MEANS FOR COOLING SOLID PARTICULATE MATERIALS WITH FLUIDS

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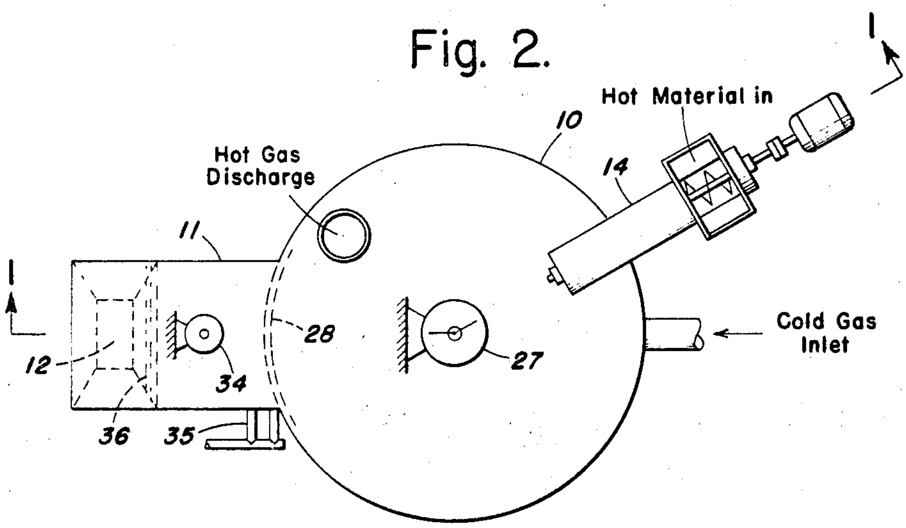
Fig. 2.



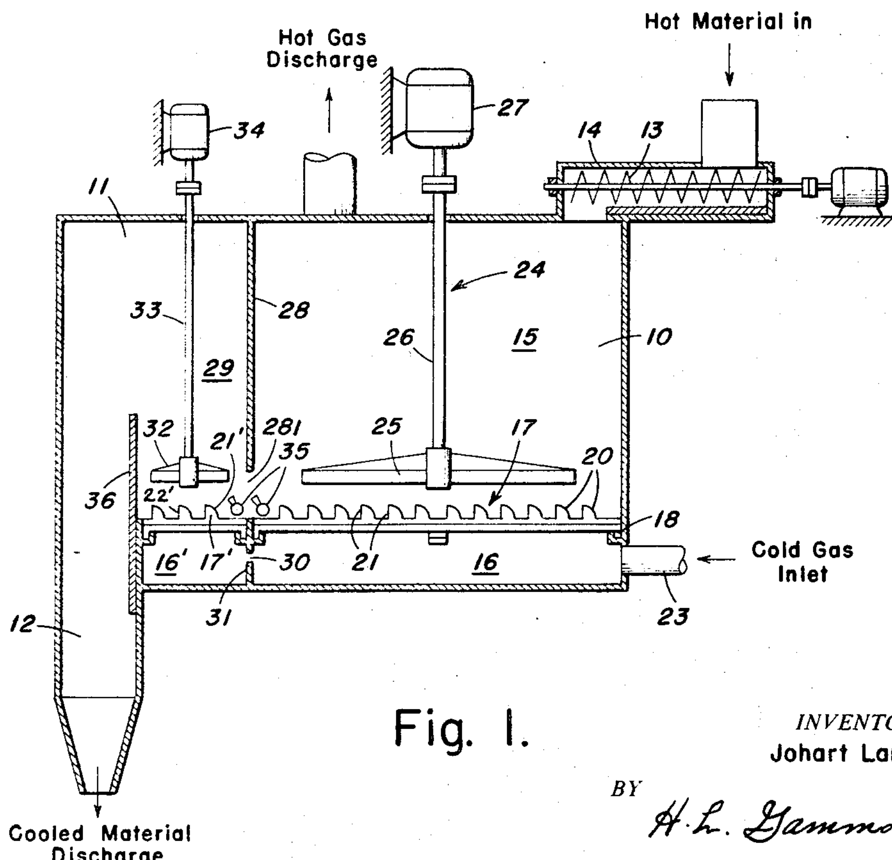


Fig. I.

