

# Operation Manual

High temperature  
WELDABLE STRIAN GAUGE  
AWH series



Tokyo Measuring Instruments Lab.



# Introduction


This manual describes the handling methods and work procedures for the **High temperature Weldable Strain Gauge AWH Series**.


In order to ensure proper installation of and measuring with this product, please read this manual thoroughly and understand the performance and handling of this product well prior to use.


Please keep this manual with care so that you can read anytime.

## ■ Notes for reading this manual


In this manual, the following indications are used to describe important matters. Please ensure to read these indications.

 **Danger** This indicates a content which erroneous handling by ignoring this indication can cause a risk of death or serious injury / disease to human.

 **Warning** This indicates a content which erroneous handling by ignoring this indication can cause a risk of injury / damage to human.

 **Caution** This indicates a content which erroneous handling by ignoring this indication can cause a physical hazard.

**Note** This indicates a note or supplement for operations that are easily mistaken, etc.

 This indicates a content and helpful information to deepen understanding of the contents of the main text.

- Reproduction or reprinting of this manual, either partially or totally, without prior permission from us is strictly prohibited.
- The contents of this manual are subject to change without notice due to improvements in performance and/or function of the product.
- If you have any questions or notice any errors or missing items regarding the contents of this manual, please feel free to contact us.

## Safety precautions



### Warning

Handling	Implement safety measures to prevent your hand from being cut by the gauge base during installation work.
Spot welding	Wear goggles to prevent welding sparks from getting into your eyes during spot welding.



### Caution

Malfunction	Do not drop or hit this product. Strong vibration or impact causes a malfunction.
	Do not disassemble or modify this product in any case. Failure to follow this instruction causes injuries or malfunction.
	Avoid the use beyond the operational temperature range. Failure to follow this instruction causes malfunction.
Trial welding	Put the welding holder tip vertically on to the metal ribbon and push the welding holder downward. In the case that a crack or hole is generated on the metal ribbon at this point, lower the output energy of the welder and try again. In the case that the metal ribbon is not welded at all, increase the output energy.
Overcurrent	Do not operate beyond the maximum allowable current of 50mA.
Exciting voltage	Continuous operation beyond the allowable exciting voltage may cause drifts and may not satisfy the specifications.
	When using any measuring device other than a strain meter, use the device with sufficiently stable exciting voltage to the bridge.
MI cable	Do not forcibly bend the MI cable. Do not put any object on the cable, do not pull the cable, and do not otherwise damage the cable.

## Check and storage

Check	Measure the insulation resistance [ $\Omega$ ] between the input/output wire of the cable and the specimen by using an insulation resistance tester (with excitation voltage of DC 50V or lower) and confirm that it is 1000 M $\Omega$ or over.
Storage	For storage, avoid a high or low temperature and/or high humid place, dirt, dust, water drops, vibration, impact, etc.

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# Chapter 1

## Overview

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## 1.1 Overview and features

High temperature Weldable Strain Gauges are installed on metal surfaces by spot welding using a dedicated welder (separately sold). As the sensing elements and lead wires are fully encapsulated in corrosion-resisting and heat-resisting alloys, they can be used for measurement in various environment including in seawaters or gases. Their maximum operational temperature is higher than that of bonded strain gauges, and coating is basically not required.

Though the AWH Series gauges have half bridge configuration with one active element and one dummy element, full bridge measurement is carried out using a temperature compensation circuit board supplied with the product. Also, the maximum operational temperature is +600°C for static strain measurement and +650°C for dynamic strain measurement.

## 1.2 Specifications

Standard type name <sup>*1</sup>	AWH-4-7A-2-11.0	AWH-4-7B-2-17.0	AWH-8-7A-2-11.0	AWH-8-7B-2-17.0	
Gauge length	4 mm		8 mm		
Resistance element material	Special alloy				
Gauge base	Dimensions (mm)	L10 × W3 × T0.8		L16 × W5 × T0.8	
	Material	Inconel 600	SUS 304	Inconel 600	SUS 304
Resistance	Approx. 60 Ω		Approx. 120 Ω		
Operational temperature range <sup>*2</sup>	Static: -196 ~ +600°C Dynamic: -196 ~ +650°C				
Temperature compensation range	Static: Room temperature ~ +600°C Dynamic: —				
Measurement target materials	Mild steel or equivalent	SUS 304 or equivalent	Mild steel or equivalent	SUS 304 or equivalent	
Applicable coefficient of expansion	11×10 <sup>-6</sup> /°C	17×10 <sup>-6</sup> /°C	11×10 <sup>-6</sup> /°C	17×10 <sup>-6</sup> /°C	
Installation method	Spot welding				
Standard lead wire <sup>*1</sup>	φ1.6mm MI cable: 2m, φ4.1mm shielded vinyl cable: 0.5m				
MI cable sheath material	Inconel 600	SUS 304	Inconel 600	SUS 304	
Connection method	Full bridge method				
Insulation resistance	1000 MΩ or more (at room temperature)				
Maximum allowable current	50 mA (at room temperature)				
Frequency response	Approx. 2 ~ 3 kHz				
Strain limit <sup>*3</sup>	0.6% (6000 μm/m)				
Fatigue life <sup>*4</sup>	1×10 <sup>6</sup> times				

