Jan. 7, 1947. F. H. VAN DOORNINCK 2,413,933

MATERIAL HANDLING APPARATUS

Filed Jan. 1, 1944 2 Sheets-Sheet 1

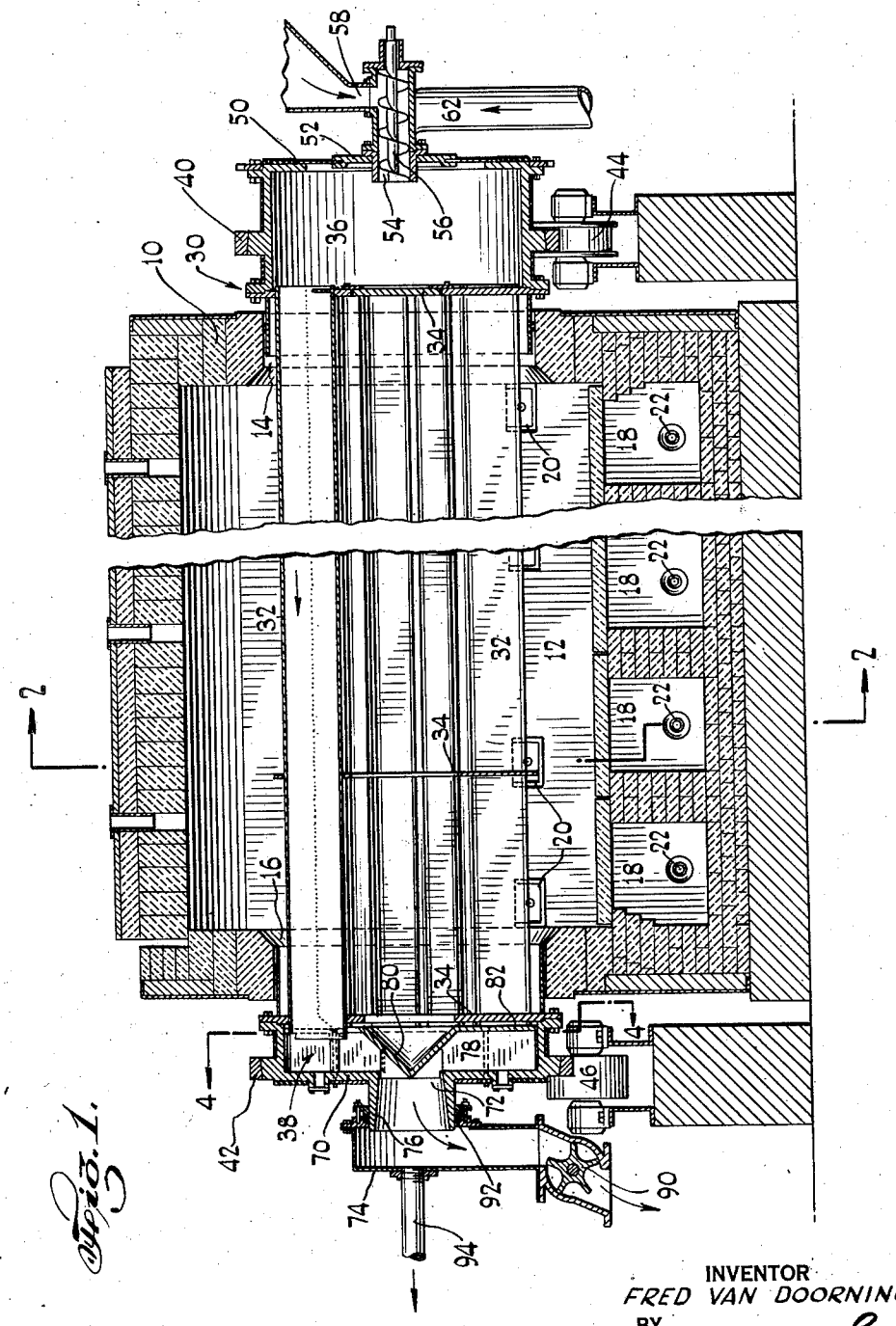


Fig. 1.

