Engine Sensor Calibration in Aircraft (and even Autos).

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I've always been surprised at how pilots and maintainers put up with erroneous engine gauges, poor instrumentation, and the lack of knowledge of how to fix both resistive, analogue, and digital sensor readings. I've flown many times knowing the oil pressure was reading 15 PSI low, but at least I knew. This paper will focus on fine tuning the oil pressure and temperature resistive sensors to give more accurate readings, so you don't have to remember "Oh Yea, the oil pressure reads low but I don't remember it that low."

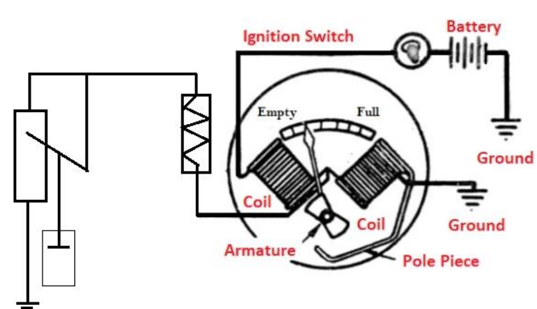
For years aircraft have had resistive sensors and analogue gauges. Take the Rotax engine for instance. Until the 912iS and 915 engines the sensors are normally VDO resistive sensors. In my Rotax troubleshooting guide I give directions on how to test if the gauge works. In the past I simply calibrated the gauge and noted the difference in the reading verses the actual. As a rule, analogue gauges generally read low at the bottom end, high at the top end and are fairly accurate in the center. It is important to size the sensor and gauge as a matched set (i.e. 180 ohm / 10 bar) to the engine limits. That said, your job as a builder/flier/maintainer is to understand the engine limits. However, as a builder/owner/maintainer you must know that the sensor as well as the gauge is reading correctly and it is prudent to correct or adjust the sensor/gauge to be more accurate in your ideal range. Here are some ways to make your gauges read more accurately.

A quick lesson in analogue sensors.

Pressure sensors of the analogue type are based on a diaphragm of some sort that deflects with an increase in pressure. The diaphragm is attached to a variable resistor or pot. The resistance varies with pressure and each sensor manufacturer charts the resistance verses pressure.

How the gauge works is there is a 12-volt fine wire coil and a needle (normally also powered by a coil rather than a magnet armature) which is really nothing more than a voltmeter. The system 12-volt power is connected to the gauge, then is reduced in voltage by the coil windings down to about 4-6 volts with 5 being the ideal and that 5-volt signal goes to the resistive sender. As the resistance changes in the sensor with pressure (or temperature) affects the 5-volt signal which affects the armature voltage, and the needle moves. The actual input voltage (12-14.5 volts normally) and output of the coil winding to the sensor does not make a large difference in the reading of the gauge as the coil and armature are normally windings and move relative to each other rather than the input voltage which is good. I tested my system from 10.5 volts to 14.5 volts and found that the sensor and gauge combination varies by only 2 PSI maximum near the high end. Below is a representative drawing of an electrical pressure gauge:

Typical Resistive Analogue Gauge Operations



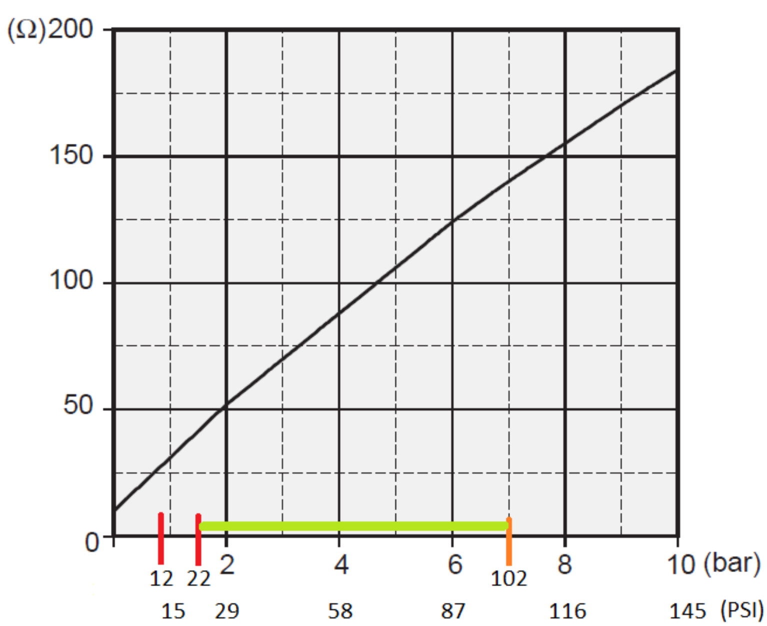
Temperature sensors work similarly to the pressure but using a bimetallic strip where when the temperature increases the resistance decreases. The gauge is simply measuring the voltage difference over the sender and gauge design range. Note that the temperature sender graph is different in that at low temperatures the resistance is high and resistance lowers as the temperature lowers.

The Resistive Pressure Sensor Calibration:

Most of the aircraft engines use resistive sensors for pressure sensing. I will use the Rotax 9xx series engines as an example. Normally these sensors are vented to the atmosphere. Oil pressure sensing limits are set by the engine manufacturer and considers the oil system plumbing, crankcase pressures and altitude concerns but does not take into effect the oil pump intake suction changes due to aircraft manufacturer plumbing of lines and oil coolers. The builder must be cognizant of any changes to his oil return and oil hose runs, thermostats and coolers and their effect on oil pressure. However, nearly all manufacturers give guidelines on oil pump intake hose and cooler resistance limits. These are critical, especially if an owner/maintainer makes changes or additions to the oil system. Any restriction of flow to the oil pump affects the pump pressure output. It is critical to ensure your sensors are calibrated to troubleshoot any change you make to your oil system plumbing or engine.

