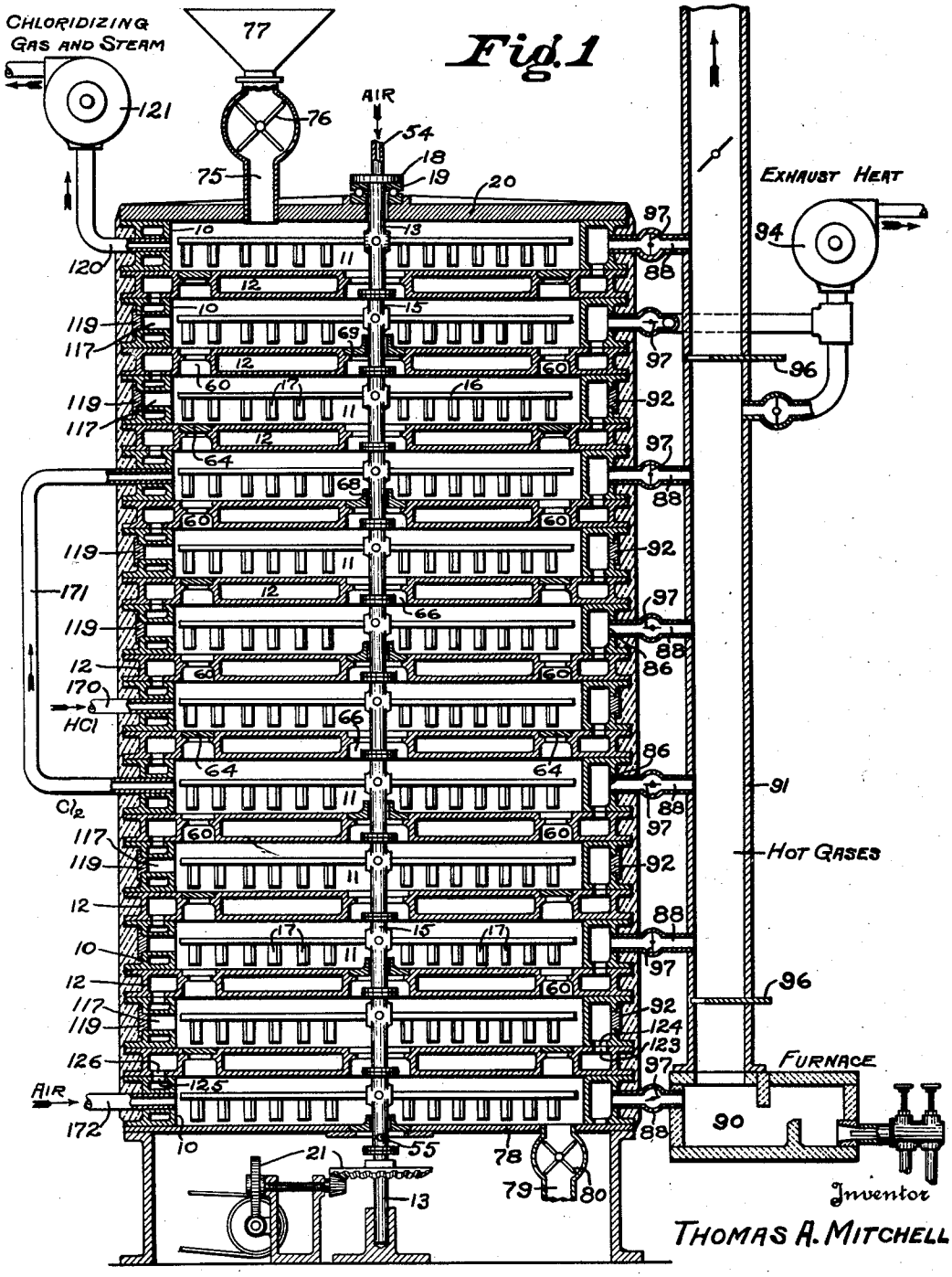
Oct. 16, 1934. T. A. MITCHELL 1,977,238

CHEMICAL APPARATUS

Filed Feb. 18, 1932 4 Sheets-Sheet 1

Fig. 1



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CHEMICAL APPARATUS

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Fig. 2

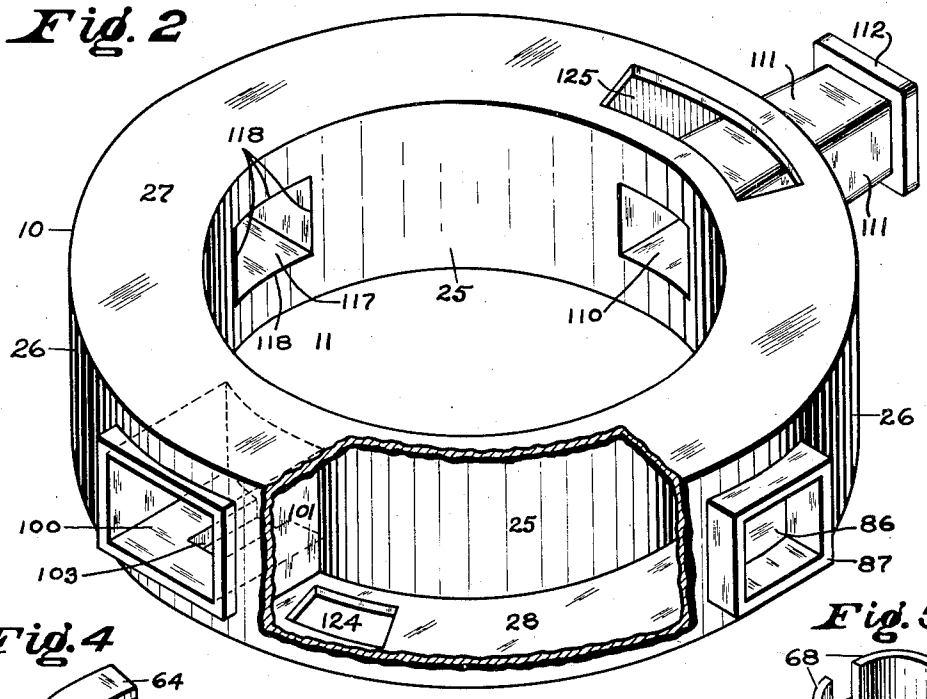
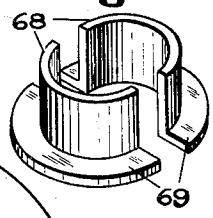