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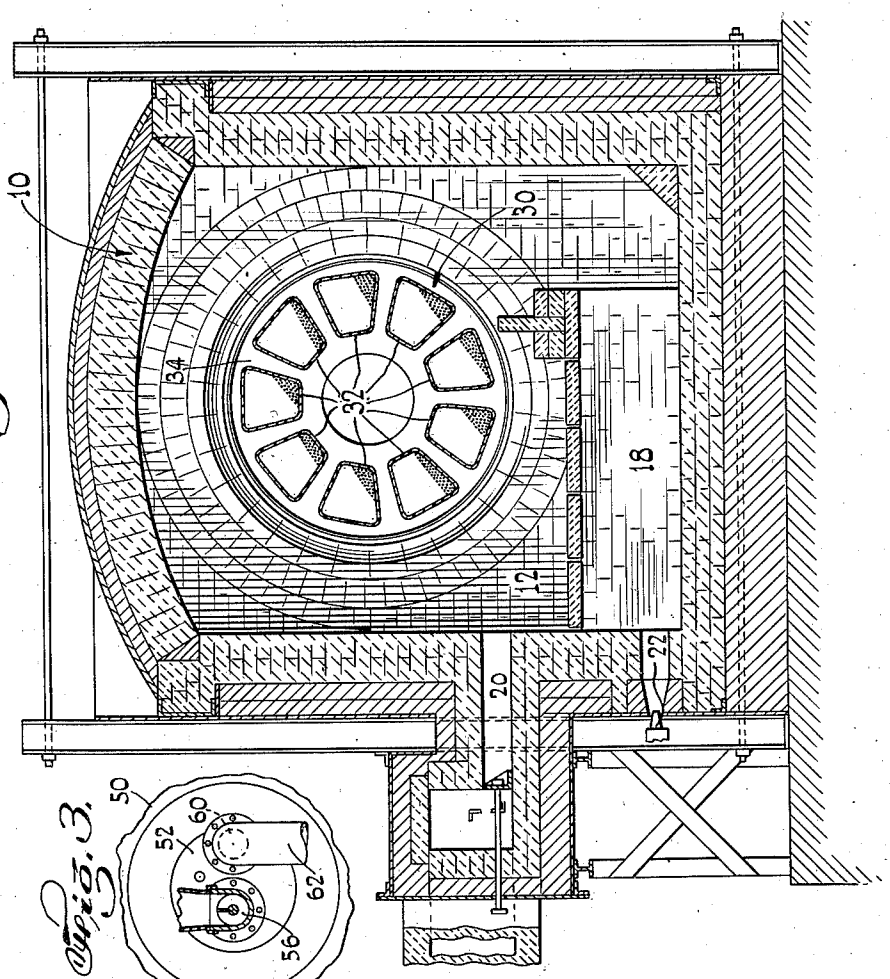


Fig. 2.

Fig. 3.

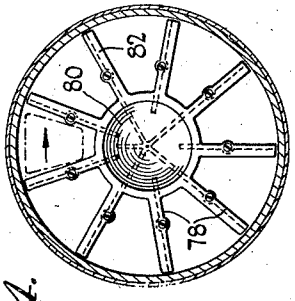


Fig. 4.

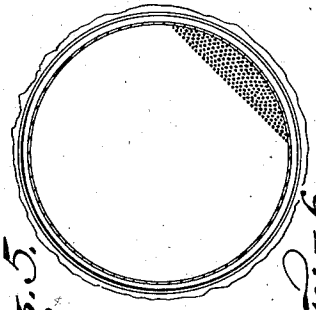


Fig. 5.

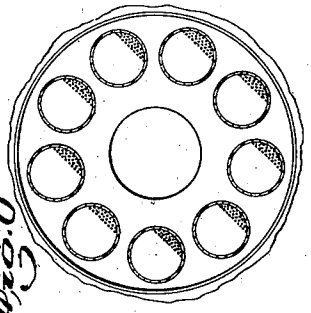


Fig. 6.

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UNITED STATES PATENT OFFICE

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MATERIAL HANDLING APPARATUS

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Application January 1, 1944, Serial No. 516,640

4 Claims. (Cl. 263—34)

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This invention relates to new and useful improvements in material handling apparatus and more particularly to rotary muffles for the heating or roasting of solid materials.

