A charge air cooler for a forced induction engine

Abstract Title: A Charge Air Cooler for a Forced Induction Engine

A charge air cooler 5 is disclosed in which a flow control flap 25; 125 is located in an inlet manifold 11 of the charge air cooler 5 to control the direct flow of charge air to a predefined number of charge air flow passages 16L in a heat exchanger core 10. The flap 25; 125 is rotatable by either a stepper motor 21 or by the mass flow of charge air between a minimum flow position 25a; 125a and a full flow position 25b; 125b. When there is a high risk of condensation occurring in the charge air flow passages 16, the minimum flow deflection position 25a; 125a is used, with the majority of the charge air flowing through the non-restricted charge air flow passages 16U. When there is little risk of condensation forming in the charge air flow passages 16, the flap 125 is moved to the full flow position 25b.

Fig.3a
A Charge Air Cooler for a Forced Induction Engine

This invention relates to a charge air cooler for a forced induction engine and in particular to a charge air cooler constructed to reduce the risk of condensation forming within the charge air cooler.

The function of charge air cooling is to reduce the temperature of the charge air that is consumed by an engine for combustion and power generation. The use of forced induction by either an exhaust-driven compressor (Turbocharging) or a belt-driven compressor (Supercharging) increases the pressure of the charge air, which helps generate more power by giving a larger mass of air to the engine but, as is well known in the art, increasing the pressure of the charge air will result in a rise in the temperature of the charge air exiting the compressor.

A Charge Air Cooler (CAC) is typically an air-cooled heat exchanger placed in the bulk airflow of a vehicle as it moves forward. The CAC uses the temperature of the ambient air to dissipate heat from the charge air as it passes through a heat exchanger core of the CAC. In some operating conditions such as, for example when the engine is operating at low engine load for an extended period of time at a moderate engine speed in a high relative humidity climate the CAC can reduce the temperature of the charge air to such a point where it drops below the dew point (i.e. the temperature at which condensation of moisture in the air occurs) and pooling of liquid water (condensation) can accumulate in the charge air flow passages of the CAC.

If the driver of the vehicle increases the load on the engine by opening the throttle when there is condensation in the charge air flow passages of the CAC, some of this condensation can be ingested in to the engine and the driver
can experience several seconds of engine hesitation as the water droplets cool the combustion chamber and do not allow proper fuel combustion to occur.

The primary cause of this condensation problem is that a conventional CAC has to be designed and sized for all vehicle operating conditions including very high engine load demand scenarios where external airflow might be limited such as, for example, low speed trailer towing up a steep hill. As a result, in low load high humidity scenarios the CAC provides too much cooling to the charge air and condensation is formed in the charge air passages used to transport the charge air through the heat exchanger core of the CAC.

It is an object of the invention to provide a charge air cooler constructed so as to reduce the risk of condensation occurring in low load high humidity scenarios while maintaining a high level of cooling capacity for high load scenarios.

According to a first aspect of the invention there is provided a charge air cooler for a forced induction engine comprising a central heat exchanger core having a number of charge air flow passages and a number of coolant flow passages, an inlet manifold to direct charge air to the charge air passages and an outlet manifold to collect charge air from the charge air flow passages and flow it out from the charge air cooler wherein a flow control flap is located in the inlet manifold to control the flow of charge air from an inlet of the inlet manifold to inlet ends of a predefined number of the charge air flow passages, the flow control flap being rotatable between a minimum flow position in which the direct flow of charge air from the inlet of the inlet manifold to the predefined number of charge air flow passages is restricted and a full flow position in which
there is substantially no restriction to the direct flow of charge air to any of the charge air flow passages.

When the flow control flap is in the full flow position, the flow control flap may divide the inlet manifold into first and second chambers and the inlet ends of the predefined number of charge air flow passages may all be located in the first chamber.

When the flow control flap is in the full flow position, the flow control flap may divide the inlet manifold into first and second chambers and the direct flow of charge air to the inlet ends of the charge air flow passages located in the second chamber may remain unrestricted irrespective of the position of the flow control flap.

When the flow control flap is in the full flow position, the flow control flap may be aligned with one of the coolant flow passages of the central heat exchanger core so that there is no restriction to direct flow to any of the charge air flow passages.

The flow control flap may be connected along one edge to a rotatable shaft.

The rotatable shaft may be driven by an actuator to move the flow control flap between the minimum and full flow positions.

The actuator may be an electric motor.

