Feb. 24, 1953 R. A. WILKINS ET AL 2,629,756

APPARATUS FOR SMELTING ZINCIFEROUS MATERIAL COMPRISING AN ELECTRIC FURNACE

Filed June 28, 1949 3 Sheets-Sheet 1

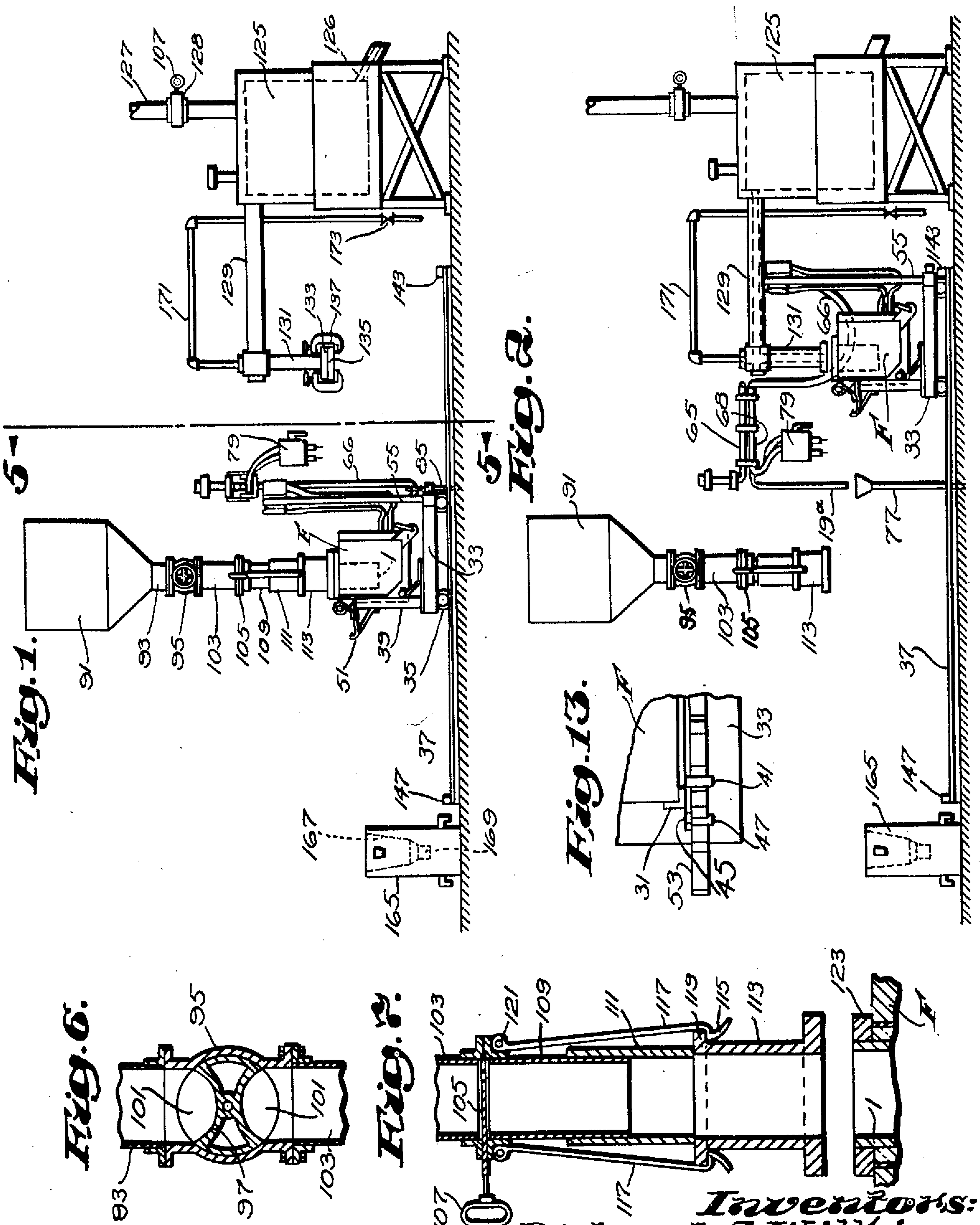

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Fig. 3.

