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Sturmon et al.

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(54) **AIR MANAGEMENT SYSTEM FOR HEAVY DUTY TRUCK UNDER-HOOD HEAT CONTROL**

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B60K 11/04 (2006.01)

(52) **U.S. Cl.**
USPC **180/68.1**; 180/68.4

(58) **Field of Classification Search**
USPC 180/2.1, 2.2, 68.1, 68.2, 68.4, 68.6; 293/193.09, 193.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,232,368	A	2/1966	Sullivan	
3,836,191	A *	9/1974	Gotz	296/190.01
4,114,714	A	9/1978	Fachbach et al.	
4,235,298	A *	11/1980	Sackett et al.	180/68.3
4,382,481	A *	5/1983	Moore	180/68.1
4,417,636	A	11/1983	Mazur	
4,519,343	A	5/1985	Hayashi et al.	
4,597,463	A	7/1986	Barnard	
4,598,786	A *	7/1986	Kirchweger	180/68.1
4,706,615	A	11/1987	Scadding	

(Continued)

OTHER PUBLICATIONS

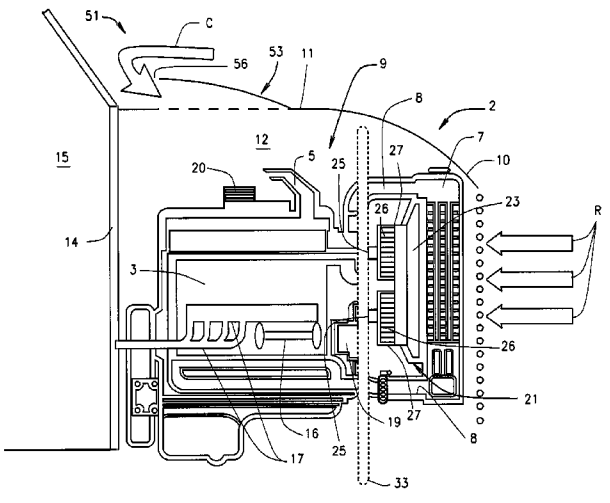
Mark O'Connell, "Will underhood heat issues with 2007 diesel engines cause 2002 maintenance flashbacks?" Fleet Maintenance, Feb. 2007. Available at http://archives.fleetmag.com/publication/article.jsp?pubID=1&id=138.

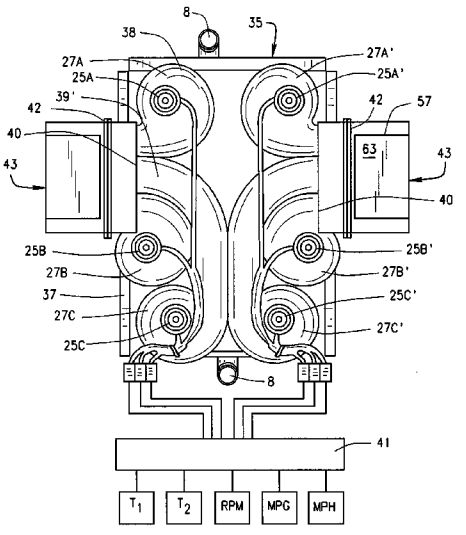
Primary Examiner — Frank Vanaman
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(57) **ABSTRACT**

A system for removing heat from the engine compartment (**9**) of a heavy duty truck. A first ventilating system removes heat from the radiator. It is isolated from a second ventilating system that removes heat from the engine compartment. The first system takes heat from the radiator through a plenum by centrifugal squirrel cage blowers, and is directs it out to ambient by ductwork. The second system draws ambient air generally from back to front of the engine compartment, preferably by cowl induction, without the use of ram air from the vicinity of the radiator. The exits of the two systems are into a slip stream of the heavy duty truck, and the exit of the second ventilating system is into a slip stream of the first, to scavenge air out of the engine compartment.

19 Claims, 7 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

4,723,594	A *	2/1988	Koehr et al.	165/44
4,726,326	A	2/1988	Charles et al.	
4,840,221	A	6/1989	Dumas et al.	
4,911,135	A	3/1990	Nishimura et al.	
4,971,172	A	11/1990	Hoffman et al.	
4,979,584	A	12/1990	Charles	
5,042,603	A	8/1991	Olson	
5,046,554	A	9/1991	Iwasaki et al.	
5,181,554	A	1/1993	Mita	
5,193,609	A	3/1993	Cowart	
5,234,051	A	8/1993	Weizenburger et al.	
5,495,909	A	3/1996	Charles	
5,579,858	A *	12/1996	Petersen et al.	180/68.3
5,588,482	A	12/1996	Holka	
5,590,624	A *	1/1997	Emond et al.	123/41.49
5,775,450	A	7/1998	Porter et al.	
6,059,061	A *	5/2000	Economoff et al.	180/68.1
6,142,213	A	11/2000	Gallivan et al.	
6,216,778	B1	4/2001	Corwin et al.	
6,230,832	B1	5/2001	von Mayenburg et al.	
6,401,801	B1	6/2002	Dicke	
6,491,502	B2	12/2002	Hunt	
6,564,857	B1	5/2003	Zobel et al.	
6,655,486	B2	12/2003	Oshikawa et al.	
6,732,681	B1	5/2004	Hendricks, Sr.	
6,809,484	B2	10/2004	Makaran et al.	
6,837,194	B2	1/2005	Banzhaf et al.	
6,840,743	B2	1/2005	Herke et al.	
7,028,751	B2	4/2006	Fischer et al.	
7,406,835	B2	8/2008	Allen et al.	
2001/0029907	A1	10/2001	Algrain et al.	
2002/0152766	A1	10/2002	Fischer et al.	
2005/0029027	A1 *	2/2005	Kunikata et al.	180/68.1
2005/0224267	A1	10/2005	Callas	