Alternatively, the flow control flap may be moved between the minimum and full flow positions by the action of the charge air impinging thereupon such that when the mass flow of charge air passing through the charge air cooler is below a predefined low mass flow limit the flow control flap
is in the minimum flow position and when the mass flow of charge air passing through the charge air cooler exceeds a predefined high mass flow limit the flow control flap is in the full flow position.

According to a second aspect of the invention there is provided a motor vehicle having a charge air cooler constructed in accordance with said first aspect of the invention.

According to a third aspect of the invention there is provided a system for reducing the risk of condensation forming in a charge air cooler constructed in accordance with said first aspect of the invention having an actuator to move the flow control flap in which the system includes an electronic controller to control the operation of the actuator and at least one input to the electronic controller indicative of the risk of condensation occurring in the charge air cooler wherein the electronic controller is operable to control the actuator in response to the input indicative of the risk of condensation occurring in the charge air cooler so as to minimise the risk of condensation occurring.

Controlling the actuator in response to the input indicative of the risk of condensation occurring in the charge air cooler so as to minimise the risk of condensation occurring may comprise moving the flow control valve towards the minimum flow position to restrict the flow of charge air through the predefined number of charge air passages as the risk of condensation is increased.

According to a fourth aspect of the invention there is provided a motor vehicle having a system constructed in accordance with said third aspect of the invention.
The invention will now be described by way of example with reference to the accompanying drawing of which:

Fig.1 is a front view of a charge air cooler for a forced induction engine constructed in accordance with a first aspect of the invention;

Fig.2 is a plan view of the charge air cooler shown in Fig.1;

Fig.3a is a scrap cross-section on an enlarged scale through an inlet manifold of the charge air cooler shown in Figs.1 and 2 showing a flow control device in minimum and full flow positions;

Fig.3b is an enlarged end view in the direction of arrow E on Fig.3a of a single charge air flow tube;

Fig.4 is a scrap cross-section on an enlarged scale through an inlet manifold of a charge air cooler intended as a direct replacement for that shown in Figs.1 and 2 showing a second embodiment of a flow control device in minimum and full flow positions; and

Fig.5 is a schematic representation of a motor vehicle constructed in accordance with second and fourth aspects of the invention.

With reference to figures 1 to 3b and 5 there is shown a motor vehicle 1 having a pair of front road wheels 7f, a pair of rear road wheels 7r and an engine 2. The engine 2 is arranged to drive two or more of the road wheels 7f, 7r by means of a driveline (not shown).

A compressor 3 is provided upstream of the engine 2 to compress the ambient air being flowed to the engine 2. The
compressor 3 can be in the form of a supercharger or a compressor of a turbocharger.

Ambient air is drawn into the compressor 3 via an intake duct 4a and the compressed charge air flows from the compressor 3 to a charge air cooler 5 via a secondary intake duct 4b. The charge air cooler 5 is positioned downstream from the compressor 3 so as to cool the charge air passing therethrough. The cooled charge air passes from the charge air cooler 5 to the engine 2 via an inlet duct 4c. Exhaust gas flows out of the engine 2 and back to atmosphere via an exhaust system 6 which as is well known in the art and which may include one or more exhaust aftertreatment device and one or more sound deadening devices.

A flow control system is shown in Fig.5 to vary the flow through the charge air cooler 5. The flow control system comprises an electronic controller 20 to control the operation of a flow control actuator 21, a number of control inputs 30 used by the electronic controller 20 to control the operation of the actuator 21 and a flow control device in the form of a flap 25 moved by the actuator 21.

The actuator is in this case in the form of an electric motor such as a stepper motor 21 and the electronic controller 20 uses pulse width modulation to control the operation of the stepper motor 21. The stepper motor 21 has a rotor shaft 22 that is fastened to one longitudinal edge of the flap 25 and a bearing (not shown) is provided at a free end of the rotor shaft 22 to rotatably support it.

When the flap 25 is in a minimum flow position it is designated as 25a on Fig.3 and when the flap 25 is in a full flow position it is designated 25b as shown in dotted outline on Fig.3. It will be appreciated that the flap 25 is moveable between these minimum flow (25a) and full flow (25b) positions by the stepper motor 21 in response to a
controlling signal received from the electronic controller 20.