As the features described here are for reference, they may change by the influence of temperature, operating conditions, etc.

\*1: The type name varies by temperature compensation range, MI cable length and supplied cable length.

\*2: Although the low-temperature side (-196°C ~ room temperature) can be used (for measurement) owing to the structure, prior check is required.

\*3: Strain limit shows a result at room temperature.

\*4: Fatigue life shows a result at room temperature with a strain level of ± 1000μm/m (15 Hz).

### 1.3 Standard accessories

Operation manual		1 copy
Test data		1 copy
Metal ribbon	Applicable coefficient of linear expansion $11 \times 10^{-6}/^{\circ}\text{C}$	Material: Inconel 600 Dimensions: L40×W5×T0.08 mm
	Applicable coefficient of linear expansion $17 \times 10^{-6}/^{\circ}\text{C}$	Material: SUS 304 Dimensions: L40×W5×T0.08 mm
		2 pcs.

### 1.4 Name of each part and external dimensions

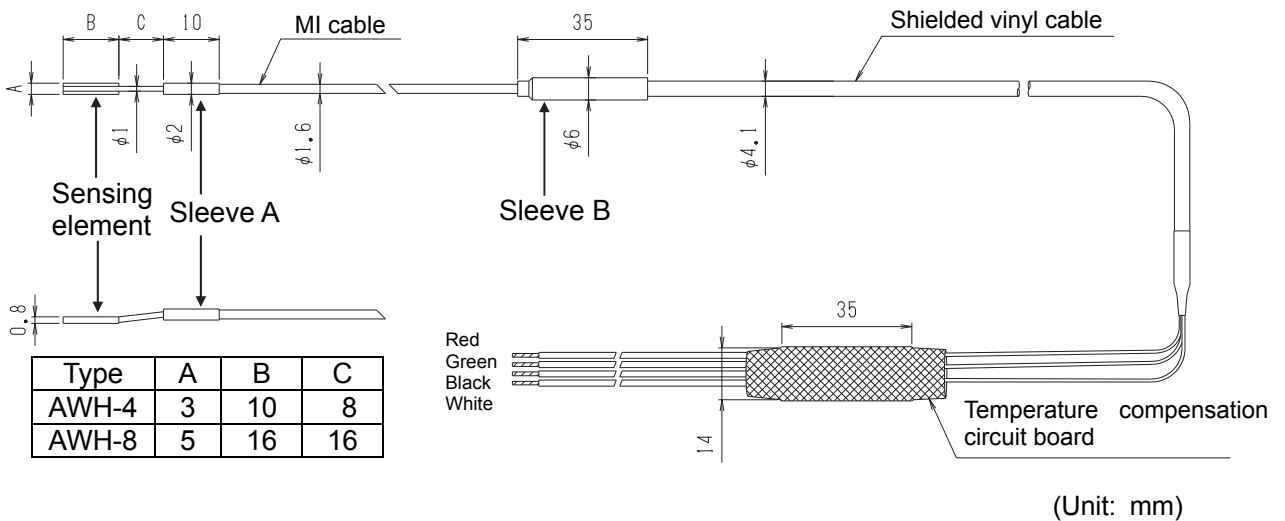


Figure 1.1: Appearance

**Caution** The cable end is processed by lead-free soldering. Use a lead-free solder (of Sn-Ag) for soldering.

The temperature compensation circuit board is supplied as a standard part to adjust the thermal output according to the temperature compensation target material.

The center of sensing element is at the center of the gauge base.

