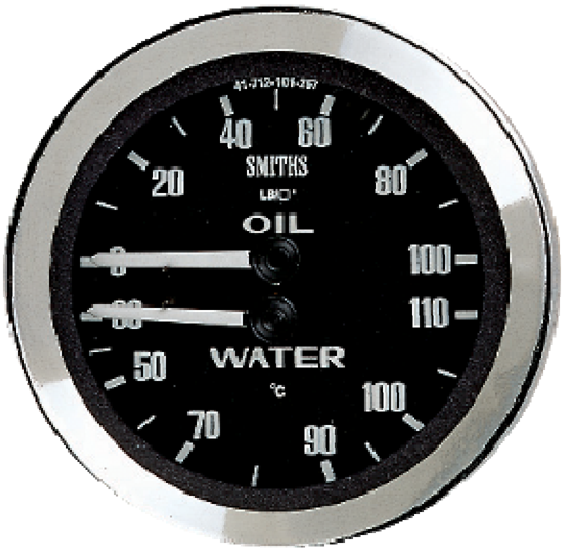
A GENTLEMAN'S GUIDE TO CLASSIC SMITHS AUTOMOTIVE GAUGES

Part I – Gauges.

Electrical senders will be dealt with in Part II.



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NOTES RE CONVENTIONS USED WITHIN THE TEXT:

Throughout the text the letter "n", or "N", has been used to denote any number. Where the gauge number is significant it has been provided in full. Otherwise irrelevant numbers have been replaced.e.g. TC 43nn/nn.

Similarly, "x" has been used to replace any letter, in gauge prefixes such as "Bx" for any bimetal gauge.

"X**.**" refers to a literal gauge prefix for older gauges such as "X.80540/2" which is an electric (early bimetal) temperature gauge.

Usually only the four numbers after the type prefix are shown. Often these will be followed by a slash and two more numbers possibly followed by one or two letters. These later numbers and letters are generally ignored as they are not relevant to the discussion. Numbers usually denote scale options such as scale and pointer colour and scale marking. Letters indicate a hardware change but do not affect operation of the basic "xx nnnn" gauge.

INTRODUCTION:

Smiths gauges are found in numerous vehicle makes and models. They are everywhere. If you have an English classic car, chances are it uses Smiths gauges. This document looks at these gauges, how they work and how they may be kept operating. "Jaeger" instruments that have "Made in England" or "Made in U.K." marked on the dial are also Smiths manufactured gauges.

Some of the information presented is from Smiths documentation and is applicable for gauges manufactured prior to about 1980. Other information was derived by testing several of the gauges themselves.

TYPES OF GAUGE:

TABLE A:- GAUGES COVERED IN THIS DOCUMENT		
Parameter	**Mechanical prefixes**	**Electrical prefixes**
Fuel level		FG, BF, ACF
Temperature	TD, TL, TG	TE, TC, BT, ACT
Pressure	PD, PL, PG	BP, ACP
Vacuum	VD, VL, VG	
Voltage		BV, ACV
Current		AM
Dual gauge	GD, GDR	DBR, DEA

Over the years that gauges have been fitted to cars, several "technologies" have been employed in gauge production. These include mechanical gauges, e.g. Bourdon tube, and electrical gauges. Electrical gauges comprise moving iron ("FG" and "TC"), bimetal ("TE", "PE" amd "Bx") and the air cored ("ACx") gauges, of which the bimetal type are the most common in cars manufactured in the mid-1960s and later.

GAUGE NUMBERING SYSTEM:

Early Smiths gauge numbers were prefixed "Z" for speedometers and tachometers and "X" for everything else. Other gauges had "UC-" (clock), "UF-" (fuel), "UP-" (pressure), "US-" (speedometer) or "UT-" (temperature), prefixes. Others had part numbers comprising several groups of digits separated with dashes. In the early 1960s Smiths rationalised their instrument numbering system using the prefixes set out in Table A above. Smiths also manufactured in Australia and this is printed on the dial but no part number is present. A label on the side of the gauge case prefixed "M" is followed by a six digit number.

It has changed again with gauges from Caerbont. The modern BF2242-00C gauge is identified as such only on a label on the side of the gauge. The dial is marked "41-822-101-87" which doesn't tell you a lot.

If working with gauges with an "X." prefix, you will need to determine the gauge type. For these gauges the number tells you nothing useful. e.g. an X. 80587 is equivalent to a PL 6202/00 Bourdon tube pressure gauge but an X. 80588, the next number in sequence, is equivalent to a TE 6201/00 bimetal temperature gauge. The "X." prefix is marked on the gauge but parts listings may only provide the number.

The numbering system used by Smiths during the 1960s and on into the 1970s (or later) provided a lot of information about the gauge itself. The gauge prefix (see table A) identified the type of gauge and was followed by a four digit number – Nnnnupper case – the number "N" has the following significance;

- 2 – two inch diameter round cased gauge
- 4 – a rectangular cased gauge – two inches wide, 1 5/8 inches high.
- 5 – 2 1/2 inch square gauge usually found in larger commercial vehicles
- 6 – a quadrant gauge, to fit a round panel or a round speedometer case as in early Minis and Triumph Herald cars, or to fit a rectangular instrument panel.
- 8 – a caseless gauge.

The significance of the other digits in this group and those following the "/" has not been decoded, though the digits following the "/" often signified scale style options.

One exception to the above numbering system was the "TC" type temperature gauge where the two inch diameter gauge was numbered "TC 43nn/nn". The "TC" type quadrant gauges used the "TC 6nnn/nn" part number format as for every other quadrant gauge.

"GD" type gauges are all 2 inch diameter Bourdon tube gauges and usually comprise an oil pressure gauge and a temperature gauge although dual air pressure gauges (for commercial vehicles) are also found. These gauges were fitted to many English sports cars.

"GDR", or "Gauge Dual Ribbon" gauges were fitted to the early 1960s Volvo P1800 cars and were dual temperature (oil, water) Bourdon tube type mechanical gauges. Instead of a pointer, these gauges moved a coloured ribbon in a viewing window. The only other ribbon gauge from Smiths that I am aware of was the range of ribbon speedometers ("SR" prefix) fitted to a number of BMC vehicles also about this time.

It is hard to reconcile the numbering of the Rover 3500S dual electrical gauges (DBR2300/00 – Fuel and Temperature, DEA2300/00 – Amps and oil pressure) with this numbering system.

MISCELLANEOUS NOTES*:*

A number of different mounting methods were used for these gauges. By far the most common are the "U" shaped bracket that clamps the gauge to a panel and the formed "legs" used with clusters and larger gauges. The bracket may have one or two nuts securing it and may be shaped to avoid a lamp or pipe fitting. For the style of gauge shown in fig 1 below, a clamping ring plate, which may also be in the form of a sub-panel retaining several instruments, slips over the gauge and is attached to the instrument panel to clamp the gauge in place.

Other methods of fitting gauges were a bayonet type fitting where (usually) three small nubs protrude from the edge of the case and enter slots cut in the panel and the gauge is turned to fix it in place tensioned with a spring either under the bezel flange or a retaining ring. One other method that is often found is a pair of brackets fixed to the case to take mounting screws that screw into the dashboard. This last is most often found within quadrant type gauges (see fig. 5 later in this document) in a gauge cluster or speedometer case but is also found on some individual gauges.

Some earlier cases were die-cast where later cases were pressed steel. The case dimensions, however, did not change.

GAUGE LIGHTING:

A number of lighting methods were used. The most common was a light fitting on the rear of the gauge. Quadrant gauges had no light fitting and relied on light spill from a bulb at the centre of the cluster to provide illumination.

Usually only found as original equipment in vehicles, gauges could be illuminated by an externally mounted lamp which often provided lighting to more than one gauge. The gauge shown in fig. 1 is of this type. Slots were formed around the front of the case and a plastic window provided to keep dust out. This window could also colour the illumination (blue here).

Figure 1: Dual gauge with ring style fixing and using external illumination

INSTRUMENT PANELS AND CASELESS GAUGES:

Smiths produced a large number of instrument panels, also known as (gauge) clusters. These can be found with both “X.” and “IP” prefixes. Each gauge used within the panel had their own part number. In most cases these panels were round and used the quadrant gauges (see figs 2 & 5) that have been mentioned previously. There could be one to four gauges in a round panel though three is the most common configuration. These are found in 3 inch, 4 and 5 inch nominal diameter assemblies. Three inch panels would contain one or two gauges where the larger panels would hold three or four in some of the 5 inch clusters.

Gauges in Instrument Panels could be of almost any type. Fuel gauges can be moving iron or bimetal. Temperature gauges can be Bourdon tube, Thermal (TE prefix), Semiconductor (TC prefix) or Bimetal (BT prefix). Oil pressure gauges are usually Bourdon tube type. Ammeters (moving iron; prefixed “AM” or marked “Lucas”) are also found as are Volt gauges (BV prefix). In most cases the part number of the gauge cannot be read without removing the gauge from the panel.

Later quadrant type gauges are secured with screws and are interchangeable. Mounting holes in early clamped quadrant gauges were a larger diameter so replacing a clamped gauge with a later gauge could be an issue

A few instrument panels were rectangular which used a different gauge mounting system with two mounting lugs, top and bottom diagonally opposed, formed as part of the case. The two quadrant gauge styles are shown in fig. 2, along with a disassembled Instrument Panel/ gauge cluster from a Triumph 2000 showing the individual gauges.

Figure 2: Photos showing the two styles of “quadrant” gauge on the left and an instrument panel and its associated gauges on the right. Panel from a Triumph 2000 Mk II

The parts listing for this instrument panel would appear similar to:

Instrument Panel (complete)	IP 3232/06
Fuel gauge	BF 6106/08
Temperature gauge	BT 6106/09
Voltmeter	BV 6100/01

The gauges could be replaced as individual items.

Caseless gauges were also produced and these are differentiated by having the gauge mechanism fully or partly exposed. (See fig. 14 for an example of such a gauge.) Earlier types were fitted to speedometer cases as for some Hillman Avenger and Hillman Imp models. There are quite a range of fitting styles for these gauges. In some cases the gauge would mount in a speedometer case and be retained by one or more screws.

