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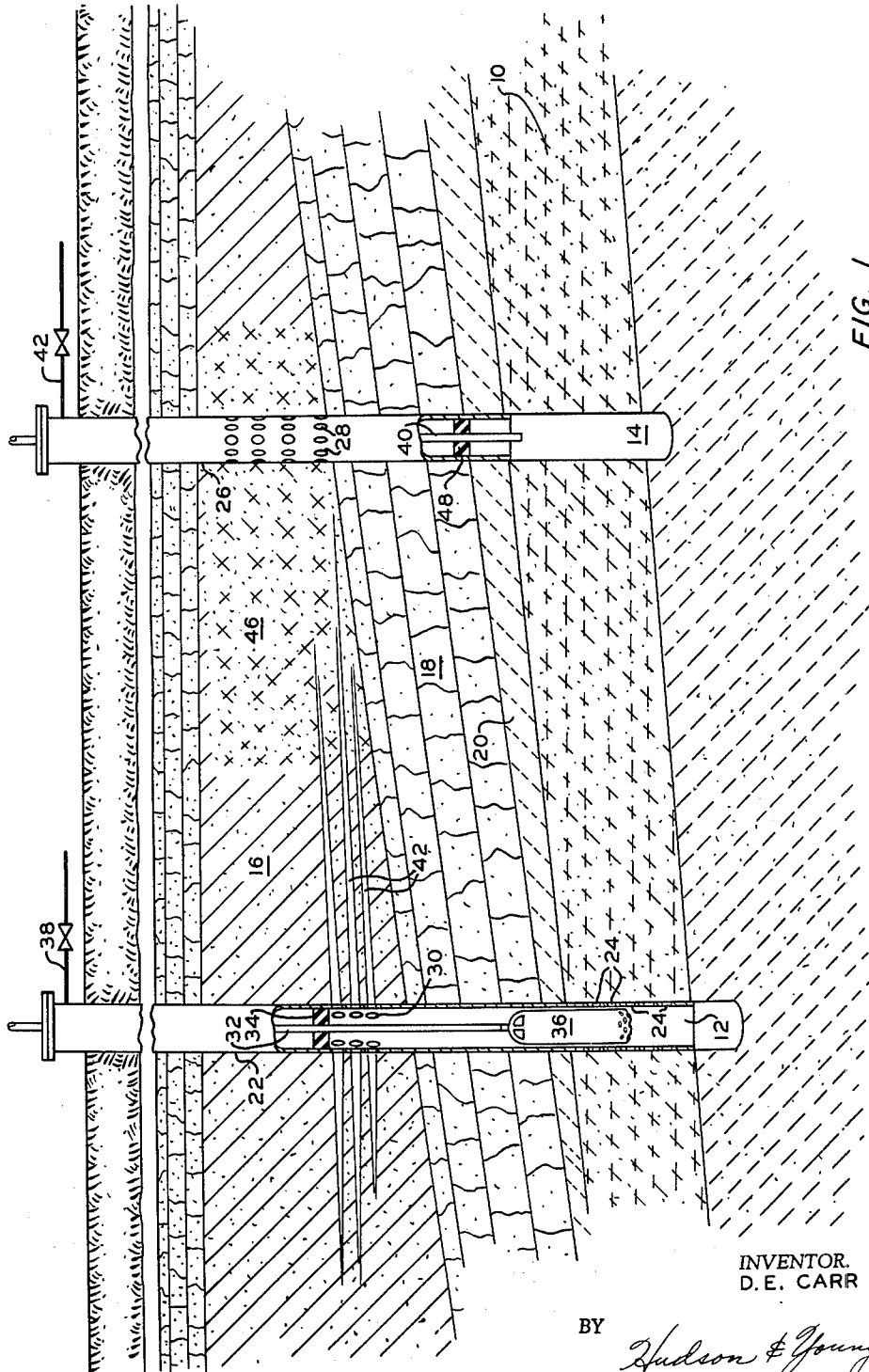
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3,072,187

