APPARATUS FOR DENSE-PHASE FLUIDISATION

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For many years past, certain methods have employed the technique, recently developed, which is known as dense-phase fluidization: more or less fine particles of a substance to be treated or to be reacted are maintained in suspension in a rising flow of gas, the speed of which is sufficient to keep the layer of particles in a violent state of agitation, but which is not sufficient to carry away out of the said layer anything but the lightest particles.

These methods become no longer operative if, as a result of high temperatures or for any other reason, the particles which come into contact agglomerate with each other in the flow of gas.

For example, in the case of gas producers, these can only operate at a relatively low temperature. In fact, if the ash of the fine particles is carried away in the form of dust, that of the larger particles falls on the grate at the bottom of the apparatus, from which it is extracted by means of a mechanical device. It is therefore necessary to avoid any inception of fusion of the ash which would rapidly block up the extraction device.

The relatively low temperature of the gasification has however the consequence that the gas produced is very far from reaching the theoretical equilibrium of reduction; it contains, for this reason, high proportions of carbon dioxide and steam which have not been reduced by the fuel to useful constituents such as carbon monoxide and hydrogen. On the other hand, the particles of coal become lighter and lighter in the course of the gasification, so that the smaller particles are finally carried away by the flow of gas, from which they must be separated. This dust is still only partially burnt and it cannot be recycled with the entering fuel without the risk of being immediately again carried away without having reacted to any substantial extent. This dust, still containing much combustible matter, must therefore be either thrown away or used for other applications, heating with pulverised fuel for example.

In the U.S. patent application Serial No. 267,948 of January 24, 1952, now Patent No. 2,772,954, for: "Gasification Method," it is proposed to improve the operation of gas-producers working by dense-phase fluidization by heating the coal and the gasifying agents (air, air and steam, oxygen and steam, oxygen and carbon dioxide) by the gas produced in order to receive the sensible heat contained in this gas; and by the use of a much higher gasification temperature. By these means, a better efficiency, a smaller consumption of gasification agents, and a gas which contains less carbon dioxide and steam but more carbon monoxide and hydrogen are obtained. The agitation due to the fluidization brings the particles to frequent and numerous collisions, and the particles which are already partly burnt and which are covered with a coat of partly fused ash, stick together and become agglomerated, until they are large enough to fall into the lower part of the gasification zone. In the application referred to, the gasification zone is in the gasification agents being introduced at that apex. As soon as the grains of ash, which take the form of small balls, become large enough, they fall down to the apex of the cone from which they can be extracted at the desired diameter by varying the speed of flow of the gasification agent.

During the pilot-plant tests of this method, which has given good results, it was found that still better results were obtained if, instead of a conical zone taking up the entire section of the apparatus, there were employed a conical zone terminating in the apparatus with a section smaller than that of the apparatus itself, the remainder of the section being supplied with gasification agents, preferably in an independent manner, through a grate slightly higher at the wall of the gas producer than at the center, so that the ash which could fall to this grate would not remain on it but should be carried away towards the center of the conical zone by their own weight and by the flow of the gasification agents.

Whereas the conical zone employed alone gives a very violent and irregular agitation which is not a true fluidization, the device described above permits a very good dense-phase fluidization, that is to say a uniform distribution and a regular agglomeration of the fine particles during the course of gasification. The gas is thus better divided by the fine particles, the reducing action of which is therefore better distributed in the flow of gas. In this way, a better reduction of the gasification agents is obtained and in consequence a gas of superior quality and a higher efficiency is formed. In addition, the advantages of the conical zone for the evacuation of the ash are obtained.

These improvements have further advantages in applications of dense-phase fluidization other than the gasification of a fuel, as will be indicated at the end of the present description.

The description which follows with reference to the accompanying drawings (which are given by way of example only, and not in any sense by way of limitation) will make it quite clear how the invention may be carried into effect, the special features which are brought out, either in the drawings or in the text, being understood to form a part of said invention.

Fig. 1 is a diagrammatic view in vertical cross-section of an embodiment of an apparatus for gasifying solid fuels, in accordance with the invention.

Fig. 2 is a partial cross-section on a larger scale of the annular grate which surrounds the central conical zone.

Fig. 3 is a plan view of this grate on a smaller scale.

