July 19, 1932. E. R. RAMSEY ET AL 1,868,472

MANUFACTURE OF SUGAR

Filed May 8, 1926 3 Sheets-Sheet 1

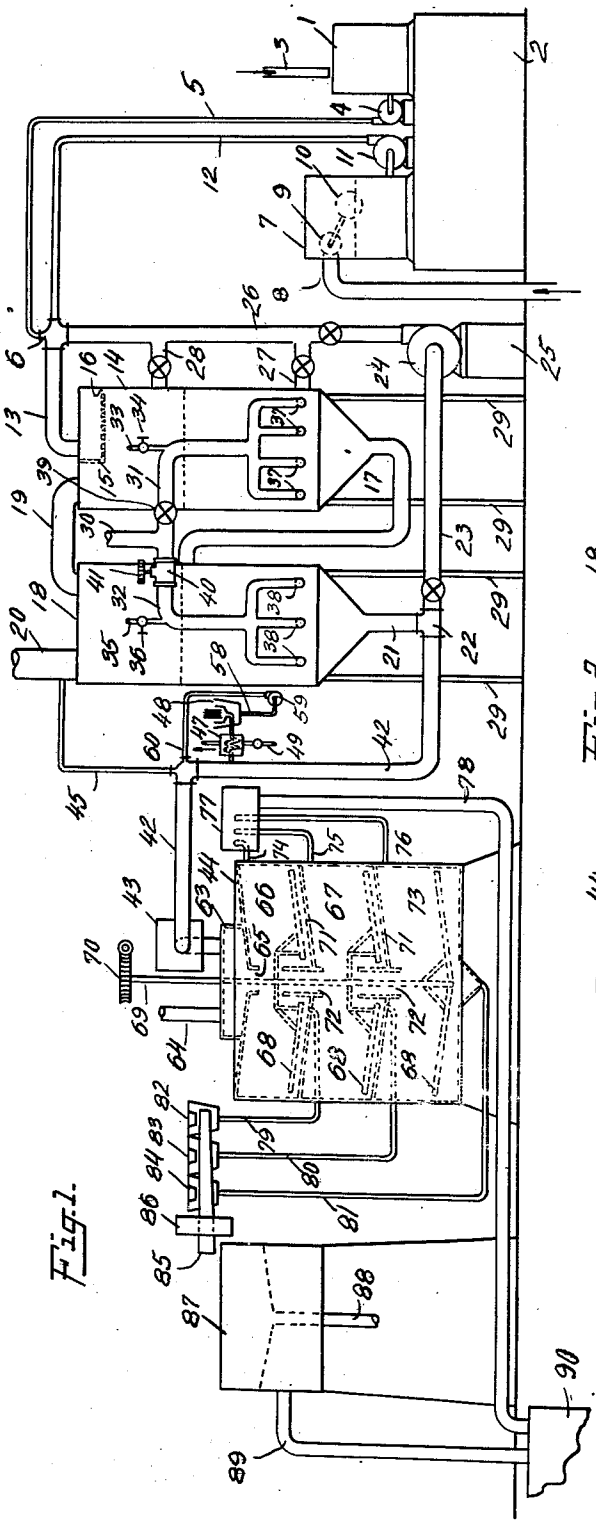


Fig. 1.

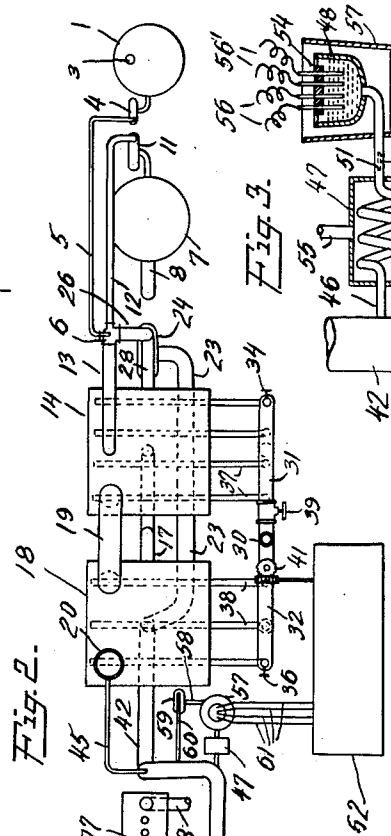


Fig. 2.

Fig. 3.

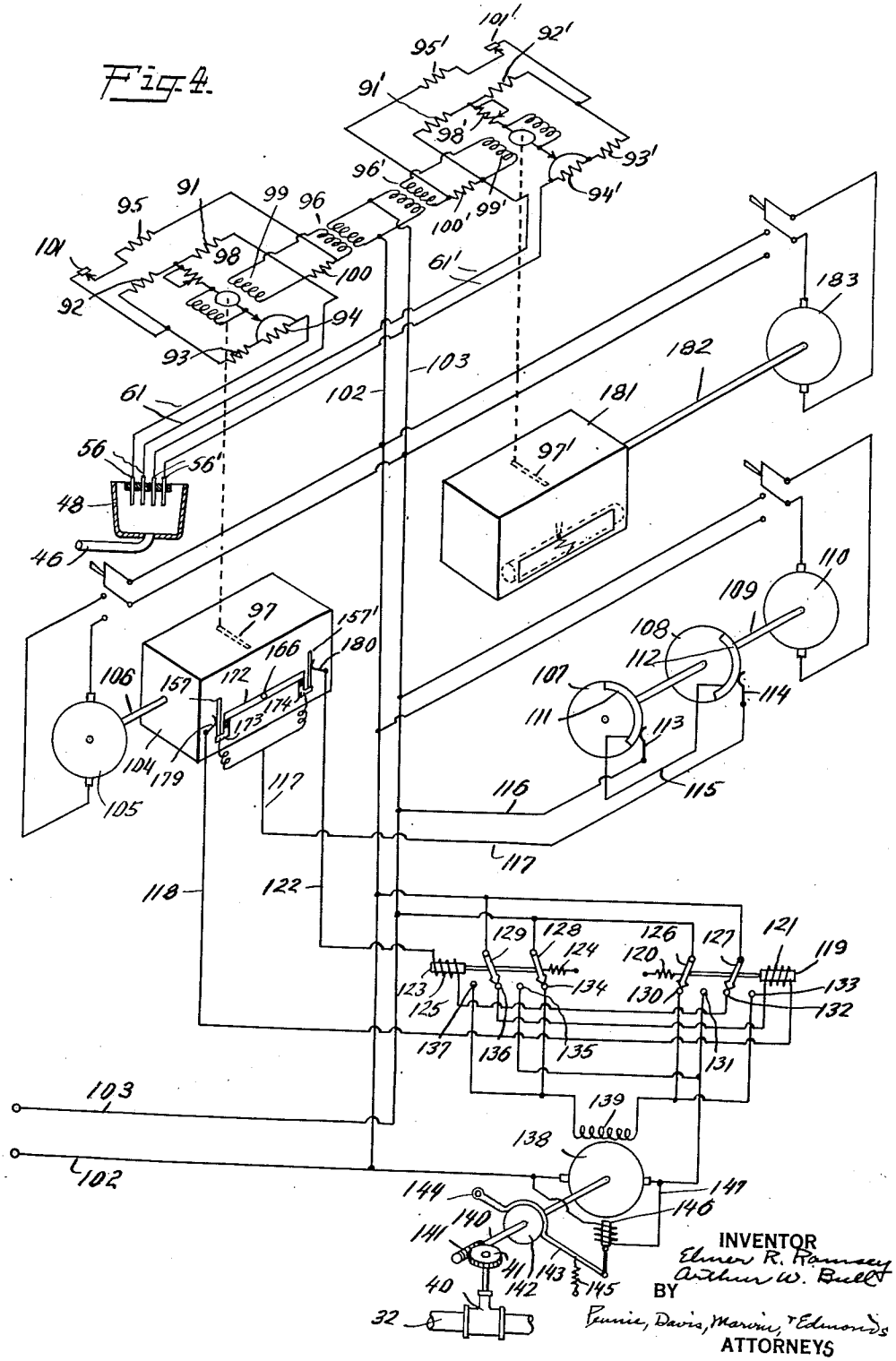
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Fig. 4.



