BEST AVAILABLE COPY

March 21, 1967 G. CAVALIER 3,309,928

APPARATUS FOR WITHDRAWING SAMPLES FROM MOLTEN METAL BATHS

Original Filed Nov. 13, 1962 2 Sheets-Sheet 1

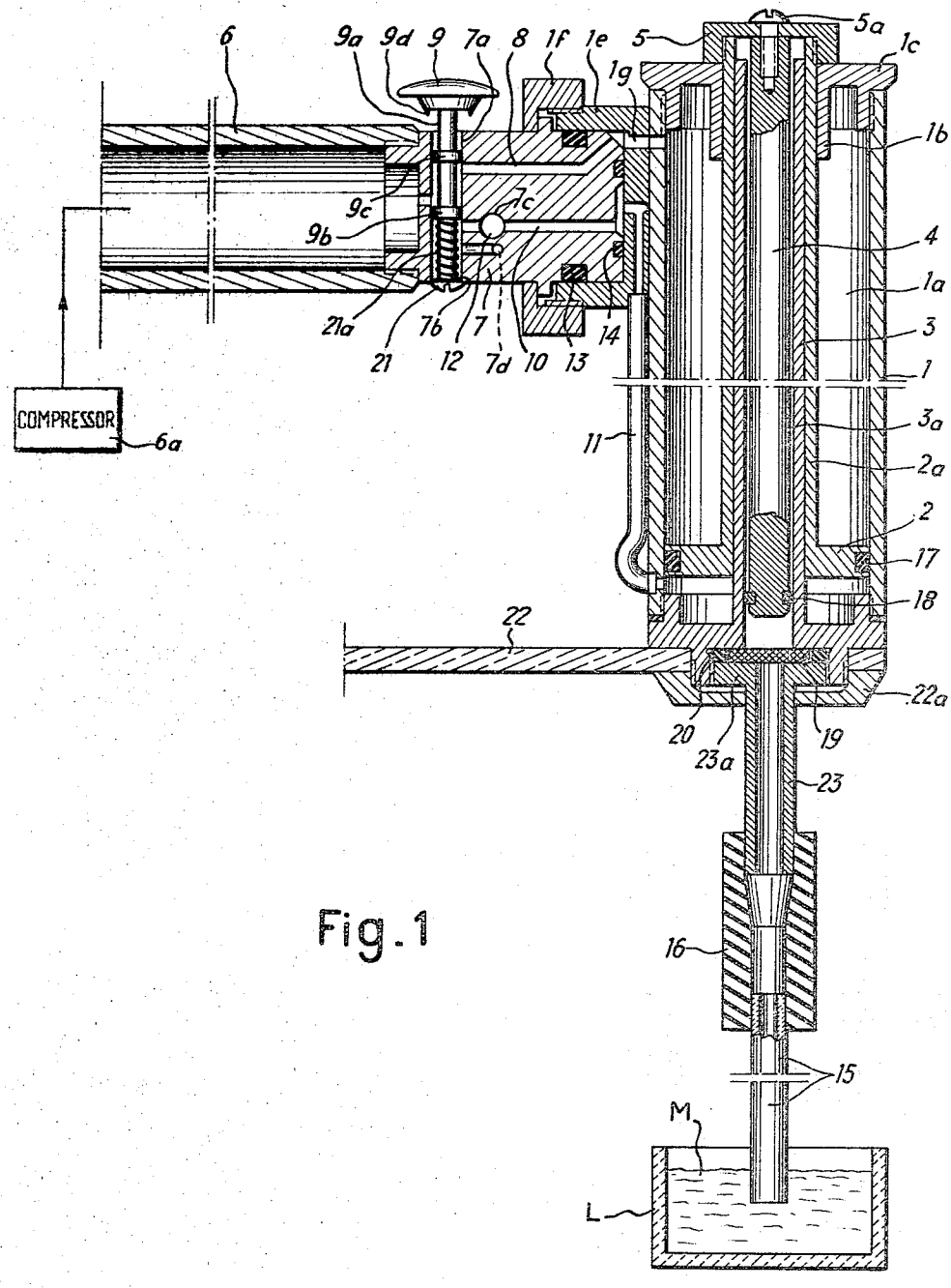


Fig. 1

Inventor
G. Albert Cavalier

APPARATUS FOR WITHDRAWING SAMPLES FROM MOLTEN METAL BATHS

Original Filed Nov. 13, 1962 2 Sheets-Sheet 2

Fig. 2

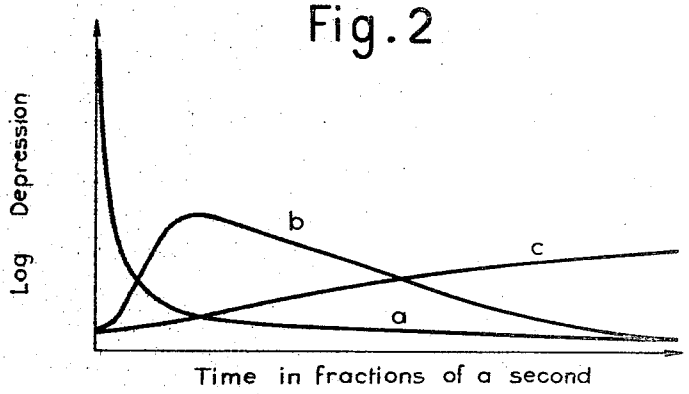


Fig. 3

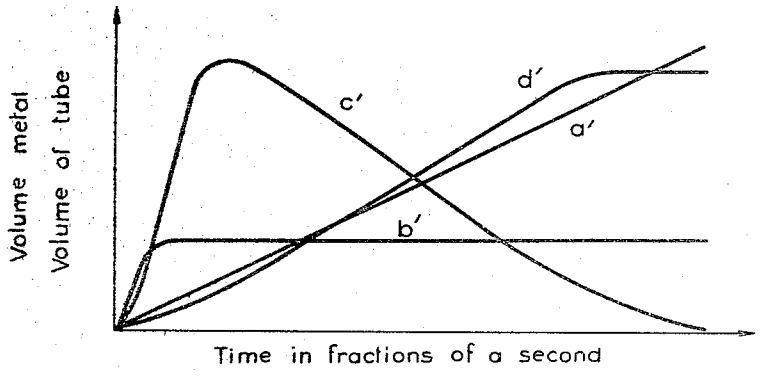
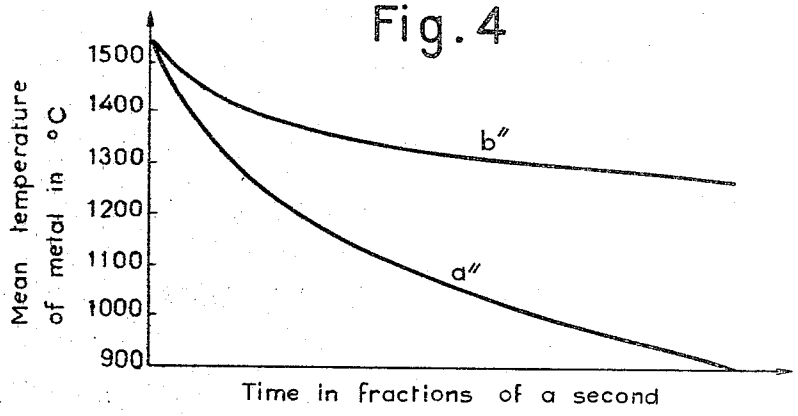


Fig. 4



Inventor
Georges Cavalier
By Michael S. Striker
Atty

United States Patent Office 3,309,928
Patented Mar. 21, 1967

3,309,928

APPARATUS FOR WITHDRAWING SAMPLES FROM MOLTEN METAL BATHS

Gilbert Cavalier, Saint-Germain-en-Laye, France, assignor to Institut de Recherches de la Siderurgie Francaise, Saint-Germain-en-Laye, France

Original application Nov. 13, 1962, Ser. No. 236,804, now Patent No. 3,255,634, dated June 14, 1966. Divided and this application Jan. 12, 1966, Ser. No. 520,249
Claims priority, application France, Nov. 14, 1961, 878,790, Patent 1,313,201
7 Claims. (Cl. 73—425.6)

This is a division of my copending application Serial No. 236,804, filed November 13, 1962, now Patent No. 3,255,634.

The present invention relates to an apparatus for withdrawing samples from molten metal, such as iron or steel. More particularly, the invention relates to an apparatus for obtaining samples of solidified metal which, without any further treatment, may be subjected to spectrographic analysis or to other types of tests.

It is customary to subject metallic substances to a spectrographic analysis which is a preferred way of testing metal because it can be carried out within very short periods of time. Attempts were made to provide an apparatus which may be used to furnish samples in all stages of production and processing of molten iron, steel and other metallic substances. Samples withdrawn from molten metal are examined with a view to determine whether or not the molten substance is ready for pouring into molds.