Fig. 4



Fig. 5



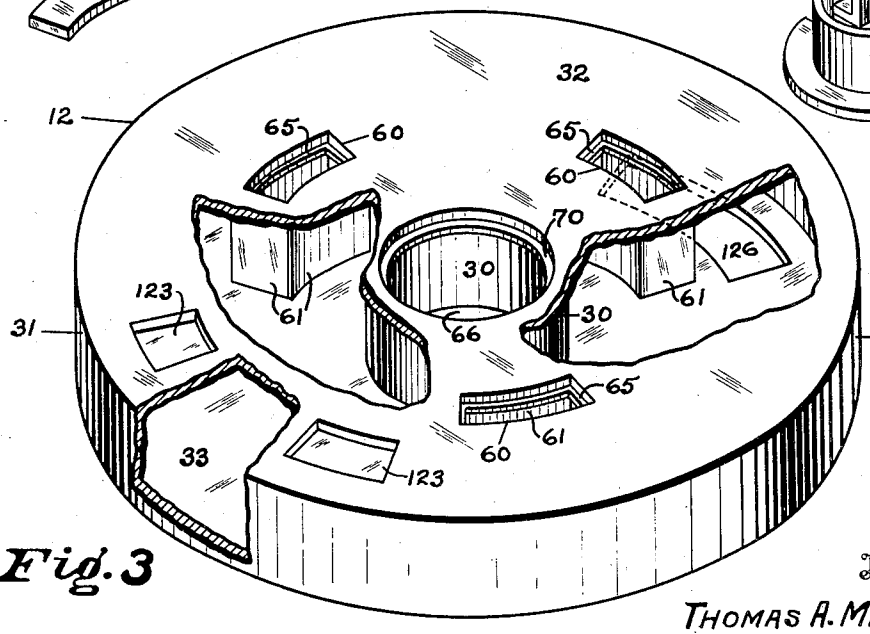


Fig. 3

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CHEMICAL APPARATUS

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Fig. 6

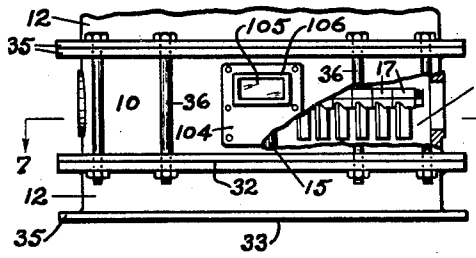


Fig. 7

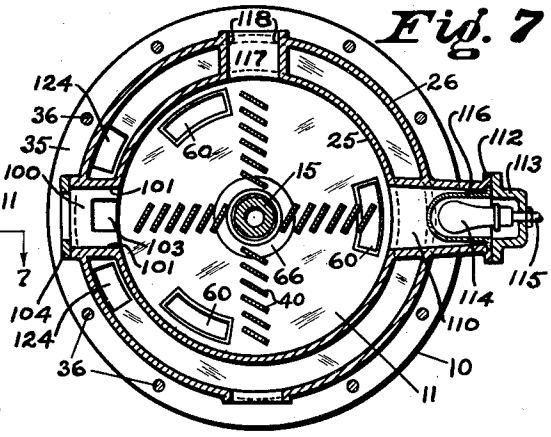


Fig. 9

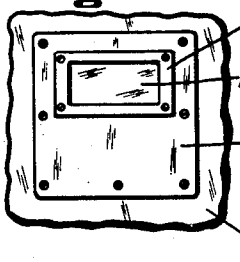


Fig. 10

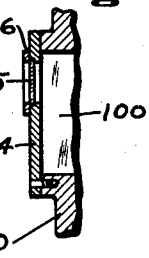
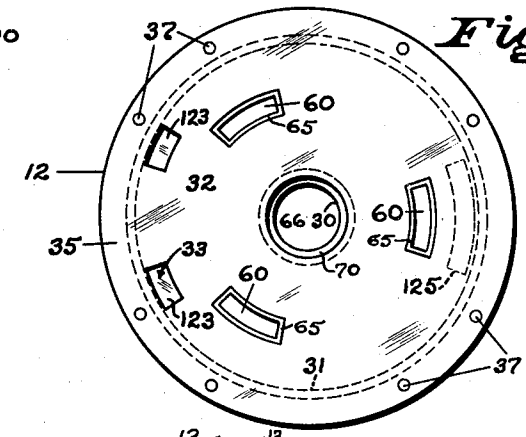


