Land Rover Series III Engine Coolant Tank Redesign

26th Feb to 12th Mar 2013

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Introduction

The vehicle has had a coolant problem for quite a time now. The typical condition is a relatively small amount of antifreeze leaking somewhere around the distributor resulting in a very small pool around the distributor base clamp – sometimes almost closer to a glaze of fluid, rather than a pool of liquid – but one which is definitely antifreeze and which doesn't go away. The puzzling thing is that the hoses in that area are all new and have all been very carefully checked and fixed tight. The thermostat housing is also well sealed. In short there is no obvious cause.

After recently up-rating the heater system (see other engineering notes) I considered it time to look more closely at this leak as it has been present for a considerable time.

Symptoms & Conditions

The last three or four times I've removed the uppermost plug bolt in the radiator (which is one of the high points in the cooling system) the level inside the radiator has been down by about 1 litre – after previously being filled to the brim. On one recent occasion, I suspected it had been continuously low for many weeks running – which confusingly suggested that this leak may not persist once the level of coolant reduced to a certain point.

Coolant loss can occur if the head gasket(s) fail but the lack of any coolant in the oil or any sludge under the rocker oil filler cap suggests this is not the case here (there also isn't any steam leaving the tail pipe or any obvious sign of oil in the coolant). A head gasket fault is therefore relatively unlikely.

It could be a problem involving the efficacy of the expansion tank – because it seems that if the tank is over filled then the system leaks, otherwise it doesn't or the leak is significantly smaller - but in all cases the fluid levels involved don't appear to make a lot of sense. For example - the expansion tank holds 1.75 litres and with this size of coolant system we should expect an absolute maximum of 0.6 litres of thermal expansion of the fluid – so why does the expansion tank need to be virtually empty in order to prevent or reduce leaks around the distributor, and why does the radiator level always appear to be very much lower than expected?

The other issue is that the expansion tank may not be working quite the way I expect it too, or the fluid loss could link to a compound problem involving two further issues. The first being the increase to the thermostat temperature some months ago (which consequentially increases the amount of fluid expansion) and the second being a chain of events where if an overfilled expansion tank caused a leak past a gasket – that leak may remain as a fault (due to the gasket being compromised) long after the fault itself has been resolved (the tank has definitely being over filled at least once in the past – so this is a potential scenario).

The icing on this particular cake is that it isn't possible to view the level of coolant in this vehicles cooling system unless the plug bolt is physically removed from the radiator.

So – with all the uncertainty and slightly confusing symptoms the only one thing we know for sure is that there is a loss of cooling fluid collecting near the base of the distributor.

However…

1. We've never quite pinned down where the fluid is coming from, nor what the precise cause of the leak is.

2. We're not sure how well or badly the expansion tank is working – or if for example some of the leaking fluid is simply being lost as it gets blown out of the vent release pipe immediately under the cap.

3. We don't know if this rather old expansion tank design is fit for purpose.

4. We've never been able to assess changes in coolant fluid level because we can't see the levels – and in fact the only way to check levels is to unbolt the brass plug[1] on the top of the radiator.

5. The fluid levels don't make a great deal of sense when viewed in the light of the fault condition.

6. We also have a number of inbuilt disadvantages with the existing coolant system design which include the following:-

    a. As mentioned above – it is not possible to visually assess the coolant levels in the system

    b. Partially draining the cooling system is apt to be messy and only generally removes about 2 to 2.5 litres. It also (again) requires the radiator plug[1] bolt to be removed.

    c. Filling the cooling system from empty must be done via the plug bolt[1] in the radiator which (again) requires it to be removed.

In order to figure this problem out a good first step would be to establish that the expansion tank is fit for purpose and working correctly. Modification may well be required in which case we could at the same time aim to simplify the maintenance of the coolant system.

Note 1 - The removal of the plug bolt at the top of the radiator is mentioned numerous times in the above notes. The problem here is that the process of tightening and loosening this bolt is starting to deteriorate both the head of the brass plug and also the flange on the radiator itself given the plug needs to be tightened firmly in order to properly seal. As the tank material is only relatively thin brass – the resulting wear and tear will inevitably cause a failure.

Overview of the existing system

The vehicle is fitted with a Rover 3.5 litre V8, and originally employed a 74°C thermostat (which in terms of minimising emissions is not ideal). The cooling system employs a sealed defender radiator (but modified to raise the outlet for the lower hose to clear the Series III steering arm), and a linked Range Rover Classic copper expansion tank holding 1.75 litres of coolant and which has one single feed pipe. The expansion tank came fitted with a pressure release cap rated at 9PSI.

The ideal temperature when running EFi is somewhere between 82°C and 88°C – primarily so the intake manifold effectively promotes the vaporisation of injected fuel minimising both CO & unburnt hydrocarbons. This links to an ideal temperature for the operation of oil. On this vehicle running a thermostat at 88°C in the hot summer months can allow the engine to marginally overheat the oil – and so a compromise was made just over a year ago to increase from 74°C to 82°C. At the time the engine employed a rather torturous path for the heater flow feed (since vastly improved), and so it took a little time to get the coolant hoses stable – but, no matter how well the hoses were fixed, there was always a puzzlingly small amount of leaking coolant fluid under the distributor clamp.

After time it became obvious that the level of fluid in the expansion tank was in some way involved. If the tank was filled to the original level of the metal marker inside the body (which was over half way up) then coolant would be virtually guaranteed to leak around the distributor base after a run. However, if the tank was more or less empty, the leak either didn't occur or was very much reduced.

Let us first look at a simplified version of the system we have now

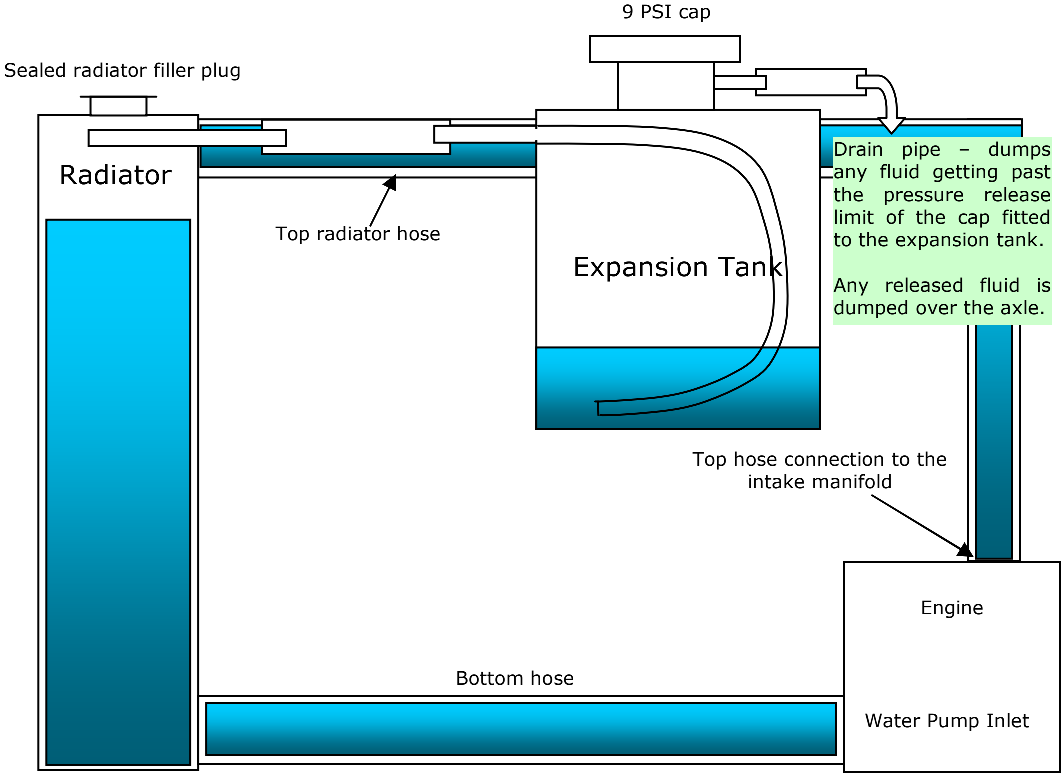


Figure 1 – Existing expansion tank design

Expansion Tank Principal

In this vehicle the radiator is sealed (i.e. it has no pressure release cap) and has a small diameter free flowing pipe at its highest point, connected via a short horizontal hose to the expansion tank at more or less the same level as shown above and on the same horizontal plane. Inside the expansion tank, the receiving pipe spirals round and down to the floor of the tank and is consequently submerged in coolant fluid. The tank is fitted with a traditional pressure release cap rated at 9PSI. When filling the system – the radiator is slowly filled to capacity and sealed. The expansion tank is then partially filled to a marker level about mid way up and sealed. Sufficient time is allowed during this process so that air in the engine and intake manifold bleeds out.

When the engine heats to normal temperature any coolant expansion in the radiator will first expand to fill whatever space may exist at the top and then go on to pass fluid through the short hose pipe into the expansion tank.

When the engine cools and the coolant contracts, that process generates a partial vacuum in the radiator compared to pressure in the expansion tank, sufficient to cause coolant to flow back from the expansion tank into the radiator so concluding the cycle.

If the expansion tank were to fill beyond capacity then the pressure release cap would open once the internal pressure reached the release point. Fluid would then be expelled via the drain pipe and dumped onto the ground – but this condition should only occur if (a) the entire system is over filled with fluid, and/or (b) the system is over pressurised beyond the limit set by the pressure release cap.

Expansion systems are certainly an improvement on older systems that simply under fill the radiator, and then dump any excess coolant onto the road. This system by contrast *contains* all expanded fluid, using it to later refill the radiator, and so helps to reduce the need for periodic top ups while also ensuring that the whole cooling system remains free of air (a cause of corrosion of the components and deterioration of the antifreeze additives).

There are however a number of disadvantages with this design. The first is that the operator cannot fill the cooling system via the expansion tank alone. The radiator or some other filling point has to be used instead. The second is the systems dependency on pressure differentials being accurately maintained in order for the transfer of the right amounts of fluid. If that doesn’t work for any reason, or is inaccurate over time, then the operation of the system will be compromised. The third is that the movement of fluid is relatively sluggish – given it operates over the time required to either fully heat the fluid from cold, or fully cool the fluid from hot. The last (in this particular case) is that the coolant level cannot be seen because the expansion tank is opaque.

A simple refinement can significantly improve this rather basic expansion tank system.

