**Abstract:**

**Title:** PROCESS FOR REDUCING THE VISCOSITY OF CRUDE OILS

**Figure 1A** Schema of the experimental set up.

**Figure 1B** Diagram of the microwave head-circulator.

**Figure 1C** Illustration of the directional coupler and power supply assembly.

**Figure 1D** Waveguide transition showing the pressure window and applicator.

**Figure 1E** View of the 3 stub tuner and reflected power.

**Figure 1F** Power supply connection and controller/data acquisition system.
PROCESS FOR REDUCING THE VISCOSITY OF CRUDE OILS

The present invention relates to a process for reducing the viscosity of crude-oils by means of treatment with microwaves.

In the oil industry, numerous applications of microwaves to the production-extraction of petroleum are claimed, in particular from reservoirs of heavy oils, oil sands, oil shales. The inventions relate to methods for the application of microwaves directly in situ, in the reservoir. The extraction of heavy crude oils and non-conventional oils is difficult due to the high viscosity of these crude oils. Particular techniques are used for their extraction, such as CSS (Cyclic Steam Simulation) or SAGD (Steam-Assisted Gravity Drainage) which are based on injections of hot vapour into the reservoir to favour the movement of the crude oil and consequently its emission. Techniques of this type are also called "thermal stimulation" of the reservoir. The use of microwaves generated in-situ in the reservoir, causes a targeted heating of the crude oil, which facilitates its movement and consequently its extraction. Applications of this kind are described for example in US 5,082,054, which describes how to apply electromagnetic radiations having a suitable frequency to favour the extraction of oils from reservoirs, essentially by means of "selective" heating induced by microwaves. The patent describes a kind of protocol for optimizing the type and conditions of irradiation to be applied subsequently in the
underground reservoir. This method is mainly applied for non-conventional oils (tar sand, oil shale).

US 2007/131591 (A1) describes the application of microwaves for producing oil from non-conventional oil sources among which: tar sands, oil sands, oil shales, oil cuttings, and slurry oil. The microwave radiations suitably used allow these materials to be at least partially decomposed, obtaining a "petroleum-based product".

US 4419214 claims an ameliorative method for the recovery of heavy oil or kerogen from oil shales, or for obtaining heavy hydrocarbons (tar) from low-grade carbons or lignites. These processes, which are conventionally effected by heating the rocks containing the oils to 450-550°C (up to 750°C for coal), can be carried out at a much lower temperature (230°C) by irradiation with microwaves having a suitable frequency. The technique described also uses a gas as expelling medium which favours the recovery of liquid hydrocarbons; this aspect is considered particular and ameliorative with respect to previous patents such as US 3,104,711, which describe the use of the energy supplied by microwaves for favouring the production of oil from reservoir formations.

The use of electromagnetic waves and in particular microwaves for stimulating the production of hydrocarbons from their reservoirs is therefore known but complex in its set-up, as it envisages the transmission of electromagnetic waves in the subsoil by
means of specific devices.

The moving and more generally the reduction in the viscosity of heavy crude oils or residues of crude oil and its processing is normally effected by flushing with lighter hydrocarbon products (e.g. gas oil) and/or by means of thermal processes (e.g. visbreaking). These thermal processes produce, by cracking the heavier molecules, the lighter and less viscous fraction, accompanied by the deposition of coke in the furnaces.

It has now been found that by suitably applying microwaves to the heavier part of crude oil, after separation of the heaviest fraction, the viscosity of this heavy fraction is considerably reduced, permanently and not temporarily, consequently favouring its movement and improving its quality.

This partially or totally avoids having to flush the crude oil or residue to reduce its viscosity. The flushing is in fact effected as indicated above, with high-quality light hydrocarbon products: the elimination or reduction in the entity of the flushing provides economical and operative advantages. In this way, a method is obtained for fluidifying and facilitating the movement of crude oils or heavy residues without having to add other products or additives.

