

3rd, July, 2013

Technical Information

Model NAP-508

(Electrochemical CO Gas Sensor)

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1. Detection principle

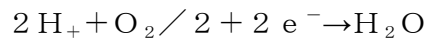
Electrochemical sensor NAP-508 is composed of working electrode which oxidation and reduction takes place, counter electrode which oxidation and reduction also occurs at the same time and reference electrode which can independently monitor the potential difference at working electrode. It is expressed as model case described in the right.

In case of detection of CO, following

reaction should occur on the surface of working electrode.



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.



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.



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

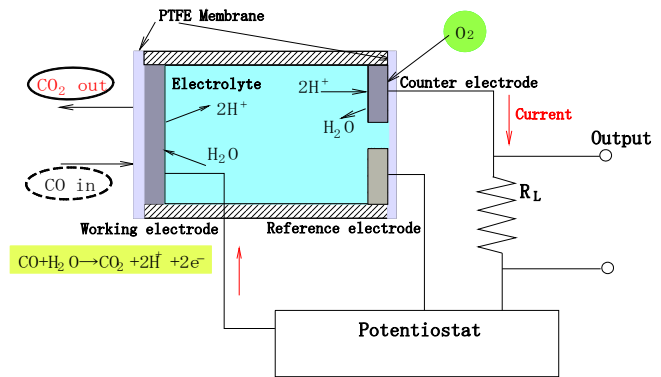


Fig.1 Detection principle

2. Comparison with conventional types

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 reputed 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 lowest price and smallest size for residential application 2001, and is available in the market from 2002. Defects of conventional type were improved as follows. NAP-508 was newly developed as succeeded sensor of NAP-505, and its main feature is with the sensor 10 years warranty.

• Short lifetime → **Lifetime of over 10 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

3. Features

3-1. Downsizing

NAP-508 is the same size as our conventional type NAP-505, and 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 1. Volume of various kinds of CO gas sensor (cm³)

NAP-508	M	F	S
2.4	11.7	7.3	5.6

3-2. Direct soldering to pins

Other sensors 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-508 can be directly soldered to pins as the same as NAP-505 since the special structure around pins are adopted in order to create excellent heat radiation from pins, additionally high temperature durable plastic PPO is also adopted. Regarding conventional sensors, contact defect between sensor pins and socket or sensor detachment from sockets were possible. But, since NAP-508 can be soldered to PCB directly, durability against mechanical vibration or contact defect by corrosion becomes improved.

3-3. 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-508 has an 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.

3-4. Detection performance in high concentration of CO

Since the electrode technology for industrial use is applicable to NAP-508, 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.

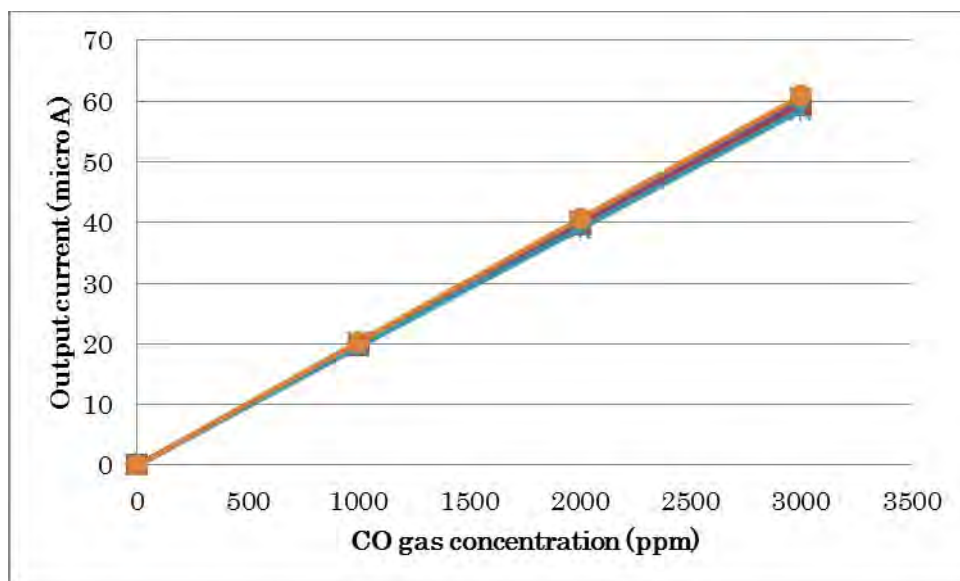


Fig.2 Linearity to CO gas

3-5. Long term stability

Long term stability in room temperature is shown in the figure 3. Since it was developed in 2008, around 5 years elapses, however it shows the excellent stability, and there is no tendency on sensitivity variation.

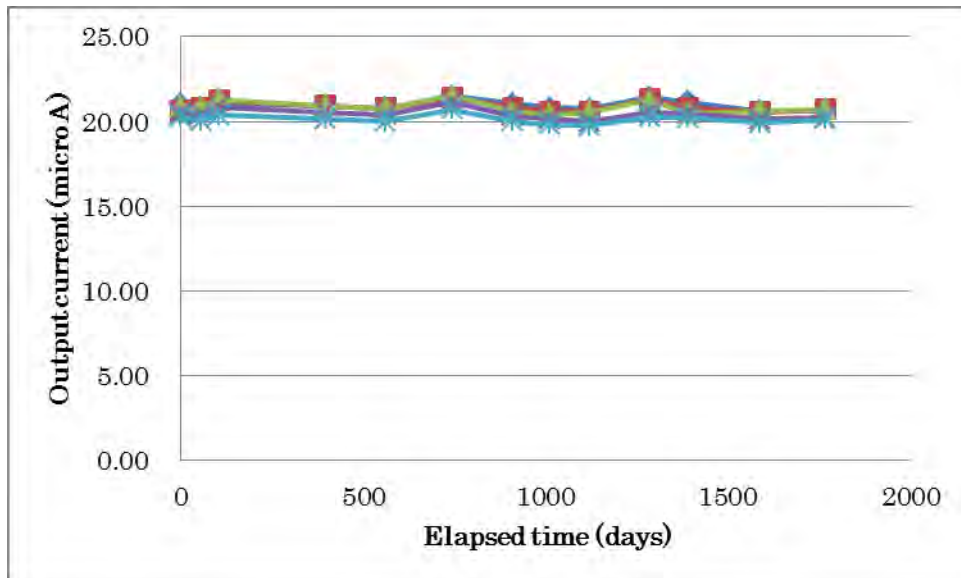


Fig.3 Long term stability of sensor developed in 2008
(CO gas concentration : 1000ppm)

3-6. Structure

Figure 4 shows the sectional structure of NAP-508. It is completely the same as 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, and then CO gas is oxidized. This capillary is protected by special filter having function to avoid water and dust.

