Porsche 968 Variocam Assembly: Inspection Procedure and Maintenance Schedule

Background

There have been a number of documented failures relating to the Variocam mechanism fitted to the Porsche 968. Porsche has not published any periodic inspection or maintenance requirements for the Variocam. Consequently even cars with a full Porsche main dealer service history may suffer undetected excessive wear or even catastrophic failures. In the worst case this will result in bent valves and major engine damage. Cars that have not yet reached the stage of catastrophic failure may still be suffering serious wear to the camshaft sprockets, requiring camshaft replacement.

This document was produced by Derek Holliday and Ugo Manfredi. Both of us have first hand personal experience of Variocam problems, which in each case required replacement of both camshafts, chain, and tensioner pads. The information contained here is based on our own experiences, and additional information obtained from the "968.net" community and other sources.

Purpose and Scope

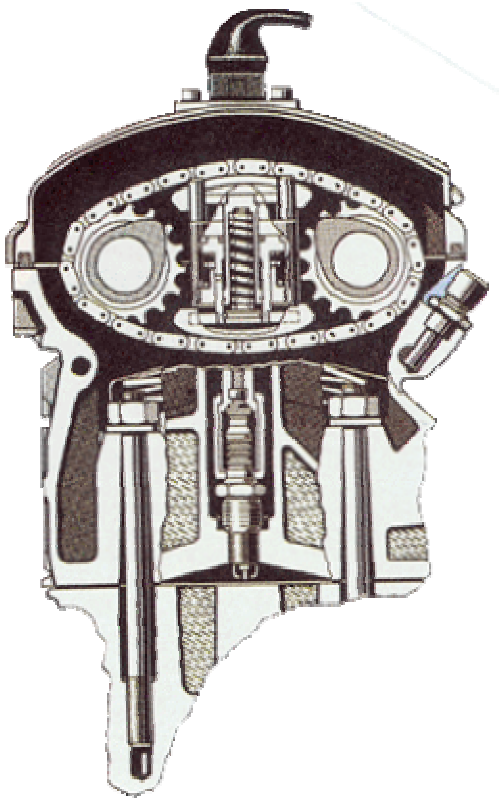
The purpose of this procedure is to describe a method for home inspection of the camshaft sprockets, cam chain, and Variocam chain tensioner pads. The procedure does not include any necessary repair work that may be necessary as a result of the inspection findings. This procedure should be suitable for all normally aspirated 968 models. Also included is a suggested schedule with recommended inspection intervals. These periodic inspections will provide regular checks of the health of your Variocam and its related parts and should ensure that wear or other problems are detected before they result in catastrophic failure.

Overview of Variocam Operation

Due to the apparent lack of detailed information on Variocam operation from Porsche, the following section is based on the authors' understanding, derived from various articles and personal observations.

Variocam is a mechanism that allows the intake camshaft timing to be varied for different engine operating conditions, thereby maximizing torque. In the 968 engine, the exhaust camshaft is driven by a toothed rubber belt from the crankshaft. Halfway along the length of each camshaft is a toothed sprocket and a connecting chain that transfers drive to the intake camshaft from the engine driven exhaust camshaft. Earlier variants of Porsche's 16 valve engines (2.5 liter 944S and 3.0 liter 944S2) used a similar setup but without the Variocam mechanism. Instead, they used a simple spring and hydraulic operated chain tensioner whose purpose was simply to maintain constant chain tension. A fundamental difference between these earlier engines and

the 968 engine is the ability for the position of the upper and lower pistons in the chain tensioner to be adjusted in a vertical plane. This vertical movement, actuated by controlled flow of engine oil, causes the lengths of the top and bottom runs of the chain between the camshaft sprockets to be varied. Since the exhaust camshaft position is fixed in relation to the crankshaft, this movement of the Variocam tensioner pistons causes the intake camshaft's relationship to the crankshaft to be changed by 15 degrees.



