United States Patent

[11] 3,619,405

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[21] Appl. No. **743,702**
[22] Filed **July 10, 1968**
[45] Patented **Nov. 9, 1971**

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[54] **GAS COMBUSTION OIL SHALE RETORTING WITH EXTERNAL INDIRECT GAS HEAT EXCHANGE**
4 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **208/11,** 201/27, 201/29, 201/34, 201/36, 202/215, 202/221
[51] **Int. Cl.** **C10g 1/00**
[50] **Field of Search** 208/11; 201/34, 29, 27, 36; 202/215, 109, 221

[56] **References Cited**

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ABSTRACT: A gas retorting system for recovering oil from shale including a vertical retort having a raw shale preheating zone at the top; an external circuit for cooling and separating product vapor and gas and an external circuit for heating cold recycle gas (from the top of the shale preheating zone) and reintroducing it into the bottom of the raw shale preheating zone.

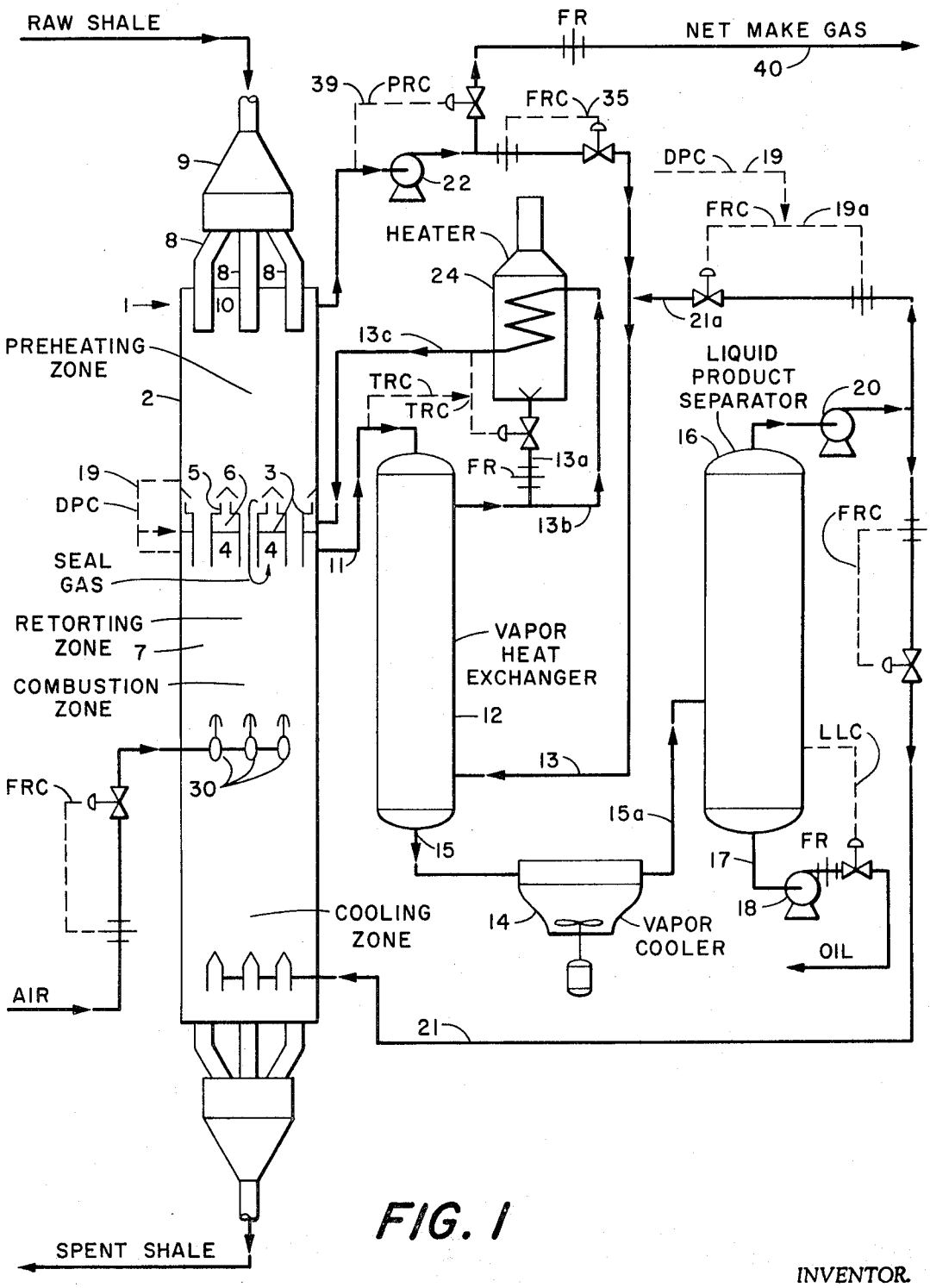


FIG. 1

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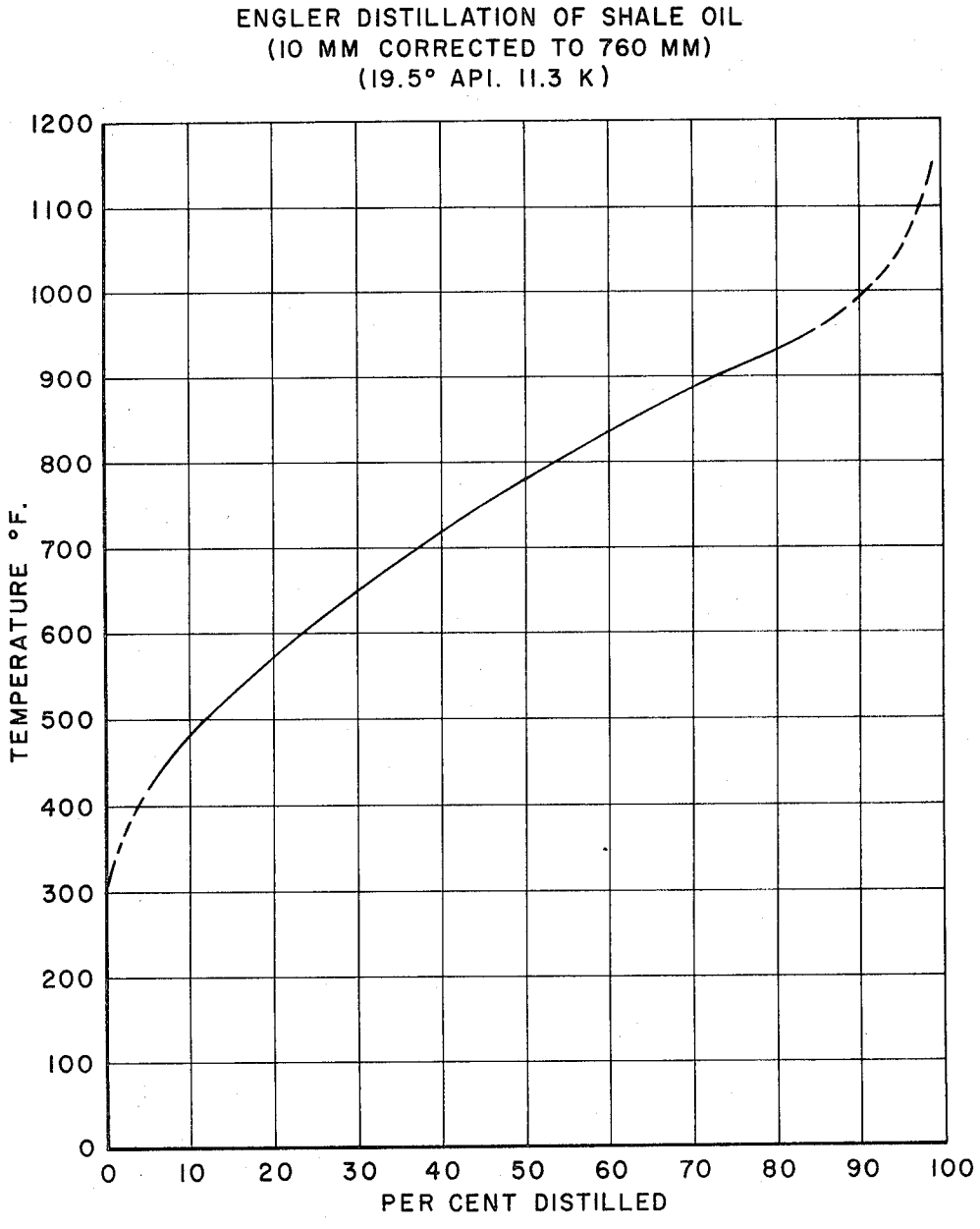


