Smiths & Jaeger Tachometer Conversion

Rev. 01

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What is Covered:

The following document briefly discusses the operation of tachometers. With that established the document presents the conversion of Smiths and Jaeger tachometers to accept newer electronic movements.

What is Not Covered:

The repair of Smiths mechanical and electronic tachometers is not discussed. Information on these operations is available on various Cobra, Lotus, Alpine/Tiger, and MG web sites on the internet.

Glossary:

A: Mechanical Tachometer. A cable driven instrument connected to the engine to measure its operating speed.

B: Current Sensing Tachometer. An electrical instrument where current for the ignition coil passes through the gauge to indicate engine operating speed.

C: Voltage Sensing Tachometer: An electrical instrument where a sensor lead is connected to the junction between the ignition coil and the distributor. The gauge monitors the voltage pulses to indicate engine operating speed.

Conversion Overview:

There are several web sites on the internet which have discussed the conversion of early Smiths tachometers to a later type. The most common discussion of this topic focuses on the substitution of a later Smiths RVC movement into a gauge originally built for the earlier RVI movement. This allows the owner to maintain a "correct" appearing dash and have a working tachometer.

This document is written to guide the reader through the steps of converting a Smiths tachometer to a late model voltage sensing movement or circuit board. A Smiths gauge (or other) may be used as a donor.

The reader will be guided through the following operations:

1) Disassembling the Smiths and donor tachometers.
2) Fitting the Smiths gauge face to the donor movement.
3) Fabricating a mounting spacer.
4) Fitting a donor circuit board.
5) Simplified calibration.
6) Cosmetic restoration.

Mandatory Tools & Supplies:

Conversion of a tachometer will require certain basic tools and supplies. The following is a list of items you must have to complete this process: screwdrivers (Phillips and slotted), hacksaw, knives, wire, wire strippers, solder & soldering iron, drill bits and a drill, taps & screws, scissors, and some form of rigid insulating material (discussed later), and an accurate reference tachometer for calibration.

Optional Tools & Supplies:

The conversion task is greatly simplified if more advanced tools and supplies are available. In addition to the supplies above it will be helpful for the reader to have some or all of the following: a sandblaster, epoxy glue & paint (for cosmetic restoration), a router and bits, access to a milling machine and lathe, a Dremel® tool or comparable (with assorted bits), a constant speed motor or spindle, a 12v power supply, assorted industrial sensors, hook up wire, circuit board material, and multi-turn potentiometers.

Basic Tachometer Operation:

Mechanical tachometers use a rotating magnetic disk in proximity to a spring biased aluminum cup mounted in needle bearings and attached to a pointer (needle). As the magnetic disk is rotated by the drive cable it induces eddy currents in the aluminum cup creating a "drag" force which rotates the cup against the bias spring. This in turn moves the needle on the gauge face. This is NOT a magnetic coupling.

Current sensing tachometers are electrical devices where the current for the engine's ignition coil passes through the instrument. Either on the back of the gauge or inside its housing the sensing wire will be looped into an induction coil or

loop. The electronics inside the gauge monitor the pulses on this induction loop and converts them into an electrical signal to move the instrument's needle.

Voltage sensing tachometers are electrical devices where a sensor wire is connected to the "low side" of the ignition coil. During normal operation of the ignition system the voltage on this sensor wire will pulse between ground and the ignition coil's supply voltage. The electronics inside the gauge monitor these pulses and converts them into an electrical signal to move the gauge's needle.

Smiths Tachometer Problems:

Mechanical tachometers have several failure modes. Obvious areas for failure are the drive gears and cables. In addition to this, the lubrication inside the tachometer can thicken or harden causing the unit to stop working or wear. Additionally, the interaction of the magnetic disk and the aluminum cup involves a needle bearing which can fail or stick. Once this bearing sticks the pointer is driven all the way around the gauge face ruining the bias spring and driving components together. Once this has occurred the gauge requires professional repair which may not be cost effective.

Current sensing tachometers were used on many British cars through the 1960s. Inside the tachometer are electrical components including electrolytic capacitors which were not designed to last 30 or 40 years. As these older components fail they can be replaced to restore operation but again, this professional repair may not be cost effective. In addition, there is a trend to replace traditional points ignition systems with aftermarket electronic ignitions. For reasons beyond the scope of this document it is often the case that the current sensing tachometers will not work with electronic ignitions. The Smiths tachometers falling into this category can be identified by the letters RVI appearing on the gauge face.

