No. 708,602. Patented Sept. 9, 1902.

# A. T. WELCH.

## DRIER.

(Application filed May 28, 1897.)

(No Model.) 3 Sheets—Sheet 1.

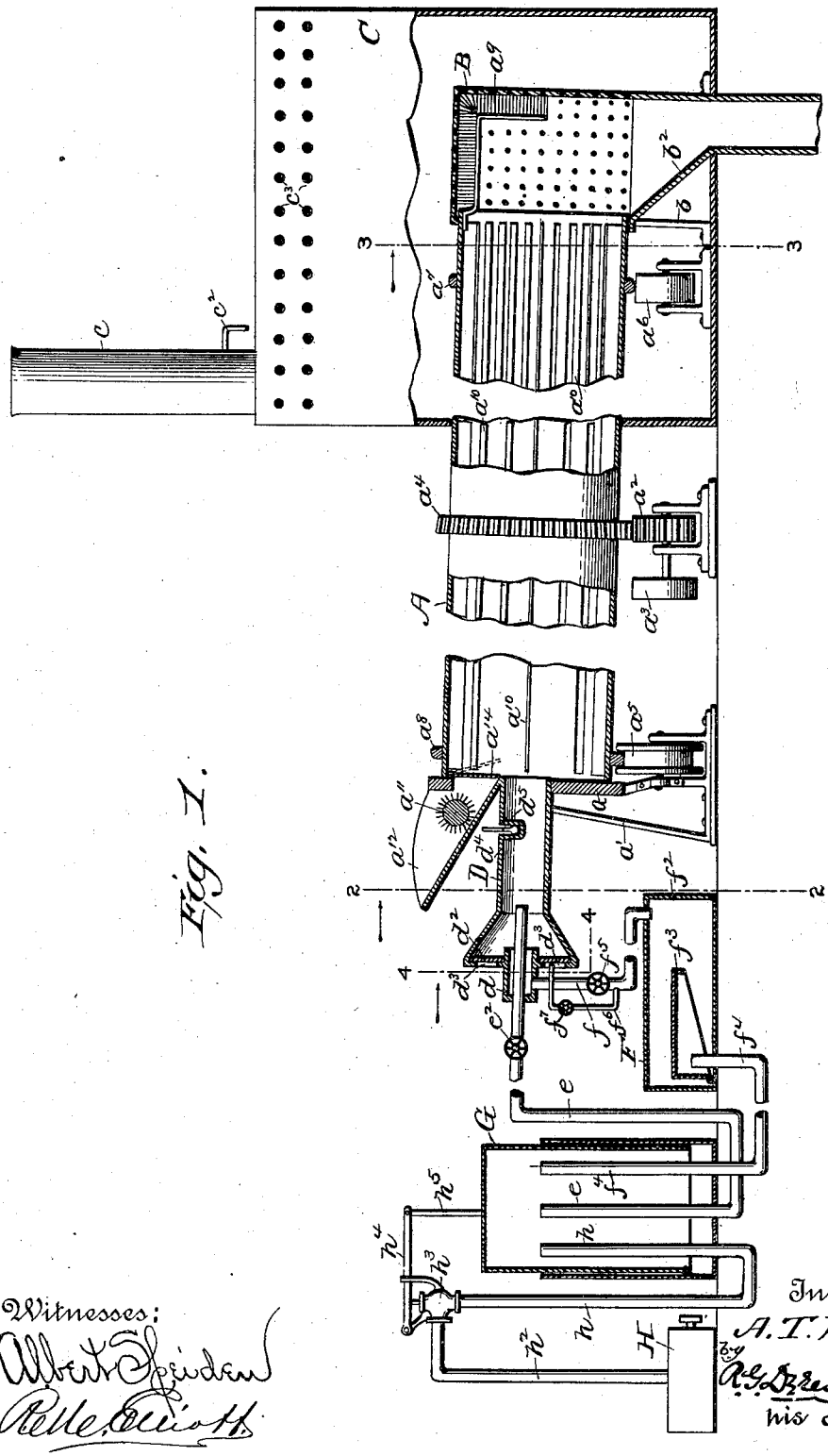

Fig. 1.

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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## DRIER.

(Application filed May 28, 1897.)

(No Model.) 3 Sheets—Sheet 2.

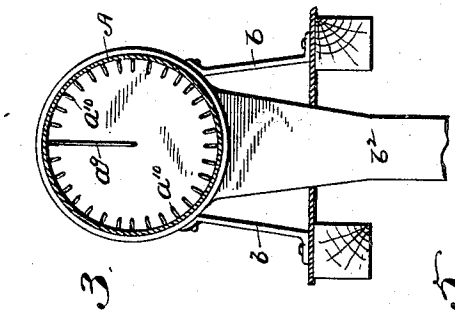

Fig. 3.

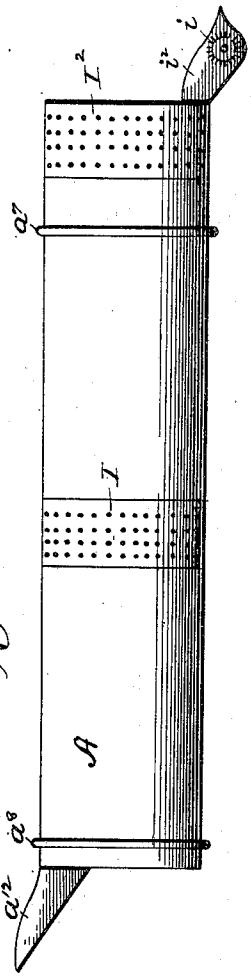

Fig. 5.