PRODUCTION AND UPGRADING OF HYDROCARBONS IN SITU

Filed May 12, 1960

3 Sheets-Sheet 1



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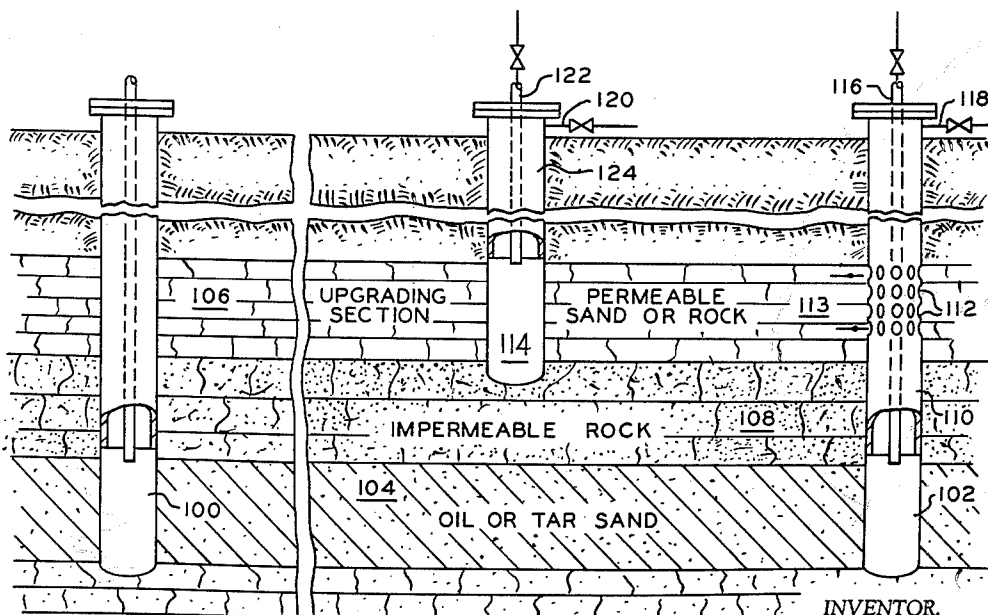
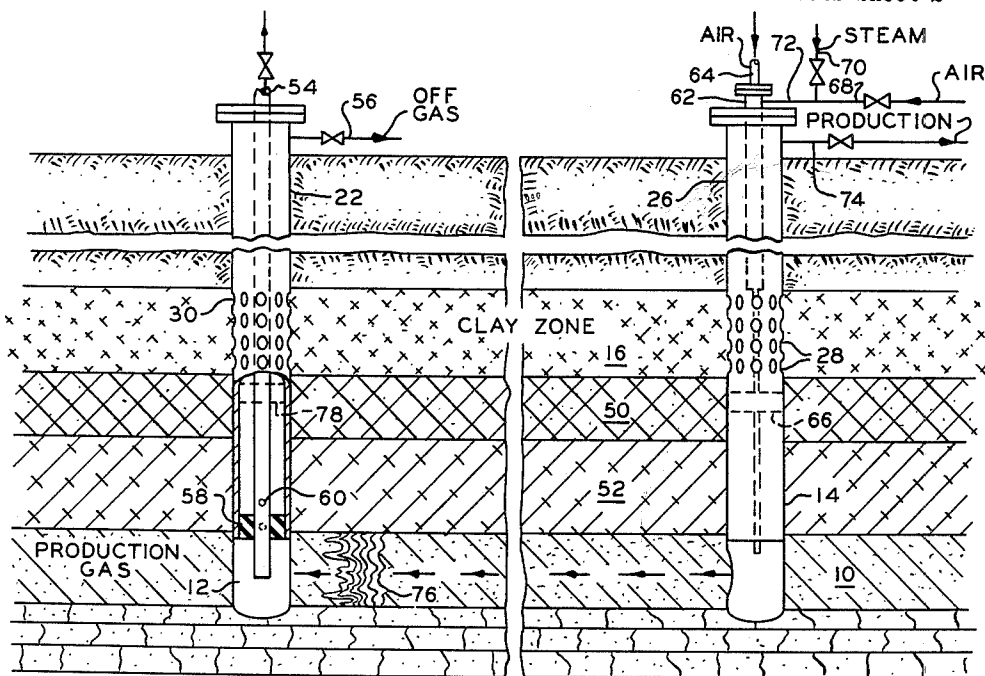
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

