

**Using the SEC3000
Electrochemical Sensor**
May, 2016 – Stephen D. Anderson
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SEC3000

SEC Document 1460004-A

1. Scope

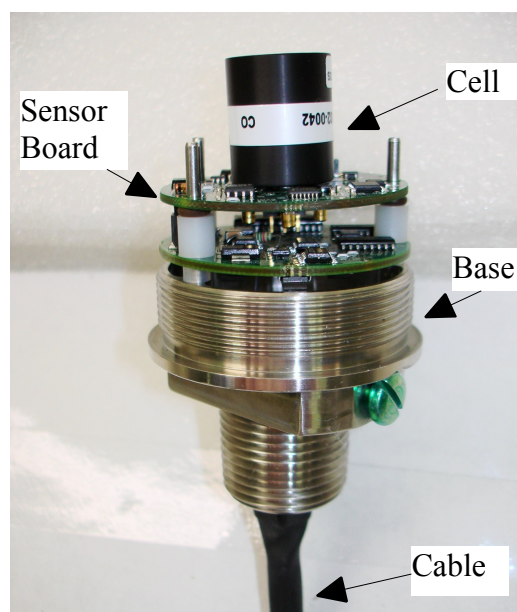
The SEC3000 gas sensor (shown on the cover and in Figure 1.1) uses an electrochemical cell as the sensing method. **There are currently about 470 variations of the SEC3000, able to detect 44 different gases at concentrations ranging from 0.5 ppm to 25% by volume.** The SEC3000 can be used stand-alone or with other SEC programming and monitoring devices. This application note explains electrochemical gas sensing and how the SEC3000 works. Troubleshooting and various problems in using the SEC3000 are explored.

2. Introduction

Electrochemical cells generate a small current in response to the presence of the analyte gas. The current is approximately proportional to gas concentration. The SEC3000 measures this current, converts it to a voltage, and applies gain and offset corrections. It also provides a correct bias voltage to the cell. The calibration, bias, and other parameters are placed into an EEPROM (non-volatile memory) that resides on the same printed circuit board (the Sensor Board in Figure 1.1) as the cell, allowing this board-cell combination to be built and shipped separately from the base Unit, when desired.

The SEC3000 base generates a 4-20 mA analog signal proportional to gas concentration. It can also communicate digitally with an SEC PCLink or SEC Transmitter, as described in Section 5.

Additional SEC3000 information may be found in the User's Manual [9.1].



**Figure 1.1 – SEC3000 Assembly
(Cover and Spacer Gaskets Removed)**

3. SEC3000 Variants

In addition to the specific analyte gas, the SEC3000 is available with any of the following:

1. Cable or wire of various lengths.
2. Intrinsically safe (see Manual [9.1] for approvals).
3. Explosion proof (see Manual [9.1] for approvals).
4. Programmable Heater.
5. Sample Draw.
6. Linear at Zero (Non-Noise Suppressed).
7. Splash Guard.

If a heater is installed, it maintains a cell temperature in the range of 20 - 40 deg C. This serves either of two purposes: (1) preventing condensation or (2) preventing the cell from becoming excessively

cold in colder environments.

Water condensation in or near the cell can prevent gas sensing in some circumstances. For example, ammonia may combine with condensed water instead of being sensed. Problems like this are often identifiable through being seasonal.

A sample draw system uses a pump to draw gas into the SEC3000. This is useful in situations where the atmosphere containing analyte gas cannot reach the device.

Normally, the SEC3000 is noise-suppressed, meaning its output is set to Zero (analog out is 4 mA) for any gas concentration that is within a few percent away from Zero. The SEC3000 can be ordered with this feature turned OFF, so that the output is “Linear at Zero.”

4. Electrical Connections and Mounting

The SEC3000 has 4 electrical connections, identified by cable (wire) color:

1. +24 volt supply (red).
2. Supply return, ground (black).
3. Digital output (white).
4. Analog output (blue or green).

These are either a cable or separate wires. An ammeter can be connected between the blue / green wire and ground to read the 4-20 mA analog output. The digital output can be read using either an SEC PCLink [9.3] or an SEC Transmitter [9.4]. These are available separately from the SEC3000 and are described in the next Section.

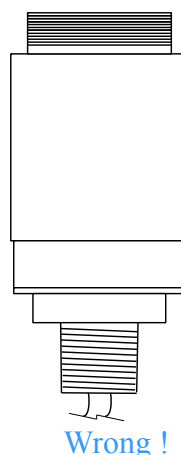
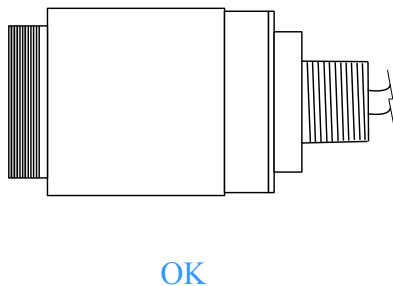
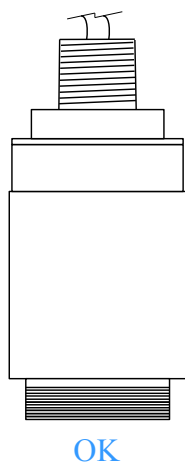


