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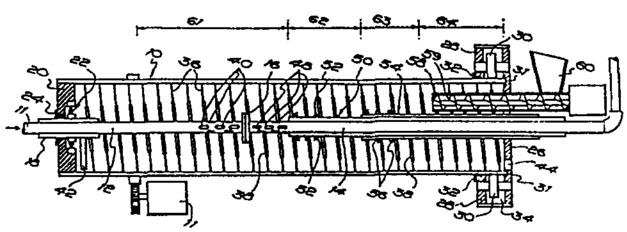
(54) **Asphalt separation and heavy oil extraction/treatment.**

(57) The removal of asphalt from heavy oil is accomplished by delivering the heavy oil, mixed with pentane, to the interior of a drum (10) provided with screw flights (38). The asphalt precipitates and rotation of the drum effects separation by progressive decantation. Delivery of washing solvent (at 52) and steam (at 54) to different regions of the drum (10) leads to discharge of asphalt which is well separated from traces of the crude oil.

The process is advantageously utilised in connection with enhanced oil recovery. Coal and limestone area added (at 58, 60) to the discharged asphalt and briquetted (at 68) to a solid fuel used to provide process heat for enhanced oil recovery operations with an advantageous financial economy.



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# ASPHALT SEPARATION AND HEAVY OIL EXTRACTION/TREATMENT

This invention relates to the upgrading and/or production of heavy oil or emulsions thereof. The oil may in particular be heavy crude oil, an emulsion thereof, or a heavy fraction obtained in the course of oil refining. However, the invention is not necessarily restricted to such oils.

Heavy oil, such as residual oil, vacuum resid or heavy crude, contains asphalt. A heavy crude oil may typically contain 10 to 40% asphalt.

It is already well known that dissolving a heavy oil in a volatile light paraffin such as propane or butane will precipitate asphalt. Various oil treatment processes (not necessarily for crude oil) utilise solution in light paraffins such as propane but necessitate the considerable complications attendant on substantial superatmospheric pressure for the process. Existing processes for deasphalting oil tend to utilise liquid/liquid separations to separate the asphalt. The technology is fairly elaborate in the equipment required, and is mainly suited to an oil refinery. Canadian Patent 940858 utilises hydrocyclonic separation of an asphaltene rich mixture from a maltene rich mixture, in the presence of a precipitating agent. This is followed by solvent addition and filtration. Other patents such as US 4440633 teach separation of an asphalt rich phase where setting of heavy liquid or sludge is facilitated by means of ultrasound.

It is already known to solvent extract a petroleum hydrocarbon solution from sand by means of a rotary separator consisting of an inclined drum with a helical screw extending inwardly from its inside surface as shown in US Patent 4098648. This apparatus however is separating a solution from sand having a density which is two or three times greater. For this purpose the helical flights of the screw within the drum have constant size and pitch, and have apertures at radially outward positions for the through flow of solvent counter-current to the sand which is carried up the rotating drum. Such an arrangement, however, would not be practical for effecting a separation where the densities of the materials were very much closer, (such as crude oil and asphaltene precipitate). Apertures at radially outward positions in the flights would allow both the solid and liquid to pass through, so that the desired separation would not occur.

This patent does not relate to removal of residual solvent from sand, which is discharged wetted with solvent.

Using a heavy hydrocarbon binder to bind solid fuel particles is known, both for making a fuel product and in the processing of metal ore. US patent 4226601 goes further and teaches incorporation of a compound which will bind (by chemical reaction) sulphur when the fuel is burnt. Asphalt is not mentioned as a binder, nor is any particular use of the fuel proposed.

When a heavy crude oil is obtained in a geographically remote location the present techniques for dealing with it are (i) transport through heated pipelines (which is done on a large scale in California and Venezuela), (ii) mixture with perhaps 15-30% by volume of a diluent, (which is done on a large scale in Canada) and (iii) building a relatively complex upgrading refinery type plant at the remote location.

The expense involved in heating pipelines is self-evident. Mixture with a diluent is of course dependent on the availability of diluent. Projects to build upgrading refineries in remote regions have been put in hand, and then discontinued due to lack of profitability, and due to the long lead time before the substantial investment could produce a return.

The object of certain aspects of the invention is to provide improved economics in so-called enhanced oil recovery, and/or in oil refining. Another object, of aspects of the invention, is to provide an improved technique for deasphalting, capable of use in geographically remote regions (so that it can be used proximate the wellheads) and requiring only moderate capital investment

According to a first aspect of this invention there is provided a process and decantation apparatus for separating precipitated asphalt from a mixture of heavy oil and lighter paraffinic hydrocarbon solvent. The apparatus can be incorporated into a treatment plant for heavy oil. This plant will generally also include means for mixing the heavy oil or emulsion with a lighter paraffin solvent, and may include means for recovering the solvent by distilling the separated supernatant solution. It may also include a briquetting press arranged to receive solid discharged from the apparatus.

The decantation apparatus comprises a drum provided with at least one inlet delivering to the drum interior intermediately between the ends of the drum, an outlet for supernatant liquid (which will be maltene/solvent mixture) at one axial end of the drum and an outlet for precipitated asphalt at the axially opposite end of the drum, a helical screw fast with the interior of the drum, the flights of which project radially inwardly from the wall of the drum and extend without aperture to an overflow level spaced from the drum wall,

means mounting the drum for rotation, the shape and orientation of the drum and the overflow levels of the screw flights being arranged such that supernatant liquid overflow over the flights is towards the liquid outlet end, the screw flights being arranged such that the volumes contained between successive flights generally decrease towards the asphalt outlet end of the drum, and

drive means for rotating the drum so as to convey material between the flights towards the outlet for asphalt.

The arrangement of the drum and the flights of the screw within it to give the required functions can be achieved in various ways. The preferred arrangement is a drum which is a right cylinder. It is then readily arranged that overflow is downwards towards the lower end, and liquid outlet is from that end. The cylinder axis may be tilted to the horizontal e.g. in the range of 5° to 15°, and is rotated to carry the denser precipitated asphalt up the incline to the outlet for it which is at the upper end. Conceivably, however, the drum could be a frustrum of a cone mounted on a horizontal axis. Then the lower half of the cone is of course inclined, and the asphalt outlet is at the narrow end while the liquid outlet is at the wide end.

It is also preferable that the volume between successive flights reduces towards the asphalt outlet. By reason of this feature there is overflow at every flight and thus as a volume of material is conveyed towards the asphalt outlet there is overflow of supernatant liquid solution at every flight and the volume of supernatant liquid between the flights progressively reduces. This requirement for decreasing volume can be achieved in various ways. If the drum is a right cylinder it is suitable for the distance by which the flights extend radially inwards from the drum wall to decrease progressively. The same result could conceivably be achieved by a progressive reduction in the pitch of the helix towards the denser material outlet end. If the drum was in the form of a frustrum of a cone the volume between flights would reduce progressively even if the distance by which the flights projected radially inwards, and the pitch of the helix both remained constant.

It is not essential that there should be a decrease in volume between every flight provided there is a progressive decrease in volume towards the asphalt outlet end. In particular there could be several turns of the helix with a constant or even increasing volume between them adjacent to the asphalt outlet end, particularly if the arrangement was such that overflow of supernatant liquid would more or less have ceased before reaching this end of the drum.

