Oct. 31, 1950 W. BONSACK ET AL 2,528,208

PROCESS OF SMELTING METALS

Filed July 12, 1946 3 Sheets-Sheet 1

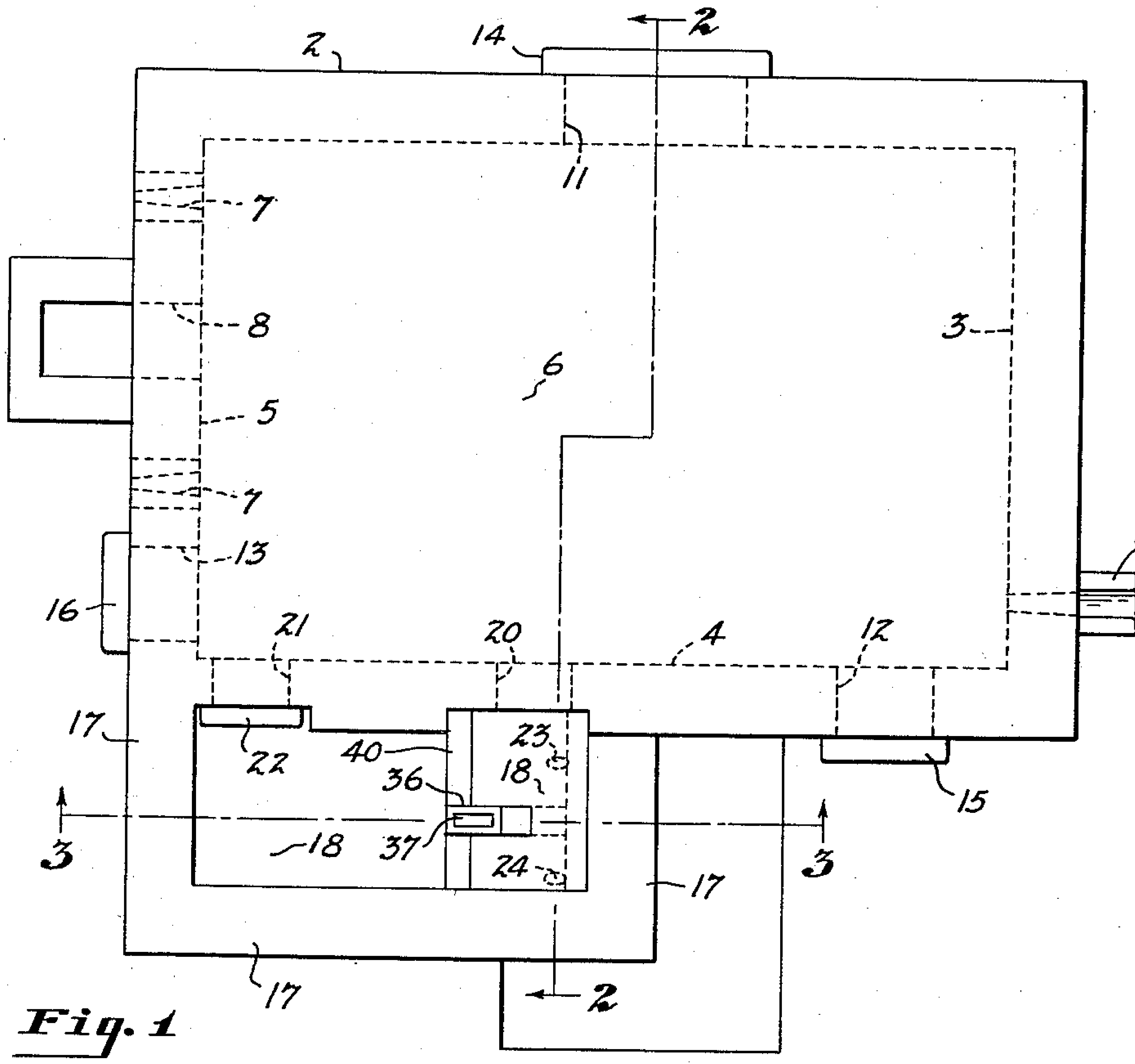


Fig. 1

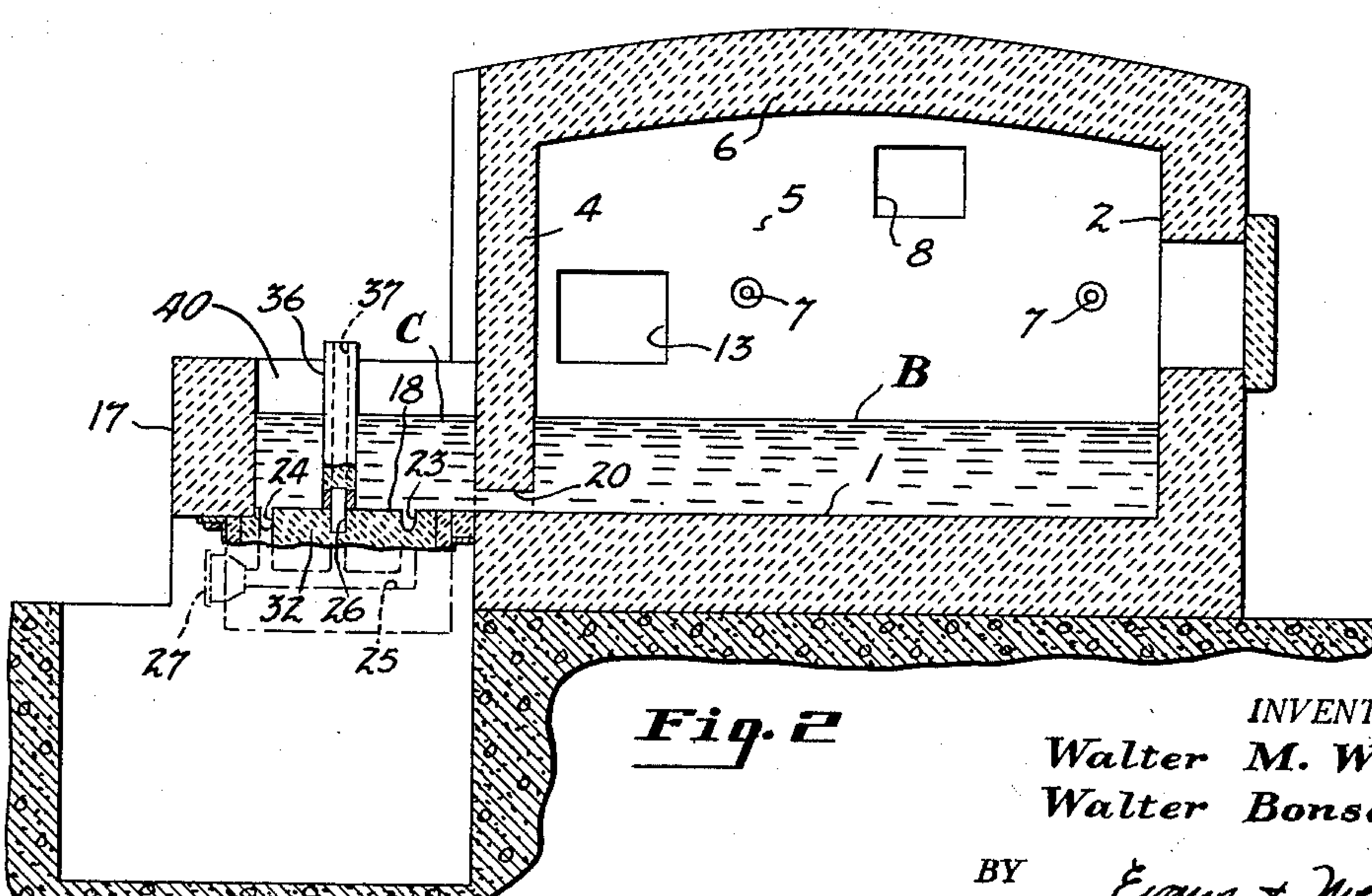


Fig. 2

INVENTORS
Walter M. Weil
Walter Bonsack

BY Evans & McCoy
ATTORNEYS