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MANUFACTURE OF SUGAR

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Fig. 6.

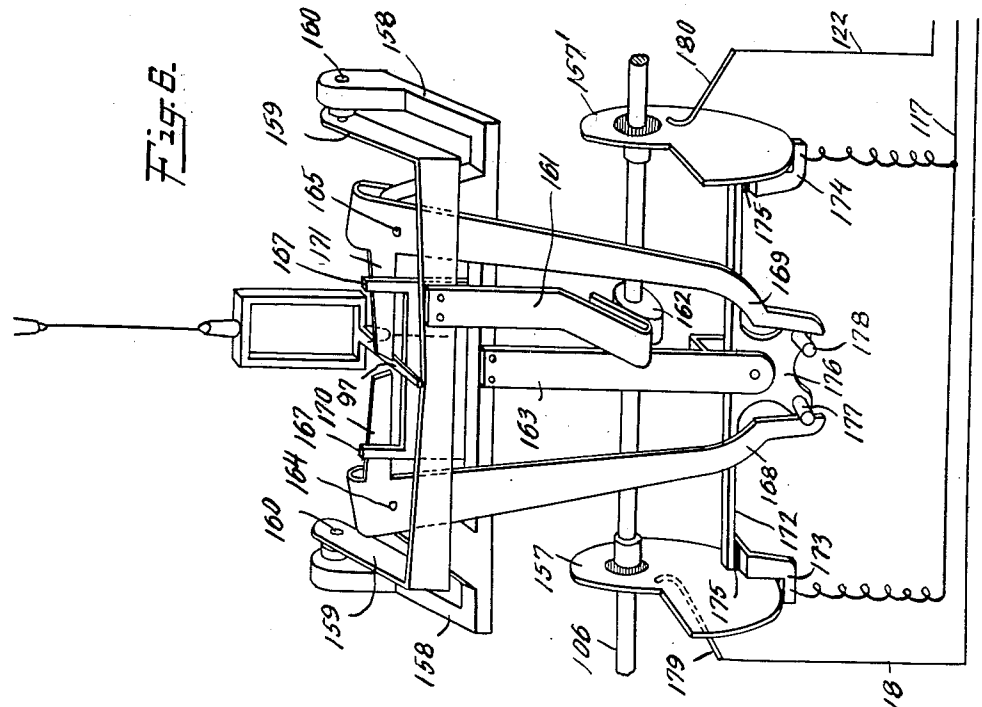
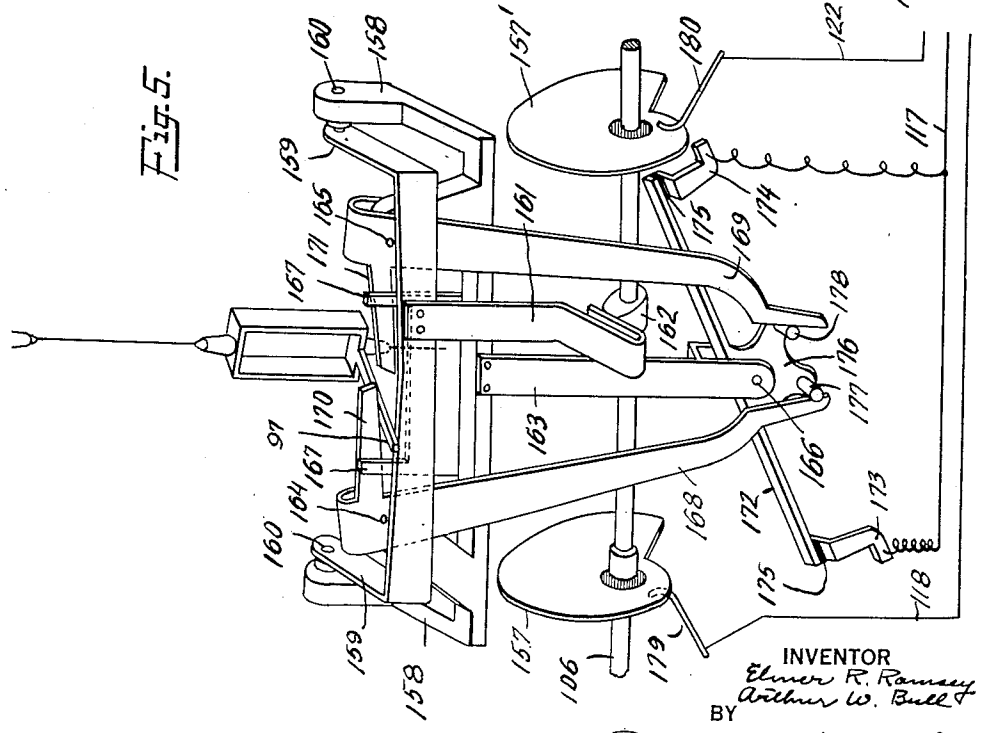


Fig. 5.



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UNITED STATES PATENT OFFICE

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MANUFACTURE OF SUGAR

Application filed May 8, 1926. Serial No. 107,579.

This invention relates to the manufacture of sugar. It is more particularly directed to the automatic control of the treatment process of sugar-bearing juices, such as beet or cane, employed in the manufacture of sugar; although the principles of the invention may also be employed with advantage in other treatment processes.

In treatment processes of numerous kinds, it has long been desirable to use a conveniently applicable method and apparatus for conducting the treatment operation within definite, prescribed, and desired limits which can be automatically controlled. It is also of advantage that such operations be conducted in a continuous manner, rather than in the more usual batch fashion. Our discovery makes such a practice possible, because by the improved method and apparatus of this invention we are able to readily conduct the treatment operation under automatically controlled conditions in such manner that the materials going into the treatment process emerge at the end of their reaction within definitely prescribed limits of content.

Again, it is also highly desirable that such preliminary automatic control of the treatment process be carried out in such manner that the subsequent steps in the treatment process may be more efficiently conducted. We are able to do this as will be hereinafter more particularly pointed out.

Briefly and in its broader aspect, our invention comprises a method and apparatus for securing an action responsive to changes in a variable component of the treatment process at a point removed from the zone of active reaction, and utilizing said action to automatically vary the content of said component to predetermined limits.

Our invention will be better understood by reference to its successful use in the manufacture of sugar, particularly in the preliminary treatment of sugar-bearing liquids with gases, as in the first carbonation step of the standard purification process, and then in the subsequent treatment of the carbonated juices whereby a separation is made between the solids and the juices.

Briefly stated, the operations involved in the manufacture of sugar from beet root are as follows: (*a*) extraction of the juice from the beet root; (*b*) clarification of the juices; (*c*) concentration of the juice to sirup; (*d*) crystallization of the sugar from the sirup; (*e*) separation of the crystals; and (*f*) treatment of the separated sirup for the working up of the after-products.

