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A LABORATORY-TESTED CONSTANT-LEVEL OIL SUMP TO PREVENT AERATION OF SCAVENGED OIL FROM AN AIRCRAFT ENGINE

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

A LABORATORY-TESTED CONSTANT-LEVEL OIL SUMP TO PREVENT AERATION OF SCAVENGED OIL FROM AN AIRCRAFT ENGINE

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SUMMARY

A combination oil sump and scavenge pump was constructed to eliminate some of the oil-system difficulties in an aircraft engine that result from the aeration of the scavenged engine oil and the air-lock of the scavenge pump. Air is prevented from entering the scavenge pump by a column of oil in the sump above the pump inlet. This column of oil is maintained by returning some or all of the scavenge-pump delivery to the sump. An automatic valve, controlled by the oil level in the sump, regulates the flow of the oil bypassed to the sump.

Laboratory oil-scavenge tests were conducted with a constant-level oil sump at sea level and the value of such a device for preventing oil aeration and scavenge-pump air-lock was determined. These tests showed that the device does prevent the aeration of scavenged oil and scavenge-pump air-lock. Tests of the device under conditions simulating altitude flight, mounted on a multicylinder full-scale engine on a torque stand, and in flight are warranted by the results of the laboratory tests. Details of the construction of the device are included.

INTRODUCTION

The investigation described in this report is part of the general study of the problem of engine oil scavenging requested by the Army Air Forces, Materiel Command. The work reported covers sea-level laboratory tests of a constant-level crankcase oil sump that is designed to prevent the aeration of scavenged oil and the air-lock of the scavenge pump.

In present oil systems the aeration of the scavenged oil occurs because the scavenge pump, which circulates oil from the engine sump to the oil tank, has a capacity as great as twice that of the pressure pump, which circulates oil from the tank to the engine. The excess capacity of the scavenge pump is satisfied with crankcase gas that flows to the oil tank with the oil where it often produces oil foam. Sufficient foam can accumulate to fill the oil-tank air space, the oil-tank vent line to the crankcase, and the crankcase. When this foaming condition exists, oil foam is observed to pour from the engine breather. The oil lost as foam can represent an appreciable part of the total oil supply.

A second oil-system difficulty that is attributable to overcapacity of the scavenge pump is the frequent loss of prime, which occurs when the scavenge pump has removed all the available oil from the engine oil sump. At altitude, where the atmospheric pressure is low, the scavenge pump is slow to prime and sufficient oil can accumulate in the crankcase to cause some oil to be lost through the engine breather with the blow-by gases. It is believed that many instances of oil loss from the engine breather are erroneously attributed to oil foaming when an air-locked scavenge pump is really at fault.

A combination sump and pump that maintains the oil level in the sump at a specified height above the scavenge-pump inlet has been constructed and tested at the NACA Aircraft Engine Research Laboratory during the period from October to December 1943. The maintenance of a column of oil above the scavenge-pump inlet at all times during level or near level flight, no matter what the rate of flow of oil into the oil sump may be, prevents air from entering the scavenge pump to aerate the oil or to air-lock the pump. The oil level in the sump is maintained by an automatic scavenge-pump-delivery bypass valve which returns some or all of the scavenge-pump delivery to the engine sump as required to maintain the sump oil level.

DESCRIPTION AND OPERATION OF CONSTANT-LEVEL OIL SUMP

A sketch of the sump and scavenge pump is shown in figure 1. The pump P is attached to the under side of sump A and is driven by hollow spindle S, running in bearings B and B'. Spindle S is powered from the engine accessory drive through gear G. Sump oil flows to the pump inlet through tube T. The large channel in bearing B is provided to conduct pump delivery oil to spindle S where an automatic valve arrangement controls the quantity of oil bypassed back to the oil sump.

