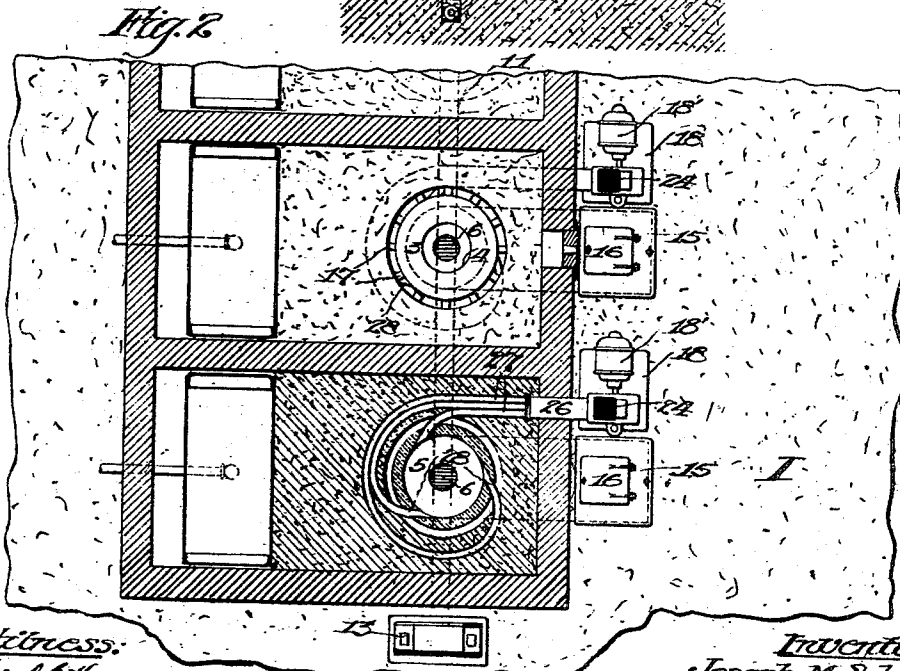
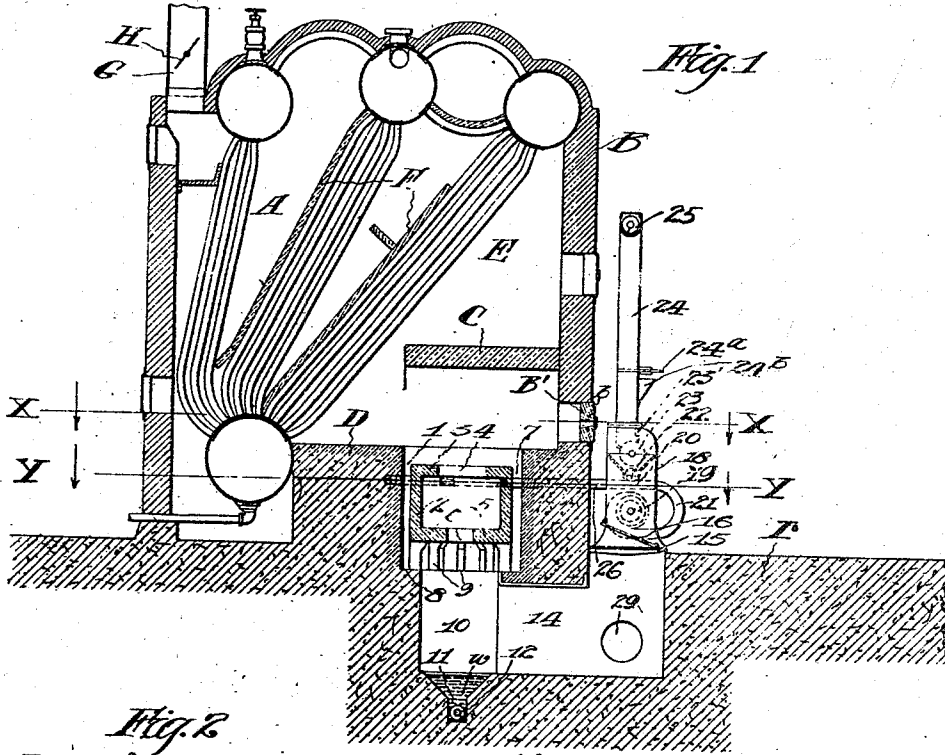


J. M. SCHUTZ.
INTROGENERATIVE FURNACE.
APPLICATION FILED FEB. 10, 1917.

1,306,234.

Patented June 10, 1919.

3 SHEETS—SHEET 1.



Witness:
E. L. H. H.

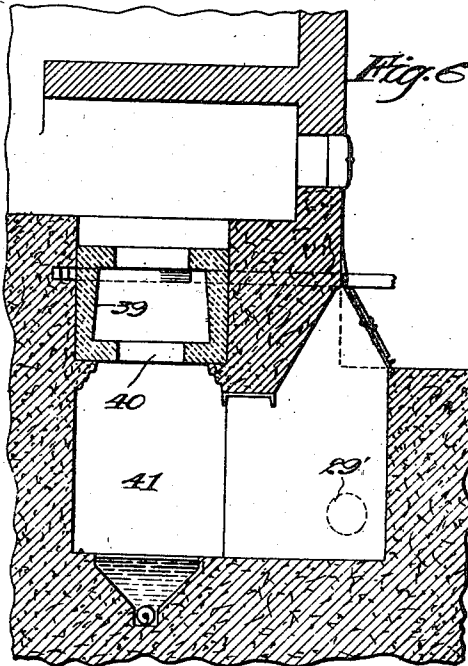
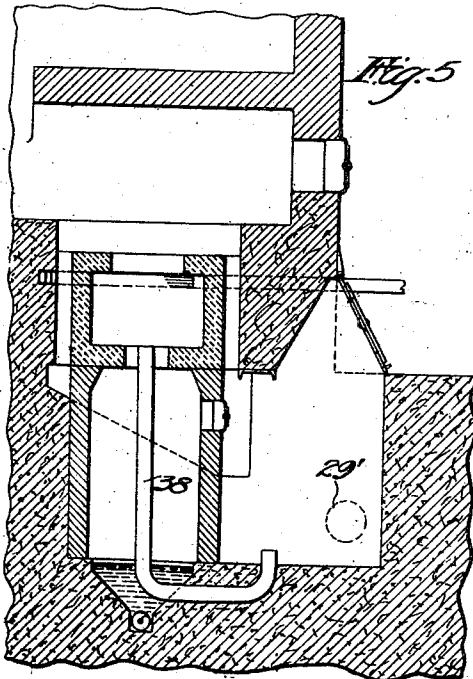
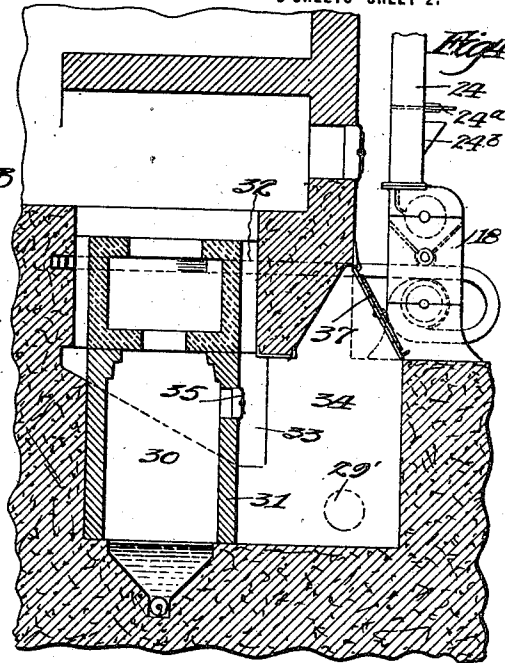
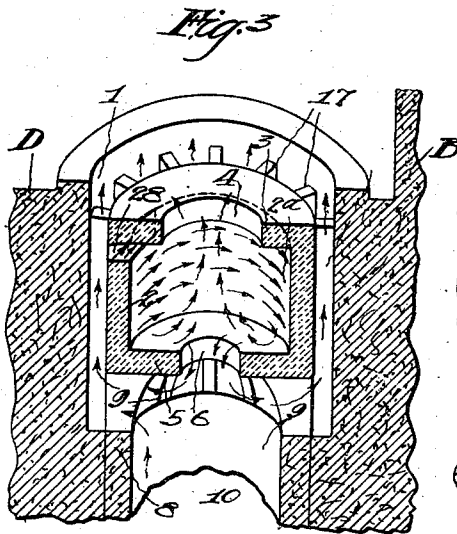
Inventor:
Joseph M. Schutz
By: [Signature]

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3 SHEETS—SHEET 2.