The calcination, decomposition or fusion of metallic ores and their salts, particularly the ores and salts of iron and chromium, is ordinarily carried out by heating or roasting the material in elongated rotary kilns. The kilns, according to conventional practice, are slightly inclined cylinders or drums, varying from 50 to 100 feet in length and from 5 to 10 feet in diameter, which are lined with refractory material and mounted for rotation at a suitable low speed. The material to be treated is charged into the elevated end of the drum, and it passes by gravity through the entire drum during rotation thereof, after which it is discharged at the lower end. A firebox is located adjacent the lower end of the kiln, and heat and gases from the combustion of coal, coke, gas or oil in this firebox sweep through the drum in contact with materials therein and exit through a flue at the upper end.

In the use of this conventional type of apparatus the material undergoing treatment remains in a layer in the bottom of the drum, and evenness of heat transfer is promoted by the overrunning of the material and the exposure of new surfaces to heating effects during rotation of the drum. For efficient and uniform heat transfer only a shallow layer of material can be treated satisfactorily, so that the thruput or producing capacity of a kiln of given size is definitely limited.

The only means of increasing thruputs when using the common type of kiln is to provide a larger drum, or to use higher heating temperatures, or to speed up the rotation of the drum. Larger apparatus, of course, is quite expensive, since the size of the drum cannot be varied without also reconstructing the furnace or firebox. Temperature increases are impracticable because the temperatures of treatment are limited by the nature of the material undergoing treatment. The speed of rotation of the drum also is limited by practical operating requirements, since a substantial increase in speed results in under-treatment of the material whenever definite temperatures and periods of treatment are required for proper process results. In the use of this common type of apparatus it therefore has been impracticable to obtain increased thruputs or capacity except by using

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larger drums, both in diameter and length, or by providing additional units of apparatus.

Other disadvantages of the conventional type of rotary drum reside in its restricted capacity for and inefficiency of heat transfer, in the possibility of incompletely or improperly treating part of the material inside the drum, and in the difficulty of controlling the composition of gases inside the kiln whenever the material demands special gas treatment.

An object of the present invention is to provide new and improved material handling apparatus of the rotary muffle type which has a substantially increased treating capacity for a given size of muffle in comparison with known apparatus for similar purposes.

Another object of the invention is to provide heat transfer apparatus of the rotary muffle type which is characterized by improved efficiency and uniformity of heat transfer. More particularly, it is an object of the invention to provide a rotary muffle which makes available a greater amount of heat energy for the treatment of solid materials; also, to increase the area of contact between the material and heat-transferring surfaces of the apparatus, thus effecting a faster rate of heat absorption; also, to increase the overrunning and the rate of exposure of the material to heating effects; and also, to reduce the depth of the material load when handling a given volume of material in a muffle of given size.

Still another object of this invention is to provide heat transfer apparatus of the rotary muffle type by which the transfer of heat to material inside the muffle is carried out indirectly and in a manner enabling close control over temperatures and other conditions of treatment.

Another object of the invention is to provide roasting apparatus for the continuous calcination or decomposition of chemical compounds by heat obtained from the combustion of fuel, which apparatus permits the recovery in concentrated form of gases evolved in the course of the decomposition without contamination of the gases by combustion products.

A further object of the invention is to provide a rotary muffle which in operation presents considerably less void space than kilns or muffles of known type and thereby improves the heat transfer and facilitates the subjection of materials inside the muffle to special gas treatment when demanded. Other objects and advantages of the invention will become apparent from the following description.

The apparatus provided by the present inven-

tion is adapted particularly for the calcination, decomposition or fusion of ores and salts of iron and chromium, although it may be used to advantage for the treatment of other metallic ores and salts, or for other analogous processes involving the handling and heating of solid material.

According to a principal feature of this invention, I have found that the capacity of a rotary muffle or kiln may be increased without increasing its size, and also that the heat transfer characteristics of the muffle and its effectiveness for various calcination and decomposition treatments may be greatly improved, by replacing the common type of single cylinder or drum by a multiplicity of elongated individual tubes of comparatively small diameter which are disposed around the axis of rotation of the muffle, preferably at equal radii from the axis, and which communicate with a common header at the upper, or charging, end of the inclined muffle and with another common header at the lower, or discharging, end of the muffle.

