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[54] METHOD AND APPARATUS FOR PROVIDING HEAT EXCHANGE

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[30] Foreign Application Priority Data
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[52] U.S. Cl. ...................... 432/16, 34/57 C, 432/78, 432/58
[51] Int. Cl. ............................................ F27b 7/02
[58] Field of Search ........................ 263/32 R, 21 A; 34/57 C

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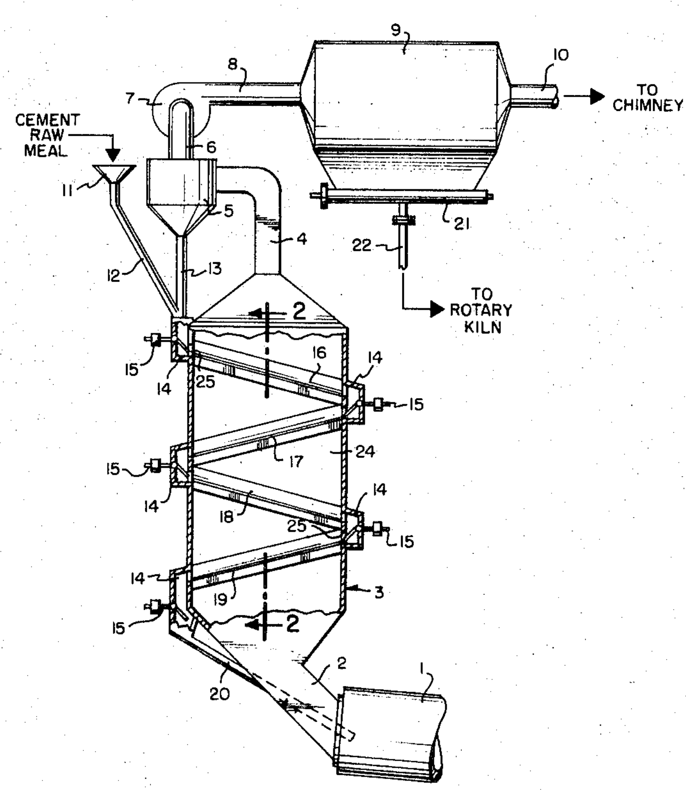
*Attorney*—Dean S. Edmonds, David J. Toomey et al.

[57] ABSTRACT

A method of and apparatus for transmitting heat between a powdered material and gas is disclosed. The material is fed to one end of a longitudinally inclined channel which includes a longitudinal opening in its bottom portion. The gas is caused to flow up through the bottom opening of the channel at a particular velocity so as to cause the gas to form eddies above the opening. These eddies entrain a majority of the material and move down along the inclined channel.

