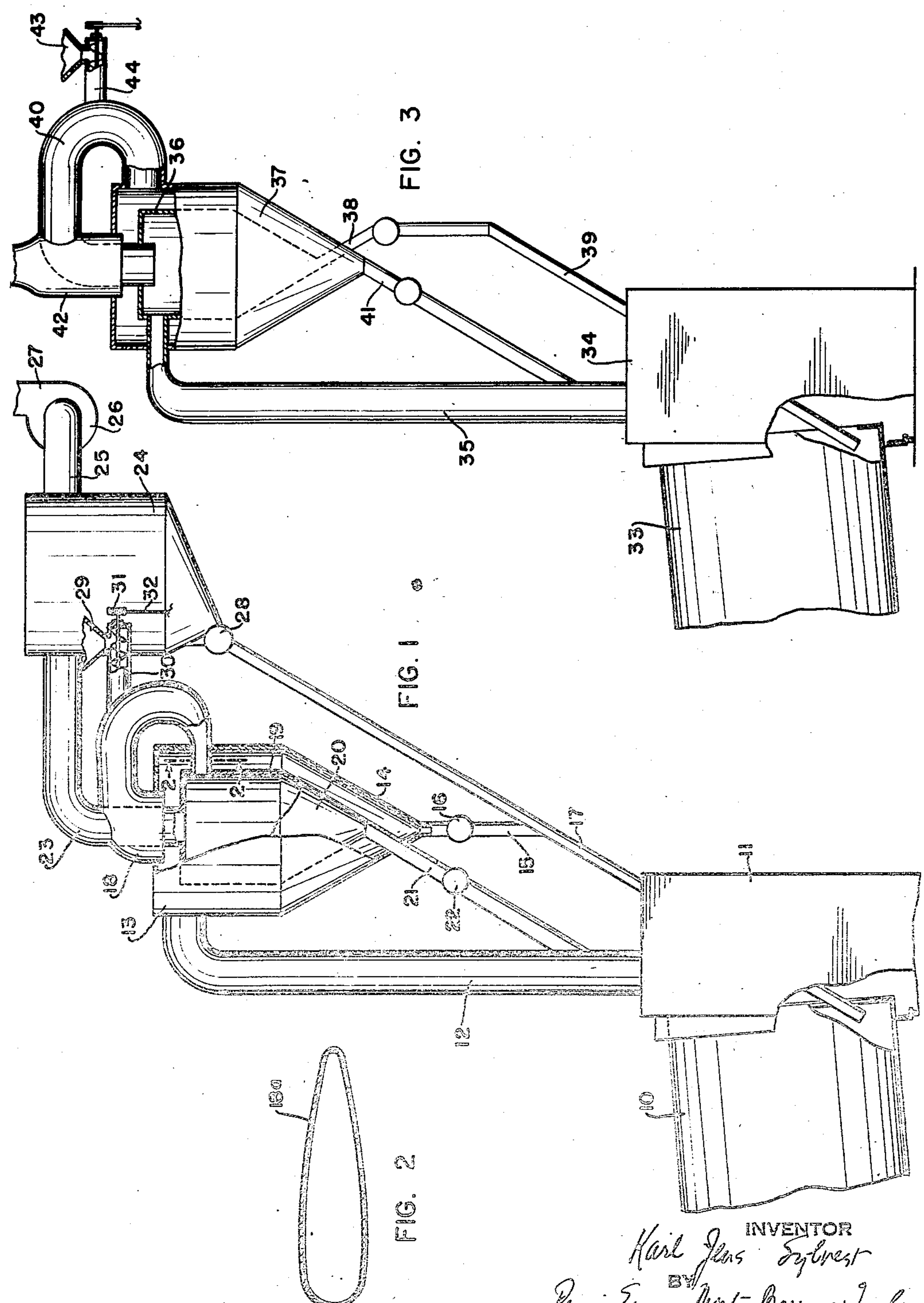
Aug. 13, 1957 K. J. SYLVEST 2,802,280

HEAT-EXCHANGE APPARATUS INCLUDING CYCLONE SEPARATORS

Filed Oct. 12, 1955 4 Sheets-Sheet 1



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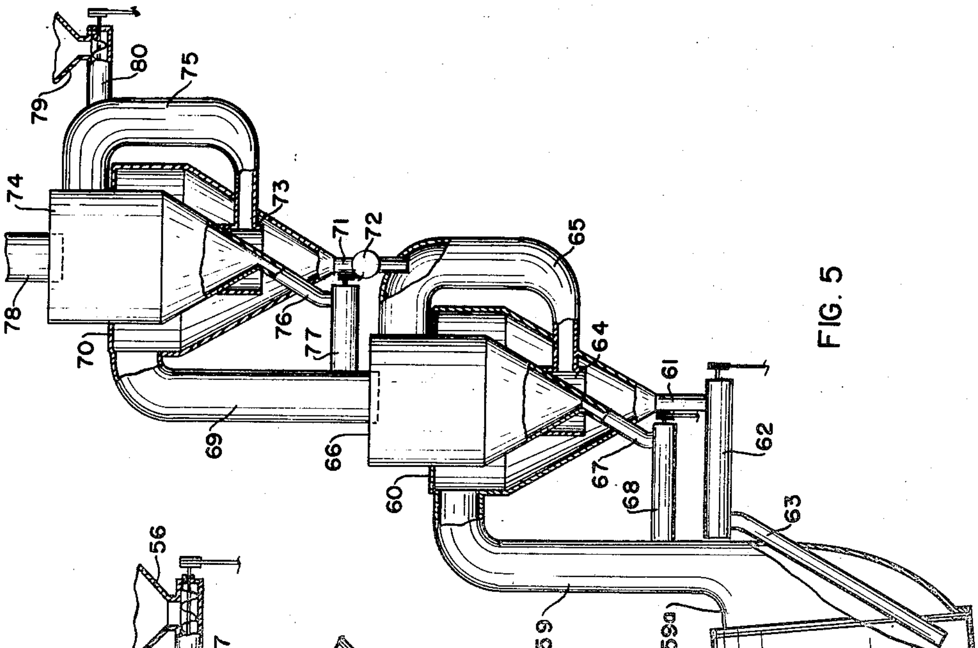