Fig. 4 shows a vertical cross-section of a device for re-cycling dust.

The gas-producer shown in Fig. 1 comprises a gasification zone surrounded by a refractory wall 1. The fine particles of solid fuel are brought into the grate from the exterior, or from heating stages which are not shown, by any suitable devices. A portion of the gaseous gasification agents, which may or may not be pre-heated, is introduced through the pipe 2 into the central conical portion 3 of the grate. This conical portion 3 has a fairly pronounced conicity (an apex angle comprised for example between 10° and 50°) and is made of a full wall coupled to a venturi 4 which ensures a uniform speed of the gasification agents in the lowest section of the cone, so that this speed will permit the extraction of small balls of ash of a very uniform size, but will prevent the falling of particles which are too small. The convergent portion of the venturi serves to increase the speed of the gas at the lower portion of the cone 3 and, in addition, to obtain, in all of the narrowed section, speeds which are as uniform as possible to prevent any of the small particles from falling, whereas on the upstream side of this con-
vergent portion, the speed of the gas is reduced so as not to hinder the descent of the large particles which have passed through the neck of the venturi. The divergent portion of the venturi is formed by the cone 3. It may be coupled to this cone if the latter has a conicity greater than that of the divergent portion of the venturi at optimum efficiency. It is desirable that the gasification agents should have a speed perpendicular to the smallest section of the venturi and that at this point they should not have any lateral movement. It is thus necessary that the length of the conduit 2a between the tube 2 and the venturi 4 should be sufficient to damp out any movement of this kind, or that this conduit should be fitted with fins parallel to the axis and fixed to the walls of the said conduit, leaving between them a clear way having a diameter at least as great as that of the neck of the venturi. The remaining part of the gasification agents is introduced through the piping system 5 under the annular peripheral grate 6. The latter is formed by radial or concentric members provided with overlapping portions. The gases can pass between these members but their overlapping portions prevent the passage of the fine particles into the lower distribution chamber 7, into which the pipe 5 discharges. By way of example, Figs. 2 and 3 show the constitution of the grate 6 by metal rings 6a which are concentrically mounted on radial supports 6b which are attached at their extremities to the wall of the chamber 7 and to that of the cone 3. These rings form between each other small gas passages 6c of zigzag shape, which are permeable to the gases coming from the chamber 7 but not to the solid particles. These passages are maintained at their correct width by means of spacers 6d with which the rings 6a are provided. Any other arrangement may be employed, for example that of radial elements with overlapping portions. The parts of the gating 6 are arranged in such a manner as to form a slight and uniform slope of the order of at least 10°, between the wall of the gas-producing and the central portion 3. There is thus obtained in the gasification chamber 8 a zone of dense and uniform fluidization. At the lower portion of this chamber, the reaction of the carbon of the fine particles with the oxygen of the gasification agents is extremely rapid and violent, converting all the oxygen to carbon dioxide with a very considerable production of heat. The carbon dioxide thus formed, that introduced with the gasification agents, and that produced are immediately brought up to the high temperature of the gasification. As these gases are also kept in intimate contact with the fine particles during the course of their passage through the dense fluidized zone 8, they are rapidly reduced to carbon monoxide and hydrogen. This reduction is carried out under very good conditions by reason of the very high temperature of reaction which is the same over all the fluidized bed, of the excellent contact between the gas and the fine particles of carbon, of the large surface of these particles and of their rapid rate of circulation produced by the fluidization.

As indicated above, this very rapid circulation and the numerous collisions which result give rise to agglomerations of the fine particles when the partially fused ashes appear on their surface. The particles thus increase in size little by little and then fall to the bottom of the apparatus. Those which fall on the slightly-inclined annular grate 6 are pushed, as is well known, by the action of the gas flow, until they fall into the cone 3. When they reach this cone, they are engaged by a fairly violent flow of gas which sends them back into the fluidized bed, in which they again come into contact with other particles and increase in size. This circulation continues up to the moment when the grains of ash, which are almost spherical, are heavy enough and fall to the bottom of the cone and pass through the venturi. The size of the balls which are extracted in this way is a function of the speed of the gasifying agents in the neck of the venturi. This speed depends in turn on the cross-section of the venturi, and also on the rate of flow and the temperature of the gasifying agents at this point. This speed can be regulated quite easily, the rate of flow through the grate being kept within wide limits without adversely affecting the fluidization.