Witness:
Edw. C. Fox

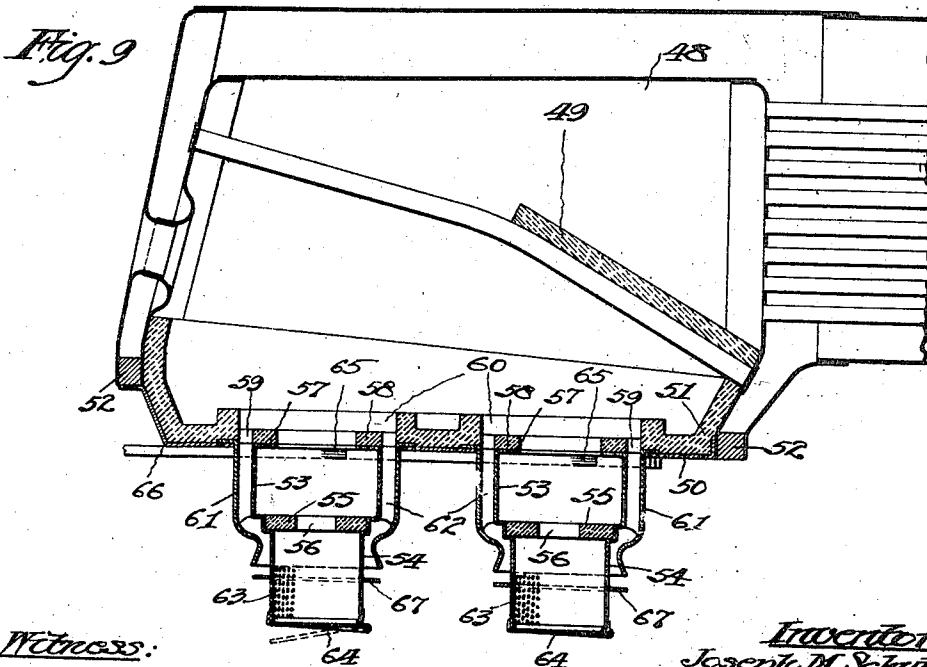
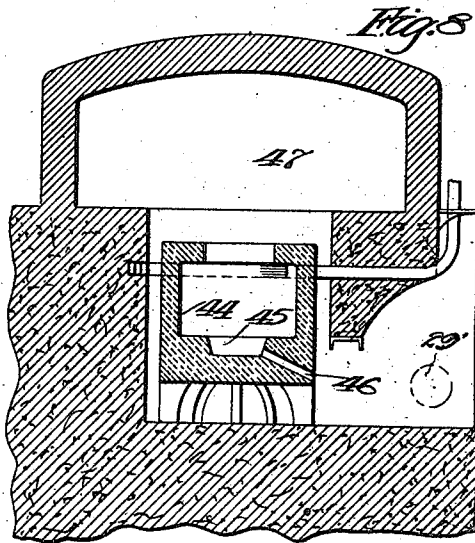
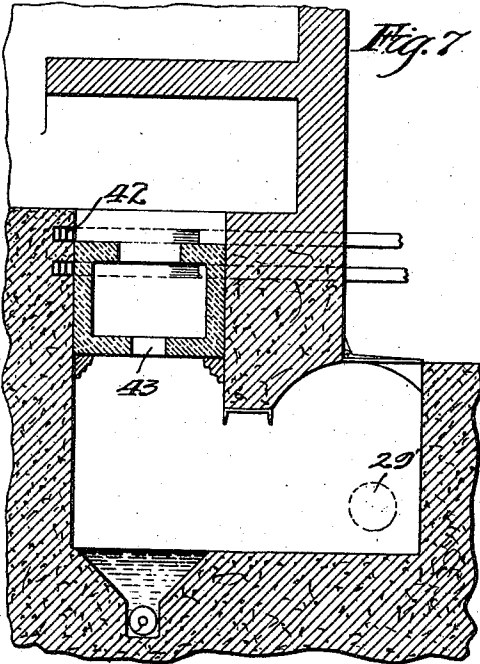
Inventor:
Joseph M. Schutz
By: [Signature] Atty.

J. M. SCHUTZ.
INTROGENERATIVE FURNACE.
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1,306,234.

Patented June 10, 1919.

3 SHEETS—SHEET 3.



Witness:
Paul E. Fournier

Inventor:
Joseph M. Schutz

By: *Charles E. Schuchman*

UNITED STATES PATENT OFFICE.

JOSEPH MARTIN SCHUTZ, OF CHICAGO, ILLINOIS, ASSIGNOR TO SCHUTZ HAWLEY COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF ILLINOIS.

INTROGENERATIVE FURNACE.

1,306,234.

Specification of Letters Patent.

Patented June 10, 1919.

Application filed February 10, 1917. Serial No. 147,759.

To all whom it may concern:

Be it known that I, JOSEPH MARTIN SCHUTZ, a citizen of the United States, and a resident of Chicago, Cook county, Illinois, have invented certain new and useful Improvements in and for Introgenerative Furnaces, of which the following is a specification.

My invention relates to the production of heat from fuel and has special reference to the combustion of coal, although adapted to other fuels, including gases and oils.

Coal in its natural state submits to combustion less readily than other fuels, such as combustible gases and liquids and artificially dried and powdered coal. As the greatest need for betterment lies in that direction, I shall particularize as to the more difficult fuels. It will follow, that improvements adapted to natural coal are also adequate for the less difficult fuels.

Of the two well-known ways of burning coal, that is, upon grates and in suspension, burning upon grates is the most common, although it is known that, weight for weight, more heat can be produced by burning it in suspension.

In burning coal upon grates the best results are obtained when the coal is in coarsely broken or lump form, free from fine particles, and when it contains much of its original moisture. In some cases it is advisable to further moisten the coal before placing it on the grate.

In burning coal in suspension, the best results are obtained when the coal is in the form of a very fine or impalpable powder, and free from moisture. And care must always be exercised to keep powdered coal dry, for it absorbs moisture from the air if exposed.

It is common practice to use comparatively coarse, screened coal, of good quality, as the raw material from which to manufacture powdered coal. Coal cannot be pulverized until it has been thoroughly dried. The cost of drying screened waste, culm and mine-dust is prohibitive. It is rarely profitable to pulverize lump coal of poor quality.

Aside from other known objections, the high cost of powdered coal restricts its profitable use to cases where coarse coal cannot be used. It is generally conceded that if conditions permit the employment of either, the coarse coal should be used; for

the greater production of heat from powdered coal does not compensate for its higher cost.

One object of my invention is to overcome the recognized inefficiency of the combustion of coarse coal, and at the same time avoid the high cost incident to the use of powdered coal. A further and distinct object of the invention is to produce more heat from a given quantity of any kind of fuel than can be obtained by burning the same upon grates or in suspension.

