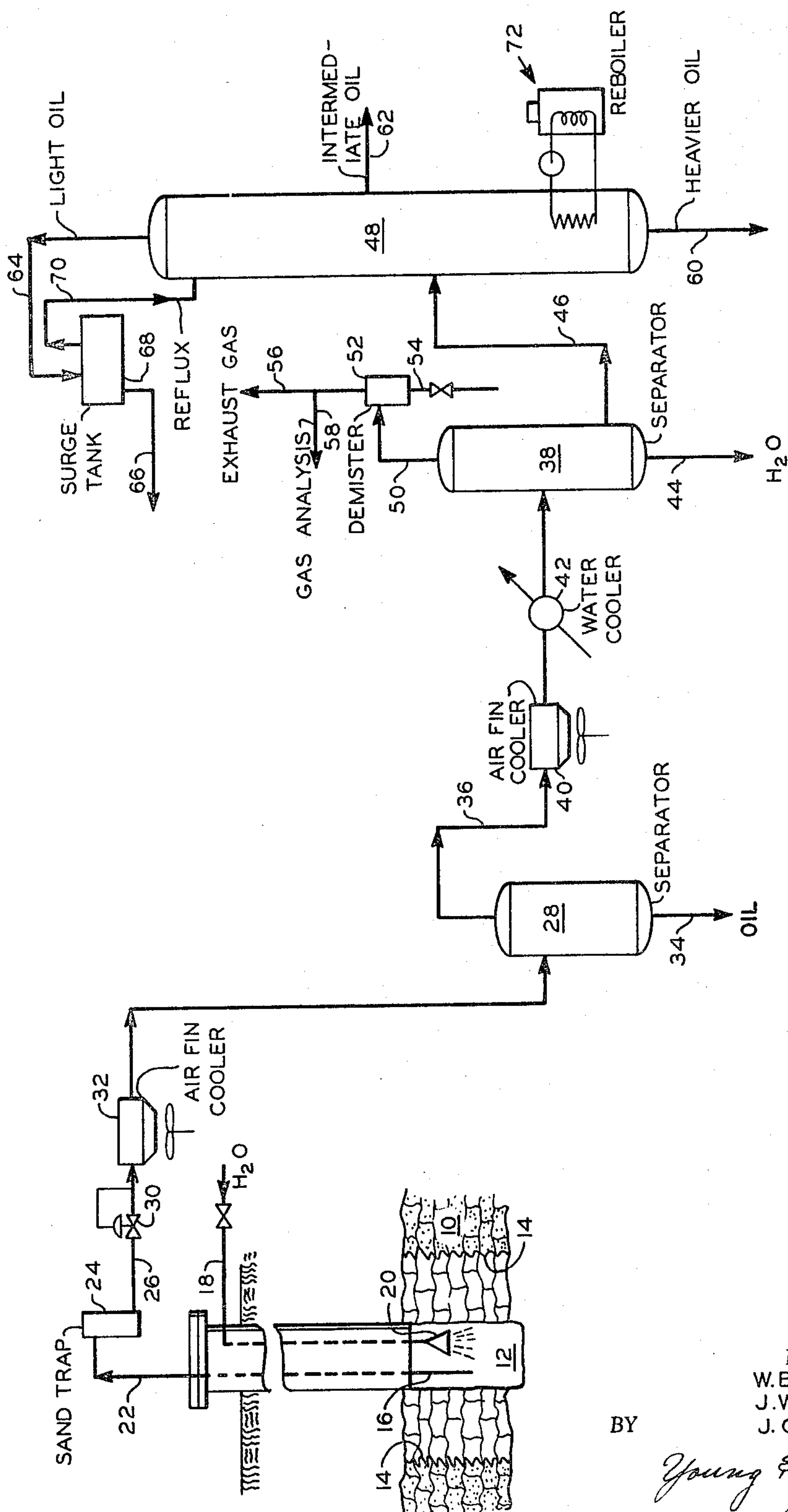


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PROCESS AND APPARATUS FOR COMBINATION UPGRADING
OF OIL IN SITU AND REFINING THEREOF
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PROCESS AND APPARATUS FOR COMBINATION UPGRADING OF OIL IN SITU AND REFINING THEREOF

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This invention relates to a process for producing oil by in situ combustion to upgrade the oil and refining the upgraded oil in the field near the well head.

