Section 6 O2 Trim

Introduction and Principle of Operation 6-1

The LMV52 features an integrated O2 trim functionality that enables the LMV52 to monitor the percentage of O2 in the stack and adjust the positions of actuators when the burner is in operation (Phase 60). When the system is trimming, the LMV52 will move the actuators that are designated as "air influencing" independently of the fuel actuator(s) in an effort to achieve an optimal percentage of O2 in the stack. Typically, only the air actuator is set to be air influencing, but the VSD (if equipped) and other actuators (Aux 1,2,3) can also be set to air influencing if the dampers that the other actuators are connected to are also to be adjusted in accordance with the percentage of O2 in the stack.

As the name implies, the O2 trim functions to regulate the amount of oxygen and therefore the amount of air entering the combustion process. Since this is the case, the LMV52 O2 trim system does not and cannot affect the position of the fuel actuator for a given load. In other words, if the LMV52 senses an O2 level in the stack that is above setpoint, it will react by slowly closing the actuators that are set to air influencing until the O2 in the stack is at the desired setpoint. The LMV52 will not open the fuel actuator to reduce the O2 level in the stack. Also, the LMV52 will not open any of the air influenced actuators further than they were open on the original Fuel-Air ratio curve to achieve an O2 setpoint.

When setting up the O2 trim curves, a total of three curves are set having to do with the measured percentage of O2 in the stack. The three curves (in order lean to rich) are:

1) **O2 Ratio Control (Fuel Lean Curve)** – This is the percentage of O2 read at the stack sensor when the actuators are at the positions that were defined on the original Fuel-Air Ratio Curves. In other words, this is the measured O2 corresponding to each point set in Section 4-1, Figure 4-1.11.

2) **O2 Control (Trim to Curve)** – This is the O2 setpoint that the LMV52 will try to achieve by backing actuators designated as air influencing down their respective curves.

   This may also be referred to as the "O2 setpoint" curve.

3) **O2 Monitor (Fuel Rich Curve)** – This curve serves as a lower limit or an alarm curve. If the measured O2 drops below this value at a certain point, the LMV52 will either deactivate the O2 trim and operate on the normal combustion curves, or it will lockout depending on what the LMV52 is set to do.

