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(54) **METHOD FOR MONITORING AND CONTROLLING COMBUSTION IN COMBUSTIBLE GAS BURNERS AND SYSTEM FOR CONTROLLING COMBUSTION OPERATING ACCORDING TO SAID METHOD**

(57) A method is described for monitoring and controlling combustion in a burner of a premix combustible gas appliance (1) with fan, of the type comprising a sensor with at least one electrode (E) placed in the flame or in the proximity thereof and suitable for being powered by a voltage generator as well as being connected to an electronic circuit suitable for measuring the resulting potential at the electrode. The method comprises a first phase of acquisition and processing of data from a series of combustion conditions of the burner and a second phase of calculating the air number (λ) in a real operating condition of the burner. The first phase comprises the steps of: identifying a plurality of combustion conditions of the burner (1), applying in each of said conditions in the burner a power ($P_1, P_2, \dots, P_n$) and applying for each power an air number value ($\lambda_1, \lambda_2, \dots, \lambda_m$), said air number expressing the ratio between the quantity of air in the combustion process and the quantity of air for stoichiometric combustion, applying in each of the ($n * m$) test conditions (P_i, λ_j) a pulsed electrical voltage signal (S) to the electrode (E) and measuring the trend over time of the resulting electrical signal (S') at the electrode, once the application of the impulsed signal (S) has ceased, said signal (S) applied to the electrode (E) comprising, in the period of the signal (S), a first impulse (N1) with a positive amplitude, followed by a second impulse (N2) with a negative amplitude, identifying, for each of

said combustion conditions, the curve of the trend over time of the response signal (S') at the electrode (E), said trend being expressed for each impulse (N1, N2) by an exponential function decreasing over time in absolute terms, calculating for a first section of the curve, relating to the first impulse (N1), as well as for a second curve section relating to the second impulse (N2), the respective first and second time constants (τ_1, τ_2), characteristic of the exponential trend for the respective first and second curve sections, thus obtaining an interpolation function or correlation table (F), based on the acquired test data, suitable for unequivocally interpolating or correlating at least one significant parameter of the combustion characteristics (power or air number) with the respective time constants of the exponential functions characteristic of the trend in the response signal measured at the electrode, in the combustion process of the burner. The second phase of calculating the air number (λ) in a real operating condition of the burner comprises the steps of: acquiring in said operating condition the electrical response signal measured on the electrode after the application of the impulsed signal, calculating, for said operating condition of the burner, the first and second time constants (τ_1, τ_2) characteristic of the respective curves sections relating to the trend of the resulting voltage signal at the electrode, following the application of the impulsed signal, calculating the estimated value of the air

number (λ_{stim}) by using the interpolation function or correlation table (F) which correlates the power (P) and the air number (λ) with the time constants (τ_1, τ_2) character-

istic of the curve relating to the trend in the response signal (S') measured at the electrode (E).

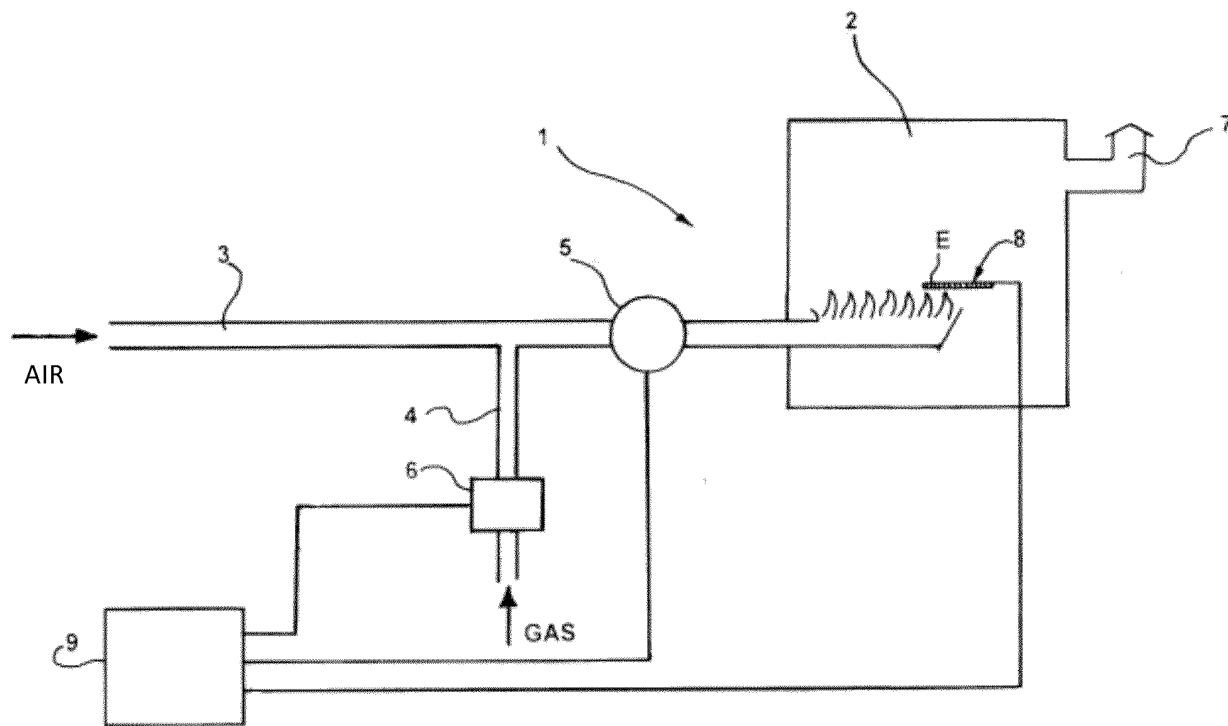


FIG.1

Description

[0001] The present invention relates to a method for monitoring and controlling combustion in combustible gas burners for appliances such as boilers, water heaters, fireplaces and the like, equipped with modulating fans for the combustion air. It also relates to a combustion control system operating in accordance with said method.

[0002] In the reference technical sector, it is known that in order to maintain efficient combustion, it is necessary for the ratio between the quantity of air and the quantity of combustible gas injected into the burner to be maintained around a predetermined optimal value, which depends essentially on the type of gas used and, in general, may also depend on the value of the power supplied by the burner, i.e. the gas flow rate.