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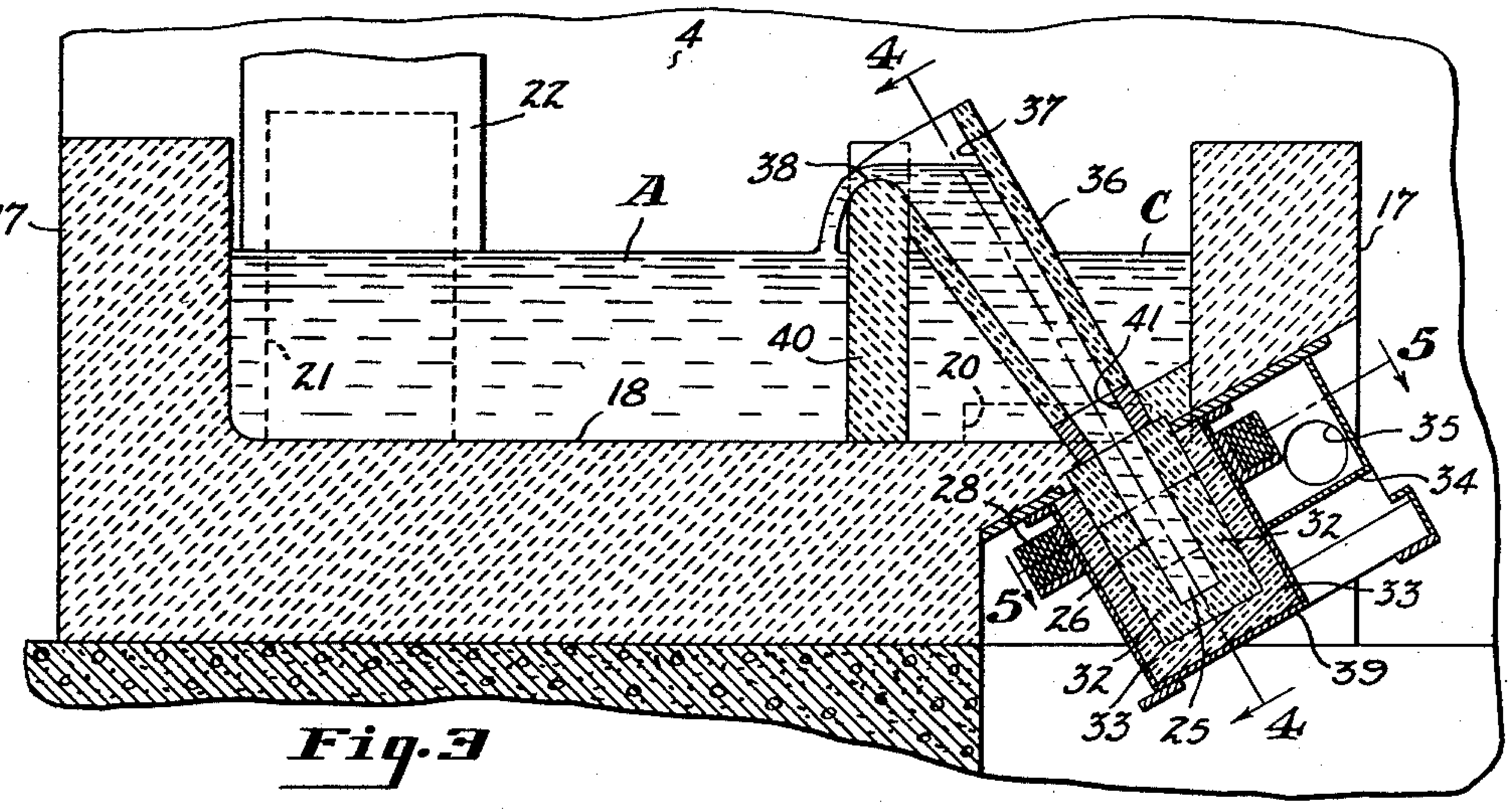


Fig. 3

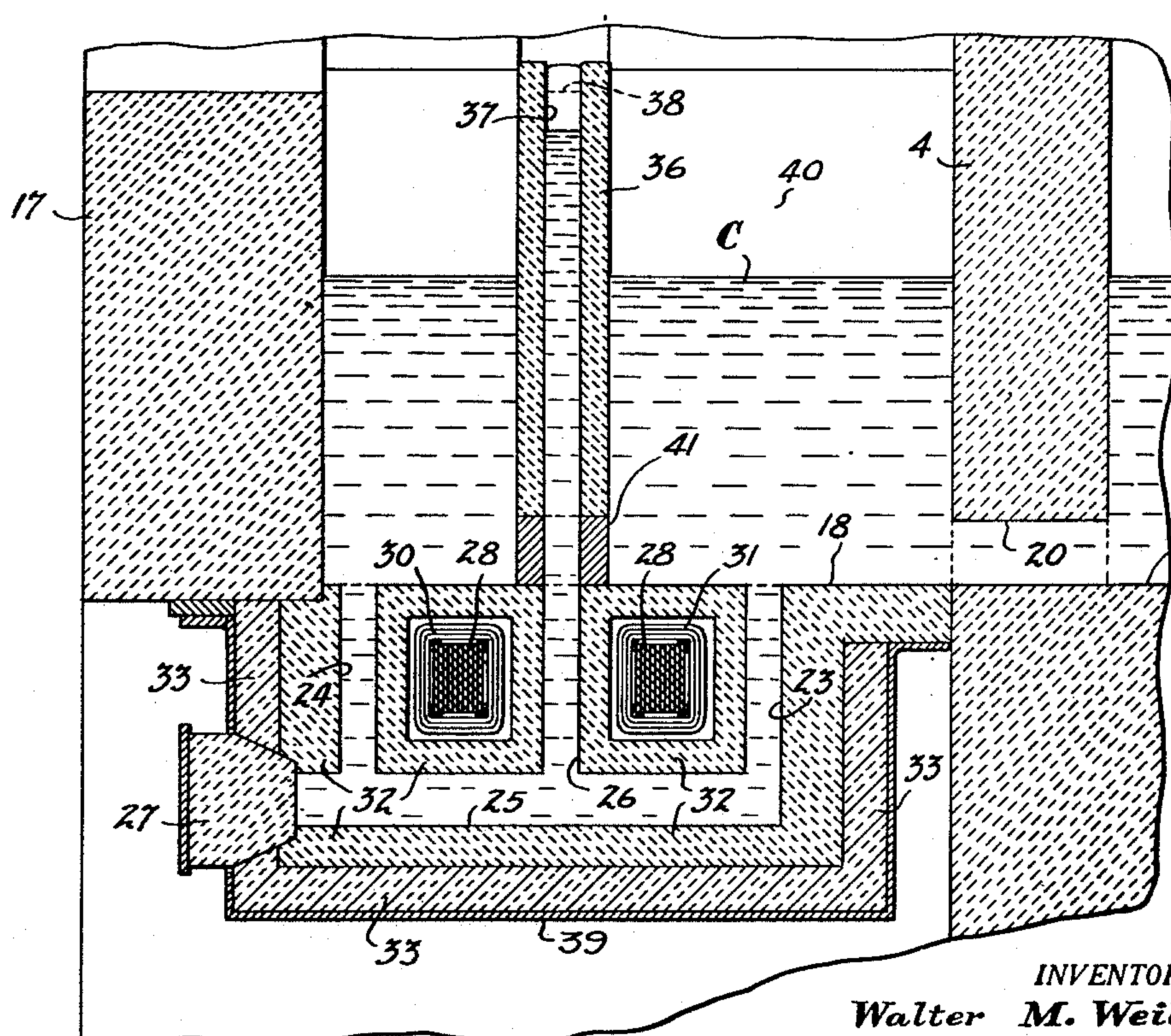


Fig. 4

INVENTORS
Walter M. Weil
Walter Bonsack
BY Evans & McCoy
ATTORNEYS

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Filed July 12, 1946 3 Sheets-Sheet 3