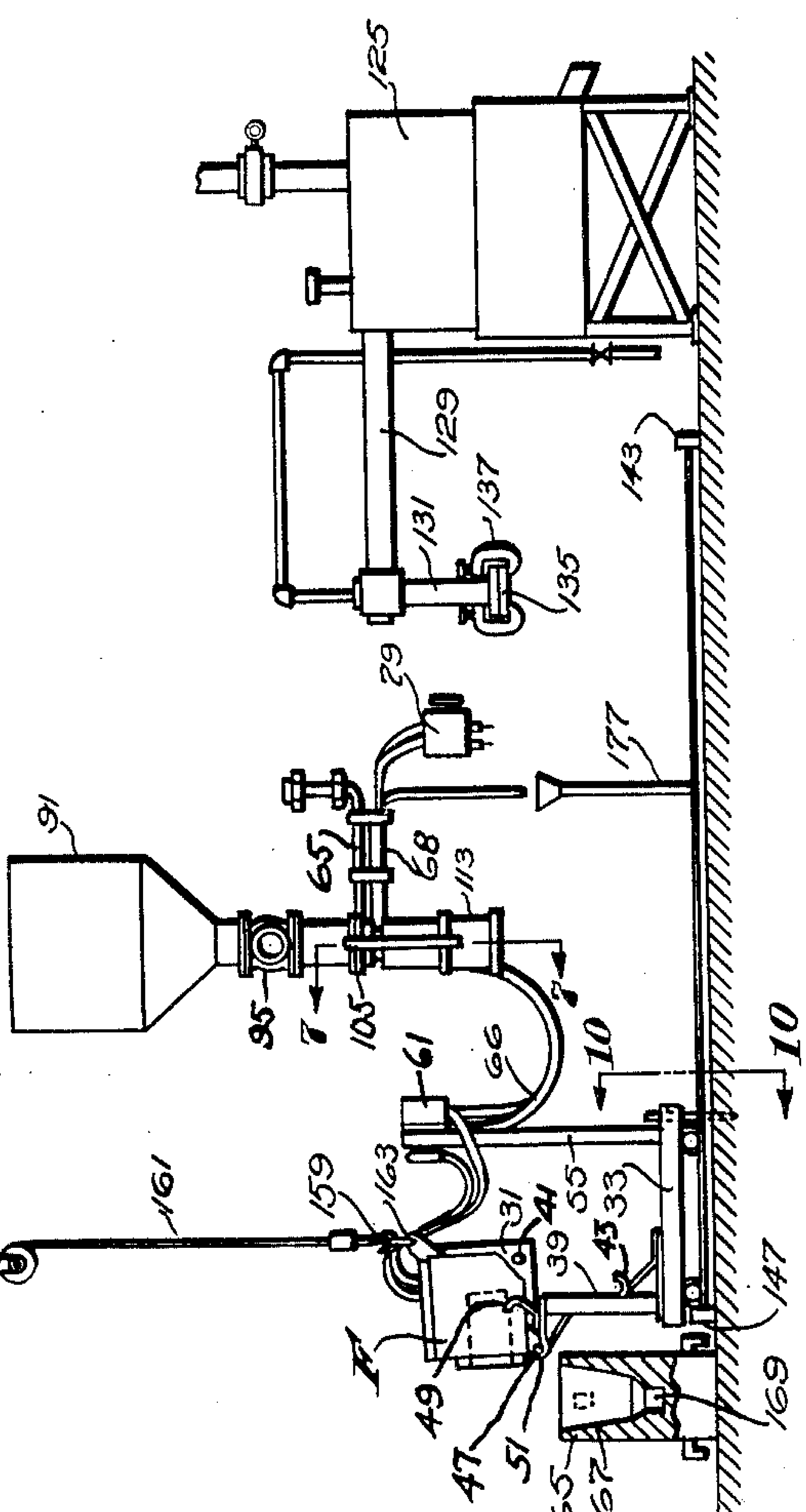

Fig. 4.

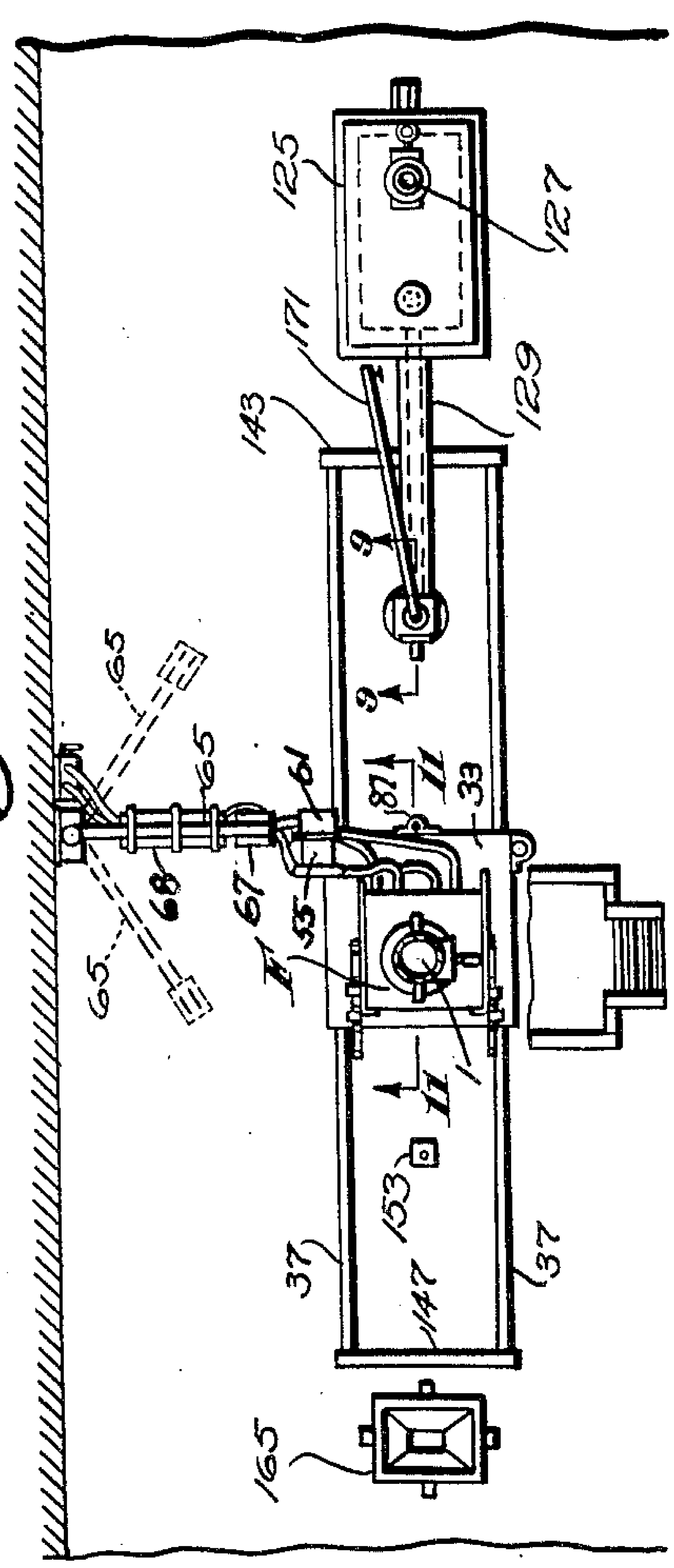

Fig. 8.

