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Kemmetmueller

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[54] **COOLING OR PREHEATING DEVICE FOR COARSE OR BULKY MATERIAL WITH HEAT SPACE RECOVERY EQUIPMENT**

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[52] **U.S. Cl.** **34/168,** 34/86, 432/90, 432/14, 34/35, 34/13
[51] **Int. Cl.** **F26b 17/12,** F26b 17/14
[58] **Field of Search** .... 34/35, 164, 13, 168, 86, 34/19; 122/4 D; 110/28 J, 8 R; 432/31, 16, 14, 83, 85, 223, 79, 90

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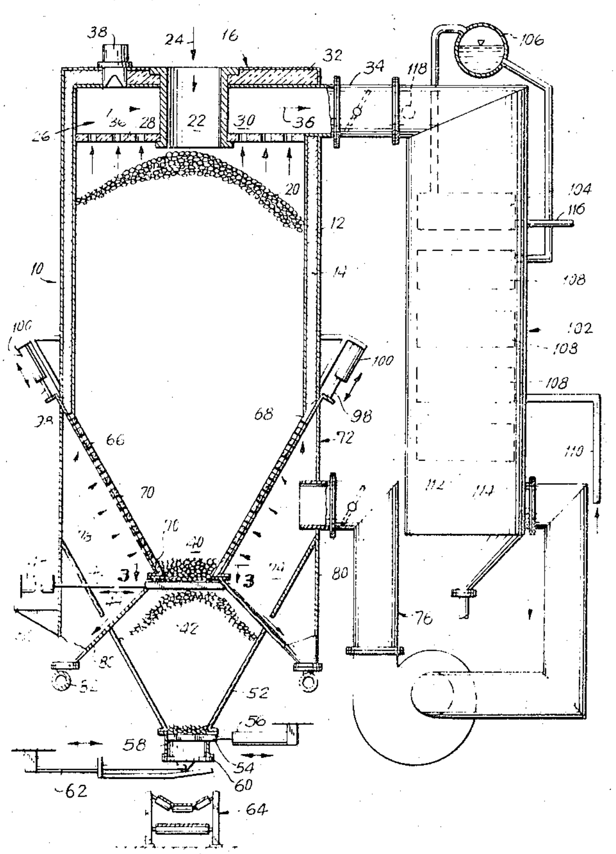
[57] **ABSTRACT**

An apparatus for treating material in bulk. An upright bunker is provided to accommodate the material in bulk while it flows gravitationally down the interior of the bunker. The bunker has at its lower discharge end a tapered wall formed with apertures to admit to the material in the bunker a gas at a temperature different from the material of the bunker while permitting those parts of the material which are small enough to pass through the apertures to fall out of the bunker through the apertures before reaching the lower discharge end. A plenum surrounds the apertures and communicates with a gas supply through which the gas is delivered to the apertures to flow therethrough, and a gas discharge communicates with the top of the bunker to discharge the gas therefrom. The material falling through the apertures is collected in the plenum and conveyed away from the latter. Where the gas flowing up through the material in the bunker is heated by the latter material, a boiler may receive the hot gas from the bunker to use the gas for generating steam, and the gas which is cooled in the boiler is then returned to the plenum.

