This invention relates to the recovery of oils, fats or waxes from materials containing these substances. More particularly, it relates to the removal by a solvent extraction method of oil from soybeans and seeds in general, fats from animal sources and oil, fat or wax from any material that may be processed by extraction methods to obtain products of commercial value.

This application is a division of our co-pending application Serial No. 207,760 which was filed May 13, 1938, and issued as Patent No. 2,334,590.

The advantages of solvent extraction in obtaining fats, oils and waxes from materials have long been recognized and a number of solvents such as carbon bisulphide, benzene and various gasoline fractions have been used for this purpose. Distinct disadvantages attend the use of such solvents, however, and as a result, the methods most extensively employed involve the use of either the hydraulic press or the so-called "expellor" type screw press. The great disadvantage of these two types of equipment is that the pressed material generally contains in the neighborhood of 5 to 13% of unremoved oil or fat which represents a distinct financial loss.

The chief disadvantages of solvents such as carbon bisulphide or benzene is that they are inflammable and highly explosive when mixed with air and as a result of this, many fatal accidents have resulted from their use. Furthermore, these solvents are distinctly toxic in all concentrations. Past experience with such solvents has shown that there is a real need for a non-inflammable, non-explosive solvent which is not highly toxic. The chlorinated hydrocarbons such as trichloroethylene and perchloroethylene meet the above requirements for a practical extraction solvent, but their use has been greatly restricted, due chiefly to the fact that a suitable extraction apparatus in which counter-current extraction by means of these solvents may be effected has not been available to the art.

Many types of extraction apparatus have been proposed and used. Among these may be mentioned one which has been employed quite generally with low specific gravity solvents such as gasoline fractions. It consists essentially of two vertical tubes or legs joined at their lower ends by means of a horizontal tube. The solvent is fed in near the top of one leg and leaves the U-shaped apparatus near the top of the other leg. The material to be extracted enters the top of the leg from which the solvent is removed and leaves the apparatus at the top of the leg at which the solvent enters. Movement of the solid mate-
design of any counter-current extraction apparatus should always take into consideration the relative specific gravities of the solvent and the oil to be extracted so that throughout the entire length of the extractor the less dense liquid will always be kept above the more dense liquid. Practically all designs of apparatus previously proposed have failed to give proper consideration to this important factor. Furthermore, so far as we are aware, no extraction apparatus has yet been used or proposed wherein a solvent having a specific gravity greater than that of the oil, fat or wax which is to be extracted may be used therein in a truly counter-current manner, i.e., so that the travel of liquid throughout the entire length of the extractor is such that the less dense liquid will always be maintained above the more dense liquid.

Accordingly, a special object of our invention is to provide a method and apparatus for the extraction of oils, fats or waxes from solid materials containing such substances by means of a solvent, e.g., trichloroethylene or perchloroethylene, whose specific gravity is greater than that of the oil or like material which is to be extracted, whereby extraction may be carried out in truly counter-current manner. This particular object may be accomplished in accordance with our invention by the use of an apparatus of the type illustrated in Fig. 2 of the drawings. A description of this apparatus, together with an explanation of its mode of operation will follow subsequently.

The removal of residual solvent from solid materials, e.g., soya bean flakes, seed meals and the like, from which oil has been extracted has always presented certain difficulties. For example, it is common practice to remove such residual solvent from soya bean flakes or meal by heating and by displacement of the solvent vapors with steam. Various methods have been proposed for effecting such treatment by passing steam through the solid material in a direction counter-current to the movement thereof. However, due to the tendency of soya bean flakes to becomeasty when wet and to the difficulty previously encountered in providing adequate exposure of the solid particles to the displacing action of steam or other inert carrier for residual solvent vapors, an entirely satisfactory removal of residual solvent has not been realized. Since the practical success of any solvent extraction process is dependent upon the economical recovery of the solvent, the need of a more practical apparatus for effecting recovery of residual solvent from the solid material has long been recognized in the art.

Accordingly, a further object of our invention is to provide an apparatus for use in conjunction with our novel extractor whereby recovery of residual solvent from solid material, especially soya bean flakes, may be realized in a more simple and economical manner. This object may be accomplished by employing the equipment illustrated in Fig. 4. A description of this equipment will be given later in the discussion below. Various ancillary objects of our invention will be apparent from the ensuing description of the invention.