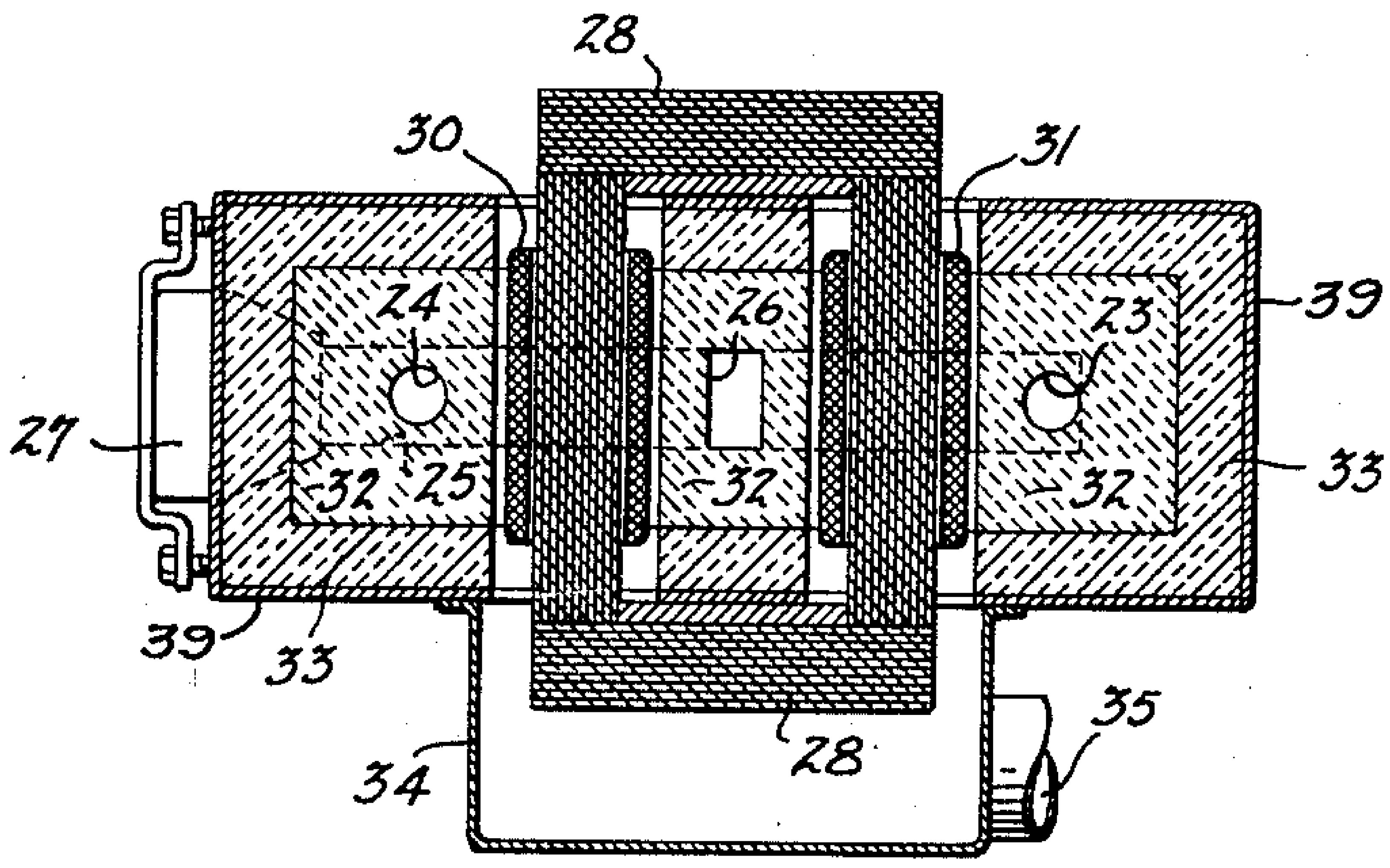


Fig. 5

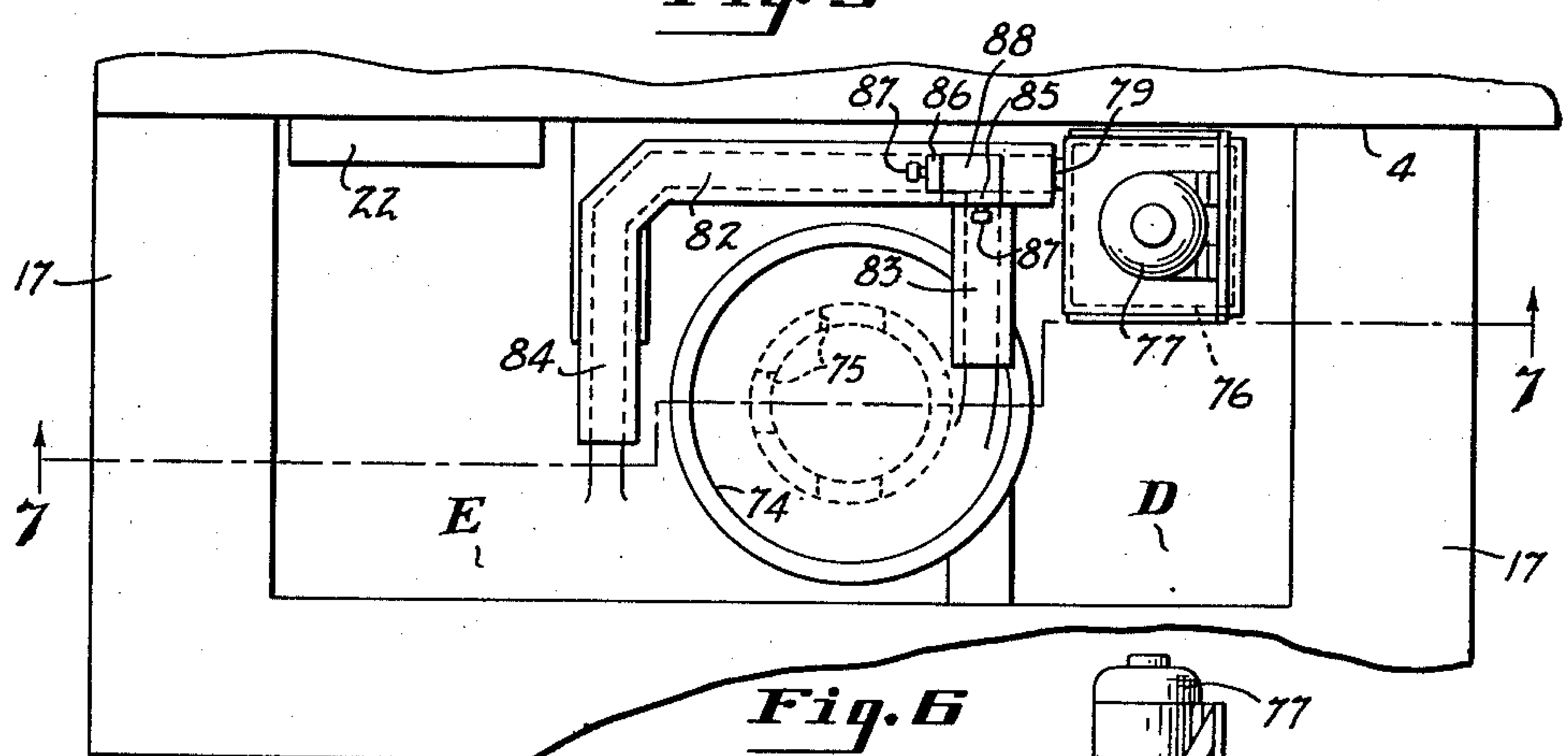


Fig. 6

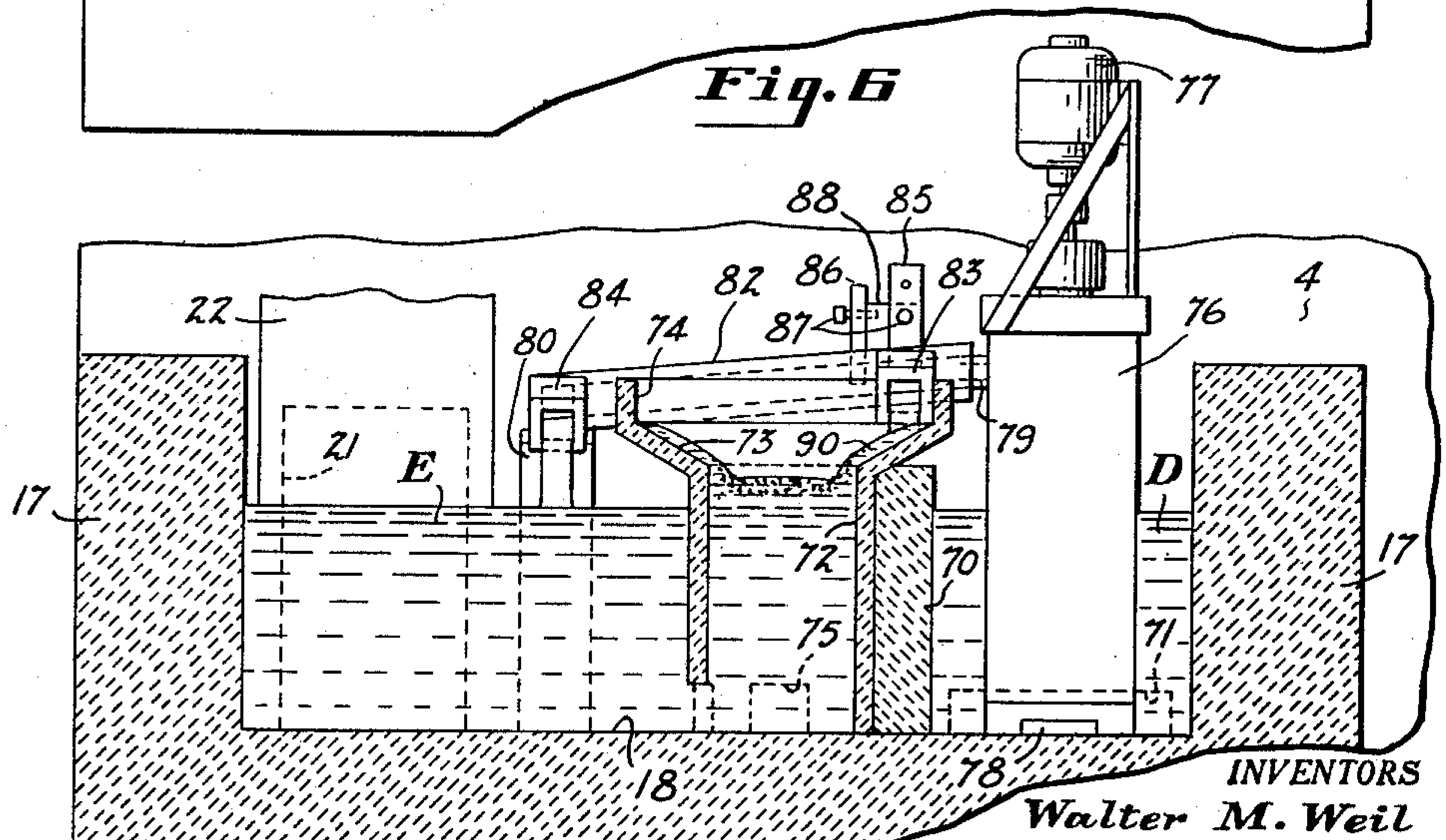


Fig. 7

INVENTORS
Walter M. Weil
Walter Bonsack

BY Evans + McCoy
ATTORNEYS

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# UNITED STATES PATENT OFFICE