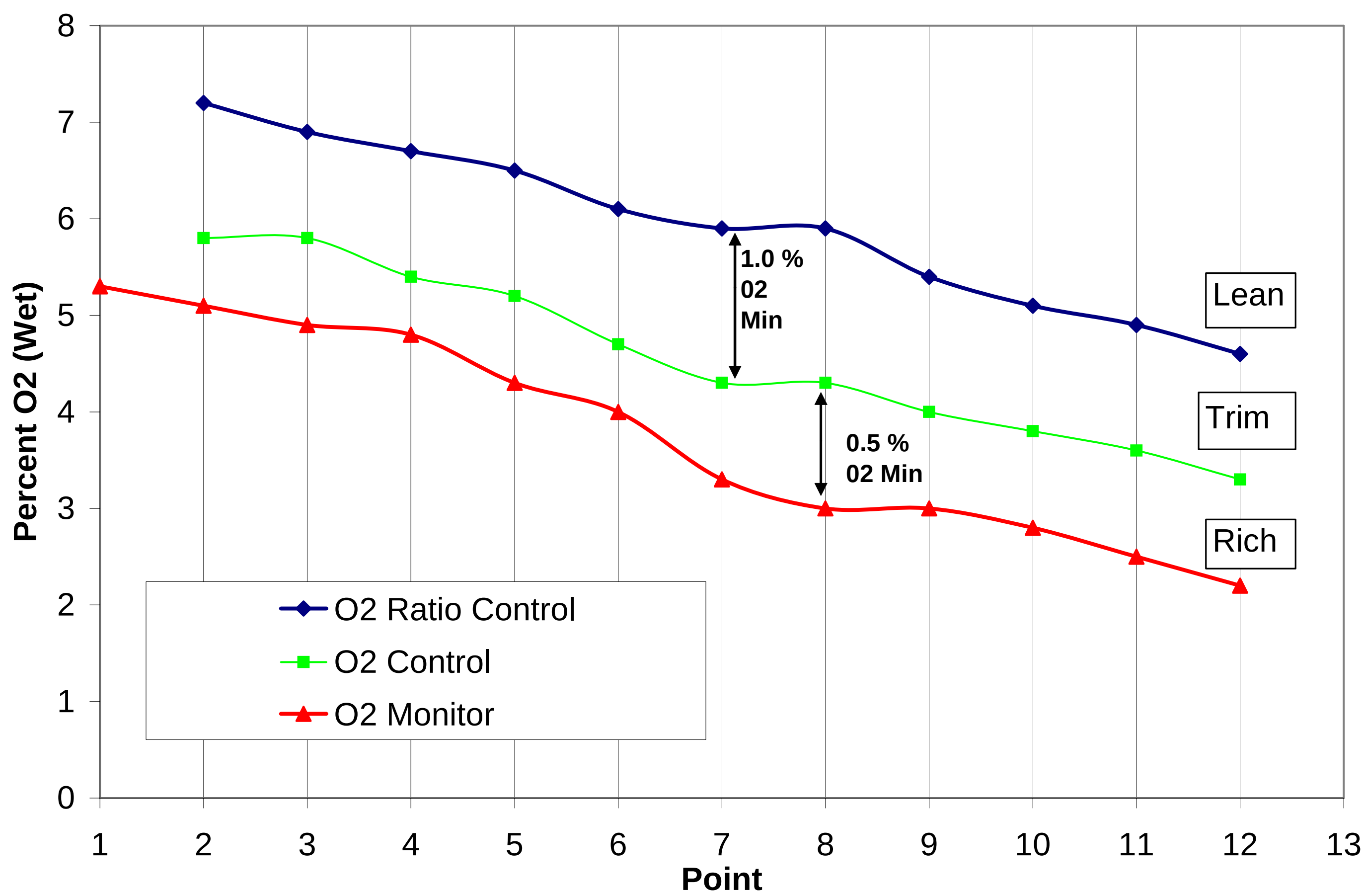
   This may also be referred to as the "O2 Guard" curve.

Figure 6-1.1 illustrates how these O2 curves might look after they have been set. Notice that for each of the three curves, a certain percentage of O2 is set and actuator positions (in degrees) or VSD % are not *directly* set during the O2 trim commissioning. The actuator positions in degrees or VSD% were directly set when the Fuel-Air ratio curves were commissioned. See section 4-1 for details on that procedure.

Figure 6-1.1 also shows that the O2 curves must be set at every point that was defined when the Fuel-Air Ratio Curves were set. For example : If 12 points were entered during the Fuel-Air Ratio Curve commissioning, then it will be necessary to enter 12 points for the O2 Monitor, 11 points for the O2 control and 11 points for the O2 Ratio Control. The LMV52 does not trim on Point 1, and this is the reason that the O2 Control and O2 Monitor curves cannot be set on Point1.

Figure 6-1.1 Fuel-Air Ratio Curve, O2 Ratio Control, O2 Control, and O2 Monitor Curves

