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MULTIPLE STAGE SHALE EDUCATION PROCESS

Filed Jan. 17, 1944

2 Sheets-Sheet 1

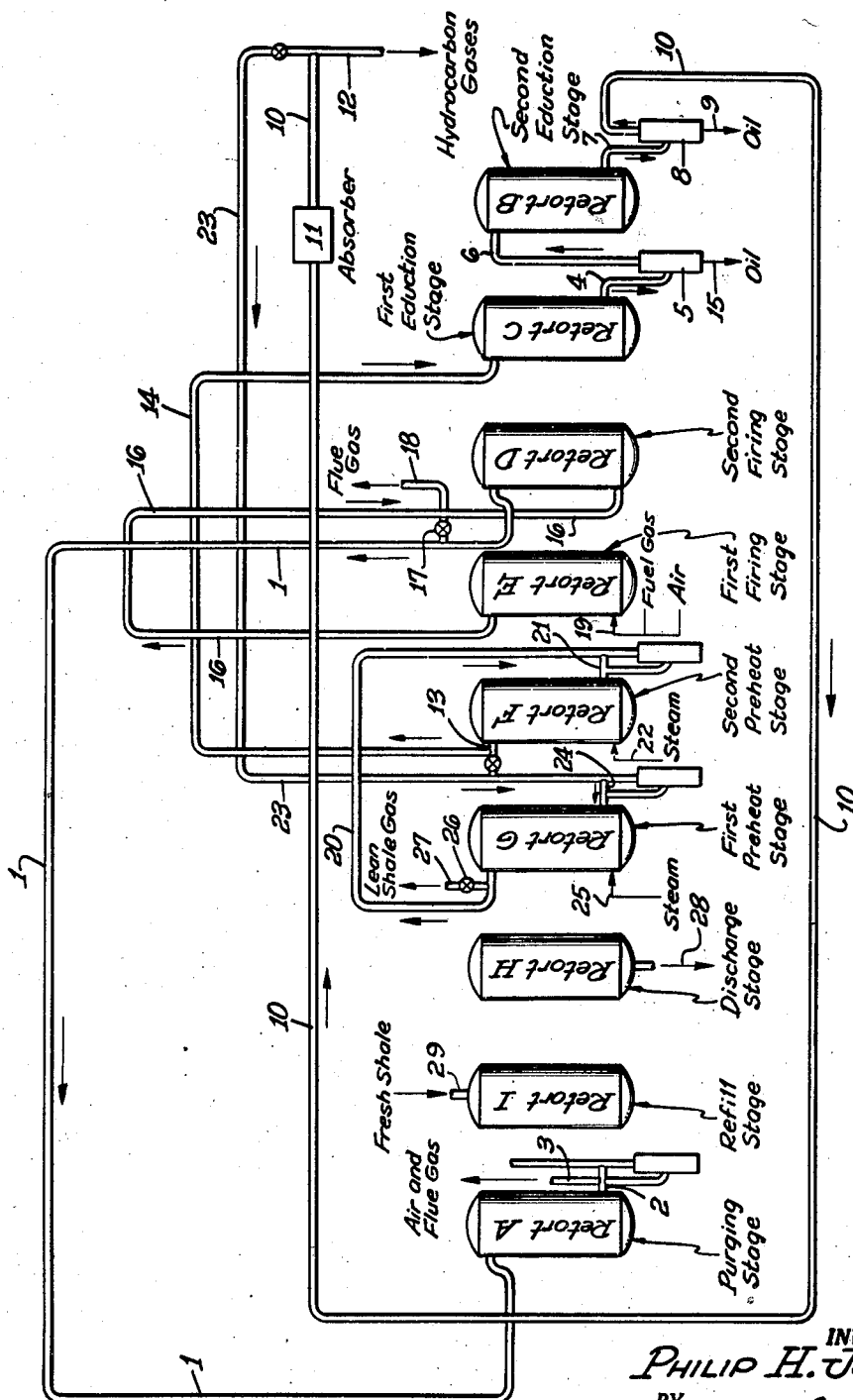


Fig. 1.