FIG. 2

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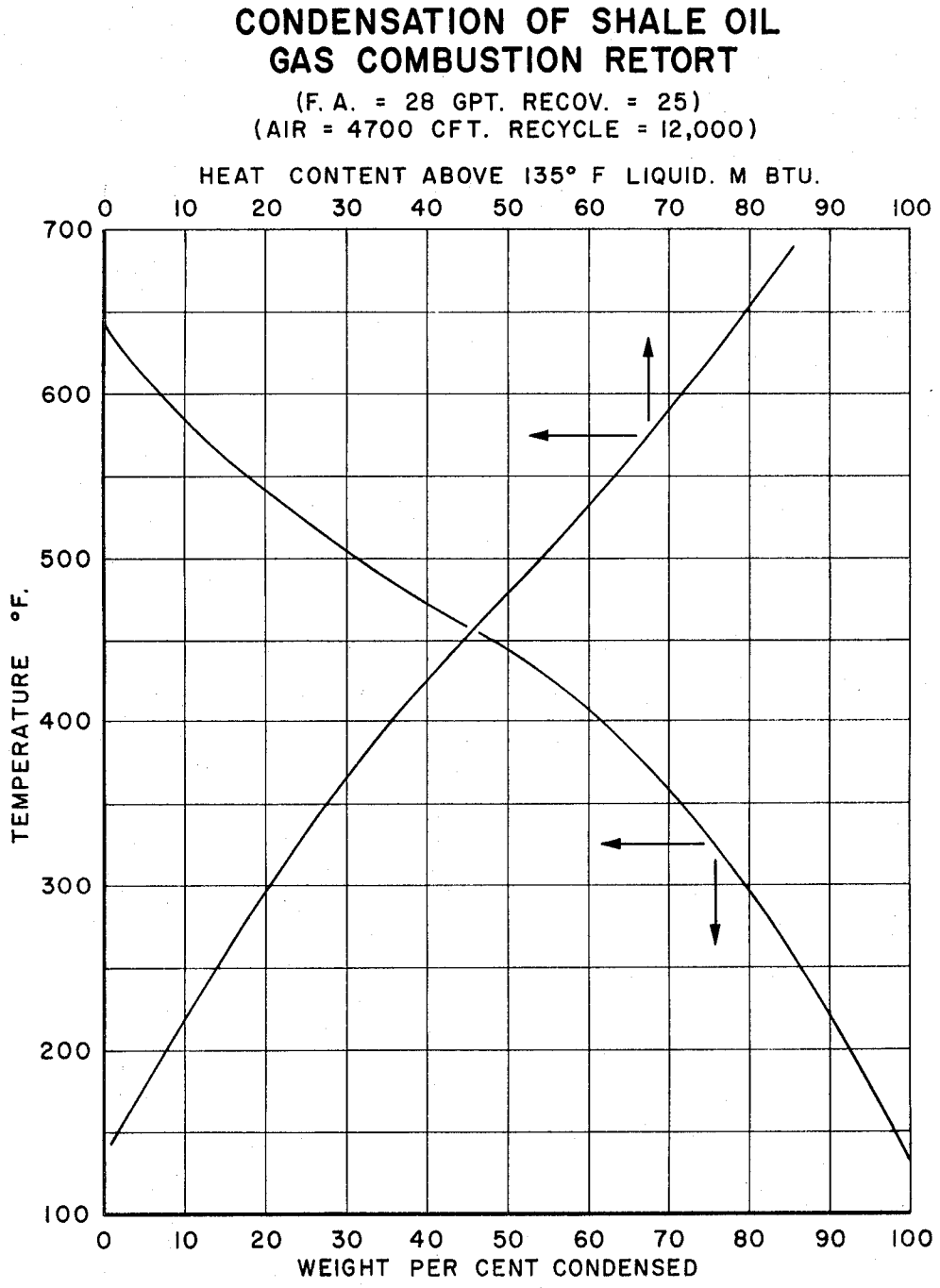