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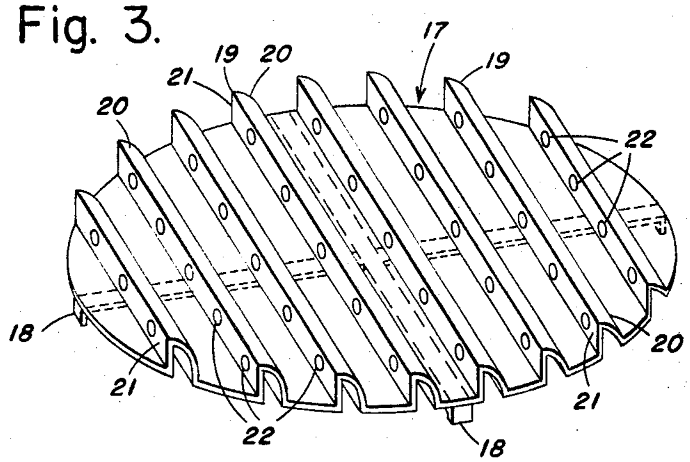
Fig. 3.



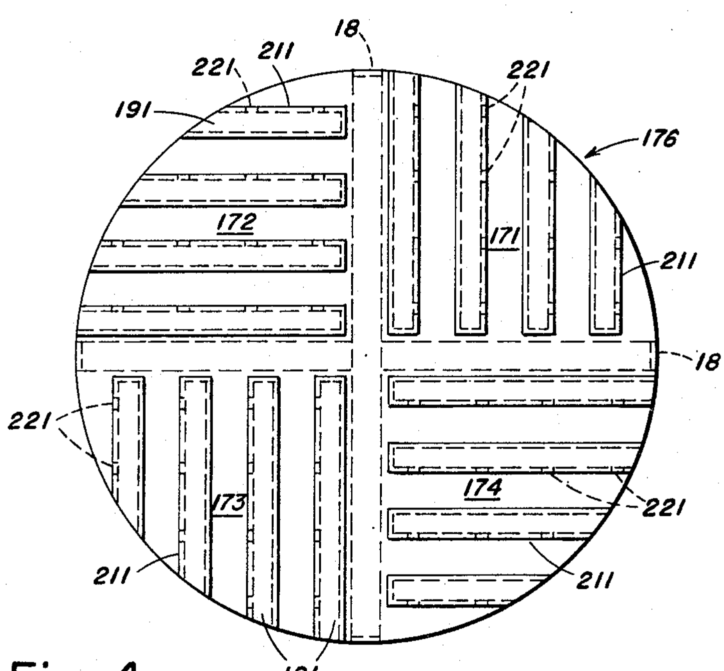


Fig. 4.

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MEANS FOR COOLING SOLID PARTICULATE MATERIALS WITH FLUIDS

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ABSTRACT OF THE DISCLOSURE

The present invention relates in general to heat exchangers and more especially to a means for cooling a hot, finely divided particulate material, by fluidizing the same with a relatively cold gas.

Background of invention

The field of art to which the invention pertains would appear to be refrigeration processes wherein a finely divided material is cooled by suspension in an upwardly directed current of cooling gases.

There are many industrial processes that involve the production of a finely divided solid material at high temperatures typical of which is the production of TiO_2 pigment either by the old and well known sulfate process or by the more recent vapor phase process. In each process a relatively hot finely divided TiO_2 material is produced which must be cooled at various stages for further processing and/or before bagging. Previous methods for cooling these hot finely divided materials include rotating screens, cooling barrels, fluidized beds of relatively cold particulate materials or air streams burdened with cold particulate materials. U.S. Patent 3,169,380, Cooling of Solids, Feb. 16, 1965, and patents referred to therein are illustrative of other prior art techniques. While these earlier techniques have been used with a modicum of success it is desirable to improve upon them both from the standpoint of economy and heat exchange efficiency.

Summary of invention

The invention pertains to a low cost, efficient means for cooling a solid particulate material, such as for example, titanium dioxide, by feeding the hot particulate material into the top of a cooling chamber in which the hot material is fluidized by admission of a cold gas into the bottom of the cooling chamber in a direction substantially parallel to the plane of its bottom surface the cold gas flowing upwardly countercurrent to the downwardly moving hot particulate material which is maintains as a relatively deep fluidized bed within the cooling chamber by a level control chamber connected to a discharge outlet at the bottom of the cooling chamber whereby highly efficient countercurrent heat exchange is made possible between the cooling gas and the hot particulate material, the efficacy of heat exchange being augmented by providing agitating means in either or both the cooling chamber and level control chamber to eliminate gas channeling and control agglomeration of the fluidized particulate material.

