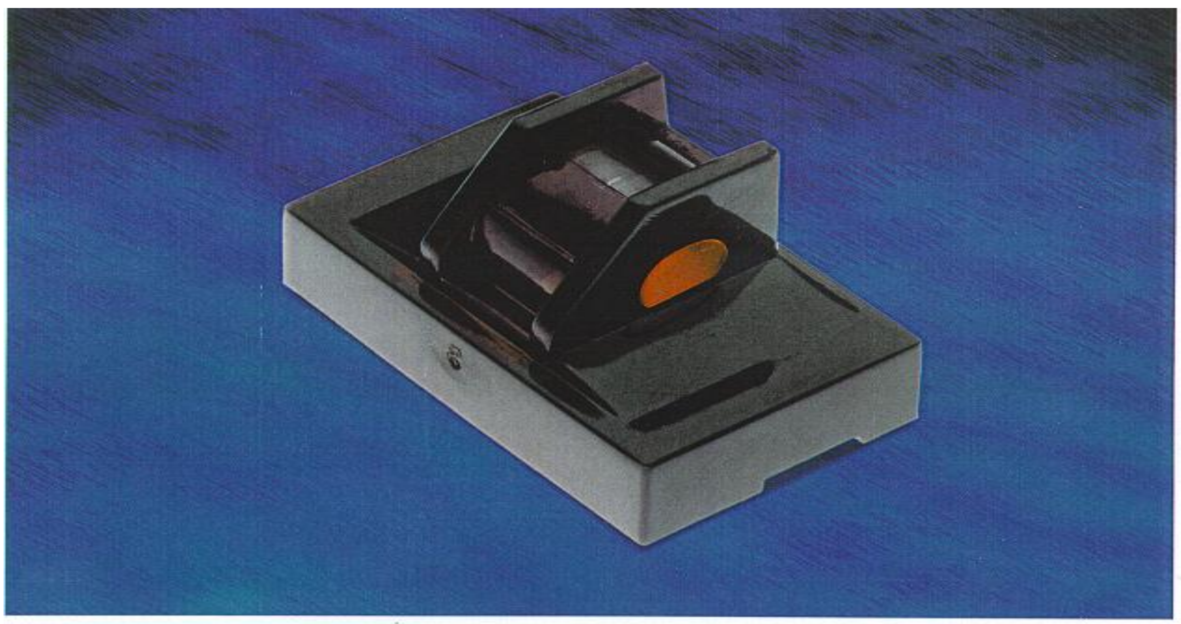
QUANTUM GROUP INC.

6827 Nancy Ridge Drive, San Diego, CA 92121
(858) 566-9959, FAX: (858) 566-9974 • Toll Free (800) 432-5599 •
http://www.QGinc.com

Solid-state "InfraRed" (SIR) BIOTECH Carbon Monoxide (CO) Detection Technology



Technical Document No. 060396 - Rev.8
May 9, 2011

QUANTUM GROUP INC.

Solid-state "InfraRed" (SIR) Carbon Monoxide (CO) Detection Technology

6827 Nancy Ridge Drive • San Diego, CA 92121 • (858) 566-9959 • FAX: (858)566-9974 • Toll Free (800) 432-5599

Version 4.0
05/02/04

QUANTUM GROUP INC.
SIR Carbon Monoxide (CO) Detection Technology

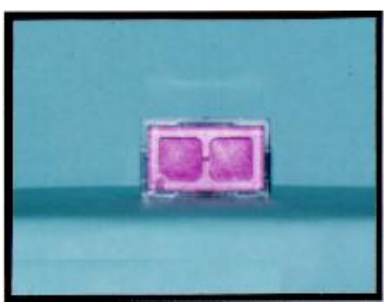
I. Introduction

A. Product Description

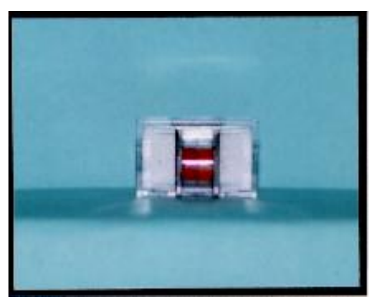
Quantum Group's biotechnology derived solid-state infrared (SIR) carbon monoxide (CO) sensor is a highly sensitive and selective CO detection device, which accurately detects CO concentrations in wide ranges, including high and low concentrations of CO. Other gases in the common household environment do not significantly affect it.

The SIR sensor comprises CO to CO2 oxidation catalyst, which consist of a supramolecular organometallic chemical complex self assembled onto a porous solid-state IR transparent substrate. Cyclodextrins derivatives are the key biotechnology compounds that stabilize the supramolecular sensing system. The purpose of the sensor is to monitor the environment for the presence of CO and in combination with the appropriate software and electronics, activate CO alarm and control devices. When exposed to CO, even to lethal concentrations (400 ppm), the sensor starts to recover in less than 2 minutes after being exposed to clean air. This rapid recovery feature will allow a detector to quickly come out of alarm in less than two minutes.

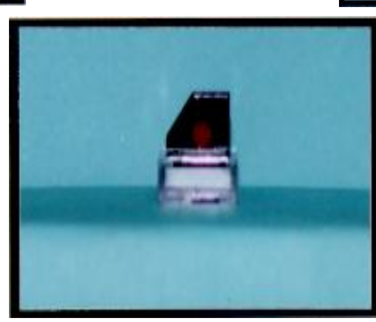
Two sensing elements are contained within housing with a filter system to protect the sensors from possible contamination from aerosols, liquids, and dust. A light emitting diode (LED) emits near IR photons that pass through the sensor. An IR detector monitors changes in photon transmittance of the sensors, which are inversely related to levels of CO concentrations in the air.



Top



Bottom



Side

B. Features and Benefits

* All solid-state IR detection system including SIR and MicroSIR

* The only technology Tested False Alarm Free to common household vapors and gases by Lawrence Berkeley National Laboratory LBNL Report 40556

* Regeneration - Rapidly regenerates to its original state when CO is eliminated from the environment

* Adaptability - Has been design engineered to meet all requirements of both Underwriters Laboratory (UL) and Canadian Standards Association (CSA) approvals currently in effect.

* Versatility - Can be powered by 9V battery, 12-24 AC/DC and 120 AC. Battery back up is an option with some line-powered applications. 9-volt battery operation allows portability and installation in any location

* Reliability – Test most reliable by Lawrence Berkeley National Laboratory LBNL Report 40556

* Flexibility - Dual-purpose detection levels of CO are adapted for warning (low-level parts per million (ppm) CO) and alarm (at immediate threat to life, i.e. high level ppm CO)

* Economical – Most value for your money

* Sensor Life - Six-years

* Automated circuit board and microprocessor self test capability

C. Short and Long Term Effects of CO

The U.S. EPA promulgated the "Air Quality Criteria for Carbon Monoxide" in June 2000 based on an extensive report by the same title referred to as EPA/600/P-99/001F June 2000. On the basis of the scientific information contained in this EPA document, the National Ambient Air Quality Standards (NAAQS) for CO exposure limits were set at levels of 9 pats per million (ppm) for an 8-hour average and 35 ppm for a 1 hour average. The EPA sought out the experts in the field in the preparation of this document. Quantum Group has used the data from the document to prepare a summary of the short and long term effects of CO exposure to the human body as presented in Table 1. The health effects on humans listed in Table 1 are correlated to CO levels that range from 15 ppm [2.5% carboxyhemoglobin (COHb)] to 500 ppm [80% COHb]. It is clear from the EPA report that there are significant and measurable health impacts on both the healthy and sensitive populations starting at 15 ppm. At 50 ppm, these effects become much more serious. The health effects below 2.5% COHb on sensitive populations are inconclusive; however, epidemiological studies by the U.S. Surgeon General indicate that CO from second-hand smoke contributes to cardiovascular disease and early death. Other similar studies conducted by Stern[1] for tunnel and bus workers indicate that there is a strong correlation between low level (10-24 ppm CO), long term exposure of CO and the risk of coronary heart disease.