* cited by examiner

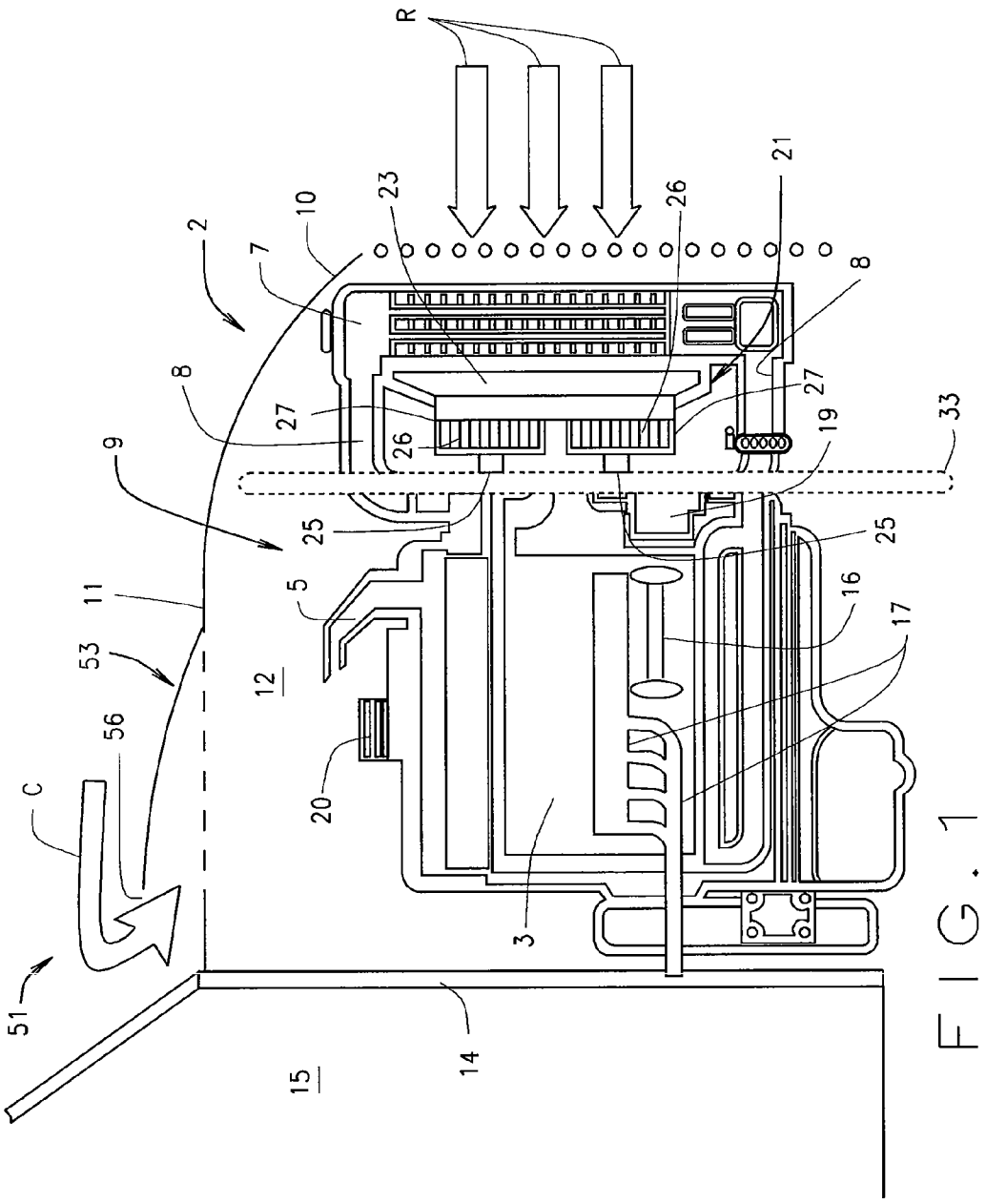


FIG. 1

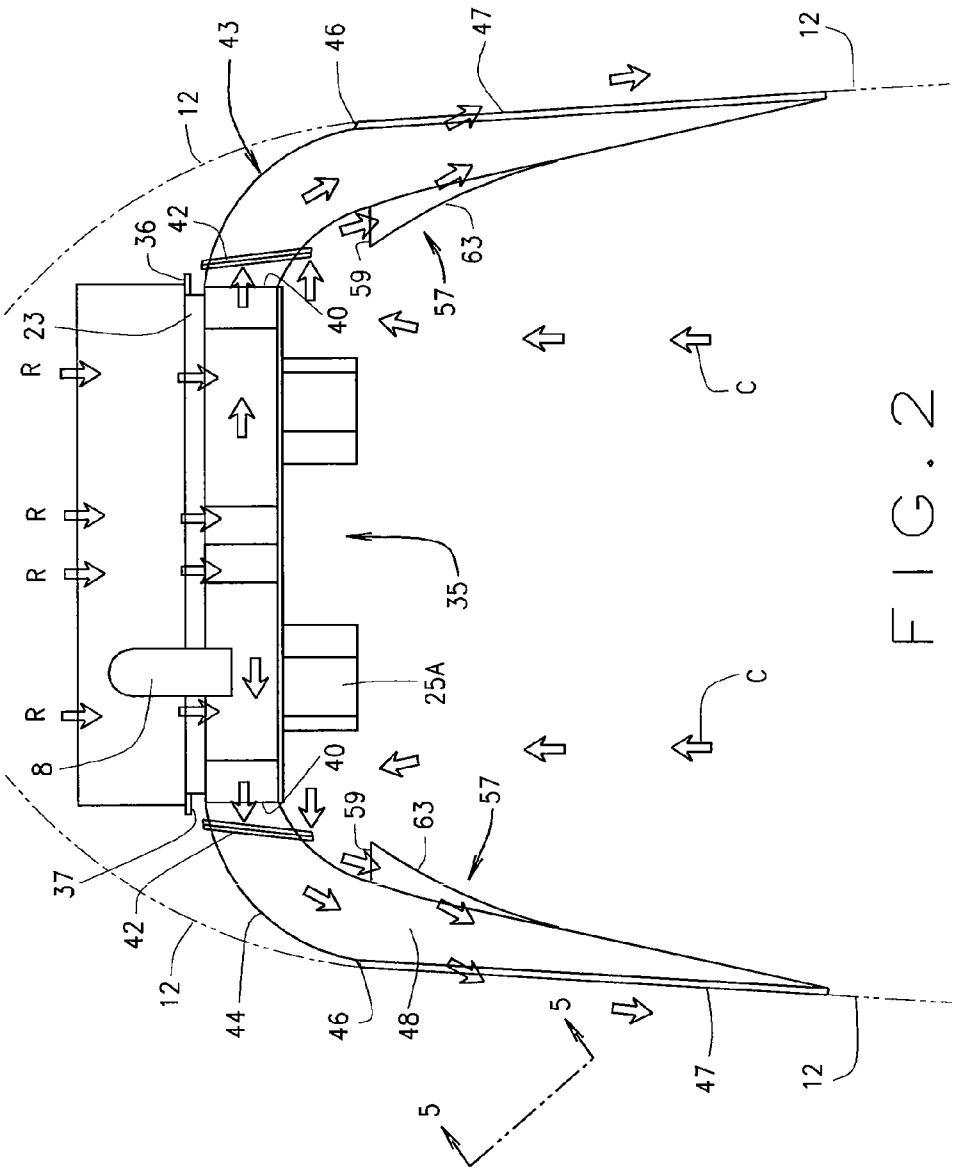

43
46
47
12
12
36
42
63
59
57
40
R 23
R
R
R
8
35
25A
C
C
37
42
12
44
46
48
5
5
47
12

FIG. 2

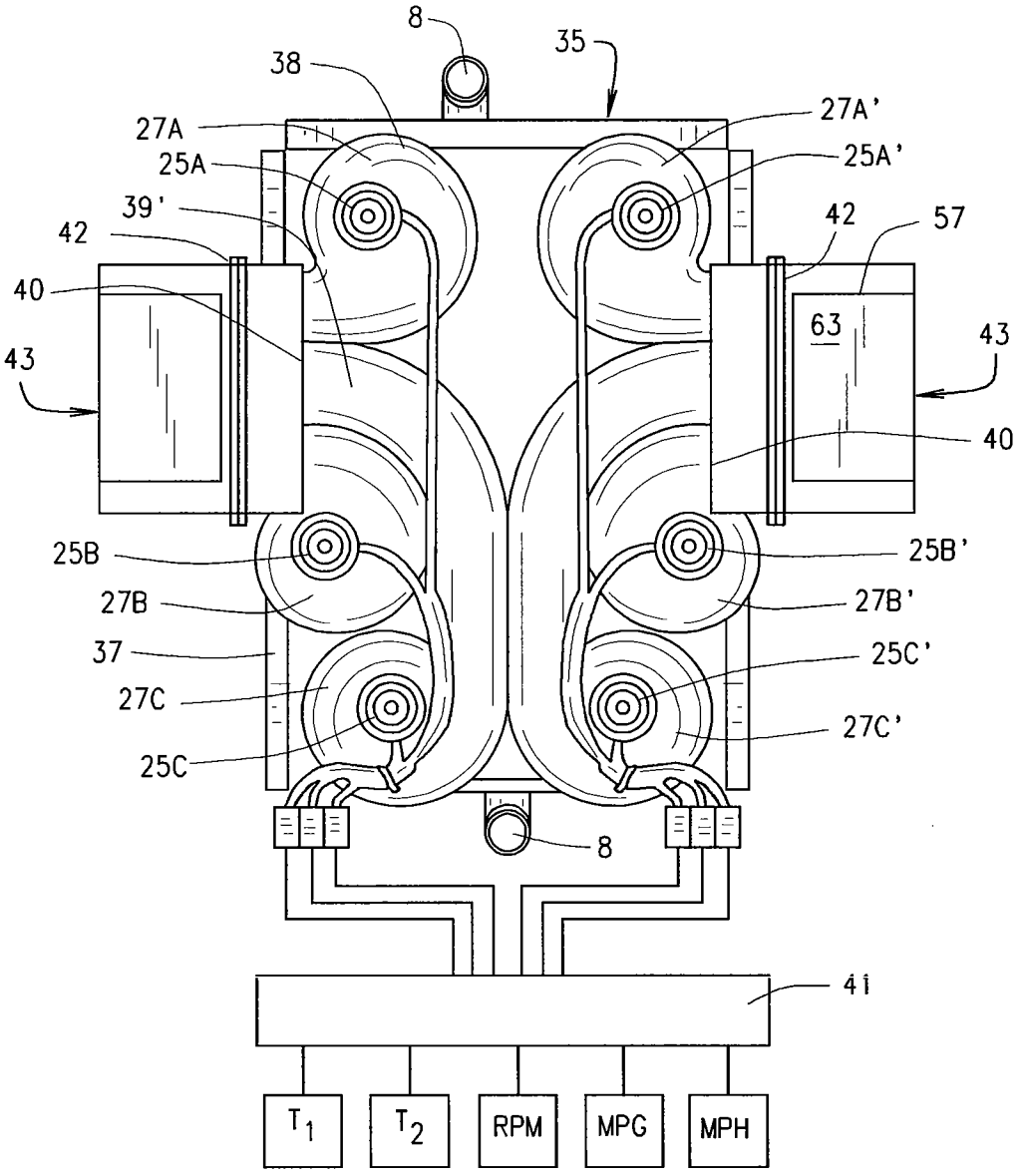

8
35
38
27A
27A'
25A
25A'
39'
42
42
57
40
63
43
43
40
25B
25B'
27B
27B'
37
25C'
27C
27C'
25C
8
41
T1
T2
RPM
MPG
MPH

FIG. 3

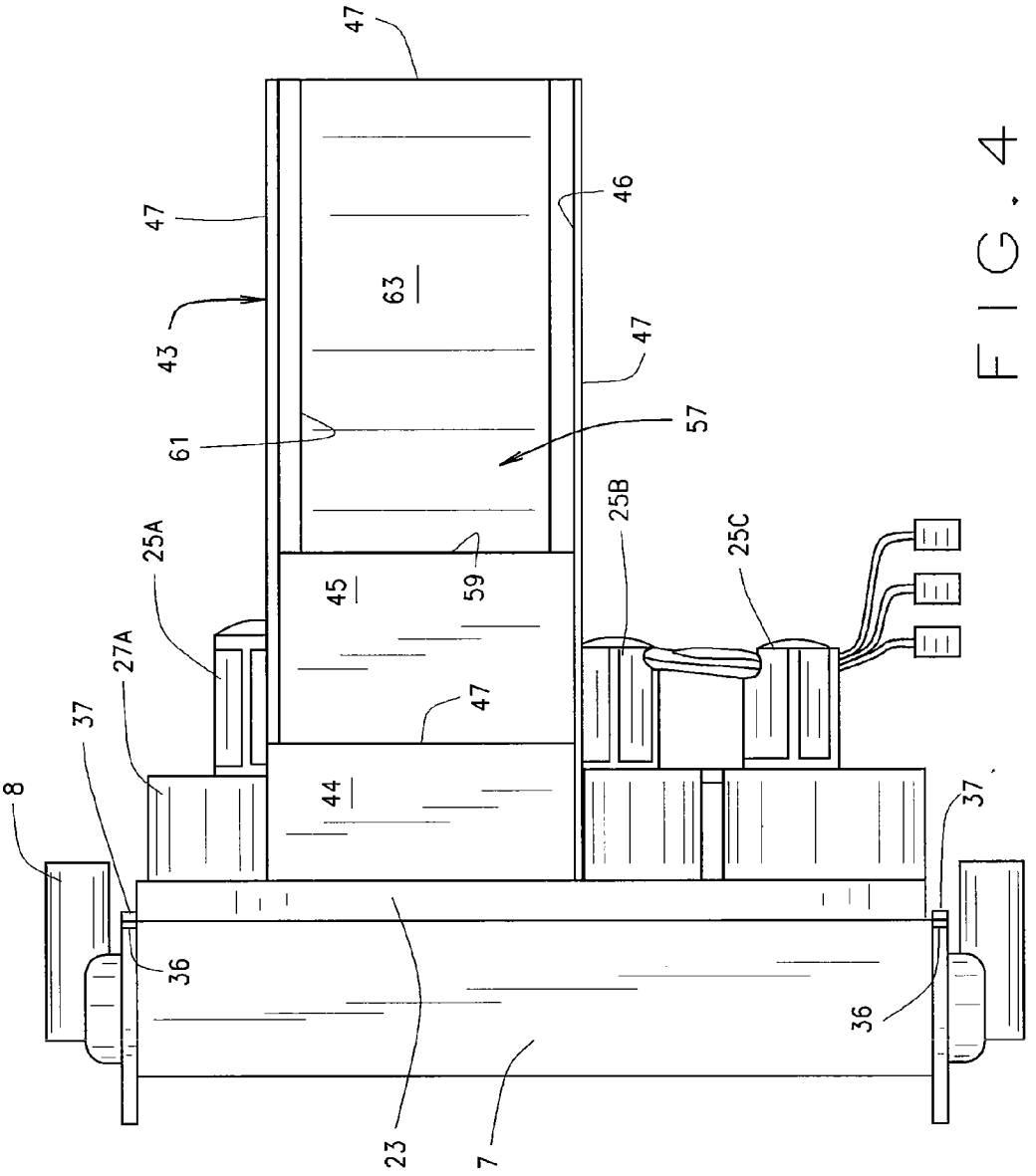


FIG. 4

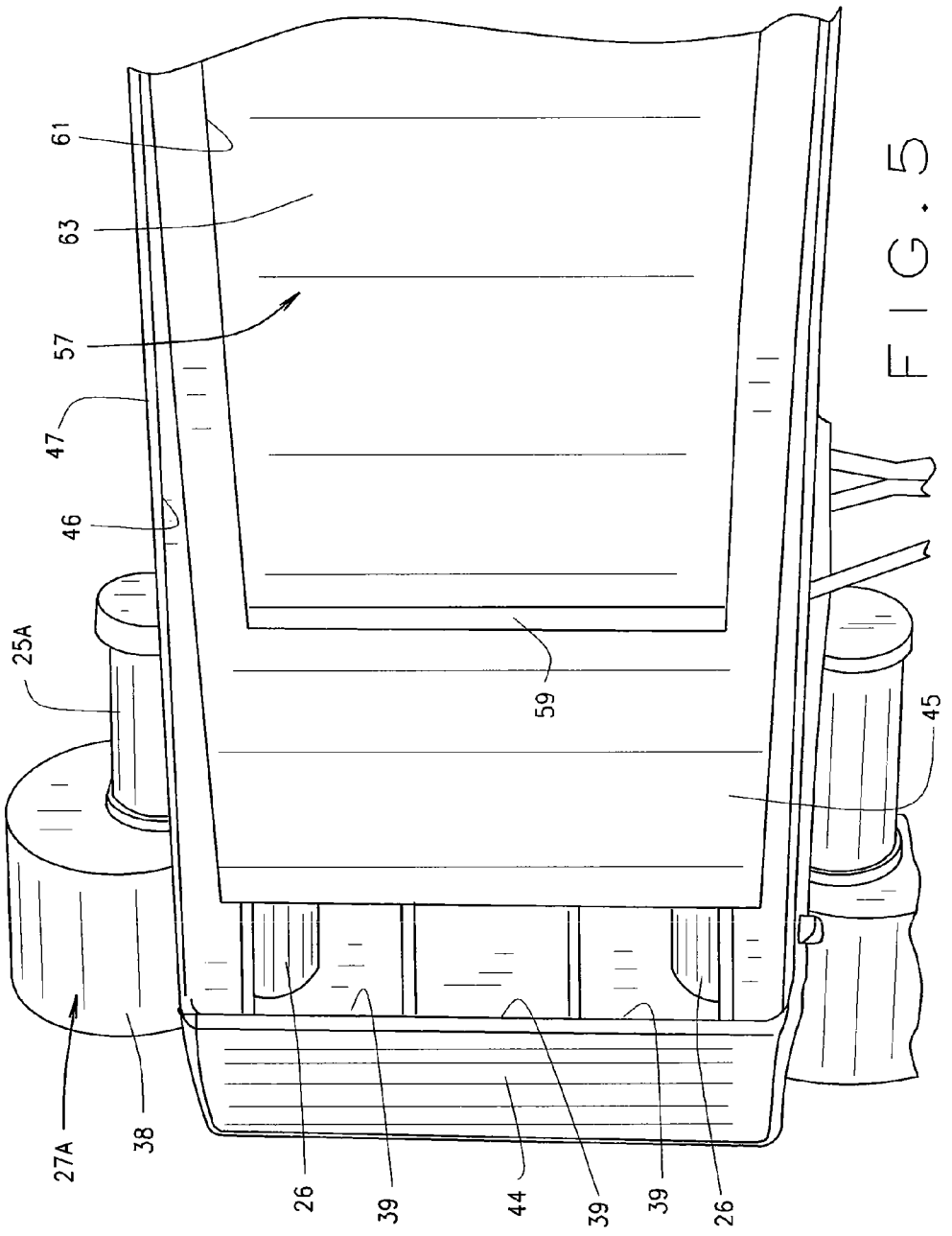


FIG. 5

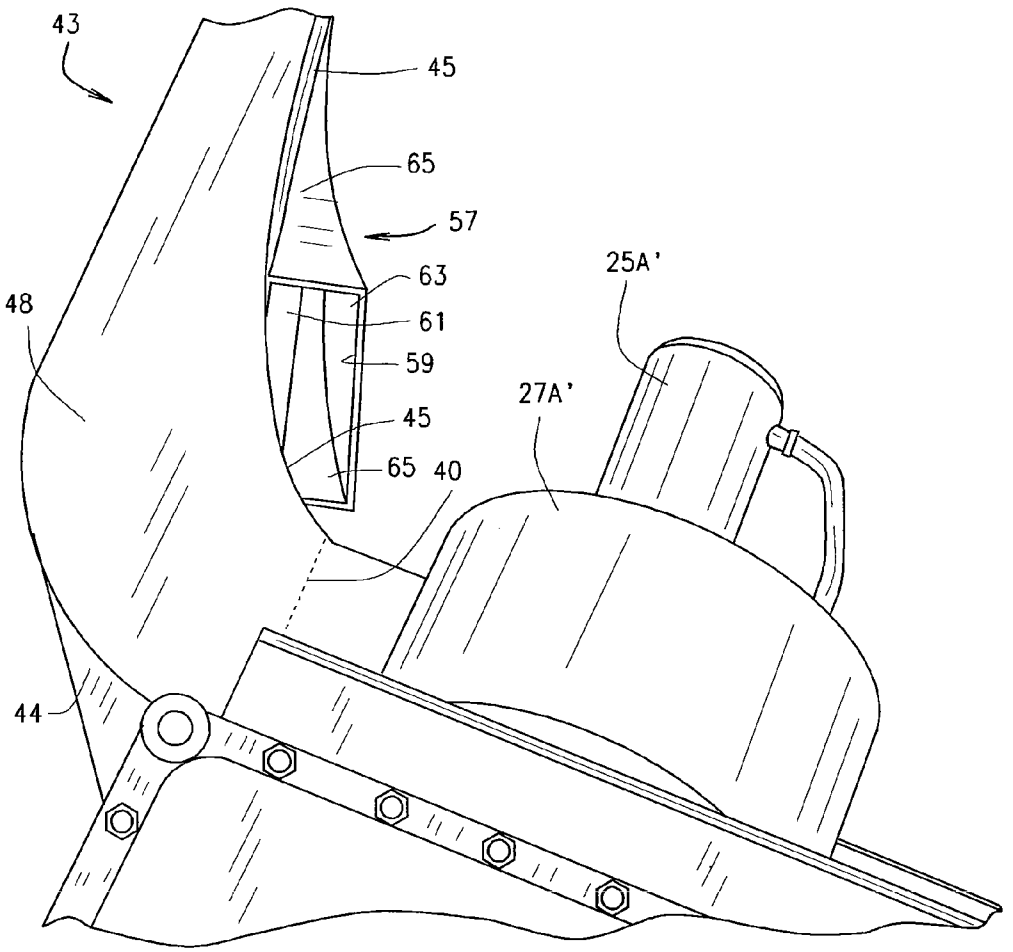


FIG. 6

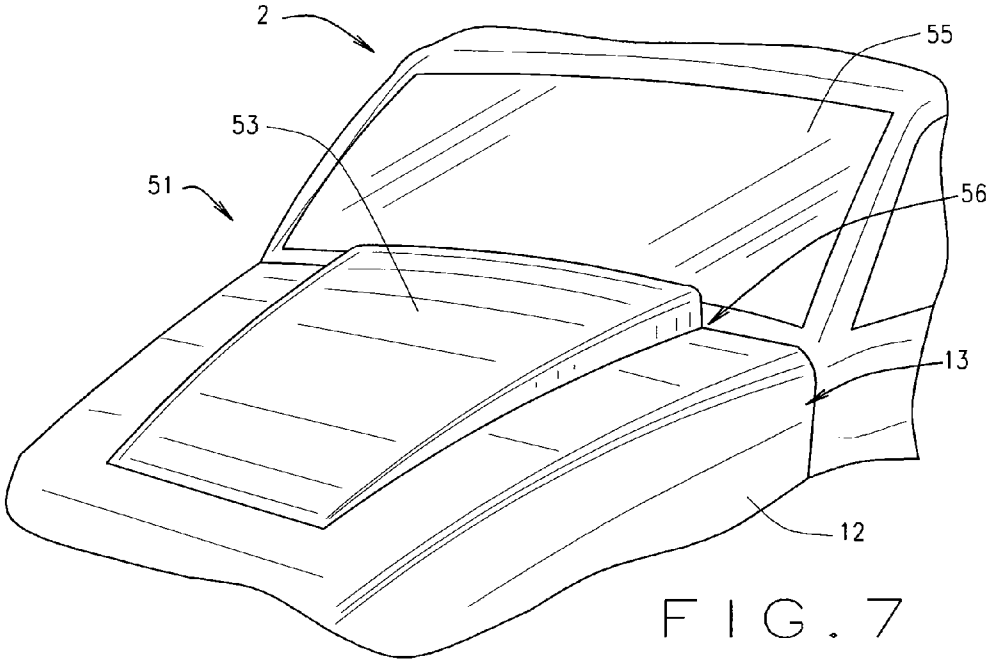


FIG. 7

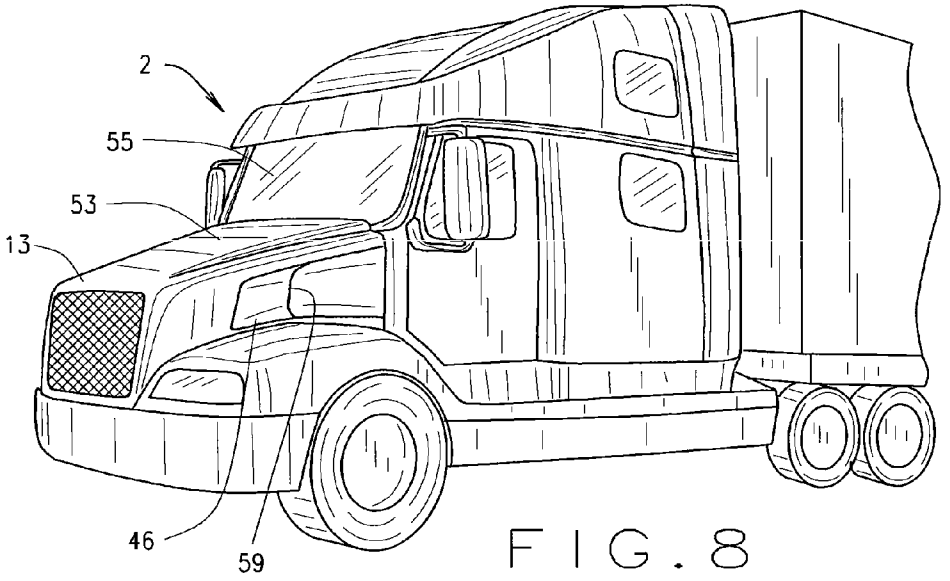


FIG. 8

AIR MANAGEMENT SYSTEM FOR HEAVY DUTY TRUCK UNDER-HOOD HEAT CONTROL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Non-Provisional application Ser. No. 11/932,393 filed Oct. 31, 2007 and PCT/US0783190 filed Oct. 31, 2007, and is related to and claims the benefit of U.S. Provisional Application 60/863,740, filed Oct. 31, 2006, the disclosures of all which are hereby incorporated by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

Not Applicable.

BACKGROUND OF THE INVENTION

This invention relates to systems for reducing temperatures under the hood of a vehicle. It has particular, but not exclusive, application to such systems for use in a heavy duty truck, more particularly to the tractor portion of a tractor-trailer rig. Heavy duty trucks are typically over-the-road and vocational vehicles considered as weight class 4 to 8. Class 4 is generally considered to include vehicles with a gross vehicle weight of 14,001 lb to 16,000 lb (6350 kg to 7257 kg). The invention is particularly useful with weight