[0003] This makes it possible to obtain and maintain over time a process of complete combustion without excessive dispersion of energy in the fumes and minimising the production of polluting gases, in compliance with the emission regulations of various countries.

[0004] To achieve this objective of maintaining the optimal air/gas ratio, different devices and methods have been developed in the reference technical field.

[0005] In the specific field of application of the invention, methods are known for monitoring and controlling combustion that are based on an analysis of the flame and, in particular, of the ionisation of the gas in the combustion zone of said flame. Typical methods provide for the use of an electrode located in the flame zone or in the proximity of the same, connected to an electronic circuit that applies a fixed or variable voltage to said electrode and measures the current that flows through said electrode. By means of current signal processing and analysis systems, a calculation is made of one or more parameters relating to the combustion process. Among the processing systems, signal frequency spectrum analysis methods are known that are suitable for identifying frequency spectrums or variations of the same indicating flame instability or sub-optimal combustion, on the basis of which systems are provided for correcting the combustion process in order to return said process to the desired conditions.

[0006] The recognisable limits of the known methods are mainly linked to the reliability of the results of the frequency spectrum analyses and their correlation with the combustion process, as well as to the complexity of the calculation and analysis algorithms used.

[0007] Limitations can also be found in the possible wear and ageing of the electrode used to receive the signal at the ionisation sensor, with consequent repercussions on the reliability and precision of the data analysed by the frequency spectrum processing algorithms.

[0008] The above-mentioned limitations are also amplified when it is desired to perform combustion control in burners of the modulating type, in which it is sought to achieve optimal combustion conditions according to var-

iations in the required power, within the range between a minimum power and a maximum permissible power for the burner.

[0009] It is also known that the volumetric ratio between the gas flow rate and the air flow rate suitable for correct combustion also depends on the type of gas. Each family of combustible gases is therefore correlated with respective and specific regulation curves (which correlate, for example, the gas flow rate with the air flow rate). One of the problems of the known combustion control systems is that relating to the identification of the family of gases and to the association of the optimal regulation curves.

[0010] The problem addressed by the present invention is that of providing a method for monitoring and controlling combustion in a burner of a combustible gas appliance, as well as a combustion control system operating in accordance with said method, that are structurally and functionally designed to overcome the limitations described above with reference to the cited prior art.

[0011] Within the context of this problem, it is an aim of the invention to provide a method and a control system that are suitable for ensuring optimal combustion over the entire range of flow rates (and for various types of gas) or power outputs for which the burner is designed, providing reliability and repeatability of results in the analysis of the signals relating to the combustion process.

[0012] Another aim of the invention is to provide a method and a control system that are simple to manage and characterise both during installation and during use of the burner of the appliance.

[0013] This problem is solved and these aims are achieved by the present invention by means of a method and a system for controlling combustion in a burner of a combustible gas appliance, produced in accordance with the claims that follow.

[0014] The features and advantages of the invention will become clearer from the following detailed description of a preferred embodiment, given by way of non-limitative example, with reference to the accompanying drawings, in which:

- Figure 1 is a schematic view of a burner of an appliance equipped with a combustion control system operating in accordance with the combustion monitoring and control method according to the invention,
- Figure 2 is a graph showing a function of interpolation between the parameters that characterise respective combustion process conditions in corresponding operating conditions of the burner,
- Figures 3 and 4 are graphs showing the trend of the respective parameters of the interpolation function of the previous figure according to variations in some of the parameters that characterise the combustion process,
- Figure 5 is a graph showing the trend of the electrical signal applied to the electrode of the burner according to the method of the present invention, in a spe-

cific operating condition with preselected power and air number values, and also showing in a corresponding manner, as the time value changes, the function of the response signal obtained, with the trend illustrated in Figure 2,

- Figure 6 is a graph showing the curves of correlation between operating parameters of a fan and of a modulating gas valve of a burner appliance operating with the combustion control method of the invention.

[0015] With initial reference to Figure 1, 1 indicates overall a burner, represented only schematically, equipped with a combustion control system, produced to operate in accordance with the combustion monitoring and control system of the present invention.

[0016] The burner 1 is housed in an appliance, not represented, intended for the production of domestic hot water and/or slaved to a room heating circuit, in a manner that is known per se and not illustrated in the figures.

[0017] The burner 1 comprises a combustion chamber 2, which is fed by a first pipe 3 and a second pipe 4, suitable for introducing into said combustion chamber 2 a flow of air and, respectively, a flow of combustible gas. Preferably, the second pipe 4 enters the first pipe 3 upstream of the combustion chamber 2 (premix burner). On the air/gas mixing section is provided a fan 5 with variable rotation speed. In the configuration of Figure 1, the fan is located downstream of the mixing zone, but may also alternatively be located upstream of said air/gas mixing zone. 6 indicates a modulating valve located on the gas pipe 4 for regulating the flow of gas injected into the burner.

[0018] The combustion chamber 2 is connected downstream to a flue 7, through which the combustion exhaust gases are evacuated.

[0019] 8 indicates a combustion monitoring sensor, described in greater detail below, which is connected to a control device 9 provided with an electronic circuit unit suitable for controlling the burner according to the method of the present invention, as illustrated below. The control device is also operatively connected both to the fan 5 and to the modulating valve 6 for regulating said units.

[0020] The sensor 8 is arranged in the proximity of the burner flame, and is suitable for being powered by a voltage generator, as well as being connected to an electronic circuit suitable for measuring the resulting potential at the sensor.

[0021] In a preferred embodiment, the sensor 8 comprises an electrode, indicated by E, which is placed in the flame or in the proximity thereof. The electrode E, designed as a mono-electrode structure, can conveniently serve both as a flame ignition element and as an element suitable for measuring the potential generated in response to the application of a voltage signal to the electrode, during the combustion process, in accordance with the method of the present invention. A suitable switching unit is provided for electrically connecting the electrode E with the respective control circuits of the above-men-

tioned functions. Conveniently, the electrode E, when it measures the response signal, is disconnected from the voltage generator (and connected to the measuring device).