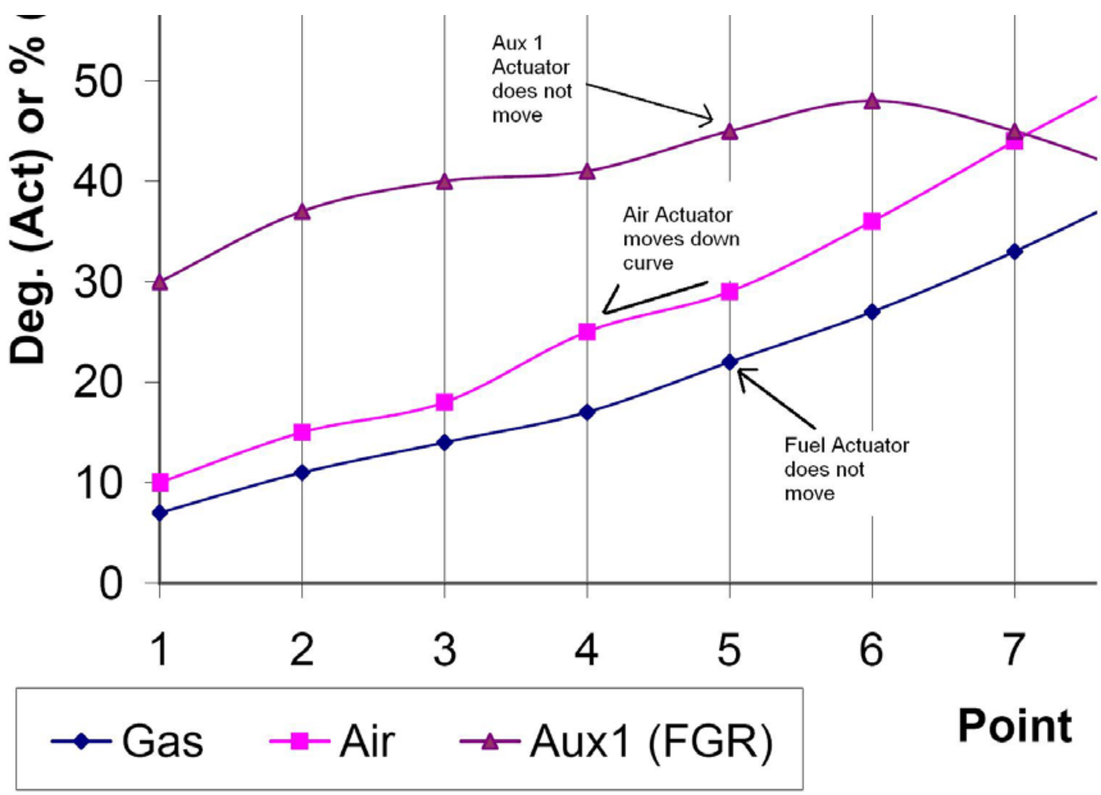
16 MM Btu/hr Gas Burner, 10 to 1 Turndown, FGR, Gas 1000 BTU /SCFH								
Set During Fuel-Air Ratio Curve Commissioning						**Set During O2 Trim Commissioning**		
Point	Gas SCFH	Load %	Gas Deg	Air Deg	Aux1 Deg	% O2 Ratio Control (wet)	% O2 Control (wet)	% O2 Monitor (wet)
1	1600	10	7	10	30	**Cannot trim on Point 1**		5.3
2	2909	18	11	15	37	7.2	5.8	5.1
3	4218	26	14	18	40	6.9	5.8	4.9
4	5527	35	17	25	41	6.7	5.4	4.8
5	6836	43	22	29	45	6.5	5.2	4.3
6	8145	51	27	36	48	6.1	4.7	4
7	9455	59	33	44	45	5.9	4.3	3.3
8	10764	67	40	52	40	5.9	4.3	3
9	12073	75	48	63	35	5.4	4	3
10	13382	84	56	72	31	5.1	3.8	2.8
11	14691	92	65	79	27	4.9	3.6	2.5
12	16000	100	73	85	20	4.6	3.3	2.2



Two additional requirements of the O2 trim are that there is at least a 0.5% O2 gap between the O2 Monitor curve and the O2 Control curve, and that there is at least a 1.0% O2 gap between the O2 Control Curve and the O2 Ratio Control curve. The LMV52 will not allow the O2 curve points to be entered if they do not meet these minimum gap requirements. These requirements should be kept in mind when commissioning the Fuel-Air Ratio Curve since the Fuel-Air Ratio Curve will usually have to be set at least 1.0 % O2 leaner than on a non-O2 trim system.

As was briefly mentioned earlier, the O2 trim is only able to move the actuators that are designated as air influenced back on their individual curves. Figure 6-1.2 illustrates this action by detailing a small piece of the same Fuel-Air Ratio curves that were shown back in Figure 4-1.11. For this example the air actuator is the only actuator designated as air-influenced and the Fuel and Aux1 actuators are at Point 5. In Figure 6-1.2 the O2 trim is responding to a measured O2 value that is higher than the O2 Control curve at Point 5. Thus, the LMV52 is moving the air actuator back down its curve to lower the %O2 that is being sensed in the stack.

