No. 708,946. Patented Sept. 9, 1902.

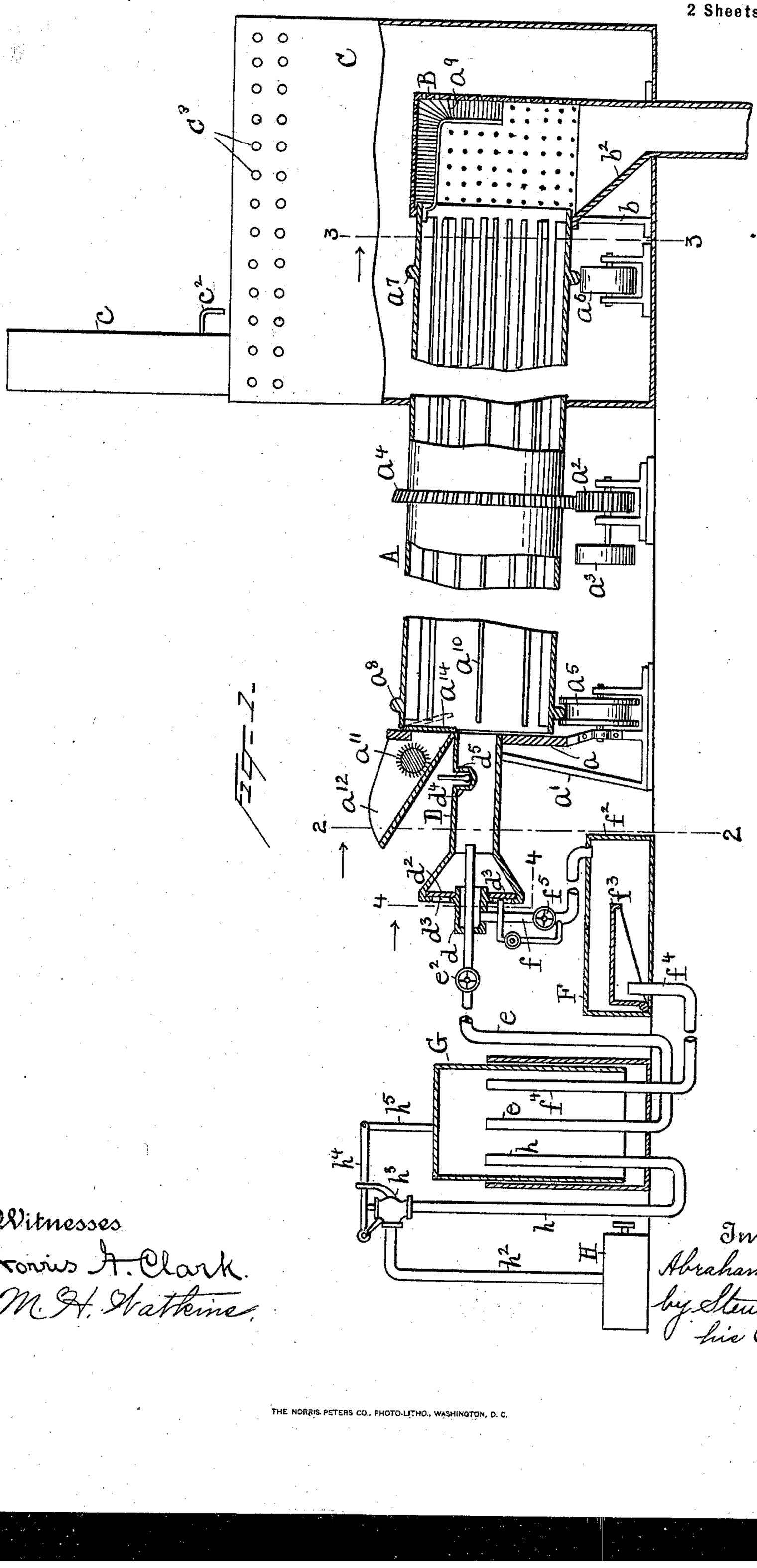
A. T. WELCH.

METHOD OF HEATING MATERIALS FOR THE PURPOSE OF DRYING OR TREATING.

