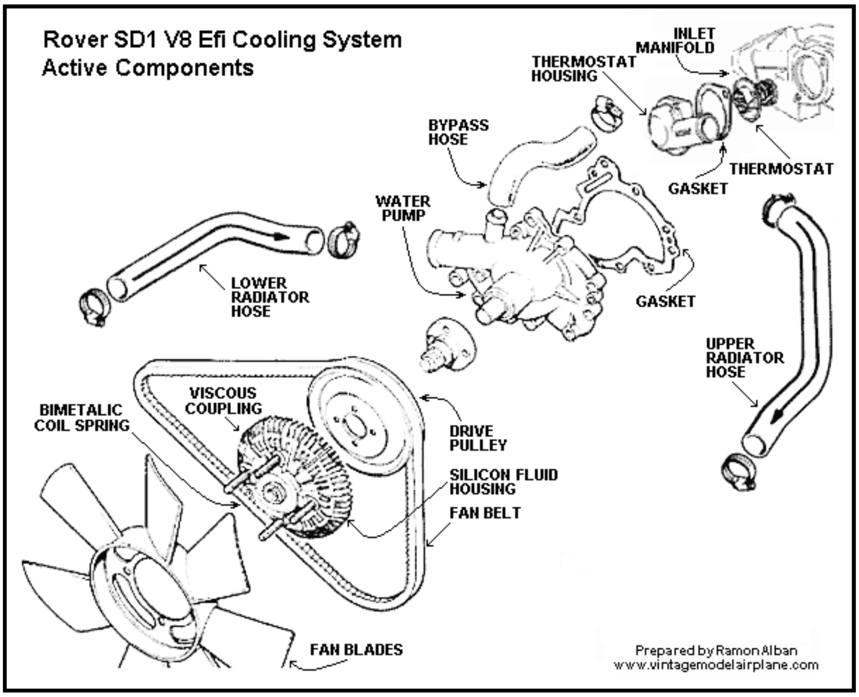
The Rover SD1 V8 (Efi) Cooling System

This Examination of the RV8 (Efi) Cooling System unearths some routine but often neglected tasks that ought to be at the vanguard of routine preventative maintenance to avoid unexpected and potentially destructive over-heating. It is also selective, describing only the parts that matter.

In truth, the RV8 (Efi) cooling system is often poorly serviced yet is simple to comprehend and the easiest SD1 system to maintain using just basic knowledge and few practical skills. Paradoxically diagnosis is not so easy because of overlapping symptoms so this examination also deals with the logical interpretation of familiar (and some not so familiar) evidence to identify actual fault conditions and determine what and how to fix them. The underlying mystery here is why a simple system is so difficult to get working properly? All will be revealed. So, be amazed!

The Basic Configuration of the RV8 (Efi) Cooling System allows the engine to reach its normal operating temperature as soon as possible after starting from cold and then maintain a stable temperature, come what may, whilst driving under a wide range of traffic/ambient conditions. Obviously, it must prevent any overheating that might occur in adverse circumstances, so the coolants in the closed loop system should readily absorb engine heat and transfer it efficiently to the radiator where, mainly by convection, thermo-dynamic heat loss may take place.



This image shows the general arrangement of the active cooling system components: the water pump, the thermostat and the viscous fan coupling, together with radiator hoses and some fitments.

The passive components: cylinder block, exhaust and inlet manifolds, radiator and cabin heater matrix are not shown.

The RV8 (Efi) Cooling System in Action is easy to visualize, starting with the water pump impeller circulating coolant into both the left and right banks of the cylinder block, around all the cylinders, absorbing heat, then upwards through galleries at the top of the cylinder block to the cylinder head(s) water jackets.

Here, crucially, significant additional heat is transferred to the coolant by the super-hot exhaust valve/manifold locations. The fluid continues through the front of the cylinder heads into and around the inlet manifold, out and back to the cabin heater matrix and eventually, the thermostat.