The burning of coal on a grate yields a large quantity of ash, some of which is fused. The fused ash forms troublesome clinkers, and in the case of a hot fire some of the fused ash is deposited on the walls and contents of the fire chamber.

When the coal is burned in suspension, the entire quantity of ash is liberated in the combustion chamber and while some of the ash is carried out through the stack much of it, both dry and as slag, falls upon the floor and contents of the chamber; a very objectionable feature, which prevents the use of powdered coal for some purposes.

Another object of my invention is to so conduct the combustion of coal that the unused or unburned residue shall be reduced to a minimum and shall be extracted or eliminated; that is, completely segregated, before the gaseous constituents and products are permitted to enter the fire or heating chamber, and to thus insure a clean flame. And a further object is to provide a process and means whereby the combustion of the coal, if desired, may be so conducted as to yield a flame which is very desirable in some industries, to wit, a flame which is devoid of both ash and free oxygen. Still another object is to provide for the certain and easy control of combustion whereby the degree of combustion and the output of heat may be varied at will.

As under present conditions only a coarse coal can be used advantageously, it is necessary that the coal shall be mined in lump form. Any other than the most careful mining methods involve the production of an excessive proportion of fine material. This fine material or waste from mines when burned does not yield heat in proportion to its actual heat value. While a small part of such waste is utilized in the arts, the greater part is wholly lost. A loss of 35 per cent.

is common where present methods of mining are employed, and still greater losses are suffered when the cheaper method of "shooting" is used. It is evident that all the coal from a mine should be burned whether coarse or fine. Yet a careful review of the art shows that inventors and engineers have accepted these great losses and have restricted their efforts to the mere bettering of the means for burning coarse and powdered coal.

Another and general object of my invention is the utilization of all of the coal taken from mines irrespective of the manner in which it is mined or the form in which the coal is produced.

In the attainment of the above mentioned objects, I find it both necessary and desirable to dispense with grates, although I may use either forced or natural drafts. I also discard as commercially impracticable, the artificial drying and powdering of coal for purposes of combustion.

Instead of firing the coal upon a grate, or in suspension, I burn it upon an imperforate surface with an air blast, and hold the coal on the surface until the coal is so far decomposed that I am able to separately discharge the gaseous products and the incombustible residue or ash. By so doing I avoid the necessity for grates and for coarse coal, and also avoid the limitations of suspension combustion. I make it possible and practical to burn, without drying, all the coal from a mine, provided it is reduced to a condition in which it can be conveyed by the stream of air, steam or gas which I employ to feed it to the furnace. I am able to burn the finest coal dust that comes from the mine and also much coarser coal. To prepare coal for use, I prefer to crush the entire mine run of coal, and as I have an effective means of fusing and discharging all incombustible solids, I do not find it necessary to sort out earthy materials and slate to the extent now common. As to the crushing operation, it is well known that all coal can be very cheaply crushed to the size of grain; and less, if the crushing operation is not carried to the point where a paste is produced and a drying operation made necessary.

Some of my earlier steps are disclosed in U. S. Patents No. 836,145, No. 836,219, and No. 751,350; and also in my previous applications, Serial No. 802,258, Serial No. 802,259, Serial No. 823,754, Serial No. 52,899 (series of 1915) and Serial No. 62,844 (series of 1915), of which this application is a continuation.

For reasons which will be made clear, I have given to my novel art of combustion the name thermo-centrifugal process of segregating the combustibles and noncombustibles of fuel; and to my novel apparatus I

have given the descriptive name introgenerative furnace, or burner.

My invention will be readily understood on reference to the accompanying drawings, in which I have disclosed my process diagrammatically, together with the preferred forms of my novel apparatus.

In the drawings Figure 1 is a vertical section of a typical steam boiler equipped with a furnace embodying my invention; Fig. 2 is a plan view showing two such boilers, the upper half being a section, as on the line X—X of Fig. 1, and the lower half a section as on the line Y—Y of Fig. 1; Fig. 3 is a sectional perspective diagram of the furnace or burner proper intended to illustrate the action of the fuel, the air, the gases, and the slag during the operation of the furnace;—Fig. 4 is a vertical section of a modified form of the apparatus in which a tight air-excluding slag pit is employed; Fig. 5 is like unto Fig. 4 with an air tube for supplying air or other combustible to the vortex at the bottom center of the furnace; Fig. 6 depicts a form in which the main supply of air is taken through the slag discharge opening in the bottom of the burner, being peculiarly suited to the burning of oils and gases;—Fig. 7 illustrates a furnace which receives its supplemental supply of air at the top;—Fig. 8 illustrates a simple form of my invention in which provision is made for either periodically or continuously discharging the slag from the bottom of the burner; Fig. 9 illustrates the adaptation of my invention to a locomotive boiler firebox.

My invention is applicable to any and every use wherein fuel of any kind is burned for any purpose. The illustrations and data herein contained convey a full working understanding of the invention, but must not be treated as limitations upon the nature, or the scope, or the essential details of the invention.

I shall first describe the structural features of the invention, and will then set forth the processes which are practised therewith.

Figs. 1 and 2 represent steam boilers, A, and their settings, B, each of well-known kind. For steam boilers of this type, I prefer to retain the usual front arch, C, and the bridge wall, D; and it is desirable that the chamber, E, containing the boiler shall be made a tortuous passage by means of the usual baffle walls, F. The exhaust stack is indicated by the reference letter, G, and contains the usual draft controlling damper, H. I intend this showing to be typical of any user of heat; and it will be obvious that the introgenerative furnace about to be described may deliver its heat and light upon any object, whether or not the object is inclosed.

As indicated, I find a grate wholly unnecessary, as I do not need to maintain a bed

of burning fuel. Likewise I find it unnecessary to employ an extensive Dutch oven, as I do not need to burn the fuel in suspension.

In dealing with a setting of the kind shown in Fig. 1, I first build a well, 1, in the lower front part of the setting, B. B' is a door in the setting, above the well, 1, and conveniently containing a peek hole, b. In the well, 1, and preferably below its top, I place an annulus or primary combustion chamber, 2, which constitutes the burner proper. The annulus has a top, 3, containing a preferably central hole, 4, for the discharge of burning gases. It has a bottom, 5, containing a preferably smaller hole, 6, for the discharge of the incombustibles or slag. As shown in Fig. 1, the annulus, 2, is of less diameter than the well, 1, and therefore an annular space or duct, 7, is formed between the wall of the well and the annulus. The well has a shoulder, 8, on which the annulus is supported by a plurality of legs, 9. The lower part of the well may be of less diameter than the upper part and will be referred to as the "slag pit." A depth of water, w, is preferably maintained therein. In its bottom is a conveyer trough, 11, and in that, a rotary conveyer, 12. The trough and conveyer are common to all of the boilers of the battery, as indicated by the dotted lines, 11, of Fig. 2. The conveyer discharges its contents into an elevator hopper beneath the floor, I, of the boiler room, from which hopper the contents (slag) is raised by a suitable elevator, 13, having perforated or self-draining buckets, this being an easy method of disposing of the slag. An air entrance duct, 14, preferably large enough to permit access to the bottom of the furnace, communicates with each pit, 10. The duct opens through the floor, I, and is closed by a man-hole door, 15, that may be raised and lowered to govern the inflow of air. The regulation of the air is further facilitated by a smaller damper door or valve, 16.

The annulus, 2, its top, 3, and its bottom, 5, are preferably formed of firebrick or other sufficiently refractory material. My invention comprehends the use of a metal annulus. The annulus may be spaced in the well by means of vertical ribs, 17, as shown in Fig. 2. These ribs are omitted from the lower part of Fig. 2 for sake of clearness, to avoid confusion with the twyers, 28, about to be described. For a boiler of the kind shown, I prefer that the annulus shall be eccentrically placed in the well, to the end that the air passages at the back of the annulus shall be somewhat smaller than those at the front, and thus compensate the tendency of the inrushing air to move directly toward the bridge wall, D, under the influence of a partial vacuum in the chamber, E.