Expansion Tank – Refinement

This refinement uses a two connection expansion tank as follows:-

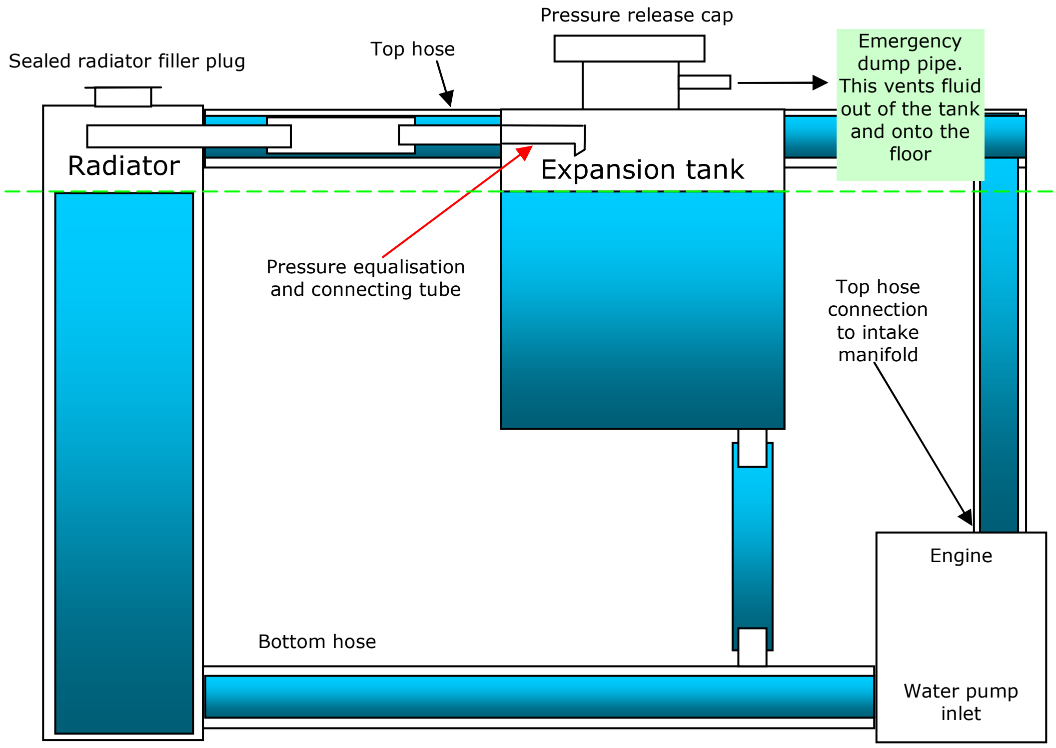


Figure 2 – Expansion system refinement

In this variant the expansion tank now has two connections. The top connection is similar to that used before but this time remains above the fluid level inside the expansion tank and is used to equalise pressure in the two vessels. A second relatively large connection links the expansion tank to the lowest point in the cooling system (usually to the lower radiator hose via a T connection).

> *In fluid dynamics this type of system is known by the collective term "connected vessels" - where the radiator and the expansion tank are the two connected vessels.*

Fluid levels in both vessels will remain at the same height (i.e. sitting on the green dashed line) so long as:-

1. Both vessels are connected below the level of the fluid
2. The rise in level is not restricted in either vessel.
3. There are no leaks
4. The relative pressure above the fluid, in both vessels, is the same.

The job of the pressure equalisation hose is to ensure that point 4 above is true at all times – in which case, and in this example, point 2 will also be true. If either of these assumptions is false then the system can and will airlock under filling conditions.

Consider the diagram below where both the pressure equalisation pipe and the top hose have been removed – and now imagine that the system is being filled, from empty via the expansion tank.

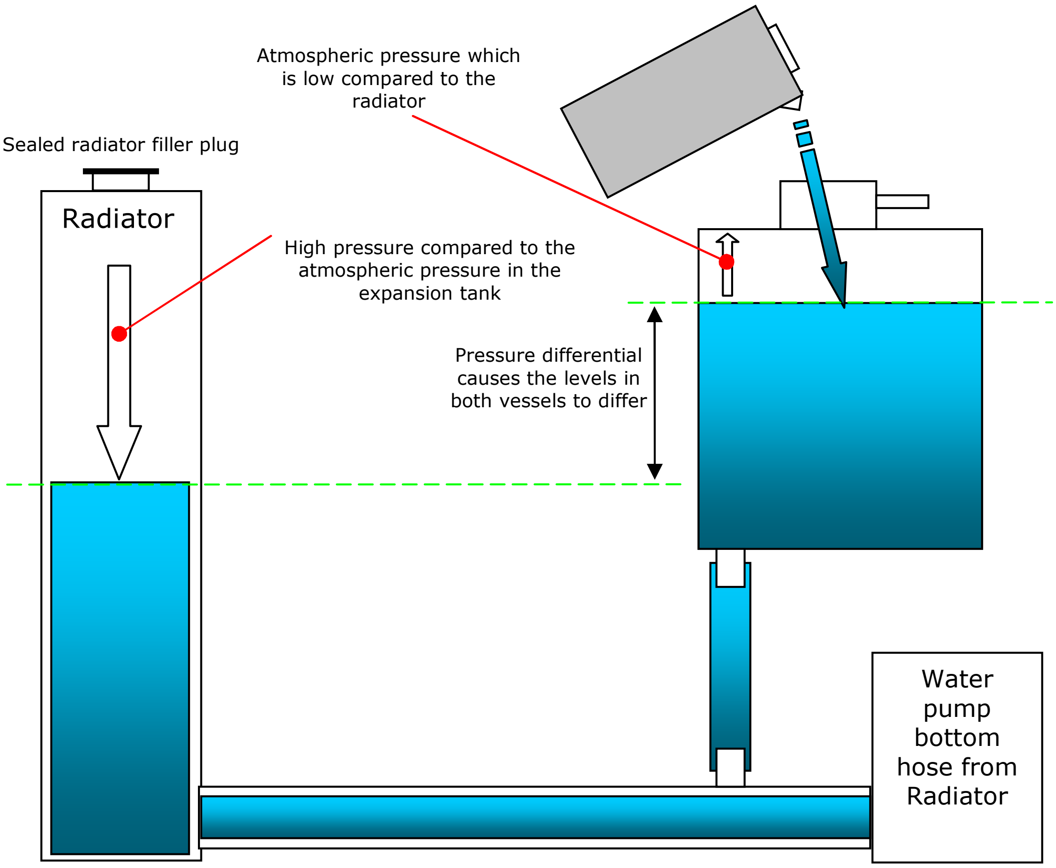
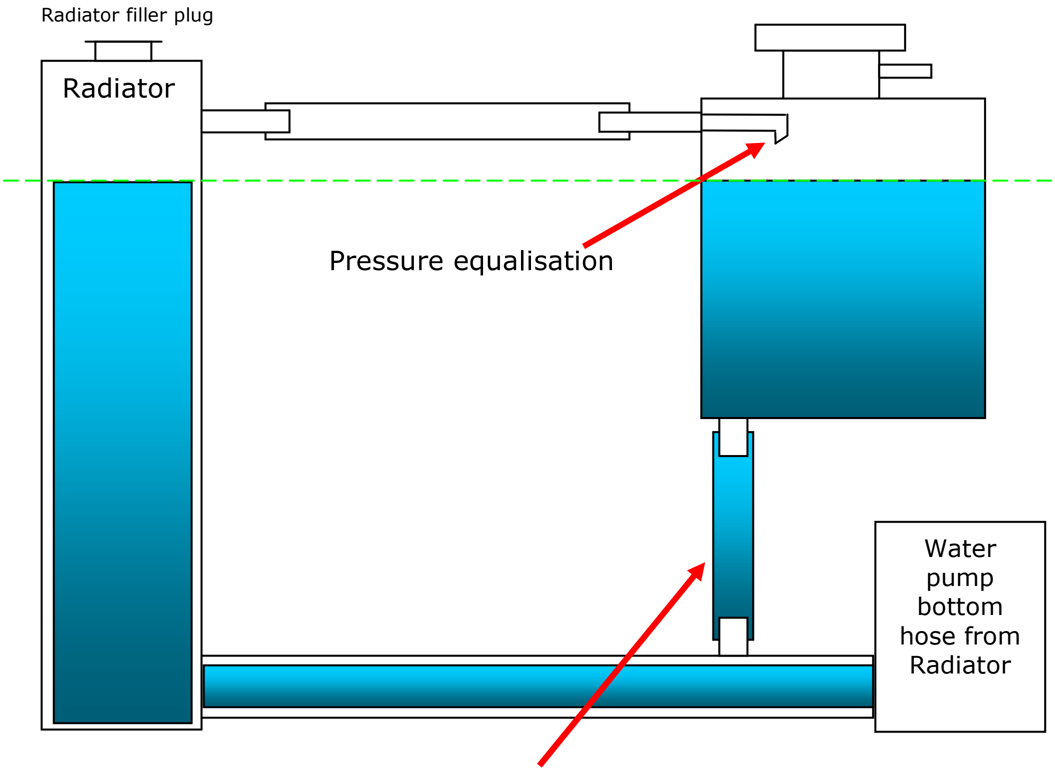


Figure 3 – Expansion tank without any equalisation

As the fluid slowly fills the system it will cause the level in the radiator to raise and in doing so will compress the air volume above the fluid, due to the increase in fluid and the fact that the air volume above cannot escape. At some point the pressure will elevate sufficiently in the radiator so that fluid will simply stop rising and will only rise in the expansion tank. The system now has an airlock.

> *Under these circumstances it would be reasonable to conclude that the system is filled based on the level in the expansion tank, not realising that the radiator was in fact only partially filled.*

The small linking pipe joining the two vessels is therefore designed to allow pressure to equalise in both connected vessels and the pressure equalisation feature extends to both the engine and the intake manifold by virtue of the top radiator hose. In effect, all vessels are connected and pressure equal. Pressure changes will therefore occur more or less simultaneously in the radiator, the expansion tank, the engine and the intake manifold.



Again – ignoring the top hose, and turning our attention to the second expansion tank hose pipe – this is typically a 16 to 20mm hose coupling the base of the expansion tank to the lower radiator hose via a T connection.

Assume for a moment that fluid in both vessels has been set at some notional "Normal" level slightly below the top of the radiator and the system is filled. Due to the equalisation pipe, the pressure in both vessels will be the same, and so the fluid level of the coolant in the radiator and expansion tank (and via the top hose the engine and intake manifold) will be the same.

If the engine is now run, the coolant will slowly expand as the engine heats and the increase in fluid volume will equally fill the free space at the top of the radiator[1] and by the same amount the free space in the expansion tank – levels will remain equal. Eventually the coolant will reach the top of the radiator when no more expansion is possible at which point the level will start to rise higher in the expansion tank. As the engine cools the fluid will contract and the decrease in volume will immediately cause the level in both vessels to reduce to their original "Normal" levels. All the time the pressure is equalised continuously throughout the heating and cooling cycles in both vessels.

The "fluid top up" effect is immediate in this system – and does not require a slow exchange of relatively small amounts of fluid to pass via a hose linking the radiator to the expansion tank under control of pressure differentials. Additionally the cooling system can be filled (from empty) via the expansion tank and if that vessel happens to be transparent, the level of fluid in the whole system is at all times clearly visible. It is for these reasons that the vast majority of manufacturers employ this system – and likewise why it should be used on this vehicle.