16 Claims, 9 Drawing Figures



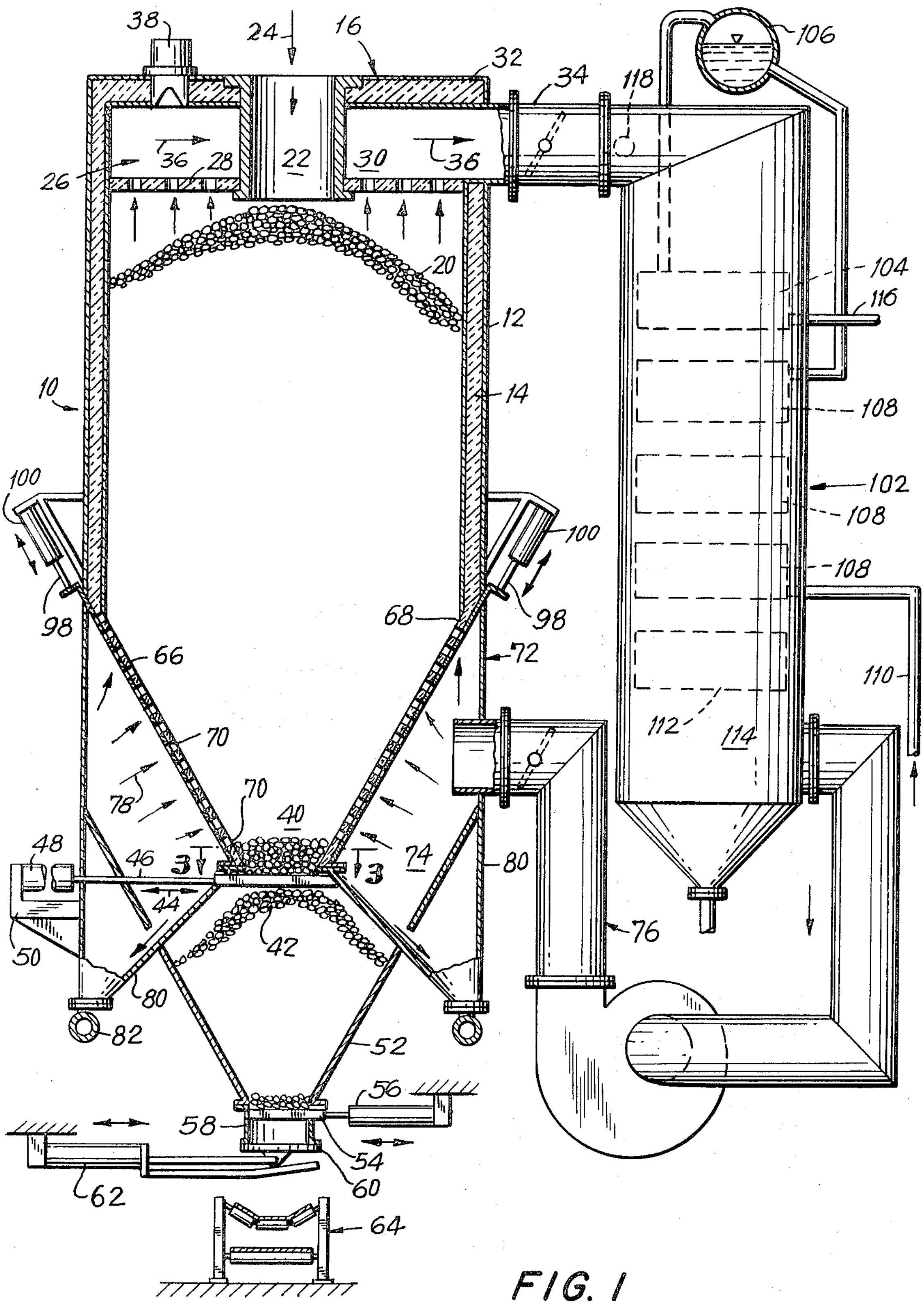

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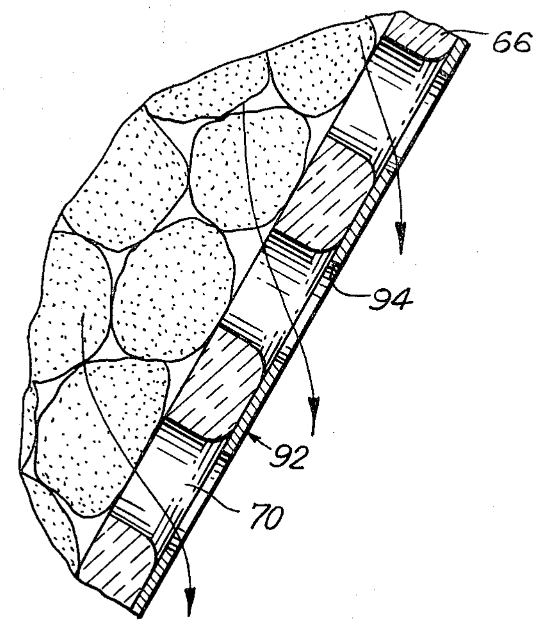
FIG. 1