Low gravity crude oil is particularly difficult to produce even though the pressure in the stratum containing the oil is substantial. In one well known sand bearing a heavy high viscosity crude having an API gravity of 8.5°, the primary recovery is limited to about 2 or 3 percent of the in-place oil even though the static reservoir pressure is 1400 p.s.i. This leaves most of the oil in the stratum to be recovered by secondary production methods. It has been found that this 8.5° API gravity oil can be produced by reverse in situ combustion so as to upgrade the oil to about 26 to 27° API gravity as it leaves the well head.

The invention is concerned with a process for producing and upgrading a heavy oil in situ and recovering various fractions of the upgraded oil from the water-containing effluent from the well head.

Accordingly, an object of this invention is to provide a combination process for upgrading a heavy oil in situ and refining the upgraded oil. Another object is to provide a process for refining an upgraded oil produced by in situ combustion and containing substantial concentrations of water while avoiding the formation of heavy oil-water or water-oil emulsions. A further object is to provide a refining process for recovering various oil fractions from upgraded crude oil produced by in situ combustion and containing large concentrations of water. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises producing an upgraded oil from a heavy oil-bearing stratum by in situ combustion whereby the upgraded hot effluent contains substantial concentrations of water and is at an elevated pressure, passing the vaporous effluent from the well head of the production well thru a pressure reducing valve to substantially reduce the pressure thereof and cooling the resulting vapor stream to a temperature not substantially above 500° F. to recover a liquid heavy oil fraction and a separate vapor stream comprising oils boiling above about 500° F. and water. The foregoing procedure comprising cooling the in situ combustion effluent to a temperature of not more than 500° F. and, preferably, at about 500° F., has the effect of preventing the formation of very refractory water-oil emulsions which are a serious problem when the heavy cut and the water are condensed together. The heavy cut is separately recovered at about 500° F. and the water in the well effluent remains in vapor form and is passed along with the lower boiling hydrocarbons to a second cooling step to cool same to a temperature substantially below the boiling point of the water in the vaporous stream and, preferably, to about 100° F. The cooled stream comprising liquid hydrocarbons and water as well as vaporous hydrocarbons is separated into water, liquid oil, and light hydrocarbon gases. The liquid oil fraction is then passed to a conventional fractionator to separate the same into several cuts of different boiling ranges.

One method of upgrading the high gravity crude oil is disclosed in the copending application of J. C. Trantham and J. W. Marx, S.N. 383,285, filed July 17, 1964, now

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U.S. Patent No. 3,232,345. However, the invention is applicable to the production of oil produced by any forward or reverse drive in situ combustion process. In a direct or forward drive process the temperature of the produced effluent is not sufficiently high for application of the invention until the fire front approaches or passes the production well. Since the combustion zone moves in a reverse direction to the flow of air in a reverse burning process and the products from the combustion zone pass thru burned over hot sand behind the combustion front on the way to the production well, the effluent from the reverse burning process is usually above 1000° F. Due to the fact that some oxygen from the injected air bypasses the hot combustion zone and appears in the production well, well bore fires destroy substantial quantities of the produced oil and damage well equipment unless precautions are taken. The injection of water or other fluid coolant into the production well adjacent the producing zone to reduce the effluent temperature to the range of 500-800° F. is practiced. This results in incorporating in the upgraded oil a substantial quantity of water in addition to formation or connate water vaporized in the combustion phase of the process and water formed by combustion.

A more complete understanding of the invention may be obtained by reference to the accompanying schematic drawing which is a flow in accordance with a preferred embodiment of the process.

Referring to the drawing, a heavy oil bearing stratum 10 is penetrated by a production well 12. A combustion zone 14 has been moved out from well 12 into the stratum by injection of combustion-supporting gas thru one or more offset injection wells. The produced effluent is recovered thru tubing string 16 and water injected from line 18 thru spray head 20 in sufficient quantity to reduce the temperature of the hot effluent to the range of about 500-800° F.