Let's assume your installation is factory standard, no thermostats, extra long cooling lines, or other restrictive oil intake restrictions and meets the engine manufacturers requirements.

The Rotax 914 UL series engine oil sensor gauge resistance vs pressure indications is shown below:



Note the resistance starts at near zero and goes up to 180 ohms.

I have added the colored ops range for an old 914UL.

12 PSI is min idle
22 is min above 3500 RPM
102 is maximum oil pressure

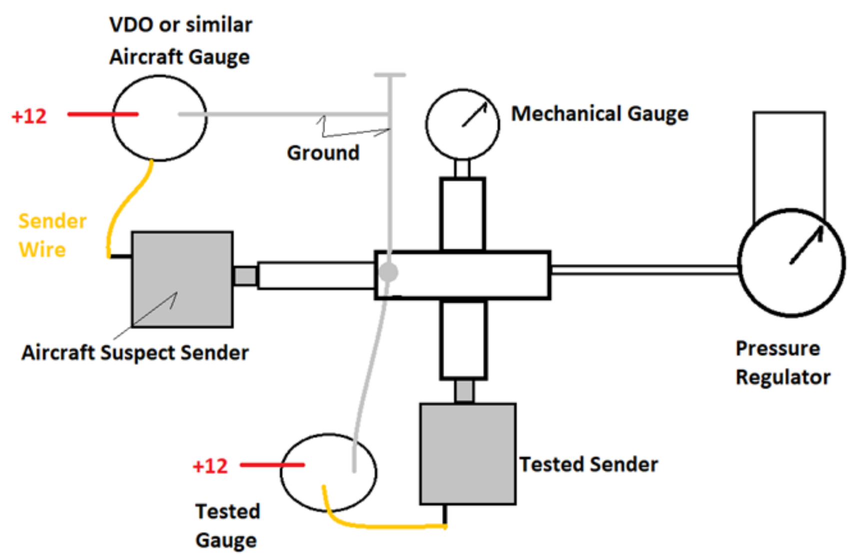
So, the gauge and sensor should be accurate between 12 and 102 PSI more so than only at 5-6 bar or 72-87 PSI in the mid range.

Below is depicted my calibration device I use to check my sensor and gauge. For ease of photography I am showing a shop VDO gauge I use on the bench but normally I use the gauge in the aircraft. Note I use air for the pressure source. It doesn't make any difference to the sender.

I use two mechanical gauges and the sensor to determine the accuracy of my electric pressure gauge when I test. If you are concerned about your sender, you can install a second electric sender to verify the questionable sender, but I find it is not necessary.

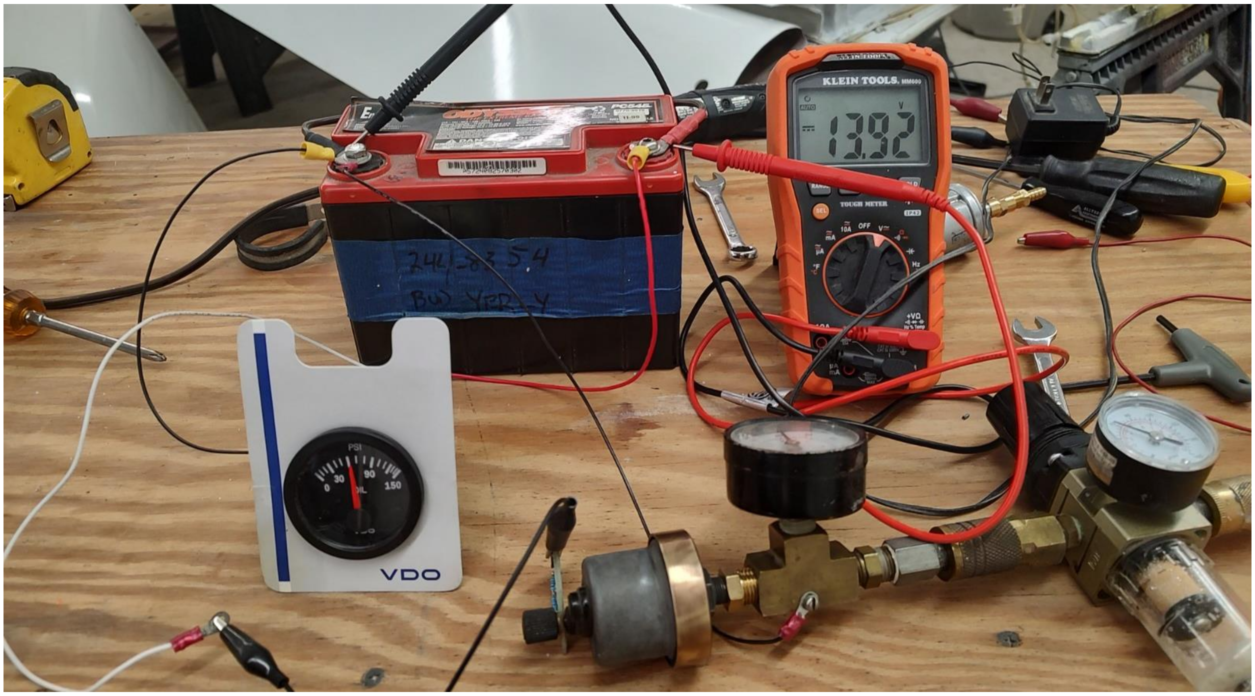
Below is my typical test setup drawing and below that my actual bench tester.