FIG. 2



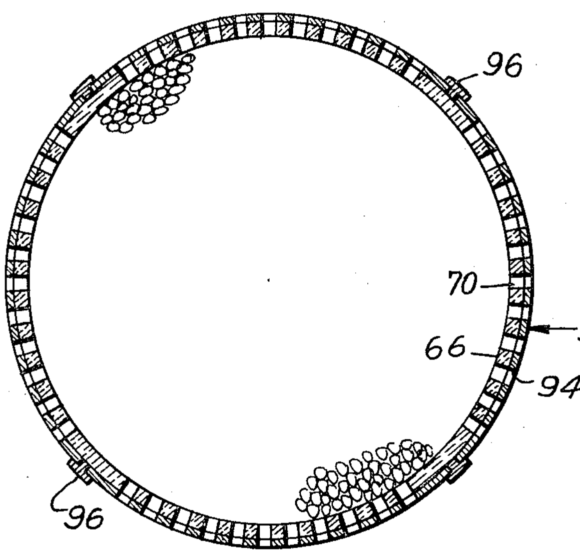


FIG. 3

FIG. 4

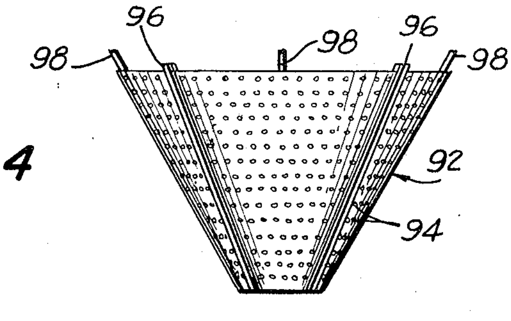


FIG. 5

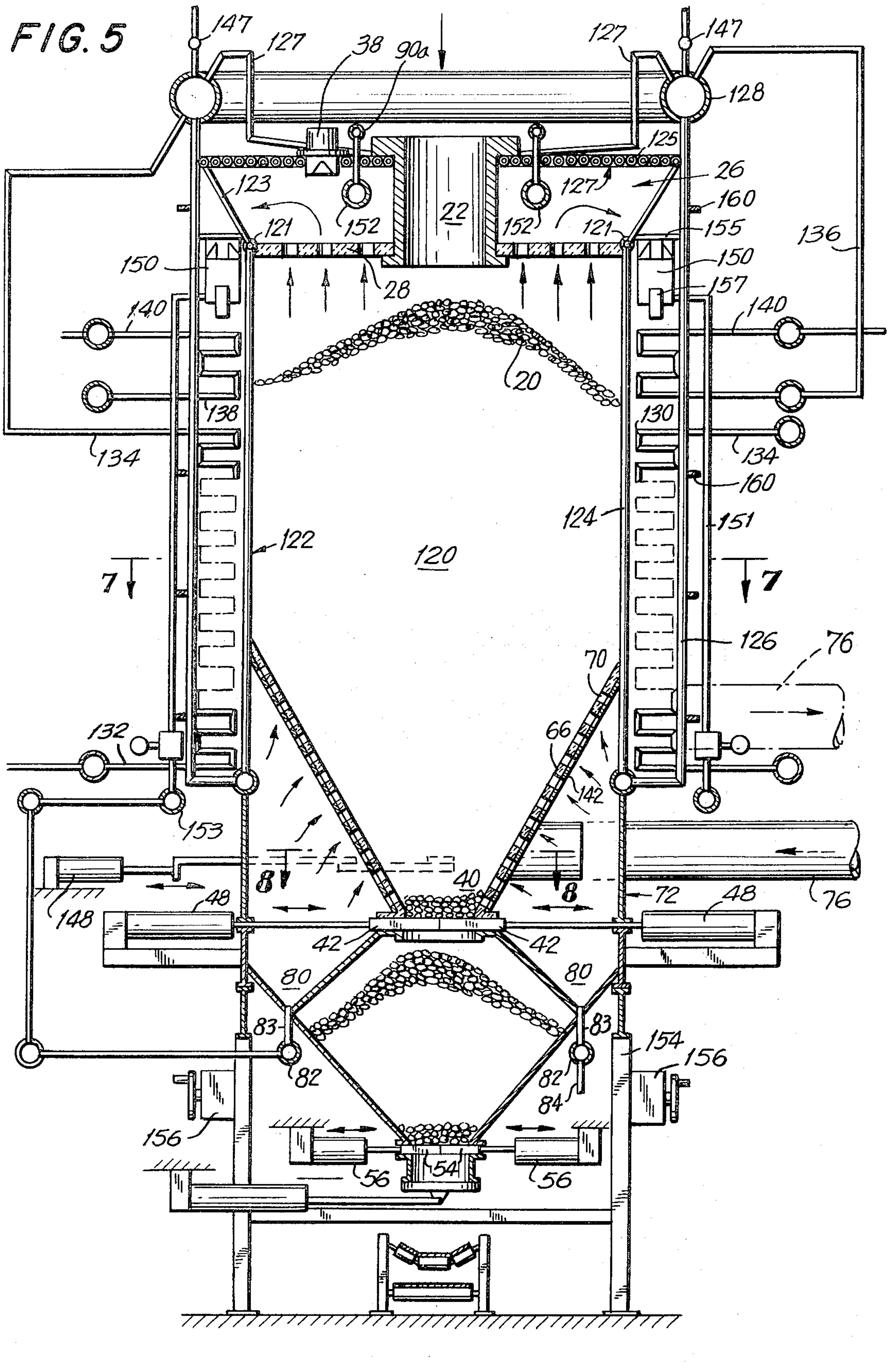

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FIG. 6

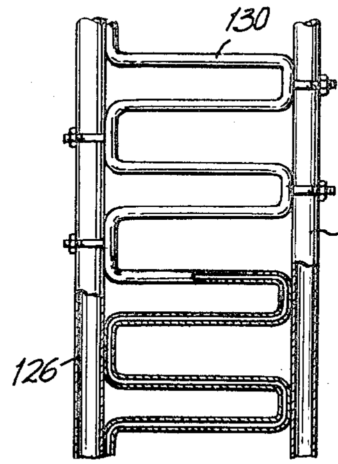


FIG. 8

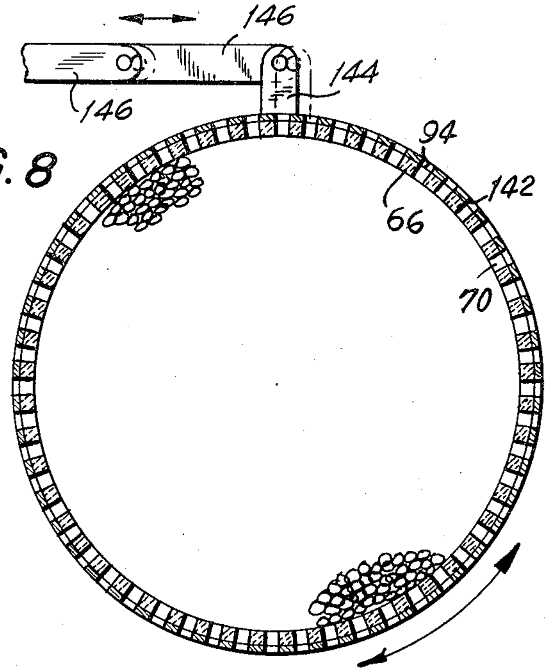


FIG. 7

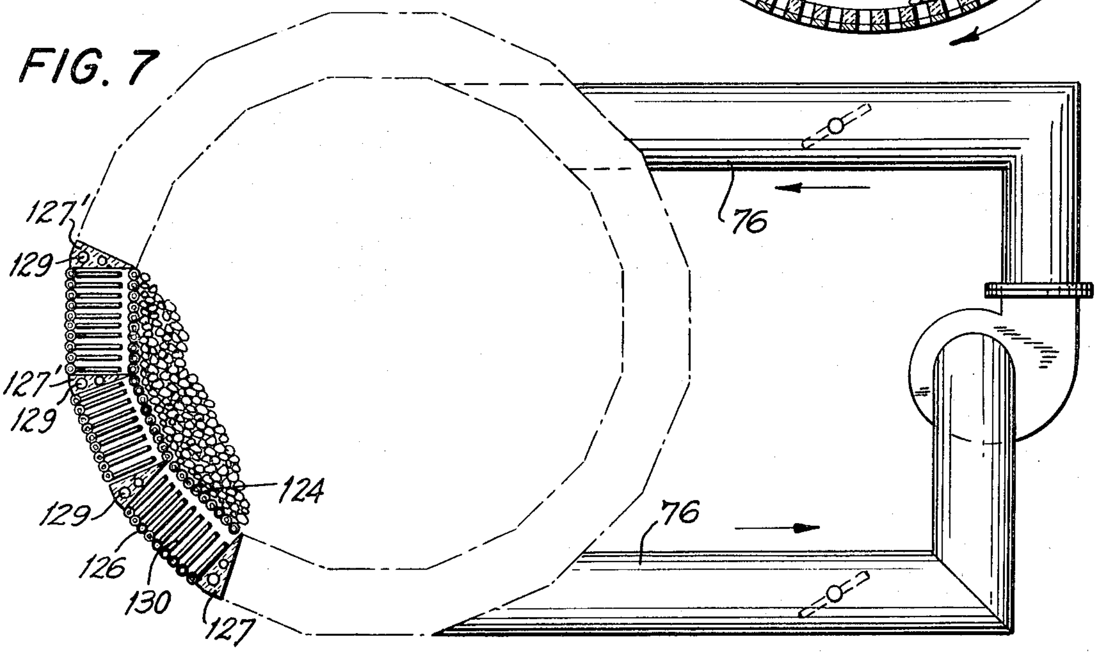
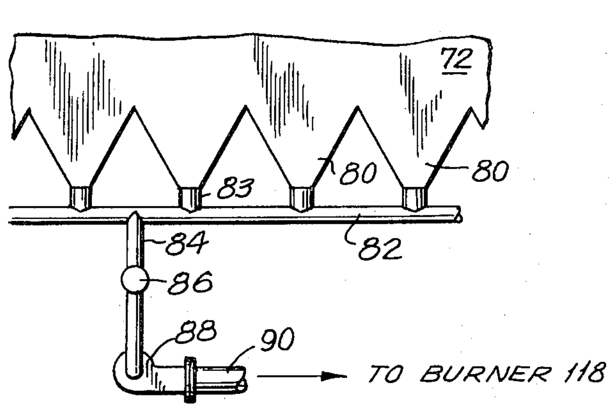


FIG. 9



COOLING OR PREHEATING DEVICE FOR COARSE OR BULKY MATERIAL WITH HEAT SPACE RECOVERY EQUIPMENT

BACKGROUND OF THE INVENTION

The present invention relates to devices for cooling or preheating coarse or bulky materials while being provided with heat-recovery equipment.

Devices of this general type are of course known at the present time. For example, in coke plants, it is conventional to situate the hot coke which discharges from the coke ovens in dry-quenching bunkers in which a gas flows upwardly through the hot coke to extract heat therefrom. The cooled coke is discharged out of the bunkers and delivered to a suitable screening station, for example.

Conventional apparatus of this type suffers from several drawbacks. Thus, it is conventional in dry-quenching bunkers to introduce the cooling gas into the bunker by way of a pipe which communicates with a gas distributor situated at the central axis of the bunker at a substantial distance above the lower end thereof. The conventional gas distributor has openings through which the gas escapes into the interior of the bunker to contact the hot material therein, and these gas discharge openings are surrounded by tapered baffles which serve to deflect the bulky material away from the gas discharge openings so that they will not become clogged. Such conventional structure of course acts to retard the downward flow of the bulky material in the bunker. In addition, the cooling gas which is delivered to the central axis of the bunker flows upwardly around the baffles and fails to come in contact with the bulky material situated beneath the gas discharge openings as well as beyond the immediate vicinity of the gas discharge openings at the elevation of the latter. As a result, a considerable amount of valuable heat which might otherwise be carried away with the gas remains in the bulky material so that the latter is not cooled in the most effective manner.