Voltage sensing tachometers were used on most cars after the 1960s. Like the current sensing tachometers, inside are electrical components which were not designed to last 30 or more years. As these older components fail they can be replaced to restore operation but again, this professional repair may not be cost effective. The Smiths tachometers falling into this category can be identified by the letters RVC appearing on the gauge face.

Repair & Conversion Methods:

The upgrading and conversion of Smiths tachometers falls into two basic categories:

1) Replace the entire Smiths tachometer (excluding the face) with a later movement (Smiths or otherwise), or
2) Replace the Smiths tachometer's electronic circuits while retaining the basic Smiths movement.

Which of these two solutions works best must be determined based on the type of tachometer being converted, the tools and equipment available, as well as the type of donor tachometers available.

In the first instance it is necessary to completely gut the old Smiths tachometer and fit its face and needle to the donor movement. It is typically necessary to fabricate insulated mounting spacers to position the face correctly in the old case. This is the only option when fitting an electronic movement to a Smiths mechanical tachometer.

In the second instance it is necessary to source a small enough donor tachometer that its circuit board can be easily fitted inside the Smiths case using a minimal amount of custom brackets. In many instances this may prove to be the easier solution. The donor circuit board may come from an existing tachometer or obtained from a number of internet sources that sell circuits just for this purpose.

Parts Sources & Selection:

It is assumed that the reader already has a tachometer in need of repair or conversion. If not, or if the reader wishes to use a different tachometer than what is currently in his/her car, they should procure what they need from a suitable source (car clubs, swap meets, online auctions, etc.)

The reader should study the gauge in need of service. Measure and record the needle's degree of angular "sweep" over the face and the maximum reading on the gauge face. One of the most common Smiths/Jaeger tachometer configurations has a range of 7000 RPM with approximately 270^{o} sweep of the needle. The reader should seek a suitable, voltage sensing, donor tachometer having the same range and sweep. If the reader cannot obtain a donor tachometer that matches the sweep and range of the Smiths unit, they should find a donor with MORE sweep for the same maximum RPM (i.e. 7000 RPM with 280^{o} sweep). Alternatively, seek a donor with the same degrees of sweep but with a slightly lower maximum RPM (i.e. 6000 RPM with 270^{o} sweep). Donor tachometers can usually be found at the same sources listed in the previous paragraph. The donor tachometer may be either a "sealed" unit from a manufacturer such as Smiths, VDO, AutoMeter, Sun, etc., OR in some instances part of a later car's dash IF the tachometer is not driven by the donor car's computer. (Unsuitable donor tachometers will NOT have a tachometer circuit board attached, they will only have the needle movement with connection wires).

The reader may wish to disassemble their Smiths tachometer and make internal measurements of the movement and its case in advance of searching for a donor tachometer. It is desirable (but not mandatory) to fit the donor tachometer's electronics inside the Smith's case so smaller donor movements are desirable.

It should go without saying, that the donor tachometer should be rated for the same number of cylinders as that of the Smiths unit being replaced.

Common Steps for All Conversions:

The following section details steps common to all conversions.

Smiths Disassembly:

The Smiths gauge will have a bezel on the front behind which is (or was) a rubber ring that contacts the glass lens. In time the rubber hardens and may glue itself to the glass. The reader may wish to spray the front and back of the bezel where it joins the case and glass with light oil such as WD-40® to soften this bond. The reader may also wish to use a sharp, fine blade screwdriver to slightly lift the locking tabs on the back of the bezel.

This Smiths mechanical tachometer will be converted to an electronic movement.

Once the lock tabs on the back of the bezel have been lifted slightly and the penetrating oil has been allowed to work, the reader should push down on the bezel and turn it while holding the case. A rubber "gripper" as used for opening stubborn jar lids may prove useful. If the gripper fails, the reader may tap the lock tabs (clockwise or counterclockwise) with a screwdriver struck with a light hammer while an assistant holds the case.

When the bezel is free to turn, rotate it while watching the back side of the case. The lock tabs on the bezel will line up with notches in the case. Once the notches line up, the bezel may be removed from the front of the case. With the bezel removed a fine blade screwdriver may be used to remove the front glass and the front reflector around it.

