Ver.2110

Technical Information

(Electrochemical CO Gas Sensor)

Model　NAP－508

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Contents

(1) Electrochemical sensor

1-1 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.

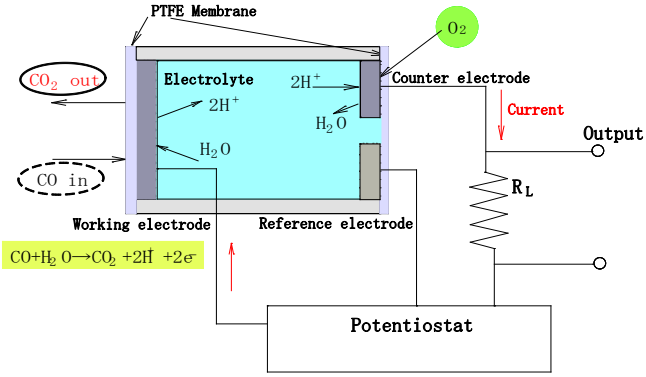


Fig.1 Detection principle

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 Merit and defect

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 & Co., Ltd. has developed NAP-505 sensor without electrolyte leakage with cheapest price and smallest size for residential application 2001. Next, we developed NAP-508 sensor of the long-life type based on the NAP-505 sensor, and is available in the market from 2008.

（2） Basic structure

Figure 2 show the sectional structure of NAP-508. 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.

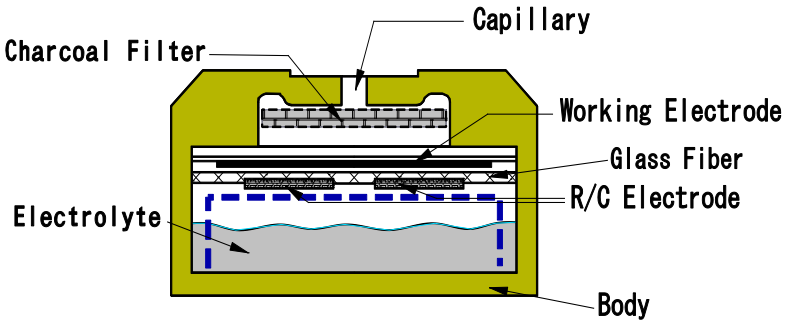


Fig.2 Sectional structure of NAP-508

(3) Characteristics of NAP-508

3-1 Features

3-1-1 Downsizing

NAP-508 has been developed making use of our vast accumulation of technologies in production of how wire type gas sensors, long research experience on catalyst, fine printing and assembling of sensors, those which we have been specialized in. This NAP-508 is small and less-expensive, but has high sensitivity, long life, and superior durability that would not allow the leakage of the electrolyte even under severer operation conditions. NAP-508 meets the severe requirements for ideal electro-chemical sensors, and is targeted to residential applications because of its low cost.

In addition to the features described in (3-2-2), NAP-508 has the following additional superiority compared to other electrochemical sensors.

3-1-2 Direct soldering

Conventional sensor cannot 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 since 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 sensor, 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.

3-1-3 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-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.

3-1-4 Detection performance of 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 0.5% with excellent accuracy. Figure 3 shows the linearity of CO till 0.5%, and it seems quite excellent.

