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(54) ELECTRONIC MEASUREMENT OF PROCESS END POINT

(71) We, EXXON RESEARCH AND ENGINEERING COMPANY, formerly Esso Research And Engineering Company, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Linden, New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and a system for the electronic measurement of the end point of a process, in which certain preselected characteristics of a product being manufactured are continuously monitored and compared with a reference standard simulating desired characteristics of the product, whereby when the difference between the actual product characteristics and the reference standard is substantially zero, this is shown on a readout device, thus making the operator aware that the desired end point has been attained and the process may be stopped for transfer of the product to a storage area or the like.

Although the present invention will be described with regard to a preferred embodiment involving asphalt oxidation, that is to say blowing molten asphalt with air it will be apparent to those skilled in the art that the invention generally is applicable to other plant operations. Heretofore the duration of the air blowing process used to produce oxidized asphalt has been based on semi-empirical relation between the length of time air is blown and the softening point. Generally, the operation requires that air be blown through the asphalt at a temperature of 480 to 500°F. for about six hours to achieve an asphalt grade having a softening point ranging from 190 to 200°F. (commonly known as 180—ox), or eight hours for an asphalt grade having a softening point range from 220 to 230°F. (commonly known as 220—ox). At the end of the period

required for the respective grades the air flow is stopped and a laboratory inspection sample is removed. The asphalt then is kept at 480 to 500°F. until the laboratory reports its findings some two hours later. If the softening point is found to be too low, air blowing is resumed for a relatively short period of time. If, on the other hand, it is too high, the asphalt is pumped into a storage tank for reblending. The foregoing procedure has proven to be quite unsatisfactory because not only is product quality control very poor—in fact, inspection of the finished products has revealed that only 40 to 50 per cent of them are within the specified limit—but the tower capacity is reduced by necessitating the holding of the product while awaiting inspection results. Further, the delay is objectionable in terms of product quality, since it has been found that even without air flow the viscosity and hence the softening point of the oxidized asphalt may increase during this waiting period. The term "softening point" as used in this specification is intended to mean that the temperature at which the asphalt contained within the confines of a ring can no longer support the weight of a steel ball of a diameter smaller than the inner diameter of the ring. A detailed description of this well-known Ring and Bell measurement for determining the softening point is given in ASTM Method D36—66T.

Depending on the extent of the air blowing process, it is possible to produce materials having desired softening points ranging from below 100 to over 230°F. The higher the softening point range the greater is the duration of air blowing required and thus, the time required for the product to remain in the tower is greatly increased and the total throughput, particularly during peak seasons, is reduced considerably.

Various attempts have been made to find a satisfactory way to increase the capacity of the plant. To provide an additional tower is not very attractive because the plant capacity is exceeded only during periods of peak

demand. Another possibility is to blend one batch of the product having a softening point that is too high with another batch having a correspondingly lower softening point. By blending the two in a storage tank, it is sought to obtain a final product within the established specification. While this approach might yield an acceptable softening point, other physical characteristics have been found to be adversely affected. It is apparent from the foregoing unsuccessful prior art attempts to increase plant capacity and product quality, that a new technique is required to overcome the failures and difficulties encountered, and simultaneously to provide for close product quality control and with an increase in plant capacity by eliminating the lengthy waiting time for laboratory evaluation of the various samples.

The present invention overcomes or mitigates both these and other prior art deficiencies by providing an electronic measuring process and system which, in general terms, continuously monitors certain predetermined characteristics of a product and compares these characteristics with those simulated by a reference standard. Before going into the various details of the specific system contemplated by the present invention, it may be well to go into the theoretical background of the present invention.

When a material is subjected to an alternating electrical field, its response to the field can be described phenomenologically in terms of a capacitor and a resistor connected either in series or parallel relation. The capacitor represents the material's ability to store electrical energy reversibly, while the resistor indicates the irreversible dissipation of electrical energy.

In a system of polar molecules, an alternating electrical field will cause displacements of the molecules from their equilibrium position as they try to orient themselves with respect to the field. This motion is opposed by the environment in which the molecule moves. The environmental effects may come from interaction of the dipoles themselves or from interactions of the dipoles with other molecules. In either case the net effect will be a slowdown of the motion of the polar molecules preventing them from moving in phase with the applied field. The resistance of the medium represents the microscopic viscosity existing in the vicinity of the dipoles. It has been recognized that the electrical resistivity or its inverse, the electrical conductivity, of a suspension of polar molecules in a nonpolar environment is directly related to viscosity of the system. It is therefore possible to correlate changes in the electrical resistivity or conductivity of a system to its internal or microscopic viscosity, provided the fre-

quency of the alternating field is less or smaller than the natural vibrational frequency of the polar molecules.