(Application filed June 7, 1901.)

(No Model.)

2 Sheets—Sheet 1.



Witnesses
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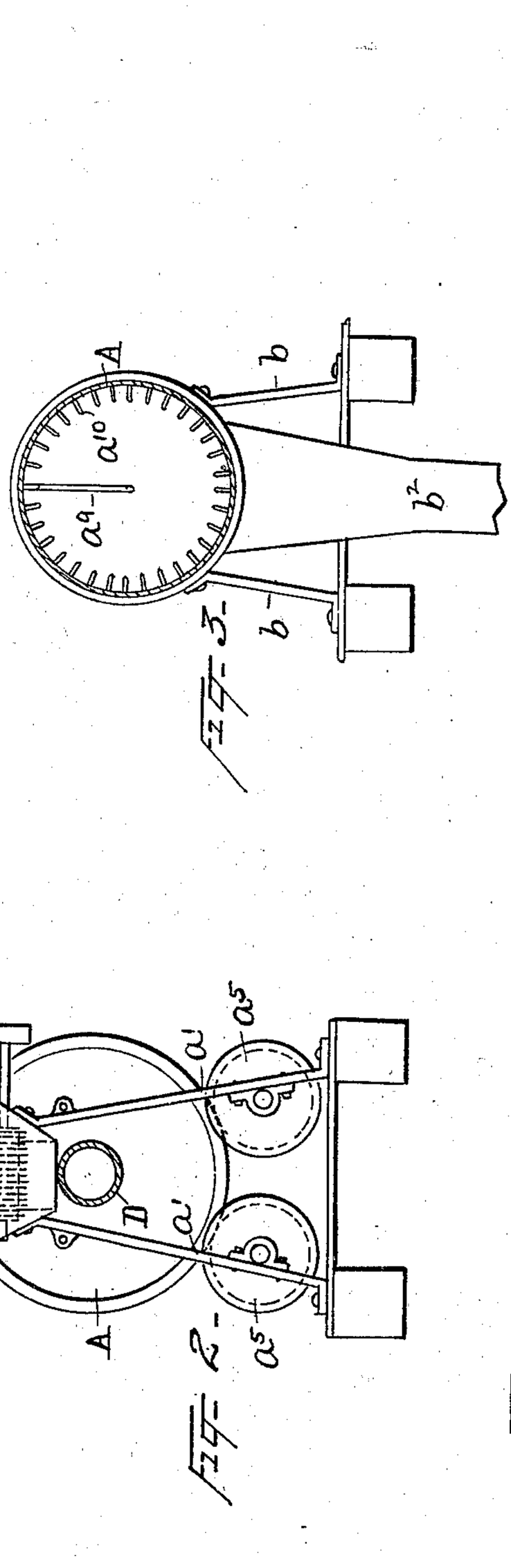

Fig. 3.

Fig. 2.

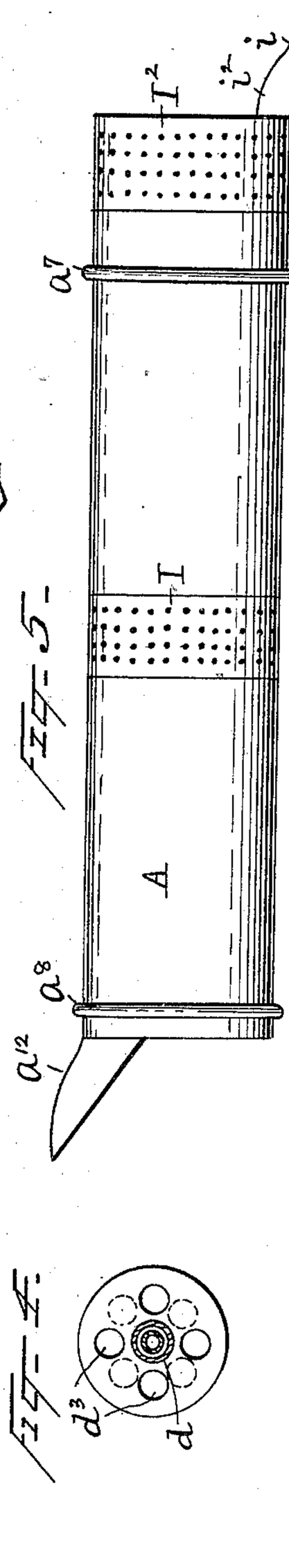

Fig. 5.