Furthermore, bulky materials of the above type will necessarily have as components thereof relatively small particles in the form of dust or granular bulky material, and these components are necessarily discharged with the remainder of the bulky material from the bunker. It is these conditions which necessitate the use of a screening station where bulky material composed of bodies only greater than a given size are separated from bodies smaller than this given size. These screening operations involve a considerable expense because of the apparatus and operations in connection with the screening itself as well as because of the necessity of conveying the bulky material to and from the screening station.

In this latter connection, the conveying of the bulky material away from the bunker with all of the components of the bulky material included in the material which is conveyed creates a problem in connection with release of dust and other pollutants to the outer atmosphere. It is possible to use for this purpose special conveyers which do not release any dust to the outer atmosphere, but such conveyers are exceedingly expensive both to construct and to operate.

As was pointed out above, there is a considerable heat loss resulting from the fact that with conventional structures of the above type the cooling gas cannot

come into contact with the bulky material which is at the region of the lower discharge end of the bunker. However, this particular heat loss is only a small fraction of the total heat loss encountered with conventional bunkers. Where the material which is treated is in the form of hot coke or the like, considerable valuable energy is present in the form of the heat which is available to be extracted from the hot coke. Of course, attempts are made to recover this energy by directing gas heated in the bunker to heat exchangers, but nevertheless even with such arrangements there is a tremendous loss of heat which results from a number of operating factors which cannot be avoided with conventional installations. Thus, one of the unavoidable large losses of heat results from heat loss through the wall of the bunker itself. Even with the best available heat-insulating techniques, the amount of heat energy which is lost by simply being stored in the walls of the bunker and transmitted therethrough to the outer atmosphere is tremendous.

A second factor which contributes to unavoidable heat loss with conventional installations results from the relatively small parts of the bulky material which are separated from the larger parts thereof at the screening station. A considerable amount of these smaller components simply float out into the atmosphere and not only pollute the atmosphere but waste heat which might otherwise be derived from these combustible materials. The remaining part of these smaller components of the bulky material which are recovered at the screening station may of course be used for combustion, but in this case also additional costs are involved in handling these smaller parts of the bulky material.

As has been indicated above, it is conventional to provide a closed cycle for gas according to which the gas flows upwardly through the bulky material in the bunker to extract heat from this material when it is hot and the gas is initially cool, and then the hot gas is directed through a steam generator to give up its heat in order to generate steam, with the gas which is cooled in this way being returned to the bunker. With conventional installations of this type there are additional heat losses resulting from the fact that the gas in the closed cycle is not properly controlled so that the best possible extraction of heat is not achieved. Furthermore, the gas which flows out of the bunker carries along a certain amount of dust from the bulky material, and this dust deposits on the exterior surface of heat-exchanging elements preventing the latter from operating with the greatest possible efficiency and necessitating undesirably large maintenance costs, so that these latter factors also contribute to undesirable heat losses.

In addition to the economic drawbacks resulting from wasting of heat energy, as set forth above, and environmental drawbacks resulting from unavoidable pollution of the atmosphere with conventional installations of the above type, there are further drawbacks with respect to safety. Thus, surveys have demonstrated that it is not at all unusual to encounter explosions with installations of the above type. There is hardly a coke plant in existence for any appreciable length of time which does not regularly encounter explosions. These explosions present considerable hazards to the equipment as well to personnel at these installations.

A further drawback of conventional installations of the above type resides in the fact that the equipment is necessarily of an extremely large size and must be spread out over a relatively large area so that undesirably large costs are encountered simply in providing for the equipment the space which is essential to accommodate all of the components thereof.

Moreover, plants which utilize equipment of the above general type are necessarily geared to handle regularly occurring breakdowns of the equipment. It is never known when part of the equipment will be rendered inoperative because of failures which are unexpectedly encountered, and it is therefore customary for plants of this type to provide installations where standby equipment is always on hand to be set into operation when breakdowns are unexpectedly encountered. These factors also contribute undesirably to the large costs which are involved in the operation of such plants.

SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide an installation capable of handling bulky material in such a way that many of the above drawbacks are eliminated while others are sharply reduced either in the frequency of their occurrence or in magnitude.

Thus, one of the primary objects of the present invention is to provide a bunker installation capable of handling bulky material in such a way that parts of the bulky material which are smaller than a given size are separated from the bulky material even before the latter is discharged from the bunker so that in this way it becomes possible to eliminate screening operations and thus avoid all of the costs and disadvantages necessitated by the screening operations.

It is a further object of the present invention to provide for handling of the smaller parts of the material separated from the bulky material at the bunker itself in such a way that these smaller parts of the bulky material will not pollute the outer atmosphere and can be economically and effectively utilized at suitable burners which make use of the heat energy of these materials which otherwise would be wasted.

Yet another object of the present invention is to provide an installation of the type in which precise highly effective controls of the gas in a closed cycle are achieved in such a way as to provide the best possible utilization of the available energy.

Furthermore, it is an object of the present invention to provide a construction of the above type which greatly reduces heat losses such as those which are encountered at the present time with conventional bunkers. This is an extremely important object of the present invention.

Moreover, it is an object of the present invention to provide an installation of the above type which for the amount of energy which is extracted requires far less space than has heretofore been possible with conventional constructions.

An additional object of the invention is to provide an installation of the above type which will enable operations to continue even if part of the structure must be taken out of operation because of a failure which may be encountered during the operation.

Also, it is an object of the present invention to provide for an installation of the above type safety components which on the one hand greatly reduces the possibility of explosions and on the other hand provide relatively safe conditions even in the rare instance when an explosion may occur.

The objects of the present ivention also include the provision of an installation of the above type which is of a relatively light weight, providing considerable savings in foundation costs and the like, while at the same time being exceedingly robust so that strength in the construction is combined with the light weight thereof.

Also, the objects of the invention include the provision of convenient and effective controls which make it possible to regulate the operation of an installation of the above type in a manner which will achieve the greatest possible efficiency and heat recovery for the particular conditions which are encountered during operation.