Our invention may be better understood from a consideration of the appended drawings, Fig. 1 of which represents schematically an apparatus assembled especially adapted for practicing the extraction of oils and like materials in accordance with our invention. Fig. 2 is a longitudinal sectional view, shown partly in elevation, of the preferred modification of the extractor proper and Fig. 3 is a cross-sectional view taken along line 3-3 of Fig. 2. Fig. 4 is a longitudinal sectional view, shown partly in elevation, of the equipment for removing residual solvent from the solid material as it is delivered from the extractor shown in Fig. 2.

Referring to Fig. 2, element 1 is a hopper whose purpose is to supply solid material, e.g., soya bean flakes, to tube 2 of the extractor. Tube 2 is joined at its lower end to a second or riser tube 3 which is inclined towards tube 2 so as to make a slight angle with respect to the vertical. Solid material is discharged from the upper part of riser tube 3 by way of tube 4. The apparatus is mounted so that point D is lower in elevation than point A. This is accomplished by inclining tube 2 at a slight angle from the horizontal, e.g., about 15°, as shown in Fig. 2. Screw conveyor 5 is positioned within tube 2 so as to rotate upon thrust bearing 7, and screw conveyor 6 is mounted within tube 3 so as to rotate upon bearings 8 and 10. These conveyors may be driven by any suitable means, e.g., by gear drives, not shown in the drawings. Fresh solvent is introduced into the extractor by way of inlet pipe 11 and lixivium is removed from the upper part of tube 2 by way of slots 12. The lixivium from slots 12 passes through box 13 and is delivered to the system for separating solvent from the extracted oil by way of outlet pipe 14. Screen 15 in box 13 serves to separate from the liquid any coarse solid particles which may have escaped through slots 12. This screen may be omitted if desired, especially when the product lixivium is to be filtered before being processed further. Preferably, one side of box 13 is removable in order to facilitate periodic cleaning of screen 15 or slots 12. As is shown in Fig. 3, the removable side 17 may be secured to the box proper by means of screws 18. Element 16 in Fig. 2 is a drain which may be provided with any suitable valve or cap arrangement not shown in the drawings. Its purpose is to provide a means for draining the apparatus of liquid when this is desired and also to serve as a well for collecting any adventitious matter, small pieces of metal or other heavy material, from which such material may be removed without interrupting operation of the extractor.

In operation, material to be extracted is fed continuously into the upper part of leg 2 by means of hopper 1 and is carried through the extractor by the action of screw conveyors 5 and 6. Solid material is discharged from tube 3 by way of down-spout 4. Fresh solvent, fed in continuously by way of inlet pipe 11, flows through the extractor counter-current to the direction of movement of the solid material therein, and the product lixivium leaves the extractor proper by way of slots 12. In elevation, solvent inlet pipe 11 should deliver solvent at a point above point A, the liquid level in leg 2. The outlet 4 should be placed several feet above point B, the liquid level in leg 3 in order that ample time may be provided for solvent to drain from the meal and return to the lower portion of leg 3. Drainage of solvent from the meal may be facilitated, if desired, by perforating the flights of the conveyor in the section of the apparatus. As shown in Fig. 2, the upper part of conveyor 6 is provided with a section of reverse thread flighting 8 which facilitates discharge of meal into spout 4.

An essential requirement of our extractor is that it be designed to maintain in that part thereof where extraction is to be effected liquid of
lower specific gravity always above liquid of higher specific gravity. In this manner the tendency for lixivium in one zone to mix with that in another is practically eliminated since convection currents in the liquid are reduced to a minimum. Referring to Fig. 2, extraction of oil from the solid material is effected substantially completely in the long inclined portion of the apparatus designated as element 2 so that liquid at the point D contains only a very small amount of oil and hence has a specific gravity substantially the same as that of the pure solvent. However, as the liquid flows from the point D to the point A its specific gravity decreases progressively due to progressively larger quantities of oil being contained therein. Therefore, the specific gravity of liquid at any given point between D and A will be less than the specific gravity of liquid at any lower point between D and A so that at all times liquid of lower specific gravity will be above liquid of higher specific gravity. Under these circumstances there will be no tendency for convection currents to form and extraction in truly counter-current manner may be realized. Substantially complete extraction in leg 2 may be realized by making this leg sufficiently long, by controlling the ratio of solids to solvent fed to the extractor and by adjusting the rate of travel of material through the extractor. By properly adjusting these factors, apparatus such as that illustrated in Fig. 2 permits the attainment of product lixivium of practically any oil content. In the commercial extraction of oil from soya beans a lixivium containing 25% oil has been found to be practical. However, a lixivium having a higher oil content may be obtained by adjusting the above mentioned factors accordingly.

