

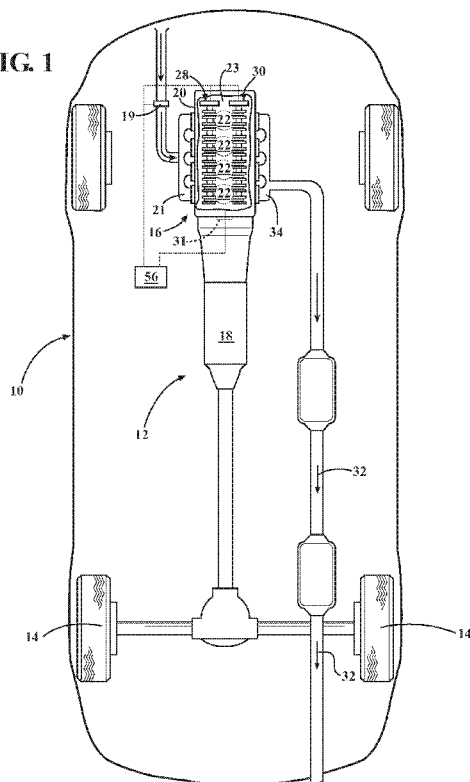


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- (71) Applicant: GM GLOBAL TECHNOLOGY OPERATIONS LLC [US/US]; 300 Renaissance Center, Detroit, Michigan 48265-3000 (US).
- (72) Inventors: HE, Yongsheng; 38209 Plumhollow Drive, Sterling Heights, Michigan 48312 (US). LIU, Jim; Room 1101, Building 12, 138 Gutang Road, Pudong, Shanghai 201209 (CN). CLEARY, David J.; House 35, The Emerald Phase Five No.118, Kang Ba Rd., Nan Hui Area, Shanghai 201315 (CN). KEATING, Edward J.; 90 Crescent Hill Drive, Ortonville, Michigan 48462 (US).
- (74) Agent: LIU, SHEN & ASSOCIATES; 10th Floor, Building 1, 10 Caihefang Road, Haidian District, Beijing 100080 (CN).
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(54) Title: INCREASED DURATION INTAKE CAMSHAFT WITH DWELL AT PEAK LIFT

FIG. 1



(57) Abstract: An internal combustion engine includes a cylinder block that defines a cylinder and a cylinder head mounted to the cylinder block. A reciprocating piston is arranged inside the cylinder for compressing a mixture of air and fuel. A crankshaft is arranged in the cylinder block and rotated by an application of combustion force on the piston. An intake valve is operatively connected to the cylinder head and controls delivery of the air to the cylinder for combustion therein. A mechanism provides a constant peak lift of the intake valve over an angle of rotation of the crankshaft that is at least 5 degrees, i.e., an extended dwell at peak lift. A vehicle having such an engine is also disclosed.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, **Published:**
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INCREASED DURATION INTAKE CAMSHAFT WITH DWELL AT PEAK LIFT

TECHNICAL FIELD

[0001] The present disclosure relates to an internal combustion engine intake
5 camshaft that has increased duration with dwell at peak lift.

BACKGROUND

[0002] Internal combustion engines (ICE's) with reciprocating pistons typically
employ one or more camshafts for operating intake, as well as exhaust valves. Each such
10 camshaft typically includes a cylindrical rod running the length of the engine's cylinder
bank with a number of oblong lobes protruding from the rod. Typically, a camshaft
includes one lobe for each valve. The cam lobes force the valves open by pressing on the
valve or on some intermediate mechanism, such as a cam follower, as the camshaft is
rotated.

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SUMMARY

[0003] One embodiment of the disclosure is directed to an internal combustion engine
that includes a cylinder block. The cylinder block defines a cylinder and a cylinder head
mounted to the cylinder block. A reciprocating piston is arranged inside the cylinder and
20 configured to compress a supply of air and fuel. A crankshaft is arranged in the cylinder
block and rotated by an application of combustion force on the piston. An intake valve is
operatively connected to the cylinder head and configured to control delivery of the air to
the cylinder for combustion therein. A mechanism provides a constant peak lift of the
intake valve over an angle of rotation of the crankshaft that is at least 5 degrees, i.e., an
25 extended dwell at peak lift.

[0004] The mechanism may include an electro-hydraulic actuator configured to
generate the constant peak lift of the intake valve.

[0005] Alternatively, the mechanism may include an intake camshaft having a cam
lobe for opening and closing of the intake valve relative to a position of the crankshaft.

[0006] The mechanism may additionally include a variable-ratio cam follower, such as a rocker arm, arranged between the cam lobe and the intake valve and configured to generate the constant peak lift of the intake valve.

5 [0007] The cam lobe may include a profile configured to generate the constant peak lift of the intake valve.

[0008] The profile of the cam lobe may include a first ramp and a second ramp bridged by a substantially flat portion that defines the constant peak lift of the intake valve.

10 [0009] The substantially flat portion of the profile of the cam lobe may enable a late intake valve closing (LIVC) that extends a closing of the intake valve further into a compression cycle of the engine.

[0010] The substantially flat portion of the profile of the cam lobe may extend over the angle of rotation of the crankshaft that is at least 5 degrees.

15 [0011] The mechanism may generate the constant peak lift of the intake valve in the range of 5-80 degrees of the angle of rotation of the crankshaft.

[0012] The engine may be a naturally aspirated spark-ignition internal combustion engine with a geometric compression ratio in the range of 12-18:1. Alternatively, the engine may be a boosted spark-ignition internal combustion engine with a geometric compression ratio in the range of 10-16:1.

20 [0013] Another embodiment of the present disclosure is directed to a vehicle having such an internal combustion engine.