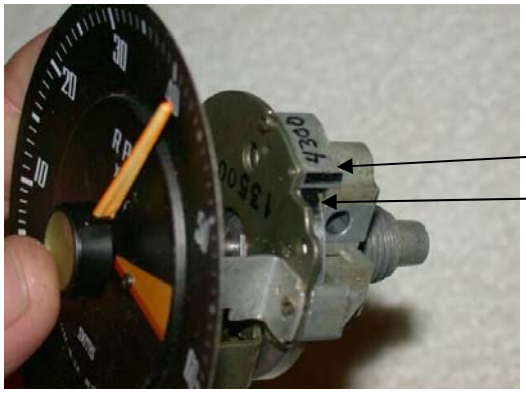
Left to Right: Smiths gauge with the bezel, front glass, and reflector removed. Back of gauge & fillister screws. Smiths gauge with the movement removed and rubber mounting isolator seen inside.

With the bezel and glass removed the movement can be removed from the case. Place the gauge upside down on a soft towel and remove the fillister head screws. The movement can then be pushed out of the housing from the rear. Push gently; the rubber mounting isolators may adhere to the surfaces.

Tachometer Pointer (Needle) Removal:

Mechanical Tachometer:

IF there is any intention to use the mechanical Smiths movement in the future, special care and steps should be taken now. Arbitrarily turn the needle on the tachometer up to some reading on the gauge face. (In the photo below the needle was turned to 4300 RPM). With the needle held in a known position use a permanent marker to mark on the aluminum cup its position relative to the fixed part of the movement. Mark on that fixed portion of the movement what the needle position is. Marking the needle position relative to a fixed part of the gauge will allow the needle to be replaced in the original position on the movement if desired.



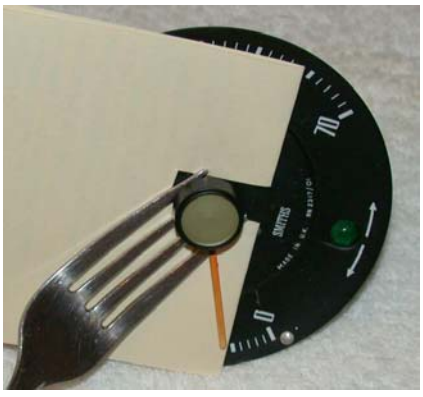
Needle held to an arbitrary position (here 4300 RPM), aluminum cup marked for position along its OD, and needle position written on the fixed part of the gauge frame.

Electronic Tachometer:

Electrical tachometers typically do not have a visible needle stop on the face for the "0" RPM position. The movement has two balanced springs, one of which holds the movement against an internal "0" stop when the meter is not operating. It is therefore possible to omit the marking step when disassembling electric tachometers. When reinstalling the needle it is only necessary to replace the needle pointing at "0" on the dial.

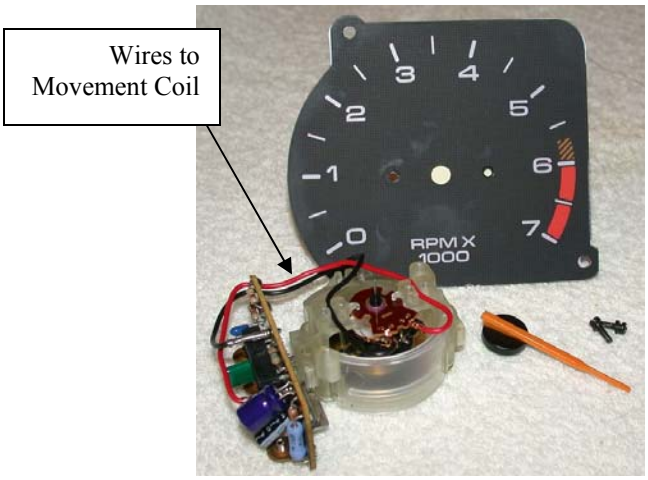
Needle Removal:

The needle can now be removed from the gauge face. Place a couple of 3x5 index cards or a piece of thin cardboard under the needle hub (covering each of the gauge face screws). Place a thin but strong fork (as in table fork) under the needle and against the cardboard. Slide the tines of the fork GENTLY under the needle as far as possible. Place your thumb over the center of the needle and use the fork to pull/pry the needle off the gauge spindle (straight up). If you pry, only apply leverage against the screws securing the gauge face. This will prevent damage to the face itself. Likewise, pry against the center hub of the pointer and not the O.D. of the decorative boss.



