Ver.2110

# Technical Information

(Electrochemical CO Gas Sensor)

# Model　NAP－505


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# Contents

## (1) Electrochemical sensor

### 1-1 Detection principle

Electrochemical sensor NAP-505 is composed of working electrode which oxidation and reduction takes place, counter electrode which oxidation and reduction also occurs at the same time and reference electrode which can independently monitor the potential difference at working electrode. It is expressed as model case described in the right.

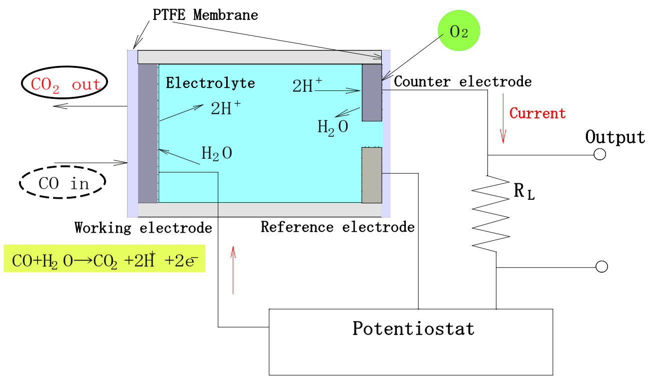



Fig.1 Detection principle

In case of detection of CO, following reaction should occur on the surface of working electrode.

$$CO+H_2O\rightarrow CO_2+2H^++2e^-$$

In this case, when working electrode and counter electrode is connected on the circuit, electron generated moves to counter electrode from working through circuit, and proton moves to counter electrode to accept electron through electrolyte. And then, hydrogen reacts with oxygen to be water.

$$2H_{+}+O_2/2+2e^-\rightarrow H_2O$$

Such an electrochemical sensor, chemically reactive energy which is generated by oxidization-reduction is transferred to electric energy, detect the target gases. Reaction model is in fig.1, and total chemical reaction is as follows.

$$CO+O_2/2\rightarrow CO_2$$

In general, generated voltage decrease easily takes place owing to polarization at near working, and inner resistance which is generated while proton moves in electrolyte in such reaction process. Then, such voltage decrease is large in higher concentration, and is one of important factor to avoid excellent linearity. Reference electrode is workable to maintain current generation in spite of voltage decrease of working, and it is possible to create current between working and counter in proportion to gas concentration. Such type gas sensor having control function of potential difference is named 3 electrode cell type, and it is widely available for many application like industrial use because of more excellent stability.

On the other hand, 2 electrode cell type without reference electrode actually exists, and it is applicable for residential application which does not require excellent detection accuracy because of cheaper cost, however it is inferior to 3 electrodes cell type in linearity, stability, accuracy and etc.

**1-2 Excellent features and defect of conventional type**

Electrochemical gas sensor has the following excellent features in comparison with semi-conductive type and catalytic type.

① **No requirement of electric power → Possible to drive by battery**
② **Liner until high concentration → Wide detection range**
③ **Very little on mechanically weak point → Resistive to drop, shock, vibration**
④ **No affection to silicone poisoning → Stable for a long term**
⑤ **No influence to humidity variation → Excellent repeatability, stability**

On the other hand, conventional type electrochemical cell was badly reputated that it is very expensive because of complicated structure, lifetime of electrode is very short, and electrolyte is easily leaked, then it was used to be employed only for industrial use which maintenance can be periodically available. However, Nemoto Sensor Engineering Co., Ltd. has developed NAP-505 sensor without electrolyte leakage with cheapest price and smallest size for residential application 2001, and is available in the market from 2002. Defects of conventional type were improved as follows.

- Short lifetime → **Lifetime of over 6 years by improvement of electrodes**
- Easy leakage of electrolyte → **Without leakage by specialized structure**
- High cost →
- Many parts and complicated structure → **Reduction of number of parts and simplified structure**

**Create excellent performance**

↓

**Low cost**

For the reference, comparison between typical detection principles for the detection of CO is shown in the table 1.

| Detection Principle / Items | **Electrochemical type** | **Semi-conductive type** | **Bio-mimetic type** |
|---|---|---|---|
| **Gas sensitivity**<br>・ **Linearity** | **Excellently linear to gas conc.** | No linearity | No linearity |
| ・ **Response, recovery** | Fast | **Very fast** | Exceedingly slow |
| ・ **Selectivity** | **Very excellent** | Very bad | Good |
| ・ **Humidity dependence** | **No influence** | Large dependence | Very sensitive<br>（Cause of false alarm） |
| **・Durability on mechanical** | Excellent<br>（No weal point mechanically） | Bad<br>（Easy break-down of wire） | Excellent |
| **・Power consumption** | **Electric power is not necessary.** | It needs large power.<br>For example,<br>TGS203: 138mW<br>TGS2442: 14mW （Pulse driving） | Fairy low<br>（Power for LED） |

Table 1. Comparison of detection principle

## (2) Characteristics of NAP-505

### 2-1 Features

#### 2-1-1 Downsizing

NAP-505 is smaller than the others as specified in the table 2. Especially, thickness of 8mm is the smallest in the world, and design of CO gas detector or CO gas densitometer became easier.

Table 2. Volume of various kinds of CO gas sensor ($cm^3$)

| NAP−505 | M | F | S |
|---|---|---|---|
| 2. 4 | 11. 7 | 7. 3 | 5. 6 |

#### 2-1-2 Direct soldering to pins

Conventional sensor can not be soldered to PCB directly because plastic enclosure is influenced by heat at soldering, consequently electrolyte may be leaked by plastic transformation.

However, NAP-505 can be directly soldered to pins since special structure around pins are adopted in order to create excellent heat radiation from pins, additionally high temperature durable plastic m-PPE is also adopted. Regarding conventional sensor, contact defect between sensor pins and socket or sensor detachment from sockets were possible. But, since NAP-505 can be soldered to PCB directly, durability against mechanical vibration or contact defect by corrosion becomes improved.

#### 2-1-3 Air-bent function

Since the electrolyte employed in electrochemical cell is highly hygroscopic, quantity of electrolyte is dependent on the humidity of installation atmosphere. This was a cause of leakage because of change of electrolyte quantity by change of inner pressure.

NAP-505 has a air-bent function to maintain inner pressure to be stable in spite of small size, and then it is available in strict circumstance which temperature and humidity are changed a lot.

### 2-1-4 Detection performance of high concentration of CO

Since the electrode technology for industrial use is applicable to NAP-505, gas detection ability is almost the same as industrial sensor, and it can detect CO from several ten ppm to around 1% with excellent accuracy. Figure 2 shows the linearity of CO till 1%, and it seems quite excellent.

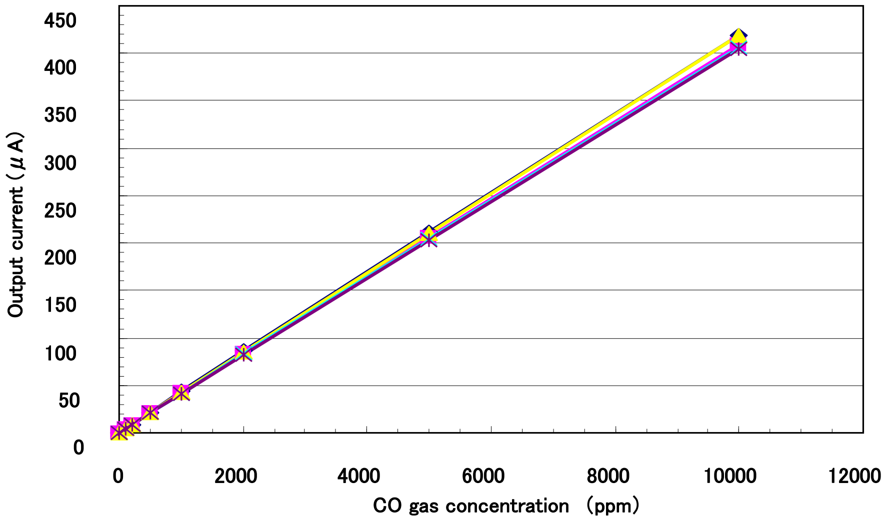



Fig.2 Linearity to CO gas

### 2-1-5 Long term stability

Long term stability of developed sensor in 2000 shown in the figure 3 employs our own electrodes as the same as NAP-505, and it shows very stable characteristics for over 6 years.

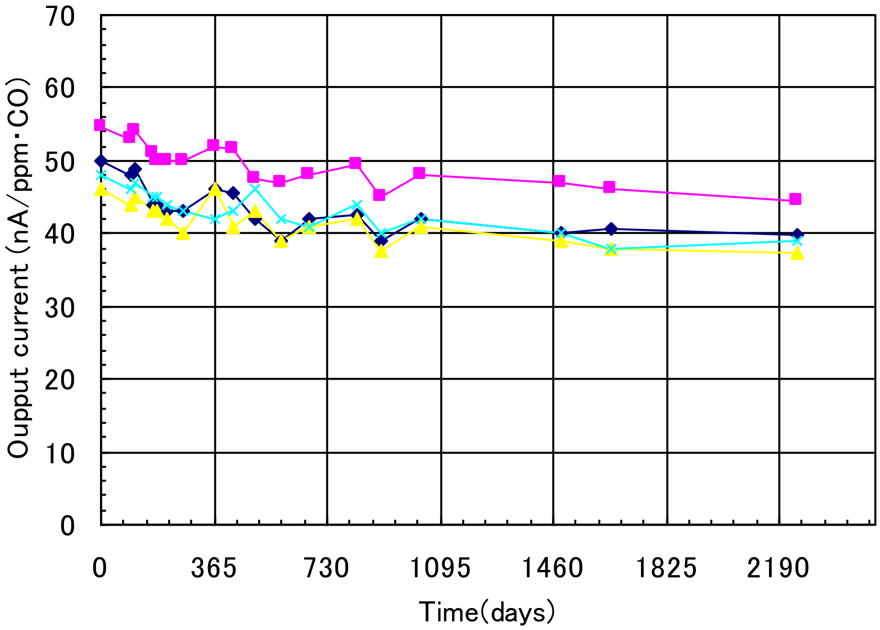


Fig.3 Long term stability of sensor developed in 2000 (Reference data)

**2-2 Structure**

Figure 4 show the sectional structure of NAP-505. Working, counter and reference are enclosed with separator, air-bent sheet and electrolyte in plastic enclosure. Detected gas including CO is inhaled through capillary to preliminary chamber having charcoal filter, and noise gases are excluded. And then, CO gas reaches to working electrode by dispersing PTFE sheet, then CO gas is oxidized. This capillary is protected by special filter having function to avoid water and dust.