[0014] The above features and advantages, and other features and advantages of the present disclosure, will be readily apparent from the following detailed description of the embodiment(s) and best mode(s) for carrying out the described disclosure when taken in
25 connection with the accompanying drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIGURE 1 is a schematic depiction of a vehicle having an engine according to the disclosure.

[0016] FIGURE 2 is a schematic partial illustration of the engine having an embodiment of a mechanism configured to provide extended dwell at peak lift of the intake valves.

5 [0017] FIGURE 3 is a schematic cross-sectional illustration of an intake camshaft lobe used by the embodiment of the mechanism shown in Figure 2.

[0018] FIGURE 4 is a schematic illustration of the engine having another embodiment of the mechanism configured to provide extended dwell at peak lift of the intake valves.

10 [0019] FIGURE 5 is a schematic cross-sectional illustration of an intake camshaft lobe used by the embodiment of the mechanism shown in Figure 4.

[0020] FIGURE 6 is a schematic illustration of the engine having yet another embodiment of the mechanism configured to provide extended dwell at peak lift of the intake valves.

15 [0021] FIGURE 7 illustrates an exemplary lift curve of an intake valve generated by the mechanism shown in Figures 2-6.

DETAILED DESCRIPTION

[0022] Referring to the drawings, wherein like reference numbers correspond to like or similar components throughout the several figures, Figure 1 illustrate a vehicle 10 employing a powertrain 12 for propulsion thereof via driven wheels 14. As shown, the powertrain 12 includes an internal combustion engine 16 and a transmission assembly 18 operatively connected thereto. The powertrain 12 may also include one or more electric motor/generators, none of which are shown, but the existence of which may be envisioned by those skilled in the art. As shown, the engine 16 includes a cylinder block 20 with a plurality of cylinders 22 arranged therein and a cylinder head 23 that is mounted on the cylinder block. The cylinder head 23 may also be integrated into or cast together with the cylinder block 20.

25 [0023] The cylinder head 23 receives air and fuel to be used inside the cylinders 22 for subsequent combustion. As can be seen in Figures 2, 4, and 5, each cylinder 22 includes a respective piston 22-1 configured to reciprocate therein. Additionally,

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combustion chambers 22-2 are formed within the cylinders 22 between the bottom surface of the cylinder head 23 and the tops of the pistons 22-1. As known by those skilled in the art, each of the combustion chambers 22-2 receives fuel and air that are combined to form a fuel-air mixture for subsequent combustion inside the subject combustion chamber. The engine 16 may include a throttle 19 (shown in Figure 1), which can be configured as a traditional movable throttle blade or another type of an arrangement that meters a volume of airflow entering the engine from the ambient and directs the air to an intake manifold 21 for distribution among the cylinders 22 for mixing with an appropriate amount of fuel and subsequent combustion of the resultant fuel-air mixture. Although an in-line four-cylinder engine is shown in Figure 1, nothing precludes the present disclosure from being applied to an engine having a different number and/or arrangement of cylinders.

[0024] As shown in Figures 2, 4, and 5, the engine 16 also includes a plurality of intake valves 24 operatively connected to the cylinder head 23 and configured to control a supply of air to each cylinder 22 for combustion with fuel therein. The engine 16 may be configured as a spark-ignition internal combustion engine that employs fuel injectors 25 configured to deliver the necessary amount of fuel and spark plugs 27 to initiate combustion of the fuel and air mixture inside the combustion chambers 22-2. The engine 16 additionally includes a plurality of exhaust valves 26 operatively connected to the cylinder head 23 and configured to control removal of post-combustion gasses from each cylinder 22. A first mechanism 28 is configured to regulate opening and closing of the respective intake valves 24 during operation of the engine 16 and is particularly provided to generate a generally constant peak lift of the intake valves 24 for an extended period of time. Specific embodiments and operation of the first mechanism 28 will be discussed in greater detail below. A second mechanism 30 is configured to regulate opening and closing of the respective exhaust valves 26 during operation of the engine 16. The second mechanism 30 may be configured as an exhaust camshaft having a plurality of cam lobes 30-1 for actuating exhaust valves 26, or include other configurations that are similar to those described below with respect to the first mechanism 28.

[0025] The engine 16 also includes a crankshaft 31 configured to rotate within the cylinder block 20. As known to those skilled in the art, the crankshaft 31 is rotated by the pistons 22-1 via respective connecting rods (not shown) as a result of an appropriately proportioned fuel-air mixture being selectively admitted into the combustion chambers 22-2 via one or more intake valves 24 and burned in the combustion chambers. After the air-fuel mixture is burned inside a specific combustion chamber 22-2, the reciprocating motion of a particular piston serves to supplement the removal of post-combustion gasses 32 from the respective cylinder 22 via one or more exhaust valves 26. The cylinder head 23 is also configured to exhaust post-combustion gasses 32 from the combustion chambers 22-2, such as via an exhaust manifold 34. As shown in Figure 1, such an exhaust manifold 34 may be configured as a separate, attachable component for scavenging the exhaust post-combustion gasses 32 from the cylinders 22, or be internally cast, i.e., integrated, into the cylinder head 23 (not shown, but known to those skilled in the art).