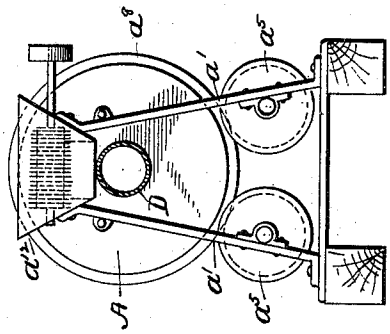

Fig. 2.

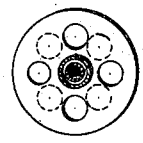

Fig. 4.

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No. 708,602. Patented Sept. 9, 1902.

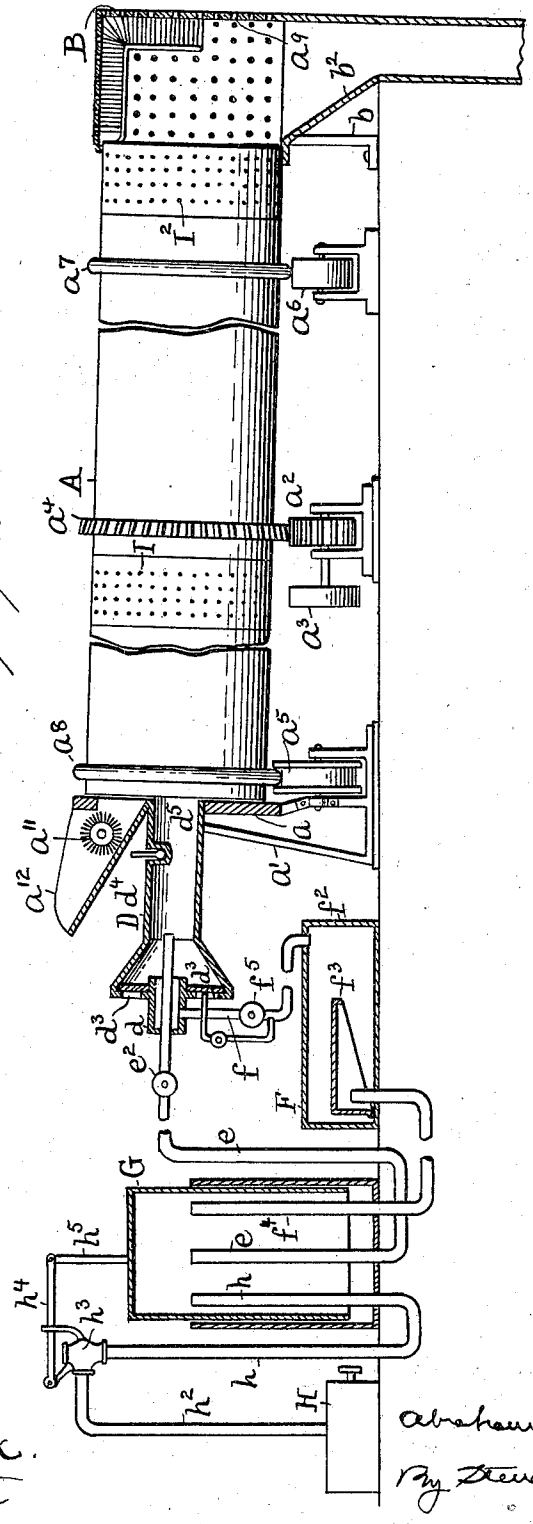
# A. T. WELCH.

## DRIER.

(Application filed May 28, 1897.)

(No Model.) 3 Sheets—Sheet 3.

Fig. 5.

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# UNITED STATES PATENT OFFICE.

ABRAHAM T. WELCH, OF BALTIMORE, MARYLAND.

## DRIER.

SPECIFICATION forming part of Letters Patent No. 708,602, dated September 9, 1902.

Application filed May 28, 1897. Serial No. 638,659. (No model.)

*To all whom it may concern:*

Be it known that I, ABRAHAM T. WELCH, a citizen of the United States, residing at Baltimore, in the State of Maryland, have invented certain new and useful Improvements in Driers; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to driers.

The objects are rapidly and evenly to dry organic or other substances to the desired degree and at the same time to effect their separation or division into parts or particles of the requisite or desired fineness; furthermore, to avoid waste of heat by utilizing the same in such manner that the moist substance or substances will be subjected to heat of the highest temperature on entering the drier and to heat of a progressively-decreasing temperature toward the discharge end, and, finally, to regulate the heat in the drier in accordance with the amount of drying to be accomplished.