Figure 6-1.2 Actuator movement in response to high measured O2 values



It should also be noted that the LMV52 cannot open any air influenced actuator farther than the point the fuel actuator is at. For Example : If the LMV52 was held at Point 5 (or 43 percent load in this example, see 6-1.1) the air actuator could never open up beyond its Fuel-Air Ratio Curve position at Point 5 of 29 degrees, even if the %O2 measured in the stack was below the O2 Control curve at Point 5. If the %O2 in the stack went lower than the O2 Monitor curve, then the O2 trim would deactivate and / or cause a lockout, depending on how parameter OptgMode is set. If this parameter is set to conAutoDeact, the LMV52 will only deactivate the O2 trim, and will continue to function. If the O2 trim automatically deactivates, the actuators will operate on the Fuel-Air Ratio curves that were defined during the Fuel-Air Ratio Control commissioning.

Step by Step Commissioning of the O2 Trim System 6-2

After verifying that the PLL52 Module, QGO20 Oxygen sensor, and ambient / stack temperature sensors (if used) are wired correctly, and that lean-tuned Fuel-Air Ratio Curves have been entered across the firing range, the O2 trim system can be commissioned and activated.

The following steps will serve as a guide for the commissioning process:

Note: A combustion analyzer is necessary for this procedure.
It is required to measure CO when setting the O2 Guard curve.
Most combustion analyzers read dry %O2, whereas the QGO20 Sensor reads wet O2.
The dry value will always be a higher % than the wet value.

Always use the %O2 displayed on the AZL52 for setting up the O2 trim.

1) With the LMV5 in standby (Phase 12) Verify that lean-tuned Fuel-Air Ratio Control curves have been set across the firing range for the fuel that will be trimmed.

   Both gas and oil can be O2 trimmed, or one and not the other. Typically, gas is trimmed and oil is monitored since oil is usually the back-up fuel. For either fuel, verify that the Fuel-Air Ratio curve has at least 10 points equally distributed across the firing range.

2) Set the relevant Parameters. This should also be done in standby.
   Explanations of all the parameters for the O2 trim can be found in Section 4-2.

   a. Under *Parameters & Display* > *O2 Module*, set O2 sensor to QGO20

   b. Under *Parameters & Display* > *O2 Module*, set the supply air temperature sensor and the flue gas temperature sensor to the type of sensor that is being used, if any. These sensors are not necessary for the O2 trim operation but are necessary for the efficiency calculation.

   c. Under *Parameters & Display* > *Ratio Control*, set which actuators or VSD are to be *air influenced*. Typically, this is only the Air Actuator. These parameters have to be set for both fuels if O2 trim is to be used for both fuels.

   d. Under *Parameters & Display* > *O2 Contr/Guard* > *Gas/Oil Settings*, set *OptgMode* to *man deact*.

   e. If the O2 trim is being commissioned on gas, under *Parameters & Display* > *O2 Contr/Guard* > *Gas/Oil Settings* >*Type ofAirChange* set to *Like P air*.
   For Oil, set *Type ofAirChange* to *like theory*.

   f. If the O2 trim is being commissioned on gas, under *Parameters & Display* > *O2 Contr/Guard* > *Gas/Oil Settings* > *Type of Fuel* is set to *naturalGasH* (above 960 Btu / Scfh) or *naturalGasL* below 960 Btu / Scfh).
   For light oil, *Type of Fuel* , *Oil EL* should be selected.

   g. Under *Parameters & Display* > *O2 Contr/Guard* > *Gas/Oil Settings* set *O2 CtrlThreshold* to the load value (%) of Point 2 or higher if desired.

   h. Other parameters that may need to be changed before or during commissioning are listed and explained in Section 4-2 under *O2 ContrGuard*.