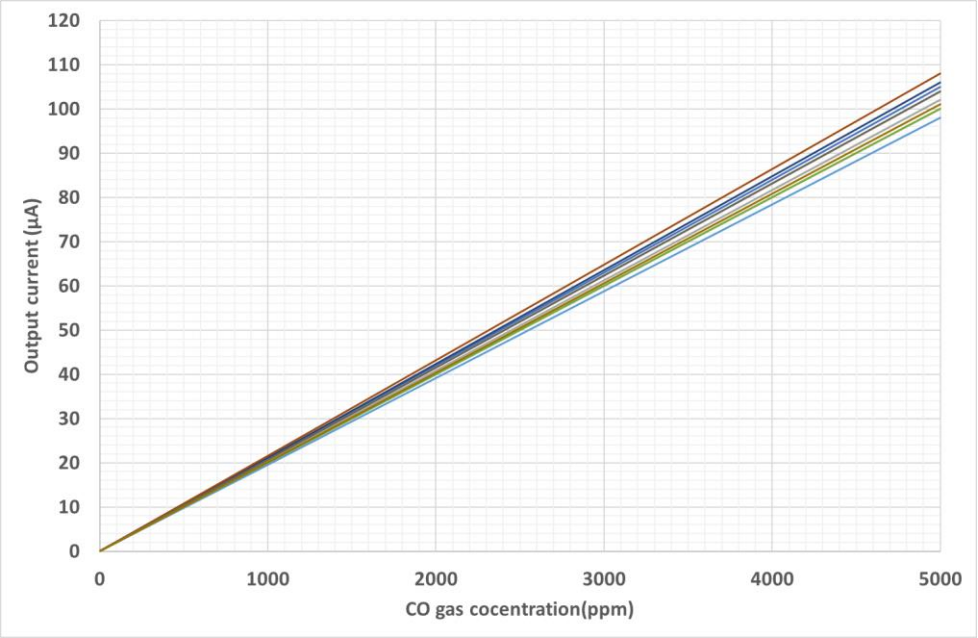


Fig.3 Linearity to CO gas

3-1-5 Long term stability

Long term stability of developed sensor in 2000 shown in the figure 4 employs our own electrodes as the same as NAP-508, and it shows very stable characteristics for over 10 years.

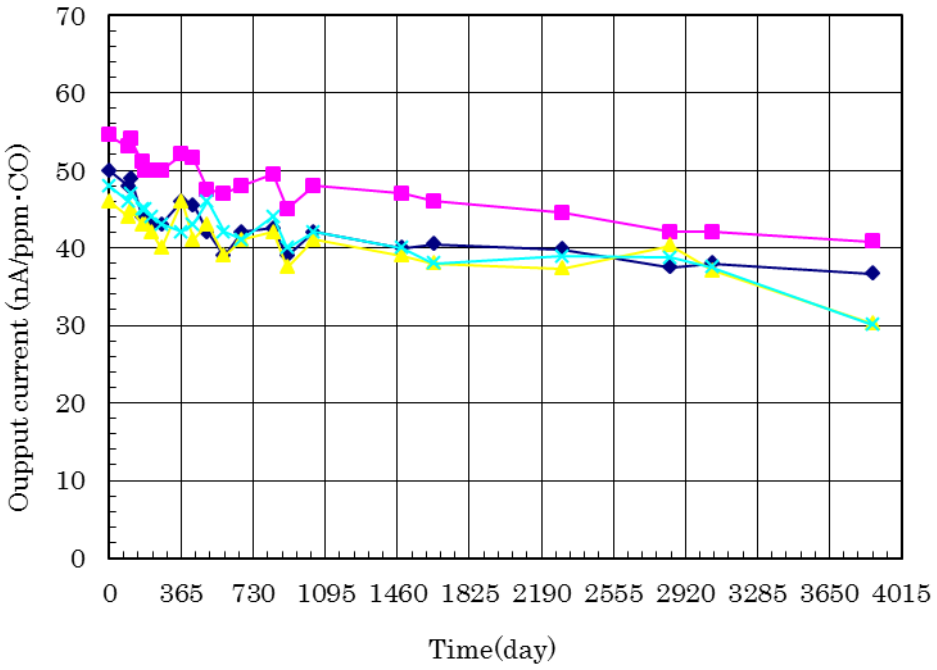


Fig.4 Long term stability of sensor developed in 2000 (Reference data)

3-2 Performance

3-2-1 Specification and features

Gas sensitivity

Detected gas	CO
Recommended detection range	0 – 2000ppm
Output current	21 ± 5nA/ppm
Repeatability	Less than 2%
Zero offset in pure air at 20 ºC	Less than 5ppm equivalent
Zero offset drift in long term	Less than 10ppm
Response time (t_{90})	Less than 45sec.
Temperature dependence of zero offset	Less than 15ppm (-20 ～ +50 ºC)
Sensitivity drift	Less than 3% per year
Expected lifetime	Over 10 years after production date