In later instrument panel assemblies with a flexible “printed-circuit” used to connect instruments and dashboard indicator lamps, the terminals often also acted as the mounting points for the gauge. Typical of this style of dashboard are those fitted to the Morris Marina (refer fig. 28), Rover 3500S and Triumph TR7/TR8 cars.

MECHANICAL TEMPERATURE, PRESSURE AND VACUUM GAUGES:

BOURDON TUBE GAUGES

The majority of Smiths mechanical pressure gauges are of the Bourdon tube type. The main element, the Bourdon tube, is essentially a partially flattened thin-walled tube bent into a circular shape. One end is sealed and pressure is introduced at the other.

For oil pressure and engine vacuum (sometimes called "Fuel Consumption") gauges, a tube connects between the gauge and the relevant part of the engine. As pressure is applied, the Bourdon tube tends to straighten out, contract for vacuum gauges, and this movement is indicated by an attached pointer.

Some temperature gauges also use a bourdon tube, using the pressure generated when a volatile liquid is heated within a closed system. A metal bulb, usually brass, filled with a suitable liquid is connected to a Bourdon-tube gauge by a length of capillary tube. As the bulb is heated, the pressure in the system increases and deflects the gauge's pointer. The gauge dial is calibrated in degrees or marked "C-N-H", rather than pressure.

Diagrams of Smiths Bourdon tube gauges are shown in fig. 1 below which shows different types of linking methods used to connect the Bourdon tube to the pointer assembly and the manner in which these gauges are adjusted in order to calibrate them.

Do not over-pressurise these gauges. An over-pressured Bourdon tube is not a pretty sight.

Not all Bourdon tubes are equal. Smiths have a range of Bourdon tubes to fit different pressure ranges and/or degrees of pointer movement.

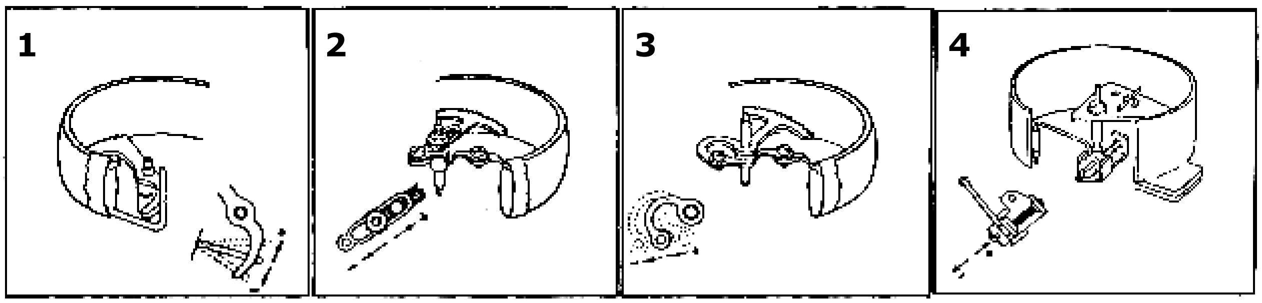
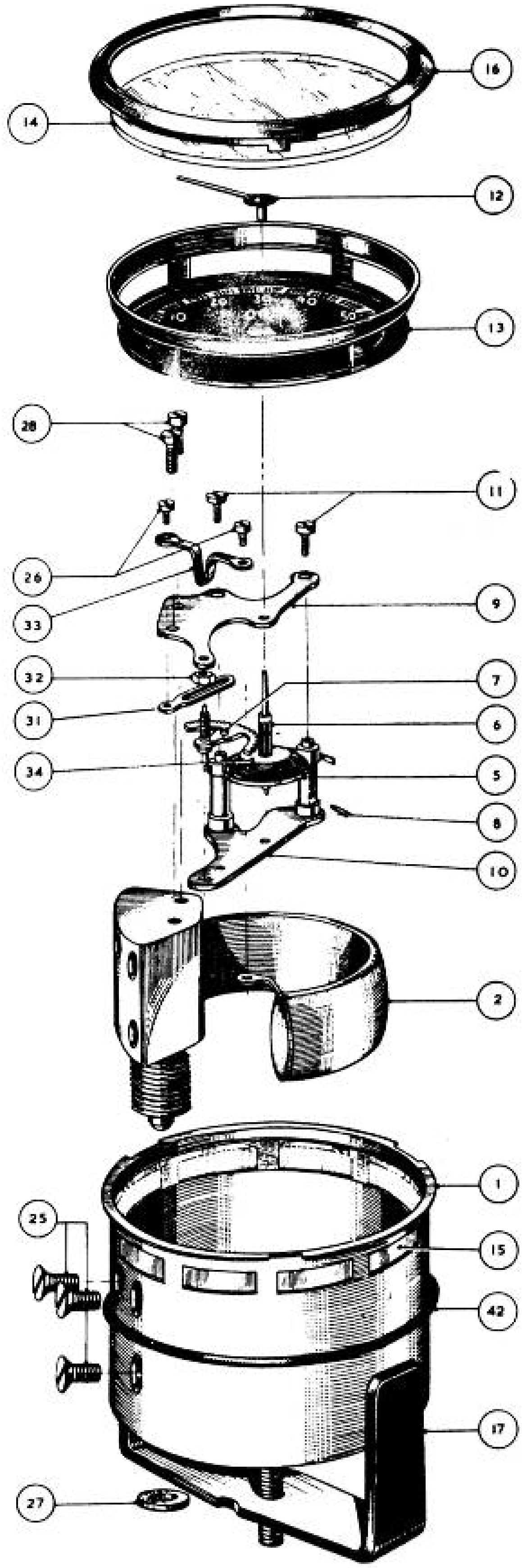


Figure 3: showing Bourdon tube to pointer assembly link styles used in Smiths gauges.
1: PL/TL/VL type gauge with fixed link between Bourdon tube and pointer assembly
2: PG/TG/VG type gauge with early style link
3: PG/TG/VG type gauge later style link
4: PL/TL/VL type gauge with alternative style link

Fig. 4 on the next page is an exploded view of a typical Bourdon tube gauge.



1 Case
2 Bracket and Bourdon Tube Assembly
5 Hairspring
6 Pinion
7 Quadrant and Spindle
8 Hairspring Taper Pin
9 Movement Plate (Top)
10 Movement Plate (Bottom)
11 Movement Plate Fixing Screw
12 Pointer
13 Dial
14 Glass
15 Celastoid Window
16 Bezel
17 Fixing Strap
25 Fixing Screw (for Type 'A' Movement)
26 Linkage Connecting Screw
27 Leather Sealing Washer
28 Movement Fixing Screw
31 Adjusting Arm
32 Adjusting Arm Lock-Nut
33 Connecting Link
34 Hairspring Shield
42 Rubber Ring (External)

Figure 4: Showing construction of Bourdon tube oil pressure (shown) and temperature gauges. (Diagram from Smiths Motor Accessories service data.)

Bourdon tube gauges are found as a stand-alone gauge, in a 2" diameter case, in square or rectangular cases and as "quadrant" style gauges included in a gauge cluster as shown in Fig. 5 at right. The quadrant style gauge may use a more compact design but these can still be re-calibrated if required. Mechanical quadrant gauges, both oil pressure and water temperature, are always of the Bourdon tube type.

Figure 5: Quadrant style oil pressure gauge.

DIAPHRAGM GAUGES:

You may occasionally come across diaphragm type pressure, vacuum and temperature gauges, though these seem to be fairly scarce and only found on older vehicles. Diaphragm gauges can be identified by the location of the pressure connection – in the centre of the gauge rather than offset as bourdon tube gauges are. (Figs 6 and 7 below.)

Figure 6: Rear view of Smiths diaphragm pressure gauge

Figure 7: Rear view of Smiths Bourdon tube pressure gauge

Diaphragm gauges rely on the resistance provided by the stiffness of the diaphragm to resist pressure and limit movement (fig. 8), though a spring may also be fitted to increase resistance to pressure.

To the best of my knowledge, Smiths have not manufactured diaphragm gauges for many years but this construction is still used in electrical oil pressure senders.

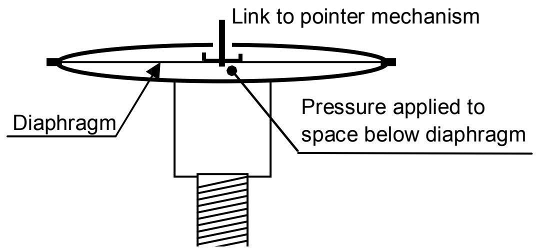


Figure 8: Sketch showing construction of a diaphragm gauge

TROUBLESHOOTING MECHANICAL GAUGES:

There is not much that can go wrong with these gauges. They work or they don't. If a mechanical temperature gauge fails to work it's almost certain that the gauge has lost the filling liquid and will need repair.

Oil gauges will not return to zero if they have been over-pressurised but may also indicate beyond full scale if the Bourdon tube has distorted, If a newly-fitted gauge fails to read at all, then check that the connection is correct and not to a blind or blocked drilling in the block.

In the case of vacuum gauges, simply remove the tube or pipe from the back of the gauge with the engine running. You should hear air being sucked into the vacuum line. A damaged vacuum gauge will behave very much like the oil gauge above.

For all gauges that have a pointer attached to a spindle (including speedometers and tachometers), the pointer is held in place by friction between two matching tapered surfaces. If these have not been properly (re-)assembled, loosening of the pointer can occur.

For an oil pressure or vacuum gauge, the pointer will remain at zero or minimum indication point or, in the case of a dual gauge, the lower gauge pointer wil hang vertically.

If such a gauge fails to indicate, remove from the dashboard and rotate it observing whether the pointer moves as you do this. If the pointer is loose and rotates, remove the bezel and glass (which may not be that easy – refer Appendix A) clean the spindle and pointer with a cloth or tissue and, holding the dial horizontal, place the pointer on the zero mark and tap the pointer boss with the handle of a moderately-sized screwdriver to fix it in place. ***Do not use adhesives, such as threadlocking compounds. They are not necessary***. If you can't see a zero mark – usually a dot just below the pointer stop – then set the pointer against the "wrong" side of the stop pin. Tap in place (as above) and carefully lift the end of the pointer and move to the "correct" side of the stop pin. Be gentle here. Lift the pointer just enough to clear the pin. In some cases the stop pin may be retractable removing any risk of bending the pointer.
Ideally you would apply a known pressure to the gauge and set the pointer at the correct pressure.