Step by Step Commissioning of the O2 Trim System 6-2 continued…

3) Allow time for the QGO20 to heat up to temperature. For the initial heat-up of the O2 sensor, the sensor should heat-soak for about 2 hours.
   This ensures the most accurate O2 readings during commissioning.

   The O2 sensor will heat the entire time the LMV52 and PLL52 are powered, and under *O2 Module > Configuration > O2 Sensor* is set to *QGO20*.

   The temperature of the QGO20 as well as other PLL52 related values can be read under *O2 Module > Displayed Values*.

   The QGO20 should heat up to a minimum of 1290 ^{o}F.

   The O2 sensor will no longer read O2 values if sensor temperature drops below about 1202 ^{o}F.

4) Turn the burner on. Verify that the O2 sensor is reading 20.9% O2 (+/- 0.6%) by the end of pre-purge. If not, extend the prepurge time.

   The burner should light off and proceed to Phase 60, which is normal operation.

   After this is done,
   the O2 Monitor, O2 Ratio Control, and O2 Control Curves must be set.

Note : There should be at least 10 points in the Fuel-Air Ratio Control curves from low to high fire, and these should be tuned at least 1.0% O2 leaner than normal.

If this is not done, please redo the Fuel-Air Ratio control curves before attempting to set up the O2 curves.

Set the O2 Monitor curve

5) This is found under:
Parameters & Display > O2 Contr/Guard > Gas/Oil Settings > O2 Monitor.

   This value must be set at every point that was defined in the Fuel-Air Ratio control curves from low to high fire.

   There are two methods for setting this curve.

   a. If the minimum safe O2 values are known across the firing rate, then values for this curve can be input directly as a %O2.

      When this is done, the LMV52 'will not' actually drive the actuators to the point in question.

   b. If the minimum safe O2 values are not known, the burner can be driven to the point in question by displaying the point, pressing enter,
      and then scrolling down to ***P air man***.

      When the *P air man* value is increased, the air influenced actuators will be slowly driven back down their curves (closed) and the minimum safe %O2 value can be effectively "probed". Increasing the *P Air Man* value will start closing the air influenced actuators and should decrease the O2 measured in the stack.

      At some point, smoke or a dramatic spike in the CO production will occur as the air influenced actuators are closed. When this is found, the value of *P Air Man* should be reduced slightly (opening the actuators, more air) until a somewhat rich but safe combustion is achieved.

      After this, *enter* can then be pressed moving the cursor to the left of *P Air Man* and saving the point.

      Next, press *escape* to exit the point.

      After this, arrow over to the next point, or press *escape* once more
      to exit *O2 Monitor* altogether.

Note : Point 1 on the O2 Monitor curve must be entered using method a.
A safe % O2 can be found (probed) at point 2, and then entered in for Point 1 using method a.

6) Repeat this process using Method a or b for every point that was defined in the Fuel-Air Ratio control curves. A curve resembling the O2 Monitor curve shown in Figure 6-1.1 should result.

   The O2 Monitor curve is now complete.

Set the O2 Ratio Control and the O2 Control Curves

7) These are both found under:
Parameters & Display > O2 Contr/Guard > Gas/Oil Settings > O2 Control.

First, the **O2 Ratio Control** needs to be set for point 2. Under parameter *O2 control*, Point 2 should appear, since it is not possible to trim on Point 1.

8) Press the *enter* key while Point 2 is displayed, and the LMV52 will drive the actuators / VSD to Point 2 on the Fuel-Air Ratio Curve. The AZL5 will then prompt the operator to press *enter* again when the displayed % O2 value has stabilized.

Note: This stabilization will be slower at low fire (average of 15-30 seconds after the actuators / VSD have driven to the point) and faster at high fire.

If the *enter* key is pressed prematurely, the recorded %O2 will NOT accurately represent the %O2 for the point on the O2 ratio control point. If this happens, delay time will NOT be measured accurately in a later step and this will cause faults during operation.

9) Once the *enter* key is pressed, the % O2 shown on the AZL5 is locked in to be the % O2 for the O2 ratio control point (actuators / VSD are at their Fuel-Air Ratio Control positions). The % O2 for the **O2 Ratio Control** is now set for Point 2.