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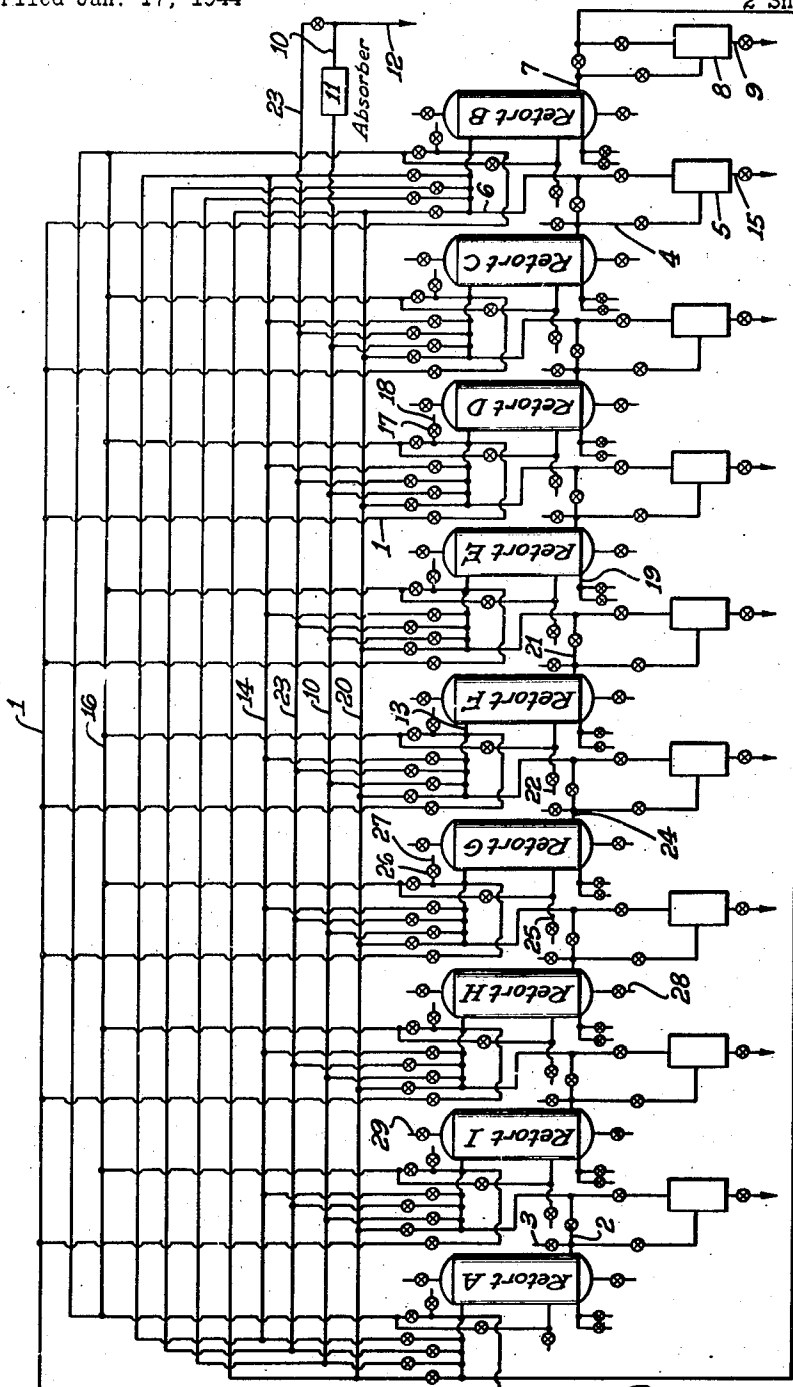


Fig. 2.

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MULTIPLE STAGE SHALE EDUCTION
PROCESS

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5 Claims. (Cl. 202—16)

1

The present invention relates to the recovery of oil from shales and the like. The invention is particularly directed to an improved process in which oil shales are rapidly educted and the oil removed immediately upon formation with a minimum of destructive pyrolysis.

It is well known in the art to recover oils from solid oil-bearing or producing materials, particularly to recover shale oil from oil shales. The recovery of the oil from the oil-bearing or producing material may be accomplished by roasting in a kiln the oil-bearing or producing material at high temperatures sufficient to educt the oil and separate it from the mineral matter. These processes have not been entirely satisfactory because the shale gas produced in the above mentioned processes usually contact flue gases and thereby become contaminated by same, with a resulting loss of valuable hydrocarbon liquid and gases. In such processes the educted oil is subject to a long period of exposure to high temperatures. As a result of this relatively long time of contact an undesirably large amount of the hydrocarbon is converted to non-condensable gases and carbon or carbonaceous solids. There are still other processes which educt shale oil from oil shale by means of external heat alone, in a suitable apparatus, or by external heat in conjunction with a limited amount of steam.