1: Stern, et. al., (1981, 1988), EPA/600/8-90/045F, P-10-41, (December 1991)

TABLE 1. The Short Term and Longer Term Effects of Carbon Monoxide on the Human Body [abstracted from EPA Air Quality Criteria for Carbon Monoxide, (EPA/600/P-99/001F, June 2000)

CO Concentration in Air	Length of Exposure	% COHb *work effort 1	% COHb *work effort 5	Symptoms on Healthy Individuals	Symptoms on Sensitive Individuals**	Longer Term Effects
15 ppm	30 days	2.72	2.55	delayed reaction exhaustion from exercise p2-9, decreased work capacity, p2-8	P2-9 Angina+	increased cardiovascular impairment, p10-40-44, increased risk of coronary heart disease
50 ppm	8 hours	6.23	8.29	Delayed reaction - exhaustion from exercise p2-9, vigilance impaired performance, visual impaired p2-18; job determinant impaired such as driving reactions	abnormal ECG Arrthythmias p10-73-84, reduction in vigilance, visual, hand & eye coordination, manual dexterity, ability to learn p2-9 complex task, Angina+	Neurobehavioral sequelae in fetuses p10-169 impact on fetal behavior; increased risk of coronary heart disease, CNS, & cardiovascular effects p10-44
100 ppm	8 hours	12.29	16.51	Delayed reaction, impaired complex jobs, exhaustion from exercise, vision	fetal deterioration, coma p2-22, Angina+ or fetal memory deficit, decline in school performance p10-166	fetal mental retardation, fetal weight reduction; CNS & cardiovascular effects p10-162
150 ppm	8 hours	18.35	24.73	slight headache, incontinence, delayed reactions	coma p2-22, CNS 10.4, Angina+, heart attack, death	sex hormone reduction, p10-173 CNS & cardiovascular effects 10.4 fetal weight reduction, fetal mental impairment, retardation
200 ppm	8 hours	24.41	32.96	headache & nausea, incontinence, delayed reaction, severe drowsiness, coma	coma p2-22, CNS 10.4, heart attack, death	heart, liver, brain kidney, muscle damage p10-176 death, CNS 10.4 fetal weight reduction, fetal death, cardiovascular impairment
300 ppm	8 hours	36.53	49.41	drowsiness, incontinence, delayed reaction, severe vomiting, coma, permanent brain damage	coma, heart attack, permanent brain damage, death	heart, liver, brain, kidney, CNS, muscle damage p10-176 death, fetal death
400 ppm	8 hours	48.64	65.86	coma, permanent brain damage, collapse, death	coma, heart attack, permanent brain damage, death	heart, liver, brain, kidney, muscle damage p10-176 death, CNS, fetal death
500 ppm	8 hours	60.76	82.30	coma, collapse, permanent brain damage, death	coma, heart attack, permanent brain damage, death	heart, liver, brain, kidney, muscle damage p10-176 death, CNS, fetal death

* Work effort, per UL2034, Appendix B1, December 11, 1994, 1. Sedentary, 3 Light work, and 5. Heavy work.
** Long term effect more than 30 days
Angina+ - Increase in Angina resulting from mild exertion such as climbing up two flights of stair

II. Quantum Carbon Monoxide Sensor Technology

A. Principles of Detection

Quantum Group initially manufactured biomimetic sensors that responded to carbon monoxide (CO) in a manner that mimics human hemoglobin's response. Carbon monoxide displaces oxygen within hemoglobin, a component in blood that transports oxygen. One of the results of this displacement is a change in the light transmittance of the blood. However, do to changes in the UL standard in 1995, Quantum began manufacturing sensor that regenerate faster than human's blood and thus the sensor are no-longer biomimetic. These sensor are now referred to as BIOTECH sensors.

As shown in Figure 1, two CO sensing elements (one red and one yellow) are at the heart of the Quantum IR sensor. Each patented sensing element is made from a porous transparent disk coated with a monolayer of a supramolecular complex, which is a catalyst. A self-assembly process is used to construct the fast regenerating sensing elements. Upon exposure to CO, one or both of the sensing elements change its spectral character and absorb photons at a rate dependent on the concentration of CO in the surrounding environment. Thus by monitoring sensors with Patent pending electronics a linear response is produced. The sensing elements reverse their spectral shift by a self-regeneration process whose rate is dependent upon the decrease of CO in the environment. By monitoring the rate of change in the amount of light transmitted through the sensing elements, the concentration of CO in the surrounding environment can be determined accurately and displayed digitally.

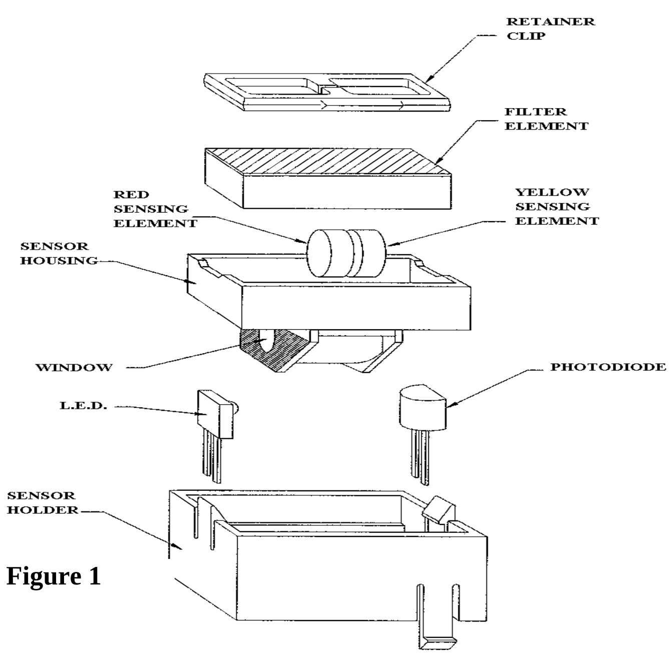


Figure 1

The CO response characteristics of a particular sensor may be designed to meet specific standards or applications by controlling the formulation process. Sensing elements can be designed to satisfy customers needs for applications in residential and

Industrial CO sensing, medical diagnostics and anesthesia gas monitoring. In addition, the S34 formulations have been designed to meet the following standards: UL-2034 (effective May 2003) and CSA 6.19-01, as well as the CPSC recommendation.

A sensor housing (Figure 1) protects the sensing elements from physical damage and harm. A filter and retainer clip holds the sensing elements in place and prevents dust, smoke particles, liquid water, and other chemicals from entering the sensor chamber.