The process, object of the present invention, for reducing the viscosity of crude oils substantially comprises a separation step of said crude oils in order to separate a light fraction and a heavy fraction
having a residual water content not higher than 1,400 ppm, preferably not higher than 1,000 ppm, more preferably not higher than 500 ppm, and a treatment step of said heavy fraction separated by irradiation with microwaves (in continuous or pulsed mode) operating at temperatures ranging from 50 to 350°C, preferably from 100 to 320°C, more preferably from 170 to 280°C, for a period of time ranging from 1 second to 120 minutes, preferably from 10 seconds to 60 minutes, more preferably from 20 seconds to 40 minutes, and with frequencies ranging from 0.3 to 300 GHz, preferably from 0.5 to 30 GHz, more preferably from 0.8 to 7 GHz.

More specifically, the treatment by irradiation with microwaves can preferably be effected on a heavy fraction of the crude oil not containing gas and the light components which boil within the range of Liquefied Petroleum Gas (LPG).

Said treatment of irradiation can be preferably carried out by a particular system of irradiation, described in the examples, which allows to concentrate the irradiation intensity in the reactor zone where the crude oil is present by obtaining better irradiation in shorter times and additional gains such as the decrease of pour point and asphaltenes and stability of p-value.

Said treatment of irradiation does not use microwave absorbent materials.

The separation step can be a flash or distillation.

For the purposes of the present invention,
separation steps of heavy fractions which can be obtained with deasphalting units are also considered effective; these heavy fractions are subsequently subjected to treatment with microwaves.

A desalting step can be present upstream of the flash or distillation, consisting of a traditional desalting step, to be preferably effected at 120°C to 130°C with the addition of de-emulsifiers until the water content useful for the application of the invention is reached.

The light fraction obtained in the separation step, after being separated from the gases, can be advantageously joined with the heavy fraction treated by irradiation with microwaves.

The following examples, whose purpose is to provide a better illustration of the invention, should not be considered as limiting the same.

**EXAMPLES**

A heavy aromatic crude oil from which the lighter fractions had been removed by distillation (sample consisting of the fraction 230°C + Gela crude oil), was used as sample for the experimentation.

**CRUDE OIL**

The crude oil, indicated as Gela 55, is a crude oil with 11.6° API and a viscosity of 2540 mPa·s at 38°C; other characteristics of the crude oil are indicated in the table:

**Table:** Properties of the sample Gela 55 as such
The 230°C+ fraction obtained by distillation (Gela 55 230+) and used for the treatment with microwaves was first characterized from a rheological point of view: it is more viscous than the starting crude oil and its dynamic viscosity, measured at the temperature of 38°C, falls within a range of values of 300,000 to 460,000 mPa·s, depending on the aging state of the sample (UV exposure, presence of an oxidizing environment, etc.).

As this, moreover, is a heavier fraction, its asphaltene percentage is also higher with respect to that of the starting crude oil: the C7 asphaltenes are in fact 18.4%.

The samples of Gela 55 230+ were treated with microwave radiation with a frequency of 2.45 GHz, adopting different plant configurations, with very different results depending on the set-up selected.

**Example 1**

Approximately 120 g of Gela 55 230+ are treated in a metallic reactor (applicator) connected to an industrial microwave generator, according to the scheme shown in figure 1a.

The microwave generation system consists of a magnetron, which emits radiations at 2.45 GHz with a maximum suppliable power of 2,000 W, connected to a
circulator for the absorption, through a water charge, of possible reflected radiation, a directional coupler for measuring the direct and reflected power (through which the power absorbed by the sample can be estimated), a 3-stub system for the impedance adjustment, a rectangular waveguide transition with a coaxial line suitable for high powers.