A pressure sender test rig

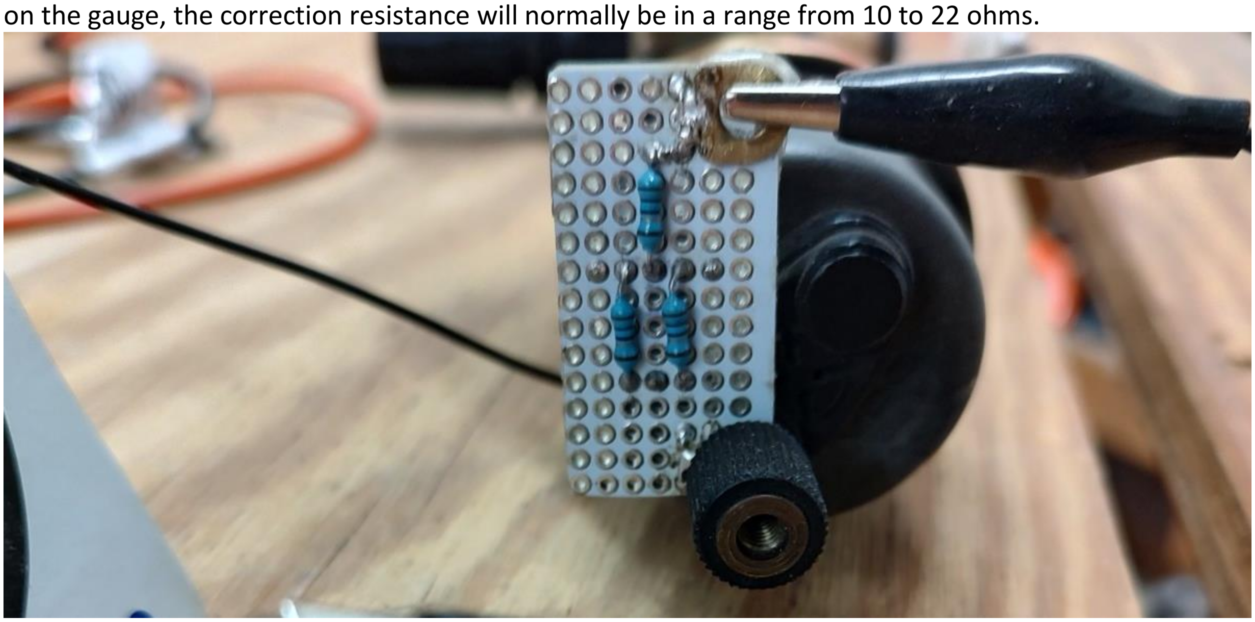


In the photo above one can see the two mechanical gauges are reading 60 PSI, but the gauge is well below that at about 35 PSI. On the aircraft gauge it was the same, so I have to suspect the sender or the wiring. I added a resistor in line between the sender and gauge of 10,15 and 22 ohms to check the effect on increasing the gauge reading. In my particular aircraft I found a 15 ohm resistor was most representative of an accurate reading in the 15 to 75 PSI area I'm most interested in.

In the next photo I have my setup at a higher battery power level and with a 15 ohm resistor.
Now all the sensors read 60 PSI.



The funny looking card attached to the sender is a board I made with 3, 10 ohm resistors (serial and parallel combo) to get exactly the resistance I needed to get the most accurate range. I find depending on the gauge, the correction resistance will normally be in a range from 10 to 22 ohms.



When all you have is a stack of 10 ohm resistors, make a series parallel test rig, it works just as well as a single 15 ohm resistor.

I charted the differences between the various resistances, voltages and pressure readings. The results are below. Note that I show the gauge readings for 12.5 volts and 13.8 volts. I seem to find in the aircraft gauge using the aircraft wiring, I found the readings similar except for the 40 and 60 PSI test points where the aircraft gauge seemed to read nearly the same reading differed if I was raising the pressure or lowering the pressure as with the pressure increasing it read low and right on with the pressure decreasing: Close enough:

12.5 -14.5 Volts

Input Pressure:	0 Ohms	Add 15 Ohm Resistor
Calibrated Pressure Reading	Indicator Reading	Indicator Reading
20	10	20
30	15	30
40	30	38-40
60	40	60-65
75	60	60
90	80	95
100	95	105

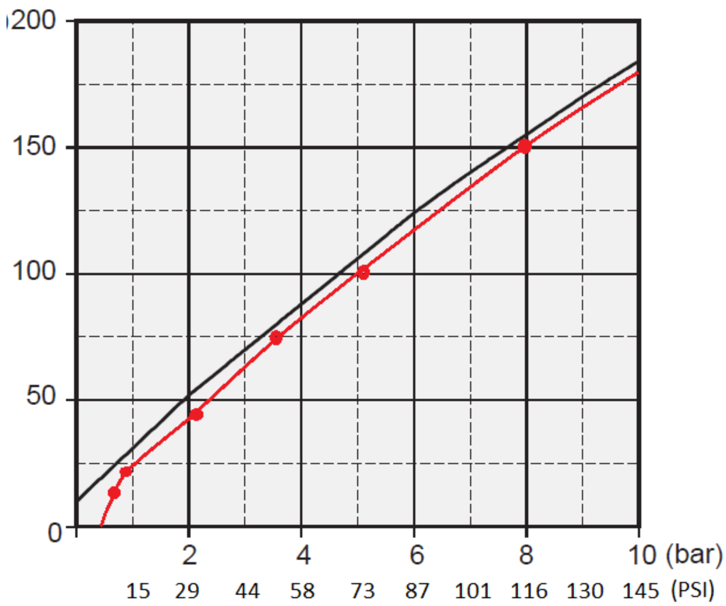
Note:	Min Rotax Oil Pressure PSI:	22
	Normal Rotax Oil Pressure Range PSI:	22-73
	Max Rotax Oil Pressure PSI:	102

