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PROCESS FOR TRANSPORTING VISCOUS FLUIDS

Original Filed Jan. 24, 1968 2 Sheets-Sheet 1

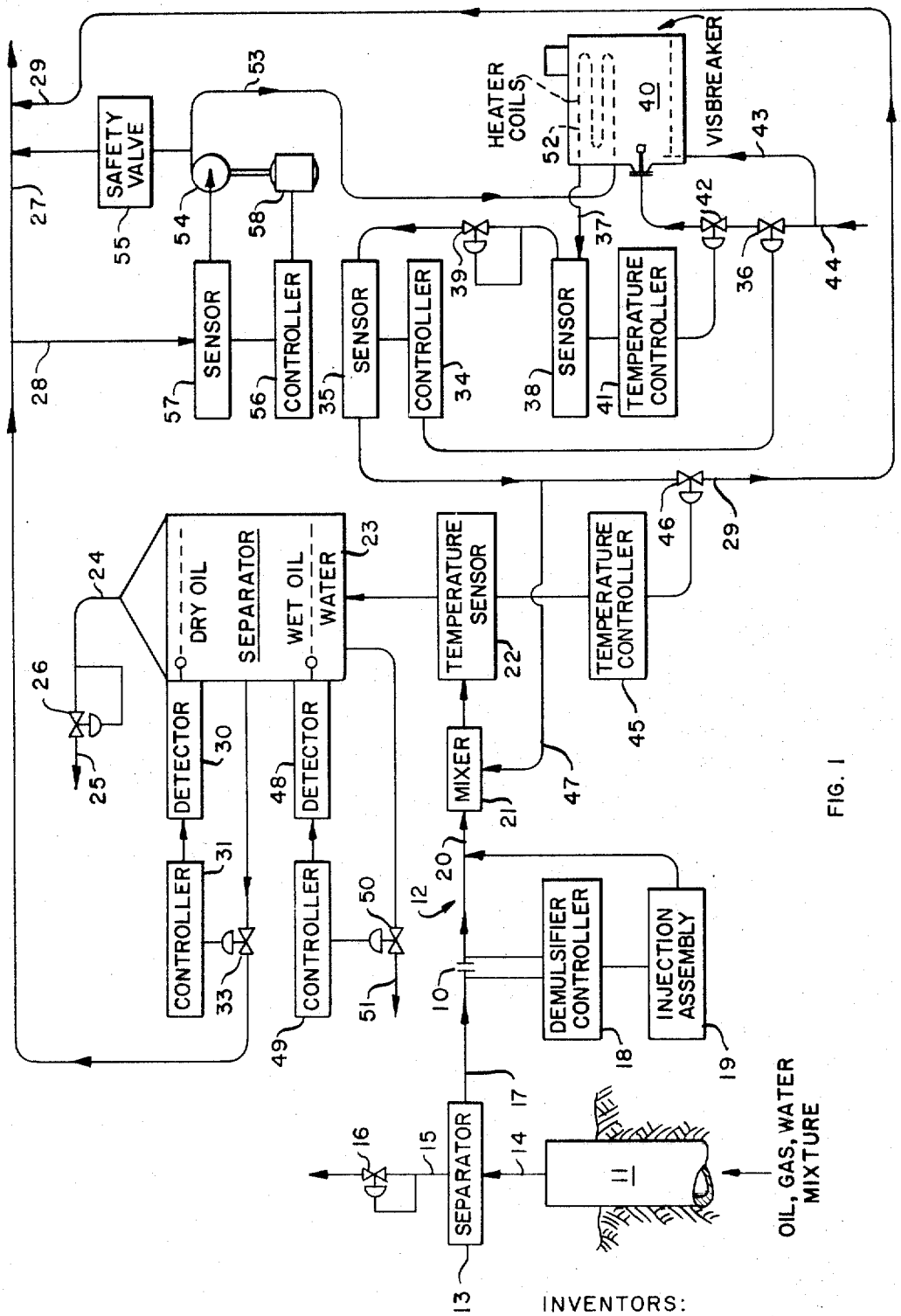

FIG. 1

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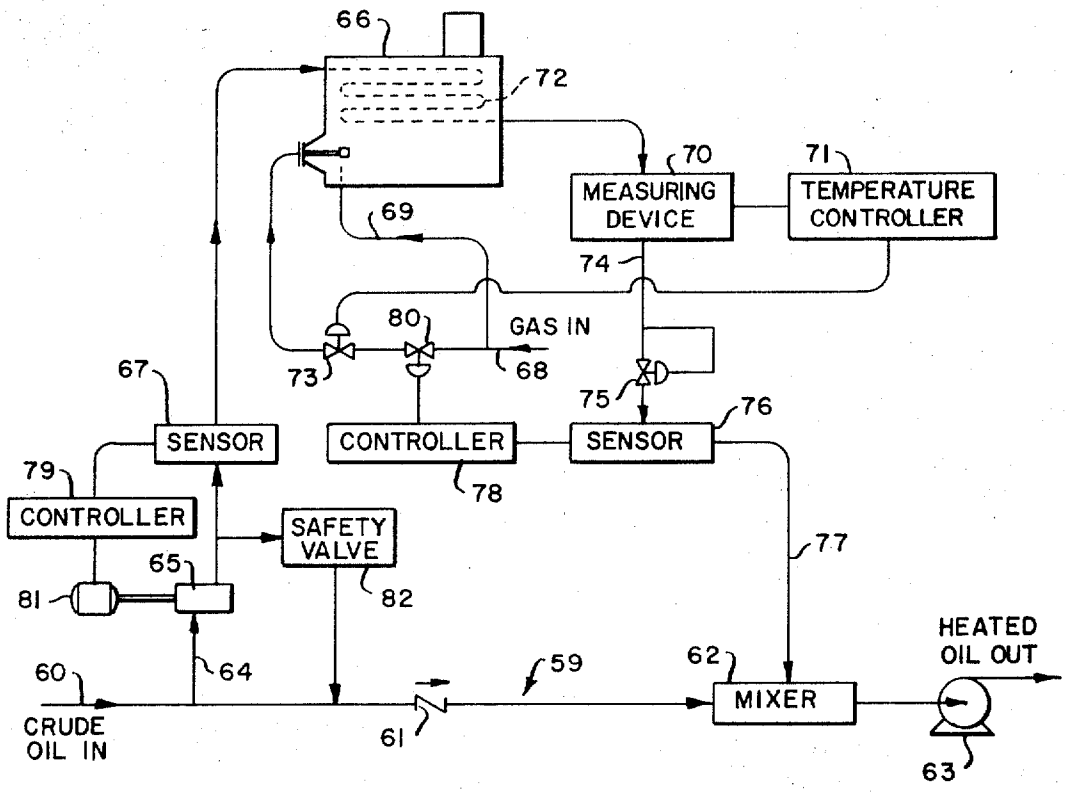

FIG. 2

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PROCESS FOR TRANSPORTING VISCOUS FLUIDS

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Int. Cl. B01d *19/00*

U.S. Cl. 55—45 8 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

A process for reducing the viscosity of a stream of viscous fluid flowing within a pipeline having constituents which solidify upon cooling. A portion of the stream is diverted and heated to a temperature at which thermal degradation of at least some of the constituents thereof takes place thus lowering its average molecular weight and viscosity. The heated portion is then blended with the remainder of the stream thereby increasing the temperature of the entire stream flowing within the pipeline.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a process for transporting viscous fluids, more particularly, to a process for reducing the viscosity of a stream of viscous fluid flowing in a pipeline having constituents which solidify upon cooling.

Description of the prior art

Vast networks of pipeline, particularly in the southwestern portion of the United States, provide a means for the transmission of petroleum crudes from production areas to refineries or transportation facilities. Similar pipelines also crisscross the other portions of the United States carrying, in addition to petroleum crudes, many other fluids, and in some cases fluid-solid mixtures.