The IR sensing elements are held in optical alignment by the sensor housing placed between an infra-red light emitting diode (LED) and a photodiode, as shown in Figure 2. Pulses of light (e.g., 940 nm) emitted by the LED pass through the first sensor-housing window and are attenuated by the sensing elements. The attenuated light exits through the second sensor-housing window and is then detected by the photodiode. A specially designed sensor holder as shown in Figure 1 may be purchased for mounting and alignment of the SIR sensor between an LED and photodiode on a detector circuit board.

Figure 2

B. Sensor Characteristics

The Quantum IR carbon monoxide (CO) sensor incorporates state-of-the-art sensor technology designed to detect CO while meeting or exceeding current regulatory standards in many countries.

Response to CO

When exposed to CO, Quantum Group's carbon monoxide sensor darkens in the IR, thereby, reducing its optical transmittance. The sensor's optical transmittance (I) is a percentage of the radiant energy transmittance through the sensor (I_t) compared to that of the unexposed sensor (I_o). (i.e. $\%I = [I_t / I_o] \times 100$).

Quantum Group uses an electronic circuit to measure the performance characteristics of its IR carbon monoxide sensors. In this standard test circuit, 940-nm infrared light passes through the carbon monoxide sensors and is detected by a photodiode. The current from the photodiode is converted to voltage. By monitoring the output voltage of the standard test circuit, we obtain a relationship between CO concentration and optical transmittance.

Shown on the next page in Figure 3 is the typical response of Quantum Group's CO sensor upon exposure to 150 ppm CO at ambient temperature and ambient humidity for 50 minutes, using the standard test circuit.

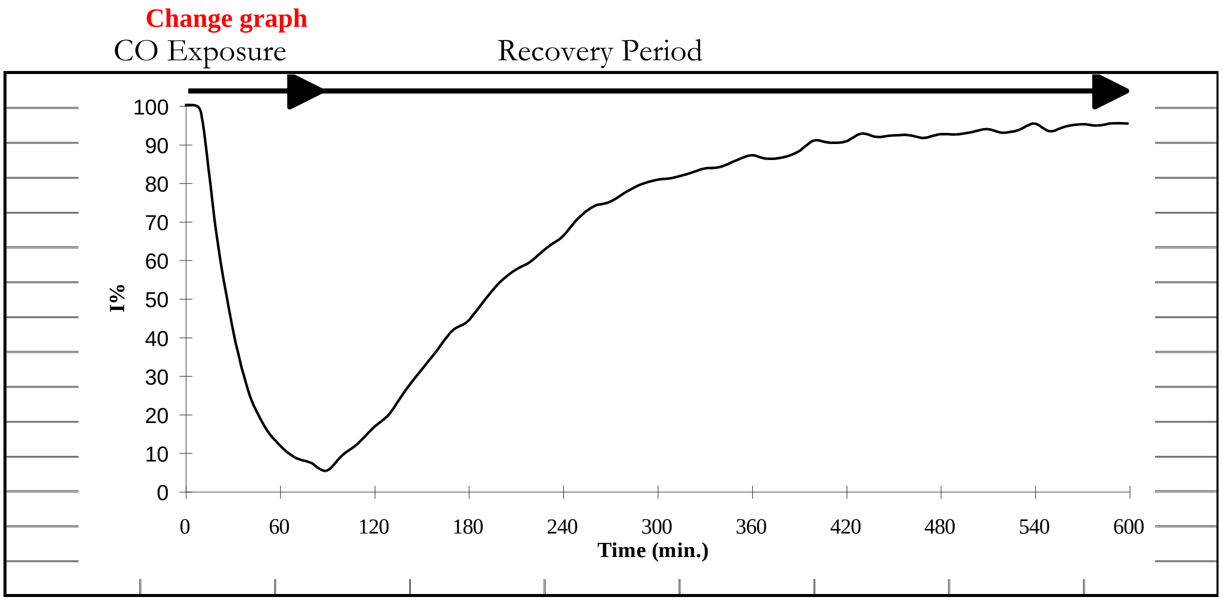


Figure 3. Response (%I) of sensor to 150 ppm CO at ambient temperature and relative humidity for 50 minutes. After 50 minutes of exposure to 150 ppm CO, the CO is removed and then the sensor starts regenerating immediately as shown above.

Upon exposure to CO, the sensor rapidly absorbs photons of 940 manometers as reflected by the rapidly decreasing value of %I. In a fixed alarm point detector, a value of 30% is typically set as the alarm point. Therefore, in such a detector, the alarm would be triggered within 40 minutes after exposure, which is well within the UL safety guidelines.

When the sensor is exposed to clean air (time = 90 minutes), the sensor immediately self-regenerating process. As the sensor reverses its spectral shift, the value of %I increases and within 2 hours the sensor has fully recovered.

Effects of Repetitive Exposure to CO

Under various conditions of temperature and relative humidity, the CO response of the carbon monoxide sensor remains stable. As shown in Figure 4, laboratory tests have proven that the sensor will perform normally through more than many cycles of exposure to 100 ppm CO and recovery like that shown above in Figure 3. For example, the slope of the sensor response ($\partial I/\partial t$) changes immediately during cycle tests, allowing rate-of-change detectors to reset within two minutes.

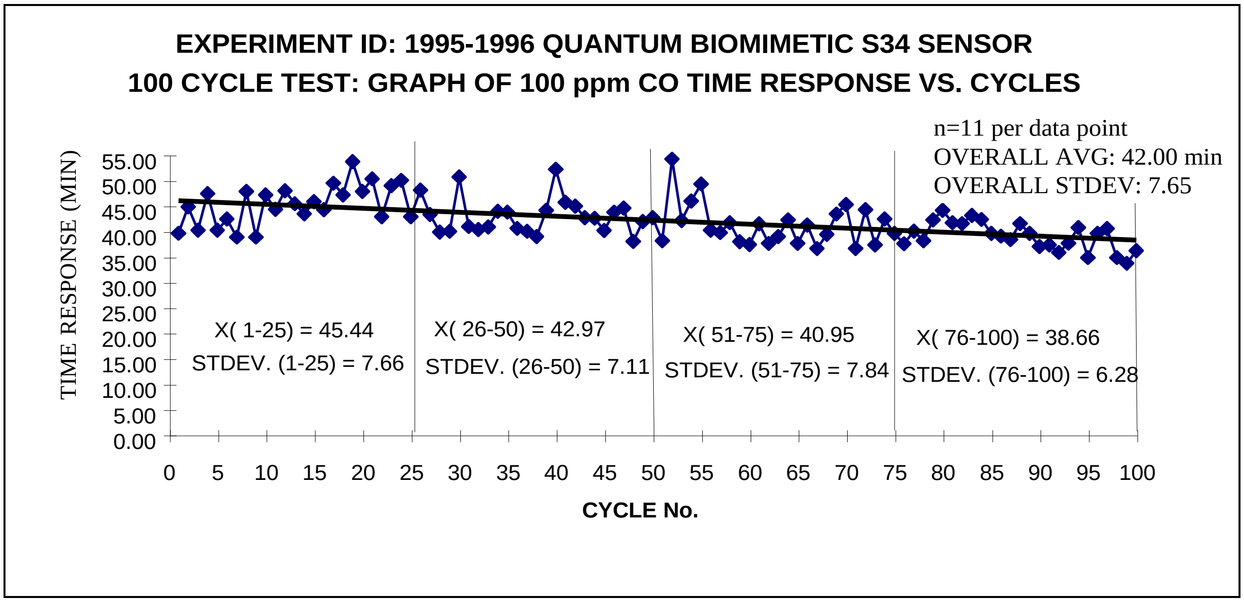


Figure 4. S34 cycle test data indicates a gradual increase in sensitivity as the number of CO exposure increase.