The above mentioned methods have proved themselves of somewhat limited value in many respects because the oil educted is usually of low specific gravity, containing a reduced percentage of lubricating stock and waxes and an excessive amount of unsaturates. Another disadvantage in the above mentioned processes is the excessive production of undesirable constituents, such as carbon monoxide and hydrocarbon gases.

I have discovered a process by which oil and hydrocarbon vapors may be readily and efficiently recovered at relatively low temperatures from oil-bearing solid substances by means of the sensible heat of hot flue gas and hot lean shale gas in conjunction with superheated steam, in a semi-continuous operation with a resulting uniform treatment. My process overcomes the above mentioned difficulties present in said processes employed for the eduction and recovery of oils from shales and the like, and permits a maximum recovery of the oils with a minimum amount of cracking, and avoids the commingling of the shale gas with flue gas.

My invention consists of a series of retorts and the necessary manifold which allows an operator by the changing of certain specified valves to place each retort into a designated stage of a complete cycle and wherein each retort within said series passes through a distinct and different stage of said cycle simultaneously with the changes of each and every other retort within said series.

2

The above cycle consists of the following nine stages: First, a purging stage, wherein air is removed from the shale packed retort by means of hot flue gases; second, a partial eduction stage, wherein the said shale is partially educted by means of relatively hot rich shale gas and steam; third, a complete eduction stage, wherein the partially educted shale is completely educted by means of hot lean shale gas and steam; fourth, a second firing stage, wherein the completely educted shale is heated to greater temperatures by means of hot flue gases; fifth, a first firing stage, wherein the carbonaceous material on the hot educted shale is burned off by means of fuel gas and air; sixth, a second preheating stage, wherein the hot educted shale by means of heat exchange gives up heat to hot lean shale gas and steam introduced therein; seventh, a first preheating stage, wherein the somewhat cool spent shale by means of heat exchange gives up heat to cool lean shale gas and steam introduced therein; eighth, a discharging stage, wherein the cold spent shale is removed from the retort; ninth, a refill stage, wherein fresh crushed shale is introduced into said retort.

It is to be understood that the above mentioned series may consist of any number of retorts arranged in any desirable manner, but the preferred series should consist of nine in number. In order to further clarify my invention each of the nine retorts will be operating in a different stage of the above mentioned cycle at any designated time during the operation of the process.

In the drawings, an apparatus adapted to perform the method according to the invention is shown in a merely diagrammatic way. Figure 1 shows the nine stages of a complete cycle wherein retorts A, B, C, D, E, F, G, and I, represent the respective stages through which retort A passes during the process of the invention. Figure 2 shows the entire apparatus and necessary manifold by which each and every retort can be transferred from one stage to the next in the above mentioned nine stages as described in Figure 1 at designated intervals.

Referring to Figure 1, rich crushed shale in purging retort A is heated and purged of air by means of moderately hot flue gas from second firing retort D by means of line 1. The air and flue gas in purging retort A is removed by means of lines 2 and 3 and disposed of as desired. After purging, valves are changed to put purging retort A into the second stage of eduction, as shown by second eduction retort B. Relatively hot rich shale gas and steam are introduced into second eduction retort B from first eduction retort C by means of line 4, trap 5, and line 6 and thereby partially educt the rich shale therein. The liquid oil produced in second eduction retort B is removed by means of line 7, trap 8 and line