[0026] With specific reference to Figures 2-7 the first mechanism 28 is configured to generate the constant peak lift of each intake valve 24, i.e., an extended dwell at peak lift of the respective intake valve, over an extended angle of rotation of the crankshaft 31. It is intended that the angle of rotation of the crankshaft 31 over which peak lift of each intake valve 24 remains constant would be at least 5 degrees, thus generating an opening at each intake valve having an increased duration versus that of a typical intake valve. Specifically, the first mechanism 28 may generate the constant peak lift of the intake valves 24 in the range of 5-80 degrees of the angle of rotation of the crankshaft 31. Such an extended dwell at peak lift of the intake valve generates an increased period of time that the supply of combustion air may be delivered to each cylinder 22, thereby facilitating an increased torque output from the engine 16 at certain engine operating conditions. An embodiment of the first mechanism 28 shown in Figure 3 may include an intake camshaft 36A having a plurality of cam lobes 38A, wherein each lobe is configured to actuate a respective intake valve 24. The cam lobes 38A include a lobe profile 40A that generates a constant peak lift of each intake valve 24 over the desired extended angle of rotation of the crankshaft 31.

[0027] As can be seen from Figure 3, the lobe profile 40A includes ramps 41A and 42A, and a generally flat portion 43A that defines a peak 44A of the cam lobe 38A. The flat portion 43A provides the extended dwell at peak lift of the respective intake valve 24 in comparison to a commonly used, relatively sharp or radiused peak that generates insignificant dwell at peak lift of an intake valve. The lobe profile 40A is characterized by a tangent 45A that remains substantially constant over the duration of the flat portion 43A. The flat portion 43A is intended to extend for more than 2.5 degrees of rotation of the camshaft 38, which corresponds to greater than 5 degrees of crankshaft 31 rotation. As shown in Figure 4, the flat portion 43A extends over 20 degrees of the angle of rotation of the camshaft 36A, which corresponds to 40 degrees of crankshaft 31 rotation.

[0028] Another embodiment of the first mechanism 28 shown in Figure 4 may include a camshaft 36B having a plurality of cam lobes 38B. Each lobe 38B includes a lobe profile 40B having ramps 41B and 42B, and provides a commonly known, relatively sharp or tightly radiused peak 44B, as shown in Figure 6, that generates substantially zero or insignificant dwell at peak lift of the respective intake valve 24. In combination with the camshaft 36B, the subject embodiment of the first mechanism 28 includes a plurality or set of cam followers 46 that transfer motion from the cam lobe 38B to the respective intake valve 24. Each cam follower 46 is configured as a variable-ratio rocker arm that generates the desired extended dwell at peak lift of the respective intake valve 24. To accomplish the desired extended dwell at peak lift of the intake valve 24 in the present embodiment, a rotatable cam-shaped roller 48 may be arranged between each cam lobe 38B and each cam follower 46, such that the rotation of the roller 48 varies an effective ratio of the cam follower. Appropriate rotation of the roller 48 may, for example, be effected by oil pressure generated by a fluid pump (not shown) mounted to the engine 16. In each of the embodiments of Figures 3 and 5, the first mechanism 28 may additionally include a camshaft phaser 37 configured to change position of the respective camshaft 36A, 36B with respect to position of the crankshaft 31 during operation of the engine 16.

[0029] Alternatively, according to yet another embodiment shown in Figure 6, the first mechanism 28 may include individual electro-hydraulic or electro-mechanical actuators 50. Each actuator 50 is configured to generate the desired constant peak lift of

the respective intake valve 24 over the extended angle of rotation of the crankshaft 31. Such actuators 50 can be employed in place of the previously described camshaft 36A or camshaft 36B with cam followers 46. The first mechanism 28 may be regulated via an electronic controller 56, such as an engine or powertrain control module. An exemplary lift curve 52 that can be generated for intake valves 24 by the first mechanism 28 of each of the embodiments described above with respect to the respective Figures 2, 4, and 5 is shown in Figure 7. The curve 52 illustrates a 20 degree angle of intake camshaft angle of rotation, which is equivalent to a 40 degree angle of rotation of the crankshaft 31 over which a peak lift of 12 mm for each intake valve 24 remains constant. In the illustrated embodiment of Figure 7, the peak lift provided by the first mechanism 28 has been extended for an additional 20 degrees of cam angle θ as compared to the typical cam lobe profile 40B. Such an extended dwell at peak lift of the intake valve generates an increased area 54 under the curve 52, as compared with the area under a curve 51 generated by the typical cam lobe profile 40B, which corresponds to the increased period of time that the supply of combustion air may be delivered to the specific cylinder 22.

[0030] The first mechanism 28 generates late intake valve closing (LIVC), as typically used in Atkinson or Miller combustion cycles, to trap a reduced amount of air and a proportionately smaller amount of fuel in the combustion chambers 22-2 by using the extended dwell at peak lift of the intake valve 24 to extend closure of the intake valves significantly further into the compression cycle of the engine 16. Typically, high engine load at low RPM results in elevated pressure inside the combustion chambers 22-2 increasing the likelihood of knock or auto ignition due to uncontrolled combustion. Therefore, limiting pre-combustion pressures inside the combustion chambers 22-2 via the first mechanism 28 generally has the effect of lowering combustion pressures and reducing the likelihood of knock or other uncontrolled combustion. Such lowering of combustion pressures is specifically beneficial in an engine employing an intake air charge boosting device (not shown), such as a turbocharger or a supercharger.

[0031] A geometric compression ratio in a naturally aspirated engine is typically set in the range of 10-11:1 primarily to manage combustion pressures and minimize uncontrolled combustion. In the engine 16, however, the geometric compression ratio

may be set above 11:1 and specifically in the 12-18:1 range as a result of the first mechanism 28 controlling pre-combustion pressures. The relatively high geometric compression ratio in the engine 16 is enabled by the pre-combustion pressures or effective compression ratio being limited by the late intake valve closing being extended

5 further into the compression cycle of the engine 16, which is itself enabled by the constant peak lift of the intake valves 24. As a result of the late intake valve closing being extended further into the compression cycle by the first mechanism 28, the combustion pressures inside the combustion chambers 22-2, i.e., the effective compression ratio, can be effectively managed during certain engine operating modes.