1 – This is an example only – as the radiator fluid level should ideally always be filled to capacity.

A cooling system schematic for this vehicle

A more realistic coolant system schematic for this vehicle showing the expansion tank, complete with modification could be illustrated as follows. Assume that our starting point is an entirely empty cooling system (including the heater matrix) and that the operator has now slowly filled the system to the MAX line of the expansion tank but has not yet run the engine. In this case we would have the situation shown below.

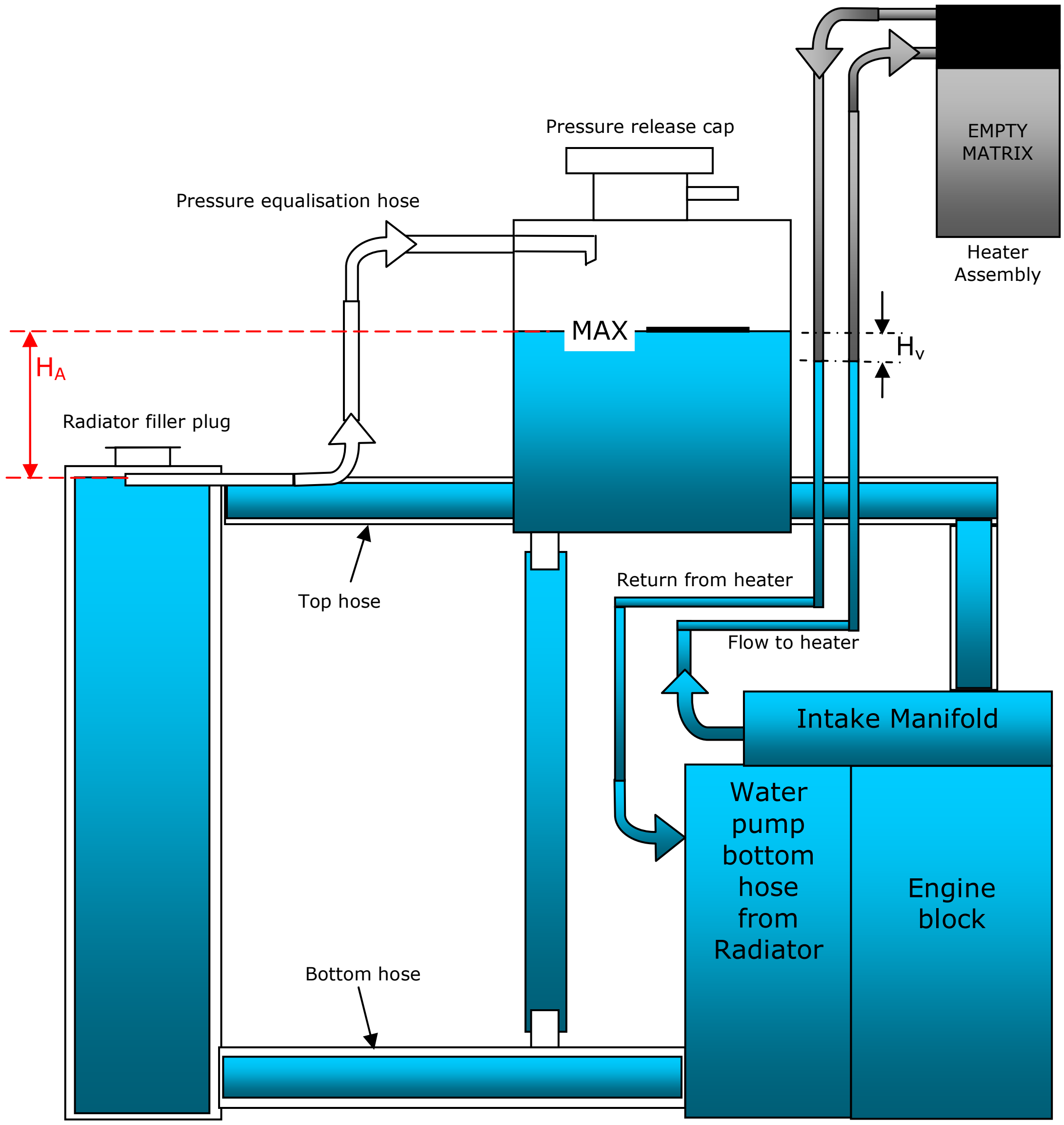


Figure 4 – Partially filled cooling system in the Land Rover

In this scenario as fluid is added to the expansion tank, the radiator will slowly fill to capacity, as will the engine, intake manifold and water pump - given they are pressure equalised via the top hose and the pressure equalisation hose. The heater matrix however *will* give rise to an airlock as it is a sealed unit mounted high and cannot equalise pressure. Even if the heater matrix was somehow able to equalise pressure (i.e. if it contained some kind of vent), the fluid in the flow and return pipes would still only ever each the MAX line of the expansion tank anyway but with the additional back pressure created by the air lock in the matrix, the coolant level will reach some level below the MAX line (see H_v above) and go no further.

The airlock in the heater matrix sounds worse than it actually is because as soon as the engine is turned over, the water pump will drive fluid from the intake manifold under pressure via the heater flow pipe into the matrix immediately filling it to capacity and causing the fluid level in the entire system to fall by a proportional amount as a consequence. The total volume of air in the heater flow & return pipes, plus the air in the matrix will then be chased into the water pump via the heater return pipe and from there to the radiator via the top hose and then onto the expansion tank via the equalisation hose.

The head distance between the MAX level on the expansion tank and the top fluid level in the radiator is shown as H_A in the above diagram. This size should be positive – in the sense that the MAX level in the expansion tank should be equal to or higher than the highest fluid level in the radiator. The more positive it is the more reserve of coolant fluid will be available.

If we assume that the above system is now cold, and that the level in the expansion tank has been topped up to the MAX line. In fluid terms, the resulting system would look as follows

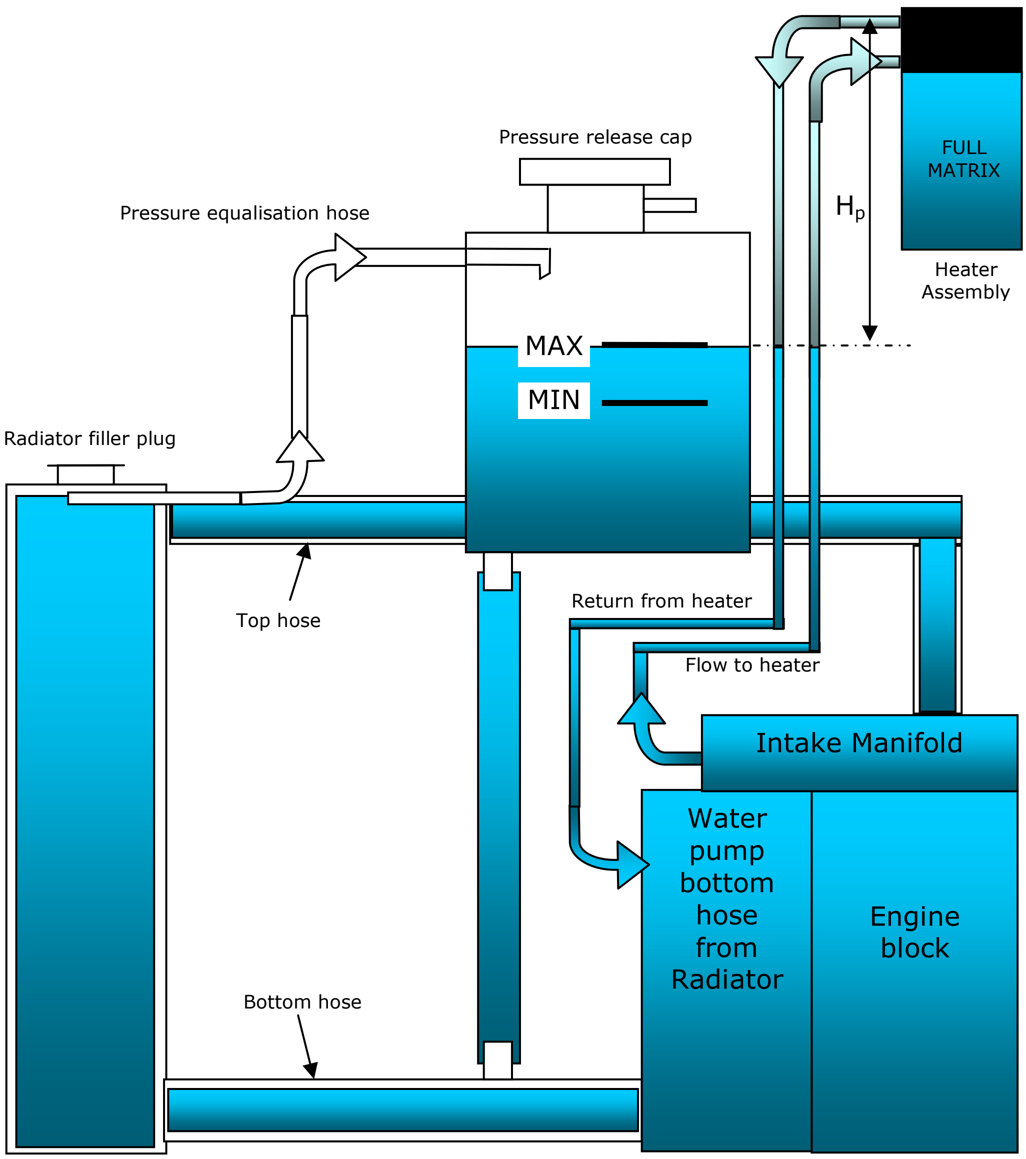


Figure 5 - Completely filled cooling system in the Land Rover

The heater matrix will now be filled to capacity, and due to the fact that the flow and return pipes feeding it are on the top of the heater assembly, will remain filled close to capacity because the coolant fluid is effectively trapped (in fact the level in the matrix will actually reduce very slightly due to thermal contraction once the fluid cools). The area above the MAX line of the expansion tank, and the top of the matrix (see line H_p above) only involve short runs of two 16mm pipes, and in fact these will actually air lock and form a low pressure area of fluid as the coolant contracts because they have no way of drawing air into the system (shown as a slightly different colour in the diagram).

As soon as the engine starts again – the pump will fill this relatively small low pressure area (H_p) instantly and so a system in this state and with no other leaks will remain stable.

Expansion tank markings

With regard to the interpretation of the tank markings we will adopt the widely used standard of MAX when the engine is cold. As a consequence the fluid level can be expected to rise above MAX when hot.

Expansion quantity

How much fluid expansion can we expect if the coolant were to be heated from say 10°C to a ceiling of 84°C?

In fact there is a useful web calculator (http://www.engineeringtoolbox.com/volumetric-temperature-expansion-d_315.html) designed to assess this particular measurement for pure ethyl alcohol and water.