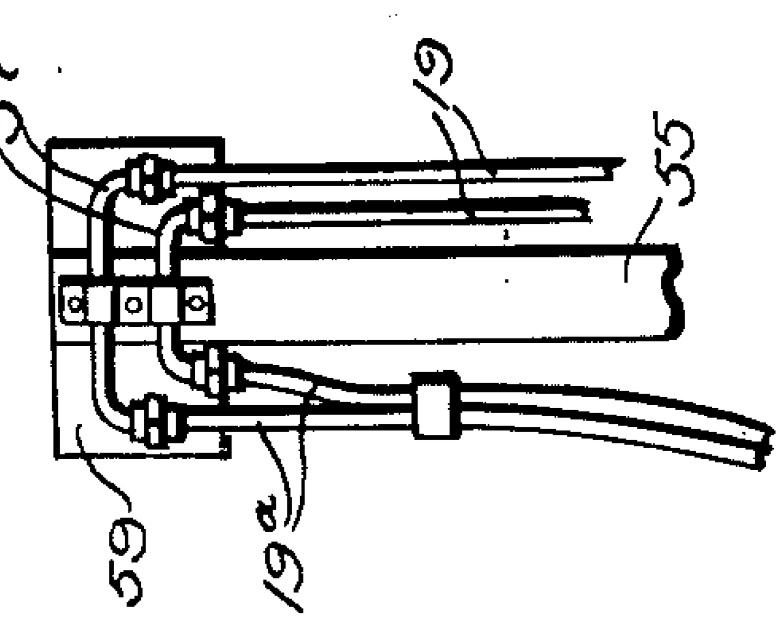

Fig. 9.