In the case of an asphalt air blowing process, it is important to note that once on temperature and at a preselected frequency of 1KHZ the resistance of the asphalt increases as air blowing progresses, while the capacitance and hence, the dielectric constant of the asphalt remains essentially constant. This confirms that the increased viscosity of the air blown asphalt is not due to oxidation of its constituents, but is due to polymerization. For the purposes of this invention and for reasons obvious to those skilled in the art, frequencies ranging from 10^4 to 10^7 HZ can be used, although frequencies of 100^2 to 10^6 HZ are preferred and frequencies between 500 and 50,000 HZ are most preferred.

Thus, it is seen that a material can be phenomenologically described as a combination of a capacitor and a resistance, provided, of course, that the appropriate capacitance and resistance values are known at a preselected frequency, for example 1KHZ. By ascribing characteristic capacitance and resistance values to the two grades of asphalt (180-ox and 220-ox), under consideration in regard to the preferred embodiment, it is possible to compare the electrical characteristics of an actual system undergoing air blowing with the predetermined desired final electrical equivalent. In this manner, the extent of difference between the two values indicates how far off the actual material's properties are from those of the desired finished product. To carry out the foregoing comparison on a continuous basis, the present invention contemplates employing a monitoring system using a circuit capable of determining independently the unbalance of both the capacitive and the resistive component. Although the resistance comparison is the prime consideration in this case, the capacitance reading is useful in those instances involving chemical changes occurring during processing.

According to the present invention there is provided a method for determining the end point of a process employed in the manufacture of a liquid product containing polar molecules which are displaceable from their equilibrium position upon application of an alternating current thereto, comprising the steps of:

- (a) electrically simulating at a preselected frequency at least one of the desired physical properties of the final product;
- (b) continuously electrically measuring at said frequency, by means of electrical sensor means in contact with the product during manufacture, at least one electrical property characteristic of the physical state

of the actual product while undergoing manufacture, each said measured property being the same as each said electrically simulated physical property in step (a);

5 (c) electrically comparing at least said one electrically simulated physical property of step (a) with the corresponding said measured electrical property of step (b);

10 (d) determining the difference between the electrical properties being compared in step (c), process end point being indicated by substantial correspondence of these properties.

15 In accordance with the invention the method is applicable to the determination of the end point of an air blowing process employed in asphalt manufacture; the method then comprising the steps of:

20 (a) electrically simulating at a preselected frequency at least the desired viscosity of the final asphalt;

25 (b) continuously electrically measuring at said frequency, by means of electrical sensor means in contact with the asphalt during blowing, the corresponding electrical property characteristic of the viscosity of the asphalt undergoing manufacture;

30 (c) comparing electrically the electrically simulated viscosity of step (a) with the actual measured electrical property of step (b); and

35 (d) determining the difference between the properties being compared in step (c) so as to indicate attainment of process end point.

40 Further in accordance with the invention an asphalt air blowing process including the end point determination method of the invention comprises the steps of:—

(a) maintaining the asphalt in a molten condition at an elevated temperature;

(b) blowing air through said molten asphalt;

45 (c) continuously measuring the electrical resistance characteristic, characterizing the viscosity of the asphalt, during the blowing;

50 (d) electrically comparing the measured electrical resistance characteristic of the asphalt with a predetermined electrical resistance reference standard which simulates electrically the viscosity characteristic of the desired end point product of the asphalt blowing process;

55 (e) determining the difference between the measured and simulated values of step (d) and terminating said blowing of air when said measured electrical resistance characteristic substantially corresponds to said predetermined resistance reference standard.