The screw flights may have no apertures at all, and extend radially inwards to an edge acting as a weir where the supernatant liquid overflows. An alternative to this, producing a similar functional effect, is for the flights to extend radially inwardly without aperture for a certain distance from the edge, but then have some form of aperture(s) before reaching (i.e. spaced outwardly from) the inner extremity of the flights. Such apertures might for example be a castellated inner margin of the flights. Such apertures, if present, would determine the overflow level, e.g. at the radially outer level of castellations, but could enable decantation from a depth within the supernatant liquid.

A process according to this invention, for separating asphalt in the solid state from crude oil, crude oil emulsion, distillation residue or other heavy oil, comprises mixing the oil or emulsion with a lighter paraffinic hydrocarbon solvent, and separating the resulting solution from precipitated solid asphalt by means of the decantation apparatus set forth above.

As mentioned above, it is already known that dissolving a heavy oil in a volatile light solvent such as propane or butane will precipitate asphalt.

I have found that when a heavy crude oil is mixed with a sufficient quantity of light hydrocarbon paraffinic solvent such as commercial pentane, or a petroleum ether distilling in a range starting at 40°C and extending not higher than 80°C at atmospheric pressure, not only do a large proportion of asphaltene, polar materials and resins form a precipitate but also, significantly, the precipitate can be separated by means of the process of this invention at only modest superatmospheric pressure. A suitable quantity of solvent is 2 to 4 times the volume of oil. Mixing is preferably accomplished at a temperature of 100-200°C.

The same is true if the crude oil is in the form of an aqueous emulsion. Moreover it is a valuable feature that adding the solvent in a sufficient quantity also breaks the emulsion so that the oil can readily be separated from the water. The precipitated solids settle into the water phase. The solids are hydrophilic, and having the solids become water wet greatly assists in separating the soluble liquid constituents and the solvent, both of which are hydrophobic, and less dense than water. A suitable quantity of solvent for a heavy crude oil emulsion is 2 to 4 times the volume of oil contained in the emulsion.

At least in preferred forms of the invention, the initial separation is continued by further treatment within the drum. Firstly, partially separated solid asphalt may be washed with additional solvent introduced into the interior of the drum by a pipe provided for the purpose. The solvent is partly separated by decantation in the same way as the original supernatant liquid and joins that original liquid to leave via the liquid outlet.

Steam may be introduced through a pipe into the interior of the drum. It will water wet precipitated asphalt and evaporate solvent liquid from the largely separated asphalt. Only low temperature and pressure steam is required. It will also partially melt the surface of the asphalt and cause it to agglomerate. It is likewise appropriate to provide an outlet for solvent vapour which can be drawn off, condensed, and recycled.

The precipitated asphalt which is discharged from the drum may be mixed with water which can be at least some water from added steam, emulsion water from the heavy oil feed, and/or added process water. Preferably most or substantially all of the water will be discharged with the asphalt, which may appear as wet powder or a mobile slurry depending on the quantity of water in the originating emulsion and the quantity of steam or process water added.

If the drum is arranged for vapour to be evaporated within it from the separated asphalt, it is preferable that the drum is arranged to retain some superatmospheric pressure.

For this reason the two ends of the drum are preferably secured to each other. It is convenient for the lower end of the drum, with the outlet for supernatant liquid, to be fixed to the drum to rotate with it, while the upper end is static but sealed to the rotating drum, e.g. with stuffing boxes.

The apparatus may be provided with means for dislodging solid asphalt adhering to the flights, and carried upwardly out of the lower part of the drum. This could be achieved by means of appropriately directed jet(s) of washing solvent or steam. A further possibility for this purpose is one or more scraping blades engaging the screw flights and arranged to rotate in the opposite sense to the drum, at an equal rate, so that their angular position remains constant.

Preferably, in the above aspects of this invention the operating conditions are arranged such that as solid particles separate they are slightly softened by moderate heat and hence are encouraged to agglomerate together. The formation of larger particles promotes ready separation from any remaining supernatant liquid.

The drum may be rotated at a relatively slow speed e.g. less than about 25 rpm so that the solid particles are encouraged to agglomerate by a gentle tumbling action rather than being centrifuged to the periphery of the drum.

It is suitable for the (relatively slow) speed of rotation to be such that the mixture and its separated constituents generally remain in the bottom half of the drum.

The supernatant liquid obtained from the drum is preferably distilled to recover the solvent, which is reused. The residue from this distillation is effectively a crude oil, but one which has been upgraded from the original heavy crude by the removal of the asphalt. In consequence the oil is less viscous and more easily pumpable. Also the sulphur and metals contents of crude oil are usually more concentrated in the asphalt fraction so that removing the asphalt effects a reduction in the sulphur and a substantial reduction in the metal contents of the oil.

When solvent is recovered by distillation and recycled, it is desirable to choose the solvent so that aromatic compounds do not progressively accumulate in the circulating solvent, because any concentrations of these increasingly dissolve asphaltene.

I have found that a suitable solvent is commercial pentane which for example may be obtained by refractionating the condensate from natural gas extraction. This preferred solvent is a cut taken after the removal of propane and most butane. It generally has a boiling range of up to 80$^{o}$C at atmospheric pressure. It is mainly pentane with minor amounts of propane and butane, and also minor amounts of hexane and heptane. It is envisaged that a cut from locally available gas condensate will be used whenever possible.

Thus the proportions of propane, butane, hexane and heptane will depend on the gas condensate qualities available. It has been found by experiment that the yields of precipitated asphalt, resins and polars do not vary greatly so long as the mixture is predominantly pentane. The boiling point of pentane at atmospheric pressure is below that of any aromatic compound. The inclusion of hexane and heptane might improve precipitation of asphaltene, but they will not distil out of the solution at 80°C. They would distil out at a higher temperature, but condensing the solvent from a distillation temperature higher than 80°C may result in a build up of any pentane present in the crude oil. It therefore seems best to utilise pentane as the main solvent constituent.

When the solvent is recovered from the oil solution by distillation, use of a solvent which is predominately pentane, which can be recovered by distillation at a temperature equivalent to around 80°C, enables the solvent to be repeatedly recycled without aromatics progressively accumulating in it. Thus the solvent mixture remains predominantly paraffinic.

It may well be that the level of some aromatics in the recirculating solvent reaches a steady state concentration which is above the level in unused solvent, but nevertheless low enough to be acceptable.

It is highly desirable that the steady state concentration of aromatics in the solvent is not substantially greater than (and preferably is lower than) the concentration of aromatics in the incoming oil.

Use of a modest superatmospheric pressure in the drum, say 5 to 15 psi (0.3 to 0.9 bar) is valuable in that it enables the temperature to be kept sufficiently high that the precipitated asphalt becomes sticky, and agglomerates in the drum. There is a "window" of useful temperatures between a lower level which should be high enough for agglomeration to occur, and a higher level low enough that aromatics do not accumulate in recirculating solvent.

