July 6, 1937. S. W. RUSHMORE 2,086,440

HIGH TEMPERATURE COOLING SYSTEM FOR INTERNAL COMBUSTION ENGINES

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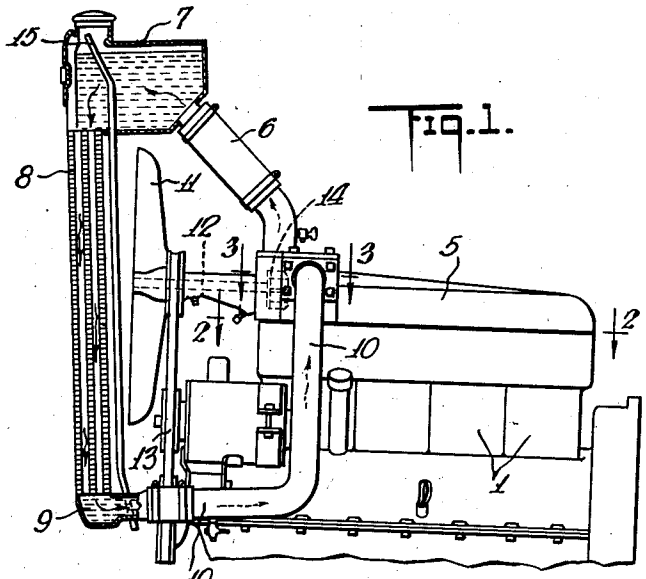


Fig. 1.

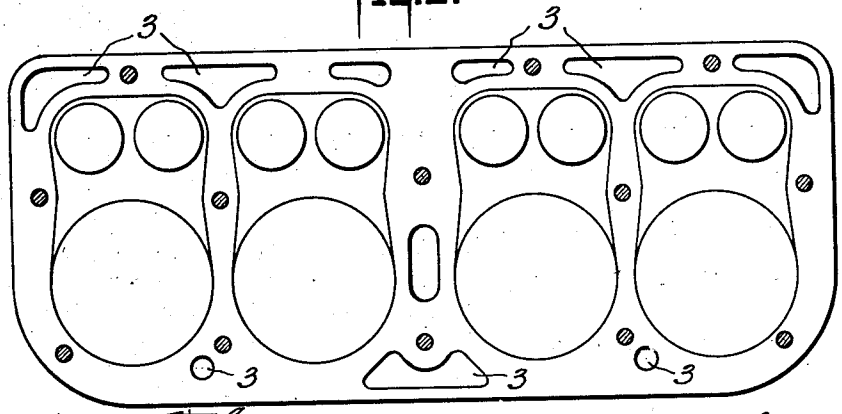


Fig. 2.

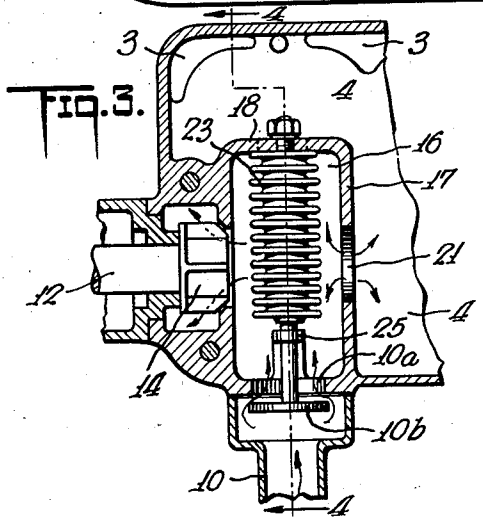


Fig. 3.

