This invention relates to a method and apparatus for drying and/or pulverizing heat sensitive granular material, and especially to a method and apparatus which maintains said material continuously gas-born throughout the process.

Among the materials whose processing requires drying, grinding or classifying, there are certain heat sensitive ones which are detrimentally affected by high temperatures and especially so if the high temperature is continued for a long time. Sometimes these materials leave an earlier process in a wet state and often having wide differences in particle size, so that further processing thereof requires either drying or grinding or both. Due partly to the different particle sizes, conventional drying will often cause overheating of portions of a particle if during the drying process the material is exposed to the applied heat for an appreciable length of time. Also, in conventional grinding when in a wet state, the somewhat gummy or plastic characteristics of certain materials will cause them to cake in the grinding equipment. Further, it sometimes is not desirable to reduce these particles to extremely fine sizes so that the grinding must be controlled within selected limits. Therefore, the problem is to reduce the particles in size while they are still wet and in a manner which will not build up excessive heat, and to dry them in a manner which will not undesirably reduce their size, but which, nevertheless, will return any oversized particles to the grinding region for further size reduction.

It is well known that a particle suspended in a turbulent drying and gaseous medium is more uniformly affected over its entire surface than if it rests in contact with other material or a foreign surface. In recognition of this, many forms of dryers keep the materials agitated or cascading down through a flow of drying gases. It is also known that gaseous fluid pulverizers of the jet type have been used to do both drying and grinding; however, gaseous fluid devices of the jet type are often limited in their application by the drying capacity of the grinding fluid, which is a function of the quantity of gas flowing, its temperature and humidity. Assuming the temperature and humidity of the entering fluid to be limited by the properties of the material to be dried, sufficient drying may be accomplished where the material is quite wet only by increasing the amount of grinding gas to whatever extent is required to provide the needed drying capacity. The result of this, however, may be simultaneously to provide an excess of grinding capacity and hence make the material finer than desired. In any event, it represents a considerable wastage of pressure energy in obtaining the desired increase in drying capacity.

In order to solve this problem we have developed a method in which we use only sufficient high pressure gas to do the desired grinding and then, while the material is carried in suspension in a turbulent and extended path, we introduce thereto a stream of low pressure drying gas in whatever amounts are necessary to give a satisfactorily dried product.

It has also been found that many materials difficult to dry, due to critical temperature range or for other causes, require so long a contact time with the drying gases that as a practical matter a considerable quantity of material must be recirculated. It has also been found that if this material laden gas is not maintained in a circulating condition, sometimes an unstable surging of the load may occur, or at other times a static condition of the material over the load may exist, either of which results in at least the possibility of both poor size classification, due to poor dispersion of the materials within the gases, and localized overheating. This problem too is solved by supplying only sufficient high-pressure gas to reduce the materials to the desired particle size and supplying all additional circulating requirements by low-pressure gas.

We also obtain a considerable saving of expense because the high-pressure jets, which are the more expensive to operate, are restricted in their action to accelerating only materials which have been substantially freed of any large accompanying volume of gas. This contrasts with certain other jet pulverizers which might be used for simultaneously drying and grinding in which the high-pressure jets must bear the additional burden of accelerating and maintaining the circulation of a mixture of gas and the material in order that proper classification may be obtained. In the herein disclosed method the more expensive high-pressure energy is used primarily for the purpose of particle size reduction, and the less expensive low-pressure gas is used for drying and circulating. The classification is substantially independent of the origin of the classifying gases since due provision may be made for this part of the operation in the design of the equipment being used.
Therefore, in solving the above problems, we have provided a method and apparatus involving a novel combination of grinding and drying elements, both of which are so inter-related as to effect the desired drying and size reduction and yet keep each in proper balance with the other. The grinding is accomplished by feeding the material into a stream of relatively high pressure gas whereby the particles are hurled and shattered against suitable means, such as an anvil or an opposed similarly loaded gas stream. The broken particles are then carried by the gas stream through a series of conduits, circulating means and separating means, where one or more supplementary streams of warm, dry, low pressure gas are introduced thereinto to effect said drying without increasing the rate of flow sufficiently to overheat or abrade the particles unduly. By appropriate classifiers the fines are continuously withdrawn from the system and conveyed to a collector, and the oversized particles are returned to the grinding operation for further processing.

