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EUROPEAN PATENT APPLICATION

21 Application number: **83302959.8**

51 Int. Cl.³: **F 02 B 75/02**

22 Date of filing: **23.05.83**

43 Date of publication of application:
05.12.84 Bulletin 84/49

84 Designated Contracting States:
FR GB IT SE

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54 **Improvements in internal combustion engines.**

57 An internal combustion engine is provided which operates on a six stroke cycle. In one embodiment, each six stroke cycle comprises a fuel/air intake stroke (7), a compression stroke (8), a first power stroke (9), a second compression stroke (10) during which the combustion products are compressed, a second power stroke (11) and an exhaust

stroke (12). As the fuel is burnt more thoroughly and for a longer period, greater efficiency results. In a further embodiment, the fuel/air mixture is compressed twice in each cycle before combustion so as to increase its temperature and pressure before ignition.

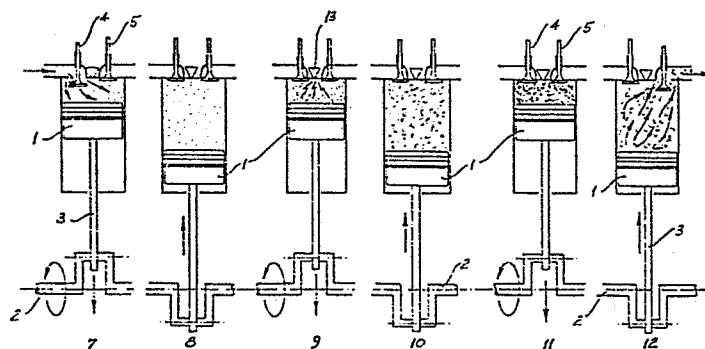


FIG. 1

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IMPROVEMENTS IN INTERNAL COMBUSTION ENGINES

The present invention relates to improvements in the operation of internal combustion engines, and to the reduction of impurities in the exhaust gases of such engines. In particular, the invention is directed to an internal combustion engine, typically an automobile engine, having
5 a six stroke cycle.

The present day four stroke petrol or diesel engine, as used in motor vehicles, is known to be inefficient mainly because it has to operate over a wide range of speeds. Typically, an automobile engine can convert only about one fifth of the energy in the gasoline fuel
10 into driving power because a large amount of heat is generated according to the Carnot cycle. Another serious disadvantage of a Carnot cycle gasoline engine is the small ratio of net work to gross work (net work refers to the difference between the work produced by expansion of burning gases (gross work) and the work of compression of
15 input gases).

It is known that when an automobile is cruising at a steady speed, it requires far less power than when it is accelerating. The present invention utilises this property to decrease the fuel consumption per unit distance yet retaining sufficient power to maintain cruising
20 speeds.

It is also known that the exhaust gases contain a significant percentage of unburnt fuel. The present invention allows the engine to use the fuel more efficiently, thereby reducing the proportion of impurities in the exhaust gases.

25 It is the primary object of the present invention to increase the efficiency of an internal combustion engine by operating the engine on a six stroke cycle.

Accordingly, in one broad form, the present invention provides

an internal combustion engine having a six stroke cycle.

According to one embodiment of the present invention, the six stroke cycle comprises the following piston strokes in cyclical succession:-

- 5 (1) an intake stroke during which a fuel/air mixture is admitted into the cylinder,
- (2) a first compression stroke during which the fuel/air mixture is compressed,
- (3) a first power stroke following ignition of the compressed
10 fuel/air mixture,
- (4) a second compression stroke during which the combustion products are compressed,
- (5) a second power stroke due to expansion of the compressed combustion products, and
- 15 (6) an exhaust stroke during which combustion gases are expelled from the cylinder.

The preferred embodiment of the present invention is characterised by a number of features:-

- (i) Unlike the conventional four stroke engine in which the
20 exhaust valve opens as the piston is on its power stroke, typically 58 degrees before bottom dead centre (BDC), the exhaust valve in the preferred embodiment remains closed during the whole of the first power stroke following the ignition of the compressed fuel/air mixture. Thus, the pressure generated by the burning gases is sustained
25 on the piston face for a longer period thereby delivering greater power to the crankshaft. Furthermore, during this extended period during which the exhaust valve remains closed, continued burning of the fuel/air mixture occurs so that the fuel is used more efficiently. The extra energy obtained during the extra period that the exhaust valve
30 remains closed is stored in the flywheel and is used in the second compression stroke when the combustion products are compressed.