An important point of construction of the apparatus illustrated in Fig. 2 is the angular relationship between the tubes 2 and 3 as well as the position of tube 2 with respect to the horizontal plane. Using a high specific gravity solvent such as trichloroethylene, the ordinary oil, fat or wax-bearing material that is to be subjected to extraction will generally have a density less than that of the solvent. Advantage is taken of the property of such material to float in the solvent in securing uniform and continuous movement of material through the extractor. In Fig. 2, the movement of material from tube 2 into the riser tube 3 is effected by allowing the material to float from the point D upward and into the flights of conveyor 6. Once the material has entered tube 3 positive upward movement in this tube is obtained by means of the conveyor. Any material which does not float will be pushed out into tube 3 where it can be picked up by the conveyor in this tube.

The angle which tube 2 makes with the horizontal should be kept small. In practice a suitable angle has been found to be about 10 to 25°, although an angle of about 15 to 20° is preferred. This tube is relatively long in comparison with tube 3, in order that practically complete extraction may be effected in tube 2. The extracted material in passing up through tube 3 is washed by the incoming fresh solvent, is then drained and finally discharged near the top by way of element 4 through which it falls by gravity directly into the meal drier.

The lower ends of tubes 2 and 3 should be connected with each other so that when tube 2 is properly positioned with respect to the horizontal plane, tube 3 will be in a vertical position or inclined from the vertical plane either towards or away from tube 2 at an angle not more than about 25°. Whether or not the shorter or riser tube 3 should be positioned to incline the vertical plane either towards or away from tube 2 will depend largely upon the particular solid material being handled and especially upon whether the density of the solvent employed is greater or less than that of the solid material after it has been rendered substantially free of oil. But regardless of what position tube 3 may assume with respect to the vertical plane, we have found that for practical purposes this tube should not be inclined from the vertical plane either towards or away from tube 2 at an angle greater than about 25°, since otherwise an impractically long riser tube would be necessary.

The movement of solid material through the extractor at the junction of the two legs thereof, point D in Fig. 2, may be materially affected by the position of riser tube 3 with respect to the vertical plane. In the arrangement shown in Fig. 2, tube 2 makes an angle of about 10° with the horizontal and an angle of 80° with tube 3 so that the latter tube inclines at an angle of about 14° from the vertical towards tube 2. As conveyor 6 in tube 2 is rotated, material is forced to move past point D and into tube 3. If the solid material is lighter than the solvent, it will tend to rise vertically and enter the compartments between the flights of conveyor 6. Because tube 3 is inclined towards tube 2, this natural tendency of the material to rise in the solvent will not be hindered by contact of the solid material with the lower side wall of tube 2, so that the filling of the compartments of conveyor 6 will be facilitated by this arrangement.

On the other hand, if tube 3 were inclined from the vertical away from tube 2, the natural tendency of the lighter solid material to rise vertically in the solvent would be appreciably hindered by contact of the material during its upward travel with the upper side walls of tube 3. In this arrangement, filling of the flights of conveyor 6 would depend entirely upon the action of conveyor 6 in tube 2 to force the solid material into the compartments of conveyor 6, and would not be aided by the buoyancy of the solid material in the solvent. If tube 3 were given a vertical position, the side walls of this tube would offer a certain resistance to the natural vertical movement of the lighter solid material, but this resistance would not be as great as it would be if tube 3 were inclined from the vertical away from tube 2.

The situation would be somewhat different if the solid material at point D in the extractor, were heavier than the solvent employed. In this case, the natural tendency would be for the material to sink upon passing point D, so that the filling of the compartments of conveyor 6 would be facilitated by having riser tube 3 inclined slightly from the vertical away from tube 2 and would be somewhat hindered by the opposite arrangement.