10 Overall, the first mechanism 28 generates an increased expansion ratio for enhanced fuel efficiency by reducing effective compression ratio in the engine 16. The above-noted air intake charge boosting devices can also be used to make up for the lower power density of engine 16 using the first mechanism 28. In such a boosted engine, the geometric compression ratio may be set in the 10-16:1 range.

15 [0032] The detailed description and the drawings or figures are supportive and descriptive of the disclosure, but the scope of the disclosure is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed disclosure have been described in detail, various alternative designs and embodiments exist for practicing the disclosure defined in the appended claims.

20 Furthermore, the embodiments shown in the drawings or the characteristics of various embodiments mentioned in the present description are not necessarily to be understood as embodiments independent of each other. Rather, it is possible that each of the characteristics described in one of the examples of an embodiment can be combined with one or a plurality of other desired characteristics from other embodiments, resulting in

25 other embodiments not described in words or by reference to the drawings. Accordingly, such other embodiments fall within the framework of the scope of the appended claims.

CLAIMS

1. An internal combustion engine comprising:
 - a cylinder block defining a cylinder;
 - 5 a cylinder head mounted to the cylinder block;
 - a reciprocating piston arranged inside the cylinder and configured to compress a mixture of air and fuel;
 - a crankshaft arranged in the cylinder block and rotated by an application of combustion force on the piston;
 - 10 an intake valve operatively connected to the cylinder head and configured to control delivery of the air to the cylinder for combustion therein; and
 - a mechanism configured to provide a constant peak lift of the intake valve over an angle of rotation of the crankshaft that is at least 5 degrees.
- 15 2. The engine of claim 1, wherein the mechanism includes an electro-hydraulic actuator configured to generate the constant peak lift of the intake valve.
3. The engine of claim 1, wherein the mechanism includes an intake camshaft having a cam lobe for opening and closing of the intake valve relative to a
20 position of the crankshaft.
4. The engine of claim 3, wherein the mechanism additionally includes a variable-ratio cam follower arranged between the cam lobe and the intake valve and configured to generate the constant peak lift of the intake valve.
25
5. The engine of claim 3, wherein the cam lobe includes a profile configured to generate the constant peak lift of the intake valve.

6. The engine of claim 5, wherein the profile of the cam lobe includes a first ramp and a second ramp bridged by a substantially flat portion that defines the constant peak lift of the intake valve.

5 7. The engine of claim 6, wherein the substantially flat portion of the profile of the cam lobe enables a late intake valve closing (LIVC) that extends a closing of the intake valve into a compression cycle of the engine.

10 8. The engine of claim 6, wherein the substantially flat portion of the profile of the cam lobe extends over the angle of rotation of the crankshaft that is at least 5 degrees.

15 9. The engine of claim 1, wherein the mechanism generates the constant peak lift of the intake valve in the range of 5-80 degrees of the angle of rotation of the crankshaft.

10. The engine of claim 1, wherein:
if the engine is a spark-ignition naturally aspirated internal combustion engine, the engine has a geometric compression ratio in the range of 12-18:1; and
20 if the engine is a spark-ignition boosted internal combustion engine, the engine has a geometric compression ratio in the range of 10-16:1.

11. A vehicle comprising:
25 a road wheel; and
an internal combustion engine configured to generate torque for driving the road wheel, the engine having:
a cylinder block defining a cylinder;
a cylinder head mounted to the cylinder block;
30 a reciprocating piston arranged inside the cylinder and configured to compress a mixture of air and fuel;

a crankshaft arranged in the cylinder block and rotated by an application of combustion force on the piston;

an intake valve operatively connected to the cylinder head and configured to control delivery of the air to the cylinder for combustion therein; and

5 a mechanism configured to provide a constant peak lift of the intake valve over an angle of rotation of the crankshaft that is at least 5 degrees (extended dwell at peak lift).

12. The vehicle of claim 11, wherein the mechanism includes an
10 electro-hydraulic actuator configured to generate the constant peak lift of the intake valve.

13. The vehicle of claim 11, wherein the mechanism includes an intake camshaft having a cam lobe for opening and closing of the intake valve relative to a position of the crankshaft.

14. The vehicle of claim 13, wherein the mechanism additionally
15 includes a variable-ratio cam follower (rocker arm) arranged between the cam lobe and the intake valve and configured to generate the constant peak lift of the intake valve.

15. The vehicle of claim 13, wherein the cam lobe includes a profile
20 configured to generate the constant peak lift of the intake valve.

16. The vehicle of claim 15, wherein the profile of the cam lobe
includes a first ramp and a second ramp bridged by a substantially flat portion that
25 defines the constant peak lift of the intake valve.

17. The vehicle of claim 16, wherein the substantially flat portion of
the profile of the cam lobe enables a late intake valve closing (LIVC) that extends a
closing of the intake valve into a compression cycle of the engine.