The system provided for irradiating the sample being charged, shown in fig. 1b, is innovative. Said system comprises in particular, a metal flange (1), preferably produced in aluminium as in these examples, to be fixed to the external conductor of the coaxial transition line (2), on which flange a window (3) of material transparent to microwaves (as PTFE (used in these examples), quartz, etc.) is assembled, which supports a cylinder (4), antenna, which is inserted in the central conductor of the coaxial transition line (5) and which protrudes from the window for an appropriate length, suitable for guaranteeing the transmission of the microwaves. This object, called also pressure window, allows the sample to be treated to be physically isolated with respect to the microwave generation system, guaranteeing however the transmission of radiation. The pressure sealing system between antenna and PTFE window is obtained with o-rings (6) made of materials transparent to microwaves (silicone, PTFE, etc.).

The applicator consists of an aluminium reactor, produced for housing the sample during the treatment:
this is a cylindrical recipient, with a useful volume of 200 cc. The material can be stirred during the treatment with a metallic anchor housed on the bottom.

The pressure measurement (P) is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement (T) is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The generator is piloted via software developed in a LabView environment and the main process parameters (P, T, Power supplied and reflected) are monitored in continuous and in real time.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen; the oil is brought to a temperature of 185°C with microwave irradiation with an average power of 600 W in 13', without stirring; this temperature is maintained almost constant for a further 30' with a power of 230 W, again under static conditions. During the treatment, an operator acts manually on the tuning system, varying the insertion depth of the stubs in waveguide in order to minimize the power reflected, which in this example is normally lower than 20-30 W.

A temperature of 195°C and a pressure of 6.3 bar are reached.

Figure 2 shows the temperature trend (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).
At the end of the test the sample is cooled to room temperature and is characterized from a rheological point of view: the viscosity of the product treated with microwaves shows a viscosity of 250,000 mPa·s at 38°C, equal to a reduction in the viscosity of 19% approximately with respect to the starting value (310,000 mPa-s at 38°C).

Example 2

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1, whereas an innovative system different from Example 1 is provided for irradiating the charge.

In particular, the sample is charged into an aluminium reactor having a useful capacity of 200 cc. The central conductor of the coaxial line protrudes from the pressure window and extends to the bottom of the reactor.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple housed in a specific metallic thermocouple-holder, protruding inside the reactor and completely immersed in the liquid.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen; the oil is brought to a temperature of 180°C with microwave
irradiation with a power of 600-800 W in 20', under static conditions; the temperature is then maintained almost constant for a further 15' with an average power of 270 W. By manipulating the stubs, the reflected power level is maintained at a value normally lower than 70 W.

The maximum temperature reached is 185°C approximately with a maximum pressure of 9 bar.

Figure 3 shows the temperature trend (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

After cooling the sample, the rheological characterization is effected: the viscosity of the oil treated is 98,000 mPa·s at 38°C, corresponding to a reduction in the viscosity of 68.5% approximately with respect to the starting value (310,000 mPa·s at 38°C).

Example 3

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator. The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1, whereas a variant of the innovative system is provided for irradiating the charge described in Example 2.

The sample is charged into the reactor, with a configuration similar to that of Example 2, except for the absence of the metallic thermocouple-holder and the presence of a resistive heating band in contact with
the walls of the reactor. In this way, it is only possible to irradiate the sample when this has reached a sufficiently high temperature.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen; the oil is brought to a temperature of 180°C with the resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves at 900 W for 3', with an average absorbed power of 790 W.

The maximum temperature reached is 200°C with a pressure of about 15 bar.

Figure 4 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

After cooling, a pressure of 4.5 bar is measured, higher with respect to the initial value of 1.5 bar, an index of the gas production.

The viscosity at 38°C of the oil treated is 48,000 mPa-s at 38°C, corresponding to a reduction of 85% with respect to the product as such characterized by a viscosity at 38°C of about 310,000 mPa-s.

Example 4

120 g of Gela 55 230+ are treated in a metallic
reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

5 The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen: the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves at 800 W for 5', with an average absorbed power of 785 W. The maximum temperature of 215°C and a pressure of 17 bar are reached.

15 At the end of the treatment with microwaves, the sample is kept at a temperature close to 180°C for 30' and is then left to cool.