The automatic bypass-valve mechanism is made up of spindle S, rotor assembly R, and sleeve valve V (figs. 1 and 2). Rotor assembly R is mounted on spindle S and turns with it by means of pin S_1, which is fastened to S and extends through cam slot R_2 in sleeve R_1. Rotor assembly R is free to rotate on spindle S within the limits imposed by the length of the cam slot R_2, which is inclined 45° to the spindle axis and is so directed that the lift and drag forces on the rotor-assembly blades moving through the oil in the sump will cause the rotor to turn and rise on the spindle. Sleeve valve V slides inside spindle S and is fastened to rotor assembly R by pin V_3. This pin extends through cut-outs S_2 and S_2' in the spindle and moves sleeve valve V with the rotor assembly. Ports V_1 and V_1' are always so positioned in cut-outs S_2 and S_2', no matter what the orientation of the sleeve valve, that the hollow center of the spindle is always in flow communication with the sump. A second pair of ports V_2 and V_2' near the lower end of the sleeve valve are exposed through spindle cut-outs S_3 and S_3' when the sleeve valve is at its lowest position (fig. 2(a)) and are completely concealed by spindle S when the sleeve valve is at its highest position (fig. 2(b)). Because the sleeve valve moves with the rotor assembly, the area of ports V_2 and V_2' exposed through cut-outs S_2 and S_2' will depend on the elevation of the rotor assembly.

One end of spring N is fixed to spindle S and the other to rotor assembly R. The spring force tends to turn the rotor assembly in the direction of rotation of the spindle and therefore acts to lower the level of the rotor assembly. The lift and drag forces on the rotor assembly spinning in the sump oil, acting through cam slot R_2 and pin S_1, exert a torque on the rotor assembly that is directed opposite to and exceeds that produced by the spring. As long as the oil level in the sump is above the highest level the rotor blades can assume, the rotor assembly is maintained at its highest level and ports V_2 and V_2' are concealed in the spindle. When the oil level falls, the rotor assembly and sleeve valve drop with it under the influence of spring N and ports V_2 and V_2' are exposed.

The constant-level sump operates as follows: Oil pours into the sump from the various sections of the engine and follows the path indicated in figure 1. If the rate at which the oil enters the sump exceeds or equals the capacity of the pump, the rotor assembly assumes its highest level and the bypass ports V_2 and V_2' are closed. Because the scavenge-pump capacity exceeds that of the pressure pump delivering oil to the engine, the sump oil level will eventually drop below the maximum rotor level. The rotor will follow the oil level, and bypass ports V_2 and V_2' will open to permit some of the scavenged oil to pass into the sump via the hollow spindle S and ports V_1 and V_1'. If the oil flow into the sump becomes steady, the rotor will assume a level such that the proper amount of scavenge-pump oil is bypassed to the sump to maintain this level. The flow of oil to the oil tank is then equal to that entering the oil sump. When the oil flow to the sump stops, the oil level, and with it the rotor, drop to the lowest rotor position. Bypass ports V_2 and V_2' are wide open and, if the various ports and channels in the bypass system are large enough, all the scavenge-pump delivery is sent back to the sump. A minimum oil-sump level is thus established that is sufficient to keep the scavenge pump and its inlet filled with oil in level or near level flight at all times. Aeration of the oil by the scavenge pump and loss of prime does not occur. Oil foaming is minimized and crankcase flooding due to slow scavenge-pump priming is prevented.

Loss of scavenge-pump prime will occur with this sump during a steep dive or inverted flight. When normal flight is resumed, the sump bypass valve will be open for a short time and the scavenge pump should prime more quickly than the scavenge pump of a conventional oil system, which must remove the air from the pump against the flow resistance of the oil in the lines to the oil tank.

DISCUSSION

Test Results

Laboratory tests of a scavenge pump-sump combination similar to the one described in this report have shown that the device is reliable and satisfactorily fulfills its function at spindle rotational speeds as low as 700 rpm. The whirling of the rotor assembly produces little or no aeration of the oil. Some oil-foam breaking is accomplished by the mechanical and centrifugal action of the rotor on the oil foam.

Design Recommendations

Aeration of the sump oil by the returning bypassed oil is avoided if provision is made for introducing this bypassed oil below the oil level in the sump. If the bypassed oil is permitted to strike the oil surface or even the walls of the sump at high speeds, considerable air will be mixed with the oil. For this reason, the throttling bypass ports corresponding to V_2 and V_2' should be immersed in the oil. In the design described, the bypass ports V_2 and V_2' are covered by a column of oil inside spindle S reaching to ports V_1 and V_1', which are large and always open wide. This oil column will always be present no matter what angle the oil surface in the sump may assume relative to the sump axis during nonhorizontal flight. Ports V_1 and V_1' should be located well below the minimum oil level. The oil-level control mechanism should be designed to operate at engine speeds as low as one-half the normal idling speed.