20 Claims, 8 Drawing Figures



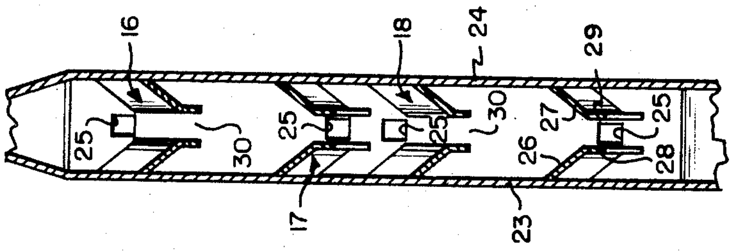



FIG. 2

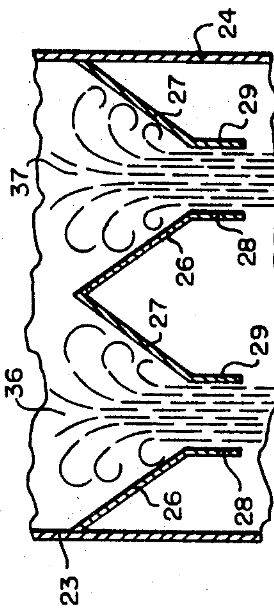



FIG. 3

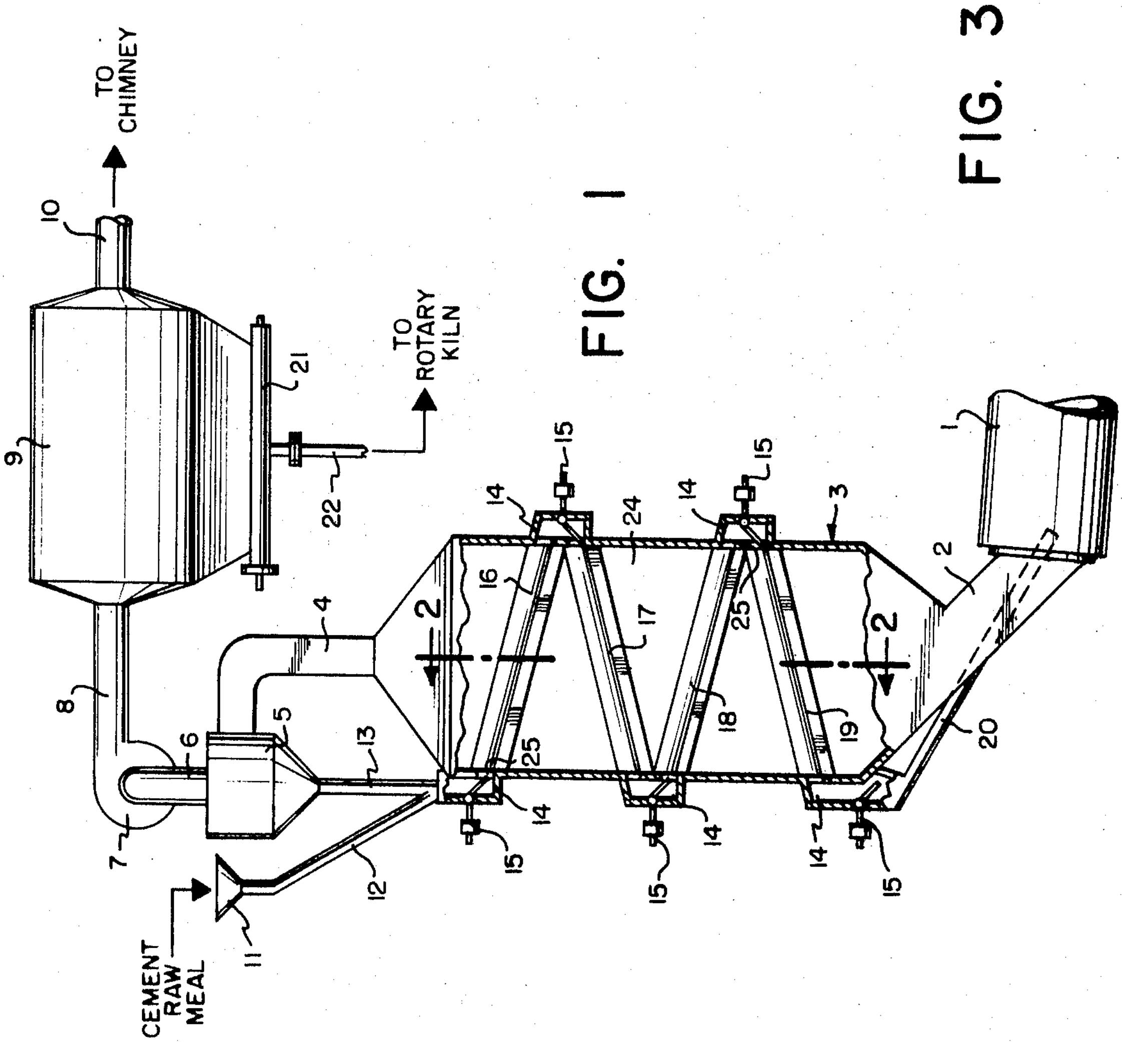



FIG. 1

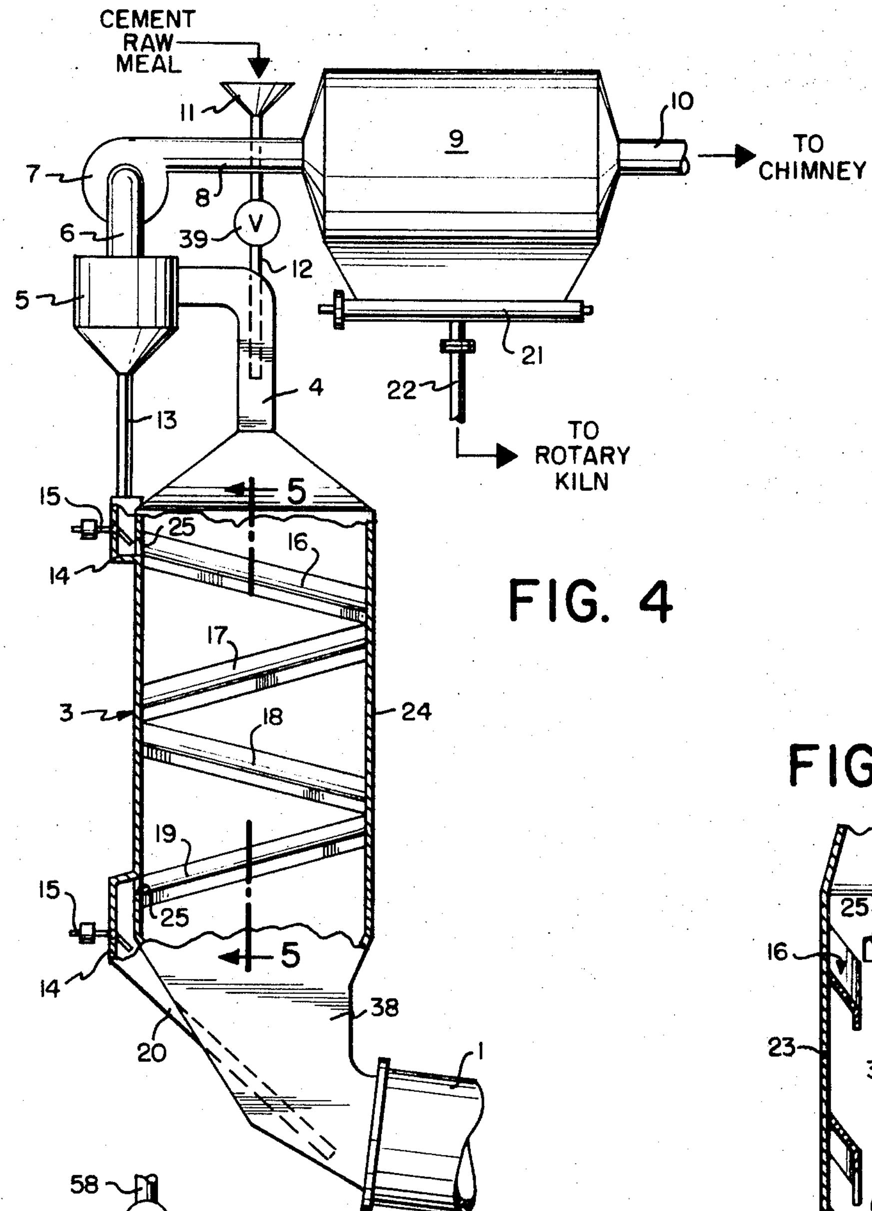



FIG. 4

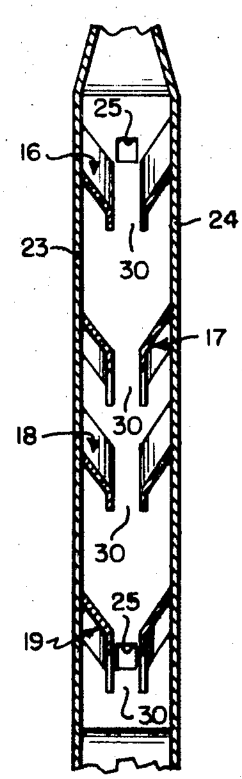



FIG. 5

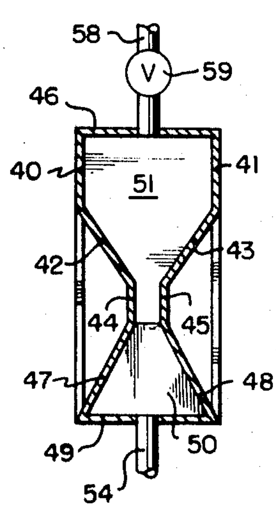



FIG. 7

FIG. 6

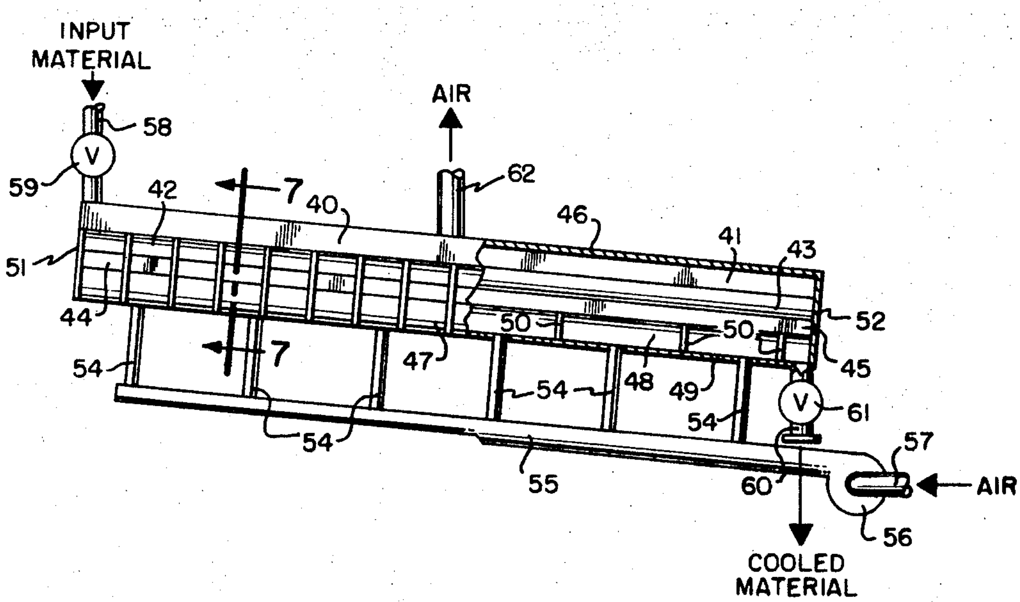