10) Next, the **O2 Control** needs to be set for point 2. This is done by increasing the ***Standard Val*** value, which drives the air influenced actuators back down their curves (closed), and should decrease the %O2 read on the AZL5. Once the desired %O2 is achieved, Point 2 can be saved by pressing the enter key to the left of the Standard Val, pressing escape once, and then pressing the enter key to finally store the point.

Note: The O2 control point must be at least 1% O2 below the %O2 value entered for the ratio control curve, and at least 0.5% O2 above %O2 entered for the O2 Monitor curve. Thus, the lean to rich band must be at least 1.5 %O2. In practice, the O2 system is easier to commission and operate on most burners if the %O2 between the O2 Control and the O2 Monitor is 1.0% O2 or more. The % O2 for the **O2 Control** is now set for point 2.

11) Once *enter* is pressed to save the point, delay time is automatically measured.
Delay time is typically measured on point 2 and at high fire (the highest point number). This is done so that the LMV52 can “learn” the response time of the boiler / burner at low and high fire.
To achieve this, the LMV52 drives the actuators from their position at the O2 control curve point back to their position at the ratio control point. The LMV52 then measures how long it takes for the %O2 in the stack to climb back up to the approximate %O2 that was locked in for the ratio control curve.
If the measured %O2 value in the stack approaches the %O2 that was locked in on for the O2 ratio control curve in less than 28 seconds, a successful delay time measurement should result.
If the delay time measurement is unsuccessful, the probable cause is an unrepresentative %O2 value for the O2 Ratio control curve, or parameter *OptgMode* is not set to *Man Deact*. Also see the above note pertaining to delay time.

12) Repeat the process outlined above for every point that was defined in the Fuel-Air Ratio curve. Delay time will also be measured a second time at high fire, which is typically highest numbered point.

13) After this is completed, the O2 trim can put into operation. This is done under parameter OptgMode. Typically, this is set to Con Auto Deact, but other settings are possible. Section 4-2 explains the different choices for this parameter.

Note: If necessary, see section 5 for additional troubleshooting information.

The PLL52 and the QGO20 Oxygen Sensor 6-3

The PLL52 in combination with the QGO20 Oxygen sensor is the heart of the O2 trim system.

The QGO20 produces millivolt signals that are read by the PLL52.

On the low voltage side the PLL52 translates these millivolt signals and sends the information back to the LMV52 digitally over the CANbus.

On the high voltage side, the PLL52 regulates the heating element amperage to the QGO20 in an effort to keep the QGO20 sensing element at approximately 1290 ^{o}F.

Three millivolt signals originate in the QGO20. These are the Nernst Voltage from the zirconium oxide O2 cell (terminals B1 and M), the thermocouple signal (terminals B2 and M), and the temperature compensation element (terminals G2 and U3).

These three signals produce an accurate, Wet %O2 value. The thermocouple signal is also used to control the PLL52's output to the QGO20. Amperage and therefore the heat output of the QGO20's heating element are varied by changing the resistance on the high voltage side of the PLL52 module.