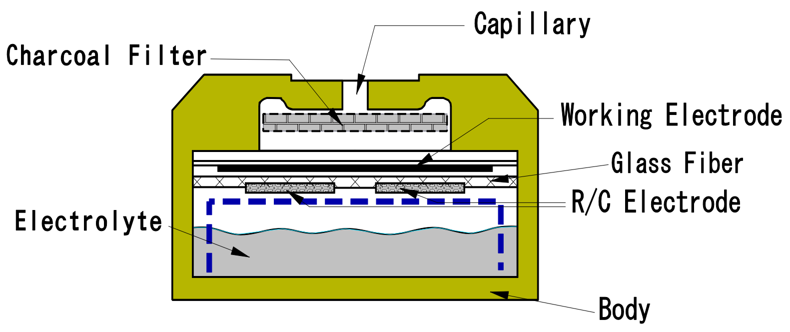



Fig.4 Sectional structure of NAP-505

**2-3 Conformity to various standards**

Excellent characteristics of NAP-505 are in conformity to various kinds of standard not only in Japan but also overseas.

Component recognition of UL (Nov., 2004, UL File No.E2406971)

Recognitions below described were already passed.

1) Normal Operation (UL 2075)
2) Sensitivity (UL 2075/with UL 2034 CO Sensitivity Limits)
3) Overload (UL 2075)
4) Circuit Measurements (UL 2075)
5) Selectivity (UL 2075 and BS EN 50291)
6) Combustion By-Products (CSA 6.19-01 and BS EN 50291)
7) 15ppm CO for 1 year Operation (UL 2075)

Conformity to EN50291 (Taiwan customer's detector was listed in 2007)

Conformity to the standard of incomplete combustion alarm for commercial use (JIA)

Conformity to the standard of incomplete combustion alarm for battery operation (JIA)

## 2-4 Performance

### 2-4-1 Specification and features

Gas sensitivity

| | |
|---|---|
| Detected gas | CO |
| Recommended detection range | 0 - 1000ppm |
| Maximum overload | 5000ppm |
| Output current | 40 ± 10 nA/ppm |
| Repeatability | Less than 2% |
| Zero offset in pure air at 20 degree C | Less than ±5ppm equivalent |
| Zero offset drift in long term | Less than ±5ppm |
| Response time ($t_{90}$) | Less than 30sec. |
| Temperature dependence of zero offset | Less than ±10ppm (-30 - +50degree C) |
| Sensitivity drift | Less than 5% per year |
| Expected lifetime | 7.5 years after production date |

( The above shows the value at 20 degree C, 60%RH, 1atm.)

Conditions in operation and storage

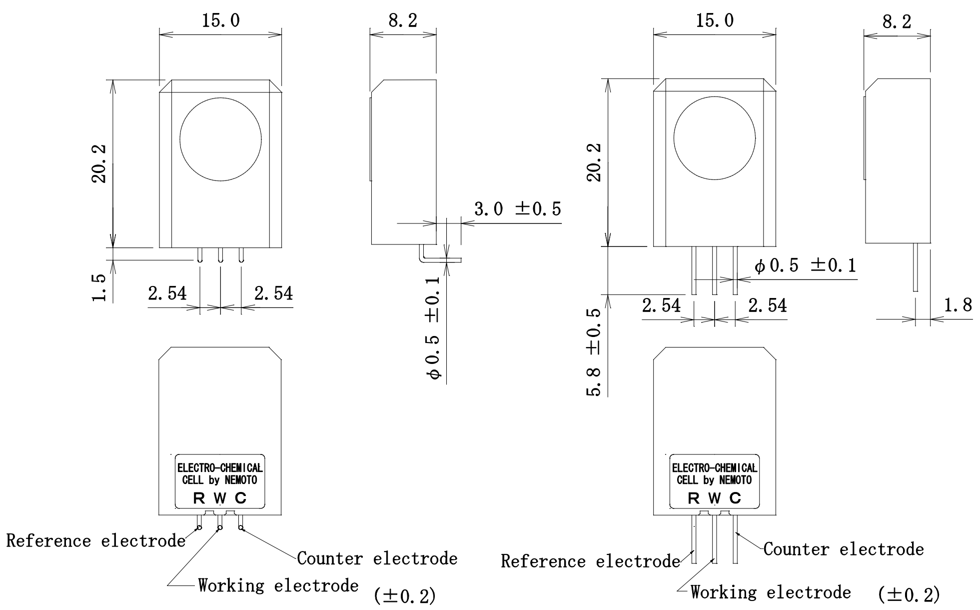
| | |
|---|---|
| Temperature in operation | −30～50 degree C (continuous)<br>−40～70 degree C (intermittent) |
| Humidity in operation | 10～95%RH |
| Pressure in operation | 1atm±10% |
| Recommended load resistor value | 10 ohm |
| Recommended temperature in storage | 0 ～20 degree C |
| Storage term | Less than 6 months |

Enclosure material

| | |
|---|---|
| Enclosure material | m-PPE |
| Cap color | Grey |
| Body color | Black |
| Weight | Approx. 2.0g |

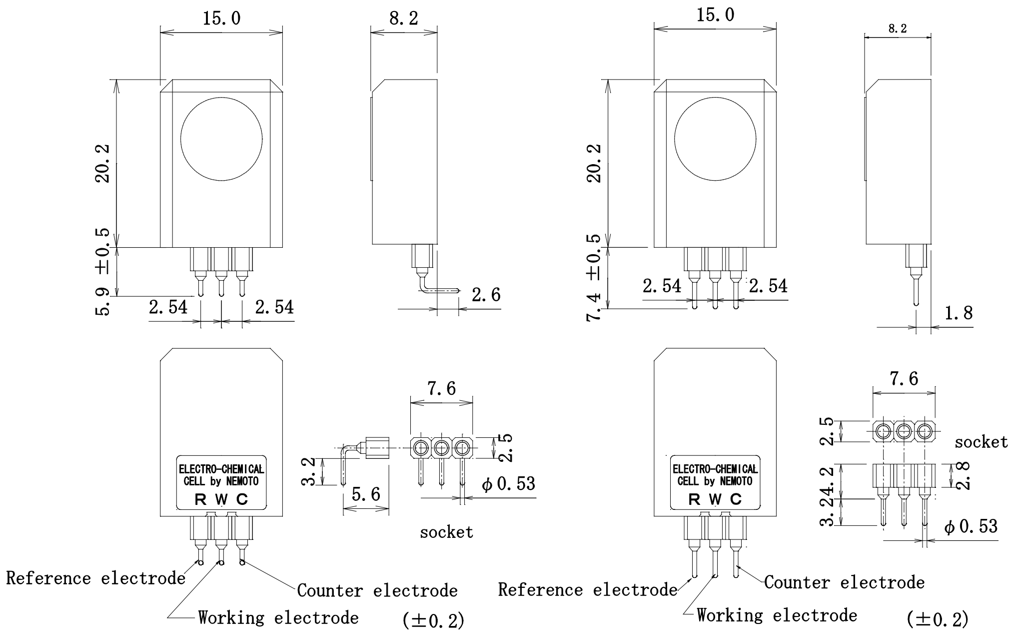
## 2-4-2 Shape

### Direct Soldering Models




NAP-505R〔right angle pin〕　　NAP-505S〔straight pin〕

### Socket Models




NAP-505RS〔right angle pin〕　　NAP-505SS〔straight pin〕

### 2-4-3 Gas sensitivity

Figure 5 shows the sensitivity characteristics to typical gases.

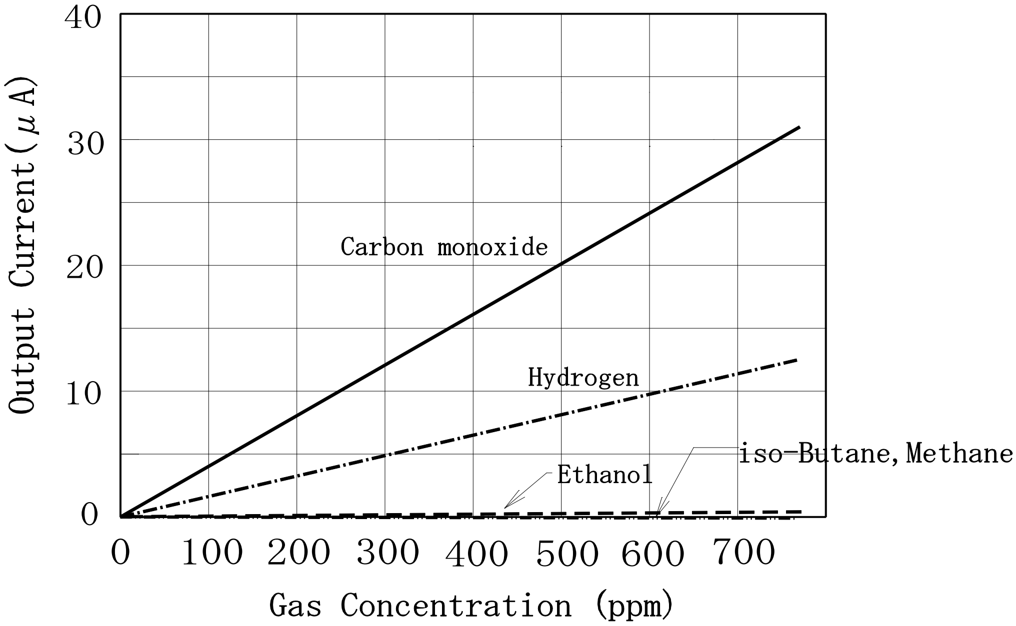



Fig.5　Gas sensitivity characteristics

### 2-4-4 Linearity

Figure 6 shows typical linearity characteristics of NAP-505.

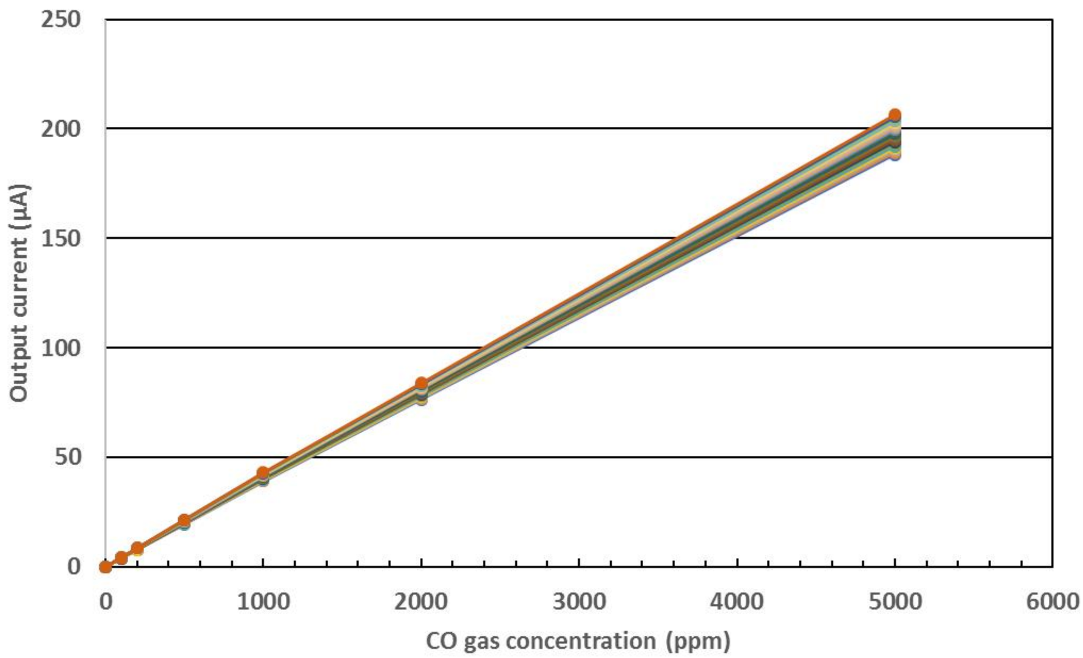



Fig.6　Linearity characteristics

### 2-4-5 Selectivity

NAP-505 possesses conformity to selectivity which international standards require, and table 3 shows the selectivity to typical noise gases defined in UL2034 and EN50291.