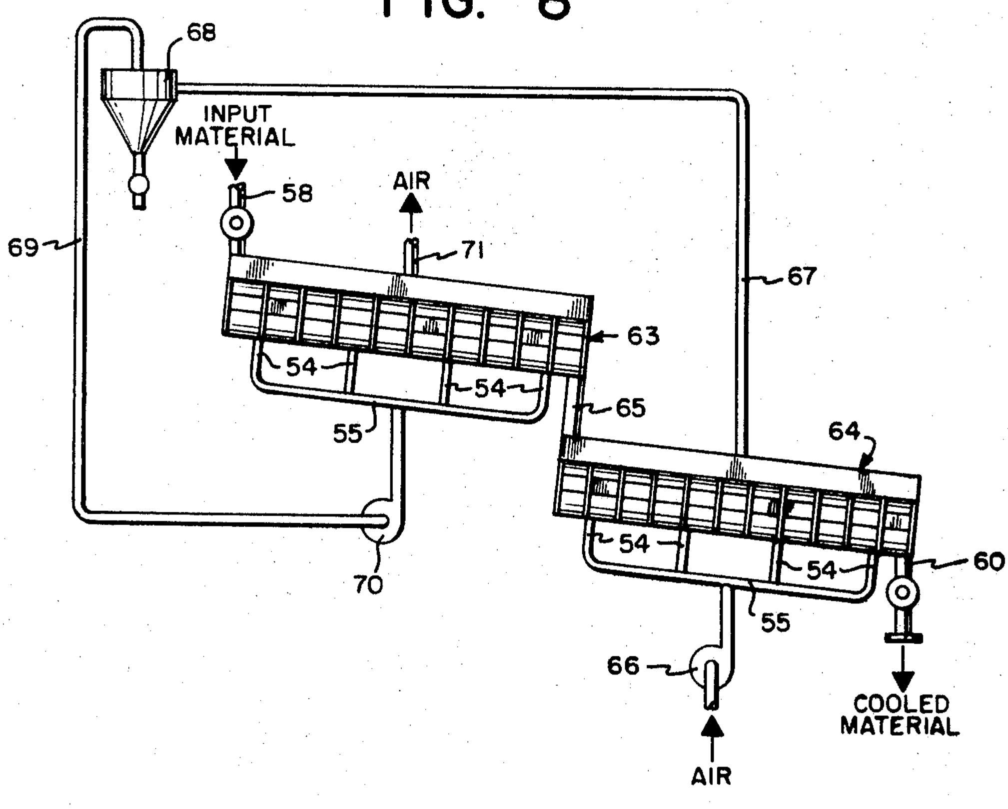

INPUT MATERIAL
58
59
V
AIR
62
7
40
42
46
41
43
51
44
50
50
52
47
45
7
48
49
54
54
54
54
V
61
54
57
55
60
AIR
56
COOLED MATERIAL

FIG. 8


68
INPUT MATERIAL
58
AIR
71
69
67
63
54
54
65
55
64
54
54
60
70
55
66
COOLED MATERIAL
AIR

# METHOD AND APPARATUS FOR PROVIDING HEAT EXCHANGE

## BACKGROUND OF THE INVENTION

This invention relates to methods of and apparatus for transmitting heat between a powdered material and gas. It is particularly applicable to the preheating of cement raw meal to be burned to cement clinker in a cement-burning kiln by exchange of heat with the exhaust gases from the kiln, but it can also be applied to the heating of other materials, and to the cooling of powdered materials, such, for example, as cement discharged from a mill or alumina discharged from a rotary kiln.