class 6 to 8 vehicles, most particularly class 7 to 8 vehicles. Class 6 includes vehicles with a gross vehicle weight of 19,501 lb to 26,000 lb (8846 kg to 11,793 kg). Class 7 vehicles have a gross vehicle weight of 26,001 lb to 33,000 lb (11,794 kg to 14,969 kg).

Vocational heavy duty trucks are adapted for various off-road jobs such as concrete mixer trucks, log-hauling trucks and other trucks which carry heavy loads and are required to operate over rough and uneven ground under off-road conditions. Such trucks are generally also capable of on-road highway travel.

The internal combustion engine of a heavy duty truck produces great quantities of heat. Heat is taken from the engine block by a liquid coolant system, including a radiator spaced in front of the engine block. The heat is dissipated by natural convection, primarily by air flow caused by motion of the vehicle, and by the air which is blown through the radiator and over the engine by an axial fan. In most trucks, the axial fan is run directly from the engine crank shaft, through a clutch. In other vehicles, the fan is electric. In either, the efficiency of the fan is relatively low, frequently on the order of forty percent. This is caused in part by the natural inefficiency of the fan itself. The short distance between the fan and the engine block is also a factor; the engine block forms a natural barrier to air flow and creates a dead space between the fan and the engine block in which positive pressure tends to prevent air flow. A heavy duty truck engine may produce on the order of 1.5 million BTUs (1.6 million kilojoules) an hour at a speed of sixty miles