If the calibration of a pressure gauge is suspect, the gauge can be checked and re-calibrated if necessary. For pressure gauges an accurate pressure source will be required. A deadweight tester is the ideal tool for recalibrating pressure gauges but comparison with a known good gauge is a reasonable option.

Vacuum gauges are commonly calibrated against another gauge of known accuracy. The gauges may be connected to a vacuum pump or even the inlet manifold of a running engine.

For Bourdon tube temperature gauges, failure of a soldered joint or breakage of the capillary tube are the most common reasons for failure. But for 2 inch gauges, including dual gauges, also check the pointer hasn't loosened on the spindle. These gauges can be repaired but need to be refilled with (diethyl) ether which may be difficult to obtain.

Smiths Classic dual gauges using Bourdon tubes are still manufactured.

ELECTRICAL GAUGES:

Smiths produced a number of electric measuring systems. And they are all different!

IDENTIFYING AN ELECTRICAL GAUGE:

You need to determine what type of gauge you are dealing with. The easy answer is to look at the ID marking on the gauge. Unfortunately, this is easier said than done – particularly if the gauge is still mounted in the dashboard. The photos below will help in identifying gauges.

Fig. 9 at right shows the faceplate from an older gauge and the ID code is plain to see. This is an electrical gauge of the "TE" type which is the only electrical temperature gauge using the "X.nnnnn" ID. This particular gauge has bullet type terminals on the rear. Any fuel gauge marked "X. nnnnn" is an "FG" type gauge.

Figure 9: Showing early "X" type gauge.

Fig. 10 shows the rear view of an "FG" or "TC" "moving-iron" gauge. Each of these gauges has nuts (arrowed) in slotted holes which are the means of calibrating these gauges. Both these gauges require a good earth connection to work. These types of gauge were produced as 2" diameter, rectangular and quadrant style gauges. "TC" gauges are all 12V gauges. "FG" gauges were available for 6V, 12V and 24V electrical systems. These gauges have small stop pins to limit pointer travel but these are not present on other gauges types. The pointer in these gauges is free to move as can be seen if the gauge is rotated.

Figure 10: FG or TC gauge

Fig. 11 shows the rear of a bimetal gauge. The two arrows show the where calibration adjustments are made. As-new, the access holes are covered by a pressed-in cork disk. Normally these remain in place and if missing may indicate the gauges have been re-calibrated, for better or for worse. Fuel and temperature gauges of this type must be supplied with a constant voltage to be accurate. Bimetal oil pressure gauges do not use the voltage regulator unless used with a resistive, rather than bimetal, sender.

Figure 11: Bimetal gauge

Fig. 12 shows the rear of an air cored gauge which has no features for calibrating the gauge. These gauges are non-repairable. Calibration is effected by means of a calibration resistor and is done during manufacture. These gauges also are 12V gauges and do not use a voltage regulator. Like the "FG" and "TC" type gauges, they also require a good earth connection in operation.

Figure12: Rear view of an Air Cored gauge.

Fig. 13 at right shows portions of gauge dials showing the gauge type; A quadrant type "TC" temperature gauge at top (TC 6210/01) and an air cored gauge (ACP 2203/03) below. While the type can be readily seen here, it can be well hidden on an installed gauge. The air cored gauge type ID can be seen when a complete gauge is viewed at an angle but is normally hidden by the dress plate that sits in front of the dial.

Figure 13: Gauge ID.

For a quadrant gauge sitting in the cluster assembly it may not be possible to read the type ID at all without removing the gauge from the cluster.

You will need to know the type of gauge you are dealing with in order to check it out properly. Troubleshooting information is provided later in this document.

As a general rule, electrical gauges were single units. Those in clusters were still individual gauges that could be removed, repaired or replaced on a "per-gauge" basis. The only dual electric gauges I have seen are those fitted to the Rover P6 3500 saloons. These are the caseless DEA2003/00 (ammeter and oil) and the DBR 2003/00 (fuel and temperature) complete with piggy-backed voltage regulator. Except for the ammeter, these were bimetal gauges and the DBR 2003/00 is shown here in fig. 14.

The dashed outline on the right-hand image shows approximately where the voltage regulator plugs in to the gauge itself.

Figure 14: Front and rear views of the DBR 2003/00 dual gauge as fitted to some Rover cars.

TROUBLESHOOTING ELECTRICAL GAUGES:

When trying to determine why an electrical gauge isn't working, there are some basic tests that apply to all gauges.

Firstly, and obviously, an electrical gauge of any type must have a supply from the battery to operate. So this is the first thing to check. A vehicle wiring diagram, if available, can be particularly useful for identifying fuses and wiring paths.

Loss of power supply to gauges is commonly due to blown fuses, which will almost certainly supply other equipment in the vehicle, and to dislodged connectors which is easily done for some types. Some types of gauges require a good earth connection to the case of the gauge as this forms a third terminal for the gauge.

If power is not available at the gauge, find and fix the cause then follow the steps in the tables below for the type of gauge that is fitted to the vehicle. (Refer to "IDENTIFYING AN ELECTRICAL GAUGE" section earlier in this document.) If bimetal fuel and temperature gauges are fitted but do not work then check the voltage regulator. If one gauge only does not work, remove the sender wire from the other gauge and connect in lieu of the sender wire to the failed gauge. If the gauge then operates there is a sender/wiring fault.

Gauges can be checked for operation by either removing the sender connection or shorting to earth. ***When checking "TE" or "PE" bimetal gauges, use a low power (dashboard) bulb in place of the sender***. Later "Bx" gauges can tolerate a short circuit to earth for a short period though using a low resistance (bulb as above) is to be preferred. Do not short out the sender for longer than necessary. A minute or two will not harm the gauge but avoid doing this for significantly longer periods.

Sender or wiring can be short-circuit, open-circuit, or be connected wrongly. Wrong connections are not likely unless wires have been removed from a gauge such as when refurbishing a dashboard and gauges or re-wiring/making changes to a vehicle's electrics. Short- and open-circuits may result from damage to wiring looms far from the gauge.

In the following texts, earth connection to the gauge is only mentioned if the gauge type requires an earth for successful operation. In the majority of cases, gauge lighting also requires an earth at the gauge.

For most English vehicles, Ford being the notable exception (Ford used Smiths gauges in some of their vehicles), the following wire colours are used for the different gauges:

Fuel sender – green wire with black stripe

Temperature sender – Green wire with blue stripe

Oil pressure sender – white wire with brown stripe (same as oil warning light)

Regulator output (to gauge) – Light green with green stripe

Battery supply to regulator – green

WIRING DIAGRAMS FOR ELECTRIC GAUGES:

Fig. 15 below sets out wiring diagrams for all electric gauges other than Voltmeter and ammeter, wiring for which are set out in figs 16 and 17.

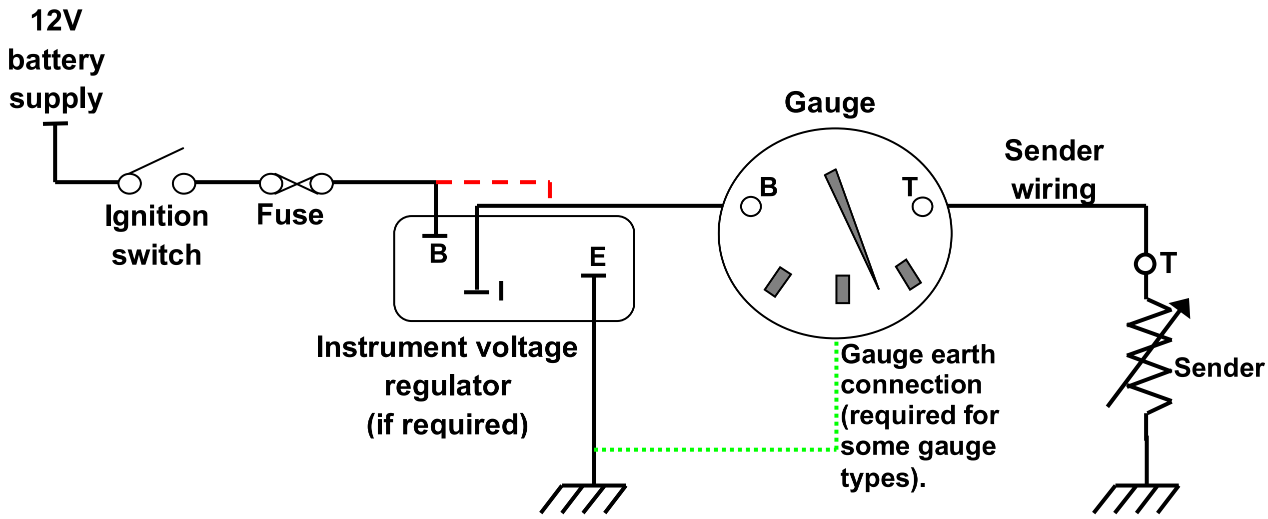


Figure 15: Wiring diagram for all electric gauges (except: volt gauge and ammeter)
Dashed red line shows connection if no instrument voltage regulator is used.
Dotted green line shows required earth connection for FG, TC and ACx gauges
The voltage regulator is only used with "Bx" bimetal gauges.

All "BF" and "BT" gauges and some pressure gauges, require an instrument voltage regulator. Other gauge types do not. The fuse may, or may not, be present.

When checking for voltage in bimetal gauge circuits, first check at the "B" terminal of regulator then at the gauge. The original regulators switched voltage at the "I" terminal on and off once they had warmed up, so when testing make sure to wait a few seconds to determine whether the is regulator is working – the voltage should start switching off and on within 30 seconds. An LED and resistor or LED test lamp is the best tester to use for this test. The LED does not have the thermal inertia of an incandescent bulb and will blink once or twice per second if the voltage regulator is working and likely to be good. Dimming of an incandescent test lamp may be hard to determine. In the case of a "solid-state" regulator, the output voltage will be a constant 10V and can be checked with a standard volt- or multi-meter.