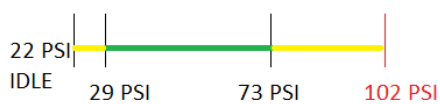
In this particular aircraft case, in the chart above, I will use a 15-ohm resistor as it is sufficiently accurate from 20-60 PSI where the Rotax 9xx series runs the most. Typically, that is 22 PSI at an idle of 1600 hot, and 45-60 PSI at cruise and pattern RPMs of 4-5000 RPM.

Should you check the gauge against known resistive values to check the gauge? Why not!
Normally I don't check the gauge separately but if you want to verify the gauge is OK I use a typical a set of common resistors. In my case I use a 10, 15, 22, 44, 75, 100, and 150 ohm resistors. Then I compare the resistors to the manufacturers chart or graph and gauge reading. The values are double checked, and I found them to be close but not exactly on the money. To test I simply powered up my panel, removed the sensor wire, and installed a jumper to a resistor then to ground. Resistive sensor leads when shorted to ground go to the zero peg and when open go to the max pressure peg.

The VDO gauge in the aircraft showed the following:
15 ohms was 10 PSI, 22 ohms was 12 PSI, 44 ohms was 30 PSI, 75 ohms was 52 PSI, 100 ohms was 75 PSI, and 150 ohms was 115 PSI. I charted it out below:

Note the red line is the particular sensors reading on the aircraft gauge.





Fuel pressure senders can be a real pain as the sensor reads in a range from 0-10 PSI for non boosted carbureted engines and 0- 20 for the Rotax 914. That is too small of a resistance change for a diaphragm and dash pot sensor. One should use an expensive but accurate digital sensor as this type sensor is far more accurate over this small of a pressure range. Consult with your engine information manufacturer for recommendations.

Resistive Temperature Sender Calibration.
VDO or Rotax Temperature Sensor in the oil or cylinder head are interchangeable.

Resistive Oil Temperature, Cylinder Head Temperature or Water Temperature sensors are easy to check, calibrate and adjust. On my Rotax I simply measure the resistance of the probe with the engine cold on my typical Florida day of 80F. Or if in the shop I measure at room temperature of 75 F and compared the ohm reading to the sensor graph as my CHT gauge doesn't come of the peg until 100F. I then start and run the engine and get it up to operating temperature. I use a simple laser pointer industrial temp sensor or calibrated thermocouple sensor and measure the sensor area and compare the gauge to the sensor. If they are within a couple of degrees (5-10 degrees F) I'm Ok with that. If the comparative readings are significantly off, I now must do a calibration. First, I check the gauge, then the sender.

To test the gauge, I will remove the sender wire and ground it to the case and note the gauge pegs high. Then I leave the sensor open (infinite resistance) and note the gauge goes to zero.

The next gauge test is to use a series of resistors, 10, 22, 100, 220 and 470 ohm resistors. These resistors represent approximately 320F, 220F, 180F, 140F, and 100F. We are most interested in 120F for our oil temperature on takeoff and for me 245F on my cylinder temperature because that is where my glycol boils in the head at 1.2 bar. I made a chart for reference below:

Resistive Gauge Calibration Rotax/VDO		
Ohms	Temperature Indication	
Resistance	10-12 Volts Gauge Reading	12-14 Volts Gauge Reading
32	240	265
47	210	225
100	170	180
200	120	140
300	Below the peg	

The Mitchel or VDO gauge normally reads from 120 to 300 for this type resistive sensor. Nominally that is about 300 to to about 22 ohms resistance to cover that range.

What if you don't have a box of resistors? Test the probe with the gauge!

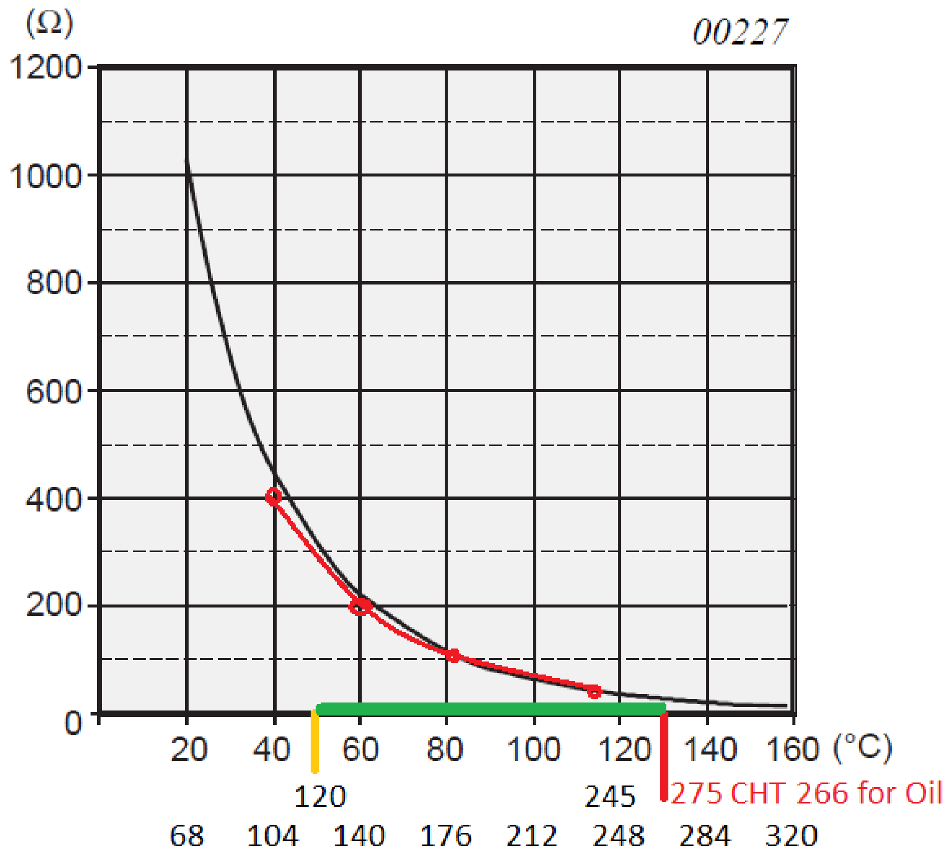
The test equipment is simple: I use a cup of water, a wire testing jumper cable, and my microwave oven. Most Rotax analogue gauges read in the range of about 100 degrees F to 300 degrees. Water boils here at sea level at 212 F so I do the following:

