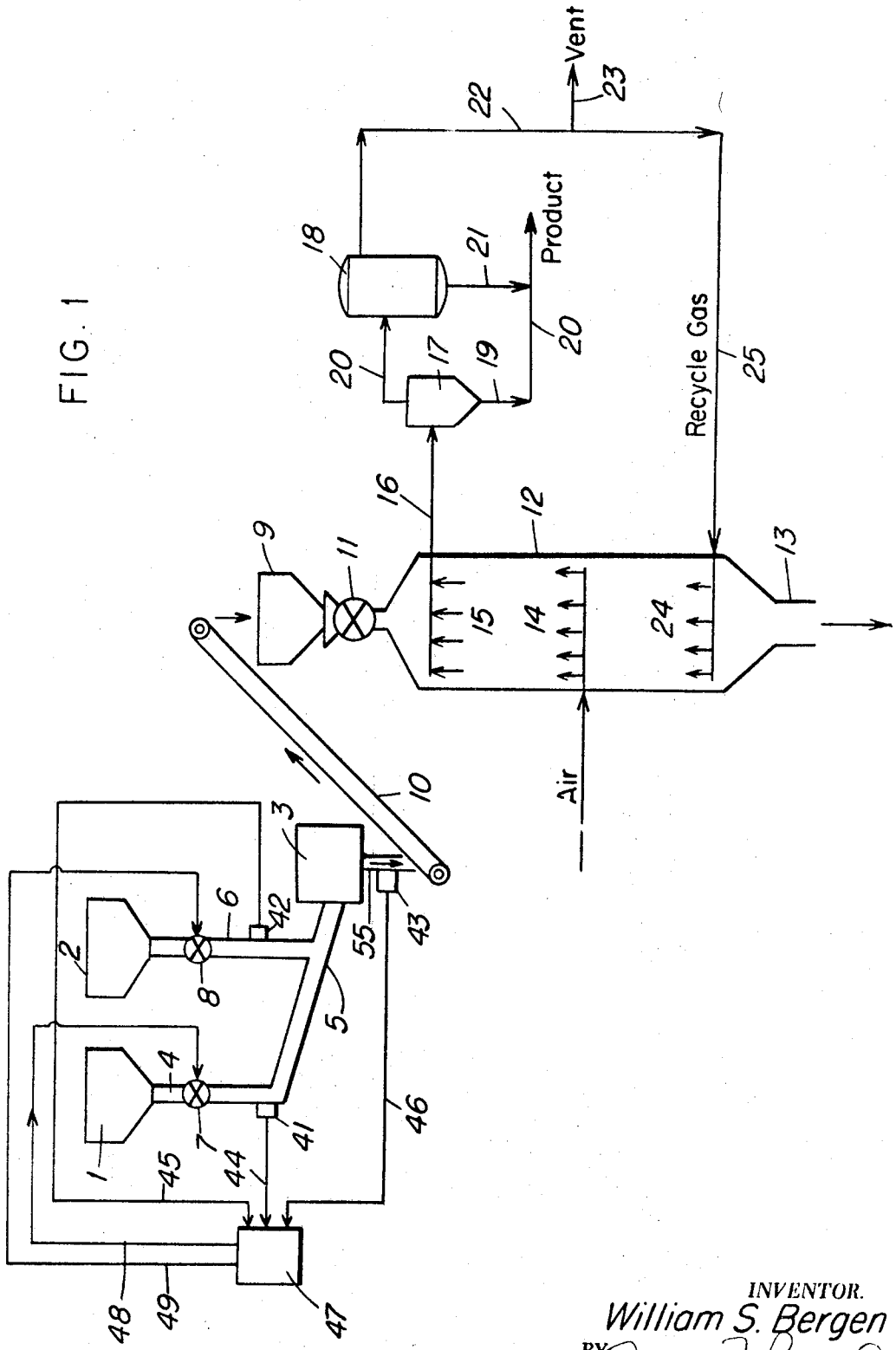
April 6, 1971 W. S. BERGEN 3,574,087

METHOD AND APPARATUS FOR RETORTING OIL SHALES

Filed Oct. 1, 1968 2 Sheets-Sheet 1

FIG. 1

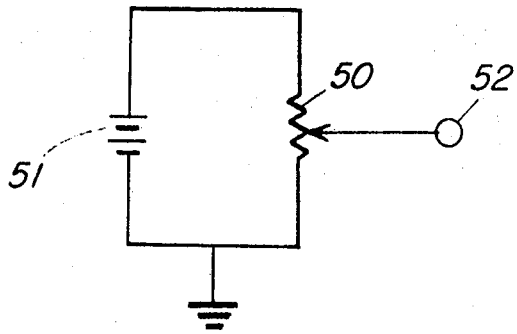


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METHOD AND APPARATUS FOR RETORTING OIL SHALES

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FIG. 2



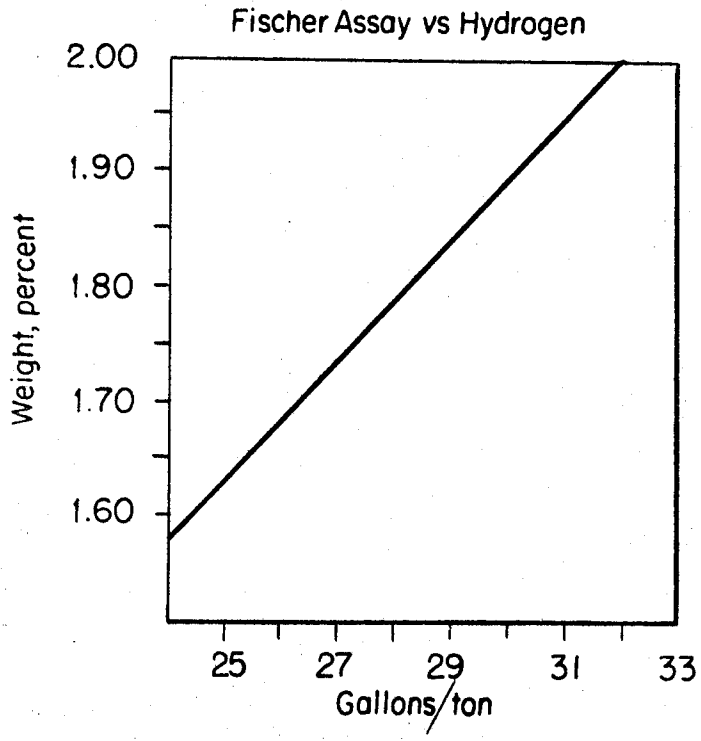


FIG. 3

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3,574,087

METHOD AND APPARATUS FOR RETORTING OIL SHALES

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Filed Oct. 1, 1968, Ser. No. 764,130
Int. Cl. C10q 1/02
U.S. Cl. 208—11 16 Claims

ABSTRACT OF THE DISCLOSURE

A system for retorting oil shales known as relatively lean and relatively rich oil shales is described wherein the shales are mixed to provide an oil shale having a general or average Fischer assay oil content in the range of from about 15 to about 36 gallons per ton and retorting the mixture thus formed in a gas combustion retort under conditions to recover higher yields of oil products than would be obtained when processing each of the different oil shales separately.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention is concerned with the processing of oil shales as a downwardly moving bed of shale particles in a gas combustion retort.

Description of the prior art

In a gas combustion retort, oil shale particles having a size of from about 0.5 to about 3 inches average mean diameter are passed downwardly through the retort as a compact bed to contact upwardly moving gas. The shale particles are preheated by gas and vapors in the upper section of the retort and then contact hot combustion gas in an intermediate section of the retort. In the combustion section, a portion of the hydrocarbons in the recycle gas is burned to heat the gas and the kerogen in the shale is thermally decomposed above the combustion section to produce hydrocarbon vapors. The vapors pass upwardly through the shale to the upper section of the retort and become cooled by the descending shale to form a mist or fog. The hydrocarbon mist is removed from the retort and separated as liquid from gaseous constituents. A portion of the separated gas is recycled to the bottom section of the retort to cool the descending shale therein as the recycle gas passes upwardly through the retort. Thus the gas passing upwardly through the retort functions as a shale heating and cooling medium as well as a scavenging means for removing oil product from the retort.