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# Chapter 2

## Installation method

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2.1 Installation method .....	2 - 2
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## 2.1 Installation method

### ■ Surface treatment of specimen

- (1) Completely remove mill scale, rust, oil, etc. on the surface to install the strain gauge before installing it. In the same manner as general bondable strain gauges, remove oil with acetone or other appropriate solvent and polish thoroughly with a sandpaper of around No. 120.
- (2) After polishing, clean the surface to install the gauge again with acetone or other appropriate solvent. Do not touch the surface with your hand or finger after cleaning.

**⚠ Caution** If the specimen and/or the gauge base is dirty during spot welding of the gauge base, a spark maybe generated.

### ■ Trial welding

- (1) Before installing the gauge, carry out trial welding with a supplied metal ribbon to check the welding conditions.
- (2) Set the welding output of the welder to approximately 10 watt per second and carry out spot welding. In the case that a crack or hole is generated on the metal ribbon at this point, lower the output energy of the welder and try again. In the case that the metal ribbon is not welded at all, increase the output.

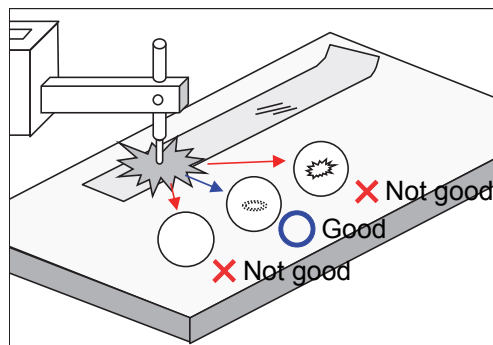


Figure 2-1: Check of trial welding

- (3) Peel off the metal ribbon after the trial welding. If a hole is formed on the welded part, this means the welding strength is sufficient.

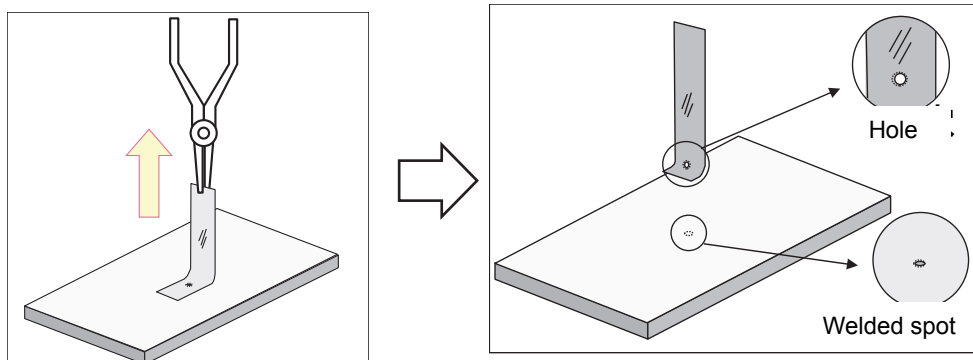


Figure 2-2: Check of peeling off of metal ribbon

**Note:** Be sure to read the operation manual supplied with the product before using our dedicated welder.

## ■ Installation of the strain gauge

- (1) The strain gauge is installed in the following order: fix the Sleeve A; fix the MI cable; and fix the gauge base.
- (2) Set the center of gauge base to the center of marking-off and fix the Sleeve A by using the supplied metal ribbon.

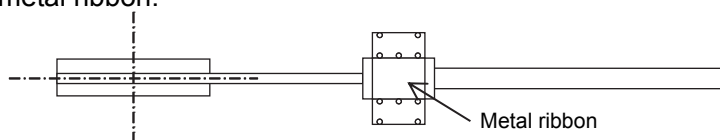


Figure 2.3: Fixing of the Sleeve A

- (3) Fix the MI cable at the appropriate length for one section, while avoiding any load on the fixed Sleeve A.
- (4) Slightly curve the MI cable and fix toward the direction of the Sleeve B, while avoiding any excessive force on the sensing element. Keep the distance of approximately 10 mm or over between the section for curving the MI cable and both of the Sleeve A and Sleeve B, and also secure the curvature diameter (approx. 10 mm or more) which is five times or more of the diameter of MI cable (1.6 mm).