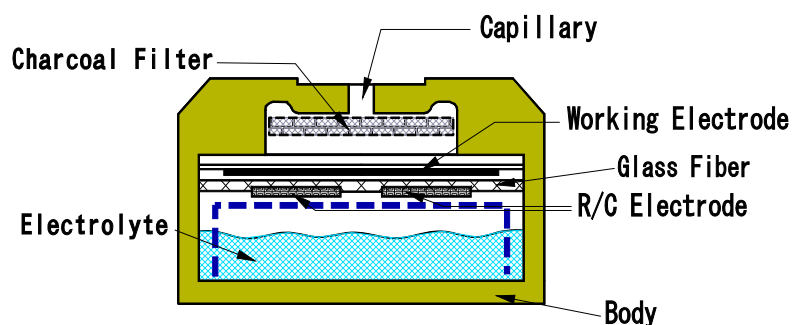


Fig.4. Sectional structure of NAP-508

3-7. Conformity to various standards

Excellent characteristics of NAP-508 are in conformity to various kinds of standard not only in Japan but also overseas. This NAP-508 meets the requirement of UL2034 and 2075, but is not listed in UL yet. Some fire alarm companies are under the preparation of UL application.

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

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

4. Ratings

Temperature in operation	-20~50 degree C
Humidity in operation	15~90%RH
Pressure in operation	1 atm ±10%
Recommended load resistor value	10 ohm
Recommended temperature in storage	0 ~20 degree C
Recommended storage term	Less than 8 months

5. Electric property

Detected gas	CO
Recommended detection range	0 - 2000ppm
Maximum overload	1%
Output current	20 ± 5 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 15ppm (-20 - +50degree C)
Sensitivity drift	Less than 3% per year
Expected lifetime	Over 14 years after production date

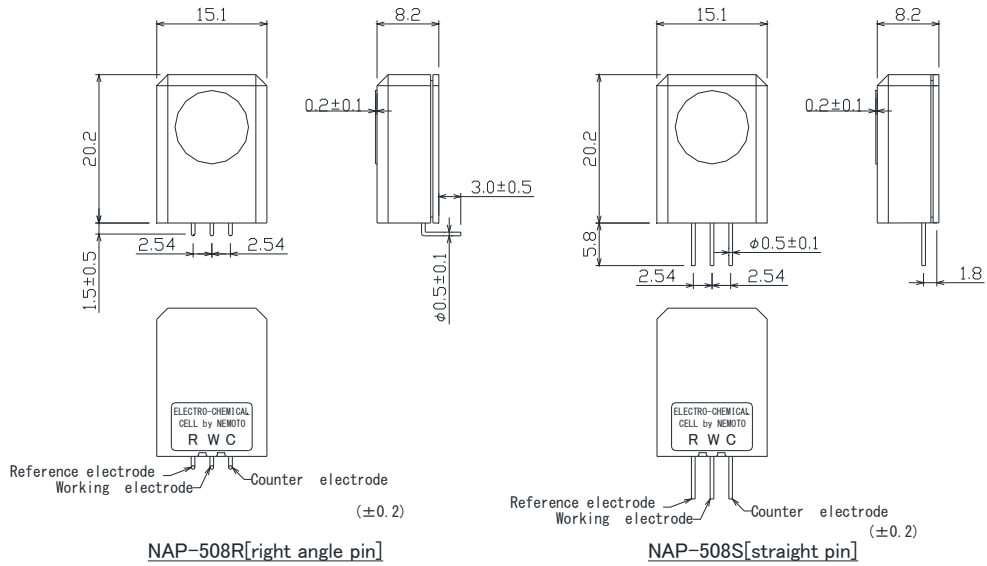
(The above values are conditioned under at 20 degree C, 50%RH, 1atm.)

