No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 1.

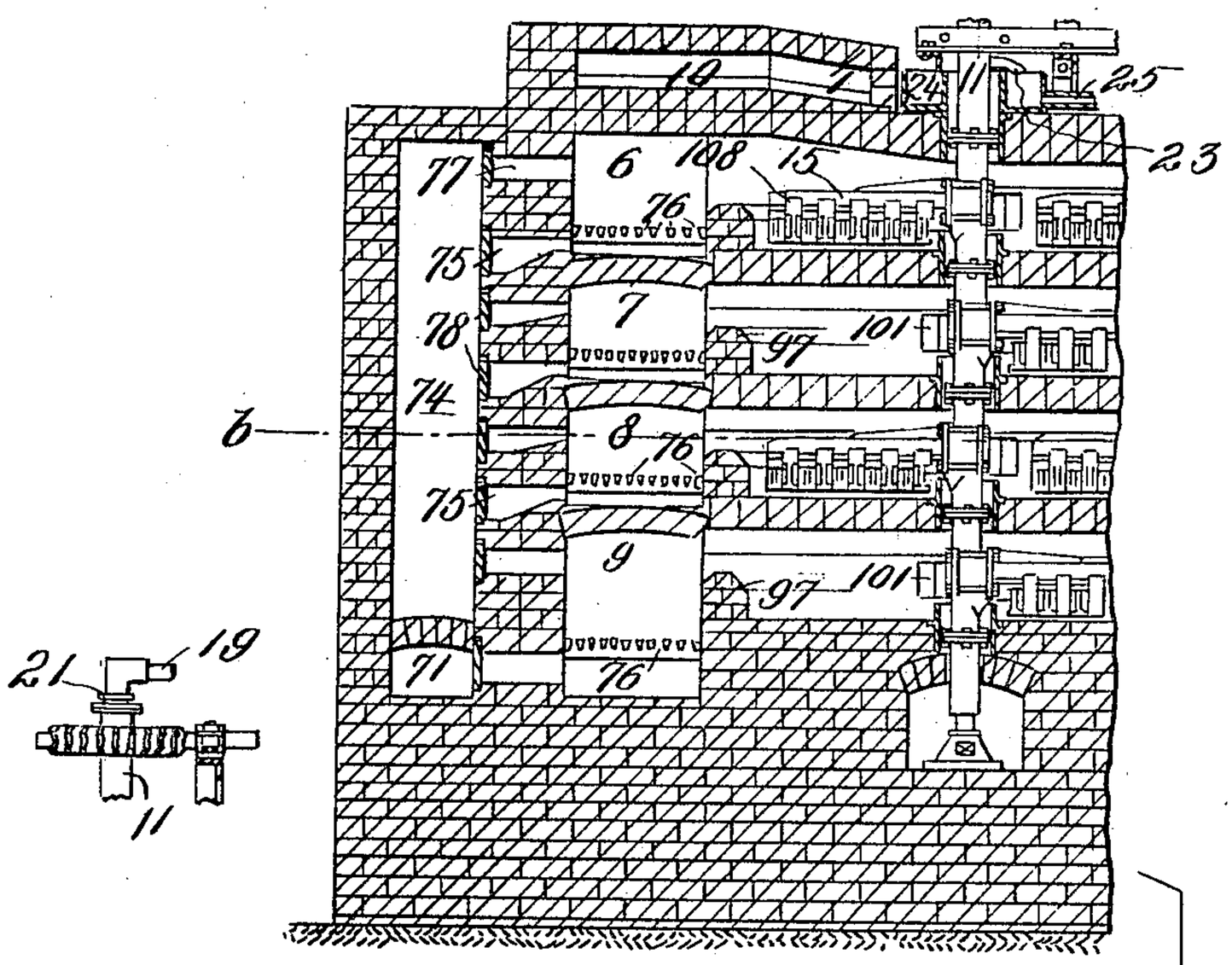
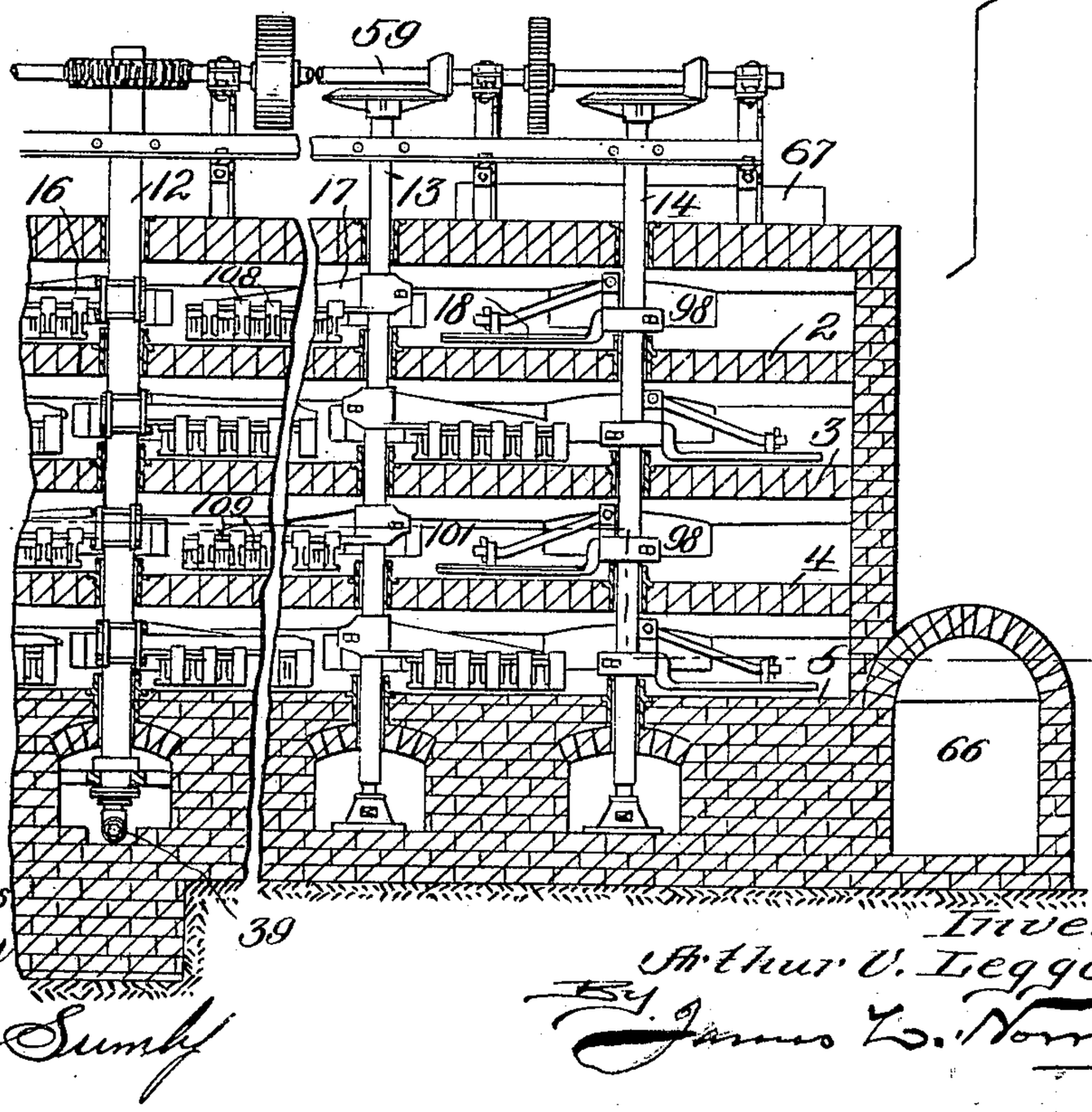


Fig. 1.



Witnesses
C. Kesler
Dennis Sumby

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 2.

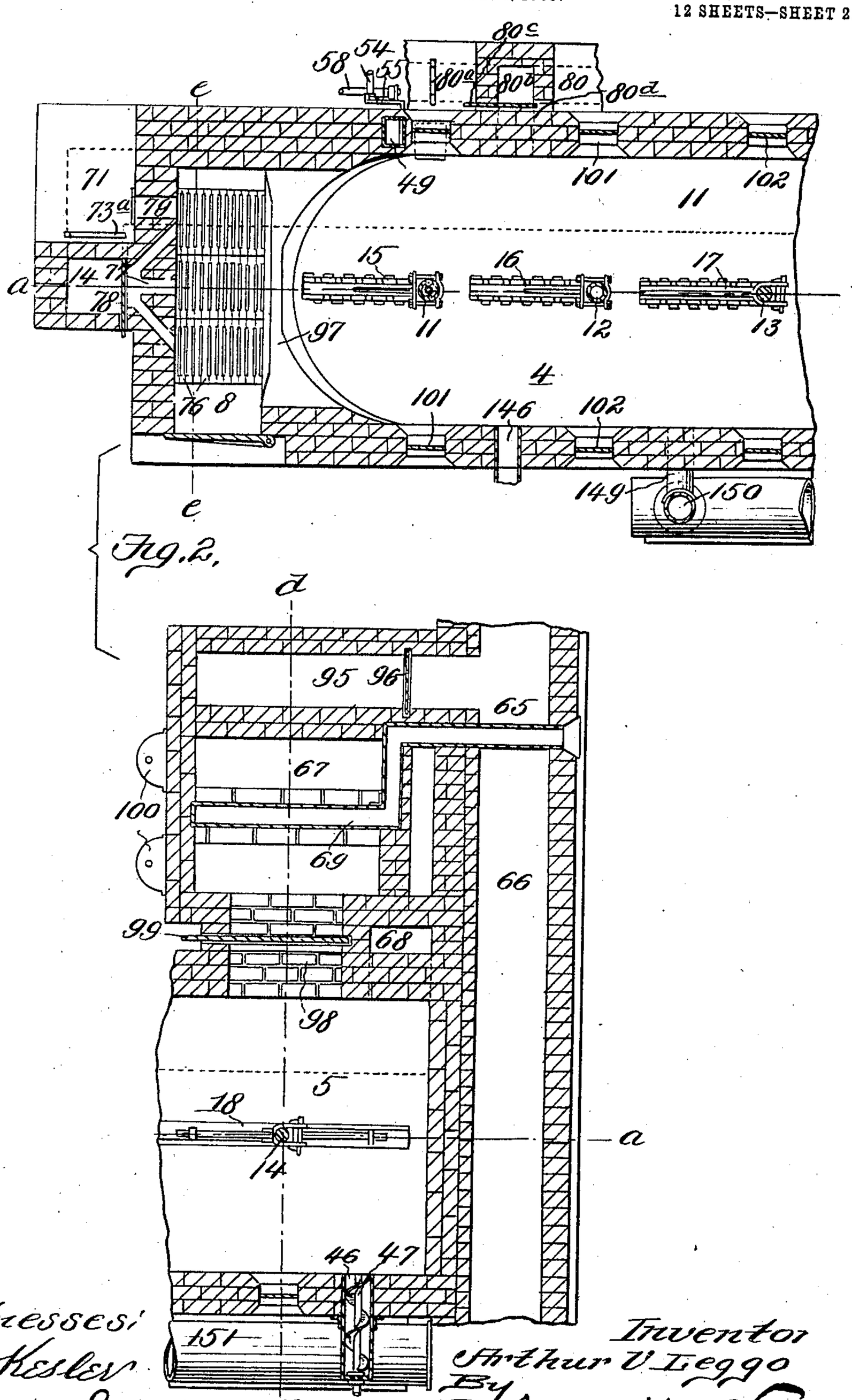


Fig. 2.

Witnesses:
C. L. Kesler
Dennis Sunby.

Inventor
Arthur V. Leggo
By James L. Norris.
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 3.

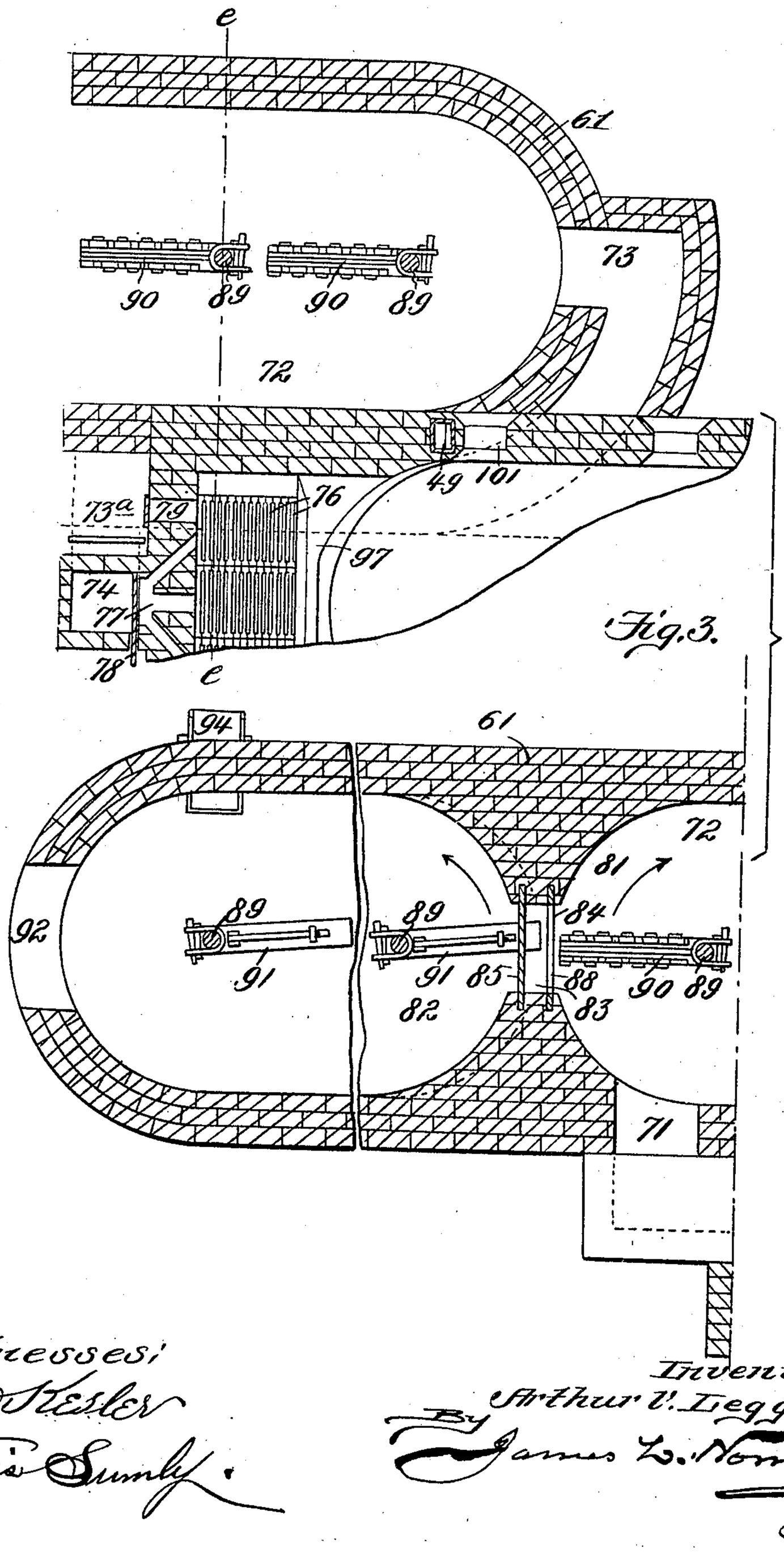


Fig. 3.

Witnesses:
C. D. Steele
Dennis Sunly.

Inventor
Arthur V. Leggo
By James L. Norris.
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 4.

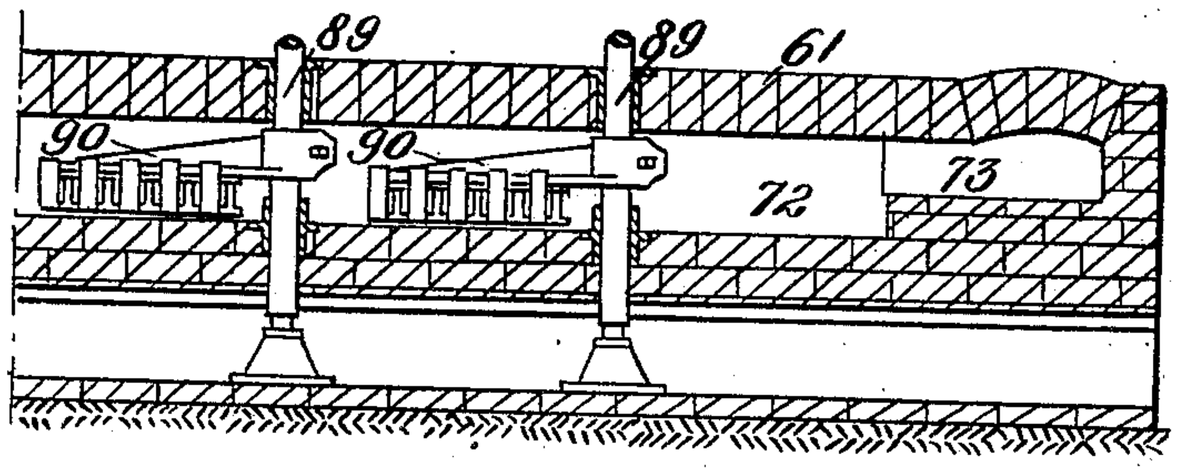


Fig. 4.