In my invention I employ a rotating drum provided on its interior with a number of shelves sharpened at their edges to form knives which as the drum revolves pick up the material and drop it through or near a flame at one end of the drum and through hot air and gas at the other end on the edges of the shelves below, thus effecting a rapid drying and breaking up or division of the material and preventing any balling or lumping thereof. The shelves in this instance increase in number from the feed end to the discharge end of the drum—that is to say, at the feed end there will be the fewest number of these shelves and at the discharge end the greatest number. This arrangement is adopted in order that the material when it first enters the drum will be picked up in large masses and be subjected to the greatest heat, and as it is moved or worked through to the discharge end of the drum the increased number of these shelves or knives will operate to break up and finally divide the material being desiccated. The feed end of the drum is closed by a head, (the plane of which is at right angles to the axis of the cylinder,) through which opens the combustion-chamber, of smaller diameter than the drum. Through this chamber is blown a stream of flame at a high temperature and in a direction substantially parallel with the axis of the drum. The combustion-chamber has its sides substantially parallel with the axis of the drum, thus causing the hot flame, gas, or air to be projected into the drum centrally without filling the whole cross-section of the drum close up to the feed end. If the combustion-chamber presented a material widening in the end toward the drum, the hot flame, gas, or air would spread out and fill the cross-section of the drum where it entered it and materially interfere with the proper action of the drier. Opening into the drum above the combustion-chamber is the hopper through which the material to be dried is fed into the drum. The discharge end of the drum is of as large a diameter as any other part of the drum and affords a free and unobstructed discharge. The rear or discharge end of the drum is surrounded by a dust-arrester consisting of a casing or hood constructed of perforated material and terminating at its lower side in a chute or discharge, the drum being provided with a brush adapted to keep the top, sides, and ends of the arrester clean and free from any accumulation of dust. This arrester and also the rear portion of the drum may be housed in a dust-room provided with a stack and a suitable damper, and also suitable inlet-openings through which atmospheric air may pass to the roof of the dust-room to cool or chill any dust which may escape from the dust-arrester and cause it to settle to permit of its being collected.

The apparatus which is the subject-matter of this application is designed to carry into effect a process of drying which has been divided out of this application and made the subject-matter of a divisional application filed by me June 7, 1901, Serial No. 63,658.

The drum being set in rotation and the flame adjusted, the goods to be dried are fed into the drum through the hopper at a suitable rate. They fall, therefore, in their wettest condition through or near the hottest part of the flame. On account of the position and shape of the combustion-chamber this part of the drum is not filled by the flame,

and the goods fall through the flame to a cooler part of the drum without the temperature being raised to the point of scorching, the time during which the material is exposed to the direct action of the flame and the time during which it is not exposed to the direct action of the flame bearing such a relation to one another that the material will not be raised in temperature to the ignition-point. The pieces are more or less broken up by falling on the sharpened edges of the shelves, which as the drum rotates pick them up and drop them again through or near the flame. The goods are thus gradually dried and by means shortly to be described are moved toward the discharge end of the drum, being subjected progressively to a lower degree of heat, and are finally discharged from the drum as dry as may be desired. The progression of the goods is caused by four means—first, by the force of the blast of flame or hot air; second, by the rate of feed, for the greater this rate the greater will be the piling up of the goods at the feed end of the drum and the greater the slope of their surface toward the discharge end, so that every time a piece is raised by the shelves and dropped it will tend to roll a short distance toward the discharge end; third, by the slope of the drum, which will act as in the last case; fourth, by the rate of rotation of the drum, which will increase the number of times per minute each piece is dropped, and hence its speed of progression to the discharge end. Of these the first two are found to be sufficient to control the proper action of the drier. The first is so important in its action that it will be especially described.

Of the various materials usually treated in a drier the larger and heavier usually contain the greater amount of moisture, and as the heat received by a particle in a given time depends on the surface, whereas the amount of moisture to be evaporated depends on the volume, we see that it takes a longer time to dry the larger and heavier pieces than it does to dry the smaller and lighter ones. Now the larger and heavier the pieces the less will they be deviated by the force of the blast as they fall through or near the flame and the more slowly, therefore, will they progress toward the discharge end of the drum. As the pieces become drier and more broken up they become lighter and are more affected by the blast of the flame. This method of discharge is of extreme importance, as it causes the rapid discharge of those pieces which are rapidly dried and allows the pieces requiring a longer time to remain longer in the drier. Indeed, it regulates the discharge of the various pieces as they reach the proper degree of dryness so well that goods containing pieces of very different sizes and very different natures may be put into the drier at the same time and all be discharged properly dried. The small section of the blast at the feed end causes great force of blast and drives small light objects rapidly out of the drum, preventing them from being scorched or burned. The force with which pieces of the goods are driven along the drum depends also on the strength and temperature of the blast. By contact with the wet goods and otherwise the temperature of the blast is greatly reduced and the density of the gases of combustion greatly increased, with a corresponding decrease in the velocity of the individual gas molecules. This velocity is also diminished by the fact that in the case of some fuels the gases of combustion at the same temperature occupy a smaller volume than the gas and air before combustion. Therefore the driving power of the blast diminishes progressively and rapidly from the feed end to the discharge end of the drum. Not only so, but the wetter the goods the greater the reduction of the temperature of the blast and therefore the greater the reduction of its driving power. Therefore, other conditions being equal, the wetter the goods the more slowly will they progress along the drum, and consequently the longer will they remain in the drum and be subjected to the drying action of the blast. It is important that the direction of the blast should be substantially parallel to the axis of the cylinder for the purpose of causing the goods to progress through the cylinder or to drive them, if light enough, out of the cylinder.