Whether pipelines are used for the transmission of petroleum crudes, other fluids, or fluid-solid mixtures, a major expense in the transmission thereof is the pumping cost. From the following equation, it can be seen that pumping cost in laminar flow will be proportional to the viscosity of the fluid.

$$\Delta P=\frac{32LVv'}{gD^2}$$

In the Hagen-Poiseuille equation (above):

ΔP=pressure drop in lbs./sq. ft.
V=velocity in ft./sec.
L=length of pipe in ft.
v'=viscosity in lbs./ft./sec.
g=acceleration of gravity in ft./sec./sec.
D=diameter (inside) in ft.

From a perusal of the above equation it can be seen that the viscosity (v') of the fluid being pumped through the pipeline plays a large role in determining the actual pumping cost. For example, if the viscosity doubles it will require twice the work to maintain a constant throughput. Likewise, it can also be shown that in turbulent flow, the viscosity of the fluid still plays an important role in determining pumping costs.

Since the viscosity of a given fluid is dependent upon the temperature of the fluid, even seasonal changes of temperature at the situs of a pipeline can considerably alter the pumping cost. For example, seasonal temperature change of approximately 25° C. can change the viscosity of No. 5 fuel oil from 87 centipoises at 25° C. to 610 centipoises at 0° C., resulting in a more than double increase in the pumping cost of No. 5 fuel oil at the latter temperature.

In addition, there are some petroleum crudes in the United States, such as certain crudes in the state of Mississippi, which have extremely high viscosity and cannot be moved by pipelines without heating to lessen their viscosity. For example, Baxterville oil has a viscosity of 17,400 Saybolt Universal Seconds (SUS) at 60° F. and a gravity of 16.4 API°, being almost a plastic semisolid. In order to pump such a viscous crude through a large diameter pipeline, a minimum line temperature of 80° F. must be maintained, and pressures as high as 1,000 p.s.i. may be required to achieve useful flow.

One technique to the transmission of viscous crudes, such as described above, is the use of oil heating equipment at pumping stations. Live steam boilers cooperating with heat exchangers can be used to provide the necessary heat to lower the viscosity of these crudes and make crudes like the Baxterville crudes pumpable. Of course, heating to improve pumpability is not limited to the highly viscous crudes above, and such boilers can be used to lower the viscosity of the less viscous crudes to achieve a reduction in pumping costs. Boilers employed in such techniques are usually fueled by natural gas or oil or a combination thereof; and, when working with viscous crudes, standby fuel supplies are a must since a failure of any boiler can be disastrous, allowing the crudes to freeze in the pipeline. A notable example of a steam-heated pipeline is the 152-mile pipeline from Eucutta, Miss., to Mobile, Ala., discussed in World Oil, March 1952, pp. 214–216, in an article entitled, "Steam-Heated Pipeline." The article describes a pipeline using 150 horsepower boilers, spaced at 9-mile intervals to prevent the crude from freezing in the pipeline.

While such oil-heating equipment at pumping stations can provide the necessary heat to lower pumping cost and/or improve the pumpability of highly viscous fluids, they are not very efficient since the heat in the combustion unit cannot be fully transferred to the pipeline fluid. Furthermore, boiler and heat exchange equipment is often expensive, and the costs of operation and maintenance can be considerable, often requiring a licensed operator. Further, the space between two heating units along the pipeline has to be large to minimize the number of units required. Thus, it is necessary that the crude be raised to a rather high temperature at each station in order to retain sufficient heat to reach the next heating unit. Of course, these high temperatures provide a large temperature differential (ΔT) between the pipeline and the local surroundings, resulting in high heat loss and extreme inefficiency.

SUMMARY OF THE INVENTION

It is an object of this invention to reduce the viscosity of a viscous fluid flowing in a pipeline.

It is a further object of this invention to lower the transportation, production and refining costs for processing a viscous fluid by lowering the molecular weight of the viscous fluid.