If we assume that the coolant volume through the system is 11.3 litre (Haynes), and that the volumetric coefficient of expansion for Antifreeze is 0.00109 (at 1°C) then if the vehicle coolant has a volume of 11.3 litres of 100% antifreeze at 10°C, it would rise to 12.2115 litres at 84°C – an increase of 0.9115 litre or just under a litre. The same calculation assuming a mix of 50:50 antifreeze and water gives the following result

1. 5.65 litres of water (where the coefficient is: 0.000214) expands to: 5.7395 litres.

2. 5.65 litres of antifreeze (where the coefficient is 0.00109) gives expansion to: 6.1057 litres

In other words when a system of 11.3 litres of fluid employing a 50:50 mix of water and antifreeze is heated from 10°C to 84°C we should expect an overall expansion volume of 0.5452 litres – resulting in a total coolant volume of 11.8452 litres.

In practise the amount of coolant fluid expansion will be smaller for two reasons. Firstly the engine typically maintains a temperature between 79 and 80°C which is four degrees lower. Secondly the temperature of coolant leaving the radiator will by definition be lower than the coolant in the rest of the engine due to the radiators cooling effect.

Regardless – this is a reasonable starting point, and means that there should be sufficient headroom when facing a blisteringly hot summer’s day.

Positioning the Expansion Tank

In terms of positioning the expansion tank – the choice is clear. The MAX line of the expansion tank must be equal to, or higher than the highest level of fluid in the radiator on the assumption that the tank must possess sufficient expansion capacity above the MAX line to cope with the thermal expansion of the coolant in the entire cooling system. The higher the MAX line is above the top most level of fluid in a full radiator, the more reserve of coolant the system has.

Allowing for under bonnet clearance and the fact that the heater matrix is currently the highest point in the cooling system, the expansion tank will have to be mounted at some level below the matrix, but ideally so that the MAX line is higher than the top of the fluid in the radiator when filled to capacity and the engine intake.

As soon as we receive the Mercedes expansion tank, we might consider approaching this as follows…

1. On the bench, block all the Mercedes expansion tank pipes, and then fill it to capacity with room temperature water.

2. Then carefully measure the fluid that must be removed in order to reduce the level from the top down to the MAXIMUM mark on the tank.

3. Out of interest, record the same measurement in order to reduce the level from MAXIMUM down to the MINIMUM mark on the tank (this isn't required but it may be useful to know)

If measurement 2 is less than half a litre, we have a problem – given we won't have enough room for the expected thermal expansion of the fluid – in which case we must go back to the drawing board. If the volume is over 0.75 of a litre we are in very good shape, but if it's between half and three quarters of a litre then the capacity is a little tight and so more checks will need to be made to ensure this will work. My guess is that we may get as much as 900cc of expansion volume above the MAX line (roughly 3cm of height) in which case continue to point 4…

4. Find the highest position you can, above the radiator and plenum, for mounting the tank whilst ensuring bonnet clearance.

Regarding mounting spots for the expansion tank – we could use a position next to the heater assembly unit, employing a steel mounting frame bolted to the mud guard under the wing. This would provide maximum bonnet clearance and so the unit could be mounted in its most elevated position, but the unit would be slightly tricky to reach for filling and top-ups due to the proximity of the bonnet. In addition the pipe work in this position would be raised and obvious (i.e. ugly). Another possible location is in the small gap where the old copper expansion tank resided. Although this space is relatively small – fitting the new tank into that position is a definite possibility and would provide good accessibility while also hiding all the pipe work (allowing for the lower elevation).

Either way - it would be worth designing the mount so that the tank can be relatively easily removed.

Potential Solution #1 – now rejected

In the first instance, I tried to fit a normal defender expansion tank – however these units have four disadvantages.

Figure 6 – Standard (old style) defender expansion tank

The first is the physical size. Given the amount of room available, it would be extremely difficult to squeeze this into the engine bay. The second is the pressure equalisation pipe is not above the fluid. It is underneath the unit (see red arrow). This means that the pressure equalisation link between the radiator and the expansion tank will be at different heights with one above and one below the fluid level. Being completely honest, I'm not 100% sure if that's a problem or not, but it feels like it might be. The third problem is that you can't see the liquid level inside. While that feature isn't exactly essential, it is a very *desirable* quality of any modified system we may make. The fourth and last problem is two fold: First the cap on these expansion tanks is rated at 15 PSI, rather than the 9 PSI I am currently using. Second because it's a screw in cap, I can't just fit another – and as far as I can see there is no alternate supplier of a lower pressure cap.

So the long and short is that a standard defender expansion tank is a non starter.

Potential Solution #2 – now rejected

The second potential solution involved purchasing the following unit.

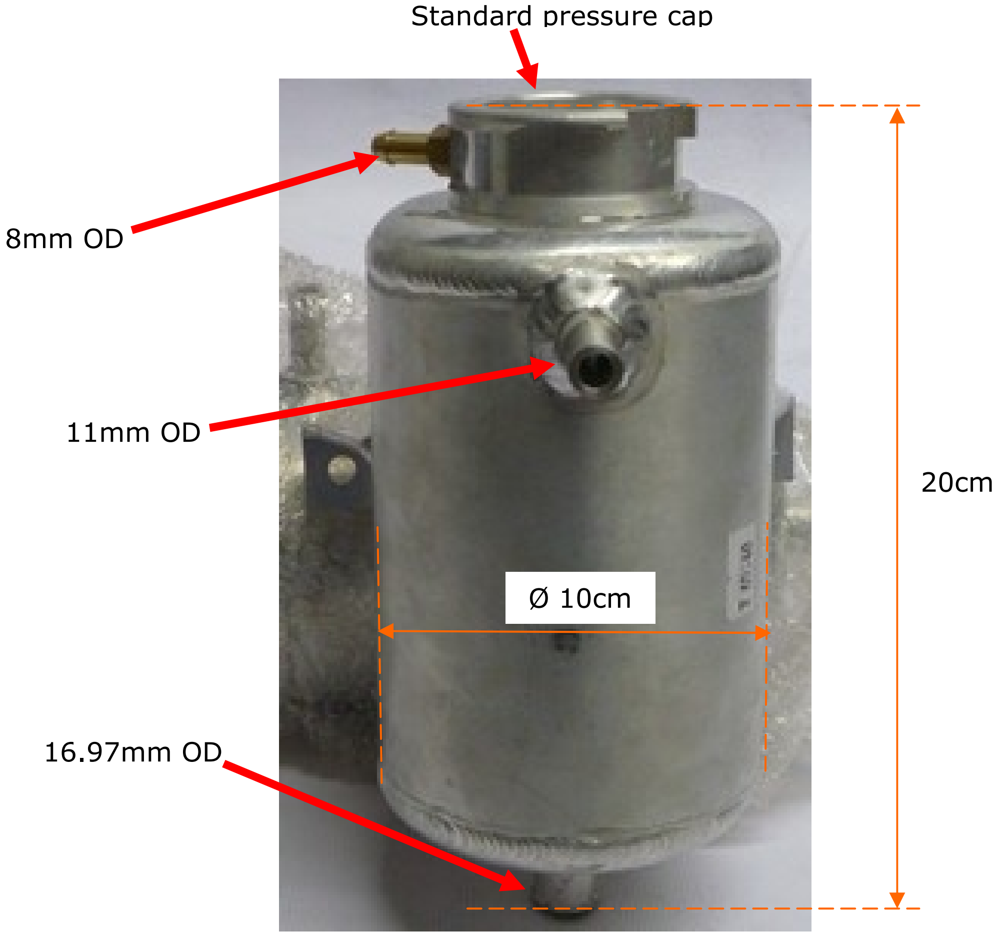


Figure 7 – The Selected Expansion tank

The specification is

1. Overall height (inc the bottom spout) is 20cm
2. Tank OD is 10cm
3. Mounting centres are 105mm apart on attached back plate
4. The boss at the top fits a standard pressure cap.
5. The bottom hose has an 16.97mm OD
6. The uppermost overflow hose has an 8mm OD
7. The equalisation hose has an 11mm OD.

On paper this looked like a good candidate. However – as soon as the old expansion tank was removed, and the new unit roughly fitted to figure out its best fitting height it quickly became clear that the available bonnet clearance meant we would only get the cylinder maybe 1 or 2cm above the radiator (allowing for the cap). The unit is made from thick wall aluminium (i.e. roughly 4.5cm radius) so each centimetre of height provides only 64cm^3 volume.

$$Vol = \pi.r^2.h \text{ ie: } 3.1415 \times 4.5^2 \times 1 = 63.6154 \text{ cm}^3$$

It would require 7cm height just to obtain ½ litre expansion and so the only mounting option would have been to place it on the bulkhead of the vehicle between the brake servo and the heater assembly where bonnet clearance is greatest, but at the cost of requiring long hose pipe runs and a rather high and inaccessible final position – a quality made even worse because the tank is opaque.

In effect the unit would have been more or less filled to the brim continuously – and as stated earlier, coolant in these expansion tanks is dead fluid. It does precisely nothing to cool the engine. This style of vertical tank was rejected for these reasons.

Solution #3 – the adopted configuration

The third solution involved purchasing the following parts – which have yet to arrive. Time will tell if these can be fabricated with the space available given it is almost impossible to confirm dimensions until the parts arrive.

I trawled a well known auction site for alloy and plastic coolant tanks – and basically nothing looked right – until I spotted these Mercedes parts. 500 SEL's use them and so unsurprisingly the volumetric capacity looks about right for a small block. Estimating the outer dimensions also confirm that the tank will snugly fit into the space where the existing tank resides. The best fit has the cap nearest to the wing – but either orientation looks feasible. The tank has a built in switch for level monitoring – which unfortunately we are obliged to fit (to fill the hole) so we could optionally use that sensor if we fancy it.