per hour (97 km/hr), producing less than twelve miles per gallon (5 km/l) of fuel usage, and may utilize up to a thirty-two inch (0.8 m) diameter fan nominally pulling 9,500 cubic feet (270 cubic meters) per minute to disperse the heat put out by the radiator. It is estimated that roughly one-third of the output of the engine is utilized to propel the truck, one-third is in the heated exhaust (as heat and unburned fuel), and one-third must be handled by the cooling system.

In addition to the heat carried from the engine block to the radiator by the coolant, the engine block itself radiates substantial heat, estimated to be up to about 20,000 BTUs (22,000 kJ) an hour at highway speeds.

Recently, large diesel trucks have begun to include exhaust gas recirculation (EGR) systems. Trucks equipped with engines over 250 horsepower (186 kW) have consequently begun to experience severe under-hood heat problems. The EGR system recirculates a portion (typically about 15%-30%) of the exhaust gas to the engine air intake. Because the exhaust gas has a temperature of about 1200° F. to about 1500° F. (about 650° C. to about 815° C.), it is cooled to about 600° F. (315° C.) by running it through an EGR heat exchanger before introducing it into the cylinders of the engine. The EGR system adds about thirty percent to the cooling system heat load, about 150,000 BTUs (160,000 kJ) per hour, most of which must be dispersed by the radiator. Because much of this heat is directed back into the engine compartment, under-hood heat loads are dramatically increased. The EGR system itself also radiates heat directly into the engine compartment.