Figure 4.1 – SEC3000 Mounting

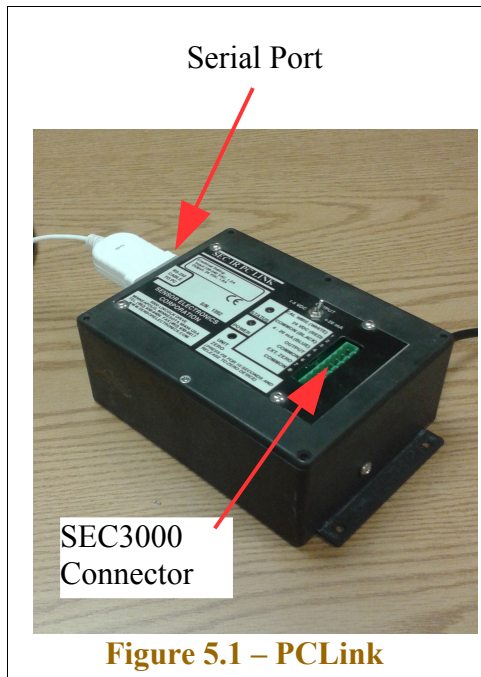
The SEC3000 should NOT be mounted with the gas opening facing up (wire end facing down). This invites impairment by liquids and dust. Keep the device either horizontal or with the opening down, as shown in Figure 4.1.

5. Digital Communication

5.1 PCLink or Transmitter

These allow the SEC3000 to communicate digitally. The PCLink, shown in Figure 5.1, connects the SEC3000 to a personal computer serial RS232 port (or USB port using an adaptor). The PCLink is supplied with software that runs in most Microsoft Windows [9.2] environments. It also contains a 24 volt power supply to power the SEC3000.

The PCLink can read or set most SEC3000 parameters. For example, it can be used to perform Zero and Span calibrations.



An example transmitter, the SEC 3100, is shown in Figure 5.2. The transmitter not only communicates digitally with the SEC3000 but is equipped with alarm relays and a display. It also reads / sets most SEC3000 parameters.

Note: The SEC PCLink and SEC3100 Transmitter work with all SEC Products, including the SEC3000 Electrochemical Gas Sensor.

5.2 SEC3000 Commands and Parameters

A partial list of SEC3000 Commands and Parameters is given in the following Table 5.1.

Command Number (in Hex)	Command	Description
19 (0x13)	Read Status	Shows either 0 (OK) or fault number.
20 (0x14)	Read Error	Shows 0 (no Error) or error number.
22 (0x16)	Read Serial Number	
53 (0x35)	Read Gas Name	String of up to 8 characters to show gas name.
55 (0x37)	Read Gas Units	String of up to 4 characters to show units (such as ppm)
10 (0x0A)	Zero (calibrate)	Start a Zero calibration.
11 (0x0B)	Span (calibrate)	Start a Span calibration.
31 (0x1F)	Read Gas Level	Read the normalized gas level (see Section 7).
17 (0x11)	Set Cal Value	Enter calibration concentration (see Section 7).
51 (0x33)	Read Range	Read range (Full Scale concentration).
23 (0x17)	Read Temperature	Read Unit temperature.
41 (0x29)	Read Firmware Version	Get Software Version.

Table 5.1 – SEC3000 Parameters

5.3 SEC3000 Fault Indications

When things go wrong, the SEC3000 has several fault indications that can be read by a PCLink or Transmitter. Each fault also results in a characteristic fixed output current for situations where digital communication is not used. The possible faults are listed in Table 5.2.

Fault	Current (mA)	Description
6 – POWER UP FAULT	0	Board Not Present, Bad Checksum, etc.
7 – CALIBRATION FAULT	1.6	Calibration Range Exceeded
11 – ZERO DRIFT FAULT	1.2	Large Offset implying negative Concentration
12 – CONFIGURATION FAULT	0	Calibration Not Done, etc.
18 – POWER FAULT	2.4	Power out of spec.

Table 5.2 – SEC3000 Fault Indications

The fault that is seen most often is probably the CALIBRATION FAULT (1.6 mA). This occurs, for example, if an attempt is made to Span the Unit under any of the following circumstances:

- 1. Calibration gas cylinder empty,**
- 2. Calibration gas expired,**
- 3. Didn't wait long enough after starting gas flow,**
- 4. Decomposition or Adsorption is occurring (see section 8),**
- 5. Cell has expired.**

More information on calibration is found in section 7.

6. Cells

An electrochemical cell is like a battery, except that it generates a tiny signal current rather than a large current to supply power. Just like a battery, the cell wears out and must eventually be replaced. Over its lifetime the cell becomes weaker or less sensitive, so that the cell / SEC3000 combination requires periodic re-calibration. The cell also

1. Has a shelf life. It is important to begin using the SEC3000 within less than 6 months of its fabrication.
2. May respond to gases other than the analyte. These are called cross gases. (see also section 6.6.)
3. Works only over a narrow temperature range. Keep temperatures within -40 °C to +50 °C.
4. Is subject to poisoning. This may destroy the cell's ability to detect the analyte gas.