Fig. 8



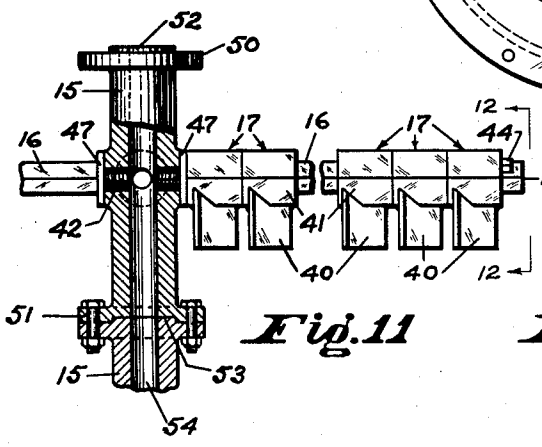


Fig. 11

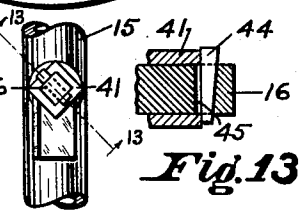


Fig. 12

Fig. 13

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CHEMICAL APPARATUS

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Fig. 14

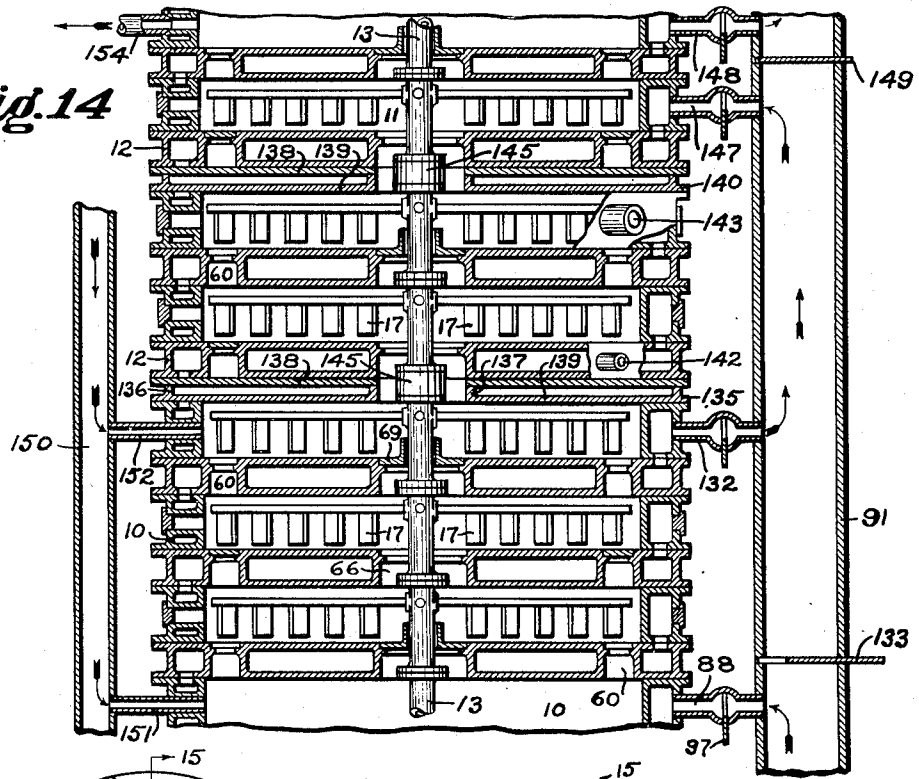


Fig. 16

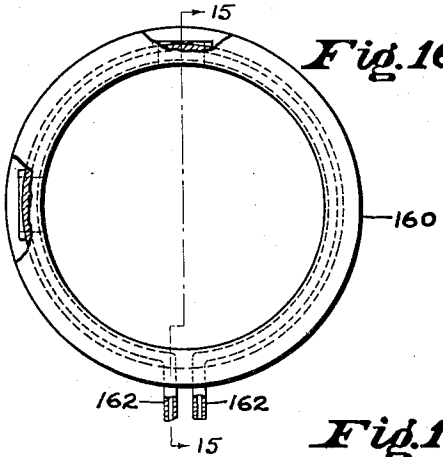


Fig. 17

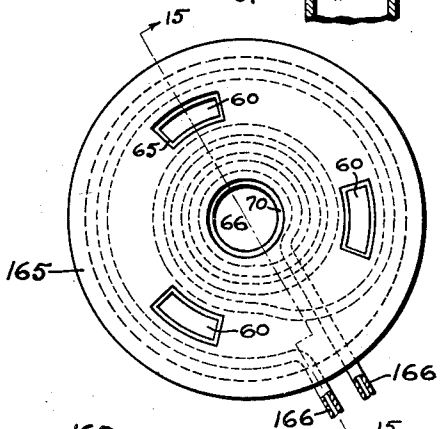
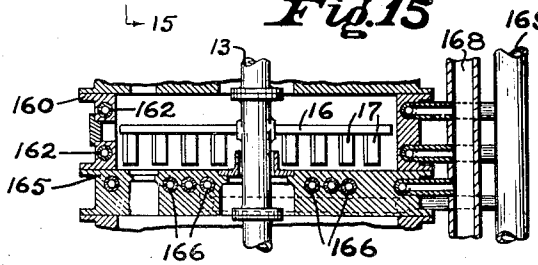


Fig. 15



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1,977,238

UNITED STATES PATENT OFFICE

1,977,238

CHEMICAL APPARATUS

Thomas A. Mitchell, Denver, Colo., assignor, by mesne assignments, to Hughes-Mitchell Processes, Incorporated, Denver, Colo., a corporation of Wyoming

Application February 18, 1932, Serial No. 593,932

27 Claims. (Cl. 23—262)

This invention relates to chemical treatment apparatus, and more particularly to a heat transfer apparatus of the muffle type adapted for chemically treating various materials.

There are numerous chemical processes requiring an indirect heat treatment while a chemical or physical process is taking place. This may involve the simple procedure of drying or desiccating a given material, or it may be desired to cause the reaction of two chemical compounds in a controlled atmosphere while being heated indirectly and maintained under a desired temperature condition. For example, it may be desired to make a deliquescent salt by a process in which the retention of water in the zone of reaction would interfere with the process. Zinc chloride is such a deliquescent salt, and a problem is found in its manufacture by the interaction of hydrochloric acid gas and zinc oxide, owing to the fact that the zinc chloride tends to dissolve in the chemical water produced by the reaction and to form a syrupy mass which prevents proper contact of the gaseous reagents with the zinc oxide as well as the egress of the chemical water formed in the material. As a further example, many zinc sulfide ores contain iron pyrite. One procedure for chloridizing such an ore involves a roasting operation to form iron and zinc oxides and the treatment of these oxides with hydrochloric acid gas to form ferric and zinc chlorides. Ferric chloride in the presence of oxygen decomposes at a temperature above the boiling point of water with the formation of chlorine and ferric oxide. On the other hand, if there is a high zinc content, the chemical water of reaction dissolves the deliquescent zinc chloride and forms a syrupy mass, if the temperature is maintained below the boiling point of water. It is, therefore, desirable to chloridize this mixture of materials at a temperature at which the chemical water will be vaporized and removed from the zone of reaction and yet to maintain non-oxidizing conditions and to control the temperature of the reaction so that the ferric chloride will not be decomposed. Many other processes likewise require a regulation and variation of atmospheric conditions and temperature at different stages.

It is accordingly one object of this invention to provide a chemical treatment apparatus in which heat may be applied indirectly to the zone of reaction and the temperature and atmosphere may be varied at various points as required, independently of the conditions present in other portions of the apparatus.

A further object of the invention is to provide an apparatus which is so constructed and arranged that deliquescent materials may be made under substantially dry conditions, decomposable materials may be held under controlled atmospheric and temperature conditions to prevent their decomposition while desired chemical reactions are being accomplished, or various other types of chemical and heat-exchanging processes may be carried on simply, economically and efficiently.

It is a still further object of this invention to provide a chemical treatment and heat-exchange apparatus which is made up of duplicate, interchangeable muffles, which in turn comprise a set of different standard units of such shape and design that any number of these units may be arranged alternately to form a series of intercommunicating reaction muffles of any desired number, for carrying on a reaction or a series of reactions which require considerable time and controlled temperature and atmospheric conditions.

Other objects, including the provisions of special details and features of use in connection with the muffle units, will be apparent in the following disclosure.

In order that this invention may be fully understood, its specific application to the treatment of an ore material containing zinc and iron oxides which is to be chloridized will be hereinafter fully set forth.