The present invention is particularly conceived for use in the treatment of heavy crude oil from an oil well, in particular extra heavy oils which have been discovered. It might be an aqueous emulsion of heavy crude oil obtained from an enhanced oil recovery operation in which steam is injected into an oil-bearing strata or in which combustion is used to heat up the strata. In these cases the invention is preferably put into practice near one or more oil wells, to give an upgraded oil suitable for pumping. However, the invention could also be used at an oil refinery for treating distillation residues, notably bottoms from an atmospheric or vacuum distillation tower.

Using a solvent deasphalting plant with a decantation drum as above, at a wellhead region is envisaged as requiring moderate capital investment at the wellhead region. It can be operated as a relatively small and simple treatment plant, so that the scale of investment before there is any return on it will be modest compared with previous projects to build complex, large-throughput, upgrading refineries in remote wellhead regions.

It is envisaged that the process will be carried out at or near to the oil well, or a cluster of wells, producing the heavy crude oil. If this is in a remote area it will not be economic to transport the asphalt, and it is a preferred feature of the invention that the separated a solids are pressed into shaped objects, such as briquettes, and burnt as a solid fuel. Pressing the briquettes serves to force out water mixed with the asphalt.

This fuel will have an appreciable sulphur content, but emission of sulphur oxides from combustion is undesirable. To reduce this, lime, magnesium oxide limestone or dolomite is preferably introduced into the decanter drum, at a point spaced from the outlet for the asphalt. This is then intimately mixed into the asphalt. On combustion the lime or magnesium oxide serves to bind the sulphur chemically as sulphate or sulphite in the resultant ash. Preferably lime is used, depending on local availability.

By incorporating lime or magnesium compound, not only sulphur, but also metal impurities such as vanadium or nickel may be bound in the ash, which is also advantageous. Additives to bind impurity metals in the ash may be admixed, along with the sulphur binding compound.

For mixing the lime or magnesium compound into the asphalt it is appropriate for the decanter drum to be provided with a feed screw to discharge into the interior of the drum fairly close to the outlet for asphalt but spaced from it by several screw flights so that the additive mixes with the separated asphalt during the final part of progress up the drum.

It is desirable that the briquettes or other shaped objects are strong enough to contain within them the sulphur fixing reactions during combustion. Prefearbly their green strength is adequate for this but as an optional additional step, the briquettes or other shaped objects may be sintered to improve their strength. It is known that during such a step the sulphur oxidation reactions would at least commence, and produce calcium or magnesium sulphates.

A further aspect of the invention concerns utilistion of separated asphalt. This aspect of the invention provides a process which comprises separating asphalt from a heavy hydrocarbon oil, or emulsion thereof, mixing together coke or coal particles, the asphalt and a solid compound to absorb sulphur on combustion, and subjecting the mixture to conditions such that the asphalt binds and agglomerates the other solids, thereby producing a combustible product, burning the combustible product, and utilising the resulting heat in a plant or process producing the heavy hydrocarbon feed.

It is strongly preferred that the resulting mixture is pressed or formed into shaped objects such as briquettes with sufficient strength to contain sulphur fixing reactions in the briquettes during combustion. In this way the solid fuel and/or the binder can import substantial sulphur into the briquettes, and yet they can be burned in conventional solid fuel boilers.

One particular use of such a process would be as a means of utilising high sulphur petroleum coke which is almost a waste product, using ashalt from vacuum resid, which is a low value material.

The invention can be expected to provide a cheaper process than the current technology for burning such materials. The present practice is to blend fuels and thus meet emission standards. A process currently envisaged is to treat stack gases to absorb sulphur dioxide, and in this way meet emission standards. A solid fuel prepared in accordance with this invention can also meet emission standards, but is more economical.

A valuable use of this aspect of the invention is to integrate it with oil production by a so-called Enhanced Oil Recovery method in which steam is injected into an oil-bearing strata or in which combustion is used to heat up the strata. In these cases the invention is preferably put into practice near one or more oil wells, so that deasphalting gives an upgraded oil suitable for pumping.

If deasphalting is employed in an oil producing area for the upgrading of heavy oil produced by Enhaced Oil Recovery operations (EOR) the admixture of coke or coal to the asphalt, and burning it as fuel, can be of great value to the overall economics of the oil extraction and processing operations.

In California and Venezuela the energy for the Enhanced Oil Recovery is predominantly provided by burning 20 to 30% of the heavy oil produced from the oil fields.

Deasphalting with pentane and a decanter drum as above would on average remove 15% of solid asphalt which would be burned to provide energy for the deasphalting and oil extraction processes. By adding coke or coal to the asphalt, a greater quantity of energy can be obtained at the combustion stage. The balance of energy required for the producing and treatment operations can be made up by this addition of coke or coal. Thus energy at present derived by burning the oil produced, is replaced, and doing so achieves a notable financial saving because the added coke or coal are considerably cheaper than the crude oil.

As an example: assume that 25% of heavy oil from an oil field is currently burnt as the energy source for an Enhanced Oil Recovery operation.

Deasphalting the oil will precipitate around 15% by weight. This is mixed with high sulphur coke or coal and briquetted. By adopting an asphalt: solid fuel ratio of 60:40 the briquettes will produce about as much energy as the 25% of the heavy oil which is burned at present.

However, the heavy oil has a value of about 120 to 140 US dollars per ton, whereas coal or coke could be provided for about 30 US dollars per ton.

The combustion would also be required to provide the energy required to run the solvent deasphalting process, so slightly more coke or coal would be needed. Nevertheless there is still a substantial economy, all the more so as the deasphalting also upgrades the oil.

The deasphalting step is preferably accomplished by the process and deasphalting decanter drum of this invention. However, it could be carried out using an older deasphalting process.

For mixing the asphalt, coal or coke, and sulphur absorbing compound, one suitable procedure is to coat the coal or coke with the asphalt by tumbling or mixing at moderately elevated temperatures, and thereafter mixing the coated and soft particles with lime in the form of limestone, or with magnesium carbonate, as the sulphur absorbing compound.

Mixing can be performed in the decanter drum of this invention, or another drum with an internal screw to convey particles along the length of the drum while its rotation serves to tumble them.

It is desirable for the coke or coal, and the sulphur absorber to be prepared so as to have similar particle sizes to the asphalt. This facilitates solids mixing. Both added solids may be delivered axially through the drum ends to appropriate points along the length of the drum. Another possibility for mixing the materials is that the coal or coke and the limestone or other sulphur absorbing compound are introduced together into the drum by means of a common feed screw.

The ratio of coke/coal to asphalt may be as high as 9 to 1, with the sulphur absorbing compound added in at least the stoichiometric quantity to bind the sulphur. Preferably an excess is used. The total amount may be 1.2 to 1.5 times the stoichiometric amount.

The drum will probably need to be heated to render the asphalt (or other hydrocarbon material) sticky and able to function as binder. This may be accomplished by injecting steam into the decanter drum of this invention.

In consequence the solid fuel particles, binder, and sulphur binding compound will agglomerate in the presence of water condensed from the steam. This water can be pressed out in the preferred subsequent step of forming the material into shaped objects e.g. briquetting.

As mentioned above, it is preferred that the shaped objects have sufficient strength while "green" (that is to say before any sintering or other heat treatment) to contain the sulphur fixing reactions within the shaped objects.

