Europäisches Patentamt
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(19) (11) Publication number: **0 167 691**
A2

EUROPEAN PATENT APPLICATION

(12)

(21) Application number: **84307380.0**

(51) Int. Cl.⁴: **F 01 L 13/08**

(22) Date of filing: **26.10.84**

(30) Priority: **10.07.84 JP 143786/84**

(43) Date of publication of application: **15.01.86 Bulletin 86/3**

(84) Designated Contracting States: **DE FR GB IT**

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(54) **Decompression apparatus for engines.**

(57) For automatic depression during starting, a decompression device (9) is rotatably supported in the cam gear (6) on the camshaft (1) of an engine. The device has a shaft (10) mounted in the cam gear, a U-shaped portion (11), and a decompression cam (12) formed on the shaft and having a semicircular cross section. Inlet valve cam (4) has a recess (4a) at a part of its periphery and the decompression cam (12) is positioned in that recess (4a). A centrifugally rotated weight (13) is mounted on the cam gear (6) and is operatively engaged with the U shaped portion (11) of the decompression device (9). The weight (13) and the decompression device (9) are so arranged that when the rotational speed of the camshaft at starting is below a speed which causes the reverse rotation of the engine, the periphery of the decompression cam (12) projects beyond the periphery of valve cam (4) to open the corresponding valve for reducing the compression pressure in the engine, and that when the rotational speed exceeds the speed which causes the reverse rotation of the engine, the periphery of the decompression cam (12) retracts to or below the periphery of the valve cam (4) to close the valve during at least a part of the compression stroke of the engine.

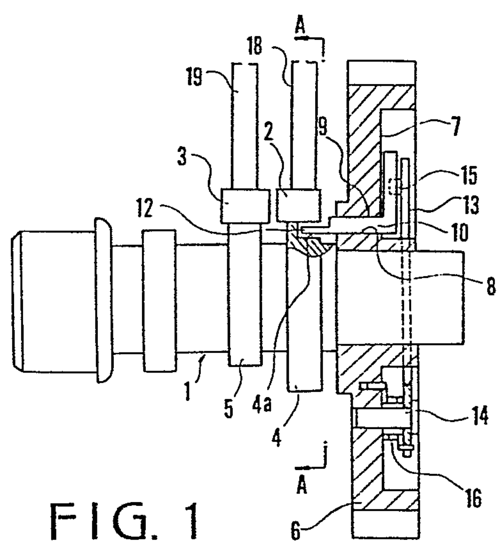

FIG. 1

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DECOMPRESSION APPARATUS FOR ENGINES

The present invention relates to decompression apparatus for an internal combustion engine, designed to make starting easier and to avoid the risk caused by reversal of rotation, or "kick-back".

A decompression device has been known which is either automatically or manually operated to open either an inlet valve or an exhaust valve a small extent to reduce the compression pressure in the combustion chambers during starting and thereby to reduce the starting load of the engine. In case of a manual decompression device, a decompression shaft, which is provided on the cylinder head or a rocker shaft, is manually operated to hold a rocker arm in a decompression position; the engine is then started using a starting handle or a recoil starter. On the other hand, Japanese Patent publication No. 50-95630 discloses an automatic decompression device which is operated by centrifugal force and which automatically reduces the compression pressure in the combustion chambers during starting of engine.

In the known device, a cam lobe for decompression is provided on an inlet valve cam. The decompression cam lobe of an ordinary gasoline engine is provided at a position adjacent bottom dead centre at the beginning of compression stroke as shown in Figure 8 of the accompanying drawings, which figure shows the relationship between crank angle and cam-lift. Accordingly, the compression period is increased and the operational load becomes heavy during starting of the engine, especially in the case of a diesel engine. In order to overcome such disadvantages, various auxiliary means other than the automatic decompression device, such as auxiliary fuel injection nozzles, means for retarding the ejecting timing and means for increasing the flywheel-mass, have been employed.

As a result of various experiments performed on the starting of a diesel engine with a centrifugal decompression device, the applicant has found that the reverse revolution phenomenon ("kick-back") occurred when decompression was released in a definite speed range of the crankshaft at cranking, as shown in Figures 9 and 10. The phenomenon is due to reversed torque which is caused when air and fuel is mixed in the cylinder during starting of the engine. Figure 9 shows a hatched zone B in which the reverse revolution phenomenon occurs, and shows that as engine temperature rises, the zone expands to a lower rotational speed. Figure 10 shows the cranking rotational speed during starting at the engine temperature C of Figure 9, the reverse revolution phenomenon occurring in hatched zone D. In Figure 10, line E represents a relationship between time and cranking speed which is too low to cause starting ignition of the engine; line F shows that the cranking speed is in the zone in which the reverse revolution occurs at a point X on the line F; line G shows a sufficient cranking speed for the engine to start; line H shows the limit of the decompression condition; line I shows the limit of decompression release; and line J shows the limit of starting of engine. Thus, in a certain rotational speed range, the reverse revolution phenomenon occurs, so that an operator attempting to start the engine with a starting handle may be subject to shock; if rope-starting is used, kick-back will cause the rope to be wound up and stress to be given to the operator's arm.