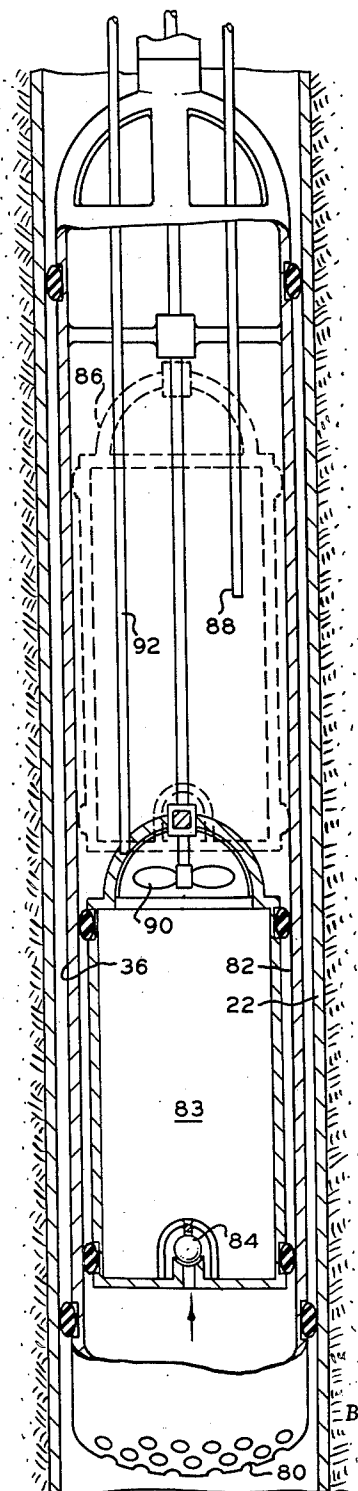


FIG. 3

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3,072,187

PRODUCTION AND UPGRADING OF HYDROCARBONS IN SITU

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18 Claims. (Cl. 166—11)

This invention relates to a process for the production and upgrading of hydrocarbons from and in subterranean strata.

Crude oils and other hydrocarbons in the form in which they are recovered from underground strata usually require upgrading by catalytic or other refining treatment in aboveground equipment in order to render them suitable for specific uses. This invention is concerned with a method of upgrading such hydrocarbons before recovering them aboveground.

Accordingly, it is an object of the invention to provide a process for producing and upgrading hydrocarbons from and in subterranean strata. Another object is to provide an in situ combustion process for producing and upgrading hydrocarbons before bringing them to the surface. A further object is to utilize the heat of in situ combustion in a carbonaceous stratum, usually dissipated in adjacent strata, to upgrade hydrocarbons produced by the in situ combustion step. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises producing hydrocarbons in liquid and/or vapor form from a subterranean stratum by in situ combustion whereby an adjacent stratum is heated by transfer of heat from the hot combustion area, this adjacent stratum containing catalytic material, and passing the produced hydrocarbons thru the hot catalytic material in the adjacent stratum to upgrade the produced hydrocarbons before passing them to the surface.

According to another embodiment of the invention a subterranean carbonaceous stratum is produced to leave a hot permeable stratum containing silica, alumina, and other natural catalytic materials usually found in petroleum rock or sands. Another carbonaceous stratum above or below the hot burned out sand is then produced by in situ combustion and the produced hydrocarbons in vapor and/or liquid form are passed thru the hot stratum so as to upgrade the hydrocarbons by catalytic cracking, reforming, or other refining or upgrading reaction before passing the same to the surface for further treatment and/or recovery of desired fractions therefrom.

In a further embodiment of the invention, catalytic material in the form of clay, bauxite, or synthetic silica and/or alumina type catalysts, which may contain the usual cracking catalyst promoters, are deposited underground in a highly permeable stratum or in fractures formed therein, and hydrocarbons produced by in situ combustion in an adjacent or nearby stratum are passed thru the deposited catalyst after the same is heated by the in situ combustion step.

During the early phase of the in situ combustion process, production by-passes the catalyst bed until the same is heated to adequate temperature to effect the desired upgrading. The temperature of the catalytic stratum should be of the order of about 500 to 1000° F. and preferably in the range of about 700 to 950° F.

In some areas a hydrous clay is found in a stratum adjacent or close to an oil sand or other carbonaceous stratum amenable to production by in situ combustion. The in situ combustion process transfers heat thru the intervening stratum to the clay stratum so as to dehydrate and render the clay stratum gas permeable. After producing a substantial section of the carbonaceous stratum,

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the adjacent clay is dehydrated and raised sufficiently in temperature to serve as a catalytic treating chamber or zone. By fracturing the clay stratum before initiation of the in situ combustion from a well opposite the ignition well toward the ignition well, the dehydrated section of the clay can be utilized as a catalytic treating zone early in the in situ combustion step of the process. It is also feasible to heat the desired clay section adjacent the ignition borehole by burning natural gas or other fuel gas therein adjacent the clay stratum. One can also utilize a dehydrated clay stratum adjacent a coal or petroleum stratum after producing the carbonaceous stratum by in situ combustion.