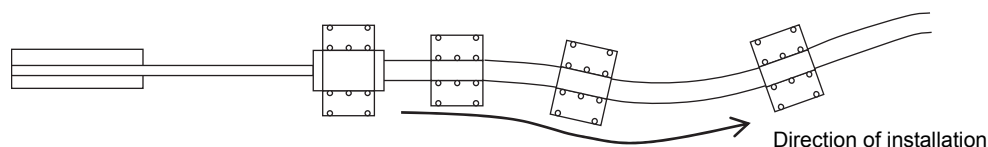


Figure 2.4: Fixing of the MI cable

- (5) Align the sensing element to the position of marking-off and temporarily fix the both sides of gauge base on each one point by spot welding.
- (6) Perform sport welding in order of the number along the gauge pipe. The appropriate welding interval is approximately 0.8mm-pitch.

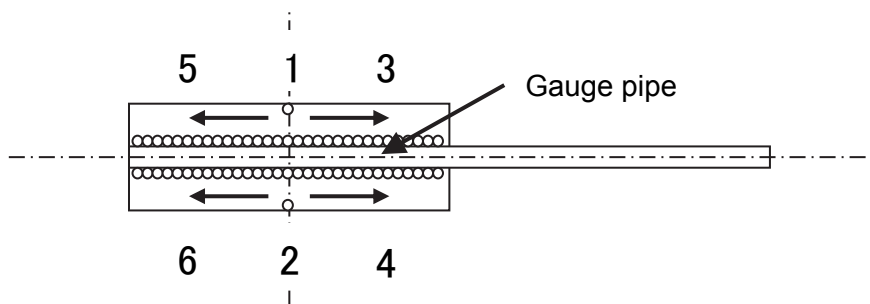


Figure 2.5: Fixing of the gauge base



Caution

Sandblast treatment has been implemented for the strain gauge to prevent sparks during welding work. Do not touch it directly by hand to avoid any dirt or damage.

■ Bending

● MI cable

When bending the MI cable, secure the bending radius of 5 mm or over and bend carefully.

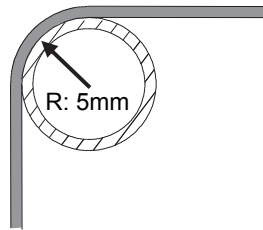


Figure 2.6: Bending of the MI cable

⚠	<p><b>Caution</b> Keep the distance of 10 mm or over between the starting point of MI cable bending and the both Sleeve A and Sleeve B.</p>	<p>Do not bend this part → 10mm or less</p> <p>A diagram of a cable with a sleeve. A double-headed arrow indicates a section of 10mm or less that should not be bent. A red 'X' is placed over this section.</p>
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The diameter of gauge protection tube to protect the sensing element is 10 mm.

● Gauge base

The strain gauge can be installed on a specimen with the diameter of 80 mm or over without bending. For diameter between 40 and 80 mm, perform bending by the following procedures.

- (1) Prepare a jig with the same diameter as the specimen and cushioning material of silicon rubber, etc.
- (2) Firmly push the gauge base to the jig with your finger and slowly bend it along the bending surface. After bending, the gauge base will slightly bend back to the original position.
- (3) Clean the gauge base with acetone or other appropriate solvent. Do not touch it with your hand or finger after cleaning.

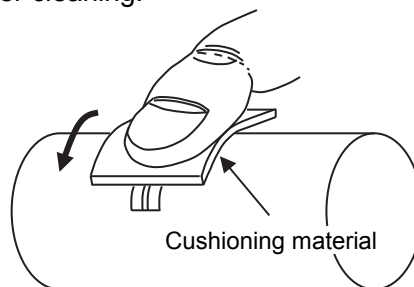


Figure 2.7: Bending of the gauge base

**Caution** The minimum diameter possible for bending the sensing element is 40 mm.

**Caution** Bending in the reverse direction after bending causes damage to the sensing element.

**Caution** As the balance of resistance value is lost by bending, the thermal output trend may be different from the property data on the supplied test data.

# Chapter 3

## Measurement

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## 3.1 Measurement method

### ■ Wiring method

- (1) Install the strain gauge on to the specimen under the procedures described in “2.1 Installation method”.
- (2) The cable end is not equipped with a connector as the standard specifications. Connect the cable wires to the terminal of a strain meter or a switching box by screwing or soldering.