An important part of my invention is the use of the flame and that at an extremely high temperature. It is evident that the higher the temperature the more rapid the drying. Moreover, there is always some heat carried off by the hot air issuing from the discharge end of the drum, and therefore the smaller the quantity of air discharging in proportion to the amount of heat introduced into the feed end of the drum the greater the economy. This proportion is reduced by increasing the temperature of the feed end. The use of the flame in the drum is far more economical than the use of this same flame to heat air and then to drive the air under pressure into the cylinder. Hot air forced into the cylinder under pressure would lose heat on expansion and could not, therefore, have the high temperature with which it started. Consequently great waste follows; but the flame produces the high temperature when the gas has lost its high pressure. Consequently the waste does not occur. Although I do not claim as my invention the use of a high temperature, I do claim that the practical use of the flame for drying goods without injuring them has never before been accomplished and that its use in this connection is so novel and results in such enormous economy and rapidity that it constitutes a very important invention. The very high temperature of the blast at the feed end of the drum causes a very low density, and hence a very small specific heat per unit of volume. Therefore when it acts on the wet goods and

heats them and evaporates the moisture its temperature is enormously reduced. In fact, we find the temperature 3,000° or 4,000° at the feed end and less than 200° at the discharge end. This enormous drop in temperature greatly diminishes the power of the air to hold the evaporated water in solution, and as the goods are always colder than the air in the drum there is danger that the moisture taken up at the feed end may be redeposited on the goods near the discharge end, and thus frustrate the whole purpose of the drier. The success of the operation therefore requires that at no point of the drum shall the hot air, gas, or flame be so overcharged with vapor that moisture will be redeposited or, what is equivalent, that at every point of the drum the hot air, gas, or flame shall always be absorbing moisture from the goods. There is thus a progressive and continuous drying and heating of the goods. The rate at which the hot air, gas, or flame can absorb moisture from the goods and heat them may be called its "drying and heating power." For convenience we shall call it merely the "power." It is greatest at the feed end, where the temperature is high and where the amount of absorbed vapor is small, and it continuously diminishes toward the discharge end, where the temperature is relatively low and the amount of absorbed vapor high. This power can always be kept large by keeping up the temperature; but there is danger then that the goods be scorched and even that they catch on fire. At the feed end the very moist goods drop through an intensely-hot flame, but remain in it a very short time. The heat of the flame is used to warm them up somewhat and to evaporate their moisture; but they pass out of the flame into a cooler region before they can be sufficiently heated to be burned. Farther down the drum the hot blast spreads until it fills the whole cross-section of the drum, and the goods, therefore, are constantly subjected to its drying and heating power. If the goods are moist enough, the steady evaporation of their moisture prevents them from becoming too highly heated; but if even on the surface they become too dry they will quickly be heated to a high temperature and be burned. The rate at which energy is being absorbed in evaporating the moisture and heating the goods may be spoken of as the "rate of doing useful work" or, for convenience, merely the "work." If the power is too great in comparison with the amount of moisture in the goods, the goods will be highly heated and burned. (This will not be so when the temperature of the hot air or gas is so low that it could not burn the goods under any circumstances; but then we should be working at very inefficient and uneconomical temperatures, and this would be commercially impractical.) On the other hand, if the power is too small in comparison to the work to be done either the goods will not be dried or moisture may even be redeposited on them. It is evident, therefore, that the power and work must substantially balance at all points of the drum. The fact that the power and work are balanced in all parts of the drier is shown to the operator by the goods coming out at the discharge end of the drum properly dried, and when they do so come out he knows that the power and work are balanced. If the goods come out moist, it shows that there is too much work for the power, and therefore either the power must be increased or the amount of work diminished. On the other hand, should the goods come out scorched it shows that the power is too great for the work and either the power must be decreased or the amount of work increased. In other words, when the power and work at all points in the receiver are balanced the goods come out of the receiver properly dried, and they are not properly dried—that is to say, they are either too moist or scorched—when the power and work are not balanced. It will be seen, therefore, that when the power and work are not balanced the same is shown by the condition of the goods coming out of the receiver and that they may be brought into balance by varying the amount of heat entering the drum or the amount of goods fed to the drum.

Further and more specific details of construction will be hereinafter described and claimed.

In the accompanying drawings, forming part of this specification, and in which like letters of reference indicate corresponding parts, I have illustrated a form of embodiment of my invention, although it is to be understood that other forms of embodiment thereof may be employed without departing from the spirit of the same, and in these drawings—

Figure 1 is a view in sectional elevation displaying a drier embodying the essential features of my invention. Fig. 2 is a transverse sectional view taken on the lines 2 2, Fig. 1, showing more particularly the feed-hopper and the feed or disintegrating drum therein. Fig. 3 is a similar view taken on the line 3 3, Fig. 1, showing more particularly the arrangement of the shelves or knives on the inside of the drum. Fig. 4 is a similar view taken on the line 4 4, Fig. 1, showing the perforated plate for regulating the supply of air to the burner; and Fig. 5 is a view in elevation of a modified form of drum. Fig. 6 shows the same parts as Fig. 1 with the addition of the cylinder shown in Fig. 5.

