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**Ebner von Eschenbach, Jennifer et al****Ladas & Parry,****Dachauerstrasse 37****80335 München (DE)**(54) **Apparatus and method for the supercritical hydroextraction of kerogen from oil shale**

(57) A method and apparatus for the recovery of kerogen as a pipelineable crude oil from oil shale. The method comprises crushing the oil shale to a predetermined particle size and mixing with toluene or similar low-boiling-point crude-oil fraction to form a slurry. Such is then supercritically heated and pressurized with naphthalene or similar H-donor mid-distillate. The kerogen materials breakdown into a pipelineable crude oil under hydro-visbreaking conditions to produce a stable product. The H-donating mid-distillate gives up its hydrogen in the reaction. The solids are separated by counter-current supercritical solvent extraction. The low-boiling-

point solvent and mid-distillate is recycled via a distillation column. The low-boiling-point solvent is also used in the slurry for water removal prior to supercritical extraction. A gas production with some light ends proceeds for hydrogen production and power generation (an alternative is to augment this with natural gas if necessary). The apparatus includes a high pressure autoclave type vessel with an internal venturi draft tube, and a plurality of high pressure decantation vessels which preferably include internal inclined plate thickeners.

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## Description

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

[0001] The present invention relates to processes for extracting the kerogen bituminous matter from oil shale to produce a pipelineable crude oil, and more particularly to extraction processes and apparatus that depend on supercritical hydrogen-donating (H-donating) solvents applied to carbonaceous oil shales with high kerogen contents and low Fischer Assay yields.

#### 2. Description of the Prior Art

[0002] Known oil shale deposits are immense, they are found on all the major continents of the world in massive deposits. The presently estimated oil shale reserves exceed known crude-oil resources by orders of magnitude. The oil shale reserves in the United States alone are estimated to represent over seven trillion barrels of oil. Such reserves are concentrated in the Green River formation of Utah, Colorado, Wyoming, and also in the Devonian-Mississippian Eastern Shale Deposits between the Appalachian and Rocky Mountains.

[0003] Retort and solvent processes are conventionally applied to the job of extracting the kerogen from the oil shales. Retorting processes are divided into in-situ and surface types. All such conventional processes require large amounts of heat. Retorting especially requires expensively high temperatures up to 574°C, and the gaseous heat transfer media used in surface retorting also need very large processing vessels for efficient production.

[0004] Such heating of oil shales creates an environmental problem because some of the constituents are swelled and the whole is too large to put back into the pit from which it came. Such spent oil shale can have a volume that is 103% of the original shale ore. Therefore, easy disposal of the spent shale in the original mine is not possible.

[0005] Retort reaction times and conditions must be carefully controlled to avoid visbreaking or cracking the heavy oil into hydrocarbon products with molecular weights that are too low. If the retort reaction times and conditions get too far out of control, largely unusable residual carbon output increases. The important hydrocarbons bound in oil shale are collectively called kerogen and have a mixture of high molecular weight components.

[0006] Kerogen is conventionally converted to more convenient forms by heating it to 350°C, or higher, to yield a range of hydrocarbons with lower molecular weights, e.g., methane to light oil. Retorting processes normally operate near 500°C. Extended reaction time leads to conversion of primary bitumen products to other lower molecular weight products and residual carbon.

Retorting also typically produces unacceptable environmental emissions, relatively low yields of bitumen and requires heavy water usage.

[0007] The challenges in the processing of oil shale include limiting the production of gas products like methane to enough to fuel the process, and keeping the production of unusable carbon residue at a minimum. Thus, it is without the conversion to secondary lighter products. Upgrading to the desired final products is more efficient in downstream processing.