It is not necessary, however, to the successful operation of our apparatus that the short riser tube thereof be given any special position with respect to the vertical, regardless of the relative densities of the solvent and the solid material after the air has been removed therefrom. Thus, excellent results may be obtained by positioning the two legs of the extractor at right angles to each other. This arrangement permits extending the lower end of the conveyor.
in the long inclined tube to the extreme lower end of this tube, leaving only enough space between the end of this conveyor and the conveyor in the shorter riser tube for proper clearance. Upon rotation of the conveyors, solid material would be forced from the end compartment of the first conveyor directly into the flights of the conveyor in the riser tube with no dead space being left between the conveyors wherein the solid material would be free to rise or sink. In this arrangement it would be of little importance whether the solid material tends to rise or sink in the solvent at the junction of the two tubes.

As stated above, the relatively long extractor tube, tube 2 in Fig. 2, should be positioned so as to make a small angle with respect to the horizontal plane and the relatively short riser tube, tube 3 in Fig. 2, should not be inclined from the vertical plane at an angle more than about 25°. It has been found that excellent results may be obtained in accordance with our invention by positioning the long inclined tube at an angle of about 10 to 25° from the horizontal plane, although we prefer that this angle be about 15 to 20°. This position of the tube insures a proper specific gravity gradient in the tube when the solvent is employed which has a specific gravity greater than that of the oil being extracted. The effectiveness of so positioning this tube is evident upon considering how the extractor would operate were the tube placed in a horizontal position. In such an arrangement, employing vertical feeder and exit tubes, no practical provision can be made to keep the high density solvent fed from one of the vertical tubes from flowing along the bottom of the horizontal extractor tube. Thus, it is evident that the extractor tube should be positioned so as to make a small angle, for example, 10 to 25°, with respect to the horizontal plane.

It may be desirable under some circumstances to effect extraction at temperatures either above or below atmospheric temperature. Thus, with some types of oil or fat-bearing materials, extraction is facilitated by operation at temperatures considerably above room temperature. In such cases, the extractor illustrated in Fig. 2 may be provided with suitable heating means for maintaining the desired temperature. Thus, tubes 2 and 3 may be provided with steam jackets or other suitable means adapted to provide the required heat. If cooling is desired, cooling liquid at the desired temperature may be circulated through jackets provided around the tubes of the extractor. It is therefore to be understood that the apparatus illustrated by Fig. 2 is not restricted to operation at any specific temperature.

The solid material is preferably reduced to small particles before being fed into the extractor in order to expose a maximum of surface to the solvent and thereby increase the rate of extraction. Seeds, beans, tubers, and the like may be flaked and animal material may be hashed. Exceedingly fine particles are undesirable in that their separation from the lixivium may become troublesome. We have found that by providing narrow slots, indicated by the numeral 12 in Fig. 2, on the underside of the long extractor tube at the point where it is desired to remove the lixivium, entrainment of solids in the lixivium is greatly reduced. These slots, cut at right angles to the axis of the tube, provide a narrow opening at the inner surface of the tube wall and a wider opening at the outer surface thereof. Ordinarily the lixivium will flow out of the lowest slot. However, if this becomes plugged the liquid level in the tube will rise, causing the lixivium to flow out of the next highest slot, and so on up the series of slots. Provision may be made to clean automatically these slots. For example, light flexible wires may be spaced radially across the shaft of the conveyor in such a way that the spring wires wipe through each slot each time the shaft is rotated. We have found, however, that the flow of lixivium through the beveled slots in conjunction with the wiper section of the conveyor flights, suffices generally to prevent permanent clogging.

There are distinct advantages to feeding the solid material into the extractor tube so as to keep the conveyor flights above the lixivium outlet well filled with material. This maintains a column of solid material above the liquid which absorbs solvent vapors, thus preventing solvent loss. Also, it has been found that when the conveyor is well filled at the point corresponding to the lixivium outlet, the amount of solid entrainment in the lixivium is reduced to a minimum by the filtering action of the column of solids. Furthermore, we have found that somewhat better operation is obtained by feeding the entering solid material into the screw conveyor at a point above the lixivium outlet since then the lixivium cannot interfere with the filling of the conveyor flights. It is not necessary, however, that the hoppers be placed at the position indicated in Fig. 2. Good results may be obtained by feeding in the solids at other points along tube 2, for example at point B. It should be noted that by inclining the riser tube 3 of the extractor at a slight angle from the vertical, as shown in Fig. 2, it is possible to discharge the meal by the action of gravity directly into equipment for removing residual solvent from the solids. We have discovered that the equipment illustrated in Fig. 4 of the drawings is well adapted for treating meal, e.g., soya bean meal, to remove residual solvent therefrom. This equipment consists essentially of a drier section connected with a steamer section, each section being provided with conveyors particularly adapted for the movement of solid material therethrough.