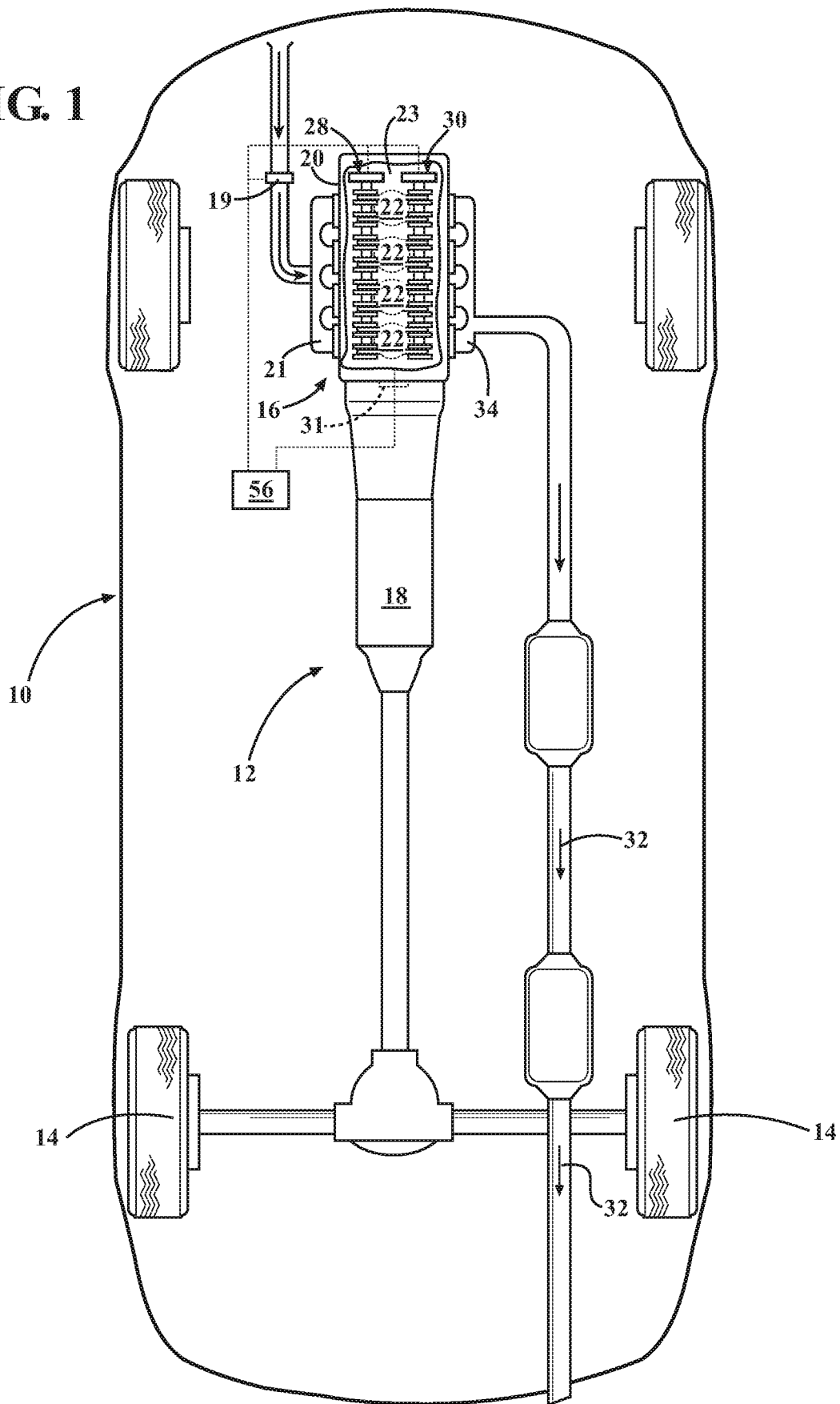
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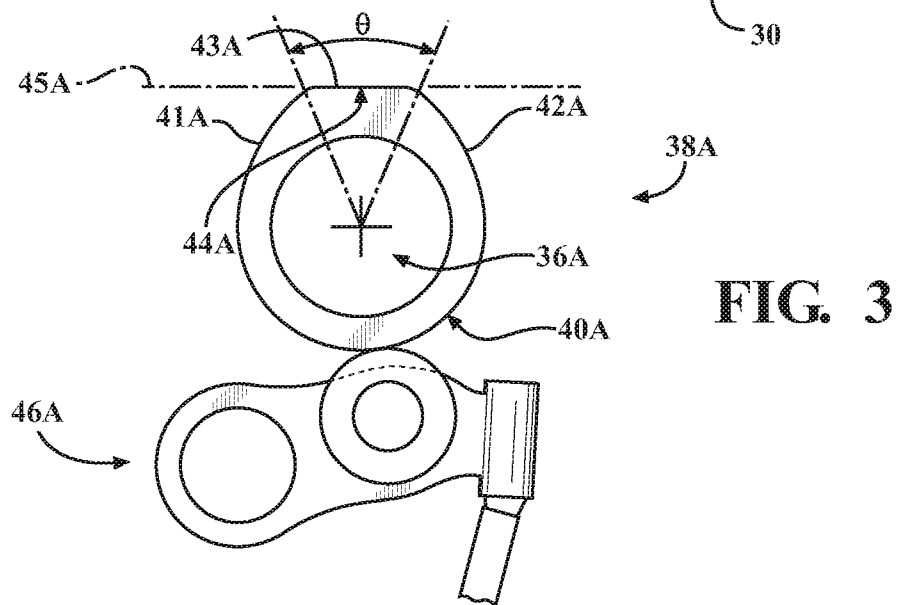
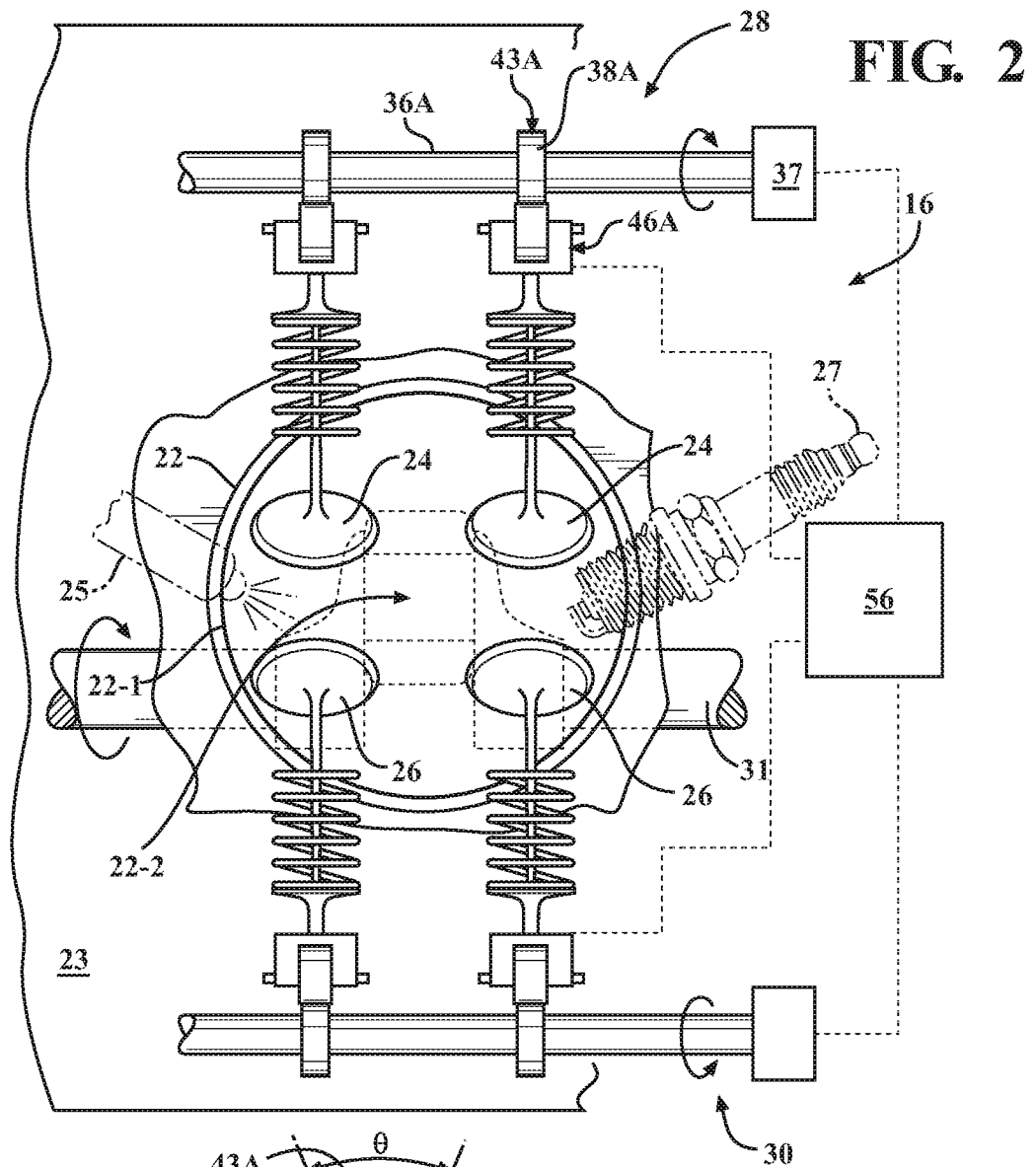
18. The vehicle of claim 16, wherein the substantially flat portion of the profile of the cam lobe extends over the angle of rotation of the crankshaft that is at least 5 degrees.