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

Conditions in operation and storage

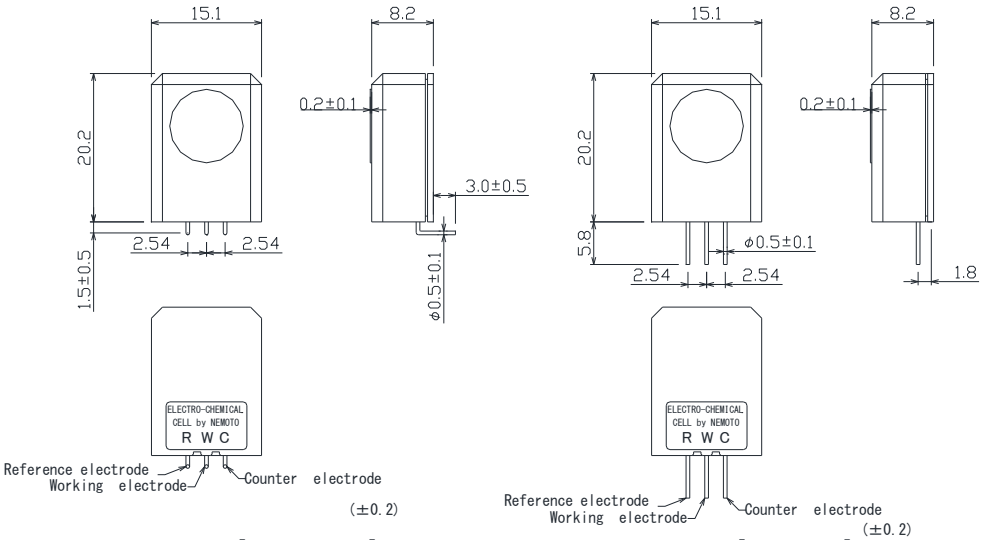
Temperature in operation	－30～50 degree C (continuous) －40～70 degree C (intermittent)
Humidity in operation	15～95%RH
Pressure in operation	1atm±10%
Recommended load resistor value	10 ohm
Recommended temperature in storage	0 ～20 degree C
Storage term	Less than 12 months

Enclosure material

Enclosure material	m-PPE
Cap color	Dark blue
Body color	Black
Electrode pin	ϕ 0.5, Ni plated Tin
Weight	Approx. 2.0g

3-2-2 Shape

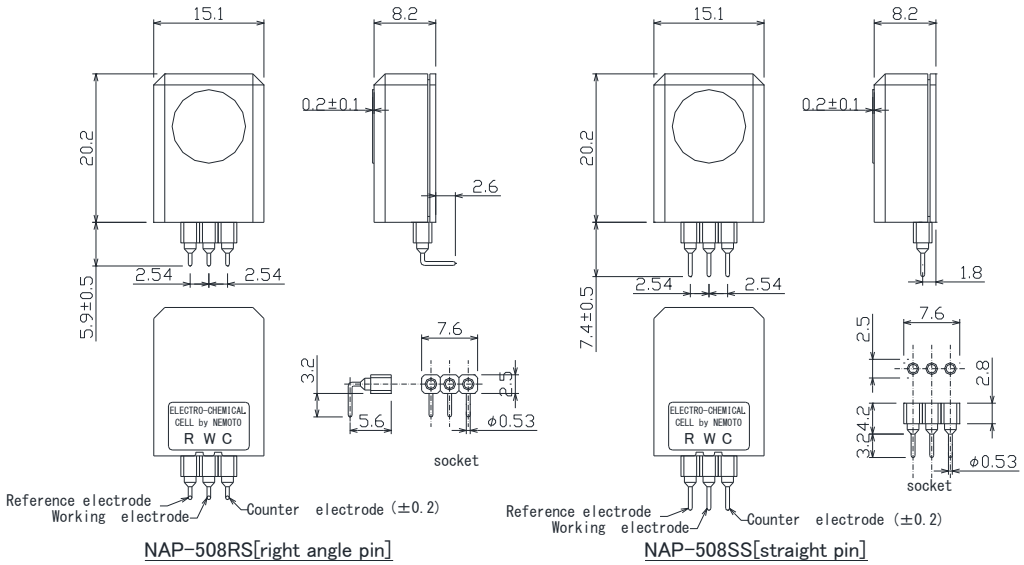
Direct Soldering Models



NAP-508R[right angle pin]

NAP-508S[straight pin]

Socket Models



NAP-508RS[right angle pin]

NAP-508SS[straight pin]

3-2-3 Gas sensitivity

Figure 5 shows the sensitivity characteristics to typical gases.