Heretofore, samples of molten metal were withdrawn with the help of evacuated sampling tubes, i.e., with tubes from which air was evacuated prior to introduction of such tubes into a bath of molten metal. Suction prevailing in the interior of an evacuated sampling tube will cause the molten substance to penetrate into the tube, and the height of the column will depend on the degree of evacuation. on the specific weight of the molten substance, on the diameter of the tube, and/or on the melting temperature of metal. However, it is a well known fact that molten material penetrating into the interior of an evacuated tube will splash and will form a series of layers along the internal surface of the tube, i.e., the sample is not of satisfactory consistency. Instead of obtaining a sample which resembles a solid rod, the resulting sample is a hollow body having a pronounced cavity along the entire or along the major part thereof and is often formed with a plurality of pores such as are found in a body of spongy consistency. Obviously, such samples are not suited for immediate spectrographic analysis.

Accordingly, it is an important object of the present invention to provide an apparatus for withdrawing samples from baths of molten metal which can furnish samples of such configuration and consistency that the samples may be tested in a spectrograph without any further processing.

Another object of the invention is to provide an apparatus of the just outlined characteristics which can furnish samples which are without pores or blowholes and without so-called pipe such as is formed at the top of an improperly teemed ingot.

A further object of the instant invention is to provide an apparatus of the above described type which can furnish samples which solidify during or immediately subsequent to withdrawal of molten metal from a bath so that the samples are ready for examination within exceptionally short periods of time.