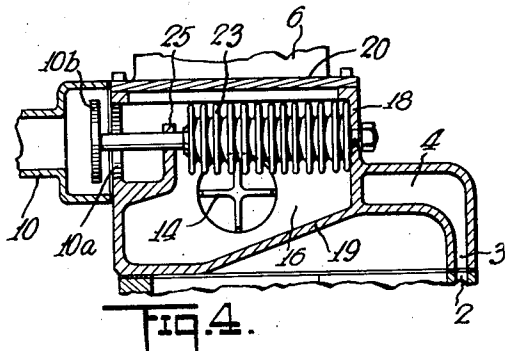


Fig. 4.

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HIGH TEMPERATURE COOLING SYSTEM FOR INTERNAL COMBUSTION ENGINES

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5 Claims. (Cl. 123—178)

My present invention is related to that set forth in my Patent No. 1,651,157, granted November 27, 1927, in that it contemplates a cooling system for internal combustion engines, including an engine jacket having a chamber in its upper end communicating with the body of the jacket only through restricted openings, and inlet and outlet pipes for cooling fluid both opening into the chamber, said chamber offering a low resistance flow path through which cooling medium is passed while the cooling medium in the body of the jacket is being raised to a temperature sufficient to cause thermo-circulation through said restricted openings.

In the patent, the cooling requires passing the water through the lower chamber of an air cooled radiator, below the cooling tubes or "honey-comb" thereof; and the water being insufficiently cooled, soon boils in the jacket; and the radiator operates as an upflow condenser for the resulting steam; but the short-circuiting chamber in fluid-interchange relation to the main body of liquid in the water jacket, is described as useful for any system where there is likely to be too much cooling of the circulating water.

My present invention contemplates using the circuit-completing jacket chamber, in combination with a cooling circuit of the conventional water cooling type wherein a pump circulates the water from top to bottom through a downflow radiator designed to take care of the maximum cooling requirements of the engine merely by water cooling, without steam condensation. This combination is designed and arranged for operation in connection with a novel thermostatic control of the circulating water, in such a way as to combine more effectively the advantages of cooling by heating water with those of boiling it to make steam, without the disadvantages attendant upon use of the upflow condenser.

My present completed invention is based on my discoveries in connection with a large number of road tests on a number of different engines having the ordinary water cooling system continuously discharging through a short-circuiting chamber such as above described. In these tests I found that it is practical to make the fluid-interchange opening or openings between said chamber and the jacket restricted enough to keep the heated water in the engine jacket, some 40° F. to 65° F. hotter than the water in said chamber. But in practice this differential is insufficient to ensure boiling in the water jacket, under average conditions; and if I attempt restricting the openings to increase the differential enough to correct this, the openings will be of such small flow capacity that under heavy load conditions, the outflow of steam from the jacket into the chamber will interfere with the reverse flow of cool water to such an extent that the engine will overheat.

However, I finally discovered that by providing means to keep the water in the circuit-completing chamber at uniform higher temperature, say, 150° F., the above 40° to 65° differential, will ensure near-boiling temperatures in the jacket, and at the same time permit use of openings between the chamber and the jacket, that are large enough to accommodate maximum outflow of steam, simultaneously with return flow of sufficient water to prevent over-heating of the engine. Therefore, broadly considered, my invention includes means for maintaining the water in said circuit-completing chamber at a predetermined minimum temperature. The specific means disclosed herein for accomplishing this is the ordinary circuit designed to take care of maximum heat of the engine simply by cooling the water in the radiator, in combination with a valve controlling the inlet of the cool water from the radiator, into the circuit-completing chamber, said valve being controlled by a thermostat preferably of the bellows type placed in said chamber and responsive to the temperature of the water therein, for the purpose and with the result that the supply of cold water from the radiator into said chamber is cut off whenever the temperature of the water in the chamber falls below a desired minimum.