Cross Section Through Variocam Assembly

The diagram above shows a cross-section through the Variocam. The actuation mechanism comprises a housing that is bolted to the engine. The housing incorporates separate moving upper and lower tensioner pistons, each having a plastic rubbing pad that acts directly onto the upper and lower chain runs. The distance between the upper and lower tensioner pads is maintained by an internal spring, supplemented by constant engine oil pressure when the engine is running. This spring and oil pressure maintains correct chain tension, in a similar fashion to the earlier 944 series cars. The vertical position of the pistons is controlled by engine oil pressure. When the engine is running, engine oil pressure, controlled by a shuttle valve actuated by an electrical solenoid attached to the Variocam body, is directed to either lift or lower the pistons, depending on engine rpm. Below 1500 rpm, the DME unit (main control computer) energises the solenoid, moving the position of the hydraulic shuttle valve in the Variocam, thereby directing oil to lift the pistons. As the pistons lift, so the plastic pad on the rising top piston pushes upwards on the upper run of the chain,

causing it to extend. At the same time, the rising lower piston allows the lower chain run to be shortened. The overall effect is that the intake camshaft is rotated anticlockwise in relation to the exhaust camshaft, thereby retarding the intake timing back to its nominal setting. Above 1500 rpm, the DME de-energises the Variocam solenoid, causing the shuttle valve to move to a different position. Engine oil pressure is then redirected to lower the pistons, extending the lower chain run and shortening the upper chain run. This causes the intake camshaft to rotate clockwise in relation to the exhaust camshaft, advancing the intake timing by 15 degrees. Above 5500 rpm, the solenoid is again energized, and the intake cam is retarded back to its nominal position.

Possible Causes of Variocam Failure

Although it is impossible to reach a general consensus on this, from the public discussion in the "968.net" community and actual examination of failed Variocams, the following appear relevant reasons for their failure:

1) Aging of the plastic pads (rails). With time and miles, the pads became much more brittle than when new, leading to an increased chance of breakage, and in any case to an increased rate of wear. In failed 968 Variocams, the pads appear very worn with deep tracks, or partially broken, or brittle with some "craters" on them, meaning the material has lost its original properties.
2) Stretching of the camshaft chain. Some stretching is inevitable with use, but the stretching increases the effective pitch of the chain links, accelerating wear of the camshaft sprockets.
3) Variocam on/off action. As described above, the Variocam is "on" (intake timing advanced) in the 1,500 to 5,500 rpm range, and "off" outside this range. The engagement of the chain with the intake/exhaust camshaft sprockets differs between these two positions, and this may affect the wear patterns on the sprocket teeth. The wearing pattern is different with respect to a non-Variocam car (eg 944 S2), and apparently reduces sprocket life. The driving style (average RPM), can also produce an asymmetric wear of upper/lower pads, and sometimes the lower pad wears more than the upper one: this is a problem, because the lower pad is more difficult to inspect.
4) Camshaft slope. To support the timing advance, the slope is "aggressive", that is has an elongated form, to open the valves very quickly. This means additional stress on chain, and when the chain gets stretched, a "hammering" effect on sprocket teeth, particularly at high RPM.
5) Given all the stress on cam sprockets, there has also been speculation that the thermal treatment during manufacture of the cams was inadequate or inconsistent.

It appears that any 968 car with more than 60,000 miles (100,000 km) can potentially develop a Variocam failure, even if luckily only a small percentage will effectively experience it. Whether problems develop or not, depends on many factors: driving style (high RPM means asymmetric and accelerated wear of Variocam parts), age of the car and the type of oil used (influencing pad/chain wear), car abuse or poor maintenance (high engine temperature and insufficient lubrication mean accelerated wear), previous Variocam maintenance, and total mileage.

Variocam Inspection

Disclaimer and Precautions:

The information contained in this document is offered in good faith but the authors take no responsibility for any errors or omissions. In the absence of any documented recommendations from Porsche, we believe that by following these steps, you should have better protection against catastrophic failures. However, we cannot guarantee this, and recommend that you seek expert advice if you have any doubts about the condition of your Variocam components.

Certain basic safety principles should be followed. These include:

- Before starting work, disconnect the battery
- Wait until the engine has fully cooled before starting work
- Work in a well ventilated area and avoid naked flames or other combustion sources

Also, when working on the engine, it's very easy to dent the front wings (fenders) by leaning on them. Place soft covers (old blankets are ideal) over them to prevent scratches and don't lean on them.