Span Drift

Span Drift is defined as the change in response time at a fixed concentration of CO exposure. Repeated exposures over an eleven-month period revealed that the sensor response time drifted 10.4 minutes as shown in Table 2. The sample tested consisted of 913 sensors.

Table 2. The 100 PPM CO response time of the Quantum sensors was determined over an eleven-month period (in minutes).

Months	0	3	6	9	11
I_0	97.6	93.4	92.6	92.8	90.2
avg. std. dev.	15.0	9.5	8.5	8.0	7.8
time response	46.5	44.1	39.6	40.9	36.1
avg. std. dev.	10.2	7.3	6.7	7.7	6.4

Effects of Humidity and Temperature

The sensing elements of the IR carbon monoxide sensors are specifically designed to respond to CO over a wide range of relative humidity and temperature, i.e., minus 40 C to plus 70 C..

As shown below in Figures 5 and 6, the response of the sensors to 100-ppm CO remains stable under various conditions of relative humilities and temperatures. In all tests, the sensors were preconditioned for 48 hours prior to exposure to CO. Upon exposure to CO (time = 180 minutes), the sensors rapidly responds by a rapid change in the slope (dI/dt) of the light transmittance with respect to a change in time. When exposed to fresh air (time = 270 minutes) the sensors immediately begin the self-regeneration process. As the sensor regenerates, the value of dI/dt correspondingly increases with a resulting change in the sign of the slope causing the alarm to silence. The slope will reverse if the CO concentration diminishes.

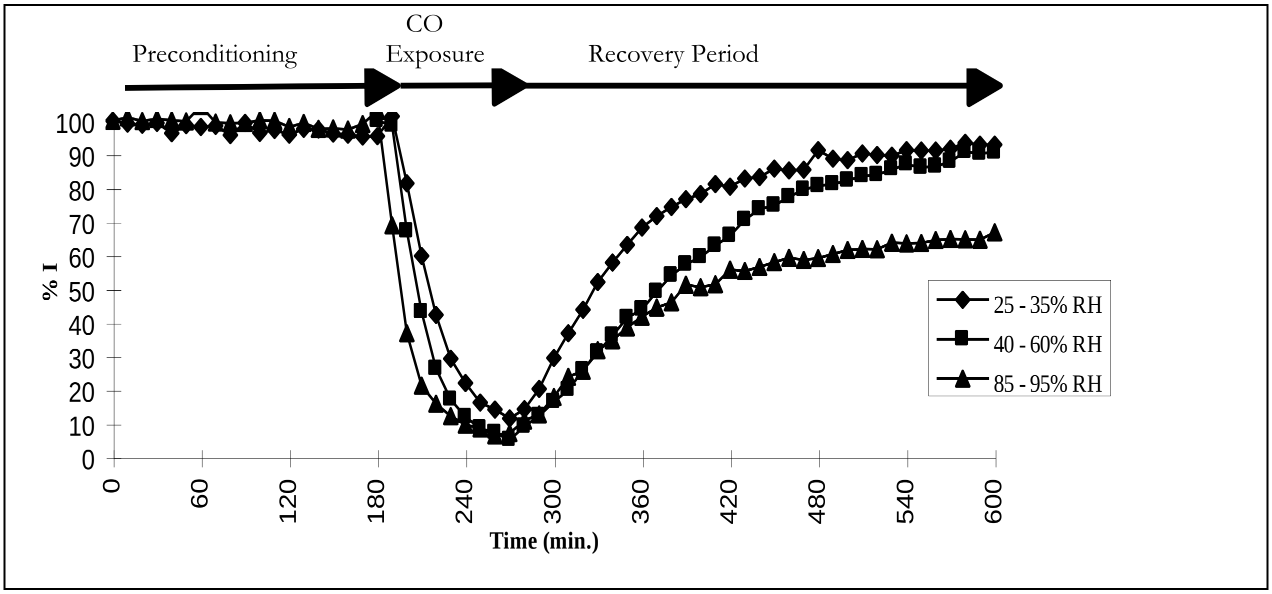


Figure 5. Response of S34 biomimetic CO sensor to 100 ppm CO for 90 minutes at ambient temperature and various relative humidities, using the standard test circuit.

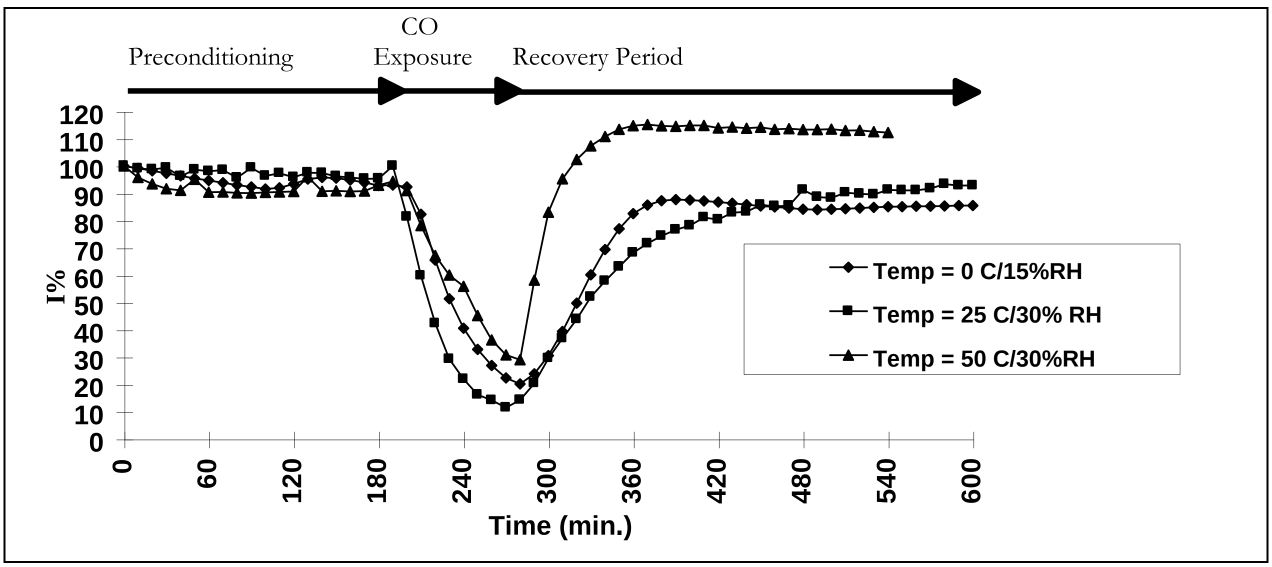


Figure 6. Response of IR CO sensors to 100 ppm CO at low relative humidities and various temperatures.

Even under the demanding conditions of high humidity (93 ±2 %RH) and high temperature (52°C), the IR sensor exhibits superior performance. Table 3 shows the response of the IR sensors to 100 ppm CO after 7 days of preconditioning. Upon exposure to 100 ppm CO at the end of 7 days, the sensor rapidly darkens, causing the dI/dt to signal an alarm. The data shows that the IR CO sensor responds to 100 ppm CO even under high relative humidity.