The right hand (offside) cylinder head feeds coolant to the intake manifold and on to the inlet hose of the cabin heater matrix. The output from the heater matrix is routed back through the intake manifold and from there back to the water pump output. (For why, see below ***)

The coolant circuit described is effectively a primary closed loop system, not including the radiator. As heating continues, it soon reaches the thermostat minimum opening temperature which in turn, starts to release the confined liquid through the top hose to the radiator, across and down through the radiator tubes and out through the bottom hose to the water pump intake where the impeller blades continue to force it through the cooling system on a continuous cycle.

Before the thermostat opens however, coolant flows out through the bypass hose adjacent to the thermostat housing to the top of the water pump allowing for continuous circulation (not including the radiator) to prevent hot spots developing anywhere in the engine (***). There is also a small, auxiliary circuit to/from the Efi plenum chamber air intake tunnel(s) heating block.

With the thermostat now opening, coolant starts to flow through the radiator giving up heat to the air flowing over the horizontal tubes and fins, created by either the rotating viscous fan unit and/or the ram air from the vehicle’s forward motion. Some radiators have automatic transmission fluid flowing in a separate circuit also giving up heat to the coolant in the radiator.

The once heated, now cooler fluid goes on to the water pump and as the thermostat continues to open, it attains a maximum flow rate restricted variously by the radiator, cylinder block, cylinder heads, inlet manifold, heater matrix and thermostat orifice. The maximum volume of coolant being moved is thus a function of all these restrictions plus the basic capacity of the water pump.

Self-evidently, partial blockages or other unwanted restrictions in any of the mentioned elements of the cooling circuit, or the pump impeller blades being below par, will adversely affect the flow and therefore the volume of coolant being circulated with obvious undesirable consequences.

Heated coolant now begins to expand and pressurize the system up to a maximum determined by the pressure relief cap, which, for the RV8 (Efi), is typically rated at 15 psi. The expansion tank connected to the offside top of the radiator should be partially filled as per the owner’s manual because, under pressure, air in the tank escapes first, but NOT the fluid. If a system is overfilled, by self-regulation, excess fluid dumps from the tank via the integral overflow tube and when the system subsequently cools the resulting vacuum draws back in exactly the right amount of air.

On the other hand, overheating expels coolant from a correctly filled system which cannot be recovered, requiring constant top-up. The worse the overheating the more serious the problem becomes. In relation to coolant expansion creating increased pressure in the system, the boiling point of water is raised (typically) 1.7°C for every 1 psi, so at 15 psi the boiling point will be 125°C. Addition of (say) ethylene/glycol antifreeze further raises the boiling point depending upon the mixture ratio. Typically for a 40% mix, the boiling point is raised to 135°C at 15 psi.

This is a very dangerous combination of pressure and temperature, much higher than the normal boiling point, and, if suddenly released, the coolant turns instantly to superheated steam capable of causing serious scalding injury. Great care must be exercised when testing a heated system.

<u>A Thoughtful Scientific Interlude</u> is called for here, hopefully easy to follow but with some repetition to emphasize the examination? It's important, so please keep reading! Step back to the point where coolant under pressure comes in contact with the very high metal temperatures in the exhaust valve area, by far the hottest place in the engine. Bubbles of steam try to form on uneven metal surfaces the same way bubbles form at the bottom of a pan of boiling water.

Mostly, these bubbles seem to want to hang around the bottom of the pan actually inhibiting efficient heat transfer by creating an insulating layer between metal and fluid. The bubbles themselves (steam) are less efficient heat absorbers than fluid, so their very existence would be detrimental to the heat transfer process. Ergo, no local bubbles of steam would be very desirable?

To demonstrate, gently stir a pan of <u>*steadily*</u> heated water and see bubbles on the base start to disappear. Stir a little faster and the bubbles actually cease. Yet, the amount of heat input to the bottom of the pan is unchanged, so if steam bubbles are not being formed, then it stands to reason the transfer of heat to the fluid must be more efficient. It takes 540 calories to change 1 gram of water at 100°C into steam. The same amount of energy will raise 540 grams of water by 1°C, so by preventing premature formation of steam, logic says the fluid will also heat up faster!