To test the earth circuit, measure voltage between instrument cases and vehicle body with the dashboard lights on. Earths usually loop from instrument case to instrument case so it may only be one gauge that is causing grief. Note that the instrument voltage regulator is often earthed via the speedometer case. If a voltage can be measured between any case and earth, then that earth connection is suspect. You may get a few millivolts here testing a good system but any more and the earthing should be checked.

BATTERY CONDITION GAUGE:

The voltmeter, or battery condition gauge wiring, is much simpler and is set out in fig. 16. Again, the fuse may not be present.

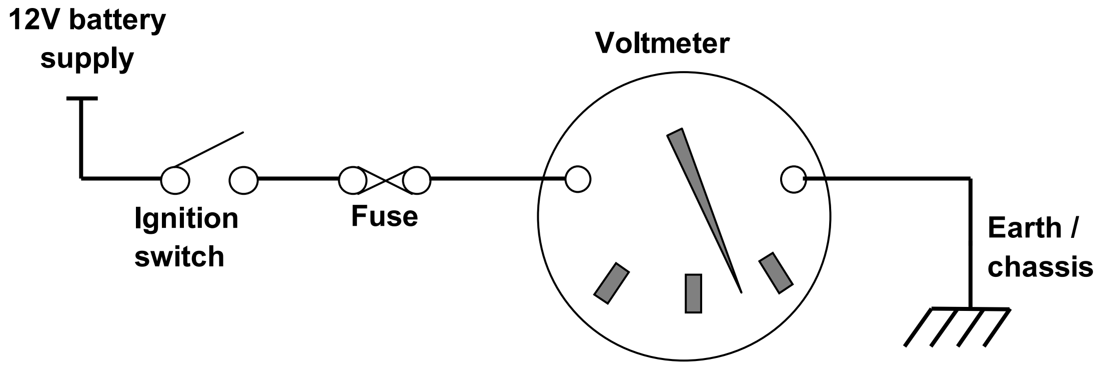


Figure 16: Wiring diagram for voltage (aka "Battery condition") gauge.

AMMETER:

Ammeters are completely different beasts and are wired in series with the main feed from the battery with large diameter wires. The only load not originally measured by an ammeter is the starter motor. If heavy loads, such as driving lights or electric radiator fans have been added to a vehicle and wired directly to the battery terminal, then these loads will not pass through the ammeter and provide a misleading reading. Ammeters do not require a connection to earth for their operation.

If fitting an ammeter, wire it in as shown in fig. 17 below and turn something on, e.g. headlights. The pointer should show "discharge" or "-". If it is indicating a charge then simply swap the connections at the rear of this gauge. (You will need to do this if converting a positive earth vehicle, fitted with an ammeter, to negative earth.) Note that each terminal on an ammeter will be permanently live so insulate all connectors. "Classic" Smiths and Lucas ammeters will not be damaged if connected back-to-front. Ammeters can really only fail if they have burnt out, in which case nothing else, apart from the starter motor should work. Replace a faulty ammeter.

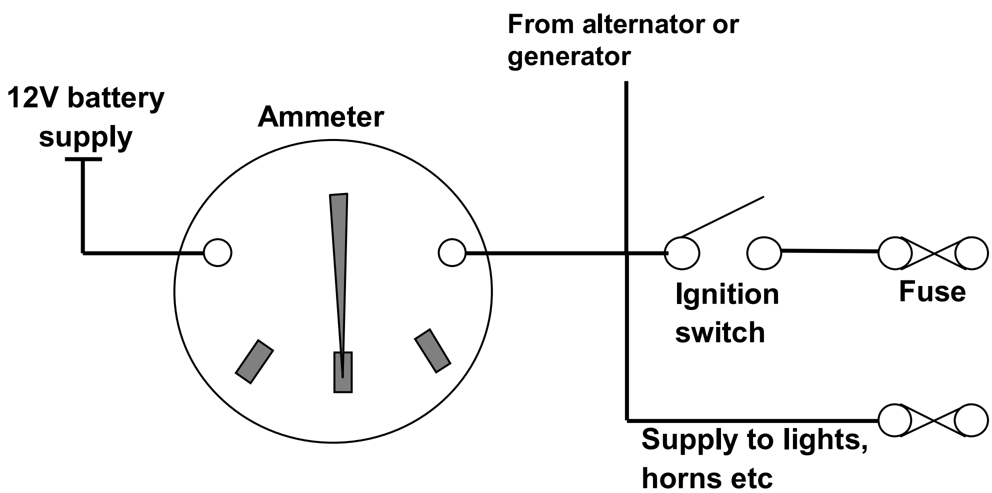


Figure 17: Wiring diagram for ammeter.

CALIBRATION CHECK OF SMITHS ELECTRICAL GAUGES:

Whether the sender is a resistive element, such as a tank unit or temperature sender, or an interrupter, such as the TT1200 and many pressure senders, a resistor can be substituted for the sender to check the gauge's calibration.

The resistors set out in the columns for "Nearest preferred value" in the following table approximate the value in Ohms (Ω) to check the calibration of the respective type of gauge which should read at, or near, low-scale mark and high-scale mark when that resistor is substituted for the sender.

Table B: Resistor values to check operation of different gauges.

Gauge type:	Empty, Cold, Zero Nearest preferred value (Ω)	Full, Hot, Full Scale Nearest preferred value (Ω)
Fuel Gauge FG or X (fuel)	4.7 Ω - 1W	68 Ω – 1W
(Bi-)Thermal TE, PE,	68 Ω – 5W	220 Ω – 2W
Semiconductor TC	560 Ω – 1W	10 Ω – 1W
Bimetal BF/BT/BP	220 Ω – 1W	22 Ω – 1W
Air Cored ACF, ACT, ACP	220 Ω – 1W	22 Ω – 1W

CAUTION: These resistors can get very hot!!

For all bimetal gauges ("TE", "PE", "BF", "BT", "BP", "BV"), it can take several tens of seconds for the gauge pointer to reach the given position. Allow two minutes for these gauges to stabilise when checking.

For voltmeters (BV and ACV) and ammeters, calibration is checked against a suitable meter.

FG (FUEL) AND TC (TEMPERATURE) MOVING IRON GAUGES:

"FG" fuel gauges have been around for a long time. Inside the gauge, two coils generate a magnetic field that causes the pointer, attached to a bow-tie shaped piece of iron, to take up a position that is a function of the magnetic field produced by each coil. This piece of iron is mounted on a spindle to which is attached the gauge's pointer. As the current through the coils changes in response to changes in the resistance of the sender, the magnetic field also changes causing the pointer to move. The gauge connects to a tank level sender which comprises a variable resistor which varies the current through the coils and thus the position of the pointer. "FG" gauges were produced in 6V, 12V and 24V forms.

The TC range (a.k.a. "semiconductor") gauges are Smiths "second generation" electrical temperature gauge. They operated in a similar manner to the "FG" fuel gauge which had been around for a while. These "TC" gauges employed a Negative Temperature Coefficient (NTC) thermistor as the temperature sensor. (A thermistor is a material, the resistance value of which depends on its temperature. "Negative Coefficient means that the resistance reduces as the temperature increases. Positive Temperature Coefficient (PTC) thermistors do exist and are used on some modern cars.)

Fig.18 at right is a diagrammatic representation of this type of gauge. "A" and "B" are the magnetic pole pieces on which the coils are wound. These attract the iron "bow-tie" to which to the pointer is attached. As the relative currents in the coils change, the pointer moves between cold and hot (or empty and full) positions indicated by dashed pointer outlines.

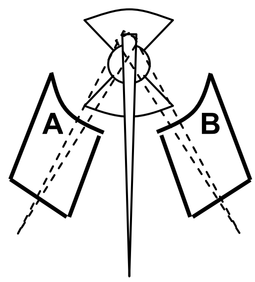


Figure 18: Moving iron fuel and temperature gauge operation

With most other gauges, the worst that can happen if there is no, or a bad, earth connection to the gauge case is that the light won't work. With these gauges, lack of a good earth will cause the gauge to sit at one end of the scale, usually "zero", all the time.

The diagram in fig. 19 is an electrical circuit wiring diagram of moving-iron gauges. (The fuel gauge has an internal resistor (shunt) connected between the B and T terminals.) Note that in each of these gauges, one end of one coil is connected to earth (circled in green) via the metal case of the gauge itself.

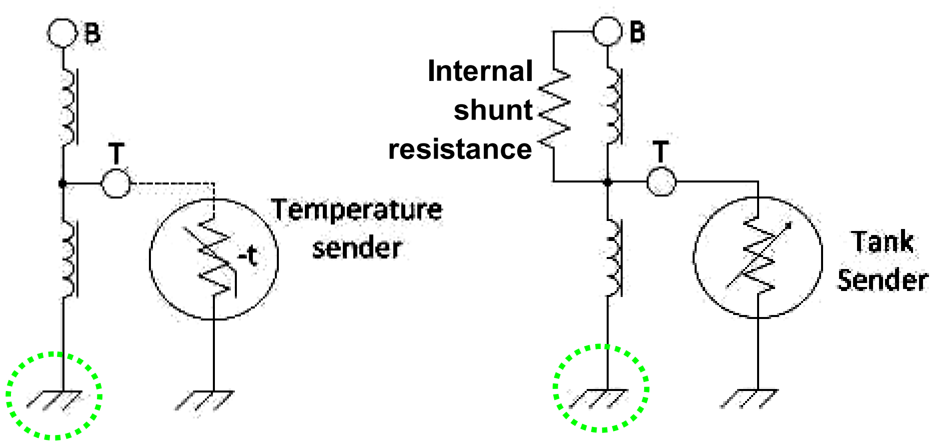


Figure19: Internal wiring diagrams for TC temperature and FG fuel gauges

Hint: If you have either or both of these gauges fitted to your vehicle and the readings change when you turn the lights on then check the earth connection to the dashboard/gauges!

Unlike bimetal gauges, these gauges must be connected to the car wiring in a specific way with the "B" terminal to the battery supply and the "T" terminal to the sender for them to work correctly. The letters "B" and "T" are marked adjacent to the terminals on the rear of the instrument.

Hint: In many cases the "B" terminal is fitted with a dual-blade connector where the "T" terminal has a single blade. This is to allow daisy-chaining of the supply for other instruments but can be a handy way of identifying the terminals when the back of the gauge is obscured.