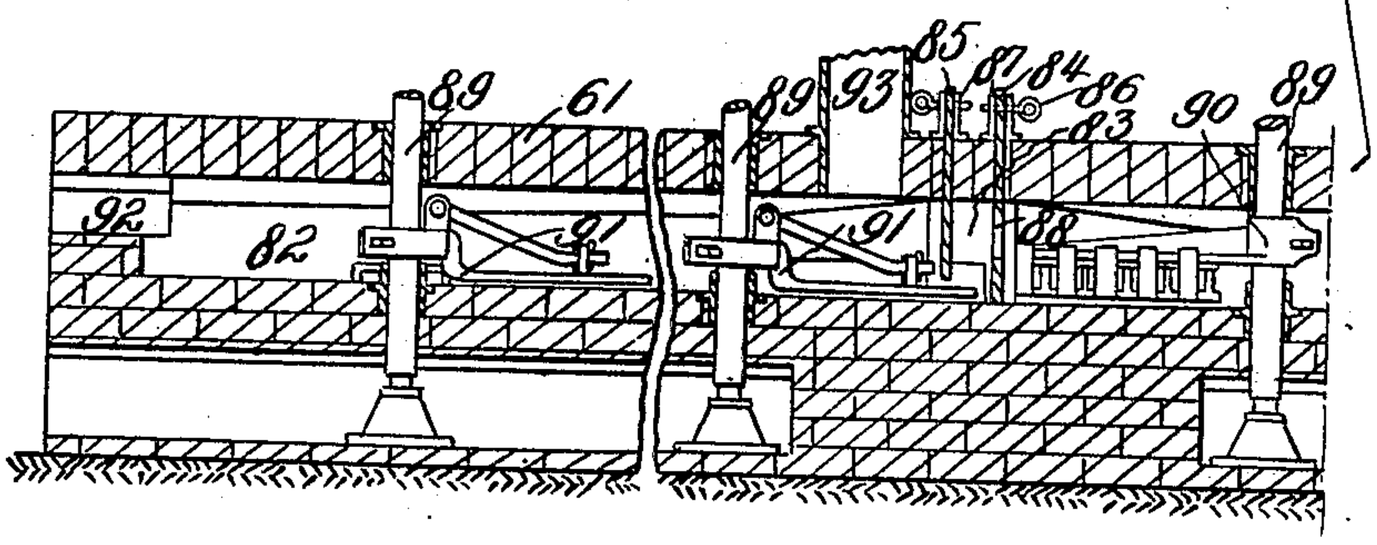


Fig. 4.1.

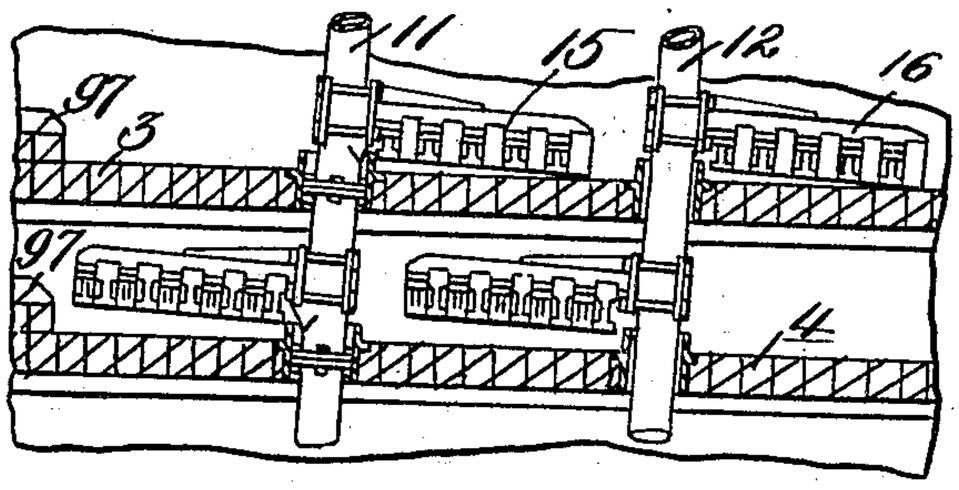


Fig. 4.1.A

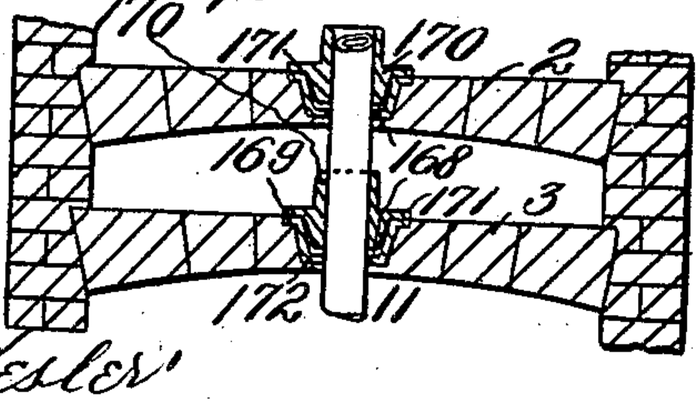
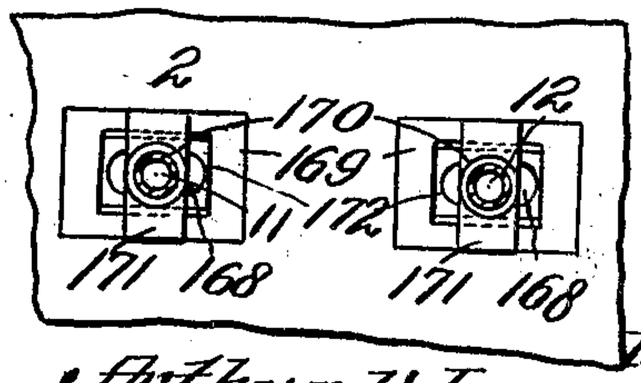


Fig. 4.1.B



Witnesses
C. D. Kesler
Dennis Sandy

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 5.

Fig. 5

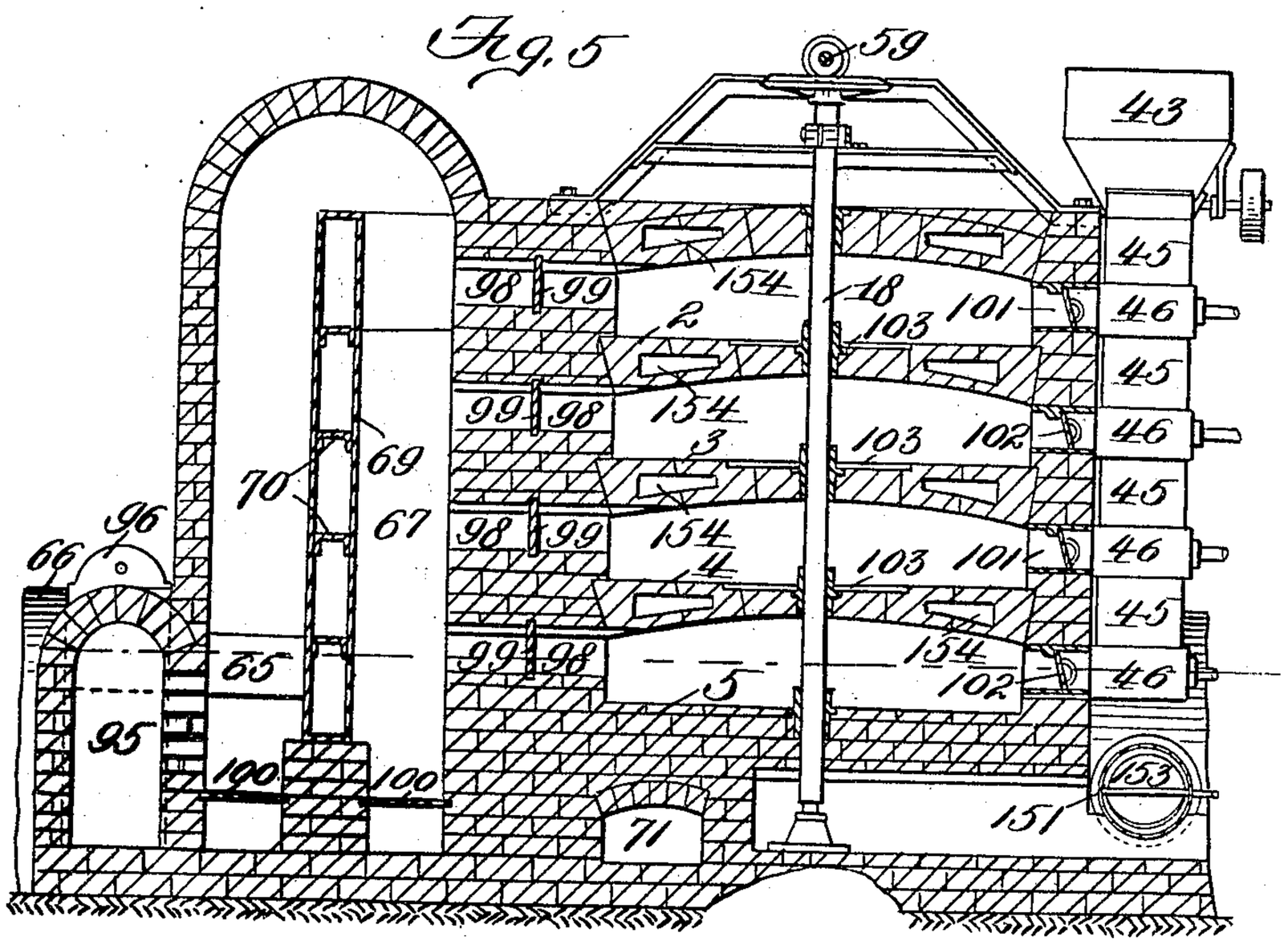
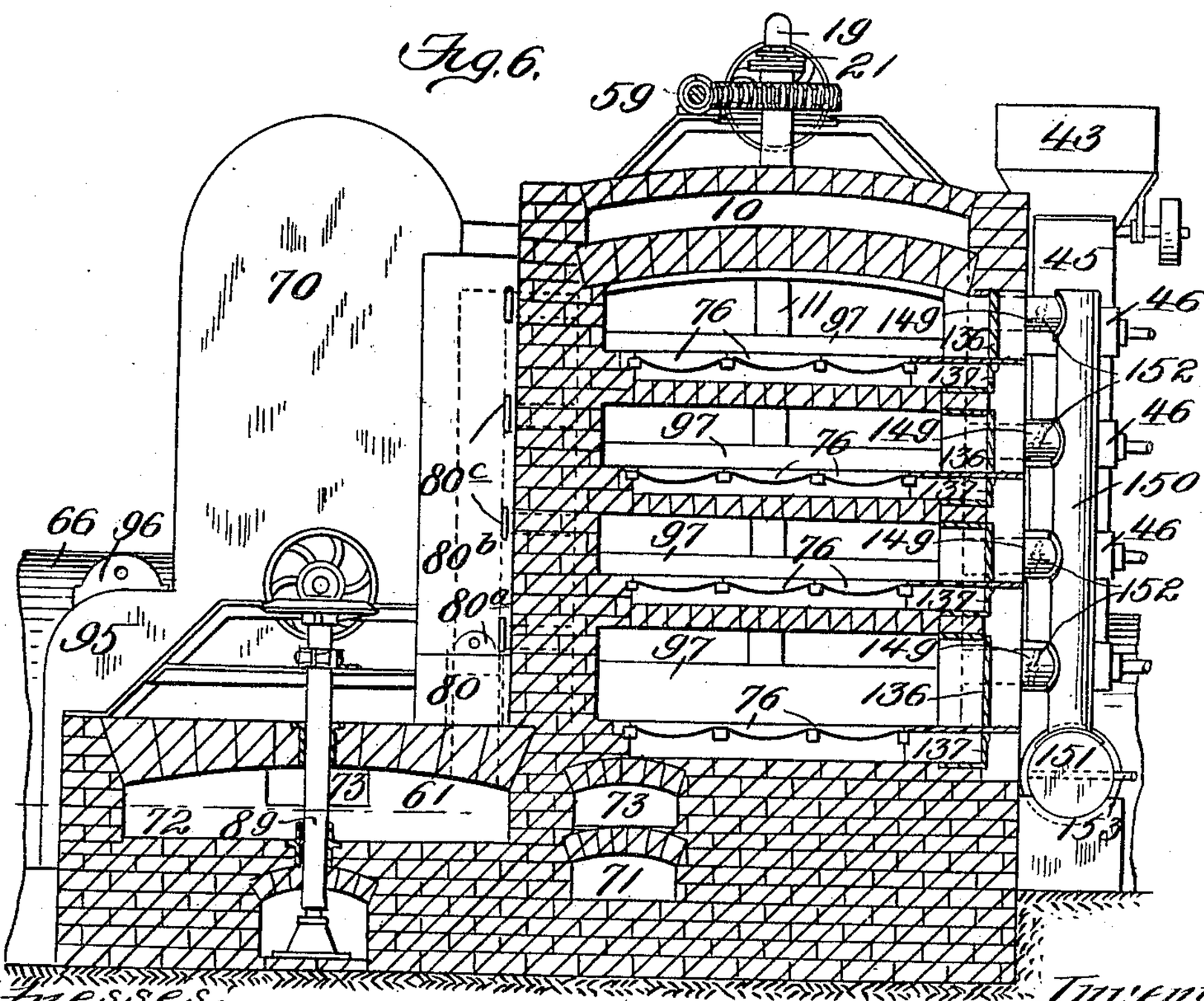


Fig. 6.



Witnesses:
G. F. Kesler
Dennis Sunby.

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 6.

Fig. 7.

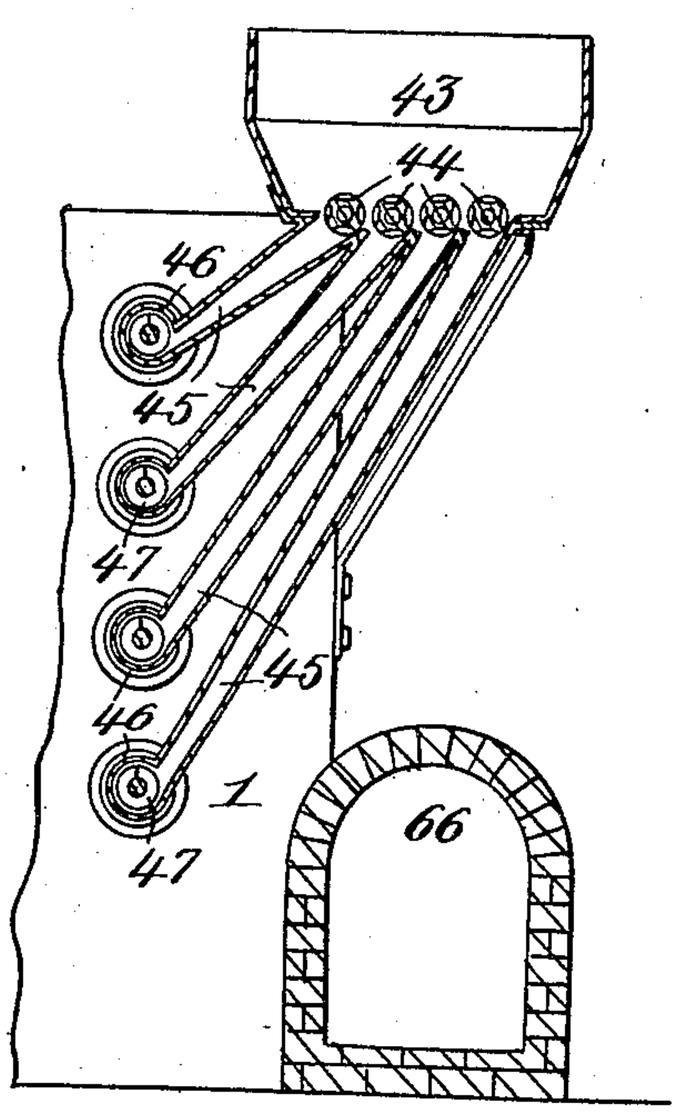


Fig. 8.

