P-51 COOLING SYSTEM

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Header Tank Inspection, Testing & Servicing

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Never exceed 110°C indicated to prevent cylinder head heat damage leading to possible: • Valve to seat leaks, • Seat to head separation and leakage, • Cracks in combustion chamber, • Coolant leaks from failed seals, • Loose valve guides

Operating Temperatures

Ideal coolant system operating temperature should be 95 °C to 105 °C. Consider 110 °C as the engines *redline*. The maximum temperature of 120°C indicated in the flight handbook is too high! Cylinder heads will suffer heat damage, leading to possible:

- Valve-to-seat leaks
- Seat-to-head separation and leakage
- Combustion Chamber Cracks
- Coolant leaks from failed seals
- Loose valve guides

Do not exceed 110°C!!

Oil temperature should be 70°C to 80°C and 100°C should be considered as the maximum.

Coolant

The P-51 Maintenance Handbook recommends a 30/70% mixture of ethylene glycol and water for warmer climates and a 70/30% ethylene glycol and water for extremely cold climates.

In practice, a 50/50% blend seems to work fine and should be suitable for all but the most extreme conditions.

Improving the P-51 Cooling System

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This White Paper is provided to educate owners and operators of *Merlin* powered P-51 aircraft on the engine coolant system, to help avoid premature engine damage caused by overheating.

Regardless of how well the engine is built, if the coolant system is not functioning properly, the engine will likely sustain damage, with reduced service life, and possible premature failure. Overhaul the coolant system along with new engine installation, to ensure the best possible performance and longevity. Our objective is to provide the highest quality engine restoration possible, with a long trouble free service life.

Water should be deionized, or if not readily available, distilled. The use of deionized or distilled water will help prevent scale build up.

Some coolant manufacturers include additives that are designed specifically for large displacement, aluminum engines with wet steel sleeve cylinder liners. One such product is the Chevron Delo ELC, which includes molybdates and nitrites to reduce possible cavitation corrosion. These additives should be very beneficial as we have many examples of merlin cylinder liners with cavitation corrosion pitting/damage.

The Chevron Delo ELC is an *extended life coolant* which includes organic acid (additive) technology (OAT). This coolant is silicate free, therefore eliminating the buildup of insulating silicate deposits on all internal cooling system components which inhibit heat transfer and cooling capacity.

Although the specifications and properties of this product appear to be very suitable for use in a P-51 cooling system, we have not disassembled and examined engines or cooling systems running this or similar OAT coolants, and therefore cannot verify its actual performance.

Using either conventional coolants or the ELC/OAT type coolants, it is recommended to drain and flush the coolant system every 100 hours or at annual. Run the engine to obtain temperatures between 80°C to 100° C. Drain Coolant.

Fill the system with clean water, run again to obtain coolant temp up to, but not exceeding 100°C. Drain water from the system, and replace with new coolant.

Bleeding Air from the System

1) As coolant is added to the header tank, *open* the main coolant system bleed line located under the left rear wing fillet fairing. Cap the line once a steady stream of coolant appears.

2) Run the engine for a few minutes — shut down — add more coolant to header tank— and open the bleed line again to release any trapped air. Repeat this process until the coolant level in the header tank is maintained at the level of the filler neck and all trapped air has been released.

3) Continual release of air or aerated coolant from the bleed line may be indicative of failed scroll tubes or chamber inside the coolant header tank.

See more under: **Header Tank**.

Bleeding air from the *aftercooler system* can be accomplished at the same time, following same procedure. The aftercooler bleed line should be located at same place, under left rear wing fillet fairing.

Radiator

The original Harrison radiator is an excellent design and very efficient - but is somewhat susceptible to plugged tubes as they are relatively thin and narrow. Keeping the coolant clean and free of contaminates is critical.

The replacement *truck core* type radiators are less efficient, having fewer tubes with a larger cross section; however they are less likely to become plugged with corrosion particles, silicates, and contaminates.

The best system is an original Harrison radiator in excellent condition having 95% or more of the tubes open and maintaining clean coolant.

Grounding

A significant factor in maintaining clean coolant, in addition to flushing the system and replacing with new every annual or 100 hours, is to ensure *all* coolant tubes and the engine itself are well grounded. This reduces electrical activity and internal corrosion and erosion of the engine which is the primary source of contaminates in the coolant that plug radiator tubes.