Prior to this invention, it has been extremely difficult to process oil shale having a Fischer assay greater than about 36 gallons per ton in a gas combustion retorting process. When processing rich oil shale, the retort becomes flooded with condensed oil above the combustion zone. The accumulated oil becomes excessively heated by upwardly moving gas and tends to agglomerate and form coke or clinkers which will bridge within the retort. This then causes a reduction and eventual stoppage of shale flow within the retort due to the bridging within the retort.

It has been proposed to reduce oil flooded by reducing oil concentration in the gas through the introduction of additional combustion air and recycle gas into the retort. The additional air was expected to increase vaporization of the oil above the intermediate combustion zone with the formation of a mist in the upper portion of the bed prior to exit from the retort. Further, it was expected that the additional recycle gas would assist in controlling undesired excessive temperatures from developing in the combustion zone while effecting a further reduction in the concentration of oil in the gas. However, it has been found that the flooding problem encountered with rich oil shale has not been satisfactorily reduced by operating in this manner. It is speculated that due to the increased gas velocity, the liquid oil mist particles was caused to impinge with greater force on the downwardly moving shale particles and thus to adhere and concentrate thereon. Further, the increased amount of air was found to cause combustion of kerogen decomposition products and thus a corresponding reduction in yields.

A method for successfully processing rich oil shales offers great economic advantage. It would permit reducing mining costs and material handling costs as compared with those obtained by processing relatively lean shale. Furthermore, it is desirable at this stage of the art to process oil shale by gas combustion retorting since this process has been made a more thermally efficient process for effecting kerogen decomposition and recovery from the shale in the form of a fog or mist. Removal of the oil product as a mist rather than as a vapor offers advantages since the oil product can be recovered by simple mechanical means such as cyclones and/or an electrostatic precipitator may be employed in combination therewith without the need for vapor cooling steps. The gas combustion retorting process therefore offers some distinct advantages over other known arrangements.

SUMMARY OF THE INVENTION

It has now been found that by mixing rich oil shale with relatively lean oil shale to obtain an average Fischer assay of between about 15 gallons per ton and about 36 gallons per ton that the gas combustion retorting of the resultant mixture can be accomplished without encountering the heretofore described flooding and associated problems within the retort. Further, it has been found that significantly increased yields are obtained from the rich-lean shale mixture having a Fischer assay within the range of from about 27 gallons per ton to about 36 gallons per ton. Thus, by the method of this invention, oil product yields are significantly increased under stable retorting conditions. Furthermore, considerable savings are realized in reducing mining and material handling costs. Thus in the method of this invention it is desirable to convert an oil shale mixture having as high an oil content as possible while maintaining at the same time stable retorting conditions so as to maintain and effect a thermally efficient utilization of a gas combustion retorting system. Thus the method of the present invention provides among other things a means for retorting relatively lean as well as relatively rich oil shale materials in a manner wherein the amount of recovered oil is greater than that which would be recovered if separately retorted. Thus by the present invention a mixture of lean and rich oil shale particle material which provides a Fischer assay coming within a range of from about 15 gallons per ton to about 36 gallons per ton, and preferably within the range of from about 27 gallons per ton to about 36 gallons per ton, is efficiently and economically processed. Shale mixtures having an oil content within the above identified preferred range permit a more efficient utilization of gas combustion retorting facilities in conjunction with providing high yields of recovered oil product.

