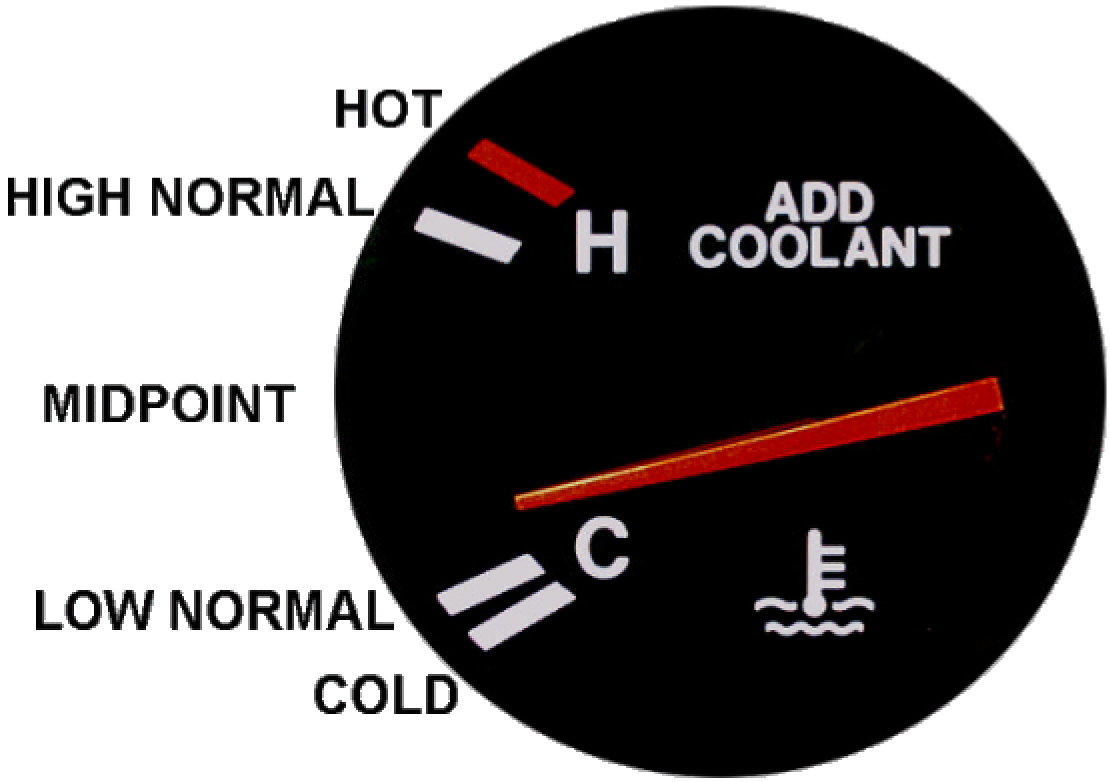
How to Linearize the Third Generation RX-7 Temperature Gauge



Five Basic Steps

This modification involves a few simple steps that can be performed in an afternoon if you have all the tools and parts.

1. Remove the gauge from the instrument cluster.
2. Solder a jumper wire on the gauge circuit board.
3. Reinstall the gauge.
4. Calibrate the gauge.
5. Drive around with a big grin on your face.

Gauge Philosophy

The following is an email that shows up in various forms from time to time on the RX7 net mailing list:

> "I was driving home yesterday when I noticed that the temperature gauge was pointing to the "H" mark. Since I was only a few blocks from my house I drove the car home and shut it off. This morning the car was very hard to start and a lot of white smoke was coming from the tail pipe. Coolant is spilling out of the overflow tank and the engine idles very rough. Did I damage the engine?"

Before you begin this modification you must search your soul and ask, what does the H mark on my 7s temperature gauge mean to me? To too many owners it means that the car is running hot and should be checked out when it's convenient. To those people I would suggest that this modification is useless. If your reaction to watching the needle move towards the dreaded red H is to pull over immediately and ascertain what is wrong, then this will be a useful modification. Remember, if your car is overheating, spending $100 in towing fees and an extra 2 hours waiting for the tow truck driver, is much cheaper and less time consuming than an engine rebuild.

The other notion you must divorce yourself from is the idea that the gauge needle points to the 9o'clock position when things are operating smoothly. After this modification the pointer will MOVE depending on what the car is doing. The important thing is to take evasive action if it moves above the highest white mark on the gauge (out of the range of normal operation).

If after trying this modification, you decide that it is not for you, it is easy to uninstall. Just clip the jumper and unplug the potentiometer. (That will make more sense after you read the directions.)