[0008] Kerogen in oil shale is relatively insoluble in most organic solvents at or below their normal boiling points. But if the environmental pressure is increased to raise the boiling point to higher than 600°K, solvents like toluene will dissolve the kerogen. Solvent extraction separates shale oil from spent shale without vaporization. The converted hydrocarbon products result from dissolution under reaction conditions, e.g., heating the oil shale and a solvent to 380°C-540°C. Sometimes hydrogenation is also needed for good conversion. In general, solvent processes have better yields than retorting processes.

[0009] Although there are a number of variations of the solvent process, such do not efficiently separate spent-shale particles from the solvent and bitumen. And apparently no prior art processes have thought to use supercritical pressures to keep the solvents liquid at temperatures where they would otherwise boil away.

[0010] In 1988, United States Patent 4,737,267, (Pao '267) was issued to the present inventor, John Rendall, and he described the difficulties associated with existing technologies attempting to use supercritical toluene as the extractant. However this process did not address the stability issues and potentially lower yields of "carbonaceous" oil shales, nor did it address the olefin content of the produced oil.

### SUMMARY OF THE PRESENT INVENTION

[0011] It is therefore an object of the present invention to provide a process for the efficient extraction of kerogen from oil shale.

[0012] It is another object of the present invention to provide a system apparatus for the efficient extraction of kerogen from oil shale.

[0013] Briefly, a process embodiment of the present invention is a method for producing pipelineable synthetic crude oil from oil shales. Such process combines a low-boiling-point organic solvent fraction with an H-donating-mid-distillate fraction and raises temperature to make kerogen in oil shales soluble, and raises pressure conditions to keep the solvents in their liquid phase at those temperatures. The solvent is recovered from the extracted kerogen in a three-stage solvent-recovery unit that is followed by a flash recovery that uses a pressure letdown and draws off the resulting solvent vapors.

[0014] An advantage of the present invention is that a process for kerogen extraction from oil shale is pro-

vided that produces higher yields of oil with reduced gas production.

**[0015]** Another advantage of the present invention is that a process for kerogen extraction from oil shale is provided that produces hydro-visbroken crude oil which is stable enough for conventional pipeline transfer to refineries.

**[0016]** A still further advantage of the present invention is that a process for kerogen extraction from oil shale is provided that produces a minimum of environmental contamination.

**[0017]** Another advantage of the present invention is that a process for kerogen extraction from oil shale is provided that recycles its solvents and heat.

**[0018]** These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiment as illustrated in the drawing figure.

#### IN THE DRAWINGS

**[0019]** Fig. 1 is a functional block diagram of an oil-shale processing plant embodiment of the present invention that implements a process for kerogen extraction from oil shale.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0020]** An oil-shale processing plant embodiment of the present invention is diagrammed in Fig. 1 and is referred to herein by the general reference numeral 100. The principle product produced is synthetic crude oil that is suitable for pipeline transportation. An oil shale input feed 102 is crushed by a size reducer 104. A crushed oil shale flow 106 is mixed with a recirculating solvent and input to a water remover 108. Any waste water 110 is removed from the system. A recovered solvent vapor flow 112 is added, condensed for heat recovery and a slurry flow 114 is output. A heat exchanger 116 provides a recovered-heat flow 118 and outputs an oil product flow 120. Hot oil product flow 122 is received from further down the process and is stripped of its elevated heat for recovered-heat flow 118, and the remainder is the cooler oil product flow 120. A kerogen converter 124 outputs a slurry 126. Reaction gases are drawn off in a flow 128. An oil separator 130 outputs an oily solids flow 132 and the oil product flow 122. A solvent extractor 134 outputs a solids flow 136 and an oil/solvents mixture 138. Any heat that can be removed from mixture 138 is returned in a heated solvents flow 140. A last solvent recovery stage 142 outputs a spent shale flow 144 and is assisted with a waste water wash. A filter cake flow 148 is added to the last solvent recovery stage 142 with a wash water flow 150. Such filter cake flow 148 is produced by an extracted-oil solids filter 152 that removes solids from the oil product flow 120 and forwards filtered

product oil flow 153.