The hot effluent under substantial pressure in the range of about 500-2000 p.s.i.g. and at a temperature in the range of 500-800° F. is passed thru line 22 to a sand trap 24 for removal of any sand contained in the produced effluent. The sand-free effluent is passed thru line 26 to a liquid-gas separator 28. An expansion valve 30 substantially reduces the pressure of the effluent to the range of about 250-400 p.s.i.g. and, preferably, to about 300 p.s.i.g. Expanded effluent is cooled in a suitable cooler, preferably, an air fin type cooler 32 to reduce the temperature to not more than about 500° F. so that the oil in the vaporous stream boiling above this temperature is condensed and is recovered from separator 28 thru line 34. The uncondensed vapors including water and lower boiling hydrocarbons are passed overhead thru line 36 to a second gas-liquid separator 38. Air fin cooler 40 in line 36 economically reduces the temperature of the vaporous stream therein substantially and water cooler 42 further reduces the temperature to substantially below the boiling point of water at ambient pressure, such as about 100° F. This condenses most of the water and the hydrocarbon fraction of the effluent boiling above 100° F. In separator 38 water and oil are separated by phase separation in the lower section thereof and water is withdrawn thru line 44 while the oil fraction is withdrawn thru line 46 and passed to fractionating tower 48. The overhead gaseous stream from separator 38 is passed thru line 50 and thru a demister 52 from which separated liquid is removed thru line 54 and gaseous material is passed thru line 56 as exhaust gas with gas for analysis being taken off in a side stream thru line 58.

The liquid oil from line 46 is separated into various fractions in fractionator 48 in conventional manner, recovering the heavier oil thru line 60 as a bottoms fraction, the intermediate oil thru line 62 as a side cut, and the

light oil fraction overhead thru lines 64 and 66 which connect with a surge tank 68. Reflux is passed from surge tank 68 to the upper section of the fractionator via line 70. Reboiler means 72 for heating the lower section of fractionator 48 is provided.

To illustrate the invention the upgraded oil from stratum 10 is quenched to a temperature in the range of 500-800° F. at a pressure of about 1400 p.s.i.g. About 23 barrels of water per hour and 11 barrels of oil per hour constitute the hot effluent passing into sand trap 24. Valve 30 is set to control the pressure downstream thereof at about 300 p.s.i.g. Air fin cooler 32 reduces the temperature to about 500° F. when cooling is required to reduce the effluent temperature. The oil fraction boiling above about 500° F. recovered thru line 34 amounts to 5.3 b./hr. The overhead vapor stream is cooled from about 500° F. to about 100° F. when passing thru heat exchangers 40 and 42 with a substantial portion of the cooling being effected in the air fin cooler. This condenses substantially all of the water in the stream passing into separator 38 along with the oil boiling above 100° F. The condensed water is recovered thru line 44 at the rate of about 23 b./hr. and the condensed oil is passed thru line 46 at about 100° F. to fractionator 48. The fractionation in tower 48 is maintained at a pressure of about 50 p.s.i.g. with a reboiler temperature of about 525° F. The heavier oil having a boiling range of 400-500° F. is recovered thru line 60 at the rate of about 2 b./hr. while the intermediate oil fraction having a boiling range of 300-400° F. is recovered thru line 62 at the rate of 1.7 b./hr. The light hydrocarbon overhead fraction having a boiling range of 100-300° F. is recovered thru line 66 at the rate of 2 b./hr.

A counterflow combustion test was run on the 8.5° API gravity oil referred to above at a pressure of about 250 p.s.i.g. and an oil of 26.5° API gravity was produced. The test demonstrated that counterflow or reverse combustion at elevated pressures produces rather light oils. A sample of the 26.5° API gravity oil was fractionated in conventional manner into 4 different boiling range fractions and the data from the distillation are presented in the table below.

TABLE

Boiling Range	Percent by Vol.	API Gravity
113-300° F.....	17.9	49.5
300-400° F.....	15.0	36.4
400-500° F.....	18.0	29.1
500+° F.....	49.1	17.2
Total Product.....	100	26.5

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

We claim:

1. A process for producing selected hydrocarbons from subterranean oil sand penetrated by an injection well and a production well, which comprises the steps of:

- (a) heating said oil by in situ combustion of a portion thereof so as to heat and crack another substantial portion thereof to lighter normally gaseous and liquid hydrocarbons, thereby producing an effluent vapor stream at a temperature in the range of about 500 to 800° F. and a pressure in the range of about 500 to 2000 p.s.i.g.;
- (b) recovering the vapor stream of step (a) from said production well;
- (c) removing any sand contained in the vapor stream of step (b);
- (d) reducing the pressure of the vapor stream of step (c) to about 300 p.s.i.g. and the temperature to not more than about 500° F.;
- (e) separating the liquid oil from the vapor fraction of

the stream of step (d) under the pressure and temperature conditions of step (d) and separately recovering each fraction;

- (f) further cooling the vapor fraction of step (e) to a temperature substantially below the boiling point of water at ambient pressure to separate a water fraction, a liquid oil fraction, and a vapor fraction and separately recovering each fraction; and
- (g) fractionating the oil fraction of (f) into an overhead light hydrocarbon fraction, at least one intermediate fraction, and a heavier bottoms fraction.