In accordance with another embodiment of the invention, a carbonaceous stratum is produced by in situ combustion to leave a hot, burned out sand or rock stratum, a nearby stratum above or below the resulting hot stratum is produced by in situ combustion, and the hot produced vapors are passed thru a restricted section of the hot burned out stratum to catalytically upgrade same. In this manner the length of travel thru the hot catalytic material (sand or rock) is controlled by controlling the length of path thru the hot stratum so as to control the contact time therein and more efficiently upgrade the hydrocarbon material.

A more complete understanding of the invention may be had by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation thru earth strata with an arrangement of wells for producing and upgrading a carbonaceous stratum; FIGURE 2 is a similar view showing an arrangement of equipment for regenerating a clay treating zone; FIGURE 3 is a fragmentary elevation in partial section of apparatus in the production well of FIGURE 1 for pretreating produced liquid hydrocarbons, and FIGURE 4 is a similar view to FIGURE 1 illustrating another embodiment of the invention.

Referring to FIGURE 1, a carbonaceous stratum 10 is penetrated by wells 12 and 14. The wells also penetrate a hydrous clay zone 16 separated from oil sand 10 by intervening thin strata 18 and 20. Well 12 is cased thru stratum 10 by casing 22 and the casing is perforated within stratum 10 at 24. Well 14 is cased to the upper level of stratum 10 by casing 26. Both casings are perforated within clay zone 16 by perforations 28 and 30.

Well 12 is provided with tubing 32 extending thru a packer 34 to treating device 36. A valved line 38 connects with casings 22 above ground for introducing or withdrawing gases from the well annulus. Well 14 is similarly equipped with well tubing 40 and valved line 42.

Before initiating in situ combustion around well 14 in stratum 10, a fracture system 42 is formed in clay zone 16 thru casing 22 by any suitable method. It is essential to early initiation of the upgrading step that fractures 42 extend at least 1/2 and preferably 3/4 of the distance thru clay zone 16 toward well 14. It is also desirable to dry out the stratum 10 between the wells in the area to be produced by in situ combustion. This can be done in conventional manner by injecting air thru well 14 and producing the water and gas driven from the stratum 10 thru well 12. This preliminary step avoids production of salt water with the produced oil. However, if dewatering or drying of the formation is not practiced, in situ combustion establishes around well 14 and driven toward well 12 by injection of air thru well 14 results in the combustion gas and vaporized hydrocarbons driving a water front thru stratum 10 toward well 12. The produced liquids are treated in well 12 by desalting and dewatering device 36 before passing the resulting hydrocarbons by pumping means (not shown) upwardly and into fractures 42 from which the hydrocarbons pass thru dehy-

drated clay 46 before passing to the annulus of well 14 thru perforations 28. It is essential in this type of operation to provide packer 48 in casing 26 of well 14 around tubing 40. Air is injected thru tubing 40 to sustain and drive the combustion zone thru the formation and the produced and upgraded hydrocarbons are withdrawn from the well via the annulus of well 14 and conduit 42 from which they are passed to separation means not shown. During the early phase of the in situ combustion step, production is passed directly out of well 12 until sufficient clay in zone 46 is dehydrated and raised to an elevated temperature sufficient for catalytic upgrading of the produced hydrocarbons when passed therethru.

In the event stratum 10 is dewatered and dried out prior to initiation of the in situ combustion process around well 14, desalting and dewatering device 36 is omitted from well 12 and the produced hydrocarbons are passed directly thru fracture system 42 into hot clay zone 46.

FIGURE 2 shows a carbonaceous stratum 10 penetrated by wells 12 and 14, as in FIGURE 1. In this embodiment of the invention, a clay zone 16 has been previously dehydrated and heated by in situ combustion effected within adjacent stratum 50. In other words, stratum 50 is a burned out sand or rock formerly containing crude oil or other hydrocarbons but produced by in situ combustion in conventional manner. During this process heat not only dehydrates and renders porous hydrous clay 16 but also transfers heat to carbonaceous stratum 10 which is a permeable oil sand or other stratum producible by in situ combustion. Intervening stratum 52 separates burned out sand 50 from stratum 10. Well 12 is cased to the top of the producing stratum 10 and is provided with tubing 54 and valved line 56 connecting with the well casing. At the stage of the process being illustrated, a packer 58 is inserted in the lower end of the well casing at the upper level of stratum 10. A passageway 60 is provided in tubing 54 above packer 58.