A proposed method of attachment of the constant-level sump to the engine crankcase is schematically illustrated in figure 3. The exact method of driving the spindle is not shown because it will depend on the design of the accessory section of the engine. The solenoid valve shown on the scavenge-pump bypass line is used to shut off the bypassed oil flow in the event of failure of the sump oil-level control mechanism or when the engine is rotated at speeds too low to cause the oil-level control mechanism to operate, as during engine starting. When the oil bypass system is closed, the sump and pump will operate in the same manner as current scavenge-pump systems.

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, April 6, 1944.

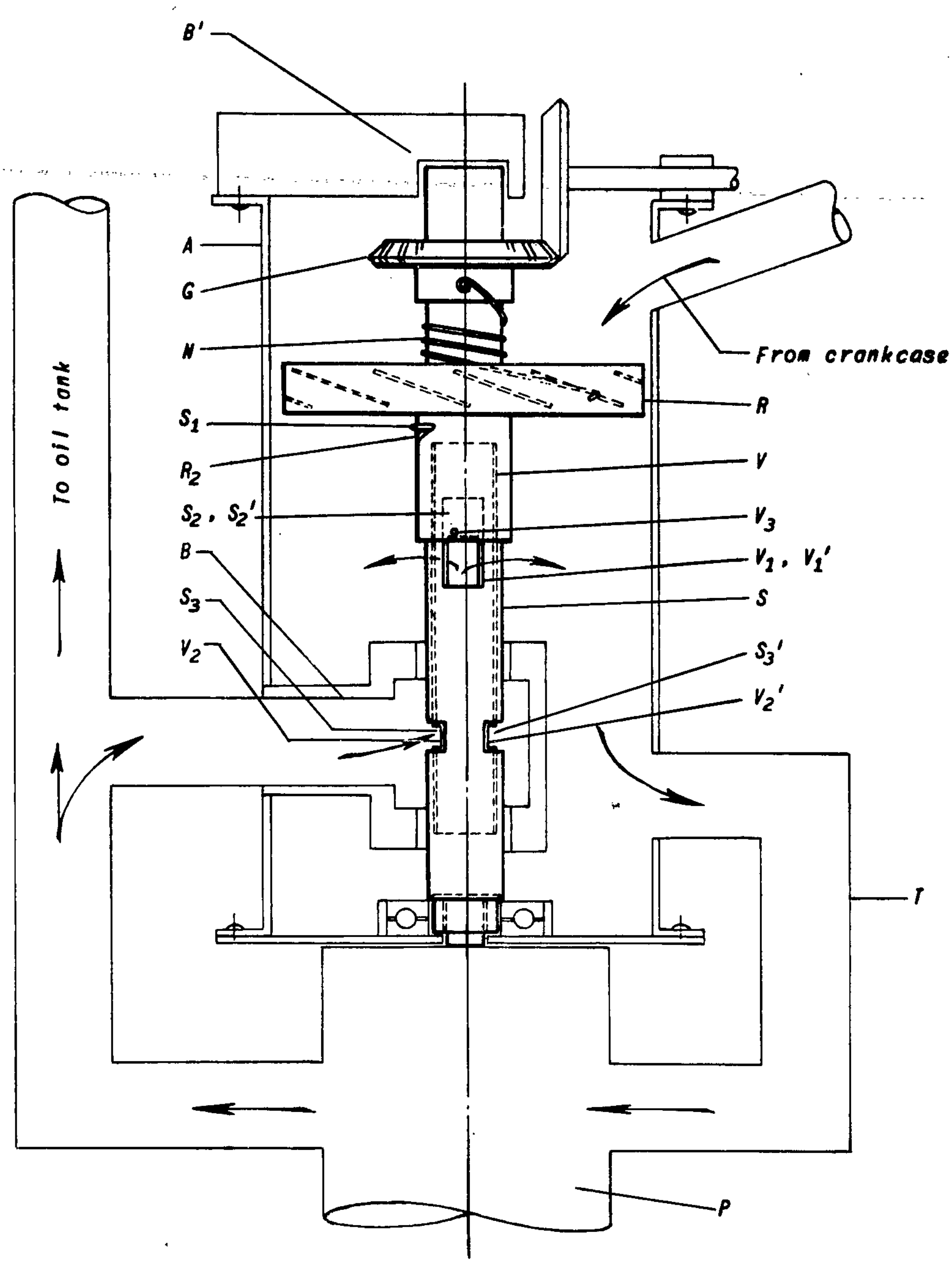

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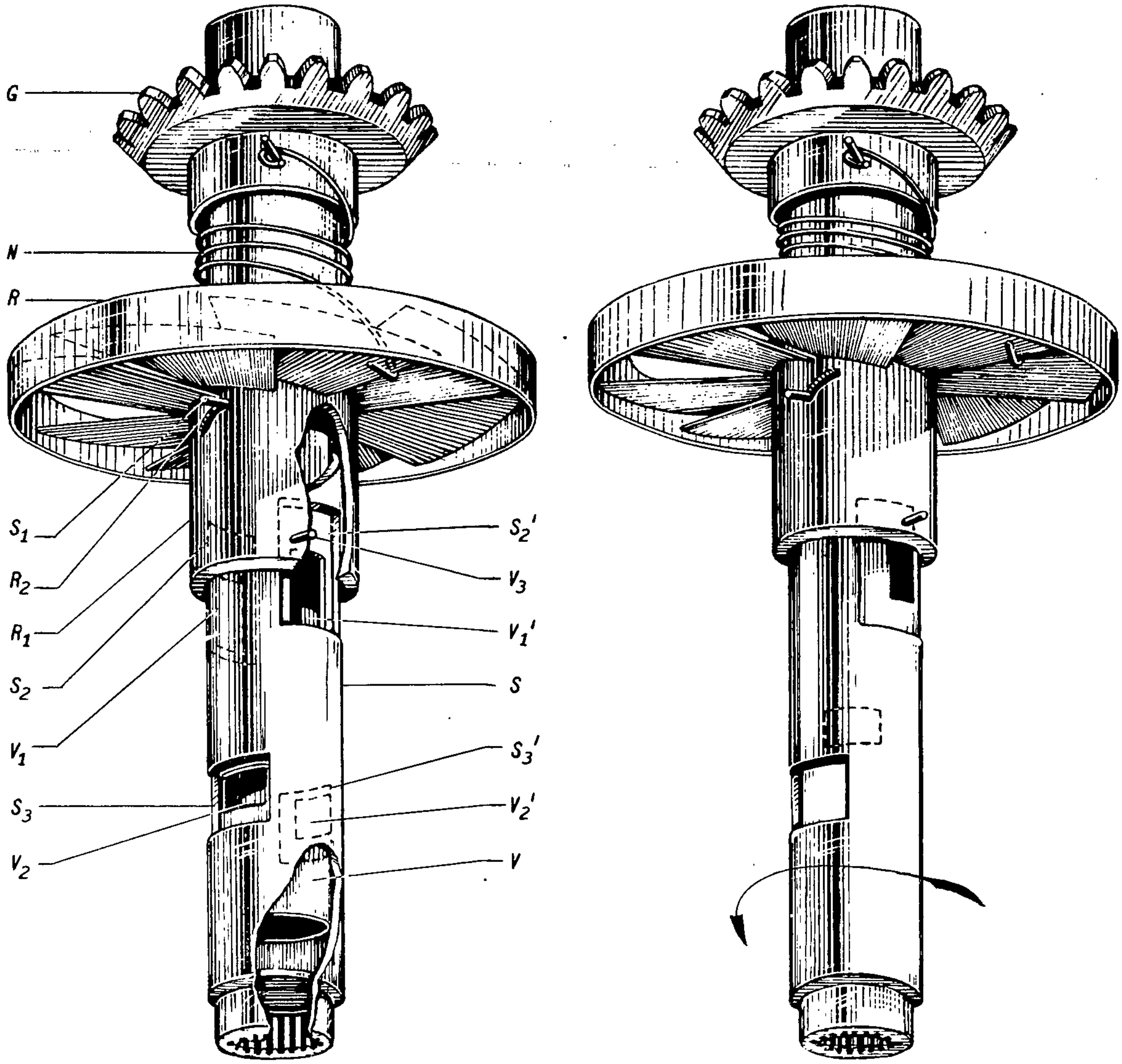
Figure 1. - Schematic view of constant-level oil-sump assembly.