Also in accordance with the present invention there is provided a system for mixing a plurality of oil shale streams to provide a retort feed stream having a predetermined Fischer assay value. The system comprises means for monitoring the streams and for generating signals representative of the respective Fischer assay values, and means for comparing the Fischer assay signals with reference signals and for generating at least one stream flow

control signal to provide a retort feed stream having a predetemined Fischer assay value.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 diagrammatically shows an arrangement of apparatus for practicing the present invention,

FIG. 2 is a schematic diagram of a circuit for generating a reference signal, and

FIG. 3 is a graph showing the correlation between Fischer assay and hydrogen content.

DESCRIPTION OF SPECIFIC EMBODIMENT

In accordance with one specific embodiment of this invention, an oil rich shale having a Fischer assay above about 36 gallons per ton is mixed with a relatively lean oil shale or other solid material to obtain a resultant mixture having an average Fischer assay of less than about 36 gallons per ton. The mixture is preferably in the range of from about 15 to about 36 gallons per ton, and more preferably from about 27 to about 36 gallons per ton. The mixture will preferably have an average particle size of between about 0.5 inch and about 3 inches mean diameter upon introduction to the upper portion of a gas combustion retort. The lean oil shale or other solid material can be obtained from overburden shale, gravel, crushed rock or oil containing lean shale normally found near or adjacent the rich shale.

Care should be taken to insure adequate mixing of the lean material and the rich oil shale prior to retorting the mixture. The mixing is effected to minimize classification or separation of rich shale and lean shale in at least the upper portion of the retort. Should significant classification occur in the retort, then flooding problems could result in those portions of the retort, wherein the rich shale is concentrated. It is thus advantageous to crush the rich and lean material to a particle size which will obviate segregation and this may be accomplished in some instances by employing a common crushing step for the different materials. As described in Bureau of Mines Bulletin 635, Development of the Bureau of Mines Gas-Combustion Oil Shale Retorting Process, 1966, the crushing step may comprise a plurality of stages.

The Fischer assay is a commonly employed method for determining the oil content of shale. The Fischer assay is expressed in terms of gallons of oil per ton of shale. For a description of the Fischer assay method, see Bureau of Mines, Report of Investigation 4447, Method of Assaying Oil Shale by a Modified Fischer Retort, Stanfield and Frost, June 1949. A number of alternative methods are available to determine oil content of shale and can be correlated to those results obtained by the Fischer assay method.

It has been determined that the compositional feature or weight percent content of organic carbon, mineral carbon dioxide, total carbon, nitrogen, ash and hydrogen is proportionate to the oil content or Fischer assay of shale. For example, FIG. 3 shows a graph which demonstrates the correlation between Fischer assay and hydrogen. The vertical axis is representative of the weight percent of hydrogen in shale, and the horizontal axis is representative of Fischer assay of the shale expressed in gallons of oil per ton. Further data showing the correlation between shale compositional features and oil content is reported in Bureau of Mines, Report of Investigation 4825, Properties of Colorado Oil Shale.

In a preferred embodiment of the present invention, shale to be retorted is substantially continuously analyzed for oil content. The amount of lean or spent shale, which ever is needed, if any, based upon the analysis, is then continuously mixed with the rich shale and crushed.

Referring now to FIG. 1, oil rich shale is provided in container **1** which relatively lean shale is provided in container **2**. A rich shale stream is directed to a crusher **3** through conduits **4** and **5**. A lean shale stream is directed to the crusher **3** through conduits **6** and **5**. The proportion of rich to lean shale directed to the crusher **3** is regulated by a pair of feeders **7** and **8**. The feeders **7** and **8** are controlled in a manner such that the Fischer assay of the shale mixture passed to the crusher **3** is not greater than about 36, preferably between about 15 and about 36 gallons per ton, and more preferably between about 27 to about 36 gallons per ton. In the crusher **3**, the shale mixture is crushed and reduced to a particle size generally in the range of from about ½ inch to about 3 inches mean diameter. A shale retort feed stream is provided by removing the shale particles from crusher **3** through a conduit **55**, a conveyor **10** to a container **9**. The shale particles in the container **9** move downwardly through a feeder **11** into a retort **12**. The rate of shale flow to the retort **12** through the feeder **11** and out of the retort **12** through a conduit **12** is regulated to maintain a downwardly moving compact bed of shale particles in the retort **12**.