Tools Required:

- 17mm and 19mm good quality open ended spanners (wrenches)
- Strong light source
- Old rags
- Inspection mirror (small dentists-type is ideal)
- Hexagon drive bits, sizes 4mm and 5mm, and suitable driver
- Spark plug socket, drive extension, and handle
- 24mm deep 6 point socket and ratchet drive handle
- Torque wrench with range to cover 10 Nm / 7 ft./lbs (desirable)

Parts Required: (assuming no repairs needed as a result of inspection)

The following parts may be required if the existing items are damaged but it is usually possible to re-use the old parts:

- Cam cover gasket (quantity 1)
    - Part number 928 104 447 09
- Sealing rings/grommets (quantity 4) for sealing the spark plug recesses
    - Part number 928 104 443 08

Inspection Procedure:

1. Disconnect battery.

2. Remove four hexagon socket head screws securing aluminium trim panel over cam cover/fuel rail, remove “Variocam” badge and trim panel.
3. Disconnect electrical connector for Variocam solenoid. Note that spring clip on connector should be pushed in to release. (See figure 1).
4. Remove two hexagon socket head screws securing seal retainer around Variocam solenoid body and gently pull off seal retainer and gasket.
5. Place rags beneath connections on two fuel hoses at rear of cam cover (see figure 1).
6. Undo both fuel line connections using 17mm and 19mm spanners. Take care to ensure that the fittings nearest brake master cylinder are held stationary and not twisted. Note: a few ml’s of fuel will be spilled during the process, hence the rags.
7. Gently pull fuel lines clear of the cam cover, taking care not to kink the lines.
8. Pull out spark plug caps/leads and remove spark plugs.
9. Insert clean rags into spark plug recesses to avoid risk of dropping loose objects into cylinders.
10. Unscrew 13 hexagon socket head screws securing cam cover. Note that these screws do not need to be removed from the cover once released but be aware that they are not held captive in the cam cover and may drop out when the cover is removed.
11. Gently pull on the cam cover to release its seal. It may be necessary to apply leverage but be careful and do not insert any sharp objects between the sealing faces.
12. When the cover is loose, gently pull away from the engine. The black rubber seal can either stay in place on the engine, or stay attached to the cam cover. When withdrawing the cover, it’s often needed to peel the seal away from parts of the engine or cover. IF COVER SCREWS ARE STILL IN THE COVER, TAKE CARE THAT THEY DON’T FALL OUT AND DROP INTO THE EXPOSED ENGINE!
13. Note that there are four black circular rubber seals around the spark plug recesses. These will hopefully stay attached to the engine when the cover is removed but may pull away with the cover.
14. With the cover removed, the inspection can begin. Take great care not to drop anything into the engine, as there are oil drain galleries below the exhaust camshaft and screws, dirt, or small tools can easily find their way into the engine. If this happens, you will need to remove the oil pan to recover them!
15. Using the light source and mirror, carefully and methodically inspect the upper and lower tensioner pads, both camshaft sprockets, the metal oil pipe feeding oil to the tensioner body, and the shiny piston rod of the upper tensioner for wear or scoring (see figures 2 & 3).
16. These checks are very subjective, there is no test gauge or tool to measure anything. The tensioner pads can be expected to have visible wear grooves (the lower tensioner pad is very difficult to inspect without removing the tensioner assembly and this requires removal of the cams). Check as far as possible for any signs of cracking in the tensioner pads, missing pieces, or excessive wear (see figure 4). Cracks tend to form in the corners of the pads. Very close inspection with a strong light is required for this. Any cracks or missing pieces will require that the pads are replaced (out of scope for this procedure). See also the section below for further information on suggested wear limits.