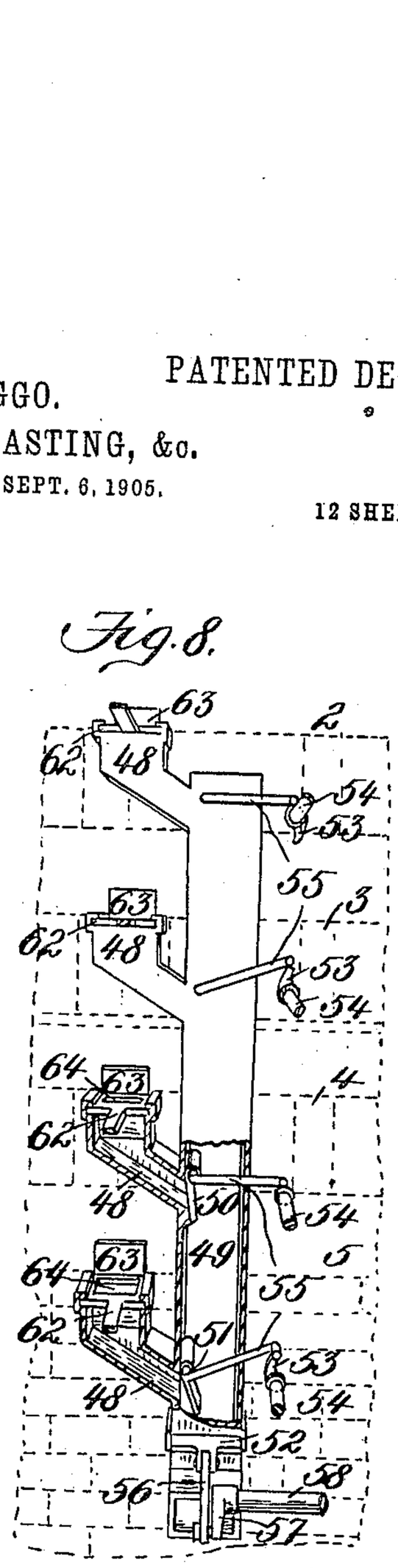
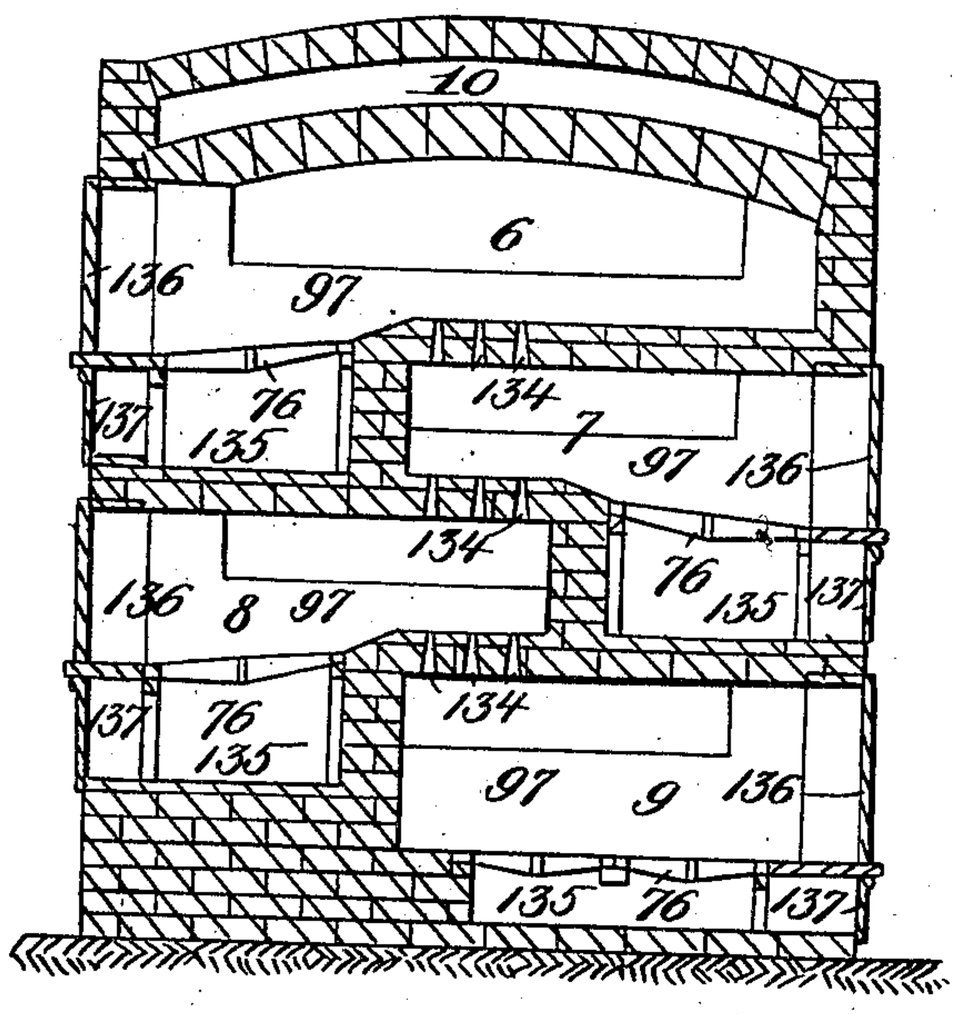


Fig. 9.



Witnesses:
C. D. Kesler
Dennis Sumby.

Inventor
Arthur V. Leggo
By James L. Norris.
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 7.

Fig. 10.

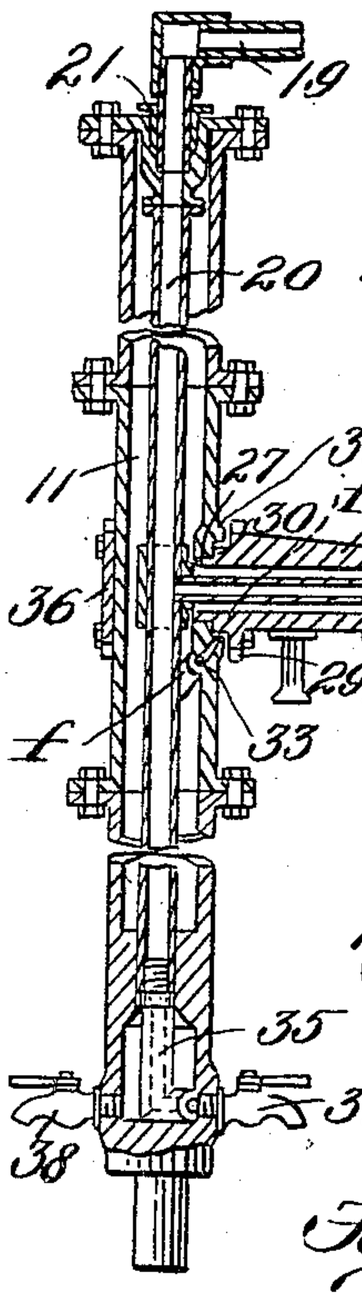


Fig. 11.

Fig. 12.

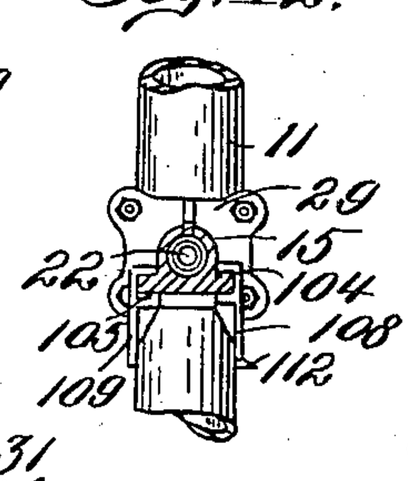


Fig. 13.

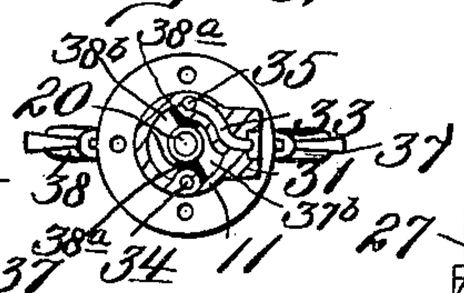


Fig. 15.

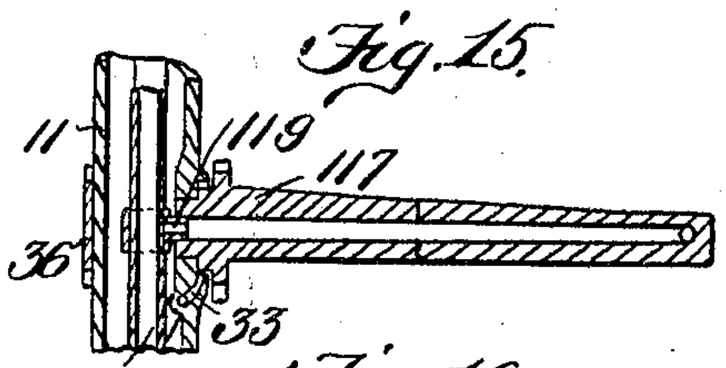


Fig. 16.

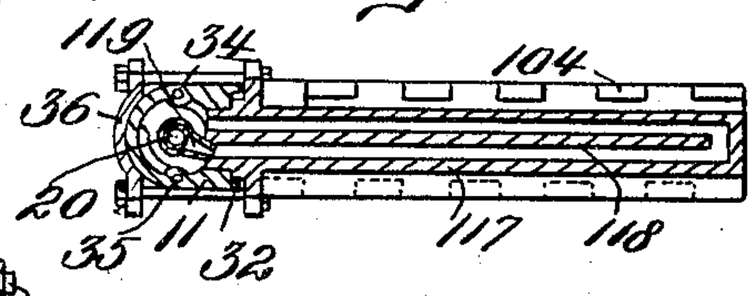


Fig. 17.

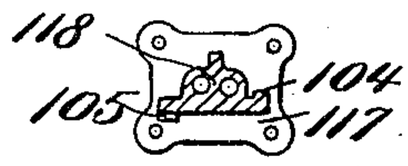


Fig. 18.

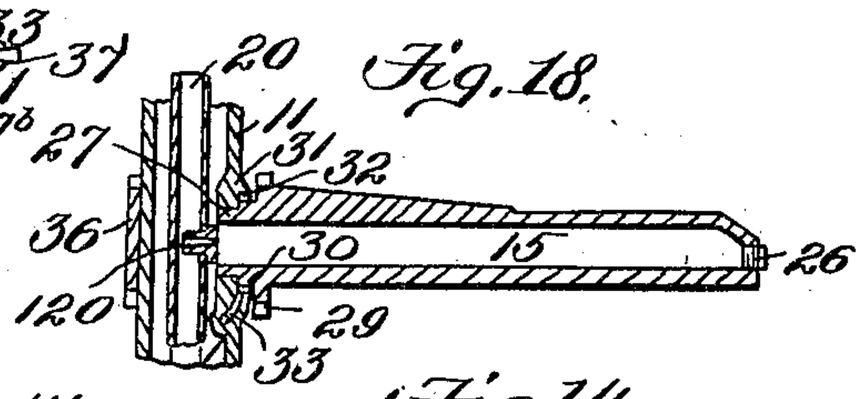


Fig 14.

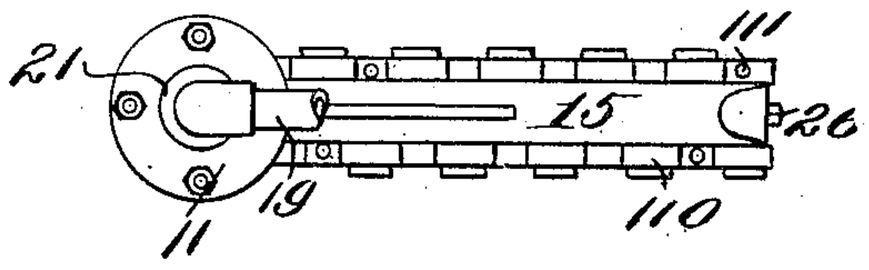


Fig. 19.

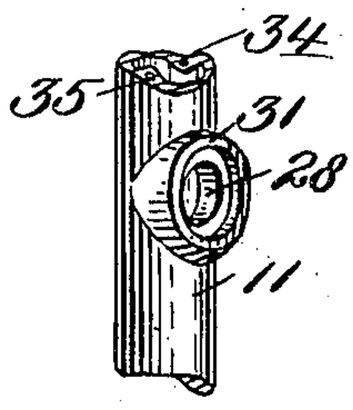


Fig. 20.

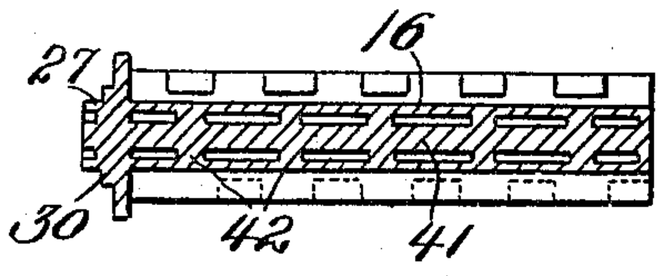
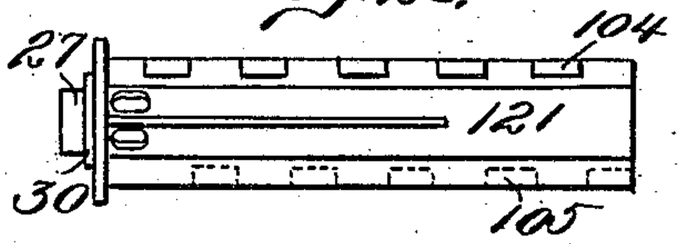
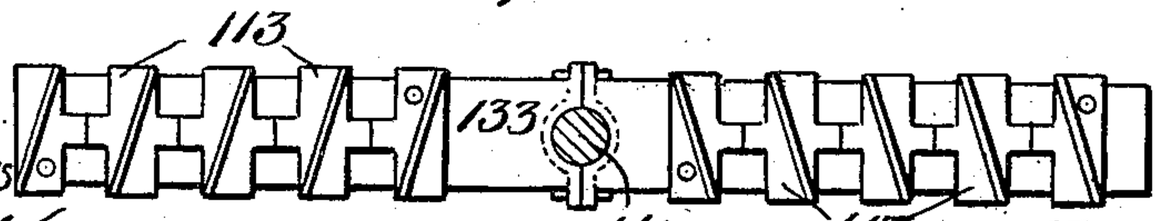


Fig. 23.





Witnesses
C. D. Kesler
Dennis Sumby.

Inventor
Arthur V. Leggo
By James L. Norris
Atty

No. 837,576. PATENTED DEC. 4. 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 8.

Fig. 24.

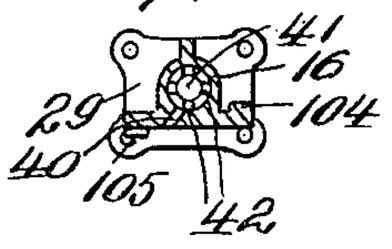


Fig. 25.

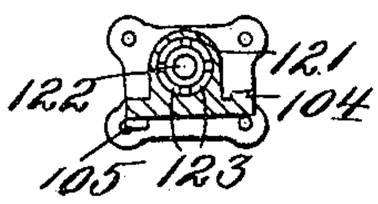


Fig. 26.

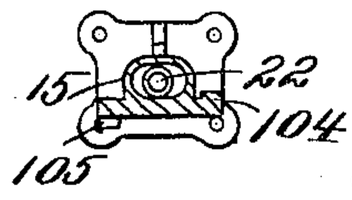


Fig. 27.

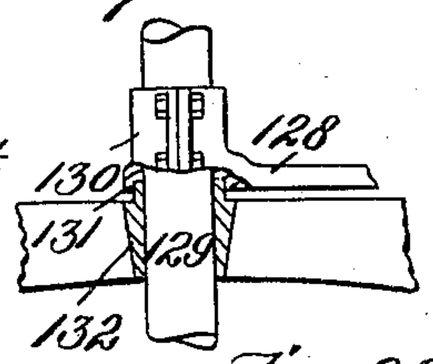


Fig. 34.

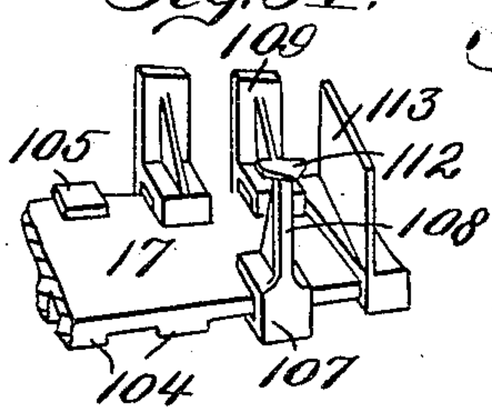


Fig. 35.

Fig. 36.

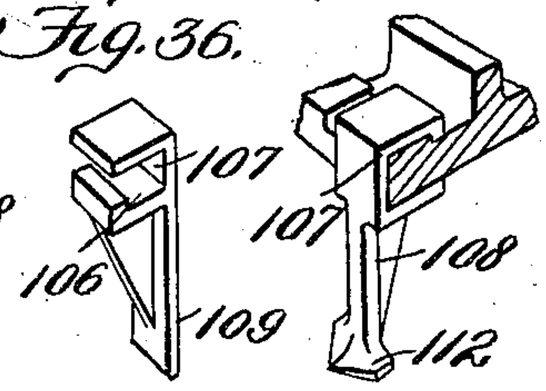


Fig. 28.

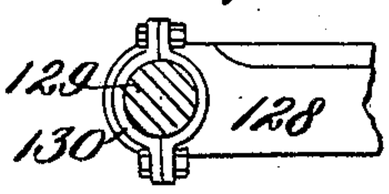


Fig. 29.

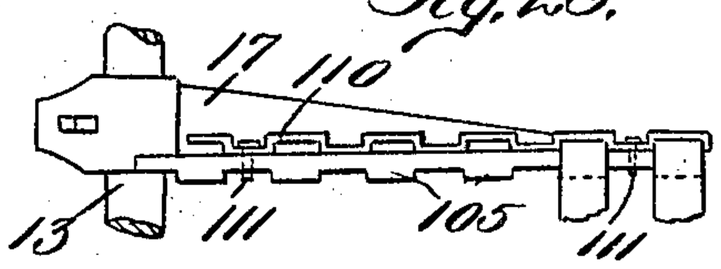


Fig. 30.

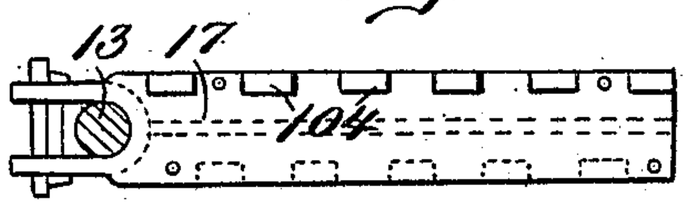


Fig. 31.