3

9 to be handled as desired. The rich shale gas in second eduction retort B is withdrawn by means of line 7, trap 8, and line 10 to be handled as desired, such as by means of absorber 11 wherein the light hydrocarbon gases are stripped from lean shale gases, and removed by means of lines 10 and 12 to be handled in any desirable manner. After second stage of eduction, valves are changed and shale submitted to the first stage of eduction, as shown by first eduction retort C. Hot lean shale gas and steam are introduced into first eduction retort C from second preheat retort F by means of lines 13 and 14 wherein complete eduction takes place. The liquid oil produced in first eduction retort C is removed by means of line 4, trap 5 and line 15, to be handled in any desired manner. The relatively hot rich shale gas in first eduction retort C is introduced into second eduction retort B, as described above. After first stage of eduction in the first eduction retort C, valves are changed and the hot carbonaceous shale is submitted to the second stage of firing, as shown by second firing retort D. Hot flue gas from the first firing retort E is introduced into second firing retort D by means of line 16 and thereby heating the carbonaceous shale to higher temperatures. The spent flue gas in second firing retort D is then divided, part is withdrawn by means of line 1, valve 17 and line 18 to be disposed of as desired. The remainder of the spent flue gas in second firing retort D is introduced into purging retort A by means of line 1 as described above. After the second stage of firing, valves are changed and the hot spent shale is submitted to first stage firing, as shown by first firing retort E. Fuel gas and air are introduced into first firing retort E by means of line 19 and burned therein so as to raise the shale to even higher temperatures. An excess of air may be introduced to burn any residual carbonaceous material left in the spent shale. The flue gas produced in firing retort E is introduced into retort D by means of line 16 as described above. After first stage of firing, valves are changed and the very hot spent shale submitted to a second stage of preheating, as shown by second preheating retort F. The hot spent shale in second preheating retort F gives up heat to hot lean shale gas and steam introduced therein from first preheat retort G by means of lines 20 and 21. If desired, additional steam may be added to second preheat retort F by means of line 22. The hot gases from second preheat retort F are introduced into first eduction retort C, and second eduction retort B, to act as an eduction medium, as shown above. After completing second stage of preheating, valves are changed and the somewhat cooled but still hot spent shale is introduced into first stage of preheating as shown by first preheat retort G. The cool lean shale gas from absorber 11 is introduced into first preheat retort G by means of lines 10, 23, and 24 wherein said lean shale gas is heated by the sensible heat of hot spent shale therein prior to passing to second preheating retort F through lines 20 and 21 as described above. Steam is added to first preheat retort G as desired by means of line 25. In this operation the spent shale would be further cooled until it was ready for discharge. The excess of lean shale gas in first preheat retort G is removed through valve 26 and stack 27 to be handled in any desired manner. After first stage of preheating, the valves are changed and the spent shale is submitted to discharging stage as shown by dis-

4

charge retort H. The discharge retort is isolated from the rest of the system and the cooled spent shale is discharged by means of line 28 to be disposed of as desired. After discharging spent shale the retort is then refilled with rich shale as shown by refill retort I by means of line 29 and the operation continued as aforementioned.

Figure 2 represents the complete process including the necessary manifold to switch and transfer the individual retorts into the proper stages. Figure 2 carries the same numbers as shown on Figure 1 which describes the relationship of the flow described in Figure 1 to the whole apparatus.

One modification of the present invention is to introduce water into discharge retort H just prior to the discharging of hot spent shale. The introduced water on contacting the hot spent shale would generate steam which could be used for operational purposes. This modification would also assist in further cooling the spent shale prior to discharge. If this steam generation step is used a separate stage would be necessary, but the purging of the spent shale would be avoided.

Another modification of the present invention would be to increase the multiple stage operations shown in the drawings from the two-stage operation for each major step in the process, i. e. firing, preheating and eduction, up to any desired number governed by expediency and operating conditions. A single stage operation may also be used, but the advantage of countercurrent flow would be lost.

The process of the present invention may be widely varied. The invention may be adapted for the recovery of oils from any solid substances, but it is particularly directed to the recovery of shale oil from oil shale.

In the practice of my invention, as shown above, the crushed rich shale is introduced into retort A until the retort is completely filled. The first retort is placed under purging conditions, which removes the air by means of warm flue gas, for a designated period of time. At the termination of this period it is then subjected to the second eduction stage. When retort A is subjected to the second eduction stage, retort B is subjected to purging of air similar to first step of retort A. After a designated period of time retort A is changed to stage three, i. e. first eduction period, simultaneously retort B changes to second eduction stage and retort C is subjected to air purging. This procedure is continued until all retorts are operating within one stage of the complete cycle. In order to transfer all retorts from one stage to another in a substantially simultaneous operation a master valve control probably should be used.

Shale should be crushed to pass a one-inch round sieve. Preferred size should pass a one-half-inch round sieve and retained on a five-mesh sieve, although larger or smaller sizes may be used.

The temperatures required for the proper eduction of shale in the first eduction retort may be between about 400° F. and 2000° F. depending on the type of shale employed and the products desired. Temperatures between about 400° F. and about 1000° F. are suitable for most operations.