TABLE 3. Response of IR CO sensor to 100 ppm CO at high relative humidity (93 ±2 %RH) and high temperature (52°C) using the threshold alarm point. I_0 is the sensor's initial optical transmittance. I_f is the sensor's final optical transmittance taken after 90 minutes of 100 ppm CO exposure.

SENSOR LOT #	**SVT-49**		**SV T-50**		**SVT-51**		**SVT-52**		**LVT-10**	
TEST DATE:	5-31-96		6-20-96		6-27-96		7-10-96		8-13-96	
	Io	**I_f**	**Io**	**I_f**	**Io**	**I_f**	**Io**	**I_f**	**Io**	**I_f**
1	92	11	103	18	104	17	93	13	93	15
2	90	15	100	16	98	12	81	15	91	9
3	94	14	96	18	98	13	79	7	106	19
4	82	14	104	18	81	10	77	17	98	17
5	101	12	82	15	98	7	83	17	78	11
6	109	18	98	17	105	10	104	34	104	17
7	92	14	89	19	83	10	98	16	100	8
8	83	10	91	16	93	14	90	21	97	9
9	102	12	97	17	93	13	81	16	85	18
10	115	20	104	20	98	8	82	12	112	22
11	90	9	107	11	97	16	98	20	86	15
avg.	**95.45**	**13.55**	**97.36**	**16.82**	**95.27**	**11.82**	**87.82**	**17.09**	**95.45**	**14.55**
std dev	10.30	3.30	7.54	2.40	7.54	3.16	9.20	6.79	10.08	4.66

Effects of Interference Chemicals

Laboratory tests have shown that the S34 sensor is not affected by interference chemicals typically found in indoor air. As shown in Table 4, even when exposed to high concentrations of interference chemicals, the S34 sensor remains unaffected.

TABLE 4. Effect of interference chemicals on SIR and MicroSIR carbon monoxide sensors.

Interference Chemicals	Chemical Class	Concentration (ppm)	Exposure Time (hours)	Effect on SIR Sensor
Methane	Hydrocarbon	500	2	none
Butane	Hydrocarbon	300	2	none
Heptane	Hydrocarbon	500	2	none
Ethyl Acetate	Ester	200	2	none
Isopropanol	Alcohol	200	2	none
Carbon Dioxide	Inorganic Gas	1000	2	none
Ammonia	Inorganic Base	100	2	none
Acetone	Ketone	200	2	none
Ethylene	Alkene	200	2	none
Ethanol	Alcohol	200	2	none
Toluene	Aromatic Hydrocarbon	200	2	none
Trichloroethane	Chlorinated Hydrocarbon	200	2	none
Nitric Oxide	Oxidizer	25	2	none
Nitrous Oxide	Oxidizer	200	2	none

Quantum BIOTECH Carbon Monoxide (CO) Sensor Specifications

A. Specifications

B. General:

Dimensions of Sensor (l x w x h):	24 mm x 14.5 mm x 15 mm
Production:	All inventories maintained on a First-In, First-Out basis.
Storage Temperature Range:	-40°C to 63°C
Operating Temperature Range:	0°C to 40°C
Operating Relative Humidity Range:	15%RH to 95%RH
Concentration Threshold:	15 ppm
Average Response Time (100 ppm CO):	45 minutes
Recovery Time with Rate of Change Circuit (100 ppm CO, 90 min.):	within 2 minutes

Lifetime:

Lifetime (useful service):	6 years guaranteed

Pre-Shipment Testing and Quality Control:

Sample Size Tested:	All units shipped. 100%
Test Conditions:	23 ± 3°C; 55 ± 10 %RH
CO Concentration:	100 ppm
Pass Rate of Shipped Sensors:	100%, CO test at 100 ppm
Storage-Packing Prior to Use:	Requirements; MILB-2291D type II, class 2, FR-5500

III. Microprocessor Technology

A. Principles of Operation

Because the BIOTEC CO sensor absorbs 940 nm photons in proportion to the level of carbon monoxide (CO) concentrations, the light absorbed by the sensor can be monitored for detecting the presence of carbon monoxide. The sensor requires no power for its operation.

The recommended application for the BIOTECH CO sensor utilizes the patented rate-of-change technology, U.S. Patent No. 5,573,953. Other methods of rate-of-change are acceptable including digital methods (Patent Pending).

A reliable rate-of-change detector can be produced which does not require calibration and provides the customer with a variety of key operational states for indicating CO concentrations ranging from unhealthy to life threatening as well as meeting all current U.S. standards. In a rate-of-change detector, the change in the amount of 940 nm photons absorbed by the sensor, rather than a fixed level, is used to determine whether the alarm should be triggered. Quantum Group's software may be licensed for incorporation into other microprocessors. The microprocessor tracks rate-of-change and the light absorbed by the sensor. The software supervises the sensor to determine end of life by a trouble signal.

The COSTAR® Model 9RV and 9SIR CO Detectors are examples of detectors that use IR CO sensor and rate-of-change technology. During normal operation, the circuit, along with integral low battery detection circuit and annunciator drivers (two LEDs and a piezoelectric buzzer), typically consumes less than 16 microamperes, on average, over time. Quantum Group recommends a rate-of-change approach for improved flexibility and long term reliability. Sample circuits and details of their recommended operating mode are discussed in detail in Sections III-B and C.

B. Sample Circuit and Recommended Operating Mode

Quantum Group's BIOTECH carbon monoxide sensor response is enhanced by the use of a rate-of-change detection circuit and software. The following section discusses the circuit elements and operating mode of a rate-of-change detector utilizing battery power and/or line power.

Battery Powered Detector

A sample circuit diagram for a battery powered rate-of-change CO detector is shown in

Figure 7.