It is known that if a rising gas passes upwards into a chamber through a relatively small opening at a suitably high velocity it will form eddies in the chamber after passing through the opening. In the invention use is made of this fact.

Several methods and apparatus have been suggested by the prior art for providing heat exchange. For example, U.S. Pat. No.'s 273,900, 803,530, 1,472,314, 2,404,944, 2,436,157, 2,513,369, 3,052,990, 3,087,255, 3,089,253, 3,243,318, 3,423,840 and 3,580,552 are illustrative of some of the prior art in this field. However, the prior art fails to provide for a method or apparatus for causing heat exchange between a powdered material and a flow of gas in the manner as described by the invention.

## SUMMARY OF THE INVENTION

In accordance with the invention, a method of and apparatus for providing heat exchange between a powdered material and a flow of gas is described. The material is fed to one end of a longitudinally inclined channel having a longitudinal opening in its bottom and the gas is caused to flow up through the bottom opening of the channel at such velocities so as to cause the gas to form eddies above the opening. These eddies entrain a major part of the material and move down along the inclined channel. An angle of inclination of the channel of 15° is normally sufficient to ensure that the eddies move down along the channel. The heat exchange in such eddies is intense.

Inevitably some particles will not be entrained by the eddies. Due to this, the upward gas velocity should be sufficiently high so that these particles are carried upwards by the gases, and not downwards through the bottom opening of the channel countercurrent to the gases. In general, it is desirable and may even be essential that substantially all the particles except a small amount carried away by the gases should reach the lower end of the channel.

On reaching the lower end of the channel the eddies are destroyed and the particles are precipitated. The destruction of the eddies can be effected most simply by causing them to strike a vertical wall. Further movement of the precipitated particles depends on whether the process is one of heating or cooling, and on the construction of the apparatus in which the process is carried out.

The length of the channel may be reduced by arranging two or more channels side by side.

An important feature of the invention is repetition of the process, in that the gases after passing through the bottom opening of one channel (or through the bottom openings of a set of channels arranged side by side) are



caused to pass through the bottom opening of another channel (or set of channels) located at a higher level than the first channel, the material carried by travelling eddies in the upper channel being precipitated from them at the lower end of the channel and then being fed to the upper end of the lower channel. This feeding may be effected by causing the eddies to pass from the lower end of the channel into a chamber which is in direct communication with the upper end of the next channel, the eddies being destroyed in the chamber, generally by striking a wall of it. The feeding to the upper end of a lower channel may, however, also be effected by causing the particles to move downwards through the bottom opening at the end of the channel. Such downward movement will take place if the channel terminates in a vertical wall by which the eddies are destroyed, because then a cloud of particles is formed at the end of the channel and is so dense as to be able to move downwards against the upwardly flowing gases. If desired, the width of the bottom opening may be increased over a short distance at the lower end of the channel so that there is local reduction in the upward velocity of the gases.

For example, in a preheater for cement raw meal, a series of channels may be arranged one above another in a vertical shaft, so that the raw meal will encounter the gases several times during the entire heat-exchanging process, the temperature of the gases being, however, higher at each encounter, as the material is moving downwards in stages. Taken as a whole, the process thus involves stepwise countercurrent, heat exchange, whereas the heat exchange in each individual channel may be regarded as cross-current heat exchange. The results of overall heat exchange is excellent.

Channels may advantageously be arranged one above another in zig-zag fashion, so that the eddies on reaching the end of one channel enter the next channel and flow in the opposite direction down it.

In a cement-burning plant, for example, the volume and velocity of the gases leaving the kiln depend essentially on the throughput, and a preheater must be designed with these factors in mind. Specifically, this involves making the bottom opening of the channel of appropriate width. As a general guide the velocity of the gases on passing through the bottom opening may be from 3 to 12 meters per second, depending primarily on the nature of the particles.