Accordingly, the major object of our invention is to provide a method and apparatus for drying and/or pulverizing a heat sensitive granular material.

Another object of our invention is to provide a method and apparatus for grinding and pulverizing a plastic having a relatively low softening point, and to control the particle size of the finished product.

Another object of our invention is to provide a method and apparatus as above stated wherein oversize particles will be returned to the feeding portion of the apparatus involved for further size reduction but without overheating.

Another object of our invention is to provide a method and apparatus for the purposes above stated which will deliver finished product continuously at an approximately constant rate.

Another object of our invention is to provide a method as above stated which can be carried out by apparatus having no operationally moving parts, and to provide such apparatus.

Another object of our invention is to provide a method which can be carried out by relatively simple apparatus, particularly apparatus free from complex controlling and controlled members, and to provide such apparatus.

Other similar and related objects will be readily apparent to one acquainted with the art on reading of the following disclosure and examining the accompanying drawings.

In the drawings:

Figure 1 represents a schematic drawing, largely in section, of apparatus embodying a method of accomplishing the above purposes.

Figure 2 represents a side view, partially in section, of a detail of the apparatus shown in Figure 1.

Figure 3 represents a schematic view, partially in section, of another form of apparatus embodying said method.

Figure 4 represents an additional unit which may advantageously be used in connection with the form of apparatus shown in Figure 1.

Other forms and kinds of apparatus will at once suggest themselves to persons skilled in the art of drying and pulverizing partially divided materials, but the apparatus herein disclosed will illustrate our method and will provide certain specific forms of apparatus capable of carrying out said method.

Referring now to Figures 1 and 2 of the draw-
able means, not shown, for collecting and/or discharging the ground and dried material. Referring now to Figure 4 there is shown additional structure which is advantageous in certain cases, particularly where the material, as plastic, is unusually wet or where it contains a ground below the size which a given device will recirculate. Entering the side of the bag-holding member 45 is a gas jet 42 which is axially aligned with an offtake pipe 43. This offtake pipe 43 discharges into pipe 44, which in turn discharges through any convenient member into the final cyclone 51. This provides an extra drying cycle for the material which was either initially very fine or which may have been broken into very fine particles in the first impact and thus may have come directly through the cyclone 11 and conduits 27 into the final cyclone 51 without any recycling and hence might still be insufficiently dried.

Referring now to Figure 3 there is shown a device having the same purpose as the above described device, but having a somewhat different construction and which is particularly applicable where the material is very wet. In this device the hopper 50 is of a convenient form and construction to receive the raw feed. The feed jet 52 is located immediately below said hopper within the hopper conduit 72 and axial therewith. This conduit opens tangentially into the lower part of the elutriation column 65. The bottom portion of said conduit is conical and has an opening in the bottom thereof, to which is attached the short connecting pipe 56. A primary gas pipe 54 enters into the elutriation column 65 in its bottom portion, from any convenient point outside thereof, and connects to a nozzle member 59 which is coaxial with the connecting pipe 56. Both the feed jet and the said primary gas pipe are operatively connected with a source, or sources, of dry gas, as steam or air, under suitable pressure.

The connecting pipe 56 communicates with an impact chamber 57 which has an impact anyvil 58 positioned to be struck by the gas stream issuing from nozzle 55. An offtake pipe 59 provides a passageway from the impact chamber 57 into the circulating column 66. Near the bottom of said circulating column is one or more low pressure secondary gas pipes as at 61. Offtake pipes provide passageways 63 and 76, and in each thereof there is contained a control damper as indicated at 62 and 79. The upper passageway enters the elutriation chamber 65 by an axially disposed inlet pipe 64 and the other pipe 76 enters into the elutriation chamber 65 by a tangential connection at 76. Within said elutriation chamber is an annular baffle 75, disposed above the lowermost part of the inlet pipe 64 and having a central opening 14 surrounding said pipe and permitting communication between the upper and the lower ends of said chamber.

Near the middle of said elutriation chamber 65 is a conical baffle 75 having an opening 66 in its lowermost part. Passageway out from the partial chamber 71 defined between the top of said tank and said annular baffle is provided by the conduit 67 which discharges directly into the cyclone 58. This cyclone is cylindrical in shape and has a conical bottom having a discharge opening 70 at its lowermost end. There is no product discharge, receiving and/or collecting means expressly shown with this structure but any conventional equipment for this purpose, as that shown in Figure 4, is satisfactory.