Remove the sensor from the engine and use an alligator clip on my test jumper wire to ground the sensor to the engine, and simply measure the ohms at room temperature and then drop it into the boiling water, allow it to get evenly warmed through, note the reading, and remove the now hot sensor with the jumper attached. That way I measure the resistance as well as checking the gauge in one shot.

As stated, I'm most interested in is my oil temp at the low end and the CHT at the high end. My oil range is 120 F min for full power takeoff considerations to 245 F on the CHT as it is the head temperature for my max boiling point of my coolant. My max oil temperature of 266F is just above max cylinder heat temp of 275F so they are close. If accurate at 212F or 100C on the gauge, it should be close enough for government work for a ground run test. If cooling is an issue, you must now test with other devices to validate your readings. Remember, other hot components such as your exhaust pipes or oil tank affect your resistive sensor. Shield them from high heat components plumbed close to the sensor.

My inflight test of temperatures is done with heat tape. It changes colors with various temperatures. I also use a long thermocouple on a handheld J or K instrument. This is very handy for cowl temps and backup cylinder temps. I can place the tape or thermocouple where needed and feed it into the cockpit. Mostly if I have calibrated my sensors, and the gauges, I trust them. The problem is those pesky nice to have sensors sometimes like water temperature sensors.

The chart below is in my aircraft build manual depicting the Rotax sender chart with the temperatures of note from the manual. I also included in red the observed difference between a known resistor and the indicator temperature. What can I say, the gauge and senders from VDO are pretty accurate considering how basic these sensors and gauges are.



Rotax Oil Temp and Cylinder Temp probes have different threads than a stock VDO sender. Otherwise the probes are identical.

My technique of checking only the room temp and water boiling (100C/212F) point works for me for initial engine runs but if you want to go to 266 or 275 F to test you must use oil instead of water. Warming oil to near 300 degrees is best done in a metal container using a proper heat source. Now you need to purchase a separate temperature reading device also. Some use a meat thermometer; however, I use a pair of electrical test devices to measure temps of the heads and oil. I simply put the thermocouple of the Harbor Freight thermocouple measuring device in the oil and read the gauge. I also have one of those laser pointer thermometers that works in a pinch also. In fact, it is pretty good.

The bottom line is one must have a pair of mechanical or electronic measuring devices known to be accurate to test an analogue gauge and sender. A box of known resistors is handy also.

Most of the time if a resistive sensor is erratic, I find the sensor ground(s) to be a major issue on a resistive temperature sensor. Especially troublesome, is the in-line hose sensors used to measure coolant temperature. They are inaccurate normally due to poor grounding. I personally will use a temperature probe with a grounded mechanical coupling to house the sender that has a ground wire terminal built into it. I ground the metal coupler and use a stock VDO type sender or if necessary, a digital sensor to suit the owner and his engine management system.

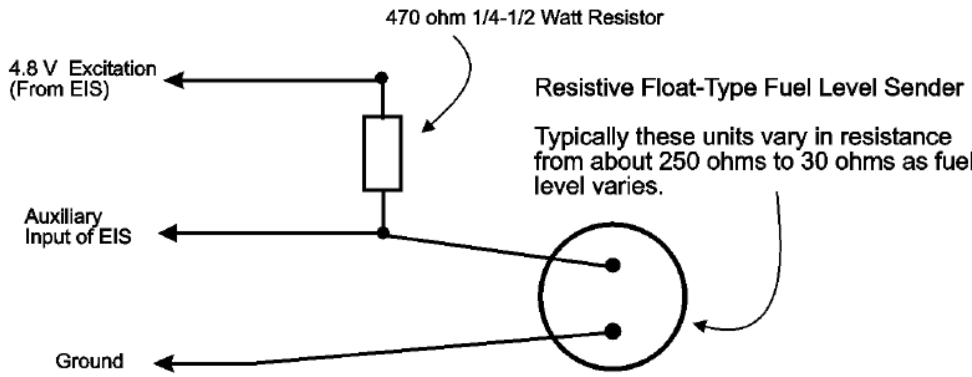
A fancy inline hose temperature device is shown below.