60 Still further in accordance with the invention there is provided a system for calculating the aforesaid end-point determination, said system comprising: means for continuously monitoring at a preselected frequency

one or more selected electrical properties of the product during the manufacture thereof; a reference standard network for electrically simulating at the preselected frequency one or more selected predetermined 70 corresponding reference electrical properties of the final product; means connecting said monitoring means and said reference standard network in an electrical comparison configuration having output terminal means; means adapted for supplying an excitation signal to said configuration at the preselected frequency, said excitation 75 supplying means being connected to means including first and second channels, said first channel including an inverting amplifier and said second channel including a non-inverting amplifier for providing out-of-phase and in-phase excitation signals respectively to said reference standard network 80 and said monitoring means; output circuit means connected with said output terminal means for sensing any unbalance and producing an output signal representative of any unbalance; phase sensitive demodulator means for receiving and resolving said output signal into resistive and reactive components, said demodulator means also being connected for receiving said excitation 85 signal to provide phase reference signals enabling the resolving, thereby to provide a resultant resolved output signal which is a function of the comparison of the said one or more selected electrical properties with the said one or more reference 90 electrical properties, thereby determining the process progress and end point.

The sensor means, such as a admittance or conductivity cell can be, for example, 95 mounted in a tank or tower containing the product so as to be in contact therewith.

More specifically, the present invention 100 contemplates continuously monitoring the electrical properties of the material by means of an admittance sensing test cell. The sensed electrical properties of the actual material are compared electrically 105 with a reference standard comprising a combination resistor-capacitor network. Also, the reference standard may comprise a sample of the finished product provided that 110 the product material is stable under the prevailing physical conditions and its electrical properties remain constant with time. The test cell and the reference standard are 115 connected in an impedance comparison configuration. A master oscillator and phasing system provide excitation and unbalance is sensed by a preamplifier whose output is fed to a demodulation or phase sensitive 120 detecting section. There the output signal is compared with the original excitation signal, and is resolved into a resistive and a reactive component. This comparison 125 is performed by means of phase sensitive 130

detectors whose outputs are used to drive the final displays or readout devices. The said excitation is accomplished by feeding the oscillator signal to an inverting amplifier and a noninverting amplifier, which provide out-of-phase and in-phase excitation respectively. Since normally the test cell is located remotely from the reference standard, interconnecting coaxial cables are used wherever necessary. The foregoing described system of the present invention has distinct advantages over the prior art in that it is low in cost by virtue of the fact that it uses commercially available items, for example, the test cell; it is adaptable for use in multiple tank or tower operations; it is simple in that operator adjustments are minimal; it is weatherproof and provides a readily ascertainable null meter readout; it is serviceable since it is of a modular construction and employs solid state devices and integrated circuits where possible; and it is safe in that low voltages are used and is readily adaptable to explosion-proof constructions. A further significant advantage of the present system is that the control signals produced thereby are available for purposes of automation, if desired.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a schematic representation of the general principle involved in the invention.

Fig. 2 is a schematic block diagram showing a preferred embodiment of this invention; and

Fig. 3 is a schematic wiring diagram of the schematic of Fig. 2 showing the details of the present invention.

In Fig. 1 there is disclosed a bridge circuit configuration, generally denoted 10. The bridge 10 comprises an input excitation transformer T1 having a primary winding T1_p and a pair of split phase secondary windings T1_{s1} and T2_{s2} having a common grounded terminal 11. Each of the secondary windings T1_{s1} and T1_{s2} are connected in one-half of the bridge circuit in series with impedances 12 and 13, and impedances 14 and 15, respectively, and a common line 16 connecting a readout display such as a null meter M between common ground 11 and common terminal 17. An excitation voltage signal E is applied to the primary winding T1, and appears across the secondary windings as equal and opposite voltages, that is across the upper secondary

windings T1_{s1} there appears a voltage signal E having a phase angle of 0°, and across the lower secondary winding T1_{s2} there appears a voltage signal E having a phase angle of -180°. This excitation voltage is controlled and therefore can be considered as stable. Thus, there is formed a pair of commonly connected symmetrical circuits. The signal E < 0° generates a current i₂ which represents certain characteristics of the actual material being sampled by the test cell. The signal E < -180° generates a current i₁ which represents predetermined simulated characteristics of the desired end product. These signals flow from each circuit through the common line 16 where they add vectorially and depending upon the phase angle relationship between the respective signals, the meter M will provide a readout representative of this summation. The readout will permit determination as to whether the desired end point has been obtained. A zero or null reading will occur when the absolute values are identical and the phase angles thereof are such that the vector summation is zero. If the phase angle of the signal representative of the sampled material, which angle is determined by the ratio of resistive to reactive component, differs from that of the reference standard, then a readout other than zero will appear and the operator is aware that further processing is required.

