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(54) Ignition system for an internal combustion engine

(57) The system comprises a power transistor T4 connected in series with the primary winding L1 of an ignition coil 7 and acting as an electronic circuit breaker, a control circuit ST for controlling the power transistor, a measuring resistor R12 for detecting the current flowing through the power transistor, and a current regulator network T1 to ZD1 for choking the current flow through the power transistor in dependence upon the attaining of a predetermined maximum current flowing through the measuring resistor, the network acting fully to block the power transistor rather than merely reduce its conduction, upon the attaining of the maximum current flow through the power transistor, the current regulator network having an electronic switch T1 for switching the power transistor back to its fully conductive state, actuable in dependence upon a predetermined voltage generated in the primary winding L1 and lying below the required ignition voltage.

FIG.1

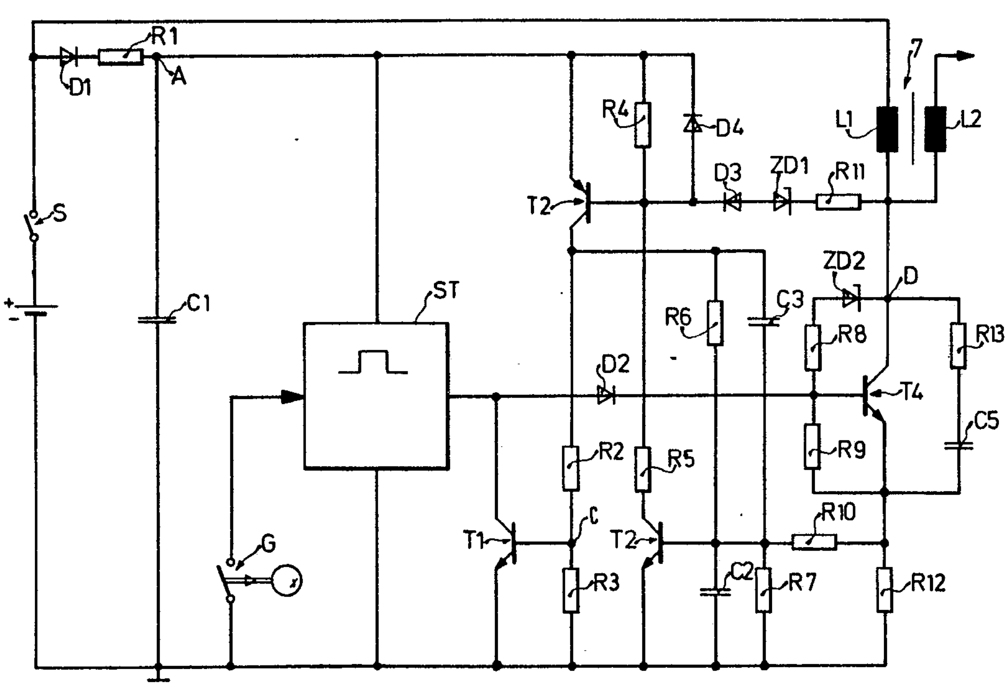

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FIG.1

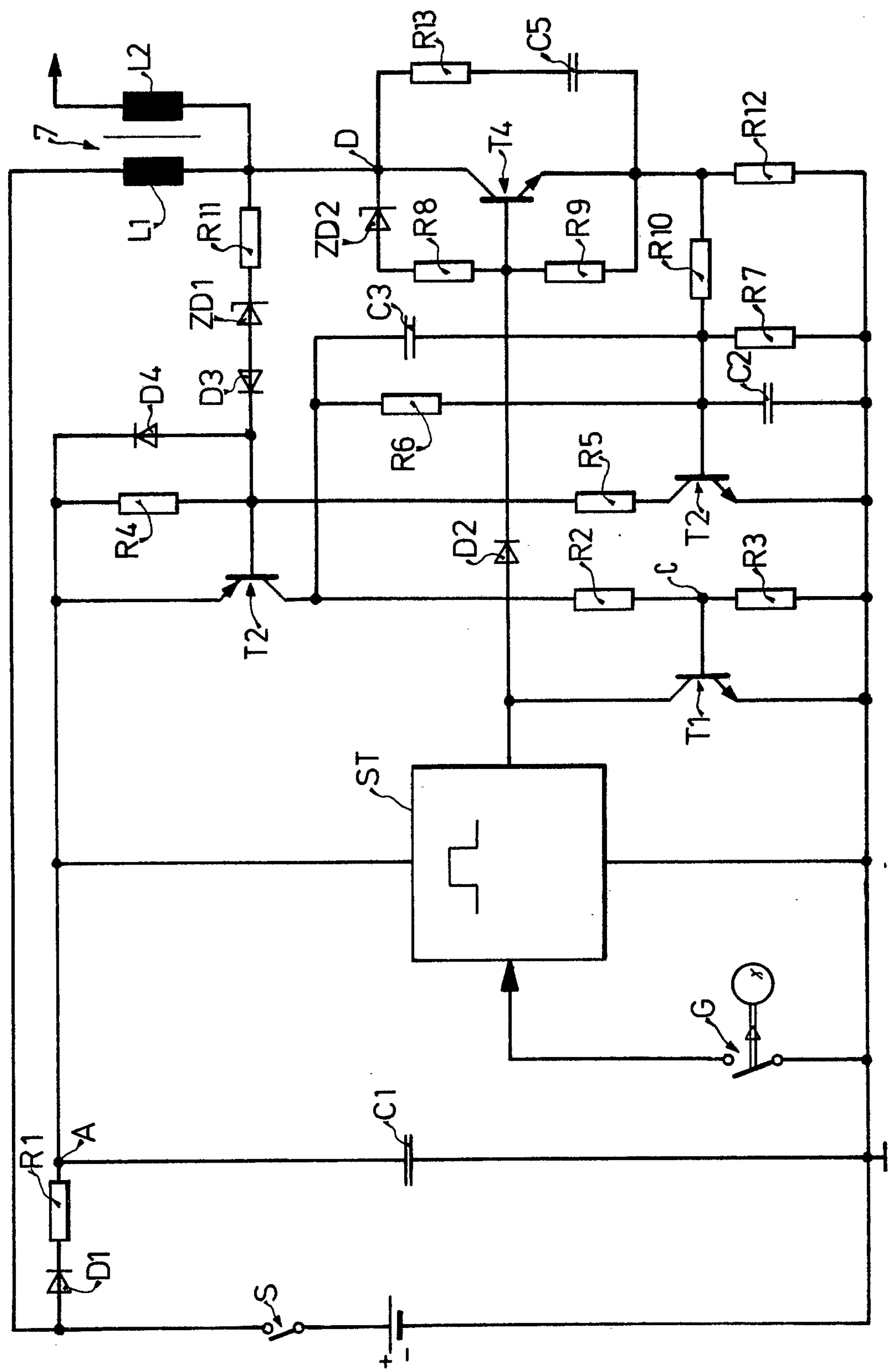

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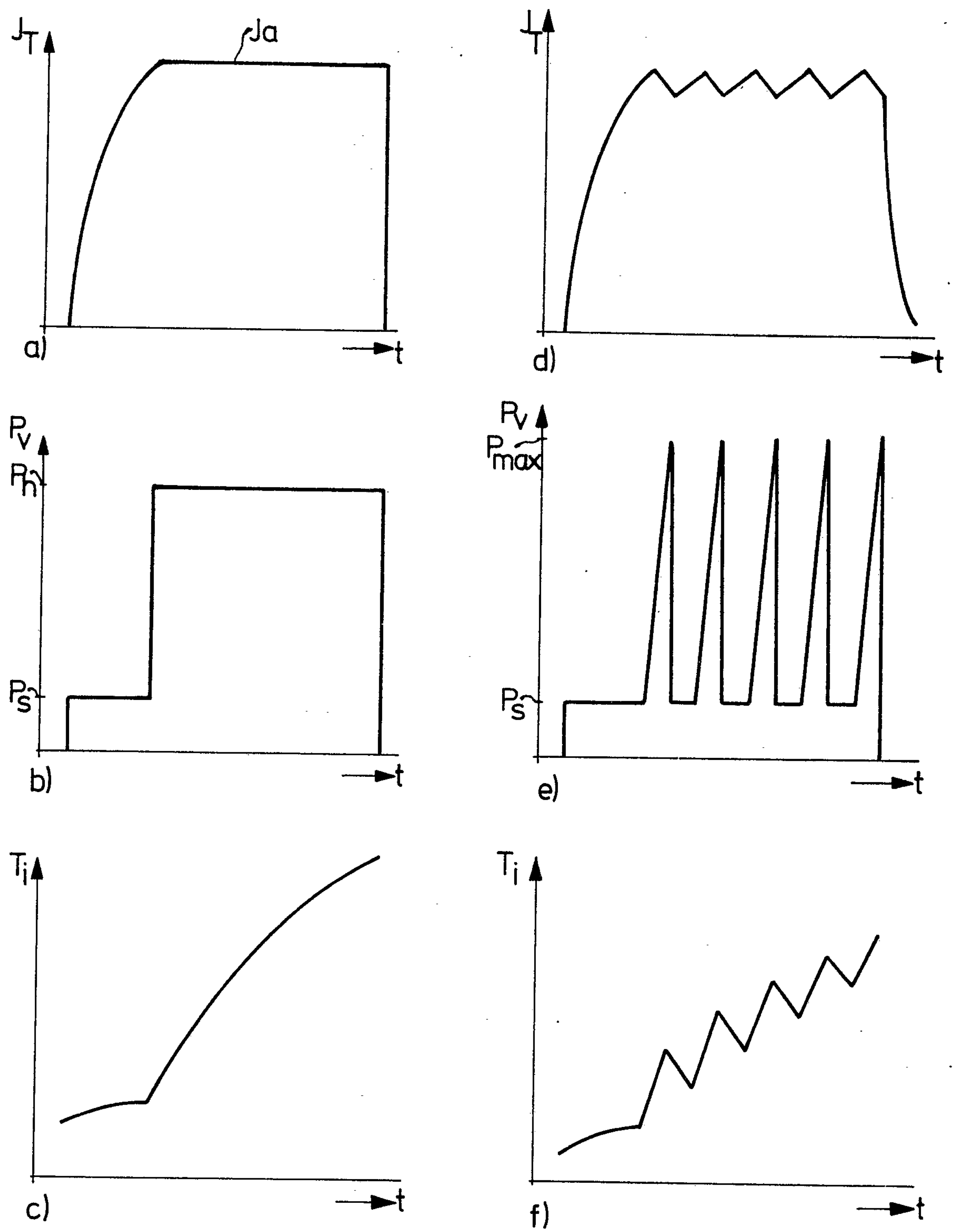
FIG.2



SPECIFICATION

Ignition system for an internal combustion engine

There is provided by the present invention an ignition system for an internal combustion engine, in which the current regulators are provided for limiting current flowing through the primary winding of the coil of the system.

Such ingition systems for internal combustion systems are known (see German Offenlegungsschrift 25 49 586), in which the current in the primary winding or the current flowing through the power transistor of a control circuit is detected by means of a measuring resistor located in the primary circuit across which the voltage drops when a so-called switch-off current is attained, this voltage being sufficient to switch into its conductive state a transistor which then draws a portion of the base current from the power transistor to reduce it conduction or "choke" the power transistor, and thus prevent a further rise in the current in the primary winding.

A disadvantage of this type of current regulation in the known ignition systems is that considerable losses occur in the power transistor during the interval of time in which its conduction is choked, thus necessitating the choice of a correspondingly expensive power transistor. Despite this, destruction of the power transistor, and thus failure of the ignition system, cannot be prevented in all cases.

It is also known (German Offenlegungsschrift 2 406 018) to provide cyclic current regulation in ignition systems for internal combustion engines, the circuit of the primary winding being interrupted upon attaining a switch-off current and a circuit in parallel with the primary winding being opened, and a discharge current then flowing in the said parallel circuit until the primary circuit is closed again and the parallel circuit is opened when either a predetermined interval of time has elapsed or a predetermined lower limiting value of the discharge current has been reached.