- (ii) When the combustion products are compressed, the heat energy contained therein is retained in the cylinder rather than wasted in the exhaust. Compressing the combustion products further increases the
35 temperature of the already heated combustion gases so that unburnt fuel is ignited thereby generating further power during the second power stroke. The compressed combustion products do not need to be electrically ignited at the end of the second compression stroke, although spark

plug ignition may be provided at this point in the cycle if desired.

(iii) It will be seen that the crankshaft undergoes three revolutions during one cycle of the six stroke engine, as compared to two revolutions for a conventional four stroke engine. Thus, for the same amount of input fuel, a fifty percent increase in distance is obtained. Although the overall power is reduced, it has been found in practice that the reduction in power amounts to only 2-3%, and sufficient power remains to maintain the automobile at cruising speed.

(iv) The six stroke engine broadens the torque spread of the engine across its range of speed, thereby enabling a simpler transmission with fewer gears to be used.

(v) Longer combustion of the fuel/air mixture, together with secondary combustion of the "burnt" gases ensures that impurities in the exhaust gases, i.e. pollutant gases are reduced to a minimum.

According to a further embodiment of the present invention, the six stroke cycle comprises the following piston strokes in cyclical succession:-

(1) an intake stroke during which a fuel/air mixture is admitted into the cylinder,

(2) a first compression stroke during which the fuel/air mixture is compressed,

(3) an expansion stroke,

(4) a second compression stroke during which the fuel/air mixture is compressed again,

(5) a power stroke following ignition of the compressed fuel/air mixture, and

(6) an exhaust stroke during which combustion gases are expelled from the cylinder.

At the end of the first compression stroke, the temperature and pressure of the fuel/air mixture have been increased. During the expansion stroke, the pressure is reduced but as the whole process occurs at a rapid rate, the heat in the fuel/air mixture is maintained to a significant extent. Furthermore, the friction between the piston and the cylinder adds further heat to the mixture. The end result is that at the end of the second compression stroke,

the fuel/air mixture is raised to a temperature higher than that at the end of compression strokes in conventional four stroke engines. This results in more thorough combustion of the fuel/air mixture.

5 Due to the inter-relationship between temperature and pressure, the pressure at the end of the second compression stroke is higher than that in normal four stroke engines. Therefore, a "turbo-charging" effect is achieved in the six stroke engine of this further embodiment.

10 A turbo-charger can be used on the six stroke engine of the present invention in the same manner as conventional four stroke engines.

 Since the operation of the six stroke engine is controlled by the cam shaft and the firing of the spark
15 plugs, electronic control means can be incorporated into the engine to switch from a conventional four stroke cycle to a six stroke cycle of either of the above-described versions. Thus, while the car is accelerating, the engine can be kept in the normal four stroke mode so that maximum power is
20 achieved, but while the car is cruising the engine can be switched to the six stroke cycle to achieve greater economy.

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

25 Fig. 1 is a schematic illustration of the six stroke cycle of the preferred embodiment, and

 Fig. 2 is a cylinder pressure diagram of the embodiment of Fig. 1.

 As illustrated in Fig. 1, the six cycles of the
30 preferred embodiment operate as follows. The intake stroke 7 begins as the piston 1 leaves top dead centre (TDC). At that time, the intake valve 4 is opened to admit the fuel/air mixture into the cylinder chamber 6. When the piston 1 reaches bottom dead centre (BDC), the intake valve
35 4 closes.

 The piston 1 is then pushed up by the rotating crankshaft 2 via the connecting rod 3 in a first compression stroke 8. Near the end of the first compression stroke 8,

the ignition system produces an electric spark at the spark plug 13. (In a six stroke diesel engine, only air is compressed so that it becomes heated to a temperature of approximately 600°C. At the end of the compression stroke, liquid diesel fuel is injected into the cylinder, and due to the high temperature, it burns instantly.) In the embodiment illustrated, the spark 13 ignites the compressed mixture and, as the mixture burns, very high pressure and temperature are produced in the combustion chamber 6 thereby forcing the piston 1 down in a first power stroke 9.

The pressurised combustion vapours which do the work consist of heated nitrogen left over from the charge of air, water vapour, carbon dioxide, carbon monoxide, unburnt fuel and a few minor ingredients which are the chemical result of combustion. The mechanical work is produced by the pressure exerted by the heated combustion vapours on the piston. The hotter the pressurised vapour becomes, the greater will be the pressure that is produced, and the greater will be the power of the engine.

In the conventional four stroke engine, the exhaust valve opens just before the piston reaches BDC. Typically, the exhaust valve opens 58° before BDC when the piston is 3-4 cm from BDC. However, in the preferred embodiment of the present invention, the exhaust valve does not open, and pressure is exerted on the piston all the way down to BDC. Due to the extra period that pressure is exerted on the piston, extra power is imparted to the crankshaft and the excess energy is stored in the flywheel. This excess energy is used to compress the combustion vapours in a second compression stroke.