The tank looks as follows:-

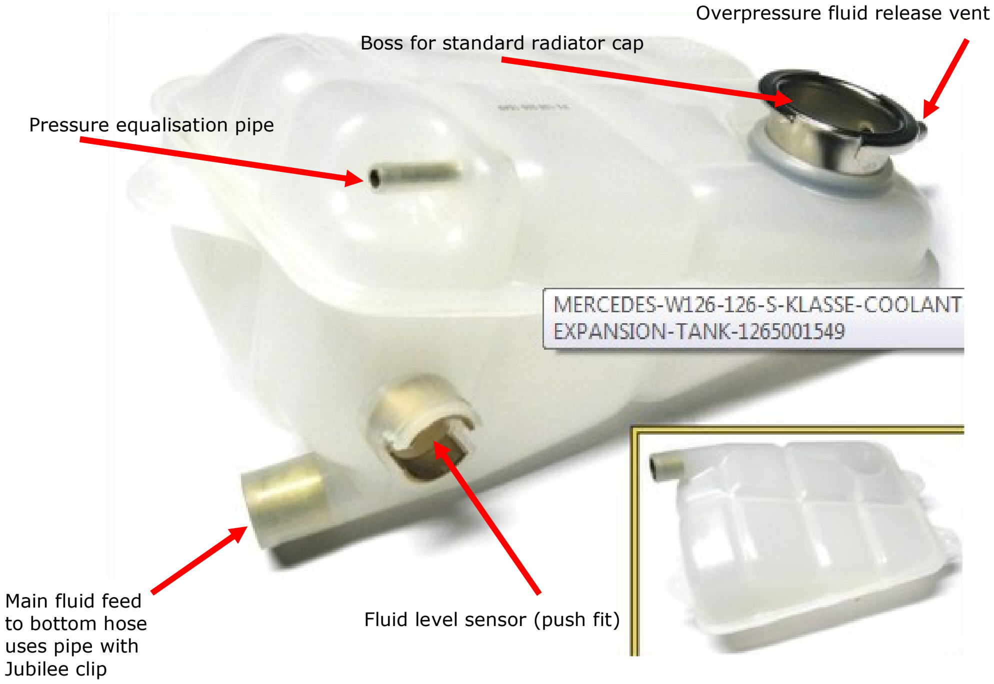


Figure 8 – Mercedes 500 SEL expansion tank

I separately purchased the connection hose for the main feed (this will connect to the T in the bottom radiator hose). It has a specially expanded end but then shrinks down to 16mm hose. We may not need this, but it might also be handy.

Figure 9 – Mercedes expansion tank connection hose

This tank has a number of desirable qualities. All the pipes on this tank couple via jubilee clips and the tank also uses the boss for a standard radiator cap. It has three very simple but strong looking mounting points (two on the end with the cap, and one on the other end) and both the pressure equalisation and main feeds exit on one side. Additional pictures of cheaper second hand, but rather rough looking items, offer useful viewpoints as follows:-

Figure 10 – Second hand Mercedes Expansion tank examples

Both images are interesting – and the 2nd of the two is helpful given we can predict the scale of the overall size, simply by reference to a radiator cap. The diameter of a radiator cap is:-

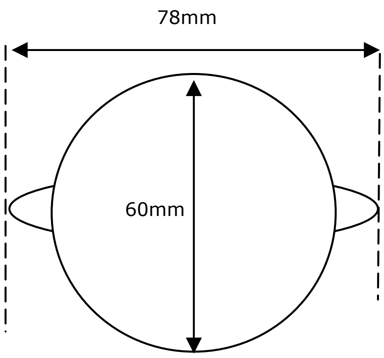


Figure 11 – Typical radiator cap dimensions

In the picture the radiator 60mm diameter is 90 pixels and the 78mm dimension is 126 pixels. That means that very roughly any pixel dimension can be divided by 1.5 to get the size in mm. In which case we get the following rough estimates

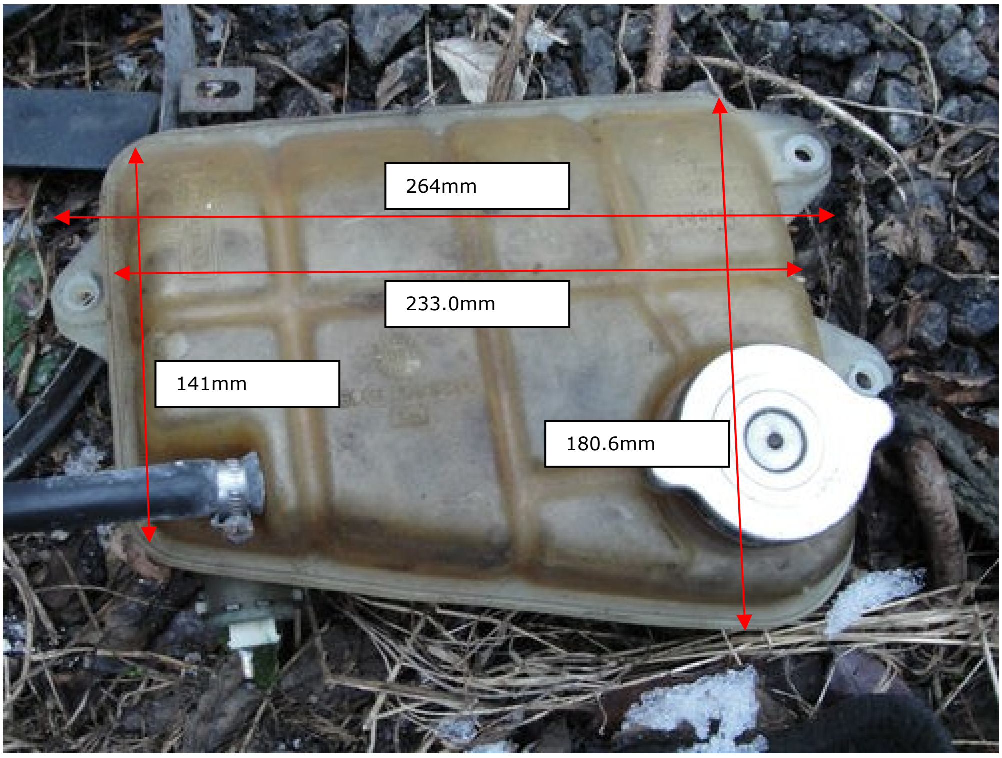


Figure 12 – Estimates of sizes for Mercedes Expansion tank

Subjectively it's a big tank but if these dimensions are used to cut a cardboard template, it is clear that we should be able to fit it somewhere under the hood. Key advantages of this tank are:-

1. The cap boss is for a standard radiator cap – so we can run a 9 or 15 PSI cap

2. All the hoses require jubilee clips and both hoses exit on one side (with the vent pipe located on the other side

3. The plastic is transparent for easy fluid level checking (remember we have bought new)

4. It has a substantial volumetric capacity. Using our estimates above, 1cm depth at the top of the unit (closest to the cap) represents a volume of something like 374.26 cm^3 – and that's just 1cm.

So – although we will have to wait a week or two for the parts to arrive – if size isn't a problem we can almost certainly make this work.

The Mercedes part numbers are…

Expansion tank	Mercedes W126 coolant expansion tank bottle SE SEL SEC 420 500 560 A1265001549
The hose for the main (lower) fluid feed. This hose will need to be butchered, but it contains the wide end – which will be the most useful – and may even reduce to 16mm which would be very useful indeed.	Mercedes W126 Coolant Tank Water Hose Pipe 1265011882
Tank coolant level sensor.	Mercedes 190 W124 W126 R107 Coolant Level Sensor 1245400244 German

Other pictures follow:-

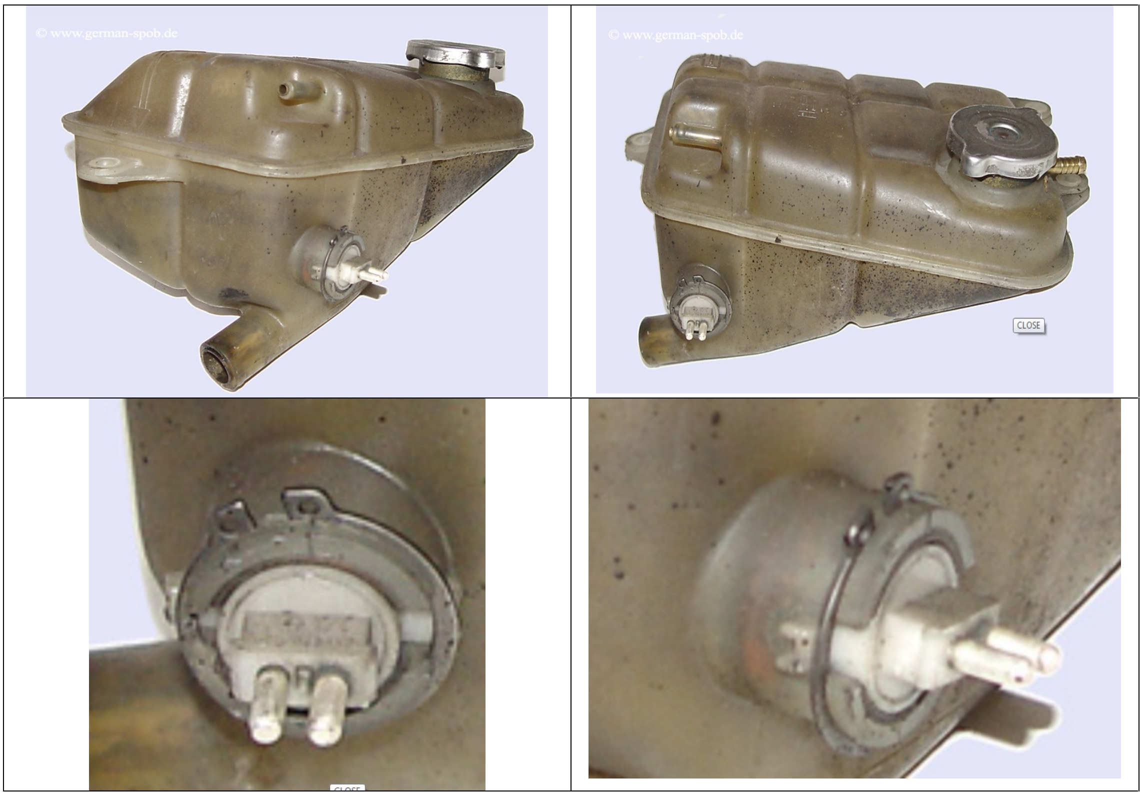


Figure 13 – Alternate views Mercedes Expansion tank (2nd hand item)

Work commences 4th March 2013 on solution #3

I started the coolant system strip down today and had a hell of an interesting day. First – the brass plug bolt at the top of the radiator rounded its shoulders when I tried to unbolt it. I then spent an exasperating 2 hours trying to get the plug unscrewed only to find it was stuck solid and simply wouldn't budge.

It is worth remembering that this is the same plug I've removed a dozen times or more since I've owned the vehicle – but no matter what I did it would not budge, and actually just broke up more as I tried.

In the end I had no choice but to grind it right down to the flange – at which point the threaded portion was easily unscrewed.

The downside is that even after extremely careful grinding, I damaged the flange on the radiator – not badly and it can be flattened off, but it is going to be a problem that may call for the removal of the radiator to sort out. The other problem is replacing the brass plug itself. I want to do two things. First obtain a new replacement plug. Second fit an alternate drain feature into the lower radiator hose so that there is no need to drain from the radiator using this plug.

Regarding the threaded plug – work researching different thread patterns now pays dividends. It turns out that the thread is not metric (doesn't match any metric thread pattern) but it has a major diameter of 20.54mm threaded with exactly 14 TPI – so it is a ½" BSP thread. I've now ordered two replacement brass plugs from a well known auction site.

The other task I did today was to remove the lower radiator hose completely from the vehicle after draining the system down. Unfortunately I rather clumsily managed to lose about a litre of fluid while doing it – but otherwise the hose came away cleanly.