Table 3. Gas selectivity

| Test gas | Relative sensitivity (CO is 100) |
|---|---|
| CO | 100 |
| Hydrogen | Less than 40 |
| Methane | 0 |
| Iso-Butane | 0 |
| Carbon dioxide | 0 |
| Carbon di-sulfate | 0 |
| Hydrogen sulfide | 0 |
| Nitrogen oxide | Less than 60 |
| Nitrogen dioxide | Less than 10 |
| Ammonia | 0*** |
| Ethyl acetate | 0*** |
| Di-chloromethane | 0*** |
| Heptane | 0*** |
| Toluene | 0*** |
| IPA | 0*** |
| Ethanol | Less than 2* |
| Hexa-methyl di-siloxan | 0** |

Exposure time :* 30 minutes ** 40 minutes *** 2 hours

### 2-4-6 Response characteristics

Figure 7 shows the typical response and recovery characteristics to CO gas on NAP-505.

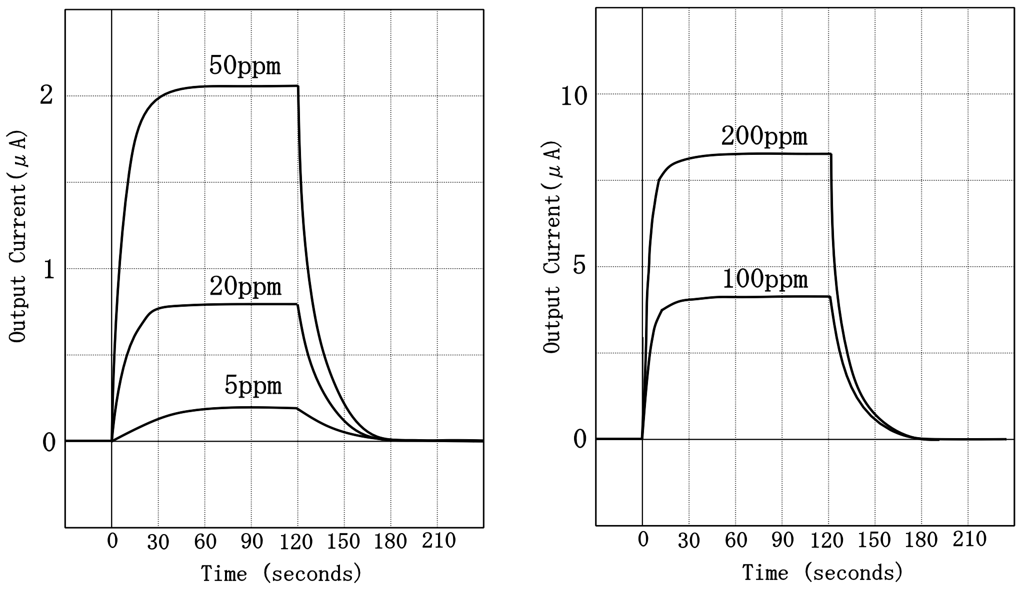



Fig. 7 Response and recovery characteristics of NAP-505

### 2-4-7 Temperature dependence of response characteristics

Response speed depends on ambient temperature, and table 4 shows the temperature dependence of response characteristics (Typical) from -20 to +40 degree C.

Table 4. Temperature dependence of response characteristics

(CO gas : 200ppm)

| Response | Response time (sec.) | | | | |
|---|---|---|---|---|---|
| | -20 degree C | -10 degree C | 0 degree C | 20 degree C | 40 degree C |
| T 60 | 6 | Less than 5 | Less than 5 | Less than 5 | Less than 5 |
| T 90 | 52 | 30 | 18 | 12 | 9 |
| T 95 | 112 | 60 | 36 | 21 | 12 |

### 2-4-8 Pressure dependence of CO sensitivity

Figure 8 shows the typical barometric pressure dependence of the CO sensitivity of NAP-505.

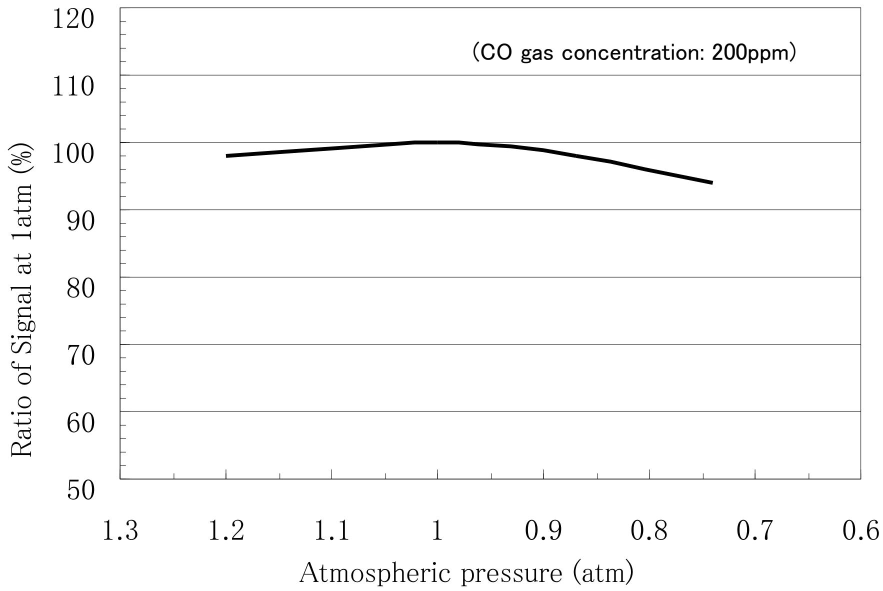



Fig.8 Pressure dependence of CO sensitivity

### 2-4-9 Initial action

Output signal of NAP-505 recovers to zero level for a short time in case that it is stored for a long term in air. Figure 9 shows the initial action (initial stabilization time) in case that the sensor is stored for 1 month normal circumstance, and figure 10 shows it in case that it is stored for 6 months.

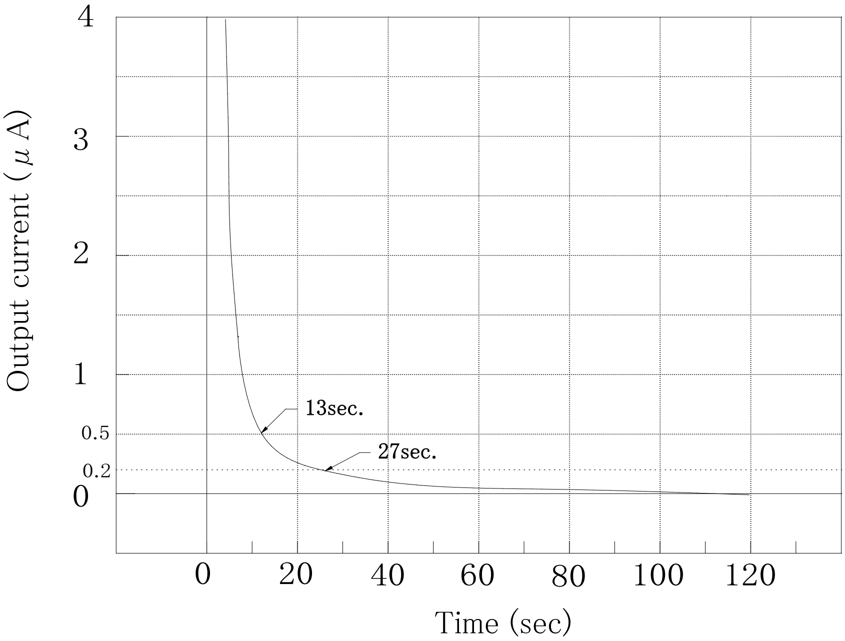



Fig.9 Initial action of NAP-505 stored for 1 month

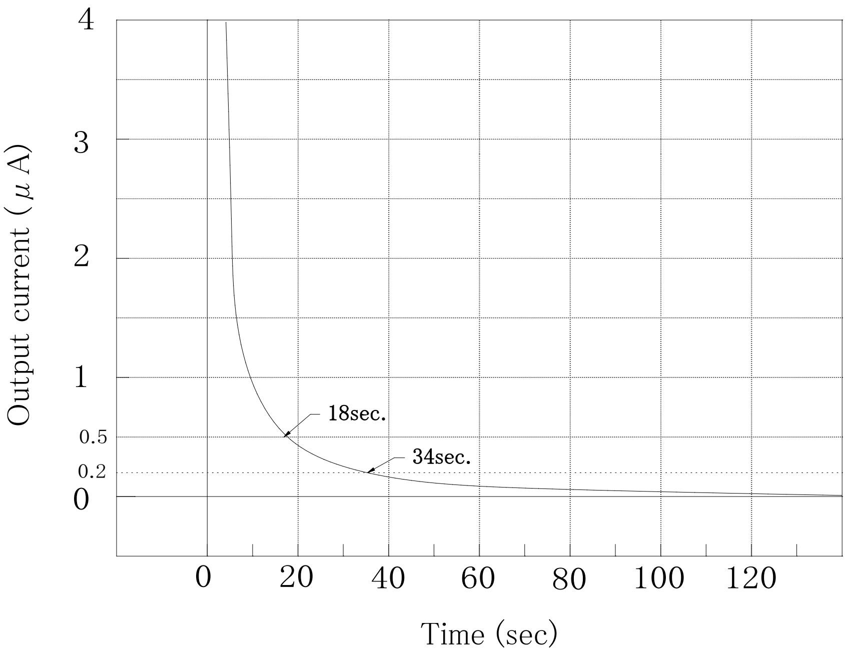



Fig. 10 Initial action of NAP-505 stored for 6 months

**2-4-10 Influence of wind speed on CO gas sensitivity**

Normally, gas sensitivity of NAP-505 is defined in case that CO gas is injected to capillary by natural diffusion. However, since inhalation volume increases in case of high wind velocity, sensitivity is dependent on wind velocity. Figure 11 shows the wind velocity dependence to sensitivity till 2m/sec.