(a) Bypass port open.

(b) Bypass port closed.

Figure 2. - Detail of oil sump level control valve.

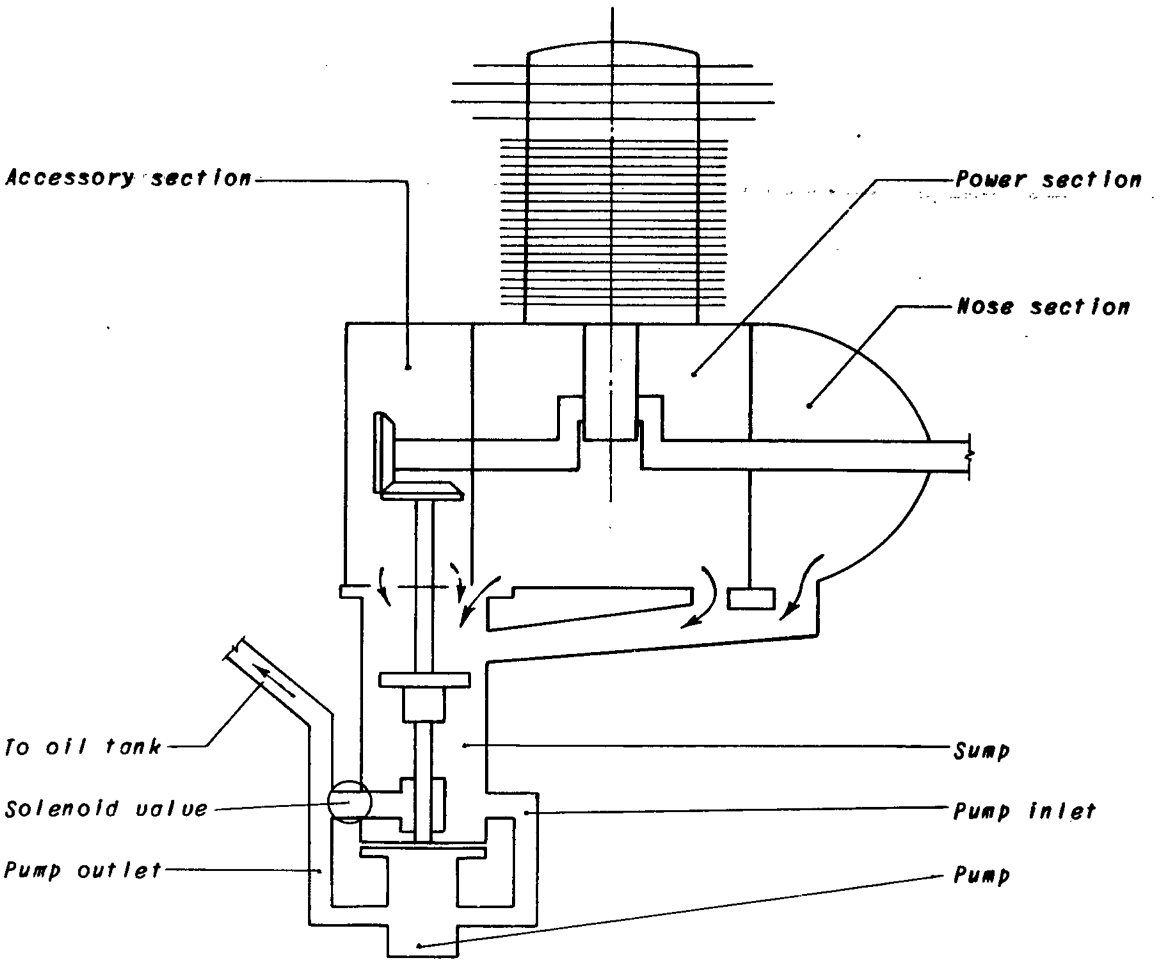


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Figure 3. - Proposed sump attachment to crankcase.