Referring to Fig. 4, tubular member 28 is connected with element 4 of the extractor shown in Fig. 2 and serves to direct material dropping from the extractor into the drier. The drier consists of a long tubular member 21 and the steamer consists of a similar member 22. Both the drier and steamer are jacketed by steam jackets 23. Running the length of tube 21 is a conveyor 24, adapted to rotate in bearings 30 and 31. The front end of this conveyor is made up of solid screw flights 25 whereas the center or main section consists of two rods wound around a central shaft so as to form two separate screws or spirals of different pitch, indicated in the drawing as elements 26 and 27. The spiral of greater pitch, 27, is broken where it crosses the spiral of lesser pitch, 26. These rod spirals are spaced from the central shaft by means of struts 28. The conveyor at the outlet end of the drier is provided with a short section 29 of solid flighting having a reverse thread to that of the other sections of the screw conveyor.

The steamer, shown connected to the drier by means of connecting tube 44, is similar to the drier except that a somewhat different type of
conveyor 32 is shown for moving the meal through the steamer. The front end of this conveyor is not provided with solid flights and the conveyor proper consists of a rod spiral type screw conveyor, the single spiral being indicated in Fig. 4 as element 38. The flights of this conveyor are supported from the central shaft by struts 34. This conveyor, at the outlet end of the steamer, is similar to the conveyor in the drier in that it is provided with a section of solid, reverse flighting 35. Conveyor 32 is adapted to rotate in bearings 36 and 37. It is to be noted that the flights of this conveyor are provided with horizontal connecting bars 38. These connecting bars are secured, e.g. by welding, to adjacent flights of the conveyor so as not to protrude beyond the outermost extremities of the flights. Preferably, alternate sets of two or three flights are connected by bars 38 on one side of the conveyor, while the intervening sets of two or three flights are connected on the opposite side, as shown in Fig. 4, since this arrangement preserves the balance of the conveyors. If desired, all of the flights may be connected by similar bar members on two opposite sides of the conveyor, but such an arrangement is generally not necessary.

Both the spiral of greater pitch 31 and the horizontal connecting bars 38 are characterized by being spaced from the conveyor shafts 24 and 32, but adapted to rotate with their respective shafts. Any segment of either spiral 27 or horizontal bars 38 has substantially less slope from a line parallel to their respective shafts than the corresponding segment of the spiral rod conveyor members 28 and 33. They are, as shown, equidistant with the corresponding spiral rod conveyor members 28 and 33 from the conveyor axis at any given point longitudinally of the conveyor.

The drier and steamer are heated by means of steam introduced by way of inlets 35 into steam jackets 23. Superheated steam is injected directly into the steamer by way of inlet 41 so as to contact the solid material and displace the last traces of residual solvent. Superheated steam or other inert gaseous carrier may be introduced into the steamer before it has been heated to points along tube 22 if desired. Solvent and steam vapors are removed from the apparatus by way of outlet 42 which may lead to a condenser and separator as indicated in Fig. 1. Condensate from the steam jackets is removed by means of tubes 40. After all residual solvent has been removed, the meal is discharged from the apparatus by way of a barrel or rotary valve 43. This valve may be operated by mechanical means, not shown, and serves to discharge solid material while the same time preventing the exit of steam or solvent vapors at this point.

We have discovered that the open flight types of screw conveyors illustrated in the drier and steamer of Fig. 4 function admirably well to convey meal through contacting the meal removing residual solvent. The solid flight type of conveyor is not suitable since solid flights hinder the escape of solvent vapors from the meal and obstruct the passage of steam therethrough. On the other hand, the open flight conveyors of Fig. 4 facilitate thorough contacting of the material with steam or other inert gas. Also, with conveyor 24 having two spirals of different pitch, the spiral of greater pitch 27 continuously turns the material over as it is moved forward by the spiral of lesser pitch 25. Spiral 27 also has a tendency to prevent sticking of meal to the walls of the casing and causes better contact with the heated surface, whereby better drying results.

The function of the horizontal connecting bars 38 in conveyor 32 is the same as that of the spiral of greater pitch 27 in conveyor 24. Hence, either of these two types of open flight conveyor may be used in either the drier or steamer of Fig. 4.