Science calls this process "nucleate boiling" and it's important to the situation inside an engine. If fluid flow is slowed for any reason, bubbles of steam try to develop more readily (sooner) at the hottest part of the engine, degrading heat transfer to the coolant. Once formed, larger and larger globs of steam would be carried down-stream where they eventually condense out in cooler liquid, but not before the extra pressure created by the now continuous local production of steam in a closed system, forces air *plus* liquid coolant from the expansion tank.

Cumulatively now, caused initially, remember, by slower coolant flow allowing bubbles to form in very hot places, the engine can start to overheat, more steam is generated, pressure increases, more coolant is lost and, over time, unless the situation is corrected, gross overheating causes collateral damage to engine cylinder heads/gaskets. Correction can only be addressed as follows:

1) Normal flow of fluid in the cooling system must be re-established so that initial generation of steam bubbles does not occur. This cannot be resolved with the vehicle in motion!

2) The flow of air over the radiator fins must be increased (without necessarily generating even more heat by going faster), normally taken care of by the Viscous Fan Coupling responding to increased temperature between the radiator and its bimetal sensor spring.

3) If fitted, the twin fans of an Air Conditioning system, or a retro-fitted electric fan, can be engaged by a thermostatic switch normally fitted in the radiator close to the upper inlet hose.

Resolutions 2) and 3) must overcome cooling system *thermal inertia*, by definition, meaning the system's reluctance to change temperature, thus any delay in the radiator receiving its urgently needed airflow simply results in non-stop temperature fluctuation. Therefore, restoring adequate coolant flow, 3), to inhibit generation of steam bubbles at the hottest parts of the engine is the only *stable* solution to a problem which had been initially caused by blockages within the cooling system or by water pump malfunction adversely affecting coolant flow.

<u>Diagnosing RV8 (Efi) Cooling System Problems</u> depends not only upon accurately ***observing*** and ***collecting*** all the evidence but also in accepting under advisement these five fundamentals:

1. The ***thermostat must not be open before its minimum operating temperature or the engine will take too long to heat up*** with consequent delay in attaining optimum performance.
2. The temperature of coolant coming through the radiator bottom hose on its return to the water pump will be at a ***stable differential compared to the inlet hose temperature.*** This differential may vary a little with ambient temperature but stability is paramount.
3. A fully functioning system will ***quickly attain and run at its design operating temperature and remain stable*** through all but the most unusual and extreme conditions, Hot or cold!
4. The inevitable expansion of coolant will expel air from the expansion tank when system pressure exceeds the pressure cap specification but ***it should never expel fluid***.
5. With an otherwise perfectly maintained engine and functioning cooling system, ***if the viscous fan coupling is faulty the RV8 (Efi) cooling system will never maintain stable temperature.***

To collect evidence, measurement of temperature could be made with a pricey infrared meter, a low cost multi-meter with a pair or thermocouple probes, two ten quid “Omega” reversible liquid crystal temperature labels or nil-cost experienced/sensitive fingers? **<u>So, multi-meter it is then?</u>**

Whichever? Here is a compilation of ***symptoms and evidence*** with their attendant ***rational diagnoses.*** Look out for ***bold italics*** in what follows, emphasizing those key details, seeking out what is generally called **<u>cause and effect!</u>** Now, read about the tricky bit, ***revealing the causes***!

<u>Temperature Differential</u> is a clever way of diagnosing problem symptoms and their cause.

- Typically, in normal conditions, with radiator inlet hose temperature at 90°C, then the outlet temperature will be in the order of 75°C, a 15°C differential that, due to expected system stability can be readily assumed normal and ***the radiator is functioning correctly.*** Individual systems may have higher/lower levels or a smaller/larger differential but the key feature to this example is to stress that ***the differential must be as reasonable and as stable as possible.***

- If the ***differential is too small, say only 5°C to 10°C,*** then the ***radiator cooling process is certainly impaired,*** more commonly by ***blocked radiator tubes*** or less likely ***reduced airflow*** affected by ***debris in the fins.*** The solution to both lies with a domestic garden hose. For the former to ***flush and reverse flush the radiator*** and the latter to ***jet away any fauna and flora.***

- On the other hand, if the ***differential is too large with inlet temperature at (say) 105°C and the outlet temperature much lower by (say) 25°C to 30°C***, then clearly the cooling function is working perfectly with excellent heat transfer to the airflow but ***the coolant flow to, or through the (not blocked) radiator is too slow,*** being restricted by either a ***partially closed thermostat,*** or by ***worn water pump impeller blades operating well below peak efficiency.***

- Examining the physical state of the hoses can support the above diagnosis. With ***top hose being extremely hot and feeling somewhat hard,*** the bottom hose is ***much cooler, but also may feel softer***, seemingly devoid of fluid and/or pressure, ***confirms slow fluid flow and inadequate fluid being returned to the cylinder block*** for either of the stated reasons.