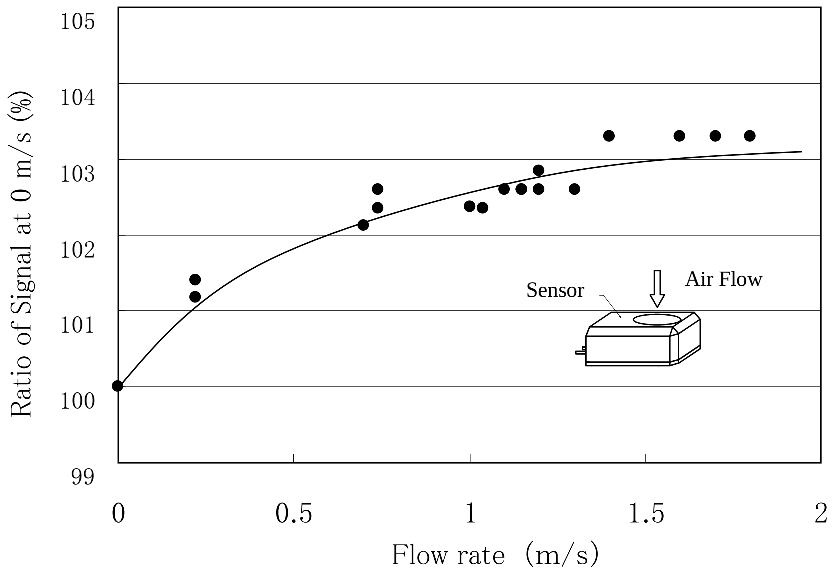



Fig.11 Wind velocity dependence

**2-4-11 Temperature dependence**

Figure 12 shows the temperature dependence of NAP-505. Maximum and minimum relative sensitivity value from -20 to +50 degree C is revealed when the value at +20 degree C is 100. Temperature compensation is necessary at actual application, and circuit diagram is shown in item 2-9.

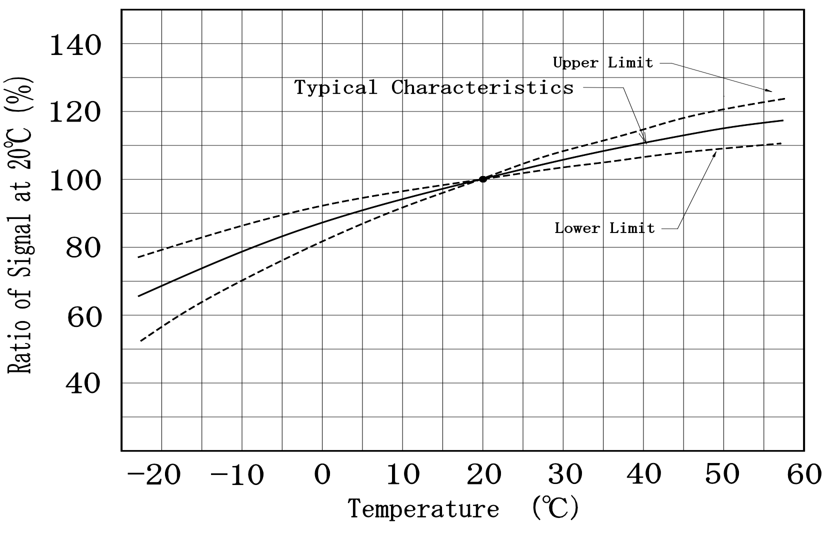


Fig.12 Temperature dependence

**2-5 Characteristics on UL20341 and UL2075**

**2-5-1 Continuous exposure of 15ppm of CO for 1 year**

At component recognition of UL, exposure test in 15ppm of CO for 1 year was implemented on NAP-505. Then, the results are shown in the figure 13, and the gas sensitivity to CO before test and after test are also shown in the table 5.

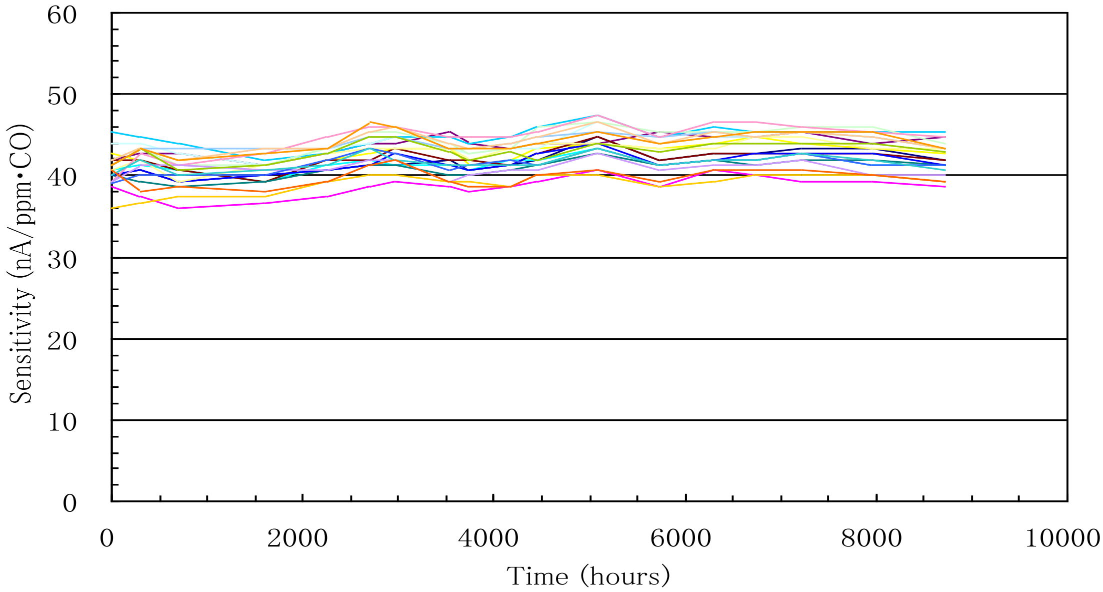



Fig. 13 Continuous exposure test in 15ppm of CO for 1 year

Sensitivity before test and after test were investigated on each CO gas concentration designated in UL2034, and the results are in the table 5. From the results, it was found that there is no change in sensitivity characteristics.

Sensor samples : 24pcs.

Temperature during test : 25+/-3 degree C

Humidity during test : 50+/-20%RH

Table 5. Sensitivity characteristics before test and after test

Dimension : nA/ppm of CO

| CO gas concentration (ppm) | 30 | 70 | 150 | 400 |
|---|---|---|---|---|
| Initial sensitivity (Measured in 18th, Oct., 2003) | 40.3 | 40.5 | 40.1 | 40.9 |
| Sensitivity after test (Measured in 29th, Oct., 2004) | 41.4 | 40.2 | 39.8 | 39.4 |
| Change ratio (%) | +2.7 | -0.7 | -0.7 | -3.7 |
| Distribution : Max/Min(%) | +7.6/+2.4 | -3.6/+0.3 | -3.2/+0.3 | -6.4/-2.8 |

## 2-6 Characteristics on EN50291

### 2-6-1 Exposure test of 5000ppm of CO

In EN50291 standards, CO gas sensor shall recover to initial stage shortly in clean air after the sensor is exposed in 5,000ppm of CO gas for 15min. Regarding some of sensor which is 2 electrodes type, output signal has gone to the direction of negative side after exposure in 5000ppm of CO, and does not recover soon. It does not comply with EN50291. On the other hand, output of NAP-505 recovers very soon after exposure in 5000ppm of CO for 15min., and it is ready to detect CO as expressed in the figure 14.

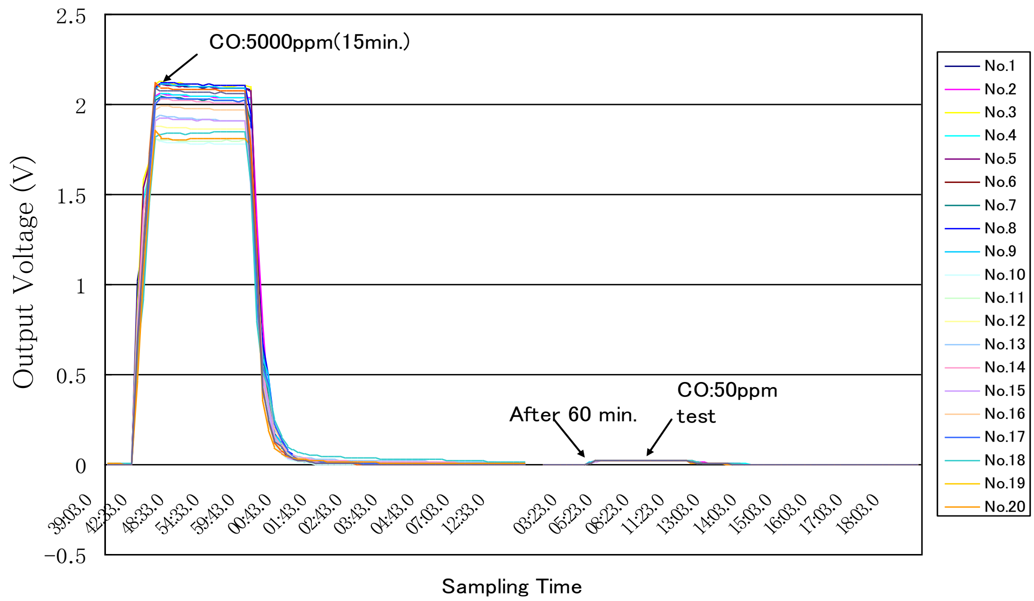



Fig.14 Exposure test in 5000ppm of CO fro 15min. (EN50291)

The vertical axis in the figure: Output voltage directly indicates the output voltage (V) of the NAP−505 basic measurement circuit. When converting this to the output current value Iout,
Iout = output voltage / $10^4$.

## 2-7 Long term stability

### 2-7-1 Stability in clean air (n=20pcs.)

Figure 15 shows the stability of zero offset. Since output signal is a little influenced by noise level CO gas, zero offset is bit fluctuated. However, as the fluctuation is less than 100nA which corresponds to less than 3ppm of CO, NAP-505 maintains excellent features for a long time.

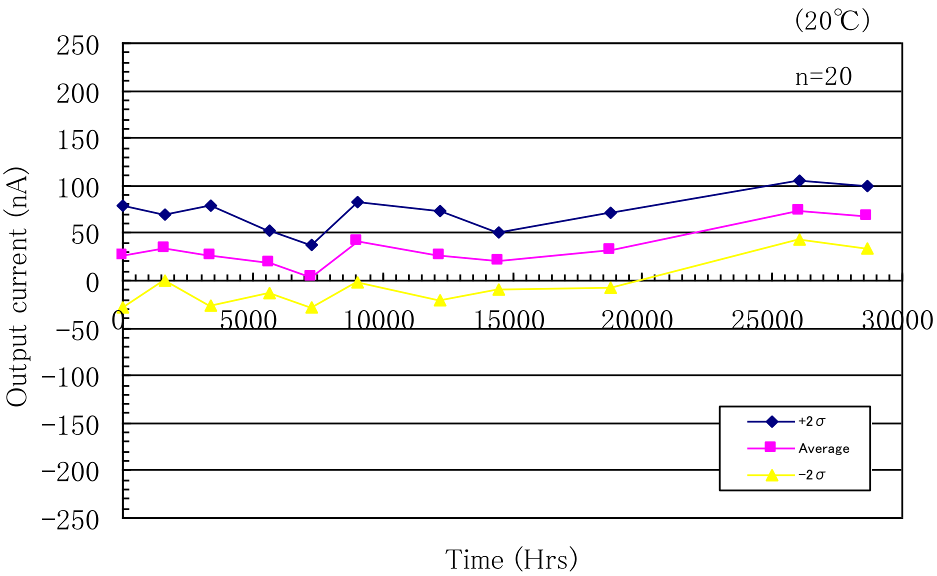



Fig. 15 Stability of zero offset

### 2-7-2 Stability of CO gas sensitivity (n=80pcs.)

Figure 16 shows the stability of sensitivity to CO. There is no tendency on sensitivity, and it keeps excellent stability for over 9 years.