What the maximum or minimum temperatures for setting of a thermostat should be will depend upon various factors. In general, it may be said that the higher the temperature of the water in the circuit-completing chamber, the larger may be the area of the opening or openings between the chamber and the jacket, thereby making thermo-circulation easier and getting quicker warming up in cold weather. In the case of a four-cylinder Ford motor, a thermostat set for minimum temperature of 165° F. in a circuit-completing chamber, gave quick boiling in the engine jackets, where a flow section of about 3⅛ square inches was provided between the circuit-completing chamber and the jacket. In this case such area was provided by a single circular opening two inches in diameter. Equivalent flow capacity could of course be provided by a larger number of holes of smaller area. As before explained, the flow resistance of the opening or openings must be such that during times of maximum steam evolution, flow of the

steam through the openings into the circuit-completing chamber, will not operate to prevent reverse flow of sufficient water from the chamber into the jacket.

Advantageous features of the new combination includes the following:

The cooling circuit including the downflow radiator is full of water, so there is a much greater margin for leaks or other contingencies, than is the case where an ordinary radiator operates as an upflow steam condenser.

The water in the jacket is entirely cut off from the water in the circulating system during the warming up period. Consequently, the jacket water will warm up in even shorter time than in the condensing system of my patent, wherein all water in the connecting conduits and the lower chamber of the radiator, must be warmed up, along with the water in the jacket.

In operation, a wider range of heat evolution in the engine can be taken care of by mere thermo-circulation and convection of heat, without much boiling, even though the jacket water is kept near the boiling point, say, 200° F. to 205° F. Consequently, there is a correspondingly higher range of great heat evolution and high exterior temperatures, throughout which the excess heat can be taken care of by boiling of the water over any part or all of the hot surfaces in the jacket.

The radiator circuit being designed to take care of all the heat by mere cooling of water in the radiator, all of the steam will be taken care of by condensation in the head jacket, and/or in the circuit-completing chamber or in the up-take pipe leading to the radiator. Consequently, the operator never sees, or has a chance to become alarmed by any visible escape of steam either from the overflow pipe, or from the filler opening when he removes the filler cap from the radiator.

An important commercial advantage is that my system may be applied to any water cooled engine, merely by providing a properly designed circuit-completing chamber and thermostatic valve in shunt relation to the water in the head jacket. This may be accomplished by substituting a new head like the original but formed with a partition for the chamber.

The above and other features of my invention may be more fully understood from the following description in connection with the accompanying drawing, in which

Fig. 1 is a side elevation, conventionally indicating a common type of four-cylinder automobile engine, to which my invention is applied;

Fig. 2 is a plan view of the cylinder block showing the conventional water circulating passages connecting the cylinder jackets with the head jackets;

Fig. 3 is a section on the line 3—3, Fig. 1; and

Fig. 4 is a section on the line 4—4, Fig. 3.

In the drawing, the upper ends of cylinders 1 are surrounded by the conventional water jacket 2 communicating through openings 3, 3, with the water jacket space 4 of the head block 5. The cooling circuit includes the uptake pipe 6, discharging into the upper header or tank 7, through which the water flows downward through the honeycomb or tubular air-cooled conduits 8 to the bottom tank 9 and through return conduit 10, to the water jacket. The air draft is drawn through the radiator cooling elements 8 by fan 11 on shaft 12 and is driven from the engine by belt 13. Circulation of water through the above circuit is forced by a suitable pump, in this case a rotor 14 such as commonly employed on the Ford motor to suck the water from the head jacket and force it into the uptake conduit 6. The circulation could be forced into the jacket by pump located in the low level part of return conduit 10, as is more common, but there are advantages in employing the high level suction pump in connection with my present invention, which will be explained in due course.

As before explained, an essential of this cooling circuit is that the cooling capacity of the radiator and the speed of circulation of the water is such that the maximum cooling requirements of the engine can be taken care of entirely by fall of temperature of liquid water during its flow from the top to the bottom of the radiator. By my invention it is possible to utilize a cooling circuit of such capacity in such a way that steam produced by boiling of water in the jacket can be wholly condensed in the upper part of the head jacket, pump and uptake without any of it escaping to the top of the radiator and thence to the exterior through the overflow pipe 15.