Solid asphalt is advantageous as a binder, because it does not carry into the agglomerated solids volatile constituents which need to be removed before combustion. During subsequent burning it is preferable that the solid matrix burns as a whole (glowing like coke) rather than that volatiles present should combust first in an intense flame while the remainder of the solid burns at a considerably slower rate.

The asphalt will not be sticky at room temperature, and may even be fairly finely divided, like sand or powder, but nevertheless will still have useful binding properties because it melts and softens at higher temperatures such as in the range of 120-160°C. Thus materials of similar volatility are mixed and this is beneficial to maintenance of flame stability.

An embodiment of this invention will now be described as an example serving to provide further explanation, and with reference to the accompanying drawings in which:

Fig. 1 shows a vertical, axial section through a decanter drum embodying the first aspect of this invention and used in the treatment of a heavy crude oil emulsion.

Fig. 2 is a radial section, showing part of a flight and illustrating a possible modification;

Fig. 3 is a diagram of a process plant for treatment of a heavy crude oil emulsion, incorporating the drum of Fig. 1; and

Fig. 4 shows a modification.

At the start of the process illustrated by the drawings a crude oil/water emulsion is treated with a light hydrocarbon solvent. The resulting mixture comprises water, a solution in the hydrocarbon solvent, and precipitated solids. This is separated in the apparatus of Fig. 1, which will now be described, after which the process will be described in greater detail.

Referring first to Fig. 1 the agglomerator has a cylindrical drum 10 mounted on an inclined axis around a central axial pipe mandrel formed by pipes 12, 14 joined at a blanking flange 16 which prevents communication between them. The pipes 12,14 are fixed, but the drum is rotated by a drive motor 11. The axis of the drum is inclined at an angle to the horizontal which will be mentioned again below.

The pipe 12 at the lower end is surrounded by a coaxial pipe section 18. The lower end of the drum is closed by an end plate 20 rotatable with the drum. A thrust bearing 22 and a stuffing box 24 are interposed between the end plate 20 and the pipe section 18.

The upper end of the drum is closed by a fixed end plate 26. An annular plate 28 around the upper end portion of the drum is secured to the plate 26. These plates 26,28 support between them at least three bearing rollers 30 on which the drum rotates. A groove 31 in plate 26 receives the end of the drum in a labyrinth seal. A stuffing box 32 is interposed between the plate 28 and the drum.

By virtue of the seals provided by these stuffing boxes 24,32, a moderate superatmospheric pressure of say 5-10 or 10-15 psig (0.3-0.6 or 0.6-0.9 bar) can be retained in the drum, with the space 34 between the plates 26,28 pressurised to the drum pressure. The mandrel pipe can be employed to hold the assembly together in the axial direction against the superatmospheric pressure in the drum. More specifically, the upper pipe 14 is surrounded by non-rotating coaxial pipe sections 50,54 fast with it. The plate 26 is fast with the pipe section 54, and hence with the pipe 14 joined to the pipe 12. There is thus a mechanical connection, through the pipe mandrel, between the end plate 26 and the thrust bearing 22, to retain the end plate 26 against the superatmospheric pressure.

Inside the drum 10, welded to its inside wall, is an inwardly-projecting helical screw 36 akin to an Archimedes screw. The flights of this screw 36 extend inwardly without any aperture to an inner edge 38 which in use acts as a weir over which liquid flows. As can be seen from Fig. 1 the radial distance from the wall of the drum to the inner edge 38 of the flights decreases up the drum. Because of the inclination of the drum the overflow level defined by each flight is nevertheless higher than the overflow level defined by the adjacent flight towards the liquid discharge end. Consequently, overflow is always down towards the lower end despite the flights reducing radial extent towards the upper end. The effect of this reducing radial extent is that the volume trapped between successive flights also reduces progressively towards the upper end, even though the pitch of the helix remains constant.

The mixture of liquid and entrained solid precipitate is fed in at 11 via the central pipe 12, emerges through the outlet slots 40 and falls into the spaces between successive screw flights. The drum is rotated slowly so that the screw 36 carries the solid up the incline towards the upper end of the drum. Because the volume retained between the flights reduces, the supernatant solvent solution is decanted over the inner edge 38 of the flights and flows downwards. Meanwhile the heavier solid particles settle into the emulsion water (and any added water)within the volumes between flights and the solids and water are preferentially carried upwards by the screw 36.

Separated supernatant solution is drawn out along the pipe section 18, from which a syphon tube 42 dips into the space below the bottom end of the screw 36. An outlet 44 for the denser precipitated asphalt and water is provided in the fixed end plate 26.

With entirely unapertured flights, overflow is over the inner edge 38, and it is solution from the top of the volume between flights which overflows. Conceivably the overflow level could be defined by apertures in the flights, outwardly from their inner edge but spaced from the wall of the drum. A further possibility is shown at the right hand side of Fig. 2. Cut outs 46 give a castellated form to the inner circumferential edge of the flights. The overflow level is at the outer level 47 of the cut-outs. This arrangement increases the rate of decantation over the flights.

The progressive diminution of the volume between flights is preferably matched to the proportions of supernatant solution and solids and water, to achieve the desired separation. Obviously the space between the flights at the upper end must be adequate to accomodate the volume of solids and some water which they are required to convey. Preferably it is arranged to accommodate all the water so that the water is discharged with the solids.

Where the solids and water make up somewhere around 50% of the volume of the emulsion, it is found appropriate to make the volume between successive flights up to the overflow level 3 to 5 times as much at the liquid outlet end as at the solid outlet end.

So far described is the basic function of separation by settling and decantation, which occurs in the lower part of the drum up to a little above the mixture inlet.

The temperature is governed by the temperature of the incoming mixture, and the extent to which heat is conducted to this part of the drum from the latter part above. The temperature is arranged to be below 80°C but sufficiently elevated that the asphalt particles are somewhat sticky. Because of this the solid particles agglomerate into larger particles which settle faster and hence separate more easily.

Some crude oils give precipitates which settle out quickly anyway and hence separate easily. Others give precipitates with a lot of fines which do not settle quickly and hence are more difficult to separate. These tend to be retained in the lower part of the drum, below the inlet. However, because they agglomerate these too can be separated. Oils which produce fines in the precipitate may necessitate a longer drum, because the separation is slower. Nevertheless because of the agglomerating action the invention can handle substantially any heavy crude oils.

The apparatus shown in Fig. 1 has a number of additional features. The upper central pipe 14 serves for removal of vapour evaporated from the separated asphalt. The vapour enters the pipe through slots 48. This pipe 14 is surrounded for part of its length by a coaxial solvent duct 50 terminating in spray nozzles 52. Additional light hydrocarbon solvent is delivered through this duct and the nozzles 52 onto the largely separated solid particles which at this stage may well have an appearance rather like wet ground coal, tumbling over as it is lifted up at the rising side of the drum as sketched at 53 at the left hand side of Fig 2.

This solvent washes these particles dissolving remaining solubles from the crude oil, and is decanted off down towards the lower end of the drum, mixing with the other supernatant solution.