FIG. 5

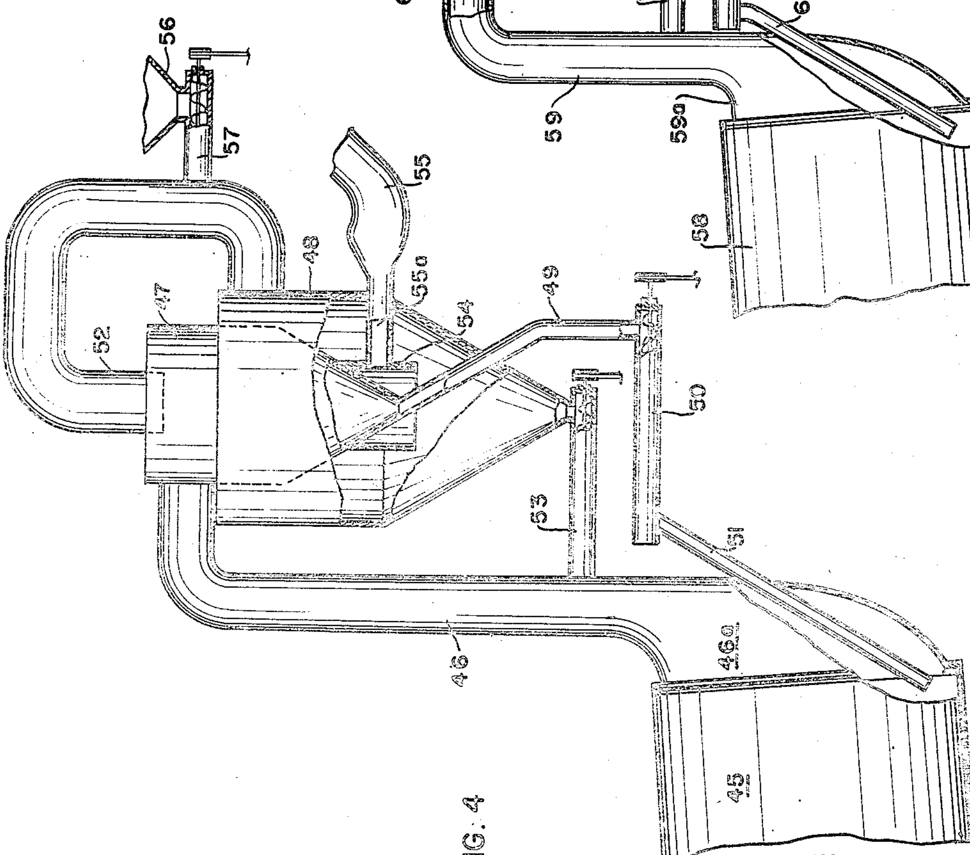

FIG. 4

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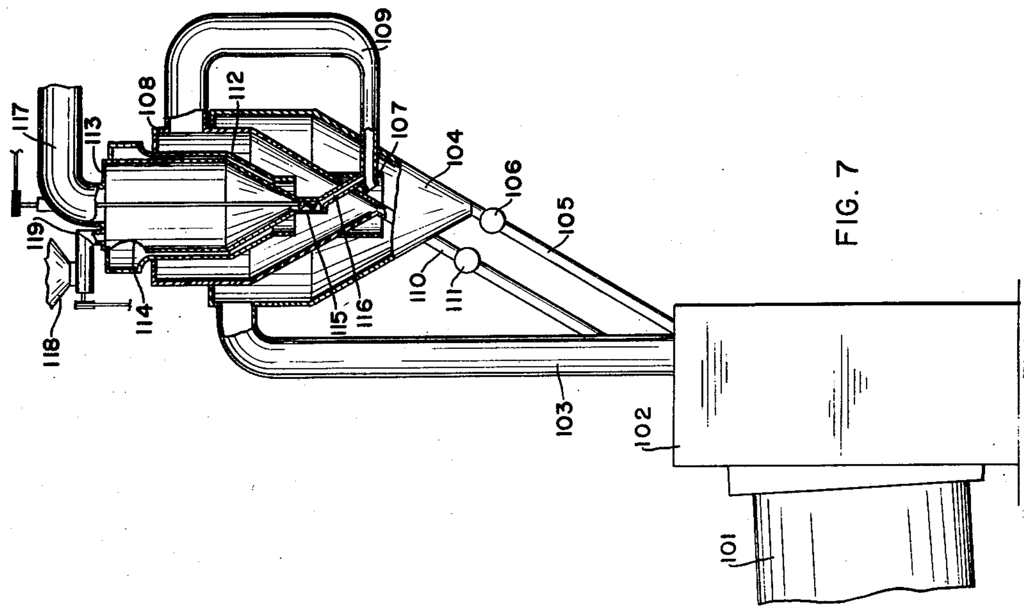