FIG. 3

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GAS COMBUSTION OIL SHALE RETORTING WITH EXTERNAL INDIRECT GAS HEAT EXCHANGE

Background

The simple Bureau of Mines gas combustion retort (e.g., U.S. Pat. Nos. 2,813,823 and 2,901,402) does not perform well enough on a large scale to be commercial, because shale oil condenses on the cold feed rock and refluxes back down into the retorting zone where the heavier ends are concentrated by redistillation of the lighter fractions. Then, the heavy tars and coke bind the shale together to form large agglomerates which hang up on the internals and distort the flows of air, recycle gas, and shale so badly as to seriously impair the efficiency of the retort and even force its shutdown.

It might appear possible to operate the process covered by U.S. Pat. No. 3,297,562 in such a manner as to accomplish essentially the results obtained from my process. This could be done by withdrawing all the product vapors from the retorting section through valve **67**, simultaneously bypassing the retorting section with sufficient hot gas from the combustion zone through line **96** to preheat the raw shale to the dew point temperature of the retort vapors, about 650° F. This would require that the flow of gases through the combustion zone be roughly twice the amount passing through either the retorting or preheating zone, necessitating an oversized combustion zone and considerably higher cost. Furthermore, the thermal efficiency of the process of that patent would be much below that of my process, requiring the use of considerably more air in situ which would cause excessive dilution of the retort product gas and lead to higher loss of shale oil product therein as uncondensed vapors.

SUMMARY OF THE INVENTION

This invention involves a gas combustion retort modified to withdraw the shale oil product while still predominantly vapor at elevated temperature and condense it externally with a net loss of only about 37 percent of its contained heat. Roughly one-fourth of the residue gas is burned to preheat the shale to offset this loss.

The process is carried out in a gas retorting system including a vertical retort having a raw shale preheating zone at the top of the retort; an external circuit for cooling and separation of product vapor and gas; and an external circuit for heating cold recycle gas (from the top of the shale preheating zone combined with noncondensable product gasses) and reintroducing it into the bottom of the shale preheating zone.

In the preferred system, the cold recycle gas is indirectly heated first in the product vapor heat exchanger, then indirectly in a fired heater. Cold gas from the final product separator is recycled to the bottom of the retort where it is preheated by the spent shale and then commingled with combustion air to control the flame temperature.

The purpose of preheating the raw shale is to prevent shale oil from condensing on the raw shale and refluxing down into the retorting zone, causing formation of heavy tars and coke which bind the shale into large agglomerates which impair efficiency.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified flow diagram of the preferred embodiment of the invention.

FIG. **2** shows the percent distillation as a function of temperature, for a typical shale oil.

FIG. **3** is a chart showing the percent of a typical shale oil condensed, within the retort, as it relates to temperature. It also shows the heat content of the shale oil within the retort as it relates to temperature.