An additional object of my invention is to provide an apparatus of the above outlined characteristics which is equally suited for withdrawal of samples from molten ferrous or non-ferrous substances.

A further object of the invention is to provide an apparatus for withdrawing samples from molten metal which is constructed and assembled in such a way that it may be readily converted for withdrawal of samples from different types of molten metals.

An additional object of the invention is to provide an apparatus which is capable of withdrawing highly satisfactory samples such as may be subjected to spectrographic analysis or to other tests without further processing and which withdraws samples in a fully automatic way.

Still another object of my invention is to provide an apparatus of the above outlined characteristics which is of lightweight construction, which may be readily handled by semiskilled persons, which can be manipulated by a single person, and which can be reused as often as desired.

Another object of the invention is to provide an apparatus which is capable of withdrawing molten metal without any splashing and which will furnish satisfactory samples without any danger to the operator.

An additional object of the invention is to provide an apparatus of the above outlined characteristics which may be readily adjusted to furnish samples of different lengths and which may be conveniently transported to different sources of molten metal so that a single apparatus will suffice to furnish samples from a large number of sources in a metallurgical plant.

With the above objects in view, one feature of my invention resides in the provision of an apparatus which comprises a sampling tube of heat-resistant material (such as silica) one end of which may be inserted into molten metal, and adjustable pressure reducing means connected with the other end of the sampling tube. Such pressure reducing means may comprise a cylinder and a plunger assembly whose cylinder is communicatively connected with the sampling tube, and means for reciprocating the plunger at a predetermined speed so that the rate at which the plunger evacuates air fom the sampling tube may be adjusted and varied within a desired range. The means for reciprocating the plunger preferably comprises a pneumatically operated motor, and the plunger may be arrested in a fully automatic way as soon as it completes a suction and a return stroke or immediately after it completes a suction stroke.

Certain other features of my improved apparatus reside in the provision of specially constructed adjusting means for the aforementioned reciprocating means, in the provision of a readily separable connection between the sampling tube and the remainder of the apparatus, in the provision of means which shields the operator from the molten metal at the time a sample is being withdrawn from the bath, and in the provision of a specially constructed sampling tube which forms samples of such smoothness that they may be used in various testing devices without any further processing.

The apparatus of my invention is preferably constructed in such a way that, when the apparatus is put to use, pressure prevailing in the sampling tube decreases despite the fact that molten metal penetrates into the tube. As a rule (but not necessarily), the apparatus comprises a cylinder whose chamber is connected to the tube and a plunger which is reciprocated by a motor so that it may evacuate air from the tube while moving in a given direction. The motor may but need not move the plunger at constant speed. The time interval during which the plunger performs an evacuating stroke at least equals the time interval during which molten metal penetrates into the sampling tube, i.e., the evacuation of air is continued at least until such time when the molten metal ceases to rise in the sampling tube.

In actual use of the improved apparatus, one end of the sampling tube is inserted into a bath of molten metal (e.g., into a ladle), and the apparatus then gradually evacuates

air from the interior of the sampling tube in such a way that the depression is a function of time whereby splashing and resultant formation of pipe or blowholes is prevented in a fully automatic way. The interior of the sampling tube may be maintained at atmospheric pressure up to the very moment when the tube is inserted into molten metal, and I prefer to utilize a tube which is maintained at room temperature or at least at a temperature which is well below the melting point of the metallic substance so that metal which is sucked into the interior of such tube as soon as the evacuating step begins may solidify within a very short period of time.

It is often preferred to regulate the evacuation of air in such a way that the drop of pressure is a linear function of time, i.e., that the evacuation progresses at the same rate as the duration of operation.

It will be seen that I provide an apparatus which can evacuate air from a sampling tube in such a way that pressure prevailing in the tube is reduced gradually while molten metal penetrates into the tube, and the arrangement is preferably such that, at the time it is immersed into molten metal, the interior of the tube is maintained at a pressure which at least approximates atmospheric pressure. The rate at which pressure prevailing in the tube is reduced is selected with a view to compensate for growing weight of metal which penetrates into the tube and also to compensate for increasing viscosity of the metal since the sample solidifies within a very short period of time.

The apparatus of my invention constitutes a substantial improvement over all such prior apparatus of which I am aware at this time. Thus, in addition to the previously described method of using a sampling tube which is evacuated prior to insertion into molten metal, it was already proposed to preheat the sampling tube and to thereupon evacuate the tube prior to immersing one of its ends into a bath of molten metal. It was found that, instead of being helpful, such preheating is actually detrimental because, as molten metal penetrates into an evacuated tube, it automatically raises the pressure prevailing in the tube since the volume of the air-containing space in the tube decreases so that, if the metal is not permitted to solidify immediately or shortly after it penetrates into the tube, it will begin to drip from the tube. As a result of such dripping, metal which remains in the tube will form a substantially tubular sample because the material adhering to the wall of the tube will solidify more rapidly than the core.