6. Enclosure material

Enclosure material	PPO
Color	Dark blue
Weight	Approx. 2.6g

7. Shape and dimension

Direct Soldering Models



Socket Models

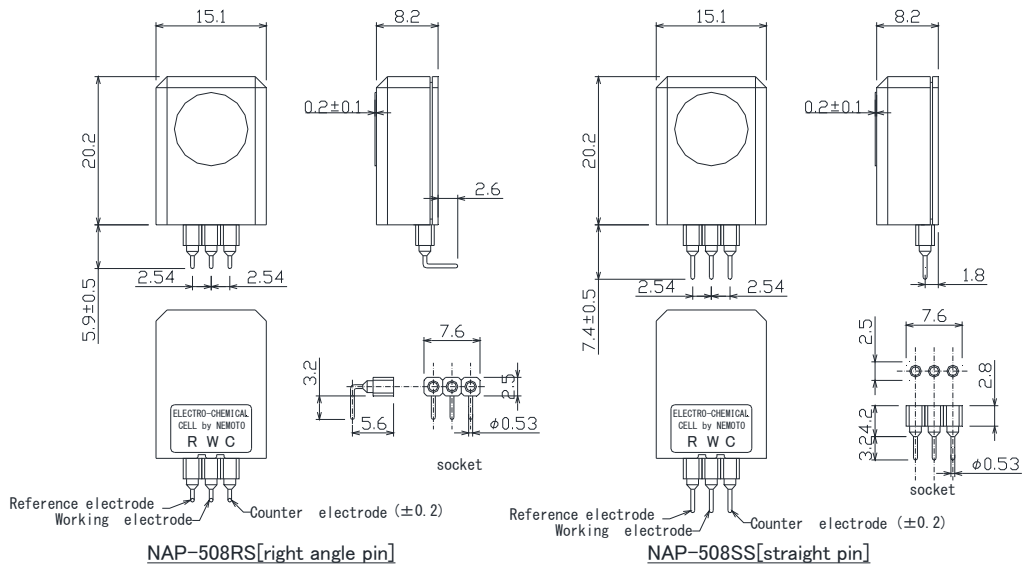


Fig.5. Shape and dimension of NAP-508

8. Electrical features

8-1. Gas sensitivity

Figure 5 shows the sensitivity characteristics to typical gases.

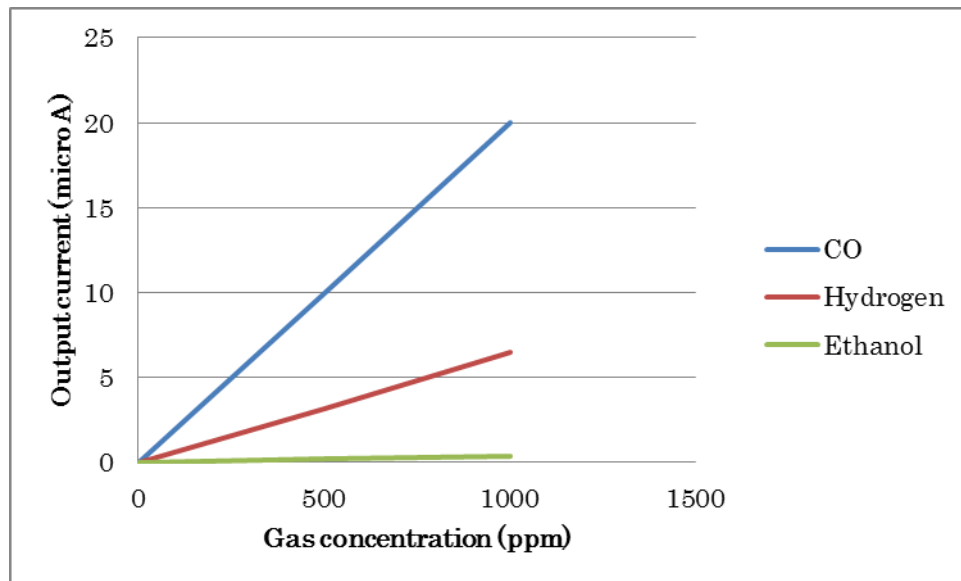


Fig.6 Gas sensitivity characteristics (Typical)

8-2. Selectivity

NAP-508 possesses conformity to selectivity which international standards require, and table 3 shows the selectivity to typical noise gases defined in UL2034 and EN50291.

Table 2. Gas selectivity

Test gas	Relative sensitivity (CO is 100) at 20 degree C
CO	100
Hydrogen	30
Methane	0
Iso-Butane	0
Carbon dioxide	0
Carbon di-sulfate	0
Hydrogen sulfide	0
Nitrogen oxide	0
Nitrogen dioxide	Less than 5
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

8-3. 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 3. 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

8-4. Pressure dependence of CO sensitivity

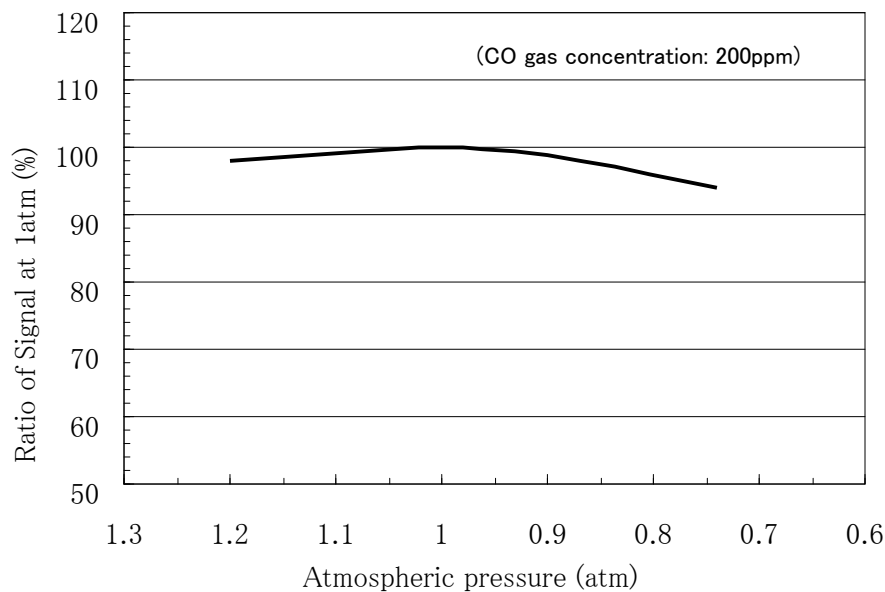


Fig.7. Pressure dependence

8-5. Initial action

Output signal of NAP-508 recovers to zero level for a short time even if it is stored for a long term in air. Figure 9 shows the initial action (initial stabilization time) in case of being stored for 1 month at normal circumstance, and figure 10 shows it in case of being stored for 6 months at also normal circumstance. In case that the sensor is assembled in the circuit, such an initial stabilization time is not long, however in case that the sensor is stored in the package, the following initial stabilization time is to be taken into account. But, it should take less than 5min.

to be stabilized.