Figure 5 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

20 After cooling, a final pressure of 5 bar is measured, much higher with respect to the initial value of 3 bar: from the mass balance, a production of 1.0 g
of gas is estimated, which proves to be methane (29%), H₂S (28%), ethane (14%), propane (7%), N-butane (2%), H₂ (2%), and other gases (18%).

The viscosity at 38°C of the oil treated is 39,000 mPa-s, with respect to the initial product with a viscosity at 38°C of about 320,000 mPa-s.

Example 5

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen: the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves at 800 W for 2', with an average absorbed power of 780 W. The maximum temperature of 200°C and a pressure of 8.5 bar are reached and the sample is left to cool.

Figure 6 shows the temperature and pressure profiles (a) and the graph of the power supplied,
reflected (values measured) and power absorbed by the sample (estimated) (b). After cooling, a final pressure of 4.5 bar is measured, higher than the initial value of 3 bar.

The viscosity at 38°C of the oil treated is 240,000 mPa·s, with respect to the initial value at 38°C of about 310,000 mPa·s.

On comparing the results obtained in the test of Example 4, carried out with the same power, can be verified the importance of the irradiation times of the sample.

Example 6

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen; the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves with an average
power of 1,200 W for 2'; the sample absorbs 1,100 W on an average. The maximum temperature of 200 °C and a pressure of 17 bar are reached and the sample is left to cool.

Figure 7 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

After cooling, a final pressure of 5 bar is measured.

The end-product has a viscosity at 38°C of 54,000 mPa · s, with respect to the initial value of about 310,000 mPa · s at 38°C.

With respect to the test of Example 5, the use of higher powers, with the same duration of the treatment, allows to obtain a much greater reduction in the viscosity.

Example 7

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the
bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen: the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves with an average power of 250 W for 15'; the sample absorbs 245 W on an average. The maximum temperature of 195°C and a pressure of 6.5 bar are reached and the sample is left to cool.

Figure 8 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

The end-product has a viscosity at 38°C of 228,000 mPa·s, with respect to the initial value of about 310,000 mPa·s at 38°C.

From the results, it is evident that the prolonged treatment times but with lower powers do not induce significant reductions in the viscosity.

Example 8

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.

The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a
pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen: the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves with an average power of 800 W for 4'; the sample absorbs 750 W on an average. The maximum temperature of 215°C and a pressure of 16.5 bar are reached; at the end of the irradiation, the sample is maintained at a temperature of about 185°C for 30' and is then left to cool. When cold, a residual pressure of 4.5 bar is measured.

Figure 9 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

The end-product has a viscosity at 38°C of 430,000 mPa·s, with respect to the initial value of about 310,000 mPa·s at 38°C.

The results show the repeatability of the treatment with respect to the data obtained from the test of Example 4, the operative conditions adopted being similar.

Example 9

120 g of Gela 55 230+ are treated in a metallic reactor connected to an industrial microwave generator.
The system upstream of the reactor (generator, directional coupler, tuner, waveguide/coaxial transition) is the same as Example 1.

The sample is charged into the reactor, according to a configuration equal to that of Example 3.

The pressure measurement is effected with a pressure transducer connected to the pressure window, whereas the temperature measurement is effected with a thermocouple by means of a cavity situated on the bottom of the reactor.

The sample is charged into the reactor, with an initial pressure of 3 bar of nitrogen: the oil is brought to a temperature of 180°C with a resistive band fixed on the side walls of the reactor; the sample is subsequently irradiated with microwaves with an average power of 850 W for 4' 30"; the sample absorbs 760 W on an average. The maximum temperature of 215°C and a pressure of 17 bar are reached; at the end of the irradiation, the sample is maintained at a temperature of about 185°C for 30' and is then left to cool. When cold, a residual pressure of 5 bar is measured.

Figure 10 shows the temperature and pressure profiles (a) and the graph of the power supplied, reflected (values measured) and power absorbed by the sample (estimated) (b).

