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(54) Dual control coil glow plug for diesel engines.

(57) A dual current control coil glow plug (10) for warming up Diesel engines. The glow plug comprises a metal body (11) from which a tubular metal sheath (13) extends, the sheath containing a heating element comprising a dual coil (14,16) electric resistance embedded in a compacted powder of an electrically insulating and thermally conductive material; the two coils (14,16) of the heating element are made with wires of the same material having a high positive temperature coefficient so as to provide a dual differentiated control of the current absorbed during the warm-up and post-heating phases, while maintaining warm-up times and temperatures at optimal values.

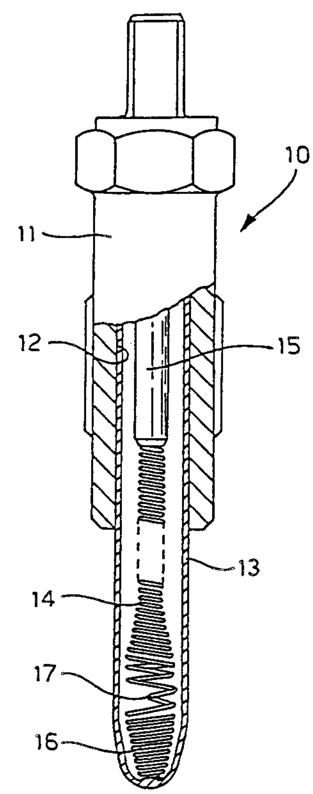

FIG. 1

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The present invention relates to a self-regulating electric heating element for glow plugs in Diesel engines, and moreover relates to glow plugs incorporating the abovementioned self-regulating electric heating element.

During cold-starting of thermal engines which run on heavy liquid fuels, otherwise known as Diesel engines, in which internal combustion occurs through strong compression of the fuel, to bring it to a temperature of spontaneous ignition, the use of appropriate glow plugs is generally required whose fore end, which extends into a precombustion chamber or combustion chamber of the engine, has to be heated rapidly, in a few seconds, to bring it to a temperature of 850 °C or more, sufficient to cause ignition of the fuel. The increasingly felt need to reduce the emission of harmful gases to a minimum, when starting, has also led car-manufacturers to extend heating time of the glow plug to a temperature which, in accordance with standars in force, must not reach or exceed 1050 °C.

The need to achieve extremely short pre-ignition times, in the order of a few seconds, has led to the design and manufacture of glow plugs with elements for self-regulating current, as well as the optimisation of suitable materials with a positive temperature coefficient for producing fast glow plugs.

Therefore dual coil glow plugs were suggested, in which an electric resistance element, situated inside a metal sheath closed at the tip, is embedded in a compacted powder of an electrically insulating and thermally conductive material. The electric resistance element generally consists of two coils connected in series of which a first heating coil at the fore ogive-shaped portion of the sheath is made from wire material suitable to withstand high temperatures and having a resistance value which is substantially constant or which slightly varies with the temperature, and a second coil for self-regulating current is made from wire material having a sufficiently high positive temperature coefficient (PTC) to enable a rapid reduction in the flowing current and hence a regulation of the temperature of the sheath, as soon as the fore part of the same sheath has reached a predetermined temperature value, generally known as the preheating temperature.

In the constant search for glow plugs with rapid operation times, various specific embodiments for the dual coil resistance element have also been proposed, or else the use of certain materials with a positive temperature coefficient (PTC) have been recommended in order to achieve heating of the metal sheath in extremely short times as well as a greater degree of self-regulation of the current which would prevent the reaching or exceeding of dangerous or damaging temperatures in respect of a long working life of the glow plug.

Examples of glow plugs of this kind are described in a number of prior art documents among which mention can be made of the patent GB 260.265 and others such as EP-A-98035, IT-A-19444/79 and EP-A-351883.

More particularly, as disclosed in the document EPA-98035, studies on self-regulating glow plugs were aimed at obtaining glow plugs with multi-coil electrical heating elements which would solve both the problems relating to short warm-up times and relating to durability of the glow plugs themselves, in relation to the operating temperatures required in Diesel engines of modern design.