Hot combustion air is introduced into the retort **12** through a conduit **14** provided with suitable air distribution means so as to effect partial combustion of recycle gas and develop a temperature profile sufficient to effect decomposition of the kerogen. The amount of air directed into the retort **12** is regulated to maintain a maximum average temperature in the combustion zone area of the retort not substantially above about 1600° F.

The hot gases passing upwardly through the descending shale preheats and decomposes the kerogen in the shale to form a vapor or shale mist recovered at the top portion **15** of the retort **12** at a temperature not substantially above about 400° F. The oil mist is removed from the retort **12** through a conduit **16** and is directed to a series of oil separation steps. Oil mist is passed through a cyclone **17** and through a conduit **20** to an electrostatic precipitator **18** wherein the oil mist is separated from the vaporous material comprising recycle gas. The oil is removed from the electrostatic precipitator **18** through conduits **21** and **20**. The gaseous material freed of oil mist is removed from the electrostatic precipitator **18** by conduit **22**. A portion of the vapor is vented through conduit **23** while the remainder is recycled to the bottom portion or preheat zone **24** of the retort **12** through conduit **25**. The recycle gas moves upwardly through the hot shale descending through zone **24** to cool the downwardly moving shale particles and heat the recycle gas. The spent shale is removed from the retort **12** through a conduit **13** at a temperature of less than about 400° F.

The Fischer assay of the shale retort feed stream is automatically controlled in accordance with the present invention by providing means **41, 42, 43** in the rich, lean and retort feed streams for generating a signal representative of a compositional feature of shale. An example of a device suitable for generating a signal representative of the hydrogen compositional feature of shale is a granular solids moisture gage, Model 2500, manufactured by Kay-Ray, Palatine, Ill., a division of Kay Electric Company, Pine Brook, N.J. This moisture gage comprises a hydrogen density channel which determines hydrogen content by utilizing the capability of hydrogen to absorb energy from high speed neutrons at a rate substantially greater than other elements. When shale is subjected to fast neutron radiation, the hydrogen absorbs their energy and creates slow or thermal neutrons, the number of which is related to the hydrogen content of the shale. The number of slow neutrons are detected by a gas ionization chamber which produces a proportional signal as a current representative of the hydrogen content of the shale.

The hydrogen content signals are applied to a computer **47** via lines **44, 45, 46**. The computer **47** compares the hydrogen signals with at least one reference signal and generates signals along lines **48, 49** to control the feeders **7, 8** and thereby control the flow rates of the rich and lean oil shale streams to provide an oil shale retort feed stream having a predetermined Fischer assay.

The computer **47** may comprise one or a plurality of reference signal generators of the type shown in FIG. 2. As shown in that figure, a battery **51** supplies a potential to a potentiometer **50** to provide an output signal at point **52** representative of a reference value. The reference signal is changed by varying the potentiometer **50**.

The lean and rich shale stream hydrogen content or Fischer assay signals **44, 45** may be applied to an averaging circuit in the computer **47**, and the output of the averaging circuit may then be applied along with a reference signal as inputs to a subtracting circuit. In this embodiment, the output of the subtracting circuit would be a deviation signal for adjusting one or both of the feeders **7, 8** to provide a desired Fischer assay for the oil shale retort feed stream.

If the Fischer assay value of the rich and/or lean streams are known, the oil shale retort feed stream signal **46** and a reference signal may be applied to a subtracting circuit in the computer **47** to generate a deviation signal for controlling one or both of the feeders **7, 8.**

In another embodiment, reference signals are generated in the computer **47** for each of the rich and lean oil shale streams. These signals are then applied to separate subtracting circuits in the computer **47** along with their respective rich and lean shale hydrogen content or Fischer assay signals **44, 45.** The outputs of the subtracting circuits provide deviation signals for controlling the feeders **7, 8** to provide an oil shale retort feed stream having a predetermined value.