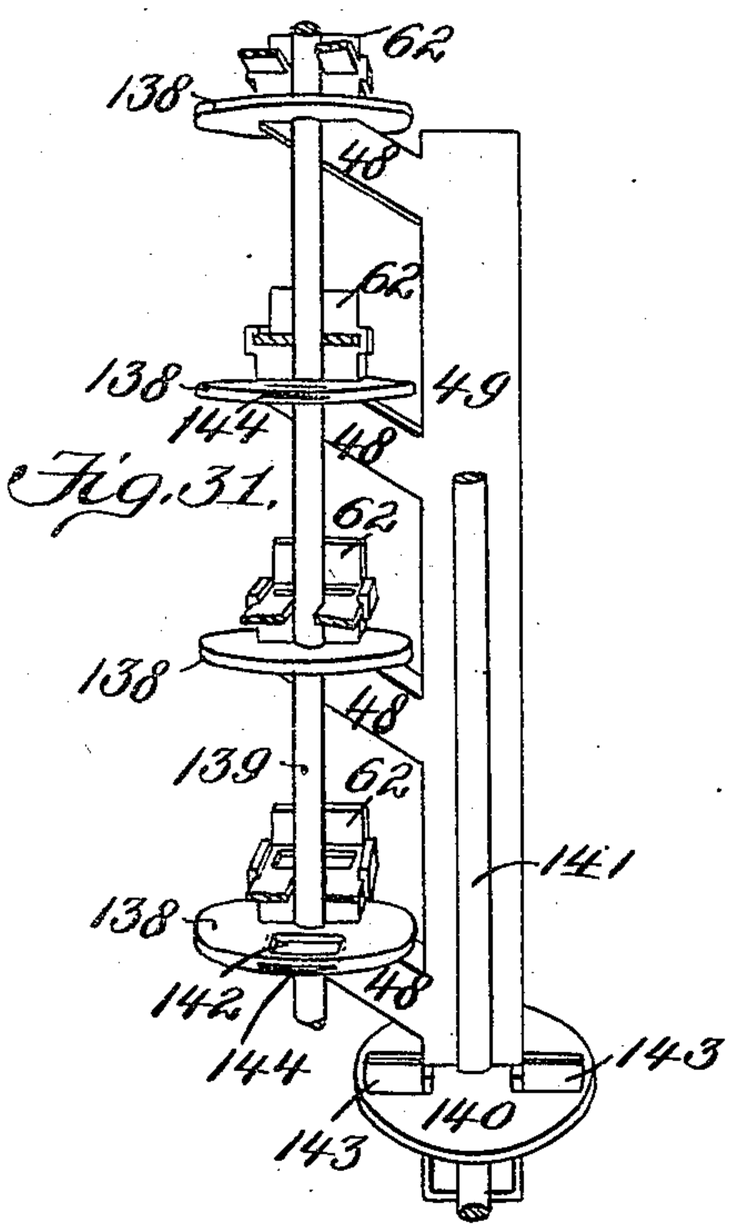


Fig. 32.

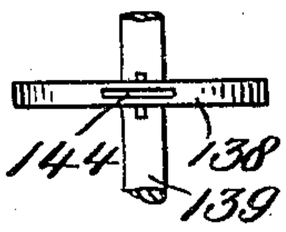


Fig. 33.

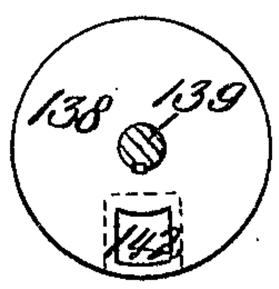


Fig. 37.

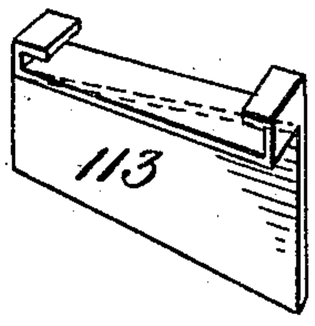


Fig. 21.

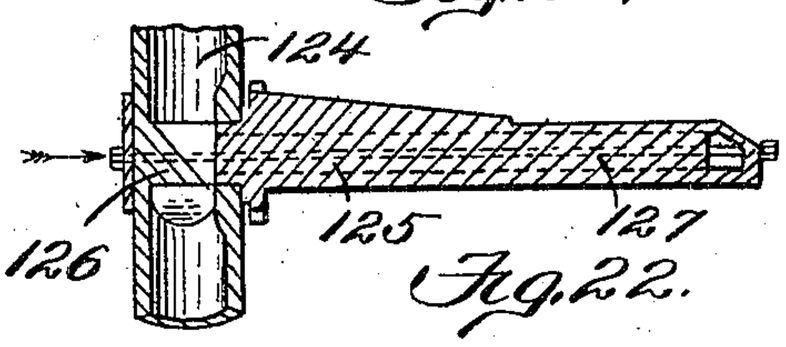


Fig. 22.

Witnesses;
C. F. Kesler
Dennis Dumbly

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 9.

Fig. 38.

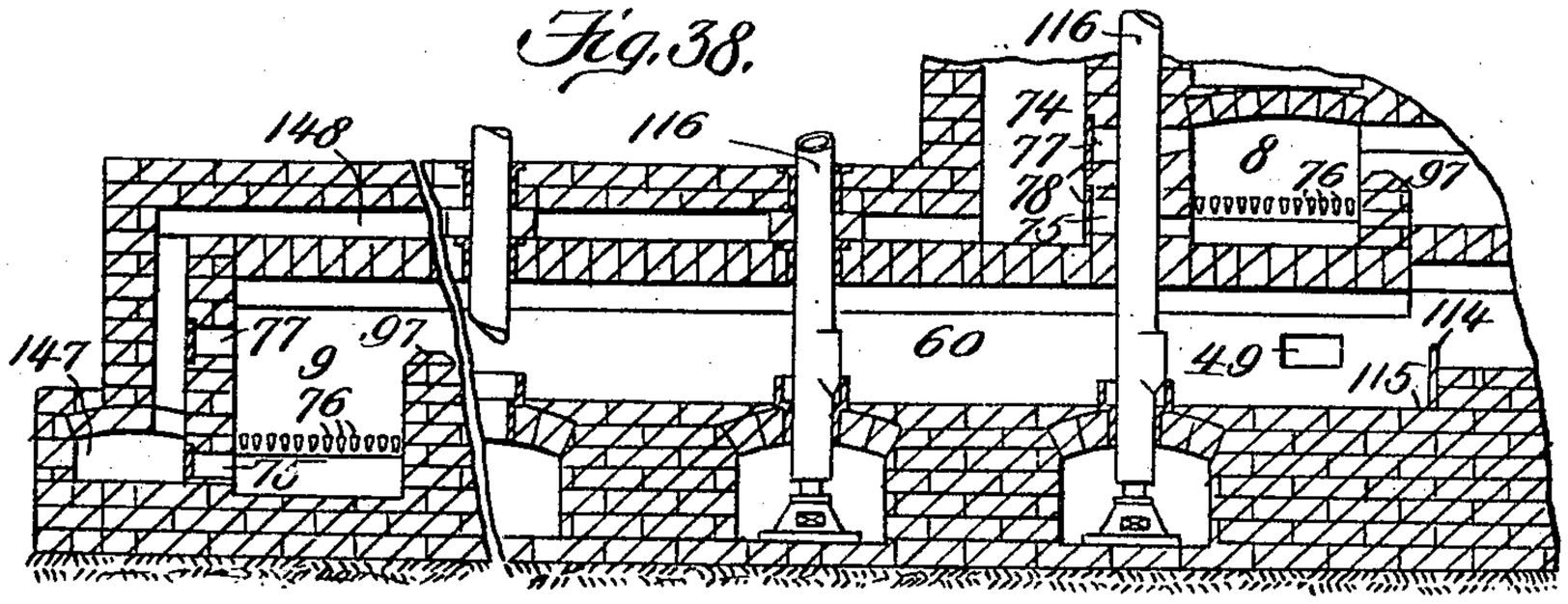


Fig. 39.

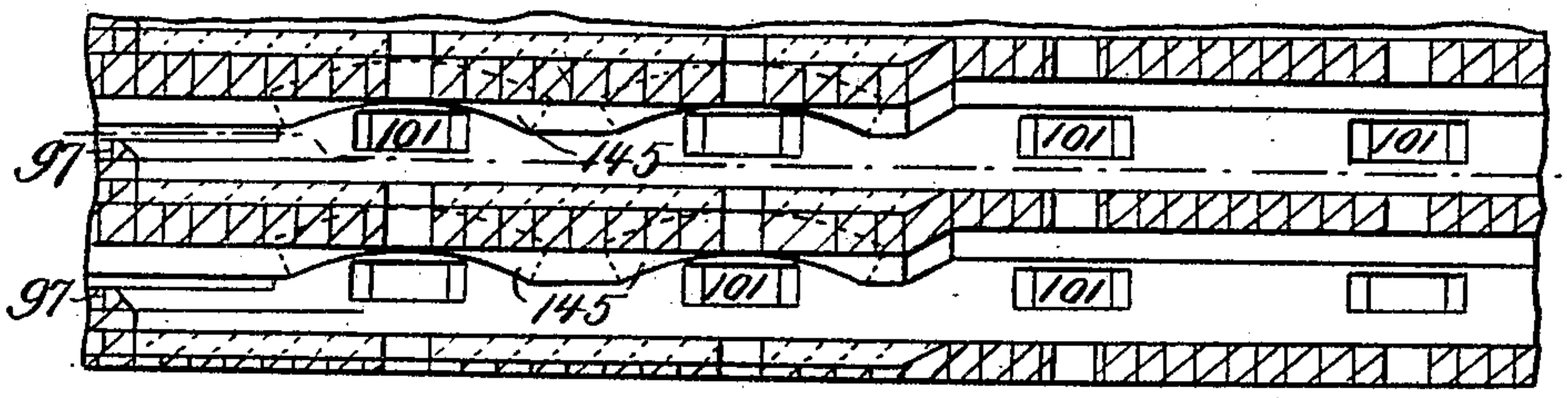
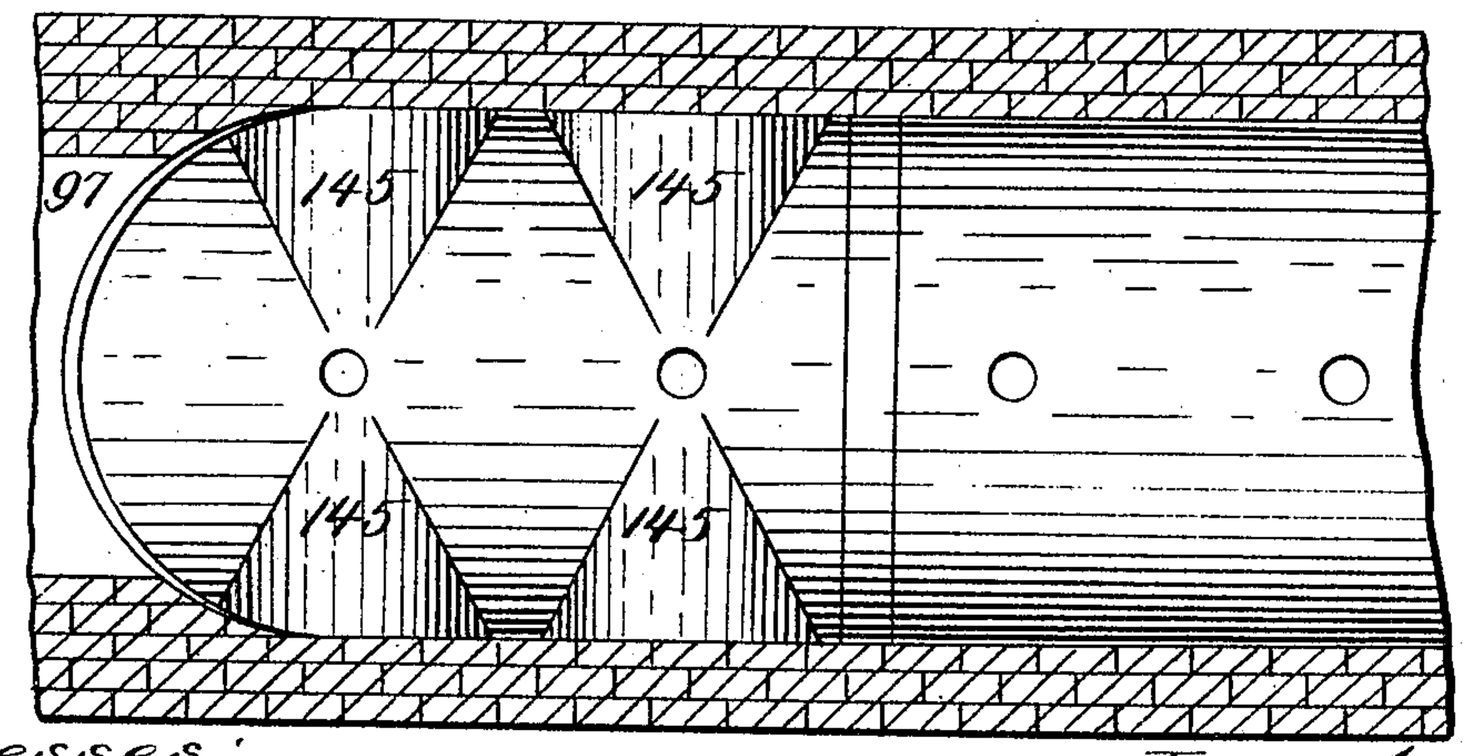


Fig. 40.



Witnesses:
C. D. Kesler
Dennis Sumby.

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 10.

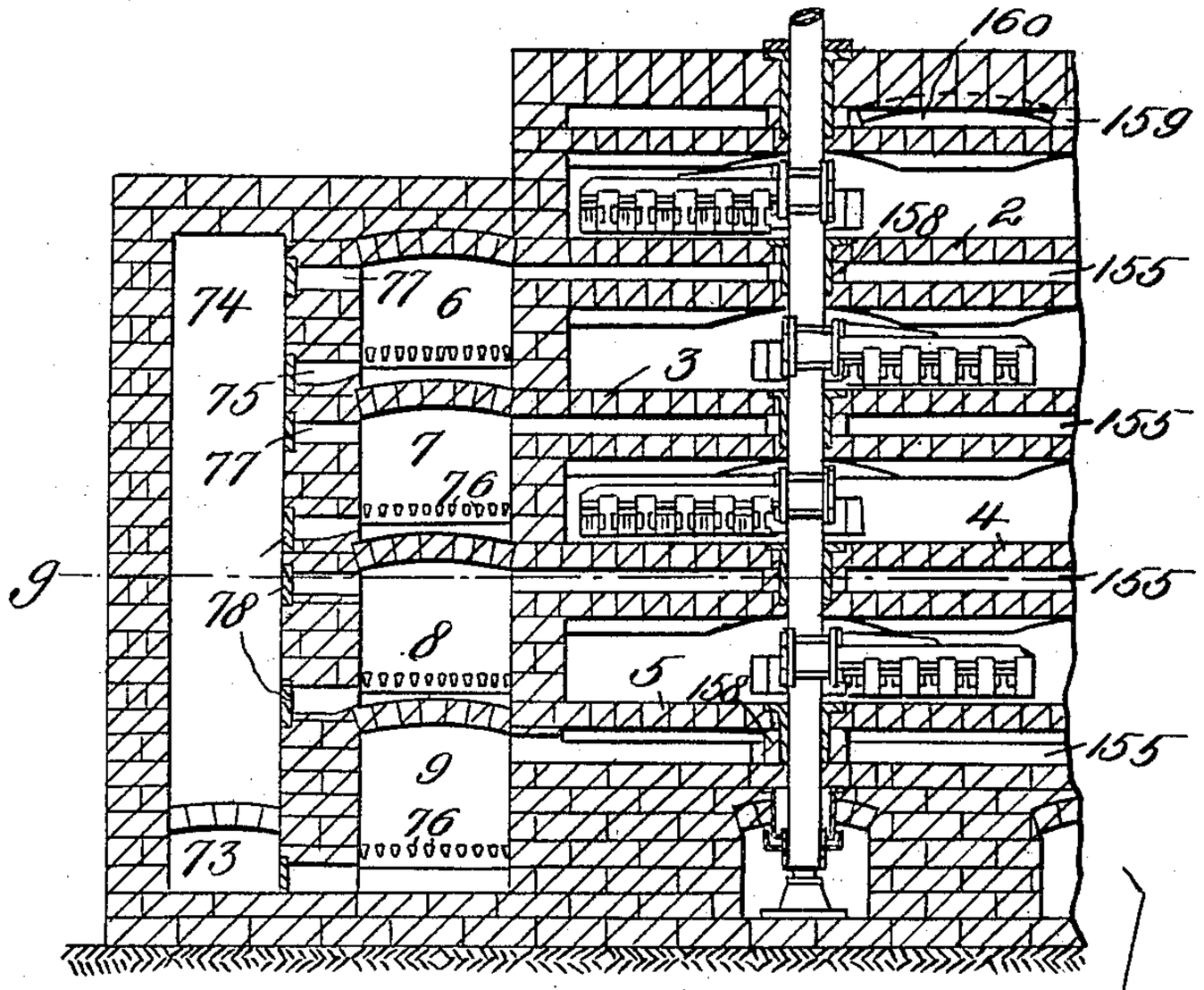
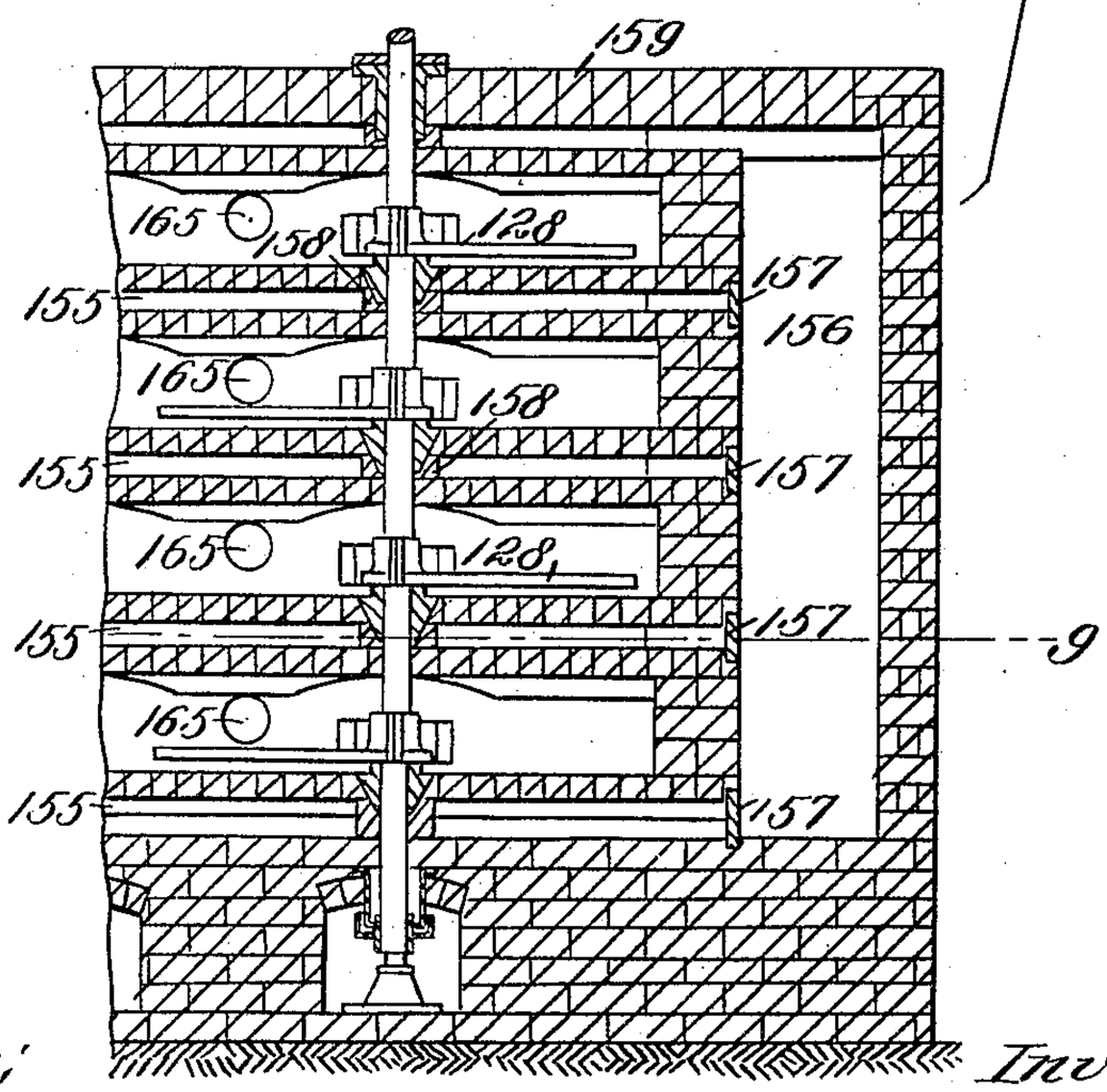