Our invention is more particulary directed towards the operation dealing with (*b*) clarification of the juices. The first operation above referred to, (*a*) extraction of the juices from the beet root, is generally carried on in so called diffusion batteries. When the diffusion juice leaves the battery it is cloudy and contains in solution or suspension the soluble constituents of the beet, namely, sucrose, potassium and sodium salts of phosphoric, sulphuric, hydrochloric, oxalic, and tartaric acids, proteins, pectins, etc., and a small amount of invert sugar. In reaction it is slightly acid.

In order to separate the suspended fibre, cellular tissue, and coagulated albumen, the juice is subjected to pulp-separation. The juice is then heated, to about 85° C., which has the effect of coagulating a portion of the albumen present, besides preparing it for clarification.

In the beet sugar factory, clarification is generally carried out in two stages: in the first, known as "defecation" or "liming", milk of lime, $Ca(OH)_2$, is added to the heated juices; and in the second, known as "carbonation", the lime, $Ca(OH)_2$, is removed by precipitation as $CaCO_3$ with carbon dioxide (CO_2) gas.

After liming (defecation), the juice is ready for the second stage of the clarifying operation, namely, "carbonation" or "saturation" with carbon dioxide gas, in which the lime is precipitated. Small amounts of mineral and organic matter are also thrown down. The original slightly acid beet juices become alkaline by the addition of an excess of lime during the liming operation. It is desirable to reduce the alkalinity to certain limits by correct additions of CO_2 in the carbonation step.

The carbonated materials are then subjected to continuous thickening to separate the clear juice from the sludge. The sludge from the thickening operation is next subjected to continuous filtering, whereby the remaining clear juices are efficiently separated from the undesirable solids.

If the clarifying steps have been well conducted, the resultant clear juices are then in condition for the subsequent operations of sugar making, steps *c*, *d*, *e*, and *f*, as outlined above. Heretofore accurate and dependable control of the alkalinity of the carbonated juices within predetermined desired limits has been difficult of attainment. This is even true in the more common practice of treatment of batches of the juices, and is more particularly true in attempted continuous methods of treatment.

The carbonation, injection of carbon dioxide gas, is usually accomplished by highly skilled operators, known as carbonators, who require long preliminary training. The ultimate recovery of sugar and the efficiency of the operation further depend very much on the way in which these skilled operators conduct the process.

The use of our invention permits an accurate and dependable automatic control of a continuous carbonation step, which also materially aids in the subsequent separation of the solids from the clear sugar juices. Moreover the dependence on "hand" control of skilled carbonators is dispensed with.

In our present practice of the invention constant volumes of preheated beet juices and lime solutions are automatically flowed together into the first of a series of carbonating vessels. Suitable pumps are employed for this purpose. An excess of lime is employed which throws the slightly acid beet juice over into the alkaline state.

A carbon dioxide bearing gas, preferably under regulated pressure, is injected into the body of limed juices on the counter-current principle. That is to say, the limed juices flow downwardly as the injected carbon dioxide gas rises upwardly from near the bottom of the carbonation tanks. The alkalinity is somewhat reduced as the lime precipitates in the form of calcium carbonate.

The preliminarily carbonated juices are then led to a second carbonator for a further treatment with carbon dioxide gas. It may here be pointed out that we have quite satisfactorily employed as many as three carbonators in series, as well as only one carbonator. However, we prefer to make use of but two carbonators in series. The foam generated in the first carbonator passes from the top of the first carbonator to the top of the second carbonator, whereas the carbonated limed juice passes from the bottom of the first carbonator to the juice level of the second carbonator.

A portion of previously carbonated juice, containing precipitated calcium carbonate, may be recirculated from the bottom of the second carbonator tank and led into the top of the first carbonator tank. The particles of calcium carbonate then tend to encourage particle growth as they pass toward the bottom of the carbonating vessel.

Automatically controlled amounts of carbon dioxide gas are passed into the already partially carbonated juice in the second carbonator to bring the juice within predetermined limits of alkalinity. This automatically controlled feature is made to depend upon the electrical resistance offered by the treated juices, coming from the last carbonator, between suitable electrodes appropriately immersed in the liquid at a point removed from the zone of active reaction of the carbon dioxide gas on the limed juices. It is important to measure this electrical resistance at a point beyond all further reaction of the added ingredients, else the electrical resistance cannot be regarded as a true criterion from which to automatically control the end point. The electrical resistance of the materials is apparently substantially unaffected by the purity, concentration of the sugar juices, or the presence of precipitated solids. On the other hand, the concentration of dissolved lime, which is the measure of alkalinity, appears to be the predominating factor. Hence, the electrical resistance will vary as the concentration of dissolved lime varies. There is an almost constant parallelism between alkalinity and electrical conductivity.

It is essential that the electrical resistance be measured after the chemical and dissolution reactions have been completed. In the carbonation tanks the reaction of carbon dioxide gas on dissolved lime takes place so rapidly that the concentration of lime in true solution is reduced below the value it would have if the gas were momentarily cut off and the remaining undissolved lime were allowed to pass into solution. For this reason we place the electrodes in a continually flowing stream of juice at some distance from the carbonation tanks so that complete solution of soluble lime will have occurred before the juice reaches the electrode chamber.

The permissible limits of alkalinity are 0.07 to 0.13 measured in grams of CaO per 100 cc. of filtered juice. We have been able to make long continuous runs in which the alkalinity was maintained within the very narrow and highly desirable range of 0.09 to 0.11 grams of CaO per 100 cc. of juice.

The control or standard resistance (one resistance arm of a Wheatstone bridge, as will be more fully explained below) may be set to correspond with an alkalinity of, let us say, 0.09 gram of CaO per 100 cc. by noting the resistances corresponding to actual alkalinities as determined by titration.

Changes in the electrical resistance corresponding to definite changes in alkalinity are so utilized as to automatically control the amounts of CO_2 injected in the last carbonator to bring the limed juices within predetermined limits of alkalinity.

The appropriately carbonated juices are then treated in such manner as to effect continuous and economical separation between the solids and the juices. The automatic and absolute control of the continuous carbonation of the juices, whereby definitely desired and predetermined limits of alkalinity are obtained, plays an important part in increasing the particle size and settling rate of the solids.

Our invention will be more fully understood by reference to the accompanying drawings, taken in conjunction with the following description, in which:

Fig. 1 is an elevational view of the apparatus;

Fig. 2 is a plan view of the apparatus;

Fig. 3 is a sectional elevation on an enlarged scale of the temperature regulator and electrode pot;

Fig. 4 is a schematic view of the electrical controller and recorder apparatus and of the electrical relay circuit;

Fig. 5 is a schematic elevational view of the controller in a non-contacting position; and

Fig. 6 is a schematic elevational view of the controller in a contacting position.

The milk of lime storage tank 1 rests upon the foundation 2. A feed line 3 leads to the tank 1. A pump 4 connects the tank 1 with the pipe 5, which leads to the T 6.

The beet juice storage tank 7 also rests on the foundation 2. A feed supply line 8 leads to the tank and is equiped with a float valve 9. The float 10 is so adjusted as to close the valve 9 when the tank 7 is filled to a predetermined level. A pump 11 connects the tank 7 with the pipe 12 which leads into the T 6.