The present invention also contemplates the use of a digital computer programmed to control the shale stream flow rates in response to parameters in addition to Fischer assay. For example, the lean, rich and retort feed Fischer assay signals **44, 45, 46** may be compared to cost and retort operating constraints to provide an economical and/or efficient system.

It is also within the scope of the present invention to combine more than two oil shale streams to provide an oil shale retort feed stream.

The following example is intended to illustrate the present invention and is not intended to limit the same.

EXAMPLE

Gas combustion retorting was carried out on shale of varying richness as shown in the table. The shale was crushed to a particle size ranging from about ¾ to about 1½ inches. The shale particles in runs **6, 7,** and **8** were obtained by mixing shale having a Fischer assay of 45 gallons per ton and shale having a Fischer assay of 28 gallons per ton.

bustion air to an intermediate combustion section of said retort under conditions to provide heat to gaseous material moving upwardly through the retort in an amount sufficient to effect decomposition of kerogen and form oil mist, removing oil as a mist from an upper portion of the shale preheat section of said retort, recovering said oil and removing retorted shale particles from the bottom portion of said retort.

2. The method of claim **1** wherein the Fischer assay of the resultant mixture of shale introduced to the retort is between about 15 gallons per ton and about 36 gallons per ton.

3. The method of claim **1** wherein the Fischer assay of the resultant mixture of shale introduced to the retort is between about 27 gallons per ton and about 36 gallons per ton.

4. A method of retorting oil shales in a gas combustion retort comprising the steps of:

directing a plurality of oil shale streams comprising at least one rich oil shale stream and at least one lean oil shale stream to means for crushing and mixing said plurality of oil shale streams,

providing an oil shale retort feed stream at the output of said crushing and mixing means,

monitoring a compositional feature of at least one of said rich, lean and retort feed streams, said compositional feature being indicative of the Fischer assay of the monitored stream,

generating a signal representative of the Fischer assay of the monitored stream,

comparing said Fischer assay signal with a reference signal representative of a predetermined Fischer assay to provide a deviation signal,

controlling a least one of said rich and lean oil shale streams in response to said deviation signal to maintain the Fischer assay of the retort oil shale feed stream at a value of not more than about 36 gallons per ton,

passing said retort oil shale feed stream downwardly as a compact moving bed through a gas combustion retort countercurrent to upwardly flowing hot retorting gaseous material,

removing oil as a mist from an upper portion of a shale preheat section of said retort,

collecting said mist as a liquid oil product, recycling gaseous material to said retort, and

removing spent shale from the lower portion of said retort.

5. The method of claim **4** wherein the Fischer assay of the oil shale retort feed stream is between about 15 gallons per ton and about 36 gallons per ton.

6. The method of claim **4** wherein the Fischer assay of the oil shale retort feed stream is between about 27 gallons per ton and about 36 gallons per ton.

7. The method of claim **4** wherein said compositional feature is the hydrogen content of the monitored stream.

8. A method of retorting oil shales in a gas combustion retort comprising the steps of:

directing a plurality of oil shale streams comprising at least one rich oil shale stream and at least one lean oil shale stream to means for crushing and mixing said plurality of oil shale streams,

providing an oil shale retort feed stream at the output of said crushing and mixing means,

continuously monitoring a compositional feature of at

TABLE

Run Number	1	2	3	4	5	6	7	8	9	10
Raw shale Fischer assay, gal./ton	18.8	19.4	19.6	28.8	27.5	36.0	35.4	35.4	38.9	39.8
Shale mass flow, rate lb./hr.-ft.^{2}	491	488	486	486	483	486	489	484	496	492
Air rate, s.c.f./ton shale	4,870	4,890	4,930	4,540	4,580	4,840	4,840	4,920	4,780	4,800
Recycle gas rate, s.c.f./ton shale	13,600	13,500	13,600	13,800	13,400	13,900	13,800	13,800	13,600	13,800
Yield—percent Fischer assay	86.3	83.7	83.1	84.9	89.8	88.6	89.9	91.7	86.5	85.2
Operation	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable	(1)	(1)

[1] Unstable retort flooding.