Fig. 4.

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METHOD OF HEATING MATERIALS FOR THE PURPOSE OF DRYING OR TREATING.

SPECIFICATION forming part of Letters Patent No. 708,946, dated September 9, 1902.

Original application filed May 28, 1897, Serial No. 638,659. Divided and this application filed June 7, 1901. Serial No. 63,658. (No specimens.)

To all whom it may concern:

Be it known that I, ABRAHAM T. WELCH, a citizen of the United States of America, and a resident of the city of Baltimore and State of Maryland, have invented certain new and useful Improvements in Methods of Heating Materials for the Purpose of Drying or Treating, (the application for which was filed in the United States Patent Office May 28, 1897, Serial No. 638,659, of which the present application is a division,) of which the following is a specification.

This invention relates to a method of heating materials for the purpose of drying or treating.

The objects are rapidly, thoroughly, and evenly to dry organic or other substances 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 the highest heat on entering the drier and being impinged upon or enveloped by a progressively-decreasing degree of heat toward the discharge, and, finally, to regulate the heat in the drier in such manner as to cause it to be proportioned to the bulk or body of the material to be desiccated.

With these objects in view the method consists of subjecting the goods in their wettest condition and largest mass to the direct or radiant action of a stream of heat in the form of a blast of air or flame of high temperature and pressure at its point of highest temperature and pressure in the drier and then successively subjecting the goods in constantly-declining quantities as they become dry to the action of the blast of flame or air, one or both, at points where the temperature is constantly declining, whereby the power and work are constantly balanced at all points in the drier.

This method may be carried into effect in many different forms of apparatus; but I will in this application describe a form which is effective to accomplish the desired result.

In a drier characterized by my invention I employ a rotary drum supported, preferably, in an inclined position, the lowest portion of the drum being at the discharge end. This drum is provided on its interior with a plurality of shelves or knives, which as the drum revolves pick up the material and drop it through the stream of heat, thereby effecting an initial, rapid-drying, and breaking up or dividing of the material and the prevention of balling or lumping thereof. These shelves or knives in this instance increase in number from the feed end of the drum to the discharge end—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 toward the discharge end of the drum the increased number of these shelves or knives will operate to break up and finely divide the material being desiccated, while the nearness to each other of the knives or shelves at the discharge end of the drum will effectually prevent any balling or massing of the material. The heat used for desiccating the material may be produced by burning gas or oil, and where gas is employed I use in conjunction with a burner a carbureting apparatus and a gravity-acting air forcing or blowing device, which in this instance is an ordinary airometer or receiver, although it is to be understood that a positive fan or blower may be employed. The gas from the carbureting apparatus passes to a burner constructed somewhat on the principle of a Bunsen burner and is there mixed with a jet of air, the air and gas thus mixed and ignited being forced into the drum in a manner that will be obvious. The inlet end of the burner is provided with an ordinary cut-off or regulating disk, by means of which the amount of air to the combustion-chamber may be controlled at will, and both the air-supply pipe and the gas-supply pipe are provided with a valve for regulating, respectively, the supply of gas and of air to the combustion-chamber. The feed end of the drum is closed by a head, 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, gas, or air, any or all, 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 stream of heat, flame, gas, or air to be projected in 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 enters it and materially interfere with the proper action of the drum. Opening into the drum above the combustion-chamber is a 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 inclosed by a dust-arrester consisting of a casing or hood constructed of foraminous or reticulated 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 end of the arrester clean and free from any accumulation of dust. This arrester and also the rear portion of the drum are housed in a dust-room, which is 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-arrester to cool or chill any dust which may escape from the dust-arrester and cause it to settle to permit of its being collected.

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

In the accompanying drawings, forming a part of this specification, and in which like letters of reference indicate corresponding parts, I have illustrated a form or embodiment of my invention, although it is to be understood that other forms or 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 line 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. Fig. 5 is a view in elevation of a modified form of drum.