Parts List

Here is a list of parts you will need. These parts can be obtained at your local electronics supply house or from an internet catalog supply. I used Digi-Key. Digi-Key's web site address is:

http://www.digikey.com/

(Notes: 1.The smaller parts come in packages of 10 so you can't buy just one.

2. Digi-Key has a $5 handling charge for orders under $25)

Part Description	Qnt.	Digi-Key part no.
16 gauge, automotive grade stranded copper wire (thicker insl., higher temp rating than standard stranded wire)	20ft	Get at auto parts store (Kragen, NAPA etc.)
1 watt (or higher) 25Ω potentiometer	1	CT2152-ND
1 watt (or higher) 22Ω resistor*	1	ALSR3F-22-ND
1 watt (or higher) 100Ω resistor	1	ALSR3F-100-ND
Fully Insulated Female Spade Disconnect 16-14AWG .250X.032	1	920044-04-ND
Insulated Male Spade Spade Tab 16-14AWG .250X.032	2	920042-04-ND
Insulated ring terminal 16-14AWG #10	1	920010-07-ND
Enclosure for potentiometer assembly cast alum. 3.63" X 1.52" X 1.07"	1	HM150-ND
Heat shrink tubing assortment	1pk	CP-KIT-ND
Alligator Clip 27mm (5amp)	1	CP-2400-ND
Grommet .312" ID	2	RP454-ND
Double sided sticky foam tape		hardware store
* This is used to calibrate the gauge, a 1W 25Ω potentiometer can be used, see the calibration instructions for details.		

Tool List

There is nothing special about the tool list except perhaps the small four-inch pliers and wire cutters, and maybe the heat gun and vise, and maybe the terminal pliers...

4" needle nose pliers

4" wire cutters

Terminal pliers (to crimp the spade, tab and ring terminals)

25 watt pencil soldering iron with small diameter tip

Swivel "PanaVise" (for holding the gauge while soldering)

Heat gun (for shrinking the heat shrink tubing).

Drill and drill bits

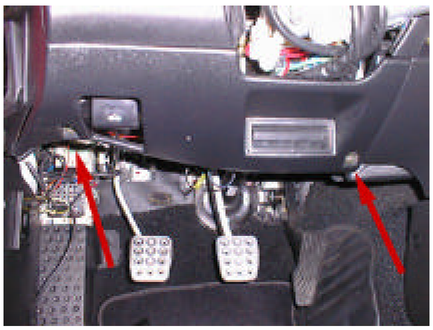
Philips screwdrivers

Metric wrench and socket set

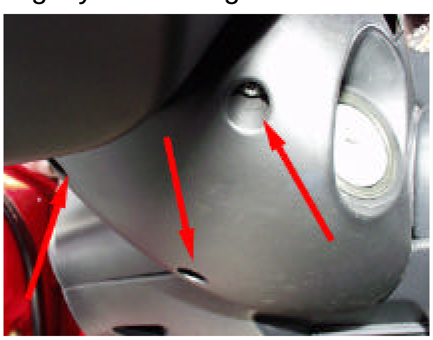
Removing the Gauge

To get to the gauge you must first remove the meter hood which contains the gauge cluster (that big black plastic thing that shades the gauges from the sun). The manual states that the steering wheel should be removed before removing the hood. If you are careful, the hood can be removed without removing the steering wheel. If you decide to remove the steering wheel follow the warnings in the shop manual on handling the air bag. So we begin:

1. Remove the lower panel that covers the vent below the steering wheel, 2 screws. (The red arrows point to the screw locations.) (Correction: There is a third screw. Remove the dashboard end panel to get to the third screw)



2. Remove the column cover, 3 screws, then carefully pop the top and bottom halves apart. Don't break the tabs. By slightly pushing in on the edge of one half and pulling out slightly on the edge of the other half you can get the tabs to release.



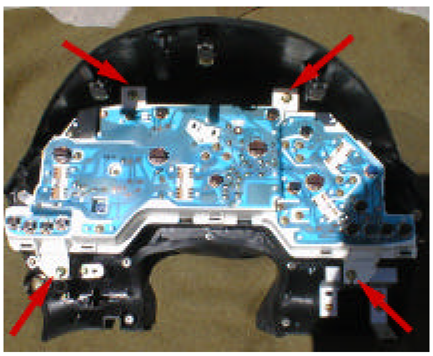
3. Remove the two screws at the bottom of the meter hood.

4. Sit in the drivers seat and grasp the top of the hood at 10 and 2 o'clock, firmly pull the meter hood in a horizontal direction towards the steering wheel. In other words, don't pull up on the hood; slide it back towards the steering wheel. If that doesn't work, it may be that it just isn't possible to remove your hood without damage so be careful.