<u>Changes in Temperature</u> also provide significant diagnostic opportunities.

- Let's say the inlet hose is very hot at idle but the ***temperature drops noticeably as the engine is gently revved*** up and then continues to ***vary down and up as engine speed gently changes.*** This thermal behavior, sympathetic to the engine speed, undeniably indicates that ***increasing water pump speed and therefore coolant flow, is having some favorable effect.***

- Here it can be diagnosed as ***the coolant level and/or (more likely) the coolant pressure is too low,*** allowing some steam to form in the ***critically hot exhaust valve/manifold areas*** at the pressure dependent, lower boiling point. Changes also being sensed locally by the gauge temperature sender. ***As the flow of coolant is increased by the raised rpm, heat transfer is improved thereby lowering the temperature and the generation of steam is reduced.*** The reverse then happens; ***temperature rises again as the fluid flow slowly decreases***.

- There are two likely reasons. ***A faulty pressure cap or a system leak.*** Either one, capable of preventing the vital increase in pressure enabling a higher boiling point condition that surely prevents ***local generation of steam at the very hot exhaust valve/combustion chamber area.*** In context, the generation of steam bubbles locally is **<u>NOT</u>** the same as coolant boiling over!

- Imagine now, ***congested/slow traffic conditions, coolant flow is low and a leak/pressure cap problem exists?*** System pressure is never high enough, steam bubbles break away from the hottest parts of the engine, rush headlong to the upper levels, the thermostat housing, upper radiator hose and top of the radiator itself, making them all super-hot by comparison, as seen on the temperature gauge. Then traffic conditions change, ***allowing a faster rotating water pump to increase coolant flow, inhibiting bubble formation, which in turn improves heat transfer to the coolant and quenches the tendency to overheat.*** Does all that sound familiar?

- A definitive but somewhat risky test to confirm this particular cause of overheating is, with the engine running; **<u>very</u>** carefully loosen the expansion tank pressure cap, where-upon, if proven, one will immediately notice ***very low or even non-existent internal system pressure.***

- Even at low pressure, what can happen is, any locally trapped steam finds an easy escape route especially from the top of the radiator. **<u>Use a thick cloth and take extreme care.</u>**

- **<u>Seriously Impaired Coolant Flow</u>** is the most usual cause of cooling system malfunction, particularly as the RV8 (Efi) gets older and more cars are coming out of long term storage.

- Along similar lines to the "<u>changing temperature</u>" scenario symptoms and diagnosis (above), and recapping the earlier scientific interlude on pg. 3, ***engine overheating coupled with pressure induced fluid loss from the expansion tank along with temperature spiking*** indicates that ***coolant flow rate is seriously impaired*** allowing steam generation and the consequences that ensue. Initially, by far the easiest solution is a complete ***flush and reverse flush of the engine block, heater matrix and radiator.***

- If that doesn't fix things, checking the water pump will probably reveal ***cavitation induced erosion of the impellor blades***. Mind you, if it's knackered, there's no way back! Replace!

Overheating Coupled with a Very Small Temperature Differential is a typical situation that describes when ***both radiator inlet and outlet hose temperatures are high,*** with the inlet hose at, say, 105°C and the outlet not much lower. From several likely causes, let's start with this one.

- The ***radiator is simply inadequate for the heat load being supplied by the engine,*** perhaps as a result of fitting an ***incorrect spare.*** Unlikely one would think? But, Hey! Muppets happen!