More particularly, in the cited document, a first glow plug is illustrated whose electrical heating element is carried out in a fully traditional manner, and in which the rear current control coil has a positive temperature coefficient (PTC) higher than the fore sheath heating coil. In the same document it is likewise proposed to form the rear current control coil in two portions of different materials of which only the front portion for connection to the heating coil is made in material having a high positive temperature coefficient. In practice, neither does this second solution differ substantially from a traditional dual coil electric resistance element.

As part of production processes and in the conditions of use of glow plugs in Diesel engines, there are other problems which have only been partially tackled or partially solved, and problems which have never been faced or considered neither at the research stage nor by proposing new solutions, to meet greater and increasingly felt needs in this specific area.

In general the approach adopted to date by manufacturers of engines and/or glow plugs of the mentioned type studying and researching new solutions, has been that of considering glow plugs as an independent element, or as a heating element forming part of the same engine.

The increasing needs for glow plugs which are highly reliable in any operating condition and of simpler construction, maintaining the features and performances of known dual coil glow plugs substantially unaltered, both in terms of times and warm-up temperatures, have led to the accomplishment of new and effective solutions.

According to the present invention more general conditions were taken as a basis, whereby glow plugs for Diesel engines form part of a system comprising the ignition circuit and the supply battery, whose durability and efficiency depend upon many factors; these include thermal shocks to which the two resistant coils of the glow plug are subjected due to the frequent and repeated ignitions, the high temperatures reached in the area of greatest incandescence, the termal difference between the maximum temperature and the post-heating temperature, as well as the high value of the absorbed current which the battery has to supply during the post-heating phase of the glow plug, particularly in cold areas or in the winter months, which may involve difficulties in starting up the same engine, and hence penalising or even damaging the same power supply battery.

According to the present invention it was assumed to provide a glow plug for Diesel engines which maintains the performances of dual coil glow plugs of the known type substantially unaltered, and which at the same time also takes into account other factors which affect operation and use of the glow plugs themselves.

Therefore, an object of the present invention is to provide a dual coil glow plug for Diesel engines, by means of which it is possible to reduce substantially the consumption of electrical energy and hence absorption of current by the battery even in heavy work conditions, for example due to repeated ignitions or prolonged post-heating times or in particularly severe environmental conditions, maintaining the features of fast warm-up, low post-heating temperatures and more generally high operative reliability of the glow plug substantially unaltered.

A further object of the present invention is to provide a glow plug, as referred above, which is less stressed thermically and which at the same time maintains an appropriate post-heating temperature with a reduced current consumption.

A further object of the present invention is to provide a dual coil glow plug, as referred above, which is easy and simple to manufacture and which at the same time enables other advantageous features to be used, which are in themselves already known and which form the object for example of prior patent applications by the same applicant.

Through studies and experience it has been noted that abovementioned objects can be accomplished with a dual coil glow plug, using in combination one with the other innovative structural and/or functional features and materials which have enabled to be achieved unexpected results or which could not be foreseen on the basis of standard technical knowledge in this field.

According to the invention there is provided a self-regulating electric resistive heating element, for heating glow plugs for Diesel engines, said heating element comprising a fore heating coil and a rear current control coil, connected in series to the aforementioned fore coil, characterised in that said fore heating coil and said current control coil are made in the same electrically conductive material having a high positive temperature coefficient and in that said fore heating coil has a specific resistance value greater than that of the rear control coil, therefore said fore heating coil acts as second self-regulating current control element during the initial moments of warm-up.

According to the state of the art, dual current control coil glow plugs, according to the teachings of the invention, are not known.

It has in fact been noted from tests and experiments that by making both the fore and rear coils of the electric resistance element from the same material having a high positive temperature coefficient and, therefore, both suitable for performing a current control function at different moments, it is possible to achieve exceptionally low warm-up times, comparable with those of dual coil glow plugs normally available commercially, reducing thermal shock and also substantially and unexpectedly reducing the consumption of current in prolonged post-heating periods of the glow plug, maintaining the required temperature values. In this way the supply battery of the ignition circuit of the engine is not penalised, being able to achieve reductions in the current absorption equal to or greater than 20%.

It is not easy to explain the reasons whereby, by using a single material having a high PTC value for both coils, it is possible to achieve exceptionally short ignition times, regulated post-heating temperatures, and at the same time exceptionally reduced current absorption. Nevertheless it is thought that this is due to the use of material having a high PTC also for the fore heating coil in that this provides a rapid self-regulating action which enables current absorption to be considerably reduced, immediately following the first instants and in any case before reaching the pre-ignition temperature of the order of $800 \div 850\,^\circ C$.