An object of the present invention is to provide a centrifugal decompression apparatus which enables an engine to be started under light load and without the danger of reverse revolution of the engine.

The present invention relates to apparatus for reducing the compression of an internal combustion engine which has a camshaft carrying an inlet valve cam and an exhaust valve cam and tappets engaged with those valves, and is characterised in that the apparatus comprises a supporting member secured to, and rotating with, the camshaft; a decompression device having a shaft which is rotatably supported in the supporting member and which has a decompression cam formed thereon, the decompression cam being engageable with the tappet of either the inlet valve cam or the exhaust valve cam to cause lifting of the tappet;

and a weight which is rotatably mounted on the supporting member so as to be subject to centrifugal force on rotation of the camshaft and which is operatively engaged with the decompression device so that rotation of the weight is accompanied by rotation of the decompression device; the weight and the decompression device being so arranged that, when the rotational speed of the camshaft is below the speed which causes reverse engine movement, the periphery of the decompression cam projects beyond the periphery of the valve cam to open the corresponding valve in order to reduce the compression of the engine, and that, when the rotational speed exceeds the speed which cause reverse engine movement, the periphery of the decompression cam is retracted to or below the periphery of the valve cam to close the valve during at least a part of the compression stroke of the engine.

The invention will be more readily understood by way of example from the following description of decompression apparatus in accordance therewith, reference being made to the accompanying drawings, in which

Figure 1 is an axial sectional view of the camshaft of an engine and includes the decompression apparatus;

Figure 2 is a side view of the embodiment of Figure 1 as viewed from the right;

Figure 3 is a perspective view of the decompression device of Figure 1;

Figure 4 shows the relationship between crank angle and cam-lift;

Figure 5 shows the relation between piston position and combustion chamber volume;

Figure 6 is a section on the line A-A of Figure 1, showing the operation of decompression device during starting;

Figure 7 is a view similar to Figure 6, showing the operation of decompression device during the ordinary operating condition of the engine;

Figure 8 shows the relationship between the crank angle of the engine and cam-lift;

Figure 9 shows the relationship between the range in which the reverse revolution of the engine occurs and engine temperature; and

Figure 10 shows relationship between cranking rotative speed during starting of engine and time at temperature C.

Referring to Figure 1, a camshaft 1 carries an inlet valve cam 4 and an exhaust valve cam 5 and has on its end a cam gear 6. Cams 4 and 5 cooperate with tappets 2 and 3, which in turn engage with push rods 18 and 19, respectively. Camshaft 1 is rotated by the engine crankshaft (not shown) through cam gear 6. A groove 7 is formed in one side of the cam gear 6 and communicates with the other side by a bore 8 which is parallel to camshaft 1. The position of the bore 8 is, as shown in Figure 2, in advance of the compression top dead centre position K of the camshaft by an angle θ, i.e. it is displaced by θ from top dead centre in the rotational direction of the cam gear.

Figure 3 shows a decompression device 9 which consists of a pin or a shaft 10, a U-shaped engagement member 11 which is formed on an end of the shaft 10 and is at right angles thereto, and a decompression cam 12 formed on the other end of shaft 10, the cam 12 having a semicircular cross section with a diametrical flat 12a.

The shaft 10 is rotatably located in the bore 8, as shown in Figure 1, with the engagement member 11 within the groove 7 and the cam 12 protruding from the cam gear 6 into a recess 4a formed in part of the periphery of inlet valve cam 4. The normal operative contour of cam 4 is unaffected, being defined by the unrecessed part of its periphery. The engagement member can turn within groove 7, the central portion of the gear 6 being cut away at 17 for that purpose. Groove 7 also accommodates a weight 13, one end of which is pivotably mounted on a pin 14 secured to cam gear 6, and the other end of which carries a pin 15 which is received between the arms of the U-shaped part 11 of the decompression device 9; the device 9 is thus interconnected with the weight 13 and turns in the bore 8 as weight 13 turns on pin 14. Pin 14 is located on a radius of the cam gear 6 which is approximately perpendicular to a line connecting the centre of shaft 10 with the centre of cam shaft 1. A coil spring 16 is provided around the pin 14, one end of the spring being anchored to cam gear 6 and the other end attached to weight 13 so as to urge the weight towards the centre of cam shaft 1. The biasing force of coil spring 16, and the mass and shape of the weight 13 are so chosen that decompression is released in a given crank speed range which is higher than the range which may cause the reverse engine movement. This crank speed range varies according to the characteristics of the engine with which the decompression device is employed and is selected by experience or experiment on the engine.