It was stated above that the purpose of this invention is to dry and pulverize materials generally and particularly that this invention would handle wet and/or heat sensitive materials in a thorough and efficient manner. The material may be supplied in ground form or in pieces the maximum size being limited by the construction of the apparatus, but they need not be of uniform size. This is placed in the hoppers 1 and 2 from which the pellets drop by gravity downwardly in front of the grinding jets 5 and 6, respectively. The high pressure gas issuing from each of these jets carries said material through each of the tubes 71 and 8 and the two streams are hurled violently against each other in the impact chamber 9. By this action the solid pieces are shattered and broken into particles of various smaller sizes. The entering gas temperature is governed by the softening temperature and heat sensitivity of the material, but in some cases it is permissible for these temperatures to be exceeded for short periods due to the cooling effects of expansion and to the evaporation of volatile matter. The pressure of the entering gas must be sufficient to insure the desired grinding action in an effective manner. Limitation of the pressure and quantity of gas used on these primary grinding jets is governed by the tendency of the material to form a glaze or coating within the impact chamber 9 or within the offtake conduit 10.

The gas and the shattered particles are carried from the impact chamber out through conduit 10 and into the circulating column 12, where there is introduced near the bottom thereof through tangential jets 13 and 14 a further supply of carrying and drying gas. This gas is of a relatively low pressure, is warm and dry and functions to dry the particles and to move them on through the subsequent apparatus without overheating.

The gas and shattered particles then move upward in the circulating column 12 and during this time the said particles give up their moisture or other volatile material, to the carrying gas, without further significant reduction in size. Since the particles contact the sides of the column and are slowed to a speed less than that of the carrying gas, the effect is that of a continual drying gas stream moving past each particle and thus the rapid drying of the particles is secured.

The material laden gas passes out of the circulating column 12 through the tangential offtake 16 and enters tangentially into the first cyclone 17. Here it follows either of two paths. The main gas stream enters said first cyclone and spirals downwardly. A portion of the gases within the first cyclone 17 together with the larger particles of material will be discharged downwardly through the short pipe 19 and into the elutriation chamber 20, and the balance of the gas and the smaller particles of entrained material will spiral upwardly and out of the cyclone through offtake 26. In chamber 20 there occurs a further division of the particle and gas flow. The gases will first move downwardly in the central zone of said elutriation chamber 20 and then back upwardly along the outer zone of said chamber to the top thereof, the baffle 21 preventing interference by said upwardly moving gas with gas entering said chamber through the
short pipe 19. From the top of said chamber it will pass downwardly between the two conical members 21 and 22 and then turn upwardly between the conical end 22 and the short pipe 19 into outlet chamber 24. However, the larger of the entrained particles continue in an unchanged path along baffle 21 back into chamber 20. By means of this extensive baffle and the resulting exposure 20 to drying gases we not only secure further drying but also cause the insufficiently reduced particles to drop to the bottom of said chamber, from which point they pass through the opening 23 into the chamber 38 and thence through the feed tubes 36 and 37 and back into the hoppers 1 and 2. From here they go through the process again until they are reduced to proper size.

The gases and the particles carried thereby pass from the outlet chamber 24 through the conduit 25 and the joint 30 into the final cyclone 31, mixing with the gas and entrained material coming directly from the cyclone 17 at joint 30. In said cyclone 31 they spiral first downwardly along the walls. Most of the solid material is collected here and passes down through the bottom of said cyclone and thence to any convenient product discharge or collection means. The spent gas together with a small amount of accompanying solids, usually fine dust, move upwardly through the middle of final cyclone 31 and out through the offtake pipe 32 into whatever collection means is provided.