According to a further feature of the invention, in order to achieve rapid warm-up times, the two coils of the electric heating element should preferably be maintained axially spaced one from the other so that the rear current control coil, which operates last, is substantially removed from the thermal effects of the fore heating coil which performs the first current control phase. These and other features of a dual coil resistance element and of a glow plug for Diesel engines, embodying the features of the invention, will be made clearer from the description which follows, with reference to the examples in the accompanying drawings, in which:

Fig.1 shows a glow plug according to the present invention;

Fig.2 is an enlarged detail of the plug in figure 1;

Fig.3 shows a second solution for the connection of the coils for the glow plug of figure 1;

Fig.4 shows a further solution for the connection of the coils for the glow plug of figure 1;

Fig.5 is a graphical presentation of the temperature and current properties of a dual control coil glow plug according to the invention, compared with similar characteristics of a dual coil glow plug normally available on the market.

Referring now to Fig.1, numeral 10 denotes a glow plug for Diesel engines having the features of the present invention.

The glow plug 10 comprises a metal body 11 having a longitudinal bore 12 wherefrom a tubular metal sheath 13, closed at the tip, protrudes.

Inside the sheath 13 an electric resistive element for heating the same sheath is provided; the resistive element substantially consists of two coils comprising a fore coil 16 having one of its ends connected to the front end 13A of the sheath, also known as heating coil, and a rear coil 14 for controlling current, connected in series to the coil 16 respectively to a current feed pin 15; the coils 14 and 16 of the heating resistive element, in a manner in itself known, are embedded in a mass of fine, electrically insulating and thermally conductive powder material, for example a magnesium oxide base.

The fore coil 16 performs a dual function, namely a normal heating function for the tip of the sheath 13, to bring it to a predetermined temperature value, and a second current control function in the first moments of warm-up; therefore it is made with a wire material suitable for withstanding to high temperatures but with minimum of resistivity at low temperatures, while the rear coil 14 performs solely the normal self-regulating function for the current and temperatures.

Unlike dual coil glow plugs of known type, in which the two coils are made with materials having properties different one from the other, and in which only the rear coil performs the self-regulating current function, the abovementioned objects have been achieved in a glow plug according to the invention, making both the coils 14 and 16 in the same material with high PTC, that is to say with high positive temperature coefficient, in the order of or higher than $10 \div 12 \times 10^{-3}$.

Materials suitable for the purpose may be chosen from iron-cobalt alloy-based materials with a high content of cobalt, equal to or greater than 90% and with an iron content equal to or less than 10%, ignoring the traces of other materials. For this purpose, for example, a material known under the trade name VACON CF8 can be used.

A preferred embodiment and the features of the electric resistive element are further illustrated in the enlarged detail of Fig.2.

As can be seen from said figure, the rear coil 14 extends for a lenght L1, for example double the lenght L2 of the fore coil 16, the two coils being axially spaced one from the other and connected one to the other by means of a welding spot 17.

The coil 14 comprises a first cylindrical portion 14A of a relatively small diameter D1, which continues with a second conical portion 14B, the maximum diameter D2 of the last turns being approximately double the diameter D1.

Contrarily, the fore coil 16 tapers conically towards the tip 13A of the sheath, starting from a maximum diameter D3, equal to or smaller than the maximum diameter D2 of the coil 14, ending with a diameter D4 equal to or smaller than D1.

The two coils 14 and 16 are axially spaced one from the other by a sufficient space for substantially reducing the diffusion of heat or for thermally insulating the fore coil 16 towards the rear coil 14 so that the former has heating times at the tip of the tubular sheath 13 which are extremely short, in the order of a few seconds, comparable with the heating times of fast glow plugs which are normally available on the market.

Preferably the two coils 14 and 16, in addition to being characterised by the use of the same material with a high PTC value, are also characterised in that they are made with wire of different diameter, for example of between 0,30 and 0,50 mm, a different linear extension and a different diameter and lenght of the turns themselves.

More particularly, the fore coil 16 is made with wire of smaller diameter, for example between 0,30 and 0,40 mm, in relation to the wire of the rear coil 14 whose diameter may be between 0,35 and 0,50 mm approximately, so that the cross section of wire of the fore coil is comprised between 65% and 85% of the section of the rear coil.