The pipe 13 leads from the T 6 to the top of the first carbonating tank 14. A baffle 15 is located directly under the outlet of pipe 13 and extends to within a relatively short distance of the side of the tank 14, so that a space 16 is provided between the end of the baffle and the side wall of the carbonating tank. The bottom of the carbonating tank has a conduit 17 which leads up to the normal liquid level maintained within the second carbonating tank 18. A foam conduit 19 leads from the top of the first carbonating tank 14 to the top of the second carbonating tank 18.

The second carbonating tank 18 is equipped at the top with a foam offtake pipe 20. A conduit 21 is located at the bottom of the second carbonating tank and connects with a T 22.

A pipe 23 leads from the T 22 back to the pump 24 resting upon the foundation 25. This pump has a connecting pipe 26 leading up to the T 6, and is also provided with offtake pipes 27 and 28 leading into the first carbonating tank 14. The offtake pipe 28 leads into the carbonating tank at a point above the normal liquid level maintained within the tank; while the offtake pipe 27 leads into the carbonating tank near the lower part thereof.

The first carbonating tank 14 and the second carbonating tank 18 rest upon supports 29. These tanks are also equipped with carbon dioxide gas supplying apparatus. The gas inlet pipe 30 is equipped with an offtake pipe 31 leading to the first carbonating tank, and an offtake pipe 32 leading to the second carbonating tank. A steam pipe 33, with a control valve 34, connects with the offtake pipe 31. A steam pipe 35 with a control valve 36 connects with the offtake pipe 32. The offtake pipe 31 branches off into the four feed pipes 37 which in turn lead into the first carbonating tank near the bottom thereof. The portions of the four pipes 37 within the first carbonating tank 14 are perforated so that gas may issue therethrough and pass up through the liquid contents of the tank.

The offtake pipe 32 is equipped with three feed pipes 38, which in similar manner to pipes 37, lead into the second carbonating tank 18. The portions of the pipes 38 which extend within the carbonating tank are perforated so that the gas may be permitted to pass up through the liquid contents of this second carbonating tank.

The offtake pipe 31 has a manually operable valve 39 which may be turned to regulate the flow of gas within the first carbonating tank. The offtake pipe 32 is equipped with an automatic control valve 40, having a gear 41, to regulate the flow of gas into the second carbonating tank. This valve is operated in such manner as to conform with variations in alkalinity of the carbonated juices.

A pipe 42 leads through the heater 43 (which may be heated in any appropriate manner such as by steam, gas or electricity) and connects with the continuous thickener 44. A foam pipe 45 leads from the top level of the pipe 42 to the foam escape pipe 20, attached to the top of the second carbonating tank 18.

A coil pipe 46 (see Fig. 3) connects with the pipe 42 and passes through a heating chamber 47 to the electrode pot 48. The heating chamber 47 has a steam inlet pipe 49 equipped with an automatically controllable valve 50. A temperature indicating bulb or coil 51 of standard make is located in the coil pipe 46 and is equipped with a registering conduit 53 leading to the control valve 50, to automatically operate the steam valve. An outlet pipe 55 is provided on the heating

chamber 47 to conduct away steam. The electrode pot 48 is equipped with a disk 54 which fits loosely in the top thereof, which disk in turn contains the four electrodes 56 and 56′. These electrodes may be made by sealing short pieces of No. 18 platinum wire into the ends of glass tubes. The exposed portions of the wires are approximately ¼″ long. Two of these electrodes 56 form a pair and are connected to a controller, and the other two electrodes 56′ are connected to a resistance recorder, such as manufactured by the Leeds and Northrup Company. The electrode pot 48 rests within the overflow vessel 57, which has an outlet 58 connecting a pump 59. A pipe 60 connects the pump 59 with the pipe 42 leading to the continuous thickener 44.

The electrodes 56 and 56′ by means of lead wires 61 are connected to the controller, recorder, contact disks, relay, and automatic gas valve control apparatus represented by 62 (in Fig. 2) which will be more fully described below in connection with Figs. 4, 5, and 6.

The continuous thickener 44 is of the tray compartment type. The pipe 42 leads into the feed chamber 63 on the top of the thickener 44. This chamber has a foam offtake pipe 64 for the escape of foam. An opening 65 leads from the compartment 63 to the first tray compartment 66. The compartment 66, as well as the second compartment 67, is equipped with a revolving rake apparatus 68, appropriately connected and operated by a shaft 69 and gearing 70, running substantially parallel to the sloping bottoms 71 of each of these compartments. Boots 72 are provided at the bottom of each of the tray compartments 66 and 67, which seal the bottoms but allow an open space from the top of each boot to the sub-jacent compartment beneath. These boots provide effective means for collecting sludge in each individual compartment. The lower compartment 73 also also has the revolving raking apparatus 68, but no use is made of a boot. Pipes 74, 75, and 76 lead respectively from near the top of the compartments 66, 67 and 73 to a clear liquid collecting vessel 77. An outlet pipe 78 is connected to the bottom of the collecting vessel 77. The tops of the pipes 74, 75 and 76 are provided with adjustable sleeves (not shown) to control, or balance, the hydrostatic pressure of the escaping supernatant liquid with the hydrostatic pressure maintained within each separate compartment 66, 67 and 73. Outlet pipes 79, 80 and 81 connect respectively with the bottoms of the tray compartments 66, 67 and 73. They lead up to the pumps 82, 83 and 84.

The pumps 82, 83 and 84 are in turn connected to the pipe 85 leading through the heater 86 (which may be heated by means of steam, gas or electricity, etc.) to the continuous filter 87.

The continuous filter 87 may be of any standard and appropriate type commonly found on the market. A solids offtake pipe 88 is provided to remove the separated solids, while the pipe 89 is connected to the filter in order to remove the clear juices. This continuous filter may be of the ordinary revolving kind, in which the filter drum is made to revolve through a trough containing the sludge to be filtered. Suction is provided on the inside of the drum to suck the clear juices from the trough, through the filter cloths, into the filter drum; while the solids adhere to the filter cloth, only to be forced off by a blast of air or scraping action, when the drum has revolved to the desired unloading position.

A clear juice tank 90 is connected with the offtake pipe 89 from the continuous filter 87, and the offtake pipe 78 from the continuous thickener 44.

All of the apparatus described, through which the juices are made to flow, are carefully insulated so that the loss of heat by radiation may be reduced to a minimum. It is important that the temperature of the treatment process be brought to and maintained at appropriate levels.

The two pairs of electrodes 56 and 56′ and the terminals of the controller, recorder and relays are preferably connected according to Figs. 4, 5, and 6, in which use is made of the Wheatstone bridge principle.

The pair of electrodes 56, forms one resistance arm of the controller bridge, and the other arms of the bridge are 91, 92 and 93. The bridge employing the pair of electrodes 56 is used in connection with the controller mechanism, which mechanism in turn actuates the relays in such manner as to operate the gas control valve 40. A shunted and adjustable resistance 94 is provided adjacent to the electrodes 56 in order to make quick readjustment to compensate for any undue changes in resistance between the electrodes. A resistance 95 is provided between the transformer 96 and the bridge arms 92 and 93 to regulate the current supplied to the bridge. A rheostat 98 is placed in the galvanometer circuit to regulate the flow of current through the galvanometer windings. A galvanometer field coil 99 is placed in the circuit of the transformer 96, and is protected by the resistance coils 100 placed in series. A key 101 is placed between the transformer and the bridge in order to cut-in or cut-out the current, which is taken from the alternating current supply lines 102 and 103. The coil values generally employed are as follows: 91, 92 and 93 equal 200 ohms each; 94 equals 100 ohms; 95 is variable and depends upon the sensitivity of the galvanometer; 98 equals 150 ohms; and 100 equals 4 to 7.5 ohms.