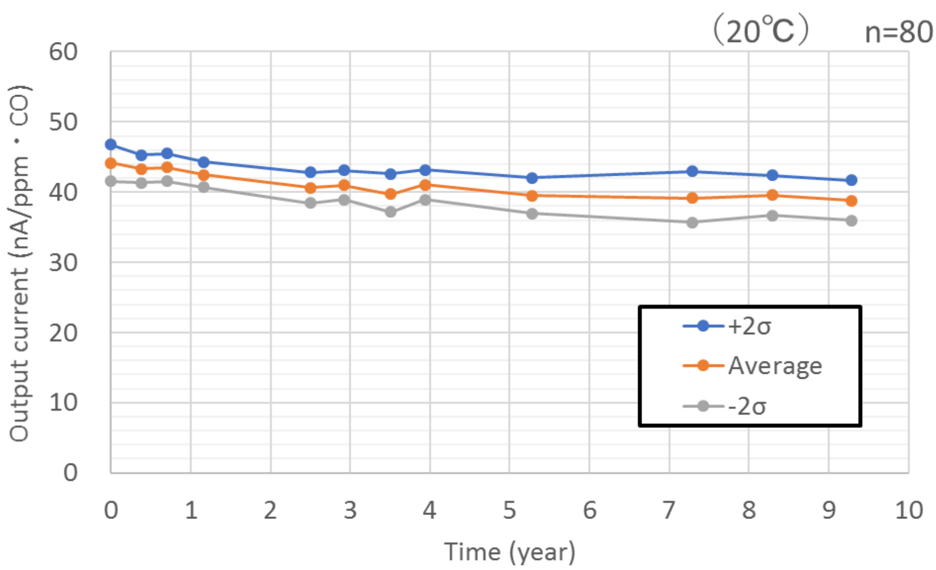
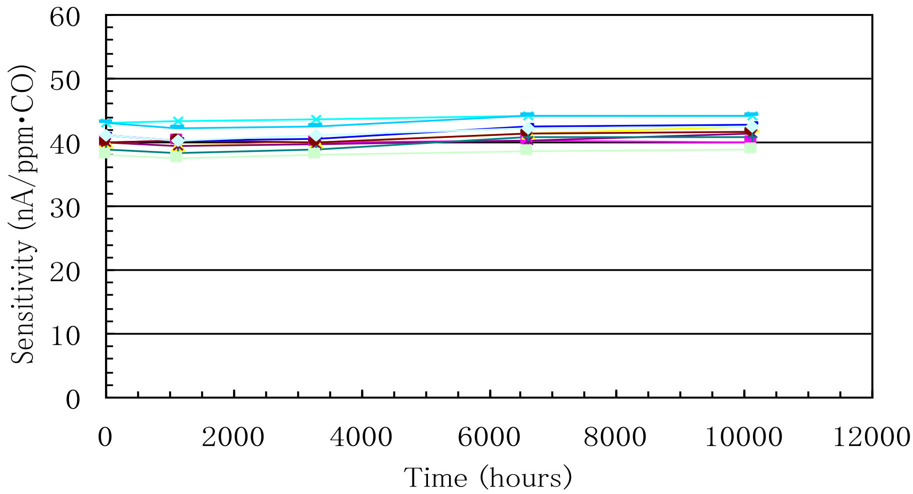


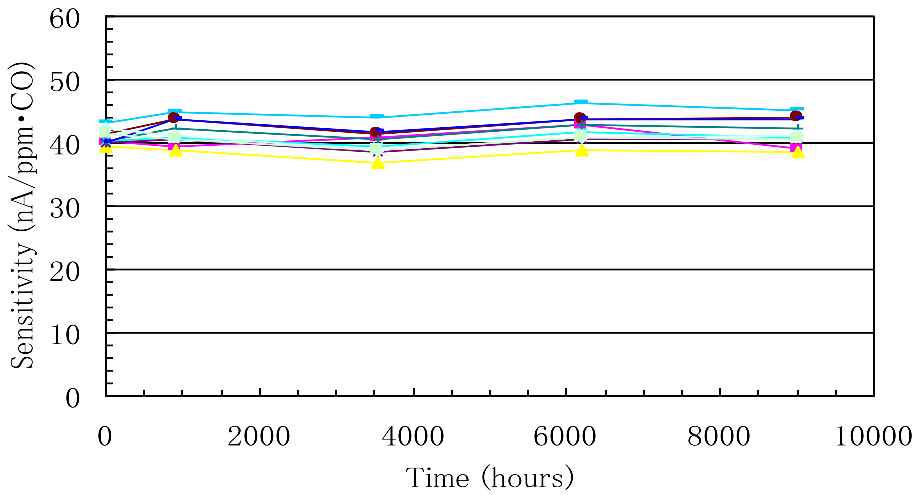
Fig. 16 Stability of sensitivity

**2-7-3 Stability of production lots (Sensitivity stability)**

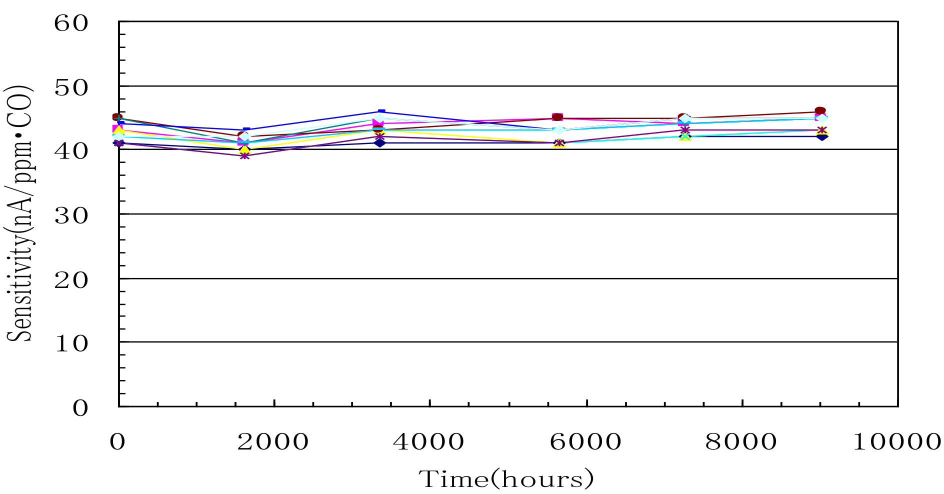
Production lot :A




Production lot :B




Production lot :C



## 2-8 Durability

### 2-8-1 Storage durability in high temperature and high humidity

Figure 17 shows the storage durability in high temperature and high humidity, and table 7 shows the sensitivity comparison before test and after test. It was found that NAP-505 maintains excellent durability for a long time, and there was no sensitivity reduction even after test.

Test conditions : Stored in 50 degree C, 95%RH for 4700hrs. without being electrified.

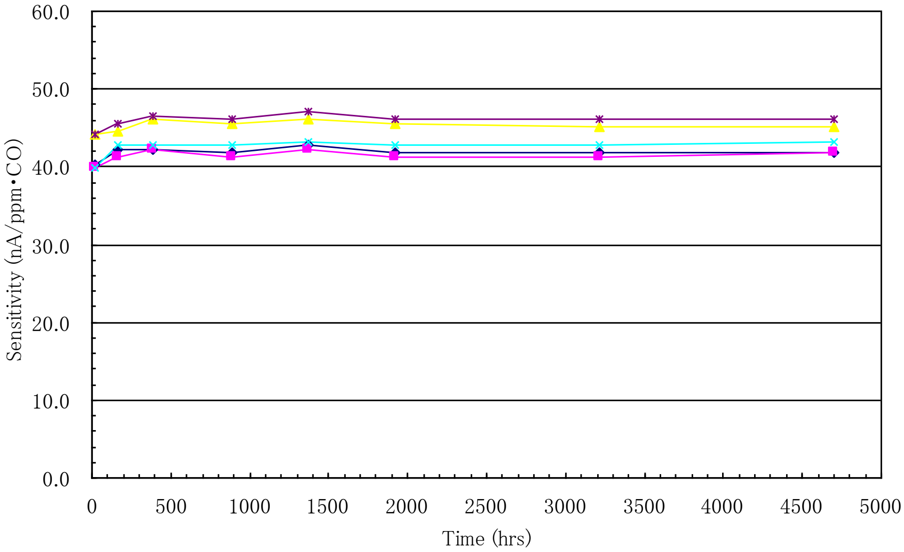



Fig. 17 Storage durability in high temperature and high humidity

Table 7. Sensitivity change after test

| No. | Sensitivity to CO (nA/ppm・CO) | | Change ratio (%) |
|---|---|---|---|
| | Before test | After test | |
| 1 | 40. 3 | 40. 5 | 0.5 |
| 2 | 39. 8 | 41. 5 | 4.1 |
| 3 | 44. 2 | 44. 4 | 0.5 |
| 4 | 39. 8 | 41. 5 | 4.1 |
| 5 | 44. 2 | 44. 4 | 0.5 |

Sensitivity measurement after test was conducted 4 weeks later stored in room temperature and room humidity in order for electrolyte quantity of sensor to recover to initial stage.

### 2-8-2 Storage durability in high temperature

Figure 18 shows the storage durability in high temperature with dry air. It was found that sensitivity decrease takes place according to time elapsed, but it was also found that sensitivity was recovered to almost the initial stage when the quantity of electrolyte was recovered to the initial stage as described in table 8.

Test conditions : Stored in 50 degree C, less than 15%RH for 4700hrs. without being electrified.