The means for utilizing the cooling capacity of this circuit so as to ensure boiling in the water jacket under average conditions, without danger of escape of steam under special conditions of maximum heat evolution in the cylinder, includes a circuit-completing chamber 16 into which the cool water return pipe 10 discharges, and from which the uptake pump 14 pumps the water into the uptake conduit 6. As shown in Figs. 3 and 4, this chamber may be formed by a side wall 17, and end wall 18, the roof of the cylinder head 19 constituting the bottom of the chamber and the top being closed in by a plate 20 which is preferably removable, for access to the interior of the circuit-completing compartment. This circuit-completing chamber has the previously described shunt communication with the head jacket space through one or more suitably restricted openings as at 21, said opening or openings being preferably in the wall of the chamber which is opposite the intake of the pump. As indicated by the arrows, the water supply to the jacket flows out through 21 and steam or hot water can flow in the reverse direction, from the head jacket 4 into the chamber 16. Such interchange of cooling fluid between the chamber and the head jacket may be simultaneously in both directions, under certain conditions; and under other special conditions may be pulsating, steam or steam-foamed hot water flowing from the head jacket into chamber 16 and then water from chamber 16 flowing into the head jacket.

As fully explained above, the flow of cold water from pipe 10 through inlet opening 10*a*, is controlled by an inlet valve 10*b* carried by a thermostat 23. This thermostat is preferably of the metallic bellows type, containing a liquid boiling at a temperature corresponding to that which it is desired to maintain in the chamber 16. As is well known in the art, the boiling point of a given liquid contained in the thermostat, may be varied somewhat by changing the pressure within the bellows, either when charging it or by applying adjusting external spring pressure after the bellows is sealed.

Such a thermostat bellows may be designed to operate as a powerful motor, operating to close the cold water inlet when the vapor therein condenses, and to open said inlet when the liquid

boils enough to produce the necessary motive power. Preferably a stop, 25, is provided to limit expansion of the bellows beyond wide open position of valve 10b.

An important feature is arranging the thermostat to be responsive to the temperature of the mixture in the restricted chamber 16, as determined by the varying volumes and temperatures of the cooled and heated fluids traversing the same; and also having said thermostat control the inlet of cool water from the bottom of the radiator. This is in marked contrast to conventional arrangements wherein a thermostat and its valve are both located in the conduit 6, leading to the top of the radiator. My novel control of the cool water inlet, leaves the uptake entirely unobstructed for free instantaneous, upward expulsion of water, during times of maximum steam evolution in the water jacket.

Special features of the design and operation of my above described apparatus, are as follows:

The pump 14 operates continuously at speed proportional to the speed of the engine. Upon starting the engine cold, the cool water inlet 10 is closed, so that there is no circulation through the cooling circuit, and, at first there is practically no interchange of water between the short-circuiting chamber 16 and the water jackets. At this stage only the water in the water jacket is being heated. As the jacket water heats up, there begins to be increasing thermocirculation through restricted communication 21; and, by the time jacket water is near boiling, the water in the circuit-completing chamber will be heated to its normal minimum, for which the thermostat is set. As before explained, the restriction afforded by 21, is such that under average conditions the water will boil in the cylinder jackets and head by the time the water in the circuit-completing chamber 16 is heated up to the critical temperature, which is predetermined in accordance with the temperature differential afforded by constrictions at 21, and may be, say, 165° F. if said differential is about 45°. When the water in chamber 16 is at or above said critical temperature, the fluid in the thermostat bellows 23, will boil and the resulting internal pressure will expand the bellows, thereby opening valve 10b and permitting inflow of cool water. Thereafter, variable condensing and boiling in the bellows, will tend to cause closing or opening movements of valve 10b, according as the temperature of the fluid mixture in chamber 16, rises or falls.

