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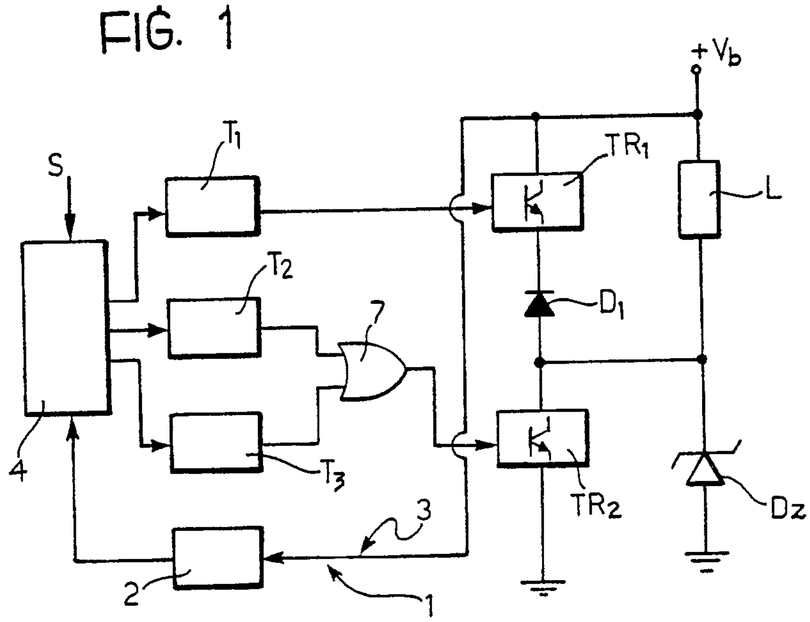
(54) **A control device for fuel injectors.**

(57) The device enables an injector (L) with a low resistance to be driven with a "peak & hold" function, reducing dissipation both in the control circuit and in the injector itself. For this purpose, the load constituted by the injector (L) is supplied by means of two power units (TR1, TR2) which are activated selectively by three timers (T1, T2, T3).

FIG. 1



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A CONTROL DEVICE FOR FUEL INJECTORS

The present invention relates to control devices for fuel injectors and has been developed with particular attention to its possible use for controlling injectors for internal combustion engines supplied with petrol.

In general, the object of the present invention is to provide a control device which reduces dissipation both in the control circuit and in the injector itself by means of so-called "peak & hold" operation.

According to the present invention, this problem is resolved by virtue of a control device having the characteristics cited specifically in the claims which follow.

The invention will now be described purely by way of non-limiting example, with reference to the appended drawings, in which:

Figures 1 and 2 show two possible embodiments of a device according to the invention, in block diagrammatic form, and

Figure 3 shows the operating sequence of a device according to Figure 1 or Figure 2, in the form of superposed time graphs with identical times scales.

The device according to the invention, generally indicated 1 in Figures 1 and 2, is intended to act as the control circuit for a load L constituted in actual fact by the excitation winding of an electromagnetically-operated injector (an electro-injector), such as, for example, a petrol injector forming part of a "single-point" injection system.

More specifically, the device 1 is intended to supply the injector S according to a so-called "peak & hold" function, that is by making a current I_c with a time trace of the type shown by the graph of Figure 3.d pass through the excitation winding of the injector L.

More precisely, the time trace of the current I_c, which is intended to be repeated for each injection operation, shows:

- an initial stage in which the current I_c rises rapidly from 0 to a maximum peak value I_p (for example, of the order of 4A) dependent on the supply voltage V_b of the injector, so as to ensure that the injector is opened fully (time interval t_1),
- a subsequent reduction stage in which the intensity of the current I_c falls (interval t_2) to a substantially fixed holding value Im (for example, 1A ± 0.3A),
- a holding stage in which the value Im is held so as to ensure that the injector remains open (interval t_3), and
- a final turn-off stage which should be as rapid and steady as possible, in which the current I_c returns to 0.

By way of reference, the injector L, as seen by the device 1, constitutes an overall load L defined by a resistance of the order of 1.5-1.7 ohms and by an inductance of the order of 2.88 mH.