Well 14 is provided with tubing 62 and an inner air line 64 extending to below packer 66 which is positioned intermediate hot clay zone 16 and producing zone 10. Air line 68 and steam line 70 connect with tubing 62 via line 72. Production is recovered thru line 74 from which it is passed to separation means not shown.

In operation with the embodiment of the invention shown in FIGURE 2, clay zone 16 is in hot condition and in situ combustion is established in conventional manner around well 12. The resulting hot combustion zone 76 is moved thru stratum 10 from well 12 to well 14 by injecting air containing between about 1.5 and 3 percent by volume of fuel gas (such as propane) thru line 64. This so called "inverse air injection" in situ combustion produces all of the hydrocarbons in vapor form because of the passage of the produced hydrocarbons thru the hot sand or rock within and behind the combustion front. The produced hydrocarbons enter tubing 54 and, because of the closure of line 56 and tubing 54 by the valves therein at the well head, produced gases enter the tubing-casing annulus thru passageway 60 and thence into clay zone 16 via the perforations 30 in the casing of well 12. The produced vapors are substantially upgraded by cracking and reforming as they pass thru the hot clay on their way to perforations 28 in the casing of well 14. The upgraded hydrocarbons are recovered thru line 74, lines 68 and 70 being closed by suitable valves therein.

In the event the clay in zone 16 becomes partially plugged by carbonaceous deposit formed during the upgrading therein, the flow of produced hydrocarbons is passed directly from the well 12 thru tubing 54 by opening the valve therein at the well head and the clay is regenerated by injecting a mixture of air and steam thru lines 68 and 70, respectively. In this manner, the regeneration gas passes thru clay zone 16 and off-gas passes into the annulus of well 12 where it is recovered thru line 56. If desired, a packer 78 may be positioned around tubing 54 just below clay zone 16 and above passageway

60. However, this is not essential, as pressure in tubing 54 and in line 56 can be controlled by injection pressure so that regeneration off-gas passes thru line 56 and production passes thru tubing 54 during the regeneration step with little mixing. After a short regeneration period which reduces the coke deposit in the clay zone and substantially restores the original permeability thereof, the flow of regeneration gas is terminated and the system is returned to the upgrading phase of the process wherein production passes thru the clay zone and the upgraded hydrocarbon material is recovered thru line 74.

While only two wells are shown in FIGURES 1 and 2, it is to be understood that these wells represent two parallel lines of wells or a central well and one well of a ring of surrounding wells with production being effected therebetween.

Referring to FIGURE 3, oil enters the perforated bottom 80 of bucket 82 in casing 22 and rises into the lower inner bucket 83 thru check valve 84. The inner bucket is then raised to its upper position shown by dotted lines 86 where water is added by way of pipe 88. Agitator 90 is rotated to mix the oil and water and the water is then permitted to settle to form a lower water phase and an upper oil phase after stopping the agitator. A volume of water equal to that added thru pipe 88 is removed via pipe 92. The desalted crude is then removed by a pipe (not shown) located behind pipe 92. The desalted crude is then injected into the fractured zone 42 of FIGURE 1 by pumping means (not shown) and it then passes thru hot permeable clay zone 46 as hereinbefore disclosed.

Referring to FIGURE 4, wells 100 and 102 penetrate carbonaceous strata 104 and 106, separated by intervening stratum 108. Stratum 106 is originally a carbonaceous stratum amenable to production by in situ combustion. This producible stratum is produced by in situ combustion, leaving the sand or rock at a temperature in the range of about 500 to 1090° F. Stratum 104 is then produced by in situ combustion, either by direct drive thru well 100 or by inverse injection thru well 100, to move a combustion zone established around well 102 toward injection well 100. In either event, the produced hydrocarbons pass up casing 110 and thru perforations 112 therein into hot stratum 106 toward well 114 spaced more closely to well 102 than is well 100 to provide a catalytic contacting section 113 of predetermined length. Well 114 is preferably spaced a distance from well 102 in the range of about 10 to 30 feet so as to provide a readily controllable upgrading section. A ring pattern of wells 114 around well 102 can be utilized to advantage in upgrading the hydrocarbons produced in stratum 104.