Various types of temperature and pressure sensors:
Many have used a digital sensor which is a three-wire pressure transducer in an attempt to gain more reliability and accuracy. These are solid state devices that vary the resistance with pressure and the measurement is by a strain gauge on a pressure diaphragm. These solid-state senders normally require aircraft power, ground, and then send a sensor voltage to the EIS or other display system of about 5 volts. Digital senders are more accurate but may not be necessarily plug and play. This type of pressure sender should be calibrated or at least checked. It is not uncommon for Engine Management manufacturers such as GRT/Dynon or other engine monitor system manufacturers to suggest or supply an alternate or compatible digital sender with their installation package because they have had accuracy issues with resistive sensors. These digital senders must be checked, and the display unit offset, or slope adjusted slightly for proper calibration. It is not uncommon to see a resistor connected to drain off voltage to match the output of the sensor to the digital measurement circuit or the installation setup has multiple programming sensor inputs or settings to compensate for the sender and its display. Always check the installation and setup manuals for proper setup for your gauge and sender.

For example:
Grand Rapids has a 4.8 volt regulated output for resistive sensors. Calibration of these resistive sensors is necessary to meet the GRT Model 4000 EIS. Only a slight adjustment to the offset and slope is normally required to get a spot-on reading. The GRT EIS normally uses a ring terminal thermocouple for CHT readings. Thermocouples can also be calibrated and adjusted within the EIS. I'll discuss thermocouples later in this paper.

Many of us have used resistive senders for fuel level or other readings and there are instructions on how to adjust these sender readings to be a bit more accurate. A fuel sender adjustment used in the RV aircraft is shown below from the GRT EIS manual. Note the need for a 470 ohm pull up resistor to improve the display accuracy on the GRT EIS. Still, a handful of resistors may be necessary to "adjust" the output value to compensate for ground plane or wiring distance issues to get an accurate reading.

The picture below is how the GRT EIS manual displays the installation of a resistive fuel sensor:



The following steps may be used to calibrate the aux display so that it displays fuel level in gallons, or any desired units.

Always consult with your gauge or electronic information system manufacturer for the proper method to correct analogue resistive sensors to their particular digital input.

Thermocouple CHT Sender Checking.
Thermocouple type sensors such as the Grand Rapids Technologies EIS supplied J type ring terminal senders <u>cannot be assumed to be accurate and without issues</u>. Many J and K thermocouples crimped to a ring terminal or probe are often over crimped, bent on installation or broken from continuous handling (like those Jabiru J type spark plug thermocouple rings) and can and will become erratic or just plain fail due to mishandling, vibration and or heat. Personally, I find the CHT thermocouple ring terminal to be easy to check. First visually check the device. If it has a worn spot or other damage, replace it. If visually OK, I drop it into a boiling cup of water and check it for accuracy. If it is fairly accurate, I reinstall it. If not check the J or K sensor voltage over its range from at least room temperature to boiling point to see if it is the sender or the gauge reading.

Checking a thermocouple gauge is more difficult. A calibrated and seriously accurate voltage source is necessary in my opinion to check the gauge output reading. If I suspect the J or K type thermocouple sender is the problem, I replace it first. Armed with a new sensor, if the gauge does not read properly and the extension wires are secure and resistance free, it's the gauge or EIS. If the gauge or engine instrument sensor is a solid-state device, test it out and then contact the manufacturer if you still have an issue.

Caution:
CHT and EGT senders are easily damaged, and most J and K thermocouple wires have nylon insulation covered wires that hopefully are covered with a heat shrink or braided covering to protect the thermocouple wire from chafing. Any hard bend or twist in one of these thermocouple wire pairs can cause a short and give a poor reading or none at all. If a thermocouple is intermittent or inaccurate, replace it.

Note:
Always complete any bench gauge tests with ground engine runs and flight test follow ups, even if successfully completing a bench test.

EGT sensors for the Rotax and most other engines are of the K type.
Most Rotax EGT senders are a bayonet K type using the 10 mm threaded bung welded to the pipe as on the 914 or a clamp with a plug/bung installed through the drilled exhaust pipe which is more common on the 912 series and other engines.

Westach makes many of these sensors. *From Wikipedia, (if it's on the internet it has to be true.) A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature.*

Because of the nature of the thermocouple wires available to manufacturers, the insulation on these wires is still a cheap nylon braid insulator that chafes and unravels quickly. Use caution handling the wires. Inspect the wire and covering carefully if it is exposed. Although the two wires are insulated with nylon braid and covered with a metal, phenolic, or plastic covering, the chances are good that the wires will eventually wear through the nylon insulation, or the insulation may become unraveled, which will short the wires between each other or to other engine components or the metal braided exterior sheath causing erroneous readings or none at all. Always handle the thermocouple wires with care and make sure the exposed wire at crimps is insulated and heat shrinked. Do not excessively bend these wires on installation, as you will most likely crimp and short the wires. Make nice smooth wire bends and secure the thermocouple wires from chafing. Do not allow a CHT/EGT thermocouple wire to rest on another hot component or it will be inaccurate. Anytime you move or wrap up a thermocouple wire, you can damage it.

As for the connections, most manufacturers require the same chromel/alumel wire be used all the way to the gauge. OK, I don't do that, but I am careful to ensure the wire type and connections are consistent, and I measure the wires resistance to ensure it is exactly the same from the coupler to the gauge to assure as accurate a voltage gets to the gauge as possible.

Personal note:
When Alcor equipped the first aircraft EGT they did not indicate a specific temperature. They knew the probes were difficult to measure and prone to drifting so their early gauges did not have numbers for the temperature. The pilot leaned to peak, then simply richened a mark or two for best mixture. I believe EGTs are still only trend instruments. If they change over time, suspect the engine, but check the senders first always. With two carbs, it is prudent to have a left and right EGT sensors should one of the carbs misbehave. If there is a difference in EGT readings and the engine is rough running or the plugs are not uniform, the pilot/maintainer may be able to use the EGT to determine if a carb is flooding or an air leak situation occurred in one or both carburetors or its induction system.