Referring to the drawings, A designates the drum, which may be made of any suitable material, preferably of iron, having its inlet or feed end closed by a hood or plate $a$, the same being held in position against the drum by braces $a'$ and its exit or discharge end open. The drum is shown in this instance supported in an inclined position, with the exit or discharge end lowest, and is driven by a gear-wheel $a^2$, on the shaft of which is mounted a

pulley $a^3$, by which power may be transmitted from any suitable source. Meshing with the gear $a^2$ is a gear $a^4$ on the drum. The drum is supported for operative movement upon two wheels or rollers $a^5$ and $a^6$, the same being engaged by bands $a^7$ and $a^8$, secured around the drum. The periphery of the roller $a^6$ is smooth; but the periphery of the roller $a^5$ is provided with two flanges, between which the band $a^8$ works to prevent longitudinal movement of the drum when the same is rotated. The rear end of the drum may be incased by a hood or dust-arrester B, consisting of frames or standards $b$, to which the hood B is secured, the same being about three-quarters of a circle and open at its bottom, so that the material may escape down a chute $b^2$ to a suitable receptacle. The top, sides, and one end of the hood are constructed of any suitable material, such as perforated screens, and are kept free from any accumulation of dust by an L-shaped brush $a^9$, carried by the discharge end of the drum. Thus as the drum is revolved this brush will scour the sides, top, and end of the hood and clear the meshes or holes thereof from dust. The dust which escapes to the outside of this hood passes into a dust-room C, in which the rear portion of the drum may be incased, the room being an ordinary chamber provided with a stack $c$, which is larger than necessary, to carry off vapors from the drier, and with a damper $c^2$. The top portion of this room is provided with a series of openings $c^3$, by which atmospheric air can pass to the interior of the room and chill and settle the dust afterward to be collected. This dust-room with the stack, constitutes a means for relieving the pressure at the discharge-outlet, and this is effected by the pull of the stack and by preventing any air which may be stirring in the room where the drier is located from affecting the operation of the drier. Of course any other means for effecting this function might be substituted for this shown, if found desirable. Secured to the interior of the drum and longitudinal of its length is a series of shelves $a^{10}$, the function of which is to agitate, pick up, and drop and separate or divide the material as it passes through the drum, and thereby present the material constantly to the action of the heat. These shelves progressively increase in number toward the discharge end of the drum—that is to say, at the feed end there will be, say, eight of these shelves a little farther on sixteen, and at the discharge end thirty-two, or this number may be increased or diminished, as found necessary or desirable. The shelves are set radially of the drum and are sharpened on their edges, so that as the material is dropped upon their edges they will cut and divide it. As the material enters the drum in a spray through the intense heat it is in its wettest condition and the shelves will pick it up in masses or bunches and drop it, thereby causing an initial disintegration and the subjection of the entire area of the material to the action of the highest heat. As the material works toward the discharge end of the drum the increased number of these shelves will tend to break up or disintegrate the dried or partially-dried material, so that by the time it has reached the discharge-chute $b^2$ it will be in a finely-divided state. Any suitable means may be employed for feeding the material to the drum, and in this instance I employ a toothed feed and disintegrating roller $a^{11}$, arranged in a hopper $a^{12}$ at the inlet or feed end of the drum, the said hopper being provided with knives or projections $a^{13}$, coacting with the teeth on the roller to break up and at the same time force the material to the drum in a spray across the path of the flame, which partially dries it and prevents balling. The opening where the material enters the drum is normally closed by a gravity operating door or valve $a^{14}$, which, as will be seen, will allow the material freely to enter the drum, but will prevent its escape therefrom, and will also in a great measure cut off the escape of foul odors or escape of gases or the entrance of cold air.

Connecting with the hood or plate $a$ is a combustion-chamber D, into which enters a pipe $e$ from a supply of air under pressure and a pipe $f$ from a supply of fuel, which may be either gas or oil. In case the latter is used the chamber $d$, surrounding the pipe $e$, may be filled with wool asbestos. The pipe B delivers air some distance ahead of the pipe $f$ to prevent extinguishing the flame when the proportion of air under pressure is large and the flame small. In this instance I have shown the fuel-supply as coming from a carbureting apparatus F, consisting of a tank $f^2$ containing oil, in which is arranged a float $f^3$, designed to deflect a current of air supplied thereto through a pipe $f^4$, opening into an airometer or holder G, the latter being supplied with air through pipes $h$ and $h^2$ from an air-forcing device H in the nature of a pump or positive blower. The pipe $h$ supports a safety-valve $h^3$, the lever $h^4$ of which carries a depending arm $h^5$, arranged in the path of movement of the hood of the air-receiver or airometer, so that when the receiver reaches a predetermined height the arm $h^4$ will be lifted and allow the air being forced from the pump to escape instead of entering the receiver, thereby establishing and maintaining a uniform pressure of air and fuel. Both the pipes $e$ and $f$ are provided with valves $e^2$ and $f^5$, respectively, by which the supply of air and gas to the combustion-chamber may be regulated at will. The rear portion of the combustion-chamber is provided with a perforated plate $d^2$, adapted to be moved to open or to close openings $d^3$ in the rear plate of the said chamber, whereby to regulate the supply of atmospheric air to the burner. To facilitate lighting the burner, a lighter-pipe $f^6$ is employed, having one of its ends tapped into the gas-pipe $f$, as shown in

Fig. 1, and its other end projecting into one of the openings $d^3$ in the rear plate of the combustion-chamber, the pipe $f^6$ being provided with a valve $f^7$, by which to control the passage of gas therethrough. The combustion-chamber D may be provided with a pocket $d^4$ for the reception of a thermometer $d^5$, by which the temperature of the chamber may be determined. The combustion-chamber, with its air and gas pipes, constitutes a compound injector—that is to say, an injector through which air and gas in predetermined or regulated quantities may be supplied to the drum.