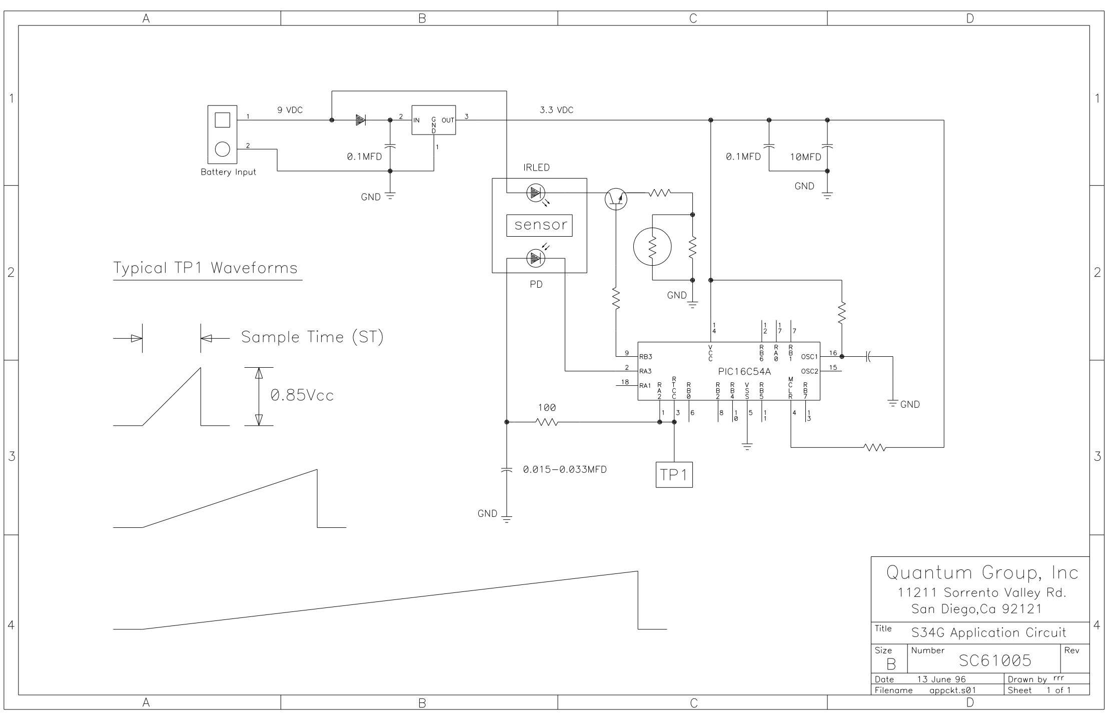


Figure 7. Sample circuit diagram for battery powered IR CO detector.

A voltage regulator provides a stable 3.3 VDC to power the processor, which in this case is a PIC 16C54A. When the temperature is steady, the resistor/thermistor network in the emitter leg of the transistor driving the infrared LED acts like a constant current source, eliminating any variations in light intensity output which might otherwise be imparted by changes in the battery voltage. When the ambient temperature varies, changes in the thermistor's impedance adjust the current supplied to the infrared LED, thus stabilizing the LED's light intensity output.

The photodiode, a Mylar capacitor and the processor comprise a pseudo analog-to-digital (A/D) converter capable of measuring the light transmittance through the sensor with surprising precision. The pseudo A/D converter measures the time needed to charge the Mylar capacitor when the infrared LED is enabled. Initially, before the infrared LED is enabled, any residual charge on the capacitor is discharged to ground through the 100 Ω (Ohm) resistor to pin 1 on the processor. Pin 1 is then configured as input (high impedance state), the infrared LED is enabled through pin 9, and a software timer in the processor is started. Pin 2 on the processor supplies a constant bias voltage to the photodiode. This voltage is very nearly the full value of Vcc since even at the highest level of photodiode current, which can be induced by the light passing through a clear sensor, the voltage drop internal to the processor (from supply pin 14 to the output on pin 2) is minimal. Because the charging current induced in the photodiode is nearly constant, the voltage on the capacitor rises linearly over time. RTCC pin 3 on the processor was designed by Microchip to sense a logic high at 0.85 Vcc (port pins typically operate at 0.6 Vcc). When the ramping voltage on the capacitor reaches 0.85 Vcc, the software clock is terminated and a *Sample Time (ST)* count is thereby obtained. As the three typical TP1 waveforms on the circuit drawing show, the voltage ramp is linear, and the sample time lengthens as the sensor darkens. Finally, the microprocessor is used to collect and process the data supplied by the A/D for the purpose of determining the level of CO concentrations in the surrounding atmosphere.

The data analysis algorithm resident on the processor tracks discrete sample time values measured over time. Since the light output from the IRLED is virtually constant, the only mechanism, by which the sample time can change, is a change in the transmittance of light by the sensor. When CO concentrations in the atmosphere surrounding the sensor increase, the sensor absorbs 940 nm photons, and the iterative sample times measured by the processor lengthen. The processor monitors this sample time rate-of-change and its magnitude can be used to trigger various operational states. The COSTAR® 9RV CO Alarm, for example, annunciates a low-level warning when CO levels are unhealthy and a high-level alarm when levels are an immediate threat to life.

C. System Detector Application Example

Figure 8 is an example of the application of the BIOTECH CO detection technology to a microprocessor based CO alarm designed for the security market. Operation is supervised by a PIC microprocessor. Periodically the PIC performs a self-test to verify normal operation, test the circuit and measure the battery voltage to determine if it needs to be replaced. Faults are issued if any errors are found or the battery voltage is low.

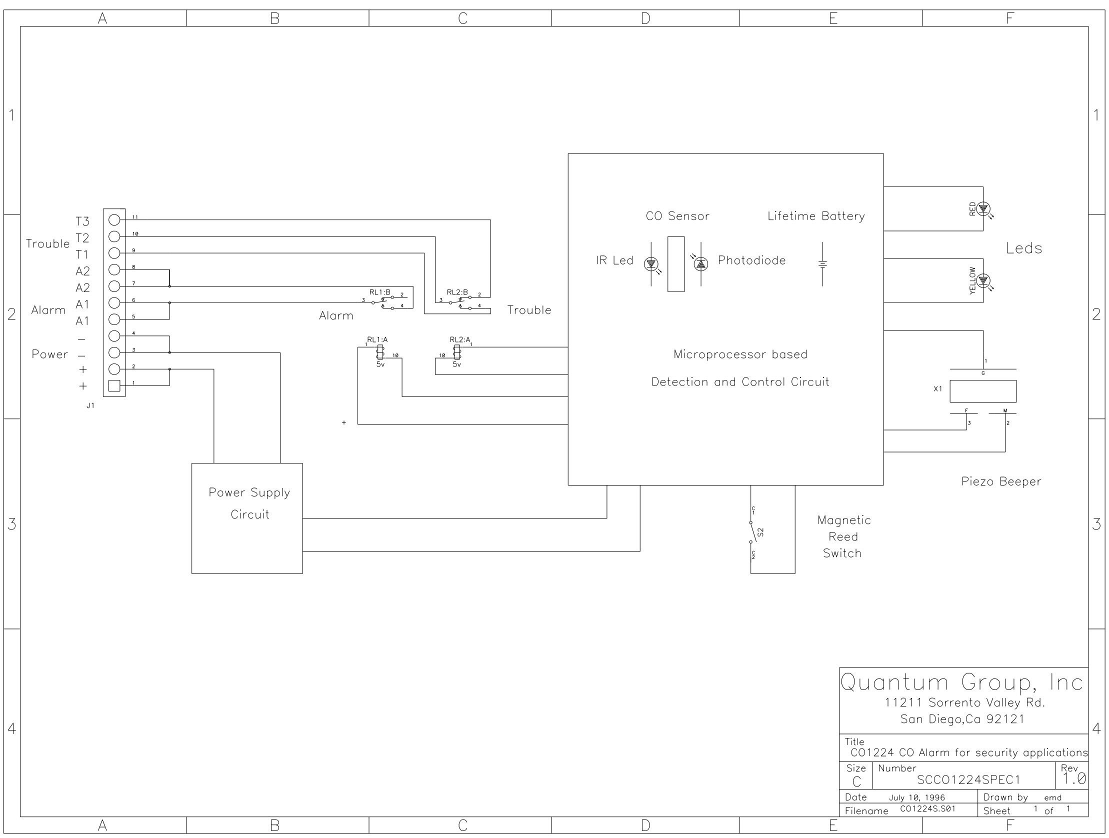


Figure 8. Sample circuit diagram for line powered S34 biomimetic CO detector.

There are several possible arrangements for the supply power. In the present design, the circuit is powered by 9-volt battery. Power consumption is approximately 15 microamps, making it compatible with systems employing smoke detector heads and other security devices. When the voltage of an internal battery drops below a predetermined threshold, a fault signal is issued, indicating that the battery should be replaced.