This eccentric relation is well shown in Figs. 1, and 2. I do not regard it as essential

and it is obvious that the desired regulation and distribution of the air may be attained in other ways.

At the side of each floor door or, regulator, 15, I place a fuel feeder, 18. I have here shown a novel feeder of my own design which is particularly well adapted for the feeding of crushed or ground coal. The feeder in itself constitutes the subject-matter of a companion application, Serial Number 149,561, and is not claimed in this application. It suffices to explain that the preferred feeder comprises a casing which contains a blower, 19, a cross duct, 20, which receives air through the elbow, 21, and which receives fuel through the rotary valve, 22. The fuel is supplied to the valve, 22, by a variable feeder, preferably comprising a slowly driven feed roll, 23, and its regulating gate, 23'. In the present case the source of fuel in each case is a vertical trunk, 24, which is kept constantly full of fuel by means of a transverse conveyer, 25; that is connected with a suitable fuel hopper (not shown). I prefer to use an independent motor, 18', for each of the feeders, 18; and further prefer that these motors shall be such that their speeds may be independently regulated within such limits as may be required for minimum and maximum operations of the furnace.

The feeder described performs the function of feeding measured, but variable, quantities of air and fuel to a duct, 26, which extends through the wall of the boiler setting. To this duct I connect one or more twyer pipes, 27. Each of these pipes or ducts terminates in a twyer, 28, that enters the annulus, 2, at a tangent to the inner wall thereof. Thus in Fig. 2 I have shown three tangential twyers. It will be found that, within mechanically reasonable limits, the greater the number of twyers the better will be the operation of the furnace.

As best shown in Figs. 1, and 3, the twyers 28 enter the annulus directly beneath its overhanging top, 3. This top will be referred to as a concentric ring or abutment and the described position of the twyers, 28, coupled with the presence of this abutment or ring, 3, causes the fuel laden air therefrom to whirl downwardly in the annulus, and, encountering the bottom, 5, to then introcede and react upwardly along the axis of the annulus.

I shall describe my process as conducted under the conditions of a natural draft at the stack, G, but I wish it to be understood that when desired the floor doors, 15, may be closed and air under suitable pressure may be admitted through a duct, 29, thus converting the apparatus into a forced draft plant. This explanation as to forced draft, relates not alone to apparatus shown in Fig. 1, but also to the apparatus shown in the

other parts of the drawings, as indicated by the dotted lines, 29', therein.

I shall now refer to Fig. 3 which is a sectional perspective diagram of the furnace shown in Fig. 1, and to which I have applied corresponding reference characters. I there introduce the mixture of air and fuel, through the twyer or twyers, 28, at a velocity of 5,000 to 25,000 feet per minute, depending on the size of the annulus and the output required therefrom.

In the best practice of my process, the proportions of air and fuel are preferably such that the volume of air supplied through the twyers is only sufficient to furnish that quantity of oxygen which is required to combine with the carbon content of the fuel and form carbon monoxid (CO) and is insufficient for the formation of any considerable quantity of carbon dioxid. But when desired, air may be introduced in sufficient quantity to insure complete combustion of the fuel within the annulus.

Due to the tangential entrance at high velocity the mixture whirls spirally or helically on the inner surface 2^a of the annulus. Centrifugal force holds the fuel on that wall or surface and the air blows over the retarded, heavier fuel. Being thus held in whirling condition on the wall and its escape at the top being opposed by the annular abutment or ring, 3, the mixture is compelled to circle toward the bottom of the annulus. There, obviously it meets the bottom, 5, and finding no other escape the whirling and constantly renewed column introcedes, or doubles within itself and passes upwardly at the center of the annulus escaping finally through the opening or throat, 4. As the column is under the double force of internal pressure and its whirling action (centrifugal force) it expands instantly upon emerging from the constricted throat, 4, and thus occupies the larger combustion space within the top of the well. Meantime air is being drawn (by natural draft) through the air feeding space, 7, and obviously the constituents of the whirling column being enveloped by the hollow column of air, from the annular space, 7, quickly and surely mix therewith.

In practice I regulate the flow of air through the annular channel or space, 7, in such manner that the volume of supplied air is little if any greater than needed to provide the quantity of oxygen required to convert the co-incidentally generated carbon monoxid (CO) into carbon dioxid (CO₂). This regulation is co-incident with the regulation of the primary air and fuel supply, and is accomplished by the manipulation of the damper, H, in the stack, and also by means of the floor doors, 15, 16.

I prefer that the width of the space, 7, shall be limited; to the end that the supple-

mentary air shall move rapidly therein, for, as hereinafter explained, I depend on the external air column for the cooling of the annulus, 2, and to prevent heat losses by radiation from the annulus.

A remarkable fact is that by the means illustrated I am able to burn both the hydrocarbons and the fixed carbons of the fuel, and to accomplish this with approximately the theoretically essential quantity of oxygen, *i. e.*, with the minimum volume of air required for the complete combustion of the given quantity of fuel. In other words, the usual loss of heat by absorption in excess volumes of air and the ordinary loss in unconsumed hydrocarbons are practically eliminated.

I have described the action as though taking place in a cold condition. My purpose thus far has been to elucidate the motions of the fuel and air and thereby facilitate an understanding of the actual process of combustion. One similarly illustrative point remains to be explained. Reverting to the whirling action of the mixture at the bottom of the furnace, and noting the existence of opening, 6, in said bottom, it may be thought that after introceding from the walls of the annulus the natural course of the fuel and air will be downward through the hole, 6, rather than upward through the hole, 4. But apparent as this may seem, such action does not take place. Instead the introceding column moves upwardly through the top of the annulus, and very little through the hole, 6. In practice I determine or govern the outflow of gases through the hole, 6, by regulating (by the means shown) the pressures in the spaces above and below the annulus with reference to the pressure of gases in the annulus. The most simple explanation is that whether set in motion by a partial vacuum in the chamber, E, or by a pressure in the space beneath the annulus, 2, the secondary or externally supplied air is in rapid upward motion in the slag pit, 10, and in the channel, 7, and tends to move upwardly through the hole, 6, in the bottom of the annulus. Further the most ready escape for the gases from the annulus is directly through the throat, 4, rather than downward through the hole, 6, and thence upward through the channel, 7. The forces are such that a vortex is created at the bottom center of the annulus and if the hole, 6, is open to the air (as explained hereinafter, this is not always the case) a considerable volume of air is drawn into the annulus. The action is pronounced in a structure of the kind shown in Fig. 1, and beside using the vortexial force as a means of adding air for combustion within the annulus, my invention contemplates the introduction of gases at this point, and also the introduction of steam or water. I may here explain that the tem-

peratures attainable are such as to dissociate water, with the resultant of temperatures attendant upon the combustion of free oxygen and free hydrogen. Strictly speaking, the foregoing explanation is relative, being true only when the furnace is in hot operation. It is, however, demonstrated in a cold state, provided the feeding of fuel is not continued to the point of accumulating in the bottom of the annulus a mass of fuel which is too coarse or heavy to be lifted by the introceding column. If that occurred, fuel would eventually be swept toward the center of the annulus and ejected through the hole, 6, by the action of gravity. In practice no fuel is thus ejected or lost, the reason being that the high temperature operation causes the dissociation of the fuel and an accumulation of heavy particles is impossible. But, as hereinafter explained, the heavy incombustibles in the form of dry ash, or slag, and in the manner described, are swept into the hole, 6, and thus ejected from the annulus. And such separation and discharge of the incombustibles, whether continuous or intermittent, is an essential feature of my coal burning process. Without it the annulus, unless operated at excessive temperatures sufficient to fully volatilize the incombustibles, would soon become clogged. It goes without saying, that it is contrary to good practice to thus volatilize the incombustibles and discharge them into the fire chamber there to condense upon the walls or upon the objects under treatment.