With reference to both Figure 1 and Figure 2, the injector S is driven by two solid-state power units (typically bipolar or MOSFET power transistors) TR1, TR2 in an arrangement in which the unit TR2 constitutes a low-side power element since, in practice, it is connected in series with the load L between the supply voltage V_b and the earth of the circuit so as to control the intensity of the current I_c which flows towards the injector L.

The unit TR1, however, is a high-side power element which, together with a diode D1 connected to it in series, constitutes a feedback branch which is in parallel with the load L and enables the injector current to be recirculated during the holding stage t_2, thus achieving a slow discharge of the energy stored in the injector through the diode D_1.

A Zener diode DZ, however, has its cathode connected to the connecting line between the load L and the unit TR2 and its anode connected to earth. The function of the Zener diode DZ (which in practice is connected in parallel with the unit TR2) is essentially to ensure a rapid discharge during the closure of the injector (interval t_4).

An analog-digital converter, indicated 2, senses the battery voltage V_b through a line 3 and supplies a corresponding digital signal to a processing unit (CPU) 4 whose function will be described further below.

In the embodiment of Figure 2, a further line 5 is also connected to the analog-digital converter 2 and constitutes the output line of a current sensor 6 which senses the current passing through the unit TR2 (and hence the value of the current I_c which passes through the injector L when it is driven by the unit TR2).

The processing unit 4 is intended to control the operation of three timers T1, T2 and T3.

The timer T1 pilots the unit TR1, whilst the outputs of the timers T2 and T3 converge at an OR-type logic gate 7 whose output in turn pilots the unit TR2.

The processing unit 4, as well as the timers T1, T2 and T3, the converter 2 and the logic gate 7, may to advantage be integrated, even partially, in a microprocessor circuit, for example, as respective functions thereof.

The operation of the device will now be described (with reference to both Figure 1 and Figure 2) with the aid of the time graphs of Figure 3. In these time graphs, it is assumed that the output signals of the timers T1, T2 and T3 can be brought selectively, as a result of a corresponding signal output by the unit 4, from a "low" or "0" logic level to a high or "1" logic level which can cause the activation of the units TR1 and TR2.

More precisely, the time graphs of Figure 3 relate to a single fuel-injection operation started by the unit 4 (time 0 of the time scale on the abscissa) as a result of the receipt of a synchronisation signal generated, according to known criteria, on the input line S.

At the start of the injection operation, that is, when the current I_c is to be brought to its peak level I_p, the unit 4 activates the timer T2 causing the activation of the power unit TR2, so that, in practice, the injector L is connected between the battery voltage V_b and earth.

The duration of the interval t_1 is determined by the unit 4 (by means of a simple calculation algorithm stored therein) in dependence on the battery voltage (V_b) which the unit 4 reads by means of the converter 2.

In brief, this is an open-loop control system: if the voltage V_b (which may vary with the charge level of the battery) is known and the desired maximum current level I_p (for example, 4 A) is known, the duration of the time interval t_1 necessary to reach that current level can be calculated. In general, if V_b drops, it will be necessary to increase the duration of the interval t_1.

Naturally, it is also possible to use closed-loop control systems, as in the solution shown in Figure 2, in which the converter 2 also supplies the unit 4 with an indication of the current I_c at any time so that threshold operations, etc. can be carried out in order to achieve an optimal final result.

At the end of the interval t_1, the timer T2 is deactivated and the timers T1 and T3 are also kept deactivated. Under these conditions, both the units TRI and TR2 are deactivated (that is, cut off) so that the injector S is discharged through the Zener diode DZ with a rapid decrease in the intensity of the current I_c which falls to the holding value I_m.

When the intensity I_c reaches the value I_m, which takes place during the interval t_2 (whose duration can easily be calculated by the unit 4 on the basis of the battery voltage V_b, the duration of t_1 and the value of I_m to be attained), the unit 4 simultaneously activates the timer T1 (thus activating TR1 and hence the feedback circuit around the load S), whilst the timer T3 (like the unit TR2 controlled thereby through the gate 7) is activated in a pulsed manner, that is, at a fixed frequency (for example 20 KHz) with a selectively variable duty-cycle.