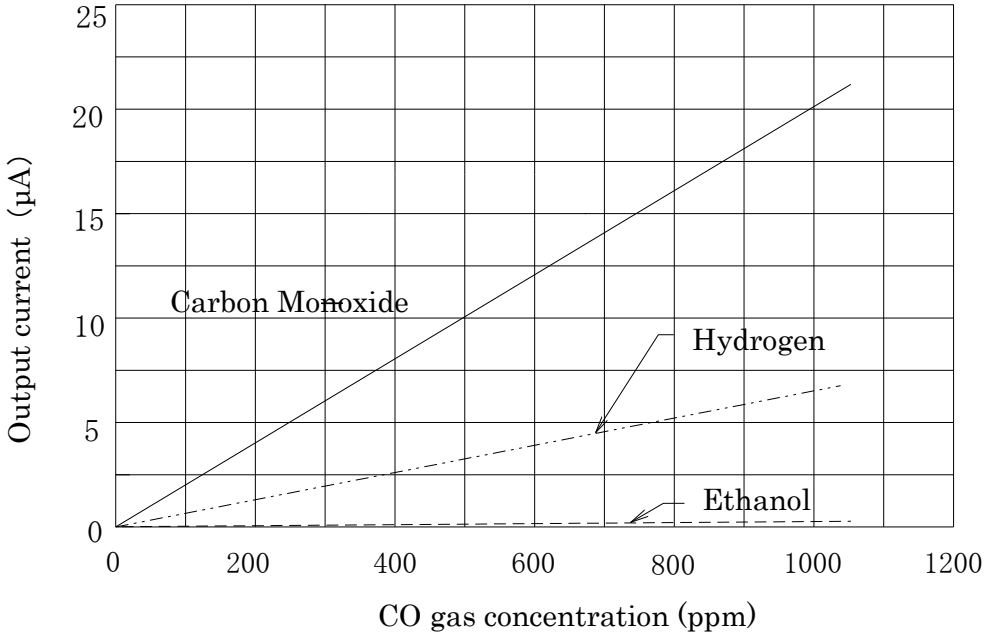


Fig.5 Gas sensitivity characteristics

3-2-4 Selectivity

NAP-508 possesses conformity to selectivity which international standards require, and table 1 shows the selectivity to typical noise gases defined in UL2034 and EN50291.

Table1. Gas selectivity

Test gas	Gas Concentration(ppm)	Relative sensitivity (CO is 100)
CO	100	100
Hydrogen	250	100
Methane	5000	0
Iso-Butane	2500	0
Carbon dioxide	5000	0
Carbon di-sulfate	25	0
Hydrogen sulfide	10	0
Nitrogen oxide	50	< 30
Nitrogen dioxide	30	< 5
Ammonia	100	0
Ethyl acetate	200	0***
Di-chloromethane	200	0***
Heptane	500	0***
Toluene	200	0***
IPA	200	0***
Ethanol	2000	< 10*
Hexa-methyl di-siloxan	10	0**

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

3-2-5 Response characteristics

Figure 6 shows the typical response and recovery characteristics to CO gas on NAP-508.