5. Very carefully, disconnect the 7 connectors from the back of the instrument cluster. The large connectors must be firmly pinched in the middle on both sides to disengage the locks while you are pulling them out. Be careful, the flexible circuit board that these connectors are attached to is brittle from age and will tear easily.

6. With the wires all disconnected tilt the meter hood until the back of it touches the windshield then rotate and wiggle it out from behind the steering wheel. If you are unsuccessful, you will have to remove the steering wheel or drop the steering column to remove the hood. (see the shop manual for instructions)

7. Unscrew the gauge cluster from the meter hood, 4 screws



8. Separate the plastic lens from the gauge cluster, 2 screws

9. Remove the oil/temperature gauge assembly, 6 brass screws on the back of the gauge cluster.

10. Do not attempt to disassemble the oil/temperature gauge assembly. You will have to do the modification with the assembly in one piece.

Modifying the Gauge

Modifying the gauge is simple in principal, just solder a jumper wire across the two unused holes on the circuit board attached to the temperature gauge (Figure 1). The difficult part is trying to avoid melting the clear plastic lens while soldering. To make things easier coat the wire with solder before soldering it to the circuit board. The wire I used was trimmed off the 22Ω resistor lead. Use the small needle nose pliers to hold the wire while you solder. Trim off the ends of the wire when you are done.

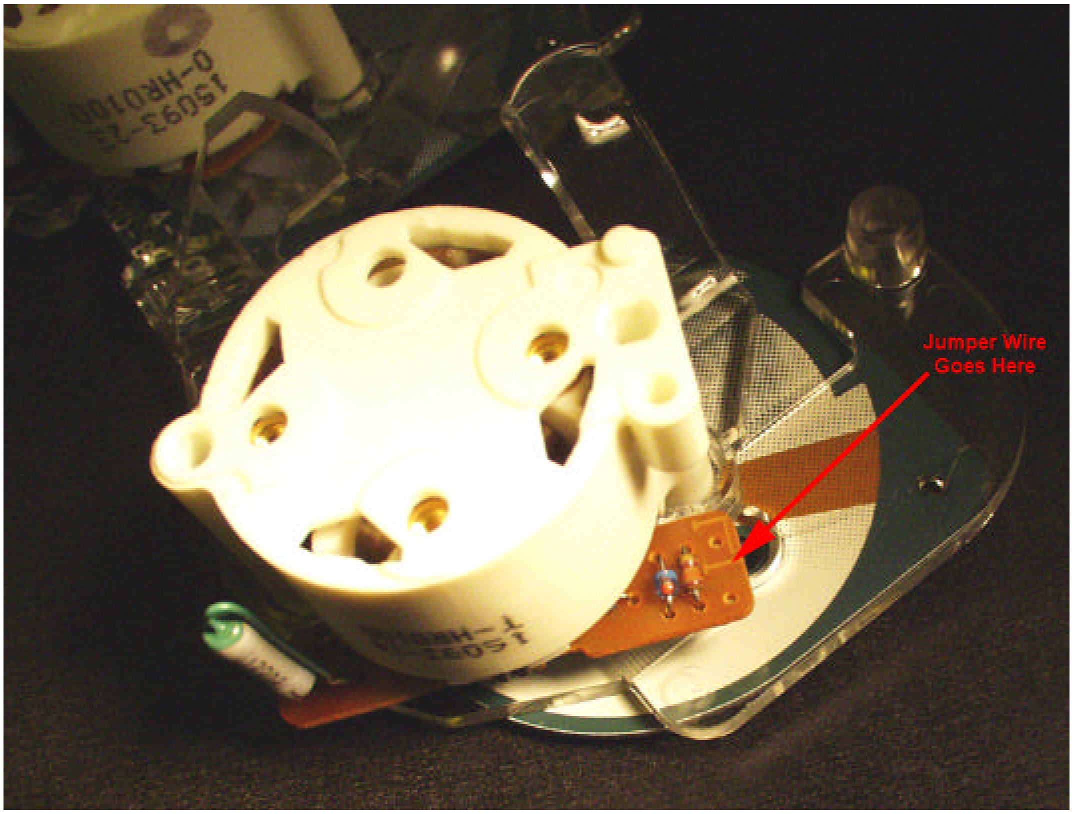


Figure 1. The temperature/oil pressure gauge assembly. Solder the jumper wire across the two unused holes shown in the figure. Be extremely careful that you do not melt the clear plastic lens with the soldering iron.