The current can thus be recirculated slowly through the diode DI (the unit TR1 being made conductive) and, at the same time, the value of the current I_c flowing through the load L is stabilised around an average level (Im) whose value depends on the duty-cycle set by the timer T3.

In general (see the time interval t_3 of the graph of Figure 3d), the current value I_c increases when the unit TR2 is conducting and decreases when the unit TR2 is cut off.

This stage is maintained continuously throughout the injection interval t_3.

In particular, in the solution according to Figure 2, the current signal detected by the sensor 6 and transferred to the unit 4 by means of the converter 2 enables a fine adjustment of the current.

Upon completion of the fuel injection (at the end of the interval t_3), the unit 4 once again switches off the timers T1 and T3 and cuts off the units TR1 and TR2, thus facilitating the rapid discharge of the load L through the Zener dioode nz with a consequent rapid fall in the intensity of the current I_c to zero (interval t_4).

With reference again to the stage t_3, it can be noted that, given the high frequency (e.g. 20 KHz) of the chopper effect on the timer T3 (and hence on the unit TR2), the injector S integrates the current which is stabilised, so to speak, around the desired average current I_m. In particular, the frequency selected is high enough to ensure that the ripple of the average value satisfies the specification (that the ripple is below a given threshold). For this purpose also, the duty-cycle generated is varied by the unit 4 in dependence on the battery voltage V_b (detected by means of the converter 2) and on the characteristics of the injector L.

It can be seen from the foregoing description that, from a strictly logical point of view, the timers T2 and T3 (which are intended to be activated alternately) could be combined in a single timer element. The circuit described above, however, may be advantageous in terms of simplicity of execution.

Naturally, the principle of the invention remaining the same, the details of construction and forms of embodiment may be varied widely with respect to those described and illustrated, without thereby departing from the scope of the present invention.

Claims

1. A control device for fuel injectors (L) for internal combustion engines, characterised in that it comprises:
- first (TR1) and second (TR2) power units which can be connected to an injector (L) in an arrangement such that they recirculate the current (D1) and control the intensity (Ic) of the current flowing through the injector (L), respectively, and
- piloting means (2 to 7; T1, T2, T3) which activate the first (TR1) and second (TR2) power units and

can be activated selectively (4) so that, for each injection operation, they effect an operating sequence comprising in order:

- the activation of the second power unit (TR2) with the first power unit (TRI) unit deactivated, causing the intensity of the current (I_c) flowing through the injector (L) correspondingly to increase to a maximum level (I_p),
- the deactivation of both the first (TRI) and the second (TR2) power units with a corresponding drop in the intensity of the current (I_c) flowing through the injector (S) to a lower level, the holding level (I_m),
- the activation of the first power unit (TR1) and the simultaneous intermittent activation of the second unit (TR2) so as to cause a certain recirculation of current through the first power unit (TR1) and to hold the intensity of the current (I_c) flowing through the injector (L) at the holding level (I_m), and
- the deactivation of both the first (TR1) and the second (TR2) power units with a consequent drop in the intensity of the current (I_c) flowing through the injector.

2. A device according to Claim 1, characterised in that the first (TR1) and second (TR2) power units are constituted by solid-state switches, such as bipolar or MOSFET power transistors.

3. A device according to Claim 1 or Claim 2, characterised in that the first power unit (TR1) has an associated recirculation diode (D_1) for the passage of the current which is recirculated from the injector (L) and flows through the first power unit (TR1) when that power unit (TR1) is activated.

4. A device according to any one of Claims 1 to 3, characterised in that a Zener diode (DZ) is associated with the second power unit (TR2) for faciliting the rapid discharge to earth of the current (I_c) flowing through the injector (L).

5. A device according to Claims 2, 3 and 4, characterised in that it includes, interposed between the supply voltage (V_b) and the earth of the device (1), two electrical branch circuits constituted respectively by:

- the first power unit (TRI) and the respective recirculation diode (DI) in parallel with the injector (L), and
- the second power unit (TR2) in parallel with the Zener diode (DZ).