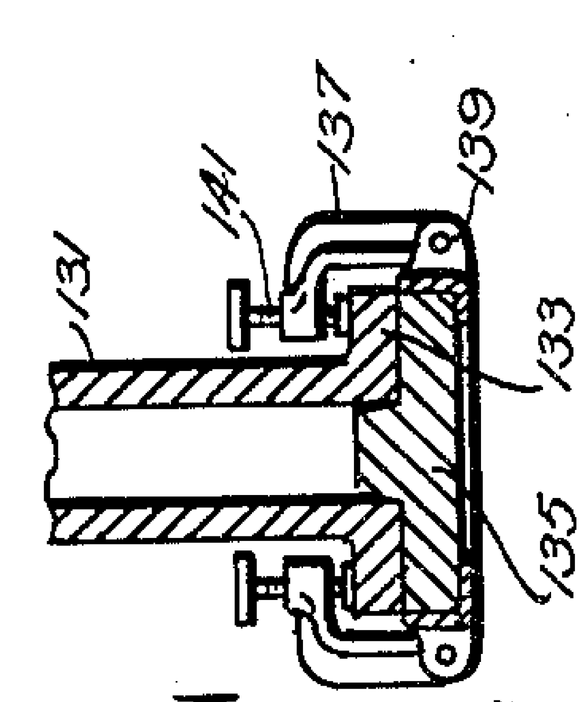

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Fig. 5. Fig. 11. Fig. 12

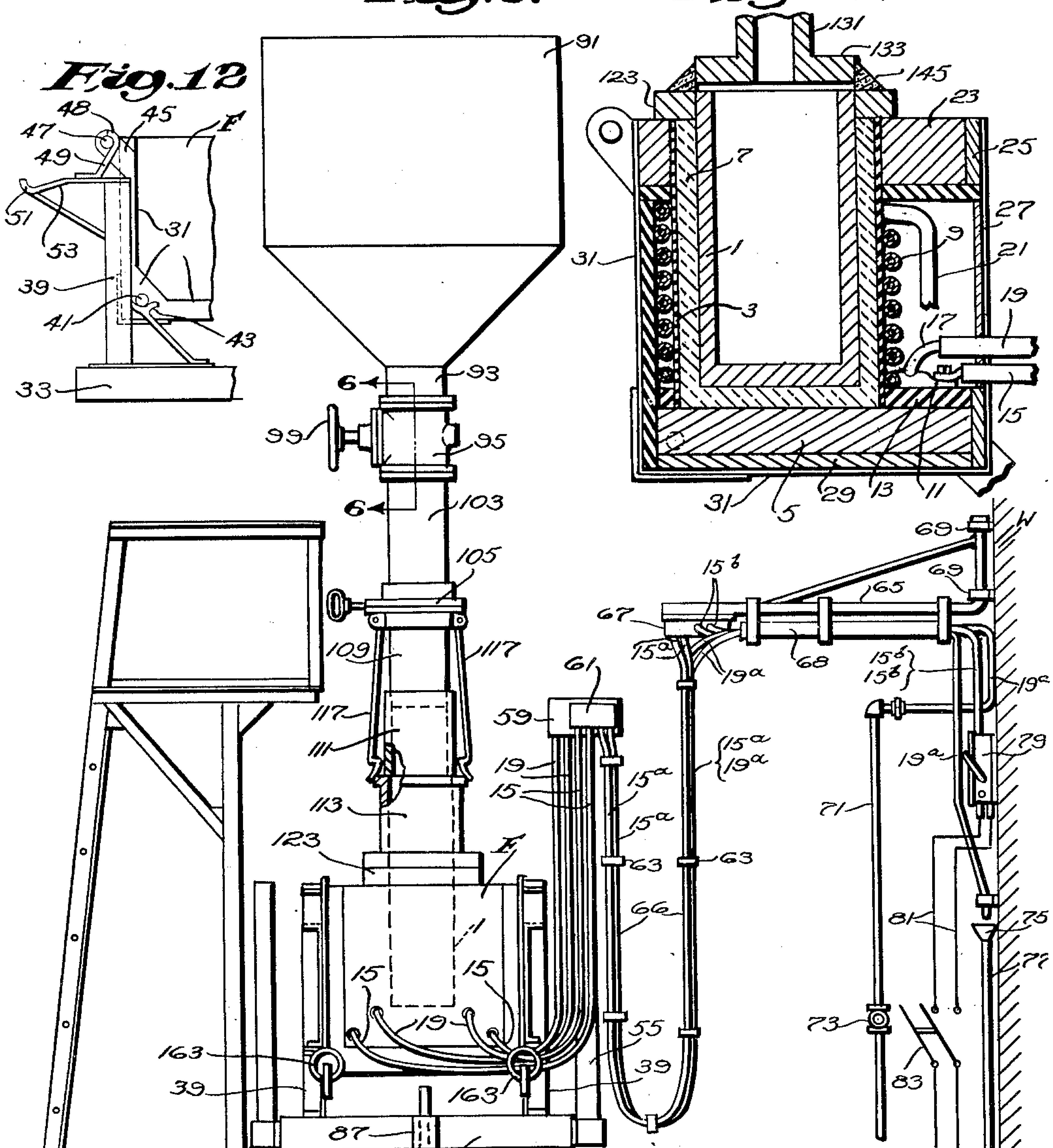
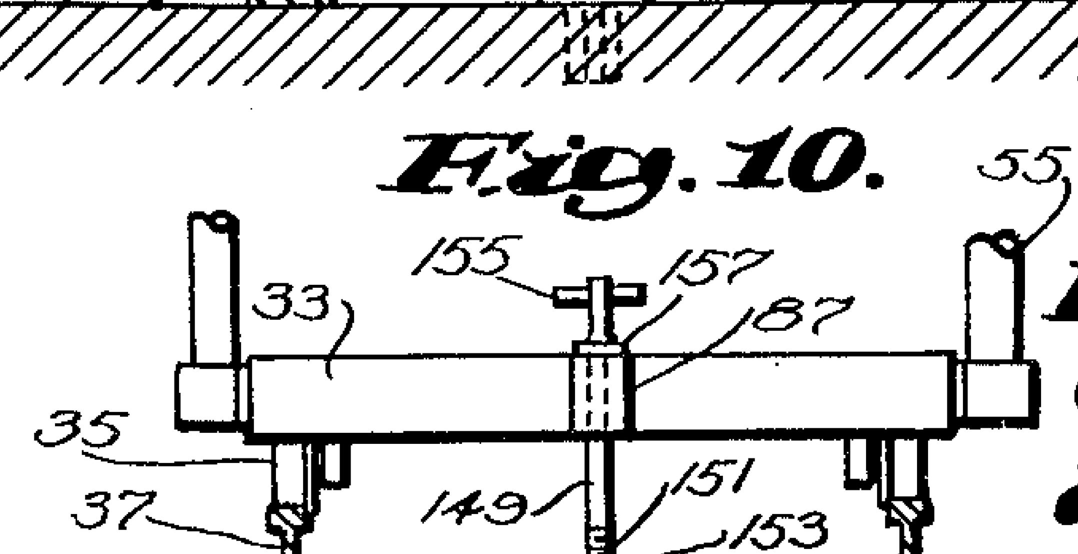


Fig. 10.



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UNITED STATES PATENT OFFICE

2,629,756

APPARATUS FOR SMELTING ZINCIFEROUS MATERIAL COMPRISING AN ELECTRIC FURNACE

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Application June 28, 1949, Serial No. 101,754

2 Claims. (Cl. 13—8)

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Our invention relates to the recovery of zinc from zinciferous materials, and particularly to the reduction of zinc from its ore concentrates known commercially as "zinc sinter" and "zinc calcine."

It will be understood that the significant zinciferous content of the ore as mined is zinc sulphide. To produce zinc sinter or calcine from the ore the latter after being mined is crushed and subjected to a separating operation for removing as much of the gangue as economically feasible. The concentrated crushed ore obtained as a result of the separating operation is roasted in the presence of air for converting the zinc sulphide to zinc oxide.

The roasted product contains some of the gangue of the original ore, which gangue is largely silica and other fusible substances capable of slagging if heated to the requisite temperature. Also the product contains other impurities among which are practically always iron, in the form of iron oxide and iron sulphide, and a small amount of the original zinc sulphide of the ore. Further, usually the product contains small amounts of copper in the form of copper matte (Cu_2S) or even metallic copper, and in most instances small amounts of the precious metals gold and silver.

In so far as the present invention is concerned, zinc sinter and zinc calcine are chemically substantially the same. They differ merely physically, in the unimportant respect so far as the present invention is concerned, in that the particles of the sinter, as its name indicates, are more or less fused. Therefore, for convenience in terminology, hereinafter and in the appended claims, both products will be referred to as "zinc sinter" or "sinter."

The invention has among its objects the recovery from the sinter of zinc in metallic form or otherwise, and the recovery of the precious metal values, if any, of the sinter. Among other objects are an apparatus and method by use and practice of which this recovery may be secured in a minimum of time and with reduced operating costs.