The controller mechanism is preferably enclosed in a cabinet 104. A motor 105, fed

from the current supply lines 102 and 103 is connected to the controller mechanism by means of the connecting shaft 106.

The other pair of electrodes 56′ is used in conjunction with the recorder mechanism. A similar Wheatstone bridge is employed, with corresponding descriptive numbers 91′, 92′, 93′, 94′, 95′, 96′, 97′, 98′, 99′, 100′, and 101′ as used in describing the controller Wheatstone bridge.

The controller mechanism 104 is in turn connected with contact disks 107 and 108. These contact disks are operatively connected to the main shaft 109 of the motor 110. The motor 110 gets its energy from the main current supply lines 102 and 103. The disks may be appropriately geared to the main shaft of the motor in such manner as to reduce or increase the speed of the same, as compared with the normal speed of the motor. The disks 107 and 108 have a contact segment 111 and 112, respectively, at the outer rim, which contact with the brushes 113 and 114 as the disks revolve. The remainder of the disks are insulated to prevent straying of the current. An appropriate current conducting wire 115 connects segment member 111 with the segment member 112. A current conductor 116 connects the main supply line 103 with the brush 113, which brush contacts with the segment member 111. A current conducting wire 117 connects the controller mechanism 104 with the brush 114, which brush contacts the segment member 112.

A relay mechanism is appropriately connected with the controller mechanism, as well as with the main current supply lines, and the gas control motor. A current conducting line 118 connects one terminal of the controller mechanism with the relay solenoid 119. A spring 120 is connected to one end of the solenoid member to keep it in a constant position when the solenoid windings 121 are not energized.

A current conducting line 122 connects another terminal of the controller mechanism 104 with the relay solenoid 123. A spring 124 is connected to one end of the solenoid member 123 to keep it in a constant position when the solenoid windings 125 are not energized.

The solenoid member 119 is equipped with two pivoting contact brushes 126 and 127; while the solenoid member 123 is equipped with two similar pivoting contact brushes 128 and 129. The brush 126 is so positioned as to brush across the contacts 130 and 131; while brush 127 is so positioned as to brush across the contacts 132 and 133. The brush 128 is so positioned as to brush across the contacts 134 and 135; while brush 129 is so positioned as to brush across the contacts 136 and 137.

The gas control valve motor 138 is provided with a motor field winding 139, which is adapted to operate the motor in either direction depending in which direction the field coil is energized. This winding connects with the contacts 130 and 133 of the solenoid 119; and with the contacts 134 and 137 of the solenoid 123. One terminal of the motor is connected with the main current supply line 102, while the other terminal is connected to the current conducting line running between the contacts 131 and 135.

The current conducting line 118, which leads from one terminal of the controller mechanism 104, after circling around the solenoid member 119, as the solenoid coil 121, passes to the contact 136 of the solenoid member 123. The current conducting line 122, which leads from another terminal of the controller mechanism 104, after circling around the solenoid member 123, as the solenoid coil 125, passes to the contact 132 of the solenoid member 119. A current conducting line connects the pivoting contact brush 126 with the pivoting contact brush 128, as well as with the main current supply line 103. A current conducting line connects the pivoting contact brush 127 with the pivoting contact brush 129, as well as with the main current supply line 102.

The gas control valve motor 138 has a main shaft 140 geared at the far end 141 to mesh the gear member 41, which gear member in turn is operatively connected to the gas control valve 40. The shaft 140 is provided with a friction disk 142 operatively connected to the brake 143 pivoted at the point 144. A spring 145 is adapted to pull the friction brake down upon the friction disk 142. A brake solenoid 146 is attached to the free end of the brake in such manner that when the solenoid is energized, the brake may be lifted freely above the friction disk 142 about the pivotal point 144. The solenoid is energized by means of the current conducting line 147, connected to terminals of the motor 138, and forming the solenoid winding coil about the solenoid member 146.

Figs. 5 and 6 are schematic views of the controller mechanism within the cabinet 104. The motor 105 drives the shaft 106 upon which are placed the cams 157 and 157′. These cams are conductors of electricity, but are insulated around the shaft 106 so that stray currents cannot escape therefrom. The galvanometer needle 97 is so positioned that it fluctuates to the right or left, depending upon how the resistance between the pair of electrodes 56 varies in the Wheatstone bridge above referred to. The controller mechanism is made to rest and hinge upon the frame work 158. A rocking frame 159 is pivotally connected to the frame 158 at the points 160. A rocking frame arm 161 is attached to the rocking frame 159 and it depends to within contacting distance of the eccentric cam 162 located on the motor shaft 106. This ec-

centric cam is so positioned on the shaft as to make the rocking frame 159 rise and fall as the shaft 106 is rotated. The lugs 167 provide means for stopping the needle in the extreme right or left position. The lever arms 168 and 169 are freely pivoted at the points 164 and 165. These lever arms have extension arms 170 and 171 which extends almost halfway across the area circumscribed by the moving galvanometer needle 97. A sufficient space between the lever arm extensions 170 and 171 is provided so that the galvanometer needle may freely rest between them when the Wheatstone bridge is in the balanced position. The lever arms are so designed that when the galvanometer needle is deflected to either the right or left, the rocking frame 159, on any of its upward movements, may lightly press the galvanometer needle against the lever arm extensions 170 or 171 and thus correspondingly move the extreme lower ends of the lever arms 168 or 169 inwardly.

A balancing arm 172 is pivoted to the member 163 and the main frame 158 at the point 166, in a freely movable position. Contact lugs 173 and 174 are attached to either end of the balancing arm 172, so as to just fail to brush across the current conducting cams 157 and 157′, when the balancing arm is in its normally horizontal and balanced position. These lugs are current conductors and are insulated from the balancing member 172 by means of the non-conducting material 175 placed between the lugs and the balancing member. These lugs are in turn connected to the current conducting wire 117, which wire is attached to the brush 114 at disk 108.

A freely movable frame 176, with lugs 177 and 178, is freely pivoted at the point 166, in working position with the lever arms 168 and 169. This frame forms a rigid part of the balancing arm 172, so that when the lugs 178 or 177 are pressed by the lever arms 169 or 168 respectively, the balance arm 172 will be relatively moved in its clockwise or anti-clockwise, position.

Contact brushes 179 and 180 are so positioned as to make contact with the current conducting cams 157 and 157′ as the cams revolve with and about the motor shaft 106. The brushes are also connected to the current conducting wires 118 and 122, which lead to the relay mechanism above described.

The recorder mechanism 181 is of a standard type used for ordinary recording purposes of this kind. It is operated by means of the shaft 182 connected to the motor 183. This recorder motor is fed by current from the main current supply lines 102 and 103.

The operation is as follows:

Milk of lime from storage tank 1, and raw diffusion beet juices from the storage tank 7, both of which have been preliminarily heated, are conducted by means of pumps 4 and 11 to join each other in the T 6. The intermingled milk of lime and beet juices thereupon flow together through pipe 13 onto the baffle 15. This baffle 15 is so positioned within the first carbonator tank 14 that the combined juices may trickle down the side wall of the carbonator tank through the space 16, between the carbonator wall and the baffle itself. This is done in order to cause as little agitation of the juices as possible, thus preventing any undue formation of foam.