The operation of the apparatus is as follows: Air from the receiver G and gas from the carbureter F are supplied to the combustion-chamber, and the gas is lighted and burns a red flame and mixes with the air farther on in the combustion-chamber. As the supply of air to the carbureter and to the pipe E are from the same source, it follows that the supply of each is exactly proportionate, the valves $e^2$ and $f^5$ being set with respect to each other. The supply of gas and air is positively supplied and gravity-controlled, as the holder of the airometer will by its weight operate to supply air under pressure to the burner, so that there will be always a uniform supply of air and gas thereto, thereby avoiding fluctuation in the supply of heat, with a corresponding variation in the desiccating power of the flame or blast of air. The advantage of this arrangement will be obvious, for it will be seen that if the valves $f^5$ and $e^2$ are set the degree of heat will remain constant without any attention being paid it through any length of time, provided, of course, the supply of oil is maintained in the carbureter and the pump H is kept at work. The flame being lighted will be projected into the drum any desired distance, its speed and force being regulated, of course, by the volume of air and fuel admitted to the combustion-chamber and their pressure in the airometers. The material is now fed to the hopper $a^{12}$, and as it passes into the drum in a spray is met by an intense heat, which will serve rapidly to dry the exterior of the material. As often as the material drops it is caught by the shelves $a^{10}$ and is again lifted and dropped, being thus intermittently subjected to the fire until it has passed beyond it, and as the material approaches the discharge end of the drum the temperature will gradually decrease. The heat absorbed by the material will as it passes through the length of the drum penetrate to the center of the material, which will then be dried to the desired degree. As before stated, the shelves increase in number toward the discharge end of the drum, so that the material will be finely broken up and divided before it escapes through the chute $b^2$. I have found in practice that moist fish can be thoroughly and effectively dried by flame without burning and that oyster-shells may at one operation be calcined by this form of drier. Other materials—such as hair, tankage, and the like—are effectively dried by flame without being burned, as the direct contact of the flame with the material is of such short duration that before the moisture is thoroughly evaporated from the exterior the material will have passed beyond the zone of the flame and will therefore be protected from scorching. In my apparatus the rate at which the fuel is supplied to the burner is automatically controlled. The rate at which the air is supplied is also automatically controlled. Hence the temperature and volume of the flame will be constant for any given setting of the apparatus. The setting may be varied, but when set the temperature and force of blast will be constant. This constant temperature and force of blast is a very important element in the practical operation of the apparatus, for the reasons that the temperatures employed are so high that unless conditions in the drier are absolutely under control burning will almost certainly result. The material to be dried can now be fed to the drum in measured quantities of known moisture and known weight. With an apparatus in which the drum has a constant speed, the number and location of shelves having been arranged to suit conditions of drying desired and the material to be dried, the strength of the blast, the temperature, and the volume of flame being constant, the only element requiring to be watched and altered to produce exact conditions is the feed, and when this is carefully regulated uniform and positive results can be obtained.

In my drier, in which the contents of the cylinder is heated by heat applied inside the cylinder alone, no matter how highly the contents may be heated the exterior shell of the vessel—that is, the cylinder itself—remains cool, and the effect is that when the hot and damp material falls against the inner surface of the cylinder there is a slight contraction of each portion of the hot material as it strikes the cooler shell, which draws the material away from the cylinder, leaving the inside of the cylinder constantly clean.

While I have shown the feed-hopper and feed-roller or disintegrating-drum in this instance as located at the inlet end of the apparatus, it is to be understood that in some instances I may dispense with the disintegrating apparatus at the inlet end and locate it at the discharge end of the cylinder. This arrangement will be found advantageous where the material is in a very wet or soft and mushy condition, as where garbage or very moist fish is to be dried, and as this passes through the drum or drier it will form into balls or lumps. These will still contain a high degree of heat when they enter the disintegrator at the discharge end of the apparatus and will be finely ground up or divided and then be forced rapidly through the air. The heat contained in the mass will cause any retained moisture to be brought to the

surface and into contact with the atmospheric air, which will rapidly cool and evaporate it.

While I have not shown the means herein, it is to be understood that the material fed to the apparatus will be weighed or otherwise measured, so that the bulk or body of the material fed to the apparatus will be proportionate to the volume of air and heat and speed of travel of material through the drier. In other words, the feed of air, the feed of gas, supply or feed of material, and speed of material through the apparatus are all interdependent. The material will drop by gravity into the receptacle and when picked up by the shelves of the cylinder will drop by force of gravity and be progressively fed to the flame or blast of air, provided the apparatus rotates uniformly.