The use of the same material for both the coils, with a high positive temperature coefficient, an adequate axial spacing of the fore heating coil from the rear control coil, and the conical configuration at the tip, according to the example in Fig.2, have enabled a fast glow plug to be achieved with very short warm-up times, and low current consumption during the post-heating phase, wich confers to a similar glow plug original features, which cannot be obtained and which are not present in known glow plugs.

That which most distinguishes and characterises a glow plug according to the present invention is the dual control of the current and hence of the temperature, in that both coils 14 and 16 having the same PTC value, and being thermally insulated one from the other, contribute in different and successive moments to providing an effective selfregulation of the current and of the heating temperatures, as will he explained hereinbelow with reference to the diagrams in Fig.5.

In the example in Fig.2, the two coils 14 and 16 are wound in opposite directions, are connected in series one to the other by the welding point 17, and are axially spaced by providing a greater pitch or greater angle of the end turns at the two facing ends of the coils. In place of the connection system shown in Fig.2, any other thermally-insulating electrical connection system can be used, for example by adopting an intermediate spacer of low electric resistance and low heat conductivity, consisting for example of a stainless steel sleeve 18, in which some end turns of small diameter 14C and 16C of the two opposite coils, as shown in Fig.3, are screwed or forced or welded or by providing a spacer element in the form of a pin member 19 provided with an annular intermediate shoulder 20 on whose ends are screwed or forced or welded the end turns 14C and 16C of the two coils 14 and 16, as shown in Fig.4, in a substantially similar manner to the previous case. It is in any case clear that other solutions are possible in order to obtain a connection in series and a substantial axial space between the two coils, for the reasons referred to previously.

The innovative and functional features of the glow plug, with dual current control coil, according to the invention, may be understood better with reference to the graph in Fig.5 wich represents, as a function of the time expressed in seconds, the supply voltage curve V, the curves T1 and T2 of the temperature at the tip, for a dual coil glow plug according to the invention (T1) and according to the prior art (T2), and the curves A1 and A2 of current absorption of the abovementioned two glow plugs respectively. The comparison tests on the two glow plugs were performed maintaining the same conditions of voltage supply and ambient temperature, measuring the temperatures at the tip by means of an optical pyrometer and the currents absorbed by means of an amperometer.

In both cases the glow plugs reached a warm-up temperature of 850 °C, in less than 7 seconds, with totally negligible differences, of the order of a few tenths of a second. On comparing the curves T1 and T2 it can be seen how, having modified the supply voltage after 10 seconds, the two curves T1 and T2 modified their trends; whereas curve T1 of a glow plug according to the invention reached the maximum value of 1110 °C of the tip temperature after approximately 20 seconds, subsequently settling at a temperature of 1045 °C at the end of a post-heating period of 60 seconds, the curve T2 of a glow plug according to the prior art increased its temperature considerably even before 10 seconds to reach a maximum of 1120 °C after circa 14 seconds, then settling at a temperature of 1035 °C at the end of the post-heating period, slightly lower than the temperature of the glow plug according to the invention.

The two curves T1 and T2 therefore demonstrate that a glow plug with dual control coil, according to the present invention, allows better control of the temperatures. The glow plug is subject to a smaller difference between the peak temperature and the operative temperature than the known glow plug. Moreover a lower current consumption is obtained after the initial transient state.

Therefore, in a glow plug according to the invention, at a slightly higher temperature during the post-heating period, comparatively higher values of absorbed current would be expected, with consequentely greater stress on the supply battery, in relation to the traditional glow plug; nevertheless, unexpectedly during the tests it was found that in a glow plug according to the invention, with a higher initial current absorption, almost double that of a traditional glow plug, current absorption was reduced to a lower value even before two seconds, then remaining constantly below the absorbed current value of a traditional glow plug, settling at a current value of circa 6 amps. The curves A1 and A2 in Fig.5 clearly show this different behaviour of the two glow plugs under comparison.

The data obtained are particularly meaningful of the operating features of the two compared glow plugs, in that in a glow plug according to the invention, with an increase in temperature of 10 °C, circa 1% in the post-heating period, in relation to a traditional glow plug, there is a smaller rise in the maximum temperature and consequently a smaller thermal shock. However what is most significant is the considerable saving in absorbed current which can be evaluated at circa 20÷25% compared to a traditional glow plug. Considering that on starting up of an internal combustion engine there are several glow plugs in the warming-up phase, all this means a considerable saving in electrical energy and less stress on the supply battery, a particularly important fact when several consecutive starts have to he performed in severe environmental conditions.