According to Smiths, these gauges can be damaged if the battery supply is connected to the "T" terminal and a good earth is also connected.

When installing or re-installing these gauges take extra care to get the "B" and 'T" connections right. If uncertain, measure resistance between each of these terminals and case. According to early Smiths data for "FG" gauges, measured resistance should be within the limits given in Table C below:

Table C	**Identifying FG gauge terminals**	
Terminals	Resistance – 12V gauge	Resistance – 6V gauge
B to case	152.5 to 168 Ohms	39 to 46 Ohms
B to T	57.5 to 63 Ohms	17 to 20 Ohms
T to case	95 to 105 Ohms	22 to 26 Ohms

No comparable published data for "TC" gauges is to hand. Two versions of this gauge have been identified. The first simply has the gauge part number printed on the dial. The second has the gauge part number followed by "MMI", as shown in fig. 20 below, and these two variants have significant differences in resistance for B–T and B-case values. The following table should provide sufficient data to enable the "B" and "T" terminals to be identified. "TC" gauges were never produced in 6V versions.

Table D	**Identifying TC gauge terminals:**	
Terminals	Resistance – MMI gauge	Resistance – non-MMI gauge
B to case	247 to 262 Ohms	226 to 233 Ohms
B to T	96 to 108 Ohms	71 to 77 Ohms
T to case	152 to 165 Ohms	152 to 165 Ohms

The above values were determined by measuring 4 of each type of gauge so are representative only. If you wish to check the calibration of a gauge then the resistor values that should have the pointer aligning with the calibration marks (arrows in fig. 20 below) are:

C – 550 Ohms (560)
N – 26.4 Ohms (27)
H – 8.8 Ohms (10)

Resistor values in brackets are the nearest standard values and will have the pointer very close to the calibration marks.

There is no difference in calibration between these two types of temperature gauge. Note that the examples in fig. 20 are both are marked "TC 6210/01.

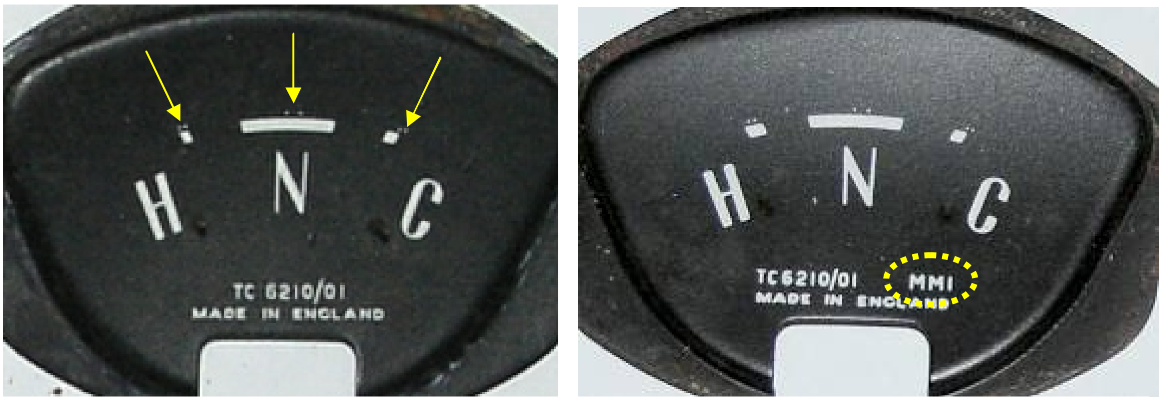


Figure 20: TC temperature gauge – non-MMI on left, MMI (circled) on right

FG GAUGES TROUBLESHOOTING:

FG gauges need a good earth at the gauge in order to work and are supplied with 12V directly from the switched ignition supply. Do not use an instrument voltage regulator with these gauges. The sender for the FG type gauge has a low resistance when the tank is empty (< 4Ω) and a higher resistance with a full tank (> 75Ω). BF type gauges use a different sender - > 240Ω empty and < 20Ω at full. If you wish to replace one of these gauge types with the other, then both gauge and sender must be replaced.

TABLE E	**FG FUEL GAUGE**	
Fault	Cause	Remedy
Gauge pointer doesn't move from EMPTY	No voltage supply to gauge	Check wiring and fuse. Check earth connection to case of gauge.
	Sender or wiring short-circuit	Remove wire from sender terminal. Sender fault if pointer moves to FULL. Else check wiring.
	Gauge faulty	Remove wire from sender terminal. Gauge faulty if pointer remains at EMPTY. Repair or replace gauge
Gauge pointer moves to FULL and remains there.	Sender open-circuit	Connect gauge "T" terminal to earth through a small bulb or resistor. Wiring or sender fault if pointer moves to EMPTY.
	Open-circuit in wiring	Disconnect at sender and briefly connect sender wire to earth. Sender faulty if pointer moves to EMPTY. Replace sender else check gauge and sender wiring.
	"B" and "T" terminals swapped	Check wiring and remedy. (Unlikely unless re-wiring of gauges has been done.)
Gauge inaccurate	Gauge out of calibration Sender out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

Note: Due to internal changes made to these gauges, some older "FG" type gauges may read EMPTY when "B" and "T" terminals have been wired wrongly. This behaviour has only been seen in gauges marked "X.nnnnn".

TC GAUGES TROUBLESHOOTING:

TC temperature gauges are similar but act opposite to the fuel gauge in operation.

TABLE F	**TC TEMPERATURE GAUGE**	
Fault	Cause	Remedy
Gauge pointer doesn't move from COLD	No voltage supply to gauge	Check wiring and fuse. Check earth connection to case of gauge.
	"B" and "T" connections swapped.	If gauge has just been installed or re-installed check these connections. Connect correctly if required.
	Open-circuit in wiring	Connect gauge "T" terminal to earth through a small bulb or resistor. Wiring or sender fault if pointer moves to HOT. Else gauge faulty.
	Sender faulty	Disconnect wire at sender and briefly connect to earth. Sender faulty if pointer moves to HOT. Replace sender else check wiring.
	Gauge faulty	Repair or replace gauge.
Gauge pointer moves to HOT and remains there.	Poor or no earth at gauge	With ignition on, check voltage between case of gauge and a good earth. Should be 0V. Make sure gauge is earthed.
	Sender short-circuit	Disconnect wire at sender. Sender faulty if pointer moves to COLD.
	Short-circuit in wiring	Check wiring, ensuring connections are correct.
	Gauge faulty	Repair or replace gauge
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

AIR-CORED GAUGES:

Late 1970s cars may be fitted with air-cored gauges, prefixed "ACx" where "x" can be "T" (temperature), "F: (fuel), "P" (pressure) or "V" (voltage). Air-cored "ACx" gauges are an updated version of the earlier "FG" and "TC" moving iron gauges.

As with the "FG" and "TC" gauges, these are also a "three-terminal" gauge requiring a good earth to operate. Unlike the earlier moving-iron gauges, these are not repairable, neither are they adjustable. Air cored gauges are theoretically capable of rotating through 360 degrees where the moving iron gauges were limited to 90 degrees.

Fig. 21 below shows the circuit diagram of the Air Cored Fuel, Temperature and pressure gauges. There is also an "ACV" voltage gauge but the internal connections are slightly different – the calibration resistor being replaced by a Zener diode.

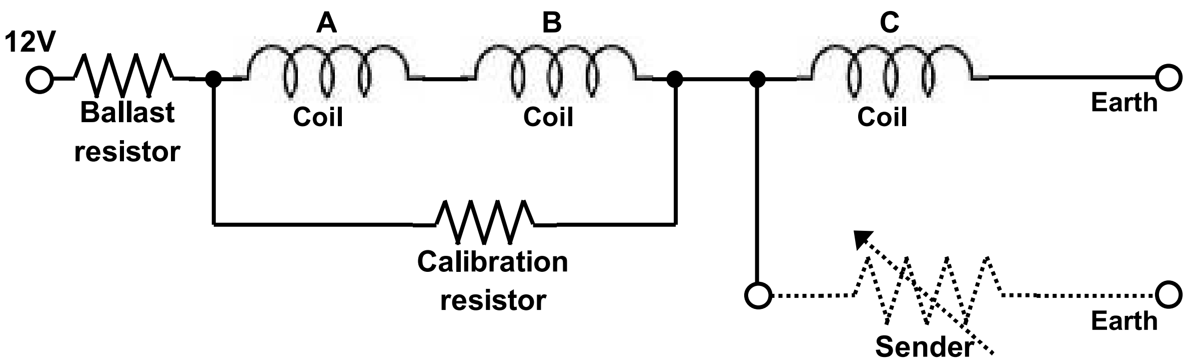


Figure 21: Circuit diagram of Smiths Air Core gauge

In operation these gauges work in a similar manner to the moving-iron "FG" and "TC" gauges. A magnetic field is generated that causes a pointer to move depending on the sender resistance and the resultant field. The significant differences between these gauges and moving iron gauges are that these have a magnetised armature driving the pointer, thus they are also polarity conscious.

Two air-core gauges I have to hand are both pressure gauges and are marked differently. Each has a male ("B") and female ("T") spade terminal on the back, in one case they are marked "B" (battery) and "T" (transmitter /sender) and in the other markings are "1" and "2". These also have only two calibration points marked on the dial. Calibration resistances are 240 Ohms (Cold/Empty/ zero end of scale) and 20 Ohms at the top end (Hot/Full/full scale).

AIR-CORE GAUGES TROUBLESHOOTING:

Note: These gauges are non repairable and cannot be recalibrated. They are also heavily damped and take a little time to fully react to a change. They are also polarity conscious and can only work on negative earth vehicles. (These gauges, with the possible exception of the voltmeter, will survive reversed polarity.)

To check a gauge, other than voltage, measure resistance between "B" and "T" terminals which should be close to 250 Ohms. Resistance between "T" terminal and earth should be about 300 Ohms.

These gauges should read at the low end of the scale with no voltage present. If the gauge indicates above zero with no voltage applied, gauge is faulty.

These gauges have a small magnet inside to return the gauge to zero when power is removed.