An adequate, working knowledge of the dimensions and proportions of the annulus or furnace proper, will be gained from the drawings and the foregoing description. However it may be added, as a rule or principle to be followed, that the annulus should be of such diameter and length, with reference to the quantity of fuel to be burned, that the desired spirally progressive combustion and the centrifugal segregation of the combustibles and non-combustibles may both occur within the annulus, and so short that the molten or liquid slag will not be permitted to cool until after it is discharged from the annulus.

To start the operation, I place a burning torch in the annulus. A small quantity of burning oily waste temporarily held in the slag-discharge hole, 6, will serve the purpose better than a larger quantity of burning kindling in the annulus. A gas torch is also a convenient means of lighting the furnace. Having applied the lighted torch, whatever its kind, I then open the stack damper, H, and one or the other of the damper doors, 15 or 16, to establish a flow of air through the furnace. Next I start the fuel and air feeder; in other words, initiate the blowing in of fuel. If the fuel be gas or oil mixed with the air, which enters, at the

twyers, 28, it will immediately ignite from the torch. When crushed or ground solid fuel, such as coal, is used any given measure of it will be found to contain a considerable percentage in a finely divided state which also immediately takes fire from the torch. A brilliant flame results under the blow pipe action of the air blast. Thereafter combustion proceeds on the walls of the annulus and the latter soon attain a state of incandescence. Proceeding in this manner with coal as the fuel, and using only the weak flame of a torch as an igniting means I have frequently succeeded in raising the annulus to incandescence within the space of ten minutes. When that state is attained, the torch, if not already consumed, may be removed, for from that time the gases evolved from the fuel are ignited by the heat from the hot walls. Thereafter the combustion proceeds continuously and varies only as the proportions of fuel and air feed are varied. Obviously the temperature within the annulus will vary with the quantity of fuel-laden air and with the plentitude or lack of air essential to first stage combustion. By increasing the volume of primary air in proportion to the quantity of fuel, the combustion may be forced to the second stage and may be conducted with great rapidity. This I find advantageous for some metallurgical purposes, but for most uses it is desirable to hold the temperature within the annulus at a point only slightly greater than that which is required to fuse the otherwise ineradicable incombustibles or ashy constituents of the fuel and to thus free the carbon content of the fuel. The temperature above the annulus depends upon the quality of the fuel used and the degree and rate of combustion in the annulus together with the supply of secondary air in the well, 1, or its vicinity. These should always be gaged to suit the use, i. e., the practical limitations of the boiler or other object which is to be heated. The conditions of operation are so well within the control of the firemen, that it is never necessary to have other than perfect combustion and hence the plant is smokeless. The firemen, with the simple means described, may vary both the temperature and the rate of combustion within wide limits and thus may operate the plant in direct response to the load which is carried or the work to be done. When the fuel and air are shut off, it is desirable, in the case of a boiler, that the dampers, such as, H, 15, 16, shall be closed to prevent a continuing rush of cold air which would too quickly cool the boiler and its setting. Furthermore, if this be done, the heat is retained in the annulus and the operation may be promptly resumed without again applying a torch thereto for the walls will instantly ignite the fuel. It will be found that this is true, even after

the furnace has stood idle for an hour or more.

After the annulus attains a sufficiently hot or incandescent state, it is capable of consuming even very wet fuel. The reasons will be made more clear hereinafter. But to insure the easy starting of the furnace, I prefer to begin with not artificially dried but at least comparatively dry coal. For this purpose I prefer to provide the coal trunk, 24, with a cut-off slide, 24^a, which may be closed just before the feeder is stopped. Indeed its closing may mark the shutting down of the furnace, for obviously after the slide is closed only the small supply of fuel beneath it remains to be discharged by the feed roll. When it is exhausted the blower should be stopped and the dampers closed as before described. Beneath the slide I provide a small gate, and filling hopper, 24^b, through which the lower part of the trunk may be filled with dry coal in readiness for the next firing of the furnace. This is needed only when noticeably wet coal is supplied to the feeder trunk. In such cases the dry coal attachment will be found to be a decided advantage as it shortens the time required to bring the furnace to the state in which it will automatically maintain the fire with wet fuel.

As indicated, the burning gases are discharged from the top of the annulus and the incombustibles are discharged from the bottom thereof. This means that a separation of combustibles and incombustibles takes place within the annulus; a matter of great importance; for once the separation is accomplished, it is obvious that the burning combustibles and the liquid or molten incombustibles may be discharged, directed, and controlled in any desired manner.

The action within the burner appears to be as follows, assuming that the furnace is in full operation with an adequate blast of air and coal through the twyers: When the coal enters the annulus and begins its spiral or helical movement upon and against the hot internal wall thereof, its temperature is almost instantly raised to a high degree. The first effect is the driving off of the moisture in the form of steam; next the driving off of the volatiles; and next the fusing of the incombustible constituents or ash and the consequent liberation of the carbon. The carbon is thus freed in the form of minute particles the largest of which have the appearance of coke, and the smallest being in a state of almost atomic fineness. The fused ash being heaviest and plastic, is centrifugally retained upon the hot wall. Meantime the blast of air sweeps across the heavier fuel particles which are centrifugally retarded, and the temperature being above that required for ignition, com-

bustion proceeds almost from the instant of admission at the twyer. This combustion directly imparts heat to the annulus.

It will be clear that the cold air and fuel entering at the twyers constantly absorb heat from the abutment, 3, and from the portion of the cylindrical wall of the annulus adjacent the twyers. If it were not for the described introcessive reaction of the burning gases, the annulus, though hot at the beginning, would thus be chilled and made inoperative by the intrushing cold air and fuel, but instead the flaming gases (at the center) which whirl upwardly within the outer whirling column (the column on the cylindrical wall) constantly radiate heat to the wall and to the entering mixture and thus the almost instant raising of the temperature of the intrushing initial mixture is insured. Hence the process of dissociation and combination proceeds reliably and continuously as long as the blast of mixture is maintained at the twyers.

The temperature required to fuse the ash of the fuel varies with the nature of the fuel. It rarely exceeds 2500° F. That my process is reliable in the matter of fusing the ash, will be clear when I explain that in actual practice temperatures approximating 3000° F. have been attained within the annulus.

The maintenance of such temperatures results in the almost explosive combination of the combustibles and a reliable and substantially perfect combustion of all combustible constituents of the air and fuel, including even the most difficult of combustible hydro-carbons which combine with oxygen at only very high temperatures.

As stated above, I prefer that the supply of air to the twyers shall be so restricted as to limit the operation within the annulus to substantially the first stage of combustion. The heat thereby evolved within the restricted confines of the annulus is amply sufficient to keep it in a condition of substantial incandescence; that is, amply hot to surely ignite the combustibles.

The fusing or liquefaction of the incombustible constituents of the fuel proceeds continuously. I shall hereafter refer to the liquefied or molten incombustibles as "slag." The term is appropriate, although the slag discharged by my furnace is not the clinker of an ordinary furnace and is distinguishable from the slags produced by other processes. It appears to contain no carbon whatever, the explanation being that the carbon constituent of the fuel when liberated by the fusing of the ash, is so much lighter that it is instantly caught and carried away by the blast of air and gases, and quickly combines with the oxygen present.

The accumulating slag which flows to the bottom of the annulus or burner, is dis-

placed by the constantly renewed stream thereof on the cylindrical wall; and further is urged inward across the bottom, 5, by the inward rushing or introceding gases that react against said bottom. Thus the slag reaches the opening, 6, and falls there-through, in drops or streams, according to quantity. It should be remarked that the walls of the hole, 6, are kept hot by radiant heat from the interior of the annulus. If not kept hot, the slag would congeal and close the opening. To further insure a constant opening, I prefer that the pressures within and surrounding the annulus shall be so adjusted as to cause the flame therein to pulsate within the opening, 6. In the case of the furnace shown in Figs. 1 and 3, the regulators easily may be adjusted to cause a small flame to burn downwardly through the opening, 6, as indicated by arrows in Fig. 3.