The contact time required for reasonably complete eduction in both of the eduction stages may be as low as 0.01 second or less, and generally

will not exceed about 24 hours, the longer times of contact within this range being required where the temperatures are in the lower parts of the above ranges and the shale fragments are relatively large.

The amount of steam and hot lean gas introduced into first and second eduction stages is controlled to obtain the proper temperatures and thereby the right degree of eduction.

The foregoing description of my invention is not to be taken as limiting my invention but only as illustrative thereof since many variations may be made by those skilled in the art without departing from the scope of the following claims.

I claim:

1. A multistage method for the recovery of shale oil from crushed oil shale which comprises treating the shale successively in the following stages: (1) purging, (2) partial eduction, (3) complete eduction, (4) further heating, (5) burning, (6) first cooling and (7) second cooling, purging the shale in said purging stage with a purging medium consisting of hot flue gas produced in said further heating stage, partially educting shale oil and rich shale gas from said purged oil shale in said partial eduction stage by means of a secondary eduction medium consisting of hot rich shale gas and steam produced in said complete eduction stage, withdrawing said shale oil and rich shale gas from said partial eduction stage, separating said shale oil from said rich shale gas, further separating said rich shale gas into hydrocarbons and residual lean shale gas, completely educting shale oil and rich shale gas from said partially educted oil shale in said complete eduction stage by means of a primary eduction medium consisting of hot lean shale gas and steam produced in said first cooling stage, withdrawing shale oil, rich shale gas and steam from said complete eduction stage, separating said shale oil from said rich shale gas and steam, employing the resulting rich shale gas and steam in said partial eduction stage as the secondary eduction medium, heating said hot carbonaceous shale in said further heating stage by means of hot flue gas produced in said burning stage, withdrawing the resulting flue gas from said further heating stage, and employing it as the purging medium in said purging stage, burning the further heated carbonaceous shale by means of fuel gas and air in said burning zone to obtain hot spent shale and hot flue gas, withdrawing the hot flue gas from said burning stage and employing it in said further heating stage, and heating said primary eduction medium consisting of lean shale gas and steam by direct heat exchange with said hot spent shale first in said second cooling stage and then in said first cooling stage.

2. A method for the recovery of shale oil from crushed oil shale which comprises employing a series of units wherein each unit within said series passes through a distinct and different stage of a complete cycle and changes simultaneously with the changes of each and every other unit, wherein each cycle comprises treating the shale successively in the following stages: (1) purging, (2) partial eduction, (3) complete eduction, (4) further heating, (5) burning, (6) first cooling and (7) second cooling, purging said oil shale in said purging stage with a purging medium consisting of hot flue gas produced in said further heating stage, partially educting shale oil and rich shale gas from the purged oil shale in said par-

tial eduction stage by means of a secondary eduction medium consisting of hot rich shale gas and steam produced in said complete eduction stage, withdrawing shale oil and rich shale gas from said partial eduction stage, separating said shale oil from said rich shale gas, further separating the rich shale gas into hydrocarbons and residual lean shale gas, completely educting shale oil and rich shale gas from the partially educted oil shale in said complete eduction stage by means of a primary eduction medium consisting of hot lean shale gas and steam produced in said first cooling stage, withdrawing said shale oil and rich shale gas and steam from said complete eduction stage, separating said shale oil from said rich shale gas and steam, employing said rich shale gas and steam in said partial eduction stage as the secondary eduction medium, heating said hot carbonaceous shale in said further heating stage by means of hot flue gas produced in said burning stage, employing the resulting flue gas from said further heating stage as the purging medium in said purging stage, burning the heated carbonaceous shale by means of fuel gas and air in said burning zone to obtain hot spent shale and hot flue gas, withdrawing said hot flue gas from said burning zone and employing it in said further heating stage, and heating said primary eduction medium consisting of lean shale gas and steam by direct heat exchange with said hot spent shale first in said second cooling stage and then in said first cooling stage.

3. A process according to claim 2 in which the eduction medium in each eduction stage is passed downwardly so as to permit recovery of liquid shale oil from the lower portion of the eduction zone.

4. A method according to claim 2 in which the hydrocarbons and lean shale gas are separated from the rich shale gas by absorption.

5. A method according to claim 2 in which more than two eduction stages are employed, the shale oil being removed from each of the stages, and the shale gas from the succeeding eduction stage being employed as the eduction medium in the preceding eduction stage.

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