Brief description of drawings

FIG. 1 is a schematic vertical elevation, in section, of the apparatus of this invention;

FIG. 2 is a schematic plan view of the apparatus of FIG. 1;

FIG. 3 is an enlarged perspective view of the gas distributor plate used in the apparatus of FIG. 1; and

FIG. 4 is a plan view of a modified form of distributor plate.

Description of preferred embodiment

Referring to the drawings, FIGURES 1 and 2 show an embodiment of this apparatus which comprises, in general, three integrated units identified by the numerals **10**, **11** and **12** respectively, the unit **10** being hereinafter referred to as a cooling chamber, the unit **11** as a level control chamber and the unit **12** as a discharge duct. The cooling chamber **10** is the unit into which the hot solid particulate material is fed and held temporarily while being cooled. The solid particulate material may be a TiO_2 material such as calciner discharge, the milled TiO_2 from a steam micronizer or the hot pigmentary TiO_2 issuing from the reaction chamber of a vapor phase process for producing a pyrogenic TiO_2 material. In any case the hot material is adapted to be fed from a supply source into the cooling chamber **10** where it is temporarily retained while being subjected to the cooling action of a cold gas arranged to pass upwardly in counter current flow through the hot material to remove the latent heat therefrom; after which the cooled material is transported to the level control chamber and from thence to the discharge duct **12** as hereinafter described. The solid hot material may be fed into the cooling chamber **10** at any point therein, i.e., at the top or bottom thereof but for purposes of illustration the feed means is shown at the top of the chamber **10**. The feed means is preferably although not necessarily a power operated screw conveyor **13** assembled in a conduit **14** mounted on the top of the cooling chamber **10** to which the hot particulate material is delivered from a supply source not shown. The cooling chamber **10** is a substantially vertical vessel or chamber preferably although not necessarily of circular cross section, see FIG. 2, and is divided into an upper cooling zone **15** and bottom plenum chamber **16** by gas distributor means **17** which, as hereinafter described, is designed to feed cold gas from the plenum chamber **16** into the cooling zone **15** of the chamber **10** at sufficient velocity to fluidize the hot particulate material therein.

In the embodiment of the invention shown in FIGURE 3 the gas distributor means **17** comprises a circular plate corresponding in diameter to the I.D. of the cooling chamber and arranged to be secured therein in a substantially horizontal plane. The distributor plate **17** may be a single unit, as shown in FIGURE 3, or may comprise a plurality of separate sections, i.e., four quadrants, **171**, **172**, **173** and **174**, held together in the form of a single unit **176** as shown in FIGURE 4. Whether in the form of a single unit or a plurality of separate sections the distributor plate is supported in the cooling chamber **10** by a spider **18** or equivalent mechanical device. Moreover, the distributor plate or as the case may be, each section of the distributor plate, is characterized by a ribbed surface which, as shown especially well in FIGURE 3, comprises, preferably, a plurality of spaced parallel hollow ridges or corrugations **19** struck up from a sheet metal plate, each corrugation being substantially tooth-shaped in cross section. More particularly each tooth-shaped corrugation **19** comprises one sloping wall **20** and one wall **21** substantially perpendicular to the plane of the plate. Further, each perpendicular wall **21** is provided with a plurality of jet apertures **22** equally spaced there-along with the axis of each jet aperture substantially parallel to the plane of the plate. With reference to the modified form shown in FIGURE 4 the tooth-shaped corrugations are identified by the numeral **191**, the vertical walls by the numeral **211** and the jet apertures by the numeral **221**. As noted above, the distributor plate **17** is supported directly above the plenum chamber **16** which is provided with a gas inlet pipe **23** for feeding cold gas at super-atmospheric pressure into the plenum chamber and from thence out of the jet apertures **22** of the distributor plate into the cooling zone **15** of the chamber **10**. Due to the disposition of these jet apertures the cold gas is discharged therefrom in a horizontal plane. The effect of this is two-fold namely, it has been found that with the axes of the gas jet apertures **22** arranged substantially parallel to the plane of the distributor plate the apertures may be made relatively large and as a consequence the pressure drop across the distributor plate is comparatively low; moreover, there is a minimum of run-back of the solid particulate material into the plenum chamber **16**. As a consequence operational costs are lowered and plugging is substantially eliminated. The cold gas may be air or any other suitable gaseous medium, and is adapted to issue from the jet apertures **22** at a linear velocity such that the solid particulate material in the cooling zone **15** will be fluidized and simultaneously cooled. Operating in conjunction with the cold gas to fluidize and cool the solid particulate material is agitating means **24**. The use of fluidized beds for cooling solid particulate materials is not in itself new but whenever they have been used they have been found to augment the dust load, to be subject to plugging and gas channeling and to provide relatively inefficient heat transfer. It has now been found that by using one or more relatively low speed agitators in conjunction with a counter current flow of cold gas the transfer of heat from the hot fluidized material to the cold gas is augmented, plugging and channeling are eliminated, and some agglomeration of the solid particulate material is effected which minimizes the dust load.