[0022] According to what is known of the physics of the plasmas that develop during combustion processes, if an external load is introduced into the plasma, said load, due to the electrical field that it produces, causes a motion of the loads that constitute the plasma; this motion increases as the introduced external load increases. However, there is an electrical field value above which the flow of load particles does not increase any further (saturation). The motion is significantly different for electrons and for ions: since electrons are much lighter and smaller, they move much more quickly and undergo far fewer collisions along their course of travel. This means that the above-mentioned phenomenon of saturation occurs much earlier in the case of positive ions, while it occurs later for electrons. The macroscopic effect generated by the introduced external load, due to the movement of the load particles, is an alteration of the electrical field of the plasma. This electrical field is propagated around the particle over a distance in the order of the 'Debye length'. This distance, as mentioned above, is greater for electrons, i.e. in cases where the introduced load is positive. On the other hand, it is smaller in the case of positive ions, i.e. when the introduced load is negative.

[0023] Returning to the method of the invention, an electrical voltage signal with a determined wave form over time is applied to the electrode E; this potential is equivalent to the interference load mentioned in the preceding description. The electrode assumes a potential value determined by the motion of the plasma loads caused by the voltage signal applied to the electrode and responding to the dynamics described above. The changes in this potential are then measured by the electronic circuit and processed in the manner that will be described below.

[0024] The underlying concept of the method of the invention is therefore the fact that the trend of the resulting response signal at the electrode E is unequivocally determined by the composition of the fuel/air mixture prior to combustion. Knowledge of this composition is essential in order to be able to predict certain key effects of the combustion process, such as the quantities of CO₂ and CO produced and the thermal power produced. In this way, among other things, it is possible to compensate for the effects of gases other than the nominal gases, referred to in the sector as G20 and G31. Therefore, knowledge of the air number (indicated elsewhere by the symbol " λ "), understood as the ratio between the quantity of air in the combustion process and the quantity of air for stoichiometric combustion, makes it possible to produce a system for controlling the combustion of a gas burner appliance.

[0025] More particularly, according to the invention, an impulsed periodic electrical voltage signal is applied to

the electrode E, and said signal has an interference effect on the motion of the loads present in the plasma, such that said electrode, once the applied impulse has ceased, assumes a potential value determined by the motion of said loads, which is measured by the electronic circuit and processed in the manner that will be described below.

[0026] The method of the invention essentially comprises two macro operating phases: a first phase, indicated by A, of acquisition and processing of data relating to operating conditions applied to the burner, and a second phase, indicated by B, of calculating the air number λ or the generated thermal power P, in a real operating condition of the burner.

[0027] Both of these phases comprise, in turn, a sequence of operating steps that will be described in detail below.

[0028] In the description that follows, the steps relating in particular to the calculation of the air number λ will be described, but these can also be applied in the same way for other parameters relating to the combustion process.

[0029] A first operating step of phase A, indicated by A1, involves identifying and reproducing in the burner a plurality (1, 2, ..., n) of combustion conditions, in each of which a respective power P (P1, P2, ..., Pn) is applied and for each power (i.e. deriving from the combustion of a corresponding flow of combustible mixture) an air number ($\lambda_1, \lambda_2, \dots, \lambda_m$) is applied, said air number λ expressing the ratio between the quantity of air in the combustion process and the quantity of air for stoichiometric combustion. Each condition can also be repeated a preset number of times, in order to verify that the measurements made are not influenced by conditions of anomalous operation of the burner or by drift or by variability of the flame.

[0030] In a second subsequent operating step, indicated by A2, an electrical voltage signal is applied in each of said (n * m) operating conditions (Pi, λ_j) to the electrode E.

[0031] Reference will be made below to the choice of operating conditions of the burner with applied power values and air numbers, it being understood that the method can be applied in a similar manner with an alternative choice of parameters characterising the operating conditions, for example with applied power and CO2 (and/or CO) concentration values.

[0032] In a third step A3, a measurement is made, for example by means of a sampling, of the resulting voltage signal at the electrode E, calculating the respective parameters of the wave form of the response signal for each of said operating conditions applied to the burner.

[0033] In a further subsequent operating step, indicated by A4, an interpolation function or correlation table is calculated, indicated by F, based on the previously acquired data, suitable to allow the unequivocal interpolation or correlation of the power P, the air number λ and the characteristic parameters of the wave form of the response signal at the electrode E in the combustion

process of the burner.

[0034] Conveniently, it is provided that in the operating step A2, in each preselected operating condition of the burner (Pi, λ_j), an impulsed periodic voltage signal S is applied to the electrode E and the trend over time of the resulting electrical voltage signal S' at the electrode is measured (measuring the dimensions of the characteristic values of the signal), once the application of the impulsed signal S has ceased.

[0035] The signal S comprises, over the signal period T, a first positive impulse N1 of preset amplitude, followed by a second negative impulse N2 of preset amplitude. The times of application of the impulses are preferably the same, for example in the order of approximately 10 milliseconds, the duration of the time interval between the first and second impulses being less than the duration of the time interval between the second impulse and a subsequent first impulse, the period of the signal S being selected appropriately, for example preferably in the order of 50 milliseconds to 1 second, and more preferably in the order of approximately 100 milliseconds. The amplitude of the impulse of the signal S is selected according to convenience and is preferably the same in terms of absolute value for both the impulses N1 and N2.

[0036] Alternatively, it can be provided that the impulsed signal S is not periodic. Figure 5 shows the trend of the voltage signal S' measured at the electrode E following the application of the first and second impulses. It has been observed that both the wave forms of the signal S' associated respectively with the first and the second impulse have a decreasing exponential trend in terms of absolute value relative to the ground potential, with different time constants for each of them.

[0037] The exponential trends of both the first and second sections of the curve of the signal S' (as responses respectively to the first and second impulses) are characterised by respective time constants τ_1 and τ_2 (or equivalently by respective gradients a_1, a_2 of the tangents at the origin of the respective exponential curves). The exponential curves can be expressed as follows:

$$\text{impulse N1: } S'(t) = S_0 + K_1 e^{-t/\tau_1}$$

$$\text{impulse N2: } S'(t) = S_0 + K_2 e^{-t/\tau_2}$$

where K_1 and K_2 are two constants and S_0 represents a residual voltage that has been observed in operating conditions and is therefore introduced into each of the exponential functions that characterise the response to the signal S applied to the electrode E.