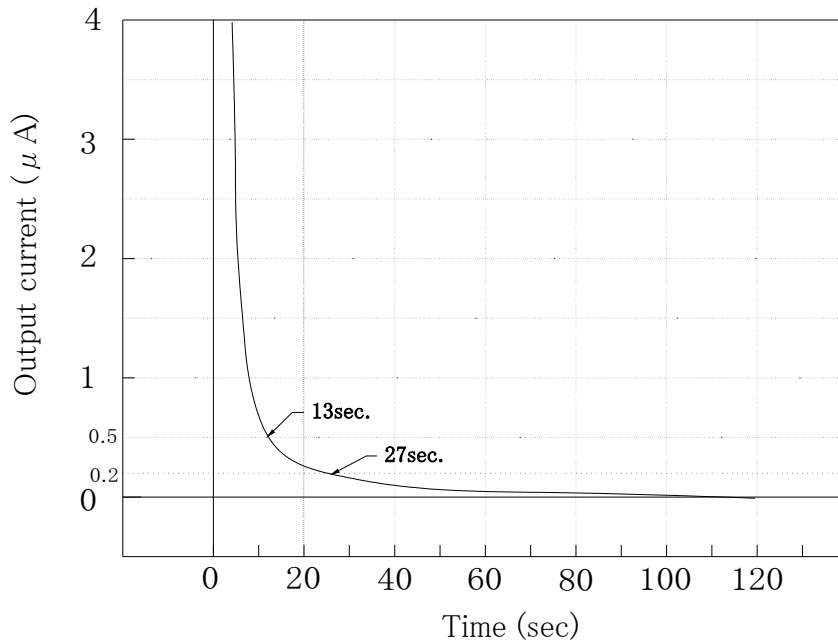


Fig.8 Initial action of NAP-508 stored for 1 month

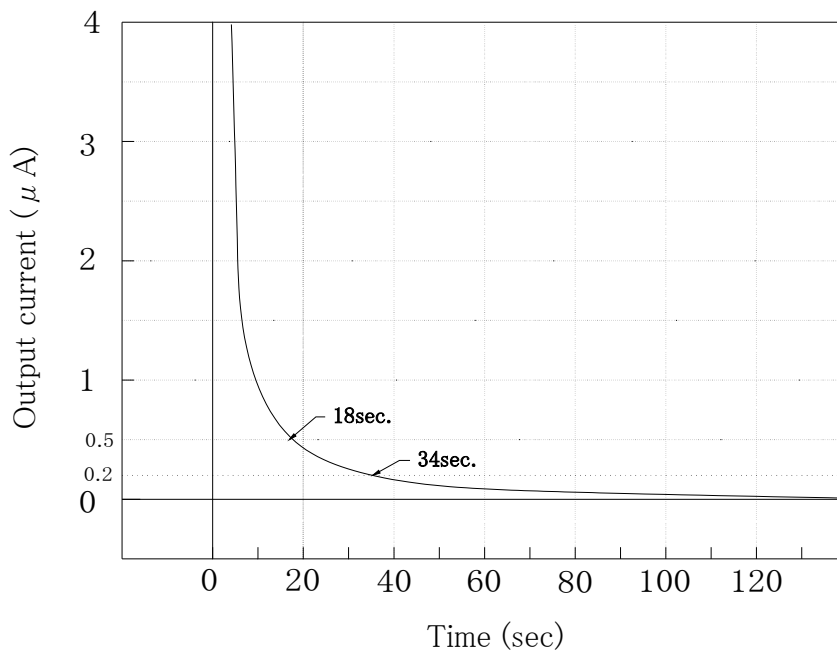


Fig. 9. Initial action of NAP-508 stored for 6 months

8-6. Wind influence to CO gas sensitivity

Normally, gas sensitivity of NAP-508 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 on sensitivity till 2m/sec.

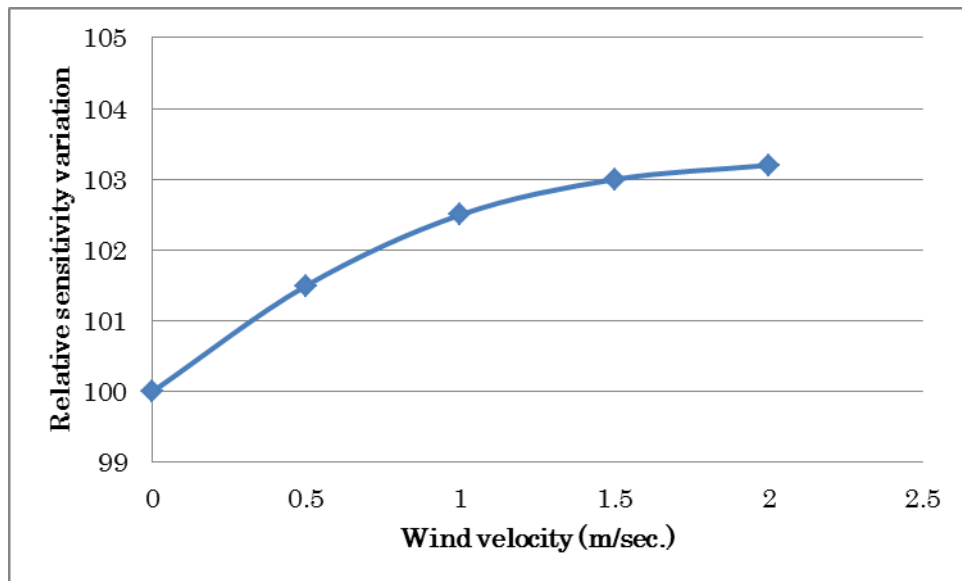


Fig.10. Wind velocity dependence

8-7. Temperature dependence (Typical characteristics)

Figure 12 shows the temperature dependence of sensitivity. Typical 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 the circuit diagram with temperature compensation is shown in item 2-9.