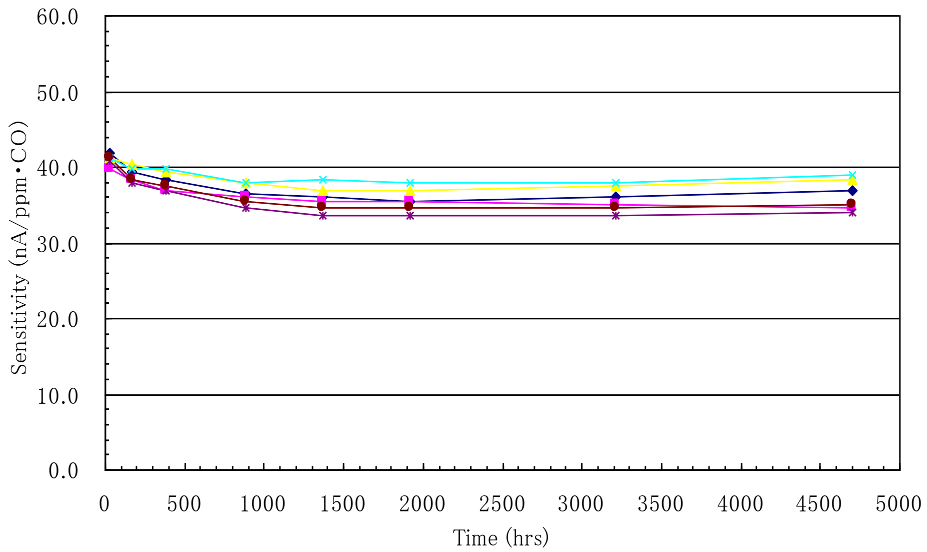



Fig. 18 Storage durability in high temperature

Table 8. Sensitivity change after test

| No. | Sensitivity to CO (nA/ppm・CO) | | Change ratio (%) |
|---|---|---|---|
| | Before test | After test | |
| 1 | 41. 8 | 39. 7 | -5.0 |
| 2 | 39. 8 | 38. 4 | -3.5 |
| 3 | 41. 3 | 39. 7 | -3.9 |
| 4 | 41. 3 | 40. 7 | -1.5 |
| 5 | 40. 8 | 37. 8 | -7.4 |
| 6 | 41. 3 | 38. 4 | -7.0 |

Sensitivity measurement after test was conducted after being stored for 4 weeks in room temperature and room humidity in order for electrolyte quantity of sensor to recover to initial stage.

### 2-8-3 Storage durability in low temperature

Figure 19 shows the storage durability in low temperature.

Test conditions：Stored in -20 degree C for 1032hrs. without being electrified.

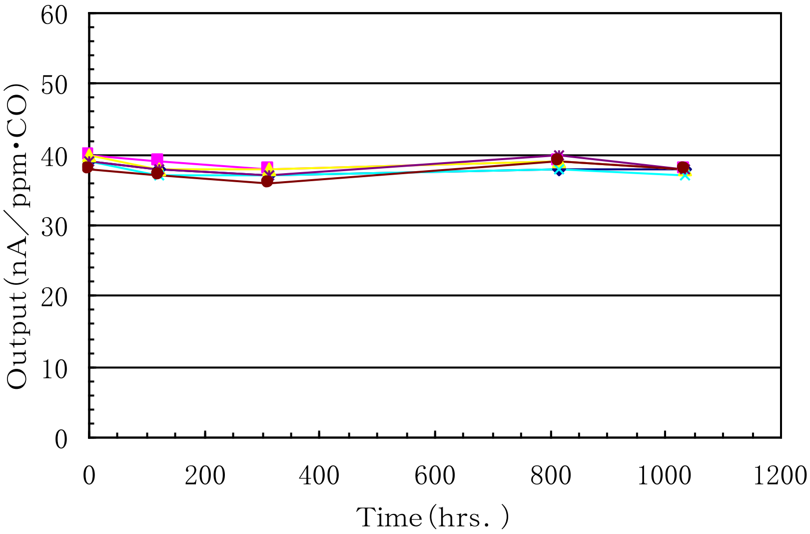



Fig. 19 Storage durability in low temperature

### 2-8-4 Heat shock

Test conditions

Sensor was maintained in -20 degree C for 30min. and in 50 degree C for 30min. alternatively, then this cycle was repeated 10 times. Transportation time between -20 degree C and +50 degree C was less than 30sec. CO gas concentration for measurement is 100ppm.

Table 9. Heat shock test

| No. | CO gas sensitivity characteristics (micro A) | | | |
|---|---|---|---|---|
| | Before test | | After test | |
| | Zero offset | CO sensitivity | Zero offset | CO sensitivity |
| 1 | 0. 10 | 4. 1 | －0. 10 | 4. 1 |
| 2 | 0. 12 | 4. 3 | －0. 03 | 4. 2 |
| 3 | 0. 08 | 4. 1 | －0. 05 | 4. 0 |
| 4 | 0. 08 | 4. 2 | －0. 07 | 4. 2 |
| 5 | 0. 15 | 4. 2 | 0. 04 | 4. 2 |

It was found that sensitivity characteristic of NAP-505 was not influenced by heat shock test.

**2-8-5 High concentration CO gas exposure test**
**(Exposure in 5000ppm for 15hrs.)**

Test conditions : Exposure in 5,000ppm of CO for 15hrs. in room temperature and humidity

CO gas concentration for measurement : 200ppm.

Table 10. High concentration of CO gas exposure test

| | Before test | | | | After test | | | |
|---|---|---|---|---|---|---|---|---|
| No. | I air (μA) | I co (μA) | ΔI (μA) | Sensitivity (nA/ppm・CO) | I air (μA) | I co (μA) | ΔI (μA) | Sensitivity (nA/ppm・CO) |
| 1 | 0.09 | 8.15 | 8.06 | 40. 3 | 0.02 | 8.10 | 8.08 | 40. 4 |
| 2 | 0.06 | 8.41 | 8.35 | 41. 8 | 0.02 | 8.50 | 8.48 | 42. 4 |
| 3 | 0.04 | 8.44 | 8.40 | 42. 0 | -0.06 | 8.30 | 8.36 | 41. 8 |
| 4 | 0.08 | 8.16 | 8.08 | 40. 4 | 0.02 | 8.02 | 8.00 | 40. 0 |
| 5 | 0.10 | 7.97 | 7.87 | 39. 4 | 0.03 | 7.76 | 7.73 | 38. 7 |
| 6 | 0.08 | 8.28 | 8.20 | 41. 0 | -0.05 | 8.07 | 8.12 | 40. 6 |
| 7 | 0.14 | 8.02 | 7.88 | 39. 4 | 0.01 | 7.75 | 7.74 | 38. 7 |
| 8 | 0.14 | 8.55 | 8.41 | 42. 1 | 0.05 | 8.37 | 8.32 | 41. 6 |
| 9 | 0.06 | 8.41 | 8.35 | 41. 8 | 0 | 8.22 | 8.22 | 41. 1 |
| 10 | 0.08 | 8.69 | 8.61 | 43. 1 | -0.01 | 8.48 | 8.49 | 42. 5 |

I air : Output current in clean air, I co : Output current in 5000ppm of CO, ΔI : Sensitivity

It was found that there was no influence after this test.

**(Exposure in 594ppm for 10days )**

Test conditions : In 594ppm of CO for 10days in room temperature without humid.

CO gas concentration for measurement : 200ppm

Table 11. Continuous exposure in 594ppm of CO for 10days

| | Before test | | | | After test | | | |
|---|---|---|---|---|---|---|---|---|
| No. | I air (μA) | I co (μA) | ΔI (μA) | Sensitivity (nA/ppm・CO) | I air (μA) | I co (μA) | ΔI (μA) | Sensitivity (nA/ppm・CO) |
| 1 | 0.19 | 8.24 | 8.05 | 40. 3 | 0.07 | 8.34 | 8.27 | 41. 4 |
| 2 | 0.03 | 8.03 | 8.00 | 40. 0 | 0.06 | 8.30 | 8.24 | 41. 2 |
| 3 | 0.07 | 8.18 | 8.11 | 40. 6 | 0.06 | 8.44 | 8.38 | 41. 9 |
| 4 | 0.03 | 8.24 | 8.21 | 41. 1 | 0.05 | 8.45 | 8.40 | 42. 0 |
| 5 | 0.06 | 8.12 | 8.06 | 40. 3 | 0.05 | 8.35 | 8.30 | 41. 5 |
| 6 | 0 | 8.12 | 8.12 | 40. 6 | 0.12 | 8.49 | 8.37 | 41. 9 |
| 7 | -0.18 | 7.67 | 7.85 | 39. 3 | 0.05 | 8.16 | 8.11 | 40. 6 |
| 8 | 0.07 | 8.06 | 7.99 | 40. 0 | 0.08 | 8.30 | 8.22 | 41. 1 |
| 9 | -0.03 | 8.13 | 8.16 | 40. 8 | 0.07 | 8.46 | 8.39 | 42. 0 |
| 10 | 0.04 | 8.10 | 8.06 | 40. 3 | 0.10 | 8.39 | 8.29 | 41. 5 |

I air : Output current in clean air, I co : Output current in 594ppm of CO, ΔI : Sensitivity

In case that NAP-505 is exposed in high concentration of CO gas for a long time, gas sensitivity characteristics after test is not different from it before test at all. Additionally, NAP-505 has kept on excellent performance during tests.

### 2-8-6 Influence of noise gases and poisonous gases

**(Exposure in 500ppm of $SO_2$ for 30min.)**

Test conditions：Stored in 500ppm of $SO_2$ in room temperature and humidity with being electrified.

CO gas concentration for measurement：100ppm

Table 12. $SO_2$ gas exposure test

| | Sensitivity characteristics（micro A） | | | |
|---|---|---|---|---|
| No. | CO sensitivity before test | Output in 500ppm of $SO_2$ | CO sensitivity in existence of $SO_2$ | CO sensitivity after test |
| 1 | 4. 2 | 0 | 4. 1 | 4. 2 |
| 2 | 4. 2 | 0 | 4. 0 | 4. 1 |
| 3 | 4. 1 | 0 | 4. 0 | 4. 1 |
| 4 | 4. 4 | 0 | 4. 3 | 4. 3 |

It was found that NAP-505 was almost insensitive to 500ppm of $SO_2$ and was not influenced at existence of $SO_2$ at all. It can detect CO accurately if $SO_2$ exists.

**(Exposure in 800ppm of $NO_2$ for 30min.)**

Test conditions：Stored in 800ppm of $NO_2$ in room temperature and humidity with being electrified.

CO gas concentration for measurement：100ppm

Table 13. $NO_2$ exposure test

| | Sensitivity characteristics（micro A） | | | |
|---|---|---|---|---|
| No. | CO sensitivity before test | Output in 800ppm of $NO_2$ | CO sensitivity in existence of $NO_2$ | CO sensitivity after test |
| 1 | 4. 0 | 1. 4 | 5. 1 | 4. 0 |
| 2 | 4. 2 | 1. 2 | 5. 6 | 4. 2 |
| 3 | 4. 2 | 1. 6 | 6. 0 | 4. 2 |
| 4 | 3. 9 | 1. 3 | 5. 0 | 3. 9 |

It was found that NAP-505 is bit sensitive to $NO_2$ around 5% of CO, and output signal of NAP-505 to CO gas is influenced in the existence of $NO_2$. But, it was also found that influence of $NO_2$ is not remained on the sensor in the clean air.

**(Exposure in 1500ppm of acetone for 60min.)**

Test conditions：Stored in 1500ppm of acetone for 60min. in room temperature and humidity with being electrified.

CO gas concentration for measurement：100ppm

Table 14. Acetone exposure test

| | Sensitivity characteristics (micro A) | | |
|---|---|---|---|
| No. | CO sensitivity before test | Output signal in 1500ppm of acetone | CO sensitivity after test |
| 1 | 4. 5 | 0 | 4. 6 |
| 2 | 4. 4 | 0 | 4. 5 |
| 3 | 4. 3 | 0 | 4. 4 |

It was found that NAP-505 is insensitive to acetone and not influenced by existence of acetone.