It was also suggested to evacuate air with the help of a spring biased piston which is released after one end of the sampling tube is immersed into molten metal. Such apparatus have met with little success because a suddenly moving piston produces an instantaneous drop in pressure so that molten metal which is being drawn into the tube behaves in the same way as if the tube were evacuated prior to its immersion into the bath. Experiments conducted with spring-biased evacuating pistons have shown that molten metal will splash onto the walls of the sampling tube and will form a sample which exhibits pronounced pipe and blowholes.

Furthermore, a piston which is biased by a spring will perform a suction stroke at such *a high rate of speed that* the evacuating step is completed before the metal has a chance to attain a desired height in the interior of the sampling tube. Therefore, at least during a portion of the sampling operation, molten metal must rise into a preevacuated portion of the sampling tube which is tantamount to evacuation prior to immersion into the bath. In other words, pressure is not being reduced during the entire duration of penetration of molten metal into the sampling tube. In fact, as soon as the spring-biased plunger reaches the end of its suction stroke, pressure prevailing in the empty space of the sampling tube begins to rise since the volume of such empty space decreases at the same rate at which molten metal continues to enter into the tube. On the other hand, the apparatus of my invention can be manipulated in such a way that pressure is reduced continuously despite the fact that the volume of the empty space in the tube decreases while molten metal is being drawn from the bath. Therefore, and particularly since I also take into consideration the fact that the viscosity of metal which is already contained in the tube increases at a rapid rate, the sample obtained in accordance with my method is of exceptionally satisfactory homogeneousness and is without cavities so that it is ready for testing in a spectograph or in another apparatus.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved apparatus itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of a specific embodiment with reference to the accompanying drawings, in which:

FIG. 1 is an axial section through an apparatus which embodies my invention;

FIG. 2 is a diagram wherein the curves represent the drop in pressure in a sample tube during withdrawal of molten metal by means of conventional apparatus and by the apparatus of FIG. 1;

FIG. 3 is a similar diagram wherein the curves represent the ratio of the volume of metal to the volume of tube in sampling tubes which form part of conventional apparatus and of an apparatus which embodies my invention; and

FIG. 4 is a further diagram wherein the curves represent mean temperatures of metallic samples during withdrawal from a bath by means of conventional apparatus and by the apparatus of my invention.

Referring now to FIG. 1 in greater detail, there is shown an apparatus which is utilized for withdrawing samples from baths of molten metal, such as molten steel or molten iron. The apparatus comprises a heat-resistant tubular member **15**, hereinafter called sampling tube, whose lower end may be inserted into a bath M of molten iron contained in a ladle L. The means for reducing the pressure prevailing in the interior of the tube **15** comprises a pneumatic motor including a double-acting cylinder-and-piston assembly which comprises an outer cylinder **1** having a downwardly extending nozzle **23** whose lower end is detachably coupled to the upper end of the tube **15** by a connecting means here shown as a resilient sleeve **16** consisting of rubber or the like. The material of the tube **15** should be capable of resisting temperatures which prevail in a bath of molten metal; for example, this tube may consist of refractory material.

The internal chamber **1***a* of the outer cylinder **1** accommodates an annular piston **2** having an upwardly extending hollow tubular piston rod **2***a* into which is telescoped an inner cylinder **3**. This cylinder **3** is rigid with the outer cylinder **1** and is coaxial with the nozzle **23**. The chamber **3***a* of the inner cylinder **3** accommodates an elongated air evacuating plunger **4** whose upper end is secured to an internally threaded cap **5** (see the screw **5***a*). This cap constitutes a coupling between the plunger **4** and the piston rod **2***a* and is provided with internal threads mating with external threads at the upper end of the piston rod which latter extends through an annular collar **1***b* forming part of a threaded cover **1***c* which is screwed into the upper end of outer cylinder **1**. It will be noted that the cap **5**, the screw **5***a* and the piston rod **2***a* form a motion transmitting means providing a rigid connection between the piston **2** and the plunger **4**, and this connection compels the plunger to reciprocate in the inner chamber **3***a* when the piston reciprocates in the outer chamber **1***a*. The piston **2** is provided with a circumferential groove for an O-ring **17** which is in sealing engagement with the internal surface of the outer cylinder **1** to prevent leakage of pressure fluid between the upper and lower portions of the chamber **1***a*. A similar sealing ring **18** is accommodated in a

circumferential groove provided at the lower end of the plunger 4.