Reinstalling the Gauge

As they say in the manual, reassembly is the reverse of assembly! Again, be careful when plugging in the connectors to the flexible circuit board.

Making the Potentiometer Assembly

The potentiometer assembly is placed between the thermistor and the gauge. Its purpose is to allow you to adjust/calibrate the gauge scale. The completed assembly is shown in Figure 2.

Figure 2. The potentiometer assembly. The potentiometer and 100 Ω resistor are inside this enclosure. I attached the back of the potentiometer to the bottom of the case with foam tape. The shaft sticks-up through the case and the potentiometer is sealed from dust and dirt by a grommet. The wires are also protected by a grommet. You can see the connectors attached to each of the three wires. The female spade connector (right) attaches to the thermistor. The male spade connector (middle) attaches to the wire originally attached to the thermistor, and the ring connector (left) attaches to ground.

1. Drill a hole in the end of the enclosure and install a grommet.

2. Drill a hole in the enclosure lid for the potentiometer shaft and install a grommet.

3. Cut three 4-foot lengths of wire (the length may vary depending on where you locate the box). Crimp the male spade tab connector to the end of one wire, the female spade tab connector to the end of the second wire and the ring connector to the end of the third wire.

4. Thread the wires through the grommet attached to the end of the enclosure.

5. The wiring diagram for the following instructions is shown in Figure 3. Put some heat shrink tubing on the wire with the ring connector. Solder one lead of the 100Ω resister to the wire and cover the bare wire with the heat shrink tubing.

6. Twist the other lead of the 100Ω resistor together with the bare end of the wire with the female spade tab connector. Slide a piece of heat shrink tubing over both wires and resistor. Solder this wire assembly to the outer lug of the potentiometer. Cover the bare wires and lug with the heat shrink tubing.

7. Put some heat shrink tubing on the wire with the male spade tab connector and solder the wire to the center lug of the potentiometer. Cover the bare wire and lug with the heat shrink tubing. Insert the assembly in the enclosure. If you have an ohmmeter attach the leads to the male tab and the female tab connectors and pre-adjust the potentiometer to 18Ω.

8. Attach the ring terminal to a convenient ground in the engine compartment.

9. Pull the wire connector off the thermistor (see Figure 4 for the thermistor location) and attach it to the male spade tab connector from the enclosure. Attach the female spade connector from the enclosure to the thermistor.

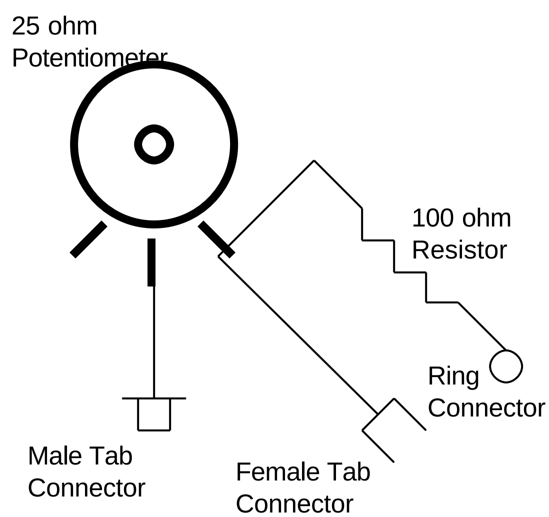


Figure 3. Solder the wire with the female spade tab connector to the outside lug. Solder the wire with the resistor and ring terminal to the outside lug. Solder the wire with the male spade tab connector to the center lug.

