conduit **21** is provided which may open to the atmosphere. A control device **7***a* may be provided to connect the gas-pressure source **7** with a gas pressure source **14** to be described subsequently so that the molten metal may be induced to flow through a syphon tube **11***a* through a conduit **11, 12** to the second vessel **10.**

Pressurized gas source **7** serves to supply the soluble gas (nitrogen) capable of affecting the metallurgy of the melt (steel) in mixture with an inert gas (argon) having no substantial metallurgical effect. The respective partial pressures may be established by a conventional flow or pressure controller **7***b* connected to the respective gas bottles **7***c* and **7***d*. A further valve **9** and its conduit supplies the gas mixture to the chamber **6***a* above the melt.

The syphon **11, 12,** comprises a valve **11***b* which is of the one-way type to prevent return of the melt to the ladle **1***a*.

The second vessel or chamber **10** comprises an insulating body **10***a* carrying a ladle or trough **10***b* communicating with the treatment ladle **1***a* via the syphon **11,** 12. The space above the vessel **10***b* is represented at **10***c* and is closed by a cover **10***d*. This space is connected via a control valve **16** with the source **14** of soluble gas. A further valve **15** supplies this gas under pressure to valve **16** mentioned earlier and a valve **17** communicating with the third or mold chamber **13.** A discharge tube **10***e* leads from the bottom of the vessel **10***b* into the mold chamber **13** which is disposed above a continuous-casting mold **13***a* surrounded by a mass **13***b* of thermal insulation and a cooling coil **13***c*. The mold **13***a* in the solidification region **18** is capable of forming an elongated body or billet **19** which is drawn downwardly at a controllable rate by the drawing device **20** which operates to controlledly resist the gravitational descent of the billet. A seal **20** prevents escape of gas around the cast billet. Since the pressure differential defined by control unit **7***a* regulates the rate of flow between chambers **1** and **10,** through the syphon **11, 12,** the control **7***a* also synchronizes the actuating device **20** which may be of conventional construction. It has been found to be advantageous to provide, in some cases, a bypass for the intermediate chambers **10** in the form of a conduit **12'** which, with its valve **12''**, communicates directly between the first and third chambers. In this case a line **17'** is used in place of valves **17** and **16** to deliver the gas with high partial pressure of soluble gas to the "third" chamber.

In operation, the soluble gas/inert gas mixture is bubbled through a melt in ladle **1***a* for a treatment period sufficient to effect the desired homogeneity of the melt and dissolution of gas therein. Usually this time suffices for steady state to be achieved. The valve **9** is briefly opened to establish the desired pressure differential between chambers **10***c* and **6***a* to drive the molten metal through the syphon **11, 12** into the vessel **10***b* past the automatically open check valve **11***b*. This brief increase in pressure does not appreciably alter the degree of dissolution of the gas since it acts upon the slag or flux layer **10***g* and to deliver the molten metal to this bath below the slag layer. After a portion of the metal is transferred as described, the pressure in space **6***a* can be returned to its usual value by venting through valve **21.**

The pressure in chamber **10** is maintained at the level necessary to control the flow via conduit **10***e* into the mold and the gas is of a higher partial pressure of the soluble component than the gas used in vessel **1.** The absolute pressure in this part of the apparatus can also be considerably higher than that at which the melt is saturated with the soluble gas in the first vessel **1.** In this manner we have been able to compensate the billet for the normal decrease in the solubility of the gas during soldification to maintain the concentration of the gas in the end product **19.**

When a constant absolute pressure is required in the entire apparatus, we omit the intermediate chamber and directly connect the first vessel **1** with the final vessel **13** via conduit **12'** so that the atmosphere in the casting chamber is at the same pressure as the atmosphere in the treatment chamber (except for the moment of transfer) but the partial pressure of the soluble gas is greater in the casting chamber than in the treatment chamber.

Various measuring, controlling and regulating devices, known to the art, may be provided for controlling the levels of metal in the various vessels, regulating temperatures and gas pressures and for establishing the metal and melt compositions. The gas may be main-

tained dissolved in the melt through solidification to appear in solid solution in the cast billet without separation in the form of intercrystalline pores.

We claim:

**1.** An apparatus for the production of an elongated body, comprising:

a treatment vessel adapted to receive a bath of molten metal;

means forming a first chamber for treating the molten metal in said vessel with a gas mixture containing a soluble-gas as a component thereof at a low partial pressure;

a continuous- casting mold provided with a further chamber for exposing solidifying molten metal therein to gas pressure;

means connecting the chambers for transferring molten metal containing solubilized gas to said continuous casting mold; and means for subjecting the solidifying molten metal in said continuous casting mold to gas pressure in said other chamber of a higher partial pressure of said solubilizing gas.

**2.** The apparatus defined in claim **1** wherein said means connecting said chambers include a direct-flow conduit.

**3.** The apparatus defined in claim **1** wherein said means connecting said chambers includes a second chamber interposed between said first chamber and said other chamber and forming an intermediate receptacle for storing the molten metal received from said vessel prior to discharging it to said continuous-casting mold, said second chamber being maintained under a gas atmosphere having a relatively high partial pressure of said soluble gas.

**4.** The apparatus defined in claim **3** wherein said means connecting said chambers further comprises a syphon tube reaching downwardly from said receptacle into said vessel below the surface of the melt therein and communicating with said receptacle below the surface of a melt contained therein, a check valve in said syphon tube, and a downwardly extending duct connecting said receptacle with said other chamber, said apparatus further comprising first means before establishing a pressure differential between said first and second chambers for displacing molten metal through said syphon tube from said vessel into said receptacle, and second means for establishing a pressure differential between said second chamber and said other chamber for controlling the flow of molten metal from said receptacle into said continuous-casting mold.

**5.** The apparatus defined in claim **4** wherein said second means includes a source of gas containing said soluble gas at high partial pressure and respective valves connecting said source with said second chamber and said other chamber.

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