17. In order to check the sprockets fully, it is necessary to turn the engine through two full revolutions. Remove the rags inserted in the spark plug recesses.
18. Attach the 24mm deep 6 point socket and ratchet handle to the main crankshaft pulley bolt. The bolt is hidden from normal view by the pulley.
19. Using the ratchet handle, slowly rotate the crankshaft in a clockwise direction when viewed from the front of the car looking backwards. DO NOT ROTATE THE ENGINE IN AN ANTI-CLOCKWISE DIRECTION.
20. As an alternative, the engine can be rotated (manual transmission only) by placing the car into a high gear and pushing the car forward. DO NOT PUSH THE CAR BACKWARDS. Because this method does not allow such fine control of crankshaft/camshaft position, the socket and ratchet method is preferred.
21. Rotate the crankshaft sufficiently to turn the camshafts so that previously hidden teeth on the sprockets can be inspected. Continue until all teeth have been properly inspected (requires two complete crankshaft revolutions). Any missing or badly damaged teeth will require camshaft replacement (see figure 3).
22. Whilst missing teeth are easy to spot, it is more difficult to judge the amount of wear on the sprockets. In many cases there will be some slight marking and pitting/galling of the sprocket teeth. Look for signs of cracks in the faces of the teeth where the chain rides. Carefully study the photos of my badly worn cams (figure 3); some used but not excessively worn cams (figure 5); and brand new cams (figure 6), to get a feel for the wear patterns. The “trough” at the bottom of the teeth is visibly worn on my old cams (figure 3) and this will be accompanied by stretch of the chain. It’s very much a subjective judgement call as to how much wear is permissible, but you should be able to spot an imminent disaster, at least.
23. It’s a good idea to take your own close up photos if possible, both for seeking second opinions and for later comparison purposes if all looks ok this time.
24. With the inspection complete, reassembly is the reverse of strip down. If the cover seal appears in perfect condition, it’s possible to re-use it. Porsche use a liquid sealant in addition to the moulded seal at the corners of the cover mating face. Old cured sealant should be removed. I personally don’t use any sealant on reassembly and I have not experienced any leaks, even when re-using the old seal.
25. Put the rags back in the spark plug recesses before refitting the cover. Check thoroughly to ensure no tools, parts, etc. have fallen into the engine.
26. Before refitting the cover, lightly lubricate the main cover seal with clean engine oil and make sure it is properly seated in the channel in the cover. Take care to ensure that it does not fall out when the cover is installed. Also make sure that the four circular black rubber sealing rings for the spark plug recesses are in their correct position on the engine (see figure 2). When the cover is seated properly on the engine, remove the rags from the spark plug recesses and check to ensure that the black sealing rings are visibly in place at the mating point halfway down each recess.
27. Check with the inspection mirror that the main cover seal appears correctly seated all round the cover.
28. Tighten the cover screws progressively. Do not overtighten! The correct torque figure is 10Nm/7ft.lbs.
29. Complete remaining assembly steps.

30. Reset clock and radio codes if necessary! (due to disconnected battery)
31. Drive and enjoy! (hopefully……!)

Suggested Variocam Wear Limits

As stated above, we are in a very subjective evaluation territory here, and there is no official data on which to rely available from Porsche. Moreover, the "wear limits" can be precisely checked only by dismounting the Variocam itself, and at this point you have done all the work, and you can substitute all the worn parts without significant extra work.

From the observed Variocam failures, it appears that a chain stretching of **4mm** coupled with a pad wear of **2mm** in at least one of the pads, is enough to produce serious and irreversible wear on the cam sprockets (particularly the intake one), ultimately leading to total Variocam (and potentially engine) failure.
We assume here that a safe "wear limit" is to stay within 50% of such observed "fatal" limits. In conclusion:

Item	Wear limit
Tensioner pads	**1 mm** (max deepness of tracks in the nylon pads)
Camshaft chain	**2mm** (half stretching of the closed chain, corresponds to 4mm of stretching of an "open" chain)

As observed before, the **pad wear** can be asymmetric, and sometimes the lower hidden pad wears more than the upper visible one: as suggested in the inspection procedure, use a small mirror to carefully inspect it as much as the limited access allows. Any signs of cracking, more probable at pad corners, means the pads need to be changed. Pay attention to signs of age, leading to brittle pads more prone to future cracking: the age is denoted by:

- Dark brown color of pads (new ones are light brown). This is not a definitive criterion, but comparing fig. 4, 5, 6 you can see that the darker pad is the worst one;
- Small "craters" visible in the wear grooves. These craters means the nylon is brittle, and small chunks of material are thrown away in stress conditions. In normal wear, the grooves have an "even" surface. If you have rough surfaces, clearly visible in Figure 4, immediately change both pads.