Fig. 42.



Witnesses:
C. D. Hesler
D. B. Sunby.

Inventor
Arthur V. Leggo
By James L. Norris
Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 11.

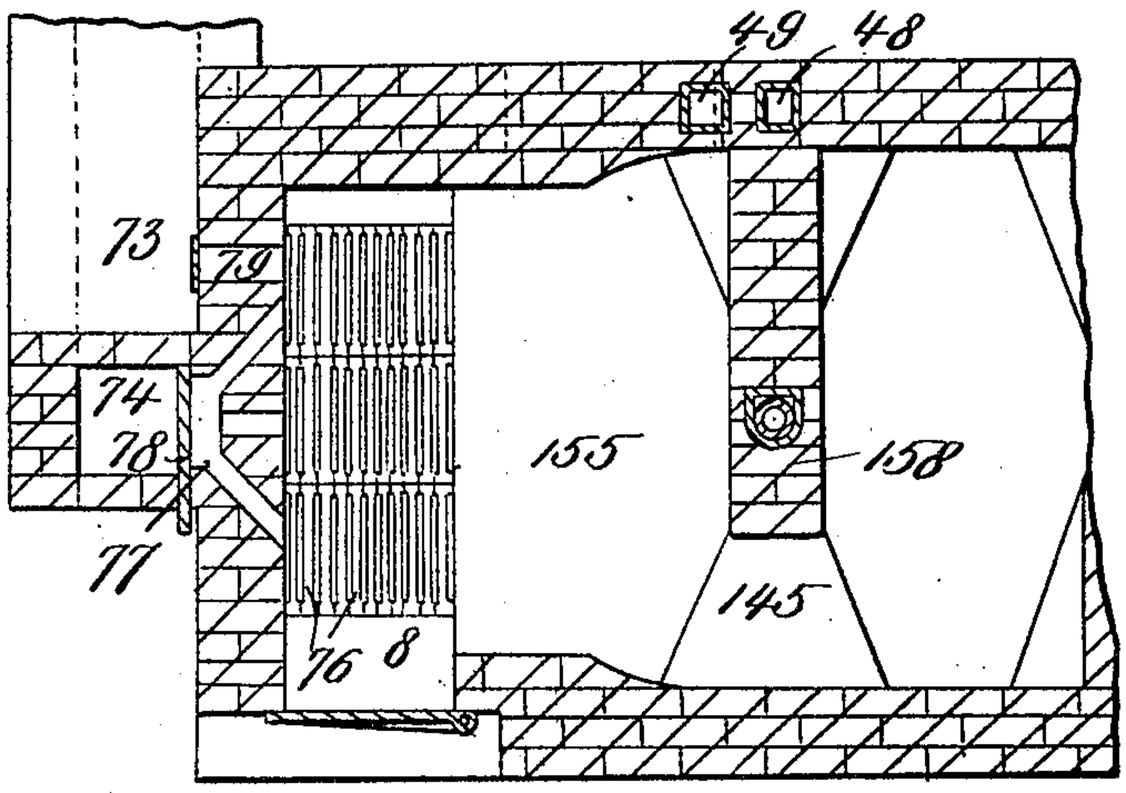


Fig. 43.

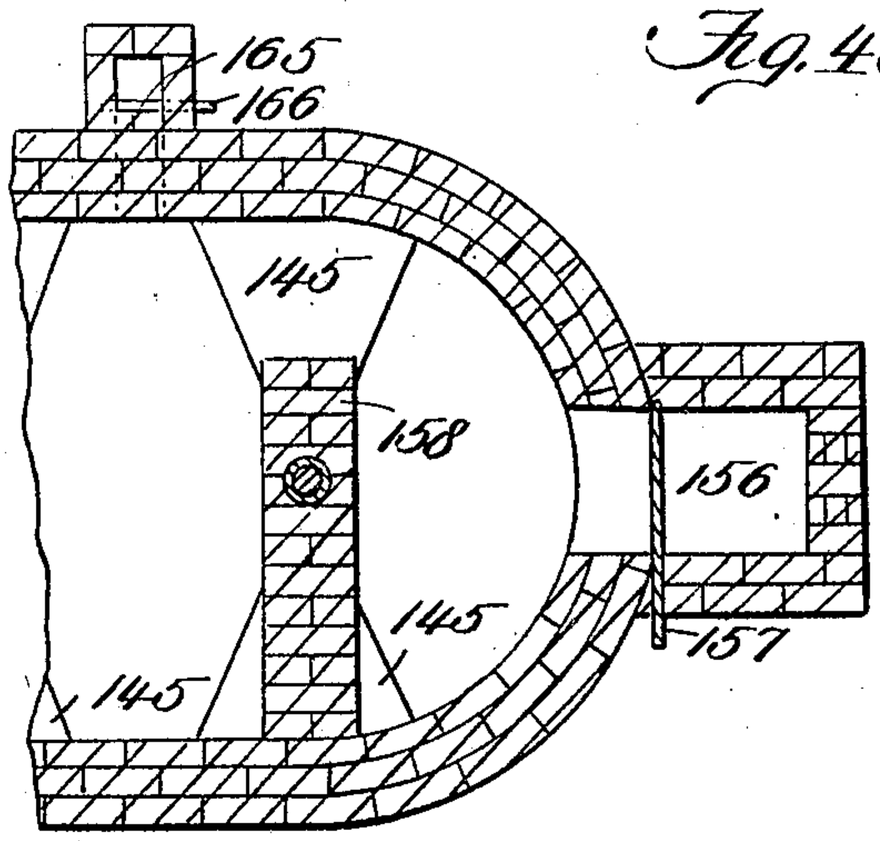
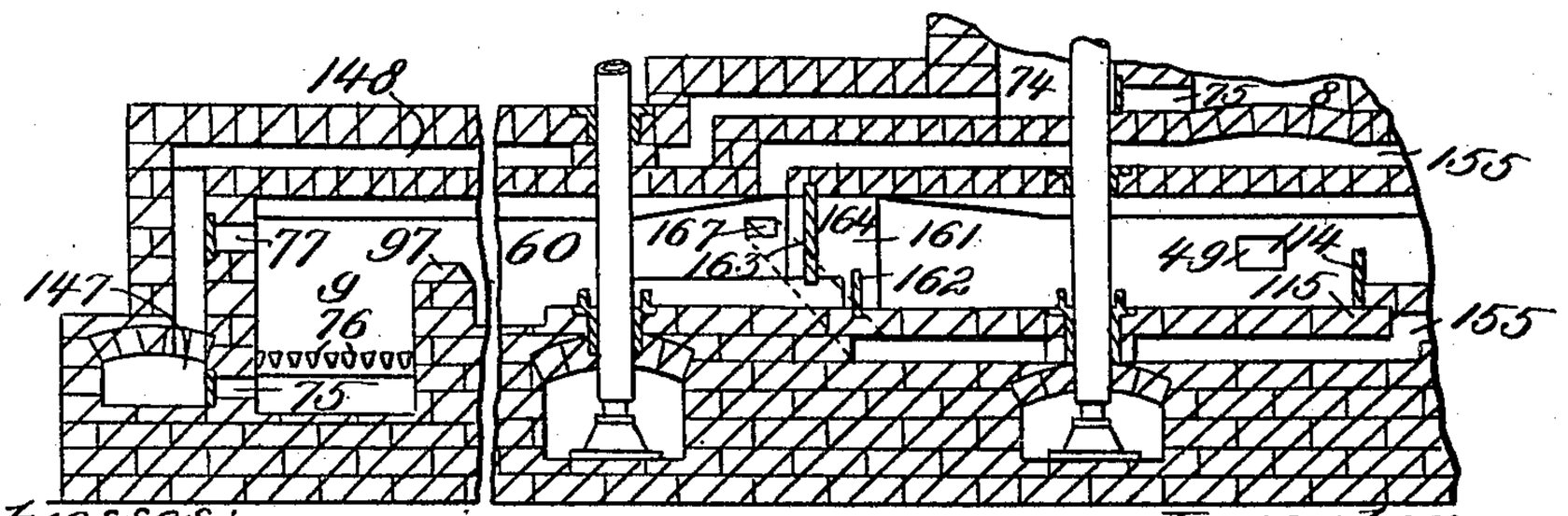


Fig. 44.



Witnesses:
C. D. Tesler
Dennis Sumby

Inventor
Arthur V. Leggo
By James Z. Norris Atty.

No. 837,576. PATENTED DEC. 4, 1906.

A. V. LEGGO.

FURNACE FOR ROASTING, &c.

APPLICATION FILED SEPT. 6, 1905.

12 SHEETS—SHEET 12.

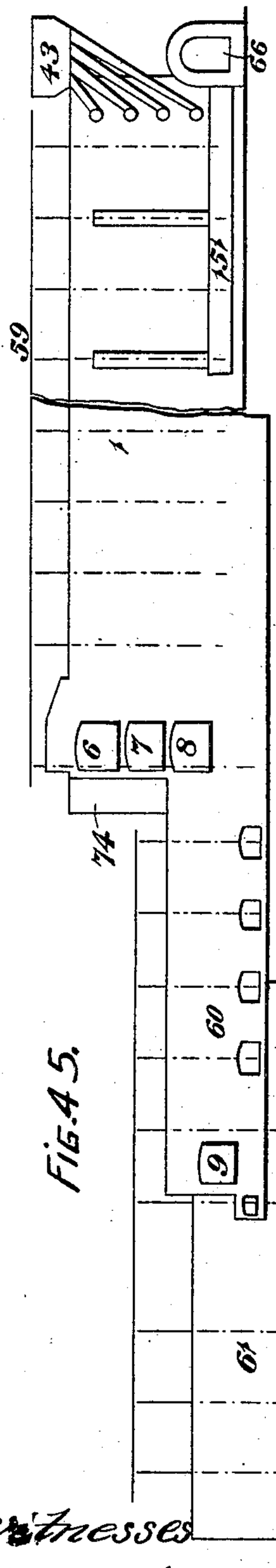


Fig. 45.

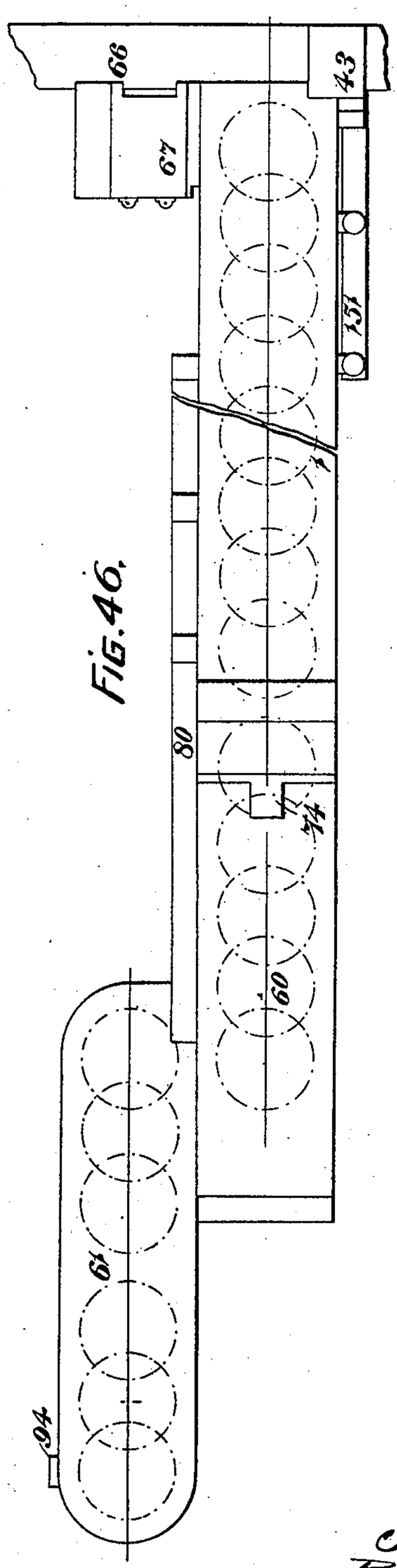


Fig. 46.

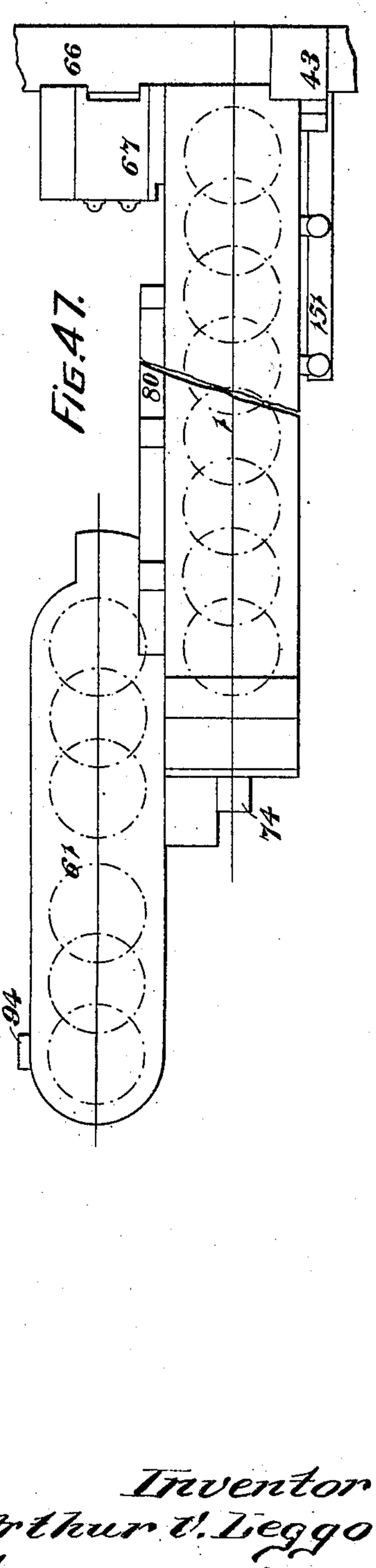


Fig. 47.

Witnesses
H. B. Keller
C. D. Kesler

Inventor
Arthur V. Leggo
By James Z. Norris.
Atty.

UNITED STATES PATENT OFFICE.

ARTHUR VICTOR LEGGO, OF BALLARAT, VICTORIA, AUSTRALIA.

FURNACE FOR ROASTING, &c.

No. 837,576. Specification of Letters Patent. Patented Dec. 4, 1906.

Application filed September 6, 1905. Serial No. 277,344.