The end-product has a viscosity at 38°C of 35,000 mPa·s, with respect to the initial value of about 310,000 mPa·s at 38°C.

The results again show the repeatability of the
treatment with microwaves with respect to the data obtained from the test of Example 4, the operative conditions adopted being similar.

CHARACTERIZATION OF THE SAMPLES TREATED

Measurement of the viscosity

The instrument used for measuring the dynamic viscosity is an AR 1500 viscometer of TA Instruments with a plate-cone coupling (40 mm, 2°steel).

For effecting the measurement, the coupling temperature is first regulated and the sample is subsequently charged at room temperature or already hot on the preheated fixed plate, using a spatula if the sample is extremely viscous, or a dropper if it is fluid. The gap between the plates is brought to 52 microns, care being taken that the sample is well-distributed and that there are no bubbles entrapped in its interior and the plate-cone is left to rotate with a torque suitable for the analysis for about 10 minutes before proceeding with the measurement.

CHARACTERIZATION OF THE PRODUCT FROM GELA 55 230+ OF EXAMPLE 2

The characterizations effected on the sample obtained in Example 2 clearly show the effectiveness of the microwave radiation in terms of both reduction in the viscosity and improvement in the quality with respect to the starting charge consisting of Gela 55 230+.

The microwave treatment in fact reduces the viscosity of the product at 38°C to 98,000 mPa-s.
against a starting value of 310,000 mPa · s at 38°C (torque applied 90 µN·m, share rate at 38°C 0.05116 s⁻¹) generating a reduction of 68.5%.

This reduction in viscosity was observed within a wide temperature range (from 38 to 90°C) and is maintained with time, except for the "hardening" due to the oxidation of the sample, UV exposure, etc. (figure 11 (a)). In particular (figure 11 (b)) five consecutive determinations of the viscosity at 38°C of the product were diagrammed, effected over a period of two months following irradiation, against the viscosity determinations at 38°C of the charge: it can be deduced that the reduction generated by the microwaves is permanent and not temporary. On comparing the distillation curves obtained with the "simulated" distillation technique SIM-DIST, a slight shift of the yield towards lighter fractions up to 570°C, can be observed in the product compared with the charge. In particular, a decrease of about 1.53% m/m of the 500°C+ fraction is observed.

The microwave treatment modifies the distribution of the high-molecular-weight molecules, as revealed by the GPC technique: the starting residue has a weight average molecular weight of 3524 with a polydispersity index equal to 5.26, whereas the sample processed has a weight average molecular weight of 2924 and a polydispersity index of 4.6.

CHARACTERIZATION OF THE PRODUCT FROM GELA 55 230+ OF EXAMPLE 4
The characterizations effected on the sample obtained in Example 4 clearly show the effectiveness of the microwave radiation in terms of both reduction in the viscosity and improvement in the quality with respect to the starting charge consisting of Gela 55 230+.

The microwave treatment in fact reduces the viscosity of the product at 38°C to 39,000 mPa·s against a starting value of 320,000 mPa·s at 38°C generating a reduction of about 88%.

On comparing the distillation curves obtained with the "simulated" distillation technique SIM-DIST, a shift of the yield towards lighter fractions, can be observed in the product compared with the charge; in particular, a decrease of about 5% m/m of the 500°C+ fraction is observed.

The measurement of the colloidal stability of the asphaltene agglomerates of the product, determined with the method Peptization Value (PV) SMS 1600-01, is PV = 2.4 slightly lower than the value of the charge equal to PV = 3.0. The transformation induced by the method, object of the present invention is surprising as it drastically reduces the viscosity with a modest depression of the PV, unlike the traditional thermal conversions.

The table shows the analysis of the gases developed during the treatment with the innovative method: paraffins and light olefins are present together with hydrogen sulfide demonstrating the transformation of
the charge at low temperature.