DETAILED DESCRIPTION

Referring to FIG. **1**, the equipment includes a countercurrent gas combustion retort **1** similar to that developed by the Bureau of Mines at Anvil Points, Colorado. At the top of the retort is a raw shale preheating zone **2** separated from said retort by two approximately spaced tube sheets **3** through which pass conduits for the gravitational flow of shale from the preheating zone into the retorting zone **7**. These shale conduits extend some distance into the retorting zone to form a void space **4** below the lower tube sheet for the purpose of disengaging the product vapors from the shale and permit their easy withdrawal from the retort. Shielded conduits **5** extend upward from the top tube sheet for conveyance of preheating gas from the plenum chamber **6** between the two tube sheets upward into the raw shale preheating zone **2**.

The raw shale feed pipes **8** extend downward from the shale feed chamber **9** into the raw shale preheating zone a sufficient distance to from a suitable void space **10** for disengaging the cooled preheating gases for easy withdrawal and recycle.

The external circuit for the retorting zone **7** consists of an indirect vapor heat exchanger **12**, a vapor cooler **14**, a liquid product separator **16**, a liquid product pump **18**, a recycle compressor **20**, plus appropriate pipes and control instruments.

The external circuit for the shale preheating zone **2** consists of a recycle compressor **22** indirect, vapor heat exchanger **12**, a fired gas heater **24** for indirectly heating combined noncondensable product gases with gases recovered from the top of the preheating zone, plus appropriate pipes and control instruments.

In operation, raw shale is fed continuously via feed hopper **9** into the top of shale preheating zone **2**. It gravitates through the preheating zone then through the retorting zone **7**. After passing through the cooling zone at the bottom of the retort, the spent shale is discharged at a controlled rate from the bottom of the retort, indirectly controlling the raw shale feed rate.

Air is fed into the middle of the retort proper through a hang of distributors **30** embedded in the shale. Combustion of gases and residual coke on the shale in the vicinity of the air distributors supplies the heat required for retorting. Cold recycle gas is injected into the bottom of the retort proper through line **21** and flows upward countercurrent to descending spent shale recovering heat therefrom.

The preheated recycle gas commingles with the combustion air at the lower edge of the combustion zone to moderate the intensity of combustion and limit the flame temperature to substantially below the spent shale fusion or clinkering temperature (about 2,100° F.). The commingled recycle and combustion gases (about 1,100–1,400° F.) continue to flow upward countercurrent to the descending shale, surrendering heat thereto to effect preheating and retorting of the shale. In the retorting zone (1 to 3 feet above the combustion zone) the kerogen is decomposed and forms shale oil vapors. The noncondensable gases and shale oil vapors mix thoroughly and flow upward countercurrent to the descending raw shale surrendering heat thereto to bring the shale up to retorting temperature (about 900° F. max.), the gases and vapors themselves being cooled in the process to approximately their dew point, which will vary from about 550°–750° F. depending upon the source of shale and the operating conditions used. By dew point, I mean the temperature at which shale oil liquid begins to condense from the vapors.

The thus cooled gases and product vapors are withdrawn from the top of the retorting zone through line **11** at approximately their dew point and are further cooled externally in indirect vapor heat exchanger **12** and vapor cooled **14** to effect condensation of the shale oil vapors. The major part of this cooling is done by exchanging heat (in vapor heat exchanger **12**) with a second recycle gas stream (line **13**) which is used for preheating the raw shale to approximately the dew point of the gas-vapor mixture leaving the retorting zone, before the shale enters the retorting zone. The cooled mixture of shale oil liquid and noncondensable gases flows from the final cooler through line **15***a* into shale oil separator **16** from which the shale oil is pumped into storage on level control. Blower **20** compresses the gases from the shale oil separator delivering a

portion thereof as unheated recycle gas to the bottom of the retort on flow rate control through line **21**. The net product gas (from combustion and retorting) plus seal gas amounting to about 500 cubic feet per ton of shale feed is delivered to the shale preheating gas loop via line **21***a* which is on flow rate control **19***a* reset by a differential pressure control **19** which maintains a very slightly higher pressure (less than 3 inches water column) at the bottom of the shale preheating section than at the top of the retorting zone. This causes a slight flow of seal gas from the preheating section into the retort proper to prevent the flow of shale oil vapors into the shale preheating section.