[0038] Figure 2 shows schematically the trend of the correlation function F relating to the plotting of the data acquired in phase A. The graph illustrates, along the three Cartesian axes, the power (P), the time (t) and the signal S' obtained in the data acquisition phases. For example,

for each power value P applied, the curves of each signal S' are reported (characterised by a pair of values for the time constants τ_1, τ_2), measured in the corresponding condition of the air number applied (P_i, λ_j).

[0039] Alternatively, the values assumed by the function F can be represented in the form of a correlation table, in which the values for the power P , air number λ and time constants τ_1 and τ_2 are correlated for each operating condition applied to the burner.

[0040] The correlation function or table F , obtained in phase A, therefore serves to correlate, in an unequivocal manner, the significant parameters of the combustion characteristics (power and air number) with the respective time constants of the characteristic exponential functions of the trend of the response signal S' measured at the electrode E in the combustion process of the burner.

[0041] This correlation function or table F is used, in the manner described below, to evaluate the combustion process in a real operating condition of the burner, in other words to derive the values of the significant parameters of the combustion process (for example, power and air number) by calculating the values of the time constants τ_1 and τ_2 that characterise the response signal S' to the signal S in that operating condition.

[0042] The second phase B provides for the following operating steps, for example designed to calculate the air number in a real operating condition of the burner.

[0043] One of the possible applications of the method may provide for phase A to be applied to a sample appliance or boiler in order to identify, by means of the correlation function or table, the relationship between the combustion parameters, while phase B is applied to the same or other appliances for verifying and if necessary correcting the combustion parameters in a real operating condition of the respective burner.

[0044] A first operating step, indicated by B1, provides for the application of the voltage signal S to the electrode E and for the acquisition, in a second operating step B2, of the electrical signal S' measured on the electrode after the application of the signal S , in a manner entirely similar to that described for phase A.

[0045] A third subsequent step B3 provides for the calculation of the time constants τ_1 and τ_2 (or equivalently the gradients a_1, a_2) that characterise the respective sections of the curve relating to the response signal S' to the impulsed signal S applied to the electrode E in the real operating condition.

[0046] From the calculated value of τ_2 it is possible to obtain, by means of the correlation function or table F , the power value P_x at the burner that characterises the operating condition in question.

[0047] Figure 3 shows the bundle of parameterised curves with the air number ($\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_n$) that represent the trend of the constant τ_2 according to changes in the power at the burner. The graph of Figure 3 is therefore a different way of visualising the data present in the table or function F of Figure 2. It should be noted that the power P is relatively insensitive to changes in the air number λ ,

and it is therefore possible to estimate, with a good approximation, the power value P_x (or a limited range of power values) to which the value assumed by the constant τ_2 corresponds. It may be provided that, for a certain value of the constant τ_2 , the average value of the power values visible in the graph at τ_2 is calculated.

[0048] With the value of the constant τ_1 , calculated in the operating step B3, on the other hand, the value of the air number λ is read by means of the function or table F .

[0049] Figure 4 shows the bundle of parameterised curves with the power value ($P_1, P_2, \dots, P_n$) that represent the trend of the air number λ according to changes in the constant τ_1 . The graph of Figure 4 therefore represents a different way of visualising the data present in the correlation table or function F of Figure 2.

[0050] In the graph of Figure 4, in order to correlate in an unequivocal manner the constant τ_1 with the air number λ (with reference to the corresponding power P), it is preferred to exclude the area of the graph relating to values of λ substantially less than 1.

[0051] Since it has been observed that for values of λ less than 1 the residual voltage assumes negative values sharply at odds with the assumed values for λ greater than 1 (in a residual voltage S' - air number λ graph, a stepped trend is seen in the residual voltage in the passage from values of $\lambda < 1$ to $\lambda > 1$), in the data acquisition phase A conditions corresponding to $\lambda < 1$ are also plotted, and a residual voltage threshold value is decided, beneath which incorrect combustion is recognised.

[0052] It follows from this that for the value of τ_1 calculated in step B3, the value of λ corresponding to the power P_x previously read in the correlation function or table F can be read in the graph of Figure 4. The estimated value of the air number (λ_{stim}) that characterises the combustion process of the analysed real operating condition is then read. It is understood that the method has useful application even if one limits oneself only to identifying the power P_x correlated with the value of the time constant τ_2 as explained in the preceding steps.

[0053] In addition, as mentioned previously, it is possible to refer in phase B to a correlation table, deriving therefrom the values for power (P_{stim}) and air number (λ_{stim}) correlated with the values of the tabulated time constants τ_1 and τ_2 , which are therefore suitable for characterising the combustion process of the analysed real operating condition.

[0054] By means of the correlation function or table, a calculation is then made of the value of the air number (λ_{stim}) correlated with the combustion process of the operating condition of the burner. By comparing A_{stim} with the target air number (λ_{ob}), i.e. the number suitable for ensuring correct and efficient combustion, it is possible to act on the control system of the burner (by acting on the fan and/or the gas modulating valve) in order to modify the conditions of the combustion process with the aim of approaching the target air number (λ_{ob}).

[0055] Since phenomena of drift may arise and affect

the curves that characterise the correlation function or table F, for example caused by the electrode being positioned outside the tolerances or by degradation of the electrode due to ageing or wear, the method of the invention may provide for a calibration or recentring cycle, which may be based on observation of the ionisation current and/or on the values of the characteristic time constants τ_1 and τ_2 (or equivalently on the values of the respective gradients a_1 , a_2).

[0056] The calibration cycle may, for example, provide for the burner to be made to operate with increasingly rich air/fuel mixtures, increasing the percentage of the gas flow delivered to the burner. In these conditions, the air number λ tends to gradually reduce from values >1 to values <1 , passing via the condition of $\lambda=1$, in which the ionisation current is known to have a maximum value and the time constant τ_1 has a minimum value. The cycle provides that, based on the operating condition identified by $\lambda=1$ (where the maximum ionisation current or the minimum value of the characteristic constant τ_1 is measured), one begins to increase the quantity of air delivered, acting on the speed of the fan until a condition is reached in which the air flow is increased for example by 30%, reaching in this condition a correspondingly increased air number value ($\lambda=1.3$); when the time constant τ_1 is used, after identifying the minimum value of τ_1 for $\lambda=1$ it is possible to find the value of τ_1 corresponding to combustion at $\lambda=1.3$ by multiplying the value by a suitably identified constant.