TABLE G	**AIR CORED GAUGE**	
Fault	Cause	Remedy
Gauge pointer doesn't move from EMPTY/COLD/ZERO	No voltage supply to gauge	Check wiring and fuse. Check earth connection to case of gauge.
	"B" and "T" terminals swapped	Check wiring. For some, if not all, gauges this should be hard to do as "T" terminal has female spade fitting and "B" terminal has male.
	Open-circuit in wiring	Connect gauge "T" terminal to earth through a small bulb or resistor. Wiring or sender fault if pointer moves upscale. Else gauge faulty.
	Sender faulty	Disconnect wire at sender and briefly connect to earth. Sender faulty if pointer moves upscale. Replace sender else check wiring.
	Gauge faulty	Replace gauge.
Gauge pointer moves to FULL/HOT/FULL-SCALE	Sender short-circuit	Disconnect wire at sender. Sender fault if pointer moves to EMPTY/COLD/ZERO. Else check wiring
	Short-circuit in wiring	Check wiring ensuring connections are correct.
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Replace gauge if out of calibration. If gauge satisfactory, replace sender.

BIMETAL GAUGES:

Bimetal elements are comprised of two pieces of dissimilar metals connected together. All things expand with heat and metals are no exception. Some metals expand a little bit and some expand a lot.

Bimetal devices are found everywhere. Commonly used as thermostats in domestic heaters and as thermometers. In cars they are found in temperature switches, automatic choke mechanisms and (older) flasher units for direction indicators/hazard warning lights as well as gauges and instrument voltage regulators. Their operation is as follows:

As the name suggests, bimetal elements comprise two different metals bonded together. Each of the metals has a different thermal coefficient of expansion and so changes in temperature cause the bimetal element to distort or change shape.

Fig. 22 shows a bimetal bar, at low temperature (top) and its reaction to heat (bottom). In this example the metals used are copper (orange) and steel (black), When this bar is heated, the copper expands more than the steel and the bar bends as shown.

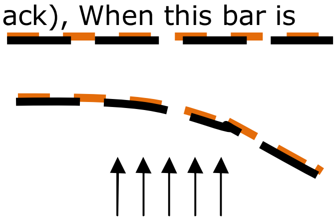


Figure 22: Bimetal element construction and operation

The degree of bending depends on both the materials used and the change in temperature. This change in shape can be used to drive a pointer or operate an electrical switch.

It is worth bearing in mind that bimetal elements have a "thermal mass" and will not respond quickly to changes. Typically a change in temperature will not be fully responded to for a period of several tens of seconds. Compare this with the action of moving iron gauges which respond immediately to any change.

Bimetal gauges are the most common Smiths electrical gauge. The first bimetal gauges were the "TE" type gauges introduced in the mid-1950s. By the mid 1960s, the bimetal "BF" gauge had replaced the earlier moving-iron FG gauge and the "BT" temperature gauge had replaced the "TC" gauge which itself had replaced the earlier "TE" type. These "new" gauges were supplied with a lower (average) voltage from the instrument voltage regulator described above.

The sketch in fig. 23 below shows the basic construction of a bimetal gauge. Operation is straightforward. The heating coil heats in response to the current flowing through the resistance wire wound around it. As the bimetal bar moves, it moves the pointer across the scale. Only two connections to the gauge are required and it doesn't matter which terminal is connected to battery or sender. The terminals are labelled "T1" and "T2" here but there are no markings on the gauge itself. Unlike the instrument voltage regulator, there really is little to go wrong.

THE DIFFERENCE BETWEEN BIMETAL/THERMAL/BITHERMAL" GAUGES:

"Bimetal" describes those gauges that require an instrument voltage regulator. "Thermal" and "Bithermal" are used interchangeably to describe those gauges that do not require the regulator and are driven by bimetal senders – "TE", "PE" and "BP" gauges. The "BV" voltage gauge is also included in this group. Within this document "bimetal" refer to all these gauges with differences noted as required.

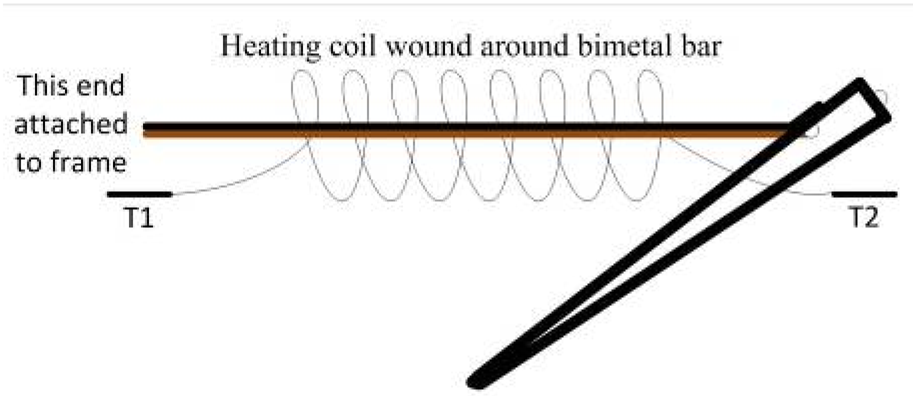


Figure 23: Smiths bimetal gauge schematic diagram.

Fig. 24 below shows the internal construction of Smiths bimetal gauge, an early gauge on the left and the later gauge on the right. The significant difference between them was the metal plate covering the adjusting plates in the earlier gauge. With the resulting large metal-to-metal contact area in the earlier gauge, it did not need much corrosion to effectively lock everything together. The later gauge did away with this cover plate and the means of adjustment can be readily seen. A special tool - easily made – is required to adjust these gauges. The adjustable support plates are very thin and easily distorted.

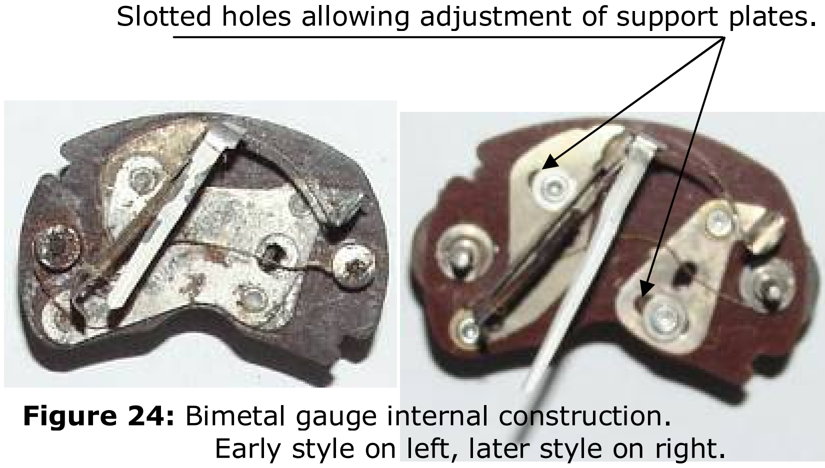


Figure 24: Bimetal gauge internal construction.
Early style on left, later style on right.

"BX" - BIMETAL GAUGES:

Later gauges, those marked "BT" (or "BF" – Fuel gauge and "BV" – Voltmeters aka "battery condition") were also bimetal instruments. Fuel and temperature gauges operated at a reduced regulated voltage (10 Volts for Smiths gauges) supplied by an instrument voltage regulator which was also a bimetal device.

These gauges were essentially the same as the TE and PE gauges mentioned earlier except that a resistive sender was used. The bimetal sender had been superseded except in the case of pressure. "BF, "BP" and "BT" bimetal gauges are calibrated at the same values" 240Ω (Cold, Empty, 0 psi), 68Ω (Normal, Half scale) and 20Ω at Hot/Full/Maximum pressure.

Bimetal gauges have a fairly long (thermal) time constant so they can work on an interrupted supply voltage. They are also slow to fully react to a large change.

“TE” TEMPERATURE AND “PE” PRESSURE GAUGES*:*

Early electric temperature gauges were marked “X.{number}” and “TE {number}”. The TE gauges were bimetal gauges that operated directly from the car’s 12V system – the associated sender unit functioning as a (variable) voltage regulator. There is no difference in operation between these gauges and the bimetal gauges mentioned later apart from the fact that the pointer of the “TE” gauge sits at the upper (hot) end of the scale with no voltage present, rather than at the lower end as the later gauges do.

“TE” and “PE” gauges are bimetal style gauges that are supplied directly from the battery and not from an instrument voltage regulator. The sender itself is a bimetal unit in which a contact (switch) within the sender opens and closes the circuit generating an average electrical current resulting from the switching duty cycle. In effect a temperature or pressure controlled voltage regulator. For testing purposes, this switching cycle can be simulated by a fixed resistance, for which values are given in Table B (page 12).

Bimetal gauges (all) give very little trouble, provided they have not been overheated, which can happen if a sender is short circuited for a significant length of time.

Note that “TE/PE” and “BT/BP” gauges are not electrically interchangeable. The “TE/PE” gauges have a heating coil resistance of about 25 Ohms. The corresponding value for the “Bx” gauges is about 62 Ohms.

The bimetal sender that “TE” gauges are used with performs as a temperature-controlled variable voltage regulator. These particular gauges are unusual in that the sender has a low (effective) resistance when cold and high when hot. More usually, sensors work the other way with a high resistance corresponding to a low measured value and a low resistance corresponding with a high value (Hot/Full/max pressure).

“TE”/”PE” GAUGE TROUBLESHOOTING:

Check for voltage between each gauge terminal and earth with the engine cold. One terminal should measure 12 - 14V and the other about half this figure. Note that, like the voltage regulator the sender interrupts the circuit so the sender terminal voltage will alternate between 12V and 0V. This will produce an erratic reading on a voltmeter but this is normal.

“TE” gauges may have bullet style terminals and these can be readily dislodged. Fig. 25 shows these connectors on such a gauge. If you have done some work behind the dashboard and the gauge stops working then these connections are first thing worth checking.

Figure 25: Bullet style terminals on TE gauge.