Other auxiliary devices are run by the engine and generate further heat. For example, an air compressor is required for operation of brakes and other components. The air compressor may have a surface temperature on the order of 250° F. (121° C.).

To meet environmental standards and to increase efficiency, a number of other devices have been added to the engine. A turbocharger, powered by the exhaust gasses, generates further heat, estimated to be on the order of 32,000 BTUs (34,000 kJ) per hour. The turbocharger may have an operating surface temperature of about 800° F. to 1200° F. (425° C. to 650° C.).

The additional heat produced under the hood of a modern heavy duty truck has raised temperatures under the hood to unacceptable levels. The additional heat and temperature reduce the lives of components in the engine compartment and reduce engine efficiency. They sometimes melt plastic components and overheat fluids in the engine compartment. The heat also can transfer into the vehicle operator cab and can make both the air temperature in the cab and surface temperatures on the floor and front wall of the cab uncomfortably high. Attempts to enlarge the radiator, by repositioning it, tilting it, or splitting it, have not been sufficient. Enlarging the fan is likewise impractical and would increase the power requirements for running it.

A modern heavy duty truck requires aerodynamic design considerations that sometimes make the hood design smaller. Packing more equipment in the engine compartment further makes airflow more difficult. All of these considerations require a completely new approach to under-hood air management.