**(Exposure in 2000ppm of ethanol for 30min.)**

Test conditions：Stored in 2000ppm of ethanol for 30min. in room temperature and humidity with being electrified.

CO gas concentration for measurement：100ppm

Table 15. Ethanol exposure test

| | Sensitivity characteristics (micro A) | | | |
|---|---|---|---|---|
| No. | CO sensitivity before test | Output signal in 2000ppm of ethanol 30min. later | Maximum output in clean air from ethanol | CO sensitivity after test |
| 1 | 4. 3 | 0 | 0. 4 | 4. 4 |
| 2 | 4. 4 | −0. 4 | 0. 6 | 4. 4 |
| 3 | 4. 6 | −0. 5 | 0. 8 | 4. 7 |
| 4 | 4. 5 | −0. 3 | 0. 9 | 4. 5 |
| 5 | 4. 3 | −0. 2 | 0. 5 | 4. 4 |

It was found that output signal of NAP-505 is bit varied to negative direction for a while, and is little increasing after excluding ethanol gas from chamber in correspondence to 10ppm of CO, but soon recover and no influence remained.

**(Exposure in 100ppm of hexa-methyl di-siloxane (HMDS) for 60min.)**

Test conditions : Stored in 100ppm of HMDS for 60min. under the room temperature and humidity. Sensors without charcoal filters is supplied.

CO gas concentration for measurement : 100ppm

Table 16. HMDS poisoning test

| No. | Characteristics before test (micro A) | | Characteristics just after test (micro A) | | Characteristics after test stored for 1day (micro A) | |
|---|---|---|---|---|---|---|
| | Zero offset in clean air | CO gas sensitivity | Zero offset in clean air | CO gas sensitivity | Zero offset in clean air | CO gas sensitivity |
| 1 | 0. 18 | 4. 3 | 0. 27 | 4. 3 | 0. 10 | 4. 3 |
| 2 | 0. 19 | 4. 3 | 0. 34 | 4. 2 | 0. 10 | 4. 3 |
| 3 | 0. 18 | 4. 2 | 0. 29 | 4. 2 | 0. 07 | 4. 2 |
| 4 | 0. 15 | 4. 3 | 0. 23 | 4. 2 | 0. 06 | 4. 2 |
| 5 | 0. 14 | 4. 4 | 0. 18 | 4. 3 | 0. 08 | 4. 3 |
| 6 | 0. 17 | 4. 2 | 0. 21 | 4. 2 | 0. 09 | 4. 2 |
| 7 | 0. 17 | 4. 3 | 0. 13 | 4. 2 | 0. 08 | 4. 2 |
| 8 | 0. 19 | 4. 2 | 0. 17 | 4. 2 | 0. 09 | 4. 2 |

In spite of sensor without charcoal filter for this test, it was found that NAP-505 was not poisoned and influenced by organic silicone compound. Then, NAP-505 with charcoal filter has more excellent durability of silicone poisoning.

**2-8-7 Vibration test**

Test conditions : Vibration with 1.5mm of amplitude for 1min. as sweeping time at 10 – 55 – 10Hz is to be supplied to the direction of X, Y, Z for 2hrs. under room temperature and humidity.

CO gas concentration for measurement : 100ppm

Table 17. Vibration test

| | CO gas sensitivity (micro A) | |
|---|---|---|
| No. | Before test | After test |
| 1 | 4. 2 | 4. 2 |
| 2 | 4. 3 | 4. 4 |
| 3 | 4. 3 | 4. 4 |
| 4 | 4. 2 | 4. 2 |
| 5 | 4. 3 | 4. 5 |
| 6 | 4. 3 | 4. 4 |

Features deterioration was not confirmed at this vibration test.

**2-8-8 Drop shock test**

Test conditions : Free drop on the concrete from height of 1m three times under room temperature and humidity

CO gas concentration for measurement : 100ppm

Table 18. Drop test

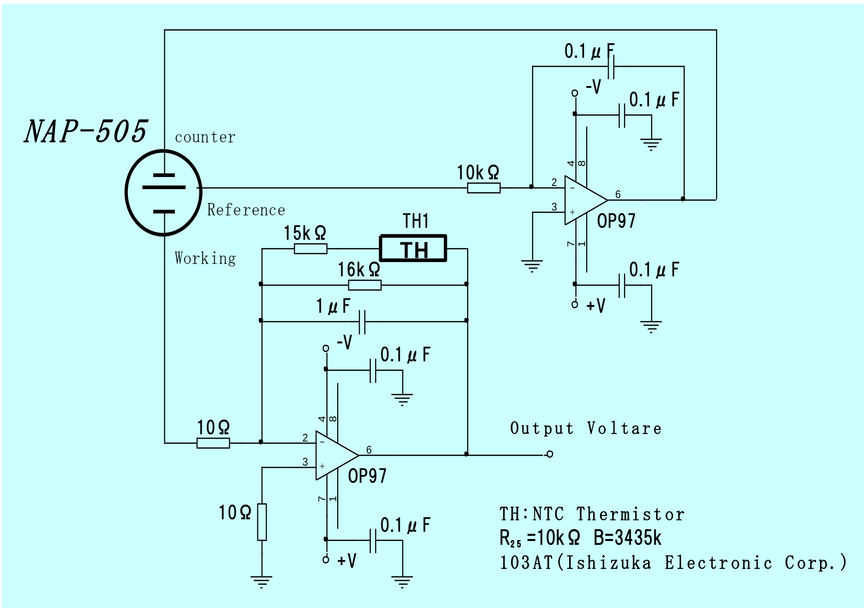
| No. | Gas sensitivity characteristics (micro A) | | | |
|---|---|---|---|---|
| | Before test | | After test | |
| | Zero offset in clean air | CO gas sensitivity | Zero offset in clean air | CO gas sensitivity |
| 1 | 0. 12 | 4. 1 | 0. 12 | 4. 1 |
| 2 | 0. 09 | 4. 1 | 0. 07 | 4. 1 |
| 3 | 0. 09 | 4. 1 | 0. 13 | 4. 1 |

| | | | | |
|---|---|---|---|---|
| 4 | 0. 06 | 4. 1 | 0 | 4. 1 |
| 5 | 0. 12 | 4. 2 | 0. 09 | 4. 3 |
| 6 | 0. 09 | 4. 2 | 0. 12 | 4. 2 |
| 7 | 0. 10 | 4. 1 | 0. 11 | 4. 2 |
| 8 | 0. 12 | 4. 0 | 0. 09 | 4. 0 |
| 9 | 0. 11 | 3. 8 | 0. 06 | 3. 9 |
| 10 | 0. 16 | 4. 1 | 0. 15 | 4. 1 |

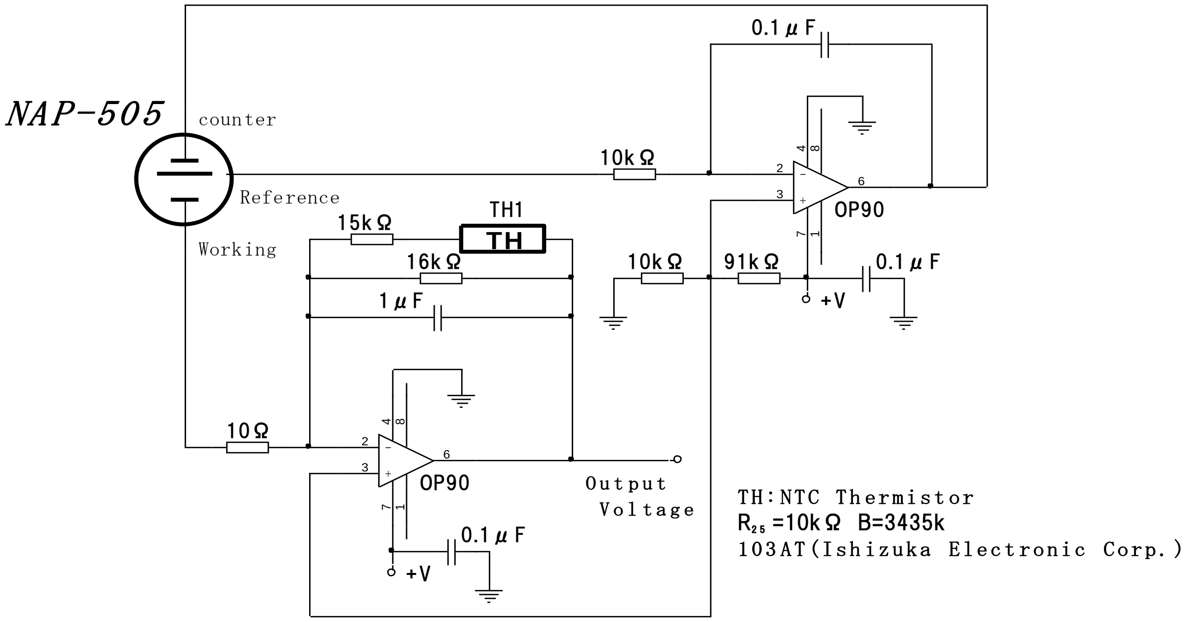
Features deterioration was not confirmed at this drop test.

**2-9 Recommended circuit diagram**

Recommended circuit diagram for evaluation of NAP-505 is shown in the right. In this circuit, OP97 which is popular and low power consumption is employed, and temperature dependence of NAP-505 is compensated by using NTC thermistor which B constant is 3435 and manufactured by Ishizuka, and then, detection accuracy is compensated within 10% from -10 to +50 degree C. By the way, this thermistor should be 3500K as B constant, and resistance value is to be round 10Kohm, manufacture is not pointed.




(Reference) Single supply circuit




+V: 10VDC or more (For UL)

+V: 15VDC or more (For EN)

**2-10 Reference : Relationship between variation of quantity of electrolyte and climate**

As mentioned in the previous page, since electrolyte employed in NAP-505 is hygroscopic, quantity gradually increases in high humid circumstance, and also gradually decreases in low humid. Figure 20 shows the relationship between temperature variation, humidity variation and weight variation when NAP-505 is installed outside, and figure 21 also shows them with sensitivity variation. And then, figure 22 shows the same relation when NAP-505 is installed inside, and figure 23 shows them with sensitivity variations. You can see from theses figures, quantity of electrolyte increases in summer season, and it decreases in winter season. For this purpose, NAP-505 was designed that the volume of reservoir which area is for reserving electrolyte is over 10 times of variation. And then, there is no case that electrolyte is leaked even if it is employed in high humid. Sensitivity of NAP-505 is bit higher in summer than in winter.