In common with the classic method of reducing zinc from zinc sinter, the improved method involves reacting the zinc oxide of the sinter with carbonaceous material. In the classic method the sinter is mixed with ground coke, coke fines, or ground anthracite coal to give about 100% excess carbon in respect to the stoichiometric amount necessary to react with the zinc oxide present. This mixture, according to the classic method, is charged into a retort and heated for about 24 hours at a temperature of about 2100° F., the zinc vapors as liberated from the charge ordinarily being condensed to liquid zinc in a condenser at the mouth of the retort. At the end of the reaction period the residue of the retort is a sticky pasty mass consisting of slag, coke or coal particles, the iron compound of the sinter, and about 35% zinc in the form of unreduced zinc oxide. This hot mass or residue, while the retort is still heated to a temperature of about 2100° F., is rabbled out by a laborious hand operation.

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According to applicants' method, however, instead of using such amount of the above mentioned carbonaceous materials as will give an excess of carbon of about 100% of that determined by stoichiometric considerations, only such amount as will give about 10 to 30% excess, preferably about 25%, is employed, this preferred amount thus effecting a saving of about 60% in the amount of coke or coal as compared to the classic method. Further, by applicants' method about 98% of the zinc value of the charge is recovered as compared to about 85% recovered by the classic method. Furthermore, instead of taking about 24 hours for treating the amount of sinter entered into a retort of the capacity employed commercially in practicing the classic method, applicants' improved method takes only about 1 to 2 hours for treating the same amount of sinter charged into a retort of the same capacity. Still further, by applicants' method the precious metal values of the sinter may be concentrated for ready recovery, and the labor involved in rabbling the residue from the retort is entirely eliminated.

According to applicants' method, after the charge is entered into the retort its temperature is raised to a value which liquefies the slag causing the retort contents to form a liquid mass that may be poured from the retort for clearing it preparatory to entering a fresh charge into it. The retort is charged, at a temperature not exceeding 2000° F., for preventing such active reaction as will cause evolution and escape of troublesome amounts of zinc fumes during the charging operation before the retort is sealed from the atmosphere. The reaction of the carbonaceous material with the zinc oxide of the sinter commences, in a commercial sense, at 1700° F. or slightly lower, and, according to applicants' invention, the temperature is gradually raised to about 2750 to 3000° F. for securing an active reaction and rendering the slag liquid.

The exact final temperature necessary to secure a pourable liquid mass in the retort will to some extent depend upon the amount of coke or coal remaining in the retort when the reaction is completed. Some of this coke or coal, which of course does not liquefy, tends to mix with the slag because of the agitation of the retort contents by the zinc vapors as the latter are liberated from the charge, and thus tends to render the slag less liquid. This reduction in liquidity can however be corrected by selecting a requisite final temperature, a higher temperature acting to increase the liquidity of the slag. With about 25% excess carbon in the form of coke or coal in the charge requisite liquidity will be secured under ordinary circumstances at a temperature of about 2750° F., and with an excess of carbon within the range of 10 to 30% in the form of coke or coal will be secured under all circumstances met with in practice without raising the temperature to more than about 3000° F. The coke or coal which floats on the slag, being dry, will readily pour from the retort with the liquid slag or the liquid mixture of slag and coke.

During the heating operation in the retort, the carbon reacts with the iron oxide of the sinter to produce metallic iron or a silicious alloy of the same, this iron or alloy almost always containing dissolved iron matte formed by the reaction of the iron with zinc or other sulphide in the sinter. This metallic iron, alloy and solution, which for convenience in terminology are in the appended claims referred to as "iron," all act to a moderate extent to take up the precious metal values of the sinter. However, the copper matte in the sinter as charged to the retort, and the copper matte formed by the reaction of metallic copper with the zinc or other sulphide in the sinter when it is heated in the retort, dissolve into the iron or iron alloy or solution very markedly to augment its property of scavenging the charge of its precious metal values. The amount of iron reduced can be controlled by holding the final temperature for the requisite time, even beyond the end of the reaction period. The molten iron or alloy or solution is poured from the retort with the molten slag into a container and is separated from the slag by liquation or other form of gravity separation. The iron or alloy or solution thus recovered may be treated, in a known manner, for recovering its precious metal values.

It will be observed from the above that there must be sufficient liquid in the retort at the end of the heating operation to render its contents pourable. Commonly enough liquid will be present if the charge contains 1% fusible slag forming material. The sinter will contain enough of such material to cause the charge to contain far more than this amount of the same. Also the coke or coal contains slag forming material which acts to increase the amount of liquid slag at the end of the heating operation. Any conceivable deficiency in slag forming material could be corrected by adding slag forming material, such as silica, to the charge.

Zinc sinter usually contains up to about 6 or 7% iron in the form of iron oxide and iron sulphide. Sufficient iron oxide, or other compound capable of being reduced to liquid metallic iron by the carbon, will be present in the charge if the metallic iron that can be so produced amounts to about 1% of the charge. In the rare case of a sinter which does not contain enough of such reducible compound the deficiency may be corrected by adding a requisite amount of the same to the charge with the coke or coal, or adding even chips of cast iron of high enough carbon content to be readily meltable.

The copper should be at least about 0.1% of the sinter to secure satisfactory results. All ordinary sinter contains at least that amount of copper in the form of copper matte or metallic copper, and also contains enough zinc sulphide to convert any metallic copper present to copper matte during the progress of the method. In the rare case of a sinter which is deficient in such substances the deficiency can be corrected by adding them to the charge when the coke or coal is added.

In the process the ground sinter may be merely mixed with the ground coke, coke fines or ground coal and charged to the retort, or the mixture may be briquetted to facilitate handling it and charging it to the retort.