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## PROCESS OF SMELTING METALS

Walter Bonsack, Lyndhurst, and Walter M. Weil, Shaker Heights, Ohio, assignors, by mesne assignments, to Walter M. Weil, Cleveland, Ohio

Application July 12, 1946, Serial No. 683,114

21 Claims. (Cl. 13—34)

This invention relates to the smelting of metal and more particularly to the smelting of light metals for purposes of refining, purifying, modifying and mixing them.

In the smelting of light metals such as aluminum the metal is reduced to a liquid state for the removal of metal oxide coatings and impurities. The heating of metal for the purpose of bringing it to a molten state has the effect, in an oxidizing atmosphere such as air, of causing further oxidation of the metal with a resultant loss in recovery. It therefore becomes desirable to heat the metal rapidly and bring it to a molten state with minimum exposure to an oxidizing atmosphere or environment while being heated.

To effect the rapid melting of light metals it has been customary in the smelting art to maintain a bath of molten metal into which solid metal is introduced. Submerging of the solid metal in the molten bath effects a rapid heat transfer from the molten metal to the solid metal particles or pieces, so that they are quickly reduced to a molten state. Large pieces of metal to be thus smelted are handled without undue difficulty, but in the case of small metal particles such as cuttings, turnings, filings and the like immersion in the molten bath is difficult. This difficulty arises not only by reason of the small light-weight and buoyant character of the particles or pieces, but because on the surface of the molten bath a layer of oxide and slag material may be present which acts as a support for the small particles and resists their introduction or movement into the bath of molten material underneath. Hence small particles of light metal, when placed on the top of a smelting bath tend to be exposed for an excessive length of time to the oxidizing atmosphere of the air and the contaminating impurities in the slag layer, while at the same time being subjected to the heat of the slag and the molten body of metal underneath.

Another problem encountered in the smelting of light metals is in connection with fluxing. To separate the metal from oxides and other impurities various fluxes are added. Such materials are customarily employed in a powdered form and are of light weight, so that in associating themselves with the oxides and impurities they buoy up these deleterious materials in the molten mass, causing the undesirable constituents to rise to the surface and form the slag layer previously mentioned. Since the fluxes are themselves light in weight, it is difficult to introduce them into the metal through the slag layer or even when there is no slag layer. Much of the flux placed on the top of a molten bath does not become thoroughly mixed into the molten metal and hence it is not employed to greatest efficiency. Accordingly, it is often necessary to employ a larger quantity of fluxing material when smelting by conventional methods than would be required if a more thorough and efficient mixing of the flux and metal could be obtained.

One practice in the smelting art is to bring metal to a viscous or pasty state in which the metal is neither liquid nor solid, but intermediate such conditions, and in which convection and flow is reduced for maintaining fluxes and other refining agents in intimate association with the metal for a longer period of time.

Advantages are also realized in the refining of metal by maintaining the metal in a pasty mix condition during a period of the smelting in addition to the benefits derived from this practice in connection with fluxing and purifying. For example it is desirable under certain conditions to introduce gases such as nitrogen, chlorine, fluorine and hydrogen fluoride into the metal during smelting and refining. These so-called refining gases, when introduced into a pasty mix of the metal, are physically entrained and the high viscosity of the metal retards the movement of the gas upwardly through the metal to the surface, where it escapes and is lost. Thus a considerable economy in refining gas can be realized by carrying such gas into a pasty mix of the metal to be refined. Thus fluxes and refiners added to metal maintained in a slush or pasty state can be more readily commingled and the tendency of the impurities, contaminants, flux and other additives to separate out and either sink to the bottom or rise to the surface of the metal by reason of greater weight or buoyancy is minimized.

It is therefore one of the principal objects of the present invention to provide an improved process for smelting metal, particularly light metal such as aluminum, which will largely overcome the difficulties mentioned above and which will obtain the advantages of simplicity, continuity, and economy of metal, fluxes, refiners and other additives; such process to include the circulation of molten metal from one body thereof to another and back again, accompanied by the transfer of heat from molten metal in one of the bodies thereof to solid metal being smelted, and the compensation for such heat transfer or the replenishment thereof by the application of heat to molten metal in the other body.

Another object of the invention is to provide a smelting process in which heat is rapidly applied to solid metal being smelted to elevate the same quickly to its melting temperature while protecting it from oxidizing atmosphere so that oxidation thereof is minimized. More specifically, the invention contemplates the rapid immersion or engulfment of the solid metal in higher temperature liquid metal, so that the solid metal is by reason of such immersion or engulfment protected or shielded from exposure to the oxidizing air or atmosphere while being melted.

A further object of the invention is to provide a process of smelting wherein a stream of molten metal is continuously withdrawn from a relatively large body of molten metal and poured or directed over, through or onto solid metal pieces or particles, so as to rapidly immerse, surround or engulf the solid metal and through intimate contact therewith effect a rapid heat transfer which quickly raises the solid metal to a pasty state, its melting point, or substantially so. In its preferred form the process of this invention is calculated to permit retention of the metal being smelted in a pasty mix, state or condition just short of complete liquefaction for a sufficient period of time to enable optimum fluxing and refining to take place. Thereafter and by the further addition of heat to the pasty mix, as by commingling additional quantities of relatively high temperature molten metal therewith, the mass is brought "to skim" in which condition impurities, contaminants and the like rise to the surface or are carried thereto by the action of the flux and are separated.

A still further object of the invention is the provision of a process which includes maintaining several bodies of metal in juxtaposition and provides for continuous circulation of molten metal between the bodies so that in refining or smelting, alloying and refining a large batch, all portions of such batch can be made homogeneous and uniform, permitting the introduction of alloying, refining and purifying ingredients in one region of the batch and obtaining proper distribution and incorporation of such ingredients throughout the mixture.

As a still further feature and object of this invention a process is contemplated in which a relatively large body of metal is maintained in a molten condition in a substanially closed furnace, which serves to furnish to the metal the bulk of the heat used in the smelting process, and a continuous stream of molten metal is withdrawn from the large body and directed into a separate and smaller body of metal, where it commingles with solid metal introduced into the smaller body, supplying heat to the latter and forming a pasty mix which is progressively built up or increased in size and maintained until refining, purifying and segregation of contaminants and impurities are substantially completed. Thereafter by the continued withdrawal of relatively hot metal from the large molten body thereof and the introduction of the same into the smaller body of pastry mix metal without further addition thereto of solid metal, the temperature of the small body of metal is increased sufficiently to completely liquefy the same and bring it "to skim" so that impurities and contaminants rise or are carried to the surface and are separated, and the underlying, refined metal is then flowed into the large body of molten metal to commingle therewith. After such a cycle of operation, during which the flow or withdrawal of molten metal from the large mass or



body thereof and the introduction of the same into the smaller body of metal may be continuous, additional solid metal to be smelted is introduced into the circuit and rapidly brought to pasty condition by commingling in the small body of metal with the hotter metal withdrawn from the large body and the cycle is repeated. In this manner the process can be continued cyclicly until a large batch or quantity of refined metal is produced and, after withdrawal from the apparatus, the latter is in condition for smelting of a succeeding batch by the same process. In each instance a small amount of metal may be left in the apparatus with which to start the first cycle of the succeeding batch. During the smelting refiners and alloying ingredients are added as desired.

As an arrangement suitable for relatively large scale operations, the present invention has as a further object the provision of an improved process for substantially continuous smelting of light metal. In the sense that it is used in this specification, "continuous" denotes the addition of succeeding quantities of metal to be smelted while the purifying and refining of previously added quantities of metal is progressing. Thus the continuous process is distinguished from the cyclic process, the latter requiring that the addition of fresh metal to be smelted be discontinued while the pasty mix metal is "brought to skim" and the impurities, contaminants and the like separated from the top of the molten bath.