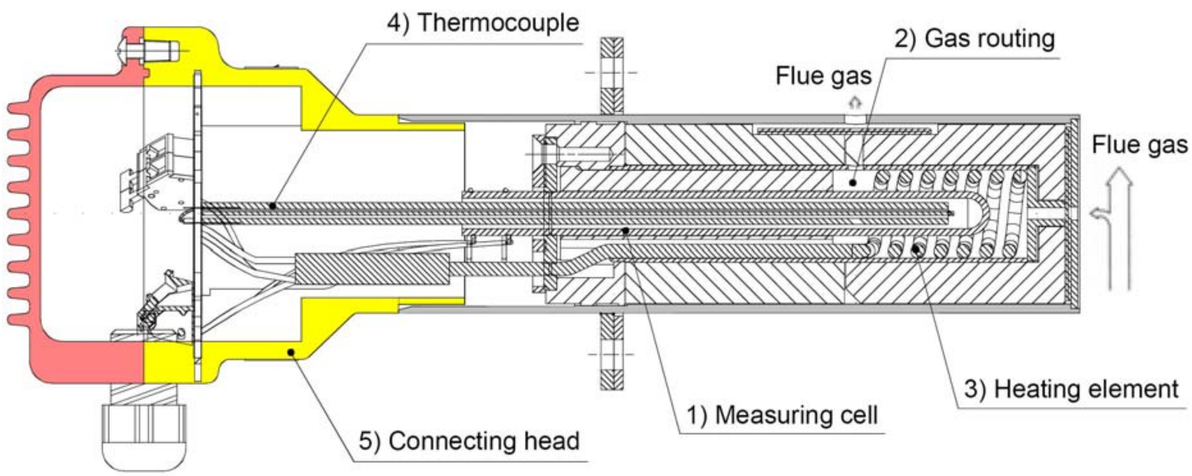
The low voltage wires from the QGO20 to the PLL52 should always be run separate from the high voltage heating element wires that also run from the PLL52 to the QGO20.

Separate shielded cables or separate conduits for the high and low voltage wires going to the sensor must be used.

Also, the PLL52 must be installed within 30 feet of the QGO20.

Figure 6-3.1 shows a cut-away of the QGO20 sensor.

Figure 6-3.1 Cut-away view of the QGO20 sensor



As previously mentioned, the QGO20 is only capable of measuring %O2 wet. This is true since it is an in-situ oxygen sensor, not needing any type of water trap, desiccant, or filter.

Most hand-held combustion analyzers measure %O2 dry, and therefore will be considerably different from the %O2 wet measured by the QGO20 sensor.

Figure 6-3.2 shows these approximate differences along with the raw millivolt signal from the zirconium oxide O2 cell.

As one would expect, the raw millivolt signal varies with sensor temperature, but this variance is compensated by the PLL52 module so the LMV52 is fed an accurate, compensated O2 value.

Figure 6-3.1 Conversion Table, %O2 Wet / Dry, Nernst Voltage (Approximate)

%O2 Wet (QGO20)	%O2 Dry (Nat Gas)	%O2 Dry (#2 Oil)	%O2 Dry (100% Methane)	Output Voltage (mV)@ 1292 F	Output Voltage (mV)@ 1320 F
0.1	0.1	0.1	0.1	111.79	113.59
1.0	1.2	1.1	1.2	63.61	64.63
1.5	1.8	1.7	1.8	55.12	56.01
2.0	2.4	2.3	2.4	49.10	49.90
2.5	2.9	2.8	3.0	44.43	45.15
3.0	3.5	3.4	3.6	40.62	41.27
3.5	4.1	3.9	4.1	37.39	38.00
4.0	4.6	4.5	4.7	34.60	35.16
4.5	5.2	5.0	5.3	32.13	32.65
5.0	5.7	5.5	5.8	29.93	30.41
5.5	6.3	6.1	6.4	27.93	28.39
6.0	6.8	6.6	6.9	26.11	26.54
6.5	7.3	7.1	7.5	24.44	24.83
7.0	7.9	7.6	8.0	22.89	23.26
7.5	8.4	8.2	8.5	21.44	21.79
8.0	8.9	8.7	9.0	20.09	20.42
8.5	9.4	9.2	9.6	18.83	19.13
9.0	9.9	9.7	10.1	17.63	17.91
10	10.9	10.7	11.1	15.43	15.67
11	11.9	11.7	12.1	13.43	13.65
12	12.9	12.7	13.0	11.61	11.80
13	13.9	13.6	14.0	9.94	10.10
14	14.8	14.6	14.9	8.38	8.52
15	15.7	15.6	15.8	6.94	7.05
16	16.6	16.5	16.7	5.59	5.68
17	17.5	17.4	17.6	4.32	4.39
18	18.4	18.3	18.5	3.13	3.18
19	19.3	19.2	19.3	1.99	2.03
20	20.1	20.1	20.2	0.92	0.94
20.9	20.9	20.9	20.9	0.00	0.00

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