According to the invention an apparatus for treating material in bulk includes an upright bunker means which has an upper receiving end for receiving the material in bulk and a lower discharge end through which the material in the bunker means discharges out of the latter while progressing gravitationally downwardly along the interior of the bunker means. The bunker means has in the region of its lower discharge end a tapered wall portion the larger end of which is higher than its opposed smaller end. This tapered wall portion of the bunker means is formed with a plurality of apertures distributed throughout the tapered wall portion for admitting gas into the bunker means to flow upwardly through the bulky material therein while those parts of the bulky material which are small enough to pass through the apertures will fall through the latter apertures out of the bunker means before reaching the discharge end thereof. A plenum means surrounds the tapered wall portion of the bunker means and a gas-supply means communicates with the interior of the plenum means for supplying to the latter gas at a temperature different from the bulk material to flow through the apertures into the bunker means and upwardly through the bulky material therein to achieve a heat-exchange relationship between the bulk material and the gas flowing upwardly therethrough. The parts of the bulky material which fall through the apertures are collected in the plenum means. A gas discharge means communicates with the interior of the bunker means at the region of its upper receiving end to receive the gas which flows upwardly through the bulk material and to discharge the gas out of the bunker means. A transporting means communicates with a lower region of the plenum means to transport away from the latter those parts of the bulk material which fall through the apertures before reaching the discharge end of the bunker means.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

FIG. 1 is a schematic side elevation of one possible embodiment of an installation according to the invention;

FIG. 2 is a fragmentary sectional elevation showing at an enlarged scale apertures of a tapered wall portion of the bunker and a shiftable adjusting plate for the apertures;

FIG. 3 is a schematic sectional plan view taken along line 3—3 of FIG. 1 in the direction of the arrows showing further details of the structure for adjusting the shiftable plate of FIG. 2;

FIG. 4 is a schematic elevation of the structure of FIG. 3;

FIG. 5 is a schematic sectional elevation of a preferred embodiment of an installation according to the invention;

FIG. 6 is a schematic fragmentary sectional illustration of details of the boiler structure of FIG. 5;

FIG. 7 is a schematic partly sectionaly plan view of the installation of FIG. 5 taken along line 7—7 of FIG. 5 in the direction of the arrows;

FIG. 8 is a schematic sectional plan view taken along line 8—8 of FIG. 5 in the direction of the arrows and showing details of the structure for adjusting an outer apertured wall of FIG. 5; and

FIG. 9 is a fragmentary schematic representation of the plenum of FIG. 5 and the transporting means for carrying material away from the plenum.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, there is illustrated therein an upright bunker means 10 which is supported in any suitable way on an unillustrated foundation and which has a wall composed of an outer steel casing 12 which is lined at its interior with a brick lining 14. The upright bunker means 10 has an upper receiving end 16 which receives the bulky material 20 which enters into the interior of the bunker means 10. The upper receiving end 16 may include a central tube 22 into which the bulky material 20 is delivered as schematically indicated by the arrows 24. This material may be delivered to the receiving end 16 from any suitable conveyer, chute, duct, or the like. The bulky material 20 may take the form of incandescent coke transported directly from a coke oven, or it may be in the form of sinter or any other coarse hot material.

As will be apparent from the description below, a gas which is heated by the hot bulky material 20 flows upwardly through this material in the interior of the bunker, and this gas is received by a gas-discharge means 26 situated at the upper receiving end of the bunker and through which the inlet pipe 22 extends. The gas discharge means 26 has a lower wall 28 formed with apertures through which the gas enters the space 30 between the wall 28 and the top wall 32 of the bunker. This space 30 surrounds the pipe 22 and communicates with a pipe 34 through which the gas flows away from the bunker in the manner indicated by the arrows 36. For safety purposes the top wall 32 is provided with one or more explosion doors 38, one of which is schematically indicated in FIG. 1.

The upright bunker means 10 has a lower discharge end 40. This lower discharge end 40 of the bunker is controlled by way of a suitable horizontal gate 42 shiftable to the right and left, as indicated by the arrow 44 and operatively connected through a suitable rod 46, schematically indicated in FIG. 1, to the piston of a hydraulic drive 48 mounted on a support 50 carried by the framework of the bunker at the exterior of the latter. Thus the hydraulic motor 48 may be operated to act through the rod 46 on the gate 42 in order to open or close the discharge end 40 of the bunker to a desired extent.

The bulky material which discharges from the bunker through its discharge end 40 is received in a hopper 52 which has a lower discharge end which is opened or closed to a desired extent by a shiftable gate 54 which is actuated by a hydraulic control 56. The gate 54 is at the top end of a lower tubular extension 58 of the hopper 52, and the bottom end of the tubular extension 58 is capable of being opened and closed by a suitable gate 60 which is in turn controlled by a hydraulic drive 62. Through these several gates and their hydraulic drives it is possible for the bulky material, after progressing gravitationally down through the bunker 10, to reach a conveyer means 64 which conveys the bulky material to any desired location such as suitable storage bunkers where the material is stored for future use.

In accordance with one of the important features of the present invention, the upright bunker means 10 includes a tapered wall portion 66 which has its larger end 68 located higher than its smaller end 70. The smaller end 70 of the tapered wall portion 66 of the bunker 10 terminates directly at the lower discharge end 40 of the bunker while the larger upper end 68 of the tapered wall portion 66 is joined the lower end of the bunker wall which is formed by the steel casing 12 and the brick lining 14. The tapered wall portion 66 is formed with a plurality of apertures 70 distributed throughout this tapered, frustoconical wall portion 66.

The tapered wall portion 66 is surrounded by a plenum means 72 which defines a closed interior chamber 74 which communicates with the apertures 70. The plenum means 72 in turn communicates with a gas-supply means 76 through which gas at a suitable pressure is supplied to the interior 74 of the plenum means 72, and this gas is capable of flowing through the apertures 70 of the tapered wall portion 66 into the bunker in order flow upwardly through the bulky material 20 therein. The flow of the gas into the apertures from the interior 74 of the plenum means 72 is indicated by the arrows 78.

A number of advantages are achieved by way of this construction. Thus, the entry of the gas through the apertures 70 of the tapered wall portion 66 enables the gas to come into contact with the entire body of bulky material which progresses gravitationally down the interior of the bunker, so that where the gas is a cold gas and the bulky material 20 is a hot material, the cold will come in contact with all of the bulky material and extract from the bulky material far more heat than has hitherto been possible with conventional installations.

However, an additional very great advantage which is achieved with this construction is that those parts of the bulky material 20 which are small enough to pass through the apertures 70 will fall downwardly through these apertures into the interior of the plenum means 72 before reaching the lower discharge end 40 of the bunker means 10. As a result the bulky material which is received by the conveyer means 64 is substantially free of any components small enough to fall through the apertures 70. The result is that screening actually takes place at these apertures 70 and it becomes unnecessary for the conveyer means 64 to convey the bulky material to a screening station.