- ***If the radiator is just underrated***, increasing the number of cores from (say) 3 to 4 has several beneficial effects. ***More tubes improve radiator flow rate and more fins allow for better heat transfer*** to the moving air so the cumulative ***overall cooling effect is enhanced, lowering the temperature of the coolant being returned to the engine.***

- Equally significant, the volume of coolant in the radiator is increased allowing for ***even more efficient transfer of the heat load to atmosphere.*** Benefit-wise, it's "Buy one, get two free"!

- A second possibility, ***airflow over the radiator fins is seriously impaired by debris*** easily detectable and resolved ***using a domestic hosepipe with a blast jet fitting to irrigate the fins.***

- A third, more likely cause, mainly due to neglect, ***a crudded radiator simply needing flush/ reverse flush, to restore functionality.*** Sadly a badly affected radiator, once cleaned, can also develop an immediate leak that may ***require re-coring or replacement.*** Specialists are legion for such repairs, so shop around! Surprisingly, some may even have exchange units on the shelf, not particularly expensive either. Minor leaks are ***readily cured using radiator sealing compound such as "Bars Fluid" or "Radweld",*** either one having an excellent reputation.

- The fourth and very likely scenario can exist, whereby ***the cooling system appears to be under-performing and some overheating is present***, mainly in an idling engine state or in slow traffic and maybe in high climatic temperature. Yet, the radiator is known to be of the correct size, it is not crudded, the fins are not blocked with debris and the coolant flow and pressure have been diagnosed as acceptable but it transpires, ***engaging the cabin heater and fan has the effect of lowering the engine operating temperature***. Weird? Not necessarily!

- The same effect on gauge temperature is seen when the opportunity to increase road speed arises, ***enhancing ram-air effect over the radiator so coolant temperature begins to fall.***

- Clearly then, due to either or both ***engaging the heater matrix/fan or faster road speed***, the ***increased airflow over the total coolant volume*** had the observed helpful effect, suggesting ***insufficient airflow over the radiator tubes/fins*** during the described adverse conditions.

- The now glaringly obvious conclusion being the ***Viscous Fan Unit is under-performing,*** just when it is being called upon to increase the airflow, ***it fails to do so.***

- A crude test for a suspect viscous fan unit that seems not to respond to the described adverse conditions is to use a rolled newspaper to try and stall the fan blades whilst the engine is very hot and idling. ***If the fan blades can indeed be stopped then the viscous fan unit has probably failed in its most common failure mode*** and should undergo further investigation.

- To be sure, **only briefly** block the front of the radiator with cardboard, cut to size, so the temperature between the radiator and the bimetal coil will definitely rise, artificially, above the expected minimum viscous unit engagement level. Now listen for the distinctive roar of an engaged viscous unit and observe greatly increased air flow coming from the fan blades.

- ***If the noise and increased airflow do NOT occur, the Viscous Fan Coupling is faulty.***

Summarizing all the above Rational Outcomes that have temperature stability as their core goal, be assured, a cooling system can be in superb condition, no blockages, good flow/pressure, thermostat and pressure cap OK, excellent radiator cooling, engine correctly tuned, indeed, every feasible remedial action taken so no single impediment exists, EXCEPT: **With a faulty Viscous Fan Unit the Rover SD1 V8 Efi Cooling System can never maintain stable temperature.**

And the reasons are easy to see! The viscous unit uses a unique property of special silicone oil whose viscosity changes with sheer force and temperature. A grooved wheel fixed to the water pump rotates within a grooved housing fixed to the fan blades. Oil is forced to move within and between the revolving grooves so a large speed differential between oil layers induces significant sheer forces which, in turn, raise both oil temperature and viscosity. The enhanced bond between wheel and housing causes the fan to rotate faster, increasing airflow through the radiator. As a result, speed differential falls, as do the sheer forces and the temperature of the oil which now gets a little thinner, the driving forces lessen and at some point, the fan speed stabilizes.

To control the process, a forward facing bimetal coil senses the heat laden airflow coming from the radiator and rotates a control valve shaft regulating the volume oil which is able to flow between the grooves. Thus, hotter air allows more fluid to enter the grooves resulting in a stronger bond, higher fan speed and increased cooling effect. Conversely, as radiator temperature falls so the bimetal reacts to close the control valve. So, when the temperature is high enough to engage the viscous unit, it is constantly reacting to changes. A classic negative feedback system!