**[0021]** A distillation column 154 outputs a final-product synthetic crude oil 156. A heat exchanger 158 outputs a flow 160 and receives a flow 162. A flow 164 is forwarded for hydrogen production and sulphur recovery. A recycle solvent 166 is provided by the distillation column 154 to the pulverized oil shale flow 106. An H-donor flow 167 is added to flow 166 from an H-donor generator 168. A mid-distillate flow 169 from the distillation column 154 is sent to the H-donor generator 168. A hydrogen plant sulfur recovery unit 171 produces a hydrogen flow 172, sulfur free fuel gas flows 173 and 178 and a sulfur flow 180. A fuel flow 173 is provided to run a power plant 174. The output from the power plant 174 is electricity 176. A sulphur flow 180 is output from the sulphur plant 171.

**[0022]** Guo Shu-Cai, et al., described some conversion steps like those of the oil-shale processing plant 100 for an experiment they conducted. Such experiment was reported in "Conversion of Chinese Oil Shales to Liquid Products using Supercritical Extraction," pp. 311-316, German Publication: Erdol und Kohle-Erdgas-Petrochemie vereinigt mit Brennstoff-Chemie, Bd. 39, Haft 7, Juli 1986. Guo Shu-Cai, et al., found that the supercritical extraction of oil shale with toluene can give up to twice the oil yield over conventional retorting. When an H-donor was added to the supercritical solvent, complete recovery of the oil-shale kerogen and high liquid-product yields was possible. But their paper did not describe a practical or complete system that recovered the solvent from the synthetic crude oil. What was described was that with a toluene/donor-solvent mixture with a tetralin content of about twenty percent, the oil yield (extract and liquids) can be enhanced as high as 200% of the Fischer Assay.

**[0023]** Earlier, in 1980, John Pratzer, II, was issued United States Patent 4,238,315, (Pratzer '315) which describes the recovery of oil from oil shale. Such patent is incorporated by reference and may be helpful to the reader in implementing embodiments of the present invention. Pratzer '315 describes the extraction of oil from oil shale with the aid of elevated temperatures and pressures so that solvents with tetralin may be employed for highly efficient oil shale processing. The reactor effluent is described as being filtered, and the resulting filter cake rinsed with toluene. Again, such did not describe a practical or complete system that recovered the solvent from the synthetic crude oil.

**[0024]** The recovery and recycling of solvents with H-donors is described by Marvin Green, et al., in United States Patent 4,325,803, (Green '803) titled "Process For Hydrogenation/Extraction Of Organics Contained In Rock," and issued April 20, 1982. A hydrogen transfer agent in its liquid phase is used to separate kerogen from oil shale. The oil separation occurs in a reactor at elevated pressure and temperature that keeps the solvent liquid. A slurry flash releases pressure and an adiabatic flash vaporization of the organic materials oc-

curs. A portion of the vaporized materials is recycled as hot recycle oil vapors. Green '803 is also incorporated herein by reference as it may be helpful to the reader in implementing embodiments of the present invention.

**[0025]** In embodiments of the process of the present invention, the H-donor generator 168 starts with a mid-distillate fraction of naphthalene ( $C_{10}H_8$ ) with a molecular-weight-128, e.g., in flow 169, and chemically reacts this with hydrogen using a catalyst. This produces H-donor products in flow 167 like decalin ( $C_{10}H_{18}$ ) (molecular-weight-138) and tetralin ( $C_{10}H_{12}$ ) (molecular-weight-132) with boiling points of 190-220°C. Up to eight percent by weight of hydrogen is available for such chemical reaction. Typical oil-shale production requires about two percent by weight hydrogen for the benefits described. About twenty percent of the total solvent mix used in the extraction/conversion is preferably H-donor mid-distillate fraction.