This unforeseeable behaviour of the glow plug with dual control coil, according to the invention, in which the same heating coil performs, in advance, a current control function, in addition to the traditional control coil, may be explained by the fact that, both coils having the same high positive temperature coefficient, but different specific resistance values, (greater resistance for unit of lenght for the fore heating coil), due to the low resistivity value of the material, they initially enforce the flowing of a high value of current in the heating coil 16; the latter, by rapidly increasing its temperature at a higher speed, compared to the control coil 14, acts with a selfregulation effect on the current in advance of the rear coil. In this way, rapid control of the current absorbed is performed both in the warm-up phase and in the subsequent post-heating phase, achieving exceptionally short heating times, comparable to those of the usual fast glow plugs, and an exceptional control of temperatures, with postheating temperature values which are considerably lower than the temperature of 1050 °C normally considered a maximum limit which cannot be exceeded for glow plugs of this kind. The operating reliability of the glow plug was also demonstrated after a high number of working cycles, without encoutering any disadvantage. The use of the same material with a high positive temperature coefficient, for both coils of the glow plug, finally entails fewer problems of manufacturing tolerance, in this way enabling a product with high structural and operative features and a high degree of standardisation to be obtained.

The intent therefore is that what has been said and shown with reference to the accompanying drawings has been given purely by way of an example of the innovative features of the glow plug with dual control coil according to the invention.

Claims

1. Self-regulating electric resistive heating element, for heating glow plugs for Diesel engines, said heating element comprising a fore heating coil and a rear current control coil, connected in series to the aforementioned fore coil, characterised in that said fore heating coil and said current control coil are made in the same electrically conductive material having a high positive temperature coefficient and in that said fore heating coil has a specific resistance value greater than that of the rear control coil, therefore said fore heating coil acts as second self-regulating current control element during the initial moments of warm-up.

2. Self-regulating electric resistive element for glow plugs according to claim 1, characterised in that said rear current control coil is axially spaced from the fore coil.

3. Self-regulating electric resistive element for glow plugs according to claim 1, characterised in that the heating coil is made with wire of smaller cross section than the wire section of the current control coil, preferably between 65% and 85% of the latter, said wires having different longitudinal development.

4. Self-regulating electric resistive element for glow plugs according to claim 1, characterised in that the diameter of turns of both coils decreases starting from the reciprocal connection area.

5. Self-regulating electric resistive element for glow plugs according to claim 2, characterised in that said coils are axially spaced by conforming the turns in the reciprocal connection portion along a spiral of greater pitch compared to the remaining turns of both coils.

6. Self-regulating electric resistive element for glow plugs according to claim 2, characterised in that said coils are axially spaced and electrically connected one in respect of the other by an intermediate spacer element in electrically conductive material, having a low heat transmission coefficient.

7. Self-regulating electric resistive element for glow plugs according to claim 1, characterised in that said electrically conductive material has a positive temperature cofficient equal to or higher than $10 \div 12 x 10^{-3}$ for both coils and consists of an iron-cobalt alloy with a cobalt content equal to or higher than 90%, and with an iron content equal to or lower than 10% respectively.

8. Glow plug of the type with a dual coil electric resistive element for Diesel engines, wherein said dual coil consists of a fore heating and of a rear current control coil connected in series to said fore coil, characterised in that said fore heating coil and said current control coil are made in the same electrically conductive material having a high positive temperature coefficient and in that said fore heating coil has a specific resistance value greater than that of the rear control coil, therefore said fore heating coil acts as second self-regulating current control element during the initial moments of warm-up.

9. Glow plug according to claim 8, characterised in that the heating coil is made with wire of smaller cross section than the wire section of the current control coil, preferably between 65% and 85% of the latter, said wires having different longitudinal development.

10. Glow plug according to claim 9, characterised in that the fore heating coil and the rear control coil are made with wire diameter of between 0,30 and 0,40 mm and of between 0,35 and 0,50 mm respectively.