Fig. 2 illustrates a block diagram of the system according to the present invention while Fig. 3 illustrates specific details thereof. The electrical properties of the sample material under test are monitored by a device such as an admittance cell generally indicated as 20. The cell equivalent is shown in Fig. 3 by parallel capacitor 21-resistor 22 network. Preferably the test cell has a plurality of capacitor-resistor (21-22; 21'-22', etc.) networks each of which has a different value corresponding to the desired grade of asphalt. A switch 27 may be provided to permit the operator to select the appropriate reference capacitor-resistor combination corresponding to the desired grade to be sampled. For example, to monitor separately the production of two grades (180-ox and 220-ox) of oxidized asphalt, the desired softening point specifications for these two products and their corresponding typical electrical specifications at 1KHZ (which are, therefore, used as the electrical specifications for the reference standard 24) are as follows:

	Product Grade	Softening Point Range °F.	Resistance Range Megohms	Capacitance PF
5	180-ox.	190—200	1.55—1.70 (R25)	50+1 (C26)
	220-ox.	220—230	2.70—2.80 (R25 ¹)	50+1 (C26 ¹)

To accurately define the desired physical characteristics of the finished product (so as to then accurately define corresponding electrical properties of that product), is important that a reliable laboratory test, such as the aforesaid Ring and Ball ASTM Method D36—66T be employed in measuring the desired softening point for this purpose. The reference standard 24, which simulates electrically the desired physical characteristics of the finished product, comprises a combination of a parallel connected resistor 25 and a capacitor 26. The standard 24 in turn is connected in parallel with the test cell 20. As shown in Fig. 3, the standard 24 may comprise a plurality of resistor-capacitor networks (25—26; 25'—26', etc.) each of which corresponds to a different grade of asphalt. A switch 23 is provided for selection by the operator of the particular tower being tested.

A master oscillator 28 and a phasing section 29 provide excitation, and any unbalance is sensed by a preamplifier 26 and is transmitted to a demodulation section generally indicated as 30 comprising a pair of phase sensitive detectors 31 and 32 whose operation is well known and does not per se form part of this invention. The sensed signal output of the preamplifier 26, which contains resistive and reactive components, is compared with components of the original excitation signal supplied to the phase sensitive detectors 31 and 32 from the phasing section 29 which receives the oscillator output signal. The comparison is performed by the phase sensitive detectors 31 and 32 whose outputs, as indicated in Figs. 2 and 3 are used to drive the final displays or, in other words, to provide a meter readout 33 for the capacitance and a meter readout 34 for the resistance. The capacitance is indicative of dielectric constant, while the resistance, which is the more significant readout, is indicative of viscosity. If desired, the capacitance readout 33 may be eliminated.

Physically, the electronic system is divided into two separate units referred to as the measurement section and the readout section. The measurement section is located outdoors near the tanks or towers (not shown) housing the asphalt or other material undergoing manufacture. These units, as shown in Fig. 2, may be separated by

quite some distance D, for example, 200 feet

The excitation circuit 35 comprises the amplifiers 36 and 37 which are of conventional solid state design. The incoming signal supplied by the master oscillator 28 is fed to the inverting amplifier 36 and the noninverting amplifier 37. These two amplifier circuits provide out-of-phase (O_1) and in-phase (I_1) excitation, respectively. Each amplifier may comprise a plurality of stages; however, the output stage of each of these amplifiers preferably is connected in voltage follower or common collector configuration to provide a low impedance drive for the bridge. Also, the configuration of each channel is arranged so as to provide a minimum of undesired signal quadrature, that is, unwanted 90° components. These signals O_1 and I_1 are coupled to the reference standard 24 and the test cell 20 by means of co-axial cables 38 and 39, respectively. This arrangement allows the sample test cell and the reference standard to be located remotely from the excitation section 35. Although the coaxial cables 38 and 39 may be of any reasonable length, it is important that cable balance be maintained and thus, equal lengths of the same type of cable are essential in connecting the cell 20 and the reference standard 24 to the excitation section.