When the decompression cam 12 has the position shown in Figures 1 and 7, the flat 12a is approximately flush with the periphery of cam 4 and no decompression occurs. However, when shaft 10 is turned through 90°, cam 12 has the disposition shown in Figure 6, with the flat 12a normal to the periphery of cam 4, and projects beyond that periphery; accordingly, decompression occurs as the cam 12 is moved past tappet 2. The position of maximum of the decompression lift, as shown in Figure 4, is at the position which is in advance of the compression top-dead centre position by angle 2θ. The lifting movement of the tappet for decompression varies with crank angle according to the conical curve in Figure 4 with decompression range K before and after the maximum point at angle 2θ from top dead centre. At the two sides of the conical shaped decompression range K, there are a first compression range L and a second compression range M. Compression ratio E_1 and E_2 of first and second ranges L and M are:

$$E_1 = \frac{Vn1 + Vc1}{Vc1} = 1 + \frac{Vn1}{Vc1}$$

$$E_2 = \frac{Vn2 + Vc2}{Vc2} = 1 + \frac{Vn2}{Vc2}$$

In the above equation, Vn1 represents, as shown in Figure 5, the volume of a combustion chamber 20 in the period from the valve closing position to decompression starting position; Vc1 is the volume of the combustion chamber during the period from the decompression starting position to the compression top dead centre position of a piston 21; Vn2 is the volume in the period from decompression ending position to compression top dead centre position; and Vn2 is the volume at the compression top dead centre position. The angle θ is chosen to make $E_1 = E_2$.

When the engine is started, the force of the return coil spring 16 is initially greater than the centrifugal force, so that the weight 13 and the decompression device 9 are held at the solid line positions in Figure 2 and as shown in Figure 6. At that time, the semicircular periphery of the cam 12 of the decompression pin 10 projects from the periphery of the cam 4, so that the semicircular part pushes up the tappet 2 and slightly opens the inlet valve to cause the half-compression condition in the combustion chamber. Thus, the compression ratio can be made smaller by dividing the compression into the first and second compression ranges L and M, which are made equal to each other in order to make the work loads equal, so that the operation requires less power.

When the rotational crank speed of the camshaft 1 exceeds the range which causes reverse engine movement, the weight 13 starts pivoting in the clockwise direction, as viewed in Figure 7, to rotate the decompression device 9. Then the semicircular periphery of cam 12 lowers to the periphery of the cam 4; in other words, cam 12 is entirely positioned on or below the periphery of cam 4, thereby lowering the push rod 18. Thus, full compression occurs in the combustion chamber and the previous decompression is released in the speed range higher than the range which causes reverse engine movement and the danger occasioned by that reverse movement is avoided.

In the operation described above, the load during starting of the engine can be lightened. As a slight rotation of weight 13 by centrifugal force can result in a large rotation of the decompression device 9, the half-compression condition can be released at an early stage of the starting operation and at a low rotational speed.

Although, in the above embodiment, the operational period of the decompression device 9 is made to overlap part of the compression stroke and the values of compression ratio E_1 and E_2 are equalized, the device 9 can be made to provide the decompression condition throughout the period of the compression stroke. Further, where the engine has a large displacement, and considering that the driver may feel on his arm the pulling force created by the negative load during the power stroke after the release of the decompression condition, the angle θ can be chosen so that the work in the first compression range becomes equal to the total work of the second compression range and of the inlet stroke. By that, the driver can easily start the engine. Further, the decompression device is not limited to the shape in the embodiment but can be changed so as to ensure a large displacement of the pin 15 on movement of the weight 13. Further, the exhaust cam may be used in place of the inlet cam to cause decompression with the decompression device. The coil spring 16 can be omitted.

According to the embodiment described, the rotational crank speed range in which decompression is released is chosen to be higher than the range in which reverse engine movement occurs, and decompression is made throughout the period or in a part of the period of the compression stroke, so that the driver is able to start the engine easily and lightly without complicated handling before starting. Also the risk of the engine reversal can be avoided.