The short sections of solid flighting 29 and 35 at the ends of the conveyors shown in Fig. 4 prevent material from packing at the end of the drier and steamer tubes and assist in causing it to fall by gravity into connecting tube 44 or the discharge tube which feeds barrel valve 45. The front end of conveyor 24 in the drier is preferably provided with a section of solid flighting 25 at the point where meal from the extractor enters the drier, since this arrangement eliminates the tendency for the meal to plug the drier at this point. Once the meal has been conveyed somewhat past the point of entry, no difficulty of this sort is experienced with the open flights.

We have shown in Fig. 4 separate drier and steamer sections connected by means of tube 44. Instead of this arrangement the two sections may be combined into one long tube, the fore part being used as the drier and the other as the steamer. Such an arrangement is not preferred since it would require an excessively long screw conveyor which might be troublesome in operation. Also, a plurality of drier and steamer sections, joined together as indicated in the drawings, might be used in place of the single drier and steamer indicated in Fig. 4. But, whatever arrangement is used, we have discovered that it is most practical to heat the meal to a temperature of at least about 100° C. before contacting it with steam.

Solid material, e.g. soya bean meal and the like, as it is discharged from the extractor illustrated in Fig. 2 has a tendency to become sticky and the removal of residual solvent from material which has reached the pasty stage is difficult. This tendency to become pasty is increased greatly if the meal is subjected to the action of steam before it has been heated to about 100° C. It is therefore highly desirable that the meal be subjected first to an effective drying treatment and thereafter to the action of superheated steam to remove the final traces of solvent. As a result of numerous experimental trials it was found that substantially complete removal of residual solvent may be accomplished with a minimum of difficulty resulting from the meal becoming pasty when the drier and steamer arrangement, including the special open type conveyors, illustrated in Fig. 4 is used.

Fig. 1 shows schematically an effective assembly of the extractor shown in Fig. 2 and the drier shown in Fig. 4, in conjunction with equipment for separating solvent from the extracted oil and for recovering solvent from the steamer and drier. In general plan, solvent is passed through a crusher, a flaker and finally into the extractor, through which it then passes in a manner truly counter-current to the direction of movement of the solvent. The solid material then falls from the top of the riser pipe of the extractor into the drier, from whence it passes through the steamer and is discharged therefrom by means of the barrel valve. The solvent enters the short or riser leg of the extractor and lixivium is removed from the slotted arrangement previously described, from
whence it passes through filters for removing finely divided, suspended, solid material. The lixivium is then preheated and passed through a stripping still where final traces of solvent are removed from the extracted oil. The solvent vapors pass into the condenser where they are condensed and separated from water to provide solvents which may be used again in the process. An absorption tower is also provided to recover solvent vapors carried by the inert or non-condensable gases from the condenser, extracted oil being used as the absorbing medium. Oil and recovered solvent from the absorb tower are fed into the preheater together with lixivium from the extractor. The arrangement of apparatus shown in Fig. 1 is highly effective and permits extraction of oil and similar materials to be accomplished without undue loss of solvent.

Our invention is not restricted to the use of any particular solid material containing extractable material nor to the employment of solid material in any particular physical form. If desired, the solid material may be pretreated, e.g., by steam or by mechanical means to facilitate extraction. Also, the invention is not limited to particular means for handling the solid material and causing its movement through the apparatus, for example, conveyors of the cup type may be employed in the extractor although generally we prefer to employ the solid flight type of conveyor illustrated in Fig. 2. Various other modifications of our invention may be practiced by those skilled in the art without departing from the scope of the invention. We therefore wish it understood that our invention is not limited by the structural details and procedural steps set forth above, which are intended to be illustrative and not restrictive of our invention, but only by the scope of the appended claims.

We claim:
1. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises, a tubular member having drier and steamer sections and means for heating said drier and steamer sections, means for delivering steam into said steamer section, means for removing solvent vapors and steam from said tubular member and means for moving solids through said tubular member, said last named means comprising an open-flight screw conveyor adapted to rotate with said shaft and forming the open-flights of said conveyor, and bar members spaced from said shaft between conveyor flights and adapted to rotate with said shaft, any segment of said bar members having substantially less slope from a line parallel with the conveyor shaft than the corresponding segment of said rod spiral, said rod spiral and said bar members being equidistant from the conveyor axis at any given point longitudinally of said conveyor.

2. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises, a tubular member having drier and steamer sections and means for heating said drier and steamer sections, means for delivering steam into said steamer section, means for removing solvent vapors and steam from said tubular member and means for moving solids through said tubular member, said last named means comprising an open-flight screw conveyor adapted to rotate within said tubular member and having a conveyor shaft running longitudinally of said tubular member, and two concentric rod spirals spaced from and adapted to rotate with said shaft, said rod spirals being of equal radii one of said spiral having a substantially greater pitch than the other and being broken where it crosses the spiral of lesser pitch.

3. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises a tubular member having drier and steamer sections and means for heating said drier and steamer sections, an inlet conduit connected to one end of said tubular member, a downwardly extending discharge conduit positioned adjacent one end of said tubular member, means for delivering steam into said steamer section, means for removing solvent vapors and steam from said apparatus and means for moving solids through said tubular member, said last named means comprising a screw-conveyor having a front section of solid flighting adjacent said inlet conduit, a middle and main section of open flighting, and a short end section of solid reverse flighting adjacent said discharge conduit for facilitating movement of solids from said tubular member into said downwardly extending discharge conduit, the flighting in said main section comprising a conveyor shaft and two concentric rod spirals spaced equidistantly from and adapted to rotate with said conveyor shaft, said spirals being of equal radii, and one of said spirals having a substantially greater pitch than the other and being broken where it crosses said spiral of lesser pitch.

4. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises, a tubular member having drier and steamer sections and means for heating said drier and steamer sections, an inlet conduit connected to one end of said tubular member, a downwardly extending discharge conduit positioned adjacent one end of said tubular member, a valve for controlling discharge through said discharge conduit, said valve being positioned in said discharge conduit, means for delivering steam into said steamer section, means for removing solvent vapors and steam from said apparatus and means for moving solids through said tubular member, said last named means comprising a screw conveyor having a front section of solid flighting adjacent said inlet conduit, a middle and main section comprising open flighting and a short end section of solid reverse flighting for facilitating movement of solids from said tubular member into said downwardly extending discharge conduit, the flighting in said main section comprising a conveyor shaft and a rod spiral adapted to rotate with said conveyor shaft and forming the open flights of said main section, and longitudinal bar members connecting some of said flights of said rod spiral.

5. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises, a plurality of superimposed, horizontal, tubular members provided with interconnecting means so as to form a continuous passage through said tubular members for said solids, an inlet conduit connected to one end of said tubular member, a downwardly extending discharge conduit connected to the other end of said tubular member, means for heating said tubular member, means for delivering steam into said members, means for removing solvent vapors and steam from said apparatus and means for moving solids through said apparatus.
said apparatus, open flight screw conveyors within said tubular members, each conveyor comprising two concentric rod spirals spaced from and adapted to rotate with a conveyor shaft, said spirals being of substantially the same radii, one of said spirals having a substantially greater pitch than the other and being broken where it crosses the spiral of lesser pitch, the screw conveyor in the top tubular member being provided with a front section adjacent said inlet conduit of solid flighting having the same thread as the open flight and with a short end section of solid reverse flighting for facilitating movement of solids into said interconnecting means, and the screw conveyor in the bottom tubular member being provided with a short end section of solid reverse flighting to facilitate movement of solids into said downwardly extending discharge conduit.

6. An apparatus for removing residual solvent from solids which have been extracted by means of a volatile solvent, which comprises, a plurality of superimposed, horizontal, tubular members provided with interconnecting means so as to form a continuous passage through said tubular members for said solids, an inlet conduit adjacent one end of said tubular members, a downwardly extending discharge conduit connected to the other end of said tubular member, a valve for controlling discharge from said discharge conduit, said valve being positioned in said discharge conduit, means for heating said tubular members, means for delivering steam into said tubular members, means for removing solvent vapors and steam from said apparatus, open flight screw conveyors within said tubular members, each conveyor comprising a rod spiral adapted to rotate with a conveyor shaft and forming the open flights of the conveyor, some of said flights of said rod spiral being connected by longitudinal bar members, the screw conveyor in the top tubular member being provided with a front section of solid flighting adjacent said inlet conduit, said front section having the same thread as the open flighting, and with a short end section of solid reverse flighting for facilitating movement of solids into said interconnecting means, and the screw conveyor in the bottom tubular member being provided with a short end section of solid reverse flighting to facilitate movement of solids into said downwardly extending discharge conduit.

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