FIG. 7

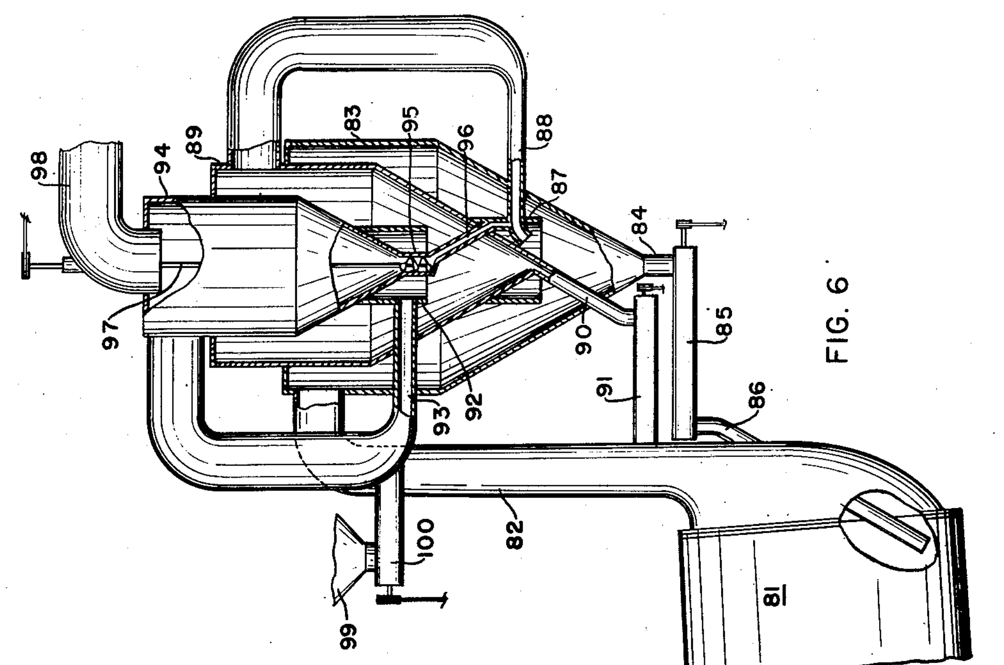

FIG. 6

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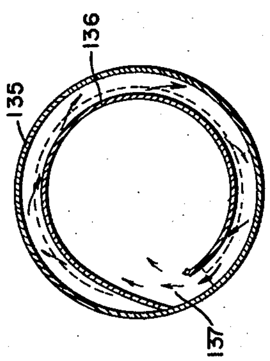