A disadvantage of these known ignition systems having cyclic current regulation is that two power switches sometimes have to be provided in the primary circuit, and special control devices for an electronic switch in the parallel circuit have to be provided.

An object of the invention is to provide an ignition system for internal combustion engines in which the current regulators are constructed such that only low power losses occur in the power transistor on the one hand and, on the other hand, a simple, inexpensive and reliable circuit construction is obtained.

There is provided by the present invention an ignition system for an internal combustion engine, comprising a power transistor which is to be connected in series with the primary winding of an ignition coil and which acts as an electronic circuit breaker, a control circuit for controlling the power transistor, a measuring resistor for detecting the current flowing through the power transistor, and a current regulator network for choking the current flowing through the power transistor in dependence upon the attaining of a predetermined maximum current flowing through the measuring resistor, wherein current regulator network is arranged fully to block the power transistor when maximum current flow therethrough is reached and the current regulator network has an electronic switch for switching the power transistor into its fully conductive state, actuable in dependence upon a predetermined voltage flowing through the primary winding and lying below the required ignition voltage.

The ignition system in accordance with the invention, has the substantial advantage that a genuine switch operation and thus a power loss having a low average value are obtained for the power transistor in the primary circuit. This advantage is obtained with a low expenditure on circuitry and without the use of additional power switches or the like.

A particular advantage of the ignition system in accordance with the invention is that, by means of the series combination comprising a resistor and a capacitor in parallel with the collector-emitter path of the power transistor, considerable power losses can be converted in a simple ohmic resistor, the magnitude of the power losses determining the period of the on-off switching cycles of the power transistor, and thus the power loss occurring in the power transistor.

The invention will be further described hereinafter with reference to the accompanying drawings.

In the drawings:—

Fig. 1 is a circuit diagram of a preferred embodiment of an ignition system in accordance with the invention, and

Figs. 2*a* to 2*f* are graphs for explaining the function of the circuit of Fig. 1.

The ignition system shown in Fig. 1 of the drawings is fed in a conventional manner from a battery whose positive (+) pole is connected to one terminal of the primary winding L1 of an ignition coil 7 by way of a switch S which is closed during operation, the other terminal of the primary winding being connected to the negative (—) pole of the battery B by the way of the series combination comprising the collector emitter path of a power transistor T4 and a measuring resistor R12, the negative pole of the battery normally being connected to earth or to a reference potential in the manner indicated in the drawings. Furthermore, the positive pole of the battery is connected by way of the switch S to the anode of a diode D1 whose cathode is connected by way of a resistor R1 to a circuit point A which is connected to reference potential by way of a capacitor C1. A control circuit ST is connected between the circuit point A and reference potential and has an input to which are fed the output signals of a signal generator G which is indicated as a mechanical generator in Fig. 1, but which, alternatively, can be a contactless generator, particularly an inductive generator.

Furthermore, the control circuit has an output which is connected to the anode of a diode D2 whose cathode is connected directly to the base of the power transistor D4.

The junction of the measuring resistor R12 and the emitter of the power transistor T4 is connected by way of a resistor R10 to the base of a transistor T3 whose emitter is connected directly to reference potential and whose collector is connected to the circuit point A by way of a series combination comprising two resistors R4, R5. The junction B of the resistors R4 and R5 is connected to the base of a further transistor T2 which is in the form of a p-n-p transistor in contrast to the transistors of the circuit which are in the form of n-p-n transistors. The emitter of the transistor T2 is connected directly to the circuit point A, whilst its collector is connected to reference potential by way of a series combination comprising two resistors R2 and R3. The junction C of the resistors R2 and R3 is connected to the base of a transistor T1 whose emitter is connected directly to reference potential and whose collector is connected directly to the output of the control circuit ST. A capacitor C3 is connected in parallel with a resistor R6, and a capacitor C2 is connected in parallel with a resistor R7. A series combination comprising a resistor R13 and a capacitor C5 is connected in parallel with the collector-emitter path of the power transistor T4. Furthermore, a series combination comprising a Zener diode ZD2 and a resistor R8 is connected in parallel with the collector-base path of the power transistor T4, whilst a resistor R9 is connected in parallel with the emitter-base path of the power transmitter T4. The end of the primary winding L1 of the ingnition coil Z connected to the collector of the power transistor T4 is connected also to the circuit point B by way of a resistor R11, a Zener diode ZD1 and a diode D3. Furthermore, one terminal of the secondary winding L2 of the ignition coil Z is connected to the collector of the power transistor T4, the other terminal of the secondary winding being connected to at least one spark plug in a conventional manner, optionally by way of a distributor. Finally, a diode D4 is connected in parallel with the resistor R4.