5th March 2013

Today I wanted to look at the damaged flange on the radiator. This is the sealing flange of a filling hole on the top of the side mounted header tank (on the driver side). This area is all made of brass and the hole itself is threaded ½" BSP – with the sealing flange raised about 4mm above the brass skin of the header. It is roughly 25mm in diameter with a 4mm sealing face and is threaded for a ½" BSP brass plug bolt.

After the difficulty of removing the original brass plug bolt yesterday, the flange had suffered some scoring. The question today was what to do about it. Quite separately from the scoring - the flange has also over time been pushed into a kind of hollow or dip where the brass of the header tank has sunk slightly – probably due to excessive force being applied to fit or remove the sealing plug bolt in the past. Using a slide hammer with a small hook inside the flange itself this area was raised to get it back into its correct position so that it was more or less flat and parallel to the ground.

Looking at the scoring after cleaning the area, one score in particular would have required the entire flange to be ground down by maybe ½ to ¾mm in order to flatten it - which would have taken the flange uncomfortably close to the top of the plug thread. An alternate method of repair would involve blocking the threaded centre of the hole with some kind of metal pipe which couldn't be soldered, and likewise fitting a containment ring round the outside of the flange so that solder would remain in place – at which point the flange could be heated and solder added to fill the scores. Later any raised areas could be filed down to obtain a smooth flat surface.

A jubilee clip around the raised flange formed the outermost closed ring, and a perfectly sized piece of aluminium pipe filled the threaded hole. The area was prepared by cleaning with petrol to remove the residual Hylomar blue on the flange and then a dab of flux applied and the area heated – while applying a little solder to fill all the scores. Within 30mins the solder was flattened down using one of the wider diameter 35mm grinding discs in the Dremel. The area was then cleaned to remove burrs etc, and a light coat of satin black applied.

> *It looks great and more importantly feels great as a finger is run over the flange. One thing to remember is that the replacement plug seal we use to seal this hole should never need to come out again if a proper drain plug is fitted to the lower radiator hose.*

The second job today was to remove the existing expansion tank along with the four mounting bolts. The two small hoses at the top of the radiator were also disconnected to provide more room (plenum return and expansion tank feed).

The special Mercedes coupling hose arrived this morning. The tank may get to me before the weekend – but I'm now basically stuck until it does.

6th March 2013

No work done today – but the coolant level sensor arrived this morning, as did the ½" BSP brass blanking plugs (they fit perfectly).

We're now waiting for the expansion tank to arrive.

7th March 2013

No work done today – but the replacement lower hose arrived as did the trunnion (used by the blend control cable on the heater).

8th March 2013

The expansion tank arrived today – all the way from Poland and just as well, as I checked with Mercedes and it turns out these are depleted stock (no longer made). These are the last ones you'll get.

Anyway – while it was pouring down with rain, I'd taken the day off to deal with other stuff, so when I got time I decided to have a look at the fit.

There are two bits of good news, and two bits of bad news.

Bad news #1 is that there is no way to fit the tank up where the heater matrix is, because it fouls the ignition coil, and due to the wing metal work would come perilously close to fouling the plenum. Even if the coil fouling was resolved it would be an awful position – and the hose pipes would look exposed and clumsy. It would look like an afterthought.

Bad news #2 is that although the fluid level switch arrived earlier in the week, it is horribly intermittent. It basically doesn't work when fitted. It sort of works when on the bench, if you press it just right, otherwise it is open circuit all the time. That's not such a big problem as I was never intending on using it anyway –

but I'm going to see if I can get it replaced anyway. Note that I used two O rings and a new circlip to fit it – and it does pass a static fluid check – but I have no idea if it will pass a pressure test.

Good news #1 is that it is possible to fit the tank in more or less the same position as the old tank – and with the bonnet clearance as it stands, it is just possible to elevate it so that fluid at the MAX position is marginally above the level of the top of the fluid in the radiator. It isn't a huge amount of elevation, but that doesn't matter at all. Fluid dynamics will guarantee that the level in the radiator will be as high as the level in the expansion no matter what.

Good news #2 is that after measuring the fluid required to drain the new tank from full (ie: fluid up to the base of the cap) down to the MAX arrow it turns out to be very close to the estimate. 800ml fluid is required – but in fact the volume will be slightly more in practise because the tank is internally split into chambers, each of which has a raised dome at the top. This means that when the tank is full to the brim (from the point of view of the pressure release cap) there is still air in each chambers dome permitting a little more fluid expansion. It is difficult to be 100% sure simply because it is rather hard to measure, but a reasonable estimate for that extra room is somewhere between 50 and 75ml based on the extra water successfully added to the tank.

So the tank has 800 to 875ml expansion volume available and theoretically the system requires something like 545.2ml. Armed with these results fabrication has started. The steel for the passenger side hanger has been cut but isn't yet welded. A job for tomorrow

That's it for today. It has been a dreadful weather day – hopefully tomorrow will be marginally better.

9th to 10th March 2013

Very busy two days – and now have the entire system in place.

The fabrication of the mounts was the starting point for today's work. Both are relatively straightforward, but took a good deal of welding, trimming, grinding and filing – before finishing with a coat of primer and satin black. M6 galvanised captive nuts were welded onto both brackets (3 in total) simply because it makes the fitting and removal of the tank very much easier. The end result is mounted as high as possible.

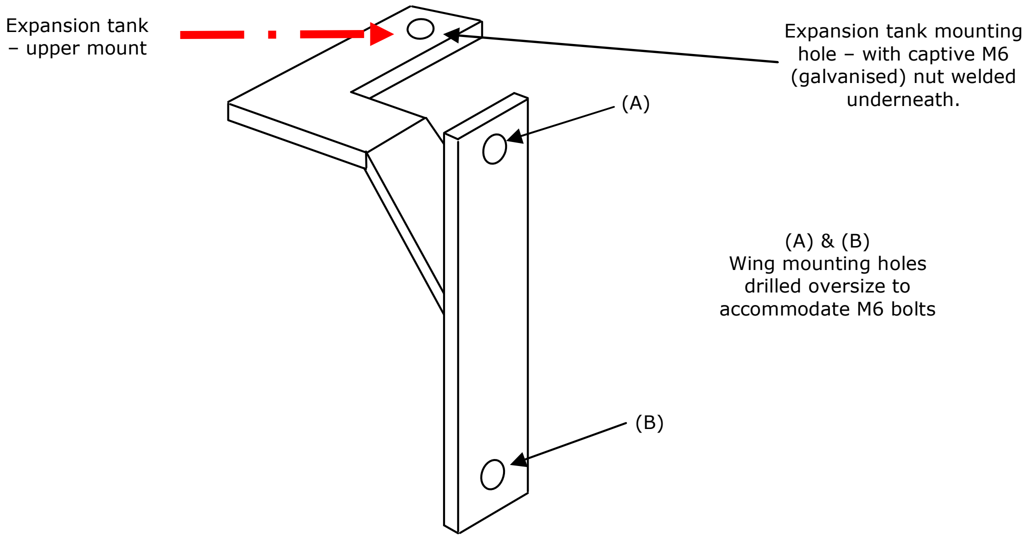
The next stage of the fabrication was the copper T piece in the lower radiator hose but when the two halves of the existing lower hose were separated from their coupling it was discovered that a piece of domestic 40mm plastic pipe had been used for the purpose. Not a huge problem in itself – and it had worked extremely well for a number of years. However the plastic was severely deformed due to the compressive action of the jubilee clips, and so it was a relief to replace what has been a single-point-of-failure.

Time was then spent fabricating the copper T structure with three objectives. First to correctly couple the lower hose (requiring the existing rubber hose leading to the radiator to be shortened somewhat). Secondly, a connection needed to be prepared and angled back up to the expansion tank so that the lower main feed of the new tank could be connected via 16mm ID hose. Third a drain cock needed to be fitted – using a standard domestic drain in order to simplify the task of partially draining the cooling system. The end result in terms of the drain angle might look a little odd on first sight, but in fact the position of the outlet makes it easy to get a drain hose pipe attached.

All of the above work (the brackets and the copper) took something like 8 hours spread over two days. After that the individual parts were all painted.

The next stage was fitting and clamping - tackled today (10th).

The photo below shows the expansion tank mount on the driver side wing. The top hole is used to mount the tank and has a captive M6 nut welded underneath, while the two other holes are drilled oversized to accommodate M6 bolts (7.5mm). Out of those two, the bolt passing through (A) also holds one of the P clips securing the loom. The steel used in the bracket is heavy gauge (roughly 4mm). A schematic and photo of the area are shown below.



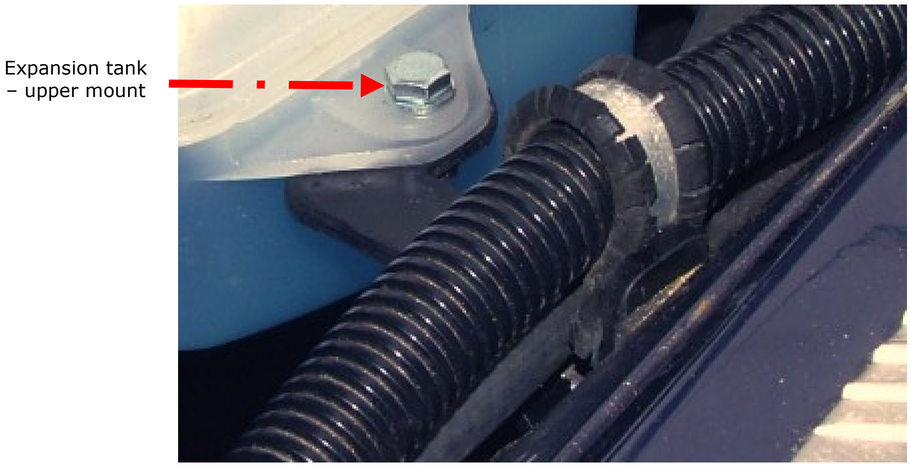


Figure 14 – Wing side expansion tank mount

The second mount is quite different from the first. Shaped a little like an L – it fixes to the galvanised structure at the front of the vehicle via two M8 bolts and uses two captive M6 nuts welded onto its reverse side to secure the expansion tank. Again it is constructed out of heavy gauge steel (roughly 4mm) – but with just enough flexibility (spring) to allow for a degree of flexing at its far end. The weld between the base plate and the L bracket is not a butt weld. Instead the L bracket is cut into a recess in the base bracket so that it is completely pinned – and then welded on the back, bottom and front. A schematic and photo of the mount are shown below