The control inputs 30 will depend upon the specific method of control used in a particular embodiment but generally speaking the relative humidity of the ambient air will be required in all cases because this determines the likelihood of condensation forming and the potential magnitude of such condensation. The output from a humidity sensor is therefore normally one of the inputs 30 to the electronic controller 20. Other potential inputs are ambient air temperature, vehicle speed, throttle pedal position, the temperature of the charge air in the outlet manifold and the temperature of the charge air exiting the charge air passages 16. These inputs are used by the electronic controller 20 to control the position of the flap 25 in order to reduce the risk of condensation forming while providing sufficient cooling of the charge air.

The charge air cooler (CAC) 5 includes a central heat exchanger core 10, an inlet manifold 11 and an outlet manifold 13. Charge air enters the inlet manifold 11 as indicated by the arrow ‘IN’ on Fig.2 via an inlet conduit 12 that defines an air flow passage 12a and flows through the central heat exchanger core 10 via a number of charge air flow passages 16 defined by aluminium tubes 16t and out into the outlet manifold 13 and then passes out of the CAC 5 as indicated by the arrow ‘OUT’ on Fig.2 via an outlet conduit 14 to the engine 2 via the inlet duct 4c that is connected to the outlet conduit 14. Typically and without limitation, the central heat exchanger core 10 may be 0.5 to 0.65m long, 0.15m to 0.25m high and 0.05 to 0.075m deep.

Interposed between the tubes 16t in the central heat exchanger core 10 are coolant air flow passages 15 through which ambient air flows, as indicated by the arrow ‘F’ on Fig.2. Each of the coolant air flow passages 15 includes a
corrugated fin 15f to improve the transfer of heat between the ambient air passing through the coolant air flow passages 15 and the tubes 16t thereby increasing the cooling effect provided to the charge air passing through the charge air flow passages 16. It will be appreciated that the corrugated fins 15f are welded or brazed to the tubes 16t to increase the conduction of heat therebetween.

The flap 25 is positioned in the inlet manifold 11 between an inlet to the inlet manifold formed by the air flow passage 12a and inlet ends of the charge air flow passages 16. The flap 25 extends longitudinally for substantially the full depth ‘d’ of the inlet manifold 11. A small clearance is required at each longitudinal end of the flap 25 between the flap 25 and a respective end wall of the inlet manifold 11 to permit the flap 25 to move freely.

In the embodiment shown a barrier wall 11w is positioned between the shaft 22 of the stepper motor 21 and the air flow passage 12a to divide the inlet manifold into first and second chambers 11L and 11U when the flap 25 is in the full flow position. Advantageously, the positioning of the flap 25 in the full flow position 25b is such that is aligned with one of the coolant flow passages 15 indicated as 15x on Fig.3a. This ensures that there is no restriction to the flow of charge air into any of the tubes 16t when the flap 25 is in this position.

The inlet ends of a predefined number of charge air flow passages 16L are located in the first chamber 11L and the inlet ends of the remaining charge air flow passages 16U are located in the second chamber 11U. The flap has no controlling effect on the direct flow of charge air to the charge air flow passages 16U located in the second chamber 11U. That is to say, the flap 25 only controls the direct flow of charge air to the predefined number of charge air
flow passages 16L having inlet ends located in the first chamber 11L.

When the flap 25 is in the minimum flow deflecting position 25a the direct flow of charge air through the predefined number of charge air flow passages 16L is considerably restricted due to the position of the flap 25 between the inlet formed by the air flow passage 12a and the inlet ends of these charge air flow passages 16L. Although some charge air can pass into these charge air flow passages, the momentum of the charge air flowing into the unrestricted charge air flow passages 16U means that the flow of charge air through the predefined charge air flow passages 16L is minimal.

Therefore, when there is a risk of condensation occurring, the charge air flow will principally be through only a few of the tubes 16t thereby ensuring that the volume or mass of charge air flowing through these passages is sufficient to prevent condensation occurring. However, when there is a large mass flow of charge air through the charge air cooler 5, the need is primarily for charge air cooling and there is little risk of condensation forming. Therefore in such conditions the flap 25 is moved to the full flow position 25b thereby maximising the cooling provided by the charge air cooler 5 by utilising all of the tubes 16t.

It will be appreciated that the flap 25 does not physically close off any of the tubes 16t and so is not a valve it merely restricts the flow of charge air to the predefined number of charge air flow passages 16L when the flap 25 is in the minimum flow position 25a.

It will be appreciated that even when the flap 25 is in the minimum flow deflecting position 25a there are a number of charge air flow passages 16U through which the charge air flows in an unrestricted manner.
When the flap 25 is moved to the full flow position 25b there is very little restriction to the flow of charge air passing through the inlet manifold 11 and so substantially the same mass flow of charge air will flow through all of the charge air passages 16. It will be appreciated that there may be small differences due to the design of the inlet manifold 11 and the resulting gas dynamics within the inlet manifold 11.