The slag-pit receives the slag from the annulus. As shown, I prefer that there shall be a body of water, W, in the bottom of the annulus, to receive the intensely hot slag. The sudden chilling of the slag causes its disruption or granulation. By the process described, the quantity or ration of slag is reduced to a minimum, and when granulated or broken up, as described, it is an easy matter to remove it from the slag pit, either intermittently or continuously, as by means of the conveyer, 12.

I regard firebrick as the most practical material from which to make an annulus or burner proper for a stationary plant. Those who are skilled in the art may question the maintenance of such an annulus under the high temperatures herein mentioned. To dispose of such doubt, I again call attention to the annular air-feeding space, 7, which surrounds the annulus. During operation, air passes upward through this channel at high speed, and two things of great importance are accomplished: First, the temperature of the air is so far raised as to absolutely insure immediate combination of its oxygen with the combustible gases emerging from the throat of the annulus; and, second, the outer walls of the annulus are constantly cooled. This explains the permanence of the annulus, notwithstanding it is composed of clay or of metal which normally melts at a temperature lower than the temperature within the annulus.

Doubtless there is a slight dissipation of heat through the lower walls of the well, 1, but aside from this it should now be apparent that my process suffers no other loss of heat. The heat which would otherwise be dissipated through the walls of the annulus is taken up by the supplementary air flowing in the channel, 7, and hence is utilized in a highly practical manner. Even when a large flame passes with the slag

through the hole, 6, its heat is not lost for it is drawn into the surrounding passage, 7, and helps heat the secondary air. Likewise the radiant heat of the slag and further all steam which rises from the water in the pit, ultimately rises through the passage, 7.

A small quantity of steam generated in the slag pit is beneficial, because it tends to prolong the flame in the combustion space (a very desirable feature in boiler practice) and because of the probable dissociation of the steam and utilization of its constituent gases in said combustion space.

It may be anticipated that the walls of the annulus will be scored and worn away by the gritty fuel mixture which travels at such high speed thereon. But this is not true. The entire interior of the annulus is found coated with slag. During operation this coating is plastic and molten, being constantly added to, and, as constantly, ejected. When the burner is cold the slag appears as a glaze on the brick. The presence of the slag obviously excludes oxygen from the walls of the annulus and thus preserves the latter.

My observations lead me to believe that the practical maintenance of the film or layer of the molten slag during operation is a beneficent result of the external cooling of the annulus, whereby the temperature of the internal surface of the annulus is so restricted as to prevent the volatilization and dissipation of the slag. In other words, the temperature at the inner surface of the annulus seems to be lower than at the center of the annulus. It is certain that the saving effect is obtained in actual practice; and the flow of molten slag from the bottom of the annulus proves that no considerable quantity of slag is volatilized and discharged through the throat of the burner. The viscosity of the slag doubtless determines its thickness on the walls of the annulus. A very thin film is sufficient to exclude destructive oxygen and other gases therefrom. The temperature attained in the annular channel, 7, is not sufficient to induce combustion of iron or the like which may be exposed on the outer surface of the annulus.

For reasons explained, the annulus or burner proper is substantially indestructible and may be used for a long period without renewal or repair.

I prefer that the walls of the well, 1, and its slag-pit, 8, shall be lined with firebrick. For obvious reasons annulus-supporting legs or brackets, 9, shown in Figs. 1 and 3, and the ribs, 17, are best when made of fire clay.

One purpose of the air blast to the twyers, 28, is as a vehicle for the coal. It is the least costly, most convenient, and most readily controlled vehicle, and for that reason I have illustrated its use. But I wish it understood that my invention comprehends the feeding

of the fuel in other ways, several of which admit of a different feeding of the air or gas required for combustion within the burner.

When dealing with large furnaces, several slag holes (like unto 6) may be provided in the bottom of the annulus. It should also be understood that while I have herein shown simple fuel-laden air twyers, the twyers may be sub-divided or two separate sets used for separately feeding the air or other gas and the fuel to the annulus. When distinct sets are used, I prefer that the fuel shall enter below the air, as illustrated in Fig. 10, which is taken from my previous application, S. N. 52,899. The air twyers are indicated at 67, and the coal feeding twyers are marked 68. As in the case of Fig. 7 hereof, the secondary air enters above the abutment ring or top of the annulus. The bottom of the annulus may be coned or dished, though better results are secured with a straight bottom, as shown in Figs. 1 to 7. Fig. 10 also illustrates a closed slag discharge pit or tube, 69, similar in function to the closed slag pit, 30, depicted in Fig. 4.

The several steps of the process above described, are not materially changed by the use of forced draft, because the relations between the pressures in the combustion chamber, E, and slag pit remains substantially the same. In either case the highest temperatures appear to be at the center of the annulus and in the combustion space above the annulus.

The operation of the furnace is substantially noiseless and smokeless, the combustion, as explained, being substantially perfect.

Observations and tests lead to the conclusion that proceeding in the manner here described, any fuel, whether it be oil, gas, coal, coke, peat, lignite, wood, refuse, or a mixture of any thereof, may be burned with a heat or combustion efficiency closely approximating 100 per cent.

By adding water vapor or superheated steam at any point in the furnace where the temperature is sufficient to dissociate the water, it is possible to force the ultimate temperature to an extremely high point. This will be found to be of special value in the metallurgical arts.

The direct smelting and the reduction of ores and metals is made possible by my process and apparatus. Further, with such temperatures I easily dispense with the use of fluxing materials, the heating and final disposition of which I conceive to be an industrial waste.

I have attained the following remarkable results: Using a boiler and furnace of the construction shown in Fig. 1, I have succeeded in maintaining, for many hours and without detriment to either, a temperature of over 3000° F. in the combustion space,

and a temperature of only 400° F. in the boiler breeching or stack. No trace of CO was found in the stack and the theoretical maximum of CO₂ was closely approximated. Furthermore, I have attained these effects with a poor grade of Indiana bituminous coal, using less thereof than would be used on a grate to accomplish a much lesser work. From these facts it will be clear that I have secured an unexpected and incomparable efficiency, of immense importance in the industrial arts. Without doubt one important factor is the accomplishment of combustion with only the theoretically or chemically requisite quantity of air; whereby the usual heat wastes are avoided. The rest is explained by the complete gasification and combustion of the fuel at the point of use, unretarded by ash; and by the direct and enforced utilization of all the heat generated within and radiated from the annulus or burner. It is remarkable also that these results are secured with apparatus which is of stable character and low cost.

I have mentioned these facts not so much for the purpose of distinguishing my inventions, but rather as guiding data which will enable engineers and others to properly design and proportion the apparatus which embodies the invention and whatever apparatus is to be used therewith. With such efficiency residing in the furnace, it becomes evident that any work to be done or service to be performed may be accomplished more economically, more perfectly and more rapidly than ever before; and that steam boilers, heating furnaces, ovens, kilns, and the like, profitably may be changed in design, and reduced in size, or operated with less fuel.

I have not herein attempted to define the many forms in which my invention may be practised or embodied, and to name the many uses to which my invention may be put. All such are comprehended by my invention; and will be obvious to those skilled in the arts and industries to which the invention is applicable. I have, however, in Figs. 4 to 9 disclosed several modified forms and uses of immediate utility.