Referring to the drawings, A designates a drum which may be of any suitable material, preferably of iron, having its inlet or feed end closed by a head or plate a, the same being held in position against the drum by means of 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 means of 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 a^8, secured around the drum. The periphery of the wheel a^6 is smooth; but the periphery of the wheel a^5 is provided with two flanges, between which the band a^8 works, so as to prevent longitudinal movement of the drum when the same is rotated. The rear end of the drum is 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 foraminous or reticulated screens, and the same are kept free from accumulation of dust by means of 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 is incased, the room being an ordinary chamber provided with a stack c for carrying off the vapors 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.

Secured to the interior of the drum and longitudinally of its length is a series of shelves or knives 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. As the material enters the drum it is of course in its most moist condition, and the shelves will pick it 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 knives or shelves will tend to break up, disintegrate, or finely divide 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 or 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, the opening where the material enters the drum being controlled 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.

Connecting with the head-plate a is a combustion-chamber D, in 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, will be filled with wool asbestos. 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-supply 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. 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 gas and of air 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 close openings d^3 in the rear plate of the said chamber, so as to regulate the supply of atmospheric air to the burner. The combustion-chamber D is provided with the 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 is supplied to the combustion-chamber and there mixed and lighted. 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 at the same relation with each other. The supply of air and gas is positively supplied and gravity controlled, as the weight of the holder of the airometer will by its weight operate to supply air under pressure to the burner so that there will always be a uniform supply of air and gas thereto, thereby avoiding fluctuation in the supply of heat with the corresponding variation in the desiccating power of the flame. 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, providing, of course, the supply of oil is maintained in the carbureter and the pump H is kept at work. The flame being now lighted, it will be projected into the drum any desired distance, its force being regulated, of course, by the volume of air admitted to the pipe E. The material is now fed to the hopper a^{12}, and as it passes into the drum is met by an intense heat, which will serve rapidly to dry the exterior of the material, this initial heat being what I term an "inducted" high temperature. As often as the material drops it is caught by the shelves a^{10} and is again lifted and dropped, being thus progressively subjected to the heat. As the material approaches the discharge end of the drum the temperature of the goods will gradually increase. Inducted heat will as the material passes through the length of the drum penetrate to the center of the material, and the slight moisture remaining will be driven out and be carried off by the gases of low temperature near the discharge end of the drum. 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 by practice that moist fish can be thoroughly and effectively dried without burning and that oyster-shells may at one operation be calcined by this form of drier. Other materials, such as hair and the like, are effectively dried without being burned, as the direct contact of the flame with the material is of such short duration that before the moisture is thoroughly eliminated from the exterior it will have passed beyond the zone of the flame and will thereby be protected from scorching.

The principle underlying this drier and that which distinguishes it from driers of ordinary construction is that the supply of air and heat are governed by gravity and by an induced draft, and by the arrangement of the burner at or near the point of entry of the material it effects the rapid drying of the material uniformly and continuously. The heat may be so regulated that at the inlet end of the drum the temperature will be but a few degrees above the atmospheric temperature and at the discharge end the same as the atmospheric temperature, or it may be raised to any number of degrees up to two thousand or more. By this regulation of the heat different materials may be dried

in the same apparatus, thereby extending its range of usefulness and adapting it for different usages. Moreover, by the regulation of the heat small or large quantities of material may be desiccated, as desired.

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 locate the feed-hopper at the inlet end and dispense with the disintegrating-drum and provide a hopper and a disintegrating-drum at the discharge end of the apparatus. This arrangement will be found advantageous where the material is in a very wet or soft and mushy condition, as where garbage has 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. As the surface of the material dries whatever moisture it contains will come to the surface and be evaporated.