**[0026]** Method embodiments of the present invention combine crushed oil shale with a mixture of toluene or other low-boiling-point range organic solvent, and tetralin/decalin or other mid-distillate. This is then fed into a slurry mixer and heated by a solvent recovery from a spent shale. Any water in the oil shale is eliminated. The slurry is then pumped with a recycle product oil stream into an autoclave where moderate temperatures and elevated pressures are used to convert substantially kerogen to a hydro visbroken stable crude oil with some gas production. The oil product is then separated under similar temperature and pressure conditions from the spent shale.

**[0027]** After separation, the oil product left after taking part for recycling is distilled for the solvent mix by a low-boiling-point fraction and a mid-distillate fraction. This mid-distillate fraction is hydrotreated and recycled to make up for any hydrogen used up. The spent shale is washed counter-current with the low-boiling-point solvent fraction under supercritical pressure and temperature conditions. This enables easy solids separation and continued conversion of the residual kerogen. The final residue of spent shale with clean low-boiling-point solvent at supercritical temperature/pressure conditions is let-down gradually in stages with almost all the low-boiling-point solvent evaporating for recovery and reuse with the final stage sprayed with water to release any remaining solvent through steam stripping. The oil product is filtered before storage and pipelining to market.

**[0028]** The gas produced is rich in methane and is used for hydrogen production needed for the mid-distillate hydrotreating. This step provides for the needed heat/power and hydrogen for the process. This art is well known and there are several methods commercially available.

**[0029]** Some embodiments of the present invention include the use of at least one autoclave wherein high pressure leaching is used to convert kerogen to oil. Such autoclave preferably includes an internal venturi draft tube to keep the slurry mixed. A pressurized extraction

vessel continues the conversion process and acts to solubilize the converted oil. A series of pressurized solvent washing shale decanters are used in which shale moves counter-current to the solvent. Distillation columns, settling tanks and a plurality of pumps and heat exchangers are used to transfer and recycle components.

**[0030]** Referring again to Fig. 1, the plant 100 begins with the mine ore flow 102 that preferably ranges in size up to forty inches. This is forwarded to conventional commercial size reduction equipment to obtain a resulting ore of about 3/8-inch screen mesh. The crushed shale is fed by flow 106 into a slurry mixer system water remover 108, e.g., as described in Rendall '267, and incorporated herein by reference. The system water remover 108 receives heated solvent vapors from the solvent recovery stage 142 and the heat received helps maintain an operating temperature near the boiling point of water. Any water vapor is condensed and drawn off in waste water flow 110 which is flushed out in spent shale flow 144. The slurry is heated by heat exchanger 116 and the pressure is increased to 600 PSIG.

**[0031]** More heat can be added to flow 118 to raise the temperature of the flow 118 entering the kerogen converter 124 to about 400°C. The kerogen converter 124 preferably includes an autoclave and provides residence times of five to thirty minutes, depending on the oil shale ore. The kerogen is converted by pyrolysis with an H-donor distillate providing hydrogen to deal with olefin formation and unsaturated hydrocarbons. Some sulphur will detach as hydrogen sulfide.

**[0032]** The reaction is chemical and continues through the entire section under elevated temperature and pressure, e.g., kerogen converter 124, oil separator 130, and three-stage solvent extractor 134. The gas flow 128 produced by the reaction comprises methane, ethane, hydrogen, and some hydrogen sulfide. The oil flow 126 is separated in stage 130 by a pressure vessel.

**[0033]** The three-stage solvent extractor 134 can be implemented similar to the three pressure decanters 712, 730, and 740, in Fig. 2 of Rendall '267.

**[0034]** The oil is removed in flow 122. The oil separator 130 agglomerates the fines which settle out with the solids output flow 132. The hot product oil is fed to distillation column 154 via a heat exchanger 116 to heat the incoming slurry then through an extracted-oil solids filter 152 before the pressure is let down to provide the energy needed for distillation. The solids with oil exit in flow 132 to a three-stage solvent extractor 134, wherein fresh hot solvent at about 400°C and about 700 PSIG is fed from flow 140 counter-current to the output spent shale.