Compressing the already heated combustion vapours raises the temperature further so that unburnt fuel components are ignited. To ensure ignition, an electric spark can be optionally provided at the end of the second compression stroke. The burning of the remaining fuel portions causes a further power stroke 11. As the piston 1 is forced down, the combustion vapours undergo expansion

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which results in a large drop in their pressure and temperature. This further increases the efficiency of the engine.

5 The second power stroke is followed by an exhaust stroke during which the combustion gases are expelled from the cylinder.

10 In accordance with another embodiment of the present invention (not illustrated), a six stroke internal combustion engine is provided in which the air/fuel mixture is compressed twice before ignition. The pressure and temperature of the compressed fuel/air mixture at the end of the second compression stroke are higher than in normal four stroke engines and greater efficiency is obtained.

15 According to a further embodiment of the present invention, the six stroke cycle comprises the following piston strokes in cyclical succession:

- (1) a first intake stroke during which a fuel-air mixture is admitted into the cylinder,
- (2) a compression stroke during which the fuel-air mixture is compressed,
- (3) a power stroke following ignition of the compressed fuel-air mixture,
- (4) a first exhaust stroke during which combustion gases are expelled from the cylinder,
- 25 (5) a second intake stroke during which only air is admitted into the cylinder, and
- (6) a second exhaust stroke during which said air is expelled from the cylinder.

30 At the end of the first exhaust stroke, an inlet valve opens to admit air (no fuel) into the cylinder when the piston travels down. This air cools the cylinder wall and piston. On the second exhaust stroke, the air is expelled into the exhaust manifold when it forces out any remaining combustion gases. This additional two-stroke phase acts as an air pump on a four stroke engine.

35 According to yet another embodiment of the invention, the six stroke cycle comprises the following piston strokes in cyclical succession:

- (1) a first intake stroke during which a fuel-air mixture is admitted into the cylinder,
- (2) a compression stroke during which the fuel-air mixture is compressed,
- 5 (3) a power stroke following ignition of the compressed fuel-air mixture,
- (4) a first exhaust stroke during which combustion gases are expelled from the cylinder,
- (5) a second intake stroke during which the combustion
10 gases of the previous stroke are drawn back into the cylinder, and
- (6) a second exhaust stroke during which said combustion gases are re-expelled.

15 In this manner, the cylinder walls and piston are maintained at a higher temperature, which is beneficial in colder climates.

Note that with suitable modification, the present invention is applicable to rotary engines.

20 The foregoing describes only two embodiments of the present invention, and modifications which are obvious to those skilled in the art may be made thereto without departing from the scope of the present invention as defined in the following claims.

CLAIMS

1. An internal combustion engine comprising at least one cylinder having a piston operating therein and intake and exhaust valves, said engine having a six stroke
5 cycle.

2. An internal combustion engine as claimed in claim 1, wherein said six stroke cycle comprises the following piston strokes in cyclical succession:-

- (1) an intake stroke during which a fuel/air
10 mixture is admitted into the cylinder,
- (2) a first compression stroke during which the fuel/air mixture is compressed,
- (3) a first power stroke following ignition of the compressed fuel/air mixture,
- 15 (4) a second compression stroke during which the combustion products are compressed,
- (5) a second power stroke due to expansion of the compressed combustion products, and
- (6) an exhaust stroke during which combustion
20 gases are expelled from the cylinder.

3. An internal combustion engine as claimed in claim 2, wherein the exhaust valve remains closed for the whole of the first power stroke.

4. An internal combustion engine as claimed in 3,
25 wherein ignition is provided at the end of the second compression stroke by an electric spark.

5. An internal combustion engine as claimed in claim 1, wherein the six stroke cycle comprises the following piston strokes in cyclical succession:-

- 30 (1) an intake stroke during which a fuel/air mixture is admitted into the cylinder,
- (2) a first compression stroke during which the fuel/air mixture is compressed,
- (3) an expansion stroke,
- 35 (4) a second compression stroke during which the fuel/air mixture is compressed again,
- (5) a power stroke following ignition of the compressed fuel/air mixture, and

(6) an exhaust stroke during which combustion gases are expelled from the cylinder.

6. An internal combustion engine as claimed in claim 1, wherein said engine is used to propel an automobile.

5 7. An internal combustion engine as claimed in claim 6, further comprising turbo-charging means for compressing the air/fuel mixture before ignition.

10 8. An internal combustion engine as claimed in claim 6, further comprising control means for switching said engine from a four stroke cycle to a six stroke cycle and vice versa.