The lower portion of the plenum means 72 is in the form of a series of hoppers circumferentially distributed about the vertical axis of the bunker means **10**, these hopper portions **80** being schematically indicated in part in FIG. **9**. The rod **46** extends between a pair of these hopper portions, and the hopper **52** is supported by beams which also extend between the hopper portions to be connected to the upper region of the plenum means 72.

Thus, the relatively small portions of the bulky material **20** which are small enough to pass through the apertures **70** will collect in the plenum means **72** at the lower ends of the several hopper portions **80** thereof. As is apparent from FIG. **9** these hopper portions **80** communicate with a pneumatic header **82**, having a series of branches **83** communicating respectively with the several hopper portions **80**. Thus, the header **82** also extends circumferentially around the axis of the bunker and is of a circular configuration. As is indicated schematically in FIG. **9**, the pneumatic header **82** communicates with a pipe **84** having a control valve **86** and communicating with the inlet of a blower **88** which serves to provide a stream of air conveying the small components of the bulky material away from the plenum means **72** and delivering this material in a stream of air along the pneumatic duct **90**. As will be apparent from the description which follows this duct communicates with one or more burners where the combustible material collected in the plenum means **72** may be burned so as to utilize the heat energy thereof, and in addition the deposition of the smaller components of the bulky material in the plenum means **72** prevents this smaller material, particularly the components thereof which have the size of dust particles, from being released to the outer atmosphere so that undesirable pollution of the outer atmosphere is avoided in this way.

Depending upon the conditions which are encountered it is desirable to cover and uncover the apertures **70** to a given extent. Some of the apertures **70** are illustrated on an enlarged scale in FIG. **2**. These apertures may have a diameter on the order of ½ inch, so that all components of the bulky material which have a size of ½ inch or less will fall through the apertures **70** to be received by the transporting means formed by the pneumatic pipe **82** and the blower **80**. For some purposes it may be desirable to cover the apertures **70**, or to partially uncover the apertures **70**, and for this purpose there is provided an outer wall means **92** engaging the tapered wall portion **66** of the bunker **10** at the exterior of the tapered wall portion and having apertures **94** which in one position register with the apertures **70** so as to completely uncover the latter, as indicated in FIG. **2**.

As is apparent from FIGS. **3** and **4**, the outer wall means **92** takes the form in the illustrated example of four curved sections of a frustocone each extending through approximately 90° about the axis of the bunker with the tapered wall portion **66** carrying T-guide strips **96** which are situated between and overlap the side edges of the vertically shiftable components of the outer wall means **92**. These several cone sections of the outer wall means **92** are respectively connected through suitable rods **98** with four hydraulic drives **100**, two of which are apparent from FIG. **1**, andd these hydraulic drives are mounted on suitable supporting frames carried by the bunker at the exterior thereof. Through suitable controls the hydraulic drives **100** can be actuated to shift the several cone sections of the outer wall means **92** upwardly or downwardly through the small extent required to bring about complete covering or uncovering of the apertures **70** or partial covering thereof. In this way it is possible to control, for example, the speed with which the gas flows into the bunker to contact the bulky material **20** therein. If it is desired to maintain in the bulky material which reaches the conveyer means **64** all components which are larger than ¼ inch, for example, then the hydraulic drives **100** are operated so as to permit only components of the bulky material which are smaller than ¼ inch to fall through the apertures **70**. However such an adjustment may be made up to a maximum size of ½ inch in the illustrated example.

The gas discharge means **26** delivers the gas at the upper receiving end **16** of the bunker means **10** through the pipe **34** to the top end of a boiler **102** which is schematically illustrated in FIG. **1** to the right of the upright bunker means **10**. The schematically illustrated boiler **102** includes an upper bank of coils **104** forming a superheater and communicating with a steam drum **106** in a well known manner. Below the superheater coils **104** are banks of evaporator coils **108**, and the lowermost bank of coils **108** forms a circulation evaporator receiving feed water from a pipe **110**, as schematically indicated in FIG. **1**. The lowest bank of coils **112** of the boiler **102** forms a gas preheater. The pipe **76** receives the gas from the lower end of the boiler **102** and delivers it to the plenum means **72**. The pipe **76** may communicate with a suitable blower which serves to maintain the gas flowing through the above-described closed cycle. The several banks of coils in the boiler **102** may be surrounded by an outer welded assembly of tubes forming a watertube wall **114** of the boiler **102**. Of course the several banks of coils and the watertube wall communicate with each other to provide for flow of water therethrough in order to achieve at the coils **104** the superheated steam which discharges out of the latter through the pipe **116** which delivers the steam to any desired location where further use is made thereof. Thus, this steam may be used to drive a turbine which in turn may drive a generator, for example.

The pipe 34 accommodates in its interior, just upstream of the boiler **102** an auxiliary burner **118** which is shown schematically in FIG. **1**. This burner is provided to control the inert gas which flows through the closed cycle described above. By way of suitable gas quality monitoring equipment the auxiliary burner **118** is regulated, and the pneumatic pipe **90** of the conveyer means which conveys the particles collected in the plenum means **72** may deliver the combustible material to the auxiliary burner **118** so that the energy of this collected material may be used at the burner **118**. This burner **118** also may be used for increasing the temperature of the boiler at the region of the superheater coils **104**, so as to regulate the quality of the steam which is delivered to the pipe **116** from the bank of coils **104**.

While it is possible with the installation of the invention described above to achieve many of the advantages of the present invention such as prevention of pollution of the outer atmosphere, control of the circulating gas of the closed cycle, and making use of available heat which otherwise would be wasted, it is possible to further improve the installation to eliminate certain advantages which are inherent in this embodiment. Thus, with the embodiment of FIG. 1 there is still a considerable heat loss through the bunker wall structure. Thus the steel casing 12 and its brick lining 14 will store a certain amount of heat which is wasted, and this heat is simply transferred to the outer atmosphere through the brick lining 14 and the steel casing 12. This heat loss amounts to 16–20 percent of the available heat, so that there is a substantial loss through this type of construction.

Furthermore, the arrangement of the boiler 102 outside of the upright bunker means 10 creates the necessity for floor space in addition to that required by the bunker itself, so that an undesirably large amount of space is occupied by the installation which is shown in FIG. 1. In addition, the steel casing and brick lining of the bunker wall makes the bunker exceedingly heavy so that a very strong foundation is required.

FIGS. 5–8 illustrate an embodiment of the invention which avoids these drawbacks of the embodiment of FIGS. 1–4. The upright bunker means 120 shown in FIG. 5 also includes a lower tapered wall portion 66 provided with apertures 70, this part of the structure being identical with that of FIG. 1. Also, the lower tapered wall portion 66 of the bunker means 120 is surrounded by a plenum means 72 which is substantially identical with that of FIG. 1. In addition, the structure beneath the lower discharge end 40 of the bunker for receiving the bulky material 20 from the bunker and conveying it to a suitable location is substantially identical with that of FIG. 1 and is indicated by the same reference characters. The only difference is that pairs of gates 42 and 54 are moved equally and oppositely by motors 48 and 56, respectively.