11. Glow plug according to claim 10, characterised in that the rear current control coil, starting from its end connected to the plug body, has a cylindrical portion of relatively small diameter which extends in a conically flaring diverging

portion having end turns of a diameter slightly smaller than the internal diameter of the tubular sheath, while the fore heating coil has a conical configuration converging in the direction of the tip of the sheath.

12. Glow plug according to claim 11, characterised in that the fore heating coil, at the end connecting to the rear coil, has turns of a maximum diameter equal to or smaller than the maximum diameter of the facing end turns of the rear coil.

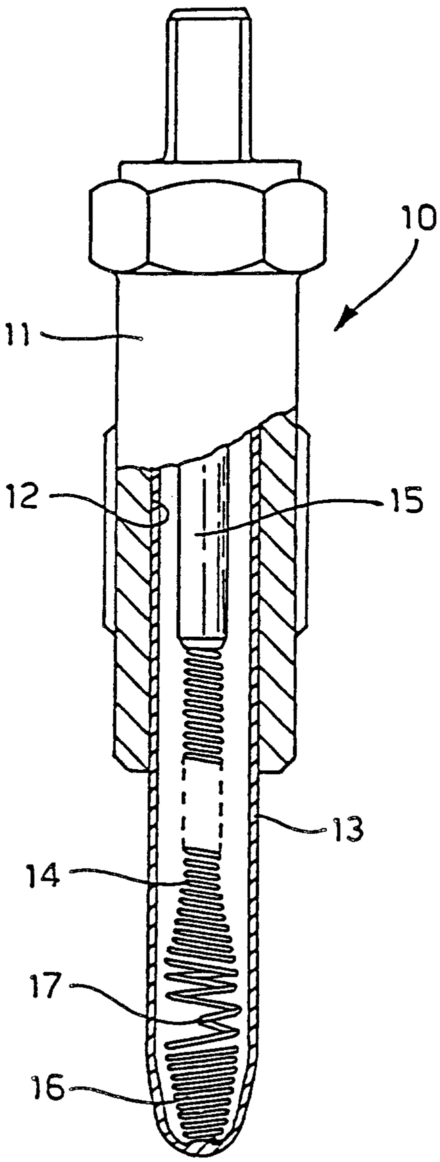
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FIG. 1