The preamplifier 26 functions as a current detector and may comprise amplifiers 40 and 41, which preferably are arranged in a current sensing operational configuration. This configuration is designed to function so that it provides stable current amplification. Any unbalance current flows into the input terminal 42 and the output voltage of the preamplifier 26 then will comprise the product of the sensed bridge unbalance current times the value of the feedback resistor 43. The amplifier 40 is an electrometer that is, it has a high input impedance input device connected in an inverting mode while the amplifier 41 is a noninverting fixed gain device that is used to increase the overall loop gain at the operating frequency. This arrangement provides for an extremely stable sensitive current detector. As shown in Fig. 3 the reference standard 24 and the test cell 20 are connected by means of co-axial cables 44 and 45 and 46 to the input

terminal 42 of the preamplifier 26. As mentioned heretofore in regard to the input coaxial cables 38 and 39, the output coaxial cables 44 and 45 should be of equal lengths and of the same type of cable in order to provide a properly balanced system.

The readout section comprises the oscillator 28 which has excellent frequency stability and purity of wave form and operates at about 1KHZ. The oscillator per se is conventional. To provide greater sensitivity selection the oscillator output may be selectively fed to a suitable attenuator network provided with a switch to select either high or low sensitivity. Although not shown, a voltage follower (common collector transistor configuration) may be provided at the output of the oscillator 28 for purposes of line driving and impedance isolation. Such configurations are characterized by high input impedance and low output impedance, thereby to provide the desired isolation.

The oscillator signal also is fed to a transformer 46 in the phasing section 29. The primary of the transformer 46 comprises a pair of series connected windings 47 and 48 connected to ground 49. The secondary of the transformer 46 comprises a single grounded winding 50 and a pair of windings 51 and 52 grounded at their common junction 53. The transformer 46 is constructed so that the single winding 50 provides a direct signal without any phase shift. The secondary windings 51 and 52 are connected in series relation with phase shifting network comprising a variable resistor 54 and a capacitor 55, which by proper adjustment of the resistor 54, provides a 90° phase shift of the reference signal applied thereto. The latter signal is shown as O_2 in Fig. 3, while the non-phase shifted signal is shown by I_2 . A pair of power amplifiers 56 and 57 are connected in the lines containing the signals I_2 and O_2 , respectively, to provide the necessary amplification required to drive the reference input phase detector transformers 58 and 59. Each transformer preferably comprises a pair of center tapped primary windings and a pair of center tapped secondary windings. The detected unbalance signal obtained from the preamplifier output terminal 60 is processed by an amplifier 61. This amplifier 61 provides a relatively small gain, but more important, it compensates for fixed phase shifts that may occur in the system. The amplifier 61 may comprise one or more stages, and also may include a power amplifier stage if deemed necessary, to provide an input drive signal to the signal input transformer 62 of the phase sensitive detectors 31 and 32. The primary of transformer 62 comprises a pair of windings 63 and 64 grounded at their common junction 65. The secondary comprises pairs of center

tapped windings 66—67 and 68—69. The phase detectors operate in substantially conventional fashion by comparing the input signal phase with the corresponding phase of a reference excitation. The capacitance readout meter 33 is connected between the center tapped secondaries of transformers 58 and 62 (66—67) and the resistive readout meter 34 is connected between the center tapped secondaries of transformers 59 and 62 (68—69). Each meter 33, 34 has a variable resistor 70, 71, respectively, connected in series relation therewith for providing a sensitivity adjustment. The outputs of the phase sensitive detectors 31 and 32 are bipolar DC signals which drive the readout devices which comprise DC microammeters 33 and 34, respectively. Since balance is represented by zero signal on each meter, zero center or a null reading are normally used for purposes of readout. Thus, the operator readily can determine whether the actual product meets the desired characteristics of the final product.

The foregoing described electronic measuring system achieves its purpose of eliminating the waiting period for analytical results, and, at the same time, it insures much better product quality because the operator does not have to depend on arbitrary time limits for the various operating times required to produce the finished product. Thus, by monitoring the readout meters 33 and 34 (although 34 alone is sufficient), the operator readily can determine when the product is finished and ready for transfer from the tower to the storage area or the consumer.

While the present system has been described with specific reference to asphalt oxidation, it is within the scope of this invention to extend its usage to other areas such as the control of water content of alcohols, esters and ethers; the control of the purity of solvents such as isoparaffins; the control of oil content in waxes; and zinc dialkyl dithiophosphate manufacture having an end point in neutralization of the corresponding acid with zinc oxide, etc.

Further, it is within the scope of this invention to employ solid state devices, such as transistors, diodes, etc., wherever possible and also, to use integrated circuits where available with the desired characteristics. Although not specifically disclosed, it is within the scope of those skilled in the art to provide suitable conventional power supply where necessary.