Next the largely separated solid particles are sprayed with low pressure steam introduced along a duct 54 leading to nozzles 56. This steam evaporates remaining solvent from the particles, so that it is not wasted. The evaporated solvent is drawn off via pipe 14, as mentioned.

In this part of the drum the temperature rises to above 80°C because of the steam injection.

Because the asphalt particles become somewhat sticky at this temperature they may stick to the flights or the drum wall and be carried round without tumbling in the liquid present. To dislodge such particles the solvent spray nozzles 52 and/or the steam nozzles 56 may be preferably directed against the rising wall of the drum above the overflow level and onto the tumbling solids as shown in Fig. 2. The solvent and/or steam may even be led out towards the wall through radial pipes.

In the upper part of the drum 10 the temperature falls back below 80°C. Here, a feed screw 59 in a tube 58, projecting through the end plate 26, acts to convey

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solids from a pressurised hopper 60. The screw 59 discharges into the interior of the drum, at a region proximate but spaced from the upper end. The solids which are introduced in this way are limestone (or magnesium carbonate rock such as dolomite) and high sulphur coal or coke. They are milled, and the resulting finely divided solids are charged to the hopper 60. The added solids intimately mix with the separated solid asphalt particles, and they are discharged together, through the outlet 44, along with the water settling between the flights.

It will be appreciated that there are a succession of zones within the drum, where different functions are performed. The lower zone 61 is principally where asphalt separates from the solution of heavy oil. Evaporated vapour is taken from the top of this zone. Zone 62 is where the precipiated asphalt is washed with extra solvent. Zone 63 is where it is treated with steam, driving off solvent, and softening the asphalt. Zone 64 is where extra solids are admixed.

The hopper 60 and tube 58 are pressurised to the pressure in the drum 10, and the hopper must therefore be provided with appropriate pressure locks for loading it.

Magnesium oxide could be substituted for lime if more conveniently available. Although the lime or magnesium oxide is principally employed to bind sulphur on subsequent combustion, it also helps to remove any clay originating from the oil emulsion and which remains suspended in the water.

As is diagrammatically indicated in Fig. 3, the outlet 44 in the fixed end plate 26 is connected by a pressure-tight connection to a hopper 65 of a briquetting press 66. The hopper 65 and the connection are pressurised to the pressure in the drum 10. The press 66 forms the discharge solids into briquettes, and the water is squeezed out and discharged at 67. The briquettes are burnt as fuel for the boiler at 68 serving for example to generate energy for the Enhanced Oil Recovery and for the process. The sulphur forms calcium sulphate and/or sulphite in the presence of the lime. The briquettes have sufficient strength to retain the sulphur and metals oxidation reactions within the briquettes during their combustion. There are indications that vanadium pentoxide formation during combustion is inhibited because of the solid matrix of the briquettes. The vanadium is retained in the ash, as glassy vanadates.

The liquid circuits of the process are illustrated by Fig. 3. Incoming feed from the wellhead, consisting of an aqueous crude oil emulsion, is pumped along line 69 to a mixer 70 where it is mixed with the light hydrocarbon solvent, preheated in a preheater 72 heated by steam 73. Crude oil emulsions usually reach the wellhead at a temperature in the 80°C-150°C range. The desired mixing temperature for the introduction of solvent in the mixer 70 is in the range of 100°C-200°C as at these temperatures the heavy oil or bitumen viscosities will range from 40-800 centipoise depending on the viscosity of the feed crude. I have found mixing to be rapid at these conditions and only moderate agitation is required. The mixture produced in mixer 70 is fed at its equilibrium pressure along line 74 to a heat exchanger 76 where it is cooled and then it flows along line 78 where the pressure is reduced, to 5-15 psig (0.3-0.9 bar). Line 78 leads to the inlet pipe 12 of the drum 10.

Solution drawn off via the pipe section 18 is pumped along line 80 to the heat exchanger 76 where it is heated somewhat. It then flows into a distillation column 82 operating at about 80°C.

The bottoms in this column are a deasphalted oil. A portion is reboiled in the steam reboiler 83 and returned to the column. The main external source of heat to the column 82 is furnished by the preheater 72. Reboiler 83 is employed to provide any balance quantities of heat. Its steam supply is indicated 84. Liquid deasphalted oil passes via line 85 to water knock out drum 86 from which the deasphalted oil product is obtained, delivered along line 87.

Solvent vapour, containing some water vapour, is drawn off from the drum along pipe 14 as mentioned. This vapour is delivered along line 88 to condensor 90. The condensate is pumped to a water knockout drum 91 provided with a vent 92. From there it is recycled to the process by pump 93 which impels it to the preheater 72 and hence to the mixer 70.

Distilled solvent vapour from the column 82 is condensed at 94, and split into two streams. Both are recycled into the process. One is supplied along line 95 to the duct 50 and so is supplied as washing solvent into the drum 10. The other stream is fed along line 96 to pump 97, and hence to join the solvent flow to the preheater 72.

Steam 73,84 for the preheater 72 and the reboiler 83 comes from the boiler 68. This also provides energy for the enhanced oil recovery, as mentioned.

The above described process achieves the following results:-

The emulsion is broken and no de-emulsifying plant is needed;

A higher API much less viscous crude has been made;

The deasphalted crude has about 80% less metals content;

The deasphalted crude usually has about 30% less sulphur content than the heavy oil feed;

The deasphalted crude is desalted and dewatered;

The deasphalted crude is more suitable for refinery operations not only because of the partial upgrading effected but also because it will produce less bottoms;

Upgrading at the refinery through hydrotreating, thermal and other cracking operations should also be easier.

Notable features of the process are that:-

The solvent recovery is facilitated by utilising oilfield waste heat;

The solvent recovery at about 80°C does not condense any aromatics from the heavy oil into the solvent;

Solvent is stripped by low pressure steam both from the deasphalted oil and from the solid asphalts.

It is foreseen that the process of Fig. 3 which achieves partial upgrading by the separation of the asphalts enhances the economics of production because of the following considerations:

Coal and asphalt rather than produced heavy oil, provide the energy for Enhanced Oil Recovery;

Neither diluent mix into the oil for pumping, nor heating of pipelines will be required for medium heavy oil 15-20$^{o}$API instead the deasphalted oil is pumpable in accordance with pipeline practice for viscosity limitations;

For extra heavy oil less than 15$^{o}$API or for bitumen less than 10$^{o}$API the deasphalted oil viscosity is reduced, and for example for a 10$^{o}$API incoming material the product viscosity range was found to be 400-600 centistokes at 100$^{o}$F (38$^{o}$C): it is a more suitable feed to simple thermal cracking such as hydrovisbreaking because of the viscosity reduction. It is generally recognised that upgrading of extra heavy oil to pumpable form will require two processes in sequence: the present invention is simpler than alternative processes suggested for one of the sequential steps;

The asphalts can be burnt in fairly conventional solid fuel boilers in an environmentally safe manner;

The separation plant is relatively simple equipment suitable for installation and operation in the oilfield on a small scale matching the drilling and commissioning of wells so that cash flow from the investment in wells becomes available as soon as any cluster of wells is put in production;

The investment for the separation plant is less than one sixth of investment required for complete upgrading;

The deasphalted oil may be a preferable feed to many of the available hydrocracking processes.