**[0035]** Most of the remaining product oil output with the solvent in flow 138 via a heat exchanger 158 (for the incoming solvent) to the distillation column 154. The solids residue with some solvent leaves three-stage solvent extractor 134 via flow 136 to a solvent recovery solvent-residue flash recovery unit 142. The solvent-residue flash recovery unit 142 consists essentially of de-

pressurizing the residue in a vessel fed from flow 136 thereby releasing most of the low-boiling-point solvent via flow 112 as a vapor to heat the incoming slurry at water removal water remover 108. The residue of spent shale is further cooled from about 200°C-300°C in a rotary drum with the remaining solvent from flow 148 joining flow 112. Filter residue from extracted-oil solids filter 152 feeds the depressurizing vessel in solvent-residue flash recovery unit 142. The water from hydrogen plant 171 and/or waste water from water remover 108 can be used to cool the solids and dampen the spent shale residue for dust control during mine backfill. The solvent-residue flash recovery unit 142 is any such system as described in Rendall '267 including depressurizing vessels and a cooling (rotary drum). The heat from the flow 136 is transferred via solvent and water (steam) vapors to the water removal water remover 108. It would aid water disposal to use acid water from the hydrogen/sulfur plant hydrogen plant 171 to cool the hot spent shale while waste water flow 110 is disposed of in flow 144 for dust control.

**[0036]** The recycle solvent to three-stage solvent extractor 134 flow 140 is fed from the distillation column 154 via flow 162 to a heat exchanger 158. This is necessary at elevated pressure of about 400 PSIG. The heat can be provided by the oil/solvent output three-stage solvent extractor 134 via flow 138 at about 400°C and leaves the heat exchanger 158 at flow 160 with temperatures about 150°C to the distillation column 154. Auxiliary heat to flow 140 can also be provided by flow heat fuel gas from power plant 174. The hot oil from kerogen conversion from oil separator 130 flows at about 600 PSIG and 400°C. Flow 122 heats incoming slurry in heat exchanger 116 from which it leaves at about 600 PSIG and 150°C. An oil product flow 120 is forwarded via an extracted-oil solids filter 152. The filter residue is fed via flow 148 to the solvent recovery solvent-residue flash recovery unit 142, for disposal of the fines. The filter can be of the metal porous cartridge type such as are readily commercially available, a pressurized rotary drum filter with engineered fabric for high temperatures about 150°C such as supplied by CJ (Zyex Hi tech yarn) or any other suitable for process conditions. All are used in refineries for removal of catalyst fines before oil product distillation. The preferred route is a metal porous cartridge type. The distillation column 154 is fed the product oil flow 153 and recycle solvent at about 150°C. Flow 153 is a depressurized flow and additional heat can be provided by a fuel gas flow 178.

**[0037]** The distillation column 154 is conventional system with a mid-distillate metered off-take at about 200°C in flow 169 for hydrotreating in H-donor 168. The recycle solvent off take at about 120°C is metered to flow 166 feeding the slurry of the incoming raw oil shale for water removal in water remover 108. The ratio of mid-distillate flow 169 hydrotreated in H-donor 168 mixing with the recycle solvent flow 166 via flow 167 is about twenty percent of mid-distillate H-donor in the flow 114

proceeding under elevated temperature about 400°C and pressure about 600 PSIG to the kerogen converter 124. The H-donor 168 for hydrotreating the mid-distillate from flow 169 is practiced by industry today, as referenced books for catalysts including, "Oil and Gas Journal Refining-Catalyst Compilations". Such catalysts usually use alumina support with combinations of cobalt molybdenum nickel etc. as active agents. The technologies are similar to those described in "Petroleum Processing Handbook" edited by John S. Meketta, published by Marcel Dekken, June 1992 or "Upgrading Petroleum Residue and Heavy Oils" by Murray S. Greg, published by Marcel Dekker Inc., NY, NY 1994. The hydrogen plant 171 receives hydrogen, hydrocarbon gases, including some light ends, some ammonia (NH<sub>4</sub>) and hydrogen sulfide H<sub>2</sub>S from flow 172.