While the presently preferred embodiment of the present invention has been shown and described, it is to be understood that this disclosure is for the purpose of illustration and that various changes and modifications may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

CLAIMS

1. Apparatus for reducing the compression of an internal combustion engine which has a camshaft (1) carrying an inlet valve cam (4) and an exhaust valve cam (5) and tappets (2, 3) engaged with those valves, characterised in that the apparatus comprises a supporting member (6) secured to, and rotating with, the camshaft (1); a decompression device (9) having a shaft (10) which is rotatably supported in the supporting member (6) and which has a decompression cam (12) formed thereon, the decompression cam (12) being engageable with the tappet (2 or 3) of either the inlet valve cam (4) or the exhaust valve cam (5) to cause lifting of the tappet; and a weight (13) which is rotatably mounted on the supporting member (6) so as to be subject to centrifugal force on rotation of the camshaft (1) and which is operatively engaged with the decompression device (9) so that rotation of the weight (13) is accompanied by rotation of the decompression device (9); the weight (13) and the decompression device (9) being so arranged that, when the rotational speed of the camshaft (1) is below the speed which causes reverse engine movement, the periphery of the decompression cam (12) projects beyond the periphery of the valve cam (4 or 5) to open the corresponding valve in order to reduce the compression of the engine, and that, when the rotational speed exceeds the speed which cause reverse

engine movement, the periphery of the decompression cam (12) is retracted to or below the periphery of the valve cam (4 or 5) to close the valve during at least a part of the compression stroke of the engine.

2. Apparatus according to claim 1, wherein the valve cam (4 or 5) has a recess (4a) in a part of its periphery such that the contour of the valve cam is unaffected, and the decompression cam (12) is located in the recess (4a) of the valve cam (4 or 5).

3. Apparatus according to claim 1 or claim 2, wherein the supporting member (6) is a cam gear.

4. Apparatus according to any one of the preceding claims, wherein the decompression cam (12) has a semicircular cross section.

5. Apparatus according to any one of the preceding claims, wherein the decompression cam (12) is operatively engageable with the tappet (2) of the inlet valve cam (4).