5 19. The vehicle of claim 11, wherein the mechanism generates the constant peak lift of the intake valve in the range of 5-80 degrees of the angle of rotation of the crankshaft.

20. The vehicle of claim 11, wherein:
10 if the engine is a spark-ignition naturally aspirated internal combustion engine, the engine has a geometric compression ratio in the range of 12-18:1; and
if the engine is a spark-ignition boosted internal combustion engine, the engine has a geometric compression ratio in the range of 10-16:1.

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FIG. 1



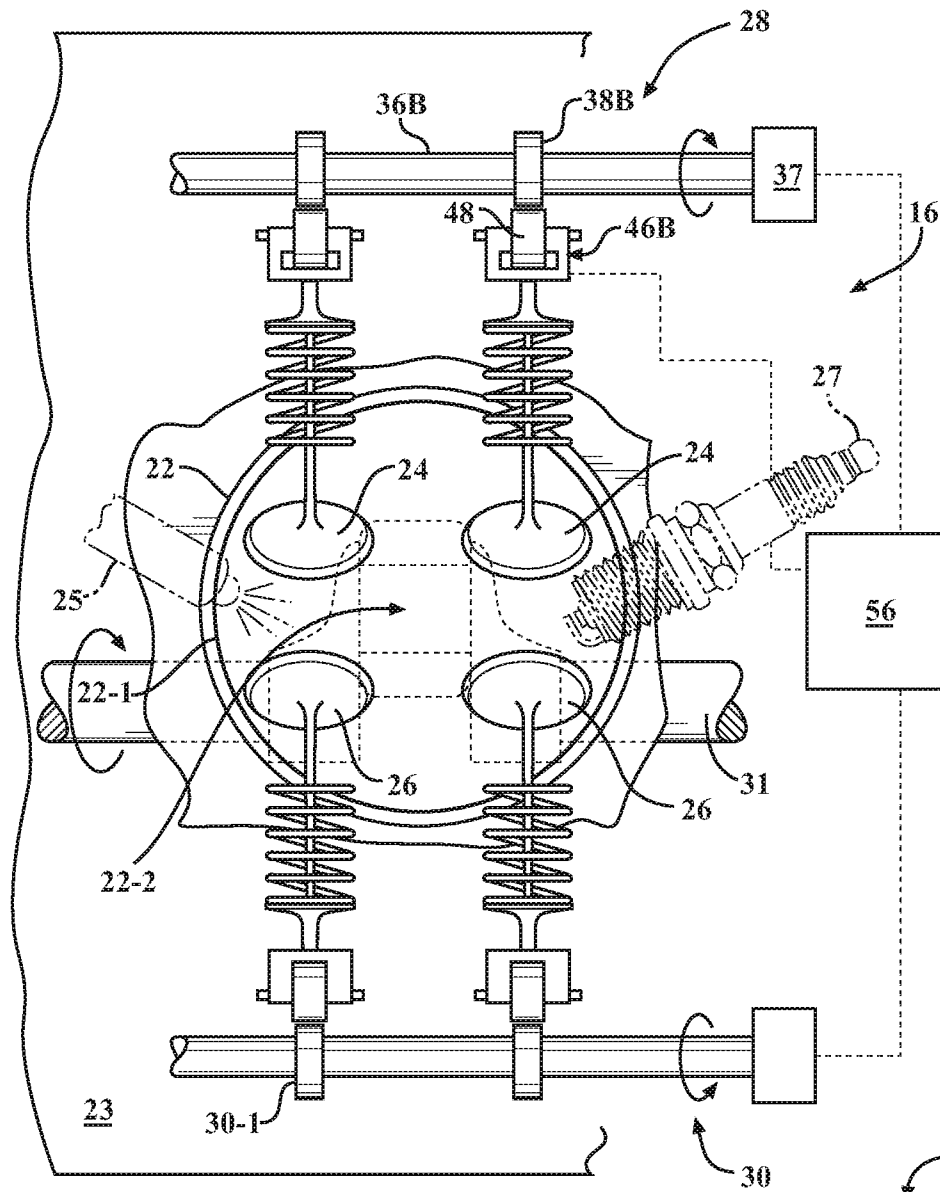
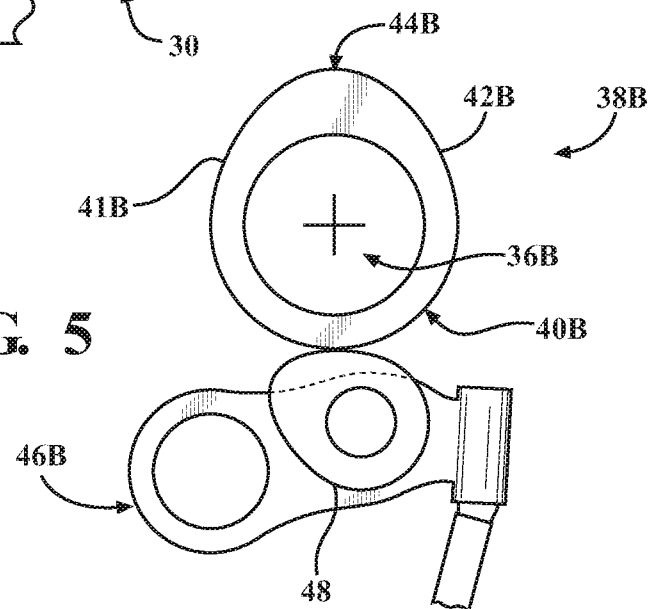