The continuous process of the present invention is performed in a furnace similar to that employed in the intermittent or cyclic batch method. An auxiliary hearth is provided upon which is maintained a body of metal, a part of such metal undergoing purification and refinement in a pasty mass condition, while another part is being brought to skim and the slag and impurities removed from the top thereof. The purified and refined metal flows back into the main furnace or heating chamber for re-circulation and re-use in the process until withdrawn from the smelter.

The fresh solid metal being added continuously or at regular intervals to the auxiliary hearth and which is being smelted, is heated to a pasty state by a continuous stream of molten metal from the large body thereof in the main heating chamber. Heat is added to that part or portion of the metal on the auxiliary hearth which is being brought to skim by continuously introducing thereinto a second or separate stream of relatively hot molten metal drawn from the large body of molten metal on the main hearth of the heating chamber. Thus heat is added to the body of metal on the auxiliary hearth at two separated points, one point being that at which the metal to be smelted is introduced, and the other point being that at which it is desired to convert the pasty mass metal into a readily flowable liquid for separation of impurities, contaminants and for skimming. By correct proportioning of the rate of flow of the molten metal into the body of metal on the hearth at the several points mentioned, the correct amounts of heat can be added to maintain the metal in a pasty state after its initial introduction to the apparatus on the auxiliary hearth and to subsequently convert it to a liquid from the pasty mass for the separation of impurities and for flowing it into the main furnace chamber.

For still further objects the invention contemplates the provision of a process which is relatively simple and readily operated with maximum efficiency and economy. The invention resides in certain combinations and sequences of steps and arrangement and treatment of the materials being processed. Other objects and advantages not specifically mentioned above will become apparent from the following detailed description of the invention which is made in connection with the accompanying drawings forming part of the specification.

In the drawings:

Fig. 1 is a plan view, partly diagrammatic, of a furnace embodying certain of the principles of the present invention and suitable for use in carrying out the process contemplated herein;

Fig. 2 is a vertical, sectional view taken substantially on the line 2—2 of Fig. 1;

Fig. 3 is a fragmentary, vertical, sectional view with parts removed taken substantially on the line 3—3 of Fig. 1 and enlarged with respect thereto;

Fig. 4 is a sectional detail taken substantially on the line 4—4 of Fig. 3 and enlarged with respect thereto;

Fig. 5 is a sectional detail taken substantially on the line 5—5 of Fig. 3 and enlarged with respect thereto;

Fig. 6 is a fragmentary plan view, with parts broken away, showing the auxiliary hearth portion of a modified form of apparatus as contemplated by the present invention for use in a continuous process; and

Fig. 7 is a vertical section with parts broken away taken substantially on the line 7—7 of Fig. 6.

Referring now to the drawings by numerals of reference which indicate like parts throughout the several views, an apparatus suitable for carrying out the process of the present invention includes a modified furnace structure, preferably of the reverberatory type, although other heaters may be employed. Such furnaces include besides a suitable metal frame, not shown, a main hearth 1 enclosed by refractory lined side walls 3 and 5, refractory lined front and rear walls 4 and 2, and an arched refractory lined dome or ceiling 6. There is thus provided in the furnace an enclosed holding and heating chamber for molten metal B. Over such metal there is maintained a controlled atmosphere which in practice is preferably slightly oxidizing in nature. Fuel such as gas and combustion air are introduced into the furnace chamber through openings 7 in the side wall 5 which accommodate conventional gas burners not shown. Spent or burned out gases are exhausted through flue 8, also located in the side wall 5.

In the side wall 3 there is formed an outlet opening communicating with the bottom of the main heating chamber adjacent the level of the hearth 1 and provided with a spout 10. This outlet opening is plugged during the smelting process and when the smelting is completed the plug is withdrawn so that the molten metal flows out through the spout 10 into ladles, ingot molds and the like, for subsequent use as desired. A number of clean-out or access openings 11, 12 and 13 are formed in the walls 2, 4 and 5, respectively, of the furnace and can be removed or opened when it is desired to clean or repair the interior of the main furnace chamber or for initial charging of metal therein.

On the outside of the main furnace chamber, along the exterior side of front wall 4, is an open or auxiliary hearth 18 which may be on substantially the same level as the main or covered hearth 1. The hearth 18 is enclosed by upright refractory lined side walls 17, thus providing an open-topped receptacle disposed on the outside of the main hearth chamber and separated therefrom by the front wall 4.

At one end of the auxiliary hearth 18 an opening or passage 20 is formed through the front wall 4 adjacent the bottom thereof. The auxiliary hearth 18 thus communicates with the main hearth 1 through the passage 20 permitting the flow of molten metal from one hearth to the other, thereby maintaining equal levels of molten metal on the two hearths. The circulation of molten metal as contemplated by this invention involves a flow from a relatively large body B of metal on the main hearth 1 through the low relatively small passage or opening 20 onto the auxiliary hearth and return to the main hearth through a relatively larger passage or opening 21 formed through the front wall 4 at the other end of the auxiliary hearth 18. A slidable or vertically movable closure or door 22 of refractory material is provided for the passage 21. Normally the closure 22 is adjusted to or just below the surface of the metal in the open auxiliary hearth compartment. The gate or closure 22 thus prevents the flow of slag or dross on the surface of the auxiliary hearth metal into the main furnace chamber and seals the main chamber and the molten metal B from the outside atmosphere, keeping the heat in and the air out.

In smelting solid pieces of metal, particles or chunks are immersed in a relatively small body A of molten metal carried on the auxiliary or working hearth 18. From the larger body B of molten metal, heated to a relatively high temperature in the main or reverberatory portion of the furnace, a substantially continuous stream is flowed onto the hearth 18 through the opening or passage 20, from whence it emerges first into the small body C and is then pumped over a cross wall or weir 40 and into heat exchanging relation with the solid metal that has been introduced into the small body A. Thus heat is supplied to the solid metal to reduce it to a molten or pasty state or condition.

To effect a flow of metal between the relatively large body B contained in the main heating chamber on the hearth 1 and the smaller body A of metal in juxtaposition thereto on the auxiliary hearth 18 any suitable pumping or flow inducing means or device may be utilized. One such device, illustrated in Figs. 1 through 5, comprises an electric induction pump, more fully described in co-pending patent application, Serial No. 683,115, filed July 12, 1946.

This pump is located generally below the level of the hearths and comprises a refractory lined structure formed with upright passages 23 and 24, disposed in spaced preferably parallel relation and opening upwardly through the floor of the auxiliary hearth 18. The bottom or lower ends of the upright channels 23 and 24 are connected by a horizontal or transverse cross channel 25, which is preferably of larger cross sectional area than the upright channels so that it does not become blocked by settling of impurities or sediment. Midway between the upright channels 23 and 24 and preferably in parallel relation thereto is a central pumping channel 26, which also communicates at its lower end with the connecting or cross channel 25. Extending around the central or pumping channel 26 and through the refractory structure of the pump is a soft iron laminated core 28, which may be of rectangular shape as shown in Fig. 5. This core carries windings 30 and 31 of copper wire which constitute the primary of the pump transformer assembly and are connected to a suitable source of alternating current such as standard frequency power for the purpose of inducing alternating electro-magnetic flux in the iron core 28. The core 28 and the primary coils 30 and 31 are insulated by refractory material 32 which separates and protects the coils from the heat of the molten metal flowing through the passages of the pump structure formed in the refractory.

Extending as an upward continuation of the central or pumping channel 26 is a passage 37 formed in a conduit which includes an upper portion 36 of refractory material and a relatively short section 41 of electrically conductive material such as carbon. The conductive section 41 is disposed at the upper end of the pumping channel 26 adjacent the level of the floor of the auxiliary hearth 18.

Referring to Fig. 4 the liquid metal in the passages 23, 24, 25 and 26, and the liquid metal on the auxiliary hearth 18 together with the conductive insert or portion 41 of the extension passage, constitute a pair of merged secondary loops around the transformer core 28. Each loop has a leg common to the other loop and comprising the molten metal in the central passage 26. The effect of an alternating current imposed on the primary coils 30 and 31 is to induce current in the molten metal secondary loops which not only heats such molten metal but causes the same to rise in the pumping channel 26 and in the extension passage 37. The direction of winding of the coils 30 and 31 is such that each induces current flow in the same direction in the pumping passage 26.