Despite these shortcomings, electrochemical cells are the only form of gas sensor that provides a combination of low-power, high sensitivity, small size, mechanical stability, and wide gas variety.

Additionally, electrochemical cells are highly specific. Other methods of gas sensing (PID, for example) lump gases together, making it impossible to know if a particular gas is present.

6.1 Electrodes and Current Flow

Cells have at least two electrodes: a Sense electrode and a Counter electrode. An electrical current flows between these two electrodes when the analyte gas is present, as shown in Figure 6.1. Inside the cell, an ionic current, equal to the external electrical current, flows between the two electrodes. Many cells also have a 3rd electrode (not shown in Figure 6.1) that effectively measures or controls the electrolyte voltage with respect to the Sense electrode.

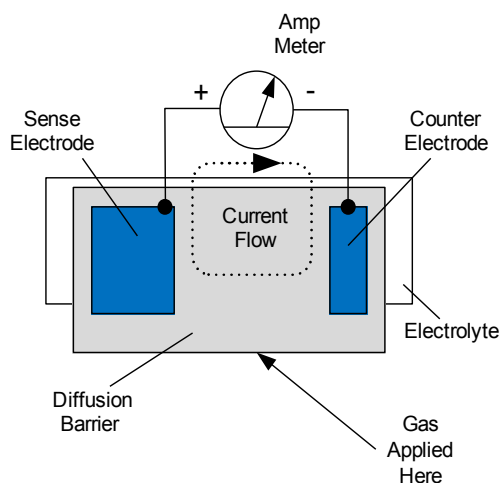


Figure 6.1 – Electrochemical Cell

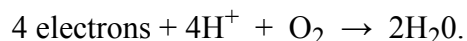
The SEC3000 is designed to use whichever electrode configuration is specified by the cell vendor.

6.2 Chemical Reaction

Exposure to the analyte gas causes a chemical reaction in the cell. Suppose that hydrogen is being sensed. Then the reaction at the cell Sense electrode is



That is, 2 hydrogen ions go into solution and 2 electrons are generated. At the Counter electrode the reaction is



Four hydrogen ions combine with 4 electrons and one oxygen molecule to produce 2 water molecules. The electrons pass through the external circuit and are the measured current.

As in this example, some cells need oxygen to complete the reaction.

This doesn't mean that the cell needs a continuous supply of oxygen to operate. If the cell has been exposed to the atmosphere, it accumulates enough oxygen to correctly operate for several minutes if the oxygen supply is suddenly cut off. In cases where the counter electrode needs oxygen, the oxygen comes through the same cell opening as the analyte gas.

6.3 Gases Versus Liquids

Can the SEC3000 sense liquids? Thanks to evaporation, yes it can. In a closed space containing some amount of liquid, this liquid will evaporate until it reaches its characteristic vapor pressure, which depends on temperature. Examples of liquid analytes that are detected by the SEC3000 are bromine, silicon tetrachloride, and acetic acid. Iodine, which is a solid at room temperature, can also be detected.

6.4 Cell Bias and Zero Offset

The cell bias, a parameter established by the cell manufacturer, is a voltage applied to the cell by the SEC3000 circuit. When the circuit is not powered, such as during shipment and installation, no bias voltage is applied. Unfortunately, this lets the cell “relax” into a state from which it must recover when the SEC3000 is powered ON.

The time to recover can be as short as a few minutes to as long as several hours, depending on the cell type. The SEC3000 may NOT correctly sense the analyte gas until this recovery time has passed. This situation is usually dealt with by just waiting about one day for the SEC3000 and cell to recover after power ON. Unless the cell is known to recover quickly, one day is the standard length of time established by SEC before factory calibration of the SEC3000.

Another way of looking at this is that the cell has two equilibrium points – one with the cell / SEC3000 powered OFF and the other with the cell / SEC3000 powered ON. It takes time for the cell to transition from one of these equilibrium points to the other.

Most cells have an offset (zero error) that appears when the SEC3000 has been OFF for some time and is powered ON. This offset is related to the change in equilibrium points discussed above. The offset, which gradually diminishes, can be mistaken for the presence of the analyte gas. It is important that the SEC3000 NOT be zeroed while this offset is present.

Zeroing the SEC3000 while an offset is present can lead to a “Zero Drift Fault.” This is indicated by an output current of 1.2 mA (see Section 5.3). The fault will also show in the display of an SEC transmitter. It is cleared by Zeroing after the offset has subsided.

6.5 Step Response and Sensitivity Variation

The measured response to quickly applying or removing the analyte atmosphere is shown in Figure 6.2 for five hydrogen cells. When exposed to hydrogen gas (starting at about 20 second in this Figure), the output rises over a period of about 30 seconds. Notice that the top of the pulse isn't necessarily flat. It continues to rise in some cases and starts to fall in others. Notice also that there is a large variation in sensitivity even among cells of the same type.