FIG. 9

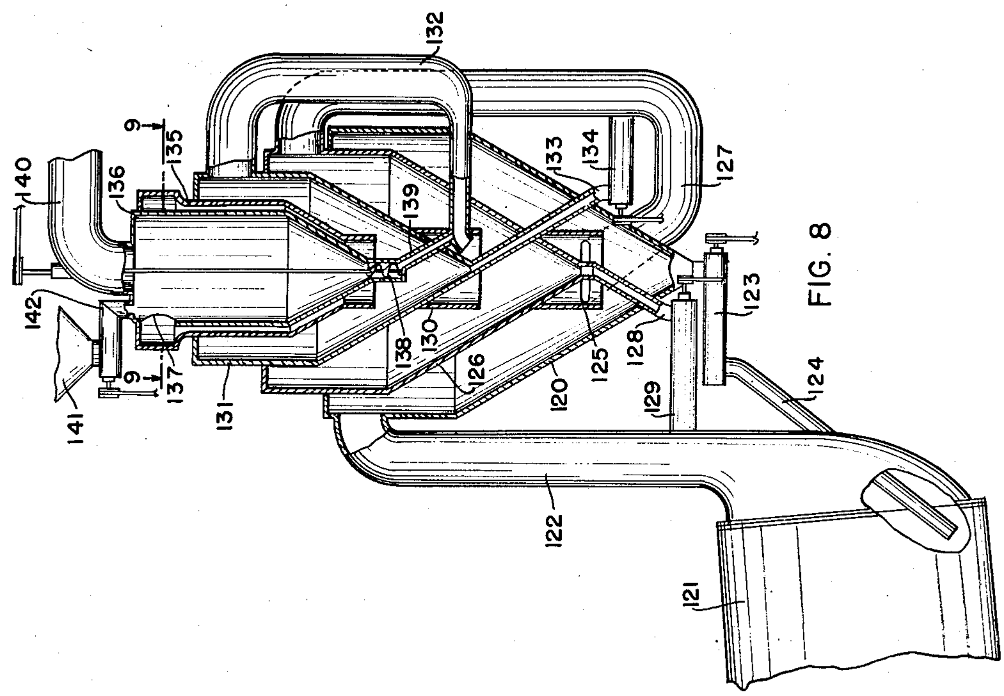

FIG. 8

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HEAT-EXCHANGE APPARATUS INCLUDING CYCLONE SEPARATORS

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Application October 12, 1955, Serial No. 540,130

Claims priority, application Great Britain October 13, 1954

11 Claims. (Cl. 34—57)

This invention relates to apparatus for the exchange of heat between gases and finely divided material in suspension therein and of the type, in which a plurality of cyclone separators are employed in series with the solids separated in the later separators being introduced into the gas streams traveling toward the preceding separators. More particularly, the invention is concerned with a heat-exchange apparatus of the type specified, in which a novel arrangement of the separators is employed with resultant reductions both in the overall height of the apparatus and in heat loss by radiation.

Heat-exchange apparatus of the multiple cyclone separator type has been commonly constructed heretofore with the separators disposed at successively higher levels in the direction of gas flow in order that the separated particles can travel through the apparatus by gravity. Such an apparatus may have so great an overall height that space limitations may prevent its use at a particular location and, in an alternative construction, the total height of the apparatus is reduced by causing the pipes leading to the separator inlets to dip downwardly and introducing the separated solids from the separators into the low sections of the piping. While this expedient saves space, the total height of the installation is still substantial.

In all forms of heat-exchange apparatus of the multiple cyclone separator type, in which solid particles are heated by hot gases, there is a substantial loss of heat by radiation from the separators because of their large surface area. While such loss can be reduced by covering the separators with insulation, the insulation is expensive to install and it does not eliminate the heat loss entirely.

The present invention is directed to the provision of heat-exchange apparatus including a plurality of cyclone separators arranged in series, in which a reduction in the total height of the apparatus and in the heat loss from the separators is effected by mounting at least one of the separators wholly or partly within another. When the apparatus includes two separators, the inner separator may be either the first or second traversed by the gases and, when more than two separators are employed, the separators may be disposed in telescoped relation in a single assembly, or the apparatus may be made up of a plurality of pairs of telescoped separators, or other arrangements may be used.

For a better understanding of the invention, reference may be made to the accompanying drawings, in which

Fig. 1 is a somewhat diagrammatic side elevational view with parts broken away of one form of the apparatus;

Fig. 2 is a sectional view on the line 2—2 of Fig. 1;

Figs. 3–8, inclusive, are somewhat diagrammatic side elevational views with parts broken away of modified forms of the apparatus; and

Fig. 9 is a sectional view on the line 9—9 of Fig. 8.