6. A device according to Claim 1, characterised in that the piloting means (4 to 7; T1, T2, T3) comprise:

- at least one detector element (2) sensitive to the level of the supply voltage (V_b) of the device (1),
- timer means (T2) for activating the second power unit (TR2) for a predetermined time interval (t_1) with the first power unit (TR1) deactivated, with a consequent increase in the intensity of the current (I_c) flowing through the injector (S) to the maximum level (I_p), and
- control means (4) which can act on the timer means (T2) selectively to vary the duration of the predetermined time interval (t_1) generally in inverse proportion to the level of the supply voltage (V_b)

7. A device according to Claim 1 or Claim 6, characterised in that it includes:

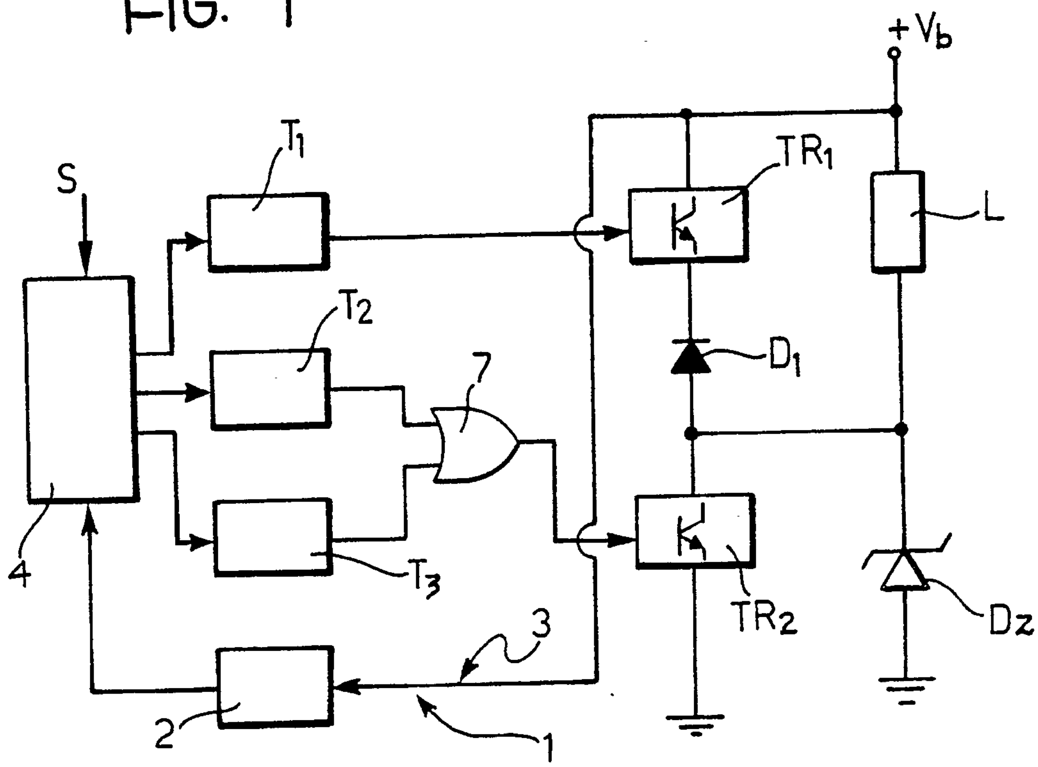
- at least one detector element (2) sensitive to the level of the supply voltage (V_b) of the device (1),
- intermittence means (T3) which can vary selectively the duty-cycle of the function of the intermittent activation of the second power unit (TR2), and
- control means (4) which can act on the intermittence means (T3) selectively to vary the duty-cycle generally in inverse proportion to the level of the supply voltage (V_b).

8. A device according to any one of the preceding Claims 1 to 7, characterised in that it includes:

- a timer element (T1) for selectively activating the first power unit (TR1), and
- at least one further timer element (TR2, TR3) for selectively activating the second power unit (TR2).