It will be observed that merely by varying a single element, namely the control damper 28 governing the off-take from the top of the first cyclone 17, it will be possible to control the amount of circulation of the material through the elutriation chamber 28 and hence it is possible to control the amount thereof which is returned for regrinding and consequently the fineness to which the material is ground. When the control damper 28 is full open it is apparent that the cyclone 11 will act as a normal cyclone collector and only a little gas will be discharged downwardly into the elutriation chamber 20, but most of the product including both coarse particles and the fines will pass into said elutriation chamber 20. Further, in this case the chamber 20 will act merely as a settling chamber for the accumulation of both coarse and fine materials. Then, by partially closing the damper 29 sufficient gas is forced into the elutriating chamber 20 to insure circulation therein and the discharge therefrom to the final cyclone collector 31 of most of the material already sufficiently reduced, and the recycling for further grinding of only that part which is still undesirably coarse. The adjustment of said damper 29 thus becomes a sufficient and accurate control over the fineness to which the material will be ground.

Drying is controlled by varying the temperature and volume of gas admitted by pipes 13 and 14. As more drying capacity is required, a higher temperature or a larger volume, or both, of drying gas is supplied.

In Figure 4 there is shown an additional means for further treating such particles as are still not sufficiently dried. Low pressure drying gas discharging from jet 42 picks up a portion of the material falling out from collector 34 and sends it back through conduit 44 into the final cyclone 31 for the necessary recirculating and further drying.

In a mill constructed and operated as above described, we have ground pellets of “Saran,” a product of the Dow Chemical Company, of an average of one quarter inch diameter using tubes 7 and 8 of 7/8 inch, inside diameter and a circulating column 12 of a height of 10 ft., and have obtained a smoothly ground product with losses by dust out of the exhaust offtake 32 of only approximately 2%. Respecting drying capacity, we have successfully run this material when the raw food contained as much as 10% by weight of moisture and obtained a product having a moisture content of approximately 0.035% by weight. As specific examples we submit the following data. In column I is shown data for the process and apparatus illustrated in Figure 1. In column II there is shown data for the same process and apparatus plus the recirculating provided by the apparatus illustrated in Figure 4.

The material involved was unplasticized “Saran” polymer.

Examples—Unplasticized Saran polymer

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<tr>
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<th>Feed Rate</th>
<th>H2O Content</th>
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<tr>
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<td>0.07%+0.02%</td>
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In Table II 34, the operation of the apparatus shown in Figure 3 is substantially the same as that above described but is particularly intended for very wet material.

Raw material enters through the raw feed hopper 51 and is moved by gas issuing from the feed jet 52 into the bottom portion 53 of the elutriation chamber 65, and is somewhat circulated therein. Thus there is effected some preliminary drying before the grinding occurs which is usually helpful and sometimes essential, since the material often becomes more frangible as it is dried. From the chamber 53 the material is aspirated into the gas stream issuing from the
grinding nozzle 55 and hurled against the impact anvil 58 and shattered. It then passes through the side pipe 61 and the material laden gas moves to the top of the column. While doing so it circulates rapidly, drying processes as in the form of Figure 1 but the solid particles do not abrade unduly against each other or against the side of the column. From the top of the said circulating column 60 the particle laden gases pass through the conduits 63 and 76 into the central portion of elutriation chamber 65. Here the particle laden gas and solids are thoroughly, further drying the suspended particles and permitting them further to abrade slightly against each other. A circulatory motion will be set up causing the larger particles to circulate downwardly along the chamber wall, falling within a confined chamber; a low part of said chamber for recirculation. However, air from feed nozzle 52, which is in excess of what can escape through pipe 56 will move upwardly through opening 66 and by the countercflow thereby set up will cause further classifying, circulating, and drying of the material. The particles of the material will pass upwardly through opening 74 into outlet chamber 77 and from there pass through conduit 67 into cyclone 68. Here the solid particles will be collected and separated from the gas, excepting only the finest dust. The collected material will pass through opening 70 into the discharge means 71 while the spent gas together with the entrained solids will pass out through offtake 85.