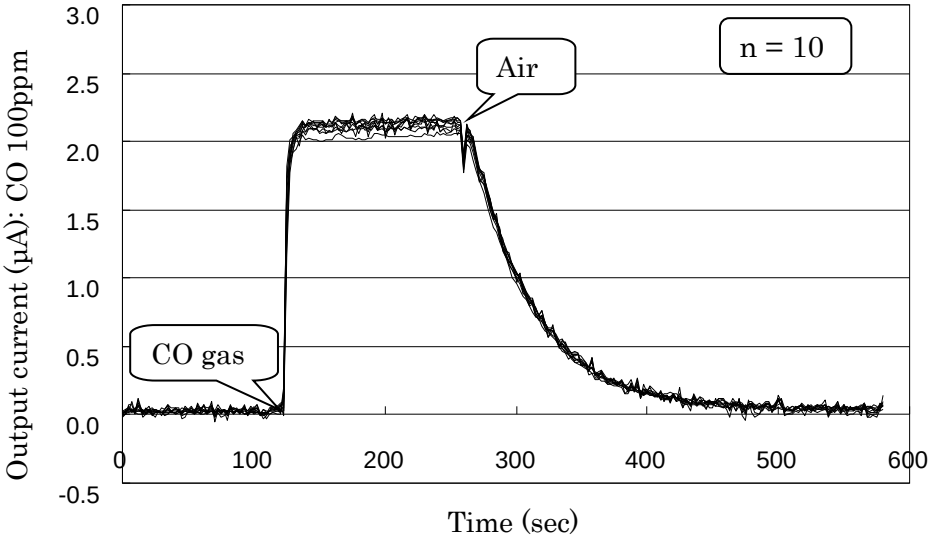


Fig. 6 Response and recovery characteristics of NAP-508

3-2-6 Pressure dependence of CO sensitivity

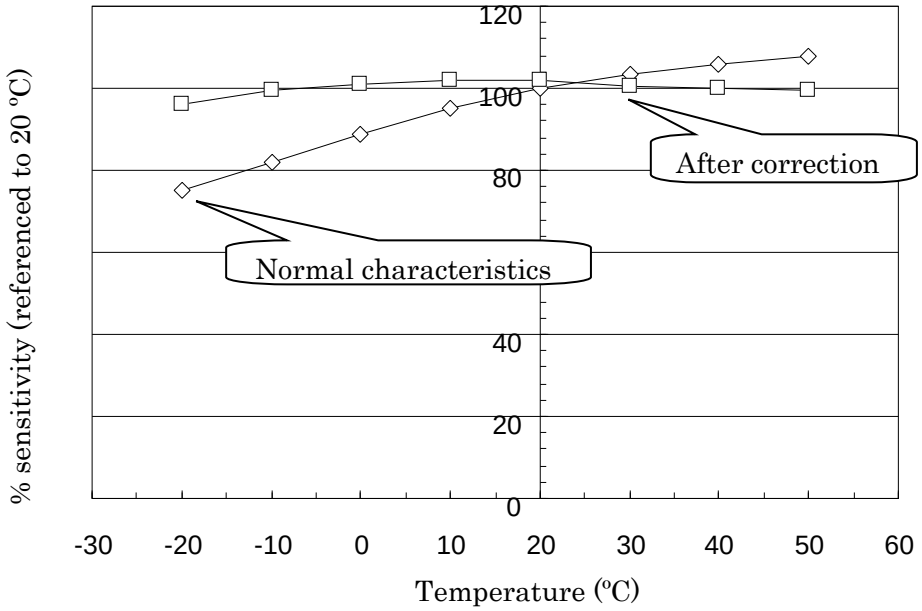


Fig. 7 shows the typical data of pressure dependence on NAP-508.

	Temperature (ºC):referenced to 20 ºC							
	-20	-10	0	10	20	30	40	50
Dependence rate (%)	75	82	89	95	100	103.5	106	108
Dependence rate after correction (%)*	96	99.4	101.1	101.8	101.8	100.7	99.8	99.3

*When you use recommended thermistor, the baseline value is not corrected by the thermistor.

3-2-7 Influence of wind speed on 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 8 shows the wind velocity dependence to sensitivity till 2m/sec.

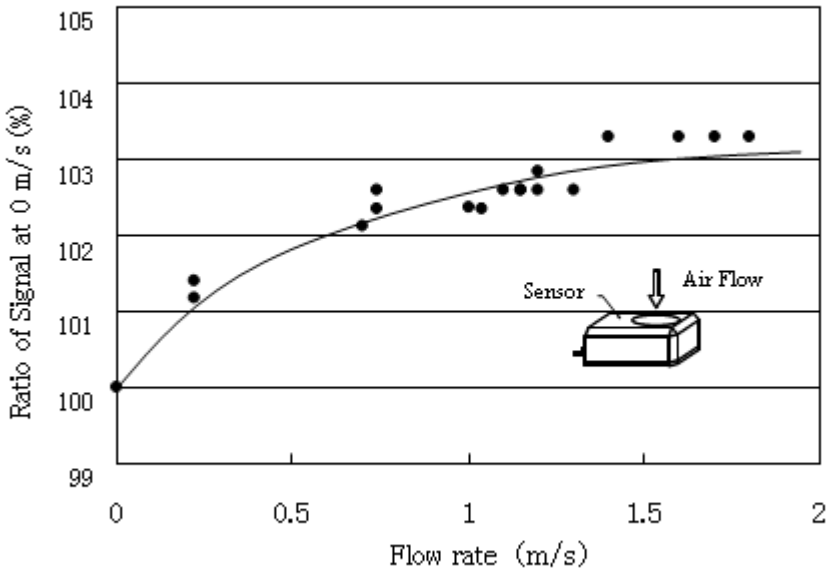


Fig. 8 shows the typical data of Wind velocity dependence on NAP-508.