Experience has shown that these ash grains, which can have a diameter from a few millimeters to a few centimeters, depending on the conditions of working of the apparatus, are practically free from unburnt material; they contain less than 0.5% of carbon.

The temperature of gasification should be in the neighborhood of the temperature of the incipient fusion of the ashes in order that these may agglomerate well together. It is thus important to be able to regulate this temperature, which is easily effected by acting on the proportions of steam or of carbon dioxide and of oxygen in the gasifying agents.

It may also be an advantage not to have the same proportions of air to steam, oxygen to steam, or oxygen to carbon dioxide in the streams of gasifying agents which pass respectively through the grate 6 and through the cone 3. It is in fact desirable to have more steam or more carbon dioxide in the portion of the gasifying agents which enters through the grate 6, in order to prevent the production, in the layer which is immediately above this grate, of a reaction which is too sharply exothermic and which, by raising the temperature excessively at one point, would be liable to cause a complete fusion of the ashes and to lead to an adhesion of the ashes on the grate.

In order to have a sufficient output per square meter of cross-section of the gas producer apparatus, fairly high speeds of gas must be adopted above the fluidized layer. The gas produced will thus carry away a portion of the fine particles which pass into the gasifying zone. These fine particles will be partly retained in the upper stages of the apparatus (not shown), which stages serve for the heating of the fine particles, but there will always be a certain proportion of coal dust carried away which it will be advantageous to collect in a cyclone or in any other separating apparatus.

As tests have shown, the dust thus separated from the flow of gas does not contain a greater proportion of ash than the initial fine particles. It is thus possible to re-cycle them and thus to convert them to useful gas. The best method of doing this is to re-introduce them into the apparatus by means of a small quantity of the gasifying agents. The re-introduction if preferably carried out below the venturi 4, as shown in Fig. 4. In this latter figure, the separation of the dust is effected in a cyclone separator 50 which could furthermore be replaced by another similar apparatus of any kind. In this cyclone, the gas to be free from dust enters through piping system 21 and the clean gas passes out through the piping 22. The dust collected at the base of the cyclone falls down in a tube 23 provided with a gas-intake 24, which gas is intended to maintain the dust in the column constantly in a slightly fluidized state in order to avoid any obstruction. This gas may be an inert gas or gas manufactured in the apparatus and extracted by the compressor 25 after cooling. At the base of the descent tube 23 for the dust is provided a valve 26 of a suitable type, or a rotary distributor. The dust falls into a chamber 27 or into any suitable device which enables it to be taken up again by a branch flow of gasifying agents arriving through the tube 28. The suspension of dust in this flow is sent through the pipe 29 into the vertical tube 2a which brings the air to the venturi 4 of Fig. 1. This intake tube 29 is preferably arranged obliquely inside the vertical tube and discharges close to the bottom of this latter so that the jet of dust is broken up against this wall and there is thus no agglomeration of dust to be feared. The intake of the tube 29 is effected of course above the intake of the tube 2 of Fig. 1. The section of the vertical tube 2a is so chosen
that the speed at that point is sufficient to cause the fine particles introduced to rise towards the gasification zone, without however impeding the descent of the large particles of ash which have passed through the venturi.

The re-cycled dust, in intimate contact with the gasifying agents, is brought very rapidly to the temperature of gasification. By reason of their large specific surface, and of their introduction into the part of the apparatus in which the reaction is most violent, they react immediately and their ashes become agglomerated with those of the fine particles in course of agglomeration.

The dust which is re-introduced is therefore no longer carried away out of the zone of gasification.

It should further be observed that, in a similar manner, one or a number of reactive substances could be introduced into the apparatus, use being made by example of a flow of air discharging into the conduit 2a, on the upstream side of the venturi 4 as a vehicle for these substances.

The improvements in the technique of gasification of fine particles of solid fuels indicated above enable to obtain an apparatus which is easy to control, requiring little attention, easy to maintain, since it does not have any moving part at high temperature, and the output of which in useful gas is very great, by virtue of the following characteristics:

(a) The reaction zone is at high temperature and the gasifying agents are immediately brought up to that temperature, the specific surface area of the fine particles present in this zone is considerable, and their agitation with respect to the flow of gas is very great, thereby assisting the reactions of reduction:

(b) The ash is discharged practically free of unburnt matter;

(c) The dust carried away is re-cycled and completely used.