It will be evident from the foregoing description and the drawings that various modifications may be made in this equipment and the manner of operating it. Such modifications will, however, fall within the scope of my invention, defined by the hereinafter appended claims, excepting as such claims may expressly provide otherwise. Having fully disclosed and described our invention, we claim:

1. For drying and pulverizing a solid material in a partially comminuted form, the apparatus: a jet connected to a source of gas under pressure and a second jet connected to a source of gas under pressure and means feeding raw material into said jet, said jets being opposed and aligned with respect to each other whereby the solid materials in the one gas stream will be hurled against the solid materials in the other gas stream to shatter the particles in both streams and the point of impact being within a confined chamber; a circulating column and a passageway conducting the gas and the shattered particles from said impact chamber thereinto; means introducing a supplementary stream of gas at a relatively low pressure into said circulating column; a first cyclone; a conduit conducting said stream of gas from said circulating column and into said first cyclone; a cyclone outlet pipe disposed axially with said cyclone and extending thereinto from the top far enough to place its end vertically below the point of entry into said cyclone of said conduit; a final cyclone and a pipe providing communication through said control means therein, from said cyclone outlet pipe to said final cyclone; an elutriation chamber; an opening in the bottom of said first cyclone and a pipe providing communication through said opening from said first cyclone into said elutriation chamber; an opening in the bottom of said elutriation chamber and means operatively associated therewith providing transfer from said chamber of over-sized solid particles back to the initial feeding means; a pair of conical members concentric with said first cyclone and at least partially surrounding said pipe at the bottom thereof but permitting passageway along the exterior of said pipe from said elutriation chamber into the hereinafter mentioned outlet chamber; an outlet chamber at least partially surrounding said pipe and communicating as above stated with said elutriation chamber; a passageway from said outlet chamber to said final cyclone; a gas offtake pipe extending from said final cyclone to a distance sufficient to place its end below the lowest point of entry into said cyclone of the material laden gas, and an outlet for solid material at the bottom of said cyclone.

2. For drying and pulverizing a solid material in a partially comminuted form, the apparatus: means introducing the raw material into the aspirating zone of a gas stream under a relatively high pressure; means cooperating with said gas stream causing said material to be shattered by impact in a confined zone; a circulating column and a passageway conducting gas and shattered particles from said confined zone thereinto; means introducing a supplementary stream of gas at a relatively lower pressure into said circulating column; a first cyclone; a conduit conducting said gas out from said circulating column and into said first cyclone; a final cyclone; an offtake for said first cyclone conducting a portion of the gas and solid particles from within said first cyclone to said final cyclone; an elutriation chamber; an opening in the bottom of said first cyclone and a conduit providing communication therefrom into said elutriation chamber; means receiving oversize material from the bottom of said elutriation chamber and conducting same back to the initial feeding means; means receiving gas borne particles of acceptable size from the upper end of said elutriation chamber and conducting same to said final cyclone; an outlet for solid material at the bottom of said final cyclones and means removing spent gases at the top thereof.

3. For drying and pulverizing a solid material in a partially comminuted form, the apparatus: means introducing the raw material into the aspirating zone of a gas stream under a relatively high pressure; means cooperating with said gas stream causing said material to be shattered by impact in a confined zone; a circulating column and a passageway conducting gas and shattered particles from said confined zone thereinto; means introducing a supplementary stream of gas at a relatively lower pressure into said circulating column; a first cyclone; a conduit conducting said stream of gas out from said circulating column and into said first cyclone; a final cyclone; an offtake for said first cyclone conducting a portion of the gas and solid particles from within said cyclone to said final cyclone; an elutriation chamber; an opening in the bottom of said first cyclone and a conduit providing communication therefrom into said elutriation chamber; at least one conical member concentric with said first cyclone and at least partially surrounding a pipe extending from the bottom thereof to said elutriation chamber but permitting passageway along the exterior of said pipe from said elutriation chamber into the hereinafter mentioned outlet chamber; an outlet chamber at least
partially surrounding said pipe and a passageway therefrom to said final cyclone; means discharging solid material from one portion of said final cyclone and sent gas from another portion.

4. For drying and pulverizing solid material having a relatively low temperature softening point, the method: introducing said material in a partially comminuted form into the aspirating zone of a gas stream and permitting said gas stream to hurt the particles of said solid against means within a confined zone by which to shatter them; conducting said gas and shattered particles axially into a circulating column and introducing tangentially thereinto additional gas under a relatively low pressure; causing said material laden gas to circulate slowly through said column and thereby drying the shattered particles; conducting said gas and material to classifying means; separating from the gas and material stream an acceptable portion of said particles and conducting same to final circulating and drying means; conducting the remainder of said stream through further circulating and drying means; separating from said stream a further acceptable portion and conducting it to said final circulating and drying means; then separating the non-acceptable particles from the gas stream and returning them into the initial feed for reprocesing; causing in the final circulating means the desired particles to drop out of the gas stream and withdrawing them therefrom.