A process very similar to Fig. 3 could be employed if the feed from the wellhead was crude oil as such rather than as an aqueous emulsion. Yet again a similar process could be applied to bottoms from a refinery distillation tower, although then it may or may not be desired to sell at least part of the asphalt rather than burning it with or without added coke or coal for process heat.

Atmospheric and vacuum residues become available from their columns in refineries at temperatures from 350°C-550°C. Thus for atmospheric or vacuum residues almost no additional heat is required for the process, whereas for crude oil emulsions heat has to be added by heating up the incoming solvent. In order to promote settling in the decanter drum, condensate can be added in lieu of steam when atmospheric or vacuum residues are being processed.

The improved economics of an Enhanced Oil Recovery operation are demonstrated by the following Example.

It is assumed that a cluster of wells produces 1000 barrels per day of 15°API heavy emulsion with 35% water.

Energy for Enhanced Oil Recovery(EOR) is derived by the burning of 25% of the gross production from the wells. Such a feed emulsion contains 8547 Kg/hr oil and 4602 Kg/hr water. The quantity of oil burnt for EOR is 2137 Kg/hr leaving 6410Kg/hr as product.

An equivalent cluster of wells with the same gross production feeds a deasphalting process, with addition of coal and limestone, as described above. The solvent ratio is 4:1. It is assumed that 15% asphalt (1282 Kg/hr) is separated and burnt with the coal and limestone. One Kg of heavy oil is thermally equivalent to 1.3 Kg of coal. Accordingly the asphalt plus 1112 Kg/hr of coal will give the same heat as the 2137 Kg/hr of heavy oil.

Thermal balance calculations indicate that 0.85 Kg of steam are needed for solvent recycle per Kg of incoming oil. Assuming that coal is burnt to generate low pressure steam with 75% burning efficiency, it can be calculated that 702 Kg/hr coal will be required for steam to effect solvent recycle, hence setting the total of added coal at 1814 Kg/hr.

It is assumed that the asphalt has a sulphur content of 7% and that the coal has a sulphur content of 3%. 1.3 times the stoichiometric quantity of limestone is 586 Kg/hr.

It is further assumed that the deasphalted oil(DEA) product and the asphalt retain solvent amounting to 1% of their own weight. With an assumed leakage of 100 Kg/hr the quantity of make up solvent is 186 Kg/hr.

The various quantities are summarised in the following table:

| | | Conventional | Solvent-Deasphalting | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Feed to Briquetting | | | Solvent Flows | | |
| | Feed Emulsion | Product after<br>Product after burning 25% for EOR | DEA Product | Asphalt | Added Coal & Limest. | Decanted Solution Feed to Column | Return from Asphalt | Return from Column | Make up |
| Oil | 8547 | 6410 | 7265 | | | 7265 | | | |
| Asphalt | | | | 1282 | | | | | |
| Coal | | | | | 1814 | | | | |
| Limestone | | | | | 586 | | | | |
| Water | 4602 | | | 4602 | | | | | |
| Solvent | | | 73 | 13 | | 33947 | 128 | 33847 | 186 |
| Total | 13149 | 6410 | 7338 | 5897 | 2400 | 41212 | 128 | 33847 | 186 |

All quantities above are in Kg/hr

Revenue Improvement per Year

On 6410 Kg/hr DEA in lieu of Heavy Oil

DEA value $ 22/Barrel at 6.8 Barrels/MT

Heavy Oil Value $ 20/Barrel

For 330 operating days per year

$$\text{DEA Improved Value} = 6410 \times \frac{24 \times 6.8}{100} (22-20) \times 330$$

$$= \underline{\underline{\$690,434}}$$

On added yield 7338-6410 = 928 Kg/hr

$$\text{Added Yield} = 928 \times \frac{24 \times 6.8}{100} \times 22 \times 330$$

$$= \underline{\underline{\$1,099,524}}$$

Less cost of added coal, price taken as \$35/MT

$$\text{Added Coal} = \frac{1814}{1000} \times 24 \times 35 \times 330$$

$$= \underline{\underline{\$502,840}}$$

Less cost of limestone, price taken as \$20/MT

$$\text{Added Limestone} = \frac{586}{1000} \times 24 \times 20 \times 330$$

$$= \underline{\underline{\$92,822}}$$

Less cost of solvent make up, Sp. Gr. taken as 0.68 and price \$190/$M^3$

$$\text{Solvent Make up} = \frac{186}{0.68 \times 1000} \times 24 \times \frac{190}{1000} \times 330$$

$$= \underline{\underline{\$411,607}}$$

$$\text{Total Added Revenue} = \underline{\underline{\$782,689}}$$

It is envisaged that the variable costs of labour etc will be the same as those which are already required for EOR and Deemulsification.

The investment required for plant is envisaged as being in the order of 1 million dollars. Thus there is an improvement in revenue of over 3/4 million per year for an investment of 1 million.

Fig. 4 shows a modification. Solids are not delivered into the drum of Fig. 1. Instead the precipitated asphalt is discharged from the outlet 44, and then delivered, with coal or coke milled at 102, and limestone or dolomite milled at 104, to a second drum which is basically akin to the solvent deasphalting drum described above. It is a drum 110 with an internal screw 112 which conveys the solids along. The drum is rotated relatively slowly, at 25 rpm or less, by motor 113 so that the drum tumbles the solid particles but does not centrifuge them to the periphery. The solids are introduced along a central pipe 114 around which the drum revolves. This pipe leads to an opening 115 to the drum interior and may contain a feed auger. Steam is introduced along a coaxial pipe 116. Discharge is through an aperture 117 in one end 118 which does not revolve.

At this end the drum is supported by rollers 120, while at the other end a bearing 122 is provided.

The mixture agglomerates into larger particles in this drum, and on discharge is fed to a briquetting press 68 as before.

CLAIMS:

1. A process which comprises mixing a heavy hydrocarbon feed which is heavy hydrocarbon oil or an emulsion thereof with a lighter hydrocarbon solvent to precipitate solid asphalt, separating the solid asphalt from the supernatant liquid,

mixing together coke or coal particles, the asphalt and a solid compound to absorb sulphur on combustion, and subjecting the mixture to conditions such that the asphalt binds and agglomerates the other solids, thereby producing a combustible product,

burning the combustible product, and utilising the resulting heat in a plant or process producing the heavy hydrocarbon feed.

2. A process according to claim 1 wherein the mixed asphalt and other solids are pressed into shaped objects for burning.

3. A process according to claim 1 or claim 2 wherein the heavy hydrocarbon feed is of heavy crude oil or an emulsion thereof obtained from an enhanced oil recovery operation in which steam only or combustion heat is applied to an oil-

bearing strata, the said burning of the said combustible product being used to generate the steam or provide the heat applied to the strata.

4. A process according to any one of claims 1 to 3 in which the said hydrocarbon solvent contains a major proportion of pentane.