Removing needle and disassembled gauge.

Perform the same needle removal steps to your donor tachometer which will be sacrificing its movement for this conversion.



Donor tachometer, before and after disassembly.

Steps Unique to Complete Movement Conversions:

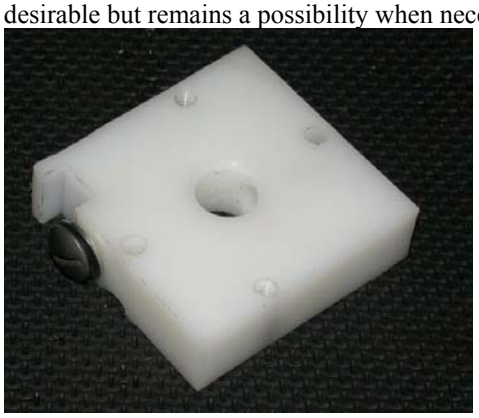
The following section details steps necessary when a complete new movement is fit to a Smiths case/face.

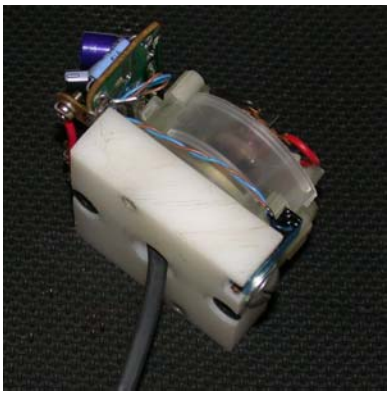
Fabricating a Movement Mounting Spacer:

When fitting a complete new movement to the Smiths case and face you will need to make a mounting spacer. This is required when replacing a mechanical movement with an electronic one. The mounting spacer will bolt to the back of the new movement and then bolt to the inside of the Smiths case. Its thickness is important as it will determine the position of the gauge face in the assembled tachometer. With the face removed, use calipers to measure the thickness of the Smiths movement from the rear mounting surface to the face mounting surface and record this value. Repeat the measurement on your donor movement. Subtract the two values to determine the thickness of the mounting spacer. Make the spacer to the required thickness and mount it to your donor movement. Temporarily fit the movement and spacer to the Smiths case and use a marker to transfer the original movement mounting hole locations through the holes in the back of the case. This will insure accurate alignment of the movement in the case. (Measure twice, cut once). Drill and tap the spacer block in the marked locations for a fastener close in size to the original Smiths mounting screws. (The Smiths screws have a unique size and pitch. It is unlikely that they will be used to mount the donor movement).

Pay attention to the orientation of your donor tachometer's movement. It is important that the side that is supposed to be "up" is mounted correctly for proper needle movement. Also pay attention to the location of lamps and other features of the Smiths tachometer which pass from the back to the front. Insure that these are not blocked by the spacer. Also pay attention to the size and shape of your donor tachometer's electronics. It may be necessary to design the spacer block to house the circuit board or at least provide clearance for it.