The behavior of hydrogen cells is typical of all cells, except that the response times may stretch into a few minutes for other cells.

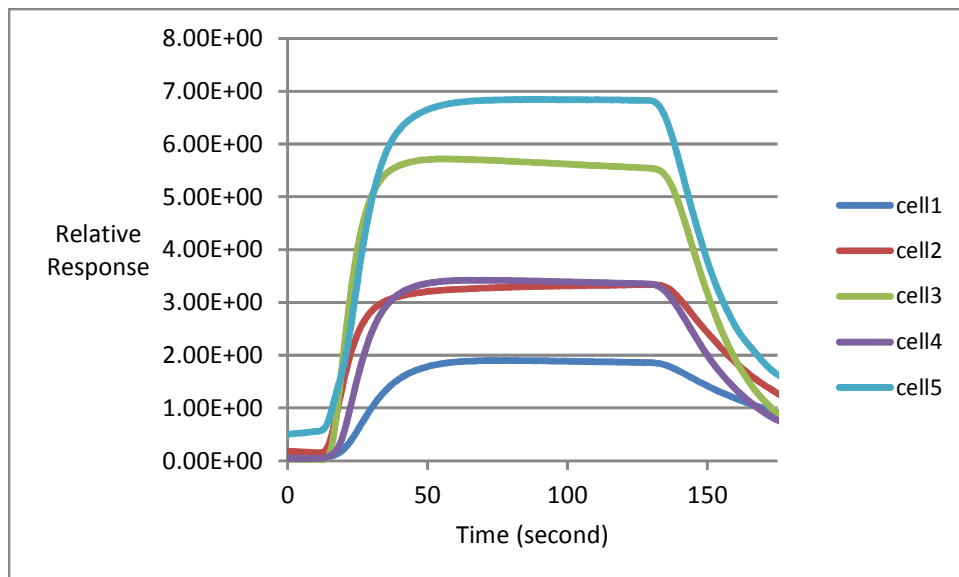


Figure 6.2 -- Transient Response to Application and Removal of Analyte

6.6 Cross Gases

Cleaning fluids and other seemingly benign materials will often cause false readings. The gas causing the false reading is known as a “cross gas.” (A table of cross gases for the SEC3000 is given in the SEC3000 User's Manual [9.1].)

If it is suspected that the SEC3000 is responding to a cross gas, then simple experimenting will sometimes reveal the source. If it is difficult or impossible to remove the cross gas, then using an alternate cell or using an adsorptive filter are possible fixes.

In some cases it may be necessary to contact SEC. SEC has been able to solve cross gas problems across several industries.

6.7 Noise

Cells can have a relatively high level of random noise. The SEC3000 lowpass filters the signal to provide noise suppression. However, this creates a trade-off between response time and noise. If the SEC3000 range is in the region of 0.5 ppm to 2 ppm, this usually translates to high amplifier gain. This, in turn, leads to higher noise and the need to slow the response.

6.8 Cell Consumption

The materials in a cell may be gradually consumed as the cell is exposed to the analyte. This usually occurs at such a small rate that it can be ignored. If, however, the cell is exposed to an extreme amount of the analyte for some length of time, then there is a concern that the cell may become weak. After such incidents, the calibration should be checked.

6.9 Cell Variation and SEC3000 Signal Conditioning

There is a wide variation in electrochemical cells, even within the same cell type. Cells are also divided into those that oxidize the analyte gas and those that reduce it, creating different signal polarities. The job of converting cell current to gas concentration takes a whole list of operations. Table 6.1 lists most of the SEC3000 cell conditioning operations.

Zero Calibration	Bias Set
Span Calibration	2 or 3 Electrode Configuration
Span Temperature Compensation	Polarity Correction
Over-Range Checking of Calibrations	Noise Filtering

**Table 6.1 – SEC3000
Electrochemical Cell Conditioning**

7. Zero and Span Calibration

After an initial factory calibration, the Zero and Span calibration can be performed by the User to adjust for cell aging or other special circumstances. The Zero is done with the SEC3000 free of analyte gas. The Span is done with the analyte gas (or surrogate gas) present.

Zeroing requires that there be little or no analyte gas in or near the SEC3000. To quickly clear the analyte gas out of the SEC3000 for Zeroing, a flow of dry air or nitrogen is sometimes used. This may be especially helpful in situations where the analyte gas is strongly adsorbed (See section 8). If, after removing the analyte gas, the current moves too slowly toward 4 mA, this is an indication that purging may help.