Referring to the drawings, which illustrate various embodiments of this invention:

Fig. 1 is a schematic view of an apparatus adapted for chloridizing an ore, which is made of superimposed units connected with various gas passages, the parts being shown as a vertical section, but in which certain ports and passages have been brought into the same plane for the sake of clarity of illustration;

Fig. 2 is an isometric view partly broken away of the annular muffle unit which surrounds the reaction or muffle chamber;

Fig. 3 is an isometric view, partly broken away, of one of the intermediate hearths, adapted to form the top and bottom of a reaction chamber;

Fig. 4 shows a cover plate for closing one of the passages in the unit of Fig. 3;

Fig. 5 shows in perspective the two parts of a collar arranged to surround the driving shaft

and prevent material from passing through the shaft opening;

Fig. 6 is a vertical elevation, partly broken away, of the units of Figs. 2 and 3 in assembled relationship;

Fig. 7 is a horizontal section on the line 7—7 of Fig. 6, showing the revoluble rakes and bearing shaft surrounded by the muffle walls of the unit of Fig. 2;

Fig. 8 is a top plane view of the hearth unit shown in Fig. 3;

Figs. 9 and 10 are details, showing a closure and sight glass for one of the openings in the outer wall of the annular unit shown in Fig. 2;

Fig. 11 is a vertical elevation, partly in section and broken away, showing two connected units of the driving shaft and the stirring arms;

Fig. 12 is a section on the line 12—12 of Fig. 11;

Fig. 13 is a section on the line 13—13 of Fig. 12, Figs. 12 and 13 showing the manner of fastening one of the stirrers to the driving arm;

Fig. 14 is a schematic view in section, partly broken away, of a modification of Fig. 1 showing how fluid may be introduced to control the temperature of various muffle units;

Fig. 15 is a view taken in cross-section along the line 15—15 of Figs. 16 and 17, showing a modified construction of muffle and hearth chambers utilizing steam or gas under pressure to control the temperature therein;

Fig. 16 is a top plan view, partly broken away, of the annular muffle unit of Fig. 15; and

Fig. 17 is a similar view of the hearth unit.

In accordance with my invention, the chemical treatment and heat-exchange apparatus is preferably made up of separate and preferably duplicate muffles adapted to be assembled in a series relationship, whereby material may be treated as it is moved therethrough by a suitable device arranged for the purpose. The apparatus is preferably made up of two units, each having walls adapted to be suitably heated and preferably independently of other muffles, whereby the temperature may be suitably regulated. In the preferred form, one muffle is a hollow annular casing having two concentric walls between which a heat exchange medium may be enclosed, the inner wall forming the outer boundary of a central reaction chamber heated or cooled by the fluid on the other side of the wall. The other preferred unit is a hollow hearth adapted to form the bottom and the top of the heat treatment chamber and to supply heat thereto.

These muffle units are so constructed that they may be adapted for many purposes. Consequently, each is provided with various openings or passages which have removable or adjustable closures so arranged that by suitably adjusting the various parts of the apparatus, a material may be caused to flow in desired paths and its treatment may be suitably regulated. Assembled in the chemical treatment chambers is an agitating apparatus, such as a series of rake arms which is preferably driven from a central supporting shaft, these serving also to transfer the material from one muffle to the next. The passages through the various units are preferably so arranged that the materials may be passed back and forth across the hearths in the successive stages of the operation. Suitable inlet and outlet openings and adjustable closures therefor are provided for supplying gaseous, liquid or solid chemicals or other selected materials to the muffle chambers at any desired point in the apparatus. Likewise, passages are provided for conducting hot or cold air or other gas or liquid to and from the surrounding heat transfer spaces within the hollow walled muffle units.

Many modifications in the set-up and arrangement of the units may be made within the scope of the invention, depending upon the use to which the apparatus is to be put. For example, the apparatus may be employed for the chloridization of an oxidized ore material, as described herein or in my copending application Serial No. 593,931 filed on even date herewith. The assembled chloridizing apparatus, as shown diagrammatically in Fig. 1, comprises similar muffles made up by alternately piling up the two muffle units shown in Figs. 2 and 3. The annular muffle unit 10 of Fig. 2 encloses the chemical treatment or muffle space 11. The hearth unit 12 of Fig. 3 forms the top and bottom walls of the chemical treatment chamber. These two units may be duplicated throughout the entire extent of the apparatus, thus making it necessary to provide only two major castings to form a series of reaction chambers of any desired number.

Passing through central openings in these units is the driving shaft 15 made up also of a series of assembled units 15 (Fig. 11) carrying horizontally disposed removable arms 16 which in turn support the rakes 17 removably mounted thereon. This shaft is supported and driven in any suitable way. As shown, the top of the shaft is provided with an enlarged flange 18 supported on ball bearings 19 mounted on the cover 20 placed over the top reaction chamber, which if desired may be made the same as one of the hearth units 12. At the lower end, the shaft is driven by means of gearing 21 from any suitable source of power, as is well understood, whereby the rakes may be revolved at a desired speed.

The annular muffle unit, shown in Fig. 2, comprises a built-up structure or preferably a single casting of iron or other metal having an inner cylindrical wall 25 and an outer cylindrical wall 26 connected by plane top and bottom walls or plates 27 and 28. The disk-shaped hearth unit 12, shown in Fig. 3, likewise has inner and outer cylindrical walls 30 and 31 connected by the top and bottom plates 32 and 33. The top and bottom walls of these two units are made flat and so shaped that the parts may be readily assembled, one on another. If desired, suitable packing may be placed therebetween, such as a sheet of asbestos, resinoid or rubber, to provide gas-proof or liquid-proof joints, the nature of the material depending on the use to which the apparatus is to be put. It will be appreciated that the inner wall 30 provides a space for the driving shaft 13 as well as for material to pass downwardly from one chemical treatment chamber to another, and for reagent gases or other fluids to pass therethrough. Figs. 2 and 3 have been simplified for the sake of clarity of illustration, but in actual practice the tops and bottoms 27 and 28 of the annular unit and 32 and 33 of the hearth unit project outwardly beyond the outer cylindrical walls to form flanges 35, as shown clearly in Fig. 6, in order that the parts may be suitably fastened together by means of bolts 36 passing through holes 37 (Fig. 8) in these projecting flanges.

As indicated in Fig. 1, the rakes 17 on the

arms 16 in adjacent chambers are arranged to move the material in opposite directions. Any suitable rake construction may be employed, but (see Figs. 7, 11, 12 and 13) they preferably comprise flat plates 40 having enlarged heads 41 separately mounted on the arms 16 at a suitable angle to their direction of travel so that as they revolve they will push the material one way or the other, as desired. In order to permit removability and ready replacements of these rakes, each of the enlarged heads 41 has a square opening therethrough adapted to slidably fit upon the bar 16 which is square in cross-section, with its corners arranged in vertical and horizontal planes. This bar 16 has its inner end 42 reduced in cross-section and screw threaded so that it may be adjustably threaded into openings in the shaft unit 15. Each of the separate rake units may be assembled in position by being slid along the bar from the outer end toward the inner, either before or after the arms have been assembled in the apparatus. In order to hold all of the rakes in a fixed position, a wedge-shaped key 44 is removably positioned in a tapered opening 45 formed in the end of each of the arms 16. It is also to be noted that the screw threads on the end 42 of the arm 16 are made right or left handed, depending on the direction of rotation of the shaft, so that the torque imposed upon the shaft by the revolving rakes 40 tends to tighten the threaded connection of the arm on the shaft. Shims 47 may be placed between the inner shoulders of the arms 16 and the shaft, which are of desired thickness to insure that when the arms 16 are tightly held in position, the rakes 40 will hang vertically therefrom.