To avoid major problems, change pads every 8 years, even if the "wear limits" are apparently not yet reached.

The **chain stretching** can be measured easily and precisely only by dismounting the old chain (requiring removal of both camshafts) and comparing it with a new one. A macroscopic difference of 3-4 mm should be detectable even by surrounding the installed chain with a thin flexible inextensible wire (eg steel or inox wire) and comparing the "ring length" with same measure on the new chain. I did not try this method, but should work.

The effects of a stretched chain, are easily visible on **sprocket wear patterns**. Figure 5 shows a used but "serviceable" camshaft, while Fig. 3 shows a badly damaged

camshaft. Even if there are few or no missing teeths, a cam has to be changed when the central teeth part is too thin, hence prone to break. Compare teeth profile of fig. 3 (bad) with that of fig. 6 (new), and you have a good idea of how to judge your cam.

If you change one camshaft, do not mix used and new ones: via the new chain, the wear pattern is rapidly transferred from the used cam to the new one, and in a few thousand miles, you will have two badly used cams. You have only two options:

1) Substitute both camshaft with new ones. This is a costly option, but gives you at least 60,000 miles, and following the maintenance many more ☺, of trouble free Variocam functioning;
2) Search for two used camshafts in good condition, coming from same engine (or matched by a true expert from different cars).

Suggested maintenance schedule

The following schedule applies in case of normal (road) use of the car. If your car is in an "unknown" status , that is in case of missing/unreliable information about previous Variocam inspection/maintenance, as soon as possible carry out the inspection procedure detailed above.

Miles	Km	Action
Unknown or greater than 60,000	Unknown or greater than 100,000	Immediately inspect the Variocam, following the procedure above. See also the section above regarding "wear limits"

It is highly recommended to do the Variocam inspection before buying a new car, as part of the pre-purchase inspection: this avoids big $$ bills for hidden problems, can be used to lower the car value, can avoid catastrophic failures when driving the car to home garage.

The following schedule applies to a "known" car, after the initial inspection and work:

Miles	Km	Years	Action
12,000	20,000	2	Re-inspect the Variocam. Reuse valve cover gasket if in good condition (no splits or cracks at borders) and no oil leakage is detected.
48,000	80,000	8	Replace both nylon pads and the camshaft chain. Replace valve cover gasket and grommets.
144,000	240,000	-	Replace whole Variocam actuation assembly unless correct functioning of all parts (oil feed pipe, electrical solenoid, spring force, …) can be verified. Substitute valve cover gaskets and grommets.

Contacts and Information

Constructive feedback, comments, or questions are most welcome:

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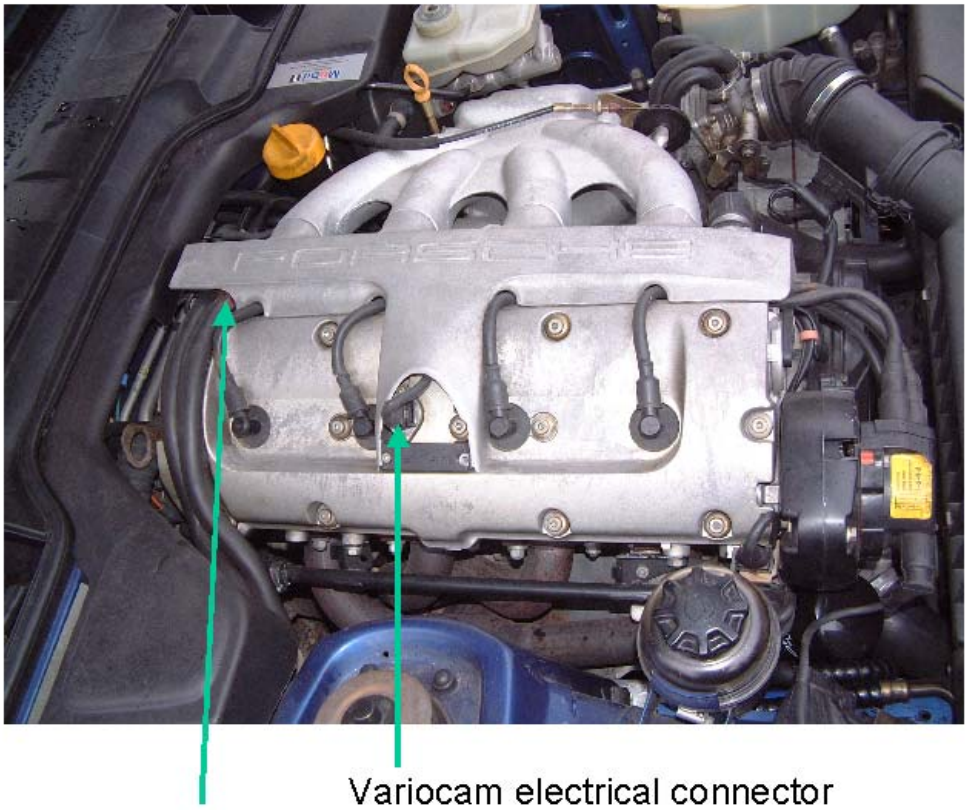