After a substantial period of upgrading, sufficient coke is laid down in the catalytic sand or rock to reduce the catalytic effectiveness of the sand and render it desirable to burn the coke off the stratum. This is done by passing production from stratum 104 thru tubing 116 and injecting O₂-containing gas thru either conduit 118 or thru one of conduits 120 or 122 leading thru casing 124 of well 114. The resulting combustion gas is then vented thru the other well opposite the O₂-injection well. After removing substantially all or most of the coke from the upgrading section of stratum, the flow of O₂-containing gas is cut off and produced hydrocarbons are again passed thru the upgrading section.

In the event stratum 106 is a cold, permeable sand or rock, upgrading section 113 can be readily heated to any suitable temperature in the range of 500 to 1000° F. or higher by injecting a premix of air and fuel gas thru this section, such as from well 102 to well 114, igniting the premix on the face of the sand in well 114 and continuing the injection, whereby a synthetic combustion front passes progressively thru the sand countercurrently to the flow of injected premix so as to heat the sand to the desired temperature. This heating step prepares the sand or rock for the upgrading step. It is also feasible to reheat the sand or rock in section 113 by this method in the event

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the sand falls below the desired temperature for the upgrading desired. This step of injecting premix can also be utilized to move a combustion front thru the stratum after coke deposit thereon to remove the coke. The premix is regulated to contain from about 1 to about 3 or 4 volume percent of fuel gas, such as propane, L.P.G., or natural gas.

The following examples are set forth to illustrate the invention but are not to be interpreted as unnecessarily limiting the invention.

EXAMPLE I

A Western Kansas sour crude normally containing 0.57 weight percent sulfur has an A.P.I. gravity of 33.5 and a salt content of 22 pounds per 1,000 barrels. This crude has the distillation range and properties and comprises the products shown in Table I.

Table I

Fraction	Crude	Gasoline	Kerosene	Gas oil	Residue	Loss
Boiling range, ° F.		1 400	400-525	525-650	650+	
Volume percent of crude	100.0	27.5	12.9	11.5	47.6	0.5
API gravity at 60° F.	33.5	61.1	40.6	35.1	18.7	
Color	(2)	+22		-12		
Reid vapor pressure	3.8	7.9				
Distill.—First drop, ° F.		104	389	481	660	
5%		127	409	528	682	
10%		151	420	535	705	
50%		255	452	559	938	
90%		344	492	590	Crkd.	
95%		362	502	599		
End point		405	514	609		
Cloud point, F.				+2		
Pour point, F.	0			+5	+65	
Total sulfur, weight percent	0.57	0.025	0.079	0.10	0.88	
Salt, lb./1,000 bbl.	22					

¹ Initial boiling point. ² Dark brown.

In passing the above desalted crude thru a clay having the composition shown in Table II and maintained at a temperature in the range of 750 to 950° F., the resulting upgraded crude has the composition set forth in Table III.

Table II

Component	Weight percent	Component	Weight percent
SiO ₂	62.4	K ₂ O	3.14
Al ₂ O ₃	21.9	TiO ₂	1.4
Fe O ₃	5.0	Loss on ignition	6.90
MgO	1.72	Total	101.94
CaO	.55	CO ₂	<0.1
Na ₂ O	.35		

Table III

Fraction	Crude	Gasoline	Kerosene	Gas oil	Residue	Loss
Boiling range		1 400	400-525	525-650	650+	
Vol. percent of crude	100.0	35.6	16.0	15.4	32.0	1.0
API gravity at 60° F.	38.6	61.4	40.2	36.0	19.4	
Reid vapor pressure	4.2	9.0				
Distill.—First drop, ° F.		102	392	480	648	
5%		126	408	525	678	
10%		148	420	533	715	
50%		252	460	558	925	
90%		345	495	589	² Crkd.	
95%		360	505	597		
End point		402	518	608		
Total sulfur, weight percent	³ 0.22	0.0015	0.02	0.10	0.61	

¹ Initial boiling point.

² 72% distilled at 1,060.

³ After topping to 100° F. and caustic wash.

It is evident that considerably more gasoline, kerosene, and gas oil can be produced from the treated crude than from the original crude, without the upgrading feature. It is also apparent that considerable reduction in the sulfur content is achieved by the upgrading.

In producing a carbonaceous stratum by in situ com-

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bustion in an area in which no suitable catalyst is available, it is feasible to inject into a porous formation or into fractures therein a suitable catalytic material such as a synthetic clay, bauxite, or other silica and/or alumina containing materials. Silica, alumina, and silica-alumina gels, which may also contain zirconia, titania, thorium, magnesium, etc., in finely divided form may be utilized. The following example illustrates one method of depositing a synthetic catalyst bed in a formation.