As the carbonator tank 14 gradually fills up with the combined milk of lime and beet juices, a part of the mixture is forced by way of the pipe 17 from the bottom of the first carbonator tank 14 into the second carbonator tank 18. The inlet level of the pipe 17 in the second carbonator tank is at the normal liquid level of the two carbonator tanks.

Any foam that is formed within the first carbonator tank 14 is permitted to pass over to the second carbonator tank 18 by way of pipe 19. A part of this foam will disintegrate into juices within the second carbonator tank, and whatever foam is not precipitated is permitted to pass up through the foam outlet pipe 20.

A gas containing carbon dioxide is fed through the supply pipe 30 and branches off to the first and to the second carbonator tanks. The carbon dioxide gas passing to the first carbonator tank 14 by way of pipe 31 is brought to a desired temperature by means of steam supplied through pipe 33 and controlled by valve 34. The mixture of carbon dioxide gas and steam are thereupon sub-divided into four main divisions by means of pipes 37. The gas is then permitted to escape through the perforations within the parts of the pipes 37 extending into the first carbonator tank. The gas bubbles up through the body of juices. The chemical reaction, $Ca(OH)_2+CO_2=CaCO_3+H_2O$ takes place. Any excess gas escapes with the foam through pipe 19 into the second carbonator tank.

The gas branching from pipe 30 through pipe 32 is likewise heated by means of steam, the steam being supplied through the pipe 35 and regulated by the valve 36. The mixture of carbon dioxide gas and steam is conducted together for a short distance, and it is then sub-divided into three main streams by means of the pipes 38. The gases are permitted to bubble up through the body of liquid within the second carbonator tank, by passing through the many perforations within those portions of the pipes 38 extending within the carbonating tank. Any excess gas escaping from the body of juices is permitted to escape with the foam up the stack 20.

The amount of gas admitted to the second

carbonator tank is automatically controlled within predetermined limits by means of the valve 40, which will be more fully explained below.

If the juices within the second carbonator tank have not been given a sufficient amount of gas, or in fact have been given too much gas, the juices may be recirculated by way of pipe 23 and pump 24 back into the first carbonator tank. Valves and piping are so arranged that the recirculated juices may be admitted near the bottom of the first carbonator tank by way of pipe 27, or above the normal liquid level of the first carbonator tank by means of pipe 28.

Since it is advantageous to increase the particle size of the calcium carbonate, $CaCO_3$, in order to make the subsequent steps of thickening and filtering more efficient, large portions of the gassed contents of the second carbonator tank are recirculated back to the first carbonator. We have found it advantageous to recirculate about six volumes from the second carbonator tank, to the first carbonator tank, to one volume of fresh combined beet juices and milk of lime, initially introduced into the first carbonator tank. The particles of $CaCO_3$ which are transferred from the second carbonator tank to the first carbonator tank induce particle growth. That is to say, freshly precipitated $CaCO_3$ in the first carbonator tank adheres to and becomes part of particles of $CaCO_3$ circulated from the second carbonator tank back to the first carbonator tank.

The completely gassed contents of the second carbonator tank are flowed by way of pipe 42 through the heater 43 into the continuous thickener 44. As the treated juices are thus passed to the thickener, a relatively small test portion is withdrawn from the pipe 42 through the pipe 46, and is preheated to a predetermined temperature. This test portion then passes into the electrode pot 48 where the electrical resistance between the pairs of electrodes 56 and 56′ are appropriately measured. Since the electrical resistance between these electrodes is inversely proportionate to the alkalinity of the test portion, use may be made of this relationship to automatically control the amount of CO_2 gas admitted to the second carbonator tank by way of the automatic gas valve 40. The test portion which continuously flows into the electrode pot 48 gradually overflows the same into the collecting chamber 57. The pump 59 continuously passes the overflowing test portion back into the line 42 by way of pipe 60.

It is very important that the test portion be taken at a point well removed from the zone of chemical and dissolution reactions within the carbonating tanks. The reaction that takes place within the last carbonator tank between the CO_2 and the $Ca(OH)_2$ is so rapid that the concentration of $Ca(OH)_2$ in true solution is reduced below the value it would have if the gas were momentarily cut off and the remaining undissolved $Ca(OH)_2$ were allowed to pass into solution. If the test portion is taken well removed from the zone of active reaction, complete solution of the soluble $Ca(OH)_2$ will have occurred before the juices reach the electrode pot.

The previously heated bodies of juices have cooled down somewhat by the time they reach the continuous thickener. For that reason the heater 43 is interposed between the second carbonator tank and the continuous thickener, so that the temperature of the combined juices and solids may be raised to the temperature found consistent with efficient and rapid thickening. Of course the use of this heater is optional, particularly if the previously gassed liquids have not appreciably fallen in temperature. Any foam which may have found its way into pipe 42 or formed within the pipe 42 is allowed to escape by way of pipe 45 into the foam outlet stack 20.

The combined juices and solids are flowed into the receiving chamber 63 of the continuous thickener 44. These find their way down through the outlet 65 of the first tray compartment 66. As this compartment gradually fills up, part of its contents pass to tray compartment 67, and ultimately to tray compartment 73. The rakes 68 are set in motion by the shaft 69, to which they are attached, which is made to revolve by a motor (not shown). As the solids settle to the bottom of the sloping tray compartment, the rakes 68 gradually carry the solids toward the center of the compartment, whereupon the solids are continuously withdrawn through the pipes 79, 80, and 81 by means of the pumps 82, 83, and 84, respectively.

The clear juices, on the other hand are withdrawn from near the top of the individual tray compartments by means of the pipes 74, 75 and 76 into the collecting chamber 77. The clear juice is then permitted to flow by way of outlet 78 into the clear juice collecting tank 90 to await further process treatment used in the manufacture of sugar, such as outlined above.

The sludge which has been pumped from the continuous thickener by means of the pumps 82, 83 and 84 is flowed into the pipe 88 which passes through the heater 86. Since appropriately heated materials will more easily lend themselves to filtering, we have found it advisable to preheat the sludge before it enters the filterer, particularly if there is a substantial drop of temperature during the thickening operation. The use of this heater is optional.

The preheated sludge is then passed into the continuous filter 87, where the remaining clear juices are finally separated from the solids. The solids escape by way of outlet pipe 88, while the clear juices are conducted

through the outlet pipe 89 to the clear juice collecting tank 90 to await further process treatment.

The beet juice clarification treatment operation of the invention has just been described, and it now becomes necessary to explain the operation of the automatic control features of our discovery, which are graphically illustrated in Figs. 3, 4, 5 and 6.

Variations in the resistance of the test portion between the electrodes 56, by means of the well known Wheatstone bridge principle, are registered by variations in the swing of the galvanometer needle 97. For example, if the bridge is perfectly balanced (i. e., when the resistance arms 91, 92 and 93 and the resistance between the electrodes 56 are all equal to one another), the galvanometer coil will not be energized and the needle 97 will consequently not be deflected. If the resistance between the electrodes becomes greater than that of its corresponding resistance arm, current will be forced through the galvanometer coil in one direction and the needle will be deflected, let us say, to the left. If the resistance between the electrodes becomes less than that of its corresponding resistance arm, current will be forced through the galvanometer coil in the opposite direction and the needle will be deflected to the right. The swing of the galvanometer needle is appropriately employed to make corresponding changes in the amounts of CO_2 admitted into the second carbonator tank through the automatic control valve 40.