9. An internal combustion engine as claimed in claim 1, wherein said six stroke cycle comprises the following piston strokes in cyclical succession:

- 15 (1) a first intake stroke during which a fuel-air mixture is admitted into the cylinder,
- (2) a compression stroke during which the fuel-air mixture is compressed,
- (3) a power stroke following ignition of the compressed fuel-air mixture,
- 20 (4) a first exhaust stroke during which combustion gases are expelled from the cylinder,
- (5) a second intake stroke during which only air is admitted into the cylinder, and
- 25 (6) a second exhaust stroke during which said air is expelled from the cylinder.

10. An internal combustion engine as claimed in claim 1, wherein said six stroke cycle comprises the following piston strokes in cyclical succession:

- 30 (1) a first intake stroke during which a fuel-air mixture is admitted into the cylinder,
- (2) a compression stroke during which the fuel-air mixture is compressed,
- (3) a power stroke following ignition of the compressed fuel-air mixture,
- 35 (4) a first exhaust stroke during which combustion gases are expelled from the cylinder,
- (5) a second intake stroke during which the combustion

gases of the previous stroke are drawn back into the cylinder, and

- (6) a second exhaust stroke during which said combustion gases are re-expelled.

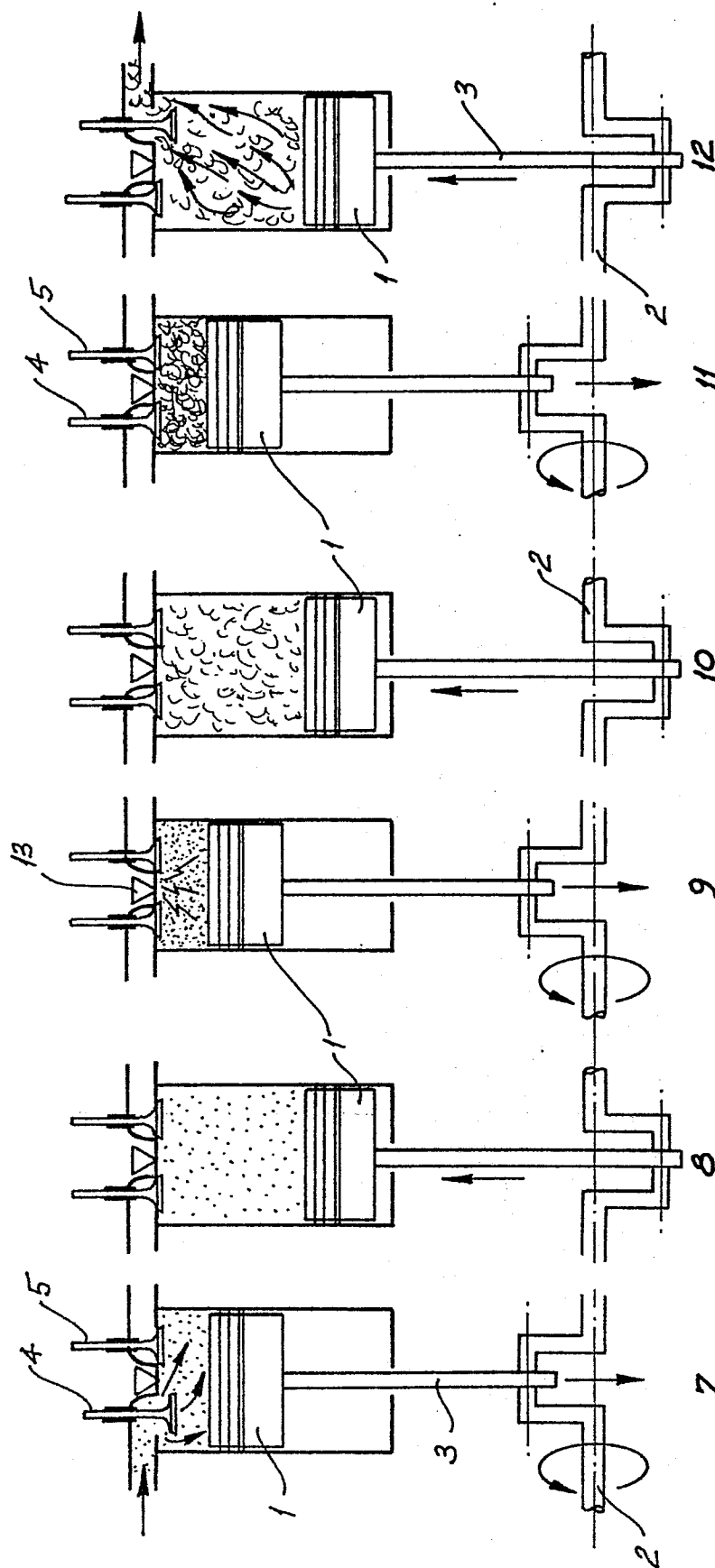
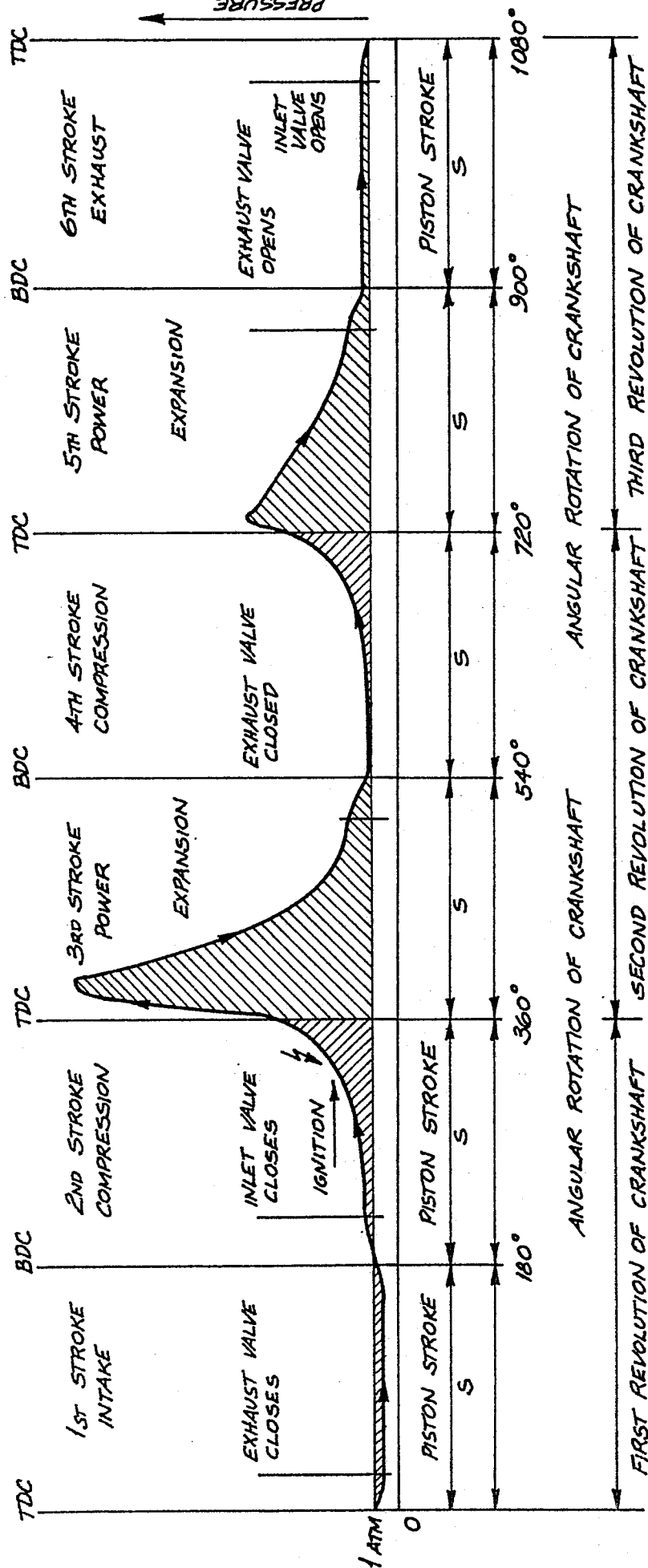


FIG. 1



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European Patent
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EUROPEAN SEARCH REPORT

Application number

EP 83 30 2959

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. ³)
X	DE-A-2 358 894 (L. BEHRENS) * Whole document *	1-4, 6, 8	F 02 B 75/02
X	DE-A-3 017 095 (F.J. DZIEDZICKI) * Whole document *	1-4, 6, 8	
X	US-A-3 709 201 (H.A. COOK) * Claims 1-4, abstract; figures 1, 2 *	1, 5	
X	DE-C- 352 231 (R. CONRAD) * Figures 2, 4 *	1, 9	
A	FR-A-2 404 109 (S. MEZAKI) * Claims 1, 2; figure 1 *	1, 9	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	US-A-4 367 700 (J.L. PACE) * Abstract; figure 4 *	1, 10	F 02 B 75/00
A	US-A-4 289 097 (C.P. WARD)		
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 30-11-1983	Examiner CANNICI B.S.E.
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