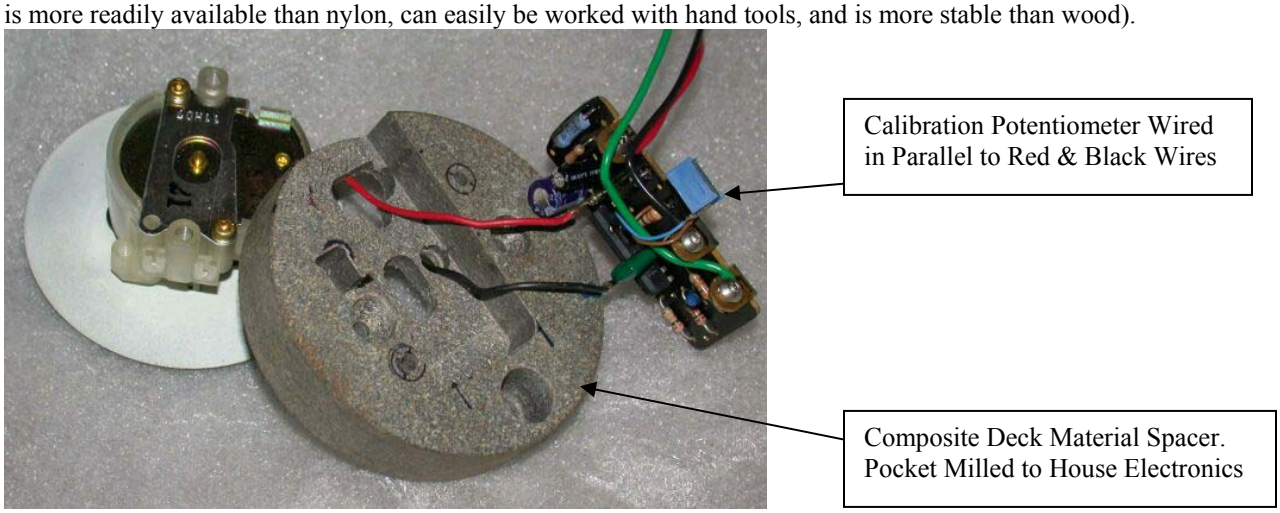
If it is not possible to fit the donor electronics in the Smiths case, it may be possible to mount them in a remote enclosure. As can be seen in the earlier pictures, the donor movement is connected by two wires to its circuit board. Mounting this circuit board remotely will simplify the gauge conversion process, but will complicate installation in the vehicle as the reader will have to find a suitable location behind the dashboard to mount the enclosure. Remote mounting the electronics is less desirable but remains a possibility when necessary.





This nylon spacer has tapped holes to attach to case and countersunk through holes to mount new movement. (The calibration potentiometer discussed later is shown in the photograph to the right connected to the blue/brown wires).

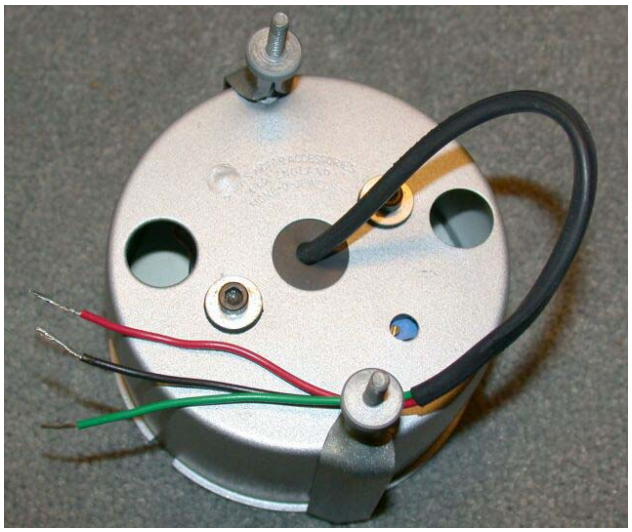
(NOTE: In the subsequent picture a round, grey spacer block is shown for a different conversion. The material selected was man-made, synthetic decking material available from home centers. This material is a wood-fiber/polyethylene composite. It is more readily available than nylon, can easily be worked with hand tools, and is more stable than wood).



Donor tachometer movement and spacer for installation in Smiths RVC case.

Mounting the Gauge Face:

You should not risk adding new tapped holes to the donor movement. Therefore, you will have to modify the Smiths gauge face with two new holes to match the mounting hole spacing on the donor movement. This can be simplified by bolting the two gauge faces together using the faces' center holes for alignment. Clamped together in this manner and oriented such that their horizontal and vertical axes are aligned with each other, the new hole locations for the Smiths face may be transferred through the holes in the donor tachometer's face. This assures the spacing will be correct and not subject to measurement errors.



Wiring Note:
Modern voltage sensing tachometers typically use the following wiring color codes.
Black = Ground, Red = +12v
Green = Signal (coil (-)), White = Lamp

Smiths tachometers typically use a color code of:
Black = Ground, Green = +12v,
White/Black = Signal (coil (-)),
Red/White = Lamp

The reader must choose which standard to follow.

For reasons explained later, a calibration potentiometer was added to the conversions shown in this document. The potentiometer is visible in the photograph to the left as the blue and brass item seen through the small bottom right hole added to the Smiths case.