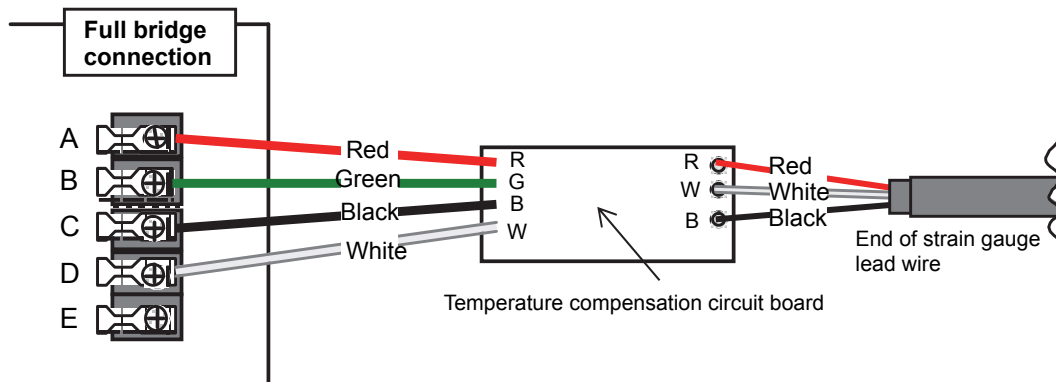







Figure 3.1: Connection to the instrument


 **Caution** The thermal output varies depending on the heated length of MI cable. Check the heating length of MI cable before the testing.

 **Caution** When temporarily disconnecting the temperature compensation circuit board on the end of the strain gauge lead wire for wiring works and so on, be sure to return it to the original position by checking the serial number.

 **Caution** The excitation voltage must be 50 V or less when checking the insulation resistance, etc.

 **Caution** The strain gauge temperature is required for organizing the measured data. Be sure to measure the temperature as well as the strain at the same time.

 **Caution** The MI cable may pick up noise if it is moved. Pay enough attention to firmly fix the MI cable in the wiring works, and prevent the MI cable from moving during measurement.

 **Caution** Lead-free soldering has been performed for the cable end. Use the lead-free solder (Sn-Ag) for soldering.

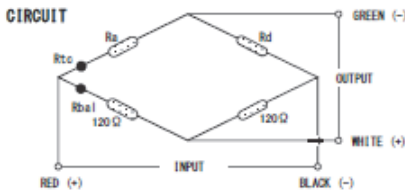
## ■ Data organizing method

In addition to the measured values of strain, it requires temperature measurement, heated length of MI cable and the test data supplied to the strain gauge for organizing the data. Check these before organizing the data. Note that necessary information such as gauge factor, rate of thermal sensitivity shift and polynomial expression of thermal output are described on the test data.

### HIGH TEMPERATURE WELDABLE STRAIN GAUGE TEST DATA

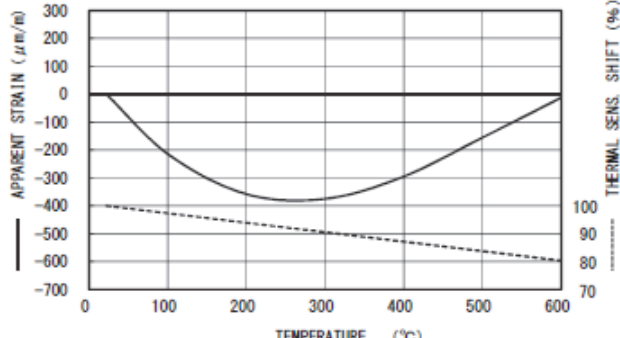
GAUGE TYPE	AWH-4-7A-2-11.0		SERIAL No.			
DATE	October 1, 2018		TEMPERATURE	22 °C	HUMIDITY	50 %

<b>GAUGE FACTOR</b> ORIGINAL G. F. $K_b = 2.96$ ADJUSTED G. F. $K_{c20} = 2.75$ SENSITIVITY SHIFT $C_k = -340$ ppm/°C (AT MI CABLE HEATED LENGTH OF 0m)	<b>OBJECT MATERIAL</b> EQUIVALENT TO MILD STEEL <b>COMPENSATION</b> TEMPERATURE RANGE 20 ~ 600 °C <b>COMPENSATION RESISTOR</b> TEMPERATURE $R_{tc} = 3.6$ Ω BALANCING $R_{bal} = 10.5$ Ω
<b>GAUGE RESISTANCE (AT ROOM TEMPERATURE)</b> ACTIVE ELEMENT $R_a = 58.51$ Ω DUMMY ELEMENT $R_d = 67.61$ Ω	<b>CIRCUIT</b> 
<b>MI CABLE</b> LENGTH                2 m CALIBRATED WITH HEATED    1 m RECIPROCATING RESISTANCE $2R_c = 1.83$ Ω TEMPERATURE COEFFICIENT $\alpha_m = 2.69E-03$ Ω/m /°C	

