(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 777 041 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
13.03.2002 Bulletin 2002/11

(51) Int Cl.[7]: **F02B 77/08**, F01M 11/10, F01M 13/00, F02B 77/10

(21) Application number: **96308618.6**

(22) Date of filing: **28.11.1996**

(54) **An internal combustion engine with an engine crankcase gas blow-by sensor and a method of evaluating performance of an internal combustion engine**

Brennkraftmaschine mit einem Durchblasgassensor und ein Verfahren zur Auswertung der Leistung einer Brennkraftmaschine

Moteur à combustion interne avec un capteur des gaz de combustion imbrûlés et un procédé pour évaluer la performance d'un moteur à combustion interne

(84) Designated Contracting States:
DE FR GB

(30) Priority: **29.11.1995 US 564419**

(43) Date of publication of application:
04.06.1997 Bulletin 1997/23

(73) Proprietor: **CUMMINS ENGINE COMPANY, INC.**
Columbus Indiana 47201 (US)

(72) Inventors:
- **Schneider, Matthew L.**
  Seymour, Indiana 47274 (US)
- **Bhagwat, Abhay P.**
  Seymour, Indiana 47274 (US)
- **Schuppe, Alfred**
  Columbus, Indiana 47203 (US)
- **Kuhns, George M.**
  Columbus, Indiana 47201 (US)

(74) Representative:
Everitt, Christopher James Wilders et al
fJ CLEVELAND
40/43 Chancery Lane
London WC2A 1JQ (GB)

(56) References cited:
FR-A- 1 428 610
FR-A- 2 641 575
US-A- 3 862 624
US-A- 4 481 828

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates generally to engine crankcase gas blow-by sensors and to a method of evaluating performance of an internal combustion engine. More particularly, this invention relates to an engine crankcase gas blow-by sensor using a venturi and a differential pressure transducer to measure volumetric flow of blow-by gases.

BACKGROUND OF THE INVENTION

[0002] Ideally, the pressure within an internal combustion engine crankcase should be maintained at a level equal to or slightly less than atmospheric pressure to prevent external oil leakage through the various gasketed joints, such as that between the valve cover and the cylinder head. As is well known, in an internal combustion engine, a so-called blow-by gas is emitted in the crankcase as a result of leaks of intake air-fuel mixture and combustion gases through the clearances around piston rings, during the compression, combustion and/or exhaust cycles. Because of these blow-by gases, the crankcase pressure will inherently rise, promoting leakage of oil from the crankcase. Originally, the crankcase pressure was vented to the atmosphere through a breather in order to solve this problem.
More recently, environmental considerations have dictated that the blow-by gases in the crankcase be vented back to the combustion chamber rather than being released to the atmosphere. Such closed crankcase ventilation (CCV) systems recycle the blow-by gas by burning these gases together with the intake air-fuel mixture.

[0003] Heavy duty and high horsepower internal combustion engines run under severe and sometimes adverse conditions, where engine downtime is expensive and service is not always available. A good method of checking an engine's "health" is to periodically, or preferably continuously, monitor the flow of crankcase blow-by gases. The greater the quantity of blow-by gases escaping around the pistons, the poorer the condition of the engine. Therefore, sensing of the amount of blow-by gas in an engine can detect catastrophic failures (i.e. an instantaneous increase in the amount of blow-by gas) or monitor engine wear over time in order to predict when the engine will require an overhaul (i.e. a slowly increasing amount of blow-by gas).

[0004] A good way to measure the volume of blow-by gas entering the crankcase is to measure the pressure of such gases in the crankcase. However, closed crankcase ventilation systems do not allow any of the crankcase gases to be vented through an orifice, which would be required in order to measure the crankcase pressure. There is therefore a need for an alternative way to measure the amount of blow-by gas entering the engine crankcase and to collect this data for making determinations of engine health. The present invention is directed toward meeting this need.

[0005] US-A-3,862,624 discloses an engine which uses oxygen and an excess of hydrogen as fuel and which has a substantially closed exhaust system which recirculates the gaseous part of the exhaust and mixes it with fresh gaseous feed and recirculated blow-by gas. A flow meter is provided for the mixture of recirculated exhaust gas, fresh gaseous fuel and blow-by gas.

SUMMARY OF THE INVENTION

[0006] According to one aspect of this invention there is provided an engine with a crankcase gas blow-by sensor as claimed in claim 1. Preferred features are claimed in the sub claims 2 to 7.

[0007] In a closed crankcase ventilation system, crankcase gases are allowed to flow through a venturi which includes high pressure and low pressure taps. The high and low pressure taps are coupled to a differential pressure transducer which produces an output that is proportional to the volumetric flow of crankcase gases through the venturi. The use of a venturi in conjunction with a differential pressure sensor offers a low resistance path for the flow of crankcase gases and allows continuous monitoring of blow-by without exceeding the operating pressure limitations of various oil seals. Such a sensor is particularly suited for closed crankcase ventilation (ccv) systems, as it doesn't require venting of crankcase gases to the atmosphere (but will also work well on open systems).

[0008] According to another aspect of this invention there is provided a method of evaluating performance of an internal combustion engine as claimed in claim 8.

[0009] Preferred features of the method are claimed in the sub-claims 9 to 11.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. la is a cross-sectional view of a preferred embodiment of the venturi of the present invention.

[0011] FIG. lb is an end view of the venturi of FIG. 1.

[0012] FIG. 2 is a top plan view of the venturi of FIG. 1 with the differential pressure transducer mounted thereon.

[0013] FIG. 3 is a cross-sectional view of the venturi and differential pressure sensor of FIG. 2.

[0014] FIG. 4 is an end view of the venturi and differential pressure sensor of FIG. 2.

[0015] FIG. 5 is a graph of differential pressure as a function of the flow transfer function of the venturi of FIG. 2.

[0016] FIG. 6 is a graph of the voltage output signal of the differential pressure sensor of FIG. 2 as a function of air flow through the venturi.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the protection claimed by the claims is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the invention as illustrated therein and as claimed by the claims, being contemplated as would normally occur to one skilled in the art to which the invention relates.

[0018] Hereinafter, when expressions such as "above" and "below" are used, it will be assumed that the piston is so oriented that its axis is vertical and the crankcase is positioned below the piston. This hypothesis is merely intended to simplify the description and therefore does not imply that the piston is in fact oriented in this way when it is mounted in an internal combustion engine.

[0019] The present invention involves the sensing of crankcase blow-by gases by measuring the volumetric flow of such gases rather than the prior art method of measuring the pressure of these gases. Volumetric flow of the blow-by gases is accomplished by routing a portion of these gases through a venturi which has high pressure and low pressure taps therein. A differential pressure sensor is then attached to the high and low pressure taps in order to measure the pressure differential between the taps. This differential pressure is related to the volumetric flow of blow-by gases through the venturi, and hence the volumetric flow of blow-by gases around the engine pistons. Both instantaneous measurement of this volumetric flow, as well as historical trend analysis, provide useful information in determining the health of the engine as well as to predict future needs for service. The sensor will therefore yield data suitable for trend analysis to aid diagnostics and prognostics, and can be used to avoid catastrophic failure.

[0020] Referring to FIG. la, a cross-sectional view of a preferred embodiment venturi of the present invention is illustrated and indicated generally at 10. The venturi 10 includes a generally cylindrical venturi body 12 having an inlet port 14 and an outlet port 16 attached thereto. The inlet port 14 includes a hose connection nipple 18 while the outlet port 16 includes a hose connection nipple 20. Crankcase gases may thus be routed to the venturi 10 via a suitable hose (not shown), and crankcase gases exiting the venturi 10 may be routed back to the crankcase via a second suitable hose (not shown). The venturi 10 is preferably formed from aluminum, steel or an injection molded engineering thermoplastic, or any other suitable material.

[0021] The dimensions of the venturi 10 will vary depending upon the engine size with which the venturi is associated. The dimensions given for the venturi 10 of FIG. la are preferred for use with a K50 diesel engine manufactured by the Cummins Engine Company of Columbus, Indiana. Because the venturi effectively amplifies the flow rate of crankcase gases through the venturi, different venturi sizes will be appropriate for different size engines.

[0022] In the preferred embodiment of FIG. la, the venturi 10 has an inlet port 14 internal diameter of 1 inch (25.4mm). The outlet port 16 also has an internal diameter of 1 inch (25.4). The venturi throat 22 has an internal diameter of 0.425 inches (10.795mm.) Dimensions for the other portions of the venturi 10 are illustrated in FIG. la. A high pressure tap 24 is formed from the exterior surface of the venturi body 12 to the inlet bore 26 which extends through the inlet port 14. Similarly, a low pressure tap 28 is formed from the exterior surface of the venturi body 12 to the venturi throat 22.

[0023] Referring to FIG. 2, a differential pressure sensor 30 is coupled to the venturi body 12 by means of four screws 32 which bore into the body 12. The differential pressure sensor 30 is preferably a variable capacitive on ceramic differential pressure sensor such as a model P604 manufactured by Kavlico of Moorepark, California, but any type of differential pressure sensor may be utilized in the present invention.

[0024] As illustrated in the cross-sectional view of FIG. 3, the differential pressure sensor 30 is mounted to the venturi body 12 such that the high pressure tap 24 is aligned with the inlet 34 to the high pressure side of the differential pressure sensor 30. Similarly, the low pressure tap 28 communicates with the inlet 36 of the low pressure side of the differential pressure sensor 30. The differential pressure sensor 30 is preferably of the wet-dry type, therefore the low pressure side of the sensor includes a filter element 38 in order to prevent liquid, such as uncombusted fuel and oil, to enter the low pressure side of the differential pressure sensor 30. The output of the differential pressure sensor 30 is a voltage which is proportional to the differential pressure across the high pressure tap 24 and the low pressure tap 28. This output voltage is supplied to a multi-pin electrical connector 40. The connector 40 additionally accepts the input voltage which is used to power the differential pressure sensor 30.

[0025] The venturi 10 of FIG. la is capable of flowing in excess of 50 actual cubic feet per minute (ACFM) (1.4 cubic metres per minute) air or crankcase gas, although the flow rate will be approximately 26 ACFM (0.728 cubic metres per minute) maximum for the model K50 engine for which the venturi 10 was designed. A flow rate of 26 ACFM (0.728 cubic metres per minute) results in approximately 30 inches (760 mm) of water pressure differential developed across the pressure taps 24 and 28. This is illustrated in the graph of FIG. 5 which illustrates the differential pressure developed across the pressure taps 24 and 28 of the venturi 10 as a function of gas flow through the venturi 10. This graph illustrates that the transfer function of gas flow vs. differential pressure for the venturi 10 is not linear.

[0026] The combination venturi body 12 and differential pressure sensor 30 is preferably mounted in a substantially vertical orientation in order to allow gas to run out of the venturi in order to prevent build-up and contamination within the differential pressure sensor 30. Such build-up will change the measured pressure and result in inaccuracies in the measurement of crankcase gas flow. The differential pressure sensor 30 is mounted to the venturi body 12 by means of an appropriate sealing gasket which forms an airtight seal between the differential pressure sensor 30 and the high pressure tap 24 and low pressure tap 28.

[0027] Referring to FIG. 6, it can be seen that the output voltage of the differential pressure sensor 30 is a non-linear function of media volumetric flow, which tracks the actual differential pressure developed across the high and low pressure taps of the venturi. The input voltage to the differential pressure sensor 30 is 5.0+/-5% VDC. Because the sensor 30 is ratiometric to the input voltage, the output voltage illustrated in FIG. 6 assumes a 5.0 VDC input voltage. It will be appreciated by those skilled in the art that the transfer function of FIG. 6 allows an engine monitoring system to determine the flow-rate of crankcase gases through the venturi by monitoring the output voltage of the differential pressure sensor 30. This information may be used in different ways by the engine monitoring system. For instance, the output voltage of the differential pressure sensor 30 may be monitored for an instantaneous increase of blow-by gas flow, indicative of a catastrophic failure within the engine. The amount of instantaneous increase necessary to signal a catastrophic failure may be made a calibratable threshold point within the engine monitoring system and is dependent upon engine size. Upon the sensing of such an instantaneous increase in blow-by gas flow, an indicator light may be used to alert the driver of the situation. The output voltage of the differential pressure sensor 30 may also be used to record crankcase gas flow rate over time in order to chart the wear of the engine and hence predict when the engine will require an overhaul. The engine monitoring system may use a filtered linear projection in order to determine at what time the engine blow-by gases have increased to the point where maximum performance is no longer available from the engine. Appropriate servicing can then be scheduled for the vehicle prior to that time.

[0028] It will therefore be appreciated by those skilled in the art that the present invention allows useful measurement of engine crankcase blow-by which was previously unavailable in closed crankcase ventilation systems. Measurement of such blow-by gases can provide information to signal catastrophic failures within the engine as well as to predict when major engine servicing will be required in the future. Such information may be used to minimize downtime of the engine and to prevent expensive catastrophic engine failure.

[0029] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment has been shown and described and that all changes and modifications that come within the scope of the protection claimed by the claims are desired to be protected.

Claims

1. An engine comprising a crankcase gas blow-by sensor and an engine crankcase operative to receive blow-by gases via a gas flow path; **characterised by**:

a venturi (10) positioned within the gas flow path such that the blow-by gases in use flow through the venturi (10) and are routed back from the venturi (10) to the crankcase;
a high pressure tap (24) extending from an exterior of the venturi (10) to an interior (26) of the venturi (10);
a low pressure tap (28) extending from the venturi exterior to the venturi interior (22); and
a sensor (30) coupled to the venturi (10) and operative to measure a differential pressure between the high pressure tap (24) and the low pressure tap (28).

2. An engine crankcase gas blow-by sensor, according to claim 1 in an internal combustion engine, comprising:

at least one cylinder;
at least one piston slidingly disposed within the at least one cylinder in order define a combustion chamber above the piston;
the crankcase being coupled to the at least one cylinder, wherein an interior of the crankcase is in fluid communication with an interior of the at least one cylinder below the at least one piston via at least the gas flow path, wherein combustion blow-by gases which blow-by the at least one piston may enter the crankcase.

3. Apparatus according to claim 1 or claim 2, wherein the high pressure tap (24) extends from the venturi exterior to an interior of an inlet bore (26) of the venturi (10).

4. Apparatus according to claim 1 or claim 2, wherein the low pressure tap (28) extends from the venturi exterior to an interior of a venturi throat (22) of the venturi (10).

5. Apparatus according to claim 1 or claim 2, wherein the sensor (30) comprises a wet-dry differential pressure sensor.

6. Apparatus according to claim 1 or claim 2, wherein the sensor (30) comprises a variable capacitive on ceramic pressure sensor.

7. Apparatus according to claim 1 or claim 2, wherein the venturi (10) is mounted substantially vertically in order to allow gas to run out of the venturi (10).

8. A method of evaluating performance of an internal combustion engine, **characterised by** the steps of:

(a) routing at least a portion of blow-by gases entering a crankcase of the engine through a venturi (10) and back to the crankcase, the venturi (10) having a high pressure tap (24) and a low pressure tap (28);
(b) measuring a pressure differential between the high pressure tap (24) and the low pressure tap (28); and
(c) outputting a signal that is proportional to the measured pressure differential.

9. A method according to claim 8, wherein step (b) is performed by a wet-dry differential pressure sensor (30).

10. A method according to claim 8, wherein step (b) is performed by a variable capacitive on ceramic pressure sensor (30).

11. A method according to claim 8, wherein the signal is a voltage signal.

Patentansprüche

1. Motor mit einem Sensor für ins Kurbelgehäuse durchblasendes Gas und einem Motorkurbelgehäuse, das Durchblasgase über einen Gasströmungsweg empfangen kann; **gekennzeichnet durch**

ein Venturi (10), das in dem Gasströmungsweg derart angeordnet ist, daß die Durchblasgase in Betrieb **durch** das Venturi (10) strömen und von dem Venturi (10) aus zu dem Kurbelgehäuse zurückgeleitet werden;

eine Hochdruckzapfstelle (24), die sich von außerhalb des Venturis (10) bis zu einem Innenraum (26) des Venturis (10) erstreckt;

eine Niederdruckzapfstelle (28), die sich von außerhalb des Venturis bis zu dem Innenraum (22) des Venturis erstreckt; und

einen Sensor (30), der mit dem Venturi (10) verbunden und wirksam ist, um einen Differenzdruck zwischen der Hochdruckzapfstelle (24) und der Niederdruckzapfstelle (28) zu messen.

2. Sensor für ins Motorkurbelgehäuse durchgeblasenes Gas gemäß Anspruch 1 in einer Brennkraftmaschine, mit

mindestens einem Zylinder;

mindestens einem Kolben, der verschiebbar in dem mindestens einen Zylinder angeordnet ist, um eine Brennkammer über dem Kolben zu begrenzen;

wobei das Kurbelgehäuse mit dem mindestens einen Zylinder verbunden ist, wobei ein Innenraum des Kurbelgehäuses in Strömungsverbindung mit einem Innenraum des mindestens einen Zylinders unter dem mindestens einen Kolben über mindestens dem Gasströmungsweg steht, wobei Verbrennungsdurchblasgase, die an dem mindestens einen Kolben vorbeiströmen, in das Kurbelgehäuse eintreten können.

3. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der sich die Hochdruckzapfstelle (24) von außerhalb des Venturis bis zum Innern einer Einlaßbohrung (26) des Venturis (10) erstreckt.

4. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der sich die Niederdruckzapfstelle (24) von außerhalb des Venturis bis zum Innern einer Venturiengstelle (22) des Venturis (10) erstreckt.

5. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der der Sensor (30) einen Naß-Trocken-Differenzdrucksensor aufweist.

6. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der der Sensor (30) einen regelbaren kapazitiven Auf-Keramik-Drucksensor aufweist.

7. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der das Venturi (10) im wesentlichen vertikal angeordnet ist, so daß Gas aus dem Venturi (10) ausströmen kann.

8. Verfahren zum Bewerten der Leistung einer Brennkraftmaschine, **gekennzeichnet durch** die Schritte:

(a) Leiten von mindestens einem Teil der in ein Kurbelgehäuse der Brennkraftmaschine eintretenden Durchblasgase **durch** ein Venturi (10) und zurück zu dem Kurbelgehäuse, wobei das Venturi (10) eine Hochdruckzapfstelle (24) und eine Niederdruckzapfstelle (28) hat;

(b) Messen einer Druckdifferenz zwischen der Hochdruckzapfstelle (24) und der Niederdruckzapfstelle (28); und

(c) Ausgeben eines Signals, das zu der gemessenen Druckdifferenz proportional ist.

9. Verfahren nach Anspruch 8, bei dem Schritt (b) durch einen Naß-Trocken-Differenzdrucksensor (30) ausgeführt wird.

10. Verfahren nach Anspruch 8, bei dem Schritt (b) durch einen regelbaren kapazitiven Auf-Keramik-Drucksensor (30) ausgeführt wird.

11. Verfahren nach Anspruch 8, bei dem das Signal ein Spannungssignal ist.

Revendications

1. Moteur comprenant un détecteur de gaz de carter et un carter de moteur permettant de recevoir les gaz de carter par l'intermédiaire d'un passage d'écoulement gazeux ; **caractérisé par** :

une buse (10) placée dans le passage d'écoulement gazeux de sorte que les gaz de carter s'écoulent, en utilisation, dans la buse (10) et qu'il sont renvoyés de la buse (10) au carter ;

un robinet haute pression (24) s'étendant d'une partie extérieure de la buse (10) à une partie intérieure (26) de la buse (10) ;

un robinet basse pression (28) s'étendant de l'extérieur de la buse à l'intérieur de la buse (22) ; et

un détecteur (30) couplé à la buse (10) et permettant de mesurer une différence de pression entre le robinet haute pression (24) et le robinet basse pression (28).

2. Détecteur de gaz de carter de moteur selon la revendication 1 d'un moteur à combustion interne, comprenant :

au moins un cylindre ;

au moins un piston placé, de façon à pouvoir coulisser, dans l'au moins un cylindre afin de définir une chambre de combustion au-dessus du piston ;

le carter étant couplé à au moins un cylindre, dans lequel une partie intérieure du carter est en communication fluidique avec une partie intérieure d'au moins un piston situé au-dessous d'au moins un piston par l'intermédiaire d'au moins le passage d'écoulement gazeux, dans lequel les gaz de carter de combustion qui se trouvent au niveau de l'au moins un piston peuvent entrer dans le carter.

3. Appareil selon la revendication 1 ou la revendication 2, dans lequel le robinet haute pression (24) s'étend de l'extérieur de la buse à une partie intérieure d'un alésage d'entrée (26) de la buse (10).

4. Appareil selon la revendication 1 ou la revendication 2, dans lequel le robinet basse pression (28) s'étend de l'extérieur de la buse à une partie intérieure d'un col (22) de la buse (10).

5. Appareil selon la revendication 1 ou la revendication 2, dans lequel le détecteur (30) comprend un détecteur de pression différentielle de type sec ou humide.

6. Appareil selon la revendication 1 ou la revendication 2, dans lequel le détecteur (30) comprend une capacité variable sur un détecteur de pression en céramique.

7. Appareil selon la revendication 1 ou la revendication 2, dans lequel la buse (10) est montée sensiblement verticalement afin de permettre au gaz de sortir de la buse (10).

8. Procédé permettant d'évaluer les performances d'un moteur à combustion interne, **caractérisé par** les étapes consistant à :

(a) diriger au moins une partie des gaz de carter entrant dans un carter du moteur dans une buse (10) puis de nouveau dans le carter, la buse (10) présentant un robinet haute pression (24) et un robinet basse pression (28) ;

(b) mesurer une différence de pression entre le robinet haute pression (24) et le robinet basse pression (28) ; et

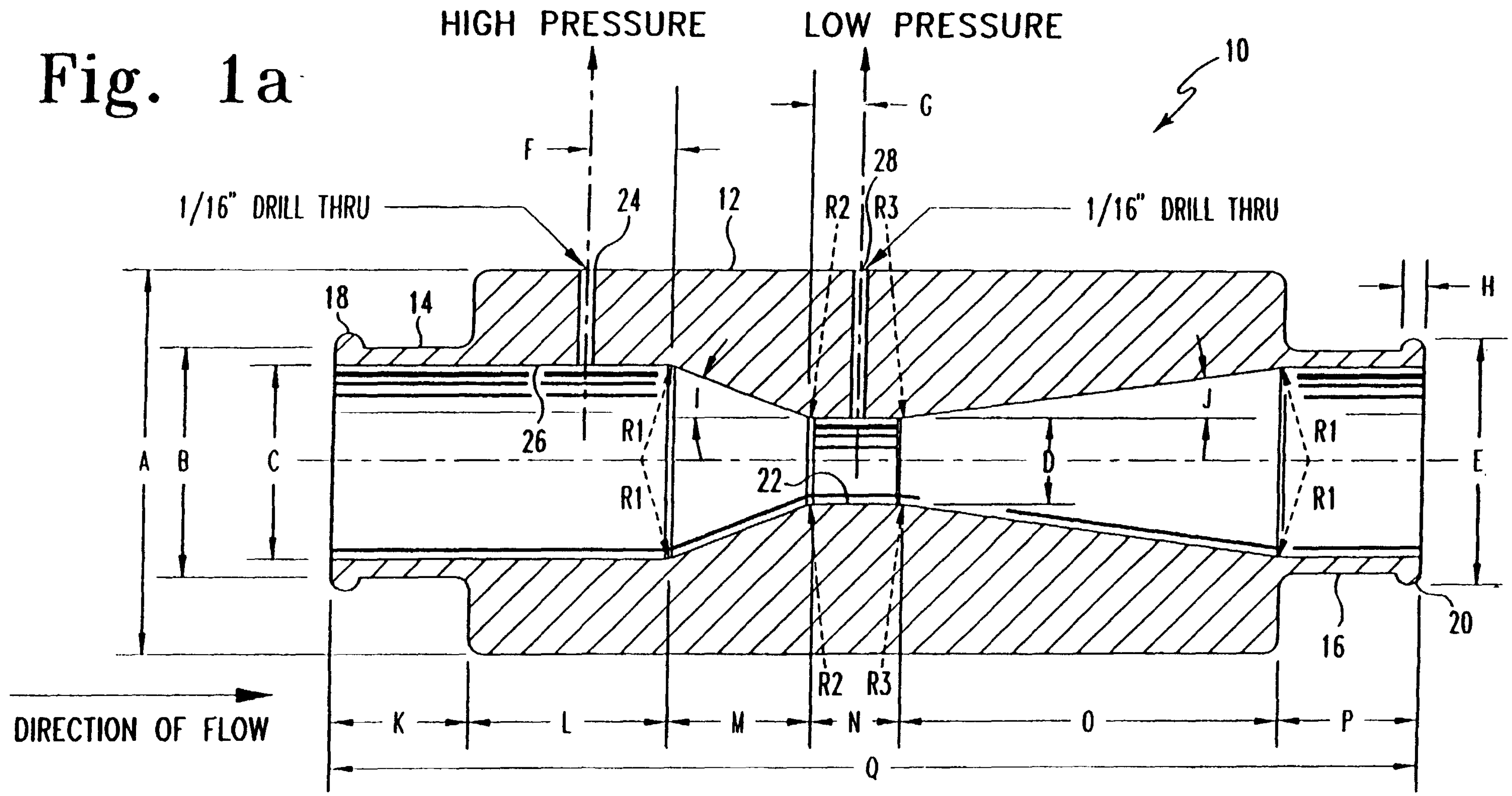
(c) émettre un signal proportionnel à la différence de pression mesurée.

9. Procédé selon la revendication 8, dans lequel l'étape (b) est exécutée par un détecteur de pression différentielle de type sec-humide (30).

10. Procédé selon la revendication 8, dans lequel l'étape (b) est exécutée par une capacité variable sur un détecteur de pression en céramique (30).

11. Procédé selon la revendication 8, dans lequel le signal est un signal de tension.

Fig. 1a



A= Ø 2.000" ± 0.015" (58.8mm ± 0.4mm)
B=Ø 1.250" ± 0.010" (31.8mm ± 0.3mm)
C=Ø 1.000" ± 0.005" (25.4mm ± 0.1mm)
D=Ø 0.425" ± 0.005" (10.8mm± 0.1mm)
E=Ø 1.375" ± 0.010" (34.9mm± 0.3mm)
F= 0.425"± 0.005" (10.8mm±0.1mm)
G=0.212"±0.005" (5.4mm±0.1mm)
H=0.080"±0.010" (2.0mm±0.3mm)
I =21° ± 0.5°
J = 8° ± 0.5°
K=0.750"±0.010" (19.1mm±0.3mm)
L=1.000"±0.010" (25.4mm±0.3mm)
M=0.750±0.005" (19.1mm±0.1mm)
N=0.425"±0.005"(10.8mm±0.1mm)
O=2.045"±0.005"(51.9mm±01mm)
P=0.750"±0.010"(19.1mm±0.3mm)
Q=5.720" (145.3mm)
R1=1.375"±0.015" (34.9mm±0.4mm) (AT 4 PLACES)
R2=1.540"±0.015" (39.1mm±0.4mm) (AT 2 PLACES)
R3=1.540"±0.015" (39.1mm±0.4mm) (AT 2 PLACES)

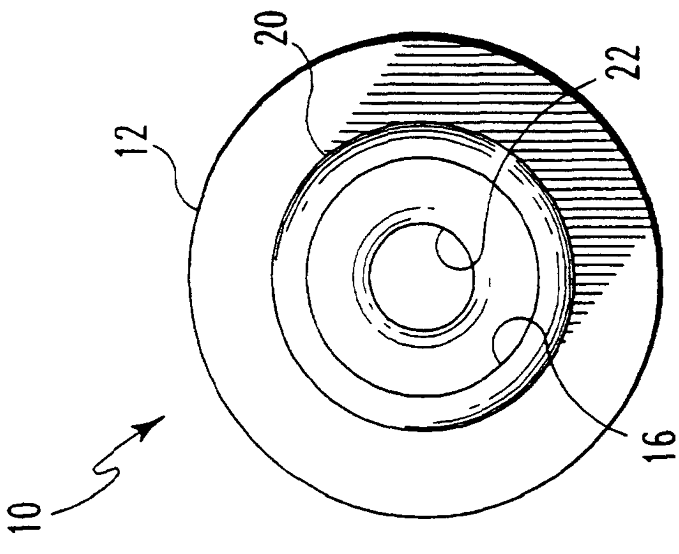


Fig. 1b

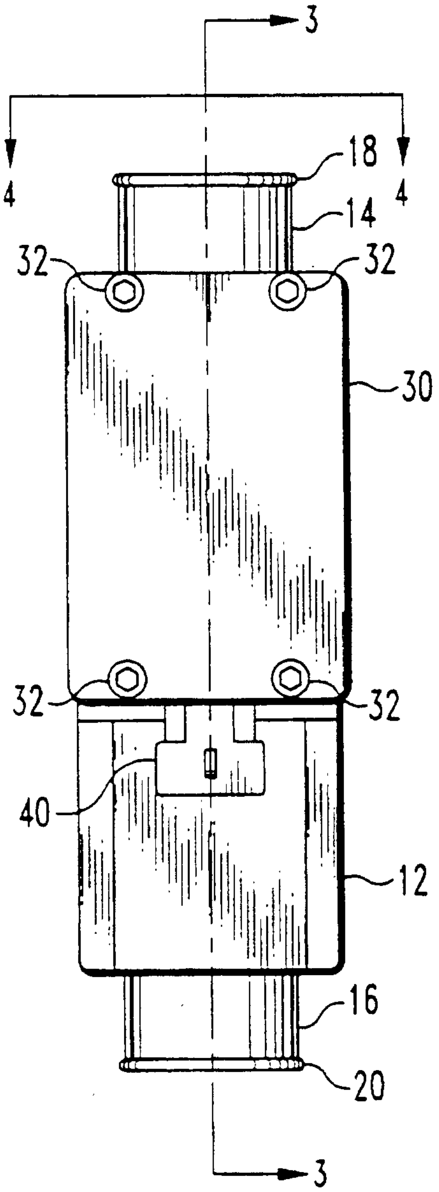


Fig. 2

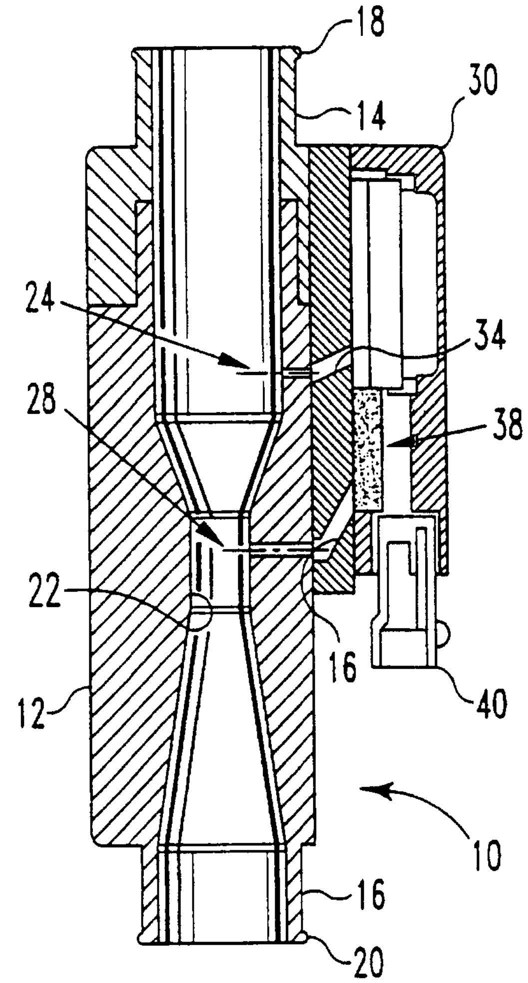
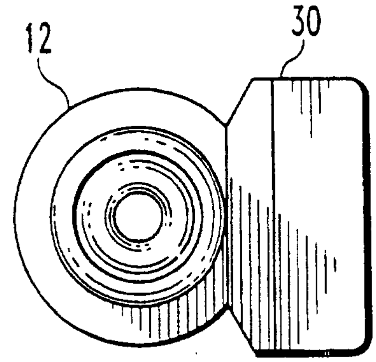


Fig. 3

Fig. 4



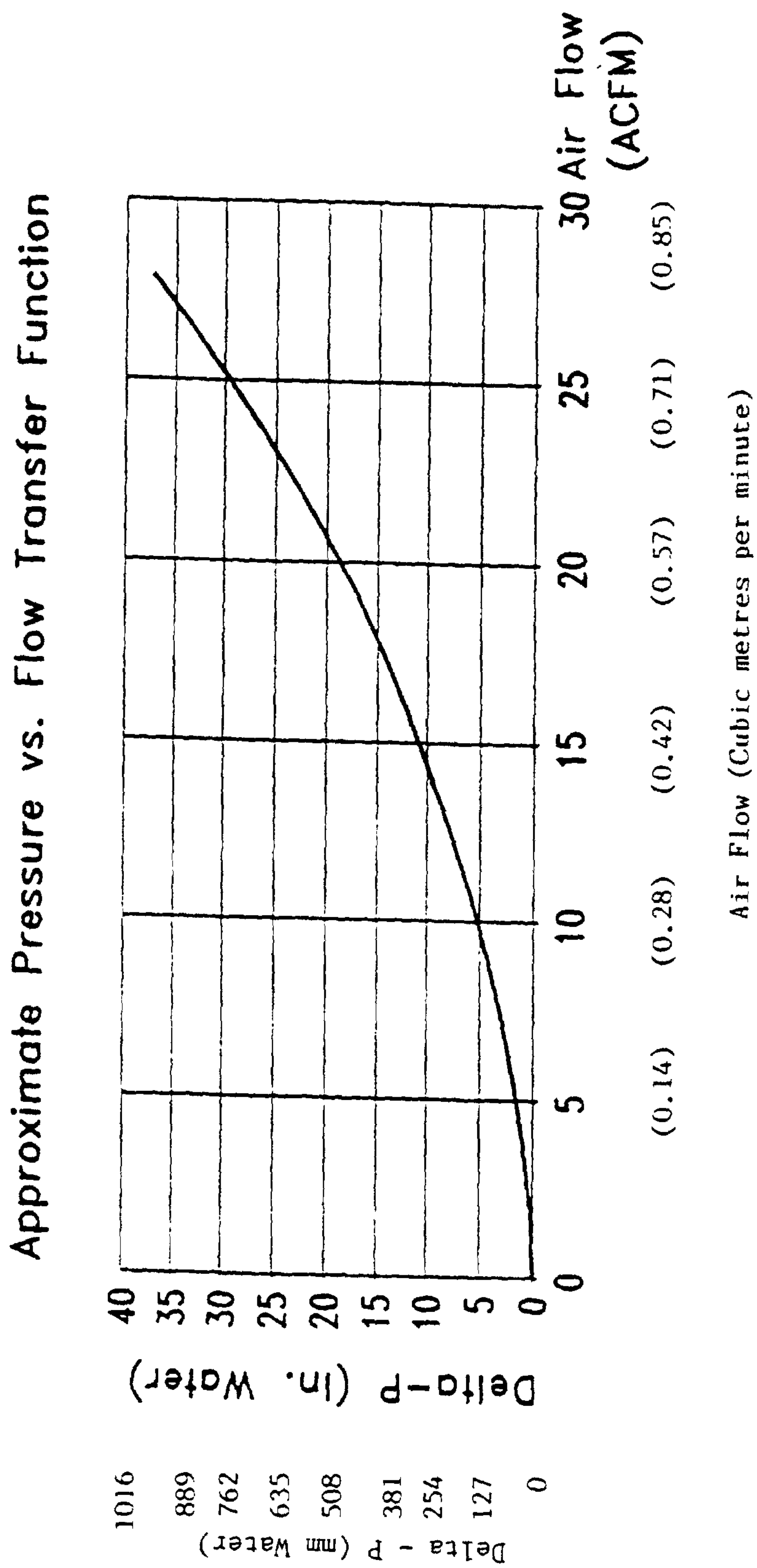

Approximate Pressure vs. Flow Transfer Function
Delta-P (in. Water)
40 35 30 25 20 15 10 5 0
Delta - P (mm Water)
1016 889 762 635 508 381 254 127 0
0 5 10 15 20 25 30 Air Flow (ACFM)
(0.14) (0.28) (0.42) (0.57) (0.71) (0.85)
Air Flow (Cubic metres per minute)

Fig. 5

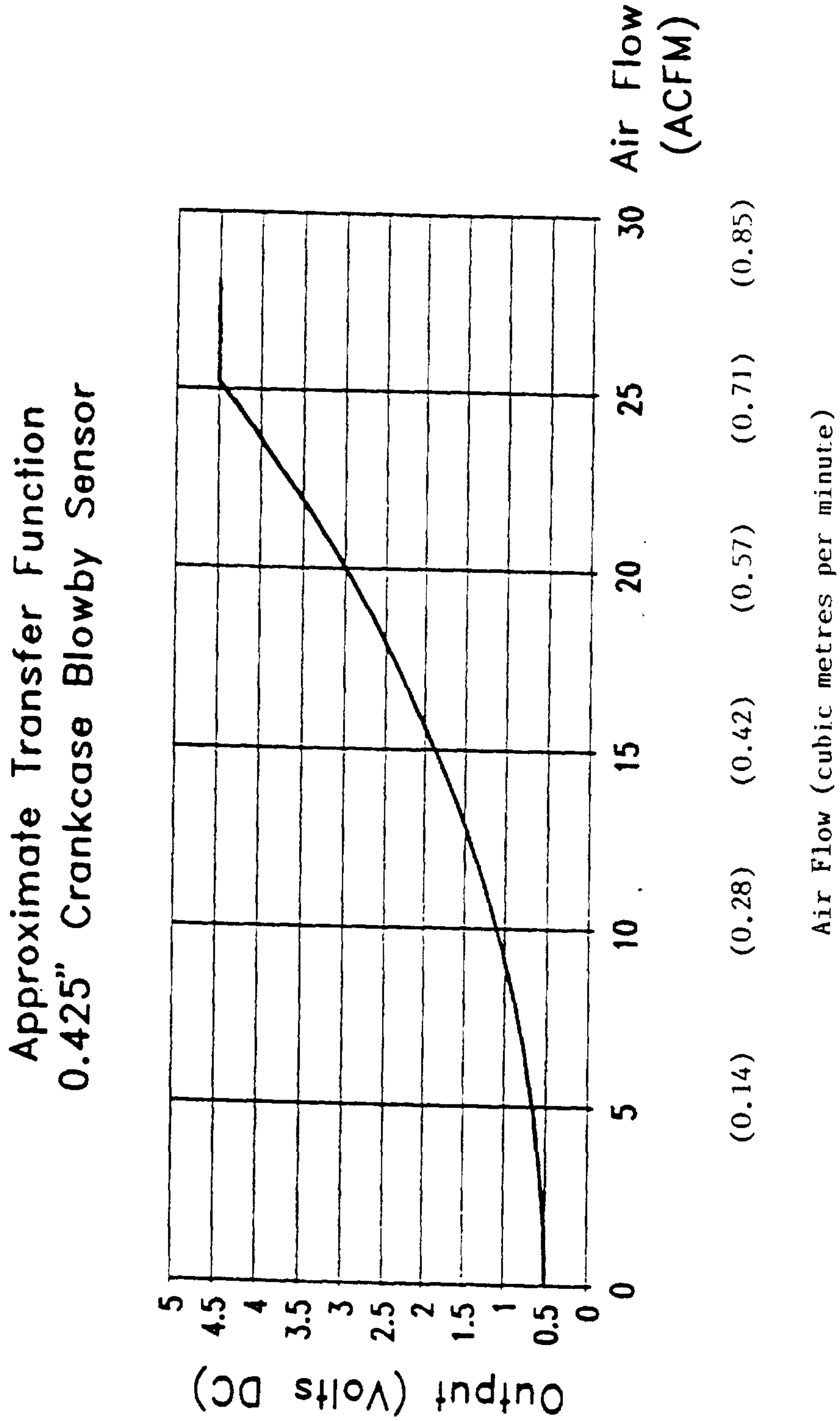

Approximate Transfer Function
0.425" Crankcase Blowby Sensor
Output (Volts DC)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25
30
Air Flow (ACFM)
(0.14)
(0.28)
(0.42)
(0.57)
(0.71)
(0.85)
Air Flow (cubic metres per minute)

Fig. 6