The objects of this invention are carried out by reducing the viscosity of a stream of a viscous fluid flowing within a pipeline having constituents which solidify upon cooling. A portion of the stream is diverted and heated to a temperature at which thermal degradation of at least some of the constituents

of the diverted viscous fluid takes place, thus lowering both the average molecular weight and the viscosity thereof. The heated diverted portion is then blended with the remainder of the stream thereby increasing the temperature of the entire stream of viscous fluid flowing within the pipeline.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 shows a flow scheme of a process for dehydrating crude oil from a production well; and

FIGURE 2 shows a flow scheme of a process for lowering the viscosity of oil flowing in a crude oil pipeline.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As used hereinafter, the term "viscous fluid" refers to any of the various fluids having constituents which solidify upon cooling and thus can be broken down so as to be more easily transportable. For example, the process of this invention is particularly applicable, but not limited, to waxy petroleum fluids and will be described accordingly.

Referring to the crude oil dehydration process of FIGURE 1, the tubing **11** of a production well is shown for introducing a mixture of oil, gas and water into system **12**. A conventional gas separator **13** communicates with the production line **14** from tubing **11**. Gas vapors from separator **13** are removed through vapor outlet **15**; a conventional gas-back pressure valve **16** engages outlet **15** so as to maintain the desired pressure in separator **13**, if desired. Oil is flowed from separator **13** through wet oil outlet **17** and through orifice meter plate **10** of a conventional proportioning demulsifier controller **18**. Controller **18** and injection assembly **19** may be required to add chemical demulsifying agents to the oil-water mixture flowing in system **12** for converting the mixture to a form that resists emulsification as is well known in the art. From there, the oil-water mixture flows through wet-oil line **20** to a hot-cold crude mixture **21** and temperature sensor **22**. From sensor **22**, the wet-oil mixture flows into a conventional crude oil-water separator **23** where the mixture separates into water, dry oil and wet oil phases as illustrated in FIGURE 1 and as is well known in the art. Gas vapors are removed through vapor outlet **24** to a storage area **25**. If desired, a gas-back pressure valve **26** may be coupled to vapor outlet **24** so as to maintain the desired pressure in separator **23**.

Hot separated oil is removed from separator **23** through oil outlet line **27** to a storage area (not shown). Hot oil bypass **29** may engage outlet **27** for feeding excess visbroken oil into the storage area.

Preferably, a conventional gas-oil interface detector **30** is associated with the gas-oil interface in separator **23** as shown in FIGURE 1. A conventional oil level controller **31** is coupled to detector **30**. A control valve **33** couples controller **31** to oil outlet **27**.

Low flow sensor **35** is coupled to a low flow gas shut-off controller **34** which is in turn coupled to a gas shut-off valve **36**. Sensor **35** is, in turn, coupled to both a hot oil bypass **29** and a temperature sensor **38**. A back pressure control valve **39** is disposed between flow sensor **35** and temperature visbroken oil discharge line **37** which is in communication with sensor **38** to maintain the preferred pressure on the fluid in the heating coils **52**. Sensor **38** is coupled to the heating coils **52** of a cracking furnace or visbreaker **40**. A temperature controller **41** is coupled to both sensor **38** and a gas control valve **42** for visbreaker **40**. A pilot light **43** for the gas supply is preferably coupled to visbreaker **40** and a gas supply inlet **4** leading from a conventional gas supply source (not shown).

A temperature controller **45** is coupled between sensor **22** and a temperature controller valve **46**. A mixer inlet line **47** couples bypass **29** to mixer **21**.

A conventional water-oil interface detector **48** is used to detect the level of the interface between the oil and water in separator **23**. A water level controller **49** couples detector **48** to a valve **50** which controls water outlet **51** from separator **23**.

An outlet **53** from visbreaker **40** is coupled to both a supply pump **54** for charging visbreaker **40** and a safety valve **55** which is coupled to oil outlet line **27**. Pump **54** is driven by any conventional motive means, such as a motor **58** which is, in turn, coupled to controller **56**. Supply pump **54** is coupled to a low flow sensor **57** which is, in turn, coupled to oil outlet line **27** through oil bypass line **28**.

In operation, a gas-oil-water mixture from a production well is flowed from tubing **11** through production line **14** into separator **13** where the vapor pressure of the mixture is reduced and any undissolved gas is removed through gas outlet **15** and pressure valve **16** as is well known in the art.