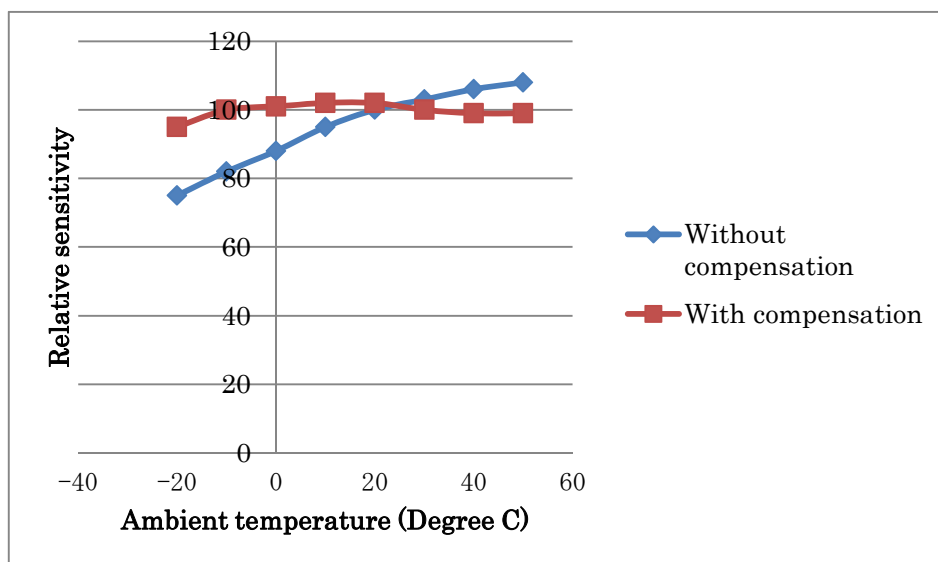


Fig. 11. Temperature dependence of sensitivity

9. Durability

9-1. 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-508 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.

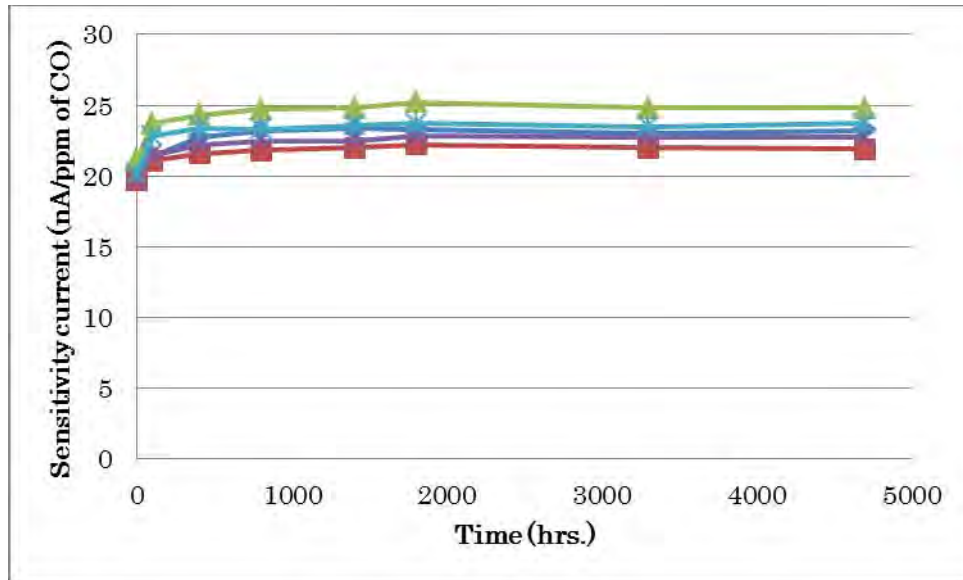


Fig. 12. Storage durability in high temperature and humidity

Table 4. Sensitivity change after test

No.	Sensitivity to CO (nA/ppm·CO)		Change ratio (%)
	Before test	After test	
1	20.2	20.3	0.5
2	19.9	20.8	4.5
3	22.1	22.2	0.5
4	19.8	20.7	4.5
5	22.0	22.2	0.9

Sensitivity measurement shown in the above table was again conducted after being stored for 4 weeks in normal temperature and humidity since the electrolyte quantity is to recover to initial stage. It was confirmed that the sensitivity recovers.

9-2. Durability in high temperature

Figure 18 shows the storage durability in high temperature with dry air. It was found that sensitivity decrease, 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.

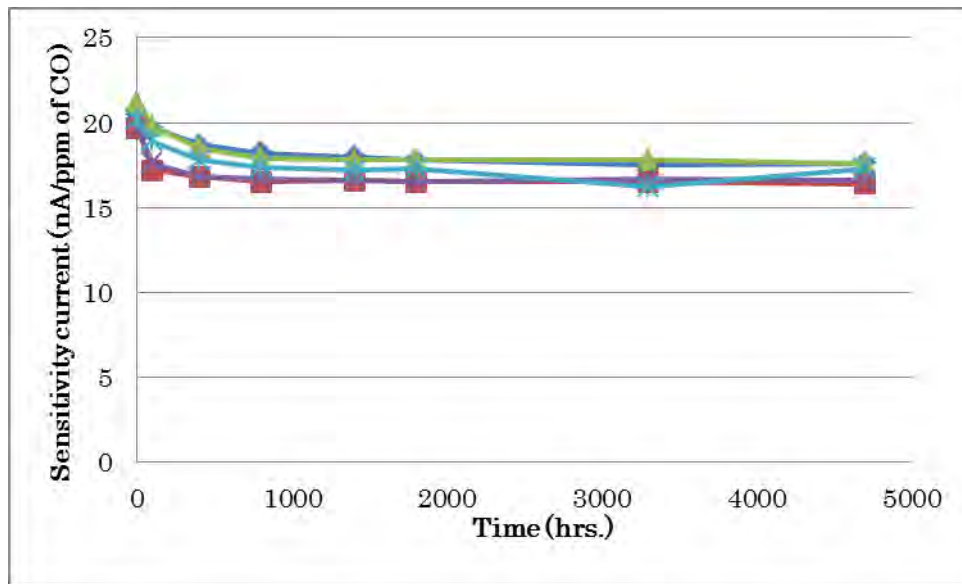


Fig. 13 Storage durability in high temperature

Table 5. Sensitivity change after test

No.	Sensitivity to CO (nA/ppm·CO)		Change ratio (%)
	Before test	After test	
1	20.9	19.8	-5.3
2	19.9	19.3	-3.0
3	20.7	19.9	-3.9
4	20.6	20.4	-1.0
5	20.5	19.5	-4.9

Sensitivity measurement shown in the above table was again conducted after being stored for 4 weeks in normal temperature and humidity since the electrolyte quantity is to recover to initial stage. It was confirmed that the sensitivity recovers.