**[0038]** The hydrogen is separated, concentrated, and reused by compressors. The hydrogen sulfide is converted to sulfur by a conventional Claus plant. Some of the fuel gas is used for further hydrogen production via a reformer for methane/light ends, and the rest for heat needed for process and electric power. About six to fifteen percent by weight of the kerogen is converted gases dependant on the source of the oil shale and the processing conditions for extraction of the kerogen. About two percent by weight of the produced oil is the hydrogen necessary for chemical reactions to produce a suitable pipelineable oil with the required viscosity and stability. Up to four percent by weight hydrogen has also been reported on particularly aromatic kerogens, producing more gas. The whole hydrogen system produces electric power. All these items in power plant 174 via flow 173 can only be quantified in specificity depending on the oil shale source and the size of the facility by those skilled in the art.

**[0039]** The Fischer Assay was developed for the oil shale industry to determine the efficiency of oil extraction processes. The Fischer Assay measures the recovery ratio of hydrocarbons from the oil shale. In prior art retorting processes, a Fischer Assay recovery of 80-100% is typical, and recoveries exceeding 100% are difficult to achieve.

**[0040]** Rendall '267, describes fifteen batch runs in which oil shale was treated with toluene under supercritical conditions ranging up to 400°C and 1200 PSIG pressure for recovery of up to 120% of Fischer Assay of hydrocarbons.

**[0041]** In the batch runs, oil shale has been slurried in toluene in a batch stirred reactor and heated to temperatures up to 400°C and held for periods ranging from zero minutes up to two hours.

**[0042]** Other data referenced on "carbonaceous" oil shales in which an H-donor mid-distillate has been used with the supercritical toluene shows kerogen conversion almost complete (about 95%). This data clearly shows oil production with negligible olefins and hydrogen consumption from the H-donor mid-distillate at two to three percent by weight of the produced oil.

**[0043]** Method embodiments of the present invention for "carbonaceous" oil shales allow almost all of the kerogen to be produced as oil and gas (a 5-15% fraction). For example, Julia Creek, Queensland, Australia, oil shales, CRA report 1967-1988, show an average of 17-18% kerogen. The Fischer Assay yield is about H-donor 70 liters/ton (14-15 gallons) representing about seven percent kerogen which is only 30% of what potentially could be available from the recovery method of the present invention. This is adequately borne out by independent research on other Chinese, Australian and Eastern US shales shown in the references. The decrepitation observed on Colorado oil shales does not occur in carbonaceous oil shales.

**[0044]** Although the present invention has been described in terms of the presently preferred embodiments, it is to be understood that the disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after having read the above disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true spirit and scope of the invention.

## Claims

1. An oil-shale processing plant for extracting kerogen and outputting a pipelineable synthetic crude oil, comprising:

a water removing stage for taking water out of a mixture of oil shale and a recycled solvent;  
 a first heat exchanger connected to receive a dewatered slurry of oil shale and a recycled solvent from the water removing stage under elevated pressure, and to heat said slurry with heat extracted from a product oil to an elevated temperature;  
 a reactor operated over a residence time at elevated temperatures and pressures that keep said solvent in its liquid phase and produce a solubility of a kerogen in said slurry received from the heat exchanger;  
 an oil separator that receives said kerogen in solution of said solvent and said oil shale from the reactor, and that separates them, wherein said kerogen is output as said product oil and forwarded to the first heat exchanger, and said oil shale and solvent exit in a second output;  
 a three-stage solvent extraction unit operated at said elevated temperatures and pressures that receives said second output from the oil separator and removes said solvent from said oil shale;  
 a second heat exchanger connected to receive said solvent from the three-stage solvent extraction unit and to remove its heat and apply

that heat to an incoming solvent flow applied to a last stage of the three-stage solvent extraction unit, wherein said elevated temperature is reduced; and

a solvent-residue recovery unit wherein said elevated pressure is reduced in a flow of oil shale received from the three-stage solvent extraction unit and that flashes said solvents into vapors that are drawn off and recycled to the water removing stage;

wherein a pipelineable synthetic crude oil is derived from said product oil.