To all whom it may concern:

Be it known that I, ARTHUR VICTOR LEGGO, a subject of the King of Great Britain, residing at Pendeen, Dawson street, Ballarat, in the State of Victoria and Commonwealth of Australia, have invented an Improved Furnace for Roasting, Desulfurizing, Chloridizing, Dehydrating, or Drying Ores and other Substances, of which the following is a specification.

My invention has been devised in order to provide a furnace for roasting, desulfurizing, chloridizing, dehydrating, or drying ores or other substances which shall be of great capacity, durability, and efficiency, while at the same time the expense of constructing, maintaining, and operating it will be found to be much less than with any other furnace at present in use. Moreover, with my furnace by the alteration, exchange, and adjustment of its various parts it can be made to adapt itself to the particular conditions necessary to any kind of roast.

Many of the improvements hereinafter described are suitable and intended only to meet the conditions peculiar to roasting certain ores or certain kinds of roast, while for another dissimilar ore or kind of roast the same improvements are quite unsuitable and the substitution of other improvements to suit the altered conditions and requirements are provided for, and it will be obvious that such alterations will in some cases necessitate the relative positions of different parts being suitably altered.

In order that those skilled in the art may more readily understand my invention, it may be well to set forth some of the disadvantages hitherto experienced in connection with existing roasting-furnaces and which disadvantages will be found to be either nonexistent in my furnace or to have been minimized to a great extent.

One of the great disadvantages of existing furnaces having superimposed hearths has been the great amount of flue-dust produced by dropping the ore from one hearth to another, said dust being carried off by the draft through the furnace. Moreover, their design and equipment have been such as to limit their capacity, as the whole of the ore has had to pass over all of their hearths, and, further, the breaking of the contact of the ore particles at each hearth prevents the conduction of the heat from the hotter particles to the cooler ones at these points.

The disadvantages of single-hearth furnaces are their great cost of construction, their great loss of heat by radiation, and the large area of floor-space necessary for them, with the consequent heavy cost of operating them.

In all roasting-furnaces there is great loss of heat in the waste gases leaving them and also in the roasted ore discharged from them, and where fuel economy is a matter of great moment I provide means, hereinafter described, for utilizing said losses of heat in operating the furnace.

My furnace consists of a series of horizontal or slightly-inclined hearths, one above and each independent of the other, each hearth preferably having a separate fire-box at its discharge end, and when cold ores—that is, ores containing a low percentage of sulfur—are to be roasted supplementary or auxiliary fire-boxes may be built on one side or arranged alternately on either side at any point or points along the length of said hearths. The said hearths are provided with rabble-arms, by means of which the ore under treatment is conveyed simultaneously along each hearth in the same direction and, preferably, at the same rate of speed, so that the ore on each hearth at any given point is at the same stage of desulfurization or roast. The ore to be treated is fed from a hopper onto the feed end of each hearth and is passed along the said hearths by means of the rabble-arms, which are fitted to vertical shafts which pass through the center of each hearth of the furnace. When the ore has traversed the whole length of the hearth, it passes through an opening in the side thereof and enters a chute which conveys it either outside the furnace or to a combined air-superheating and roasted-ore-cooling hearth (hereinafter called a "cooling-chamber") situated below the level of the bottom hearth and preferably at one side thereof.

The cooling-chamber is so arranged and constructed as that the air passed over the heated ore in the hottest part thereof to cool it is on becoming hot passed either to the combustion-chambers or roasting-chambers, where it assists in the combustion of the fuel or oxidation of the ore in the said roasting-chambers.

In lieu of delivering the ore either outside of the furnace or to the cooling-chamber I prefer, when a "sweet" roast is required and a considerable increase in temperature is nec-

essary to attain it, to deliver the ore from each hearth to a finishing-chamber, which is constructed as an extension of the bottom hearth of the furnace, and from said finishing-chamber the ore is rabbled to a discharge-chute in the side thereof. If desired, the ore may be delivered from the finishing-chamber to the cooling-chamber through the discharge-chute before referred to.

The rabble shafts and arms, which are situated in the hottest part of the furnace, are preferably hollow and supplied with a continuous circulation of water or air, or both combined, while those in the cooler parts, which are not subjected to any excessive heat, are solid.

Hitherto in most cases where water has been employed to keep the rabble shafts and arms of superimposed hearth-furnaces cool the excessive expansion and contraction of the metal have affected the joint where the arms form a junction with the rabble-shaft, and the consequent leakage entering the furnace has been very detrimental to the satisfactory operation of the furnace. Now by my invention I provide means whereby any leakage from the said joint may be caught in an annular recess surrounding said joint and directed from the bottom thereof to a passage which leads to a vertical channel cast integrally into the thickness of the shaft, and the water may be withdrawn therefrom by means of a tap placed at the bottom and side thereof.

Each rabble-shaft is usually provided with only one rabble-arm above each hearth, which is quite sufficient in roasting many ores. Some ores, however, on being heated assume a sticky consistency, and in roasting such I provide each rabble-shaft with two rabble-arms above each hearth and so position the teeth or tines on each arm that the ore left stagnant by those on one will be stirred by those on the other and the teeth being thus spaced farther apart on the two arms than they would be on only one more effectually stir the ore.

The furnace can be heated with either solid, liquid, or gaseous fuel, or, where it is available and desirable, with the waste heat from other metallurgical furnaces, and in certain cases the roasting operation can be continued when sufficient heat has been generated without the addition of any fuel, when fire-boxes or combustion-chambers need not be added, the sulfur of the ore being sufficient for this purpose. In the drawings hereto annexed I have shown the combustion-chambers provided with grates for burning solid fuel; but the equipment for burning liquid or gaseous fuel, if required at all, would obviously be simpler and more easily arranged.

In roasting ores containing a high percentage of sulfur excessive heat is generated in the earlier stages of the roast and the fumes produced are very voluminous. To prevent and provide for these, I use means hereinafter described for removing said gases from their respective hearths at any intermediate point or points in the length of such hearths. These means also permit of the use of shallow roasting-chambers of great length, with their consequent economy in construction, and at the same time help to prevent dusting by lessening the amount, and therefore the velocity, of the draft passed over those parts of the hearths adjacent to the throats.

Where the surfur gases of calcination are required for the manufacture of sulfuric acid, sulfite pulp, &c., and it is necessary to fire the furnace with fuel, the furnace can be muffled and the roasting-chambers heated externally in order to avoid the dilution of said calcination gases by the gases of combustion of the fuel. Such indirect method of firing, however, sometimes prevents the attainment of a sufficiently high temperature to oxidize the last remaining portion of the sulfur in the ore when a sweet roast is desired— as, for instance, in roasting zinc-blende when it is desired to utilize the sulfur in the ore for making sulfuric acid, &c., and at the same time the roasted ore is required sweet to suit the after metallurgical operations on it. In such a case I eliminate nearly all the sulfur from the ore in the muffled chambers, utilizing said sulfur as aforesaid, and then immediately pass the ore onto a direct-fired hearth to finish the operation, the direct firing of this hearth allowing of the attainment of a sufficiently high temperature for this purpose.

In the drawings hereto annexed the same reference-numerals refer to the same parts wherever they occur.

Referring to the drawings, Figure 1 is a longitudinal sectional elevation of the furnace on the line *a a*, Fig. 2. Fig. 2 is a sectional plan of the furnace on the line *b b*, Fig. 1. Fig. 3 is a plan in section of the cooling-chamber. Fig. 4 is a sectional elevation of the cooling-chamber. Fig. 5 is a vertical cross-section on the line *d d*, Fig. 2. Fig. 6 is a vertical cross-section of the combustion and cooling chambers on the line *e e*, Figs. 2 and 3. Fig. 7 is a sectional elevation of the feed-hopper and chutes depending therefrom. Fig. 8 is a perspective view of a chute (fitted with shutters and slide) for conveying the ore from the roasting-hearths to the cooling-chamber or finishing-chamber or direct to the outside of the furnace. Fig. 9 is a vertical cross-section of fire-boxes designed to obtain a maximum amount of combustion-space. Fig. 10 is a sectional elevation of a hollow water-rabble shaft and arm, also in section. Fig. 11 is a plan of Fig. 10. Fig. 12 is a cross-section of the rabble-arm shown in Fig. 10. Fig. 13 is a cross-section of the

rabble-shaft on the obliquely-dotted line *f f*, Fig. 10. Fig. 14 is a perspective view of that portion of the water-rabble shaft to which is attached the rabble-arm. Fig. 15 is a sectional elevation of another design of water-rabble. Fig. 16 is a horizontal cross-section of the rabble shown in Fig. 15. Fig. 17 is a cross-section of the rabble-arm shown in Figs. 15 and 16. Fig. 18 is a sectional elevation of the water-rabble arm and portion of the rabble-shaft, showing other means for circulating the water. Fig. 19 is a plan in section of an air-rabble arm. Fig. 20 is a plan of a combined water and air rabble arm. Fig. 21 is a sectional elevation of another form of air-rabble shaft and arm. Fig. 22 is a sectional elevation of the rabble-shaft shown in Fig. 21 viewed in the direction of the arrow. Fig. 23 is an inverted plan of a double rabble-arm having oblique teeth. Fig. 24 is a cross-section of the air-rabble arm illustrated in Fig. 19. Fig. 25 is a cross-section of Fig. 20. Fig. 26 is a cross-section of a water-rabble arm. Fig. 27 shows another method of connecting a flat rabble-arm to the rabble-shaft and means for preventing the escape of fine ore down the openings in the hearths to receive the said shaft. Fig. 28 is a plan of Fig. 27. Figs. 29 and 30 are elevation and inverted plan, respectively, of another solid rabble-arm with teeth removed. Fig. 31 is a perspective view of a chute (fitted with disks) for conveying the ore from the hearths to the cooling or finishing chamber or direct to the outside of the furnace. Figs. 32 and 33 are elevation and plan, respectively, of the disks operating in the inclined chutes shown in Fig. 31. Fig. 34 is a perspective view of portion of a rabble-arm inverted with teeth attached. Fig. 35 is a perspective view of a front tooth. Fig. 36 is a perspective view of a back tooth. Fig. 37 is a perspective view of an oblique tooth. Fig. 38 is a longitudinal sectional elevation of the finishing-hearth. Fig. 39 is a longitudinal sectional elevation of portion of the furnace, showing arches over the port-holes and part of the arch lowered. Fig. 40 is a plan of Fig. 39. Fig. 41 is a sectional view of portion of the furnace, showing the rabble shafts and arms set at an inclination to the roasting-hearths. Fig. 41^{A} is a cross-section of a portion of the furnace, showing means for varying the inclination of the rabble-shafts. Fig. 41^{B} is a plan of portion of Fig. 41^{A}. Fig. 42 is a longitudinal sectional elevation of a modified form of furnace in which the hearths are muffled. Fig. 43 is a sectional plan on the line *g g*, Fig. 42. Fig. 44 is a longitudinal sectional elevation of the finishing-hearth as used in connection with the modified furnace shown in Fig. 42. Fig. 45 is a diagrammatical view, in side elevation, of the furnace, finishing-hearth, and cooling-hearth. Fig. 46 is a diagrammatical plan view of the same, and Fig. 47 is a diagrammatical plan view of the furnace and cooling-hearth. Figs, 1, 2, 3, 4, 5, 6, 7, 9, 38, 39, 40, 41, 41^{A}, 41^{B}, 42, 43, and 44 are drawn to a smaller scale than the others.

1 represents the furnace, which is of rectangular form and is constructed of masonry and strengthened and bound together with suitable stays, straps, and rods. Said furnace has two or more (four being shown in the drawings) separate and independent superimposed horizontal or inclined hearths 2 3 4 5, which can be of any desired length. At the discharge end of each hearth is when required a separate fire-box or combustion-chamber 6 7 8 9, though it is obvious one combustion-chamber may be made to serve two or more hearths. Owing to the greater available space for the top and bottom fire-boxes 6 and 9 for heating hearths 2 and 5, respectively, and the greater radiation of heat from said hearths, the said fire-boxes 6 and 9 are of greater capacity than those between them—viz., fire-boxes 7 and 8 for heating hearths 3 and 4, respectively. 10 is a chamber to contain any non-conducting material to prevent radiation of heat from the top combustion-chamber 6. Passing vertically through the center of the furnace 1 are a number of rabble-shafts, (four only of which are shown in the drawings, though any number may be used,) numbered, respectively, 11, 12, 13, and 14, fitted with rabble-arms 15, 16, 17, and 18. These rabble-arms may be bolted or keyed to the rabble-shafts and the means of attaching the same shown in the drawings permit by the use of suitable tools of their being renewed or replaced from the outside of the furnace, thereby obviating the necessity for cooling down the furnace to effect repairs. The rabble-shafts can be driven at any suitable speed and are so arranged that when in motion the paths of the arms on each shaft overlap to a greater or less extent the paths of the arms on the shafts next adjacent. Said shafts 11, 12, 13, and 14 are supported in foot-steps (which can be adjusted both vertically and laterally) or in any other approved manner.

In Fig. 1 the rabble-shafts are shown fitted with only one rabble-arm above each hearth. When required, they can, as hereinbefore stated, have two. Where single-arm rabbles are used, they may work all in one direction or alternately in left and right hand directions, the latter being generally preferred. Where double-arm rabbles are used, they must work alternately in left and right hand directions, so as to avoid the rabble-arms on each shaft coming in contact with those on those next adjacent. The rabble-shaft 11, which is situated nearest the combustion-chambers 6, 7, 8, and 9, and is consequently in the hottest part of the furnace 1, is made

hollow and a continuous supply of cool water is fed to the top of the shaft 11 by means of the fixed supply-pipe 19 and circulates through said shaft. When it is more convenient, the water for cooling the rabble shaft and arms can be introduced through the bottom of the rabble-shaft. In the center of and attached to the top of the shaft 11 is a vertical down-pipe 20. Said down-pipe is closed at the bottom and connected at the top with pipe 19 by the stuffing-box 21. Projecting at right angles from the down-pipe 20 and entering the rabble-arms 15 are pipes 22, which are open at their ends.

23 is an overflow-pipe.

24 is a trough having pipe 25 attached to the bottom thereof for the purpose of conveying the water therefrom.

26 represents screw-plugs in the ends of arms 15.

On one end of the rabble-arm 15 is a spigot 27, which enters a hole 28 in the rabble-shaft 11, which shaft is thickened at this point. Between said spigot 27 and the flange 29 on the arm 15 is a collar 30, which is of smaller diameter than the annular ring 31, cast integrally with and on the side of the rabble-shaft 11. The space between the outside of the collar 30 and the inside of the ring 31 when the arm is in position forms an annular recess 32, which directs any leakage of water at the junction of the rabble-shaft 11 and rabble-arms 15 to the passage 33, leading to one or other of the passages 34 and 35, which pass down opposite sides of the rabble-shaft 11 to the bottom of the said shaft, where they meet. The rabble-arm 15 is securely fastened to the rabble-shaft 11 by means of bolts passing through the flanges 29 of the arm 15 and the coupling-piece 36, situated on the opposite side of the said shaft 11. When there is much leakage of water from the junction of said rabble-shaft 11 and said rabble-arm 15, the small space between the edge of the annular ring 31 and the flange 29 when the arm is in position can be calked with asbestos fiber or other suitable material. The two passages 34 and 35 are only required when for economy in construction these rabble-shafts are made in sections. When these rabble-shafts are cast all in one piece, only one of these passages 34 or 35 will be required and the passages 33 all made to lead to it.

37 is a tap to withdraw the contents from the said passages 34 and 35. 38 is a tap to withdraw the water from the rabble-shaft when same requires cleansing of any solid matter deposited in it without withdrawing the rabble from the furnace.

It will be observed by an inspection of Fig. 13 that there are openings 38^a through the projection 38^b on the inside of the rabble-shaft 11. The said projection 38^b surrounds the bottom of and is for the purpose of preventing any lateral motion of the down-pipe 20. The openings 38^a through the projections 38^b permit of the water in the upper portion of the rabble-shaft passing to the tap 38.

Usually between the hollow water-shafts 11 and the solid rabble-shafts 13 and 14, which are situated in the cooler part of the furnace 1 and are fitted with solid rabble-arms 17 and 18, are other hollow rabble-shafts 12, carrying hollow rabble-arms 16, through which a continuous circulation of cold air passes upward from the air-supply pipe 39, leading from a fan. (Not shown.)

40 represents holes in the bottom and near the ends of the said rabble-arms 16, through which the air passes and assists in the oxidation of the ore passing through the furnace. Said rabble-arms 16 have a core 41 passing horizontally through and supported in its center by the projections 42. Said core 41 bears all the stress of the weight of the rabble-arm and teeth, and the air passing through the rabble-arm prevents said core 41 from being overheated. Where the double-arm rabbles are used, the flange 29 of the second rabble-arm simply takes the place of the coupling-piece 36, the flanges of the two rabble-arms being thus bolted to each other. When the rabble-arms are comparatively short and great strength is not required at the joint, they can be simply screwed into the rabble-shafts or attached in any other more suitable manner. As, for instance, where the rabble-arms are hollow a bolt may be passed right through the arm or arms and the shaft, when on screwing up the nut or nuts of said bolt the arm or arms are firmly fixed to the shaft.

It will be readily understood that the furnace can have any number of either water, air, and solid rabbles or any number of any one of these kinds of rabbles without any of either of the others.

The temperature of the roasting-chambers when no fuel is used, or when said roasting-chambers are muffled and fuel is used, will not generally require water-rabbles being used in them. In such cases air and solid rabbles or solid rabbles only may be used.

43 is a feed-hopper.

44 represents fluted rollers to feed the raw ore from the hopper 43 to the depending oblique chutes 45 below.

46 represents horizontal chutes connected to the bottom of the depending chutes 45.

47 represents Archimedean screws, which feed the ore from chutes 46 on to the coolest or feed ends of the hearths 2, 3 4 5.