Warning.
Don't hook any old ohm or volt meter to an EGT gauge that uses a thermocouple without consulting the manufacturers guidance. There is a chance an old analogue ohm meter may damage the gauge due to too high of a voltage. However, todays digital Volt Ohm meters are quite good and safe to use.

It is essential to use a quality digital volt ohm meter in testing EGT probes. The typical Nickel Chrome type wire thermocouples will read about 31 mv (millivolts) at 1400 degrees F or 760C and 1.0 mv at 15C/59 F. That's a small voltage. Note the EGT instrument/gauge will only be labeled over part of that range and typically indicate from the 700F to 1700F range so very high temperatures are needed to check the sender and gauge.

Test Example: Cylinder 4 reads 1700F and cylinder 3 reads 1400F on your 4-cylinder engine. Is a carb lean, the manifold leaking or is the probe bad?

Test 1: Is the engine balanced and running smooth? Look at the plugs. If they are a nice tan and the #3 and 4 plugs look the same as the 1 and 2, it time to test the EGT probes. Normally, I buy two probes and simply remove and replace as it is from a maintenance point, cost effective for me and the client if it is the probe. However, if cost is your concern and you have the equipment and time to troubleshoot, you will gain confidence in your EGT readings through testing. I do the following:

First swap the probes at the wire connections and go fly or run up to full power. If the temp indications are swapped on the indicator, one of the probes is clearly bad on the high end for sure. If the temps are still high on the one cylinder, check the carb and manifold per the maintenance manual. After the mechanical corrections are complete, retest. Normally if the indications are that one probe is reading high or low, I jump to Test 4. If not go to the next test.

Test 2: If the initial swap of the connections did not indicate a significant difference, drag out the volt ohm meter. Measure the millivolts of each probe at room temp. If they are the same, one of two things may have occurred, you have uneven resistance in the wiring of the probes to the gauge or a calibration issue with the probe(s) or possibly a grounded probe or smashed wires.

First check the probe internal resistance. Due to the unchanging nature of thermocouple characteristics, all that should ever be needed to check thermocouple probes, is a simple go/no go test: With the thermocouple disconnected from the gauge, connect an ohmmeter to the output pins of the thermocouple (the probe does not need to be heated for this test). The ohmmeter should be set to its lowest resistance range. The ohmmeter should read about 2.5 ohms but may be as low as 0.6 to 1.6 ohms for a good EGT probe on the average. If the ohmmeter shows an open circuit (infinite resistance), or one or the other wire to the braid or probe is clearly grounded, discard the bad probe and replace it.

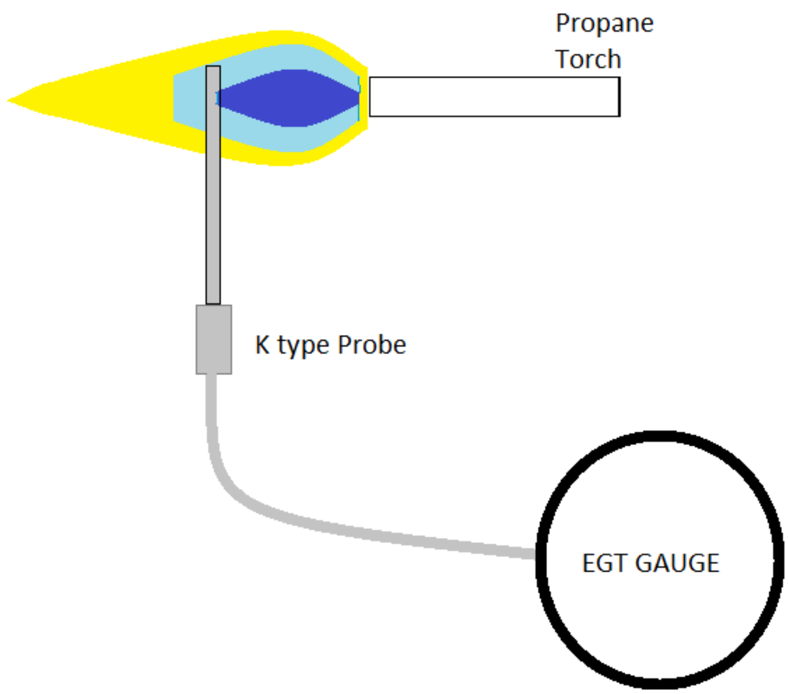
If the probe wires are secure and the ohm readouts were about what your manufacturer says it should read, go into the panel and disconnect the two sender <u>wires at the gauge</u> and measure the resistance in the wire connector from the probe to the instrument. Even a few ohms here can make a difference as the output of the thermocouple probe is so anemic. Zero resistance is desired. If using a switch and a single gauge, one of the switch joints/contacts could have a bad solder joint, crimp or corrosion and one should test the wires from their extension connections but <u>disconnected from the gauge. Check the resistance from the probe all the way to the sender connections.</u> They should be very close to zero. Clean the contacts and reconnect both senders if they are good. Swap the EGT probes with one another and check the millivolts at the wires end at the gauge to see if they both are reading the same millivolt at the wires going to the gauge, if they are, it is most likely a high-end reading probe issue.