The lower portion of the cylinder chamber 1*a* communicates with a pipe 11 leading to a channel 10 provided in a reversing valve 7 which is detachably secured to a nipple 1*e* fixed to the upper portion of the outer cylinder 1. The connection between the nipple 1*e* and the valve 7 comprises an internally threaded annular hut 1*f*. A second channel 8 of the reversing valve 7 communicates with a duct 1*g* leading to the upper portion of the cylinder chamber 1*a*. Suitable gaskets 13 and 14 prevent leakage of compressed fluid between the nipple 1*e* and the valve 7 as well as between the channels 8, 10. The means for alternatively admitting compressed fluid to the channels 8, 10 comprises a manually operable valve member 9 whose stem 9*a* extends through a transverse bore 7*a* drilled into the body of the reversing valve 7. The length of the stem 9*a* exceeds the length of the bore 7*a* and its lower end, as viewed in FIG. 1, is connected to a screw 21 whose head acts as a stop by normally abutting against the underside of the reversing valve 7 in response to the bias of a helical spring 21*a* which is inserted into the bore 7*a* and which acts between an internal shoulder 7*b* of the reversing valve and a collar 9*b* on the stem 9*a*. The diameter of the head of the screw 21 is greater than the diameter of the passage in the shoulder 7*b* so that the spring 21*a* cannot eject the valve member 9. In the position of FIG. 1, the collar 9*b* prevents the flow of compressed fluid from a supply pipe 6 to the channel 10, and a second collar 9*c* of the stem 9*a* simultaneously seals the upper end of the bore 7*a* while permitting compressed fluid to flow from the pipe 6 through the channel 8 and duct 1*g* and into the upper portion of the cylinder chamber 1*a*. In other words, the fluid is free to move the piston 2 to its lower end position in which this piston expels fluid from the lower portion of the cylinder chamber 1*a*. The pipes 6, 11, the channels 8, 10 and the duct 1*g* together constitute a conduit means which connects a source 6*a* of compressed fluid with the chamber 1*a* at the opposite sides of the piston 2.

When the operator depresses the head of the valve member 9 against the bias of the spring 21*a*, the collar 9*c* seals the pipe 6 from the channel 8 but the collar 9*b* permits compressed fluid to flow through the channel 10 and pipe 11 into the lower portion of the cylinder chamber 1*a*. At the same time, the collar 9*c* permits escape of spent fluid through the channel 8 and through the upper end of the bore 7*a* so that the piston 2 may move upwardly to entrain the plunger 4 which evacuates air from the interior of the sampling tube 15 to thereby draw molten iron from the ladle L at a speed which is determined by an adjusting screw 12 serving as a means for regulating the rate of fluid flow through the channel 10. This adjusting screw is preferably provided with a pointed tip and its threads mate with internal threads of a bore 7*c* in the valve 7, this bore communicating with the channel 10. It will be readily understood that, by turning the screw 12, an operator may regulate the rate at which compressed fluid can flow to the underside of the piston 2 to thereby control the speed at which the plunger 4 moves to its upper end position. In other words, the screw 12 may adjust the speed at which pressure in the tube 15 drops and hence the rate at which molten iron rises in this tube.

The head of the valve member 9 is provided with one or more projections 9*d* which prevent it from sealing the upper end of the bore 7*a* when the valve member is depressed against the bias of the spring 21*a*. One or more fluid evacuating ports 7*d* which communicate with the bore 7*a* at a point close to the shoulder 7*b* permit the fluid to escape from the channel 10 when the valve member 9 is not depressed.

A fluid-permeable filter 19 is inserted into the outer cylinder 1 to prevent entry of metal into the inner chamber 3*a*. This filter may comprise several layers (for example, three layers) of fine netting consisting of nickel wire with a diameter of 0.5 mm. As shown, the filter 19 is accommodated in a recess provided in the underside of the outer cylinder 1 and is retained therein by a threaded boss 23*a* which is rigid with the upper end of the nipple 23 and which is screwed into the outer cylinder. A gasket 20 prevents leakage of air about the boss 23*a*.

A tinted panel 22 of translucent material (e.g., Plexiglas) is secured to the lower end of the cylinder 1 by a cap screw 22*a* and enables an operator to observe without any danger to his eyes the tube 15 at the time the latter is immersed into the bath M. For example, the panel 22 may be tinted green.

In the illustrated apparatus, compressed fluid supplied by the pipe 6 is air delivered by a suitable source here shown as a compressor 6*a*.

The apparatus of FIG. 1 operates as follows:

At the time an operator desires to withdraw a sample from the bath M, the piston 2 assumes the position of FIG. 1 because the lower portion of the outer cylinder chamber 1*a* is free to communicate with the atmosphere via port 7*d* and because the pipe 6 communicates with the duct 1*g*, i.e., the collar 9*b* of the valve stem 9*a* seals the supply pipe 6 from the channel 10 because the valve member 9 is in its inoperative position. The pressure prevailing in the sampling tube 15 equals atmospheric pressure.

The operator then inserts the lower end of the sampling tube 15 into the bath M and depresses the valve member 9 to its operative position so as to connect the pipe 6 with the lower portion of the chamber 1*a* whereby the plunger 4 is caused to ascend and to reduce the pressure prevailing in the interior of the sampling tube. Molten iron begins to rise and forms in the tube 15 a solid column or bar whose height depends on the ratio of the volume of the inner chamber 3*a* to the volume of the tube 15. When the plunger 4 reaches the upper end of its stroke, the operator releases the valve member 9 and withdraws the tube 15 from the bath M. The tube 15 is then detached from the nipple 23 and the sample is removed to be subjected to spectrographic examination in a manner not forming part of this invention. Once the head of the valve member 9 is released, the spring 21*a* immediately returns the stem 9*a* to the idle position of FIG. 1 and the piston 2 automatically descends to its lower end position because the pipe 6 is free to communicate with the duct 1*g* while air contained in the lower portion of the outer cylinder chamber 1*a* is free to escape via port 7*d*. The speed at which the plunger 4 is caused to rise in response to depression of the valve member 9 depends on the position of the adjusting screw 12, i.e., on the extent to which the tip of this screw obstructs flow of compressed fluid into the conduit 11.