[0057] With respect to this known operating condition, the curves of the correlation function or table F can then be recentred and calibrated, recovering any previously accumulated deviations or drifts.

[0058] Using the above method, it is also possible to diagnose conditions of the appliance that differ from the nominal conditions, for example caused by the electrode being positioned outside the tolerances or by degradation of the electrode due to ageing. To achieve this end it is sufficient to use, instead of λ_j , a suitable parameter that represents the condition of the appliance (nominal or anomalous) existing in the condition "j".

[0059] It should also be noted that, unlike the known methods for monitoring and controlling combustion, the method of the invention, based on voltage measurements, is not based on measurement of the ionisation current and is therefore less affected by problems arising from wear and ageing of the electrodes.

[0060] Another advantage is linked to the speed with which the response to the voltage signal applied to the electrode is obtained, which renders the method extremely rapid compared with the known solutions.

[0061] A further advantage resides in the fact that the electrode used in the method of the invention makes it possible to use quite low voltage potentials. This property makes the electrode less costly compared with the traditionally proposed solutions.

[0062] A further advantage is that the method of the invention advantageously provides for the use of a single

electrode for applying the voltage signal in the flame and receiving the response signal.

[0063] A system for controlling and regulating combustion, for the burner 1, operating with the method of the invention, provides for example the following operating phases, with reference to the graph of Figure 6, where the abscissa expresses the number of revolutions (n) of the fan, the ordinates of the upper quadrant express the current (I) of actuation of the modulating gas valve, and the ordinates of the lower quadrant express the flow rate (Q) of gas delivered (correlated with the power need).

[0064] The curves C, C' of regulation of the above-mentioned parameters are typically preset in the control circuit, as illustrated in the diagram. Thus, for example, a number of revolutions n1 and a current I1 correspond to a need Q1.

[0065] If the power need changes from Q1 to Q2, the number of revolutions is increased to n2, in which condition the control circuit associates the current value 12 with the modulator. These values are correlated with a target air number (λ_{ob}) considered optimal for combustion. In this new operating condition, the effective air number (λ_{stim}) is calculated using the method described above, and a comparison is made between λ_{ob} and λ_{stim} , making the appropriate corrections to the parameters - current I - or - number of revolutions n - in order to obtain an air number essentially coincident with the target air number. Preferably, the current to the modulator is altered, for example by increasing it to the value I2'. At this point, the operating curve C is further updated for the air number equal to the target air number, and thus becomes the curve C'.

[0066] The updating of the regulation curve may for example be performed by accumulating a certain number of correction points and calculating the regression curve that correlates with them, said curve becoming the new regulation curve. Alternatively, it is possible to perform exclusively a correction, where appropriate, on each operating point, based on the comparison - $\lambda_{ob} / \lambda_{stim}$ - without identifying a new operating curve (by means of linear regression).

[0067] The regulation system described above represents simply a non-limitative example for the application of the combustion monitoring and control system of the invention. It is understood that by this method it is possible to provide specific logics for controlling and regulating the burner according to the respective operating and system needs, said logics providing for a comparison between a target air number, optimal for combustion, and the air number calculated by the method of the invention.

[0068] The invention therefore achieves the proposed aims, overcoming the limitations pointed out with respect to the prior art, demonstrating the advantages described with respect to the known solutions.

Claims

1. Method for monitoring and controlling combustion in a premix combustible gas burner (1) with fan, of the type comprising a sensor with at least one electrode (E) placed in the flame or in the proximity thereof and suitable for being powered by a voltage generator as well as being connected to an electronic circuit suitable of measuring the resulting potential at the electrode, said method comprising:
 - a first phase of acquisition and processing of data from a series of combustion conditions of the burner, comprising the following steps:
 - identifying a plurality of combustion conditions of the burner (1), in each of said conditions
 - applying in the burner a power (P1, P2, ..., Pn) deriving from the combustion of a corresponding flow rate of combustible mixture, and applying for each power an air number value ($\lambda_1, \lambda_2, \dots, \lambda_m$), said air number expressing the ratio between the quantity of air in the combustion process and the quantity of air for stoichiometric combustion,
 - applying, in each of said (n * m) test conditions (Pi, λ_j), an impulsed electrical voltage signal (S) to said electrode (E) and measuring the trend over time of the resulting electrical signal (S') at the electrode, once the application of the impulsed signal (S) has ceased, said signal applied to the electrode (E) comprising, in the period of the signal (S), a first impulse (N1) of positive amplitude, followed by a second impulse (N2) of negative amplitude,
 - identifying, for each of said combustion conditions, the curve of the trend over time of the response signal (S') at the electrode (E), said trend being expressed for each impulse (N1, N2) by an exponential function decreasing over time in absolute terms,
 - calculating, for a first section of the curve relating to the first impulse (N1), as well as for a second curve section relating to the second impulse (N2), the respective first and second time constants (τ_1, τ_2), characteristic of the exponential trend for the respective first and second curve sections,
 - thus obtaining an interpolation function or correlation table (F), based on the acquired test data, suitable for unequivocally interpolating or correlating at least one significant parameter of the combustion characteristics (power or air number) with the respective time constants of the exponential functions characteristic of the trend in the response signal measured at the electrode, in the combustion process of the burner,
 - said method comprising a second phase of calculating the air number (λ) in a real operating condition of the burner, comprising the following steps:
 - acquiring in said operating condition the electrical response signal measured on the electrode after the application of the impulsed signal,
 - calculating, for said operating condition of the burner, said first and second time constants (τ_1, τ_2) characteristic of the respective curve sections relating to the trend in the resulting voltage signal at the electrode, following the application of the said impulsed signal,
 - calculating the estimated value of the air number (λ_{stim}) by using the interpolation function or correlation table (F) which correlates the power (P) and the air number (λ) with the time constants (τ_1, τ_2) characteristic of the curve relating to the trend in the response signal (S') measured at the electrode (E).
2. Method according to claim 1, in which provision is made, in the said second phase, for preliminarily obtaining the power value (Px) characteristic of the operating condition of the burner, by introducing into said interpolation function or correlation table (F) the value of the second time constant (τ_2) calculated for said operating condition, and for subsequently obtaining the estimated value of the air number (λ_{stim}) for said operating condition, by introducing into the said interpolation function or correlation table (F) the power value (Px) and the value of the first time constant (τ_1) calculated for said operating condition.
3. Method according to claim 1 or 2, in which the impulsed signal (S) applied to the electrode (E) is periodic.
4. Method according to one of the preceding claims, wherein provision is made for recording the value of a residual voltage (S₀), in order to express the exponential function of the response signal (S') at the electrode (E) relative to the time constants (τ_1, τ_2).
5. Method according to one of the preceding claims, said burner comprising:
 - a combustion chamber,
 - a first pipe suitable for introducing air into said combustion chamber,
 - first regulation means associated with said first pipe, suitable for varying the quantity of air introduced into said first pipe,
 - a second pipe suitable for introducing a combustible gas into said combustion chamber,