EXAMPLE II

As the clay catalyst, an illite type clay from Fithian, Illinois, having the composition set forth in Table IV provides an excellent catalytic material for upgrading hydrocarbons.

Table IV

ANALYSIS OF ILLITE¹

Constituent:	Weight percent
SiO ₂	58.13
Al ₂ O ₃	16.45
Fe ₂ O ₃	8.60
MgO	1.96
CaO	2.46
Na ₂ O	1.89
K ₂ O	3.68
TiO ₂	.85
Loss on ignition	5.98
Total	100.00

¹ Dry basis, moisture (110° C.) 3.48 wt. percent.

This clay is injected into an extensive fracture system close to the carbonaceous stratum to be produced by in situ combustion and separated therefrom by an impervious thin layer of cap rock. Equal parts by weight of the clay and a one per cent aqueous solution of dodecylamine acetate are mixed and injected into the fractures, such as those illustrated as fractures 42 in FIGURE 1. These fractures are extended completely across from well 12 to well 14 by fracturing thru both of the wells until the fractures join. After deposition of the clay in the fractures, air is passed therethru so as to dry out the catalytic material. The air is heated so as to increase the rate of drying. After the drying step, in situ combustion is initiated around well 12 and a countercurrently moving combustion front is moved from this well to well 14 by injecting air containing two percent by volume of propane thru well 14. The produced hydrocarbons are in vapor form at a temperature of about 900 to 1000° F. and are passed thru fractures 42 containing the catalytic clay. During the early phase of the process, the upgrading is slight until the hot gases raise the temperature of the catalytic material to the required range of about 700 to 1000° F. After a relatively short period, such as a week or 10 days, heat from the hot rock around well 12 produced by the hot combustion travels upwardly to fractures 42 which are only a few feet from the hot combustion zone and this heat adds to the heat of the hot produced gases, thereby giving maximum effect to the catalytic process. Analysis of the crude produced by initial combustion and by catalytic upgrading in a synthetic clay deposit are set forth in Table V.

Table V

Fraction	Initial production			Bypassed production		
	Yield, vol. percent	API gravity	B.M.C.I.	Yield, vol. percent	API gravity	B.M.C.I.
Total crude		24			28	
Gasoline, I.B.P.						
400° F.	6.5	34.6	50	34.7	35.1	52
Distillate 400-650° F.	45.4	27.8	60	33.5	28.2	65
Gas oil 650-900° F.	46.6	18.7		30.3	17.4	
Residue 900° F. +	12.2			12.4		

¹ Solid (weight percent).

It may be noted that the catalytic treatment in the synthetic clay deposit increases the gravity of the crude by 4 points and the gasoline content from 6.5 to 34.7 volume percent of the crude produced.

It is also feasible to deposit the catalyst in a porous or fractured stratum contiguous to the carbonaceous stratum being produced. In this type of operation, utilizing inverse air injection technique, a packer is placed across the well where combustion is initiated at the upper level of the carbonaceous stratum. This packer should be positioned after a self-propagating combustion front is well established thru the vertical expanse of the stratum and several feet into the same from the ignition well. Thereafter, with the packer in place, produced gases are forced upwardly thru the adjacent stratum containing the catalytic material. In this manner of operation heat transfer to the catalytic zone is effected more quickly than with the catalytic zone spaced farther from the stratum being produced; however, it is more difficult with this method to assure flow of produced hydrocarbons thru any extended section of catalytic material. This is true because the burned out area behind the combustion zone is highly permeable and the produced gases pass thru this burned out area in preference to an extended catalytic zone contiguous therewith, at least until the gases arrive at the vicinity of the production well where they must divert thru the catalytic material because of the packer.

EXAMPLE III

When passing produced hydrocarbons from an in situ combustion operation thru a bauxite bed adjacent or near the producing stratum substantial improvement in the hydrocarbons is effected. This is illustrated by passing a West Texas crude thru a bauxite bed maintained at a temperature of about 700° F. Certain values for comparable gasoline boiling range fractions from (400° F.E.P.) the undesulfurized crude and the bauxite treated crude are set forth in Table VI.

Table VI

	Undesulfurized	Bauxite treated
0 cc. TEL.....	53.7	57.0
1 cc. TEL.....	60.0	67.6
3 cc. TEL.....	67.5	76.6
Total sulfur, weight percent.....	0.182	0.021
Mercaptan sulfur, weight percent.....	0.070	0.001

It can be seen that bauxite treating of crude greatly reduces the sulfur content while upgrading the constituents thereof.