The new muffles embodying this arrangement are preferably made of strong, corrosion-resistant, creep-resistant metals, such as, for example, the chromium irons and steels alloyed in smaller percentages with metals such as nickel, tungsten, molybdenum and manganese. Parts of the apparatus that are subject to contact with decomposing materials and corrosive gases are thus rendered resistant to corrosion at temperatures below 2200° F.

The transfer of heat to the muffle and its contents is preferably effected by combusting a suitable fuel, such as oil, from burners located at selected points in a firebox or furnace which surrounds the muffle tubes. Heat thus supplied to the walls of the muffle is transmitted to materials inside the several muffle tubes by conduction and radiation. With this system the feeding and discharging of solid materials and gases may be carried out under positive control while keeping the muffle closed against the entrance of uncontrolled amounts of air or combustion gases.

According to another important feature of the present invention, the several muffle tubes in an arrangement such as disclosed above are made polygonal, and preferably quadrilateral, in cross section. In preferred embodiments of the invention the muffle comprises a multiplicity of elongated individual tubes, each quadrilateral in cross section, which are straight and parallel and are disposed in circularly spaced relation around the axis of rotation of the muffle, at substantially equal radii from its axis. I have found that the use of tubes of quadrilateral cross section results in further advantages, as compared with tubes of other form, with respect to the efficiency and uniformity of heat transfer to materials in the tubes. I have also found that the quadrilateral tubes give added advantages in the treatment of certain types of materials and in the construction of the muffle. These advantages, together with the important advantages which accrue from the multi-tube rotary muffle irrespective of this particular cross-sectional shape of the tubes, will be explained more fully hereinbelow.

An illustrative form of apparatus, typifying a preferred embodiment of the invention, is shown in the accompanying drawings, in which

Figure 1 is a vertical longitudinal section showing material handling and heating apparatus

comprising an assembly of the new rotary muffle with a surrounding furnace or firebox.

Figure 2 is a vertical transverse section, approximately along the line 2—2 of Figure 1.

Figure 3 is a fragmentary end view of the muffle, as viewed from the right hand end of Figure 1; and

Figure 4 is a vertical transverse section through the muffle, approximately along the line 4—4 of Figure 1.

Figure 5 is a diagrammatic view, in vertical cross section, illustrating the form and action of the common type of rotary kiln comprising a single large cylinder or drum, and

Figure 6 is a similar view showing a rotary muffle, of the same over-all diameter, that is constructed with a multiplicity of tubes according to the present invention, the tubes in Figure 6 being circular in cross section.

As illustrated in Figures 1 and 2, a furnace or firebox 10, constructed of suitable refractory material, comprises an elongated heating chamber 12 through which extends the rotary muffle 30. The end walls of the furnace are provided with oppositely disposed openings 14 and 16, and opposite end portions of the muffle project through these openings. A plurality of burner chambers 18 are located in the lower part of the furnace. Flues 20 communicate with the heating chamber 12. Burners 22 are arranged to inject fuel, for example, fuel oil, into the respective burner chambers, where combustion takes place to heat the muffle.

The rotary muffle 30 is generally cylindrical in form. It comprises a multiplicity of comparatively small elongated tubes 32 which are supported in parallel relation and are circularly disposed around the axis of supporting spiders 34. In the illustrated embodiment there are nine muffle tubes. The tubes extend through the heating chamber 12, and at one of their ends they open into a common charge header 36. At their opposite ends they communicate with a common discharge header 38. The walls of tubes 32 are made of suitable heat-conducting material, such as sheet metal. To withstand strains and the corrosive effects of certain materials, gases and decomposition products at high temperatures, the muffle tubes and header walls are preferably made of strong corrosion-resistant metal, such as the chromium iron and steel alloys mentioned hereinabove.

Means are provided for rotating the muffle, including tubes 32 and headers 36 and 38, at any suitable speed. For example, tires or rings 40 and 42 are secured to the muffle adjacent its opposite ends, and these tires ride on appropriate rollers 44 and 46 which may be driven to cause rotation of the muffle. The entire muffle may be mounted quite horizontal, or at a slight inclination. In either event, the accumulation of material in the header 36 and the rotation of the muffle cause the material to travel through the muffle by gravity, at a suitable rate which may be varied by changing the rate of rotation.