Each of the separate shaft units 15 has a top flange 50 and a bottom flange 51 so shaped and arranged that the units may be assembled and secured together by bolts passing through suitable openings in these flanges. The upper and lower ends of these shaft units are provided with projections 52 and recesses 53 adapted to interfit, as illustrated clearly in Fig. 11, in order that the shaft parts may be quickly assembled and held together rigidly. These units may be of desired length and extend through one, two or more of the chambers. By having short units, as shown, which correspond in length with a multiple of the thickness of a hearth and an annular unit, it is feasible to build up the apparatus by one or more reaction chambers at a time, or to add more at any time without removing the assembled shaft units. The shaft is preferably made hollow for convenience in manufacture and to avoid having excessive weight in the apparatus. Air, water or other coolant or heated fluid may be conducted into an opening 54 in the top end of the shaft and out through the exit 55 at the bottom (see Fig. 1) and be caused to flow therethrough to cool or to heat the shaft. The coolant may flow if desired into the arms by making the arms hollow and suitably connecting the various passages. If desired, fluid material may be introduced to the reaction chambers through these arms, by providing openings therein.

In order that the material may be raked outwardly across the hearths and discharged near the peripheral wall 25 of the chamber, the three passages 60 are provided through the hearth. These passages are formed by walls 61 extending from openings in the top plate 32 to openings in the bottom plate, thus preventing intermingling of the material and the gases within the muffle chambers. Cover plates 64, shown in Fig. 4, are adapted to be fitted upon the ledges 65 formed at the upper portion of the walls 61. These walls are so shaped as to close the openings when fitted in place and to lie with their top faces flush with the top surface of the plate 32. Thus, by closing each of these openings, material may be prevented from passing therethrough and may pass only through the central passage 66 formed by the wall 30. The passage 66 may likewise be closed at its upper end by the two half collars 68, shown in Fig. 5, which are provided with flanges 69 adapted to fit upon a countersunk shoulder 70 formed at the upper portion of the wall 30. The parts are so arranged that when the half collars are put in position, they form a fence, as it were, around the drive shaft units 15 which are sufficiently high, as compared with a depth of material ordinarily placed in the chemical treatment chamber, to prevent the material from escaping through the central opening. The top face of each of the flanges 69 is arranged to lie flush with the top of the cover plate 32. In Fig. 1, as will be observed, every other hearth unit is provided with a central closure and the alternate muffle units have the cover plates 64 in position, so that the material will be caused to pass back and forth as it is stirred by the revolving arms.

The material to be treated may be introduced through the top cover 20 by means of a suitable pipe 75 which is shown as provided with a rotary feeder 76 and a hopper 77, the feeder being adapted, as is well understood, to prevent the exit of gases from the apparatus as the raw material is being fed therethrough. A similar construction is applied to the bottom plate 78 of the assembled apparatus, an opening therethrough communicating with a pipe 79 likewise provided with a rotary feeder 80. It will be understood that various types of feeding apparatus may be employed.

In order to heat the chemical treatment chamber indirectly by the transfer of heat through the walls 25, 32 and 33, either or both of the two muffle units have suitable openings or passages adapted to communicate with outside heating apparatus adapted for the introduction of a heating or cooling medium thereto. For example, a gas or oil flame may be introduced directly into these muffle chambers for combustion of a suitable heating medium therein or electric heating units may be employed if desired. In the form illustrated, the heated gaseous products of combustion of an oil fired furnace are conducted into the annular unit shown in Fig. 2. For this and other purposes, these units are provided with a series of openings or passages. One opening 86 is formed in the outer wall 26 and communicates with a short length of pipe 87 which is adapted to be interfitted with suitable piping 88 illustrated diagrammatically in Fig. 1. The pipe 88 may lead from a oil or gas fired furnace 90 or from the furnace stack 91 which opens to the outside atmosphere. As illustrated in Fig. 1, any of the openings 86 in the annular muffles may be closed with a suitable plate 92 while other openings are connected with the furnace chamber 90 or the stack 91, as desired. An exhaust fan 94 may be connected to any of the muffle units or indirectly thereto by opening from the upper

portion of the stack, as shown, suitable piping and dampers being provided to control the exit of the gases through the fan. One or more dampers or valves 96 may be placed in the stack to direct the gases, as required, into or from the apparatus units. Similarly, each one of the pipes 88 may be provided with a slide damper or a rotary valve 97 in order to control the admission and exit of gases to and from the muffle chambers.

The annular muffle unit 10 is provided with an opening 100 (Figs. 2, 6, 7, 9 and 10) adapted for the introduction of material into the chemical treatment chamber or for inspection of the material or for control or manipulation of the process as may be required. This opening is formed by the side walls 101 and the top and bottom walls 27 and 28 which are suitably shaped in the casting for the purpose. It will be observed that in Fig. 2 the lower wall of the opening 100 is thicker than the bottom plate 28 but is provided with a cut-out portion 103 which is arranged to permit removal of the rakes from the arms. As shown in Figs. 9 and 10, this opening 100 is adapted to be closed by means of an outer cover plate 104 suitably fastened in place, as by means of screws. Each of these cover plates is preferably provided with a sight glass 105 held in place by a removable ring or collar 106, whereby the chemical operation may be observed without permitting any of the gases to escape from the chamber.

A further feature of the invention, which aids one to see what is going on in the chemical treatment chamber, comprises means for lighting the interior of this chamber. To this end, as shown in Figs. 2 and 7, the casting is provided with a passage 110 of rectangular cross-section formed by the walls 111 which pass through the annular muffle unit and communicate solely with the interior of the chemical treatment chamber. The pipe 111 has an outer flange 112 upon which is adapted to be mounted a cup-shaped cap 113. This cap, as shown in Fig. 7, has a central opening therethrough, within which an electric light bulb 114 may be mounted on a pipe 115 suitably fastened in position. This bulb is suitably covered with a glass globe 116 suitably clamped in position between the cap and the pipe 111. This globe serves to ward off the heat from the bulb and to insure that no gases may contact with the metal work of the electrical fixtures. The light opening 110 is positioned opposite the sight opening 100 so that the material may be readily inspected through window 105 as it is being treated.

A fourth opening 117 is preferably provided in each annular unit 10, so that gases or liquids may be admitted to or delivered from the chemical treatment chamber. This opening 117 is formed by walls 118 (Figs. 2 and 7) passing from the cylindrical wall 25 to the outer cylindrical wall 26 and preventing the intermingling of gases within and outside of the muffle. A cover plate 119 is provided for closing the outer end of this passage, if it is not intended to be used. As indicated diagrammatically in Fig. 1, the passage 117 in the top unit is adapted to be connected through a pipe 120 with an exhaust fan 121, which serves to draw the gases through and out of the reaction chambers. Any of the units may be provided with pipe connections for the introduction and removal of gases to and from the reaction chambers.