The ignition system described above with reference to Fig. 1 operates in the following manner:

The diode D1 acts as a protection against connection with incorrect polarity, whilst the resistor R1 serves as a current limiter for the control circuit and the current regulators. The capacitor C1 serves to smooth the voltage at the circuit point A. The control circuit ST operates in dependence upon the output signals of the generator G in a conventional manner, which will not therefore be further described, and normally produces an output signal in the form of a square-wave pulse train which controls the open and closed times of the power transistor T4 the latter acting as a circuit breaker.

The current regulators comprising the measuring resistor R12, the transistors T1 to T3 and their associated components and the series combination D3, ZD1 and R11 between the collector of the power transistor T4 (circuit point D) and the circuit point B also largely operate in a conventional manner in the first instance after a predetermined switch-off current in the primary circuit has been attained. In detail, as soon as the so-called switch-off current is attained across the measuring resistor R12 has led to a corresponding voltage drop the transistor T3 is switched to its conductive state by the voltage appearing at the tapping of the voltage divider comprising the resistors R7 and R10, so that a base current can flow to the base of the transistor T2 by way of the resistor R5 and switches the transistor T2 to its conductive state, the transistor T1, hitherto non-conductive, then being switched to its conductive state by the transistor T2 by way of the latter's collector voltage divider comprising the resistors R2 and R3. The transistor T1 then draws the entire base current from the power transistor T4 which was hitherto fully conductive, so that the power transistor T4 is fully cut-off and is not merely reduced to a state of lower conductivity by attenuation of the base current in the manner customary hitherto.

Owing to the fact that the power transistor T4 is fully blocked, the current flowing through the primary winding L1 of the ignition coil Z rises steeply in the same manner as during an ignition operation until a voltage which in all cases lies below the ignition voltage and which lies at, for example, approximately 3000 volts, is reached at which the Zener diode ZD1 becomes conductive and allows a voltage to become effective on the base of the transistor T2 to render the transistor T2 non-conductive. Since the base current for the transistor T1 flows through the emitter-collector path of the transistor T2, the transistor T1 also assumes its non-conductive state virtually simultaneously with the blocking of the transistor T2. The output voltage of the control circuit ST can then become fully effective again on the base of the power transistor T4, the power transistor T4 thus being switched to its fully conductive state again. The current flowing through the power transistor T4 then jumps to an initial value which corresponds to the residual energy in the primary winding L1 and which, owing to the unavoidable losses in the ignition coil, is lower than the switch-off current and then rises again up to the switch-off current, whereupon the operations described above then take place cyclically again until the closing time, determined by the output signal of the control circuit ST, has expired and the power transistor T4 is finally blocked to trigger an ignition operation, or remains blocked if it was already blocked at the instant of ignition.

In the above explanation of the circuit of Fig. 1, it was not taken into account in the first instance that the series combination comprising the resistor R13 and the capacitor C5 is provided in parallel with the emitter-collector path of the power transistor T4. This arrangement in the circuit has the advantage that the relatively small losses occuring without this series combination are substantially increased during the non-conductive period of the power transistor T4, thus leading to a prolongation of the switching cycles and thus to further reduction of the power loss on the power transistor T4. In detail, the capacitor C5 is charged by way of the resistor R13 each time the power transistor T4 is rendered non-conductive and then is discharged again when the power transistor T4 is triggered again, a relatively high loss of power occurring on the resistor R13, whilst only pure switching losses occur on the power transistor T4.