The fluted rollers 44 can be operated separately and when necessary driven at different speeds to permit the required amount of ore being fed to each hearth.

It is obvious that means other than that specified can be employed for feeding the ore on to the respective hearths.

48 represents short inclined chutes at one side and opening into the discharge end of the said hearths 2 3 4 5, down which the treated ore passes to the main chute 49. 50 and 51 are hinged shutters at the bottom of the inclined chutes 48.

52 is a slide in and near the bottom of the main chute 49. 53 represents cams keyed to the rotating horizontal shafts 54, and which said cams bear against the arms 55 of the shutters 50 and 51. 56 is a connecting-rod joining the crank 57 to the slide 52. The arms 55 of the shutters can be so arranged and formed that two of the said shutters may be operated by one of the cams, and obviously any ordinary mechanical means can be employed for operating the shutters 50 and 51 and the slide 52. The horizontal shaft 58 is rotated at twice the speed of the horizontal shafts 54, and they may each be operated from the main shaft 59, which imparts motion to the gearing, rotating the rabble-shafts 11, 12, 13, and 14 of the furnace 1 by any means, such as belts and pulleys. The rabble-arms 15 on the rabble-shaft 11, or such other shaft as may be located at this point, are so arranged in relation to the cams 53 and the crank 57 that during the rotation of the rabble-arms 15 and immediately before they reach the inclined chutes 48 the alternate hinged shutters 50 or 51 at the bottom thereof are opened by the cams 53 and are closed immediately the ore fed to the inclined chute 48 by the rabble-arms 15 has passed to the main chute 49, where it falls on the slide 52.

In the interval between the closing of the shutters 50 and the opening of the shutters 51 the slide 52 is opened and closed by the rotation of the crank 57, and the ore resting on said slide 52 falls down the continuation of the chute 49 to the outside of the furnace or to the finishing-chamber 60 or to the cooling-chamber 61. By these means any current of air is prevented from passing upward from the main chute 49, at the same time allowing a free passage for the roasted ore from the roasting-hearths 2, 3, 4, and 5 to the finishing-chamber 60 and thence to the cooling-chamber 61 or direct either to the cooling-chamber or to the outside of the furnace, the cooling-chamber when used being placed, preferably, below the level of the bottom hearth 5 and at one side of the furnace and the finishing-chamber when used being preferably a continuation of the bottom hearth, as shown in Fig. 38.

It is obvious that the finishing-chamber 60 and the cooling-chamber 61 when used may extend in any direction desired.

62 represents adjustable slides fitting over the opening of the inclined chutes 48.

63 represents projections standing upward at right angles to the slides 62, over which projections the ore passes from the roasting-chambers and through holes 64 in the said slides 62 to the inclined chutes 48. When a more rapid discharge is desired, the slides 62 are withdrawn, and the ore then passes direct to the inclined chutes 48.

65 is a flue to supply air to the furnace 1. This flue crosses and then runs parallel with the main flue 66, which leads to the chimney-stack (not shown) along one side of the dust-chamber 67 to the downcast 68. Midway across the dust-chamber 67 the flue 65 enters the hollow baffle-wall 69, where the air in its passage around horizontal partitions 70 in said wall 69 becomes heated and subsequently enters flue 71, running from the downcast 68 parallel to and entering part 72 of the cooling-chamber 61, in which it becomes superheated. The impact of the furnace-gases against the hollow baffle-wall 69 and the simultaneous cooling of said furnace-gases also cause any dust in them to be deposited in the dust-chamber 67, from the bottom of which said dust can easily be withdrawn by opening sliding dampers 100. Only one hollow baffle-wall is shown in the drawings; but it is obvious that any number can be used, according to the extent of utilization of heat and deposition of dust desired. When more than one hollow baffle-wall 69 is used, they can be so positioned that the hot furnace-gases will be made to pass alternately over and under them or around the alternate sides of them, so as to bring said hot gases the better in contact with the surfaces of said hollow baffle-walls 69. The dust-chamber 67 is preferably made of large capacity, so as to lessen the speed of the gases through it, thereby giving the dust in them a better chance to settle and the heat in them a better chance of being absorbed by the air passing through the hollow baffle-wall 69.

73 is a flue to lead the superheated air from the part 72 of the cooling-chamber to the upcast 74. Said flue 73 passes above and runs parallel with flue 71.

73ª is a damper to regulate the amount of superheated air passed through flue 73.

75 represents inlets for the passage of the superheated air underneath the fire-bars 76 in the combustion-chambers 6, 7, 8, and 9.

77 represents inlets to allow the superheated air to enter and pass over the fires in the said combustion-chambers.

78 represents sliding dampers to distribute the supply of air to the inlets 75 and 77.

The air entering the combustion-chambers creates a reducing or oxidizing flame, according to whichever inlet, 75 or 77, the air passes through. When desired, cold air may also be admitted to the combustion-chambers through the adjustable ash-pit doors 137 and through passages 79 at the back end of the said combustion-chambers.

80 is a flue to convey the superheated air from the part 72 of the cooling-chamber direct to the roasting-hearths when required.

80[a] is a damper to regulate the amount of superheated air passed through 80. 80[b] represents vertical flues leading from 80 at any point or points along the length of the hearths. 80[c] represents dampers for the regulation of said superheated air through the inlets 80[d] to the roasting-chambers. If desired, said flues 80 and 80[b] can be built into the thickness of the said furnace-walls. When supplementary firing along the sides of the hearths is practiced, the air for combustion can also be supplied from said flue 80. When necessary, a fan can be used to cause the circulation of air through the circuits above described.

Across the cooling-chamber 61 and about midway of its length is a wall 81, which divides said cooling-chamber into two parts 72 and 82. In part 72 the ore which is discharged from the furnace-hearths 2 3 4 5 or finishing-hearth 60 is partially cooled, the air used for that purpose passing when heated by flue 73 to the combustion-chambers or roasting-chambers. Part 82 is simply a cooling-chamber. In the center of said wall 81 is an opening 83 of any suitable width and height. Sliding vertically and smoothly in the opening 83 are two adjustable slides 84 and 85, placed a few inches apart and held in any desired position by the pins 86, which pass through the standards 87 and holes (not shown) in the slides 84 and 85. That slide 84 which is nearest to the feed end of the cooling-chamber 61 rests on or extends below the surface of the hearth. 88 is a hole in said slide 84 a few inches from the bottom. The slide 85 extends downward until its bottom end is below the bottom of the hole 88 in the slide 84, and the hearth of part 82 may be lower than the hearth of part 72.

89 represents solid, vertical, or inclined shafts passing through the center of the cooling-chamber 61.

90 represents solid rabble-arms fitted with movable teeth and attached to the shafts 89 in part 72 of the cooling-chamber 61.

91 represents rabble-arms attached to those shafts 89 which are situated in the opposite end of the said cooling-chamber 61. The rabble-arms on either side of the adjustable slides 84 and 85 rotate in opposite directions and are arranged in relation to each other, as shown in Fig. 3.

92 is an opening for the ingress of cold air to part 82 of the cooling-chamber 61.

93 is an upcast through which the air escapes from the part 82 of the cooling-chamber 61.

94 is a discharge-chute through which the ore is passed from the cooling-chamber 61.

95 is a flue connecting the dust-chamber 67 to the main flue 66.

96 is a sliding damper in flue 95.

97 represents bridge-pieces dividing the hearths 2, 3, 4, and 5 from the fire-boxes 6, 7, 8, and 9.

98 represents the throats or passages through which the products of combustion and calcination pass from the furnace to the dust-chamber 67.

99 represents sliding dampers in said passages 98 to distribute the required amount of draft over each hearth for the proper oxidation of the ore being roasted upon it.

101 represents port-holes in the side walls of the furnace above the level of the hearths for the admission of air when required to assist in roasting the ore and through which observations can be made and any repairs effected to the rabbles or interior of the furnace that may be required. 102 represents doors over said port-holes. Said doors 102 can be of any design and when required means can be provided in them for allowing any amount of opening or no opening at all, so that the amount of air let into the roasting-chambers can be accurately adjusted or altogether stopped.

To provide for the expansion of the hearths in consequence of the great heat in the furnace, a slight depression 103 is formed in and along the center of the said hearths. The said depression 103 allows the hearths to rise without coming in contact with the rabble-teeth on the rabble-arms.

104 represents rectangular projections on the top, and 105 rectangular projections on the bottom, of the rabble-arms, over which the recesses 106, formed in the jaws 107 of the front and back teeth 108 and 109, respectively, are passed.

110 represents spacing-bars to keep the teeth forming any row at given distances apart. 111 represents pins which pass through and hold the said spacing-bars 110 to the rabble-arm.

The back teeth 109 are broader than the front teeth 108, and their effect on passing through the ore is to form deep furrows in it, thereby exposing as great a surface of ore as possible in a given hearth area. The front teeth 108 are narrower and have at their bottom end a broad foot 112. These front teeth 108 immediately preceding, as they do, the back teeth 109 effectively open up the ridges of ore forming the furrows made by the back teeth on the previous revolution of the rabble, and a very thorough and frequent exposure of the ore particles to the oxidizing atmosphere is thereby attained. To connect the said teeth 108 and 109 to the rabble-arms, the jaws 107 are passed over the arms between the rectangular projections 104 and 105 and then slid along the arm until the recess 106, formed in the jaws 107, covers the said projections, when the teeth will be firmly secured. When the inclination of the

hearths is found to be insufficient to cause the ore to pass through the furnace with sufficient rapidity, I remove some of the end teeth 108 and 109 of the rabble-arms and substitute one or more teeth 113, which are so constructed as that they offer oblique surfaces to the ore and force it more rapidly from the path of one arm to that of the next. When it is desired to retard the passage of the ore through the furnace, the teeth 113 are reversed, when the required result will be effected.

When the finishing-hearth 60 is used, the ore discharged from the bottom hearth 5 of the furnace is rabbled over the slide 114 (the height of which can be adjusted) in the step 115, formed by lowering the hearth 5 when extending said hearth to form a finishing-hearth.

116 represents hollow shafts passing vertically through the center of the finishing-chamber 60 and carrying, preferably, hollow water-rabble arms similar to any of those described herein, or these rabble shafts and arms can be cast in one piece, and thereby avoid the necessity for making the joints of arms to shafts within the furnace, and in this case said shafts 116 need not extend through the finishing-hearth. Said rabble-arms convey the ore (delivered from the furnace-hearths 2, 3, 4, and 5 on to the feed end of the finishing-hearth) to a discharge-chute (not shown in the drawings) in the end of the finishing-chamber similar to the discharge-chute 94 in the end of the cooling-chamber. The rabble-shafts 116 are driven in the same manner as the shafts 11, 12, 13, and 14 of the furnace I. The holes in the arch of said finishing-chamber 60 must be of such size and shape as will suit the rabbles to be introduced therein.

In some cases, particularly where a low-arched furnace is being used, I prefer to dispense with the rabble-arms 15 and the pipes 22, as described and as illustrated in Figs. 11, 12, and 13 of the drawings, and substitute therefor a hollow rabble-arm 117, (see Figs. 15, 16, and 17,) having a vertical partition 118, extending nearly the whole of its length, and a jet 119, which screws into the down-pipe 20. The mouth of the said jet 119 completely covers the opening on one side of the partition 118, and the water forced therefrom passes along one side, round the end, and back the opposite side of the partition 118 to the rabble-shaft 11. On turning the said down-pipe 20 in the rabble-shaft 11 the jets 119 are disengaged from the openings in the rabble-arm 117 and can be withdrawn through the top of the rabble-shaft. In some cases I prefer to omit the pipes 22, and in substitution for them I provide the down-pipe 20 with a jet 120, Fig. 18, for each rabble-arm 15 attached to the shaft. Said jet 120 does not enter the rabble-arms, but is so positioned that it directs a stream of water to the center of the hollow rabble-arm, as shown. The water in the down-pipe 20 is maintained at any suitable pressure, and the velocity with which the water enters the rabble-arm from this jet causes a central current of cool water to flow from the inner to the outer end of the arm, which in turn is heated and displaced by the cool water continuously injected, the heated water from all the arms returning to the rabble-shaft and overflowing through pipe 23. Thus a continuous circulation of water is effected through each arm to keep it cool, and the down-pipe 20, with the jets 120, can be withdrawn from the rabble-shaft through its top for the purpose of renewal or repairs without interfering in any way with the rabble shaft or arms in the furnace.

Where water is scarce and only a minimum quantity can be employed in the cooling of the rabble shafts and arms, I provide a modified form of arm 121, (see Figs. 20 and 25,) which has both a water-passage 122 and an air-passage 123. The said air-passage 123 surrounds the water-passage 122 and is open in the roasting-chamber at both ends. A circulation of air and water passes continuously through their respective passages, the circulation of water being effected in a similar manner to any of those herein described.

In Figs. 21 and 22, where I have shown a modified form of air-rabble shaft and air-rabble arm, 124 is the shaft, 125 is the rabble-arm, and 126 represents partitions in the rabble-shaft passing obliquely from one side of the shaft to the other. That portion of the partition 126 which abuts against the vertical partition in the air-rabble arm is made vertical. The vertical partition 127 in the rabble-arm extends from the vertical portion of the oblique partition 126 in the rabble-shaft nearly the whole length of the rabble-arm. The junction of the arm to the shaft may be constructed in the same manner as the water-rabble arm and rabble-shaft hereinbefore described. Cool air enters the bottom of the shaft, and it will be seen that the said air must circulate through every division of the rabble shaft and arms before it escapes from the shaft-top, and if necessary to induce the flow of air the shaft-top can be extended vertically. Any suitable valve may be placed in the top of the shaft 124 for regulating the amount of air allowed to pass through the rabble shaft and arms.

128 (see Figs. 27 and 28) is a flat rabble-arm attached to the rabble-shaft 129 by means of a coupling-piece 130 and is for use in very shallow roasting-chambers. 131 is an annular recess in the bottom of the arm 128 and coupling-piece 130. 132 is a bush built into the hearth of the roasting-chamber and projecting upward into the recess 131 to prevent the ore falling from one hearth to another. Said rabble-arm 128 and shaft 129

are shown solid in the drawings; but it is obvious that when they have to stand a high temperature both the rabble-arm 128 and rabble-shaft 129 can be made hollow and water circulated through them in any manner herein described.

133 (see Fig. 23) illustrates a double rabble-arm fitted with oblique teeth 113, those on one arm stirring the ore left stagnant by those on the other and the teeth on one arm being placed at the opposite angle to those on the other arm, so that when in motion the outwardly-throwing effect of those on the one arm will be counteracted by the inwardly-throwing effect of those on the other. It is quite obvious that rabble-shafts with more than two rabble-arms attached above each hearth may be used, and the paths of the rabble-arms of one shaft can overlap those of the rabble shaft or shafts next adjacent without coming into contact so long as the rabble-shafts are made to rotate alternately in right and left hand directions.

In the drawings I have shown the rabble-shafts 11, 12, 13, 14, and 89 operated by worm and bevel gearing; but it is obvious that other means can be used, and when more convenient they can be driven from beneath the furnace instead of from above it, as shown.

The hearths may have a shallow step or steps introduced at any point or points along their length when it is desired that the ore operated by the rabble arm or arms below said step or steps shall not return said ore back toward the feed end of said hearths.

In order to obtain a maximum amount of combustion-space, a modified form or construction and arrangement of fire-boxes is illustrated in Fig. 9, where 6, 7, 8, and 9 are the fire-boxes. 76 represents the fire-bars. 134 represents holes for the passage of air to and the escape of ashes from the inner ends of the fire-boxes. 135 represents ash-pits. It will be seen that the inner ends of the fire-boxes or combustion-chambers 6, 7, 8, and 9 overlap and the fire-doors 136 are on alternate sides of the furnace structure. When this arrangement of fire-boxes is used and the air for combustion is heated, as hereinbefore described, the position of the upcast 74 and passages 75 and 77 must be modified to suit the altered positions of the ash-pits 135 and fire-boxes 6, 7, 8, and 9. When the air for combustion is not heated, it can be simply allowed to flow in from the atmosphere through either or both of passages 75 and 77, or instead of entering under the fire-bars by passages 75 it can enter through passages 79 and through the front of ash-pit 135 by the adjustment of doors 137. This arrangement of fire-boxes can of course be used when required on either side of the furnace at any point or points along the length of the furnace as well as at the end.

In Fig. 31 another method of controlling the discharge of the ore from and preventing the entrance of cold air to the hearths is illustrated, the object being to more perfectly seal the roasting-chambers at these points. 48 represents the short inclined chutes leading from the hearths to the main chute 49. 62 represents the slides in the top thereof. 138 represents disks keyed to a vertical shaft 139. 140 is a disk keyed to a vertical shaft 141. Said shafts 139 and 141 are operated by the same mechanical means and at the same rate of speed. 142 represents holes in said disks 138. Said holes 142 are situated on opposite sides of the shafts 139 in each alternate chute. 143 represents holes in disk 140. 144 represents openings in the edges of the said disks 138 and 140 to receive a piece of thin metal plate to adjustably close the holes 142 and 143 in the disks 138 and 140 when desired. As will be well understood, when this method is used the ore passing down the inclined chutes 48 passes through the holes 142 in any two alternate disks 138 when said holes 142 are in line with said chutes 48. After passing through the said holes 142 in the said disks it falls on the disk 140 in the main chute. When either of the holes 143 in the said disk 140 is in line with the main chute 49, the ore therein passes to the cooling-chamber or finishing-chamber or direct to the outside of the furnace. It is obvious that instead of using the disks 138 and 140, as above described, or the shutters 50 and 51 and slide 52, hereinbefore described, the disks 138 may be used in combination with the slide 52 or the shutters 50 and 51 may be used in combination with the disk 140.