To these ends the agitating means **24** comprises a multi-bladed sweep **25** carried on the lower extremity of a shaft **26** the upper end of which extends through the top of the cooling chamber and is connected to suitable drive means indicated generally at **27**. In this connection the effectiveness of the agitating means depends not only upon its speed of rotation, but also on the depth of the fluidized bed and the location of the agitator therein. For fluidized beds ranging from 4–26 inches in height the speed of rotation of the agitator is relatively slow, i.e., from 8 to 130 r.p.m. Moreover, while the location of the multi-bladed sweep **25** in the bed is not critical it is preferably located adjacent the bottom of the bed where it serves also to augment discharge of the cooled solid particulate material from the cooling zone into the level control chamber **11**.

As mentioned above the level control chamber **11** comprises one unit of the cooling apparatus and serves to assure countercurrent flow of the particulate material and the cooling gas by buffering the discharge of cooled material from the bottom of the cooling chamber so as to maintain a relatively deep bed in the cooling chamber **10**. It has been found that if no level control chamber is used and the particulate material in the cooling chamber is discharged therefrom directly through a bottom port an efficient countercurrent cooling effect can not be maintained. However by using the level control chamber **11** in conjunction with the cooling chamber **10** to maintain a relatively deep bed of particulate material in the cooling chamber counter current cooling for maximum heat exchange is assured. As shown in FIGURE 2 the level control chamber **11** is positioned on the side of the cooling chamber **10** substantially opposite the feed means **14**. A divider wall **28** having a connecting passage **281** to the bottom of the cooling chamber separates the level control chamber **11** from the cooling chamber **10**. The level control chamber **11** consists of an upper zone **29**, and air distributor plate **17'**, which is preferably although not necessarily coextensive with the air distributor plate **17**; an air plenum **16'** joined to the plenum **16** of the cooling chamber **10** by passage **30** through a divider **31**; and an agitator **32** carried on the lower end of a shaft **33** driven by drive means **34**. The air distributor **17'** is identical to air distributor **17** except for overall size; and air at superatmospheric pressure is adapted to issue from its jet apertures **22'** to maintain a fluidized bed of particulate material in zone **29** of the level control chamber **11**. The air plenum **16'** which supplies air to the level control chamber **11** by way of the jet apertures **22'** of the distributor plate **17'** receives air at superatmospheric pressure through passage **30** from plenum **16**. As in the cooling chamber **10** the agitator **32** in the level control chamber **11** is adapted to be rotated at relatively slow speeds, i.e., from 8 to 125 r.p.m. to control agglomeration and prevent air channeling.

Located adjacent the juncture of the level control chamber **11** with cooling chamber **10** is one or more air jet booster devices **35** which in the embodiment shown comprises two pipes each having a plurality of small holes in its upper wall. The air jets from these pipes are adapted to loosen up and assist the movement of the solid particulate material as it is transferred from the bottom of the cooling chamber **10** into the level control chamber **11** and to this end air under superatmospheric pressure is delivered to the apertured pipes **35** from a source not shown and issues from the holes therein as high velocity air jets.

The upper end of the discharge duct **12** opens into the level control tower **11** immediately above the distributor plate **17** and is adapted to be closed off therefrom by a manually operated gate valve **36** which serves to control the discharge of cooled material from the level control tower **11**.

The following examples will serve to further illustrate the invention.