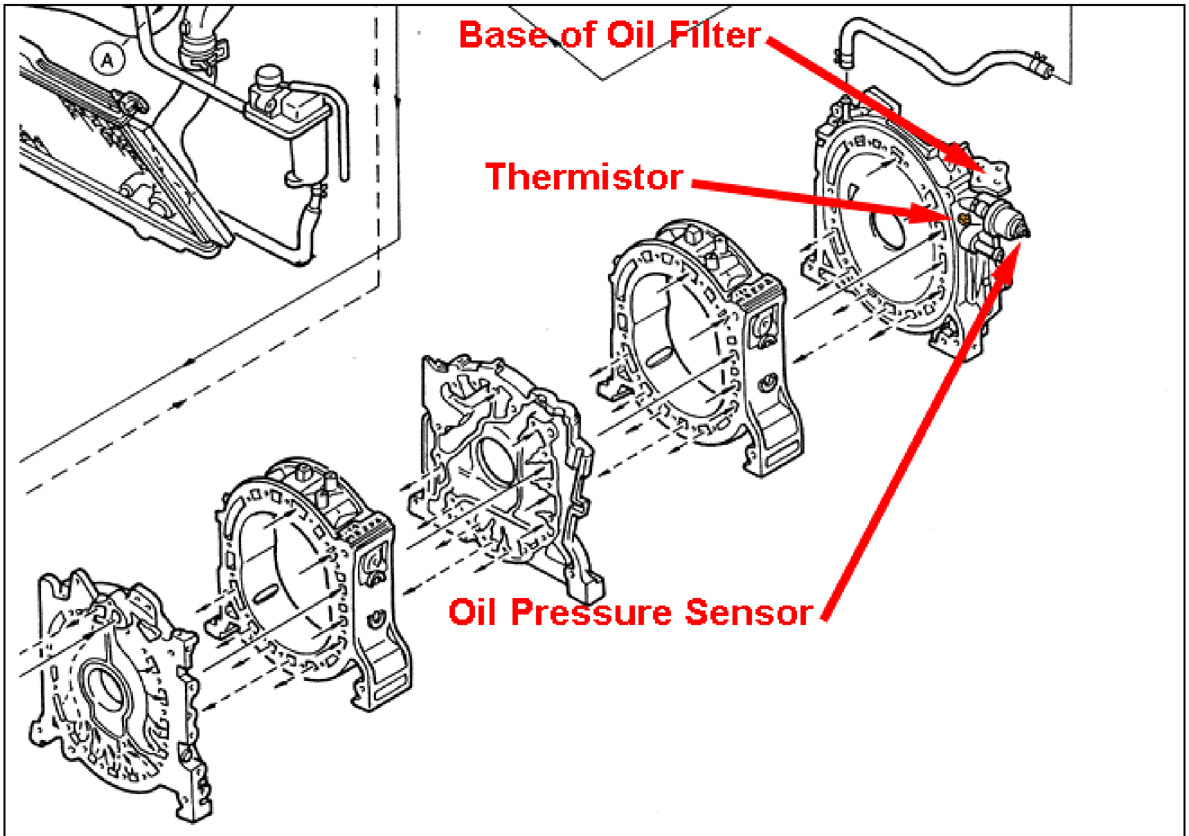


Figure 4. The thermistor is located slightly below and slightly in front of the base of the oil pressure sensor. The oil pressure sensor is below the oil filter. It is difficult to see the thermistor as it is screwed in almost flush with the housing. Look/feel for a black connector that appears attached to the housing.

Calibrating the Gauge

Now, that you have the gauge reinstalled and the potentiometer case plugged-in you need to calibrate the gauge. Calibration involves substituting a resistor for the thermistor then adjusting the potentiometer so the gauge needle is pointing at the red H mark. My recommendation is to use a 22Ω resistor for calibration. Looking at Figure 5, this represents a coolant temperature of approximately 247 °F (119 °C). If you are using just water and water-wetter use a 25Ω resistor. Based on Figure 5 this represents approximately 237 °F (114 °C).

If you have an ohmmeter available, you can use a potentiometer instead of a fixed resistor for calibration. Using the ohmmeter, adjust the potentiometer to correspond to your favorite Hot temperature (based on Figure 5) then use the potentiometer as you would the fixed resistor. I recommend that you do not set the potentiometer outside the 22-25Ω resistance range.

Table 1 gives you some temperature data to work with if you decide to pick your own hot temperature. One word of caution, Figure 5 is the ideal thermistor response based on data provided by Mazda. When choosing your hot temperature remember that the thermistor is only measuring a temperature at a single point and it is a mass-produced item with some manufacturing tolerances. So, don't set the hot temperature too close the boiling point of your coolant mixture.