5. A petroleum treatment plant for separating asphalt from heavy hydrocarbon oil or emulsion thereof characterised in that the plant includes decantation apparatus comprising:

a drum provided with at least one inlet for the oil or emulsion and a lighter hydrocarbon solvent, which inlet(s) deliver to the drum interior intermediately between the ends of the drum, an outlet for supernatant liquid at one axial end of the drum and an outlet for precipitated asphalt at the axially opposite end of the drum,

a helical screw fast with the interior of the drum, the flights of which project radially inwardly from the wall of the drum and extend without aperture to an overflow level spaced from the drum wall,

means mounting the drum for rotation, the shape and orientation of the drum and the overflow levels of the screw flights being arranged such that supernatant liquid overflow over the flights is towards the liquid outlet end, the screw flights being arranged such that the volumes contained between successive flights generally decrease towards the asphalt outlet end of the drum, and

drive means for rotating the drum so as to convey material between the flights towards the asphalt outlet, so that solid asphalt which separates from the hydrocabon liquid within the drum is discharged from the outlet therefor.

6. A treatment plant according to claim 5 wherein the drum is a right cylinder, mounted on an inclined axis.

7. A treatment plant according to claim 5 or claim 6 wherein the said screw has a uniform pitch, and the radial distance from the drum wall to the said overflow levels of the screw flights progressively decreases from the supernatant liquid outlet end to the asphalt outlet end.

8. A treatment plant according to any one of claims 5 to 7 wherein further comprising a briquetting press, arranged to receive solid discharged from the said asphalt outlet of the drum.

9. A treatment plant according to any one of the preceding claims wherein the drum interior contains, in order from the

said inlet for the oil or emulsion, an opening leading into a vapour outlet duct, thereafter at least one opening for the inlet of washing solvent and thereafter at least one inlet for the admission of steam, arranged in succession in the direction towards the asphalt outlet end of the drum.

10. A process according to any one of claims 1 to 4, wherein separation of the asphalt is carried out by means of decantation apparatus as set forth in any of claims 5 to 9.

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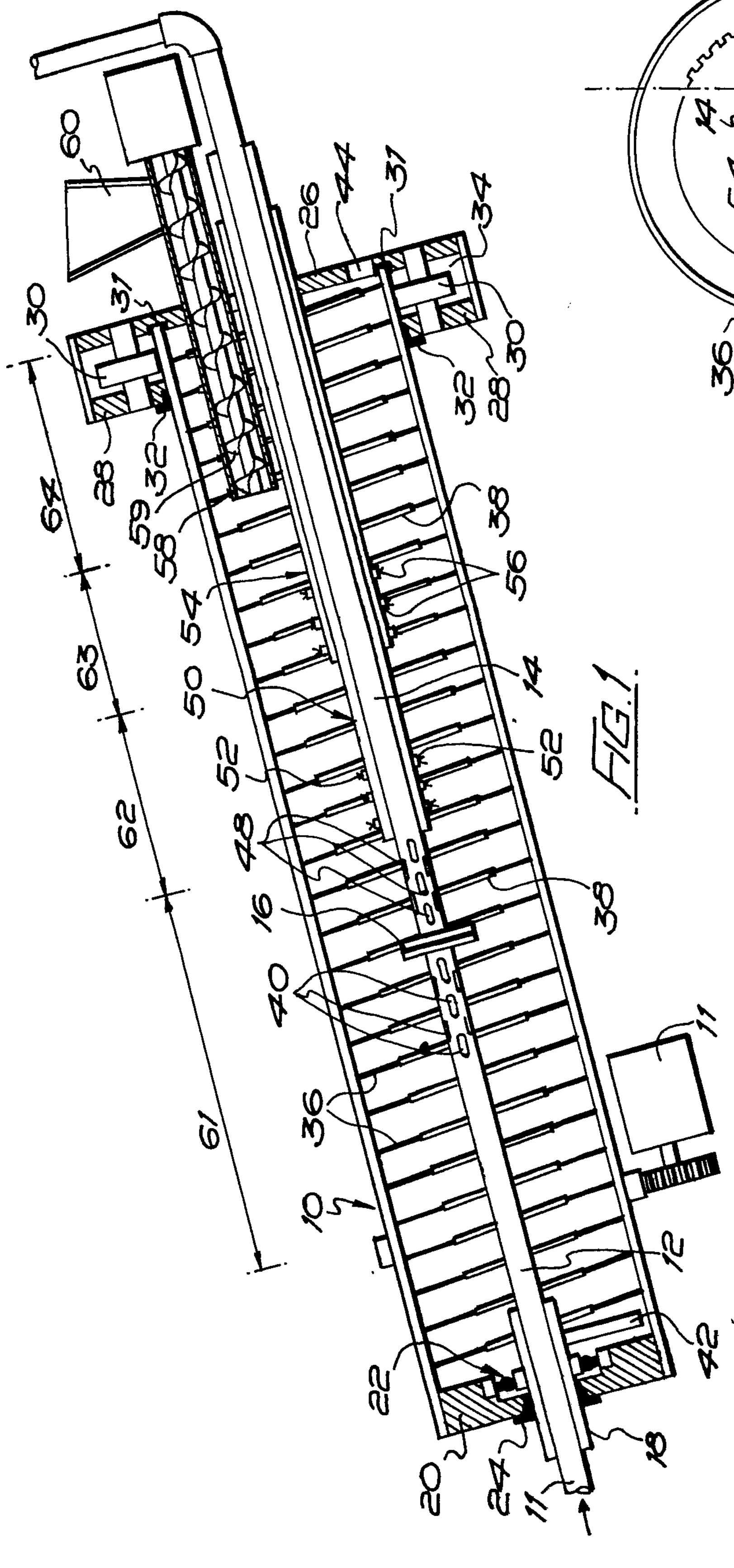