In a further feature of the illustrated circuit the resistor R6 and the capacitor C3 connected in parallel therewith act as a positive feedback branch for improving the triggering response when the transistor T3 is switched to its conductive state upon the attaining of the switch-off current and then switches the transistor T2 to its conductive state. On the other hand, the capacitor C2 prevents the transistor T3 from immediately becoming non-conductive after the power transistor T4 has been blocked as a result of the triggering of the transistor T1, since the voltage across the measuring resistor R12 drops to zero virtually immediately at this instant. Taking into consideration the resistance values of the resistors R6, R7 and R10 connected to the capacitor C2, the capacitance of capacitor C2 is chosen such that it maintains the transistor T3 in its conductive state until the transistor T2 is blocked by way of the Zener diode ZD1 in dependence upon the voltage across the primary winding L1. Finally, it may be mentioned that the Zener diode ZD2 and the resistor R8 protect the power transistor T4 against over-voltages during an ignition operation, and that the diodes D2, D3 and D4 act as blocking diodes, whilst the resistor R11 acts to limit the current upon the triggering of the Zener diode ZD1. Furthermore, the resistor R9 serves to eliminate the flow of charge carriers upon the blocking of the power transistor T4.

The relationships described above are shown more clearly in Fig. 2 whose component Figures 2*a*, 2*b* and 2*c* show, plotted against time *t*, the current I_T flowing through the power transistor, the power loss P_v on the power transistor and the temperature characterisic P_i of the power transistor in the case of a known ignition system having current control, whilst the component Figures 2*d*, 2*e*, 2*f* show, plotted against time, the time characteristic of the current I_T flowing through the power transistor T4, the power loss p_v on the power transistor T4 and the temperature characteristic T_i of the power transistor T4 in the case of the illustrated ignition system. It will be seen that the current I_T, which is held at a predetermined value in the known ignition system after the switch-off current I_a has been reached, fluctuates between the switch-off current I_a and a lower limiting current I_g in the illustrated embodiment of the invention. The changes from a rising current to a dropping current are then effected with a relatively high frequency, so that although a blocking potential, sufficient fully to block the transistor T4, is fed to its base, the power transistor T4 never becomes completely currentless until the instant of ignition, indicated by the symbol ⚡, is reached.

In the known circuit, as is shown in Fig. 2b, linear current regulation results in a small power loss P_s, corresponding to the saturation voltage of the power transistor, up to the attaining of the switching-off current I_a, and then a constant, high power loss P_h during the phase of current regulation, whilst, in the illustrated system of the present invention, power loss peaks, exceeding the power loss P_s corresponding to the saturation voltage, up to a maximum power loss P_{max}, which is still higher tahn the power loss P_h, appear on the power transistor T_4 during the non-conductive phases after the switch-off current I_a has been reached for the first time. On the other hand, the power loss always drops again to the value P_s between these two power loss peaks in the phases of current rise in which the power transistor T4 is switched to its fully conductive state, so that a lower average power loss P_v ensues. This is also made clear by the temperature graphs of Fig. 2*c* and 2*f* which show that the final temperature reached by the power transistor is substantially higher in the known ignition system than in the illustrated system.

CLAIMS

1. An ignition system for an internal combustion engine, comprising a power transistor which is to be connected in series with the primary winding of an ignition coil and which acts as an electronic circuit breaker, a control circuit for controlling the power transistor, a measuring resistor for detecting the current flowing through the power transistor, and a current regulator network for choking the current flowing through the power transistor in dependence upon the attaining of a predetermined maximum current flowing through the measuring resistor, wherein current regulator network is arranged fully to block the power transistor when maximum current flow therethrough is reached, and the current regulator network has an electronic switch for switching the power transistor into its fully conductive state, actuable in dependence upon a predetermined voltage flowing through the primary winding and lying below the required igniion voltage.

2. A system as claimed in claim 1, wherein a series combination comprising a resistor and a capacitor is provided in parallel with the collector-emitter path of the power transistor.

3. A system as claimed in claim 1 or 2, wherein a Zener diode is provided for fixing the threshold voltage for switching the power transistor into its fully conductive state.

4. An ignition system substantially as hereinbefore described with reference to Figure 1 and Figures 2*d*, *e* and *f* of the accompanying drawings.

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