Various attempts have been made to solve somewhat similar problems with automobiles and off-highway vehicles. For example, Charles, U.S. Pat. Nos. 4,979,584 and 5,495,909 disclose an automotive engine bay ventilation system using ram air through openings around the radiator of a transverse-engine automobile. Likewise, Corwin et al., U.S. Pat. No. 6,216,778, discloses a cooling system for an off-highway vehicle which is stationary or moves at very low ground speed. These systems are not easily adaptable to the needs of a heavy duty truck.

BRIEF SUMMARY OF THE INVENTION

Briefly stated, the present invention provides a system for removing heat from the engine compartment of a vehicle by

isolating heat from the radiator from the engine compartment (above and to the sides of the engine block). The invention provides a new design which separates the heat loads and provides separate exhaust exits, but allows the systems to operate together or separately as needed.

Heat from the radiator is taken from a plenum behind the radiator, preferably by centrifugal squirrel cage blowers, and is directed out of the engine compartment, rather than against the engine block. The blowers are preferably controlled thermostatically to allow some or all of the blowers to operate as needed. The use of predictive computer control of the blowers is also contemplated.

The engine block and its associated devices (such as the EGR valve and the turbocharger) are cooled by a separate system which draws ambient air generally from back to front of the engine compartment, preferably by cowl induction, without the use of ram air from the vicinity of the radiator.

Both the radiator ventilating system and the engine compartment ventilating system preferably exit to ambient through side walls of the engine compartment, near the front of the engine compartment. The exits are preferably configured to exhaust hot air into the slip stream of the truck, which tends to draw air from the system. Further, the exit of the engine compartment ventilating system is preferably behind the exit of the radiator ventilating system and is configured to utilize the flow of air from the radiator ventilating system to ambient to draw air out of the engine compartment. Air flow around each exit is preferably primarily laminar.

The systems of the invention may include one or more standard radiator, plenum and blower packages sized for particular classes of vehicles or engine sizes. It may also include a standard cowl induction system also sized for particular classes of vehicles or engine sizes. Ducting for each system, however, is likely to be dependent on particular vehicle designs, including such considerations as available space in the engine compartment, internal configuration of the engine compartment and placement of engine components inside the engine compartment affecting air flow within the engine compartment, combustion air intake configuration of the engine, and air flow patterns around the outside of the engine compartment.

The foregoing and other objects, features, and advantages of the invention as well as presently preferred embodiments thereof will become more apparent from the reading of the following description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

In the accompanying drawings which form part of the specification:

FIG. **1** is a schematic sectional view in side elevation of an internal combustion engine compartment in a heavy duty truck, modified in accordance with one embodiment of the present invention.

FIG. **2** is a view in top plan, showing air flow through a part of an illustrative embodiment of the system of FIG. **1**.

FIG. **3** is a view in rear elevation, showing an illustrative radiator cooling system package of the present invention.

FIG. **4** is a view in side elevation of the package of FIG. **3**.

FIG. **5** is a view in perspective of parts of the system of FIGS. **2-4**, taken along line **5-5** of FIG. **2**.

FIG. **6** is a view in perspective of an engine compartment air outlet of the system of FIGS. **2-5**.

FIG. **7** is a schematic view in perspective showing a cowl induction scoop in accordance with an embodiment of another part of the invention.

FIG. **8** is a view in perspective of an over-the-road truck incorporating the embodiment of FIGS. **1-7**.

Corresponding reference numerals indicate corresponding parts throughout the several figures of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The following detailed description illustrates the invention by way of example and not by way of limitation. The description clearly enables one skilled in the art to make and use the invention, describes several embodiments, adaptations, variations, alternatives, and uses of the invention, including what is presently believed to be the best mode of carrying out the invention.

As shown in the FIGURES, an internal combustion engine in a large heavy duty truck **2** (FIGS. **1** and **8**) includes the engine block **3**, air intake **5**, and a radiator **7** which cools coolant circulated from inside the engine block **3** through passages **8**. All of these components of the engine are contained in an engine compartment **9** having a front **10** (usually at or just ahead of the radiator), a top **11**, and sides **12**. The top and much of the sides are generally formed as a raisable hood **13** (FIG. **8**), which is typically hinged to the body of the truck in the area of a lower front end of the truck. At the back of the engine compartment **9**, a fire wall **14** separates the engine compartment from an operator cab **15**. A turbocharger **16**, exhaust piping **17**, and an air compressor **19** add to the heat load in the engine compartment **9**. In a conventional heavy duty truck, the heat radiated by the engine and the heat blown back into the engine compartment by an axial fan raise the temperature of the engine compartment. In recent years, an exhaust gas recirculation (EGR) system, including an EGR valve **20**, adds further to the heat load on the radiator and the temperature in the engine compartment, particularly because the EGR system typically circulates on the order of 15% to on the order of 30% of the hot exhaust gas back into the engine. The total heat load in the engine compartment **9** of a modern heavy duty truck **2**, other than that emitted by the radiator **7**, is estimated to be about 60,000 BTUs (63,000 kJ) per hour.

This illustrative embodiment of the invention removes the axial fan and replaces it with an isolated radiator ventilating system **21** including a plenum **23** mounted to the back of the radiator **7**, preferably in sealing relationship with the radiator. Therefore, all ram air reaching the radiator **7** when the truck is in forward motion is directed through the radiator **7** and is concentrated in the plenum **23**. Mounted on the plenum **23**, preferably on its back, are multiple motors **25** driving squirrel cage (centrifugal) fans **27** behind the plenum **23**. The squirrel cage fans **27** draw heated air axially from the plenum and redirect the air **900** to discharge it outwardly (laterally) into air ducts **43** as described hereinafter.

If desired, the back side of the plenum **23**, the fans **27**, and air ducts **43** may be provided with insulating material in the form of a coating or a separate insulative layer or barrier. As indicated by broken line **33**, this arrangement effectively shields the engine, its components, and add-ons in the engine compartment **9** from the approximately 650,000 BTUs (700,000 kJ) or more per hour being dissipated to ambient by the radiator **7** when the truck **2** is at highway speed. Exhausting the heated air in this fashion will remove the constant reinforcement of heat into the engine compartment. The problem of heat generation in the engine compartment is thus reduced to the 60,000 BTUs (63,000 kJ) per hour generated under the

hood by the turbocharger **16**, EGR **20**, engine block **3**, and other engine compartment components.

The motors **25** are operated thermostatically, with individual motors or groups of motors being operated only when required. Predictive algorithms for controlling the operation of the cooling fans **27** will be apparent to those skilled in the art. Such algorithms may include such factors as engine coolant temperature, rate of rise of coolant temperature, engine surface or oil temperature, engine compartment temperature, ambient temperature, engine speed, and truck speed, for example.

The arrangement thus far described has the further advantages that it reduces the power (estimated to be sixty-five horsepower) required to operate a bladed fan. This could provide considerable fuel savings (7-9%). It also eliminates the fan clutch that has shown to be a high maintenance item. The electric squirrel cage fan blowers **27** are far more efficient in removing heat from the radiator **7** than the bladed axial fan. Because plural fan blowers **27** are preferably provided, air flow can be stepped up and down and controlled more effectively by controlling which blowers are powered. Moreover, the fan blower's DC motor can become a generator when it is off and free wheeling from ram air, thereby charging the truck's batteries.

The isolated radiator ventilating system **21** described thus far may be implemented in a standard package **35**; a few such packages will accommodate a wide range of heavy duty trucks. The package **35** may include a radiator **7**, a plenum **23**, and a plurality of fans **27**. Such a package may include a radiator **7** having a height of from about two to three feet (0.5 m to one meter) and a width of about 18" to about 36" (0.4 m to one meter), with a plenum **23** about one to two inches (2.5 cm to 5 cm) deep, sized to fit the back of the radiator. The package **35** may be mated to a ductwork system which is tailored to a particular truck style to create both the radiator ventilating system **21** and a part of an engine compartment ventilating system.