For apparatus of small or medium capacity, a single conical portion 3 will obviously be employed for the extraction of the ash. In the case of apparatus of large capacity, it may be desirable to use two or more conical portions working in parallel for the extraction of the ash.

By way of alternative construction, the uniform conical surface may be replaced by any other type of flared surface or that of a pyramid.

As has already been stated in the preamble to the present description, the invention is adapted to applications other than the gasification of fuels.

For example, the U.S. patent application Ser. No. 267,948 of January 24, 1952, for: "Gasification Method," already referred to, describes the production of hydrogen from producer gases, by reduction of the steam by means of iron or iron oxide, the latter being previously reduced by the producer gas, the reduction taking place by dense-phase fluidization and the iron oxide being employed in the form of powder. For this production, a gas producer comprising a fluidization zone arranged at its base in accordance with the present invention could be used for the production of the producer gas from fine coal particles.

Swiss Patent No. 292,859 describes a continuous method of manufacture of iron or steel by treatment and reduction of oxides, of hydrate or of metallic salt, the said substances being used in the form of powder and all or part of the various stages of the treatment and the reduction being effected by means of currents of reducing gas that maintain this powder in a state of dense-phase fluidization. There will be an advantage in using a fluidization zone arranged in accordance with the invention, especially in the stage of reduction of the FeO in order to extract the particles of agglomerated iron, especially in the case of ores which require a fairly high reduction temperature giving rise to agglomeration by sintering of the particles of iron as when they are reduced.

Swiss Patent No. 292,727 also describes the application of fluidization to the manufacture of cement. A zone of dense-phase fluidization constructed in accordance with the invention, will be used with advantage in the part of the apparatus in which the clinkers form, the latter being evacuated, when they are of a sufficient size, through the central cone and the venturi.

French Patent No. 1,050,572 describes the manufacture of zinc by reduction of ore by means of coal in a dense-phase fluidization apparatus which could be preferably constructed in accordance with the present invention, the elimination of the agglomerates formed by the coal ash and the matrix of ore being carried out through the central cone and the venturi.

It will of course be understood that modifications may be made to the forms of embodiment which have been described above, in particular by the substitution of equivalent technical means, without thereby departing from the spirit or from the scope of the present invention.

What we claim is:

1. An apparatus for the treatment of substances in a dense-phase fluidized mass comprising, in combination, means defining a fluidizing chamber, said chamber having a side wall, a substantially vertical conduit disposed below said chamber and having an upper end, an upwardly divergent duct connected to said upper extension of said conduit and having an upward divergence comprised between 10 and 50°, said duct being bounded by a substantially continuous wall and having an upper end opening into said chamber at a radial distance from said side wall, means for delivering a gaseous fluidizing agent to said conduit to create and ascending gaseous flow through said divergent duct, an upwardly divergent grate gradually sloping outwardly and upwardly from said upper end of said duct to said side wall and having a divergence substantially greater than that of said duct with said grate extending substantially closer to the horizontal than to the vertical, and means externally of said duct for supplying a gas to said chamber through said grate, whereby said gases enter said fluidizing chamber both from said duct and through said grate.

2. An apparatus as defined in claim 1, wherein the slope of said grate extends at an angle of about 10° with respect to the horizontal.

3. An apparatus as defined in claim 2, wherein said grate comprises overlapping elements in staggered formation to define a plurality of passages for the gas issuing from said gas supply means, said passages opening into the fluidizing chamber in a substantially vertical direction.

4. An apparatus as defined in claim 1 wherein said extension is a Venturi smoothly connecting said conduit with said divergent duct, the delivery point of the fluidizing agent delivering means being positioned below said Venturi, whereby said Venturi is traversed by an ascending gaseous flow.

5. An apparatus as defined in claim 4, further comprising means externally of said fluidizing agent delivering means for introducing minute reactive particles into said conduit at a point thereof intermediate said delivery point and said Venturi, whereby said particles are entrained upwardly towards the fluidizing chamber by the ascending gaseous flow.

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