Particularly when the invention is used for cooling powdered materials, it may be more advantageous to arrange two or more channels in line, the lower end of the first being above the upper end of the second and so on. Basically the best arrangement depends upon the most appropriate use of the available space.

The invention includes a heat exchanger for carrying out the method. This apparatus comprises a housing having an inlet for a flow of gas and an outlet for the gas. The housing further includes, in its interior, a longitudinally inclined channel with a longitudinal bottom opening arranged such that the gas flow has to pass from the inlet to the outlet upwards through the opening. The housing is provided with means for supplying powdered material to the inclined channel and means for removing powdered material from the channel.

One example of a heat exchanger, which is particularly useful when used as a preheater for preheating cement raw meal prior to the burning of the raw meal in a kiln, comprises a vertical or substantially vertical shaft with a gas inlet at its lower end and a gas outlet at its upper end, the shaft being internally spanned by a longitudinally inclined channel with a narrow longitudinal bottom opening, or by two or more such channels arranged side by side, so that gas flowing up the shaft must pass through the opening or openings. In addition the shaft has an inlet for material at the upper end of the channel or channels and an outlet at the lower end, each being constructed to prevent gas from by-passing the channel or channels.

Another example of a heat exchanger, which may be used as a cooler for cooling cement in a cement grinding plant, comprises a horizontally elongated housing internally spanned by a longitudinally inclined channel with a narrow longitudinal bottom opening, or by two or more such channels side by side, so that cooling atmospheric air flowing through the housing must pass through the opening or openings. The cooling air enters the housing through one or more inlets in the bottom of the housing and leaves through an outlet in the top.

## BRIEF DESCRIPTION OF THE DRAWINGS

Apparatus according to the invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a view of part of a plant for preheating and burning cement raw meal, the preheater being in vertical section;

FIG. 2 is a section through the preheater taken along line II—II of FIG. 1;

FIG. 3 is a section through a modified form of a preheater.

FIG. 4 is a view of part of a plant for preheating and burning cement raw meal similar to FIG. 1 illustrating various modifications;

FIG. 5 is a section taken along line V—V of FIG. 4;

FIG. 6 is a side elevation view partly in section of a cooler;

FIG. 7 is a section taken along line VII—VII of FIG. 6 and is on a larger scale.

FIG. 8 is part of a plant including two coolers of the kind shown in FIG. 6 operating in series.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a plant for preheating cement raw meal and feeding it to the upper end of a slightly inclined rotary kiln 1. The hot gases from the kiln pass through a pipe 2 to a preheater 3. In the preheater the gases give off heat to the raw meal, which is later burned to cement clinker in the kiln, and are themselves cooled. The gases leave the preheater 3 at its upper end through a pipe 4 leading to a cyclone 5, in which raw meal entrained in them is precipitated. A pipe 6 takes the gases from the cyclone 5 to the suction side of a fan 7, the delivery side of which is connected by a pipe 8 to the inlet end of an electrostatic dust precipitator 9. A pipe 10 leads from the outlet end of the dust precipitator to a chimney (not shown) through which the gases escape into the atmosphere.

The preheater consists essentially of a narrow casing, rectangular in cross-section, with two main parallel walls 23 and 24 and two relatively narrow side walls. The main walls 23 and 24 are spanned by four channels 16, 17, 18 and 19, each downwardly inclined, and arranged in zig-zag fashion as shown. Each channel is formed by two inwardly and downwardly inclined side walls 26 and 27 which merge into vertical skirts 28 and 29, these defining a continuous opening 30 along the bottom of each channel. Each channel is open at the top so that gases flowing upwards through the opening 30 in one pass onwards through the casing to pass through the opening 30 in the next, or from the channel 16 to the pipe 4.

At each end of each channel there is a small chamber 14 projecting out from a side wall of the casing. Each chamber 14 has an outlet opening 25 controlled by a sealing device 15 which allows the raw meal but not the gases to pass. This device 15 is a weight-loaded tiltable flap which yields under the weight of the raw meal, which then prevents the passage of the gas flow, the flap otherwise closing the opening 25.