The ratio between the effective surfaces of the piston 2 and plunger 4 is sufficiently large to insure that the speed at which the plunger 4 rises depends mainly on the position of the adjusting screw 12. Also, the internal diameter of the tube 15 is sufficiently small to insure that the speed at which the plunger 4 rises is not affected by the fact that the lower end of the tube 15 is sealed at the time this tube dips into the bath M. For example, the air evacuating action of the plunger 4 may be selected in such a way that a sampling tube having an internal diameter of 3.5 mm. would draw 8 $cm.^3$ of water while the plunger 4 moves from its lower to its upper end position. This would correspond to withdrawal of 3 $cm.^3$ of mercury from a mercury bath, i.e., to a column having a height of close to 30 cm. Under ideal conditions, the same apparatus would withdraw a sample bar of molten iron with a height of about 40 cm. However, the height of the sample bar is always less than 40 cm. because the metal is cooled very rapidly and hardens in the tube.

The speed at which the plunger 4 rises may be in the range of 10 cm./sec., but such speed will be changed slightly if one wishes to use the apparatus first for with-

drawal of molten iron and thereupon for withdrawal of molten steel or vice versa.

It will be noted that, in contrast to conventional apparatus of which I am aware at this time, the apparatus of FIG. 1 begins to evacuate air only after the tube **15** is inserted into the bath M and that such withdrawal of air is gradual. In other words, at the time the lower end of the tube **15** is immersed into molten metal, the interior of this tube is maintained at atmospheric pressure, and the pressure thereupon drops gradually to avoid splashing of metal. Such splashing will occur invariably whenever an evacuated tube is immersed into a metal bath. Splashing is due to the fact that a stream of molten metal is sucked at a high speed when one end of an evacuated tube is immersed into the bath. The aspirating effect of an evacuated tube causes the metal entering the evacuated space to ascend along the walls of the tube and to form a series of layers or laminations which in their entirety constitute a tubular rather than a solid bar- or rod-like sample. At the very best, the sample obtainable with an evacuated sampling tube is of spongy consistency having at its upper end a depression analogous to so-called pipe which develops in the upper portions of ingots. Such tubular or spongy (i.e., highly porous) samples are not suited for spectrographic analysis or for other types of tests.

Referring to FIG. 2, there is shown a diagram with curves *a, b* and *c* which are respectively illustrative of pressures prevailing in sampling tubes forming part of two conventional apparatus (curves *a* and *b*) and in the sampling tube **15** of an apparatus of the type shown in FIG. 1 (curve *c*). The curve *a* illustrates how the pressure in a sampling tube varies if the tube is evacuated prior to immersion into a bath of molten metal. It will be noted that the pressure rises very rapidly as soon as the tube is immersed into the bath because the volume of its internal space decreases within a few fractions of a second. This is due to the fact that molten metal rises with a sudden splash.

The curve *b* is indicative of pressures prevailing in a sampling tube which is evacuated by a spring-biased plunger. This curve shows that the pressure rises very rapidly so that it invariably causes splashing of molten metal along the internal surface of the sampling tube.

The curve *c* indicates that evacuation of the sampling tube **15** is gradual so that no splashing occurs and that the sample withdrawn from a bath may assume the form of a solid rod. Thus, while the curve *b* indicates that a sampling tube which is evacuated by means of a spring already constitutes an improvement over a sampling tube (curve *a*) which is evacuated prior to immersion into the bath, FIG. 2 shows that gradual drop in pressure (as indicated by the curve *c*) will insure gradual withdrawal of molten metal without splashing and without resultant pipe or blowholes in the hardened bar.

The curves shown in the diagram of FIG. 3 illustrate the rate at which a sampling tube is filled with molten metal in an ideal apparatus (curve *a'*), in an apparatus which evacuates the tube prior to immersion into the bath (curve *b'*), in an apparatus whose sampling tube is heated prior to immersion into the bath (curve *c'*), and in the apparatus of my invention (curve *d'*). Curve *b'* shows that molten metal rises very rapidly and that the rate of ascent thereupon suddenly drops to zero which is indicated by the horizontal portion of this curve. Curve *c'* illustrates that a preheated tube is filled within a small fraction of a second and that molten metal thereupon flows back into the bath because it does not harden in the tube. This is due to the fact that a preheated tube prevents rapid hardening of the sample. It will be noted that the curve *d'* approaches rather closely the ideal curve *a'*, i.e., the sampling tube **15** of my apparatus is filled gradually because it is not preheated and because the plunger **4** or **4'** insures that evacuation of air is gradual and is proportional to the speed at which molten metal rises in this tube.

The curves *a''* and *b''* in the diagram of FIG. 4 illustrate the rate at which a sample is cooled in the sampling tube **15** (curve *a''*) and in a preheated tube (curve *b''*). It will be noted that metal in a preheated tube does not harden at the same rate at which it is being withdrawn from the bath (compare curves *b''* and *c'*), whereas a tube which is maintained at room temperature or at a temperature well below the melting point of the metal insures that the metal hardens at the same rate at which it is being sucked from the bath (compare curves *a''* and *d'*). The total time necessary for withdrawing a sample from the bath is normally less than one-fifth of a second, this being the time necessary to allow for hardening of a sample bar whose length is between about 10–30 cm.