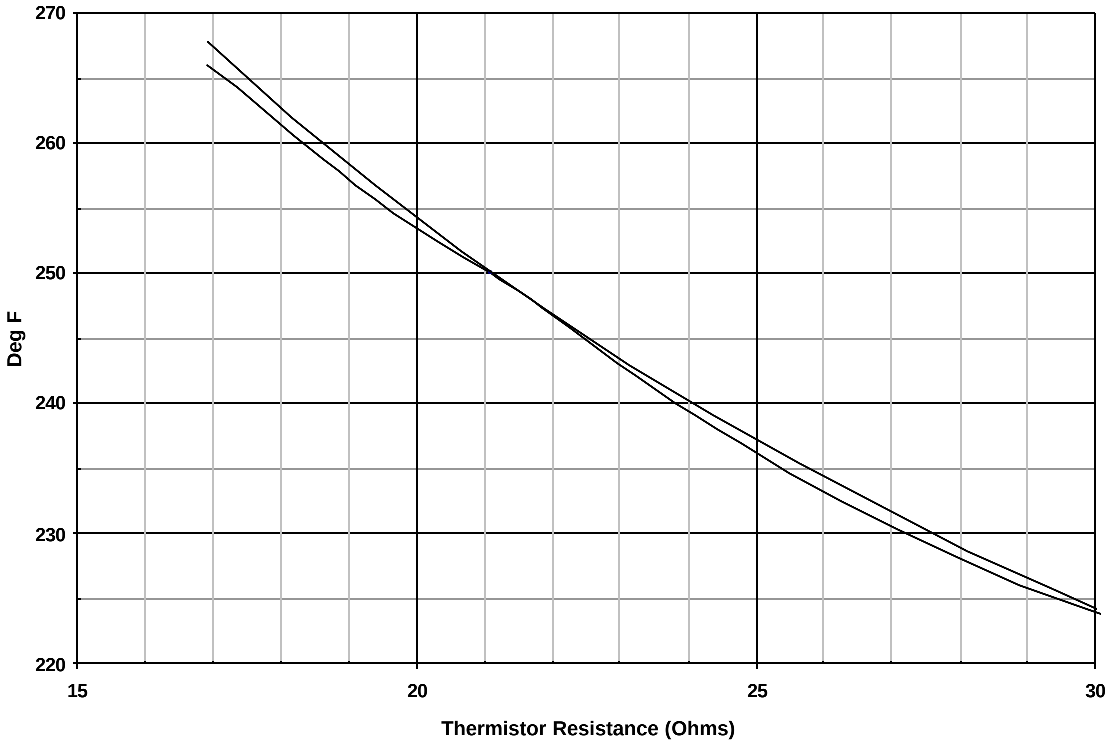


Figure 5 Theoretical response of the Mazda thermistor. For best gauge response, use a calibration resistance between 22 and 25 Ω. See the text for details.

Table 1. Temperature data for the 3rd Gen. RX-7

Condition	°F	°C
Normal coolant operating temperature	158 - 221	70 - 105
Fans turn on low (no ac)	221	105
Fans turn on medium (no ac)	226	108
Thermostat opening temp	177 - 182	80.5 - 83.5
Thermostat fully open temp	203	95
Pure water boiling point (0.9 bar {13psi} radiator cap)	246	119
50-50 antifreeze boiling point (0.9 bar {13psi} radiator cap)	261	127

To make the cable used to calibrate the gauge:

1. Cut two 2.5-foot lengths of wire.

2. Solder one end from each wire to each end of the resistor.

3. Cover the bare wires connected to the resistor with heat shrink tubing.

4. Attach a male spade connector to one end and an alligator clip to the other end (Figure 6).

Fig 6. The cable used to calibrate the temperature gauge

To calibrate the gauge:

1. Connect the alligator clip to the negative battery post.

2. Disconnect the wire attached to the thermistor (this wire has the blue female connector shown in Figure 2. It is NOT the wire with original Mazda black connector). Connect the blue female connector to the other end of the calibration cable. If you wired the potentiometer as shown in Figure 3, then a clockwise adjustment will give a higher gauge reading for a given temperature. Counter clockwise will lower the gauge needle.

3. Turn the ignition to on (don't start the car) and adjust the potentiometer in your enclosure counterclockwise so the needle points to below the red H mark. Slowly turn the potentiometer clockwise until the needle rises and points directly at the red H mark. The gauge has about a 5 °F hysteresis so be sure you follow this sequence.