The calibration is a straight-line fit to the cell / SEC3000 gain and offset. The ideal normalized gas level as a function of concentration is

$$G_N = 164 + 656 \cdot \left(\frac{C}{C_R} \right)$$

where G_N is the normalized gas level, C is the concentration, and C_R is the Range (Full Scale Concentration). The corresponding output current is

$$I_{out} = 4\text{mA} + (16\text{mA}) \cdot \left(\frac{C}{C_R} \right)$$

It is often convenient to Span the Unit using an analyte concentration less than C_R . This might be done, for example, to avoid stocking a different calibration gas for each Range. The concentration of the calibration gas is a parameter of the SEC3000 and is called the “Cal Value”. Suppose that the Cal Value is half of the Range concentration. Then a Span target value for G_N is $G_T = 164 + 328 = 492$. Similarly, the target current is $I_T = 4\text{ mA} + 8\text{ mA} = 12\text{ mA}$. In general

$$I_T = 4\text{mA} + (16\text{mA}) \cdot \left(\frac{C_S}{C_R} \right) \quad (**)$$

where C_S = Cal Value (Span Concentration).

Note: The SEC3000 accepts a Cal Value of $0.1 \cdot C_R$ to C_R . However, to avoid calibration inaccuracies the Cal Value should not be set to less than about $0.2 \cdot C_R$.

7.1 Zero and Span of a Stand-Alone SEC3000

To Zero the SEC3000, connect a current meter between the blue (or green) wire and Ground (see section 4). Start the Zero calibration by connecting the White Wire to Ground for about 15 second (minimum of 10 second, maximum of 20 second) and then disconnecting the White Wire from Ground. The current will jump to a fixed value near 2.2 mA and remain there during Zeroing. After several seconds the Zeroing is complete and the current will either change to 4.00 mA or will jump to a small value to indicate that there is a fault. (Fault current values are tabulated in section 5.3.)

Next, apply the Span calibration gas mixture to the SEC3000. If the Unit has been previously Spanned, then the current may change in response to the analyte presence. After it appears that the output is no longer changing, start the Span calibration by connecting the White Wire to +24V for about 15 second (minimum of 10 second, maximum of 20 second) and then disconnecting it. The current will jump to a fixed value near 2.0 mA and remain there during Spanning. After several seconds the Spanning is complete and the current will either jump to the value given by the formula (**) above or to a small value (Fault current values are tabulated in section 5.3.) to indicate that there is a fault.

Span should be initiated only with the analyte gas present. If there is no analyte gas or if there is a deficiency of analyte gas, the SEC3000 tries to increase its gain without limit, resulting in a Span fault. To recover from a Span fault, re-Span the Unit with the correct concentration of analyte gas present.

7.2 Zero and Span With the PCLink or Transmitter

The calibration procedure is identical to that in the preceding section 7.1, except that Zeroing and Spanning are initiated by a command from either the PCLink or Transmitter. Use command 10 (hex 0A) to Zero and command 11 (hex 0B) to Span. During either the Zero or Span, the output current indications are the same as in the preceding section. Also, during either the Zero or Span, other PCLink or Transmitter functions may not be available.

An example calibration setup inside of a hood using a PCLink and 40-station calibration panel is illustrated in Figure 7.1. In this case an air delivery cup is being used (see above discussion on using dry air or nitrogen) along with the analyte delivery cup; and only two of the 40 stations are populated.