When contacting the produced hydrocarbons with bauxite, the temperature should be maintained in the range of 650 to 800° F. The amount of cracking and reforming increases at the higher temperatures in this range.

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.

I claim:

1. A process for producing and upgrading hydrocarbons which comprises driving gaseous hydrocarbons out of a first hydrocarbon-containing stratum at one level into a first well therein by passing a driving gas therethru; passing said gaseous hydrocarbons from said first well directly into a second permeable stratum adjacent said first well containing at least one catalyst of the group consisting of silica and alumina; heating said second stratum to a temperature in the range of 500 to 1000° F; passing said hydrocarbons thru said second stratum while at said temperature to a second well therein so as to catalytically upgrade said hydrocarbons; and recovering the upgraded hydrocarbons from said second well.

2. The process of claim 1 wherein the driving step is

effected by in situ combustion of said first stratum wherein a combustion zone is moved thru said stratum between said first well and another well therein.

3. The process of claim 2 wherein combustion is initiated in said first stratum around said first well and combustion supporting gas is passed to the ignited area thru said first stratum from said another well to move the resulting combustion front from said first well to said another well.

4. The process of claim 1 wherein said second stratum comprises bauxite.

5. The process of claim 1 wherein said second stratum comprises clay.

6. The process of claim 1 wherein said catalyst is deposited in said second stratum by fracturing same and injecting a slurry of the catalytic material into the fracture.

7. The process of claim 6 wherein said slurry comprises clay.

8. The process of claim 6 wherein said slurry comprises bauxite.

9. A process for producing and upgrading hydrocarbons which comprises driving hydrocarbons from a hydrocarbon-containing stratum by in situ combustion wherein said stratum is ignited around a first well therein and the resulting combustion zone is moved toward a second well therein by feeding combustion-supporting gas to said zone thru one of said wells; and passing the resulting hot hydrocarbons in vapor form, before passing same to ground level, directly thru a subterranean permeable deposit of catalytic material selected from the group consisting of silica and alumina, at a temperature in the range of about 500-1000° F., so as to upgrade said hydrocarbons; and producing the upgraded hydrocarbons thru a well in said stratum.

10. The process of claim 9 wherein said hydrocarbons include sulfur-containing compounds in admixture therewith and a substantial proportion thereof is converted to H₂S by contacting same with said catalytic material.

11. The process of claim 9 including the steps of continuing the passing of hydrocarbons thru said deposit until a substantial deposit of coke forms thereon; then terminating the flow of hydrocarbons thru said deposit and contacting same with hot regenerating gas to remove a substantial proportion of said coke and heat condition said deposit; and again contacting the hot deposit with said resulting hot hydrocarbons.

12. The process of claim 9 wherein said deposit of catalytic material comprises an initial carbonaceous stratum in hot condition resulting from producing same by in situ combustion.

13. The process of claim 9 wherein said hydrocarbons contain a substantial amount of sulfur, said catalytic material consists essentially of bauxite, and said temperature is maintained in the range of 650 to 800° F.

14. A process for producing and upgrading hydrocarbons subterraneously comprising heating a restricted section of catalytic, permeable, first stratum adjacent a production well therein to a temperature in the range of 500 to 1000° F.; producing hydrocarbons by in situ combustion in a carbonaceous second stratum near said first stratum so as to drive said hydrocarbons into said production well; passing resulting produced hydrocarbons from said production well directly thru the resulting hot adjacent section of said first stratum so as to upgrade same; and recovering the upgraded hydrocarbons thru at least one offset well in said first stratum relatively close to said production well.

15. The process of claim 14 wherein said first stratum is a hot stratum resulting from producing hydrocarbons by in situ combustion therein.

16. The process of claim 14 wherein said in situ combustion is effected by igniting said second stratum around said production well and injecting combustion-supporting gas thru an injection well remote from said production well to move a combustion front thru said second stratum

from said production well toward said injection well; and said first stratum is heated by conduction from the hot second stratum.

17. The process of claim 14 wherein said restricted section is heated by passing a combustible mixture of air and fuel gas therethru from one to the other of said wells and said mixture is ignited in said other well, whereby a synthetic combustion front moves thru said section to said one well to heat the intervening stratum.

18. The process of claim 17 wherein upgrading deposits coke on said section, flow of production therethru is cut

off, said coke is burned off with O₂-containing gas, and while hot from the coke removal step flow of production is again passed therethru.

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