2. A process for producing selected hydrocarbons from subterranean oil sand penetrated by an injection well and a production well, which comprises the steps of:

- (a) heating said oil by in situ combustion of a portion thereof so as to heat and crack another substantial portion thereof to lighter normally gaseous and liquid hydrocarbons, thereby producing an effluent vapor stream in said production well comprising oil and combustion gases at a temperature of at least 1000° F.;
- (b) water quenching the effluent from step (a) within said production well to a temperature in the range of 500 to 800° F. and a pressure in the range of 500 to 2000 p.s.i.g.;
- (c) recovering the vapor stream of step (b) from said production well;
- (d) removing any sand contained in the vapor stream of step (c);
- (e) reducing the pressure of the sand-free vapor stream of step (d) to about 300 p.s.i.g. and the temperature to not more than about 500° F.;
- (f) separating the liquid oil from the vapor fraction of the stream of step (e) under the pressure and temperature conditions of step (e) and separately recovering each fraction;
- (g) further cooling the vapor fraction of step (f) to a temperature substantially below the boiling point of water at ambient pressure to separate a water fraction, a liquid oil fraction, and a vapor fraction and separately recovering each fraction; and
- (h) fractionating the oil fraction of step (g) into an overhead light hydrocarbon fraction, at least one intermediate fraction, and a heavier bottom fraction and separately recovering each fraction.

3. The process of claim 2 wherein the oil in said sand is a heavy viscous crude oil and the combustion of step (a) is a reverse drive operation with air being injected thru said injection well and ignition initiated at said production well.

4. The process of claim 2 wherein temperature reduction in step (e) is effected principally by indirect heat exchange with air in air fin cooler and in step (g) first by indirect heat exchange with air in an air fin cooler and then by indirect heat exchange with water.

5. Apparatus comprising in combination:

- (1) a well head connected by casing and tubing with an oil producing zone;
- (2) a sand trap connected by a first conduit with said well head for flow of fluid from said zone to said trap;
- (3) a first liquid vapor separator having an inlet for an oil feed, an outlet for liquid oil in a lower section, and a vapor outlet in an upper section;
- (4) a second conduit connecting said sand trap with the oil feed inlet of (3);
- (5) an expansion valve and an air fin cooler downstream thereof in said second conduit;
- (6) a second liquid-vapor separator having a feed inlet in an intermediate section, a water outlet in a lower section, a liquid oil outlet in a section intermediate said water outlet and said feed inlet;
- (7) a third conduit connecting the vapor outlet of the first separator of (3) with the feed inlet of the second separator of (6);

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- (8) an air fin cooler and a water cooler downstream thereof in the third conduit of (7);
- (9) a fractionator having a feed inlet for liquid oil in an intermediate section, an outlet for a bottoms fraction, an outlet for an overhead fraction, an outlet for an intermediate fraction, a reboiler connected with the lower section; a reflux means connected with the upper section thereof and with the overhead outlet; and
- (10) a fourth conduit connecting the liquid oil outlet of the second separator of (6) with the feed inlet of the fractionator of (9).
- 6. The apparatus of claim 5 including:
 - (11) spray means adjacent the lower end of the casing and the producing zone of (1); and
 - (12) a water line connected with the spray means of (11).
- 7. Apparatus comprising in combination:
 - (1) a well head connected by casing and tubing with an oil producing zone;
 - (2) a first liquid-vapor separator having an inlet for an oil feed, an outlet for liquid oil in a lower section, and a vapor outlet in an upper section;
 - (3) a first conduit connecting said well head with the feed inlet to the first separator of (2);
 - (4) an expansion valve and an indirect heat exchanger downstream thereof in the first conduit of (3);
 - (5) a second liquid-vapor separator having a feed inlet in an intermediate section, a water outlet in a lower

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- section, a liquid oil outlet in a section intermediate said water outlet and said feed inlet;
- (6) a second conduit connecting the vapor outlet of the first separator of (3) with the feed inlet of the second separator of (5);
- (7) indirect heat exchange means in the second conduit of (6);
- (8) a fractionator having a feed inlet for liquid oil in an intermediate section, an outlet for a bottoms fraction, an outlet for an overhead fraction, an outlet for an intermediate fraction, a reboiler connected with the lower section; a reflux means connected with the upper section thereof and with the overhead outlet; and
- (9) a third conduit connecting the liquid oil outlet of the second separator of (5) with the feed inlet of the fractionator of (8).

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