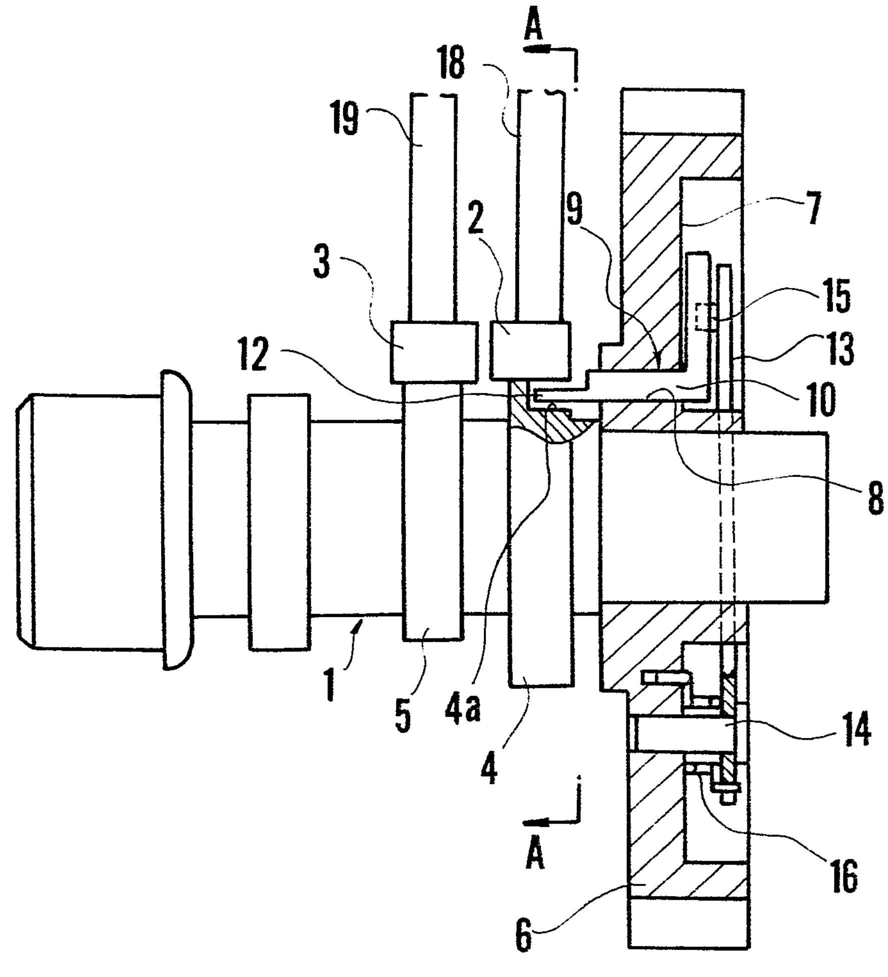


FIG. 1

FIG. 2

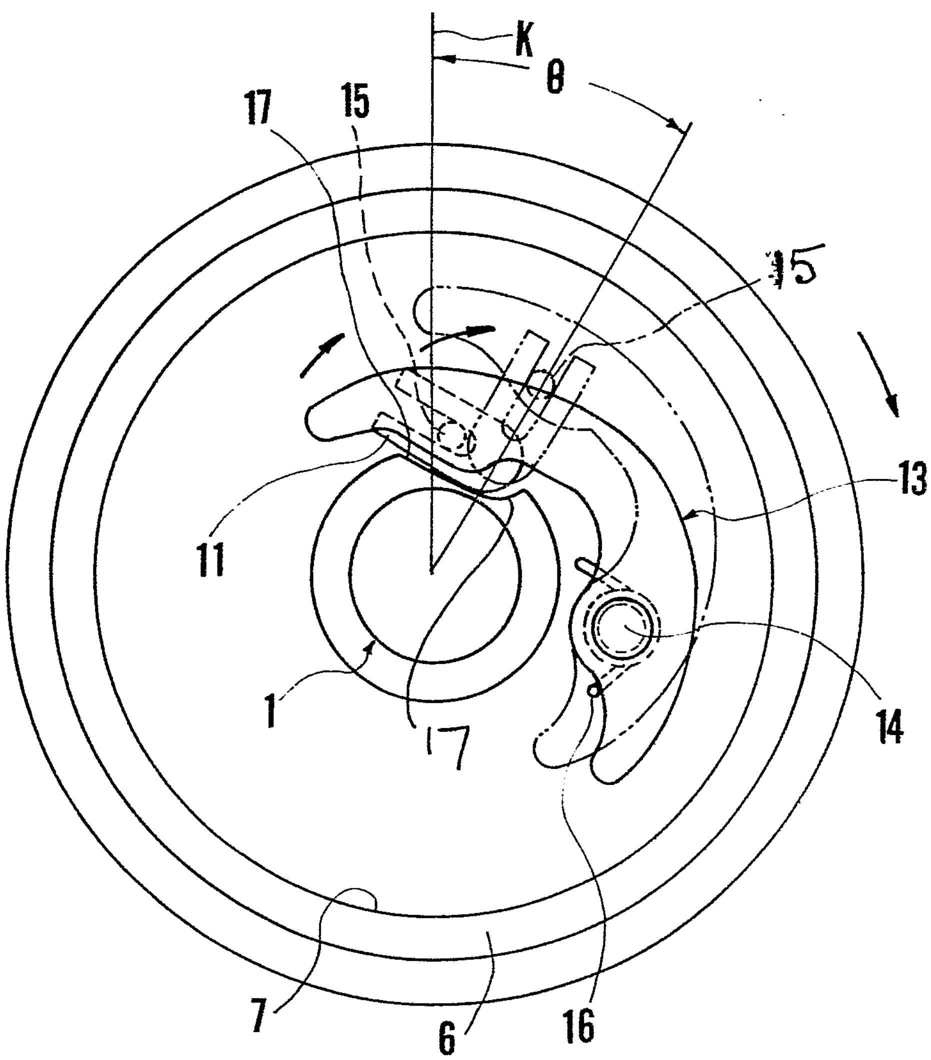


FIG. 3

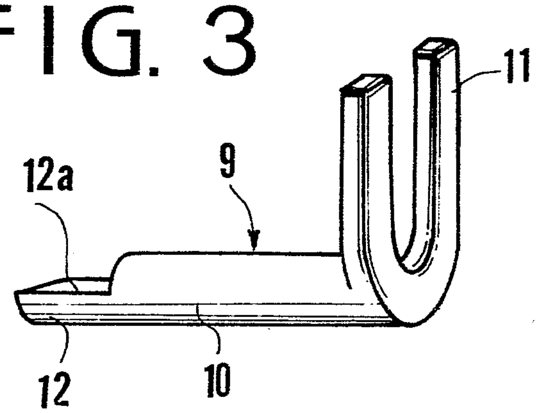


FIG. 4

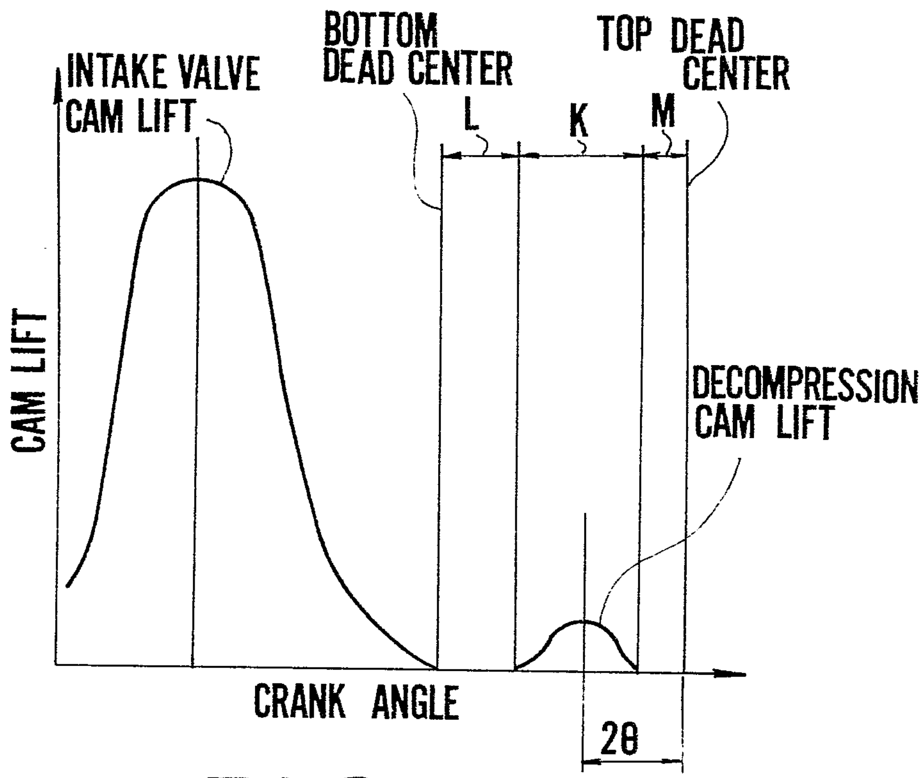