Under normal conditions of weather, and under normal load, the thermostatic valve will permit the entrance of only sufficient cold or cooled water to maintain the temperature in the compartment at the value for which the bellows is adjusted. Alternately, with increasing load, the bellows will open the valve wide and thereafter, with further increase in load and steam evolution, the valve will remain wide open and the temperature of the water in the compartment and the temperature of the water discharged to the radiator will rise, but no steam can escape to atmosphere until the temperature of the discharge water reaches 212°, at sea level.

As the bellows will thus, at times, be exposed to temperature which would cause excessive internal pressure, it is important that the ether or other expansive fluid therein be limited to but little if any more than required to give the full valve movement at the desired minimum water temperature. Then a rise in temperature above the desired minimum will result only in superheating the ether or other vapor, without important increase in the pressure within the bellows. This adjustment for temperature is termed "limit filling".

An important advantage of placing the pump in the outlet from the jacket is that at the higher engine speeds, when the load is the greatest, there will be an appreciable vacuum created in the jacket space, with a corresponding reduction in the boiling point.

I have found in practice, owing to the slippage in the pump, the vacuum in the engine jacket is not appreciable at ordinary running speeds, so that the jacket temperature is normally little if any below 212°. At the higher speeds, however, the four-cylinder Ford engine will show as much as four pounds below atmospheric pressure, and, in consequence, the boiling point of the water in the jackets will drop to around 205°. This drop in the jacket temperature under heavy load and high speed is advantageous in that it compensates to a considerable extent for the increase in the temperature gradient through the cylinder walls which, under ordinary conditions, causes the internal surface of the cylinders to be heated far above the desired constant value of 212°.

It will be understood, of course, that the vacuum created, as above explained, is due to the flow resistance offered by the radiator core, the pipe connections and, particularly, by the resistance of the valve, and for this reason I limit the size and flow capacity of the valve to give the desired amount of vacuum under maximum speed.

The above described sequence of internal operations may be better understood from consideration of effects in a particular case, as follows:

In the case of a Ford engine driving a Ford car at full speed, with wide open throttle, when the engine will give its maximum output, more than half of the water in the engine jackets will be displaced by the violently agitated foam, due to the voluminous steam evolution in the jackets. If then the throttle is closed or the load is largely reduced there will be a sudden reduction in the rate of boiling and a sudden backflow. Under winter conditions this backflow water from the top tank may be heated only to approximately the temperature of, say, 160° for which the thermostat is adjusted and this sudden inrush of cooler water may cause a momentary drop of 5° to 10° in the engine jacket, but which in a minute or two recovers to the normal 212°. In warmer weather, or under conditions of sustained heavy load, the water in the tank may be considerably above the 160° thermostat setting, in which case a sudden dropping of the load will result in little or no change in the jacket temperature.

Consequently, while I may employ the usual downflow radiator and the usual water circulating pump, I find that, as indicated in Fig. 1, it is desirable to make the top tank or reservoir considerably larger than is required with the usual water cooling system; first, to serve as a surge tank to take care of the above described large amount of water displaced from the engine jackets by the steam or foam under conditions of heavy load; and second, to provide at all times an abundant reserve of heated water to be returned to the jackets when, upon a sudden reduction in load the generation of steam may be suddenly reduced or may cease altogether.

It will be understood that I may employ a water cooling radiator of the conventional type and dimensions, and have the reserve water or "surge" tank placed at any convenient point and con-

nected in shunt or series with the outflow from the circuit-completing chamber; but I prefer simply to enlarge the usual top radiator tank for this purpose, because my system permits the water temperatures in the radiator to be higher and the air cooled core so much more efficient per unit cooling area, that a radiator core of the usual cross section, may be made much shorter vertically than is required for the conventional cooling system in which the radiator water is so much nearer air temperature. There is thus available space for the surge tank above the radiator core.

While I have referred to water as the cooling medium, it will be obvious that other liquids of higher or lower boiling point may be employed, some of them without change of the apparatus as above described and others by merely changing the adjustment or the liquid in the thermostatic bellows, with or without change in the degree of constriction of the shunt communication 21, between the short-circuiting chamber and the jackets.