The charging of solid material into the muffle, usually in pulverized or granular condition, is effected by charging means communicating with header 36. An illustrative arrangement appears in Figures 1 and 3. The muffle end wall 50 joins rotatively with a stationary central wall section 52, and the latter provides a port 54 through which the material may be fed into the header. A screw conveyor 56, supplied from a feed tube

58, constitutes a suitable charging device. The charging device and the connection between end wall 50 and wall section 52 are preferably made substantially gas-tight in order to permit control over atmospheric conditions in the muffle.

In addition, means are provided for introducing controllable amounts of air or other gas into the muffle. For this purpose, wall section 52 may comprise a second port 60 communicating with a gas supply pipe 62 by which air or other gas may be supplied to header 36 and thence to the muffle tubes.

At the lower or discharge end of the muffle, means are provided for handling and discharging materials as they leave the muffle tubes 32. For example, an end wall 70 of header 38 comprises a centrally located outlet opening 72 which communicates with a stationary hood 74 through an annular flange 76. The muffle tubes 32 discharge into header 38, and the material is then delivered into hood 74, through opening 72 and flange 76, by suitable means such as, for example, the radial vanes or lifters 78, which rotate with the muffle, and a centrally disposed discharge cone 80 which directs material falling from the lifters into the outlet opening. The lifters 78 and cone 80 may be mounted on a common supporting spider 82. Since it is often desirable that the atmosphere surrounding the material in the muffle be controlled, either for efficient gas recovery or in order to maintain particular atmospheric conditions in the muffle, the discharge of the material from hood 74 is preferably effected by gas-tight means, such as a star wheel 90. It is also preferable to arrange hood 74 in sealed relation to the muffle, as by means of a packing or gland 92 which fits around flange 76 in such manner as to prevent substantial leakage of gases. Since the muffle chambers are closed and separated from the firebox in which the heating fuel is burned, it is possible to effect complete recovery of decomposition gases from the muffle, in concentrated form, without contamination of the gases by products of combustion. The hood 74 may have any suitable gas connections, such as connection with an exit pipe 94, in order to draw off gases from the muffle.

The handling or treatment of material in the muffle should now be apparent. The material is charged into header 36 during rotation of the muffle, and as the material accumulates in the header it is distributed into the inlet ends of the several muffle tubes 32. A layer forms in each tube, and the material in each layer continually overruns and exposes new surfaces during rotation of the muffle, while also gradually progressing lengthwise of the respective tubes. When the material finally reaches the lower or outlet ends of the tubes, it falls into header 38, from which it is continually discharged into hood 74 by means such as described hereinabove. Discharge of material from the entire system is effected by rotation of star wheel 90.

The transfer of heat to material in the muffle takes place by transmission and radiation from the heat-transferring walls of the muffle tubes 32, which in turn are heated directly by combustion of fuel in the surrounding furnace. Important advantages with respect to efficiency and uniformity of heat transfer are obtained in the use of the multi-tube muffle, regardless of any particular cross-sectional shape of the muffle tubes, for reasons now to be explained by comparing the common type of kiln or muffle, consisting of a single large cylinder as illustrated diagrammatically in Figure 5, with a multi-tube muffle using tubes that are cylindrical, or circular in cross section, as illustrated diagrammatically in Figure 6.

A first advantage of the multi-tube rotary muffle over the common type of single cylinder is that it increases the area for heat energy absorption. By illustration, assuming that the muffles illustrated in Figures 5 and 6 both have an overall diameter of 3 feet, the former has a surface area of about 113 sq. in. for every inch of length, while the multi-tube muffle has a surface area of about 219 sq. in. for every inch of length. Thus it is evident that the available heat energy which may be absorbed by the material in process is nearly doubled in the case of the new rotary muffle, assuming that all other factors affecting the heat exchange are the same.

A second advantage of the multi-tube rotary muffle is that the material in the muffle has a much greater surface exposure and thus is able to absorb heat much faster than in the case of the common type of apparatus. A volume of 61.5 cu. in. of material per inch of length, in the drum of Figure 5, has an exposure surface of about 23 sq. in. In the case of a multi-tube rotary muffle of the same overall size, the same volume of material has an exposure surface of over 54 sq. in.