**CHARACTERISTICS**



**THERMAL OUTPUT**  
 $\epsilon_{app} = a + b \times T^1 + c \times T^2 + d \times T^3 + e \times T^4 + f \times MI \times (T - RT)$

**Fig. 1 THERMAL OUTPUT QUARTIC COEFFICIENT**

a	8.842E+01	RT	22
b	-4.191E+00		
c	7.645E-03		
d	-1.034E-07		
e	-4.797E-09		
f	5.306E-01		

$\epsilon_{app}$  : THERMAL OUTPUT (μm/m)  
 $a \sim e$  : THERMAL OUTPUT QUARTIC COEFFICIENT  
 $f$  : MI CABLE HEAT EFFECT COEFFICIENT  
 $MI$  : MI CABLE HEATED LENGTH (m)  
 $T$  : MEASUREMENT TEMPERATURE (°C)  
 $RT$  : TEMPERATURE WHEN CALIBRATED (°C)  
 $\epsilon_g$  : MEASUREMENT VALUE AFTER CORRECTION (μm/m)  
 $h \sim k$  : STRAIN CORRECTION COEFFICIENT

**CORRECTION OF MEASUREMENT VALUE**  
 WHEN SETTING GAUGE FACTOR BY INSTRUMENTS  
 $\epsilon_g = (\text{MEASUREMENT VALUE} - \epsilon_{app}) \div [1 + (T - RT) \times C_k \times 10^{-6}]$

**CALCULATION OF ACTUAL STRAIN**  
 $\text{ACTUAL STRAIN} = h \times \epsilon_g + i \times \epsilon_g^2 + j \times \epsilon_g^3 + k \times \epsilon_g^4$

**Fig. 2 STRAIN CORRECTION COEFFICIENT**

h	9.116E-01
i	7.393E-05
j	2.960E-08
k	-2.816E-12



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Tested by : \_\_\_\_\_

Judgement

Passed

(Form K40-106)

Figure 3.2: Example of the test data of AWH Series

- (1) Determine the thermal output at the measurement temperature by using the polynomial expression for thermal output on the test data.

$$\varepsilon_{app} = a + b \times T^1 + c \times T^2 + d \times T^3 + e \times T^4 + f \times MI \times (T - RT) \quad \text{<Expression 1>}$$

- (2) Determine the measured value corrected by the thermal output and the rate of thermal sensitivity shift.

When the gauge factor correction is made by the instrument:

$$\varepsilon_g = (\text{measured value} - \varepsilon_{app}) \div \{1 + (T - RT) \times Ck \times 10^{-6}\} \quad \text{<Expression 2>}$$

- (3) Determine the actual strain by performing linearity correction of the corrected measured value.

$$\text{Actual strain} = h \times \varepsilon_g + i \times \varepsilon_g^2 + j \times \varepsilon_g^3 + k \times \varepsilon_g^4 \quad \text{<Expression 3>}$$

Legend for the expressions

$\varepsilon_{app}$	: Thermal output ( $\mu\text{m/m}$ )
$a \sim e$	: Thermal output quartic coefficient
$f$	: MI cable heat effect coefficient
$MI$	: MI cable heated length (m)
$T$	: Measurement temperature ( $^{\circ}\text{C}$ )
$RT$	: Temperature when calibrated ( $^{\circ}\text{C}$ )
$\varepsilon_g$	: Measured value after correction ( $\mu\text{m/m}$ )
$Ck$	: Rate of thermal sensitivity shift ( $\text{ppm}/^{\circ}\text{C}$ )
$h \sim k$	: Strain correction coefficient



**Caution** The thermal output varies depending on the heated length of MI cable. Check the MI cable heating length before testing.



**Caution** In the case of a rapid change in test temperature (thermal transient), performance of strain gauge may be different from the property data on the supplied test data. In this case, it is recommended to carry out thermal output test at no load prior to the actual test and obtain polynomial expression of thermal output.



The gauge factor in the property data on the supplied test data has been corrected by Kc20.

**Note** Use a value which is corrected by the gauge factor for the measured value.

**Note** As unit conversion such as  $\text{ppm}/^{\circ}\text{C}$  has been performed for the expressions, use the values on the supplied test data as they are.

Example: Determine the thermal output and the actual strain when the MI cable heated length is 1m and the measurement temperature is 501°C.