EXAMPLE I

The solid particulate material to be cooled was, in this case, hot TiO_2 pigmentary material discharged from a micronizer the temperature of the pigment being about 340° F. The hot pigmentary TiO_2 was fed at the rate of about 65.3 lb./min. into the top of a cooling chamber **10** which consisted of a cylindrical tank five feet in diameter and about 38 in. high. The cooling zone **15** above the air distributor plate **17** was about 32 in. high and the depth of the bed material therein was about 11 in. The agitating means, which comprised two sweep arms set at 2 in. and 11 in. respectively above the distributor plate was rotated at 8 r.p.m. As shown especially well in FIGURE 1 the level control chamber **11** was substantially rectangular in cross section and extended radially from the side of the cooling chamber substantially opposite the material feed means. Cold air (40° F.) was introduced into the plenum chamber and passed upwardly through the distributor plate and issued from the horizontal jet apertures thereof at the rate of about 765 c.f.m. corresponding to about 55.2 lbs./min. at standard temperature and pressure. The hot pigmentary TiO_2 was thereby fluidized and simultaneously cooled by the upwardly flowing cold gas. Moreover the relatively slow sweep of the agitator eliminated air channeling in the bed and produced a mild agglomeration of the pigment particles which minimized dust load and augmented heat transfer from the hot pigmentary material to the cold air. The velocity of the cold gas entering the level control chamber was the same as in the cooling chamber **10** and contributed some additional cooling effect. The agitator **32** was rotated at about 120 r.p.m. The heat loss of the pigment in B.t.u./hr. sq. ft. bed section was 8800 and the temperature of the pigmentary TiO_2 discharged from the cooling tower was about 115° F. Pressure drop was 4 inches water gauge.

EXAMPLE II

A second lot of hot pigmentary TiO_2 was cooled using the equipment described in Example I but in this run the temperature of the air was 75° F. and it was introduced into the cooling zone at the rate of 1238 c.f.m. or 91.8 lb./min. standard temperature and pressure. The agitator was rotated at 130 r.p.m. and the pigmentary TiO_2 was fed into the cooling zone at a temperature of 330° F.

and at the rate of 79.2 lb./min. to form a bed about 16 inches deep. The heat loss of the pigment in B.t.u./hr. sq. ft. bed section was 7800, the temperature of the pigmentary TiO_2 discharged from the cooler being 165° F. Pressure drop was 5.1 inches water gauge.

EXAMPLE III

Another run was made using the equipment described above but in this case the temperature of the air was 95° F. and it was introduced into the cooling zone at the rate of 1058 c.f.m. or 75.7 lb./min. standard pressure and temperature. The initial temperature of the pigment was 330° F. and it was fed into the cooling zone at the rate of 29.3 lb./min. to form a bed 14 inches deep. The heat loss of the pigment was 7800 B.t.u./hr. sq. ft. bed section the final temperature of the pigment being 165° F. Dust load was 300 lb. per hour and pressure drop 9.2 inches water gauge.

From the foregoing examples it is clear that the invention is characterized by the novel concept of cooling a hot solid particulate material by simultaneously fluidizing and cooling the material with a cold gas which is introduced into the bottom of a bed of the material through a plurality of jets at substantially right angles to the longitudinal axis of the bed; maintaining a relatively deep bed of fluidized material by discharging the bed material from the bottom of the cooling chamber into a level control chamber so as to assure countercurrent heat exchange; and simultaneously agitating the fluidized bed with a relatively slow moving sweep; and that the combined effect of the countercurrent heat exchange and mild agitation of the fluidized material is a relatively efficient heat exchange between the hot particulate material and the cold gas together with minimum dust load and absence of plugging, channeling, run-back and high pressure drop.

While this invention has been described and illustrated by the examples shown, it is not intended to be strictly limited thereto, and other variations and modifications may be employed within the scope of the following claims.

I claim:

1. Apparatus for cooling a solid particulate material by contact with a gaseous coolant comprising in combination: a cooling chamber having an inlet at its upper end and an outlet at its lower end, a level control chamber connected to the outlet of said cooling chamber, distributor means constructed and arranged to divide said cooling chamber into a cooling zone and a plenum chamber, feed means constructed and arranged at the inlet of said cooling chamber to feed said solid particulate material thereto, means constructed and arranged to feed a gaseous coolant into said plenum chamber for passage upwardly through said distributor means into said cooling zone at a linear velocity sufficient to fluidize the solid particulate material therein, said distributor means comprising a composite plate-like member consisting of a plurality of separate sections, means arranged to support each of said sections in a common substantially horizontal plane, each section constructed and arranged with a plurality of spaced parallel upstanding hollow ridges on its upper surface and a plurality of gas passages in each hollow ridge arranged to direct the flow of gaseous coolant therefrom in a plane substantially parallel to the plane of said distributor means; means in said cooling zone constructed and arranged to agitate the fluidized solid particulate material therein, means arranged to buffer the flow of the cooled material from the outlet of said cooling chamber into said level control chamber, and valve-means arranged to discharge the cooled material from said level control chamber.