Preferably, the retort employed in applicants' improved method is in the form of a crucible of a high frequency electric induction furnace, the material of the crucible or retort selected for such use being electrically conductive so that it will be directly heated by the inductive field for heating the charge when the electrical conductivity of the latter is impaired by consumption of the coke or coal toward the end of the reaction period. A high frequency induction furnace, unlike one of low frequency, does not require a conductive molten metal core to secure heating, and therefore lends itself to use in the practice of applicants' method. It will be understood that the coke or coal of the charge is electrically conductive and is directly heated inductively, so as to augment the heating effect on the charge by the container especially during the first part of the reaction when the coke or coal content is high, and that this results in a speedy operation.

Commonly the zinc of the vaporous or gaseous mixture given off by the retort in the practice of applicants' invention will be recovered by leading the mixture to a condenser and therein condensing the zinc vapors of such mixture to liquid zinc. However, if desired, a condenser of known design may be employed that will produce zinc powder instead of liquid zinc from the zinc vapors of the mixture. Also it is feasible to conduct such vaporous mixture to a chamber and therein in a known way combine the zinc vapors of the mixture with air to produce a pure form of zinc oxide.

Suitable apparatus for practicing the above invention is shown by the accompanying drawings in which:

Fig. 1 is an elevation of the apparatus according to the invention with parts omitted;

Figs. 2 and 3 are, respectively, elevations of the apparatus according to Fig. 1, with the parts in different operative positions;

Fig. 4 is a plan view of the apparatus according to Fig. 1 with parts omitted;

Fig. 5 is a section on the line **5—5** of Fig. 1 on an enlarged scale;

Fig. 6 is a section on the line **6—6** of Fig. 5;

Fig. 7 is a section on the line **7—7** of Fig. 3 on an enlarged scale with the furnace moved into its position shown by Fig. 1;

Fig. 8 illustrates a detail;

Fig. 9 is a section on the line **9—9** of Fig. 4 on an enlarged scale and with parts omitted;

Fig. 10 is a section on the line **10—10** of Fig. 3 on an enlarged scale, with parts omitted and parts broken away;

Fig. 11 is a vertical medial section of the furnace on an enlarged scale, corresponding to a section on the line 11—11 of Fig. 4 when the parts are in their position shown by Fig. 2;

Fig. 12 is an elevation of a fragment of the furnace according to Figs. 1 to 5 and 11 on an enlarged scale; and

Fig. 13 is a plan of the parts shown by Fig. 12.

The furnace illustrated in the drawings is of the high frequency induction type hereinbefore referred to, which furnace is operated conveniently at about 1000 cycles per second and at from 900 to 1300 volts, with a power input sufficient to secure the requisite temperature of the charge, although neither the frequency nor voltage is critical and may be varied within very wide limits. The furnace shown is of a known type, and consequently will be described only with such particularity as necessary to show how it cooperates with other parts of the embodiment of applicants' invention illustrated.

As shown, the furnace comprises a crucible 1 (Fig. 11) of circular cross-section forming a retort for receiving the charge, the material selected for this crucible being of heat refractory electrically conductive material such as graphite, hard carbon, silicon carbide, or the like. In spaced relation to the walls of the crucible is shown a thin walled cylinder 3 of heat refractory electric insulating material, while below the crucible in spaced relation thereto is a layer 5 of heat refractory electrically non-conductive firebrick, the space between the crucible and the cylinder 3 and between it and the firebrick layer 5 being filled with a molded body 7 of heat refractory heat insulating electrically non-conductive material. The cylinder 3 is surrounded by a solenoid coil 9, of hollow copper tubing, the lower end terminal portion of which tubing is deformed to close it and to provide an electric terminal 11 supported by an insulating block 13. To this terminal is connected a flexible insulated electric cable 15. Adjacent the terminal 11 the coil is shown as formed with a tubular branch outlet 17 to which is connected a flexible water hose 19 of synthetic rubber or other electrical non-conductive material. The opposite end of the coil is provided with an extension 21 which terminates in a like terminal 11 (not shown) resting on the insulating block 13 for connection thereto of a second flexible insulated electric cable 15, the extension 21 adjacent its terminal being also provided with a branch outlet 17 (not shown) for connection thereto of a second flexible water hose 19. The crucible and heating coil, as shown, are received in a box-like casing, formed of heat refractory heat insulating electrically non-conductive material preferably of so-called "asbestos lumber," the casing comprising the parts 23, 25, 27 and 29 (Fig. 11) and having its corners reinforced by the metal angle frame 31 best shown in Figs. 3 and 12.

As illustrated, the furnace F is mounted on a carrier constituted by the movable carriage 33 having wheels 35 supported on horizontal rails 37. This carriage is shown as provided at one end with spaced vertical posts 39 (Figs. 1, 5 and 12) between which the furnace is positioned adjacent a pair of its opposite vertical corners. The furnace, which exteriorly is approximately in the form of a square prism, is tiltably mounted on these posts so that the crucible may be poured. For so mounting it the furnace is provided at the lower portion of its sides adjacent the posts with diametrically opposite projecting horizontal pins 41 (Figs. 12 and 13), which pins are pivotally supported on the hook-like brackets 43 carried by the posts. Adjacent its corners at the tops of the posts the furnace is provided with extending lugs 45 from which project the diametrically opposite horizontal pins 47. Tilting of the furnace under the force of gravity to the right, as viewed in Fig. 12, about the pins 41 as a fulcrum is prevented by engagement of the pins 47 with the hook-like ends 48 of the brackets 49 carried by the posts. The furnace may be tilted to the left, as viewed in Fig. 12, about the pins 41 as a fulcrum until the pins 47 are engaged by the hook-like ends 51 of the brackets 53 carried by the posts, whereupon further tilting of the furnace may be effected by swinging it about the pins 47 as a fulcrum to move it to its position shown by Fig. 3 for pouring its contents. When lowered from the position shown by Fig. 3 the furnace will swing by gravity about the pins 47 as a fulcrum while they are engaged by the hook-like ends 51 until the pins 41 are engaged by the brackets 43, and then the furnace will swing by gravity about the pins 41 as a fulcrum until the pins 47 are engaged by the hook-like ends 48 of the brackets 49.