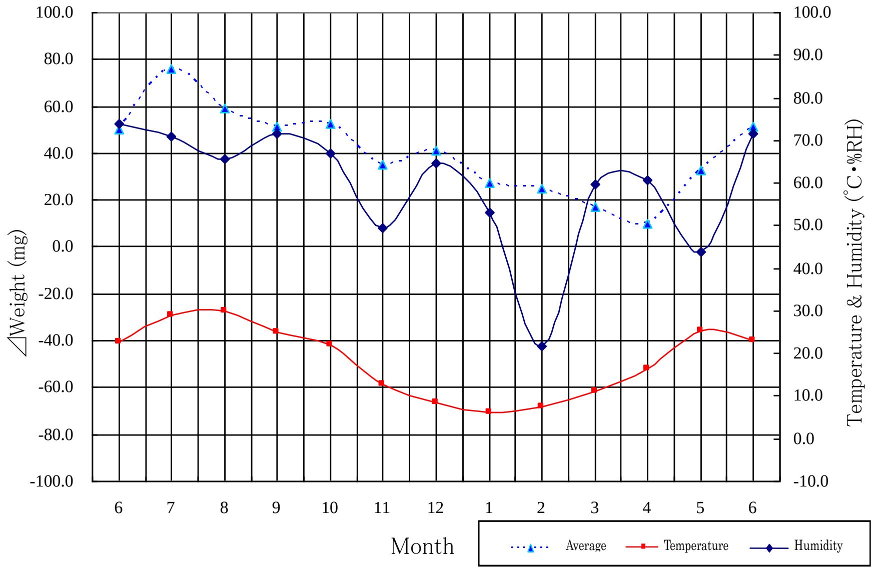



Fig. 20 Relationship between electrolyte quantity and climate variation (Outside)

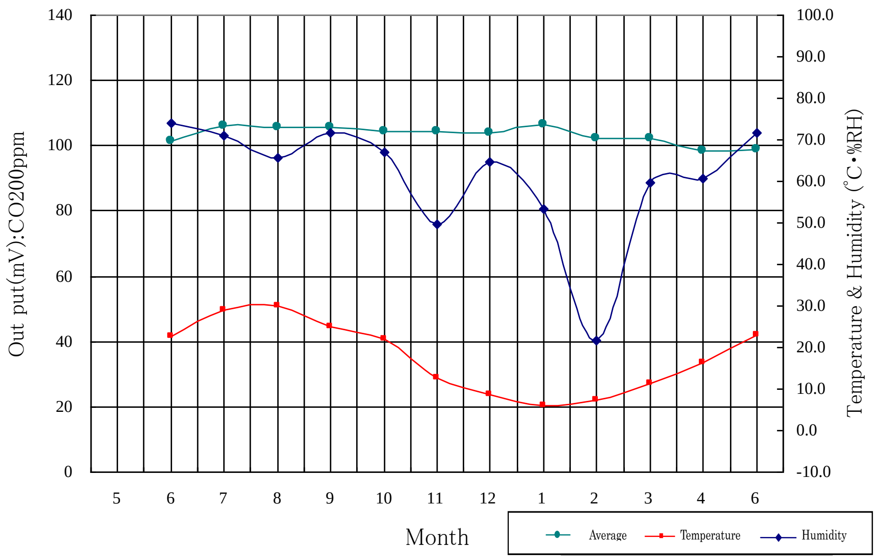



Fig. 21 Relation between CO gas sensitivity and climate variation (Outside)

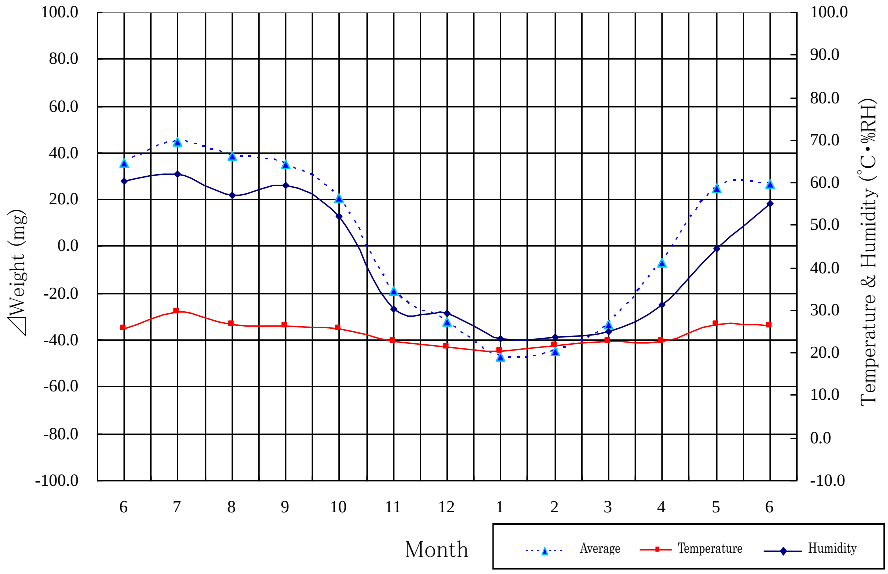



Fig. 22　Relationship between electrolyte quantity and climate variation (Inside)

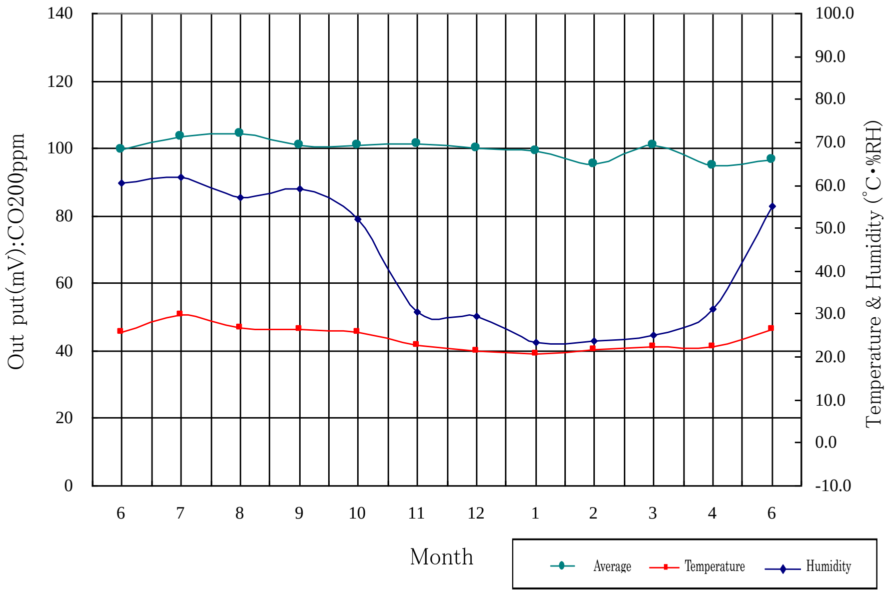



Fig. 23　Relation between CO gas sensitivity and climate variation (Inside)

## 2-11 Handling precautions

### 2-11-1 Long term stability of sensitivity

Regarding electrochemical cell, there is a problem that oxidization ability on working electrode is gradually decreasing, however this sensitivity reduction ratio of NAP-505 was improved to less than 5%/year. Reduction of 2-3%/year was actual, but since reduction can not be prevented even a little like other electrochemical, such reduction ratio shall be considered at the design of application circuit diagram.

### 2-11-2 Seasonal variation of sensitivity

As mentioned in previous, since electrolyte is hygroscopic, sensitivity is dependent on large seasonal variation like Japan, it means that quantity of electrolyte increases in summer and sensitivity is bit higher than in winter which quantity of electrolyte decreases. If possible, such temporary variation should be also taken into account at circuit design.

There is a case that 10-20% of sensitivity decreases annually in conventional sensors, however sensitivity variation less than 5% at maximum was feasible by creation of the most optimum design of electrodes structure and oxidization improvement of working electrode. Such sensitivity variation by season is tentative phenomenon, and sensitivity recovers to almost initial sensitivity when quantity of electrolyte recovers to initial stage.

### 2-11-3 Storage of sensor

It is recommended that electrochemical sensor is to be stored in clean air under room temperature and humidity, possibly less than 20 degree C.

Recommended storage time after delivery is 6 months. If the storage time is longer, please think about that assured time is shortened. This is because sensitivity of electrochemical cell is not dependent on used or unused different from catalytic type and semi-conductive type. Control of storage time is very important in order to maintain quality of sensor.

### 2-11-4 Precaution for actual application to PCB

- Electrodes have to be connected correctly. If connection is wrong, it does not work.
- Thermistor for temperature compensation is to be positioned near to sensor, and far from heat source like power transformer.
- Sensor installation direction, vertically positioned or horizontally positioned, does not influence to characteristics.
- NAP-505R and 505S types can be directly soldered to pins but soldering has to be conducted by hand and temperature of soldering iron has to be less than 370 degree C for less than 3sec. respectively.

- Exclusive sockets have to be necessary for NAP-505RS and 505SS. Both are possible to be soldered with sockets like 505R and 505S.
- Automatic soldering system and reflow line are not available at any time.

**2-11-5 Precaution for design of gas alarm or densitometer**

- Calibration of gas alarm or densitometer is to be conducted after zero offset value in clean air is stabilized.
- Sensitivity of annual reduction is to be considered as 5%/year at design of gas alarm. If more accurate detection is required for gas densitometer, periodical calibration like once or twice a year is recommended according to requirement of detection accuracy.
- Gas injection face is covered with water or oil, it is difficult to detect correctly. In case that such issue is considered, design of alarm or densitometer is to be seriously carried out in order to prevent from water or oil.
- Since CO is bit lighter than air, CO alarm should be installed at the ceiling or higher position of wall.
- It is guaranteed for 5years, in case that it is employed in normal circumstance.

**2-11-6 Other precautions**

- Characteristics on NAP-505 except items 2-4-1 and 2-4-2 are not guaranteed features but typical features.
- NAP-505 shall be used according to specifications.
- Gas sensitivity characteristic is to be implemented in clean air without any noise gases.
- If detection gas is injected to detection face of sensor directly, higher sensitivity is obtained. It is recommended that gas sensitivity measurement is conducted in a chamber with gentle agitation.
- Measurement is to be carried out by recommended circuit for evaluation, and electric power has not to be supplied to pins directly. If over DC 1.23V is supplied to pins, remarkable deterioration of sensitivity characteristics may take place.
- Pins should not be bended at all in any case.
- Overweight over 5Kg/cm$^2$ should not be supplied to sensor enclosure.
- Since cause of sensitivity reduction is considered by mesh blocked, please do not cover or spoil the gas injection face.
- Please do not inject anything to gas injection face because of possibility of leakage of electrolyte.
- Please do not add exceeding vibration or shock.
- If there are some defects on enclosure, please do not use it.
- In case that sensor is exposed in high concentration of CO, it takes long time that

zero offset recovers to the initial stage.

- Please do not use it in organic solvent, paint solvent, oil, other reagents and high concentration of gases.
- In case that it is used in strict circumstance, please consult us.
- Please do not decompose. It may be a cause of electrolyte leakage.
- Please do not touch electrolyte because of scald.

Note)

Since NAP-505 includes a little dangerous electrolyte inside of sensor, if the leakage takes place, it is recommended to wash hand promptly.

If the sensor is disused, it is recommended to ask professional disuse company or to ask distributor or subsidiary which distributes it.