At the upper receiving end of the bunker means 120 the material enters also through a pipe 22, and the gas discharges out of the bunker through an apertured wall 28.

However, with this embodiment the boiler 122 directly surrounds the bunker and in fact has an inner water-tube wall 124 which forms that part of the bunker wall which extends upwardly from the tapered wall portion 66 thereof. The inner watertube wall of the boiler 122 not only receives heat directly from the material 20 in the bunker itself, but part of this wall extends downwardly beyond the top end of the tapered wall portion 66 so that the lower portion of the inner watertube wall 124 is heated by heat which travels through the lower tapered wall 66 and is situated in the upper part of the plenum means 72.

The boiler 122 includes an outer watertube wall 126 which communicates with the upper boiler drum 128 which may have an annular configuration.

In the space which is defined by the inner and outer watertube walls 124 and 126 of the boiler 122 there are banks of convection coils 130. These banks of convection coils 130 are arranged in the manner illustrated in FIG. 7 in separate groups of coils which are separately supplied through cold water inlet pipes 132 and separately communicate with steam discharge pipes 134 which communicate with the boiler drum 128. The watertube wall 126 is made up of a series of flat sections releasably connected to vertical spacers 127′ of wedge shaped cross section to form the polygonal configuration illustrated in FIG. 7, and as a result it is possible if any one of the banks of coils 130, fixed as by welding to the flat sections of wall 126, respectively, becomes defective to remove this bank with the section of wall 126 fixed thereto while the operations go forward with the other convection coil units 130. Spacers 127′ are formed with vertical passages 129 receiving feedwater from pipes 132 and communicating with pipes 134.

The steam delivered through the pipes 134 to the boiler drum 128 flows from the latter through pipes 136 into a series of superheating coils 138 situated between the walls 124 and 126 above the convection coils 130. Superheated steam is discharged out of the superheating coils 138 by way of the discharge tubes 140.

With the embodiment of FIG. 5, the lower wall portion 66 is surrounded by a tapered apertured wall 142 illustrated in FIGS. 5 and 8 and having apertures corresponding to the apertures 94. These apertures 94 are also capable of registering with the apertures 70 when the latter are completely uncovered. The tapered wall 142 which matches the configuration of the tapered wall 66 and engages the latter at its exterior surface is slidable around the axis of the bunker for adjusting the extent to which the openings or apertures 70 are covered or uncovered. For this purpose the outer wall means 142 of this embodiment is fixed with a radially extending arm 144 connected through a rod 146 with a hydraulic drive 148. The rod 146 may extend through suitable fittings of the plenum means 72.

The gas flowing upwardly beyond the bulky material 20 in the bunker means 120 of FIG. 5 flows through the apertures of the wall 28 into the gas discharge means 26 of this embodiment. In this case also the top wall of the bunker is provided with an explosion door 38. In addition, the safety is increased by connecting safety valves 147 to the boiler drum 128. Just before the gas in the gas discharge means 26 reaches the top end of the space defined between the inner and outer watertube walls 124 and 126 of the boiler 122, the gas encounters a dust collecting means formed by inclined baffles or the illustrated series 150, and thus dust is prevented from entering into the boiler 122. This dust will enter suction pipes 151 communicating with cyclones 150, respectively, and with a circular header 153 which communicates with header 82 (FIG. 9) to be carried away by the transporting means shown in FIG. 9 and described above. Wall 155 carries the cyclones and fills the spaces therebetween so that all gas from discharge means 26 must pass through cyclones 150. From the latter, the cleaned hot gas flows through pipes 147 downwardly through the boiler.

The interior of the gas discharge means 26 also accommodates auxiliary burners 152 which may be supplied by the pneumatic pipe 90, as from branches 90a and 90b thereof so that the material collected in the plenum means may be burned at these auxiliary burners 152. The burner gas may also be derived from green coke with the addition of oxygen if necessary and with the admission of nitrogen if necessary to prevent explosions.

From drum 128 water flows down the tubes of watertube wall 126 and up the tubes of watertube wall 124 to flow through circular header 121 into a small number of widely spaced tubes 123 which respectively communicate with the outer ends of a number of flat spiral tubes 125 which form the top wall 127. The inner ends of tubes 125 communicate through tubes 127 with drum 128, thus completing the closed circuit through the boiler walls.

The watertube walls may be covered with Gunnite which is sprayed thereon in the form of a ceramic spray deposited on the fins and coils of the watertube walls to increase the heat resistance thereof. In addition it is possible to surround these watertube walls at their interior and exterior surfaces with heat-resistant steel plates or cast iron may be used if desired.

As may be seen from FIG. **6**, it is also possible to fix the coils such as the convection coils **130** directly to the watertube walls **124** and **126**, so that in this case an exceedingly strong construction will result with the fixing of the interior coils to the inner and outer watertube walls forming the same effect as a girder construction where beams are reinforced by struts extending between and fixed to the beams. The coils may be welded to the inner and and outer watertube walls or they may be bolted thereto in the manner shown schematically in FIG. **6**. The same fixing of the coils to the inner and outer watertube walls may be provided for the superheater coils **138**. In this way while the entire boiler structure of FIG. **5** is lighter than the brick lined steel wall of FIG. **1**, nevertheless it is exceedingly strong, and at the same time the foundation for the embodiment of FIG. **5** need not be as strong as the foundation required for the embodiment of FIG. **1**.

Thus, FIG. **5** shows a strong but relatively light supporting framework **154** which carries the entire installation of FIG. **5**.

According to a further feature of the invention this framework **154** carries a vibrator means formed by a plurality of vibrators **156** in the form of suitable electrical motors carrying rotary discs provided with eccentric weights so that when the motors are operated a controlled vibration for the entire assembly will be provided. Through this vibrator means **156** it is possible to increase the extent to which the relatively small components of the bulky material **20** drop through the apertures **70** into the plenum means **72**.

Thus, with the above-described structure of the invention it is possible to cool or preheat course material through an orifice plate-type bunker so that the most uniform gas flow through the bulky material is achieved. The elimination of dust from the bulky material before it reaches the discharge of the bunker means has the great advantage of creating less problems at a screening station if the material from the bunker is delivered to a screening station and in fact renders in many cases screening stations superfluous.

The collected dust may be used at the auxiliary burners, as pointed out above, before the waste heat boiler and/or gas preheater. These auxiliary burners have the double function of increasing the steam production at the boilers and controlling the gas condition in the closed cycle.