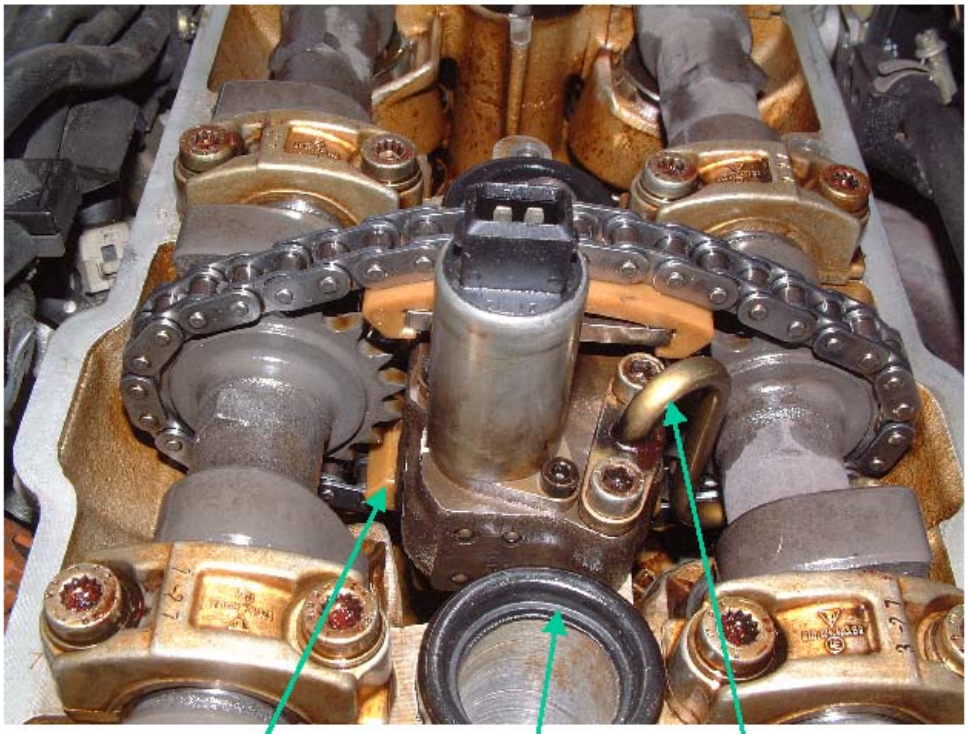
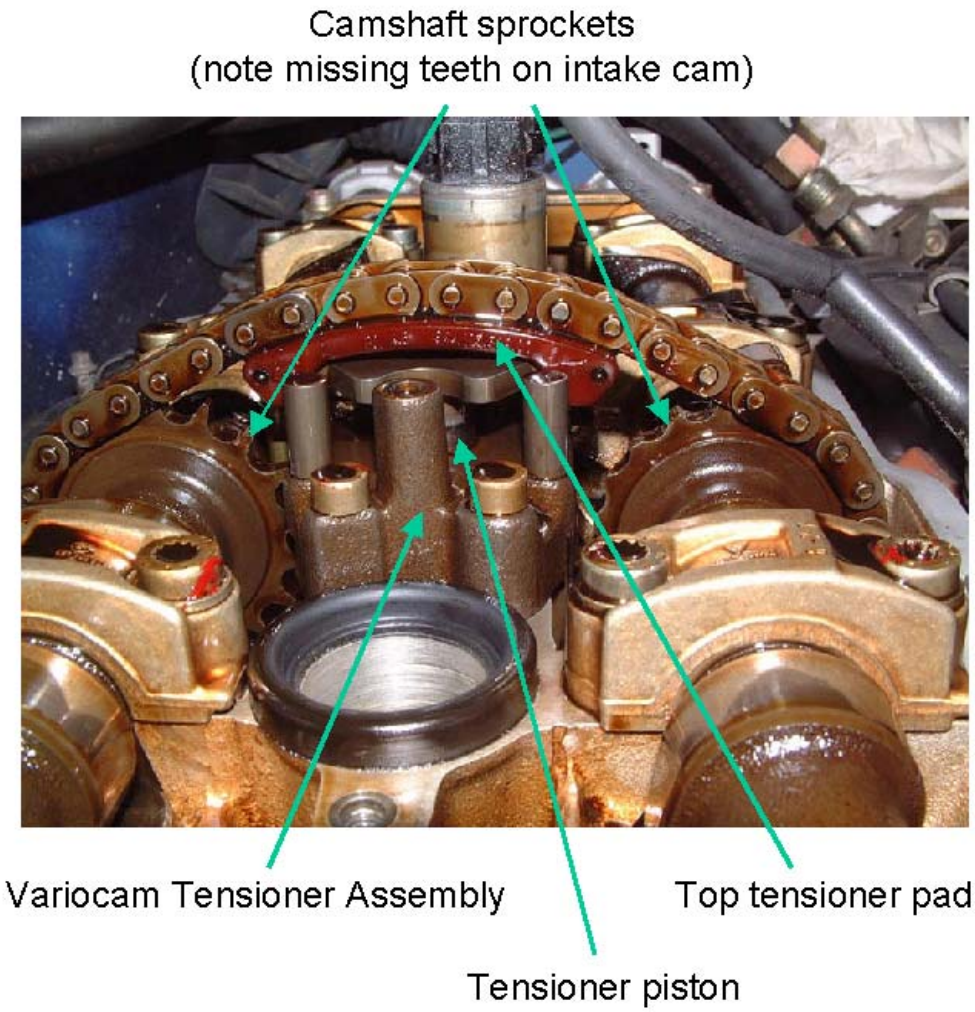