The furnace depicted in Fig. 4 is identical with that shown in Fig. 1, except the slag pit, 30, is tightly closed within its own wall, 31, and is thus separated from the annular air feeding channel, 32. A lateral duct, 33, joins the channel, 32, with the air pit, 34. A door, 35, in the wall, 31, is a convenient point from which to apply the torch to the burner. The structure illustrated is very desirable from the standpoint of the better support afforded the burner or annulus, and operates in the same manner as before described. A pressure of gases accumulates in the closed slag pit, 30, and balances the pressure in the annulus. The air entrance regulator, 37, shown in Fig. 4, is of slightly dif-

ferent construction than that before described but serves the same purpose, being also a door through which workmen may enter the pit, 34.

5 Fig. 5 is identical with Fig. 4, except for the addition of a central air, gas, or steam admission duct, 38, positioned to deliver such aids to combustion into the vortex in the bottom of the annulus.

10 In Fig. 6 I have illustrated a modified form of my introgenerative furnace which is well adapted to the burning of oil and gases. Incidentally it discloses the fact that whenever I have herein spoken of the cylindrical
15 wall of the annulus, it is intended that the term "cylindrical" shall also mean walls, 39, which are tapered toward either the top or bottom of the annulus. Fig. 6 also discloses the fact that in some cases I contemplate dispensing with the inclosing air channel and that secondary air may be fed through the central slag hole, 40. However, when this is done, the slag hole should be larger than in other cases, to further remove its walls from the influence of a column
20 of cold air from the slag pit, 41.

Fig. 7 illustrates a construction similar to Fig. 6, but wherein secondary air is supplied through an upper series of air-feeding openings or twyers, 42, which may be either tangential or radial. In this case a relatively small slag hole, 43, suffices.

I prefer that in every case my introgenerative furnace shall continuously discharge its
35 slag through a central, or approximately central hole in the bottom. Nevertheless, such an arrangement is not essential, for, as shown in Fig. 8, the annulus, 44, may be provided with its own slag pit, 45, which may be drained, either continuously or intermittently, through a lateral duct, 46. If the draining is to be intermittent, the duct is normally plugged and the plug withdrawn at intervals. Fig. 8 also indicates another
40 use for my invention, the furnace being positioned to deliver its heat to an oven, 47.

One of the most important uses of my invention is in connection with the fireboxes of locomotive boilers. Such an arrangement is
50 illustrated in Fig. 9. The locomotive firebox, 48, is of familiar form and preferably contains an arch or baffle, 49. The bottom of the box is closed by a plate, 50, covered with refractory material, 51, except at the openings of the two introgenerative furnaces. The refractory walls, 51 should rise some distance above the mud ring, 52. In this illustration, I have chosen to show two of my furnaces, though in ordinary cases one
55 will be found sufficient. For convenience in building the furnaces and attaching them to the boiler, I prefer that they shall be mainly formed of metal, though it is obvious that the firebrick construction may be retained.
60 Each burner comprises a metal annulus, 53,

having a slag-pit extension, 54. The two compartments are partially separated by a firebrick ring, 55, which forms the bottom of the annulus and provides the slag hole, 56. The annulus has a flange, 57, at the top, and
70 on this rests a fire brick ring, 58, having projections, 59, by which it is centered within the cylindrical combustion space, 60. The mixing space, 60, is formed by an upward extension of the firebrick bottom, 51, and is
75 of greater diameter than the annulus, 53. Surrounding the annulus is a preferably insulated metal wall, 61. This is spaced away from the annulus, and forms the secondary air supply channel, 62, which opens into the
80 chamber or space, 60. The extension, 54, is preferably perforated, as indicated at 63, and is provided with a perforated drop-bottom, 64. The fuel and air twyers are indicated at 65, and 66 is one of the air feeding
85 trunks which lead from the fuel and air feeder (not shown). The operation of the furnace is as before described, except in the matter of the disposal of the slag. The slag which falls from the annulus is caught within the perforated pit and is there granulated
90 by cold air and the vibration of the locomotive. The granulated slag sifts out upon the right of way, or may be discharged by the opening of the drop bottom, 64. Lest it be
95 assumed that the metal walls, 53, will be burnt out by the intense heat, I here call attention to the before recited facts concerning the slag protection of those walls and the protection which they receive through
100 the absorption of heat by the air rushing through the heating channel, 62. Though I have illustrated metal annuli, I prefer that the cylindrical walls shall be either formed from, or coated with a thick layer of, refractory
105 clay, or the like, to the end that the burner shall retain its heat for a longer time when its operation is interrupted. The rings, 67, are adapted and intended to be raised to close the mouths of the air channels, 62, at such times to prevent the sudden
110 chilling of the boiler. With the equipment illustrated and described, the fireman's task of firing the boiler is reduced to a mere regulation of the fuel and air feeds. At
115 times when further steam is not required the furnace may be entirely shut off and then instantly put to work again by merely renewing the supply of fuel.

It should be understood that the deep air
120 and slag pits depicted in the drawings are matters of convenience, not necessities. Obviously these pits may be of no greater size than required to supply the air actually used in the furnace.
125

The main features of my invention are workable without restriction to a vertical axis for the annulus; and I shall so claim the invention. By way of example I have illustrated in Fig. 11 a furnace thus em-
130

bodying my invention, in which I have arranged for a double reaction within the annulus. The particular structure shown in Fig. 11 is imported from my earlier application, S. N. 52,899. In this example (Fig. 11) the annulus has a horizontal or substantially horizontal axis and is open from end to end. It has an abutment ring, 70, at each end. The fuel and air enter, preferably on opposite tangents, through twyers, 71. In each case these twyers are placed at the inner side of the abutment ring, 70, as in the vertical type. A slag discharge opening, 72, is provided at the middle bottom of the annulus and there may be a slag collecting groove, 73, for conducting the slag to said opening. Two whirling and burning columns of fuel laden air are generated. Each moves inwardly, away from its respective abutment ring, 70. In each end of the double annulus, the distilling, ignition, decomposition, and combustion of the fuel proceed in the manner hereinbefore described. Obviously the two whirling columns abut at substantially the middle transverse plane of the annulus and each column reacts against the other. In consequence, as hereinbefore described, internally and introcessively formed columns of gases are created and caused to discharge through respective throats, 74. Incidentally the non-combustible constituents of the fuel are slagged due to the action of the whirling outer columns, collected in the groove, 73, and thus are finally discharged through the slag hole, 72. One purpose in here referring to the structure is to make clear the fact that a reaction bottom composed of refractory material is not always an essential element of the annulus or burner proper; instead the reaction bottom of the annulus may be formed by a body of gas in any such manner as here explained and which quite as effectively interrupts the longitudinal travel of the primary or outer column. For virtually all uses I regard the single reaction vertical type of furnace, herein mainly illustrated, as the best, the most cheaply constructed and most easily maintained.

50 The chief reasons for my preference for the vertical type are: First, the component bricks may be laid more easily in that form;—second, no special devices are required to secure the bricks which compose 55 or inclose the twyers and it is therefore practicable to increase the number of tangential twyers and thus advantageously subdivide the supply streams of fuel and air; and, third, the vertical type provides the 60 most simple and effective means for collecting and discharging the slag.

It is obvious that other solids may be fed with, or separately from, the fuel, to produce a slag or composition adapted to special 65 uses.

Among other things, which the invention comprehends is the generation, saving and compression of carbon-monoxid from the annulus. When conducting the process with this purpose in view, the supply of secondary air is shut off and means are employed to draw the gases from what is otherwise the combustion space of the furnace. At such times combustion is limited and controlled by limiting the supply of primary air and the flame is virtually restricted to the confines of the annulus.