From the table, it can be seen that retorting oil shale having a Fischer assay above 36 gallons per ton results in unstable and undesirable operation. Further, by employing shale mixtures having a Fischer assay in the range of from about 15 to about 36 gallons per ton, it is possible to retort shales under stable operating conditions at high yields in a gas-combustion retort.

What I claim is:

1. A method for retorting oil shales in a gas combustion retort which comprises mixing a rich oil shale having a Fischer assay above about 36 gallons per ton with a relatively lean oil shale material to obtain a resultant mixture having an average Fischer assay less than about 36 gallons per ton, passing said oil shale mixture in a nonfluidized state to said retort and downwardly as a compact moving bed through said retort, introducing com-

least two of said rich, lean and retort feed streams, said compositional feature being indicative of the Fischer assay of the monitored streams,

generating signals representative of the Fischer assay of the monitored streams,

generating a reference signal representative of a predetermined Fischer assay for said retort feed system,

generating a retort feed stream deviation signal in response to said monitored stream signals and said reference signal,

controlling at least one of said rich and lean oil shale streams in response to said deviation signal to maintain the Fischer assay of the retort oil shale feed stream at a value of not more than about 36 gallons per ton,

passing said retort oil shale feed stream downwardly as a compact moving bed through a gas combustion retort countercurrent to upwardly flowing hot retorting gaseous material,

removing oil as a mist from an upper portion of a shale preheat section of said retort,

collecting said mist as a liquid oil product, recycling gaseous material to said retort, and

removing spent shale from the lower portion of said retort.

9. The method of claim **8** wherein the compositional feature of each of said rich, lean and retort feed streams is monitored.

10. The method of claim **8** wherein the Fischer assay of the oil shale retort feed stream is between about 15 gallons per ton and about 36 gallons per ton.

11. The method of claim **8** wherein the Fischer assay of the oil shale retort feed stream is between about 27 gallons per ton and about 36 gallons per ton.

12. The method of claim **8** wherein said composition feature is the hydrogen content of the monitored stream.

13. A system for mixing a plurality of oil shale streams

to provide a retort oil shale feed having a predetermined Fischer assay comprising:

means for mixing the plurality of oil shale streams,

means for providing a plurality of oil shale stream input conduits to said mixing means and a retort feed stream output conduit from said mixing means,

means in at least one of said conduits for generating a signal representative of a composition feature of the shale stream, said compositional feature being indicative of Fischer assay,

means responsive to said compositional feature signal for generating a signal representative of the deviation of the Fischer assay of the retort feed stream from the predetermined Fischer assay, and

means responsive to said deviation signal for controlling the flow rate in at least one of said input conduits to reduce said deviation signal.

14. The system of claim **13** wherein said compositional feature is the hydrogen content of the shale stream.

15. The system of claim **13** wherein said mixing means comprises means for crushing oil shale.

16. The method of claim **1** wherein said resultant mixture has an average particle size of between about 0.5 inch and about 3 inches mean diameter.

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HERBERT LEVINE, Primary Examiner

U.S. Cl. X.R.

202—120

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,574,087 Dated April 6, 1971

Inventor(s) WILLIAM S. BERGEN

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 12, "EMBODIMENT" should read --EMBODIMENTS--
Column 3, line 72, "which" should read --while--.
Column 4, line 16, "conduit 12" should read --conduit 13--
Column 6, TABLE, the Raw shale Fischer assay, gal./ton of Run Number 9 reading "38.9" should read --38.7--.
Column 5, line 74, after "said" delete --oil--.
Column 6, line 34, "a" should read --at--.
Column 7, line 7, "system" should read --stream--.
Column 8, line 16, after "the" insert --shale--.

Signed and sealed this 24th day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents