Title: WATER SEPARATOR FOR AIR INTAKE SYSTEMS OF INTERNAL COMBUSTION ENGINES

Abstract: The invention describes a water separator (2) for an air intake system (1) of internal combustion engines. The air intake system (1) operating under negative pressure and comprising an untreated air suction duct (D) presenting a curve (C) to direct the suctioned air stream from a suction point (S) to the adjoining water separator (2). The water separator (2) consists of an outer duct (3) and an inner duct (4), the inner duct (4) being concentric to and projecting into the outer duct (3), wherein the water separator (2) is positioned substantially in vertical direction and presents between the inner duct (4) and the end of the outer duct (3) an annular gap (G) for the water outlet. The water separator (2) of the present invention operates continuously without a discharge valve and with minimal pressure loss.
Description
WATER SEPARATOR FOR AIR INTAKE SYSTEMS OF INTERNAL COMBUSTION ENGINES

Technical Field
The present invention relates to a water separator for air intake systems of internal combustion engines. The air intake system of the present invention operates under negative pressure, resulting from the air suction generated by the internal combustion engine, and comprises an untreated air suction duct with a curve to direct the air stream from a suction point to an adjoining water separator. The water separator consists of an outer duct and an inner duct, the inner duct being concentric to and projecting into the outer duct.

State of Technology
In internal combustion engines the air intake system comprises an air cleaner with a filter media to remove particulate material from the air stream that enters into the engine. As a rule the air intake system includes also a water separator in the untreated air duct placed upstream from the air cleaner. As it is known, water in the incoming air stream can degrade and turn less efficient a filter media of the air cleaner, thus being necessary the use of a water separator to remove the water, especially for high performance engine applications.

There are several technical solutions for water separators in air intake systems with air cleaners. US 6,540,802 B2 discloses an air intake system including a water separator with an inner pipe projecting into an outer pipe. The outer pipe of the water separator presents guide vanes that introduce a swirl motion to the incoming air stream. Due to the swirl the water droplets in the incoming air stream are projected against the wall of the outer pipe, so that the incoming air in the central area of the pipe contains no longer water droplets. The inner pipe conducts the air stream without water droplets to the combustion engine. The outer pipe is provided with a water outlet which is positioned tangentially to the direction of the swirl. This solution presents a complex design with a comparatively high pressure loss due to the swirl motion introduced to the air stream.
US 3,885,935 discloses a centrifugal device for separating entrained liquids from a gaseous stream. The device presents an outer and an inner duct. A helical deflector positioned inside the outer duct produces a swirl motion to the incoming air stream, thereby conducting the liquid droplets against the internal wall of the outer duct, the outer duct presenting a drain for collecting the separated liquid. A barrier element is positioned at the tip of the protruding inner duct to avoid that the separated liquid enters the gas outlet at the inner duct. Similar to US 6,540,802 B2 the cited disclosure presents also the disadvantage of high pressure loss due to the swirl motion introduced to the incoming air stream and a complex design with the necessity of barrier elements and deflectors to avoid the reentrainment of the separated liquid.

US 8,425,641 B2 presents an inlet air filtration system with a series of inertial filter elements. The individual inertial filters consist of a tube, a swirl element with a plurality of blades, a separation region downstream from the swirl element, a reducer, an annular outlet and an expander. The gas incoming under positive pressure inside the inertial filter receives a swirl motion by the swirl element. Thereby the liquid droplets or gas components with a higher density, entrained in the incoming gas stream are directed by the swirl motion against the inner wall of the separation region. The separated components or liquids are conducted by the positive air flow to the reducer. At the reducer, due to a reduction in diameter of the inertial filter tube and consequent acceleration of the gas flow, the separated components or liquids are forced in direction of the annular opening, leaving the inertial filter. The gas stream free from the separated components or liquids enters the expander reducing thereby its velocity. The device has the disadvantage that it operates only with an air stream with positive pressure directed from the swirl element to the expander. The operation under negative pressure would result in the suction of air through the annular opening into the filtration system and the deposition of separated components or liquid before the reducer inside the tube. Furthermore the proposed solution with the annular opening to the atmosphere and the swirl element represent a high pressure loss for the system.

US 6,902,595 B2 discloses an intake water separator for air cleaners of internal combustion engines. The technical solution presented includes an inlet pipe with an elbow to direct the suctioned air stream to the interior wall of the separator, the water separator presenting an inner tube that protrudes inside an outer tube, forming a water separa-
tion cavity between both tubes. The water droplets are directed against the inner wall of the water separator due to the change in direction of the air stream. They flow due to gravity downward from the water cavity to a drain tube. It is informed further that in this type of water separator nearly 90% of the water in the air stream can be separated. Although the disclosed water separator presents a high efficiency with a relatively low pressure loss it has the disadvantage of having an open drain to the atmosphere. This open drain allows the entrance of air in the system increasing the pressure loss. To avoid pressure loss a valve may be installed at the end of drain, but this solution would increase the cost of the water separator.

It is the object of the present invention to provide a water separator for an air intake system which presents high separation efficiency with low pressure loss and a low production and maintenance cost.

**Disclosure of Invention**

The present invention discloses a water separator for air intake systems of internal combustion engines. The air intake system of the present invention operates under negative pressure, resulting from the suctioned air stream generated by the internal combustion engine, and comprises an untreated air suction duct with a curve to direct the suctioned air stream from a suction point to an adjoining water separator positioned downstream. The water separator consists of an outer duct and an inner duct, the inner duct being concentric to and projecting into the outer duct, wherein the water separator is positioned substantially in vertical direction and presents between the inner duct and the end of the outer duct an annular gap for water outlet.

The untreated air stream with moisture entering the suction point is directed by the curve to the internal wall of the suction duct upstream to the water separator. The water droplets directed against the internal wall of the suction duct will flow by gravity downward to the substantially vertically positioned water separator. Reaching the water separator the coalesced water droplets will flow between its outer and inner duct in the direction of the annular gap.

After starting the internal combustion engine, the negative pressure generated inside the air intake system will result in a small air flow through the annular gap directed to
the inside of the water separator. The moisture in the suctioned air stream, which is directed against the inner wall of the suction duct, will as mentioned coalesce to droplets and flow downwards by gravity between the inner and the outer duct of the water separator in the direction of the annular gap. At a certain moment after the starting of the internal combustion engine the amount of coalesced water between the outer and inner duct of the water separator will seal the annular gap against the air flow from the outside. A water column will continuously build up between the outer and the inner duct of the water separator. When the pressure of the water column over the annular gap is sufficiently high to overcome the negative pressure inside the air intake system the water will flow to the outside of the water separator through the annular gap. Due to the continuous build up of the water column over the annular gap a continuous water flow to the outside of the water separator will occur. The water column over the annular gap will, as mentioned, seal the interior of the water separator against the outside reducing thereby to zero air intakes which result in pressure loss for the air intake system. No drain valve is necessary to control the water outlet at water separator of the present invention, thus no maintenance is required.

The annular gap between the outer duct and the inner duct of the water separator is also alternatively defined by a barrier element which may be disposed in radial direction around the outside wall of the inner duct. On this alternative solution the distance between the barrier element and the inner wall of the outer duct of the water separator will determine the annular gap. It is also possible to have a tapered configuration between the inner and outer duct of the water separator at the region of the annular gap.

Depending on the desirable height of the water column formed between the inner and the outer duct and the negative pressure inside the air intake system the dimension of the annular gap can be adjusted, the invention being therefore applicable to different sizes of water separators and air flow rates.

The water separator of the present invention, as mentioned above, consists of basically two parts, an outer duct and an inner duct, which can be produced separately from the ducts of the air intake system. The parts of the water separator can be attached to the ducts of the air intake system on a fixed manner, e.g. by welding or gluing, or on a detachable manner, e.g. by clasps or threaded devices.
The two parts of the water separator can be easily manufactured, e.g. by injection molding of plastic, reducing also its production cost.

**Embodiment of Invention**

The present invention will be described in detail based on one embodiment shown in the drawings. The figures showing:

- **Figure 1** is a side view of the air intake system with the water separator;
- **Figure 2** is a longitudinal cut of the water separator;
- **Figure 3** is a side view of the inner duct of the water separator;
- **Figure 4** is a top view of the inner duct of the water separator;
- **Figure 5** is a schematic view of the inner duct and the outer duct of the water separator in an assembled position, with a sectional cut presenting the interconnecting elements;
- **Figure 6** is a detail view of figure 5 presenting the inner duct and the outer duct in the region of the annular gap; and
- **Figure 7** is a graphic of the efficiency of water separation and pressure loss against the volume flow rate of an embodiment of the invention.

**Detailed Description of the Figures**

As it can be seen from figure 1, at a suction point S from the air intake system 1 untreated air containing moisture is suctioned inside the system 1. The air stream is conducted through the curve C and air suction duct D to the water separator 2. The water droplets of the moisture contained in the suctioned untreated air, due to the change in the flow direction of the air stream at the curve C, will contact the inner wall of the suction duct D and coalesce to bigger water droplets. The water separator 2 which is positioned in essentially a vertical direction downstream to duct D receives the flow of the water droplets flowing along the inner wall of duct D.

At the embodiment shown in figure 1 the outer duct 3 of the water separator is integral with duct D. It is also possible to have a fixed union through welding or gluing between the outer duct 3 of the water separator 2 and the duct D. Also detachable unions through clasps or threaded unions are possible. A similar situation occurs with the inner
duct 4 of the water separator 2 and the air intake ducts to the internal combustion engine.

In figure 2 the two parts of the water separator 2, the outer duct 3 and the inner duct 4, are shown on an assembled position. The longitudinal cut shows the positive union between the two parts, the inner duct 4 and the outer duct 3 being fixed against each other in vertical and rotational directions.

Support elements 6 are placed circumferential equally spaced apart at the outer surface of the inner duct 4. These support elements 6 will guarantee the positive union between the inner duct 4 and the outer duct 3 and that the annular gap G is kept constant between the inner duct 4 and the outer duct 3. The number of support elements 6 may vary, from four as shown in the embodiment to any number that guarantees a constant annular gap G between the inner duct 4 and the outer duct 3. Usually at least three support elements 6 are used.

The inner duct 3 presents an inwardly tapered lip 9 which facilitates the insertion of the outer duct 3 over the inner duct 4 during assembly. Furthermore the inwardly tapered lip 9 facilitates the flow of the coalesced water droplets between the outer duct 3 and the inner duct 4.

The support elements 6 present retain elements 7, 8. A nose 8 on the upper part of the support element 6 engages through a snap fit connection into a corresponding window at the outer duct 3. The nose 8 limits the movement of the inner duct 4 in vertical and rotation direction in relation to the outer duct 3. A stopper 7 of the support element 6 receives the edge of the outer duct 3 limiting its movement in vertical direction against the inner duct 4.

Figure 3 shows the inner duct 4 of the water separator 2 on a side view. In an embodiment of the invention a circumferentially continuous radial barrier element 5 projects from the outside wall of the inner duct 4 in the region of the annular gap G. The barrier element 5 facilitates the formation of a water column H due to a further restriction of the distance between the outer duct 3 and the inner duct 4 at the region of the annular gap G. The radial height R of the barrier element 5 may be defined from zero to nearly the
radial height of the support element 6 depending on the parameters of the system, i.e. the moisture content of the intake air, the intake flow rate, the height of the water column H over the annular gap G.

A top view of the inner duct 4 is shown in figure 4 and the inwardly tapered lip 9, the nose 8 of the support element and the barrier element 5 can be easily viewed. The radial height R of the barrier element 5 can also be seen.

As already mentioned the barrier element 5 is an optional feature of the invention. Other solutions to define the annular gap G are possible, as for example the uniform distance between the inner 4 and the outer duct 3 given by the support elements 6 or a tapered configuration between the inner 4 and outer duct 3 in the region of the annular gap G. The tapered configuration could be from the inner 4 and/or the outer duct.

In the schematic view of figure 5 the interaction of the outer duct 3 with the inner duct 4 is shown. The window 10 of the outer duct 3 receives the nose 8 in a snap fit connection and the edge of the outer duct 3 engages against the stopper 7. The droplets of moisture due to gravity flow between the inner wall of the outer duct 3 and the outer wall of the inner duct 4 until they reach the barrier element 5.

In the detail view shown in figure 6 it is possible to identify the annular gap G formed between the inner wall of the outer duct 3 and the barrier element 5. The radial height R of the barrier element 5 defines in this embodiment the annular gap G. The continuous flow of droplets will result in a water column H over the annular gap G. This water column H will seal the water separator 2 from the outside and avoid any pressure loss on the water separator 2. As already mentioned the radial height R may be defined depending on the height of the water column and the negative pressure inside the air intake system. Due to the continuous build up of the water column H a continuous flow of water through the annular gap G is assured. At the end of operation of the internal combustion engine the negative pressure inside the air intake system 1 ceases to exist and the water column H will flow completely through the annular gap G. No maintenance or cleaning of the water separator is therefore necessary.
The water separator 2 of the present invention has also a considerably high efficiency of water separation with a very low pressure loss. One example considering a diameter of the suction duct of 100 mm and an annular gap of 1 mm is shown in figure 7. The example shows that at an internal pressure of 710 mm Hg, a temperature of 24 °C, a water concentration 215 g/min and nominal flow of 10 m²/min the efficiency of water separation of the water separator 2 of the present invention lies at 99.5% with a pressure loss of only 1.4 mbar.

Having described one preferred embodiment, it should be understood that the scope of the present invention contemplates other possible variations, being limited only by the content of the attached claims, including possible equivalent solutions.

**List of reference numbers**

1 - Air intake system
2 - Water separator
3 - Outer duct
4 - Inner duct
5 - Barrier element
6 - Support element
7 - Stopper
8 - Nose
9 - Inwardly tapered lip
10 - Window
C - Curve
D - Air suction duct
G - Annular gap
H - Water column
R - Radial height of barrier element
S - Suction point
Claims

1. Water separator (2) for air intake systems (1) of internal combustion engines, the air intake system (1) operating under negative pressure, comprising an untreated air suction duct (D) presenting a curve (C) to direct a suctioned air stream from a suction point (S) to the adjoining water separator (2), the water separator (2) consisting of an outer duct (3) and an inner duct (4), the inner duct (4) being concentric to and projecting into the outer duct (3), characterized in that the water separator (2) being positioned substantially in vertical direction and presenting between the inner duct (4) and the end of the outer duct (3) an annular gap (G) for water outlet.

2. Water separator according to claim 1, characterized in that the inner duct (4) presents circumferential equally spaced apart support elements (6) projecting in radial direction from the inner duct (4).

3. Water separator according to claim 2, characterized in that at least three support elements (6) present retain elements (7, 8) to retain the outer duct (3) in vertical direction against the inner duct (3) and prevent rotation between the outer duct (3) and the inner duct (4).

4. Water separator according to claim 3, characterized in that a nose (8) interacts with a corresponding window (10) in the outer duct (3) and a stopper (7) interact with the inferior edge of the outer duct (3).

5. Water separator according to claim 1, characterized in that the inner duct (4) and/or the outer duct (3) present a tapered shape at the region of the annular gap (G).

6. Water separator according to claim 1, characterized in that a circumferentially continuous radial barrier element (5) projects from the outside wall of the inner duct (4) in the region of the annular gap (G).

7. Water separator according to claim 1, characterized in that the inner duct (4) presents an inwardly-tapered lip (9).

8. Water separator according to anyone of claim 1 to 7, characterized in that the inner duct (4) and the outer duct (3) are produced by injection molding of plastics.

9. Water separator according to anyone of claims 1 to 8, characterized in that the inner duct (4) and the outer duct (3) are connected to the ducts of the air intake system (1) though a fixed union and/or a detachable union.

10. Water separator according to claim 9, characterized in that the fixed union is produced by a welding or gluing process and that the detachable union is provided by clasps or threaded devices.
A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M35/022 F02M35/08 F02M35/10 F02M35/02

ADD.

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)
F02M

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

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category</th>
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<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>GB 2 Oil 273 A (FIAT VEICOLI IND) 11 July 1979 (1979-07-11) abstract figure 2</td>
<td>1-10</td>
</tr>
<tr>
<td>X</td>
<td>US 3 791 112 A (LIDSTONE J) 12 February 1974 (1974-02-12) figures 1-3 column 2, lines 7,8 column 2, lines 61-68 - column 3, lines 1-7</td>
<td>1-5, 8-10</td>
</tr>
<tr>
<td>X</td>
<td>JP S60 92618 U (UNKNOWN) 25 June 1985 (1985-06-25) figures 1-6</td>
<td>1-4, 8-10</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

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Authorized officer:
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
<tr>
<td>X</td>
<td>JP S59 21164 U (UNKNOWN) 8 February 1984 (1984-02-08) figures 1-4</td>
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</tr>
<tr>
<td>A</td>
<td>-----</td>
<td>3,4</td>
</tr>
<tr>
<td>X</td>
<td>JP S59 203860 A (NAKAMURA SHIROU) 19 November 1984 (1984-11-19) abstract figure 1</td>
<td>1,8-10</td>
</tr>
<tr>
<td>A</td>
<td>-----</td>
<td>3</td>
</tr>
<tr>
<td>X</td>
<td>JP S59 54310 U (UNKNOWN) 10 April 1984 (1984-04-10) abstract figure 1</td>
<td>1,5-10</td>
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<tr>
<td>A</td>
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<td>3</td>
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<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
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<tr>
<td>GB 2011273 A 11-07-1979</td>
<td>AT 376020 B 10-10-1984</td>
<td></td>
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<tr>
<td>DE 2854866 AI 05-07-1979</td>
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<tr>
<td>DE 7837590 UI 10-04-1980</td>
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<tr>
<td>FR 2413558 AI 27-07-1979</td>
<td></td>
<td></td>
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<tr>
<td>GB 2011273 A 11-07-1979</td>
<td></td>
<td></td>
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<tr>
<td>IT 1091641 B 06-07-1985</td>
<td></td>
<td></td>
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<tr>
<td>SE 441464 B 07-10-1985</td>
<td></td>
<td></td>
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<tr>
<td>US 4212659 A 15-07-1980</td>
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<tr>
<td>US 3791112 A 12-02-1974</td>
<td>CA 965660 AI 08-04-1975</td>
<td></td>
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<tr>
<td>JP S4866165 U 22-08-1973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP S5222696 Y2 24-05-1977</td>
<td></td>
<td></td>
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<tr>
<td>US 3791112 A 12-02-1974</td>
<td></td>
<td></td>
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<tr>
<td>JP S6092618 U 25-06-1985</td>
<td>NONE</td>
<td></td>
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<tr>
<td>JP S5921164 U 08-02-1984</td>
<td>NONE</td>
<td></td>
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<tr>
<td>JP S59203860 A 19-11-1984</td>
<td>NONE</td>
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<tr>
<td>JP S5954310 U 10-04-1984</td>
<td>NONE</td>
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