INTAKE VALVE
CAM LIFT
BOTTOM
DEAD CENTER
TOP DEAD
CENTER
L
K
M
CAM LIFT
DECOMPRESSION
CAM LIFT
CRANK ANGLE
2θ

FIG. 5

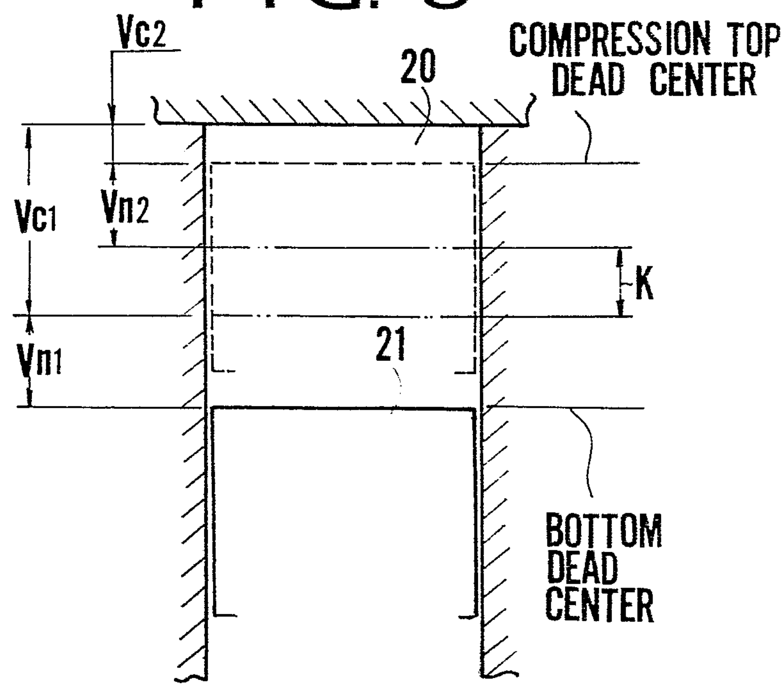

Vc2
20
COMPRESSION TOP
DEAD CENTER
Vc1
Vn2
K
Vn1