<table>
<thead>
<tr>
<th>Gas</th>
<th>% Moles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>2.16</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>2.23</td>
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<tr>
<td>Carbon dioxide</td>
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<td>Methane</td>
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</table>

100.00
Claims

1. A process for the reduction of the viscosity of crude oils, substantially comprising a separation step of said crude oils in order to separate a light fraction and a heavy fraction having a residual water content not higher than 1,400 ppm and a treatment step of said heavy fraction separated by means of microwave irradiation, operating at temperatures ranging from 50 to 350°C, for a time period of between 1 sec. and 120 min. and with frequencies ranging from 0.3 to 300 GHz where said irradiation is carried out by a system comprising a metal flange (1) to be fixed to the external conductor of the coaxial transition line (2), on which flange a window (3) of material transparent to microwaves is assembled, which supports a cylinder (4), antenna, which is inserted in the central conductor of the coaxial transition line (5), said antenna protruding from the window for an appropriate length, suitable for guaranteeing the transmission of the microwaves.

2. The process according to claim 1, wherein the treatment step by means of microwave irradiation is effected operating at temperatures ranging from 100 to 320°C, for a period of time of between 10 sec. and 60 min. and with frequencies ranging from 0.5 to 30 GHz.

3. The process according to claim 2, wherein the treatment step by means of microwave irradiation is effected operating at temperatures ranging from 170 to 280°C, for a period of time of between 20 sec. and 40
min. and with frequencies ranging from 0.8 to 7 GHz.

4. The process according to claim 1, wherein the light fraction, after being separated from the gases, is mixed with the heavy fraction by means of microwave irradiation.

5. The process according to claim 1, wherein the separation of the crude oils is effected so as to have a heavy fraction having a residual water content not higher than 1,000 ppm.

6. The process according to claim 1, wherein the separation of the crude oils is effected so as to have a heavy fraction having a residual water content not higher than 500 ppm.

7. The process according to claim 1, wherein the separation step is a flash or a distillation.

8. The process according to claim 1, wherein upstream of the flash or distillation there is a desalting step.
Figure 1A Schema of the experimental set up.
Figure 2 - Trends of the power supplied, reflected and absorbed (b) and of the temperature (a) registered during the test of Example 1.
Figure 3 - Trends of the power supplied, reflected and absorbed (b) and of the temperature (a) registered during the test of Example 2
Figure 4 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 3.
Figure 5 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 4
Figure 6 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 5
Figure 7 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 6
Figure 8 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 7
Figure 9 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 8
Figure 10 - Trends of the power supplied, reflected and absorbed (b) and of the temperature and pressure (a) registered during the test of Example 9
Figure 11 - (a) Viscosity measurements in relation to the temperature of the charge (Gela 55 230+ as such) and product (Gela 55 230+ MW treated), (b) Viscosity measurements at 38°C in relation to the aging time of the charge (Gela 55 230+ as such) and product (Gela 55 230+MW treated)
INTERNATIONAL SEARCH REPORT

International application No
PCT/EP201Q/007284

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10G15/08 C10G32/02 B01J19/12

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G B01J H05H H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
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<td>A</td>
<td>US 2007/056880 AI (MOREI RA ELIZABETH M [BR] ET AL MOREI RA ELIZABETH MARQUES [BR] ET AL) 15 March 2007 (2007-03-15) paragraphs [0038] [0049] [0057] [0060] [0064] [0068] [0071] [0076] [0078] figure 1</td>
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<td>A</td>
<td>WD 96/13621 AI (KROGH OLE D [US] ; SAWIN HERBERT J [US]) 9 May 1996 (1996-05-09) page 11, line 25 - line 31; figures 1, 2 page 13, line 2 - line 5</td>
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<td>A</td>
<td>US 4 067 683 A (KLAÏ LA WILLIAM J) 19 January 1978 (1978-01-10) the whole document</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search
29 April 2011

Date of mailing of the international search report
10/05/2011

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<td>IT MI20 091 833 AI (ENI SPA) 23 April 1 2011 (2011-04-23) page 7, line 19 - line 23; claim 1; figures 1,2</td>
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