As shown in FIGS. **2-7**, for example, a radiator and plenum 33" (84 cm) tall by 22" (56 cm) wide may be provided as a standard package **35**. The radiator **7** is illustratively 6" (15 cm) deep with a flange **36** extending around its periphery, and the plenum is 1.25" (3 cm) deep and includes a peripheral flange **37** attached to the flange **36** of the radiator. As best seen in FIG. **3**, attached to the plenum are six squirrel cage fans **27**A, **27**B, **27**C, **27**A', **27**B', and **27**C', each including a motor **25**A, **25**B, **25**C, **25**A', **25**B', and **25**C', respectively, a squirrel cage impeller **26**, and a housing **38** having a side outlet **39**. Illustratively, each fan draws 530 cfm (15 cubic meters per minute) of air, and has a brushless 3" (7.6 cm) diameter, 3,000 rpm, 24 volt DC motor. The draws of the centrifugal fans are sized for particular applications. The housing **38** of each fan **27** is about 9" wide by about 10" tall by about 4" deep (22.5×25.5×10 cm), and each housing has a 4" (10 cm) square outlet **39**. It will be seen that the upper left fan **27**A and the two lower right fans **27**B' and **27**C' have the same handedness (clockwise rotation), and that the upper right fan **27**A' and the two lower left fans **27**B and **27**C have the opposite handedness (counterclockwise rotation). The lowermost fans **27**C and **27**C' have extended outlets **39'**, exiting between the exits of the two fans above them, so that all of the outlets on each side of the plenum align vertically to form a 12" by 4" (30×10 cm) rectangular outlet **40** on each side of the package.

As shown particularly in FIG. **3**, each motor **25** is individually electrically connected to a control system **41** having inputs, illustratively T**1** representing coolant temperature, T**2** representing engine compartment temperature, RPM representing engine speed, MPG representing instantaneous or integrated fuel consumption, and MPH representing vehicle speed. These inputs permit the controller to operate the fans **27** individually or in groups in order to insure that engine temperature remains in a desired range, in accordance with algorithms which will be easily applied by those skilled in the art. In simplest form, the fans are turned on in pairs as the temperature of the coolant, represented by T**1**, exceeds predetermined values and turned off when T**1** drops below a second value. They also permit operation of the fans in unusual circumstances when T**2** exceeds a predetermined value while T**1** is relatively low, to cool the engine compartment **9**, as described hereinafter. Inputs RPM, MPG and MPH permit predictive operation of some or all of the fans **27**, to begin drawing ram air through the radiator to provide cooling while the temperature of the coolant is still rising. The controller will also make possible the regenerative use of the fans to charge the battery of the truck when ram air is flowing through them and they are not energized.

This radiator cooling package **35** is mated to a duct system **43**. At least the rearward portion of duct system **43** is preferably, but not necessarily, mounted on the inside of the hood **13**. The juncture between the hood-mounted ducts **43** and the package **35** may be sealed in any known manner. For example, as shown solely in FIGS. **2** and **3**, the rectangular outlet **40** of the package **35** may terminate in a compound bevel **42** having a gasket on its open (upper) face to seal with a complementarily sloped bevel on the hood-mounted ducts. This arrangement permits unimpeded opening of the hood **13** and seals the duct system **43** to the package **35** when the hood **13** is closed. Alternatively, an end section of the package duct or the hood-mounted duct may be longitudinally moveable via an automatic or manual operating mechanism to mate with the other section of the duct. Likewise, the duct system may be permanently attached to the radiator ventilating system package **35** and may simply align with an opening in each side **12** of the hood.

The duct system **43** of this illustrative embodiment includes a curved outside wall **44** mated to a forward wall of the outlet **40** and a curved inside wall **45** mated to a rearward wall of the outlet **40**. The outside wall **44** terminates in a generally flat vertical rectangular opening **46** having a peripheral edge **47** aligned with a rectangular opening of similar size in the side wall **12** of the hood of the truck. It will be noted that the shape of this opening will be to some extent dictated by the contour of the truck's hood. In this embodiment, the opening **46** is substantially twelve inches (30 cm) tall, the same height as the outlet **40** of the radiator ventilating package. The inside wall **45** of the duct system **43** is spaced four inches from the outside wall **44** along a curved inlet portion attached to the outlet **40**. When the inside wall **45** reaches a position opposite the opening **46**, it then curves gently outward into the rear edge **47** of the opening **46**. The outside and inside walls **44** and **45** are connected to each other by upper and lower horizontal walls **48**. It will be seen that the walls **44**, **45** and **48** form a smooth open channel guiding air exhausted from the radiator ventilating system **21** into the ambient slip stream of the heavy duty truck when the truck is moving forward.

To cool the engine block **3** and its associated under-hood components in the engine compartment, a separate engine compartment ventilating system **51** is provided. The second ventilating system **51** in this illustrative embodiment is sized to remove the approximately 60,000 BTUs (63,000 kJ) per hour of heat produced in the engine compartment. In brief, the 60,000 BTUs (63,000 kJ) per hour can be effectively controlled by cowl air induction strategically located on top of the hood, using the high pressure area at the windshield to flow cool ram air into the engine compartment and causing the

engine compartment air to exit through hood side ducts arranged to draw air into a low pressure area adjacent the exit of radiator fan air into ambient. As shown in FIGS. **1**, **2**, and **8**, the engine compartment ventilating system **51** includes an induction cowl **53** in front of the windshield **55** of the truck **2**. Cowl induction systems have long been used in race cars, but their use in a heavy duty truck is believed to be novel. As is known, the rear **56** of the cowl **53**, adjacent the windshield, is open to the engine compartment. At operating speeds, even relatively low operating speeds, air is compressed at the base of the windshield **55** and is drawn into the engine compartment through the rear of the cowl **53** as shown at **56**.

Air within the engine compartment **9** is expelled through air exit ducts **57** mounted on the inside walls **45** of the ducts **43**, as shown particularly in FIGS. **2-6**. As seen particularly in FIGS. **3** and **4**, the exit ducts **57** are in this embodiment about nine inches high and three inches wide (23 cm×8 cm) at their mouths **59**, and are vertically centered on the inside walls **45** of the ducts **43**. The inside walls **45** of the ducts **43** include rectangular openings **61** into which exit ducts **57** empty. Each exit duct **57** includes a vertical inner wall **63**, which curves to meet the inside wall **45** at its rear, and upper and lower horizontal walls **65** which join the inner wall **63** of the exit duct to the inner wall **45** of the radiator ventilating duct **43**. Although the exit ducts **57** are entirely open to ambient, they are also in the slip stream of the hot air being forcibly expelled through the exits **46** of the radiator ventilating system **21** and in the slip stream of the truck. Therefore, air is further drawn out of the engine compartment by a venturi effect created by the flow of hot air from the plenum through the exits **46**. Forward movement of the truck **2** will also create a slip stream tending to pull hot air from both the exits **46** of the ducts **43** and the exits **57** from the engine compartment **9**. In the unlikely circumstance that the engine compartment were to reach an undesirable temperature while the fans **27** are turned off, the fan motors **25** can be turned on to draw air through the ducts **43** and suck air out of the engine compartment **9**.