Make sure all ground straps are in place!

Temperature Probe

The location of the temperature probe has a significant impact on indicated temperature readings.

The original design placed the temperature probe within a coolant tube in the region of the wheel well in the wing. This location will provide a temperature reading of 3°C to 4°C lower than the actual coolant temperature as it exits the front of the cylinder head. A later T.O. moved the temperature probe to the coolant outlet elbow on the front of the cylinder head, which provides a more accurate reading. A set-up with two gauges and a probe in each location is a good plan as it provides a backup to this very critical monitoring function.

Header Tank

The header tank is one of the most critical components of the coolant system, and probably the least understood.

Figure 1. *P-51 Header Tank*

The header tank performs several functions;

- Serves as the coolant reservoir and expansion chamber
- Separates air and vapor from the coolant
- Reduces suction head on the pump
- Controls pressure in the system

One of the most critical functions is to *separate air and vapor from the coolant (de-aerate the coolant)*. A header tank with damaged internals will not perform this function and can actually have the opposite effect which, in-turn, will contribute substantially to overheating problems.

Figure 2a. *Header Tank Internals*

Figure 2b. Oblique View Showing Broken Scroll Chamber

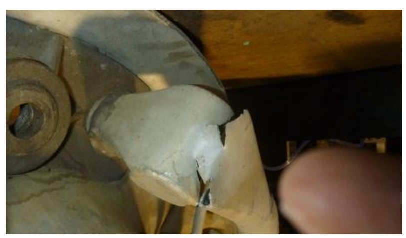

Figure 2c. *Failed Header Tank Scroll Chamber*

Figure 2d. *Broken Welds at Outlet End of Scroll Tube*

The internal structure of the tank is mostly *not* visible; however there are a couple methods of inspection and testing.

Header Tank Inspection and Testing

Drain the coolant and remove the tank from the airframe.

1) Remove the pressure relief valve.

2) Using a flashlight, view inside each of the two outlet castings, where the ends of the scroll tubes are visible.

3) There are 3-point welds around the ends of these tubes that must be intact.

4) Insert a wood dowel in the end of the scroll tube and apply force side to side to determine if the 3-point welds are broken loose.

A tank with these welds broken must be overhauled and repaired prior to use.

Testing Scroll Tube Assemblies

The next step is to test the *scroll tube assemblies* for cracks or failures.

1) Obtain two plumbing type rubber plugs with center thumbscrew that fit the inside diameter of the two ports on the inlet casting.

Figure 4. *Thumbscrew Rubber Plugs*

2) Turn the tank upside down and secure with strap or bungees to table leg or other stand to maintain firmly in position.

Figure 5. *Secured for Testing*

3) Insert a plastic or rubber hose in the opening of the scroll tube that is visible inside each outlet casting. Attach a funnel or plastic squeeze bottle to opposite end of the hose.

Figure 6. *Inserting Fill Tube with Attached Funnel*

4) Fill the scroll tube with water using a bright food coloring.

Figure 7. *Filling the Tube*

5) Fill only to level just visible inside the tube.

Figure 8. *Visible Fluid*

Try to avoid over-flowing or spilling the colored water out of the scroll tube.

Repeat on opposite side scroll tube. When colored water is visible in both tubes, slap the tank a couple times to splash a small amount of water from the ends of the bleeder tubes that terminate inside the tank. This is not visible from the outside.

6) Wrap and secure a small piece of white cloth to a piece of wire,

Figure 9. *Test Swab Attached to Wire Rod*

and insert through the threaded hole in the inlet casting where the pressure relief valve was removed.

Figure 10. *Inserting Swab into Header Inlet Ports*

Bend the wire and swab the bottom of the tank shell, cleaning and drying any spilled or overflowed colored water.

Figure 11. *Swabbing Tank for Signs of the Test Solution*

Use a suction bulb and small tube if necessary, then follow with cloth on the wire to clean and dry the inside of the tank.

7) Ensure colored water is still visible in the scroll tube ends, inside the outlet castings.

If the colored water is not visible and a large amount of water was removed from the inside of the tank via the pressure relief valve hole, then it is likely the scroll tube assembly is broken or failed.

It is not possible to pressure test the scroll tube assembly, as there is a bleeder line that terminates inside the tank which would be very difficult to cap for a pressure test. The static water test should be sufficient.