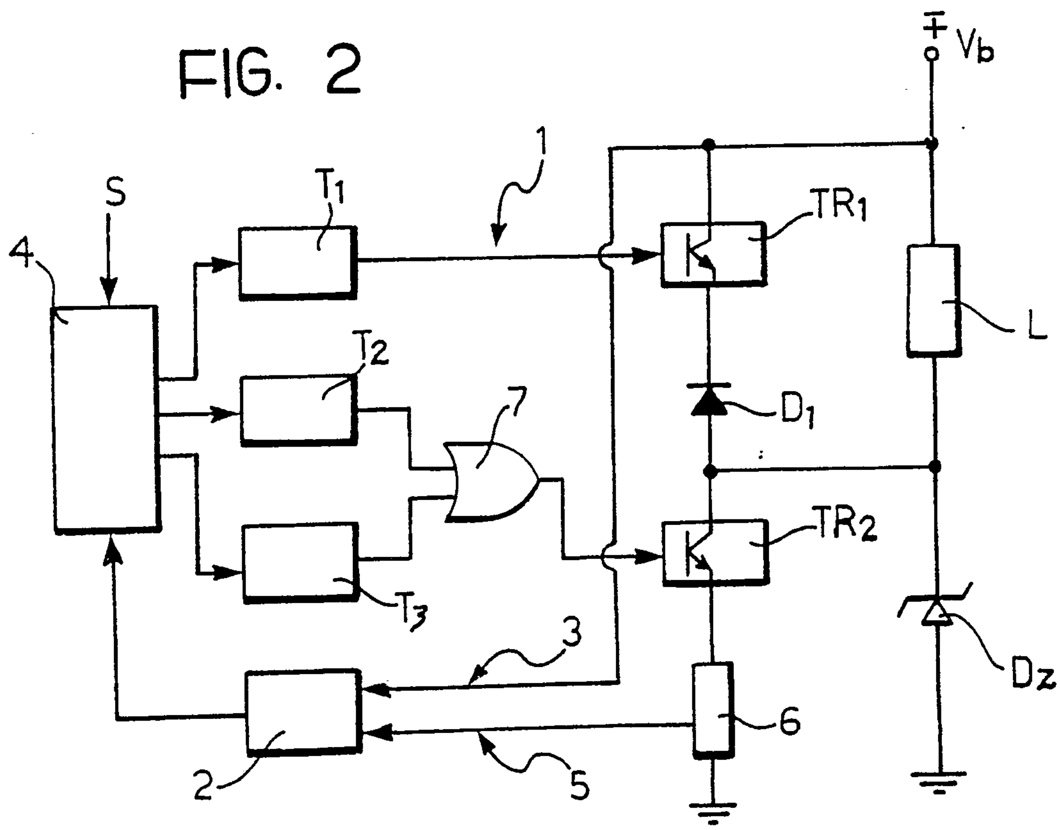
9. A device according to Claim 8, characterised in that it comprises first (T2) and second (T3) further timer elements for activating the second power unit (TR2), the first (T2) and second (T3) further timer elements being interconnected to activate the second power unit (TR2) according to a general logic sum configuration (7)