When power is first applied, the circuit waits 3 seconds for the power supply voltages to reach a steady state, and then performs an A/D and battery test. A single 10 ms beep is then issued, confirming that the test was successfully completed, and signaling the commencement of normal operation.

The detector operates on a 3-second wake up cycle. After 10 wakeups are counted, a measurement cycle is initiated. A sensor reading is made and the value is compared with programmable limits. If the sensor reading is too light or too dark, a fault is indicated. Then the reading is compared with the value from the previous measurement and the difference is stored in one of 5 storage registers. Every measurement cycle, the 5 storage registers are summed and placed in the sum register, and also added to the alarm register. If CO is present, the sensor will begin to darken, and successive readings will increase gradually. The resulting differences will be positive, so the value in the alarm register will increase. An alarm is issued when the value in the alarm register reaches full scale. The type of detector response to CO is determined by the value of the sum register. An intermediate register value is chosen to indicate a health danger from low levels of CO, and a LOW LEVEL WARNING is issued. The TROUBLE RELAY is energized, and the BEEPER sounds and the YELLOW LED flashes for 250 ms five (5) times every three seconds. Larger values in the sum register indicate greater changes in sensor darkening, which could only be due to higher levels of CO, so a HIGH LEVEL ALARM is declared. The RED LED is turned on, the ALARM RELAY is activated and the BEEPER sounds continuously. If the CO is removed, the sensor will begin to regenerate. The values in the sum register will become negative, causing a reduction of the alarm register. Since the sensor will not reverse in the presence of CO, any reduction indicates that the CO was removed, and the alarm will switch from HIGH LEVEL ALARM to LOW LEVEL WARNING. Once the reduction is confirmed by successive measurements, the LOW LEVEL WARNING will be canceled, and the alarm will resume normal operation. When the ALARM RELAY is activated, it is latched on, and may be cleared only by dropping the system power momentarily.

The sample circuit has a special silence feature. A silence period is initiated by a brief dropping of the system power. A LOW LEVEL WARNING is indicative of lower values of CO so dropping the power will silence the beeper for 2 hours. The YELLOW LED will remain on. The silence period is repeatable. In HIGH LEVEL ALARM, the silence period may have 2 different values. For moderate values of CO, the silence period will last for 30 minutes. If the CO concentration is too high, the silence period will last only 4 minutes. In either case, only one silence period is allowed in the case of HIGH LEVEL ALARM.

As outlined above, each sensor measurement is compared with upper and lower limit values. An error is reported as a fault. In addition, proper A/D operation is verified every 20 operating cycles, or about every 10 minutes. The integrating capacitor is discharged, and then allowed to charge by means of the current supplied by a test resistor. The timer makes a measurement as if a sensor was present and the resultant number must lie within programmed limits. These checks for excessive leakage or shorting of the measurement components. Any failure sets the fault flag. After the A/D test, the battery is tested. The voltage detector monitors the battery voltage. If a low battery condition is detected, the TROUBLE RELAY is activated, and a single YELLOW LED flash is issued every 30 seconds. After an automatic 72-hour delay, the BEEPER begins chirping once every 30 seconds, along with the YELLOW LED. If any fault is detected, the TROUBLE RELAY is energized, and the YELLOW LED flashes and the BEEPER beeps for 250 ms twice every 30 seconds. If the power is dropped momentarily, a silence delay of 24 hours is initiated.

In addition, a manual test mode is provided. Placing a magnet along the left side of the alarm enters the test mode. The YELLOW LED will turn on, the RED LED will blink and one beep will be issued. The magnet may then be removed. A sensor reading is taken, and then a small amount of current is reduced from the infrared LED current. Successive measurements are made from the reduced light. This special "starved" mode simulates a CO exposure. The measurement rate is increased to a sample every 3 seconds, and the software accumulation algorithm operates in the normal way, with the "starved" data. An alarm will occur within about 6 to 10 cycles, sound for 3 seconds and then reset and then normal will be resumed. The alarm relay will remain latched, and may be cleared by momentarily dropping the power.

All of the RELAY, infrared LED and BEEPER functions are software programmable, and may be modified as desired. For factory tests, the PIC transmits information concerning the current alarm operation in a special proprietary serial format. A small reader box converts the data to RS 232 format and makes it available to a computer.

Other Detector Designs

A "plug-in" CO detector using a microprocessor may be designed for the residential market. The circuit used would be nearly identical to the circuit described above, but with the relays removed.

Quantum Group also makes IR detectors using a microprocessor that shut off gas powered appliances if CO is detected. The 9SSO and 12-24SIR family of CO detectors is designed specifically for safety shut off systems in particular product applications. The safety shut off detector systems are used in hunting cabins to shut off gas powered refrigerators.

IV. Carbon Monoxide Sensor Test Data

The following test data shows the performance and reliability of the SIR carbon monoxide sensor.

Performance

The performance of two thousand one hundred SIR sensors exposed to 100 ppm CO under ambient conditions was determined. Tests were conducted over a six months period and the results are summarized below:

Average time to alarm:	49.7 minutes
Standard deviation	6.8 minutes
Percentage within 1σ	78.3%
Percentage within 2 σ	90.2%

The distribution curve in Figure 9 represents a typical production lot of S34 biomimetic carbon monoxide sensors. The distribution curve is a measure of individual sensor time responses using the fixed alarm point of 30% light transmission. The time response is defined as the time an individual sensor takes to darken to 30% light transmission during an exposure to 100 ppm CO.

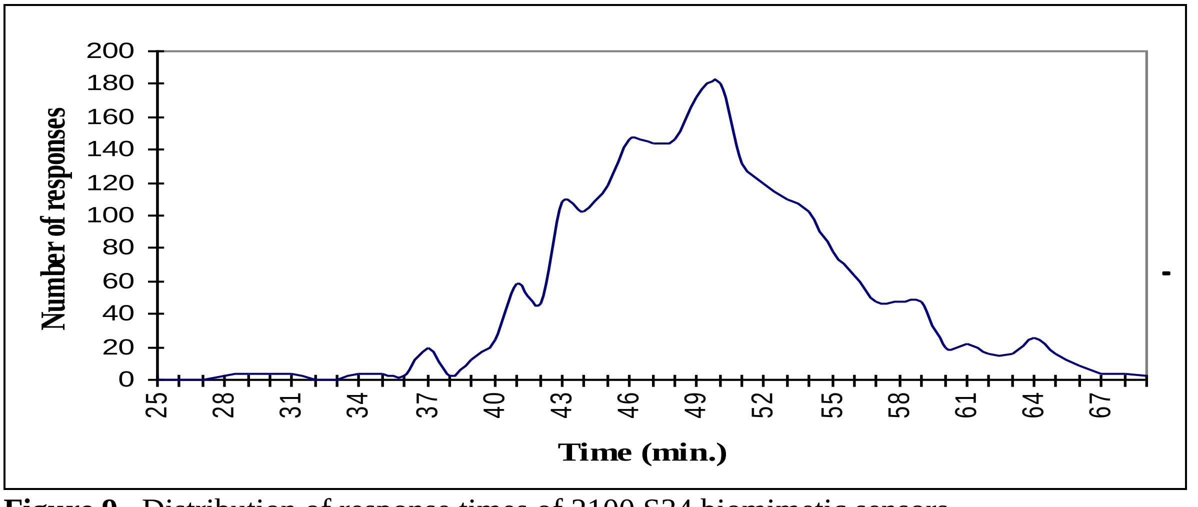


Figure 9. Distribution of response times of 2100 S34 biomimetic sensors.