In this case, it is supposed that the measured value at the measurement temperature of 501 °C is 1000µm/m, and also that the conditions are as described in the Table 3.1.

Table 3.1: Example of the test data

Thermal output quartic coefficient	a:	6.087E+01
	b:	-2.943E+00
	c:	6.259E-03
	d:	-1.925E-06
	e:	-1.632E-09
MI cable heat effect coefficient	f:	9.062E-02
Temperature when calibrated	RT:	22°C
Rate of thermal sensitivity shift	Ck:	-370 ppm/°C
Strain correction coefficient	h:	6.591E-01
	i:	2.143E-04
	j:	-1.207E-08
	k:	2.945E-13

(1) Determine the thermal output at the measurement temperature of 501°C.

$$\begin{aligned}
 \varepsilon_{app} &= a + b \times T^1 + c \times T^2 + d \times T^3 + e \times T^4 + f \times MI \times (T - RT) \\
 &= 6.087E+01 + (-2.943E+00) \times 501^1 + (6.259E-03) \times 501^2 + (-1.925E-06) \times 501^3 \\
 &\quad + (-1.632E-09) \times 501^4 + (9.062E-02) \times 1 \times (501-22) \\
 &= -144 \mu\text{m/m}
 \end{aligned}$$

(2) Determine the value corrected by the thermal output and the rate of thermal sensitivity shift.

$$\begin{aligned}
 \varepsilon_g &= (\text{measured value} - \varepsilon_{app}) \div \{1 + (T - RT) \times Ck \times 10^{-6}\} \\
 &= (1000 - (-144)) \div \{1 + (501-22) \times (-370) \times 10^{-6}\} \\
 &= 1390 \mu\text{m/m}
 \end{aligned}$$

(3) Determine the actual strain when the measurement temperature is 501°C and the measured value is 1000µm/m.

$$\begin{aligned}
 \text{Actual strain} &= h \times \varepsilon_g + i \times \varepsilon_g^2 + j \times \varepsilon_g^3 + k \times \varepsilon_g^4 \\
 &= (6.591E-01) \times 1390 + (2.143E-04) \times 1390^2 \\
 &\quad + (-1.207E-08) \times 1390^3 + (2.945E-13) \times 1390^4 \\
 &= 1299 \mu\text{m/m}
 \end{aligned}$$

■ In the case that the MI cable heated length is not known

Determine the MI cable heated length at the measurement temperature.

(1) Disconnect the temperature compensation circuit board at the measurement temperature by using a soldering iron.

(2) Measure the wire-to-wire resistance of the lead wire.

Color of the vinyl sheath	Wire-to-wire resistance of the lead wire
Red – White	$R_1 = R_a + 2R_{cT}$
White- Black	$R_2 = R_d + 2R_{cT}$
Black - Red	$R_3 = R_a + R_d + 2R_{cT}$

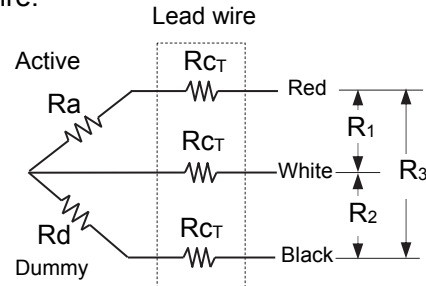


Figure 3.3: Expressions to determine the wire-to-wire resistance and the circuit diagram

(3) Calculate the total resistance value of the MI cable at the measurement temperature.

$$2R_{cT} = R_1 + R_2 - R_3 \quad \text{<Expression 4>}$$

(4) Determine the MI cable heated length.

$$MI = (2R_{cT} - 2R_c) \div \{\alpha m \times (T - RT)\} \quad \text{<Expression 5>}$$