The embodiment of FIG. **5** is of particular advantage because it is light and at the same time strong and in addition requires far less floor space than the embodiment of FIG. **1**. The strength of the installation is greatly increased by the fixing of the inner coils of the boiler to the inner and outer watertube walls thereof so that there is a stiffening between these walls providing the effect of a box girder in a bridge. In addition, the exterior watertube wall **126** fixedly carries stiffening rings **160** which are brazed directly onto the exterior watertube wall and serve to add to the stiffness and strength of the entire structure. This added stiffening also increases safety in the case of an explosion.

Particularly with the embodiment of FIG. **5**, loss of heat is reduced to a minimum. A minimum surface is exposed to the open air with the embodiment of FIG. **5**, so that an extremely large amount of heat can be used for power generation or gas preheating. With the embodiment of FIG. **5**, because the heat losses are reduced to a minimum, the outside watertube wall temperature will not exceed 400° F, and of course with proper insulation which is provided the heat losses are reduced to an absolute minimum.

A pipe system **76** similar to that of FIG. **1** receives cool gas from the boiler and delivers it to the plenum means **72**.

What is claimed is:

1. In an apparatus for treating material in bulk, upright bunker means through which the material to be treated is adapted to move in a downward direction, the material in bulk being in a heated condition when received in said bunker means at an upper portion thereof and in a cooled condition when discharging from said bunker means through a lower portion thereof, gas supply means communicating with said lower portion of said bunker means for supplying a gas at a relatively low temperature to flow upwardly through said bunker means to be heated by the material in bulk therein by extracting heat therefrom while the material in bulk is cooled by the upwardly flowing gas prior to discharge of the material in bulk from the lower portion of said bunker means, gas-discharge means communicating with said upper portion of said bunker means for discharging from the latter a hot gas heated by the material in bulk while the latter is cooled by the gas flowing upwardly through said bunker means, and upright boiler means operatively connected between and communicating with said gas-discharge means and said gas-supply means for receiving hot gas from said gas-discharge means and generating steam therefrom while cooling the hot gas and for delivering cooled gas to said gas-supply means to be recirculated by the latter upwardly through said bunker means for operating with heat from the material in said bunker means.

2. In an apparatus for treating material in bulk as recited in claim **1**, said bunker means having an upper receiving end for receiving the material in bulk and a lower discharge end through which the material in said bunker means discharges out of the latter while progressing gravitationally downwardly along the interior of said bunker means, said bunker means having in the region of said discharge end thereof a tapered wall portion the larger end of which is higher than its opposed smaller end, said tapered wall portion of said bunker means being formed with a plurality of apertures distributed throughout said tapered wall portion for admitting gas into said bunker means to flow upwardly through the bulky material therein while those parts of the bulky material which are small enough to pass through said apertures will fall through the apertures out of the bunker means before reaching said discharge end thereof, plenum means surrounding said tapered wall portion of said bunker means and said gas-supply means communicating with the interior of said plenum means for supplying to the latter gas to flow through said apertures into said bunker means and upwardly through the bulk material therein to achieve a heat-exchange relationship between the bulk material and the gas flowing upwardly therethrough, the parts of the bulky material which fall through said apertures being collected in said plenum means said gas discharge means communicating with the interior of said bunker means at the region of said upper receiving end thereof for receiving the gas which flows upwardly through the bulk material and for discharging the gas out of said bunker means, and into said boiler means, and transporting means communicating with a lower region of said plenum means for transporting away from the latter those parts of the bulk material which fall through said apertures before reaching said discharge end of said bunker means.

3. The combination of claim 2 and wherein an outer wall means is located directly next to said tapered wall portion of said bunker means in engagement therewith and is formed with apertures which in one position of said outer wall means respectively register with said apertures of said tapered wall portion, and adjusting means operatively connected with said outer wall means for adjusting the position thereof with respect to said tapered wall portion for controlling the extent to which said apertures of said tapered wall portion are covered or uncovered by said outer wall means.

4. The combination of claim 1 and wherein said boiler means is spaced from said bunker means.

5. The combination of claim 4 and wherein said bunker means includes above said tapered wall portion thereof an outer steel casing and an inner brick lining covering the interior surface of said steel casing.

6. The combination of claim 2 and wherein said boiler means directly surrounds and is carried by said bunker means, part of said boiler means forming a wall of said bunker means which extends upwardly from said tapered wall portion thereof.

7. The combination of claim 1 and wherein said boiler means directly surrounds and is carried by said bunker means, part of said boiler means forming a wall of said bunker means and said wall of said bunker means which is formed by part of said boiler means being a watertube wall forming an inner wall of said boiler means, said boiler means including an outer watertube wall spaced from and surrounding said inner watertube wall thereof which forms part of said bunker means, and convection coils extending between and fixed at least to said outer watertube walls of said boiler means for forming a substantially rigid tubular assembly therewith, said inner and outer watertube walls defining between themselves a space in which said convection coils are accommodated and said space having an upper end region communicating with said gas-discharge means to receive the hot gas therefrom and a lower end region communicating with said gas-supply means for supplying cool gas thereto.

8. The combination of claim 7 and wherein a dust-collector means is situated between said gas-discharge means and said upper end region of said boiler means for preventing dust from entering said boiler means with the hot gas delivered to said boiler means by said gas-discharge means.

9. The combination of claim 7 and wherein a burner means is situated in said gas-discharge means for increasing the steam production of said boiler means and for controlling the gas condition in the closed cycle defined by said bunker means, boiler means, and gas-supply and discharge means.

10. The combination of claim 9 and wherein a transporting means transports the material collected from said bunker means away from the latter to said burner means to be burned thereby.

11. The combination of claim 7 and wherein said convection coils are divided into separate banks which are separately removable so that if necessary one of said banks can be removed while operations continue with the remaining banks.

12. The combination of claim 2 and wherein said transporting means is in the form of a pneumatic means communicating with the lower region of said plenum means for transporting material out of the latter in a stream of air.

13. The combination of claim 12 and wherein a valve means is situated between said plenum means and pneumatic means for controlling the flow of material from said plenum means to said pneumatic means.

14. The combination of claim 2 and wherein a vibrator means is operatively with said bunker means means for vibrating the latter to promote the falling of part of the bulk material through said apertures.

15. The combination of claim 2 and wherein a conveyer means is situated in part beneath said discharge end of said bunker means for receiving the bulk material therefrom and for conveying the bulk material away from said bunker means, whereby screening of the material carried by said conveyer means is rendered unnecessary because of the falling of part of the bulk material through said apertures.

16. The combination of claim 1 and wherein said boiler means directly surrounds said bunker means and boiler means having a common watertube wall.

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