WHAT WE CLAIM IS:—

1. A method for determining the end point of a process employed in the manufacture of a liquid product containing polar molecules which are displaceable from their equilibrium position upon application of an

terminal 42 of the preamplifier 26. As mentioned heretofore in regard to the input coaxial cables 38 and 39, the output coaxial cables 44 and 45 should be of equal lengths and of the same type of cable in order to provide a properly balanced system.

The readout section comprises the oscillator 28 which has excellent frequency stability and purity of wave form and operates at about 1KHZ. The oscillator per se is conventional. To provide greater sensitivity selection the oscillator output may be selectively fed to a suitable attenuator network provided with a switch to select either high or low sensitivity. Although not shown, a voltage follower (common collector transistor configuration) may be provided at the output of the oscillator 28 for purposes of line driving and impedance isolation. Such configurations are characterized by high input impedance and low output impedance, thereby to provide the desired isolation.

The oscillator signal also is fed to a transformer 46 in the phasing section 29. The primary of the transformer 46 comprises a pair of series connected windings 47 and 48 connected to ground 49. The secondary of the transformer 46 comprises a single grounded winding 50 and a pair of windings 51 and 52 grounded at their common junction 53. The transformer 46 is constructed so that the single winding 50 provides a direct signal without any phase shift. The secondary windings 51 and 52 are connected in series relation with phase shifting network comprising a variable resistor 54 and a capacitor 55, which by proper adjustment of the resistor 54, provides a 90° phase shift of the reference signal applied thereto. The latter signal is shown as O_2 in Fig. 3, while the non-phase shifted signal is shown by I_2 . A pair of power amplifiers 56 and 57 are connected in the lines containing the signals I_2 and O_2 , respectively, to provide the necessary amplification required to drive the reference input phase detector transformers 58 and 59. Each transformer preferably comprises a pair of center tapped primary windings and a pair of center tapped secondary windings. The detected unbalance signal obtained from the preamplifier output terminal 60 is processed by an amplifier 61. This amplifier 61 provides a relatively small gain, but more important, it compensates for fixed phase shifts that may occur in the system. The amplifier 61 may comprise one or more stages, and also may include a power amplifier stage if deemed necessary, to provide an input drive signal to the signal input transformer 62 of the phase sensitive detectors 31 and 32. The primary of transformer 62 comprises a pair of windings 63 and 64 grounded at their common junction 65. The secondary comprises pairs of center

tapped windings 66—67 and 68—69. The phase detectors operate in substantially conventional fashion by comparing the input signal phase with the corresponding phase of a reference excitation. The capacitance readout meter 33 is connected between the center tapped secondaries of transformers 58 and 62 (66—67) and the resistive readout meter 34 is connected between the center tapped secondaries of transformers 59 and 62 (68—69). Each meter 33, 34 has a variable resistor 70, 71, respectively, connected in series relation therewith for providing a sensitivity adjustment. The outputs of the phase sensitive detectors 31 and 32 are bipolar DC signals which drive the readout devices which comprise DC microammeters 33 and 34, respectively. Since balance is represented by zero signal on each meter, zero center or a null reading are normally used for purposes of readout. Thus, the operator readily can determine whether the actual product meets the desired characteristics of the final product.

The foregoing described electronic measuring system achieves its purpose of eliminating the waiting period for analytical results, and, at the same time, it insures much better product quality because the operator does not have to depend on arbitrary time limits for the various operating times required to produce the finished product. Thus, by monitoring the readout meters 33 and 34 (although 34 alone is sufficient), the operator readily can determine when the product is finished and ready for transfer from the tower to the storage area or the consumer.

While the present system has been described with specific reference to asphalt oxidization, it is within the scope of this invention to extend its usage to other areas such as the control of water content of alcohols, esters and ethers; the control of the purity of solvents such as isoparaffins; the control of oil content in waxes; and zinc dialkyl dithiophosphate manufacture having an end point in neutralization of the corresponding acid with zinc oxide, etc.

Further, it is within the scope of this invention to employ solid state devices, such as transistors, diodes, etc., wherever possible and also, to use integrated circuits where available with the desired characteristics. Although not specifically disclosed, it is within the scope of those skilled in the art to provide suitable conventional power supply where necessary.