The cement raw meal to be preheated is fed through a hopper 11 which opens into the top chamber 14. A pipe 13 delivers the meal precipitated in the cyclone 5 into the same chamber, from which the combined amounts pass into the channel 16. On entering the channel the particles of raw meal are immediately entrained by the gases flowing up through the bottom opening 30 and become suspended in eddies which form above the opening, as illustrated in FIG. 3. Due to the inclination of the channel, the eddies travel downwards from the upper to the lower end of the channel, and during this movement there is intense heat exchange between the hot gases and the colder raw meal. When an eddy reaches the next chamber 14 it is destroyed, and the raw meal is precipitated in the chamber. It then successively enters the channels 17, 18 and 19 where the process is repeated, until it reaches the bottom chamber 14, from which it flows through a pipe 20 into the kiln 1.

Dust precipitated in the electrostatic dust precipitator 9 enters a worm conveyor 21 and is conveyed by flights of opposite hand to a pipe 22, through which it may be returned to the rotary kiln or delivered elsewhere, for use, for example, as a fertilizer.

Increased capacity can be obtained by widening the casing and duplicating each channel, as shown in FIGS. 3, in which it is convenient to show the eddies at 36 and 37.

The preheater shown in FIGS. 4 and 5 resembles that shown in FIGS. 1 and 2 so closely that most of the reference numerals are the same. The first and most important modification is that the chambers 14 interconnecting the channels 16 and 17, 17 and 18, and 18 and 19, have been omitted. Each of the channels 16, 17 and 18 now terminates in a vertical wall of the preheater 3. The result is that the eddies travelling down these three channels are destroyed on striking the vertical wall, form the dense clouds described hereinabove, and pass downwards through the bottom opening in each of these channels into the channel below. The vertical side walls of the preheater 3 are unbroken from top to bottom except for the outlet 25 from the chamber 14 through which the raw material enters the channel 16 and for an opening through which the preheated material leaves the channel 19.

FIG. 4 illustrates a second modification, namely, that the fresh raw material is fed through a hopper 11 and pipe 12 into a riser pipe 4, where it is entrained by the ascending gases and carried into the cyclone 5. Thus, the raw material receives heat from the gases passing through the pipe 4. Of course the cyclone 5 must then be such that as much as possible of the raw material as well as of the particles entrained by the gases is separated in it, leaving only dust to flow to the precipitator **9**. To prevent the hot gases passing upwards through the pipe **12**, a rotary gate valve **39** or an equivalent device is provided in the pipe.

A third modification shown in FIG. **4** comprises altering the shape of the connection between the upper end of the kiln **1** and the lower end of the preheater to that shown at **38**. This shape is more advantageous in guiding the kiln gases into the preheater.

Naturally any one of the three modifications shown in FIGS. **4** and **5** can be used without the others.

Referring now to FIGS. **6** and **7**, a single channel is formed between vertical side walls **40** and **41** which merge into inclined walls **42** and **43**, which in turn merge into vertical skirts **44** and **45**. The top of the channel is closed by a cover **46**. Below the channel there is a space hounded by downwardly and outwardly inclined walls **47** and **48** and a bottom plate **49**, and divided into separate compartments by partitions **50**. Each of these compartments is fed with air through a pipe **54**, all the pipes **54** branching from an air supply duct **55** which is connected to the delivery side of a fan **56**. This fan draws in atmospheric air through its suction side **57**. Air is thus delivered upwards through the bottom of the channel, the ends of which are closed by plates **51** and **52**. The air all leaves through an outlet **62**.

The material to be cooled is introduced through a pipe **58** which is controlled by a rotary gate valve **59** or similar device, and the cooled material leaves through an outlet **60** controlled by a similar rotary gate valve **61**.

In the cooling of alumina, in particular, it is advantageous to arrange two such coolers **63** and **64** in series, as shown in FIG. **8**. The outlet from the cooler **63** is connected by a pipe **65** to the inlet of the cooler **64**. A fan **66** delivers air to the cooler **64**, and the air leaving this cooler flows through a pipe **67** to a cyclone **68** in which any solid material that may be suspended in the air is precipitated and collected. The air leaving the cyclone **68** flows through a pipe **69** to the suction side of the fan **70**, and is delivered by it into the cooler **63**, from which the air leaves through a pipe **71**. The material to be cooled is of course fed to the cooler **63** through a pipe **58**, and it leaves the apparatus from the cooler **64** through a pipe **60**.

I claim:

**1.** A method for providing heat exchange between a powdered material and a flow of gas comprising;

a. feeding said material to one end of a plurality of longitudinally inclined channels in a housing, each channel having a longitudinal opening in its bottom portion; and

b. allowing said gas to flow up through the bottom openings of said channels at a sufficient velocity to cause the gas to form eddies above the openings, said eddies entraining a major portion of the material and moving down along the inclined channels.