The oil-water mixture is then passed from separator **13** through outlet **17** then through orifice meter **10** and into wet oil line **20** where chemical demulsifying agents may be added to the mixture, if required, by means of the demulsifying controller **18** and proportioning and injection assembly **19** as is well known in the art.

The oil-water mixture is next passed from wet oil line **20** to a mixer **21** where the water-oil mixture (i.e., the wet crude oil) is mixed with hot crude oil from visbreaker **40** as will be described further hereinbelow. This mixture of the hot crude oil heats the entire crude oil stream to the desired temperature which is then passed into temperature sensor **22** and water separator **23**. In separator **23**, dissolved gas vapors are separated through vapor outlet **24** which is controlled by valve **26** and leads to a storage area **25**. As illustrated in FIGURE 1, the water is removed from separator **23** through water outlet **51** which is controlled by valve **50**. A conventional controller **49** and detector **48**, operatively engaging valve **50**, cooperates with the water level in separator **23** to control the level of the water therein; in like manner, a conventional controller **31** and detector **30**, operatively engaging valve **33**, controls the oil level in separator **23** as is well known in the art.

Oil is removed from separator **23** through oil outlet line **27** which is controlled by valve **33** and leading to a storage area (not shown). A bypass **29** operatively engages line **27** for introducing excess heated oil back into line **27**.

A portion of the dry oil is passed from separator **23** through oil-bypass line **28** to low flow sensor **57** which is in communication with pump controller **56**. From there, the dry oil is passed to supply pump **54** which is driven by motor **58** and is controlled by controller **56**.

From supply pump **54**, the dry oil is passed through outlet **53** and into the coils **52** of visbreaker **40** where the dry oil is heated to the desired temperature. A safety valve **55** may be disposed between outlet **27** and outlet **53**, if desired. The necessary gas for heating visbreaker **40** may be introduced from a source (not shown) through supply inlet **44** and into visbreaker **40**. A pilot light **43** is preferably disposed between inlet **44** and visbreaker **40** as can be seen in FIGURE 1.

The heated oil is passed from the coils **52** of visbreaker **40** through sensor **38**, control valve **39**, sensor **35** and into mixer inlet line **47**. The desired quantity of hot oil is diverted from bypass line **29** through mixer inlet line **47** and into mixer **21** to raise the temperature of the wet oil-visbroken oil blend to a desired operating temperature for separator **23**.

The temperature controller **45** controls valve **46** and operatively engages both sensor **22** and bypass line **29** for controlling the temperature of the wet crude oil going into separator **23** as is well known in the art. Temperature controller **41** controls valve **42** and is disposed between temperature sensor **38** and gas supply inlet **44** for

controlling the temperature of visbreaker **40**. Gas supply controller **34** controls gas shut-off valve **36** and is disposed between gas supply inlet **44** and flow sensor **35**.

In addition to the crude oil dehydration process of FIGURE 1, the viscosity of oil flowing in a crude oil pipeline may be lowered as illustrated in the system of FIGURE 2. Referring to FIGURE 2, cold crude oil from either a storage area or a previous station (not shown) is passed into system **59** through oil inlet line **60**. The main stream of cold crude oil passes from line **60** through a conventional check valve **61** and into a mixer **62**. In the mixer **62**, the cold crude oil mixes with the hot visbroken crude as will be explained further hereinbelow. The heated oil mixture passes through main pump **63** to the end of the pipeline or the next station (not shown).

A cold oil inlet line portion **64** branches off of oil inlet line **60** and passes into a charger pump **65** for a cracking furnace or visbreaker **66**. A safety valve **82** may be installed as illustrated in FIGURE 2, if desired. A flow sensing device **67** is disposed between pump **65** and visbreaker **66**. Gas for operating visbreaker **66** is provided from a gas supply (not shown) through gas supply line **68** leading to visbreaker **66**. A pilot light gas supply **69** is disposed between visbreaker **66** and line **68**. A conventional temperature measuring device **70** and temperature controller **71** is disposed between the heating coils **72** of visbreaker **66** and a temperature control valve **73** operatively engaging gas supply line **68**.