While the drawing and the above description relate to a preferred arrangement and application, it will be understood that my invention may be employed in other arrangements, as for marine or stationary work, where air cooled radiators are not employed and/or where the discharge water is thrown away.

Where, as on the automobile, it is desired to maintain the jacket temperature within close limits under widely fluctuating loads, I prefer to employ the circuit-completing compartment containing the thermostat, but I may dispense with the pocket and, by locating the thermostat bellows at a suitable point within the engine jacket, and by arranging the valve controlled by the thermostat to discharge the incoming cool water at or near the jacket water outlet, I may maintain the jacket temperature, at least in that portion surrounding the cylinders, at a fairly constant optimum temperature.

I therefore claim the broad idea of an engine with a thermostatically controlled valve in the inlet of cool water to the jacket, where the jacket is in shunt relation to the pump operated cooling circuit; also, the same in combination with a surge tank or a reservoir adapted to hold a supply of heated water to be available automatically to replenish the water in the engine jacket upon a sudden reduction in or cessation of the evolution of steam within said jacket.

1. A cooling system for internal combustion engines, including a water jacket for the cylinder and head portions of the engine, a closed cooling circuit including a pump and an air-cooled radiator, means associating said cooling circuit in thermo-circulatory relation with the water jacket, said means including a chamber of small volume as compared with the head portion of the jacket and in series with said cooling circuit, said chamber communicating with the upper part of the engine jacket only through restricted flow paths through which the thermo-circulation is induced by heating in the water jacket, in combination with a valve controlling the cool water inlet to said chamber and a thermostat in said chamber for operating said valve, designed to prevent fall of temperature of the water, below a desired minimum at the point of communication with the jacket, during operation of the engine.

2. A cooling system for internal combustion engines, including a water jacket for the engine, a closed cooling circuit including a pump, and an air-cooled radiator; means associating said cooling circuit in thermo-circulatory relation with the water jacket, said means including a chamber in series with said cooling circuit and communicating with the upper part only of the engine jacket and only through restricted flow paths through which thermo-circulation is induced by heating in the water jacket; a valve controlling the cool water inlet to said chamber and a thermostat in said chamber for operating said valve, the restriction of said flow paths being predetermined to ensure a predetermined temperature differential between the heated jacket and the cooled chamber adequate for permitting outflow of steam without preventing adequate inflow of water, during times of maximum boiling in the jacket; and said thermostat being designed and operated to maintain minimum temperature of the water in said chamber high enough in relation to said differential resulting from the restriction of the flow paths, to ensure boiling in the water jacket under average conditions of operation of the engine.

3. A cooling system for an internal combustion engine, including a water jacket for the cylinder and head portion of the engine, an air-cooled water circuit which in cooperation with the water jacket is of cooling capacity adequate for taking care of the maximum cooling requirements of the engine merely by lowering the temperature of the water, means associating said circuit in fluid interchange relation with the top of the water jacket, and including a circuit-completing chamber of small volume as compared with the head portion of the jacket and which chamber communicates with the water jacket only at the upper part thereof, through flow paths sufficiently restricted to insure boiling in the jacket, and a thermostatic valve for controlling flow of water in said circuit into said chamber in accordance with the temperature effect of the fluids therein and closing when a minimum temperature of the fluid in said chamber is reached.

4. A cooling system as defined in claim 3, together with a surge tank to accommodate water displaced from the engine jacket under heavy load and to supply water for return flow to the water jacket as the rate of steam evolution decreases from decreasing load or stopping of the engine.

5. The cooling system as set forth in claim 3, and wherein a pump for circulating the cooling water is connected to the outlet from the chamber, whereby with increasing speed of the pump and engine, the pressure and the boiling point in the jacket are lowered, for the purpose described.

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