5. In means for pulverizing and drying a heat sensitive material in partially comminuted form, the combination comprising: first means providing a gas stream; second means introducing said material into said gas stream; means cooperating with said first means effecting impact pulverization of said material in a confined zone; a first circulating column of substantially cylindrical shape having its axis vertically positioned and of such size with respect to the volume of the total gas stream hereinbefore and hereinafter mentioned that the particles of said material will not move sufficiently rapidly to materially abrade against its walls but yet that said particles will be carried upwardly by said gas stream; a passageway conducting said gas stream and material carried thereby from said confined zone to said circulating chamber and introducing said gas and material axially thereinto at the bottom thereof; a conduit tangentially introducing into said circulating column a supplementary gas stream at a low pressure with respect to the original gas stream, and located adjacent the lower end of said circulating column; a first cyclone; an offtake from said circulating column near its upper end discharging gas and material into said first cyclone; a second circulating chamber arranged below said first cyclone and receiving material gravitated from said first cyclone; a final cyclone; a conduit receiving material from the upper portion of said first cyclone and discharging it into said final cyclone; means receiving material from said second circulating chamber and returning it to the said second means for reprocesing.

6. For drying and pulverizing a solid material in partially comminuted form, the apparatus: first means providing a gas stream; second means introducing said material into said gas stream; means cooperating with said first means effecting impact pulverization of said material in a confined zone; a circulating column and a passageway conducting the gas and the shattered particles from said confined zone thereinto; means introducing a supplementary stream of gas at a relatively low pressure into said circulating column; a first cyclone; a conduit conducting said stream of gas and gas borne material out from said circulating column and into said first cyclone; a cyclone outlet pipe disposed axially with said cyclone and extending thereinto from the top far enough below the point of entry into said first cyclone; a final cyclone; a passageway having a flow control means therein, from said cyclone outlet pipe to said final cyclone; an elutriation chamber; an opening in the bottom of said first cyclone and a pipe providing communication through said opening from said first cyclone into said elutriation chamber; an opening in the bottom of said elutriation chamber and means operatively associated therewith providing transfer from said chamber of oversized solid particles back to the initial feeding means; a pair of conical means concentric with said first cyclone and at least partially surrounding said pipe but permitting passageway along the exterior of said pipe from said elutriation chamber into the hereinafter mentioned outlet chamber; an outlet chamber at least partially surrounding said pipe and communicating as above stated with said elutriation chamber; a passageway from said outlet chamber to said final cyclone; a gas offtake pipe extending into said final cyclone a distance sufficient to place its end below the lowest point of entry into said cyclone of the material laden gas, and an outlet for solid material at the bottom of said cyclone.

7. For drying and pulverizing a solid material in partially comminuted form, the apparatus: first means providing a gas stream; second means introducing said material into said gas stream; means cooperating with said first means effecting impact pulverization of said material in a confined zone; a circulating column and a passageway conducting the gas and the shattered particles from said confined zone thereinto; means introducing a supplementary stream of gas at a relatively low pressure into said circulating column; a first cyclone; a conduit conducting said stream of gas out from said circulating column and into said first cyclone; a cyclone outlet pipe disposed axially with said cyclone and extending thereinto from the top far enough to place its end vertically below the point of entry into said cyclone of said conduit; a final cyclone; a passageway, having a flow control means therein, from said cyclone outlet pipe to said final cyclone; an elutriation chamber; an opening in the bottom of said first cyclone and a pipe providing communication through said opening from said first cyclone into said elutriation chamber; an opening in the bottom of said elutriation chamber and means operatively associated therewith providing transfer from said chamber of oversized solid particles back to the initial feeding means; a conical member concentric with said first cyclone and at least partially surrounding said pipe at the bottom thereof but permitting passageway along the exterior of said pipe from said elutriation chamber into the hereinafter mentioned outlet chamber; an outlet chamber at least partially surrounding said pipe and communicating as above stated with said elutriation chamber; a passageway from said outlet chamber to said final cyclone; a gas offtake pipe from the top of said final cyclone and
an outlet for solid material at the bottom of said cyclone.

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<td>JOHN L. SPEIRS.</td>
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