Test 3: Hook up the wires to the gauge again and test at the plane. Remove the probes from the exhaust pipes. <u>Do not be alarmed if upon removal of the probes you break one or both of them, buy another or two.</u> An old probe which has gone through many heat cycles will become brittle, corroded, carboned up and may be destroyed upon removal. Be prepared to purchase two new probes.

Note:

To test the probes, a small propane torch, burning in air, with no added air pressure (flame only) when burning a clean blue flame, the tip of the blue end of the flame is about 1500F depending on the torch. Armed with that vague knowledge, we can test the probe and gauge together. Heat one probe, then the other, or both at the same time if you have a secure holder or a lot of hands that are heat protected and

Testing an EGT Probe Check With A Torch.



test the probes together. If each probe, when heated at the same spot on the flame, reads the same, it is a carb problem, but most likely the probes are off, especially if the carbs are balanced and the plugs are good.

Because K type thermocouples are so consistent, charts are available to compare temperature to voltage.

In testing, volt / ohm meters must be accurate. I've never scrimped on tools. I have great confidence in my Fluke volt / ohm meter and tester. I use my tester and measure the voltage, which is in micro volts, to initially check my thermocouples. I also have a thermocouple temperature test device which is a Harbor Freight unit, but it has proven to be quite accurate, but a bit tedious to use. Below is a typical chart for a K type thermocouple:

Type K thermocouple chart

K Reference terminal temperature: 0℃, 10 degrees μv value

Ambient Temp

Probe Temp ℃	0	10	20	30
0	0	397	798	1203
100C/212 F	4095	4508	4919	5327
200C/392F	8137	8537	8938	9341
300/572F	12207	12623	13039	13456
400C/752F	16395	16818	17241	17664
500C/932F	20640	21066	21493	21919
600C/1112F	24902	25327	25751	26176
700C/1292F	29128	29547	29965	30383
800C/1472F	33277	33686	34095	34502
900C/1652F	37325	37724	38122	38519
1000C/1832F	41269	41657	42045	42432

As I stated before, I simply heat the EGT probe carefully holding the probe in a safe manner clear of the aircraft engine but still connected to the aircraft with the wires played out far enough to work safely and check the aircraft EGT gauge reading with the thermocouple immersed in the flame of the torch. If I have little confidence in the gauge reading, I then disconnect the probe from the indicator plug and heat and measure the probe output voltage directly and check against the chart. If the voltage and my temperature differ, I prefer to replace the probe.

Test 4 is the normal quicky check: If one probe is suspect but you don't know which one, buy another probe from the same manufacturer. Remove the probes to the bench and simply secure in a padded vice or holder and heat the probe with a butane/propane torch and measure the proper millivolt output. If you suspect a probe is bad, you now have three to test against. If the millivolts are different, install the two most closely matched probes back into the plane. It is always a good idea to always check the wiring when faced with EGT problems, so going back to Test 2 may be prudent, even though it is more time consuming. That said, when in the field and impatiently working to get airborne, one can simply replace the high/low reading probe after a close carb inspection. If the new probe works out, press on. If the probes are still significantly different, go back to step 2 and check everything. Consider rebuilding the carbs, check the intake manifolds for leaks and the rubber manifold to carb rubber isolation mount for cracks per the Rotax manual if even the plugs are not burning even.

The "rule of threes" is if you need to test one thing you need a matched set of mechanical and another electric sensor and or gauges to determine which one is correct as well as a measuring device. A word of advice is just purchase another probe or two and test.

The fastest of the test methods is the most expensive!
In practice, I buy at least two probes at a time as it is faster and much less testing. It is more costly as probes aren't cheap, but neither is my time in the shop, or your time stuck on the ground. I bench check the new probes milli or micro volt output before install as I have seen many defective probes over the years. I even fire up my mini torch to test the voltage output. If the probes are reading nearly the same at room temperature, I connect the probes to the aircraft gauge or my Volt Ohm Meter then heat them with the torch and check the indications. If they are within 100 degrees, I install the probes and note the difference. I find that old probes are just that, old probes and prone to corrosion, wire damage and heat stress. I believe it is a time saver to just pull the two probes and replace them both.

I also find that when using an EGT switch to select each probe, there are small differences in resistance in the extension wire and switch. Note the difference and swap probes to get them to nearly equal readings. Always recheck the resistance from the probe wire connection to the unit upon installation of a probe if there is still a difference in the EGT readings. If the probes read within 100F I am a happy guy. Note the difference in the logbook and go fly, thus saving time and hours of troubleshooting.

In conclusion, it is tedious and boring test work to be sure, but if you want readings you trust, you must test and calibrate properly. I now test all my sensors on installation and at my 5 year hose change or phase on the engine. After all, sensors do go bad over time as heat and vibration takes its toll on them. It is simple and easy to do the quicky checks I've outlined for both analogue and digital engine instrumentation. Run the engine, use your laser or thermocouple test gauge for the oil temp and CHT, then after shutdown and the engine temps stabilize compare again. Unscrew the oil pressure sensor and pressure test it right at the engine hooked to an air hose and compare the pressure to your gauge reading. After maintenance, run the engine and look at the EGTs and compare again. If the EGTs are even, don't mess with it as they are trend instruments in my opinion. At least you checked the indicators work and are confident of the readings.

Don't be lazy and just ASS-U-ME you will remember the oil pressure is off 25 PSI or the CHT is off when the engine has a hiccup. Fix it now that you know how. It only takes a couple resistors, some plumbing, an air compressor or tank with a regulator and a few minutes to chart out the oil pressure differences and perhaps a cup of hot water for a thermocouple CHT check. Buy a hand held thermometer also speeds things along. A nice warm shop out of the elements and a coffee pot helps also.