In order to permit inter-communication between the two muffle units, the hearth unit 12 is provided with openings 123 through the top wall 32, as shown in Fig. 3. Likewise, the annular unit 10 of Fig. 2 is provided with an opening 124 in the bottom wall 28, these openings 123 and 124 being so located that when the units are piled properly one on top of the other, the openings will communicate. It will be observed that the openings 124 are located on opposite sides of the walls 101 forming the passage 100, but this passage 100 may be smaller in cross-section so as to permit the gases to flow around the annular chamber past the same. Likewise, the top wall 27 of the annular unit 10 (Fig. 2) is provided with an opening 125 which communicates with the muffle space on each side of the passage 110. This opening 125 lies beneath a similar opening 126 in the bottom wall 33 of the hearth unit 12.

It will now be seen that when gas is admitted to the annular chamber through the lowermost pipe 99, as shown in Fig. 1, the gas will pass through this annular chamber until it comes to the opening 125. The walls forming the passage 110 do not close off the entire space in the annular chamber so that heating gases may pass readily by the walls 111 into the far side of the annular chamber and so transmit heat to the whole interior thereof. The heated gases pass upwardly through the openings 125 and 126 into the hearth chamber 12 and travel around through the space therein to the openings 123 in the top wall at the opposite side thereof and then into the openings 124 in the bottom wall 28 of the annular unit above. Thus, the heating gases will pass back and forth through the entire interior of each of these heating units and so heat the top and bottom walls of the hearth units and the inner annular wall 25 of the annular units and thereby heat the chemical treatment chamber.

Referring now to Fig. 14 of the drawings, it will be seen that a cooling fluid may be employed for the purpose of cooling a part or all of this apparatus. As there shown, the separate units 10 and 12 may be piled up in a series and the shaft and rake arms assembled the same as in Fig. 1. The lower muffle units may be heated by gases passing from the furnace pipe 91 through the lowermost transverse inlet pipe 88 to the muffle unit 10. This heating gas passes back and forth through the various hearths and annular units until it reaches the outlet pipe 132 and returns to the stack 91. The damper 133 in the stack is utilized to control the passage of gases to the particular units. Located immediately above the uppermost of these particular units is the spacer unit 135. This unit serves to prevent the passage of heating or cooling materials above or below that particular point in the apparatus. This spacer may be made up of the annular walls 136 and 137 connected with the top and bottom plates 138 and 139. The top plate 138 may, if desired, be made separate from the other portions for convenience in manufacture and assembly. Likewise, a second spacer unit 140 made like the other is placed higher up in the assembled apparatus. These two units thus serve to separate the intermediate sections from the top and bottom muffle portions of the apparatus.

It is therefore possible, by means of this construction, to introduce a fluid of different temperature from that in the other portions of the

apparatus and to give a special treatment to the materials being treated in these intermediate reaction chambers. As illustrated, water may be introduced through the inlet pipe 142 in the lowermost of the hearth units and exhausted from the outlet pipe 143 in the uppermost one of these units. Thus, this particular portion of the apparatus may be kept at the temperature of the cooling or the heater water applied thereto. Suitable packing or cement will be applied between the different parts to prevent leakage in the apparatus. It will also be noted that separate spacer elements 145 are employed to lengthen the shaft 13 sufficiently so that the standard size of units may be employed in the device.

The adaptability of this apparatus for control of the temperatures will be further appreciated by noting that the units above the water cooled portion may be again heated by gases issuing from the stack 91, these passing through the inlet pipe 147 and the outlet pipe 148 located at any suitable position above. A damper 149 in the stack serves to control the passage of gases through the upper unit. For introducing reagent gases or liquids into the reaction chamber, the conduit 150 may be provided and arranged to communicate through the cross pipes 151 and 152 with the interiors of the reaction chambers. The gaseous reagent material may be exhausted through the pipe 154 at the top of the apparatus.

It may be desirable in certain cases to have the lower units, or any of the series heated to a high degree. In such a case, the muffle units may be made of special metal, such as a nickel-chrome alloy, or the parts may be lined with firebrick or a suitable refractory material, such as a brick made of bonded crystalline alumina, silicon carbide, zirconia, magnesia and so forth. In such a case, the units may be made larger in cross-section and height, if desired, and the castings will be suitably designed for the purpose.

Referring to Figs. 15, 16 and 17, it has there been shown how the annular unit may be so constructed as to provide for heating the same by water, steam or gases under normal or high pressures. In this case, one or all of the annular units 10 is replaced by a unit 160 comprising a single cylindrical wall within which is embedded the tube 162 of suitable shape, material and construction for the purpose of conducting the heating or cooling fluid within the wall of the castings. Likewise, the hearth unit 165 is a metal casting having the metal tube 166 likewise imbedded therein. These tubes may be arranged in any suitable manner but, as illustrated in Fig. 17, the annular unit 165 has the tube 166 passing as a helix within its walls and connected at the outer ends, as shown in Fig. 15, to the unit inlet pipe 168 and exhaust pipe 169, suitable valves, pumps and control devices being employed to regulate the flow of the heating medium. This type of unit may be made by suitable methods understood in the industry, and the castings and tubes may be made of desired material, depending upon the nature of the ingredients to be treated therein and the type of heating fluid, as well as the pressure employed. Each of these units may be provided with the openings and closures as above described for the introduction of materials to the reaction chambers and for inspection thereof.

The various forms of apparatus herein described are adapted for many uses, since it is possible to heat or to cool the assembled units at any point. The apparatus, as set up and illustrated in Fig. 1, is for the purpose of chloridizing a roasted ore containing zinc and ferric oxides as well as residual zinc sulfide and other difficultly chloridized materials. This is accomplished by means of hydrochloric acid gas and chlorine gas. For this purpose, the pipe 170 is provided in one of the intermediate sections for the introduction of hydrochloric acid into the chemical treatment chamber, and this hydrochloric acid will pass in counterflow relation to the ore material descending through the apparatus until it escapes through the exit pipe 120 provided at the top of the apparatus. Likewise, a pipe 171 is provided to connect two of the openings 117 in the annular units for by-passing chlorine or any other gas which may be developed in the lower part of the apparatus around the point where the hydrochloric acid is introduced, thus not permitting them to mix. The exhaust fan 121 creates a sub-pressure within the apparatus and causes the gases to flow as desired through the pipe 170, and any hydrochloric acid gas drawn downwardly into this pipe will issue again into the reaction zones above and so perform useful work.