For cosmetic reasons you may wish to plug the old, unused gauge face mounting holes. This is easily achieved by applying a small piece of cellophane tape to the **front** of the gauge face over the old holes. From the back side of the face, fill the holes with epoxy. Once the epoxy has cured, remove the tape from the front side and paint over the plugged holes. (Light from the gauge's illumination will likely pour out if you do not plug and paint the old screw holes). Once the face has been modified, attach it and the spacer block to the donor movement and fit them to the Smiths case.

Needle Installation:

The spindle of the donor movement will likely have a different diameter than the Smiths. This will complicate mounting the needle. In the event that the donor tachometer's spindle is larger than the hole in the Smiths needle you will need to measure the diameter of the donor spindle and drill out the Smiths needle about 0.001" smaller (to full depth) and then about 0.001" larger to about 1/2 the depth of the boss on the back of the Smiths needle. Micro-drill bits held by a pin-vise are available from most hobby stores and are suitable for this task. In the event that the hole in the Smiths needle is larger you will need to "shim" the bore of the needle to fit. An easy way to do this is to remove a single strand (filament) of copper wire from a stranded 18 AWG wire (such as from an extension cord). Take the single strand of fine copper wire, flatten it slightly with

pliers or a hammer, and bend it into an “L” shape. Insert the short leg of the “L” into the hole of the Smiths needle. Now press the needle onto the spindle. The wire will deform and fill the gap. Trim off the excess copper wire.

Steps Unique to Circuit Board Conversions:

The following section details steps necessary when only a new donor circuit board is fit to a Smiths movement.

Disassembly:

Complete the disassembly steps outlined above for all movements. Once those steps are complete, unsolder the wires from the movement. These are shown in earlier pictures. With the wires unsoldered, locate the screws securing the circuit boards to the Smiths movement and remove them. It may be necessary to cut or unsolder additional items if the particular Smiths tachometer being serviced has two parallel circuit boards joined by components. Eventually you will be able to remove the old circuit board(s).

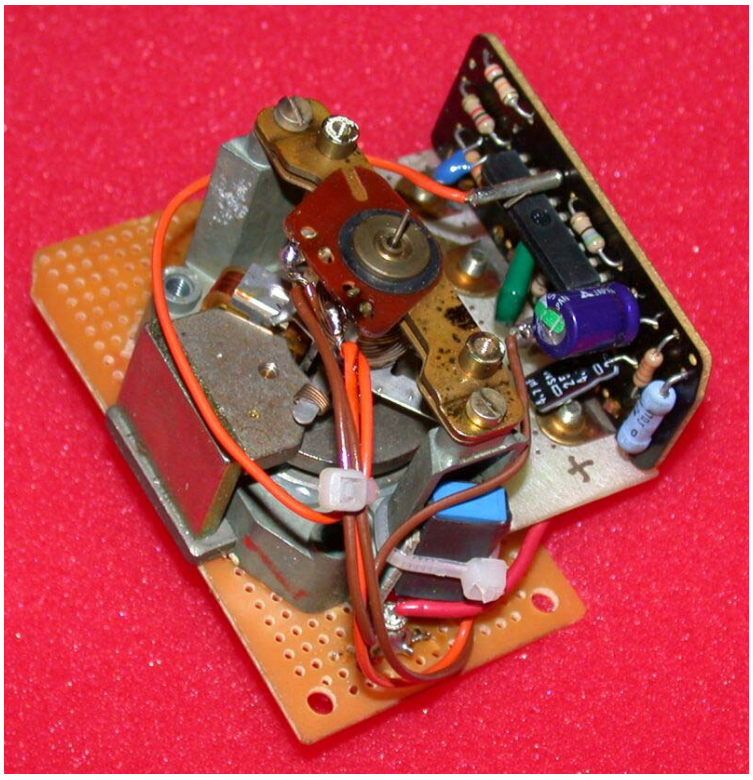
Reassembly:

Remove the circuit board from your donor tachometer. As before, this unit should have two wires going to its movement. Unsolder and remove the donor board noting the connection points for its movement wires and the connections for its power, ground and signal.

Examine what is left of the old Smiths movement and the size of your donor circuit board. Determine a location inside the Smiths case to mount the donor board keeping in mind the location of lights that may have to pass through the case. Determine what brackets or supports are necessary for your application and fabricate them preferably out of insulating material such as circuit board stock (available at Radio Shack).