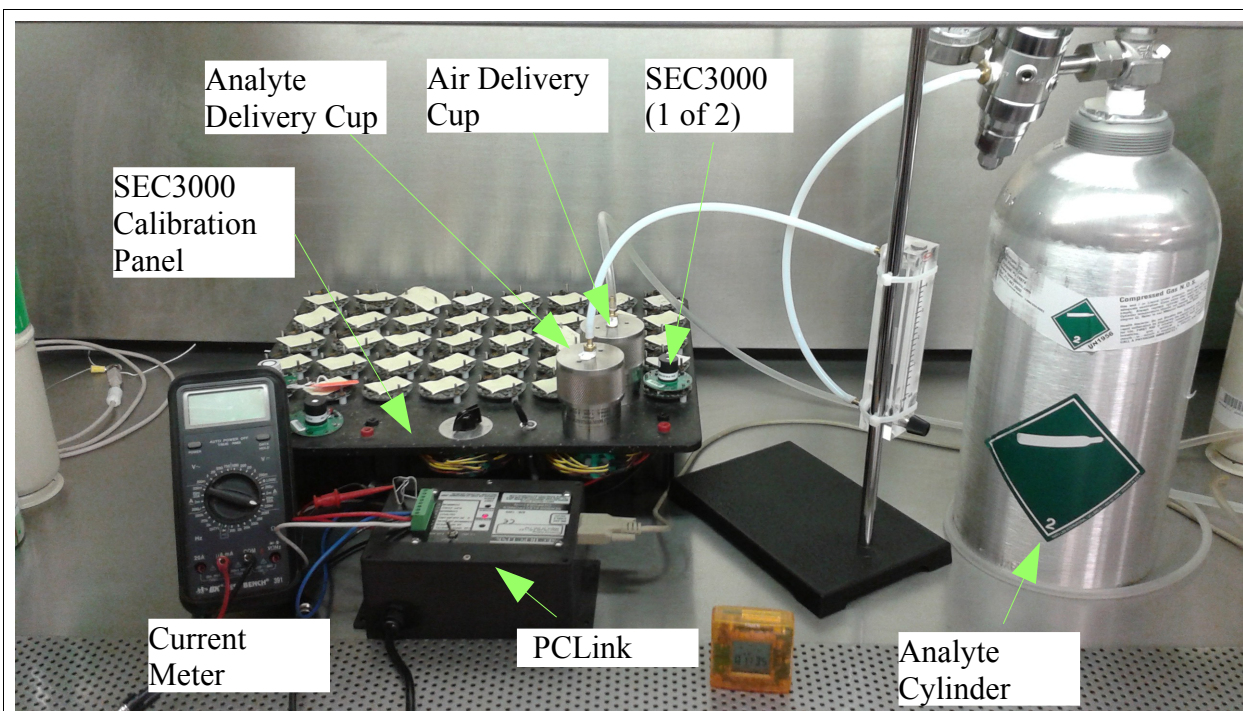


Figure 7.1 – SEC3000 Calibration Setup

Because the top of the step response is not well-defined (see section 6.5), a common question related to Span calibration is “When do I start the calibration?” The standard SEC practice is to start the Span when the SEC3000 output is no longer changing rapidly. For the cells of Figure 6.2 this would be at about 50 or 60 second. As explained in section 7.8, it is not possible to calibrate to the level of accuracy and repeatability typical of (for example) temperature and pressure sensors.

7.3 CAL Value and Stand-Alone SEC3000

When the SEC3000 is used stand-alone (without the ability to change the operating parameters), the Cal Value cannot be changed from the factory setting. If a Span calibration is performed, then either the calibration gas concentration must equal the Cal Value ($C = C_S$) or else some error in the calibration must be tolerated. This may be acceptable in instances where the Unit is being used to alarm at some gas level. Or else the alarm level can simply be adjusted to cancel the error in calibration.

As an example, suppose that the gas is ammonia and the Range is 100 ppm. The Cal Value is set to 50 ppm but the actual concentration of the calibration gas is 70 ppm. Then, after Spanning, the actual detection range is 0 to 140 ppm. That is, a current of 20 mA corresponds to 140 ppm. A current of 12 mA corresponds to 70 ppm. Suppose that an alarm is needed at 50 ppm. Then the alarm level should be set to 9.7 mA.

7.4 Calibrating in Fault

If the SEC3000 Unit is showing either Fault 7 or Fault 11 (See Table 5.2), then it can still be calibrated. The only difference from the procedures described above in Sections 7.1 – 7.3 is that the Unit will be showing the current associated with the Fault (1.6 mA or 1.2 mA) instead of a current proportional to the analyte.

Start by completely removing the analyte from the Unit. Initiate a Zero and observe that the current goes to 2.2 mA for a short time while Zeroing occurs. Then apply the correct concentration of analyte gas and initiate a Span. Observe that the current goes to 2.0 mA for a short time while the Span occurs. If these steps are successful, then, after the Span, the Faults will be cleared and the current will become proportional to the analyte concentration.

7.5 Calibration Flow

A convenient calibration flow chart for the SEC3000 is presented in Figure 7.2. The initial “Wait !” period after SEC3000 Power ON is discussed in 6.4. The “Observe Current ...” at the lower right of the chart says that the Current will increase above 4.0 mA. This happens if the calibration is already somewhat close to being correct. If the calibration is entirely correct, then the amount of the observed Current will equal the value given in Equation (**) of section 7.

Note that, if a Fault has occurred, then the current will go to one of the values of Table 5.2 in section 5.3. The calibration should only be re-attempted if the Fault is either 7 or 11, as described in section 7.4.

The “Current Stable?” decision block at lower right of the chart is asking whether the current is stable according to the criterion of the Sidebar in section 7.2.