The partly roasted and pulverized material is introduced through the hopper 77 into the upper chamber and by rotating the rake arms, this material is caused to travel back and forth through the chemical treatment chambers until it reaches the exit pipe 79. In this particular process, it is desired to maintain the temperature above the boiling point of water throughout the whole apparatus and the dampers 97 in the pipes 88 are controlled to this end. As the material descends through the apparatus and meets the hydrochloric acid gas, the zinc oxide is first chloridized to form zinc chloride. When the zinc oxide has been substantially fully satisfied, then the ferric oxide will be likewise converted to ferric chloride. When sufficient ferric chloride has been produced, the material has by that time reached the lower portion of the apparatus. In order to recover the chlorine taken up by the iron oxide and to put it to useful work, air is introduced through the pipe 172 and the temperature of the lower muffle is maintained at least as high as 250° C. This causes the ferric chloride in the presence of air to decompose and form ferric oxide and chlorine gas. This nascent chlorine will attack the difficultly chloridized materials and form further metal chlorides. It will be observed that the hydrochloric acid is introduced into the middle portion of the apparatus and the temperature at this portion is maintained at such a point as will insure the substantially complete evaporation of all chemical water produced by the reaction of hydrochloric acid on the zinc and iron oxides. In this way, it is possible to prevent the zinc chloride from being dissolved in its chemical water and forming a syrupy or viscous mass which would prevent penetration of the hydrochloric acid gas to the ore material. The ore will be stirred by the revolving arms and so will not cake together or form balls or lumps, as has heretofore been found in carrying on a process of this type.

If the zinc content is low and it is desired to carry on the hydrochloric acid treatment at a low temperature, the arrangement shown in Fig. 14 may be employed, whereby water of a required temperature may be introduced to regulate the temperature of this zone of reaction. Also, by using steam under pressure in the apparatus of the type shown in Figs. 15 to 17 in-

clusive, the temperature may be regulated closely and maintained as desired between 100° C. and 500° C. or higher. By lining the muffle chambers with firebrick or refractory materials capable of withstanding high temperatures, the apparatus may be adapted for high temperatures, where required.

It will now be appreciated that the apparatus is capable of many uses, such as desiccating or drying vegetables, powdered ores, chemicals or various other materials. It may be used for treating ores or chemicals with various gases. For example, it may be used for roasting sulfide ores or for treating such ores with sulfur-oxygen gases to produce sulfates, sulfides, and the like. Various liquors may be passed downwardly through the apparatus and treated with precipitating agents while the material is stirred by the rabble arms, and if desired the liquid may be evaporated to form only a dry powder. The use of heated or cooled muffle chambers makes it possible to produce many types of chemical compounds without danger of contaminating them with undesired ingredients.

As above described, one may carry on the method of forming a hygroscopic or deliquescent salt of a metal, by means of reagents which result in the production of chemical water, by a series of steps in which the material is produced at a temperature above the boiling point of water and thereby preventing the material from taking up water after it has been formed. This is accomplished by vaporizing the chemical water as soon as it is formed. The invention further contemplates the production of chemicals in an atmosphere of controlled composition. For example, as above explained, ferric chloride may be produced at a temperature above that at which it would decompose in the presence of oxygen, by excluding oxygen during its formation. It will be observed that the excess of oxygen introduced through the pipe 172 will be by-passed through pipe 171 around that part of the apparatus where the ferric chloride is to be formed. When used as a drier, one may pass inert gases over the material, or reactive gases. An exhaust apparatus may be employed to decrease the atmospheric pressure for the operation of vacuum drying. The construction permits many variations in its use.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A chemical apparatus comprising a series of separate, similar units having peripheral and top and bottom walls forming adjacent reaction chambers, the top and bottom walls therebetween having openings adjacent both the center and the peripheral wall for intercommunication between the chambers, means for supplying reagent materials to and removing the reaction products from the apparatus, revolvable rakes for moving the material across the bottom walls in either direction, and removable closures for said openings, whereby the material may be moved either outwardly or inwardly across the chamber bottom.

2. A chemical apparatus comprising a series of separate muffle units which are capable of being removably assembled and which have hollow walls surrounding and separating a series of reaction chambers, the hollow walls having intercommunicating openings for the transfer of a heat exchanging medium from one muffle unit to another, and the wall separating two reaction chambers having a set of openings therethrough for the passage of reagent material, and replaceable covers for the openings which may be employed to control the flow of said material.

3. A chemical apparatus comprising two sets of individually replaceable hearth and annular muffle units, duplicated in each set, which are alternately superimposed on one another to form a series of intercommunicating reaction chambers, the hearth unit having hollow walls adapted to contain a heat transfer medium and to conduct heat to the space above and below the same, and the other unit having hollow walls for a heat transfer medium and surrounding a central space serving as the reaction chamber.

4. An apparatus of the type covered by claim 3 in which the adjacent hearth and annular units have communicating passages for the flow of the heat transfer medium serially therethrough.

5. A chemical treatment apparatus having separate, individually removable duplicate muffles, each comprising two different units, duplicates of which are arranged alternately in a series, one unit having walls defining a hollow hearth which serves as the top of one muffle and the bottom of another, the other unit being annular and having hollow walls defining the sides of the muffle, means for supplying a heat exchange medium to the hollow hearth and annular unit and for controlling the temperature in each muffle and means whereby reagent materials may be introduced into and passed successively through the series of muffles.

6. An apparatus of the type covered by claim 5 in which each unit has walls defining a central opening for the passage of reaction material from one chamber to another and a removable annular closure for said central opening arranged to surround a central shaft.

7. An apparatus of the type covered by claim 11 in which each unit has walls forming two passages therethrough and removable closures for covering any of said passages, whereby duplicate units may be employed in the series but the material may be moved in different paths therein and from one unit to another.

8. A chemical apparatus comprising a set of separate muffle units arranged in series to form intercommunicating reaction chambers, and a centrally located shaft passing through the units having laterally projecting rake arms, said shaft being made up of separate units and removable connections, the lengths of the units corresponding with multiples of the lengths of the muffle units, so that any number of muffle and shaft units may be assembled to provide an apparatus of the required length.

9. A hearth muffle unit casting comprising a substantially cylindrical hollow metal body having concentric cylindrical walls connecting parallel plane end faces and forming a central tubular passage, a tubular wall forming a second passage through the unit, and means providing passages for conducting a heating medium to and from the space between the walls, said unit being arranged to form the top or bottom of a muffle chamber and to be piled with other units to provide a series of such chambers.

10. A muffle unit of the type covered by claim 9 having a plurality of openings in each hearth arranged near the center and the outer portion of the chamber and removable cover pieces arranged to close said openings as desired, whereby

the material may be passed radially either towards the center or outwardly for transfer to the next chamber.