In both action and appearance my novel apparatus differs from others employed in the art. In number of functions it exceeds a mere burner or nozzle that emits a combustible mixture; likewise it differs from all suspension combustion apparatus; and, obviously, it is wholly unlike all forms of furnaces in which perforated bottoms or grates are employed. The operation of my furnace is continuous and with the exception of the small amount of heat radiated from the walls of the well or container, all of the heat developed is actually used. Nevertheless, my furnace cannot be defined as a regenerative furnace for in all regenerative furnaces waste heat is used to raise the temperature of the entering air or gases; whereas, in my apparatus waste heat is not relied on, but on the contrary, the heat initially developed is immediately and progressively utilized in the measure required to condition the incoming air and fuel for combustion. For these reasons none of the customary names used for other kinds of furnaces are applicable. I have therefore called it an introgenerative furnace. By my method, and disregarding the relatively incombustible nitrogen, the combustibles and incombustibles of the fuel are completely separated, this being important as a means of securing the largest possible quantity of combustibles from the fuel;—and after such separation takes place, the combustion or further use of the practically pure combustibles is placed within the positive and intelligent control of the operator. It should be clear that the matter of first importance is this preparation of the fuel for later use, and that what is done with the combustibles is of secondary importance in its relation to the whole process of combustion. The combustible constituents of the fuel having been freed from the hampering effects of the incombustibles, it is possible to use them in many new and better ways. When an oxidizing flame is required, the operation of the furnace may be so nicely regulated that only products of incomplete combustion are discharged into the firebox.

By increasing the velocity of the air and proportioning the furnace to suit, very coarse coal may be burned in my furnace. For it is clear that I therein retain the fuel

upon the walls until wholly decomposed and until the incombustible solids have been separated. However, I can see no good reason for undertaking the expense of producing coarse coal, when coarseness is no longer essential to good combustion; nor any reason to accept the expense of reducing coal to an impalpable condition. It will be found that the greatest economy is attained by the use of the crushed coal hereinbefore mentioned, because such coal is not only the cheapest to produce, but is also the cheapest to handle and transport. As my furnace automatically rejects the incombustible matter, less than ordinary care is required in ridding the coal of slate and earthy matter at the mine. The whole mine run may be utilized in its most economical form.

As various modifications of the herein described processes and apparatus will readily suggest themselves to one skilled in the art, I do not limit my invention to the specific disclosures hereof.

The double tangential twyer arrangement, for the supply of primary air and of secondary air, shown in Fig. 7, hereof, is specifically described and claimed in my subsidiary application, Serial No. 274,129, renewed January 30, 1919, originally filed November 21, 1913.

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

1. A fuel burning furnace, comprising a refractory walled chamber or pot having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said chamber from the top to the bottom thereof, and the top of said chamber being open for the free discharge of the burning gases.

2. A fuel burning furnace, comprising a refractory walled chamber having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said chamber from the top to the bottom thereof, said bottom containing a central slag-discharge opening and the top of said chamber being open for the free discharge of the burning gases.

3. A fuel burning furnace, comprising a refractory walled chamber having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said chamber from the top to the bottom thereof, the bottom of the chamber containing a slag-discharge opening, the top of the chamber being open for the free discharge of the burning products and means

above said open top for admixing air with said products therefrom.

4. A fuel burning furnace, comprising a refractory walled chamber having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl spirally downward upon the inner vertical wall of said chamber from the top to the bottom thereof, the top of said chamber being open for the free discharge of the burning products, and means above said open top for admixing additional air with said products.

5. A fuel burning furnace, comprising a refractory walled chamber having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl spirally downward upon the inner vertical wall of said chamber from the top to the bottom thereof, the bottom of the chamber containing a slag-discharging opening, a closed slag-chamber wherewith said opening communicates, and a fire chamber into which the top of said refractory chamber opens.

6. A fuel burning furnace, comprising means forming a pit, a refractory annulus arranged in said pit and in spaced relation to the inner wall thereof, said annulus having a refractory bottom and the axis being substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said annulus from top to the bottom thereof, and the top of said annulus being open for the free discharge of the burning gases.

7. A fuel burning furnace, comprising means forming a pit, a refractory annulus arranged in said pit, and in spaced relation to the inner wall thereof, said annulus having a refractory bottom, in combination with means for causing fuel-laden air to whirl helically downward upon the inner wall of said annulus from top to bottom thereof, said bottom containing a central discharge opening, and the top of said annulus being open for the free discharge of burning gases adapted to commingle with secondary air enveloping said annulus.

8. A fuel burning furnace, comprising means forming a pit, a refractory annulus arranged in said pit, and in spaced relation to the inner wall thereof, said annulus having a refractory bottom and the axis being substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said annulus from top to bottom thereof, the bottom of the annulus containing a slag discharge opening, the top of the annulus being open for the free discharge of air, and means for admitting air to the gases discharged from said annulus.

9. A fuel burning furnace, comprising means forming a pit, a refractory annulus arranged in said pit, and in spaced relation to the inner wall thereof, said annulus having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said annulus from the top to the bottom thereof, the bottom of the annulus containing a slag discharge opening, the bottom of the pit being closed and forming a slag chamber communicating with said slag discharge opening.

10. A fuel burning furnace, comprising means forming a pit, a refractory annulus arranged in said pit, and in spaced relation to the inner wall thereof, said annulus having a refractory bottom and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said annulus from the top to the bottom thereof, the bottom of the annulus containing a slag discharge opening, the bottom of the pit being closed and forming a slag chamber communicating with said slag discharge opening, and a fire chamber into which the top of said annulus opens.

11. A fuel burning furnace comprising a refractory annulus having a refractory bottom, and the axis of which is substantially vertical, in combination with means for causing fuel-laden air to whirl helically downward upon the inner vertical wall of said annulus, from the top to the bottom thereof, said bottom containing a central slag discharge opening, the top of said annulus being open for the free discharge of the burning gases and means for admitting air, gas, or similar medium to said annulus through said slag-discharge opening.

12. The improvement herein described comprising a combustion chamber in the form of a refractory cylinder having a contracted central discharge opening at one end, said cylinder being provided with a tangential air and fuel inlet inwardly of but adjacent to its contracted discharge end and also provided with a slag discharge opening in its lower part, at a point remote from said inlet.

13. The improvements herein described, comprising a combustion chamber in the form of a refractory cylinder having a concentric contracted discharge opening at one end, means for introducing fuel and air

tangentially into the cylinder inwardly of but adjacent to its open discharge end and distant from its other end, said cylinder being provided with a slag discharge opening at the latter end.

14. A fuel burning furnace comprising a fire box or chamber having a suitable exhaust opening, in combination with a refractory walled primary chamber at one end of which is a large opening for the free discharge of flame into said fire chamber, means at that end of the primary chamber for directing combustibles helically away from said opening and along the inner peripheral wall of said primary chamber toward the other end thereof, and a slag pit for receiving the incombustible residue from said primary chamber, substantially as described.

15. A fuel burning furnace comprising a fire box or chamber having a suitable exhaust opening, in combination with a refractory walled primary chamber at one end of which is a large opening for the free discharge of flame into said fire chamber, means at that end of the primary chamber for directing combustibles against the inner peripheral wall of the primary chamber and helically toward the other end thereof, a slag pit for receiving the incombustible residue from said primary chamber, and means between said chambers for feeding air to the flame from said opening, substantially as described.

16. A fuel burning furnace comprising a fire box or chamber having a suitable exhaust opening, in combination with an air supply passage communicating with said fire chamber, means for regulating the flow of air therethrough, a refractory annular chamber situated in said passage and having openings in both its ends, the opening in the end near the fire chamber being large, for the free discharge of flame therein, the opening in the other end of the annular chamber being positioned to discharge incombustible residue into said passage, a plurality of twyers adapted to direct combustibles against and helically along the inner peripheral wall of said primary chamber beginning at the end thereof which contains said large opening, and means for feeding combustibles to said twyers, substantially as described.

In testimony whereof, I have hereunto set my hand this 8th day of February, 1917.

JOSEPH MARTIN SCHUTZ.