The heat-exchange apparatus of the invention in the form illustrated in Fig. 1 is employed in association with a kiln **10**, the upper end of which enters a smoke chamber **11**. The hot gases from the kiln pass through the chamber and through a riser pipe **12** to the tangential inlet of a cyclone separator **13** having the usual conical lower end **14**. A pipe **15** containing a rotary gate valve **16** conducts the separated solids from the separator **13** into a second pipe **17**, which extends through the smoke chamber **11** and enters the upper end of the kiln **10**. Separator **13** has an outlet for gases through its top and the gases are conducted away through a pipe **18**.

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A smaller separator **19** is disposed wholly within separator **13** coaxially therewith and the inner separator has a tangential inlet, to which pipe **18** leads. The pipe has a section **18***a* crossing the space between the two separators and, since this section lies in the path of the whirling gases, it has the streamlined cross-sectional shape shown in Fig. 2. The inner separator has a conical lower end **20** with an outlet for separated solids, and a pipe **21** containing a rotary valve **22** conducts the separated solids to pipe **12** and discharges the solids into the path of the gases traveling upward through that pipe.

The inner separator **19** has an outlet at its top for gases and a pipe **23** extends upwardly through the outlet and through pipe **18** to conduct the gases to a filter **24**. The outlet from the filter is connected by a pipe **25** to the inlet of a blower **26**, the outlet of which is connected by a pipe **27** to a stack (not shown). The filter has an outlet for separated solids at its bottom and pipe **17** leads from the outlet. The pipe contains a rotary gate valve **28**.

The raw material to be heated is supplied from a storage bin, the lower end of which is shown at **29**, and the bin has a bottom outlet, from which a connection **30** leads into pipe **18**. In the construction illustrated, the connection is a screw conveyor, the screw shaft of which has a pulley **31** driven by a drive belt **32**.

In the operation of the apparatus illustrated in Figs. 1 and 2, the hot gases from the kiln enter the smoke chamber **11** and then travel through the riser pipe **12** and enter the first or outer separator **13** through its inlet. The gases travel with a circular movement through the separator and the solid particles are thrown outwardly against the separator wall by centrifugal action and collect in the conical lower end of the separator whence they are discharged through pipe **15** into pipe **17** leading into the kiln. The rotary gate valve **16** prevents gases from the kiln traveling back through pipe **15** into the separator. The gases leaving the outer separator **13** enter the second or inner separator **19** through pipe **18** and separated solids leaving the outlet at the lower end of the inner separator travel through pipe **21** and rotary gate valve **22** to be discharged into the path the gases rising through pipe **12**. The gases issuing from the inner separator enter the filter **24** and the separated dust collected in the filter is conducted through the pipe **17** into the kiln. The gases freed of dust then pass through blower **26** and are discharged into the stack. Material to be heated is continuously introduced from the container **29** into the pipe **18** and takes up heat from the gases while traveling in suspension therein into the inner separator **19**. The separated solids leaving separator **19** and entering the pipe **12** again take up heat from the gases while traveling in suspension to the outer separator **13**. The material leaving the outer separator and combined with the dust from filter **24** is at a relatively high temperature as it enters the kiln.

In the apparatus of Fig. 1, the outer separator **13** is provided with the usual insulation. However, the inner separator is insulated by the gases between the two separators and little or no insulation on the inner separator is required.

The apparatus shown in Fig. 3 is generally similar to that shown in Fig. 1, except for a reversal of the position of the separators. In the Fig. 3 construction, the gases issuing from the kiln **33** pass through smoke box **34** and enter riser pipe **35** leading to the tangential inlet of a separator **36**, which lies wholly within an outer separator **37** and is coaxial therewith. Pipe **35** has a section of streamlined shape in the space between the separators. Separator **36** has a bottom outlet, from which a pipe **38** leads to a pipe **39**, the latter extending through the smoke box and discharging into the upper end of the kiln. The inner separator also has a gas outlet at its top, from which a pipe **40** leads to the tangential inlet of the outer separator **37**. Separator **37** has a bottom outlet, from which a pipe **41** leads into the riser pipe **35**, and it also has a gas outlet at its top, from which a pipe **42** leads. Pipe **42** encloses a section of the pipe **40** leading from the gas outlet of the inner separator and may lead to a blower discharging into the atmosphere, but preferably leads to a filter similar to filter **24** and having a bottom outlet connected to pipe **39**.

In the Fig. 3 construction, the raw material is contained within a bin **43** having a bottom outlet with a connection **44** leading into pipe **40**. The connection may be a screw conveyor similar to conveyor **30**.