The upper end of the conduit 36 is supported on a cross wall or weir 40, which divides the auxiliary hearth 18 into two zones one of which contains the "working" body of metal indicated at A (and which is in communication with the metal B on the main hearth 1 through the opening 21) and a smaller or "feeder" body of metal indicated at C (which also is in communication with the metal B on the main hearth 1 through the passage 20). The top of the weir or cross wall 40 is formed with a pouring lip 38 which extends as a continuation of the passage 37 in the conduit 36. Metal which is drawn into the pumping structure through the upright passages 23 and 24 from the feeder body C is thus forced around and upwardly through the pumping passage 26, through the extension passage 37 and over the lip 38 of the weir or wall 40 to pour onto the mass of metal A and any solid metal pieces or particles which may have been placed adjacent the wall or weir 40.

The pumping apparatus is illustrated as being disposed at an angle to the vertical, which facilitates access for servicing or repair. It may, however, be disposed at other angles than that shown. A suitable enclosing and supporting metallic casing 39 may be employed for the pumping structure and includes a housing 34 which is disposed in sealing relation around one end of the openings which receive the iron core 28 and the primary coils 30 and 31. A suitable fan or air blower (not shown) communicates with the interior of the housing 34 through an opening 35 to force or draw cooling air over the transformer coils to prevent excessive temperature rise. The metal casing or supporting structure 39 for the pump may be separated from the refractory material constituting the walls of the passages by insulation indicated at 33. A removable clean-out or access door or plug 27 is provided at one end of the transverse or connecting passage 25.

In operating the furnace or smelter in accordance with the principles of the present invention, an initial starting or heel charge is provided as by leaving a small amount of metal from a preceding batch in the furnace or by introducing a quantity by pouring molten metal onto the auxiliary hearth 18 from whence it flows onto the hearth 1 through the opening 21; or a quantity of solid metal may be charged directly into the main furnace chamber through the door opening 11 and melted by heat from the combustion of gases supplied through the burner openings 7.

The initial quantity of metal placed or charged onto the hearths of the smelter may not and preferably will not be as large in quantity as indicated in the drawings, which represent an intermediate stage in the complete process. For descriptive purposes, however, the relative quantities shown in the drawings are used to indicate the cyclic operation. Actually, the relative levels will rise and fall depending on the rate of addition of fresh or solid metal, the viscosity or condition of the metal in the different bodies, the skimming of slag and contaminants, and the action of the pumping unit. The total metal charge in the furnace includes the main or relatively large body B, and a smaller body in juxtaposition thereto comprising the masses A and C in the two zones of the auxiliary hearth 18. The large body of metal B under the controlled atmosphere in the main heating chamber is heated to a temperature substantially above its melting point in the manner previously mentioned.

Energization of the submerged induction pump structure flows molten metal from the mass indicated at C on one zone of the auxiliary hearth, over the weir or cross wall 40 and onto the metal A in the other zone of the auxiliary hearth. The metal A from the auxiliary hearth flows into the metal B in the heating chamber through the opening 21. A continuous circulation or flow of the molten metal is thus established, the metal being heated primarily in the controlled atmosphere chamber over the main hearth 1, but also heated in a secondary manner in passing through the pumping structure by reason of the resistance of the metal to the flow of the electrical currents induced therein.

Metal to be smelted is submerged in the metal A on the auxiliary hearth where it rapidly absorbs heat from the relatively high temperature molten metal continuously supplied to this melting or mixing and commingling zone through circulation of the metal induced by the pumping structure. Small pieces or particles of metal to be smelted such as turnings, cuttings, spillings and the like are introduced into the mixing zone adjacent the cross wall or weir 40, where the down flowing metal from the pump outlet passage 37 promptly engulfs and submerges such small particles, carrying them below the surface of the metal A and minimizing oxidation of the solid metal. Fluxing materials, refiners and the like can also be added to the metal A in the down flowing stream from the outlet of the pumping structure. In this manner the additives are thoroughly mixed and distributed in the metal A, so that uniform refining, purification and modification of the metal results.

The addition of a large quantity of solid metal to the metal A results in lowering the temperature of the molten or circulated metal so that a viscous pasty mass having a slush-like consistency results. This pasty condition is beneficial in the refining process especially when the metal being smelted is scrap containing removable impurities and contaminants such as dirt and other foreign elements, as well as oxides of the metal being smelted. Flux added to the metal A for purification thereof is mixed through and entrained in the pasty mass and is evenly distributed by reason of being introduced at the region of the inflowing metal delivered by the pumping structure. The viscous nature of the pasty mass prevents rapid rising of the fluxing material upwardly through the metal being purified, allowing an intimate association of the flux with the metal being purified for a relatively long period of time, resulting in more efficient action of the flux and improved purification, so that segregation of the impurities is substantially completed in the pasty state of the mass.

Refining materials added in a similar manner to the mass of metal A are evenly and thoroughly distributed therethrough and by reason of the viscosity of the metal in the pasty condition are prevented from separating out and being lost.

When the purification, refining and treatment of the metal A has been substantially completed in the pasty state, the addition of solid metal is suspended for a time while the flow of relatively hot molten metal through the pumping apparatus or structure is continued. This continuous addition of hot molten metal from the large body thereof in the main heating chamber on the hearth 1 to the working mass of metal on the auxiliary hearth raises the temperature of the pasty mass of metal sufficiently to liquefy the same. In this manner the metal A, with the segregation of the impurities and contaminants therein substantially completed is liquefied, permitting the relatively light fluxing materials to rise to the surface, carrying with them the segregated impurities and contaminants. This step is commonly known as "bringing to skim."

The continued flow of molten metal over the weir or cross wall 40 effects a flow of the purified metal through the opening 21 onto the main heating hearth 1, where it is further raised in temperature and commingled with the larger mass of metal on the main hearth.

The oxides and other contaminants carried to the surface of the metal A are separated therefrom by mechanical or hand skimming. When the contaminants are thus separated the smelting cycle is completed and the apparatus is in condition for repetition of the cycle by the addition of solid metal introduced into the metal A on the auxiliary hearth. The cycle is repeated with the total mass of metal contained in the apparatus increasing each time until the furnace is full and ready to be tapped or emptied through the spout 10. By reason of the continuous circulation of the molten metal under the influence of the pumping structure, all of the metal in the furnace is brought to uniform composition regardless of the fact that it may include metal of widely varying composition added during different cycles of the smelting process. The metallurgist is therefore able by sampling at one point to determine accurately what refining and alloying materials should be added to bring the entire charge to the proper composition before tapping. Additionally the materials to be thus added in modifying the metal can be introduced rapidly, without waste or loss thereof, by placing them in the stream of metal flowing out of the pumping structure.

In Figs. 6 and 7 is illustrated a modification of the invention which includes a feature particularly useful when smelting metal in the form of relatively fine particles, such as turnings, cuttings, borings and the like. This modification also illustrates a suitable apparatus for performing the present process or method "continuously" in the manner previously mentioned. The main furnace structure used in this modification may be the same as that shown in the preceding figures and a complete showing thereof has been omitted for simplicity. Front wall 4 of such furnace is designated in Figs. 6 and 7, it being understood that the remainder of the structure not included in Figs. 6 and 7 corresponds generally to that previously described. Certain parts or portions of the modified structure and which correspond to parts described in connection with the preceding figures have been indicated by the same numerals of reference, as for example, the auxiliary hearth 18, side walls 17, return passage 21 and the adjustable gate 22 for the return passage.

A cross wall or partition 70 of fire brick or similar material divides the body of metal on the auxiliary hearth 18 into a feed portion D and a refining portion E. The levels of the metal portions D and E shown in the drawings are purely arbitrary since the levels will rise and fall slightly relative to one another, depending upon the viscosity of the metal and other factors. During the building up of a batch of metal in the furnace from the original heel, the general level of the metal will progressively rise.

The level of the feed portion D of metal is maintained by gravity substantially equal to that of the molten metal on the main hearth inside the heating portion of the furnace by flow through a low level opening or passage 71, which corresponds to the opening 20 previously described.

The position of the partition wall 70 is such that the refining portion E of the outside or auxiliary hearth metal is several times larger than the feed portion D, the latter serving merely to supply the pump which lifts the molten metal over the partition 70 for flow into different zones of the refining metal E.

At one end of the refining metal E, as adjacent the partition 70, is a receiver or hopper into which metal to be smelted or refined is introduced. This receiver is constructed of heat resistant material such as graphite or silicon carbide and may include an upright cylindrical confining pedestal portion 72 surmounted by an open topped funnel or cone 73. About the upper peripheral edge of the funnel 73 is a cylindrical retaining flange 74 which prevents metal deposited on the receiving funnel 73 from overflowing. The parts of the receiver may be of integral molded construction and at the bottom of the pedestal portion a plurality of openings 75 are provided for the out-flow of metal from the interior of the retaining pedestal onto the hearth 18.

A pumping apparatus, which may be of the type disclosed in copending patent application, Serial No. 714,463 filed December 6, 1946 is mounted on the auxiliary hearth 18 in the feed metal D. This pump, comprising an upright body 76, containing the vertical shaft, impeller, chambers and passages of the device, and an actuating motor 77, has a bottom inlet 78 through which metal is drawn from the feed portion D and an outlet 79 above the level of the partition or dividing wall 70 through which molten metal is discharged.