2. The oil-shale processing plant of claim 1, further comprising:

a distillation column that receives said product oil from the first heat exchanger and that outputs said pipelineable synthetic crude oil.

3. The oil-shale processing plant of claim 2, wherein:

the distillation column further outputs a mid-distillate recycle flow that is converted to at least one of tetralin and decalin for an H-donor addition to said solvent.

4. The oil-shale processing plant of claim 2, wherein:

the distillation column further outputs toluene in a recycle solvent flow, and a mid-distillate recycle flow that is converted to at least one of an H-donor tetralin and decalin, and wherein said solvent comprises both said toluene and at least one of an H-donor tetralin and decalin.

5. An improved method for extracting oil products from oil shale, comprising said steps of:

crushing a mined oil shale ore into a pulverized oil shale feed;  
 mixing said pulverized oil shale feed with a hot organic solvent recycled from a distillation column to form a slurry, wherein said solvent is hot enough to strip water from said slurry;  
 transferring said slurry for kerogen conversion under supercritical conditions for said organic solvent with an H-donor distillate such that said kerogen is converted into a stable, pipelineable crude oil;  
 transferring said slurry to recycle solvent extraction stage at a supercritical conditions of temperature and pressure for further reaction, and producing an oil product and a separated solid phase;  
 filtering at less than supercritical conditions said oil product for distillation of a recycle sol-

vent and a mid-distillate fraction, with said oil product being sent to storage;  
hydro-treating a mid-distillate fraction recycled from said distillation to provide an H-donor for kerogen conversion; 5  
withdrawing a spent shale after solvent extraction and desolventizing oil shale solids at less than supercritical conditions, wherein a solvent is flashed off with a water to be recycled to a water removal means; and 10  
providing hydrogen, fuel gas and electric power from any gas products of conversion of said kerogen and from a distillation of said solvents.

6. The process of claim 5, wherein: 15

the steps are such that a low-boiling-point-solvent supercritical temperature-and-pressure of about 400°C and 500+ PSIG is used;  
the steps are such that said oil shale ore is crushed to about 3/8 inch; 20  
the steps are such that said residence time in said supercritical region is in a region of five to thirty minutes;  
the steps are such that an H-donor mid-distillate recycle with a boiling point of approximately 200°C is about twenty percent of a low-boiling-point solvent recycle; and 25  
the steps are such that an oil filtration system includes a porous metal cartridge. 30

7. The process of claim 5, wherein:

the steps are such that a hydrogen make-up to hydro-treat a mid-distillate recycle is derived from gases produced in said process. 35

8. The process of claim 5, wherein:

the steps are such that pressure vessels are used for kerogen conversion, oil separation, and solvent extraction. 40