3-3 Long term stability

Stability of CO gas sensitivity

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

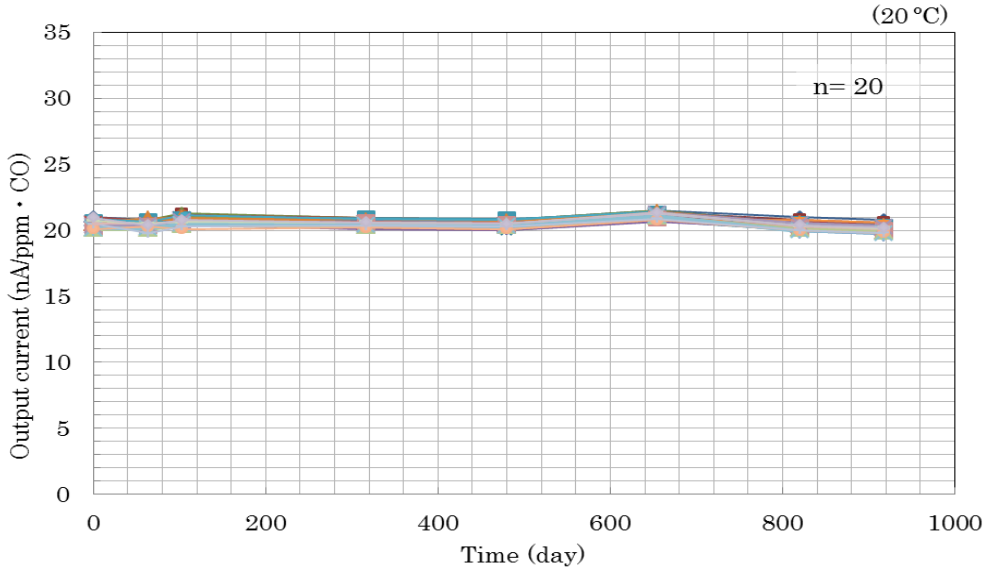
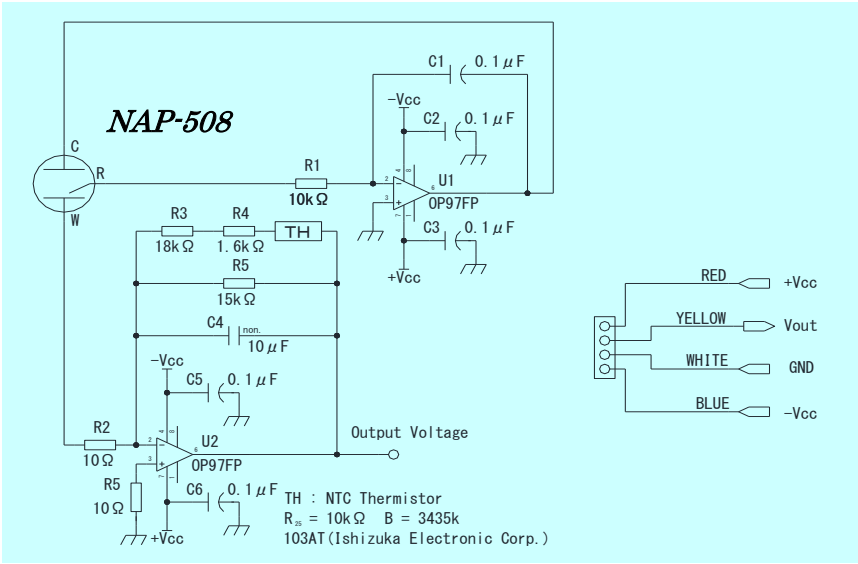


Fig. 9 Stability of sensitivity

3-4 Recommended circuit diagram

Recommended circuit diagram for evaluation of NAP-508 is shown in the right. In this circuit, OP97 which is popular and low power consumption is employed, and temperature dependence of NAP-508 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 ºC. By the way, this thermistor should be 3500K as B constant, and resistance value is to be round 10Kohm, manufacture is not pointed.



(4) Handling precautions

4-1 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-508 was improved to less than 5%/year. Reduction of 2-3%/year was actual, but since reduction cannot be prevented even a little like other electrochemical, such reduction ratio shall be considered at the design of application circuit diagram.

4-2 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.

4-3 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 ºC.

Recommended storage time after delivery is 12 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.

4-4 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 NAP-508S 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 370ºC for less than 3sec. respectively.
- Automatic soldering system and reflow line are not available at any time.

4-5 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.

4-6 Other precautions

- Characteristics on NAP-508(H) except items 2-4-1 and 2-4-2 are not guaranteed features but typical features.
- NAP-508(H) 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.
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- 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-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 distributor or subsidiary which distributes it.