A third advantage of the multi-tube rotary muffle is that it provides a larger area of contact between the material and the muffle and thus effects a faster rate of heat absorption. Referring again to the illustrations, 61.5 cu. in. of material per inch of length in Figure 5 has a contact area with the drum of about 24.7 sq. in. In Figure 6, the same volume of material has a contact area with the muffle of about 65.25 sq. in.

A fourth advantage of the multi-tube rotary muffle is that it reduces the depth of the material load for a given volume of material. By comparison of Figure 5 and Figure 6 it will be understood that a 4 inch material load in the common apparatus corresponds to a load of about 1.6 inches maximum depth in the multi-tube muffle of circular cross-section. The advantages of a thin material load are several; for example:

(*a*) It reduces the core area, or zone of partially processed material;

(*b*) In the handling of materials which evolve decomposition gases, it minimizes the area within the material where the partial pressure of the decomposition gases becomes so great that the decomposition rate is materially reduced; and

(*c*) Under the same circumstances as (*b*), it permits a neutral gas more efficiently to carry away from the material the decomposition gases evolved in process.

A fifth advantage of the multi-tube rotary muffle is that it reduces the void space in the muffle. The volume not occupied by material in Figure 5 is about 956 cu. in. for every inch of length. In Figure 6 the void space is about 363 cu. in. for every inch of length. This reduction in void space gives important benefits in processing when the material demands special gas treatment.

A sixth advantage of the multi-tube rotary muffle is that it enables faster absorption of radiant heat because the distance between the material and the muffle wall is reduced. This reduction in length of heat travel would offer no advantage in a clear, dust-free atmosphere, but

in the commercial operation of rotary muffles dusting always takes place, and the amount of radiant heat passing to the material varies inversely with the quantity of dust in the muffle atmosphere and the distance the radiant heat must travel through the dust-laden atmosphere before it reaches the material.

A seventh advantage of the multi-tube rotary muffle is that this type of construction permits the use of thinner walls without loss of muffle strength and thus permits faster heat transfer through the muffle walls.

As heretofore mentioned, another important feature of this invention resides in constructing the tubes of the multitube rotary muffle so that they are polygonal, and preferably quadrilateral, in cross section. This feature is embodied in the preferred form of apparatus as seen in Figure 1 and Figure 2 of the drawings. Referring particularly to Figure 2, it is apparent that each of the muffle tubes 32 is quadrilateral in cross section; also that this form of tube results in special handling of the material during rotation of the muffle such as not obtained by the use of tubes of circular cross section.

More specifically, the several muffle tubes 32 as illustrated in Figure 2 are preferably disposed circularly and in equally spaced relation around the axis of rotation of the muffle, at equal radii from the axis. Each tube is substantially trapezoidal in cross section, with the sides of the trapezoid extending radially from the axis of rotation. For best results in the feeding and distribution of the material, the radius of the corners of these tubes should not be less than one inch.

The multi-tube type of rotary muffle having tubes of quadrilateral cross section provides special advantages which are not obtained by the use of tubes of circular cross section. The differences in the action of these embodiments of the present invention, and also a further comparison with the common type of single drum, may be gathered by reference to Figures 2, 5, and 6. These figures represent the different constructions as being of the same overall diameter, in a manner by which direct comparisons may be made.

One of the special advantages of the multi-quadrilateral tube rotary muffle is that it exposes an increased area of muffle wall for heat absorption and therefore possesses a greater capacity for passing heat energy from the outside to the inside of the muffle. The approximate relationships for muffles having an overall diameter of 3 feet are:

Figure 5—113 sq. in. per inch of length.
Figure 6—219 sq. in. per inch of length.
Figure 2—256 sq. in. per inch of length.

Another special advantage of the multi-quadrilateral tube rotary muffle is that the area of contact between the material and the muffle wall is increased, the approximate relationships being:

Figure 5—24.7 sq. in. per inch of length.
Figure 6—65.25 sq. in. per inch of length.
Figure 2—72.95 sq. in. per inch of length.

Another advantage of the rotary muffle having a multiplicity of tubes of quadrilateral cross section is that this construction does not permit a core area to exist in the material, but, instead, it effects positive and complete turn-over of the material during rotation of the muffle. A further advantage is that the sliding of material through the muffle is substantially reduced, if not positively eliminated.