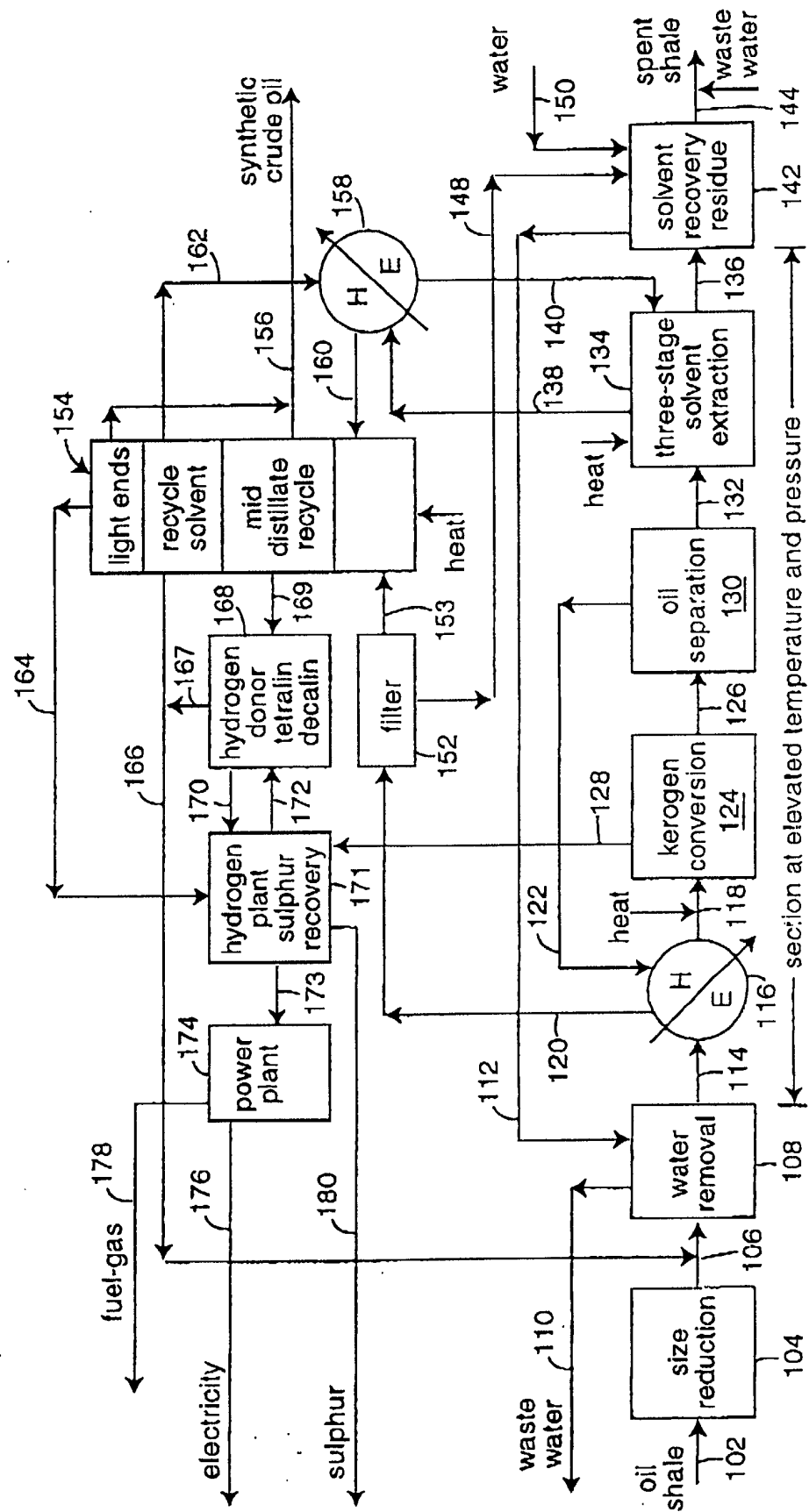
9. The process of claim 6, wherein: 45

the steps are such that a spent shale is cooled for disposal via a rotary drum internally sprayed with water.

10. The process of claim 8, wherein: 50

the steps are such that said pressure vessels used include an autoclave with a draft-tube venturi. 55

Fig. 1







European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 02 01 0622

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.C1.7)
D,A	US 4 737 267 A (PAO ET AL) 12 April 1988 (1988-04-12) * claims 1,3,8,13-15 * * column 3, line 51 - column 10, line 49 * * figures 1,2 * -----	1,2,5,6,8-10	C10G1/00
			TECHNICAL FIELDS SEARCHED (Int.C1.7)
			C10G
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 November 2002	Examiner De Herdt, O
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503.03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 02 01 0622

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
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25-11-2002

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