9-3. Storage durability in low temperature

Figure 19 shows the storage durability in low temperature. It was confirmed that the sensors maintain the excellent stability during storage time.

Test conditions : Stored in -20 degree C for 1100hrs. without being electrified.

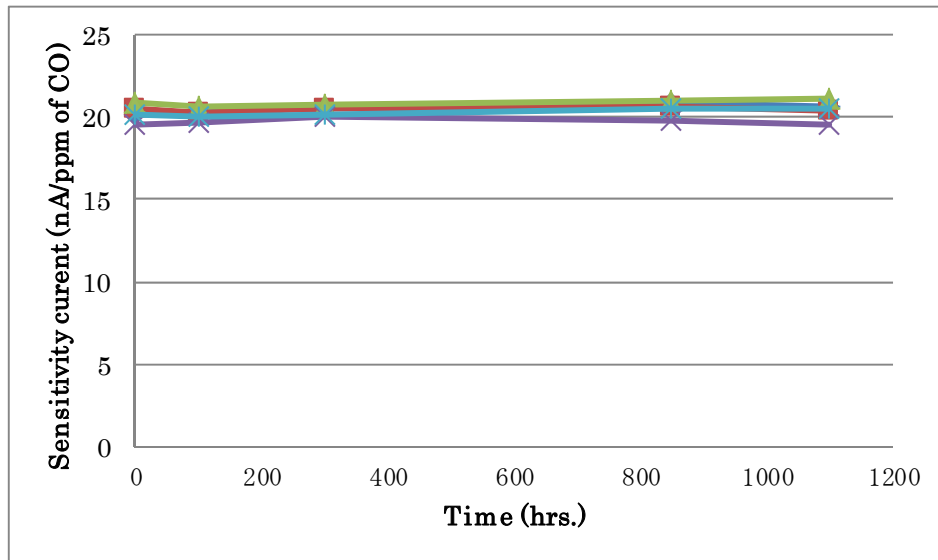


Fig. 14. Storage durability in low temperature

9-4. 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 6. Heat shock test

No.	CO gas sensitivity characteristics (micro A)			
	Before test		After test	
	Zero offset	CO sensitivity	Zero offset	CO sensitivity
1	0.11	2.03	-0.09	2.11
2	0.11	2.12	-0.03	2.05
3	0.05	2.04	-0.02	2.02
4	0.04	2.13	-0.04	2.12
5	0.12	2.10	-0.01	2.12

It was found that the sensitivity characteristic was not influenced by heat shock test.

9-5. Exposure test in high concentration of CO gas

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

It was confirmed that there was no influence to sensitivity characteristics during the test and after the test shown in the next table.

Table 7. High concentration of CO gas exposure test

No.	Before test		After test	
	Zero offset (micro A)	Sensitivity (nA/ppm·CO)	Zero offset (micro A)	Sensitivity (nA/ppm·CO)
1	0.12	20.1	0.08	20.3
2	0.08	20.6	0.04	21.5
3	0.11	21.1	0.07	20.8
4	0.04	19.8	0.06	20.0
5	0.12	19.7	0.11	19.5

**9-6. Influence of noise gases and poisonous gases
(Exposure in 500ppm of SO₂ for 30min.)**

Test conditions : Stored in 500ppm of SO₂ in room temperature and humidity with being electrified.

CO gas concentration for measurement : 100ppm

Table 8. SO₂ gas exposure test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.11	2.07	0.08	2.05
2	0.07	2.11	0.10	2.10
3	0.04	1.96	0.05	1.98

It was found that NAP-508 was almost insensitive to 500ppm of SO₂ and was not influenced by SO₂ at all. It can detect CO accurately if SO₂ exists.

(Exposure in 800ppm of NO₂ for 30min.)

Test conditions : Stored in 800ppm of NO₂ in room temperature and humidity with being electrified.

CO gas concentration for measurement : 100ppm

Table 9. NO₂ exposure test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.06	2.03	0.07	2.02
2	0.05	2.03	0.11	2.04
3	0.09	2.13	0.09	2.11

It was found that NAP-508 is bit sensitive to NO₂ by around 5% correspondence to CO, but opposite signal, and then output signal of NAP-508 to CO gas is influenced if NO₂ exists. But, it was also found that influence of NO₂ 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 10. Acetone exposure test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.12	2.13	0.09	2.11
2	0.08	1.94	0.12	1.98
3	0.07	2.07	0.09	2.06

It was found that NAP-508 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 11. Ethanol exposure test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.09	1.97	0.09	2.02
2	0.04	1.99	0.07	1.97
3	0.14	2.04	0.12	2.08

It was found that output signal of NAP-508 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 12. HMDS poisoning test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.06	2.06	0.07	2.05
2	0.07	2.13	0.09	2.14
3	0.07	2.07	0.10	2.07

In spite of sensor without charcoal filter for this test, it was found that NAP-508 was not poisoned and influenced by organic silicone compound. Then, NAP-508 with charcoal filter has more excellent durability for silicone poisoning.

9-7. 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 13. Vibration test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.13	2.18	0.10	2.13
2	0.05	2.04	0.07	2.08
3	0.11	2.09	0.14	2.11

Features deterioration was not confirmed at this vibration test.