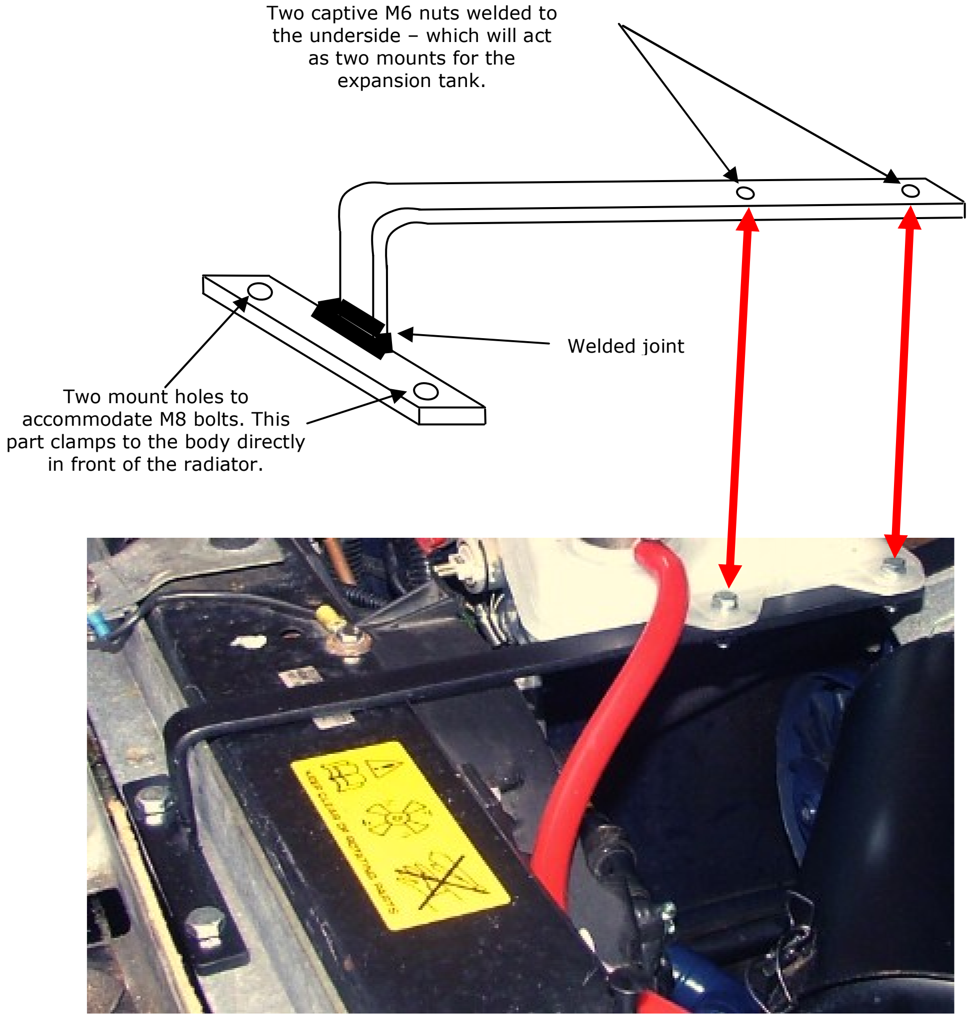


Figure 15 – Second long expansion tank mount (using two captive nuts)

The fit of the bottom hose copper T piece came next. This had a number of objectives. It first needed to couple the two halves of the custom lower radiator hose – something that required the hose to be shortened by about 3 inches. Second it needed to clear the steering system and the oil filter while at the same time presenting a good line for the connection to the expansion tank main feed. Third it needed some way to easily drain the cooling system down using a domestic drain valve.

A picture of the complete assembly (after painting and fitting) is shown below

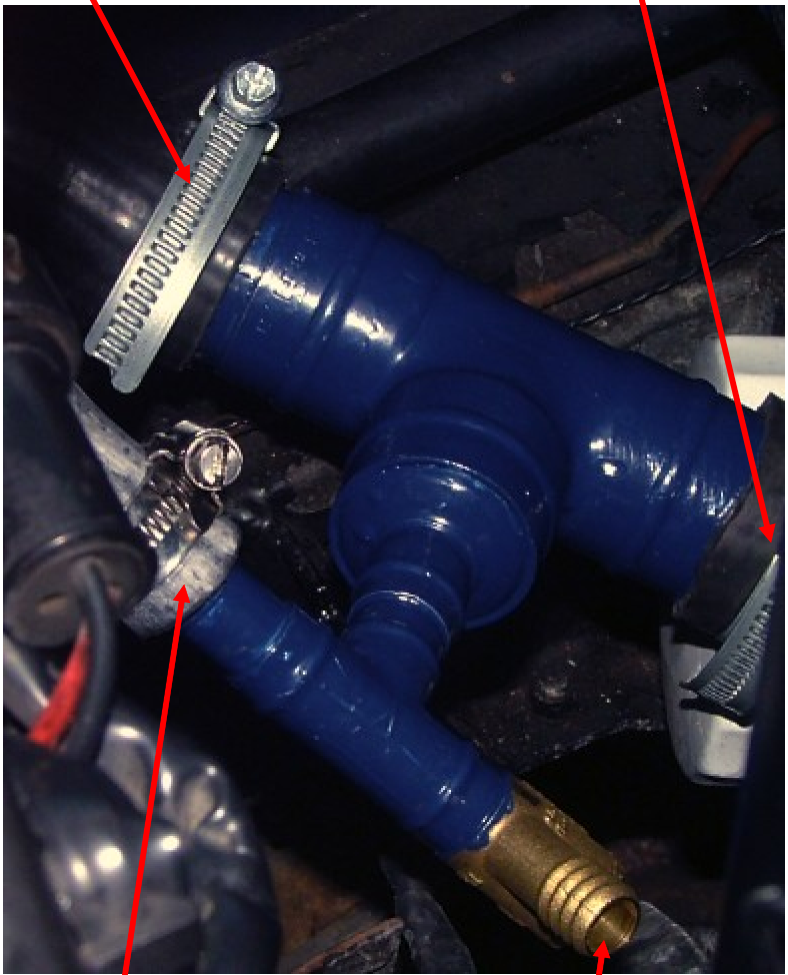
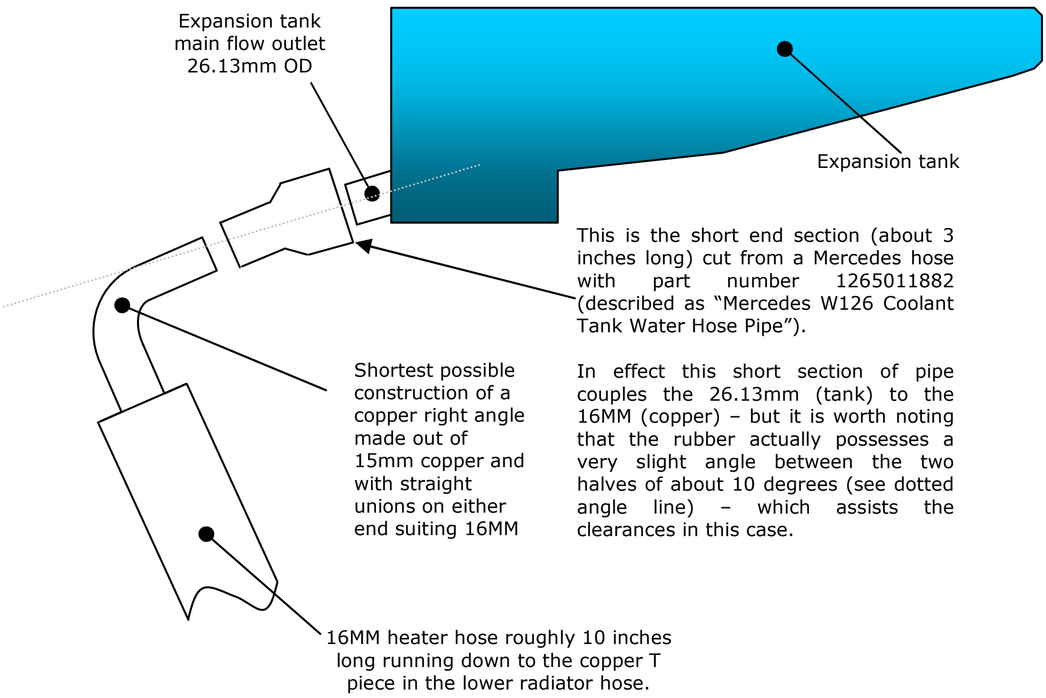


Figure 16 – Main copper coupling (expansion tank to lower radiator hose)

In order to partially drain the coolant fluid in the past the process started by removing the brass plug bolt at the top of the radiator with all the commensurate wear and tear that caused followed by the insertion of a narrow (silicon) hose to the bottom of the radiator tank at which point the fluid could be siphoned out. Typically 2 to 2.5 litres of coolant could be removed in this way.

With this new arrangement it is easy to drain a full 5 litres of fluid from the system.

The photo below shows the main outflow feed from the expansion tank – which itself connects to the lower radiator hose T piece shown above. This connection is built as follows:-



A straight length of 16mm ID hose connects the copper right angle under the expansion tank to the lower radiator hose T coupling. The end result is a good solid connection with no hose stressed. The top view is shown below with the level sensor in the fore view.

Figure 17 – Expansion tank main feed and copper union

Looking now at the other connections to the top of the radiator – and specifically the pressure equalisation hose, and the plenum return feed – there was a problem with these. The radiator used a fixed pipe braised to the header with 8mm OD, while the second pipe was threaded into the header but only with an OD of 6.3mm – which didn't suit any of the plumbing.

Interestingly – the 8mm feed (which was originally being used by the plenum return) was actually better suited to the task of pressure equalisation for two reasons. The first is its position at the very highest point inside the radiator. The second is its construction – given it is protected by an internal baffle which effectively shrouds the pipe from fluid inside the radiator.

The 6.3mm pipe, by contrast, is a threaded adapter screwed into the body of the header tank and is simply an exposed pipe inside the radiator fitted roughly 1cm down from the top.

The 6.3mm threaded outlet was therefore unscrewed and its flared pipe flange removed. A piece of copper pipe with OD 8mm was then soldered onto the original 6.3mm pipe in order to provide the required diameter. A flared end was then added by soldering & smoothing a solder lip. The adapter was then threaded back into the radiator with a new copper washer, and Hylomar blue sealant. The hoses were then connected – red silicon as the pressure equalisation hose, and the existing (black) plenum return hose.

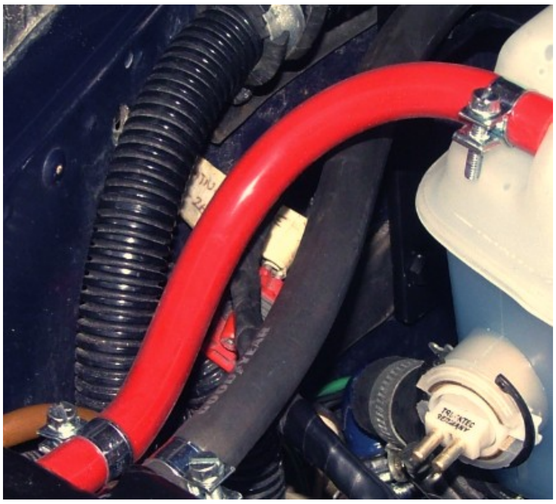


Figure 18 – Radiator pressure equalisation hose (red) and Plenum return hose

At the same time a new ½" BSP brass plug was threaded into the now repaired radiator flange, and sealed with Hylomar blue. It was tightened using an 18mm socket (but not using an impact gun) as shown below.