As shown in FIGS. **1** and **2**, ram air represented by arrows R at the front of the heavy duty truck, is directed entirely through the radiator **7** and into the radiator ventilating system **21**, while the engine compartment **9** is cooled by cowl induction air, represented by the arrows C, moving generally from the rear to the front of the engine compartment. Movement of air from back to front of the engine compartment **9** also removes heat from the area of the fire wall **14** and reduces the heat load on the cab **15**.

Appropriate guards are preferably provided over all accessible openings. Numerous such guards are well known and may include, for example, thin horizontal vanes.

Numerous variations in the vehicle under-hood temperature control system of the invention, within the scope of the appended claims, will occur to those skilled in the art in light of the foregoing disclosure. Merely by way of example, other closed systems for cooling the radiator may be provided. As previously noted, the configuration and size of the exhaust ducts will of course be varied somewhat to accommodate the geometries and engine compartments of different trucks, as exemplified in FIG. **8**. The engine compartment cooling system may include other air inlets in the top or sides of the engine compartment, including induction air systems and ram air inlets. Preferably, the air inlets are spaced away from the front of the truck. Ram air inlets in general are not presently preferred except for use in a cab-over design. The engine compartment cooling system may include other exhaust ports and may include powered fans of various sorts if desired. For example, powered fans could be provided at the outlets of the engine compartment ventilating system. Many temperature-controlled systems are known or easily adapted for controlling the operation of the fans, or for moving baffles and the like. In the illustrative embodiment, other motors, including for example variable speed motors and, less desirably, hydraulic motors may be used to operate the squirrel cage fans; the size and number of fans may be altered as required for an application; and the shapes, numbers and sizes of the blades of the squirrel cage fan may be changed to suit the requirements of particular applications. Electric fan motors may be driven from different voltages, illustratively 12V to 42V. The bottom of the engine compartment may be enclosed for aerodynamic or internal air flow purposes. These variations are merely illustrative.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

All patents and patent applications mentioned herein are hereby incorporated by reference.

The invention claimed is:

1. A vehicle capable of on-road highway travel, the vehicle comprising:

an operator compartment,

a windshield forming a part of a front wall of the operator compartment,

an engine compartment,

an engine in the engine compartment,

a radiator in front of the engine, the radiator receiving coolant from the engine,

a first ventilating system attached behind the radiator and forming an enclosure behind the radiator, the enclosure preventing air drawn through the radiator from entering the engine compartment, the first ventilating system comprising at least one fan,

a duct attached to the first ventilating system, the duct forming a smooth channel guiding air exhausted from the first ventilating system rearwardly along an exterior surface of the vehicle, the air exhausted from the duct being directed into the ambient slip stream of the vehicle when the vehicle is moving forward, and

a second ventilating system arranged to flow air through the engine compartment, the second ventilating system comprising an induction cowl cooperative with the windshield to flow ambient air into the engine compartment when the vehicle is moving forward and an exhaust exit into a low pressure area of the duct forward of the cowl and downstream of the fan.

2. The vehicle of claim **1** wherein the first ventilating system forms a plenum behind the radiator.

3. The vehicle of claim **1** further comprising a hood defining at least a part of the engine compartment, the hood being rotatably mounted to a body of the vehicle, the duct attached to the first ventilating system leading to ambient through the hood, the duct comprising a first section fixed with respect to the radiator and a second section attached to the hood.

4. The vehicle of claim **3** further comprising a gasket between the first section and the second section of the ducting.

5. The vehicle of claim **1** wherein the vehicle is a vocational heavy duty truck adapted for off-road use as well as on-road highway travel.

6. The vehicle of claim **1** wherein the vehicle is a tractor portion of a tractor-trailer over-the-road rig.

7. A vehicle capable of on-road highway travel, the vehicle comprising:

an operator compartment,

a windshield forming a part of a front wall of the operator compartment,

an engine compartment,

an engine in the engine compartment,

a radiator in front of the engine, the radiator receiving coolant from the engine,

a first ventilating system attached behind the radiator and forming an enclosure behind the radiator, the enclosure preventing air drawn through the radiator from entering the engine compartment, the first ventilating system comprising at least one fan and a duct attached to the first ventilating system downstream of the fan, the duct forming a smooth channel guiding air exhausted from the first ventilating system rearwardly along an exterior surface of the vehicle, and

a second ventilating system arranged to flow air through the engine compartment, the second ventilating system comprising an induction cowl cooperative with the windshield to draw air into the engine compartment when the vehicle is moving forward and an exhaust exit into a low pressure area of the duct.

8. The vehicle of claim 7 wherein the duct of the first ventilating system comprises a channel extending along the outside of a side wall of the engine compartment.

9. The vehicle of claim 7 wherein the vehicle has a gross vehicle weight of at least 11,794 kilograms and is capable of on-road highway travel at a speed of at least ninety-seven kilometers per hour.

10. The vehicle of claim 7 further comprising a hood defining at least a part of the engine compartment, the hood being rotatably mounted to a body of the vehicle, the duct attached to the first ventilating system leading to ambient through the hood, the duct comprising a first section fixed with respect to the radiator and a second section attached to the hood.

11. A vehicle capable of on-road highway travel, the vehicle comprising an operator compartment; an engine compartment; an engine in the engine compartment; a radiator in front of the engine, the radiator receiving coolant from the engine;

a first ventilating system behind the radiator, the first ventilating system comprising a plenum attached to the radiator forward of the engine, at least one fan mounted to the plenum, and ducting having an exhaust exit to ambient, said at least one fan being arranged to draw air through the radiator, and to push air through the ducting and out the exhaust exit of the first ventilating system, the first ventilating system being constructed to prevent air drawn through the radiator from entering the engine compartment; and

a second ventilating system constructed to remove heat from the engine compartment, the second ventilating system being constructed to flow ambient air into a rear part of the engine compartment and to exhaust air heated by the engine compartment toward an exit in a forward part of the engine compartment, the system being so constructed and arranged that exhaust air from the first ventilating system draws air out the exit of the second ventilating system into a low pressure area created by the first ventilating system downstream of the fan at the forward part of the engine compartment.

12. The vehicle of claim 11 wherein the vehicle has a gross vehicle weight of at least 6350 kilograms and is capable of a highway speed of ninety-seven kilometers per hour.

13. The vehicle of claim 12 wherein the vehicle is a heavy duty truck having a gross vehicle weight of at least 11,794 kilograms.

14. The vehicle of claim 13 wherein the vehicle is a vocational heavy duty truck adapted for off-road use as well as on-road highway travel.

15. The vehicle of claim 13 wherein the vehicle is a tractor portion of a tractor-trailer over-the-road rig.

16. The vehicle of claim 11 wherein the second ventilating system further comprises air induction structure on at least one of the top or sides of the engine compartment, the air induction structure being adapted to flow ambient air into the engine compartment when the vehicle is moving forward.

17. The vehicle of claim 16 wherein the second ventilating system comprises a windshield forming a part of a front wall of the operator compartment, the vehicle further comprising an induction cowl cooperative with the windshield.

18. The vehicle of claim 11 wherein the second ventilating system comprises an air outlet in a side wall of the engine compartment.

19. The vehicle of claim 11 further comprising a hood defining at least a part of the engine compartment, the hood being rotatably mounted to a body of the vehicle, the ducting comprising a first section fixed with respect to the radiator and a second section attached to the hood.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 8,556,013 B2
APPLICATION NO.	: 12/427400
DATED	: October 15, 2013
INVENTOR(S)	: George R. Sturmon and Edward M. Murray

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

In Column 4, line 54, after the word "air" change "900" to --90°--.

Signed and Sealed this
Seventeenth Day of December, 2013

Margaret A. Focarino

Commissioner for Patents of the United States Patent and Trademark Office