- second regulation means associated with said second pipe, suitable for varying the quantity of gas introduced into said second pipe;

said method comprising the additional phases of: 5

- setting one of said first and second regulation means to a first setting value,
- associating, on the basis of regulation curves preset in the control circuit, a corresponding setting value for the other regulation means, said values being correlated with a target air number (λ_{ob}) considered optimal for combustion, 10
- calculating, in the operating condition achieved, the actual value of the air number (λ_{stim}) by using the method of one or more of the preceding claims, 15
- comparing the target air number (λ_{ob}) with the actual air number (λ_{stim}) and correcting one and/or the other of the said first and second regulation means in such a way as to obtain an actual air number (λ_{stim}) essentially coincident with the target air number (λ_{ob}). 20

6. Method according to claim 5, wherein said first regulation means comprise a fan with a preselected regulation curve (number of revolutions - air flow), and said second regulation means comprise a gas valve of the modulating type with a preselected regulation curve (current - gas flow), said setting values being the speed of the fan and/or the pilot current of the valve modulator 25 30
7. System for controlling combustion in a burner (1) of a combustible gas appliance, operating according to the method of one or more of the preceding claims 35
8. Use of a system for controlling combustion in a burner (1) of a combustible gas appliance, operating according to the method of one or more of claims 1 to 6. 40

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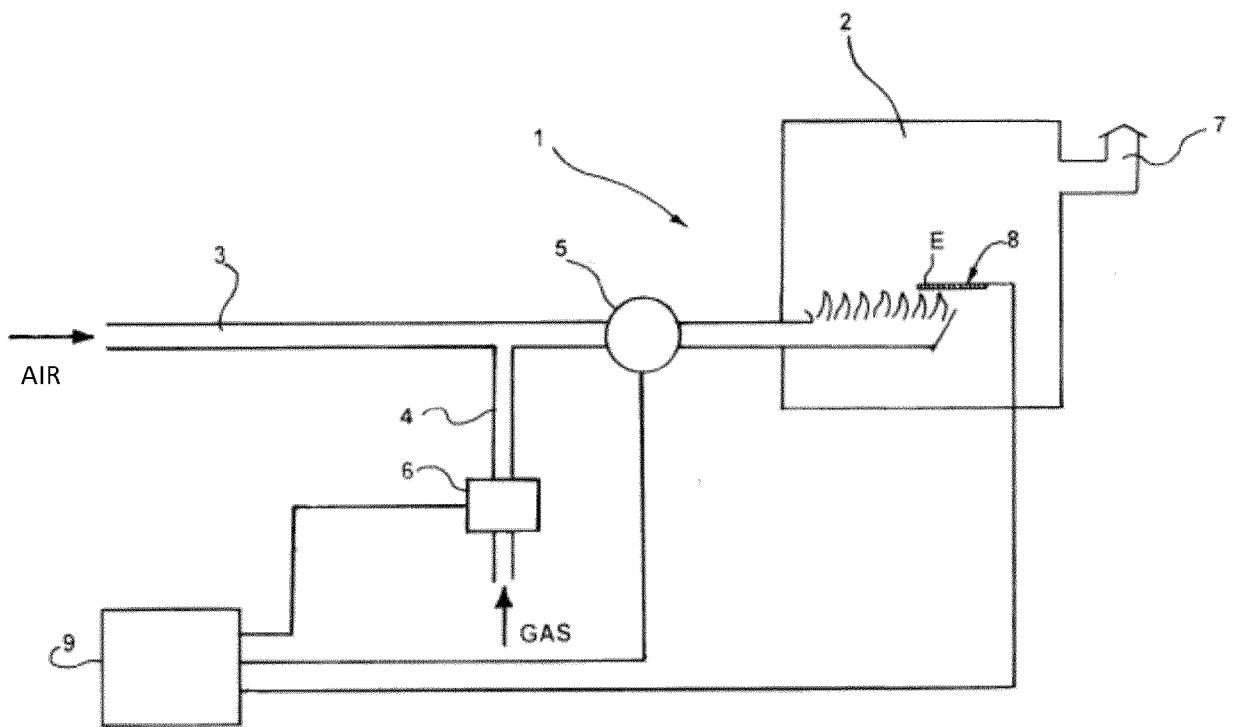
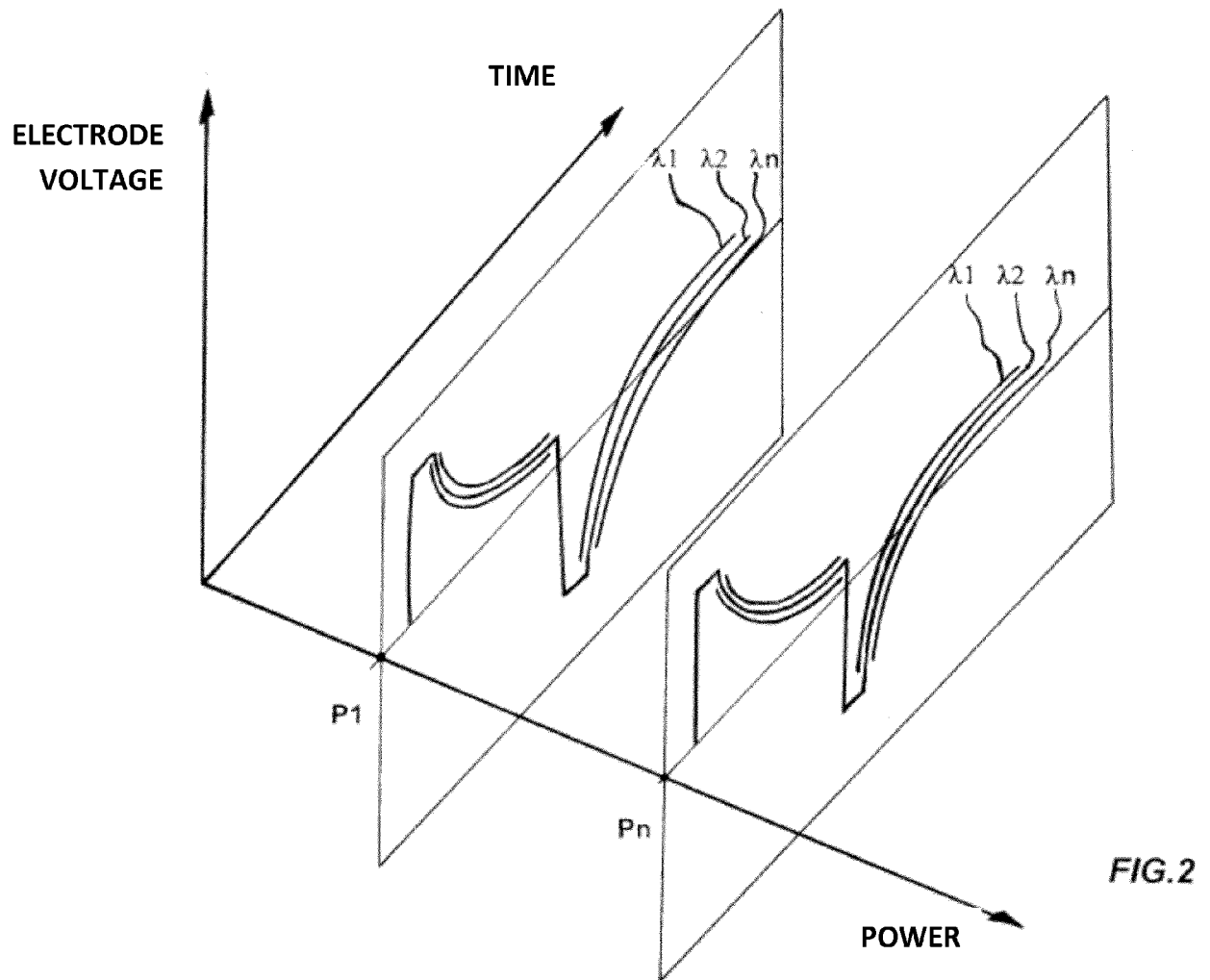