"TE" GAUGE:

TABLE H	TE TEMPERATURE GAUGE	
Fault	Cause	Remedy
Gauge pointer doesn't move from HOT	No voltage supply to gauge Sender or wiring open-circuit Gauge faulty	Check wiring and fuse Remove wire from sender terminal and connect wire briefly to earth through a low value resistance (e.g. small dashboard lamp) . Sender fault if gauge moves toward COLD. Else check wiring. Remove wire from sender terminal of gauge and connect to earth through a gauge bulb or similar**. Sender or wiring fault if pointer moves to COLD. Repair or replace gauge
Gauge pointer moves to COLD and remains there.	Sender short-circuit Short circuit in wiring	Remove wire from sender terminal. Wiring or sender fault if pointer moves to HOT. Reconnect sender wire to gauge and disconnect at sender. Sender faulty if pointer moves to HOT. Replace sender else check wiring.
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

** A direct short to earth can damage these gauges!!

"PE" GAUGES:

The PE gauge is the same as the TE gauge apart from the fact that the pointer sits at the lowest point on the scale when power is removed.

TABLE I	**PE PRESSURE GAUGES**	
Fault	Cause	Remedy
Gauge pointer doesn't move from ZERO	No voltage supply to gauge Sender or wiring open-circuit Gauge fault	Check wiring and fuse Remove wire from sender and connect to earth through a gauge bulb or similar**. Sender fault if pointer moves to FULL-SCALE. Else check wiring Remove wire from sender terminal of gauge and connect to earth through a gauge bulb or similar**. Sender or wiring fault if pointer moves to COLD. Repair or replace gauge
Gauge pointer moves to FULL-SCALE and remains there.	Sender short-circuit Short circuit in wiring	Remove wire from gauge sender terminal. Wiring or sender fault if pointer moves to ZERO. Reconnect sender wire to gauge and disconnect sender. Sender faulty if pointer moves to ZERO. Replace sender else check wiring.
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

** A direct short to earth can damage these gauges!!

BIMETAL GAUGES (EXCEPT "BP" AND "BV" GAUGES):

There is little to go wrong. Provide voltage and a sender and they should work.

Note that these gauges react slowly to changes. Allow several seconds after making a change to the sender input to allow the gauge to move to its new position.

If the gauge is simply indicating a wrong value and responds to changes normally then either the sender or gauge is out of calibration. Replace sender or have gauge calibrated.

TABLE J	**BIMETAL GAUGE**	
Fault	Cause	Remedy
Gauge pointer doesn't move from EMPTY/COLD	No voltage supply to gauge Open-circuit in wiring Sender faulty Gauge faulty	Check wiring and fuse. Check earth connection to case of gauge. Connect gauge "T" terminal to earth through a small bulb or resistor. Wiring or sender fault if pointer moves to FULL/HOT Else gauge faulty. Remove wire from sender terminal on gauge and connnect to earth through a small bulb or resistor. Sender faulty if pointer moves to FULL/HOT. Replace sender else check wiring. Repair or replace gauge.
Gauge pointer moves to FULL/HOT.	Sender short-circuit Short-circuit in wiring	Disconnect wire at sender. Sender faulty if pointer moves to EMPTY/COLD. Check wiring ensuring connections are correct.
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

"BP" GAUGES:

Internally these gauges are identical to the BF/BT gauges. The difference is in the way they are wired in a vehicle. The original pressure transmitters used with these gauges were bimetal devices that were essentially a pressure-sensitive voltage regulator and they were supplied with unregulated 12 Volts. It is also possible that some of these were provided with variable-resistor type senders in which case I would expect these to be supplied from the instrument voltage regulator. Later pressure senders used with air cored gauges are variable resistance type senders.

"BP" BIMETAL GAUGES TROUBLESHOOTING:

Testing "BP" gauges is exactly the same as testing the "PE" gauge but the senders and calibration resistance values differ.

TABLE K	**BP PRESSURE GAUGES**	
Fault	Cause	Remedy
Gauge pointer doesn't move from ZERO	No voltage supply to gauge Sender or wiring open-circuit Gauge faulty	Check wiring and fuse Connect gauge to earth through a small bulb or resistor. Sender faulty if gauge reads FULL-SCALE. Else check wiring Remove wire from sender terminal on gauge and connnect to earth through a small bulb or resistor. Gauge fault if no change. Repair or replace gauge
Gauge pointer moves to FULL-SCALE and remains there.	Sender short-circuit Short circuit in wiring	Remove wire from sender terminal on gauge. Sender faulty if pointer moves to ZERO. Check wiring.
Gauge inaccurate	Sender out of calibration Gauge out of calibration	Check gauge with test unit or resistance values provided later in document. Re-calibrate or replace gauge if out of calibration. If gauge satisfactory, replace sender.

VOLTMETERS AND AMMETERS:

Voltmeters connect between switched 12V supply and earth. Provided connections are good they should work unless the gauge is damaged. The resistance of the heating element in the "BV" gauge is 122 Ohms rather than the 62 Ohms of other bimetal gauges. Replace a faulty gauge. "ACV" gauges are wired the same way. Replace if faulty.

For ammeters, see ammeter wiring section. These go or they don't. Replace a faulty gauge.

THE BIMETAL INSTRUMENT VOLTAGE REGULATOR:

The diagram in fig. 26 shows how this regulator reduces the effective voltage to the gauges. The ratio of on time to off time will be 5:1 at 12V. As the voltage increases, this ratio will change due to the more rapid heating of the bimetal strip and the on time will reduce. Similarly a reduction in voltage will cause an increase in on time.

FIGURE 26: BIMETAL INSTRUMENT VOLTAGE REGULATOR

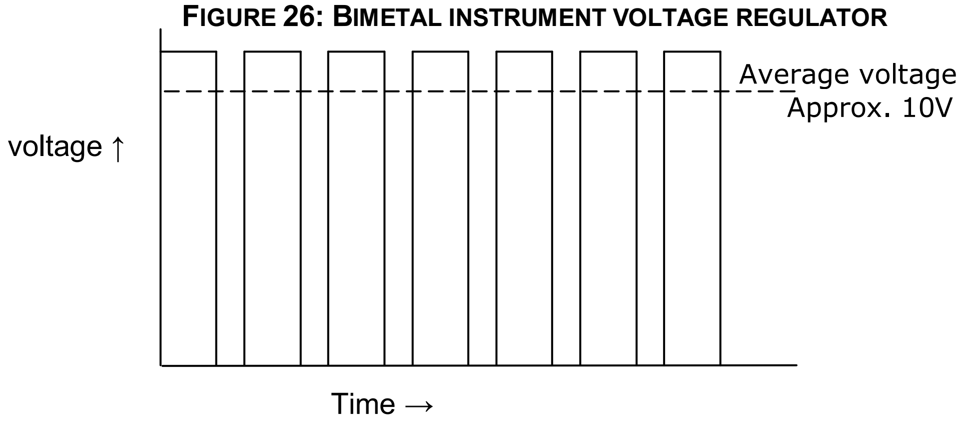


Fig. 27a shows the Smiths instrument voltage regulator looking from above. As shown, the bimetal element is not a simple bar but is a square "U" shape. The bimetal element itself is made as a single piece of metal. It is anchored to the base plate (not shown) at the end of one of the arms and this is the "I" terminal of the device. One end of the heating coil is connected to this terminal through the bimetal element itself. The contact to make or break the supply to the gauges is on the end of the opposite arm which also carries the heating coil. The black line at the base of the U at the left of the diagram represents a bent up section of metal to resist bending as can be seen in fig. 27b, which shows a side view of the works of this voltage regulator.

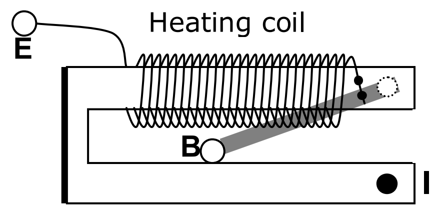


Fig. 27a: Instrument voltage regulator plan view

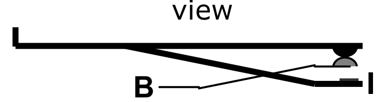


Fig. 27b: Instrument voltage regulator elevation

Bimetal devices respond to temperature from any source including changes in ambient temperature. And that is the reason for the U shaped element. The lower arm, the arm without the heating coil, will bend due to changes in ambient temperature and so compensate for any change in the other arm that performs the switching (regulating) function. This same construction is found in all bimetal gauges and in oil pressure senders but not in bimetal temperature senders such as the TT 1200/00, which respond to changes in "ambient" temperature – "ambient" temperature in the case of a temperature sender is the temperature of the water in the car's cooling system. In the case of the gauge itself, the "ambient" temperature of the gauge can increase markedly when the dashboard lights are turned on. An incandescent bulb is an effective heater and it is operating within an enclosed space for those gauges with the lamp fitted inside the gauge case.

Things to note about this regulator are that it needs a good earth connection in order to work and that, unlike the senders for “TE/PE/BP” type gauges, the switching off and on is constant. It is also very important to connect to the correct terminals. Some regulators such as the BR 1307/00 had dual male spade terminals for battery connection and dual female spade terminals for instrument connection. This made it hard to get wrong. The BR 1300/00 was similar but with male connectors only. A mounting plate was fixed to the case of most regulators. These were designed to mount on the rear of a speedometer. Those regulators without a mounting flange, such as the BR 1303/20, are intended to plug in to connectors on the rear of an instrument panel as can be seen in the photo of part of a Morris Marina instrument panel in fig. 28 at right and in fig. 14 earlier in this document. This same style of regulator was used in the dual bimetal gauge shown in fig. 14 earlier.

Figure 28: Voltage regulator mounted at rear of a Morris Marina instrument panel.

If replacing one of these regulators, there are a few points to keep in mind. Quite apart from the connector/mounting styles you must get a 10 Volt unit for Smiths instruments. AC Delco used 7 Volts from memory, and VDO instruments used 5 Volts.

For those regulators fitted with male spade terminals only, make sure when refitting that the correct wires go to the correct terminals. If the “B” and “I” terminal connections are swapped, the supplied gauges may read briefly then not at all. The bimetal bar will “overheat” and may develop a “set” that will prevent it making contact with the “B” terminal and the regulator will need replacing (again).