Mount your donor movement to your brackets and temporarily clip its movement wires to the Smiths movement. Use jumpers to connect your half-built tachometer to either your car or a calibration source. Operate the car or source for just long enough to confirm that the movement is responding. If it is not, reverse the movement wire connections and repeat the test. Once you see the Smiths movement move away from its rest position, remove the tachometer and return to the bench. Solder the movement wires in place and begin the process of reassembling your converted tachometer.

Refer to the calibration section below and attach a calibration potentiometer in parallel to the movement’s coil wires. Once you have mounted the potentiometer in an accessible location (drilling extra holes in the gauge case as necessary) fit the tachometer to the Smiths case. Continue with the calibration steps described below.



The picture to the left shows a Smiths RVI movement with a donor circuit board and calibration trim pot. The light colored piece of circuit board (with the “+” sign) attaches to the Smiths movement using the screw holes for the original Smiths circuit board. This board serves as a mounting bracket for the donor circuit. The calibration trim pot appears as the blue brick shape cable tied to the movement. It is connected in parallel to the wires between the circuit board and movement. The perforated circuit board on the bottom of the Smiths movement serves as a locating surface for the electrical connectors while closing off unused case openings.

This method gives superior results when a small enough donor circuit board is available. No mounting spacer is required and no modifications to the gauge face are necessary. As the Smiths coil movement and its matched needle are retained, response and accuracy throughout the operating range are improved.

CALIBRATION:

SINGLE-POINT CALIBRATION:

Single-point calibration is ONLY possible when the entire donor tachometer is mounted behind the Smiths face and only when the range and degrees of needle sweep are identical between the donor and original Smiths movements. If the reader is replacing only the circuit board or was unable to locate a nearly identical complete donor movement they should proceed to Multi-Point Calibration below.

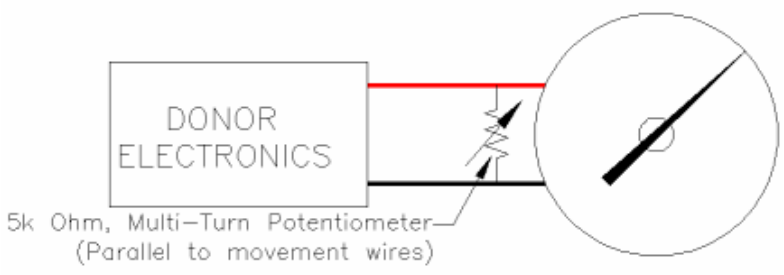
After the movement has been installed in the Smiths case basic calibration of the movement is required. This can be performed on the bench if you have suitable equipment or on a vehicle if you can hold its engine speed constant. In both cases you will need another tachometer you trust as a reference.

If the donor movement has the ***exact*** same degrees of swing and the same full scale (maximum) reading as the Smiths unit, you need only calibrate at a single point. To calibrate your new movement, connect it (and your reference tachometer) to your calibration equipment/engine. Establish a known speed of interest, hopefully close to mid-scale on the donor tachometer (or where you expect the engine to operate most of the time). Hold the engine/equipment at this desired, known speed and put the Smiths pointer on the donor movement such that it lines up with the RPM indicated by the reference tachometer. Press the needle onto the spindle to secure it… but not too hard. Now vary the engine/equipment speed and compare the readings of the two tachometers. It is not likely that they will be identical across the entire range of speeds you measure, but if they are within 100 RPM or so you should feel comfortable. Keep in mind that you are matching your converted tachometer to another gauge. Unless you know the accuracy of the reference gauge, you don't know which tachometer is more correct (if either). Once you are comfortable with the performance of your donor tachometer push the needle firmly down on the movement's spindle.

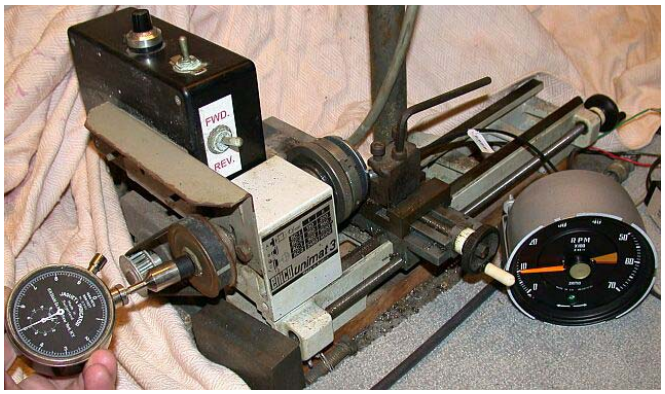
MULTI-POINT CALIBRATION:

When sourcing donor tachometer movements the reader was advised to seek a donor movement that exactly matched their Smiths for maximum RPM reading and angular sweep. When this was not possible he/she should seek a movement with a lower RPM for the same angular sweep or more sweep for the same maximum RPM. Either of these configurations will allow the pointer to be calibrated to the Smiths scale.