The gases from the top of the preheating zone are recovered at a temperature approximating their dew point with respect to water, i.e., at a temperature of about 110°–160° F. A second blower **22** compresses these cold gases from the top of the shale preheating zone delivering a major portion thereof via a flow rate control **35** to combine with the remaining portion of noncondensable gases delivered through loop **21***a* to pass through vapor heat exchanger **12** then via line **13***b* through heater **24** into the bottom of the raw shale preheating zone **2** at about 600°–800° F., preferably 700°–750° F. A portion of this gas is used as fuel for the fired heater via line **13***a*. The net make gas is delivered offsite via line **40** on pressure control **39** which maintains essentially atmospheric pressure at the top of the raw shale preheating section.

Table I lists the compositions and other properties of various gas streams in the retorting zone. The make gas from the retorting zone (line **21***a*) includes the water contained in the feed air and that formed by combustion, in addition to that formed by decomposition of the kerogen. The sum of total water in the off gas from the preheating zone and the furnace fuel (lines **13***a* and **40**) also includes that water released in drying and dehydrating the raw shale. The net water leaving the retort is equal to that amount which would saturate the off gas from a single stage retort at 135° F. and 12.5 p.s.i.a. This is based on observations that the make gas from a typical gas combustion retort is thus saturated.

TABLE I

Gas Stream Properties

Modified Gas Combustion Retort

Component, SCF/T	Make Gas Retoring Zone	Off Gas Preheating Zone	Furnace Fuel Gas
H_2	306	231	75
CO	216	163	53
C_1–C_4	172	130	42
C_5 +	72	54	18
N_2	3,722	2,810	912
CO_2	1,594	1,203	391
H_2O	476	1,257	309
Total	6,558	5,848	1,800
Pounds	527	440	138
Pounds/mol	30.5	28.5	29.1
LHV/B.t.u./SCF	102.0	86.3	91.0
Heat Content B.t.u./MSCF			
135° F.	0		0
300° F.	3,560		3,530
500° F.	8,140		8,070
700° F.	13,160		13,010

Table II lists the fractional composition and ideal "K" values (vapor-liquid equilibrium constants) for a typical shale oil with gravity and distillation shown in FIG. 1. Table II also lists "K" values for fractions of the retort off gas. These "K" values were used for calculating the shale oil condensation curve shown in FIG. 3.

TABLE II.—PROPERTIES OF TYPICAL SHALE OIL
Fractional composition (Per ton of shale)

Fraction	MBP	Gal.	#/Gal.	Pounds	#/Mol	Mol
A	370	1.25	6.83	8.53	145	.0588
B	450	1.25	7.076	8.85	174	.0509
C	525	2.50	7.296	18.25	205	.0890
D	610	2.50	7.505	18.77	248	.0757
E	715	5.00	7.752	38.76	305	.1270
F	830	5.00	7.989	39.95	380	.1052
G	930	5.00	8.212	41.06	456	.0902
H	1,020	1.25	8.386	10.49	530	.0198
I	1,120	1.25	8.570	10.72	620	.0173
Total	775	25.00	7.815	195.38	308	.6339

Ideal V–L equilibrium constants at 12.5 p.s.i.a.