4. Disconnect the calibration cable and reconnect the wire with the blue female connector to the thermistor.

5. Find a suitable location and secure the potentiometer case in the engine compartment (Figure 7)

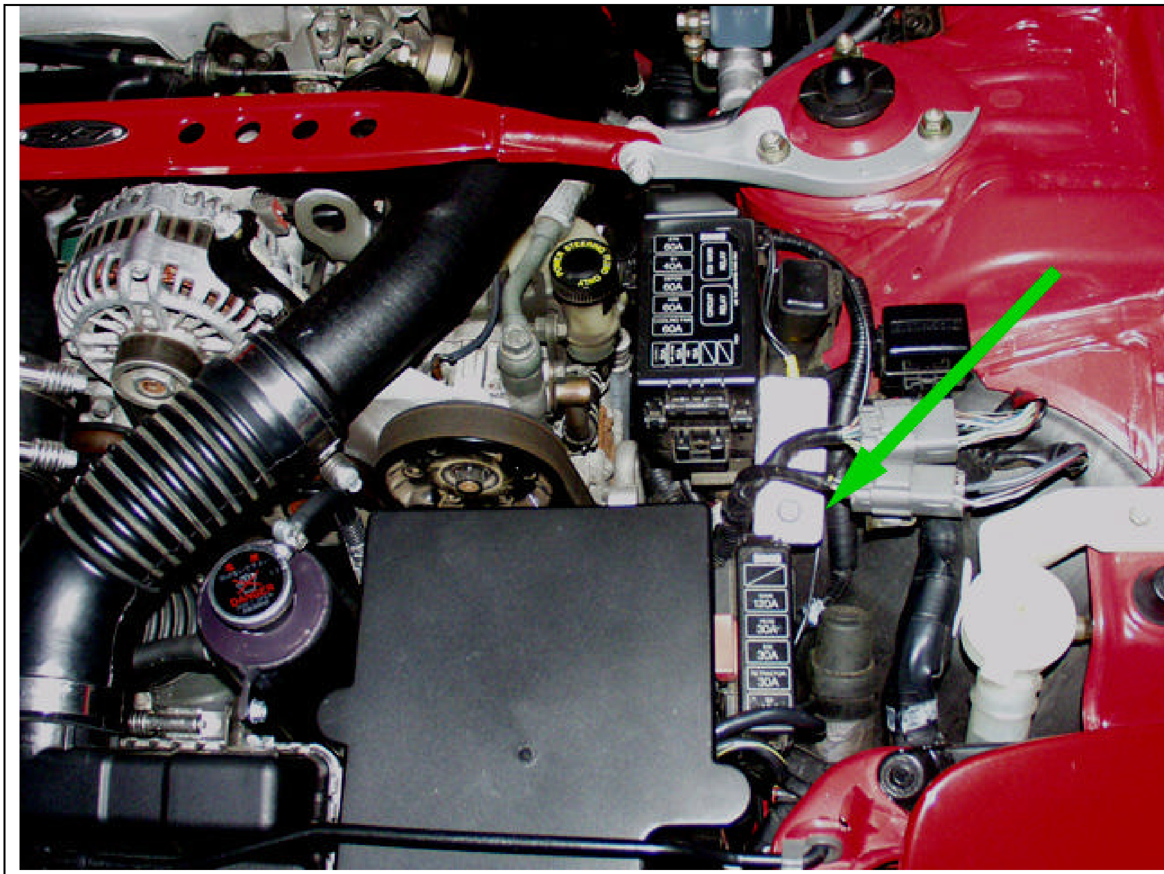


Figure 7. The installed potentiometer case.

Observations

First test - start the car and drive it around for 20 minutes, observe the needle behavior (it should be between low and high normal). Pull into the driveway and let the car idle until the cooling fan comes on (ac off), note the needle location, this is 221 °F (105 °C). At this temperature, the gauge needle should be above the gauge midpoint and below the high normal mark.

If you are running just water and water-wetter, and you calibrated the gauge with a 25Ω resistor, you will find, when driving around town, the gauge is typically in the upper half of the normal range. Consider this a reminder that the boiling temperature of your coolant is 15 °F closer to the normal operating temperature of the engine.

This modification has not been tested in January at International Falls, Minnesota. If your winter weather is similar, keep in mind that the stock gauge was overly optimistic in indicating when the engine was warmed up. You may find that the needle doesn't move much higher than the C mark under very cold conditions.

Why go to all this trouble calibrating the gauge? Why not just specify a fixed resistance value instead of a potentiometer? Unfortunately, not everyone has the same gauge, coolant mixture or radiator cap. There are two types of gauges installed in the third generation RX-7, a "cold region" gauge and a "all other regions" gauge. If your car was not new when you bought it, location is not a good way to tell what type of gauge your car has. To further complicate things, Mazda issued a coolant recall. Part of this recall involved replacing the original 1.3 bar radiator cap with a 0.9 bar radiator cap. While almost all cars have had the recall done, not all dealers replaced the cap. Hence, the need for adjustability.

Just a note, with a 0.9 bar radiator cap and a 50% antifreeze mixture, the coolant boils at approximately 261 °F (127 °C). The hot mark on the standard stock unmodified gauge indicates 266 °F (130 °C). Do the math. Boiling coolant is not good for rotary engine longevity.

What do I do if one day the coolant temperature rises out of the normal range?

If the needle rises above the highest white mark, immediately pull over! Get out and determine if you have a coolant leak. If you have a leak, shut off the engine and call a tow truck. If there is no sign of a leak and the "add coolant" light is not on, leave the car idling, turn the heater on full hot, the heater fan on "1" and turn the AC on. This should kick your radiator fans on high. If the fans don't come on, or your coolant temperature continues to climb, shut off the engine and call a tow truck.