Operation of the charge air flow control system is as follows.

The electronic controller 20 uses the control inputs it receives to determine the likely risk of condensation and what action is required to reduce the risk of condensation occurring while providing sufficient cooling to the charge air.

For example, the time spent at the same speed, average pedal position for predefined period of time, relative humidity, torque demand from the engine over a predefined period of time (for example 30 minutes) could be used to determine the probability of condensation occurring.

Current torque demand from the engine can be used to infer the current cooling needs of the charge air and the two sets of parameters (condensation risk and cooling requirement) can be used by the electronic controller 20 to provide an output to the stepper motor 21 to produce a desired flap position.

If, for example, the condensation risk parameter exceeds a pre-defined cut-off point (high risk of condensation limit), the flap 25 would be moved to the minimum flow position 25a so that only a limited number of the charge air passages 16U of the central heat exchanger
core 10 are fully utilised thereby limiting the cooling effectiveness of the CAC 5. Conversely, if the condensation risk parameter does not exceed the pre-defined cut-off point, the flap 25 would be moved to the full flow position 25b so that all of the charge air passages 16 of the central heat exchanger core 10 are fully utilised thereby maximising the cooling effectiveness of the CAC 5. In a case where the cooling parameter indicates an immediate need for cooling of the charge air such as, for example, a demand for maximum torque from the engine, then the flap 25 could be moved immediately to the full flow position 25b because the risk of condensation occurring is then minimal.

Alternatively, the parameters could be used vary the position of the flap 25 in a step manner so that it is moved in predefined increments from the minimum flow deflecting position 25a towards the full flow position 25b as the need for cooling increases and the risk of condensation reduces and from the full flow position 25b towards the minimum flow position 25a as the need for cooling reduces and the risk of condensation increases.

It will be appreciated that the relationship between risk of condensation and need for cooling is not a fixed relationship but will depend upon many factors including, but not limited to, the current relative humidity and the ambient temperature. For example, in a climate where the relative humidity is very low and the ambient temperature is very high there is substantially no risk of condensation occurring and so the control of the flap 25 can be biased to keep the flap 25 in the full flow position 25b even if the torque demand from the engine is low. Whereas, in the case of a climate where the relative humidity is very high and the ambient temperature is low, there is a far greater risk of condensation occurring and so the control of the flap 25 can be biased to keep the flap 25 more towards the minimum flow position 25a even if the torque demand from the engine
is not particularly low. That is to say, the electronic controller 20 preferably adapts to the climate in which the motor vehicle 1 is operating so as to optimise the control of the flap 25.

Although an electrical actuator is shown and described it will be appreciated that other types of actuator could be used such as for example a pneumatic actuator or a hydraulic actuator. Furthermore it will be appreciated that there could be a mechanical linkage or gearing between the actual actuator and the flap.

With reference to Fig.4 there is shown an alternative embodiment of a flow control system that is intended to be a direct replacement for the flow control system shown in Figs.3a, 3b and 5. Identical parts use the same reference numbers and will not be described again in detail modified parts have number 100 added to them.

The primary difference between this embodiment and that previously described is that the flap 125 is not moved by an actuator it is moved by the flow of charge air flowing through the charge air cooler 5. Although such an arrangement is less accurate than the use of a powered system it is less expensive to manufacture and so is particularly suited to use on less expensive motor vehicles.

As before, when the flap 125 is in a minimum flow position it is designated as 125a on Fig.3 and when the flap 125 is in a full flow position it is designated 125b as shown in dotted outline on Fig.4.

As before, a barrier wall 11w is positioned between a rotatable shaft 122 and the air flow passage 12a to divide the inlet manifold into first and second chambers 11L and 11U when the flap 125 is in the full flow position 125b.
Advantageously, the positioning of the flap 125 in the full flow position 125b is such that is aligned with one of the coolant flow passages 15 (indicated as 15x on Fig.4). This positioning ensures that there is no restriction to the flow of charge air into any of the tubes 16t when the flap 125 is in this position.

The inlet ends of a predefined number of charge air flow passages 16L are located in the first chamber 11L and the inlet ends of the remaining charge air flow passages 16U are located in the second chamber 11U. The flap 125 has no controlling effect on the direct flow of charge air to the charge air flow passages 16U located in the second chamber 11U. That is to say, the flap 125 only controls or restricts the direct flow of charge air to the predefined number of charge air flow passages 16L having inlet ends located in the first chamber 11L.