FIG.1

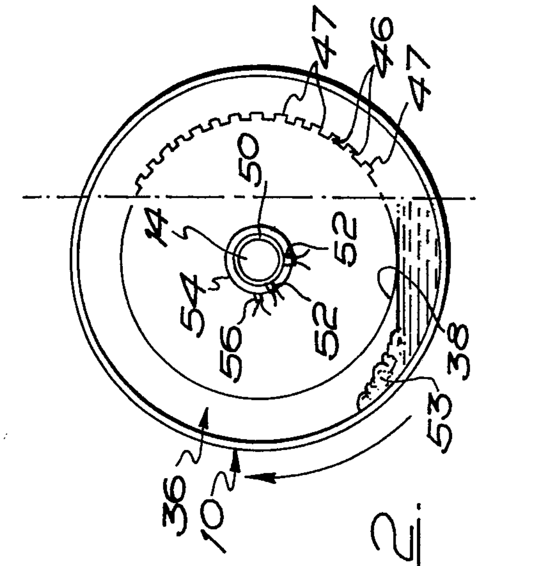

FIG.2

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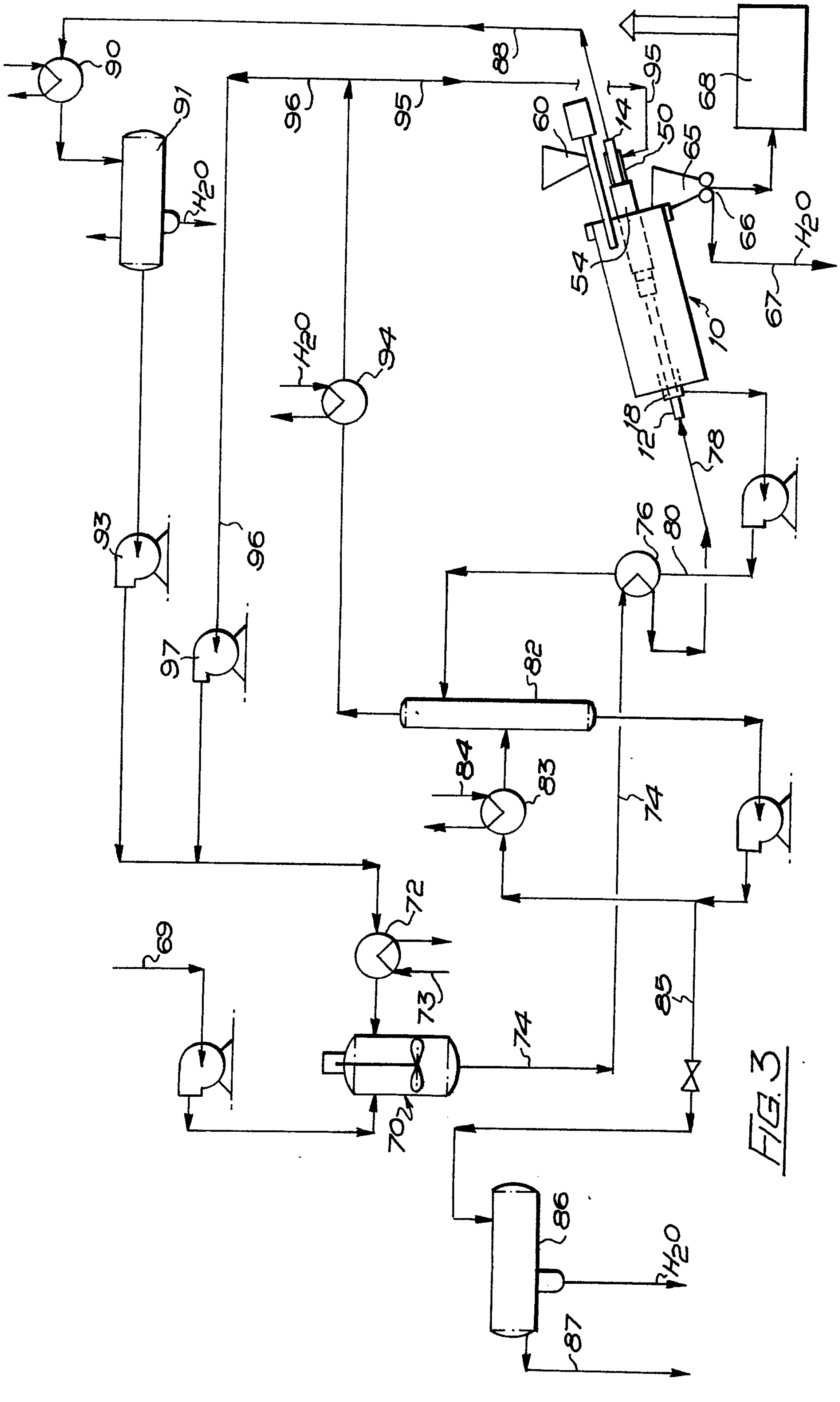


FIG. 3

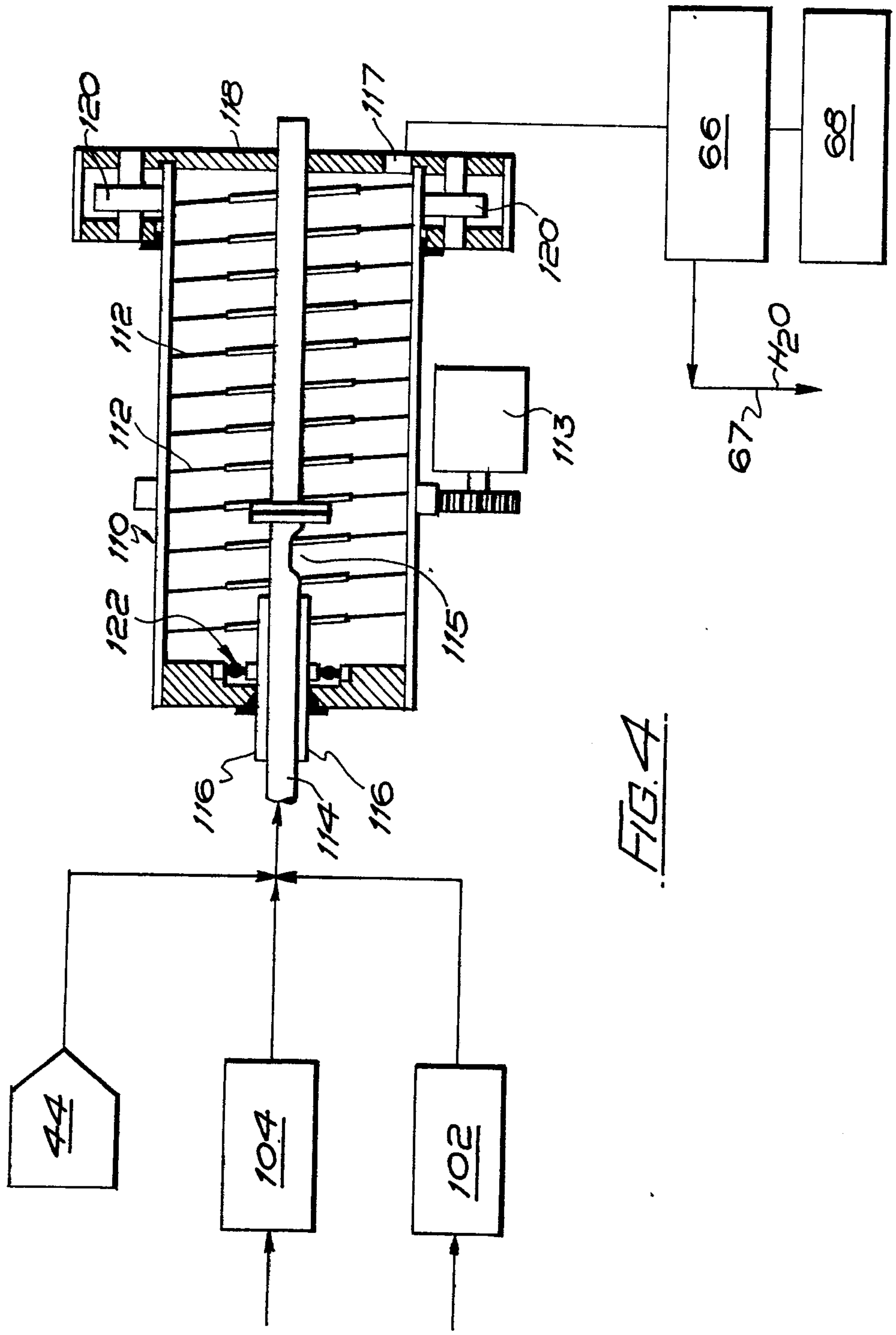
120
118
117
120
112
112
110
122
115
116
114
116
113
66
68
$H_2O$
67
44
104
102

FIG. 4