In Fig. 5 I have shown a form of drum in which the fine particles of material may be separated from the coarser particles and be removed from the drum when quick drying is required, so as to obviate waste of heat and also injury to the material. To effect this, I employ screens or sieves as sections of the walls of the drum, one of these screens I′ being located, preferably, at about the middle of the drum and the other, $I^2$, at the discharge end. By this means all the finer dry material can be separated from the coarser damp material, which will be subjected to a further disintegrating process, consisting in this instance of a disintegrating-drum $i$, arranged in a hopper $i^2$ at the discharge end of the drum. As will be seen, the discharge end of this hopper curves upward and outward, so that as the material is thrown out by the disintegrating-drum $i$ it will be scattered out in a sheet, thus to effect the final drying. This latter step would be advantageous for the reason that it will avoid driving off the contained ammonia in the nearly dry material, as if this fine material were subjected directly to the action of a too-high degree of heat the result would be that part of the ammonia would be driven off and there would be danger of burning some materials. The operation just described would consist in the subjection of the goods to the action of fire and subsequently the agitation of the hot partially-dried goods in the presence of air cooler than that to which the goods were originally exposed. It is essential that the temperature used in the second stage of this operation should be less than the temperature used in the first operation for the reason that goods which are nearly dry will burn if exposed to as high a temperature as that to which they were originally exposed when very moist. Another advantage in employing the disintegrating-drum at the discharge end of the drier is that a platform may be arranged adjacent to this hopper upon which the material may be thrown by the action of the disintegrator to allow remaining moisture to escape and also to save the fine and valuable dust, which might otherwise be lost if thoroughly dried in the drier.

Heretofore many attempts have been made to employ flame directly upon goods for the purpose of drying, evaporating, or heating; but these efforts have always resulted in burning the material, because the time during which the materials were exposed to the flame or air and the proper proportion between the power and the work given it to do were not understood and regulated in such manner as to secure the beneficial effects of the flame while preventing it from injuring the goods. The difference between all these attempts and my invention lies in the application of the direct or direct-radiant action of a flame to the materials, regulated in such a way as to balance the power and the work. None of the previous efforts in this line have attempted to dry light goods and heavy goods and goods of varying heat-absorbing capacity by subjecting them to the direct or radiant action of a flame regulated as mentioned, and none of the devices known to me in which flame is applied directly to the goods are capable of adjustment or use so as to accomplish this result. Another important difference between my method and the prior art lies in the fact that I apply to a given mass of material in its wettest condition the direct or radiant action of a flame at its point of highest temperature in the receiver for a period of time dependent upon the amount of moisture the goods contain and then gradually withdraw the material from the higher temperature and subject it to a gradually-declining temperature as the amount of moisture in the goods diminishes. Another important difference between my method and the prior art lies in the application of the highest temperature to the greatest quantity of material in its wettest condition and then gradually reducing the quantity of material and the temperature of the air or gas to which it is exposed as the material becomes drier. Another important difference lies in the regulation of the temperature, force, and volume of the blast, so as to adjust it to the quantity and nature of the material to be treated. Another important difference lies in the projection of a blast into the cylinder in a line substantially parallel to the axis of the cylinder and maintaining the force of the blast at the point of inlet higher than at any other point in the cylinder.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent of the United States, is—

1. The combination in a drier of a chamber, means for blowing or injecting flame thereinto at one end through an opening of smaller diameter than that of the end of the chamber and located some distance above its base, means for supplying to said end of the chamber material to be treated and means operating to advance the material progressively to-

ward the other end of the chamber, substantially as described.

2. The combination in a drier of a chamber, means for blowing or injecting flame thereinto at one end through an opening of smaller diameter than that of the end of the chamber, and located at substantially the center of said end, means for supplying to said end of the chamber material to be treated, and means operating to advance the material progressively toward the other end of the chamber, substantially as described.

3. The combination in a drier of a chamber, means for blowing or injecting flame thereinto at one end through an opening of smaller diameter than that of the end of the chamber and located above the material to be treated, means for supplying to said end of the chamber material to be treated, and means operating to advance the material progressively toward the other end of the chamber, substantially as described.

4. A drier comprising a shell or drum, having its interior provided with a series of shelves, the same increasing in number from the inlet to the exit end of the drum, in combination with means for supplying heat to the drum, substantially as described.

5. A drier comprising a shell or drum, having its interior provided with a series of shelves, the same increasing in number from the inlet to the exit end of the drum, substantially as described.

6. A drier comprising a shell or drum having its interior provided with a series of shelves, a dust-arrester arranged at the discharge end of the drum, comprising an open-work structure, and a brush carried by the drum for removing accumulations from the interior walls of the said arrester, substantially as described.

7. The combination with a chamber of a burner in communication with the inlet end thereof, an air-supply pipe in connection with the burner and projecting beyond the same, substantially as described.

8. The combination with a revoluble drum, of a burner in communication with the inlet end thereof, an air-supply pipe in connection with the burner, and projecting beyond the same, substantially as described.

9. A drier comprising a shell or drum having its interior provided with a series of shelves, a dust-arrester arranged at the discharge end of the drum, comprising an open-work structure, and a dust-room inclosing the dust-arrester, and provided with means for introducing cooler air whereby to chill fine particles of material escaping thereto, substantially as described.

10. The combination with a revoluble drum of a stationary head-plate carrying a combustion-chamber, means for supplying a blast to the said chamber, a burner arranged at the outer end of the said chamber, a fuel-supply pipe entering the combustion-chamber, and means for regulating the supply of fuel to the burner, substantially as described.

11. The combination in a drier of a chamber open at one end and closed at the other, means for blowing flame into the closed end under pressure, and means for supplying to the chamber at the closed end material to be dried.

12. The combination in a drier of a chamber open at one end and closed at the other, means for blowing flame into the closed end under pressure in a direction substantially parallel to the line of discharge, and means of supplying to the chamber at the closed end material to be dried.

13. The combination in a drier of a chamber having a discharge-outlet, means for blowing flame partially therethrough from a passage-way alined with the line of discharge, means for supplying to the said chamber material to be treated, and means operating to advance the material through the chamber without burning, at a varied speed dependent upon the weight of the pieces.