The apparatus of my invention is especially suited for withdrawal of samples from ladles. The ladle is filled with molten metal which is withdrawn from an open-hearth furnace, from a converter or from another source of molten metal, and the lower end of the sampling tube is then dipped into the liquid material. In the next step, the operator depresses the head of the valve member **9**. If the apparatus is used for withdrawal of samples from a bath of molten steel, it is applied after the usual deoxidation. As a rule, the entire operation including the filling of a ladle may be completed within 30 seconds. The surfaces of bars obtained upon solidification of molten metal are glossy and free of oxide layers. If the surfaces of the sampling tube are finished to a high degree of polish, the surfaces of the samples are equally smooth, and I have found that the samples are perfectly quenched. The cooling occurs rapidly since, and as explained hereinabove, a bar with a length of 10–30 cm. and with a diameter of about 3.5 mm. will harden within a fraction of a second. In fact withdrawal and hardening of a sample bar are completed even before the plunger **4** reaches the upper end of its stroke. To insure that the bar cools without further delay, the tube **15** is removed from the nozzle **23** and is dipped into a water bath.

The samples obtained with the apparatus of my invention are of exceptionally satisfactory homogeneousness not only in lonigtudinal but also in transverse direction. When samples are drawn from phosphor-containing or hematite iron, there is no appreciable precipitation of graphite which is of considerable importance for determination of carbon contents by spectrographic analysis.

One of the most important factors which influence the quality of sample bars is the rate at which pressure is being reduced in the sampling tube during withdrawal of molten metal from a bath (FIG. 2). The total time of withdrawal is of lesser importance provided, of course, that such total time is less than the time necessary for solidification of the sample. Thus, as long as the apparatus of my invention is capable of regulating the evacuation of air in a manner to insure that pressure in the interior of the tube drops gradually, i.e., that such pressure is not permitted to rise while molten metal is being withdrawn, splashing with resultant lamination, porousness and/or tubularity of the sample will be avoided. As explained hereinabove, I prefer to construct the apparatus in such a way that, during withdrawal of a sample, the pressure prevailing in the interior of the sampling tube decreases gradually and that such drop in pressure occurs at a more or less constant rate. Any rapid changes in evacuation of air from the interior of the molten tube will cause splashing with all such detrimental effects which have been pointed out hereinabove.

The temperatures prevailing in the bath of molten metal do not have too much bearing on the operation of the apparatus. However, such temperatures must be taken into consideration in determining the dimensions and in selecting the material of the sampling tube. As a rule, a sampling tube which is used for withdrawal of samples from molten iron may be used for withdrawal of samples from molten steel. While a tube made of Pyrex (trademark) will be satisfactory for withdrawal of samples from

molten tin, a tube with greater resistance to heat (such as one consisting of pure silica) should be used in connection with molten iron or steel.

Another rather important factor which must be considered in selecting the dimensions and the material of a sampling tube is the difference between the temperature of molten metal and the temperature at which the sample chills. This difference does not vary beyond a certain range (about 200° C.) even if one deals with greatly different types of metals. As a rule, such difference is less if the melting point of a metal is rather low. I have found that, if the material of the sampling tube exhibits a great resistance to heat, the same tube may be used with many different types of metals. Of course, a sampling tube which is just resistant enough to stand a temperature corresponding to the melting point of tin cannot be used for withdrawal of samples from a bath of molten iron. On the other hand, a sampling tube which can withstand temperatures in the range of 1,600° C. and which can also withstand rapid cooling to a temperature at which molten tin begins to solidify will be made of a material which is different from the material selected for a tube which is used exclusively for withdrawal of molten iron or the like, i.e., a material which solidifies at much higher temperatures.

A further factor which influences the selection of material for the sampling tube is the specific heat of the metal and the rate at which molten metal can transmit heat to the walls of the sampling tube. Such factors influence the rate of speed at which the sample chills because they determine the rate of heat exchange between the metal and the surrounding air. The influence of these factors is rather difficult to determine with great accuracy since the area of contact between the sampling tube and the material which is being withdrawn from a bath of molten metal varies continuously when the material is sucked into the tube, i.e., the area of contact increases in dependency on the diameter of the tube and on the extent of evacuation of air from the tube.

The internal diameter and the wall thickness of the sampling tube determine the diameter and the cubic contents of the sample. Consequently, the dimensions of the sampling tube determine the rate at which the sample chills and hence the crystalline structure of the sample. Furthermore, the dimensions of the tube affect the dynamic conditions which exist during withdrawal of molten metal, particularly the influence of surface tension which, in turn, influences the length of the sample and the speed at which molten metal rises in the tube. The diameter of the tube may be selected arbitrarily within a certain range provided, of course, that the remaining factors which influence the length, the structure and the cooling of a sample are selected in conformity with such arbitrarily selected value. I have found that it is of considerable advantage if the speed at which air is being evacuated from the interior of the sampling tube is selected in conformity with the characteristics of a particular metal. For example, the wall thickness of the sampling tube will be selected in dependency on the characteristics of the material of the tube and on the difference between the melting point and the solidification temperature of the metal. Also, it is generally desirable to select the volume of the space in the evacuating cylinder 3 in dependency on the nature and temperature of a particular metallic substance. For example, the ratio between the useful volume of the space in the cylinder 3 and the volume of the space in the sampling tube will be about 2:1 when the apparatus is used for withdrawal of samples from molten iron, whereas such ratio is preferably about 10:1 or even 20:1 when the apparatus is used for withdrawal of samples from molten steel.