The multi-tube rotary muffle having quadrilateral sections gives substantially the same surface exposure of the material as in the case of the circular sections. The maximum depth of the material load is somewhat greater, the relationship being approximately 2.12 inches to 1.6 inches, but this depth is still almost half of that obtained in the use of the common type of single drum, and the improvement in the overturning of the material more than compensates for the increased maximum depth as compared with tubes of circular cross section.

While I have shown and described specific features of preferred embodiments of this invention, together with numerous details of construction, I am aware that the novel features of the invention may be employed in many other forms and for the treatment of various types of material. I therefore desire that the invention be accorded a scope fully commensurate with its contributions to the art, as limited only by the fair requirements of the appended claims.

I claim:

1. Material handling apparatus for the calcination, decomposition or fusion of metallic ores or salts comprising a closed rotary muffle including a multiplicity of elongated individual tubes disposed around and in parallel relation to the axis of rotation of the muffle, a common charge header connected with and enclosing all of said tubes at one of their ends and a common discharge header connected with and enclosing all of said tubes at their other ends, a firebox surrounding said tubes between said charge header and said discharge header, a plurality of burners in said firebox arranged to heat said tubes substantially uniformly longitudinally thereof as the muffle is rotated, each of said tubes being made of heat- and corrosion-resistant metal, means for feeding the material to be treated into said charge header during rotation of the muffle, wherefrom the material passes into the respective tubes and from which it passes into said discharge header, means for discharging material from said discharge header during rotation of the muffle, a sealed stationary hood arranged in substantially gas-tight relation to said discharge header for receiving material discharged therefrom, means for introducing gas into said charge header and thence into said tubes and means connected with said hood for exiting gases from the muffle.

2. Material handling apparatus for the calcination, decomposition or fusion of metallic ores or salts comprising a closed rotary muffle including a multiplicity of elongated individual tubes disposed around and in parallel relation to the axis of rotation of the muffle, a common charge header connected with and enclosing all of said tubes at one of their ends and a common discharge header connected with and enclosing all of said tubes at their other ends, a firebox surrounding said tubes between said charge header and said discharge header, a plurality of burners in said firebox arranged to heat said tubes substantially uniformly longitudinally thereof as the muffle is rotated, each of said tubes being made of heat- and corrosion-resistant metal and being quadrilateral and substantially trapezoidal in transverse cross-section with the sides of the trapezoid extending substantially radially from said axis, means for feeding material to be treated into said charge header during rotation of the

muffle, wherefrom the material passes into the respective tubes and from which it passes into said discharge header, means for discharging material from said discharge header during rotation of the muffle, a sealed stationary hood arranged in substantially gas-tight relation to said discharge header for receiving material discharged therefrom, means for introducing gas into said charge header and thence into said tubes and means connected with said hood for exiting gases from the muffle.

3. Material handling apparatus for the calcination, decomposition or fusion of matallic ores or salts comprising a closed rotary muffle including a multiplicity of elongated individual tubes disposed around and in parallel relation to the axis of rotation of the muffle, a common charge header connected with and enclosing all of said tubes at one of their ends and a common discharge header connected with and enclosing all of said tubes at their other ends, a firebox surrounding said tubes between said charge header and said discharge header, a plurality of burners in said firebox arranged to heat said tubes substantially uniformly longitudinally thereof as the muffle is rotated, each of said tubes being

made of heat- and corrosion-resistant metal, means for feeding the material to be treated into said charge header during rotation of the muffle, wherefrom the material passes into the respective tubes and from which it passes into said discharge header, means for discharging material from said discharge header during rotation of the muffle, a sealed stationary hood arranged in substantially gas-tight relation to said discharge header and having an axial opening thereinto through which to receive material discharged therefrom, said discharging means including a plurality of radial vanes in said discharge header and a cone disposed axially with respect thereto and projecting into said opening for receiving treated material from said tubes and discharging such material through said opening, means for introducing gas into said charge header and thence into and through said tubes, and means connected with said hood for exiting gas from the muffle.

4. Apparatus as described in claim 1, said hood having substantially gas-tight means for removing treated material therefrom.

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