FIG.1



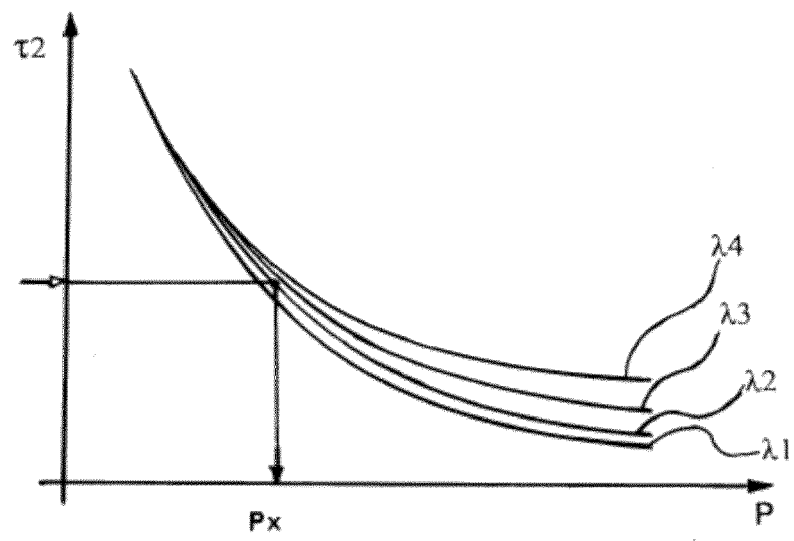


FIG. 3

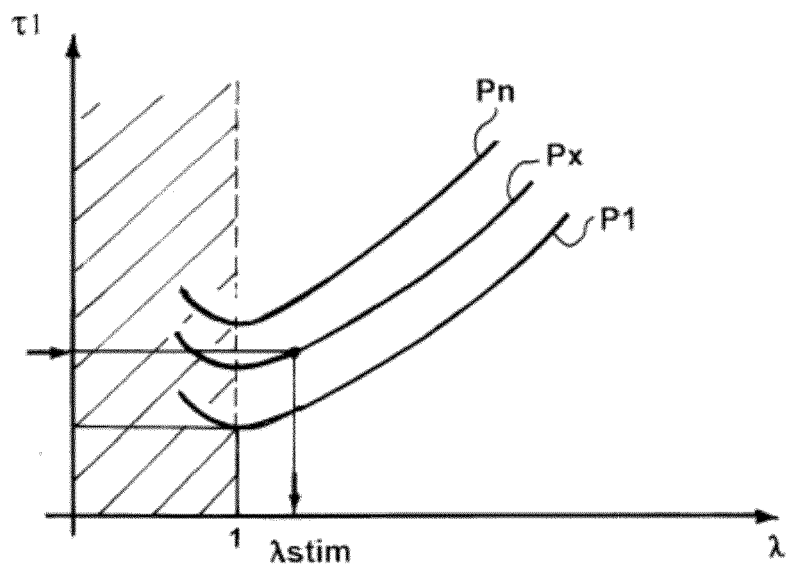


FIG. 4

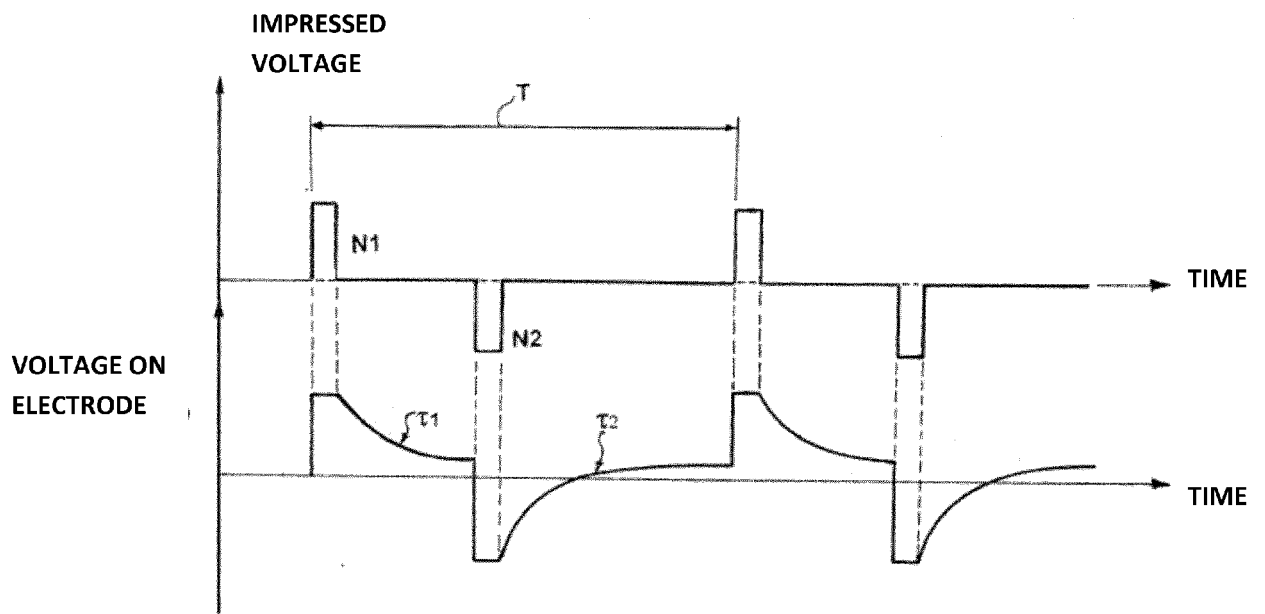


FIG.5

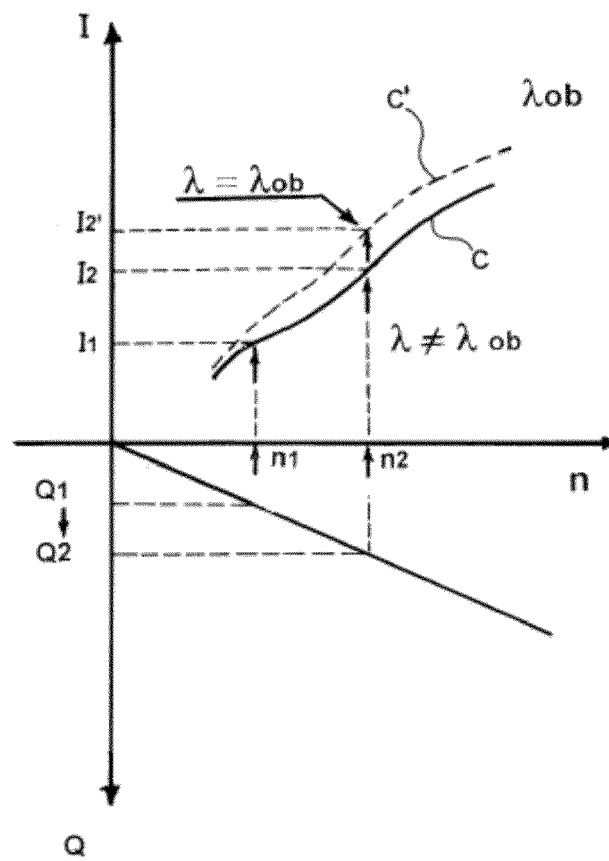


FIG.6



EUROPEAN SEARCH REPORT

Application Number
EP 16 18 1377

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2014/049502 A1 (SIT LA PRECISA S P A CON SOCIO UNICO [IT]) 3 April 2014 (2014-04-03) * page 4, line 1 - page 18, line 17 * * figures 1, 2 * * claims 1-17 *	1-8	INV. F23N1/00 F23N1/02 F23N1/04 F23N3/00 F23N5/12 F23D14/02
A	US 5 971 745 A (BASSETT WILLIAM W [US] ET AL) 26 October 1999 (1999-10-26) * column 9, line 42 - column 16, line 7 * * figures 1-10 * * claims 1-27 *	1,4	
A	WO 2013/117516 A1 (SIT LA PRECISA S P A CON SOCIO UNICO [IT]) 15 August 2013 (2013-08-15) * page 3, line 21 - page 11, line 17 * * figures 1-4 * * claims 1-18 *	1,4	