The process control chart is used for tracking the S34 biomimetic CO sensor production lot variations. It is used as a quality tool to evaluate the manufacturing process. Figure 10 shows a well defined manufacturing process that is kept within the three standard deviation limits.

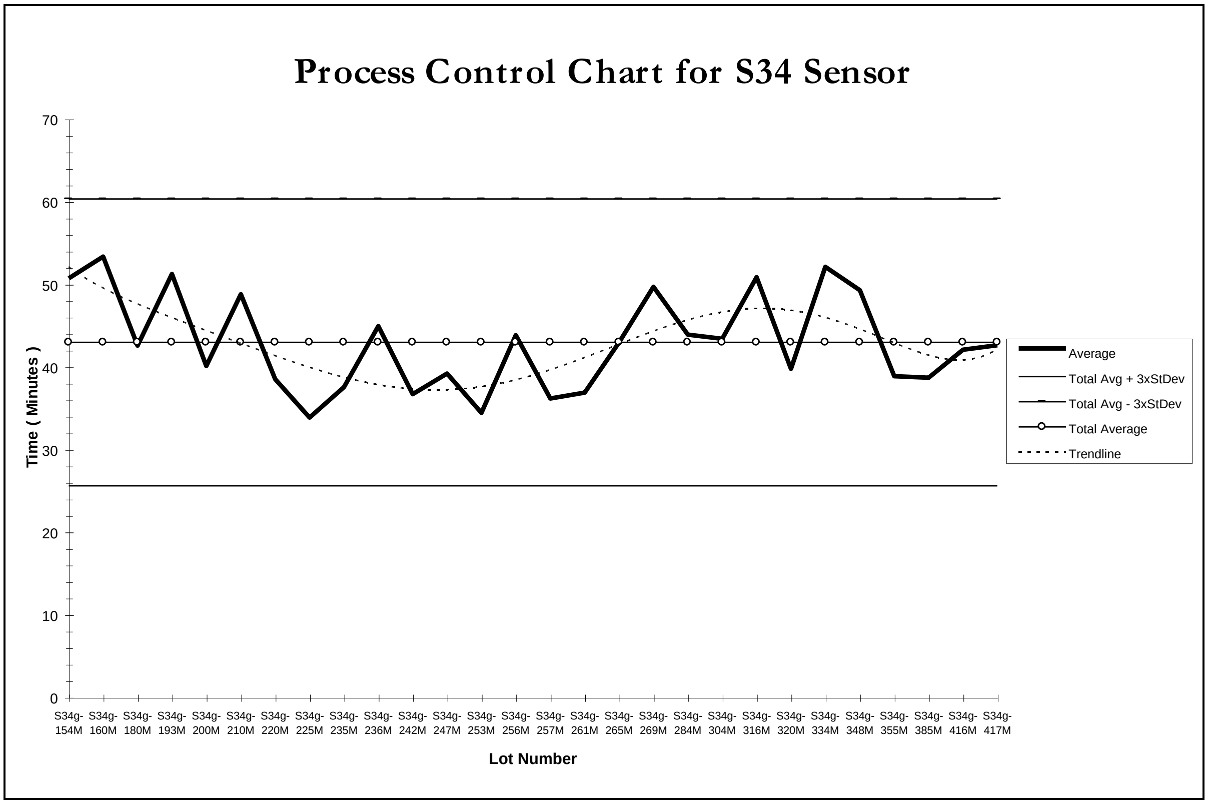


Figure 10. The process control chart shown above is the plot of average time responses for production lots, using the fixed alarm point of 30% light transmission.

V. Regulatory Compliance and Independent Certification

Quantum Group's alarms and controls are approved by a variety of agencies. The SIR sensors system (SIR carbon monoxide sensor combined with Quantum Group's reservoir and getter system) and microprocessor and software technologies are fully compliant and exceed UL-2034 specifications in effect on May 1, 2003 as well as CSA 6.19-01 and the US Consumer Product Safety Commission's recommendations.

These technologies are embodied in Quantum Group's COSTAR Carbon Monoxide Detector, Model 9SIR, 12SIR, 12/24SIR, 9RV and 12RV, 12Marine and 9Marine and other COSTAR Products. These products are the first UL approved biomimetic carbon monoxide detectors using rate-of-change microprocessor technology, end-of-life sensor monitoring and advance PVMA getter system.

Compliance with other national and international standards can be achieved to satisfy customer needs. Carbon monoxide detectors can be designed to meet either the Japanese standard for CO detectors, or the British standard for CO detectors using S50 and S5K sensors, respectively. The COSTAR Model 9SIR was UL and CE[1] approved and 9RV was CSA and UL 2034 approved. Please contact Quantum Group for further information. (See Appendix D).

1 Community European

VI. Intellectual Property

As an innovator in the field of carbon monoxide detection, Quantum Group's technology is the subject of numerous pioneering patents and pending patent applications. A partial listing of relevant documents is given below:

1. TOXIC GAS DETECTOR SYSTEM HAVING CONVENIENT BATTERY AND SENSOR REPLACEMENT, United States Patent number 5,280,273, Jan. 18, 1994
Mark K. Goldstein, Ph.D.
2. METHOD FOR ENHANCING THE RESPONSE OF A BIOMIMETIC SENSOR, United States Patent number 5,573,953, November 22, 1996
Earl M. Dolnick, Glenn Marnie and Ivan Nelson
3. PHOTON ABSORBING BIODERIVED ORGANOMETALLIC CARBON MONOXIDE SENSORS, United States Patent number 5,618,493, April. 8, 1997
Mark K. Goldstein, Ph.D., Michelle S. Oum and Kathleen L. Kerns
4. AIR QUALITY CHAMBER: RELATIVE HUMIDITY AND CONTAMINATION CONTROLLED SYSTEMS, United States Patent number 6,251,344 B1, Jun. 26, 2001
Mark K. Goldstein, Ph.D.
5. Method and apparatus for Determining the Concentration of a Target Gas Using an Optical Gas Sensor System, United States Patent number 6,096,560, Aug. 1, 2000
6. Target Gas Detection System with Rapidly Regenerating Optically Responding Sensors, United States Patent number 6,172,759, Jan 9, 2001
7. Nano-Size Gas Sensors Systems, Mark K. Goldstein, Ph.D., Nov. 16, 2004 United States Patent Number 6,819,911 B1.

THERE ARE NUMEROUS PATENTS AND PATENTS PENDING.

VII. Contact Information

For further sensor or detection technology information, please contact:

Mark Goldstein, Ph.D.
President
mgoldstein@QGinc.com

David Saucedo
Customer Service
CS@QGinc.com

Quantum Group Inc.
6827 Nancy Ridge Drive.
San Diego, CA 92121

Phone:	(800) 432 - 5599 (858) 566- 9959
Facsimile:	(858) 566-9974
E-mail:	mgoldstein@QGinc.com

or visit our Internet/World Wide Web Site at: http://www.QGinc.com and www.quantumGuardian.com

Printed Attachments and Appendices are available by Mail upon request.