FIG. 1



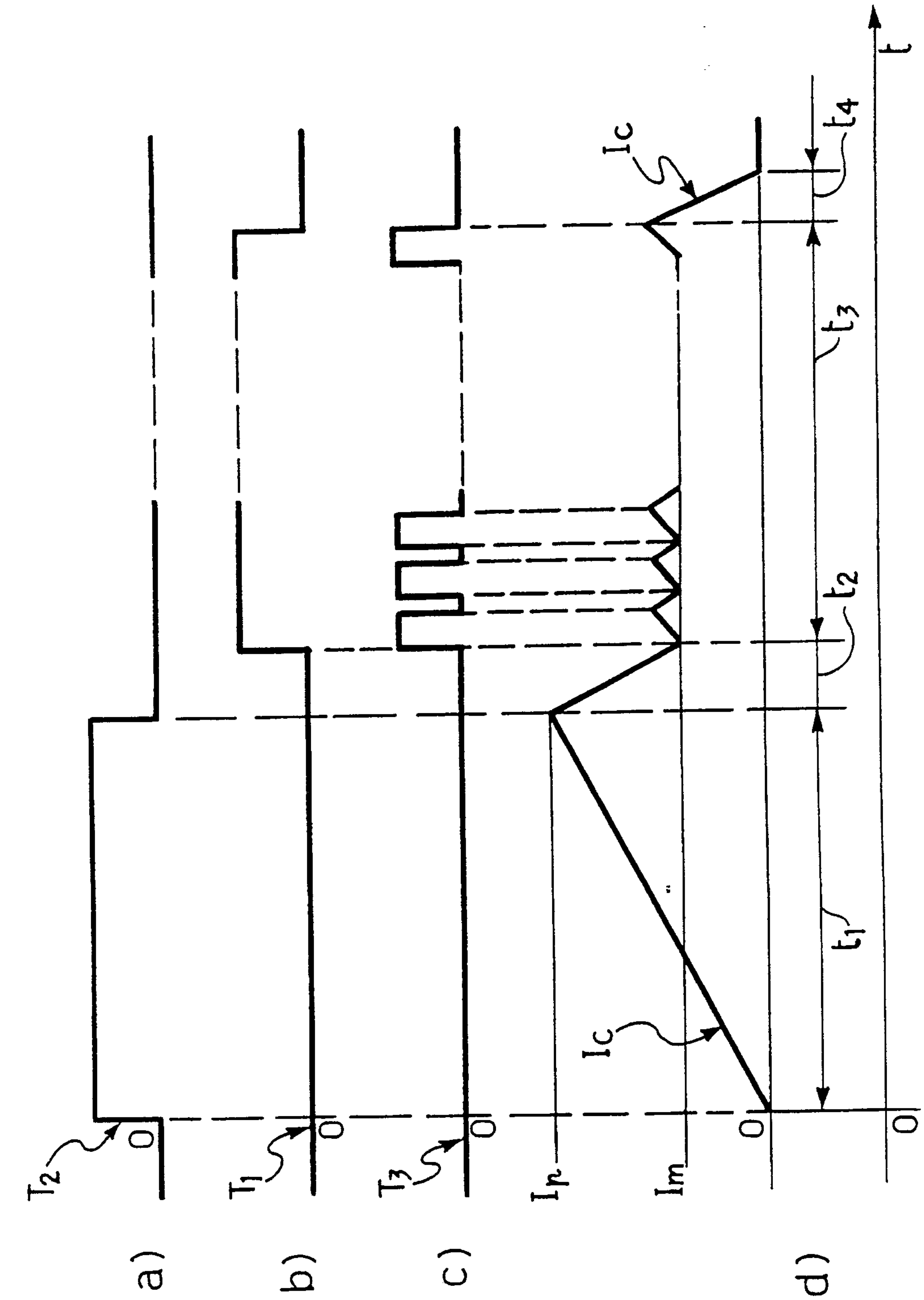
+Vb
S
T1
TR1
L
T2
D1
7
4
T3
TR2
Dz
3
2
1

FIG. 2



+Vb
1
S
T1
TR1
4
L
T2
D1
7
TR2
T3
3
Dz
6
2
5

FIG. 3



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EUROPEAN SEARCH REPORT

Application Number

EP 90 12 1007

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	US-A-4 536 818 (NIELSEN) * Whole document * – – –	1-6,8,9	F 02 D 41/20
X	US-A-4 631 628 (KISSEL) * Abstract; figures 1,2 * – – –	1-6,8,9	
Y	FR-A-2 345 595 (BOSCH) * Whole document * – – –	1-9	
Y	US-A-4 213 181 (CARP et al.) * Summary of the invention * – – –	1-9	
A	PATENT ABSTRACTS OF JAPAN, vol. 9, no. 67 (M-366)[1790], 27th March 1985; & JP-A-59 200 024 (NIHON DENSHI) 13-11-1984 – – – – –		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
F 02 D

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	18 December 90	GAGLIARDI P.

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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