FIG. 4



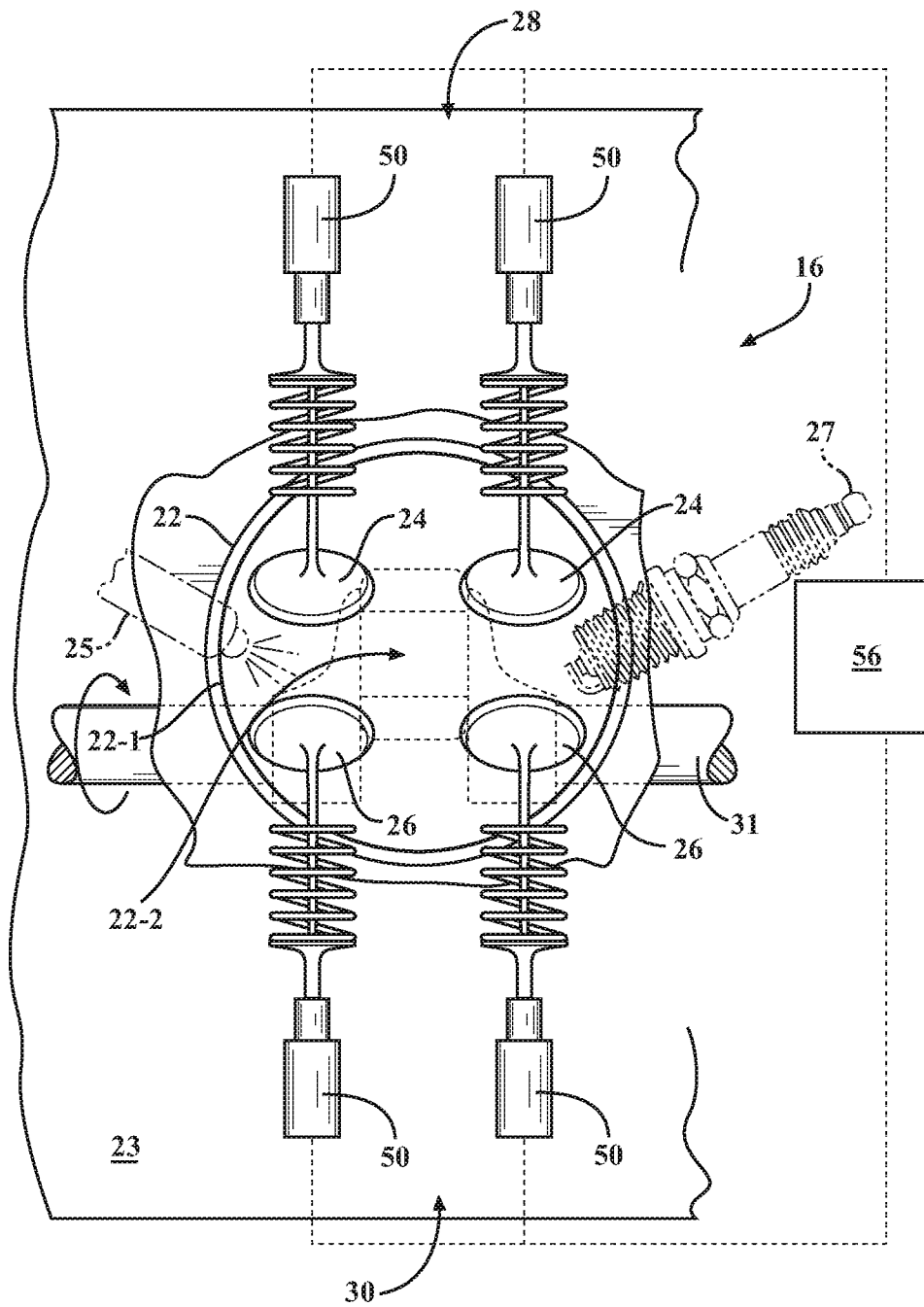


FIG. 6

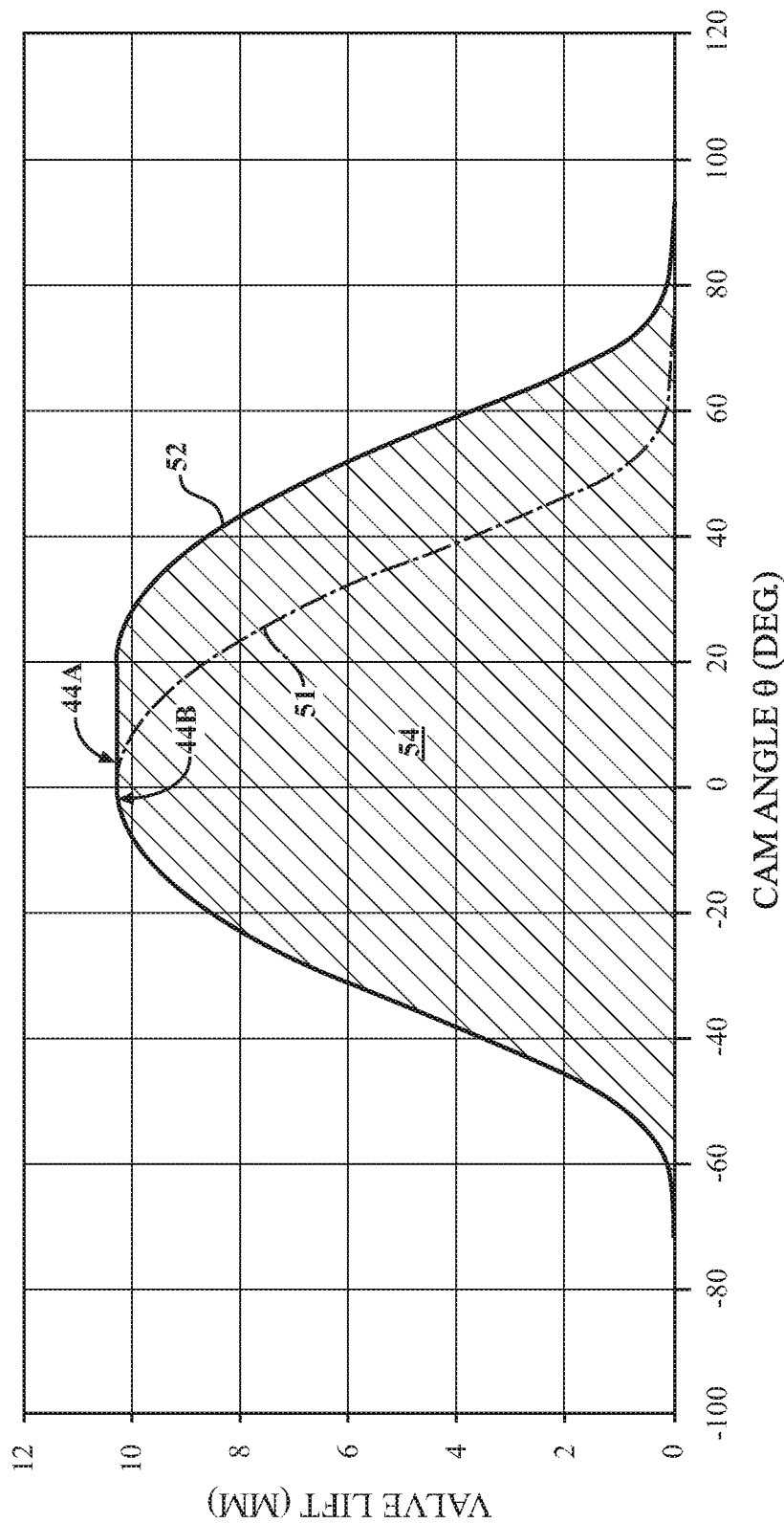


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

F01L 13/00(2006.01)i; F01L 1/08(2006.01)i; F01L 1/18(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,CNKI,EPODOC,WPI, valve, lift, peak, maximum, constant, maintain

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

27 November 2015

Date of mailing of the international search report

21 December 2015

Name and mailing address of the ISA/CN

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Authorized officer

LI, Caifen

Telephone No. (86-10)62085336

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/074185

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				EP	1916392	B1	19 September 2012
US	2007151532	A1	05 July 2007	US	7367299	B2	06 May 2008