9-8. Drop 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 14. Drop test

No.	Before test (micro A)		After test	
	Zero offset	Sensitivity	Zero offset	Sensitivity
1	0.04	1.96	0.07	1.94
2	0.03	1.93	0.04	1.94
3	0.11	2.03	0.10	2.01

Features deterioration was not confirmed at this drop test.

10. Recommended circuit diagram

Recommended circuit diagram for evaluation of NAP-508 is shown in the next page. As you can see from the circuit, this is the quite the same as for NAP-505, then it is easily replaceable of NAP-505. Please note that the temperature dependence on sensitivity can be compensated, not the zero offset value. OP97 is employed in this circuit diagram, however since this OP97 seems bit expensive for residential applications, please consult us if so.

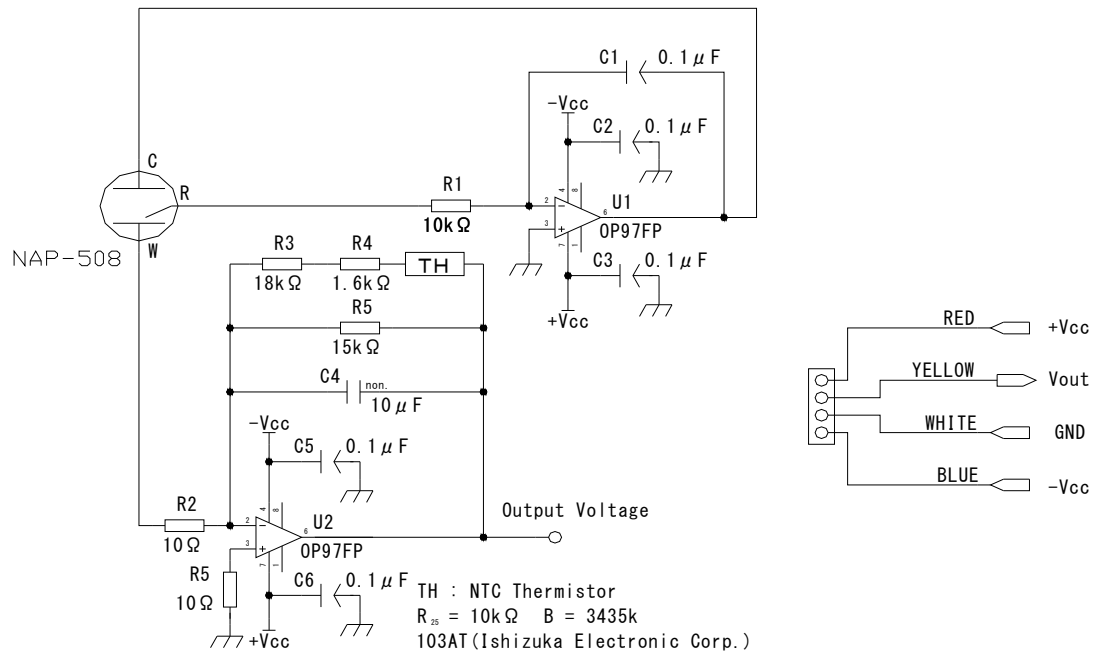


Fig. 15. Recommended circuit diagram for NA-508

Since the recommended circuit diagram for NAP-508 is the same as for NAP-505 as described in the previous page, please refer the technical materials on battery operation or cheaper circuit for NAP-505.

11. Field test

NAP-508 sensor has been monitored at 5 variations regions around 660 locations described as below for over 5 years, and it was confirmed that all sensors without any exception maintained quite excellent features.

- 1) North area, average temperature is less than 10 degree. Lots of snow in winter season, and very cold. Not so hot even in summer.
- 2) Japan sea side, average temperature is around 10 to 15 degree C, but a lot of snow in winter season, however very hot and high humidity in summer.
- 3) Pacific sea side, average temperature is around 15 degree C, no snow in winter, but very dry, and very hot and humid in summer.
- 4) Pacific sea side, average temperature is 15 to 20 degree C, no snow in winter, but dry. Very hot and humid in summer season.
- 5) The island in pacific ocean, average temperature is over 20 degree, very warm even in winter, and summer is very long.

If the actual data is required, please contact us.

12. Acceleration test for lifetime estimation

12-1. Acceleration test

Since around 5 or 6 years still elapses after NAP-508 was developed, acceleration

test was conducted for lifetime estimation instead of actual long term stability data. It was internally clear that such kind of sensor has been deteriorated under high temperature, and then long term stability at various ambient temperatures, 50 degree C, 60 degree C and 70 degree C were carried out respectively.

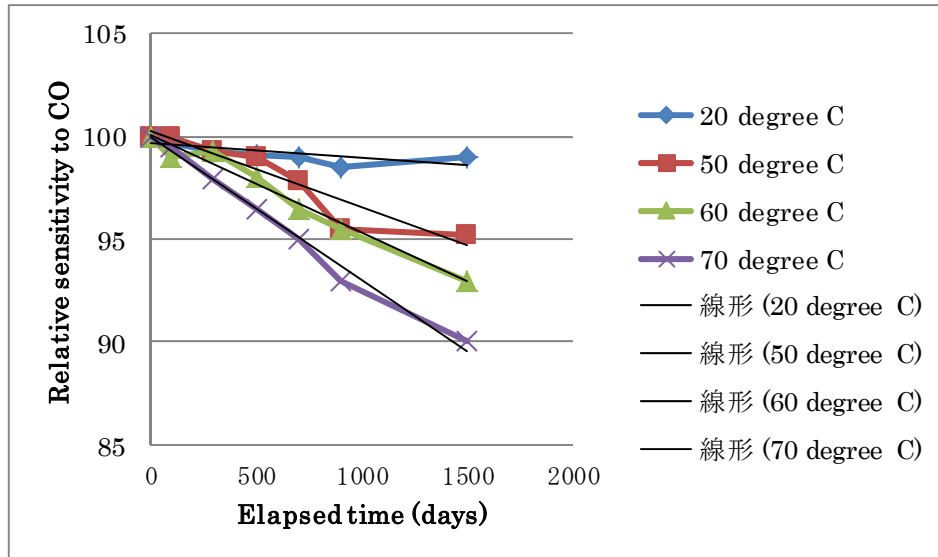


Fig. 16. Long term stability in various kinds of temperature

From the above data, extrapolation lines on each temperature are obtained, and then presuming that the sensitivity deterioration tendency is quite linear, and deterioration speed is expressed by activation energy function on temperature, lifetime estimation is shown in the figure 21. At this time, the lifetime is defined as the time that sensitivity will reach 70% of original value.