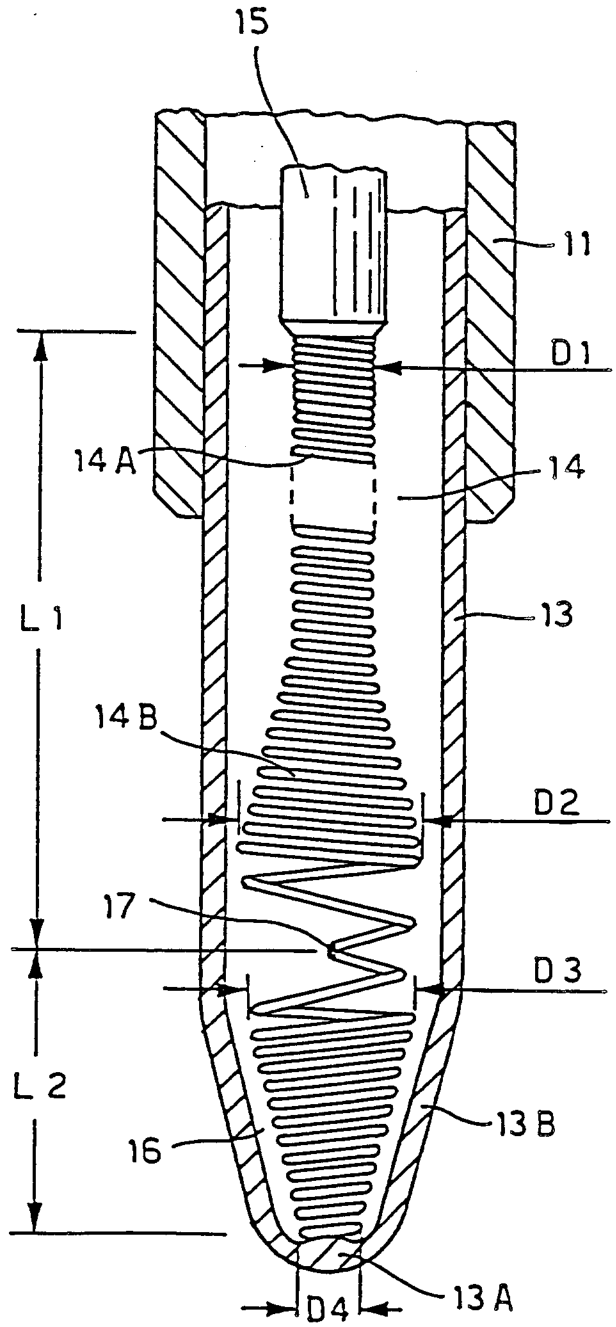

15
11
D1
14 A
14
L 1
13
14 B
D2
17
D 3
L 2
16
13 B
13 A
D4

FIG. 2

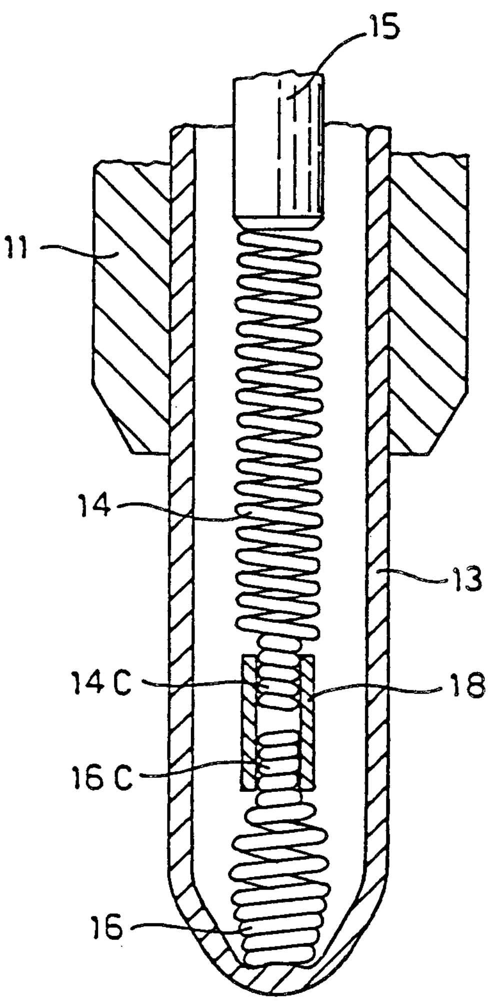


FIG. 3

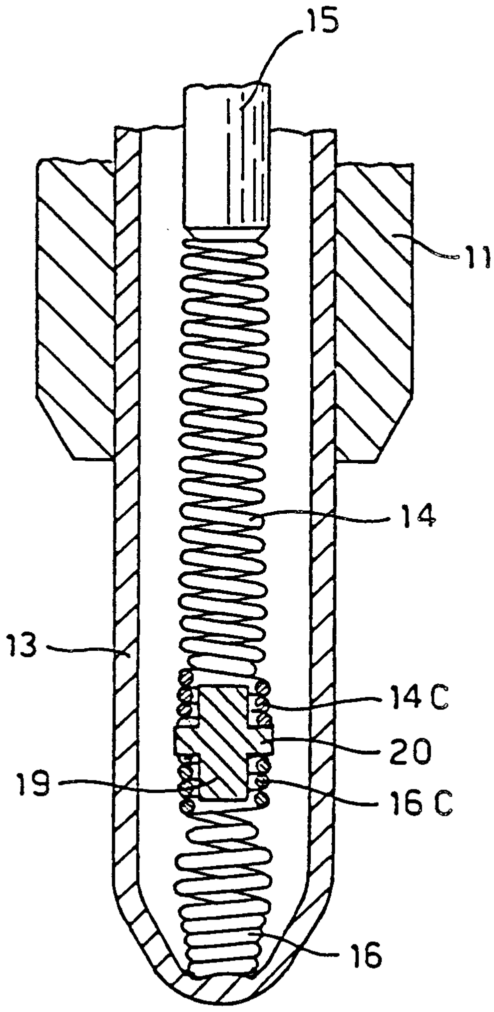
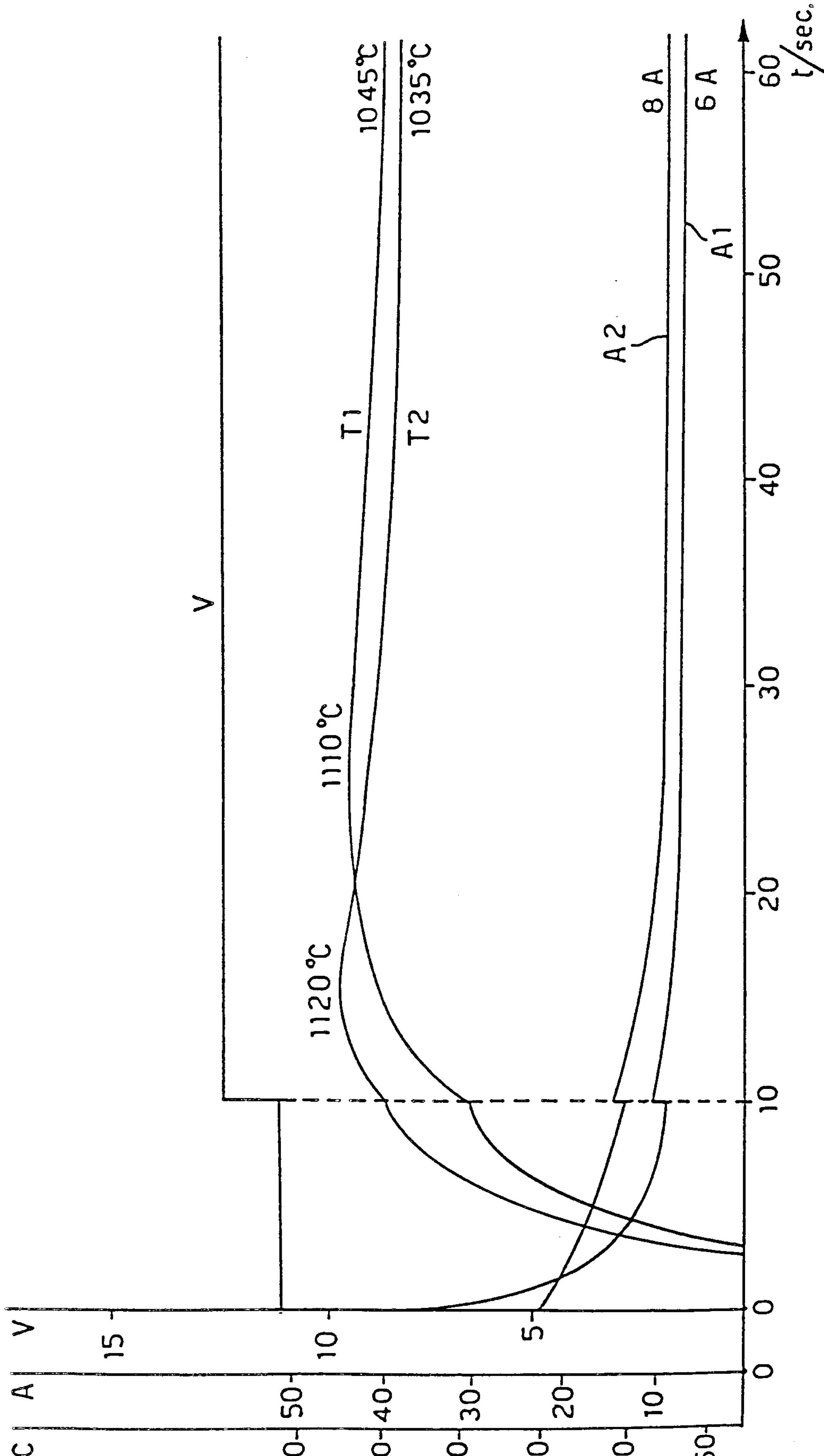


FIG.4


T °C
A
V
1150
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50
60
t/sec.
V
1120°C
1110°C
1045°C
1035°C
T1
T2
A2
A1
8 A
6 A

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 20 3524

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	EP-A-0 365 258 (WELLMAN) * claims 12-15; figures * ---	1,4	F23Q7/00
X	GB-A-2 216 952 (WELLMAN) * the whole document *	1	
A	---	7	
A	FR-A-2 131 437 (BOSCH) * the whole document * ---	1,3,8	
A	EP-A-0 392 181 (BOSCH) * column 4, line 23 - line 28; figure 1 * ---	2,5	
A	EP-A-0 240 650 (B80S.R.L.) * abstract * -----	2,6	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

F23Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 March 1994	Vanheusden, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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