11. A muffle unit casting for a chemical apparatus comprising concentric annular metal walls and parallel end walls forming a central reaction space and an annular space for a heat exchange medium, said walls having openings into the space for the conduction of a heat exchange fluid to and from the annular space and means forming a tubular passage through the annular walls for the admission of material to the central reaction chamber.

12. A muffle unit for a chemical apparatus comprising concentric walls and end walls forming a central reaction space and an annular space for a heat exchange medium, tubular walls forming a plurality of passages through the concentric walls to the inner space and removable means for closing any of said passages.

13. A chemical apparatus for treating an ore material comprising walls forming a central reaction space, means for passing ore material and a gaseous reagent into said space, means providing a sight opening for observing the material in said space, an electrical device for artificially illuminating the material in said space which is located at a point remote from the sight opening, and means for preventing access of the reagent gas to the corrosive parts of the electrical device.

14. A chemical apparatus comprising hollow walls forming a muffle chamber, means for introducing material to and removing it from said chamber, means defining passages for conducting a heat exchange medium to and from the space within the hollow walls, means forming two tubular passages through the hollow walls, a transparent closure for one, and means within the other passage for artificially illuminating the material within the chamber, whereby the material being treated may be readily observed during the reaction.

15. A muffle comprising a set of separate, individually removable, hollow hearth units and a set of annular hollow muffle units which are shaped and arranged to be piled alternately on one another and form a series of reaction chambers, each unit having openings arranged to communicate with openings in the adjacent units for the conduction of a heat exchange medium through the series and cause its circulation around the sides and tops and bottoms of the reaction chambers, means providing a passage for introducing a heat exchange fluid into any one of the units and means for regulating the flow of fluid through each passage whereby the temperature of each reaction chamber may be controlled.

16. A chemical apparatus comprising a set of separate muffle units constructed and arranged to be piled up and form a series of reaction muffle chambers, each unit having hollow walls for a heat transfer fluid and openings arranged for communication with the adjacent units for the flow of said fluid, closures arranged to prevent the flow of said fluid between two sets of adjacent units, thereby isolating a section of muffle units, means for transmitting a heating or cooling fluid to said section and means for heating or cooling other muffle units outside of said section, whereby the temperature of the process may be controlled at different stages thereof.

17. A chemical apparatus comprising peripheral, top and bottom walls forming a reaction chamber and a revoluble member therein to move material progressively over the bottom wall, the peripheral wall being substantially solid and having formed therein a pipe-like passage for circulating fluid through the wall to control its temperature, and external pipe connections for introducing fluid to said passage.

18. An apparatus of the type covered by claim 17 in which the bottom wall of the chamber is made of metal and has a pipe-like passage formed therein for circulating fluid to control the temperature thereof.

19. A chemical apparatus comprising a series of separate units, which are individually removable castings arranged to be assembled to form intercommunicating reaction chambers, each of the units having two peripheral walls connected by spaced end walls which form an annular passage for a heat exchange medium, each alternate unit having its inner peripheral wall of short circumference so as to form a hearth bottom having a small, central tube therethrough and having a second tube connecting openings in its end walls for the passage of the material being treated, each of the other units having the inner peripheral wall of large circumference adapted to form a reaction chamber between the hearth units and being so located that said second tubes connect adjacent reaction chambers, and means comprising a rotatable shaft passing through the central tubes and revoluble rake arms which are arranged to move material across the hearth in each reaction chamber and cause it to pass through a tube to the next chamber.

20. A chemical apparatus of the type covered by claim 19 in which each central tube is larger than the shaft so as to provide for the passage of material therethrough and the second tube provides a passage through each hearth unit adjacent to the outer wall of the reaction chamber, and in which removable closures are arranged to close either passage, whereby the material may be moved in either direction across the hearth unit.

21. A chemical apparatus comprising a series of separate, alternately duplicated units arranged to be piled on one another to form a set of intercommunicating reaction chambers, each unit having two peripheral walls connected by spaced top and bottom walls to form an annular chamber for a heat exchange medium, the inner peripheral wall being of small circumference in alternate units and providing a hearth having a central shaft opening, and the inner peripheral wall of each of the other units forming a reaction chamber between the hearth units, each of the hearth units having a second tube remote from the central opening which connects two adjacent reaction chambers for the passage of material therebetween, a rotatable shaft in the central shaft openings having rake arms arranged to move material across the hearths and thus transfer it from one reaction chamber to another below it, and means for introducing a heat exchange medium into said passages to control the temperatures of the reaction chambers.

22. An apparatus of the type covered by claim 21 in which the top and bottom walls of the units are provided with openings which interconnect the annular heat exchange chambers of adjacent units in the pile, whereby fluid may flow directly from one unit to the adjacent one.

23. A chemical apparatus of the type covered by claim 21 in which a tube is arranged to conduct a heat exchange fluid through the outer peripheral wall of a unit and the top and bottom walls of adjacent units are provided with interconnecting openings for the direct passage of heat exchange from one annular chamber to another.

24. A chemical apparatus of the type covered by claim 21 in which the top and bottom walls of adjacent units are provided with interconnecting openings for the direct passage of heat exchange fluid from one annular chamber to another, and means are provided to cause the fluid to circulate through the annular space of each unit before it passes to the next in the series.

25. An apparatus of the type covered by claim 19 in which a portion of the annular chambers have interconnecting passages for the circulation of heat exchange fluid therebetween and comprising means which closes certain of the interconnecting passages in two sets of spaced units, and means for conducting a heat exchange medium to and from the intermediate units so as to control their heat independently of the other units.

26. A chemical apparatus comprising a series of spaced inner and outer peripheral walls and top and bottom walls forming inner reaction chambers surrounded by annular chambers for a heat exchange fluid, inner and outer peripheral walls and top and bottom walls forming hollow muffle hearths having central tubular shaft openings therethrough, said hollow hearths forming the tops and bottoms of all of the reaction chambers, means providing connecting passages between the inner spaces of the hearths and the annular chambers for the circulation of heat exchange fluid therebetween, a rotatable shaft within the shaft openings, rake arms thereon arranged to move material progressively across the hearths, means providing passages from one reaction chamber to another which are so arranged that the material may be moved on adjacent hearths in opposite directions and transferred from one hearth to another, and means for conducting a heat exchange medium to and from the apparatus.

27. An apparatus of the type covered by claim 26 comprising means forming a tubular passage through each hearth remote from its central opening, the inner shaft opening being larger than the shaft for the passage of material therethrough, and removable closure plates for the shaft opening and said tubular passage, whereby the material may be moved either outwardly or inwardly across the hearth.

THOMAS A. MITCHELL.

CERTIFICATE OF CORRECTION.

Patent No. 1,977,238. October 16, 1934.

THOMAS A. MITCHELL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, line 118, claim 7, for the claim numeral "11" read 5; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of November, A. D. 1934.

Leslie Frazer

(Seal) Acting Commissioner of Patents.