WHAT WE CLAIM IS:—

1. A method for determining the end point of a process employed in the manufacture of a liquid product containing polar molecules which are displaceable from their equilibrium position upon application of an



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alternating current thereto, comprising the steps of:

(a) electrically simulating at a preselected frequency at least one of the desired physical properties of the final product;

(b) continuously electrically measuring at said frequency, by means of electrical sensor means in contact with the product during manufacture, at least one electrical property characteristic of the physical state of the actual product while undergoing manufacture, each said measured property being the same as each said electrically simulated physical property in step (a);

(c) electrically comparing at least said one electrically simulated physical property of step (a) with the corresponding said measured electrical property of step (b);

(d) determining the difference between the electrical properties being compared in step (c), process end point being indicated by substantial correspondence of these properties.

2. A method according to claim 1, wherein the said continuously measured electrical property characteristics of the product comprises resistance.

3. A method according to claim 1 or claim 2, wherein said electrical sensor means comprises means immersed in said product for electrically measuring resistive and capacitive components.

4. A method for determining the end point of an air blowing process employed in the manufacture of asphalt comprising the steps of:

(a) electrically simulating at a preselected frequency at least the desired viscosity of the final asphalt;

(b) continuously electrically measuring at said frequency, by means of electrical sensor means in contact with the asphalt during blowing, the corresponding electrical property characteristics of the viscosity of the asphalt undergoing manufacture;

(c) comparing electrically the electrically simulated viscosity of step (a) with the actual measured electrical property of step (b); and

(d) determining the difference between the properties being compared in step (c) so as to indicate attainment of process end point.

5. A method according to claim 4, wherein said electrical sensor means comprises a sensor immersed in said asphalt for measuring said electrical property characteristic of said viscosity.

6. A method according to claim 4 or claim 5, wherein the measured electrical property of said asphalt comprises its resistance which is indicative of the viscosity of the asphalt.

7. A process for the air blowing of asphalt comprising the steps of:

(a) maintaining the asphalt in a molten condition at an elevated temperature;

(b) blowing air through said molten asphalt;

(c) continuously measuring the electrical resistance characteristics, characterizing the viscosity of the asphalt, during the blowing;

(d) electrically comparing the measured electrical resistance characteristic of the asphalt with a predetermined electrical resistance reference standard which simulates electrically the viscosity characteristic of the desired end point product of the asphalt blowing process;

(e) determining the difference between the measured and simulated values of step (d) and terminating said blowing of air when said measured electrical resistance characteristic substantially corresponds to said predetermined resistance reference standard.

8. An electronic measuring system for determining the end point of a process employed in the manufacture of a product containing polar molecules which are displaceable from their equilibrium position upon application of an alternating current thereto, comprising: means for continuously monitoring at a preselected frequency one or more selected electrical properties of the product during the manufacture thereof; a reference standard network for electrically simulating at the preselected frequency one or more selected predetermined corresponding reference electrical properties of the final product; means connecting said monitoring means and said reference standard network in an electrical comparison configuration having output terminal means; means adapted for supplying an excitation signal to said configuration at the preselected frequency, said excitation supplying means being connected to means including first and second channels, said first channel including an inverting amplifier and said second channel including a non-inverting amplifier for providing out-of-phase and in-phase excitation signals respectively to said reference standard network and said monitoring means; output circuit means connected with said output terminal means for sensing any unbalance and producing an output signal representative of any unbalance; phase sensitive demodulator means for receiving and resolving said output signal into resistive and reactive components, said demodulator means also being connected for receiving said excitation signal to provide phase reference signals enabling the resolving thereby to provide a resultant resolved output signal which is a function of the comparison of the

- said one or more selected electrical properties with the said one or more reference electrical properties, thereby determining the process progress and end point.
- 5 9. An electronic measuring system according to claim 8, wherein said reference standard network comprises resistance and capacitance components of predetermined value at the selected frequency, which correspond to characteristics of a desired end
- 10 grade of said product.
10. An electronic measuring system according to claim 9, or claim 10, wherein said monitoring means comprises a plurality
- 15 of cells for monitoring a corresponding plur-

ality of batches of said product, and switch means for selecting one of said cells to monitor the electrical properties of the selected one of said batches of said product.

11. A method as claimed in claim 1 and substantially as herein described with reference to the accompanying drawings. 20

12. A system as claimed in claim 8 and substantially as herein described with reference to the accompanying drawings. 25

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