A	US 5 899 683 A (NOLTE HUBERT [DE] ET AL) 4 May 1999 (1999-05-04) * page 5, line 16 - page 16, line 14 * * figures 1-14 * * claims 1-19 *	1,4-6	TECHNICAL FIELDS SEARCHED (IPC) F23N F23D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 December 2016	Examiner Rudolf, Andreas
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 18 1377

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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09-12-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014049502 A1	03-04-2014	CA 2885494 A1	03-04-2014
		CN 104813104 A	29-07-2015
		EP 2901080 A1	05-08-2015
		KR 20150059756 A	02-06-2015
		US 2015276221 A1	01-10-2015
		WO 2014049502 A1	03-04-2014

US 5971745 A	26-10-1999	AU 710622 B2	23-09-1999
		AU 7680696 A	05-06-1997
		EP 0861402 A1	02-09-1998
		US 5971745 A	26-10-1999
		WO 9718417 A1	22-05-1997

WO 2013117516 A1	15-08-2013	NONE	

US 5899683 A	04-05-1999	AT 202837 T	15-07-2001
		CA 2204689 A1	09-11-1997
		DK 0806610 T3	15-10-2001
		EP 0806610 A2	12-11-1997
		ES 2158400 T3	01-09-2001
		US 5899683 A	04-05-1999