If the *colored water* is visible in each scroll tube, and the inside of the tank has been cleaned and dried, allow the tank to sit overnight and check the following day.

Any colored water that appears on the white cloth swab from the bottom of the tank indicates a crack or pinhole in one of the scroll tube assemblies and the tank must be overhauled before use.

An alternate test procedure can be performed on the airplane, but may not provide as decisive results as the upside down static water test.

Testing on the Airplane

1) Run engine for a few minutes to bring coolant temperature up and build some system pressure.

2) Shut down engine and remove cap on system bleeder line at left rear wing fillet fairing, and ensure steady stream of coolant - no trapped air.

3) Remove cap on coolant header tank and add coolant, to bring up to level of filler neck

4) Repeat the run/shut down cycle and confirm the coolant level is at filler neck.

5) Install and torque the cap and let the system sit overnight.

6) The following day, remove the filler cap on the header tank. If a significant amount of coolant pours out of the filler neck, it indicates a crack or pinhole in the scroll tube assembly, and the tank must be removed and overhauled prior to use.

Double check the Avamo seals to ensure leakage is not occurring at the inlet seals.

When the system is right, there is a 'liquid lock' in the scroll tube assemblies in the header tank, and it will remain full of coolant. A crack or pinhole in the scroll tube system would allow coolant to slowly drain out of the tube assembly, raising the level of coolant in the tank above the filler cap.
A broken or failed scroll tube or chamber will drain out almost immediately; in which case the preceding test is not effective. It is also likely however, that the system will not purge the air out - and removal of the cap on the bleeder line at rear wing fillet will result in continuing releases of air and/or aerated coolant.

If the system will not purge properly after repeated attempts, or the coolant level rises in the tank after sitting for a day, the tank should be removed from the airplane and static water test performed.

Header Tank External Leak Testing

1) Install plugs in two inlet ports

2) Install plugs in outlet castings

3) Install a pipe fitting in the pressure relief valve port with pressure gauge and Shrader valve.

4) Wrap a belt or ratchet strap around the two outer 'legs' of the tank and apply some tension, tending to pull the legs inward slightly.

5) Apply 50 psi to the tank and submerge in water looking for air bubbles to indicate any leaks.

If the tank has the depressions on the backside for clearance on 600-series cylinder banks, limit the pressure to 35 psi.

Pre-Pressure on Header Tank

Applying a pre-pressure to the header tank not exceeding 15 psi, with a pressure gauge installed in the cockpit is good practice and provides valuable information such as:

- Pressure bleeding down in flight would be indication of a leak in the system and provide early warning to land before excessive coolant loss and engine temperatures climb beyond red-line.
- Pressure in the system is proportional to temperature and can therefore serve as a backup temperature gauge and good cross reference.

Header Tank Installation

The header tank must be installed using proper rubberized cork gasket material between the tank and straps, and above all, the straps ***must not be over-torqued!*** The gasket should be 1/4" wider than the strap, and installed with 1/8" protruding beyond each side of strap.

The tank will expand and flex somewhat under pressure and temperature and the clamps must not be so tight as to prevent any movement. Over tightening the clamps will reduce the only area for movement to the center area of the tank with the likely result of cracks at the ends of the inlet casting.

This has been noted on numerous tanks - including originals and reproductions.

Operation, Coolant and Oil Doors

If coolant temperature gauge exceeds 100°C on the ground, per the operations manual, turn the airplane into the wind and run up to 1500 rpm. The *coolant door* and *oil door* should be operated manually to the *full open* positions.

If coolant temperatures exceed 105°C in flight, position the *coolant door control switch* to *manual* and run the door open until temperatures drop to around 100°C. The actuator should be adjusted accordingly.

If door is *full open* and coolant temperature will not drop below 105°C, the radiator may be partially plugged and should be removed and inspected.

In a similar manner, oil temperature should be 70°C to 80°C. The oil door position/actuator should be adjusted to achieve this operating temperature range.

Engine Storage

If the engine is to be stored for any length of time, both the main coolant system and aftercooler system *must* be kept full. Coolant for storage would be a 50% to 70% ethylene glycol and deionized or distilled water.

If possible, for extended storage, ground the airframe to a floor grate or grounding rod.

If the engine is removed from the airframe, it will require sealed block off plates be fabricated for the inlet port on the coolant pump and the coolant outlet fitting on the supercharger.

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