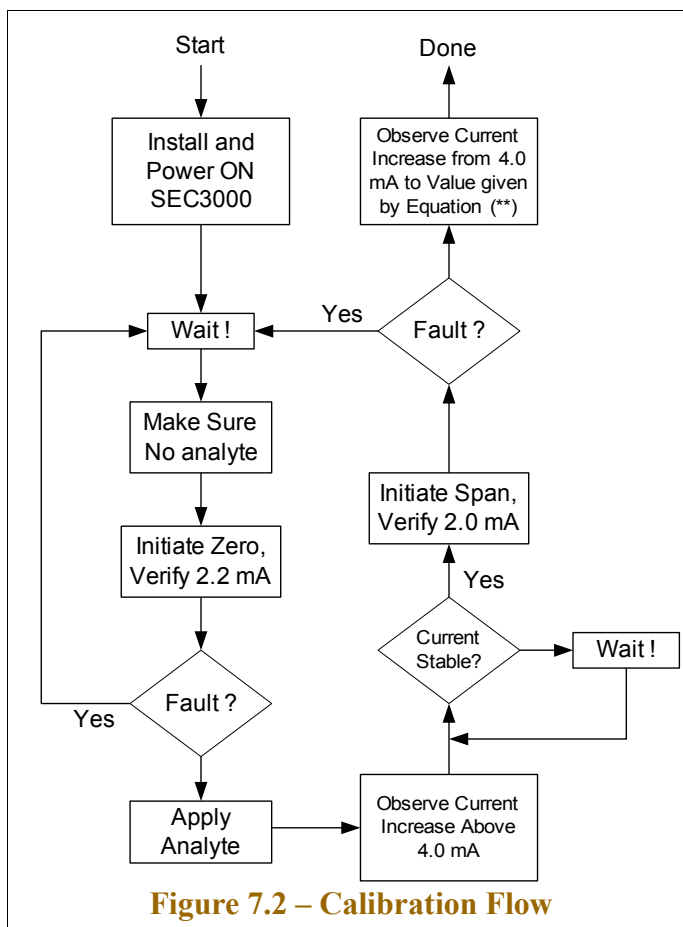


Figure 7.2 – Calibration Flow

7.6 Calibration Gases

The SEC3000 Span calibration is done using gases of known (measured) concentration, known as calibration gases. The calibration gas is a mixture of the analyte and some base or balance gas such as nitrogen or dry air. The balance gas is obviously chosen so that it does not react with (and deplete) the analyte gas. The ratio of base gas to analyte is typically 1000 to 1 or more. The base gas effectively carries the analyte to the cell.

Note: SEC can provide calibration gases and supplies.

Most calibration gases are prepared and shipped in metal cylinders of various sizes. A flow regulator and, in some cases, a pressure regulator are typically used. The flow is usually set to either 0.5 liter / minute or 1 liter / minute. In cases where adsorption (see section 8) is a problem, a higher flow and / or special tubing may be needed. Many gases sensed by the SEC3000 are considered toxic and should be dispensed in a hood.

For relatively low concentrations, a permeation generator is sometimes used instead of a gas cylinder. This generates a calibrated concentration from a porous glass tube, using controlled temperature and flow. Permeation generators are available from several sources, including Kin Tek [9.5].

Another source of calibration gas is to use a controlled chemical reaction to generate the analyte. This is used, for example, in the CAL2000 device [9.6], which is useful in generating chlorine and hydrogen cyanide.

Gases supplied in cylinders usually have a life time. It is important to dispose of (or return for deposit) a cylinder that has expired.

7.6 Surrogate Gases

A surrogate gas is sometimes used when the analyte calibration gas is difficult to buy or use. For example, chlorine is often used in place of hydrogen fluoride. Chlorine is less dangerous and less corrosive. The response to the surrogate gas versus the analyte gas is not always 1 to 1. SEC can provide guidance on the use of surrogate gases.

7.7 Maintenance Schedule

Electrochemical sensors, including the SEC3000, are NOT “set and forget” devices. Testing and calibration should be performed on a regular basis.

Typical SEC3000 maintenance intervals are every 3 months or every 6 months, depending on the application. A Bump test is often done when the SEC3000 is first installed.

7.8 Bump Test

A bump test is a short exposure of the device to analyte gas to verify that it responds. This is often done within a few days of the initial installation.

7.9 SEC3000 Accuracy

The analysis of Table 7.1 provides some feel for the SEC3000 accuracy. This assumes fresh calibration gas and a recent calibration of the SEC3000. Table entries 5 and 6 related to the cell are estimates or a condensation of data for many cells. Similarly, the calibration gas tolerance is taken from a variety of gases, with certifications of 2% and 5% being common.

Item	Error Source	Error (max %)
1	Calibration Gas Tolerance	2 to 10
2	Uncompensated Zero Error	3
3	Error in Compensating Span Temp Effect	3
4	Error in Spanning (see sidebar in Section 7.2)	5
5	Cell Linearity	2 to 10
6	Cell Repeatability	2

Table 7.1 – Error Sources
(Items 1, 5, 6 are Outside of SEC3000 Control)

The worst-case error from Table 7.1 (using 5% calibration gas tolerance and 5% cell linearity) is 23 %. The RMS error (under the same assumptions) is 4.0%. Much of the error in Table 7.1 arises from the cell and the calibration gas, suggesting that accuracy is not so much a function of the SEC3000 conditioning. Items 2 and 4, related to calibration technique, depend on the experience of the person performing the calibration. If these are reduced to 0 the RMS error drops to 3.2%.

Cell noise has not been included. But it can also cause error, especially in devices with Range values of 1 to 3 ppm.

7.10 Cell Replacement

As indicated earlier, cells have a finite lifetime. Eventually they must be replaced. SEC supplies replacement sensor boards (see Figure 1.1), equipped with a new cell and fully calibrated and compensated.

Can the Cell Alone be Replaced?

User replacement of the cell alone is not recommended. The handling and installation of the cell require special procedures that, if not followed, may damage the cell or the SEC3000 circuits. Additionally, there are factory calibration steps outside the scope of this application note that, if not performed, may prevent operation of the SEC3000.