When the flap 125 is in the minimum flow position 125a the direct flow of charge air through the predefined number of charge air flow passages 16L is considerably restricted due to the position of the flap 125 between the inlet formed by the air flow passage 12a and the inlet ends of these charge air flow passages 16L. Although some charge air can pass into these charge air flow passages, the momentum of the charge air flowing into the unrestricted charge air flow passages 16U means that the flow of charge air through the predefined charge air flow passages 16L is minimal.

Therefore, when there is a risk of condensation occurring, the charge air flow will be through only a few of the tubes 16t thereby ensuring that the mass flow of charge air flowing through these charge air flow passages 16U is sufficient to prevent condensation occurring. However, when there is a large mass flow of charge air through the charge air cooler 5, the need is primarily for charge air cooling and there is little risk of condensation forming. Therefore
in such conditions the flap 125 is moved by the mass flow of charge air to the full flow position 125b thereby maximising the cooling provided by the charge air cooler by utilising all of the tubes 16t.

It will be appreciated that the flap 125 does not physically close off any of the tubes 16t and so is not a valve it merely restricts the flow of charge air to the predefined number of charge air flow passages 16L when the flap 125 is in the minimum flow position 25a.

It will be appreciated that even when the flap 125 is in the minimum flow deflecting position 125a there are a number of charge air flow passages 16U through which the charge air flows in an unrestricted manner.

The flap 125 is weighted to only move to the full flow position 125b when the mass flow demand of the engine increases above a predefined threshold. A weight 126 could be fastened to the flap 125 to achieve the correct operation if an un-weighted flap 125 is found to move to the full flow position 125b at too low a mass flow rate.

It will be appreciated by those skilled in the art that although the invention has been described by way of example with reference to one or more embodiments it is not limited to the disclosed embodiments and that alternative embodiments could be constructed without departing from the scope of the invention as defined by the appended claims.
Claims

1. A charge air cooler for a forced induction engine comprising a central heat exchanger core having a number of charge air flow passages and a number of coolant flow passages, an inlet manifold to direct charge air to the charge air passages and an outlet manifold to collect charge air from the charge air flow passages and flow it out from the charge air cooler wherein a flow control flap is located in the inlet manifold to control the flow of charge air from an inlet of the inlet manifold to inlet ends of a predefined number of the charge air flow passages, the flow control flap being rotatable between a minimum flow position in which the direct flow of charge air from the inlet of the inlet manifold to the predefined number of charge air flow passages is restricted and a full flow position in which there is substantially no restriction to the direct flow of charge air to any of the charge air flow passages.

2. A cooler as claimed in claim 1 wherein, when the flow control flap is in the full flow position, the flow control flap divides the inlet manifold into first and second chambers and the inlet ends of the predefined number of charge air flow passages are all located in the first chamber.

3. A cooler as claimed in claim 1 wherein, when the flow control flap is in the full flow position, the flow control flap divides the inlet manifold into first and second chambers and the direct flow of charge air to the inlet ends of the charge air flow passages located in the second chamber remains unrestricted irrespective of the position of the flow control flap.

4. A cooler as claimed in any of claims 1 to 3 wherein, when the flow control flap is in the full flow position, the flow control flap is aligned with one of the
coolant flow passages of the central heat exchanger core so that there is no restriction to direct flow to any of the charge air flow passages.

5. A cooler as claimed in any of claims 1 to 4 wherein the flow control flap is connected along one edge to a rotatable shaft.

6. A cooler as claimed in claim 5 wherein the rotatable shaft is driven by an actuator to move the flow control flap between the minimum and full flow positions.

7. A cooler as claimed in claim 6 wherein the actuator is an electric motor.

8. A cooler as claimed in any of claims 1 to 5 wherein, the flow control flap is moved between the minimum and full flow positions by the action of the charge air impinging thereupon such that when the mass flow of charge air passing through the charge air cooler is below a predefined low mass flow limit the flow control flap is in the minimum flow position and when the mass flow of charge air passing through the charge air cooler exceeds a predefined high mass flow limit the flow control flap is in the full flow position.

9. A motor vehicle having a charge air cooler as claimed in any of claims 1 to 8.

10. A system for reducing the risk of condensation forming in a charge air cooler as claimed in claim 6 in which the system includes an electronic controller to control the operation of the actuator and at least one input to the electronic controller indicative of the risk of condensation occurring in the charge air cooler wherein the electronic controller is operable to control the actuator in response to the input indicative of the risk of condensation
occurring in the charge air cooler so as to minimise the risk of condensation occurring.

11. A system as claimed in claim 10 wherein
controlling the actuator in response to the input indicative of the risk of condensation occurring in the charge air cooler so as to minimise the risk of condensation occurring comprises moving the flow control valve towards the minimum flow position to restrict the flow of charge air through the predefined number of charge air passages as the risk of condensation is increased.

12. A motor vehicle having a system as claimed in claim 10 or in claim 11.

12. A charge air cooler for a forced induction engine substantially as described herein with reference to the accompanying drawing.

13. A motor vehicle substantially as described herein with reference to the accompanying drawing.

14. A system for reducing the risk of condensation forming in a charge air cooler substantially as described herein with reference to the accompanying drawing.
Amendments to the claims have been filed as follows

Claims

1. A charge air cooler for a forced induction engine comprising a central heat exchanger core having a number of charge air flow passages and a number of coolant flow passages, an inlet manifold to direct charge air to the charge air passages and an outlet manifold to collect charge air from the charge air flow passages and flow it out from the charge air cooler wherein a flow control flap is located in the inlet manifold to control the flow of charge air from an inlet of the inlet manifold to inlet ends of a predefined number of the charge air flow passages, the flow control flap is connected along one edge to a rotatable shaft and is rotatable between a minimum flow position in which the direct flow of charge air from the inlet of the inlet manifold to the predefined number of charge air flow passages is restricted so that there is a minimal flow of charge air through the predefined charge air flow passages and a full flow position in which there is substantially no restriction to the direct flow of charge air to any of the charge air flow passages.

2. A cooler as claimed in claim 1 wherein, when the flow control flap is in the full flow position, the flow control flap divides the inlet manifold into first and second chambers and the inlet ends of the predefined number of charge air flow passages are all located in the first chamber.

3. A cooler as claimed in claim 1 wherein, when the flow control flap is in the full flow position, the flow control flap divides the inlet manifold into first and second chambers and the direct flow of charge air to the inlet ends of the charge air flow passages located in the second chamber remains unrestricted irrespective of the position of the flow control flap.
4. A cooler as claimed in any of claims 1 to 3 wherein, when the flow control flap is in the full flow position, the flow control flap is aligned with one of the coolant flow passages of the central heat exchanger core so that there is no restriction to direct flow to any of the charge air flow passages.

5. A cooler as claimed in any of claims 1 to 4 wherein the rotatable shaft is driven by an actuator to move the flow control flap between the minimum and full flow positions.

6. A cooler as claimed in claim 5 wherein the actuator is an electric motor.

7. A cooler as claimed in any of claims 1 to 4 wherein, the flow control flap is moved between the minimum and full flow positions by the action of the charge air impinging thereupon such that, when the mass flow of charge air passing through the charge air cooler is below a predefined low mass flow limit, the flow control flap is in the minimum flow position and when the mass flow of charge air passing through the charge air cooler exceeds a predefined high mass flow limit the flow control flap is in the full flow position.

8. A motor vehicle having a charge air cooler as claimed in any of claims 1 to 7.

9. A system for reducing the risk of condensation forming in a charge air cooler as claimed in claim 5 in which the system includes an electronic controller to control the operation of the actuator and at least one input to the electronic controller indicative of the risk of condensation occurring in the charge air cooler wherein the electronic controller is operable to control the actuator in response to the input indicative of the risk of condensation
occurring in the charge air cooler so as to minimise the risk of condensation occurring.

10. A system as claimed in claim 9 wherein controlling the actuator in response to the input indicative of the risk of condensation occurring in the charge air cooler so as to minimise the risk of condensation occurring comprises moving the flow control valve towards the minimum flow position to restrict the flow of charge air through the predefined number of charge air passages as the risk of condensation is increased.

11. A motor vehicle having a system as claimed in claim 9 or in claim 10.

12. A charge air cooler for a forced induction engine substantially as described herein with reference to the accompanying drawing.

13. A motor vehicle substantially as described herein with reference to the accompanying drawing.

14. A system for reducing the risk of condensation forming in a charge air cooler substantially as described herein with reference to the accompanying drawing.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<td>WO 2004/040106 A1 (SCANIA) - Whole document, especially figure 1</td>
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F02B

The following online and other databases have been used in the preparation of this search report

EPODOC WPI
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