In order to follow the operation of the controller mechanism, let us assume that the galvanometer needle 97 has been deflected to the left (as shown in Fig. 5). The motor 105 which continuously drives the shaft 106 also makes the cams 157 and 157′ revolve continuously. These revolutions take place at intervals of approximately 6 seconds each. For each revolution the eccentric cam 162 strikes the rocking frame member 161 which in turn forces the rocking frame 159 up against the bottom of the galvanometer needle. This movement of the rocking frame pushes the top of the galvanometer needle against the bottom of the lever arm extension 170, whereupon the lever arm 168, which is pivoted at point 164 bears over to the right and strikes against the lug 177. Since this lug and its frame 176 are rigidly attached to the balance arm 172, the balance arm is swung away from its normally horizontal position; and the contact lug 173 is forced downward, while the opposite contact lug 174 is swung upward. The eccentric cam 162 very soon releases the rocking frame 159, and the galvanometer needle is at once free to move in any direction in response to any new changes in alkalinity which may in the meanwhile have taken place in the test portion, and which has correspondingly affected the resistance between the electrodes 56.

As the cams 157 and 157′ are revolved, cam 157′ gradually brushes against the contact lug 174 and forces it down into its normally horizontal position, while the opposite contact lug 173 rises to its normally horizontal position, (as shown in Fig. 6).

During the interval that the cam 157′ has been brushing against the contact lug 174, a continuous conductor has been provided for carrying the alternating current through 117 to 122 and back again; the continuous conductor being:—the current conducting wire 117, the contact lug 174, the current conducting cam 157′, the brush 180, and the current conducting line 122.

It is quite apparent that if the galvanometer needle 97 is swung in the righthand direction, that the operation of the mechanism shown in Figs. 5 and 6 will be reversed; and that the cam 157 will this time brush against the contact lug 173, whereupon current may pass through the current conducting line 117, the contact lug 173, the current conducting cam 157, the brush 179, and the current conducting line 118.

Suppose on the other hand, that the Wheatstone bridge does not become unbalanced, due to the exact conditions of alkalinity maintained in the test portion, the galvanometer needle 97 will not deflect either to the right or to the left. The eccentric cam 162 will nevertheless force the rocking frame up against the galvanometer needle; but, since a space is provided between the lever arm extensions 170 and 171 sufficiently large to allow for the free up and down movement of the galvanometer needle, it is apparent that the lever arms 168 and 169 will not be moved; and, consequently, that the balance arm 172 will therefore continue in its normally horizontal position. When this takes place, neither the cam 157 nor the cam 157′ will brush against the contact lugs, and there will therefore be no conductor provided for carrying the alternating current from the current supply line 117 to the current supply line 122, or back again.

Every time the cams 157 and 157′ are revolved and make contact with the contact lugs 173 or 174, the automatic gas control valve 40 would normally be correspondingly opened or closed to control the amount of CO_2 gas admitted into the second carbonator tank. Such frequent changes (once every 6 seconds) in the amount of CO_2 gas admitted to the second carbonator tank would obviously be inadvisable, because after such a change has been made a considerable time elapses before the alkalinity of the juices coming from the second carbonator tank shows a change corresponding to the change in the amount of gas admitted. For this reason, it is desired to turn the valve 40 less frequently, and it has been found that about 100 seconds should be

allowed between changes of the gas valve to make sure that the full effect of one change has been obtained before another one is made.

In order to utilize the 6 seconds' interval action of the controller mechanism just described, but at the same time to modify its ultimate effect on the control valve 40, provision has been made to make the valve changes at 100 second intervals by means of the contact disks 107 and 108 in cooperation with movements of the controller mechanism. The motor 110 is fed from the main current supply lines 102 and 103. An appropriate gearing, not shown, may be used in conjunction with the driving shaft 109 to slow or speed up the disks 107 and 108. These disks have contact segments 111 and 112, which can be so positioned relatively to one another as to lengthen or retard the time of simultaneous contact with the brushes 113 and 114. The alternating current passing through the contact disks is taken directly from the main current supply line 103, and through the current supply line 117 which is intimately associated with the controller mechanism just described above, as well as the relay system now to be described. Although the controller mechanism revolves once every 6 seconds, there can be no passage of current through the cams 157 and 157′ until the brushes 113 and 114 brush against the contact segments 111 and 112 during the interval that these brushes are simultaneously pressing against their corresponding contact segments, and the current passes through the current conducting line 115 connecting the two contact segments.

Let us again assume that the galvanometer needle 97 has been deflected to the left (as shown in Fig. 5), the cam 157′ will then brush against the raised contact lug 174 and thus form a conductor between the current conducting lines 117 and 122. If at the time that the cam 157′ brushes against the lug 174, the brushes 113 and 114 simultaneously bear against the contact segments 111 and 112 of the contact disks 107 and 108, current will pass from the main current supply line 103 through 116, through brush 113, segment 111, current conducting line 115, segment 112, brush 114, line 117, lug 174, cam 157′, brush 180, and line 122 which winds its way through the relay circuit back to the main current supply line 102. It is thus seen that a complete current conducting line has been provided between the main current supply line 102 (through the contact disks, the controller mechanism, and the relay mechanism) and the other main current supply line 103, or vice versa.

Assuming that the galvanometer needle 97 has been deflected to the right, that is in the opposite direction, it will be apparent that cam 157 will then brush against the now raised contact lug 173. If at the same time the brushes 113 and 114 are simultaneously bearing against the contact segments 111 and 112 of the contact disks 107 and 108, current will again alternate between the current supply lines 103 and 102 as just described. In this situation, however, the current supply line 118 will be substituted for the current conducting line 122. In other words, a complete circuit will then be provided between the main current supply line 103, line 116, brush 113, contact segment 111, line 115, contact segment 112, brush 114, line 117, contact lug 173, cam 157, brush 179, and the line 118 which winds its way through the relay mechanism, back to the main supply line 102, or vice versa. It is thus again seen that a complete current conducting line has been provided between the main current supply line 102 (through the contact disks, the controller mechanism, and the relay mechanism) and the other main current supply line 103, or vice versa.

In order to follow the operation of the relay mechanism, let us again suppose that the galvanometer needle 97 has been deflected to the left (as shown in Fig. 5) and that the controller mechanism and the contact disks are simultaneously in such a position as to allow current to alternately pass completely through the system. As the current passes down through the line 122 and through the solenoid coils 125, the solenoid core 123 is pulled to the left. The current passes to the pivoted brush 127 at the contact lug 132, and passes from thence back to the main current supply line 102. As the solenoid core 123 is pulled to the left, the pivoted contact brush 129 is swung over to the contact lug 137, which then provides a current conductor from the main current supply line 102, through contact 137, through the field winding 139 of the gas valve control motor 138. The current continues from the field winding of the motor up to the contact lug 130, through the pivoted brush 126, and from thence back to the other main current supply line 103. Since the motor windings are energized by connecting one terminal of the motor with the main current supply line 102 and the other motor terminal with the relay circuit connecting the lugs 131 and 135 (which latter line is dead when the solenoids are in their normal position; that is, when they are not energized). The energizing of the motor field winding 139 will make the motor revolve in one direction, with consequent turning of the gas valve in a corresponding direction.