7.11 Oxygen Sensing

The SEC3000 oxygen sensor is unique in having a slightly different calibration procedure. To zero the device, a flow of nitrogen is required. To span, replace the flow of nitrogen gas with synthetic air (air with “correct” concentration of oxygen).

8. Problems

There are circumstances in which the SEC3000 may appear to give incorrect results. Many SEC3000 problems are found to be incorrect calibration and have already been discussed. There are others, however, that are not so easily solved. These are discussed next.

8.1 Analyte Adsorption, Decomposition, and Pooling

Three effects that can lead to SEC3000 errors are:

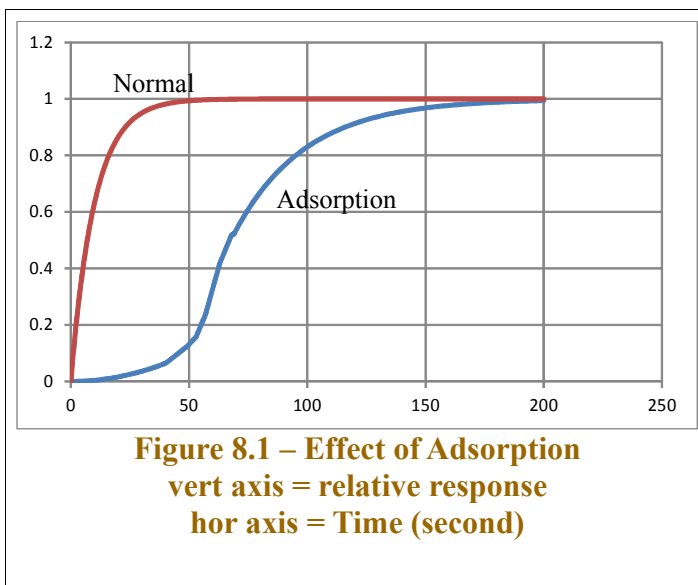
1. Decomposition (conversion of the gas into other products).
2. Adsorption of the gas or its products, preventing the full concentration from reaching the measurement cell.
3. Pooling (heavy analyte collects below the sensor).

If a gas reacts with oxygen, water vapor, or some other component of the air, then detection of this gas becomes problematic, even when the gas is supplied with a balance of nitrogen or argon. If the cell detects anything at all, it may be the end product of the reaction rather than the analyte gas, itself.

Adsorption can occur without any decomposition of the gas, but the two effects of adsorption and decomposition are often seen together when trying to detect highly reactive gases.

Adsorption means that the gas sticks to various surfaces. This is an useful property in chromatography, where a gas mixture is separated into its components for analysis. It is also useful in keeping some cross gases from reaching the SEC3000, so that only the desired analyte is measured.

With respect to the SEC3000, adsorption usually hinders rather than helps. The analyte gas can adsorb onto the tubing, flow meters, etc. used to deliver the gas. In extreme cases it can adsorb onto the components of the SEC3000, itself. This occurs until these component surfaces become saturated with the gas. Only then is the correct concentration of gas delivered to the SEC3000. The effect, illustrated in Figure 8.1, is rather like a lowpass filter with a delay. The following steps should be taken to reduce adsorption:



1. Examine the gas properties and use tubing and other materials that do not adsorb.
2. Keep tubing as short as possible.
3. Use a high flow rate (2 to 4 liter / minute) to more quickly saturate the adsorbing areas.
Note: This may require a large gas cylinder.
4. Use dry air or nitrogen (or argon) to remove (purge) the adsorbed gas prior to Zeroing.

If adsorption is suspected, it can often be verified by monitoring the SEC3000 output after the gas source is removed. After purging for a short time, observe the output. If it creeps upward, this is a sign that the gas is desorbing from various surfaces and being sensed by the SEC3000.

8.2 Toxic and Semiconductor Gas Considerations

Many highly reactive toxic gases such as arsine, phosphine, silicon tetrachloride (and others used in the semiconductor industry), do not have a well-defined exposure limit. This leads to the purchase of SEC3000 Sensors down at the 0.5 ppm and 1 ppm ranges as “safety” devices. But placing one of these Units in the middle of a room and expecting it to generate a warning may fail. These gases either decompose or are adsorbed onto other surfaces (or both) before they even get close to the SEC3000.

The SEC3000 must be used similarly to the way it is calibrated / tested. That is, the analyte gas must be delivered with a balance of inert gas and at a sufficient flow that adsorption is overcome. The SEC3000 should only be used in other ways if experiments verify that it performs as expected.

9. References

- 9.1 SEC3000 User's Manual (SEC part number 1460003).**
- 9.2 Microsoft Windows Operating System, Microsoft, Redmond, Washington.**
- 9.3 SEC PCLink (SEC part number 1420636).**
- 9.4 SEC 3100 DIN Rail Transmitter (SEC part number 3100100 and 3100100DIN).**
- 9.5 KIN-TEK Laboratories, Inc., La Marque, TX 77568.**
- 9.6 Advanced Calibration Designs, 2024 W. McMillan St., Tucson, AZ 85705.**