While I have not shown the same 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, feed of gas, supply of feed of material, and speed of material through the apparatus are all proportionate, and all these steps are controlled by gravity, for it will be seen that the weight of the holder of the airometer will both regulate and effect the feed of air and fuel to the combustion-chamber. The material by its inherent weight will drop by gravity into the receptacle and when picked up by the shelves of the apparatus will drop by force of gravity and be progressively fed through the apparatus, providing the apparatus rotates uniformly. In other words, as the material becomes dry, and consequently lighter, the force of the blast will have a proportionate greater effect upon the goods to drive the same through the drum. The speed of travel of the material through the drier is dependent upon the effect upon it of the blast and the rolling of the pieces down the incline of the pile of goods in the drum. Given a blast of hot air and flame having a certain pressure the effect of this blast upon the pieces will be inversely proportionate to their weight and superficial area modified by such reduction of the driving force of the blast as will result from the condensation of the hot gases surrounding any particle of material. The dry piece or pieces nearly dry will have little or no effect to condense the hot gases and will consequently be driven out of the flame so quickly as not to be burned. As the drum rotates the incline of the pile of goods will cause the particles to roll down the incline and be driven out of the drum by gravity. Thus the power and work are balanced at all stages of the operation. 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 the feed end of the drum is not filled by the flame, and the goods fall through the flame to the cooler part of the drum without being raised to the point of scorching, the time during which the material is exposed to the direct action of the fire or hottest air and the time during which it is not exposed to the direct action of the fire or hottest air 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 or hottest air. They are also disintegrated by the action of the heat expanding the inclosed moisture. 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 a 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, and by regulating the inclination of the discharge end of the cylinder according to the character of the material being dried the regulation of these two means will be all that is necessary. 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 greatest 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 driving 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 a flame directly upon the goods for the purpose of drying 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 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; 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 an 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 continually 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 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 heat-blast spreads until it fills a larger 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 be-

coming 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 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 would 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 with 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 be substantially balanced at all points of the drum. The balancing of the power and work so that the material will be thoroughly dried and not burned is accomplished by regulating the amount of goods fed to the driving-cylinder, the force of the flame and the force of the air-blast, and the inclination of the drum. It is impossible to state any exact rule by which this can be done; but any one skilled in the art of drying would have no difficulty in so regulating these different elements as to accomplish the desired result, which is to balance the power and work. The fact that the power and work are balanced in all parts of the drier is shown to the operator by the fact of 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 are balanced at all points in the receiver 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.

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, so as to obviate waste of heat and also injury to the material. To effect this, I employ screens or sieves in the length of the drum, one of these screens, l', being located preferably about the middle of the length of the drum and the other, l^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 in a hopper i^2 at the discharge end of the drum. As will be seen by reference to Fig. 5, 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, so as to effect the final drying.

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

1. The process of heating materials continuously without burning for the purpose of drying or treating, which consists of dropping the same through flame intermittently, and then subjecting the material to gradually-declining heat, substantially as described.

2. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the same initially in large bulks, with agitation, to the action of high heat, and then in gradually-diminishing bulks to progressively-decreasing heat, and increasing agitation whereby thoroughly to dry the substances, and at the same time, finely divide the same, substantially as described.

3. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the goods to successive portions of a flame of diminishing intensity.

4. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the goods to successive portions of a flame of diminishing intensity, and agitating the materials in the air.

5. The method of heating materials without burning for the purpose of drying or treating, which consists of dropping them through, or near, flame intermittently to heat them, and progressively decreasing the heat, substantially as described.

6. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the pieces to the direct or direct radiant action of a blast-flame for a period of time dependent upon and controlled by the moisture to be evaporated.

7. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the material intermittently to the direct or direct radiant action of flame, the period of subjection to the higher temperature, and the period of subjection to the lower temperature, being so proportioned that the temperature of the material will never rise to the ignition-point.

8. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the materials to the direct or direct radiant action of flame and a blast for a period of time dependent upon and controlled by its weight.

9. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the materials

to the direct or direct radiant action of flame and a blast for a period of time dependent upon and controlled by its weight, and the amount of moisture to be evaporated.

10. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the material intermittently to the direct or direct radiant action of flame for a period of time dependent upon its weight, and the speed of feed.

11. The method of heating material without burning for the purpose of drying or treating, which consists of subjecting the material to the direct or radiant action of a flame, the work and the power being substantially balanced at all stages of the process, substantially as described.

12. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the materials to be heated to the direct or radiant action of a flame for a period of time, then withdrawing the material from the action of the flame at a speed directly proportional to the temperature of the flame.

13. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the materials to be heated to the direct or radiant action of a flame intermittently, and subjecting the material to the action of the flame in quantity substantially proportional to the temperature of the flame.

14. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the materials to be treated to the direct or radiant action of a flame, and then subjecting successive portions of said materials to constantly-declining temperatures, in quantities substantially proportional to the temperatures, and simultaneously feeding fresh material to the flame.

15. The method of heating mixed materials of varying size and weight, without burning, for the purpose of drying or treating, which consists of subjecting the material to be treated to the direct or radiant action of a flame and blast, intermittently passing the materials through the flame and blast, whereby the lighter and drier materials will be driven by the blast away from the flame toward its point of minimum temperature, while the heavier particles will be driven proportionally a less distance.

16. The method of heating material without burning for the purpose of drying or treating, which consists of subjecting the greatest quantity of material to be dried in its highest heat-absorbing condition, to the direct or radiant action of a flame at its point of maximum temperature, and gradually reducing the quantity as the temperature of the flame diminishes, substantially as described.

17. The method of heating materials without burning for the purpose of drying or treating, which consists of subjecting the greatest quantity of material to be treated, in its highest heat-absorbing condition, to the direct or radiant action of a flame, at its point of maximum temperature, intermittently subjecting the material to the direct action of the flame in constantly-declining quantity as the temperature decreases.

18. The method of heating materials continuously without burning, for the purpose of drying or treating, which consists of subjecting the maximum quantity of material to be heated, in its highest heat-absorbing condition, to the direct or radiant action of a flame, gradually withdrawing the material from the action of the hottest flame and subjecting it in constantly-reducing mass to a gradually-reducing temperature, and simultaneously supplying fresh material in its highest heat-absorbing condition.

19. The method of heating mixed materials of varying size and weight, without burning, for the purpose of drying or treating, which consists of subjecting the greatest quantity of material to be heated, in its highest heat-absorbing condition, to the direct or radiant action of a flame at its point of maximum temperature, intermittently passing the material through the flame, whereby the lighter and drier materials will be driven by the blast of the flame from the point of maximum temperature of the flame toward its point of minimum temperature, while the heavier particles will be driven a less distance from the point of maximum temperature of the flame.

20. The method of drying material which consists in subjecting the wettest goods to the direct action of flame for a period of time dependent upon and controlled by their contained moisture, and then withdrawing them from the action of the flame, and then subjecting them to a gradually-decreasing temperature.

21. The method of drying materials which consists of subjecting the wet goods to the direct action of flame for a period of time dependent upon and controlled by the contained moisture, and then automatically withdrawing them from the action of the flame.

22. The method of drying materials which consists of subjecting the wet goods to the direct action of a flame for a period of time dependent upon the contained moisture, and regulating the effective temperature of the flame upon the goods, by regulating the quantity of goods fed to the flame.

23. The method of drying materials which consists of subjecting the wet goods to the direct action of a flame for a period of time dependent upon and controlled by their contained moisture and then withdrawing them from the action of the flame automatically by agitation and blowing.

24. The method of drying materials which consists of subjecting the wet goods to the

direct action of a flame for a period of time dependent upon and controlled by their contained moisture and then withdrawing them from the action of the flame by agitating an inclined mass and blowing.

25. The method of drying materials which consists of subjecting the wet goods to the direct action of a flame and regulating the effect of the flame upon the goods by regulating the quantity of goods fed to the flame.

26. The method of drying materials which consists of subjecting the wet goods to the direct action of a flame for a period of time dependent upon their contained moisture, and regulating the effects of the flame upon the goods by regulating the quantity of goods fed to the flame.

27. The method of drying which consists of subjecting the goods while passing through the drier to the direct action of a flame and hot air, while so maintaining the relative temperatures of the air and goods that the air will always continue to absorb moisture.

Signed by me, at Baltimore city, State of Maryland, this 22d day of May, 1901.

ABRAHAM T. WELCH.

Witnesses:
HOWARD D. ADAMS,
NORRIS F. CLARK.