21
BOTTOM
DEAD
CENTER

FIG. 6

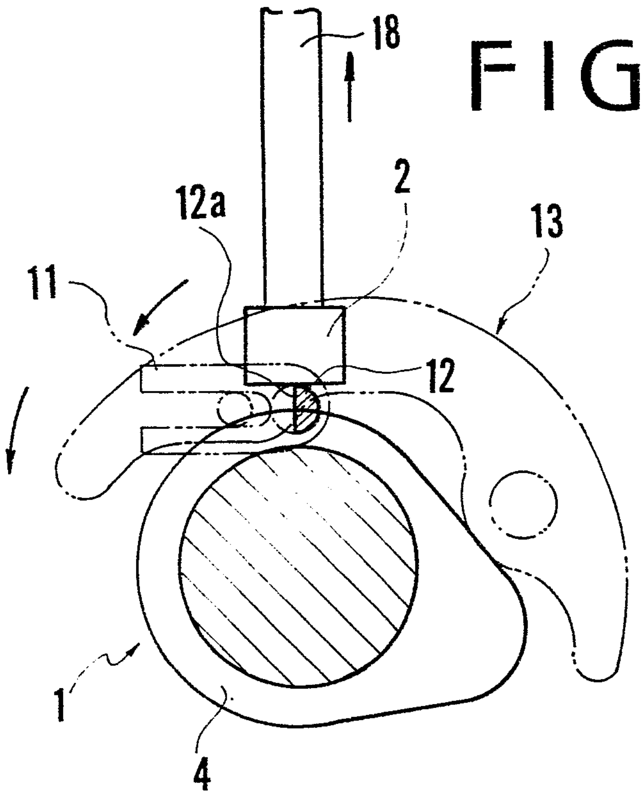
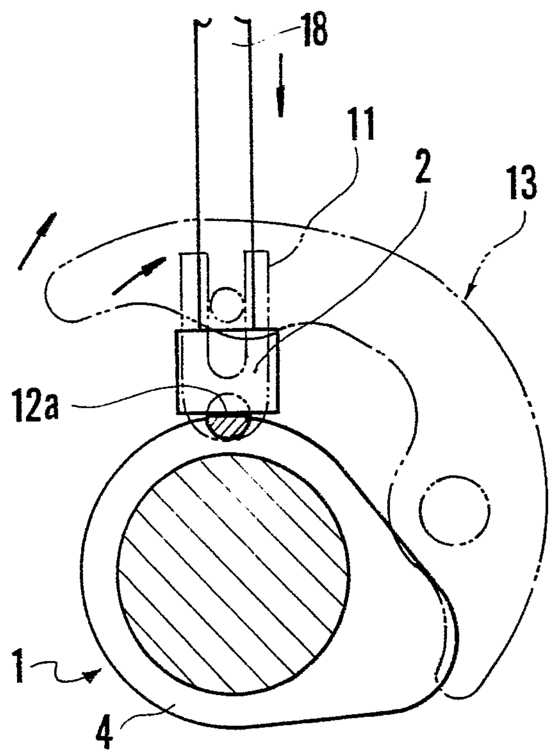


FIG. 7



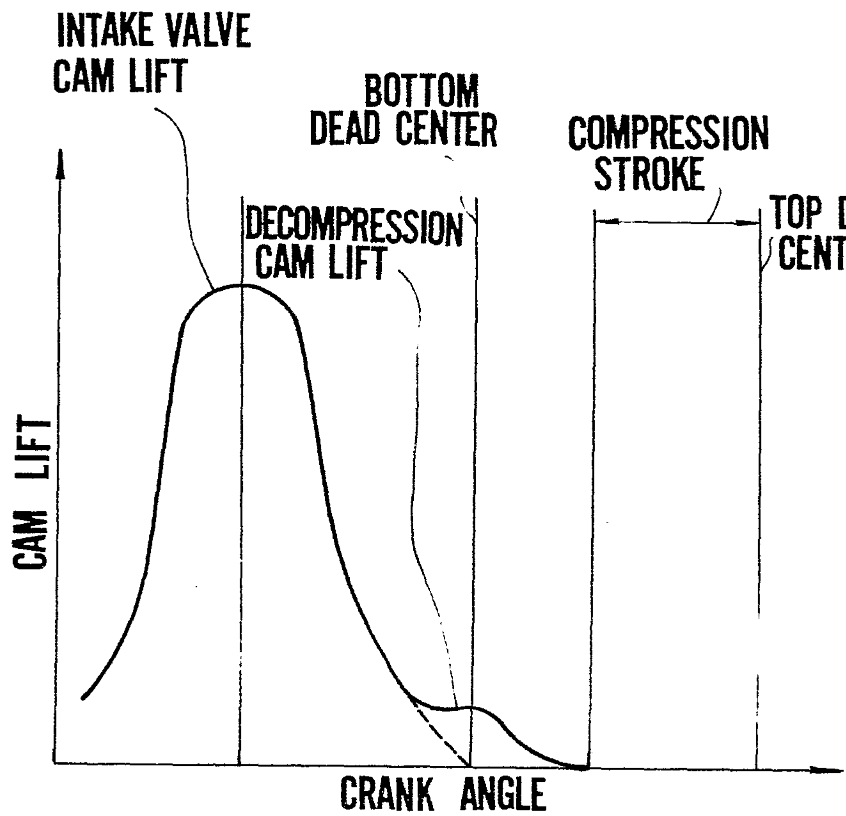
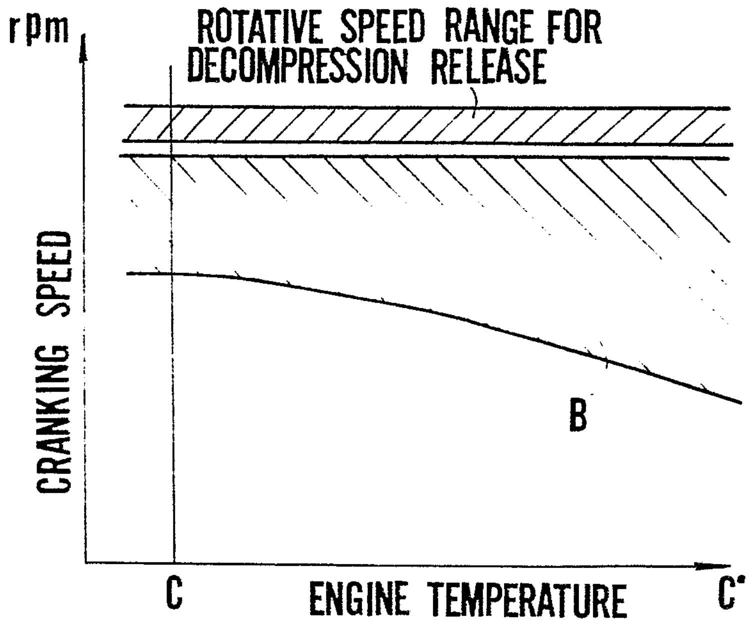