In Figs. 39 and 40 I have illustrated the method I employ of constructing a furnace in which shallow roasting-chambers are required. The arches 145 over the port-holes 101 are at right angles to the length of the furnace and are so constructed as to permit of free access to the rabble shaft and arm. The distance from the crown of the arch to the roasting-hearth may vary at different points in each roasting-chamber, and at the same time the hearths above may be kept level, the depression caused by lowering the brick arches being made up by thickening the said arches or by filling with sand or other material.

146 (see Fig. 2) represents chutes in the side of the furnace 1 for the introduction of salt to the ore on the hearths during the later or any other stage of the roast when a chloridizing roast is being effected. The salt may be fed automatically from a hopper situated above the furnace to the hearths by any ordinary mechanical means, and the ore can, if desired, be discharged direct from the roasting-hearths into pits to "after chlorinate." The introduction of carbon into the roasting-

chambers during the later or any other stage of the roast is sometimes desirable for well-known metallurgical reasons, and in such cases the carbon can be delivered into the said roasting-chambers in the same manner as the salt for a chloridizing roast.

When the finishing-hearth 60 is used without the cooling-hearth 61, the air for the whole of the combustion-chambers 6, 7, 8, and 9 may be admitted through the opening 147 to the flue 148, the air for combustion-chamber 9 being supplied through inlets 75 and 77 from said flue 148 and that for combustion-chambers 6, 7, and 8 through the inlets 75 and 77 from the upcast 74, to the bottom of which flue 148 is extended by passing it along the top of the arch of the finishing-chamber 60, and thereby the heat radiated by said arch is absorbed by the air supplied to combustion-chambers 6, 7, and 8. When both the finishing and cooling hearths are used, the superheated air from the part 72 of the cooling-chamber 61 can be conveyed by flue 73 to the opening 147 and distributed, as above described, or that for the combustion-chambers 6, 7, and 8 can be conveyed direct to the bottom of upcast 74 and that for the combustion-chamber 9 to the opening 147, in which case the lateral extension of flue 148 above the arch of finishing-chamber 60 will not be required. Sometimes the fire-box 9 will be sufficient to heat the whole furnace, and in such cases the fire-boxes 6, 7, and 8 can be omitted and an upcast similar to 74, but connected with the interior of and leading from the top of the finishing-chamber 60, is substituted. Said upcast opens into each roasting-chamber above each hearth 2, 3, and 4, and thereby conveys the heat taken by it from said finishing-chamber to said roasting-chambers above said hearths 2, 3, and 4, the amount of heat supplied to each roasting-chamber above each hearth 2, 3, 4, and 5 being regulated by the dampers 99 in the throats 98.

149 (see Figs. 2, 5, and 6) represents horizontal flues through which any excess of heat and (or) gas in the roasting-chambers of the furnace can be withdrawn therefrom. Flues 149 are connected to the vertical flue 150, which is connected to the horizontal flue 151, which enters the main flue 66.

152 represents valves in flues 149, and 153 is a valve in flue 151. These valves are for the purpose of controlling the draft in said flues. Suitable openings provided with covers may be made in any part of flue 151 for the removal of dust therefrom.

In lieu of removing the excess gas, as illustrated in Figs. 2, 5, and 6, I may, where the conservation of heat is of importance, convey such excess from the roasting-chambers by means of flues 154, (built in the arches and opening into the top of the roasting-chambers,) which lead direct to the main flue 66.

Sometimes a furnace of large capacity is desired and at the same time it is not convenient to give the amount of inclination to the hearth or hearths that the operation requires in order to pass the ore through quickly enough. In such a case I do with little or no inclination on the hearth or hearths, but alter the position of the rabble-shafts 11, 12, 13, and 14, (carrying the rabble-arms 15, 16, 17, and 18,) as shown in Fig. 41, from an angle of exactly ninety degrees to the hearth or hearths and incline them at an angle of less than ninety degrees toward the feed end of the hearth or hearths, so that the angle formed by the shaft and the discharge end of the hearth or hearths is of correspondingly more than ninety degrees. The rabble-arms 15, 16, 17, and 18, which are at right angles to the rabble-shafts 11, 12, 13, and 14, therefore rotate obliquely to the hearths. By this means each rabble-arm at each rotation (in either right or left hand directions) conveys more ore toward the fire or discharge end of the hearth when going toward it than it brings back toward the feed end when returning toward it, and thereby the ore is conveyed quickly along the hearth or hearths from the feed to the discharge end without the assistance of inclination to the hearth or hearths, and the speed of rotation of the rabbles need not be unduly hastened. It is obvious that the shafts can be quite perpendicular or inclined and the hearths can be inclined or quite level so long as the angle of the rabble-shafts to the hearth or hearths, as above mentioned, are respectively less and more than one of ninety degrees, and, if required, ore could by this means be made to travel up a slightly-inclined hearth. This construction further permits of the rabble-shafts 11, 12, 13, and 14 being placed farther apart lengthwise, thereby giving a greater length of hearth for a given number of rabbles, with its obvious economy in construction.

Where it is difficult to predetermine the amount of inclination to be given to the rabble-shafts to suit the ore intended to be roasted, the openings in the hearths through which the rabble-shafts pass can be elongated, so as to permit of said inclination being varied after the hearths are built. This construction is illustrated in Figs. 41[A] and 41[B], where 2 and 3 are the hearths, and 11 and 12 are the rabble-shafts.

168 represents the elongated openings in the hearths 2 and 3, through which the rabble-shafts 11 and 12 pass. The hearths 2 and 3 are supported around said elongated openings 168 by a strong frame 169 built into it. Fitted loosely to the shafts 11 and 12 are collars 170, the bottom of each of which loosely fits the width of the openings 168. Said collars 170 may have flanges 171 projecting from them, which rest on the top of

the frame 169 and are thereby supported in position. When the shafts 11 and 12 and collars 170 are fixed in the desired position in the longitudinal openings 168, that part of said opening 168 not occupied by them can be filled with suitably-shaped masonry or other filling, which rests on the lip 172 on the frame 169.

It is obvious that the length of the openings 168 will not require to be the same in all of the hearths, but must be longer where said rabble-shafts are moved to a great extend to give the desired inclination. It is also understood that any ordinary method can be adopted for adjusting the driving mechanism of the furnace so that it will be in accord with the altered inclination of the shafts after they are adjusted, thereby causing the toothed gearing to work truly and smoothly.

In Figs. 42 and 43, where I have shown a modification of the furnace, as hereinbefore described, 1 is the furnace, which may be of any desired length. 2, 3, 4, and 5 are the roasting-hearths. Said roasting-hearths are muffled. 6, 7, 8, and 9 are fire-boxes to heat the said hearths 2, 3, 4, and 5, though it is obvious that one fire-box may be made to serve two or more hearths. The products of combustion pass from one end of the furnace to the other through broad interrupted flues 155, built into the hearths 2, 3, 4, and 5 or arches of the furnace, to the upcast 156. 157 represents dampers for regulating the draft through the flues 155. In roasting some ores it will be preferable for the flues 155 not to extend the full length of the hearths, as the temperature of the products of combustion in them may be lower than that of the ore within the roasting-chambers, in which case it would only have a cooling effect on said ore. In such cases said flues may terminate at any point in the length of the furnace and the gases be withdrawn from them through the side wall. Projecting alternately at right angles to and from either side of the broad flues 155 are a number of walls 158, which pass around the rabble-shafts in the furnace and project beyond the center of the said flues 155, and thereby increase the length of the circuit of the products of combustion. When said increased circuit is not desired, walls 158 are dispensed with and rings of brickwork surrounding the rabble-shaft may be built solidly into the top and bottom of the flues 155. From the top of the upcast 156 and running the whole length of the top hearth 2 is a broad interrupted flue 159 to convey the products of combustion from the flues 155 below to the outlet 160, through which they pass to the main flue, (not shown) and thence to the stack. (Not shown.) The method of heating and superheating the air for combustion and calcination is as well, if not better, applicable to this modified form of the furnace.

124 and 129 are the rabble-shafts, passing through the center of the furnace 1 and carrying the rabble-arms 125 and 128, respectively. Said shafts 124 and 129 may be placed at right angles to or inclined to the hearths 2, 3, 4, and 5. The ore is fed to, conveyed through, and discharged from the furnace-hearths substantially as described, and illustrated in Figs. 7, 1, and 8, respectively.

When the finishing-hearth 60 is used in combination with the muffled roasting-hearths to effect a "sweet" roast, it is formed by removing the bottom fire-box 9 and extending and lowering the bottom hearth 5. The ore is discharged from the hearths 2, 3, and 4 on the hearth 5 below the step 115, formed by lowering the said hearth 5. From the bottom hearth 5 the ore is rabbled over the adjustable slide 114 in the step 115 and is further rabbled along with the ore from the hearths 2, 3, and 4 to a wall 161, crossing the finishing-chamber at a sufficient distance from the step to allow the rabble-arm (not shown) to rotate freely between the said step 115 and said wall 161. Sliding horizontally in the wall 161 are two adjustable stops or slides 162 and 163, similar to those already described in Figs. 3 and 4, so placed that when the ore is passing through the opening 164 in the wall 161 a seal is formed, which prevents the products of combustion and calcination from fire-box 9 and finishing-hearth 60 from entering the bottom muffled hearth 5 and diluting the sulfur gases produced therein. Said stops 162 and 163 must be of suitable material to withstand the higher temperature of the finishing-chamber. The arms on the rabble-shafts on either side of the wall 161 are placed in the same relation to each other as those on either side of the wall 81 in the cooling-chamber 61, and the finishing-hearth 60 may be lowered from the point between the stops 162 and 163 to its discharge end. The fire-box 9, removed to allow the extension of the bottom hearth 5 to form the finishing-hearth 60, is employed for directly heating the ore in said finishing-hearth to a sufficiently high temperature to insure a sweet roast of the ore being effected. The gases of combustion from said fire-box 9 after passing through the finishing-chamber enter the two bottom flues 155, passing under and heating hearths 4 and 5. The gas which heats the bottom hearth 5 is passed through the flues 167 in the wall 161 downward to the bottom flue 155, while the gas which heats hearth 4 is passed upward to the flue 155, running between the two bottom roasting-chambers. The sulfur or other gases generated in the roasting-chambers of the furnace are withdrawn therefrom through outtakes 165 and led where desired to be used in the manufacture of sulfuric acid, sulfite, pulp, &c. Said outtakes 165 may be placed at any point or points along the length

of the furnace and have dampers 166 in them to regulate the amount of draft passed through each muffled roasting-chamber.

In cases where the fire-box 9 is sufficient to heat the whole of the muffled roasting-chambers after heating the direct-fired finishing-hearth 60 the fire-boxes 6, 7, and 8 can, as hereinbefore explained, when the hearths are "direct-fired" be omitted and the upcast similar to 74 substituted, the bottom of said upcast being connected with flue 155 from the finishing-chamber and the amount of heat supplied to each flue 155 beneath the muffled hearths 2 3 4 5 regulated by the dampers 157. 145 represents arches over port-holes 101, arranged at right angles to the length of the furnace to allow free access to the rabble-arm and shaft and interior of the roasting-chambers.

When the conservation of floor-space is of importance, the direct-fired finishing-hearth 60 could be placed beneath a muffled hearth or superimposed muffled hearths, and, when required, the muffled hearth or hearths could be quite level and the finishing-hearth slightly inclined. It will be understood that the hearths 2 3 4 5 can be worked unmuffled in conjunction with the finishing-hearth 60 and the calcination-gases from said hearths 2 3 4 5 kept from being diluted with the combustion-gases from said finishing-hearth 60 by the ore seal in the wall 161 of said finishing-hearth. In this case the said combustion-gases can be delivered away from the furnace immediately after passing over said finishing-hearth 60.

The mode of operation is as follows: The fires are lighted in the combustion-chambers 6, 7, 8, and 9 when said combustion-chambers are required, and the ore is fed from the hopper 43 down the depending chutes 45 to the chutes 46, from which it is fed onto the end of each hearth farthest from the fire-box or discharge ends of said hearths, and consequently the coolest end of the roasting-chambers of the furnace 1, by means of the Archimedean screws 47, motion at the same time being given to the rabble-shafts 11, 12, 13, and 14. The rotation of the rabble-arms on the said rabble-shafts causes the ore to pass along from the coolest end of each hearth to the discharge end, in its passage being brought gradually to a greater heat as it nears the fire-box and being continuously exposed to the oxidizing-gases passing through the furnace. When the ore has traversed the whole length of the hearths, it is discharged over the projections 63 on the slide 62 through the hole 64 therein either to the outside of the furnace or to the cooling-chamber 61 or to the finishing-chamber 60 by way of inclined chutes 48 and main chute 49.

When the treated ore is fed from the furnace 1 or from the finishing-chamber 60 into the cooling-chamber 61, it is conveyed along the hearths of the said cooling-chamber 61 by means of the rabble-arms 90, attached to rotating shafts 89, until it reaches the wall 81, when it is passed through the hole 88 in the slide 84 and falls between the said slide 84 and the slide 85, where it forms a seal which prevents air from the part 82 entering the part 72 of the cooling-chamber 61. The rabble-arm 91, attached to the rotating shaft 89 adjacent to the wall 81 in the part 82 of the cooling-chamber 61, passes under the slide 85 and at each revolution removes a given amount of ore from between the slides 84 and 85, the amount of ore between the said slides being replenished immediately by the revolution of rabble-arms 90 adjacent to the wall 81 in the part 72 of the cooling-hearth. The ore after passing through the hole 88 is conveyed to the discharge-chute 94 by the other rabble-arms 91.

Having now fully described and ascertained my said invention and the manner in which it is to be performed, I declare that what I claim is—

1. The combination with a series of hearths, one above and each independent of the other, of means for supplying ore to each hearth, means for conveying the ore simultaneously along each hearth in the same direction and at the same rate of speed, and means for discharging said ore from the said hearths.

2. The combination with a series of hearths, one above and each independent of the other, each hearth having a fire-box at each discharge end, of a hopper having at its bottom fluted rollers, chutes leading from said hopper for supplying the ore direct to each hearth, a plurality of solid rabble-shafts passing through all of said hearths, and a plurality of hollow rabble-shafts passing through all of said hearths, rabble-arms on each of the shafts to convey the ore simultaneously along each hearth in the same direction and at the same rate of speed to a discharge-outlet, substantially as herein described.

3. The combination with a series of hearths, one above and each independent of the other, of a separate fire-box at each discharge end of each hearth, the upper and lower fire-boxes being of larger dimensions than the intervening boxes, substantially as described.

4. The combination with a series of hearths, one above and each independent of the other and having a separate fire-box at the discharge end of each hearth, and a cooling and finishing hearth having communication with one of the hearths, substantially as herein described.

5. The combination with a series of hearths, one above and each independent of the other and having a separate fire-box at the discharge end of each hearth, and a cooling-hearth, substantially as described.

6. The combination with a series of hearths, one above and each independent of the other

and having a separate fire-box at the discharge end of each hearth, and a finishing-hearth, substantially as described.

7. The combination with a series of hearths, one above and each independent of the other, of a cooling and finishing hearth in communication with the delivery end of each of said hearths, and means for conveying the ore along said cooling and finishing hearths, substantially as described.

8. The combination with a series of hearths, one above and each independent of the other, of a cooling-hearth in communication with the delivery end of each of said hearths, and means for conveying the ore along said cooling-hearth, substantially as described.

9. The combination with a series of hearths, one above and each independent of the other, of a finishing-hearth in communication with the delivery end of each of said hearths, and means for conveying the ore along said finishing-hearth, substantially as described.

10. The combination with an ore-roasting furnace, of a cooling-chamber having two compartments, means for cooling one of the compartments for partly cooling the ore, means for completely cooling the other of said compartments and the ore contained therein, and a combustion and roasting chamber in communication with said cooling-chamber.

11. The combination with an ore-roasting furnace, of a cooling-chamber having a dividing-wall provided with an opening therein, adjustable slides for closing said openings, rotatable rabble-arms within said chamber, means for supplying air to said cooling-chamber, and means for supplying ore thereto, substantially as described.

12. The combination with an ore-roasting furnace, of a finishing-chamber having a dividing-wall provided with an opening therein, and adjustable slides for closing the opening, substantially as described.

13. The combination with an ore-roasting furnace, of a finishing-chamber having a dividing-wall provided with openings therein, slides for closing said openings, and flues arranged in said wall, substantially as described.

14. The combination with a series of hearths, one above and each independent of the other, of hollow baffle-walls having flues, a cooling-chamber, means for delivering heated air to the cooling-chamber, and fire-boxes having communication with the said means to convey the superheated air to the said boxes, substantially as described.

15. The combination with a series of hearths, one above and each independent of the other, of a main chute, inclined chutes in communication with the hearths and leading to the main chute, slides fitted in said inclined chutes at the mouth portion of each, hinged chutes at the discharge end of each inclined chute, and means for operating the said slides and chutes.

16. The combination with a series of hearths, one above and each independent of the other, of a main flue, a plurality of horizontal flues leading from the hearths, a vertical flue in communication with the said horizontal flues, and means in communication with the vertical flues and the main flue for withdrawing any excess of heat and gas from the hearths, substantially as herein described.

17. In an ore-roasting furnace, the combination with a series of hearths, one above and each independent of the other, of a combustion-chamber at one end of each hearth, of a fire-box at the side of each hearth, the inner ends of said combustion-chamber and fire-boxes overlapping each other, substantially as described.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

ARTHUR VICTOR LEGGO.

Witnesses:

WALTER SMYTHE BAYSTON,

FRANK BAYSTON.