A hot oil outlet line **74**, controlled by a back pressure valve **75**, leading from measuring device **70** passes through a low oil flow sensing device **76**. From device **76**, a hot oil line **77** feeds into mixer **62**. Sensing device **76** is also coupled to a low oil flow controller **78** connected to a gas shut-off valve **80** disposed between controller **78** and gas supply line **68**.

In operation, a portion of the cold crude oil, from either the storage area or a previous station, is flowed into system **59** through oil inlet line **60**. A portion of the cold crude oil is drawn off from line **60** and passed through line portion **64** to pump **65**. Meanwhile, the remainder of the cold crude oil is passed through check valve **61** and into mixer **62** where it meets the hot visbroken crude oil coming from the coils **72** of visbreaker **66** as will be explained further hereinbelow.

The cold crude oil passed into pump **65** driven by pump drive **81** is pumped through the heating coils **72** of visbreaker **66**. This hot, visbroken oil is then passed through measuring device **70**, oil outlet line **74** which is controlled by valve **75**, low oil flow sensing device **76** and into oil line **77**. From line **77**, the hot oil flows to mixer **62** where it is blended with the cold crude oil. This mixing is carried out on the suction side of the main pump **63** and the mixture of the cold crude oil with the hot crude oil brings the entire oil stream to its desired temperature. The resulting mixture is then passed to pump **63** and out to the end of the pipeline or the next pumping and heating station (not shown).

Gas for firing visbreaker **66** is supplied through line **68** from a source (not shown) and into the visbreaker **66**. Temperature controller **71** controls valve **73** and is coupled to measuring device **70** for controlling the temperature of the visbreaker **66**. Low oil flow controller **78** is coupled to sensing device **76** and controls gas shut-off valve **80** coupled to gas supply line **68**. Controller **79** is coupled to sensing device **67** and pump drive **81** and controls the fluid flowing through visbreaker **66** as is well known in the art.

Although preferred systems of conventional controllers, sensors, valves, etc., has been set forth hereinabove, it is to be understood that various types and arrangements thereof may be provided within the scope of invention.

Heating is thus the preferred method disclosed herein for removing water from and reducing the viscosity of a viscous fluid, such as a waxy petroleum fluid, flowing within a pipeline. The systems disclosed hereinabove propose that, rather than heating all of the oil to a desired temperature, only a portion of the oil is heated to a temperature significantly higher than the final desired temperature. A portion of the oil is heated sufficiently hot, as, for example, 800° to 1000° F., so as to cause thermal degradation of some of the constituents in the oil which solidify upon cooling. This lowers the average molecular weight of the oil, thereby lowering its viscosity. The hot stream of "visbroken" oil is then blended with the remainder of the oil, thus increasing the temperature of the oil in the entire system to the desired temperature. The portion of the oil subjected to the visbreaking treatment and the visbreaking temperature is dependent upon the properties of the oil and the desired final oil temperature.

Heating costs are thus not appreciably higher than the cost required to heat all of the oil to the desired line temperature. A greater viscosity reduction is attained at the same final temperature than when all the oil is heated because the average molecular weight of the visbroken oil is lower. This lower average molecular weight facilitates the "start up" of wax-containing systems.

The process of this invention results in overall benefits in the entire system of processing viscous fluids. For example, the visbreaking may be done in the field, thus lowering refining costs. The lower volatile loss plus the addition of the lower molecular weight material from the visbreaking results in a net lowering of the viscosity of the material to be transported by pipeline, thus lowering transportation costs per barrel. Reducing the viscosity of a portion of the oil by visbreaking results in lower water separator temperatures, thus lowering volatile losses and chemical costs. The final result is more barrels of production oil at lower costs per barrel.

Operating conditions for a typical visbreaker in accordance with both the foregoing preferred processes of the invention with respect to a crude oil may be as follows.

Crude oils: API gravity at 60° F.=14 to 24,
Operating temperature, 0° F.=850 to 900,[1]
System pressure, p.s.i.g.=200 to 400,[2]
Space velocity, lbs./hr./ft.[3] volume of coils=1000 [3] to 1500.