Among the above figure, since the clear sensitivity variation at 20 degree C can not be observed yet, extrapolation data of 20 degree C is excluded because it is not so realistic.

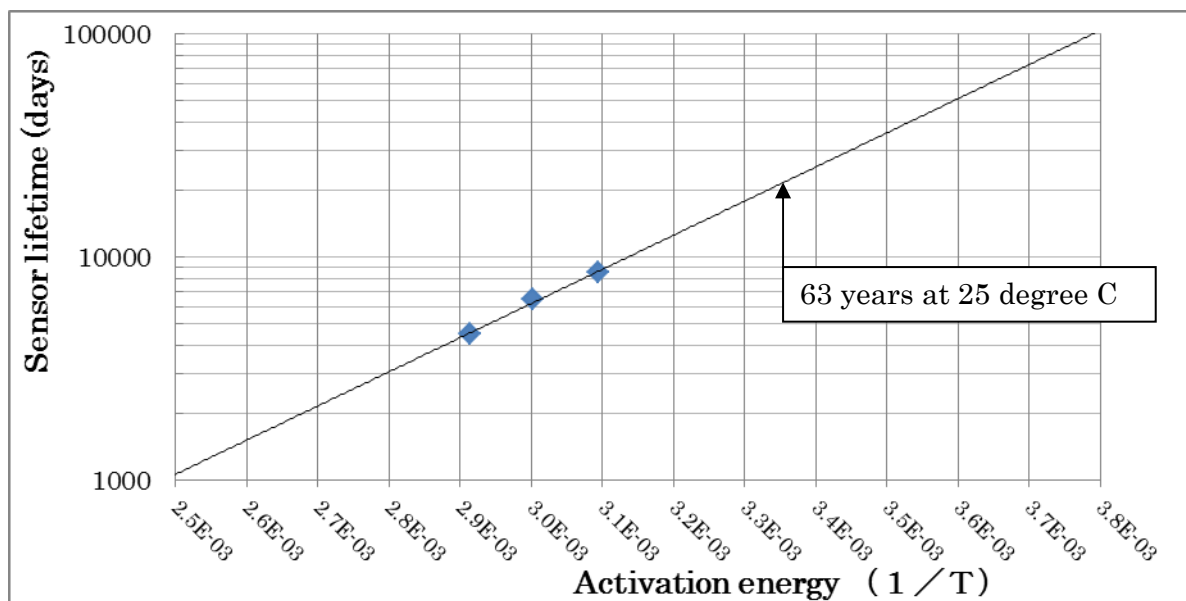


Fig. 17. Lifetime estimation by thermal acceleration test

12-2. Warranty of lifetime

According to acceleration tests and field monitor data, warranty lifetime is 10 years excluding the storage time for 8 months, and the expected lifetime of NAP-508 is **at least 14 years** after production date since it is confirmed that the maximum yearly sensitivity reduction is less than 3%.

13. Handling precautions

13-1. Long term stability of sensitivity

As shown in the above data, very gradual deterioration of oxidization ability on working electrode because of high ambient temperature is observed, however this sensitivity reduction ratio of NAP-508 was fairly improved less than 3%/year. Reduction ratio is too small to confirm the clear tendency by now.

But, since the reduction can not be prevented even a little like other electrochemical, such reduction ratio is possibly considered at the design of application circuit diagram.

13-2. Seasonal variation of sensitivity

As described in the technical materials of NAP-505, since the electrolyte is hygroscopic, sensitivity is strongly dependent on seasonal variation. It means the quantity of electrolyte increases in summer and rainy season, and sensitivity is little higher than in winter because the electrolyte quantity decreases. NP-508 has such tendency, however it is quite smaller than NAP-505, and such temporary variation is reversible, then it may not be taken into account at circuit design.

13-3. Storage

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 less than **8 months**. If the storage time may be longer than our recommendation, please think about that warranty time is shortened.

13-4. 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-508R and 508S types can be directly soldered to pins, but soldering has to be conducted by manual and temperature of soldering iron has to be less than 350 degree C for less than 3sec. respectively.

- Exclusive sockets have to be necessary for NAP-508RS and 508SS. Both are possible to be soldered with sockets like 508R and 508S.
- Automatic soldering system and reflow line are prohibited at any time.

13-5. 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.
- If the accurate detection is required for gas densitometer or detector, periodical calibration like once or twice a year is recommended according to requirement of detection accuracy.
- If gas injection face is covered with water or oil, it is difficult to detect correctly. In case that such trouble is considered, design of alarm or densitometer water or oil proof structure is to be created.
- Since CO is bit lighter than air, CO alarm should be installed at the ceiling or higher position of wall.
- Warranty period in normal temperature and humidity is **10 years** excluding storage time of 8 months.

13-6. Other precautions

- NAP-508 shall be used according to specifications.
- Gas sensitivity characteristic is to be investigated in clean air without any noise gases.
- If the target 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 of inner air.
- Measurement for evaluation is to be carried out by recommended circuit, and electric power has not to be supplied to sensor 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 any case.
- Overweight over 5Kg/cm² should not be supplied to sensor enclosure.
- In case that the cause of sensitivity reduction is considered by mesh block, 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 bit long time that zero offset recovers to the initial stage.
- Please do not use sensor in organic solvent vapor, paint solvent vapor, oil vapor, other reagents and high concentration of any gases.

- In case that it is used in specific 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-508 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 distributors or subsidiaries which distributes it.

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