14. The combination in a drier of a chamber having a discharge-outlet, means for forcing flame partially therethrough, in a line substantially parallel to the line of discharge, means for supplying such chamber with material to be treated, and means operating to advance the material through the chamber without burning, toward the outlet, at a speed dependent upon the heat-absorbing capacity of the material.

15. The combination in a drier, of a chamber closed at one end and having a discharge-outlet at the other, an inlet through said closed end having substantially parallel walls, and an area in cross-section less than that of the chamber, means for blowing flame into said chamber through said inlet, means for relieving the pressure at the discharge-outlet and means for supplying to the chamber material to be dried.

16. The combination in a drier, of a chamber provided with a discharge-outlet, a contracted inlet, of an area in cross-section less than that of the chamber, means for blowing the flame through said inlet in a direction substantially parallel to the line of discharge, means for relieving the pressure at the discharge-outlet and means for supplying to the chamber at or near the flame-inlet material to be dried.

17. The combination in a drier of a chamber having a discharge-outlet, means for blowing flame thereinto, in a direction substantially parallel to the line of discharge, means for relieving the pressure at the discharge-outlet, and means for supplying to the chamber at, or near the fire-inlet, material to be dried, and means for agitating the material so as to bring it into the line of the blast.

18. The combination in a drier of a chamber having a discharge-outlet, means for blowing flame thereinto under pressure in a direc-

tion substantially parallel to the line of discharge, means for relieving the pressure at the discharge-outlet, and means for supplying to the chamber at, or near the fire-inlet, material to be dried, and means for subjecting the material intermittently to the action of the blast, first to the highest temperature, and subsequently to the constantly-declining temperature.

19. The combination in a drier of a chamber having a discharge-outlet, means for forcing flame partially therethrough in a line substantially parallel to the line of discharge, means for regulating and controlling the temperature of the flame and force of the blast, means for supplying to the said chamber material to be treated, and means operating to advance the material through the chamber without burning.

20. In a drier the combination of a cylinder, means for revolving the cylinder, means for projecting a flame under pressure into one end at or about its center, and means for feeding to the cylinder material to be dried, at the same end as the blast.

21. In a drier the combination of a receiver and agitator for the goods, said receiver being provided with a discharge-outlet, of means for feeding material to be dried to the receiver always at substantially the same point, and means for projecting a flame under pressure directly over the goods in the direction of discharge, the point of maximum temperature in the receiver being substantially opposite the point of maximum bulk of the goods.

22. In a drier the combination of a receiver having a discharge-outlet, means for agitating the goods in the receiver, means for feeding material to be dried to the receiver, always at substantially the same point, and means for projecting a flame directly over the goods in the direction of discharge, the point of maximum temperature in the receiver being opposite the point of maximum bulk of the goods.

23. In a drier the combination of a receiver having a discharge-outlet, means for agitating the goods, means for feeding material to be dried to the receiver always at substantially the same point and means for projecting a flame directly over the goods in the direction of discharge, so located that the point of maximum temperature in the receiver will be opposite the maximum bulk of goods.

24. In a drier the combination of a receiver having a discharge-outlet, the means for feeding the material to be dried to the receiver at one end, always at substantially the same point, whereby a maximum bulk of goods is maintained at the feed end, which gradually declines to the discharge end, means for agitating all the goods to prevent burning, and means for projecting a blast over the goods, the point of inlet of blast being over and opposite the maximum bulk of goods, and above the level of the discharging goods at the discharge end.

25. In a drier the combination of a receiver having a discharge-outlet, embodying a receiving-bed, having a rear wall forming an abrupt angle with the bed, with means for feeding material to be dried to the bed, immediately in front of the abrupt wall, means for agitating all the goods on the receiving-bed, and means for blowing a blast over the goods, the point of inlet of blast being opposite to the point of maximum bulk of goods, and above the level of the discharging goods at the discharge end.

26. In a drier the combination of a receiver, means for projecting a blast thereinto, means for regulating and controlling the force, volume and temperature of the blast to produce a desired power, means for advancing the material to be dried through the chamber, and means for supplying to the receiver material to be dried, and acted upon by the blast so as substantially to balance the power and work at all points in the receiver.

27. In a drier the combination of a receiver, means for projecting a flame thereinto under pressure, means for regulating and controlling the force, volume and temperature of the blast, to produce the desired power, means for advancing the material to be dried through the chamber, and means for supplying to the receiver material to be dried, and regulating the volume of material fed to the receiver, and acted upon by the blast so as substantially to balance the power and work at all points in the receiver, substantially as described.

28. In a drier the combination of a receiver, means for projecting a blast thereinto, means for regulating and controlling the pressure, volume and temperature of the blast to produce a desired power, and means for supplying to the receiver material to be dried in regulated quantity, so as to present to the power at all points in the receiver an amount of work proportional thereto.

29. In a drier the combination of an inclined rotating drum, open at one end and closed at the other by a stationary wall, means for projecting a flame through said wall into said drum at a substantial distance above the base of said drum, means for feeding material to be dried into said drum through said wall, and means for rotating said drum.

In testimony whereof I affix my signature in presence of two witnesses.

ABRAHAM T. WELCH.

Witnesses:
E. T. BRANDENBURG,
R. M. ELLIOTT.