The apparatus of Fig. 3 functions in the same manner as that shown in Fig. 1, except that the first separator entered by the gases leaving the smoke chamber is the inner one. As the inner separator contains the gases at the highest temperature and is insulated by the gases in the outer separator, there is less loss of heat by radiation in the Fig. 3 construction than in that shown in Fig. 1, assuming the same solid insulation is present in both forms of apparatus.

The apparatus shown in Fig. 4 is similar to that shown in Fig. 3, except that the separators are only partially telescoped. The gases issuing from kiln **45** enter the enlarged lower end **46***a* of the riser pipe **46** and enter the separator **47** through its tangential inlet. The separator extends downwardly through the top of an outer separator **48** and the inner separator **47** has a bottom outlet, from which the separated solids are conducted through a connection leading into the upper end of the kiln. The connection includes a pipe **49** connected to the outlet, a screw conveyor **50**, and a pipe **51** leading from the conveyor into the kiln.

The inner separator **47** has a gas outlet at its top, from which a pipe **52** leads to the tangential inlet of the outer separator **48**. The outer separator has an outlet at its bottom for solids, which are conducted through a connection **53** into pipe **46**, the connection shown being a screw conveyor. The conveyors **50** and **53** both advance the material and prevent flow of gases backward into the respective separators.

The outer separator **48** has an outlet for gases, which takes the form of a casing **54** secured to and enclosing the lower end of inner separator **47** and thus closed at its top. A pipe **55** leads from the casing and the pipe has a section **55***a* of streamlined form between the casing and the wall of the outer separator. Pipe **55** may lead to a blower or to a filter, as in the Fig. 1 construction.

The raw material to be heated is contained within a bin, the lower end of which is shown at **56**. The bin has a bottom outlet, from which connection **57**, in the form of a screw conveyor, leads into pipe **52**.

The apparatus of Fig. 4 functions in the same manner as those previously described and the apparatus has the advantage that, since the inner separator is only partially enclosed in the outer one, the operations of erecting the separators and of dismantling them for repairs are easier to carry out than in a construction, in which one separator is wholly within the other.

The apparatus shown in Fig. 5 is constructed to perform the heat exchange in more than two stages and the apparatus includes four separators arranged as two pairs with one member of each pair partly within the other. The gases from the kiln **58** travel upwardly through pipe **59** having an enlarged lower section **59***a* and enter the outer separator **60** of the first pair through its inlet. The separator has an outlet at its bottom for solids, which are conducted through a connection into the upper end of the kiln, the connection including a pipe **61**, a screw conveyor **62**, and a pipe **63**. The outer separator has a gas outlet including a casing **64** secured to the inner separator, and a pipe **65** leads from the casing to the inlet of the inner separator **66**. The inner separator has a solids outlet at its bottom, from which material is conducted through a connection into pipe **59**, the connection including a pipe **67** and a screw conveyor **68**. The inner separator has a gas outlet at its top, from which leads a pipe **69**.

The second pair of separators includes an outer separator **70** having an inlet, to which pipe **69** leads, and this separator has a bottom outlet with a pipe **71** containing a rotary gate valve **72** and conducting the material into the gas stream flowing through pipe **65**. Separator **70** also has a gas outlet including a casing **73** secured to the lower end of an inner separator **74** and a pipe **75** leads to the inlet of the inner separator. Separator **74** has a bottom outlet, from which the material is led through a connection into pipe **69**, the connection including a pipe **76** and a screw conveyor **77**. The gases leave separator **74** through a top outlet, from which a pipe **78** leads to a blower discharging to the atmosphere or, if preferred, to a filter similar to filter **24**.

The raw material is contained in a bin, the lower end of which is shown at **79**. A connection in the form of a screw conveyor **80** leads from the bottom outlet of the bin into pipe **75**.

In the operation of the apparatus of Fig. 5, the hot gases leaving the kiln enter the outer separator **60** of the first pair carrying with them separated materials discharged from the inner separator **66** of that pair. The solids separated in the outer separator are discharged into the upper end of the kiln through the connection from the outlet of the outer separator and the gases from the outer separator enter the inner separator carrying with them in suspension the solids received from the outer separator **70** of the second pair. The gases leaving the inner separator **66** of the first pair enter separator **70** carrying with them solids received from the inner separator **74** of the second pair. Gases from the separator **70** enter the inner separator **74** carrying with them the raw material received from the bin **79**. In the Fig. 5 apparatus, the material is heated in four stages, namely, while it is in suspension in the gases in pipes **75**, **69**, **65**, and **59**, and in the separators, and a good heat recovery is thus obtained.