Choosing Alternative Components and/or Upgrading the RV8 (Efi) Cooling System is seen, occasionally, as either desirable or necessary. Why So? Using the car for competitive purposes would be a justifiable reason. Continuous exposure to very extreme climatic conditions, likewise. Cost/availability of spares may also justify some decisions to modify, but rarely for the better!

Generally though, Rover SD1 enthusiasts are converted by Darth Vader to embrace the dark side variously due to prior or current neglect, components wrongly removed, wrong items previously fitted, un-expelled (trapped) air, poor maintenance, but most sadly, system malfunction hither-to resisting effective diagnosis. Take these three completely different situations, for example:

1. A poorly flowing system has partial crudding and has not been flushed or reverse flushed! Undiagnosed, this may lead an owner to consider fitting a ***high volume or supplementary water pump*** to fix a problem, achieving short term success! ***The radiator remains crudded!***

   The owner then praises the efficacy of the solution to a mate in the pub, perhaps not even owning the same marque of car, or promotes it on a favorite forum. All of a sudden, spates of mates are fitting alternate water pumps ***instead of grabbing the garden hose!***

2. The ***availability/cost of replacing a Viscous Fan Coupling*** seems prohibitive so, from the mythology of much dubious advice, a person ***decides to fit a cheaper or S/H electric fan replacement.*** Why not, for goodness sakes, when such units are fitted to most modern cars? Snag is, their design includes a specially located sensor to maintain stable temperature. New cars with varying temperature don't sell! But SD1's were designed with a negative feedback system based upon bimetallic detection of temperature variation in a very cosy, confined and shrouded airflow location between the center of the radiator and the front of the fan blades.

   In slow or stationary traffic and/or in hot climates, rapid feedback creates subtle changes in fan speed according the changing bimetal temperature and the responding oil viscosity, thus, as airflow over the radiator fins changes, so does the transfer of heat to that changing airflow.

   Rover took great care to seal the edges of the fan shroud to the rear face of the radiator tanks, so the fan blades pulled cooling air through the whole frontal area of the radiator. Removing the shroud impairs fan efficiency. Worse! Poking a fan thermocouple under the edge of the top hose prohibits direct feedback between fan and radiator fins. Yes, the system will work! Temperature control takes place, but expect it to be unstable. ***Exactly what Efi V8's dislike!***

3. Frequently, one hears opinions that ***a lower temperature thermostat cures overheating.*** How weird is that? Once open, it plays no further part in heat control until the coolant temperature drops back to within the range of the device. Open temperatures of, commonly, 82°C or 88°C are not anywhere near to (say) the 100°C to 115°C of an overheating engine! No! The true purpose of the thermostat is ***to block the flow of coolant to the radiator until the engine has warmed up as fast as possible to minimize engine wear, deposits and emissions.***

   Comparatively, the ***88°C thermostat allows an engine to reach its operating temperature more rapidly***, as it happens ***most beneficial for the Rover SD1 V8 Efi fuel system*** where-as the ***82°C item allows coolant to flow to the radiator sooner in the heating process, making for a slower rise in temperature*** which turns out to be ***better tolerated by carburettor cars.***

   As always, there are conflicting considerations. In hot climates/seasons, is it logical to use an 82°C unit ***to get the coolant circulating fully sooner rather than later?*** Conversely in cold climates/freezing conditions, might it be best to use an 88°C item ***permitting block and coolant to reach higher temperature more quickly*** before the thermostat opens? By the same token the 88°C device will make full cabin heat available much sooner via the heater matrix.

In Conclusion, the fitting of alternate parts or even removing key bits, relates to a mythology of car repair that speaks thus: ***"No matter how neglected an RV8 (Efi), there's always a snake oil solution to put things right"*** and takes this conclusion right back to my introductory allegation:

"In truth, the RV8 (Efi) cooling system is often poorly serviced yet is simple to comprehend and the easiest SD1 system to maintain using just basic knowledge and few practical skills."

Now, armed with the above set of symptoms and diagnoses, conceivably, outcomes **will** amaze?

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