The following is from a British Leyland – Triumph service note. This applies only to the bimetal regulator:

> "The first step should be to check the correct output of the voltage stabilizer which, in the case of the models previously mentioned, should be 10 volts. To do this accurately, the use of an ordinary Triumph TR-4 or Spitfire (***bimetal***) temperature gauge taken from stock will be most useful. Connect a 12 volt 2.2 watt bulb (dash illumination bulb) in series with the test gauge. This will introduce sufficient resistance in the circuit to allow the gauge to just read full scale when 12 volts is applied.
>
> Next, connect the gauge to a 10 volt source. For example, to the "l" terminal of a known properly functioning stabilizer on a new car. Allow at least 2 minutes for the gauge to register and stabilize, then mark the front of the dial opposite the pointer. The gauge has now been calibrated to read 10 volts.
>
> If you have a suspected stabilizer to test, disconnect the lead from the "I" terminal on the stabilizer. Connect one end of your test gauge to the "I" terminal on the stabilizer, the other to ground, and after 2 minutes note the readings on the test gauge. This should read 10 volts if the stabilizer is in proper working order.
>
> Incidentally, the bulb which is in series with the gauge will also serve as an indicator; and if the circuit is functioning properly, this bulb should glow for approximately 30 seconds and then commence flashing."

Another method of testing these regulators is provided on the next page.

BIMETAL VOLTAGE REGULATORS TROUBLESHOOTING:

Generally these regulators supply more than one gauge so if the regulator fails, multiple gauges can be affected. Usually, fuel and temperature gauges. If only one of several gauges is affected, the regulator is not the problem.

A quick test can be done to check the bimetal-type instrument voltage regulator output but the calibration dots printed on the scale of the gauge used must be visible. Connect a 68 Ohm, 1 Watt resistor in place of either the fuel or temperature sender and turn the ignition on. (Disconnect the coil if you are not running the engine.) Allow the gauge reading to stabilise for a minute or two then observe the location of the pointer relative to the two centre calibration dots. Refer to fig. 20 which shows these. (In some gauges the dots may be replaced by a short bar as in fig. 29 below.) The pointer should sit mid way between them. If the pointer is well outside the dots then the regulator must be suspect. (This assumes that the gauge calibration itself is good.)

TABLE L	**BIMETAL INSTRUMENT VOLTAGE REGULATOR**	
Fault	Cause	Remedy
Gauges reading high	Bad or no earth connection at regulator Regulator out of adjustment or faulty	Check earth wiring Briefly short out the 'B" and "I" terminals of the regulator. If' no increase in the gauge reading, the regulator is faulty. Adjust or replace regulator.
Gauges reading low	Regulator out of adjustment.	Adjust or replace regulator
Gauges not reading	no voltage supply to regulator Regulator connected wrongly Dirty contacts in regulator	Check fuses and regulator connections. Check wiring Replace regulator

There are now a number of "solid-state" regulators on the market and should be much more reliable than the bimetal type. These are polarity sensitive, and are available in positive and negative-earth versions. Be careful testing these regulators. Too much current draw, may destroy them. These also require a good earth connection. Test these regulators with a voltmeter. If the output voltage measured is not very close to 10 Volts then the regulator or earth connection is faulty.

Figure 29: Gauge scale showing mid-point calibration "bar" in lieu of the more usual dots.

MECHANICAL SPEEDOMETERS:

I'm not going to do a document on these. A document readily available on the internet, "Repairing-Jaeger-and-Smiths-Speedometers" by Anthony Rhodes is worth reading if you want to know more about these instruments. He has it pretty well right.

There is no real difference between mechanical speedometers and tachometers. Essentially a mechanical tachometer is a mechanical speedometer without the odometer bits.

In the event you want to change a speedometer, either because the old one is shot or you want one that reads in km/h or for any other reason then there are a number of things to take into consideration.

Physical size is pretty obvious but then you may be creating a custom dash in which case that will not be an issue.

The presence, or absence, of warning lights may be a consideration. Warning lights are readily installed elsewhere.

The cable fitting on the back of the speedometer may be different, in which case a new cable will be required. Chances are a suitable cable exists for another vehicle that will do the job though it is a straightforward exercise to have a custom cable made up depending on the inner cable diameter. This can be of 3 mm or "4mm" (actually 3.5mm) diameter. There are, or were standard cable fittings that would get around this little problem. You will almost certainly need to change the fittings if swapping for a "metric" instrument.

Standard 3mm and 4mm fittings can be seen on a Spitfire (and others) with the mechanical tachometer, where the speedometer uses a 4mm cable and the tachometer a 3 mm cable. The drive cable fitting on the rear of each instrument is very different.

A most important parameter is the turns per mile or turns per kilometre, which will be marked on the dial of a Smiths speedometer. If you want to change from an imperial (miles/h) to a metric speedometer then you will need a speedometer of (tpm x 0.625) tpk. For example, a speedometer of 1184 tpm can be changed to a metric speedo @ 740 tpk. (Most non-Smiths speedometers were fixed at 1000 turns per mile / 625 turns per kilometre. This required a lot of changing of drive gears to re-calibrate.) As long as this number remains the same or equivalent and provided no changes have been made to transmissions/differential ratio/tyre sizes then you should be good to go.

There are two parts to speedometer calibration; Odometer and Speed indication. Both are quite separate and repairing/re-calibrating a speedometer involves both. Smiths used a gear and pawl and ratchet combination to drive the odometer and a magnet and hairspring to calibrate for speed. For the odometer part, the gears available had a pitch of 20, 25 or 32 teeth (per inch) and ratchet wheels were available from 20 teeth to about 60 teeth. Later on, a twin-start 25 pitch gear was produced giving a fourth option of effectively 12.5. (Metric speedometers fitted to late model Triumphs, such as the 2500S and Stag, are 512.5 turns per kilometre which obviously requires the 12.5 pitch gear.) The odometer calibration was pitch x number of ratchet teeth and this is the tpm/tpk figure on the dial. The degree of magnetisation of the rotor magnet, could be adjusted within fairly wide limits to give the correct speed reading. If you drive the speedometer at the same number of revolutions per minute as the tpm/tpk number printed on the dial then the speedometer should indicate 60 – mph or km/h as appropriate. So with a bit of old cable to fit the speedometer, an electric drill to drive it and a calculator you can quickly check the speed calibration. The revolutions per minute to indicated speed is linear for magnetic instruments – half the rpm should indicate half the speed etc. The calculation to do this is: (drill rpm / tpm) x 60 and this calculated value is what the speedometer should indicate. With a two-speed drill you can check at each drill speed to estimate the linearity of the speedometer. It should be good unless someone has fiddled with it. The same comments apply to chronometric instruments as fitted to many British motorcycles but the earlier governor type instruments (pre mid 1930s mainly) were not at all linear across the indicated range.

As mentioned above, if you have made changes to the transmission etc then you may need to re-calibrate the speedometer. This is not really the sort of thing you can do in the home workshop though the equipment required is not unduly complex but is most definitely specialised.

Another option may be to use a speedometer from a car with different specifications.

It is possible to check your odometer's accuracy on the road. Somewhere, hopefully not too far away, is a speedometer check area on the road. These usually cover about 3 km but sometimes more and are marked with small signs beside the road. Using an odometer and calculator (they are almost all in metric measurement (km) these days) then rocking up to one of these and using a tripmeter (or odometer if it has a tenths of a mile/km indication) to check distance recorded will give you a measure of the odometer's accuracy and the likely calibration it should have. (Ideally you would have a counter on the cable that accurately counts the number of turns.) It is an unfortunate fact that the majority of these speedometer check areas are in 100km/h zones and often in the middle of nowhere. There may also be a measured mile or kilometre in some cities if you know where to look.

So if you have changed something significantly in your car's drive train then it may be a good investment to have the speedometer (of your choice) recalibrated to suit your car's gearing. It might also help to protect your wallet from plunder resulting from driving too fast or too slow.

Check the speedometer drive gear oil seal when an opportunity arises, such as when working on the clutch or driveshaft. This should be done as a matter of course when overhauling/re-conditioning a gearbox. Oil in a speedometer is not something you want to happen as repairs are usually very expensive – particularly in older speedometers as hypoid oils and some brasses do not go well together. Plastic gears etc are unaffected but any particulate matter in the oil will act like grinding paste!

Appendix A:- Tabbed bezel removal:

For many gauges the bezel is retained against the rim of the case by three tabs. To remove a bezel, rotate the bezel relative to the case until the tabs align with "slots" in the case's rim and pull off. Often this is not easy to do. Various methods can be employed to remove "difficult" bezels and some are listed below.

Note that bending the tabs up will permanently distort, and possibly crack, the bezel adjacent to the tabs. Don't do it if it can be avoided.

If it is not possible to turn the bezel by hand, the following tips may help.

With a small screwdriver, or similar tool, placed between a bezel tab and the case, carefully lever the tab away from the case just enough to cause the tab to move. Repeat for all tabs. Run a thin blade between the bezel and the rim of the case in between the tabs. This will break any bond that may have formed between the bezel and the case rim. In some cases this may be all that is required to free the bezel sufficiently for it to be removed.

Grip the bezel and case firmly in your hands and try turning the bezel. If it still doesn't move try turning the bezel one way then the other. This may be sufficient to move the bezel and once it has started moving, keep going until it turns sufficiently to line the tabs with the slots in the case and you're done.

Tom Hayden, from Ohio, advises that he has used a shallow pan of hot water to free stuck bezels. Water temperature should be between 50°C and 60 °C or the temperature from a tempered hot water system tap (nominally 55 °C). Depth of water needs to be just sufficient to cover the bezel and case rim when the instrument is placed in the water face-down. 3/8 inch or 9mm is plenty for a flat-bottomed pan. Allow to soak for a few minutes then remove the bezel.

If necessary soaking in hot water could be repeated. Tom also notes that hot water is good for removing hardened seal material from the bezel itself.

Note: Do not use boiling water if using this "hot water" method! There is a risk that hot water contacting a cold glass could cause the glass to crack. In order to reduce the risk, ensure that the instrument (glass) itself is as warm as possible which will be achieved if the instrument has been sitting in a reasonably warm room for a while.

CHANGE LOG

Date	Version	Change list
Aug 2020	1.0	Initial release
Oct 2020	1.1	Minor updates and clarifications
Nov 2020	1.2	Added in section on clusters and minor rewrites.
March 2021	1.3	Minor re-writing of some sections. Corrected typos and references