Figure 1



Variocam Assembly Viewed From Rear
(new cams, chain, tensioner pads)

Figure 2

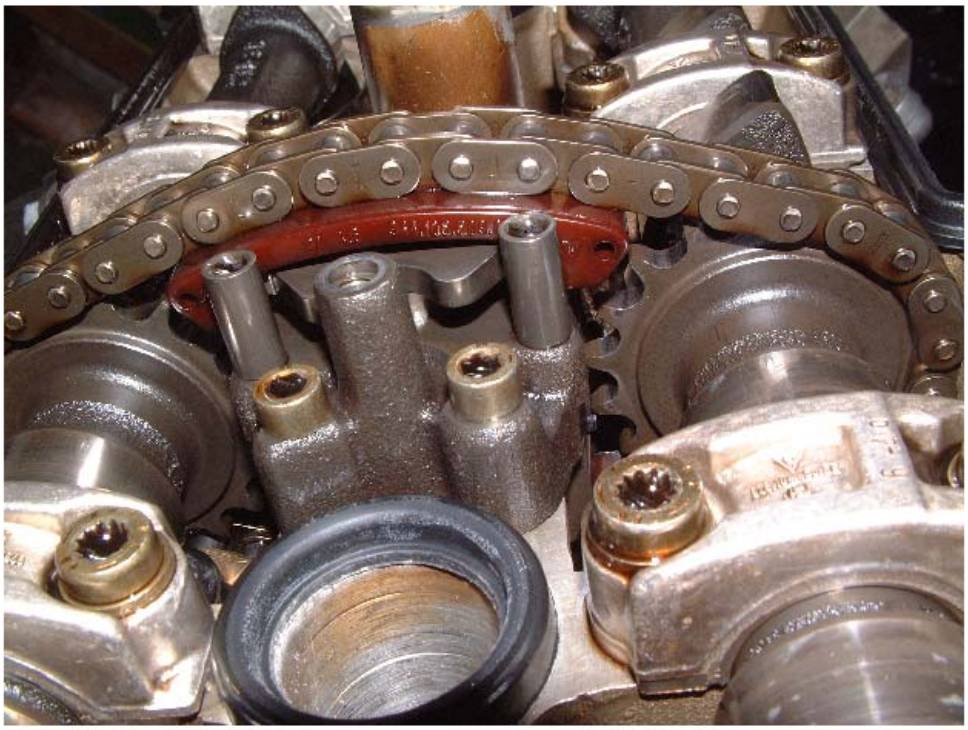


Damaged cams, 144,000 kms (89,000 miles)

Figure 3

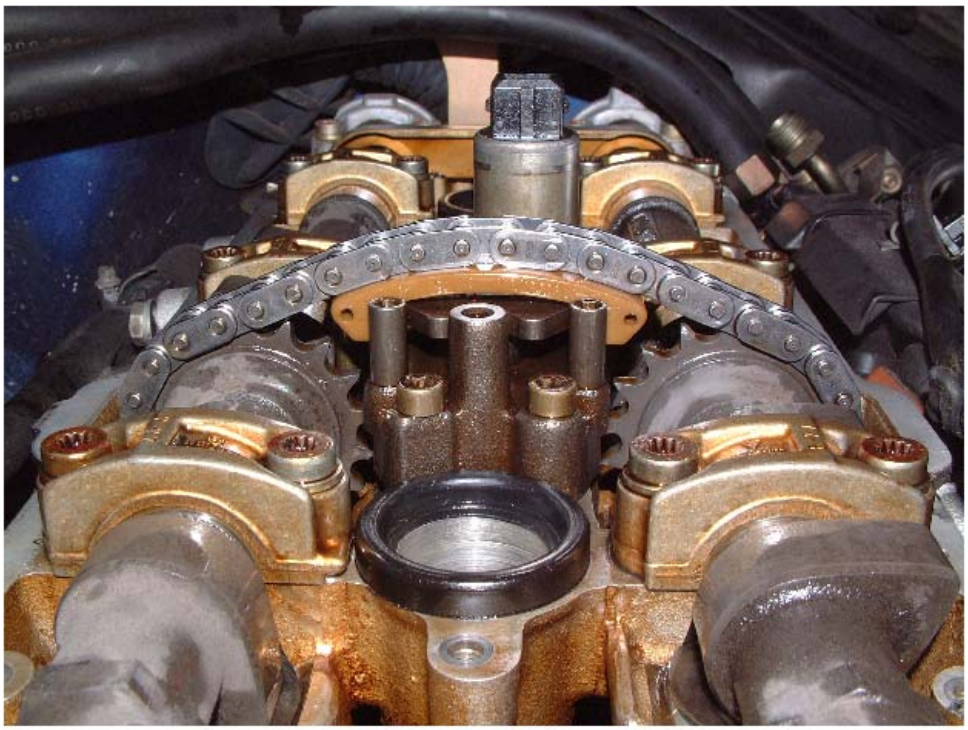
Old Tensioner Pads

Figure 4



Serviceable Cams, 130,000 km car

Figure 5



Brand New Cams, Chain, Tensioner Pads

Figure 6