Credits

Derek Vanditmars did all the circuit analysis for this modification. With his analysis and simulation he was able to simplify the gauge modification to just one jumper, making major rework of the circuit board unnecessary.

If you have a technical bent, Figure 8 is a graph of Derek's simulations using a 100Ω parallel resistor and several values for the series potentiometer, it is probably accurate within +/-5 °C. If you have an ohmmeter, instead of making the calibration cable you could use this graph to adjust the series potentiometer for the response you want.

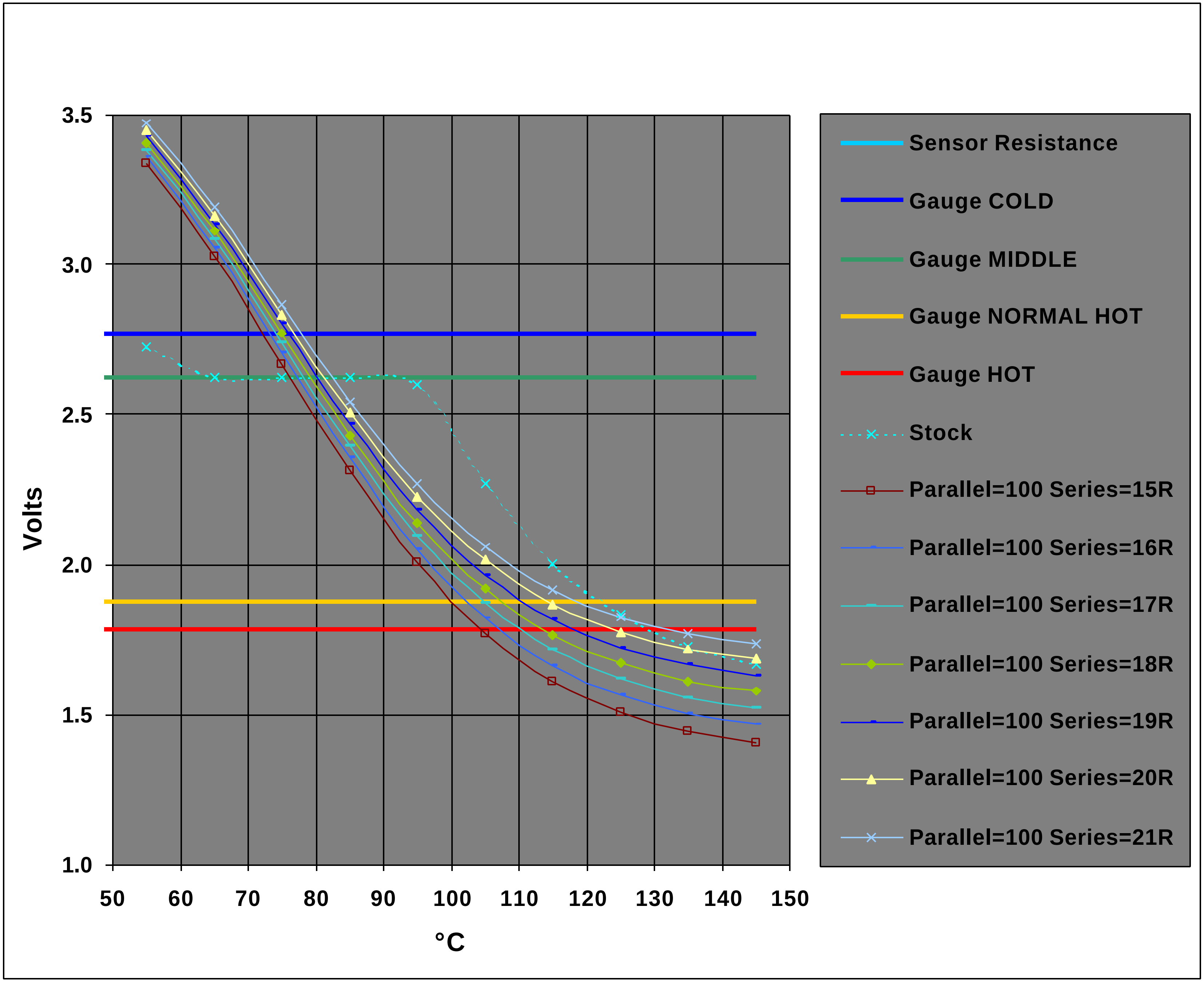


Figure 8. Derek's circuit simulation of the gauge response obtained by varying the resistance of the in-series potentiometer.