**2.** A method according to claim **1** wherein said channels are arranged in side by side relation along at least two levels of the housing.

**3.** A method according to claim **2** wherein said channels arranged side by side have substantially the same angle of inclination and incline to the same side.

**4.** A method according to claim **2** wherein the gas flow after passing through the bottom openings of a first set of channels arranged in side-by-side relation is caused to pass through the bottoms openings of a second set of channels arranged in side-by-side relation and located at a higher level than the first set of channels, the material being advanced downwardly by travelling eddies in the upper channels and being released from at the lower ends of the upper channels, and subsequently being fed to the upper ends of the lower set of channels.

**5.** A method according to claim **4** wherein the second set of channels is longitudinally inclined to the opposite direction to the first set of channels.

**6.** A method according to claim **1** wherein the powdered material comprises cement raw meal and the gas comprises smoke gases from a cement burning kiln, whereby heat exchange in the eddies occurs between the gases and the cement raw meal which is thereby preheated prior to burning in the kiln while the gases are cooled.

**7.** A method according to claim **1** wherein the powdered material comprises a pulverant end product from a rotary kiln and the gas comprises atmospheric air, the pulverant material thereby being cooled and the air being heated.

**8.** A method according to claim **1** wherein the powdered material comprises finished cement which has been discharged from a cement mill, and the gas comprises atmospheric air, the powdered cement thereby being cooled and the air being heated.

**9.** A heat exchanger for providing heat exchange between a powdered material and a flow of gas comprising a housing with inlet means for supplying a flow of gas and means for removing the gas, said housing further including within its interior a plurality of longitudinally inclined channels, each channel having a longitudinal opening in its bottom portion and arranged such that the gas flow has to pass from the inlet means to the outlet means upwards through the opening at a sufficient velocity to cause the gas to form eddies above the openings, the housing including means for supplying powdered material to the inclined channels and means for removing powdered material from the channels.

**10.** A heat exchanger according to claim **9** wherein said channels are arranged in side by side relation along at least two levels of the housing.

**11.** A heat exchanger according to claim **10** wherein the inclined channels have side walls which converge downwardly towards the bottom opening.

**12.** A heat exchanger according to claim **11** wherein two edges of the bottom opening in the inclined channels extend downwardly each forming a separate vertical flap.

**13.** A heat exchanger according to claim **10** wherein alternate channels or sets of channels are inclined in opposite directions whereby the powdered material is easily passed from the lower ends of one set of channels to the upper ends of the set of channels below.

**14.** A heat exchanger according to claim **10**, including means for preventing the gas flow from by-passing the channel openings comprising tiltable flaps.

**15.** A heat exchanger according to claim **10** wherein the housing is a substantially vertical shaft, the gas inlet being at the lower end of the shaft and the gas outlet being at the upper end of the shaft.

16. A heat exchanger according to claim **10** wherein the housing is horizontally elongate having one or more inlets, for feeding in gas, in the bottom of the housing.

17. A heat exchanger according to claim **10** wherein the heat exchanger is a cement clinker cooler, the inlet feeds in atmospheric air, and the outlet removes heated air from the cooler.

18. A plant for burning cement raw meal comprising a heat exchanger used as a raw meal preheater including a housing having an inlet for a flow of gas and an outlet for the gas, the housing further including in its interior, at least one longitudinally inclined channel with a longitudinal bottom opening arranged such that the gas flow has to pass from the inlet to the outlet upwards through the opening, the housing being provided with means for supplying powdered material to the inclined channel and means for removing powdered material from the channel; an inclined rotary kiln in which the burning takes place; a smoke gas pipe through which the smoke gases from the rotary kiln may be fed to the lower end of the raw meal preheater; an outlet pipe for passing the gases from the raw meal preheater into the atmosphere; means to maintain the flow of gas through the kiln and the raw meal preheater; means for supplying cold raw meal to the raw meal preheater; and means to feed the preheated raw meal from the raw meal preheater to the upper end of the inclined rotary kiln.

19. A plant according to claim **18** wherein the outlet gases from the raw meal preheater are fed through a dust precipitator before passing into the atmosphere.

20. A plant according to claim **18** wherein the heat exchanger is a cement clinker cooler, the inlet feeds in atmospheric air, and the outlet removes heated air from the cooler.

* * * * *