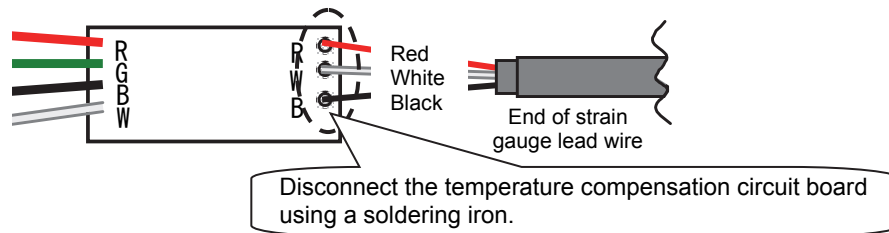


Figure 3.4: Disconnection of the temperature compensation circuit board

Legend for the expressions	
$R_1, R_2, R_3$	: Wire-to-wire resistance of the lead wire ( $\Omega$ )
$R_a$	: Gauge resistance of the active element ( $\Omega$ )
$R_d$	: Gauge resistance of the dummy element ( $\Omega$ )
MI	: MI cable heated length (m)
$2R_{cT}$	: Total resistance of MI cable at the measurement temperature ( $\Omega$ )
$2R_c$	: Total resistance of MI cable at room temperature ( $\Omega$ )
$\alpha m$	: Temperature coefficient of resistance of MI cable ( $\Omega/m/^\circ C$ )
T	: Measurement temperature ( $^\circ C$ )
RT	: Temperature when calibrated ( $^\circ C$ )

**Note** When measuring resistance values, use a high-precision resistance tester that can read 0.001 $\Omega$ .

**Caution** When temporarily disconnecting the temperature compensation circuit board on the end of the strain gauge lead wire for wiring works and so on, be sure to return it to the original position by checking the serial number.

**Caution** Lead-free soldering has been performed for the cable end. Use the lead-free solder (Sn-Ag) for soldering.

Example: Determine the MI cable heated length at the measurement temperature of 501°C. The conditions are supposed to be the description in the Table 3.2.

Table 3.2: Example of the test data

Total resistance of the MI cable at room temperature	2Rc: 2.833Ω
Temperature coefficient of resistance of the MI cable	αm: 3.219×10 <sup>-3</sup> Ω/m/°C
Temperature when calibrated	RT: 22 °C

- (1) Disconnect the temperature compensation circuit board at the measurement temperature of 501°C and measure the wire-to-wire resistance of the lead wire.

Wire-to-wire resistance of the lead wire

Wire-to-wire resistance between red and white	R <sub>1</sub> : 114.197Ω
Wire-to-wire resistance between white and black	R <sub>2</sub> : 124.268Ω
Wire-to-wire resistance between black and red	R <sub>3</sub> : 234.091Ω

- (2) Calculate the total resistance of MI cable at 501°C.

$$\begin{aligned}
 2R_{CT} &= R_1 + R_2 - R_3 \\
 &= 114.197 + 124.268 - 234.091 \\
 &= 4.374 \Omega
 \end{aligned}$$

- (3) Determine the MI cable heated length.

$$\begin{aligned}
 MI &= (2R_{CT} - 2Rc) \div \{\alpha m \times (T - RT)\} \\
 &= (4.374 - 2.833) \div \{3.219 \times 10^{-3} \times (501 - 22)\} \\
 &= 0.999m
 \end{aligned}$$

### ■ Correction of the strain gauge height

The sensing element of this product sits somewhat distant from the surface of test body. Accordingly, the sensitivity is slightly different between tension and bending. Sensitivity correction is required when it is used for measurement of bending strain. The height of sensing element of this product is 0.41mm.

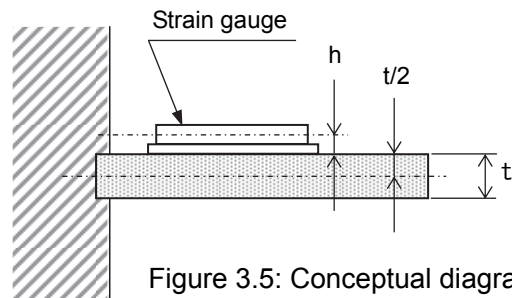


Figure 3.5: Conceptual diagram

$$K_b = K_{c20} \times \frac{h + (t/2)}{t/2} \quad \text{<Expression 9>}$$

Legend for the expression

h : Height of sensing element (mm)

t : Thickness of specimen (mm)

K<sub>b</sub> : Gauge factor by bending

K<sub>c20</sub> : Gauge factor

Example: Determine the gauge factor at room temperature when the thickness of specimen is 20mm. The conditions are supposed to be the description in the Table 3.3.

Table 3.3: Example of conditions

Height of sensing element	h : 0.41mm
Thickness of specimen	t : 20mm
Gauge factor	K <sub>c20</sub> : 2.75

$$K_b = K_{c20} \times \frac{h + (t/2)}{t/2}$$

$$K_b = 2.75 \times \frac{0.41 + (20/2)}{20/2}$$

$$\doteq 2.86$$



High temperature WELDABLE STRAIN GAUGE **AWH series**

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