For permitting tilting of the furnace, the flexible cables 15 and flexible water hoses 19 loosely extend upward to the top of a post 55 (Figs. 5 and 8) carried by the carriage 33. This post adjacent its top carries at one of its sides a pair of connectors 57 (Fig. 8), of insulating material, to one of the ends of which are connected the water hoses 19 and to the other ends of which are connected the continuing flexible water hoses 19^a of the same material as the hoses 19. The post at its opposite side adjacent its top carries a panel 59 on which is mounted a junction box 61 (Fig. 5) which the ends of the cables 15 enter for connection to continuing flexible insulated electric cables 15^a. The two cables 15^a and the two hoses 19^a are bunched together by suitable tying means 63, and extend downward from the top of the post and then upward to the free end of a beam 65 to form a flexible bight 66. The beam at its free end carries a junction box 67 (Fig. 5) which the two cables 15^a enter and in it are connected to further continuing flexible insulated cables 15^b. The two cables 15^b and the two water hoses 19^a extend through a trough-like conduit 68 fixedly carried by the beam and extending lengthwise thereof. The beam is shown as pivotally mounted for horizontal swinging in bearings 69 carried by a wall W. The cables 15^b and hoses 19^a extend from the end of the conduit 68 adjacent the wall and turn downward. One of the hoses 19^a is connected to a pipe 71 provided with a control valve 73 for supplying cooling water to the coil 9 of the induction furnace. The other hose 19^a discharges the cooling water from the coil into a funnel 75 carried at the upper end of a pipe 77 leading to a sewer or other convenient place of disposal of the water. The two flexible cables 15^b are shown as extending to a further junction box 79 carried by the wall, and in it are connected to the leads 81 controlled by the switch or other suitable instrumentality 83 for controlling the energizing of the induction coil of the furnace. The swinging beam 65 and bight 66 permit the carriage 33 to be moved from its position shown by Figs. 1 and 5 into its two other positions hereinafter described.

The carriage is held in its position shown by Fig. 1, in which position the charge is entered into the retort, by a removable bar 85 (Figs. 1 and 5) inserted by the operator through a perforated lug 87 fixedly carried at the end of the carriage 33 into the perforation of a bushing 89 fixedly set into the floor.

The prepared mixture constituting the material to be charged is stored in a hopper 91 from which leads a downwardly extending chute 93. In this chute is shown a measuring valve 95 having the rotatary member 97 (Fig. 6) adapted to be turned by the handwheel 99 (Fig. 5). By rotating the valve, the material from the hopper received in the recesses 101 of the valve when those recesses are uppermost is discharged into the portion 103 of the chute below the valve when those recesses are lowermost. Below the measuring valve the chute 93, 103 is provided with a gate valve 105 (Figs. 5 and 7) having an operating handle 107. When the gate valve is closed a measured quantity of the charge may be entered into the portion of the chute between that valve and the measuring valve by rotating the latter, whereupon the gate valve may be opened to discharge such measured quantity from the chute. Thus the portion of the chute between the two valves constitutes a receptacle for receiving a measured quantity of the charge to be entered into the retort. The portion 109 of the chute below the gate valve is received in the upper end of the sleeve 111 which is slidably mounted thereon, and below this sleeve is a connector sleeve 113, of heat refractory material, on which the sleeve 111 rests. The connector sleeve 113 and sleeve 111 are held in their positions shown by Fig. 7 by reason of engagement of the hooked ends 115 of the latches 117 with the annular flange 119 at the upper end of the sleeve 113, the latches at their upper ends being pivotally carried at 121 by the casing of the gate valve.

When the carriage is moved to place the furnace beneath the opening of the sleeve 113 in registry therewith the latches may be disengaged from the flange 119 to release the sleeves 111 and 113 to permit the latter to rest, as shown by Figs. 1 and 5, upon the ring-like member 123 (Figs. 5 and 11), of refractory material, which surrounds the upper projecting end of the retort. Under these conditions when the gate valve 105 is opened the measured quantity of material between that valve and the measuring valve 95 will discharge into the retort chamber, whereupon the sleeve 113 may be raised to cause it to be engaged by the latches 117 to permit the carriage to move the furnace away from its position shown by Figs. 1 and 5 after the positioning bar 85 is withdrawn, it being understood that, as hereinbefore explained, the furnace is charged when its temperature is below that at which active reaction of the carbon with the zinc sinter does not occur so as to prevent troublesome emission of undue amounts of zinc fumes from the retort prior to its being connected to the zinc condenser as hereinafter described.

As shown, the apparatus comprises a condenser 125 for converting to liquid zinc the zinc vapors generated by the reaction of the carbonaceous material with the zinc oxide of the charge in the retort. As shown, this condenser is provided with a tap 126, a vent pipe 127, and an inlet conduit 129, the vent pipe having a control valve 128. Normally the tap will be open and the valve 128 closed so that liquid zinc formed in the condenser will be discharged therefrom together with the carbon monoxide generated in the retort and passing into the condenser with the zinc vapors. The carbon monoxide may be burned as it issues from the tap. If desired, however, the vent pipe valve may be normally partially open to cause the vent pipe to conduct carbon monoxide to any desired place of using it as a fuel gas.