The apparatus illustrated in Fig. 6 is employed for heat treatment in three stages and the gases used for the purpose are obtained from a rotary kiln **81** and travel upward through pipe **82** to the inlet of separator **83** having a bottom outlet, through which separated solids enter a connection leading into the upper end of the kiln. The connection includes a pipe **84** connected to the separator, a screw conveyor **85**, and a pipe **86**. The separator **83** has a gas outlet including a casing **87** and a pipe **88** extends from the interior of the casing out through the wall of the separator and to the inlet of an intermediate separator **89**.

The separator **89** extends into separator **83** through the top of the latter and is coaxial therewith. At its lower end, separator **89** has an outlet for separated solids, which are conducted through a connection consisting of a pipe **90** and a screw conveyor **91** into pipe **82**. Separator **89** has a gas outlet comprising a casing **92**, from which a pipe **93** leads to the inlet of an inner separator **94** projecting into separator **89** through its upper end. Separator **94** has a bottom outlet, from which separated solids are conducted through a connection into that part of pipe **88** lying within casing **87**, the connection including a screw conveyor **95** and a pipe **96**. The shaft **97** of the screw conveyor extends upwardly and out of the top of separator **94**. A pipe **98** leads gases from a gas outlet at the top of separator **94** to a blower or a filter.

Raw material is supplied to the apparatus of Fig. 6 from a container, the lower end of which is shown at **99**. The container has a bottom outlet, from which the material discharged is conducted through a connection **100** into the interior of pipe **93**, the connection in the apparatus illustrated being a screw conveyor.

In the operation of the apparatus shown in Fig. 6, the gases travel through the separators in succession and the material to be heated enters the gas stream flowing to the third separator or the one last in the series. The solids separated in the third separator are then introduced into the stream flowing to the second separator and the solids separated in the second separator are introduced into the stream flowing to the first separator. The material separated in the first separator is introduced into the kiln.

The apparatus shown in Fig. 7 is of the three-stage type and includes only a single pipe for transferring gases from one separator to the next. The apparatus is shown in use in connection with a kiln **101**, the gases from which pass through a smoke chamber **102** and enter a pipe **103** leading to the inlet of an outer separator **104**. This separator has a bottom outlet, from which a pipe **105** containing a rotary gate valve **106** conducts separated material into the upper end of the kiln. The separator has a gas outlet including a casing **107** attached to the lower end of an intermediate separator **108** extending into separator **104** through its upper end. A pipe **109** leads from the interior of the casing to the inlet of the intermediate separator. Separator **108** has a bottom outlet, from which a pipe **110** containing a rotary gate valve **111** leads into the pipe **103**. The gases leave separator **108** through a casing **112**, the lower end of which serves as the outlet from separator **108**. Casing **112** extends out through the upper end of separator **108** and surrounds an inner separator **113** having an inlet **114** within the casing. Separator **113** has a bottom outlet, from which a connection leads separated material into that part of pipe **109** lying within casing **107**, the connection including a screw conveyor **115** and a pipe **116**. The separator **113** has a gas outlet at its top, from which a pipe **117** leads to a blower or a filter.

The raw material to be heated is contained within a bin, the lower end of which is indicated at **118**, and a connection in the form of a screw conveyor **119** leads from the bottom of the bin into the upper end of separator **113**.

The operation of the apparatus of Fig. 7 is similar to that of the apparatus of Fig. 6, but, in traveling from the intermediate separator to the inner separator, the gases pass between the inner separator and its surrounding casing **112** and do not travel through an exposed pipe. The apparatus of Fig. 7 thus functions with less heat loss than that shown in Fig. 6.

The apparatus shown in Fig. 8 includes four telescoped separators, of which the outer separator **120** receives gas from a rotary kiln **121** through a pipe **122**. At its lower end, the separator has an outlet for separated solids, which are conducted through a connection including a screw conveyor **123** and a pipe **124** into the upper end of the kiln. The separator has a gas outlet, which includes a casing **125** secured to and surrounding the lower end of a separator **126**, which projects into separator **120** through its upper end. A pipe **127** leads from an opening in the wall of the casing and conducts gases from separator **120** to the inlet of separator **126**.

Separator **126** has an outlet at its lower end for discharge of separated solids, which are conducted through a pipe **128** to a screw conveyor **129** discharging into pipe **122**. Separator **126** has a gas outlet, which includes a casing **130** surrounding and mounted on the lower end of a separator **131**, which projects into separator **126** through its upper end. A pipe **132** leads from the interior of casing **130** to the inlet of separator **131**. The solids collected in the lower end of separator **131** are conducted from the separator outlet through a pipe **133** to a screw conveyor **134** discharging into pipe **127**. The gases leave separator **131** through a casing **135**, which extends into separator **131** through its top and encloses a separator **136** having an inlet **137** within the casing adjacent its upper end.