The donor movement will have two leads going to the magnetic coil that moves the movement's needle. (These can be seen in the images on page 5). A 5k Ohm, multi-turn variable resistor (potentiometer) should be wired in parallel to these wires (see the figure below). As the potentiometer's resistance is decreased, more and more of the current that would normally flow through the movement flows through the potentiometer thus reducing the amount of needle deflection. When this potentiometer is installed it is necessary to perform multi-point calibration.



To perform a multi-point calibration of your new movement, connect it (and your reference tachometer) to your calibration equipment/engine and operate at low speed. (NOTE: the converted tachometer MUST be oriented as it will be installed in the vehicle… i.e. horizontal with "0" near the bottom in most instances). Place the needle on the donor movement's spindle so it's position corresponds to the speed shown on the reference tachometer. The driving signal (engine speed) is then increased to a much higher RPM, equivalent to cruising speed, and held there. While operating at this higher speed, the calibration potentiometer is adjusted until the needle on the donor movement matches the RPM shown on the reference tachometer. The driving signal is then reduced to a low speed and compared to the reference gauge again. This approach may require re-positioning of the needle multiple times at low RPM followed by recalibration at high RPM until the gauge behaves suitably across its operating range. As mentioned in single-point calibration, you can only have confidence in your results when you have confidence in the reference tachometer used for calibration.



Bench calibration equipment: DC drive min-lathe rotating a 6-lobed wheel. A photo-sensor counts the lobes of the wheel and sends pulses to the tachometer. A hand-held mechanical tachometer measures the lathe RPM for reference. The photograph at the left shows the low-speed calibration point at 1000 RPM. The photograph at the right shows the high-speed calibration point.

COSMETIC RESTORATION:

Completed conversion. Cosmetically restored with electronic movement inside.

It is likely that the Smiths tachometer will be in need of cosmetic restoration. This is best achieved while the unit is disassembled, prior to installation of the donor movement. The outside of the case may be cleaned by sandblasting or other mechanical means to remove rust. Once cleaned, any electrical contact points (spade lugs, mounting studs, bulb sockets, etc.) should be masked and the case painted. If the inside requires cleaning use mild soap and water with a soft cloth. The cleaned interior may be touched up with semi-gloss or satin white spray paint. The gauge face is much more delicate and requires extreme care. The graduations and text on the gauge face are easily damaged or removed when cleaning. Only clean water on a soft cotton swab, cloth, or tissue should be used. DO NOT use soaps or detergents. When working around the text and graduation use a water moistened cotton swab. Any blemishes on the paint or markings may be touched up using model paints and a very fine detail paint brush. Chrome bezels may be cleaned using any fine grade of commercial metal polish. Once cleaned the bezel may be protected by spraying with clear lacquer or similar.

FINAL ASSEMBLY:

Once the calibration is complete you should refit the front glass and bezel to your gauge. This is a reversal of the steps used during disassembly. It may be necessary to replace the rubber seals in contact with the glass. While proper seals may be available from some sources, generic o-ring cord stock may be used in most instances. A 1/16” cross-section o-ring or annular disk of black gasket paper is usually located between the glass and the front reflector ring. A 1/8” cross-section ring is usually between the bezel and the glass.

Smiths RVC Tachometer before and after conversion and cosmetic restoration.

COMPLETION:

After the gauge has been converted, cosmetically restored, and calibrated complete your work by attaching a label to the back. The label should indicate what each electrical connector (or wire) is for and the polarity of the tachometer. (This will almost certainly be "negative ground"). Also note on the label any extremes in operation noted during calibration (i.e. "Not accurate below 700 RPM" or similar statements). Show pride in your work by signing and dating the label.

Revisions:
01 May 17, 2005 – Draft changes implemented.