INTAKE VALVE
CAM LIFT
BOTTOM
DEAD CENTER
COMPRESSION
STROKE
DECOMPRESSION
CAM LIFT
TOP DEAD
CENTER
CAM LIFT
CRANK ANGLE

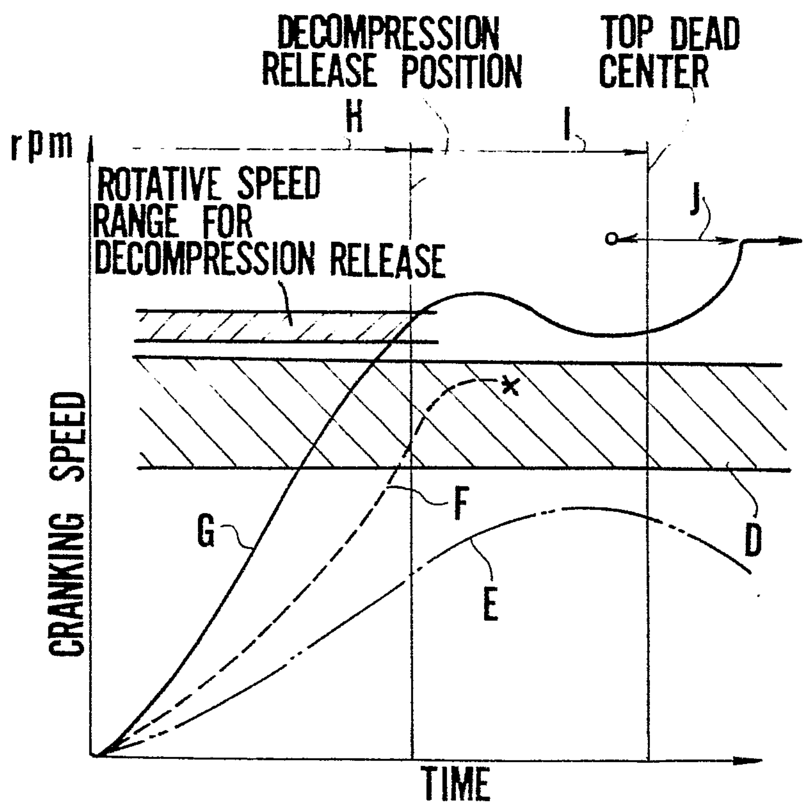
FIG. 8

FIG. 9



rpm
ROTATIVE SPEED RANGE FOR DECOMPRESSION RELEASE
CRANKING SPEED
B
C
ENGINE TEMPERATURE
C'

FIG. 10



DECOMPRESSION RELEASE POSITION
TOP DEAD CENTER
H
I
rpm
ROTATIVE SPEED RANGE FOR DECOMPRESSION RELEASE
J
CRANKING SPEED
G
F
D
E
TIME