If we now assume that the galvanometer needle has been deflected to the right, and the cam 157 contacts with the now raised lug 123, as the brushes 113 and 114 simultaneously bear against the contact segments 111 and 112 of the contact disks 107 and 108, current will pass down through the line 118 to the solenoid coil 121 of the solenoid 119. The current passes through the solenoid coil 121

to the contact lug 136, through the pivoted brush 129, and from thence back to the main current supply line 102. During the passage of the current through this circuit, the solenoid member 119 is energized in such manner as to draw the solenoid core to the right. When this takes place the pivoted brush 127 swings over to the contact lug 133. As soon as this takes place, current passes from the main current supply line 102 down through the pivoted brush 127, the contact lug 133, and the motor field winding 139, contact lug 134, the pivoted brush 128, and from thence back to the other main current supply line 103. We therefore see that the motor field winding has been energized in a direction opposite to the one described above, when the galvanometer needle was swung in the opposite direction, and the motor will therefore run in the opposite direction, and reverse the operation of the gas control valve 40.

In order that the operation of the gas control valve may be quickly stopped as soon as the relay circuit solenoids have gone back to their normal position, provision is made for quickly stopping the motor, instead of letting it gradually die down, as it normally would. The motor shaft 140 is provided with a friction disk 142, over and upon which an appropriate brake 143 is placed. As soon as current has passed through the terminals of the motor, the brake solenoid coil 147 is energized and the solenoid member 146 is pulled upwardly. This upward movement of the solenoid lifts the brake freely above the friction disk 142, and there is no brake action. The motor may then freely rotate. As soon as the relay circuit solenoids have been brought back to their normal position, by means of the springs 120 or 124, the current no longer flows through the motor terminals and the solenoid windings 147 are thereupon de-energized. The spring 145 thereupon draws the brake tightly down upon the friction disk 142, about the pivotal point 144, and the motor is quickly stopped.

The recorder mechanism 131 is of a standard type, and it merely records in a conventional way the variations in resistance between the electrodes 56′ as determined by the differences in alkalinity from the set standard, by means of a Wheatstone bridge. This recording may be on the usual graph paper placed upon a revolving cylinder, upon which an inked pen traces the curves represented by corresponding variations in resistance.

It is thus seen that in the practice of our invention we are able to continuously treat sugar juices in the manufacture of sugar under automatically controllable conditions. This represents a step far in advance over the usual batch methods of treating such sugar containing juices now generally employed in the making of sugar.

The alkalinity of the carbonated juices is not only continuously and automatically controlled within desired and predetermined limits, but the completely carbonated juices are likewise subjected to continuous separations of the clear juices from the undesirable solids.

Moreover, we are able to increase the particle size of the solids, over the size obtainable by batch methods, and thus increase the settling and filtering rate of the solids. The density to which the solids will settle represents an increase of about 100% over that obtained under batch operations. We have also found that we can continuously filter our continuously treated juices about 20% faster than under the old batch system heretofore employed.

We claim:

1. A method of treating juice in the manufacture of sugar which comprises continuously flowing together sugar juice and milk of lime, subjecting the body of limed juice to carbon dioxide gas, measuring the electrical resistance of a representative test portion taken from the body of limed juice undergoing carbon dioxide treatment at a point removed from the zone of chemical and dissolution reactions, and automatically controlling the amount of carbon dioxide gas passed into the body of limed juice as measured by said electrical resistance to bring the juice within predetermined limits of alkalinity.

2. A method of continuously treating juice in the manufacture of sugar which comprises flowing together approximately uniform volumes of sugar juice, and milk of lime, passing said limed juice through a plurality of connecting bodies, separately subjecting the limed juice to carbon dioxide gas in each body, measuring the electrical resistance of a representative test portion taken from the last body at a point removed from the zone of chemical and dissolution reactions, automatically controlling the amount of carbon dioxide gas passed into the last body of juice to bring the same within predetermined limits of alkalinity by an action responsive to changes in said electrical resistance, and constantly removing the carbonated juice.

3. A method of carbonating limed juice in the manufacture of sugar which comprises, subjecting a series of connected bodies of the limed juice to carbon dioxide gas, recirculating carbonated juice from a later to an earlier body of the series, automatically regulating the amount of carbon dioxide gas injected into the last body of limed juice in the series by utilizing changes in the electrical resistance of a test portion taken from the last body undergoing carbon dioxide treatment at a point removed from the zone of chemical and dissolution reactions to

maintain said last body of juice within predetermined limits of alkalinity.

4. A method of carbonating juice containing compounds of lime and sugar which comprises, subjecting a series of connected bodies of the limed juice to carbon dioxide gas, automatically regulating the amount of carbon dioxide gas injected into the last body of limed juice in the series by utilizing changes in the electrical resistance of a test portion taken from the body undergoing carbon dioxide treatment at a point removed from the zone of chemical and dissolution reactions to maintain said last body of juice within predetermined limits of alkalinity.

5. A method of carbonating limed juice in the manufacture of sugar which comprises subjecting the limed juice to carbon dioxide gas in a carbonation zone with the proportioning of the juice and gas controlled in amount to bring the juice within predetermined limits of alkalinity, said control being effected by measuring the electrical characteristics of a representative test portion taken from the body of the limed juice undergoing carbon dioxide treatment after the dissolution of the lime has gone to completion, utilizing changes in the electrical characteristics of said test portion to maintain the carbonated juice within predetermined limits of alkalinity, and recirculating the carbonated juice to increase particle growth of the solids.

6. A method of continuously carbonating limed juice according to claim 5, which comprises continuously flowing limed juice into the carbonation zone, repeatedly returning portions of the juice to the carbonation zone in order to encourage particle growth of the solids, and continuously withdrawing carbonated juice from the zone.

7. A method of carbonating juice containing compounds of lime and sugar which comprises subjecting a series of connected bodies of the limed juice to carbon dioxide gas, recirculating carbonated juice from a later to an earlier body of the series, automatically regulating the amount of carbon dioxide gas injected into the last body of limed juice in the series by utilizing changes in the electrical resistance of a test portion taken from the body undergoing carbon dioxide treatment after the dissolution of lime has gone to completion to maintain said last body of juice within predetrmined limits of alkalinity.

8. A method of carbonating limed sugar juice to obtain maximum coagulation of impurities therein which consists in mixing sugar juice and lime countercurrently with carbon dioxide gas while maintaining the mixture alkaline, completing chemical reaction between the lime and juice, completing dissolution of unreacted lime and juice, circulating a portion of the carbonated juice after said reactions have been completed through a sampling zone, and automatically electrically indicating the degree of alkalinity of the carbonated juice in said zone.

9. A method of carbonating limed sugar juice to obtain maximum coagulation of impurities therein which consists in mixing sugar juice and lime countercurrently with carbon dioxide gas while maintaining the mixture alkaline, completing the chemical and physical reactions between the lime and juice, circulating a portion of the carbonated juice after said reactions have been completed through a sampling zone continuously indicating the degree of alkalinity of the carbonated juice in said zone and using said indication to electrically operate a control of the proportion of gas and juice being mixed.

10. A method of carbonating limed sugar juice to obtain maximum coagulation of impurities therein which consists in mixing sugar juice and lime countercurrently with carbon dioxide, gas while maintaining the mixture alkaline, completing chemical reaction between the lime and juice, completing dissolution of unreacted lime and juice, circulating a portion of the carbonated juice after said reactions have been completed through a sampling zone automatically electrically indicating the degree of alkalinity of the carbonated juice in said zone, and using said indication to control the proportion of gas and juice being mixed to maintain their mixture between predetermined limits of alkalinity.

In testimony whereof we affix our signatures.

ELMER R. RAMSEY.
ARTHUR W. BULL.