An additional important factor which influences the quality of samples is the finish of internal surface of the sampling tube. As a matter of fact, and insofar as I am informed at this time, this factor may exert a major influence on the quality of samples. An important requirement is that there be no generation of gases at the time the sampling tube is heated by contact with molten metal. Consequently, I prefer to avoid using sampling tubes which consist of frit (i.e., of a substance using sand as starting material). In such materials, large quantities of gases are entrapped in the pores between the individual particles and, when molten metal penetrates into the tube, such gases are heated and expand to thereby increase the pressure in the tube with resultant expulsion of molten metal back into the bath. Therefore I prefer at this time to use heat-resistant materials which are free of pores and without gas bubbles. For the same reasons, I prefer to avoid using sampling tubes whose internal surfaces are coated with films consisting of a substance which is likely to produce gases in response to decomposition at elevated temperatures. A very satisfactory material for use in the manufacture of sampling tubes to be employed in the apparatus of my invention is fused quartz. Such material may be used for the production of transparent sampling tubes which enable an operator to observe the formation of a sample bar. However, sampling tubes made of low-quality pure silica will be acceptable in many instances since the presence of minor quantities of gases will have no appreciable detrimental effect on the withdrawal of molten metal.

The apparatus of my invention may be put to use at all stations of a metallurgical plant, such as at the point where metal is tapped from a furnace, on the platforms of steel manufacturing plants, in blast furnaces, and elsewhere. As will be readily apparent upon perusal of the preceding description, the manipulation of my apparatus requires very little skill so that the apparatus may be entrusted to semiskilled or unskilled workers. The apparatus may be put to use without necessitating the provision of special conduits or conductors since valves for connection to a source of compressed air are always available in all modern metalurgical plants.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of my contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is:

1. An apparatus for withdrawing samples from molten metal, comprising a sampling tube of heat-resistant material having a first end insertable into molten metal and a second end; and adjustable pressure reducing means connected with the second end of said tube for evacuating air therefrom and for thereby causing molten metal to penetrate into the tube when said first end is inserted into a supply of molten metal, said pressure reducing means comprising a first cylinder, a second cylinder located within and coaxial with said first cylinder and communicating with the second end of said tube, an annular piston reciprocably received in said first cylinder and surrounding said second cylinder, a plunger reciprocable in the interior of said second cylinder, a hollow piston rod slidably guided on said second cylinder and connecting said piston and said plunger, a source of compressed gas, a pair of conduit means respectively providing communication between said source of gas and opposite ends of said first cylinder, and valve means in said conduit means for controlling the flow of a fluid into and from said first cylinder to thereby move said plunger whereby the plunger evacuates air from said tube while moving in a given direction, said valve means comprising a manually operable valve member normally assuming a first position in which it permits compressed gas to flow from said source through one of said conduit means to

said first cylinder and to compel said piston to move in a direction counter to said given direction, said valve member being movable to a second position in which the fluid flowing from said source through the other of said conduit means to said first cylinder compels the plunger to advance in said given direction, and adjustable throttling means in said other conduit means for throttling flow of compressed gas therethrough to regulate the speed of movement of said plunger in said given direction in dependence on the adjustment of said throttling means.

2. An apparatus as set forth in claim 1, further comprising connecting means for detachably coupling said cylinder with said sampling tube.

3. An apparatus as set forth in claim 1, wherein said sampling tube consists of quartz glass.

4. An apparatus as set forth in claim 1, wherein said sampling tube consists of transparent material.

5. An apparatus as set forth in claim 1, further comprising a protecting shield of translucent material secured to said pressure reducing means to permit observation of said sampling tube when said first end of the tube is inserted into molten metal.

6. An apparatus as set forth in claim 1, further comprising air-permeable filter means disposed between said sampling tube and said second cylinder to prevent penetration of molten metal into said second cylinder when the plunger is moved in said given direction.

7. An apparatus as set forth in claim 1, wherein said pressure reducing means further comprises a nipple communicating with said second cylinder and a sleeve of resilient material connecting said nipple with the second end of said sampling tube.

References Cited by the Examiner

UNITED STATES PATENTS

1,442,444	1/1923	Reeve.	
1,552,696	9/1925	Hartsock	103—51
1,941,453	1/1934	Whittington	103—50
2,083,522	6/1937	Morgan	137—544 X
2,485,526	10/1949	Bennett	103—50 X
2,987,047	6/1961	Young.	

JAMES J. GILL, *Acting Primary Examiner.*

RICHARD QUEISSER, *Examiner.*

J. MYRACLE, *Assistant Examiner.*