Figure 19 – ½" BSP plug bolt on radiator

The final task was to extend the pressure release vent outlet (immediately above the pressure release cap) via a silicon hose, and down initially to the floor (via the cross member). In order to tidy this, the hose was P clipped to the radiator mounting bracket and a previously created (and rather crude) plastic catch-canister with an 8mm brass connection was further modified so that it could be dropped into the large fixed hole in the chassis and self lock into position.

The canister is shown below with an 8mm flared connection at the top, a number of vent holes for pressure equalisation and two galvanised wires about 3 inches long passing straight through and which are folded down (to lock) and then secured with a cable tie. While really quite crude the catch-can should never be required, and so is purely a fall back to prevent fluid loss occurring in unusual circumstances.

Figure 20 – Modified pressure release catch-canister

When fitted to the chassis, the catch-can looks as follows. It is very easy to remove and empty if need be.

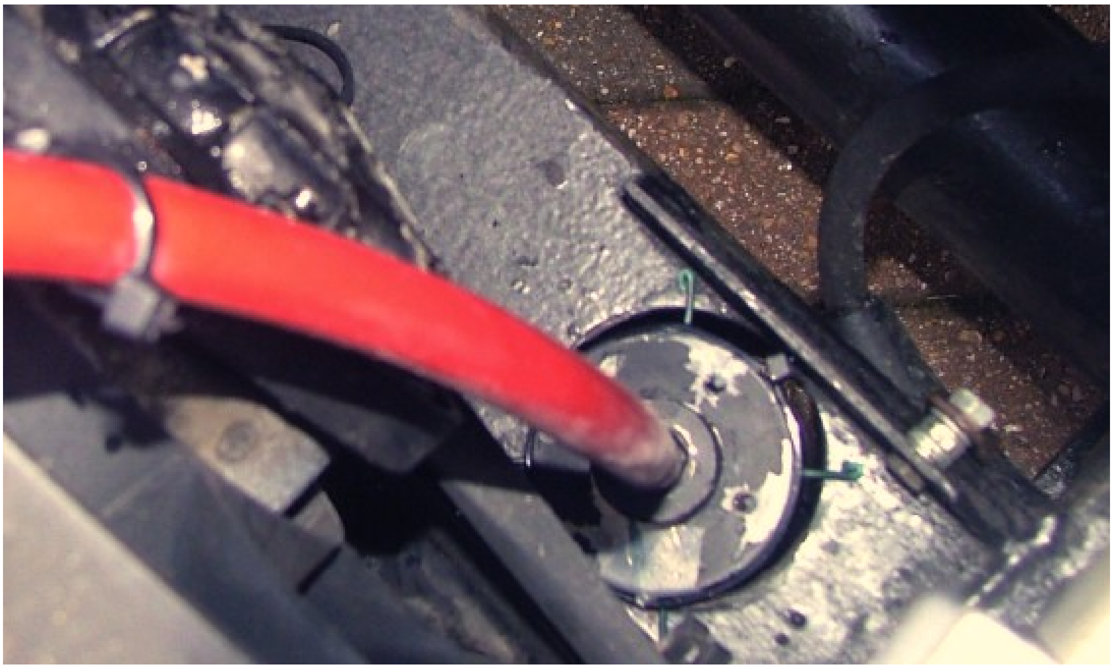


Figure 21 – Catch-canister fitted into chassis

The end result of the expansion tank is shown below, using two different viewpoints.

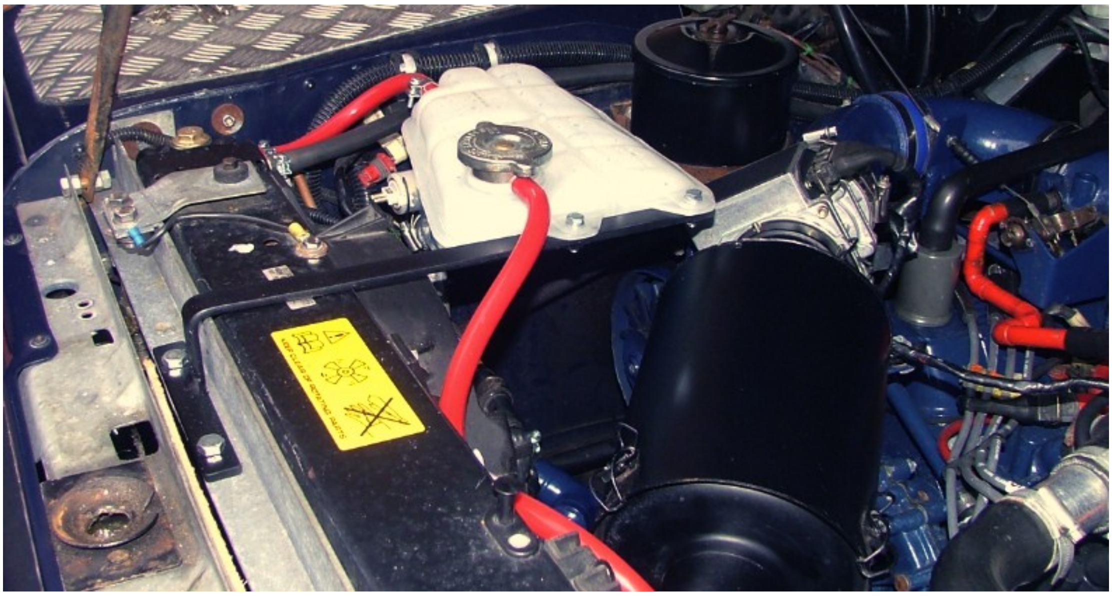


Figure 22 – Final fixing viewed from passenger side front

Figure 23 – Final fixing viewed from drivers side rear

With this expansion tank fitted – we know precisely what it does, and we know it will work. We can also view coolant fluid levels and can drain twice the amount of coolant fluid with far less mess. We also don't need to disturb the plug bolt on the radiator.

The next task is to locate and resolve the leak near the distributor

11th March 2013 First major tests

Today at lunch I took the vehicle (in sub zero weather) for a 10mile round trip. At the half way point I switched off, and stepped out of the cab – only to see a cup of coolant slowly spitting out of the overflow pipe and into the catch-can. The amount of fluid spitting out was also interesting given the pressure release outlet on the expansion tank was actually *above* the level of coolant in the tank.

Two rather revealing symptoms!

The coolant system should be running at a working pressure of 15PSI. All Land Rover V8's running at 82°C or above should run at 15PSI, so fitting the original 9PSI cap was all about sticking to what Rob had originally used for the engine while also (as I thought with the old expansion tank) reducing the pressure load on the coolant system (and thus the leak).

The interesting point here is that this exact same situation must have been occurring with the old expansion tank given it had the same pressure release point of 9PSI – which would as a result have been spitting fluid under pressure straight onto the front of the engine – something I was definitely unaware of.

That immediately raised the question had there ever been a leak at the front of the engine? Might it be that coolant fluid pooling at the bottom of the distributor was all the time collecting from fluid escaping from the expansion tank pressure release vent spitting under pressure randomly at the front of the engine? Some of that fluid would fall to the ground while some would land on hot metal and simply evaporate. The rest could easily collect in the one area that tends to have fairly cool flat metal surfaces – namely on the timing cover right under the distributor clamp. A longer term test using a higher pressure cap on the expansion tank would rule this out.

The pressure release cap was increased from 9PSI to the more standard 15PSI cap while the excess fluid previously lost was carefully washed away. The vehicle was then parked and left to fully cool before a much longer test drive (60 miles) was undertaken. Immediately before the start of the test the coolant level was topped up.

11th March 2013 – after a 60mile round trip

After a 60mile round trip into London, the distributor area of the engine was completely bone dry – for the first time in months. There was not even a hint of coolant loss. In addition, the catch-canister was empty, and the fluid levels held perfectly (further confirmed the following morning).

This was astonishingly welcome and confirmed that there never had been a leak of coolant around the water pump or intake manifold of the engine.

It also helped clarify some of the more puzzling aspects of the fault.

We now know that the cause of the fluid loss was linked to the design of the original expansion tank coupled with the use of a low rated 9PSI pressure release cap and made worse by the elevation of the engine running temperature to 82°C.

As soon as the system became pressurised, the expansion tank 9PSI pressure release cap would periodically open and then randomly spray fluid on the front of the engine whenever the tank contained fluid. Much of that fluid would have been lost but some would have collected around the flat and relatively cool area of the timing cover directly under the distributor clamp.

This also explained why the leak significantly reduced whenever the expansion tank was empty and pretty much stopped altogether when the tank was empty **and** the radiator fluid level low. In this case coolant fluid wouldn’t expand high enough in the radiator to ever reach the expansion tank after being heated – and so there would be no fluid to spit out when the pressure venting took place.

Perhaps the worst aspect of this fault was that the leak problem only *appeared* to improve if the radiator fluid level was in the order of 20% lower than it should be.

Summary

By making this change – the source of the fluid loss soaking the front of the engine has been identified and resolved and we now know that the important coolant hose area at the front of the intake manifold is not leaking fluid. We have also gained a number of very desirable advantages due to the re-designed expansion tank system.

1. There is the thermal efficiency advantage given the increase of pressure from 9 to 15PSI increases the boiling point of coolant fluid. An unpressurised system using pure water would run at the normal sea level atmospheric pressure of 14.7PSI and would boil (convert to steam) at 100°C. If we force the system to run at double that pressure (14.7 plus our 15PSI cap) then the boiling point elevates to roughly 124°C. The greater the pressure, the higher the boiling point and the lower the risk of our coolant boiling off to steam.

2. It is now easy to visually inspect the coolant fluid level

3. It is now easy to top up and fill (from empty) the cooling system

4. The resulting system is fully pressure equalised between the engine, intake manifold, radiator and expansion tank.

5. Filling the system from empty via the expansion tank actually means that the cooling system is being filled from the bottom up. When that attribute is combined with a fully pressure equal system and an expansion tank designed to actively prevent fast filling (by back splashing through the cap if excessive coolant flows into the tank) the risk of air lock is eliminated.

6. It is easier (and far less messy) to partially drain down coolant fluid from the system and we have doubled the amount of coolant fluid that can be removed in this way.

7. We now know with complete certainty that whenever the expansion tank is correctly filled, the radiator will likewise be filled to capacity. This fact alone ensures that we have minimised internal corrosion of the cooling components while also minimising the oxidisation damage resulting whenever antifreeze additives are exposed over long periods of time to air.

It is an ideal end result.

CJB: 12th March 2012