The condenser inlet conduit 129, as shown, has a downwardly extending portion 131 the lower end of which is provided with an annular flange 133 (Figs. 1 and 9). The conduit, when the retort is not connected to it, normally is closed by a cap 135 releasably secured to the lower end of the conduit by C-clamps 137, the lower ends of which clamps are pivoted at 139 to the cap, as shown by Fig. 9, and the upper ends of which have manually operated screws 141 adapted to engage the upper side of the flange. Preparatory to pushing the carriage to its position shown in Fig. 2, in which position the wheels of the carriage adjacent the condenser are against the positioning stop 143 on the rails 37, the cap is removed. When in the position shown by Fig. 2 the conduit is in registry with the retort chamber of the furnace for receiving the zinc vapors generated in the retort and conducting them to the condenser for there condensing them to liquid zinc. The joint between the conduit and the retort is preferably sealed, while the zinc fumes are being evolved, by a ring-like mass 145, of fireclay, applied while it is plastic to the joint between the flange and the ring-like member 123 at the mouth of the retort, as best shown by Fig. 11.

It will be understood that the furnace is energized after it is moved to its position shown by Fig. 2 to heat the contents of the retort for liberating the zinc from the zinc oxide, reducing the iron compound of the charge, and rendering the contents of the retort pourable. When the furnace is to be poured it is moved from its position shown by Fig. 2 to its position shown by Fig. 3, in which latter position the wheels at the left hand end of the carriage are brought up against the positioning stop 147 on the rails. In this position the carriage is secured against tilting relative to the rails by the operator inserting through the perforation of the lug 87 on the carriage a rod 149 (Fig. 10) having a screw-threaded end 151 adapted to be screwed into the threaded perforation of a bushing 153, fixedly secured to the floor, by the operator turning the rod by means of the handle 155 at its upper end, the rod also having a collar 157 which is brought up against the upper end of the lug when the rod is so screwed into the bushing. When in this position the furnace is tilted, in the way hereinafter described, by engaging the hooks 159 of a bridle at the free end of the cable 161 of a hoist with the rings 163 (Figs. 3 and 5) carried at one end of the furnace.

Conveniently, when the furnace is tilted its contents are poured into a movable mold 165 having a tapered mold chamber 167 at the bottom of which is a reduced diameter portion 169. This chamber is so proportioned that the iron, which sinks and separates by liquation from the contents of the crucible poured into the mold chamber, will be received by the reduced diameter portion of that chamber, while the slag will be retained in the portion of the chamber above the iron, which enables the iron to be separated from the rest of the mass molded by the chamber by striking the iron with a sharp blow with a sledge after such mass solidifies by cooling and is removed from the mold.

When the furnace is moved from its position shown by Fig. 2 to that shown by Fig. 3 it is first necessary to break away the seal 145 of fireclay and move the furnace from beneath the condenser inlet conduit before the cap 135 can be replaced. During the interval which elapses between opening of the conduit to the atmosphere in this way and the replacement of the cap atmospheric air will be drawn into the condenser if means are not taken to prevent it. For preventing this, communicating with the upper end of the downwardly extending portion 131 of the condenser inlet conduit is a pipe 171 controlled by a valve 173 for entering a downwardly projected supply of inert gas, such as nitrogen, or, preferably, a burnable inert gas, such as carbon monoxide, into said portion of the conduit. This gas which is so admitted, when the furnace is about to be moved away from its position shown by Fig. 2, tends to escape from the lower end of the conduit and, if burnable, will be ignited by the hot contents of the retort as soon as the fireclay seal is broken to permit the gas to contact with the atmosphere, and will burn until the supply of gas is interrupted or the cap is replaced. When the cap is again removed preparatory to moving the furnace again beneath the condenser inlet conduit the supply of gas to the conduit may be reestablished and, if burnable, ignited with a torch, such supply being continued until the furnace is in place and the joint sealed with fireclay as above explained. By use of a combustible gas for this purpose the gas is ineffective in respect to having any harmful effect on the operators of the apparatus.

The energization of the furnace may be continued if necessary until after it is poured. However, after the furnace is poured it is permitted to cool, as hereinbefore explained, to such a temperature as will not generate troublesome amounts of zinc fumes during the charging operation and while it is being moved from its position shown by Fig. 1 to that shown by Fig. 2.

It will be understood that within the scope of the appended claims wide deviations may be made from the forms of the invention described without departing from the spirit of the invention.

We claim:

1. Apparatus for separately recovering metallic zinc and iron from a mixture containing zinc oxide, carbon reducible iron compound, and electrically conductive reaction carbon comprising a furnace having a substantially closed retort chamber provided with an electrically conductive lining and having a charging port for said chamber provided with an upwardly facing entrance opening, means for charging said chamber with the mixture comprising a discharge means presenting a downwardly facing opening, a movable carrier for said furnace having a position of movement in which said upwardly facing opening of said charging port is positioned below said downwardly facing opening of said discharge means in registry therewith whereby said chamber may be charged with the mixture, a condenser for condensing zinc vapors to liquid zinc, which condenser has an inlet conduit presenting a downwardly facing inlet opening, the carrier having a second position of movement in which said entrance opening of said charging port is positioned below said inlet opening of said condenser inlet conduit in registry therewith, electric circuit means for inducing a high frequency heating current in the reaction carbon of the charged mixture for reacting the zinc oxide and iron compound of the mixture with the reaction carbon to produce vaporous zinc and molten iron and discharge the vaporous zinc into said condenser when said entrance opening of said charging port is in registry with said inlet opening of said condenser inlet conduit and for also inducing a high frequency heating current in said lining for augmenting the heating of the mixture and for maintaining the iron molten upon depletion of the reaction carbon of the mixture.

2. Apparatus according to claim 1 in which the furnace it tiltably mounted on the movable carrier for pouring, from the retort chamber through the charging port when the carrier is moved to a third position, the molten iron maintained in liquid condition by the current in the electrically conductive lining.

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