[1] Thermal cracking likely to occur at temperatures higher than 900° F.
[2] The back pressure must be sufficient to keep the crude oil in the visbreaker heater coils in a liquid phase.
[3] A space velocity of about 1000 is required to prevent coke deposits. At a lower space velocity, coking may occur.

The following table shows two visbreaking test runs on asphaltic and waxing crudes in accordance with the teachings of this invention.

TABLE 1.—VISBREAKING OF ASPHALTIC AND WAXY CRUDES

	14° API asphaltic	29° API waxy
Visbreaking conditions:		
Temperature, ° F	860	870
Cool velocity, lbs./hr./ft.[3] volume	1,340	1,000
Residence time, sec	118	124
Recovery, percent	99.1	99.1
Yields, no loss basis:		
Gas:		
Percent weight	1.6	0.8
S.c.f./100 lbs. product	20.1	12.6
Total liquid product, percent weight	98.4	99.2
Gas composition, percent weight of gas:		
Hydrogen	0.4	0.7
Methane	17.6	30.1
Ethylene	1.3	4.1
Ethane	13.7	19.6
Propylene	6.9	10.2
Propane	17.8	17.1
Butylenes	8.8	5.2
Isobutane	3.4	1.8
n-Butane	8.9	5.1
Amylenes	4.0	1.3
Isopentane	3.2	1.0
n-Pentane	2.7	0.8
Hexanes	1.1	0.5
Heptanes and heavier	0.6	
Carbon monoxide	2.3	0.7
Carbon dioxide	6.0	1.8
Average molecular weight of gas	30.2	24.1

Viscosity of Original Feed Stock and Visbroken Products (cs.)

	14° API asphaltic crude (Kern River)		20° API waxy crude (Wonsits)	
	Untreated feed	Total visbroken product	Untreated feed	Total visbroken product
Temperature, ° F.:				
140	270	39	18	9
120	600	68	28	12
100	1,500	132	50	19
80	4,600	300	300	70
70	8,500	465	500	120
60	18,000	800		

We claim as our invention:

1. A process for dehydrating a gas-oil-water mixture obtained from a production well wherein the oil includes constituents which solidify upon cooling, the process comprising the steps of:

reducing the vapor pressure of the gas-oil-water mixture by removing undissolved gas therefrom, thereby obtaining a mixture consisting of substantially oil and water;

separating the oil-water mixture into its oil and water components;

diverting a preselected portion of the separated oil;

heating the diverted preselected portion of oil to a temperature at which thermal degradation of at least some of the constituents of the oil takes place, thus lowering both the average molecular weight and the viscosity of the diverted oil;

blending the heated diverted oil with the water-oil mixture prior to separating the oil and water therefrom, thereby increasing the temperature and reducing the viscosity of the entire stream of separated oil; and

thereafter separating said blended mixture of diverted oil and oil and water prior to diverting said preselected portion.

2. The process of claim 1 including the step of, prior to blending the heated diverted oil with the oil-water mixture, adding preselected amounts of demulsifying agents to said oil-water mixture so as to convert the oil-water mixture into a form that resists emulsification.

3. The process of claim 1 including the step of controlling the temperature and flow of the diverted preselected portion of oil prior to the step of blending said diverted portion with said oil-water mixture.

4. The process of claim 3 including the step of controlling the temperature and flow of the blended oil-water mixture prior to separating said mixture.

5. The process of claim [6] *4* including the step of controlling both the amount of oil separated from said oil-water mixture and the amount of oil diverted from the separated oil.

6. A process of pipeline transporting highly viscous difficult-to-pump crude oil having an API gravity at 60° F. of from about 14 to about 24 comprising withdrawing a portion of said crude oil, thermally degrading the withdrawn portion of said crude oil at a temperature within the range of from 800° F. to 1000° F. to lower its average molecular weight and viscosity and blending said hot thermally degraded oil with the portion of said crude oil not thermally degraded in an amount sufficient to form a pumpable blend and pipeline transporting said blend to a terminal station.

7. The process of claim 6 wherein the crude petroleum oil is a waxy crude petroleum oil.

8. The process of claim 6 wherein the crude petroleum oil is an asphaltic crude petroleum oil.

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U.S. Cl. X.R.

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