2. Apparatus for cooling a solid particulate material by contact with a gaseous coolant comprising in combination: a cooling chamber having an inlet at its upper end and an outlet at its lower end, a level control chamber connected to the outlet of said cooling chamber, distributor means constructed and arranged to divide said cooling chamber into a cooling zone and a plenum chamber, feed means constructed and arranged at the inlet of said cooling chamber to feed said solid particulate material thereto, means constructed and arranged to feed a gaseous coolant into said plenum chamber for passage upwardly through said distributor means into said cooling zone at a linear velocity sufficient to fluidize the solid particulate material therein, said distributor means having a plurality of gas passages therein constructed and arranged to direct the flow of gaseous coolant therefrom in a plane substantially at right angles to the vertical axis of said cooling chamber, a multi-bladed sweep constructed and arranged to be rotatably mounted in said cooling zone in contact with said fluidized solid particulate material to agitate said material, means arranged to discharge the cooled material from the outlet of said cooling chamber into said level control chamber, and valve-means arranged to discharge the cooled material from said level control chamber.

3. Apparatus for cooling a solid particulate material according to claim 2 wherein said solid material feed means comprises a screw conveyor constructed and arranged to feed said solid material into said chamber.

4. Apparatus for cooling a solid particulate material by contact with a gaseous coolant comprising in combination: a cooling chamber having an inlet at its upper end and an outlet at its lower end, a level control chamber having a passage at its lower end connecting with the outlet of said cooling chamber, said level control chamber also having an outlet, a distributor plate constructed and arranged in a substantially horizontal plane to divide each of said chambers into an upper zone and a plenum chamber, feed means constructed and arranged at the inlet of said cooling chamber to feed said solid particulate material into said cooling chamber, said material being adapted to move down in said cooling chamber and to be discharged therefrom into said level control chamber via the passage thereof, means constructed and arranged to feed a gaseous coolant into the plenum of said cooling chamber and said level control chamber respectively for passage through said distributor plate into the upper zone of said level control chamber and said cooling chamber respectively at a velocity to fluidize the solid particulate material in each of said upper zones, said distributor plate having a plurality of gas passages therein constructed and arranged to direct the flow of gaseous coolant therefrom in a plane above and substantially parallel to the plane of said distributor plate, a rotating blade mounted in the upper zone of said cooling chamber and said level control chamber respectively constructed and arranged to agitate the fluidized solid particulate material therein; and valve-means constructed and arranged to discharge the cooled material in said level control chamber from the outlet thereof.

5. Apparatus for cooling a solid particulate material according to claim 4 wherein the plenum chamber is subdivided into two interconnected chambers by an apertured divider.

6. Apparatus for cooling a solid particulate material according to claim 4 wherein a plurality of gas jets are arranged in the passage between said cooling chamber and said level control chamber said gas jets being adapted to augment flow of said material from said cooling chamber into said level control chamber.

7. In apparatus for cooling solid particulate material by contact with a gaseous coolant wherein the particulate material is fed into a cooling chamber and from thence into a level control chamber and the particulate material in each chamber is maintained in a fluidized condition by gas issuing from gas distributor means in the bottom of each chamber the improvement comprising: gas distributor means comprising a composite plate-like member consisting of a plurality of separate sections,

and means arranged to support each of said sections in a common substantially horizontal plane, each section constructed and arranged with a plurality of spaced parallel upstanding hollow ridges on its upper surface and a plurality of gas passages in each hollow ridge arranged to direct the flow of gaseous coolant therefrom in a plane substantially parallel to the plane of said distributor means.

8. Gas distributor means for use in apparatus for cooling a solid particulate material by fluidizing said material with a gaseous coolant said gas distributor means comprising a composite plate-like member consisting of a plurality of separate sections and means arranged to support each of said sections in a common substantially horizontal plane, each section constructed and arranged with a plurality of spaced parallel upstanding hollow ridges on its upper surface and a plurality of gas passages in each hollow ridge arranged to direct the flow of gaseous coolant therefrom in a plane substantially parallel to the plane of said distributor means, at least one section of said composite plate-like member having its parallel ridges at right angles to the parallel ridges of one other of said sections.

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JOHN J. CAMBY, *Acting Primary Examiner.*