Mounted above the level of the metal on the auxiliary hearth 18 and supported as by the partition wall 70, a shelf along the main furnace wall 4, and a short guide wall 80, is a manifold flume or duct structure comprising a cross conductor 82 and lateral conductors 83 and 84. The cross conductor 82 receives hot molten metal from the outlet 79 of the pump structure and carries it to the lateral conductors 83 and 84. By reason of the high temperatures to which the manifold and conductor structure is subjected, it is preferably made of heat resistant or refractory material and may be molded or machined from solid pieces. As shown in Fig. 7, the conductors or flumes are inclined downwardly in the direction of flow of the molten metal, so that the metal moves by gravity therethrough.

Adjustable gates 85 and 86 are provided to proportion the flow of metal through the cross conductors 83 and 84. These gates may be formed of refractory material, movable vertically through slots in the upper walls of the conductors, so as to vary the available cross section within the respective conductors for the flow of molten metal therethrough. Removable pegs 87 are fitted through selected holes of a number formed in the gates 85 and are engaged in sockets in a block 88 to hold the gates in desired adjusted vertical positions. The gate 85 controlling the flow of molten metal through the lateral conductor 83 is disposed at the connection of such conductor to the cross conductor 82. The gate 86 controlling the flow through the lateral conductor 84 is disposed in the cross conductor 82 just beyond the connection of the lateral conductor 83. By thus positioning the gates relatively close to the pump outlet 79, the freezing of metal in the flume, should one or both of the gates be closed, is avoided.

The lateral conductor 83 extends tangentially over the circular skirt or flange 74 of the funnel-shaped receiver adjacent the periphery of the latter so that molten metal flowing out of the flume or conductor is discharged tangentially onto the outer edge of the conical funnel. Thus there is provided a continuous vortex or whirlpool of hot molten metal substantially covering the upwardly directed open topped cone or funnel of the receiver. Metal to be smelted and introduced into the receiver in relatively finely divided form, such as prevails in the case of turnings, borings, cutting and the like, is quickly engulfed in a swirling vortex 90 of molten metal on the receiver and carried downwardly into and through the cylindrical retainer 72.

Refiners, purifiers, and fluxing materials to be added during the process are likewise introduced into the receiver vortex and are rapidly engulfed and carried below the surface of the molten metal in the cylindrical retainer. They are kept submerged by the incoming fresh material.

The relative quantity of molten metal flowed onto the conical portion of the receiver through the lateral conductor 83 is so regulated by means of the adjustable gate 85 that the heat thus introduced into the receiver is just sufficient to make a pasty mass or mix of all of the materials and metals added through the receiver. This pasty mix, which holds the metal to be refined in intimate association with the refining materials and fluxes, moves continuously outwardly through the bottom of the receiver cylindrical portion 72 through the opening 75 in the latter and into the main mass of the refining portion E of the metal on the auxiliary hearth. A general flow over the auxiliary hearth 18 is thus induced in the metal. The level of the mixed metals rises somewhat in the cylindrical receiver 72 over the prevailing level outside of the receiver on the hearth 18 as shown in Fig. 7.

Heat is added to the pasty mix by the molten metal flowing into the refining body E through the lateral conductor 84. The outlet of this conductor is relatively remote from the main outlet passage 21, which leads into the main hearth or heating chamber of the furnace, so that metal in a pasty mix or mush on the auxiliary hearth 18 is continuously being converted to a molten condition and brought to skim.

In the refining process the metal is agitated or worked during the heating and while being brought to skim, by hand puddling or by mechanical mixers or puddling devices lowered into the mass of metal on the auxiliary hearth. At this stage of the process when the metal is at a relatively high temperature, refiners or refining gases may be added to the liquid metal to effect refinement and purification which was not accomplished at the lower temperature of the pasty mush or mix. Such refiners may be introduced through the stream of molten high temperature metal issuing from the conductor 84 or they may be mixed directly into the body of metal on the auxiliary hearth.

The slag, dross and contaminants rising and carried to the surface of the molten metal adjacent the left-hand end of the auxiliary hearth, as viewed in Figs. 6 and 7, are separated or skimmed therefrom and the purified or refined metal flows into the main heating chamber through the passage 21.

By thus utilizing separate streams of molten metal flowing between the body of molten metal B and the body of molten or partially molten metal A on the auxiliary hearth, one stream for initial heating of solid metal to bring it to a pasty state and another stream to connect the pasty mix to liquid metal, a smelting furnace may be operated continuously. The metal to be smelted is introduced at uniform intervals or continuously into the swirling vortex 90 in the receiver and is rapidly engulfed and reduced to a pasty mix condition with the refining materials and fluxes in the retainer portion of the receiver. The pasty mix mass thus produced travels forward over the auxiliary hearth during the refining process and while impurities and contaminants are segregated. Thereafter the addition of further heat by the other or second stream of molten metal flowing through the supplemental conduit or flume 84 completes the melting of the metal being smelted, bringing it to a liquid state or to skim, so that the segregated impurities and contaminants rise or are carried to the surface and can be separated or skimmed in the usual manner. Thus metal is being brought to a pasty state or condition in one zone of the auxiliary hearth and other metal is being changed from a pasty state or condition to a molten state in another zone of the auxiliary hearth.

The large body of molten metal developed in the furnace may be tapped from time to time and a portion only of the smelted metal withdrawn at each tapping, the smelting process thus being carried on indefinitely. If desired, the smelting process may be interrupted after a batch has been refined and purified and the entire body of molten metal removed during a single withdrawal or tapping. In either case and regardless of the manner of withdrawal of the smelted metal from the furnace, the process is "continuous" with respect to the smelting steps, inasmuch as the addition of metal to be smelted to the receiver may be continuous rather than cyclic.

Reference is made to our copending application for U. S. patent, Serial No. 30,963 filed June 3, 1948, for Apparatus For Smelting Metals which describes and claims common subject matter.

The principles of the present invention may be utilized in various ways, numerous modifications and alterations being contemplated, substitution of parts and changes in construction being resorted to as desired, it being understood that the embodiments shown in the drawings and described above and the particular method set forth are given merely for purposes of explanation and illustration in accordance with the patent statutes and without intending to limit the scope of the claims to the specific details disclosed.

What we claim is:

1. The process of smelting metals which comprises maintaining a first body of molten metal in a fixed location and a second body of at least partially molten metal in a fixed location adjacent the first body and at an elevation with respect thereto such that the bottom of each is lower than the surface level of the other, maintaining said bodies in communication with each other along a first path disposed below the surface level of both, withdrawing molten metal from below the surface of said first body of metal and forcibly conducting it along a second path and into said second body of metal, adding solid metal to said second body of metal and commingling it therewith to effect heat transfer therebetween for melting the added metal, withdrawing molten metal from below the surface of said second body of metal and conducting it along said first path and into said first body of metal.

2. The process of smelting metals susceptible to rapid oxidation at elevated temperatures which comprises maintaining a large body of molten metal in a fixed location and a relatively small body of at least partially molten metal in a fixed location adjacent the large body and at an elevation with respect thereto such that the bottom of each is lower than the surface level of the other, maintaining these bodies in communication with each other along a first path disposed below the surface level of both, withdrawing completely-molten metal from below the surface of said large body of metal and conducting it along a second path and into said small body of metal for adding heat thereto, simultaneously adding solid metal to said small body of metal and commingling it therewith to effect heat transfer therebetween for melting the added metal, withdrawing molten metal from below the surface of said small body of metal and conducting it along said first path and into said large body of metal, and adding heat to the large body of metal for maintaining its molten condition.

3. The process of claim 2 in which alloying materials are added to said small body of metal during the process.

4. The process of claim 2 in which the molten metal withdrawn from said large body of metal is further heated during its travel to said small body of metal.

5. The process of claim 2 in which the molten metal withdrawn from said large body of metal is further heated by electrical induction during its travel to said small body of metal.

6. The process of smelting metals susceptible to rapid oxidation at elevated temperatures which comprises maintaining a large body of molten metal at a fixed location in an enclosed chamber and a relatively small body of at least partially molten metal at a fixed location adjacent and in communication with the large body of metal along a first path disposed below the surface level of both, withdrawing completely-molten metal from below the surface of said large body of metal and conducting it along a second path and into said small body of metal for adding heat thereto. simultaneously adding solid metal to said small body of metal and commingling it therewith to effect heat transfer therebetween for melting the added metal, conducting molten metal from below the surface of said small body of metal and along said first path into said large body of metal, the flow of molten metal along said first path being effected by difference in static pressure at opposite ends of said first path, and adding heat to the large body of metal for maintaining its molten condition.