Fraction	Temperature, ° F. 250	350	450	550	650
A	.16	.88	3.2	8.8	20.
B	.038	.26	1.2	3.8	10.
C	.0088	.080	.42	1.6	3.6
D	.0011	.015	.11	.52	1.8
E	.00010	.0020	.020	.12	.56
F	.00002	.00020	.0020	.018	.10
G		.00003	.0003	.0032	.024
H			.00004	.0004	.0044
I				.00005	.0005
C_4 and L	Inf.	Inf.	Inf.	Inf.	Inf.
C_5–C_7	4.8	14.	34.	Inf.	Inf.
C_8+	.75	3.1	9.2	22.	42.

The following example shows typical specifications, operating conditions, and results.

EXAMPLE

(Basis: 1 Ton 28 Fischer Assay Shale)

	Pounds Per Ton	Flow Rate Per Ton	Temp. °F.
Raw shale to hopper **9**	2,000		60
Spent Shale	1,587		400
Shale oil product (line **17**)	195	25 gal.	135
Air rate to **30**	360	4,700 s.c.f.	120
Line **40**	440	5,848 s.c.f.	150
Line **13**	1,695	22,058 s.c.f.	150
Line **13***a*	138	1,800 s.c.f.	500
Line **13***c*	1,557	20,258 s.c.f.	717
Line **21**	964	12,000 s.c.f.	150
Line **31**	1,404	20,848 s.c.f.	135
Line **31***a*	1,128	15,000 s.c.f.	150
Line **21***a*	567	7,058 s.c.f.	150
Line **15**	1,726		322
Line **15***a*	1,726		135
Line **11**	1,726	19,298 s.c.f.	650
Seal gas: 500 s.c.f.			

The only drawback of the system of FIG. **1** is the extra cost over the simple Bureau of Mines version. To help offset the higher cost, this modified design will give a higher yield from elimination of refluxing and permitting a higher recycle gas rate. Also, this modified version is capable of retorting rich shale, assaying up to 40 gallons per ton or more and particles smaller than one-fourth inch which cannot be processed in the Bureau of Mines retort.

The improved control of the temperature pattern in the retorting zone will permit a reduction in air rate which enhances the yield. The combination of less mineral carbonate decomposition plus the recycling of a drier cooling gas results in less hydration of spent shale. This, together with higher recycle gas rate, lowers spent shale temperature to lessen disposal problems.

What is considered new and and inventive in the present invention is defined in the hereunto appended claims, it being

understood, of course, that equivalents known to those skilled in the art are to be construed as within the scope and purview of the claims.

1. In a gas combustion process for recovering oil from oil shale comprising the steps of passing said shale downwardly moving bed through a preheating zone, a retorting zone, a combustion zone, and a spent shale cooling zone, passing hot gasses including combustion gases upward from said combustion zone through said retorting zone, and recovering the oil and vapor products of the retorting of said shale, the improvement which comprises:

a. removing the product vapors from the upper portion of said retorting zone;

b. cooling said product vapors of step (a) by passing said product vapors in indirect heat exchange with the combined gases of step (e) hereinafter described;

c. separately recovering shale oil and noncondensable gases from said colled product vapors;

d. recycling a portion of said noncondensable gases to the bottom of said spent shale cooling zone;

e. combining the remaining portion of said noncondensable gases with the gases recovered from the top of said preheating zone;

f. heating said combined gases of step (e) in two stages with said first stage being an indirect hear exchange with the product vapors of step (b) and the second stage being an indirect heat exchange in a gas fired heater utilizing a part of said combined gases as fuel for said heater, and introducing said heated gases into the bottom of said preheating zone; and

g. maintaining a higher pressure at the bottom of this shale preheating zone than at the top of the retorting zone to aid in preventing the product vapors at the top of the retorting zone form mixing with the combined gases of step (f).

2. The process of claim 1 wherein the product vapors of step (a) are removed at a temperature approximating their dew point.

3. The process of claim 2 wherein the combined gases of step (f) are heated to about 600°–800° F. before introducing them into the bottom of said preheating zone.

4. The process of claim 1 wherein the pressure differential described in step (g) is about 3 inches of water.

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