Separator **136** has an outlet at its lower end and solids leaving the separator travel through a connection including a screw conveyor **138** and a pipe **139** into that part of pipe **132** lying within casing **130**. Separator **136** has a gas outlet at its top, from which a pipe **140** leads to a blower or to a dust filter.

The material to be heated is contained within a bin, the lower end of which is shown at **141**, and the material issuing from the bin enters a screw conveyor **142** dicharging into separator **136** at its top. Separator **136** carries a partition adjacent its inlet **137** leading to the inner wall of casing **136** to direct the gases rising through the casing to the inlet and separator **113** in the apparatus of Fig. 7 is preferably provided with a similar partition.

The forms of the apparatus illustrated are for heat exchange, in which finely divided material takes up heat from hot gases while carried in suspension therein. The apparatus may be used equally well for the cooling of finely divided material, in which event cool air or other gas enters the first separator in the series and the hot material is introduced into the apparatus at the point, at which the material is supplied from a bin in the forms of the apparatus shown.

In some instances, the gases available for heating the particles in the apparatus may be very high, as, for example, of a temperature of 1000° C., and, if such hot gases are led first into a separator lying within another one, the insulation of the inner separator by the gases contained in the outer one may be so effective that the wall of the inner separator will reach a temperature higher than it can withstand. In such instances, the gases may be preliminarily reduced in temperature by including in the apparatus as the first separator in the series an ordinary cyclone separator having its wall cooled by the surrounding atmosphere. The gases issuing from the first separator are then passed to the inner separator previously mentioned.

I claim:

1. A heat-exchange apparatus for transfer of heat between gases and finely divided material in suspension therein, which comprises at least two cyclone separators, one of the separators being mounted to be at least partly enclosed within the other with a space between the peripheral walls of the separators, each separator being complete in itself and having an inlet and separate outlets for gas and solids, a riser pipe leading to the inlet of the first separator for conducting a gas thereto, a pipe for conducting separated solids from the solids outlet of the first separator out of the apparatus, a pipe connecting the gas outlet of the first separator to the inlet of the second separator, a pipe for conducting separated solids from the solids outlet of the second separator into the riser pipe leading to the inlet of the first separator, a connection for conducting gas from the gas outlet of the second separator, a container for pulverulent material having a bottom outlet, and means for conducting material from the container outlet into the gas pipe leading to the inlet of the second separator.

2. The heat-exchange apparatus of claim 1, in which the pipe leading from the solids outlet of the first separator and of the apparatus and the pipe for conducting separated solids from the solids outlet of the second separator with the riser pipe contain means for passing solids while preventing flow of gas into the separators.

3. The heat-exchange apparatus of claim 2, in which

at least one of the means for passing solids is a conveyor.

4. The heat-exchange apparatus of claim 1, in which the first separator is at least partly enclosed within the second separator.

5. The heat-exchange apparatus of claim 1, in which the second separator lies within the first and the gas outlet of the first separator is connected to the inlet of the second separator by a pipe, part of which lies inside the first separator and is of streamlined cross-section.

6. The heat-exchange apparatus of claim 1, in which the first separator lies within the second and the gas outlet of the first separator is connected to the inlet of the second by a pipe having a part within and coaxial with the gas outlet of the second separator.

7. The heat-exchange apparatus of claim 1, in which the inner separator projects out through the top of the outer separator and the gas outlet of the outer separator includes a casing within the separator having an open lower end and a pipe leading from the interior of the casing through the separator side wall.

8. The heat-exchange apparatus of claim 7, in which the separators are coaxial and the casing encircles the lower end of the inner separator and is mounted on the wall thereof.

9. A heat-exchange apparatus for transfer of heat between gases and pulverulent material in suspension thereon, which comprises a cyclone separator having a tangential gas inlet through its side wall near its top, a gas outlet through its top, and an outlet at its bottom for separated solids, a second cyclone separator enclosing the lower end of the first separator and having a tangential gas inlet through its side wall near its top and an outlet at its bottom for separated solids, and a casing surrounding and spaced from the side wall of the first separator, the casing being closed at its upper end and having an open lower end serving as the gas outlet from the second separator.

10. The heat-exchange apparatus of claim 9, which includes a container for pulverulent material having an outlet and a connection for conducting material from the container outlet into the first separator through an opening in the top of the separator.

11. The heat-exchange apparatus of claim 10, in which the connection leading from the container outlet contains means for passing material while preventing flow of gas from the separator into the container.

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