7. The process of smelting metals susceptible to rapid oxidation at elevated temperatures which comprises maintaining a large body of molten metal at a fixed location in an enclosed chamber and a relatively small body of at least partially molten metal at a fixed location adjacent and in communication with the large body of metal along a first path disposed below the surface level of both, substantially continuously withdrawing completely-molten metal from below the surface of said large body of metal and conducting it along a second path and into said small body of metal for adding heat thereto, simultaneously adding solid metal to said small body of metal and commingling it therewith to effect heat transfer therebetween for melting the added metal, withdrawing molten metal from below the surface of said small body of metal and conducting it along said first path and into said large body of metal, and adding heat to the large body of metal for maintaining its molten condition.

8. The process of smelting light metals which comprises maintaining a large body of molten metal in a fixed location and a relatively small body of at least partially molten metal in a fixed location adjacent the large body of metal. withdrawing molten metal from below the surface of said large body of metal and conducting it along a first path and into said small body of metal, adding solid metal to said small body of metal and commingling it therewith to effect heat transfer therebetween, continuing the addition of solid metal and molten metal to said small body of metal while proportioning their rates of addition to produce a pasty mass of partially molten metal therein, then reducing the ratio between the rate of addition of solid metal and the rate of addition of molten metal for liquefying said pasty mass, withdrawing molten metal from below the surface of said small body of metal and conducting it along a second path and into said large body of metal, and adding heat to the large body of metal as required for maintaining its molten condition.

9. The process of smelting light metals which comprises maintaining a large body of molten metal in a fixed location and a relatively small body of at least partially molten metal in a fixed location adjacent the large body of metal, withdrawing molten metal from below the surface of said large body of metal and conducting it along a first path and into said small body of metal for adding heat thereto, adding solid metal to said small body of metal and commingling it therewith to effect heat transfer therebetween, continuing the addition of solid metal to said small body of metal at a rate adjusted with respect to the rate of addition of heat thereto to produce a pasty mass of partially molten metal therein, then reducing the ratio between the rate of addition of solid metal and the rate of addition of heat for liquefying said pasty mass, withdrawing molten metal from below the surface of said small body of metal and conducting it along a second path and into said large body of metal at a point below the surface of the large body of metal, and adding heat to the large body of metal as required for maintaining its molten condition.

10. The process of smelting contaminated metals which comprises maintaining a large body of molten metal at a fixed location in an enclosed chamber and a relatively small body of at least partially molten metal at a fixed location adjacent and in communication with the large body of metal along a first path disposed below the surface level of both, continuously withdrawing molten metal from below the surface of said large body of metal and conducting it along a second path to a higher elevation for continuous discharge into said small body of metal, adding solid contaminated metal to said small body of metal and commingling it therewith and with the entering molten metal, regulating the rate of flow of molten metal and rate of addition of solid metal to said small body for heating the added solid metal first to a pasty condition and then to a molten condition, withdrawing molten metal from below the surface of said small body of metal and conducting it along said first path and into the large body of metal at a rate controlled essentially by the surface levels of the two bodies and by the fluidity of the metal therein, and adding heat to the large body as required to maintain it in a molten condition.

11. The process of claim 10 wherein fluxing materials are added to said small body of metal prior to the formation of the pasty mass therein and the rates of flow of molten metal and addition of solid metal are regulated to maintain the pasty condition for a time sufficient to effect substantially complete segregation of contaminants contained in the added solid metal, whereby separation of said contaminants occurs during subsequent conversion of the metal of the pasty mass to a molten condition.

12. The process of smelting light metals such as aluminum which comprises maintaining a body of metal in an at least partially molten condition, introducing a stream of molten metal into said body at a selected zone, adding fluxing material and contaminated solid metal to said body at said selected zone whereby they are closely surrounded primarily by the molten metal introduced at said zone, the proportion of added molten metal and added solid metal being regulated to produce and maintain a pasty mixture for retarding separation of the fluxing material until segregation of contaminants therein is substantially complete, and then suspending the addition of solid metal while continuing the introduction of molten metal for liquefying the pasty mixture, whereby separation of the segregated contaminants is effected.

13. The process of smelting light metals such as aluminum which comprises maintaining a reservoir of molten metal, continuously withdrawing molten metal from below the surface of said reservoir, continuously mixing the withdrawn metal with added pieces of solid metal and added fluxing materials in a mixing zone to effect heat transfer therebetween, the withdrawn metal and the solid metal being so proportioned as to continuously form a pasty mix for segregation of impurities, continuously moving said pasty mix into a melting zone, continuously heating the pasty mix in the melting zone to progressively liquefy the pasty mix and permit segregated impurities to separate and rise to the surface thereof, skimming off separated impurities, and continuously withdrawing molten metal from below the surface of the metal in said melting zone and conducting it into said reservoir of molten metal.

14. The process of claim 13 wherein a portion of the metal withdrawn from said reservoir of molten metal is introduced directly into said melting zone for heating the pasty mix therein.

15. The process of smelting contaminated metal, which comprises maintaining a body of metal in molten condition, continuously withdrawing molten metal from said body, mixing contaminated solid metal pieces into the withdrawn metal to mix and commingle the same and effect a heat transfer therebetween, adding fluxing materials to commingle with the mixed metals, the withdrawn metal being included in such quantity and at such a temperature that a pasty mixture results, maintaining the mixture in a pasty condition until the contaminants segregate from the metal, withdrawing additional molten metal from said body and adding the same to the pasty mixture to heat and liquefy the latter for separation of the contaminants in the presence of the fluxing materials, and separating the contaminants from the liquefied mixture.

16. The process of smelting contaminated light metals such as aluminum which comprises maintaining a body of metal in molten condition, continuously withdrawing molten metal from said body, adding contaminated solid metal to the withdrawn metal to produce a pasty mixture upon the transfer of heat between the withdrawn and contaminated metal, adding fluxing materials to the withdrawn and added metal for inclusion in the pasty mix, maintaining the fluxed pasty mix in heat conducting relation to the body of molten metal during segregation of contaminants, introducing additional molten metal into the pasty mix to liquefy the same for separation of the segregated contaminants, and continuously conducting liquid metal from the liquefied mixture into the body of molten metal.

17. The process of smelting contaminated light metals such as aluminum which comprises maintaining a body of metal in a pasty mix condition, simultaneously introducing predetermined proportioned quantities of molten metal and contaminated solid metal into a common zone of said pasty mix so that the solid metal is closely surrounded primarily by the liquid metal with which it is introduced, said predetermined proportions being such as to maintain the resulting mixture in a substantially pasty condition during

segregation of contaminants, adding flux, and thereafter introducing a continuous stream of molten metal into the mixture to supply heat for liquefying the mixture, whereby separation of the segregated contaminants is effected.

18. The process of smelting aluminum scrap which comprises feeding the scrap into a bath of molten metal in the presence of a flux and in such proportion as to form a pasty mix for segregation of impurities, flowing a substantially continuous stream of molten metal into the pasty mix to liquefy the pasty mix so that segregated impurities rise to the surface thereof, removing the impurities, and circulating a portion of the liquefied metal through a heating zone and return.

19. The process of smelting light metals such as aluminum to minimize oxidation which comprises feeding solid metal to a relatively small body of molten metal in such proportion as to form a pasty mix, adding fluxing materials to commingle with the pasty mix metal, maintaining the pasty mix in heat conducting relation to a relatively large body of molten metal while segregation of impurittics occurs in the pasty mix, flowing a substantially continuous stream of molten metal from the large body into the pasty mix to liquefy the pasty mix so that segregated impurities rise to the surface thereof, removing the impurities, and commingling the liquefied metal of the pasty mix with the large body of molten metal.

20. The process of smelting light metals such as aluminum which comprises maintaining a body of metal in molten condition, continuously withdrawing molten metal from said body, mixing the withdrawn metal with solid metal pieces to effect a commingling thereof and a heat transfer therebetween, adding fluxing materials to commingle with the mixed metals, the withdrawn molten metal being present in the commingled mass in such proportions as to form a pasty mix for segregation of impurities, heating the pasty mix to liquefy the same so that segregated impurities rise to the surface thereof, and commingling the liquefied metal with the body of molten metal.

21. The process of smelting light metals such as aluminum which comprises maintaining a body of metal in molten condition, continuously withdrawing molten metal from said body, continuously mixing withdrawn metal with solid metal pieces in a mixing zone to effect a heat transfer therebetween, the withdrawn metal and the solid metal being so proportioned as to continuously form a pasty mix for segregation of impurities, adding fluxing materials to commingle with the pasty mix metal, continuously heating the pasty mix in another zone to progressively liquefy the pasty mix so that segregated impurities rise to the surface thereof, removing the impurities, and continuously commingling liquefied metal of the pasty mix with the body of molten metal.

WALTER BONSACK.
WALTER M. WEIL.

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