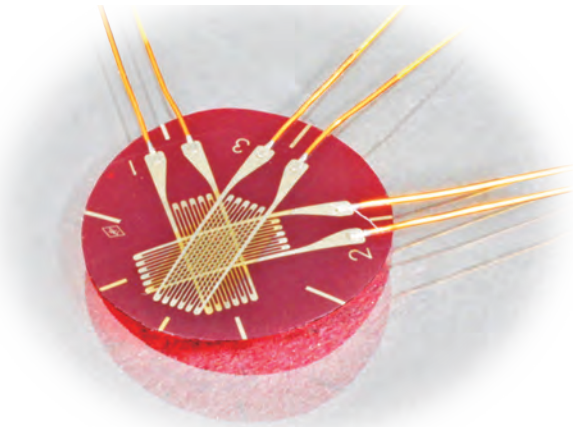
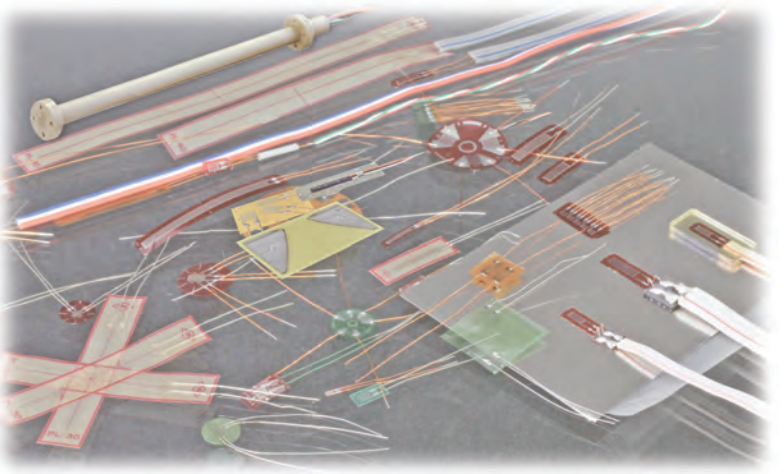
TML Pam E-1007A

TML

Precise & Flexible

STRAIN GAUGES





Tokyo Sokki Kenkyujo Co., Ltd.

TML
STRAIN GAUGES
Tokyo Sokki Kenkyujo Co., Ltd.

INTRODUCTION

This catalog presents the full range of TML standard strain gauges and associated products including bonding adhesives and coating materials manufacutred by Tokyo Sokki Kenkyujo Co., Ltd.
TML is a registered trade mark of the company.
It also describes how to find specific strain gauges, introduces typical applications, and defines the most commonly used technical terms.

Prior to using the catalog, please check the information listed below.

CHANGES IN SPECIFICATIONS

In the interest of product improvement, the specifications in this catalog are subject to change without prior notice.

DIMENSIONS

Dimensions are mainly given in milimeter. Strain gauge patterns are shown in actual size, with enlargements of some miniature patterns.

PRICES

Prices are not listed in this catalog. For price information or orders, please contact TML or your local representatives.

HANDLING STRAIN GAUGES

1. The technical data supplied herein do not reflect the influence of the leadwire. The data must be corrected in accordance with the effect caused by the leadwire.
2. The service temperature of a strain gauge depends on the operating temperature of the adhesive, etc.
3. Insulation resistance should be checked at a voltage of less than 50V.
4. Do not apply an excessive force to the gauge leads.
5. Apply adhesive to the back of the strain gauge and attach the gauge to the specimen.
6. The back of each strain gauge has been washed and degreased. Do not contaminate it by touching it directly.
7. For maintaining quality, store products in a dry place.

HANDLING BONDING ADHESIVES AND COATING MATERIALS

1. Read the operation manual carefully before using bonding adhesives and coating materials.
2. After using an adhesive, wipe all remaining adhesive off the container and nozzle with a cloth, and replace the cap.
3. After using an adhesive, put the container back in the package and store it in a cool, dark place away from fire.
4. If an adhesive contacts skin or clothing, wash well with soap and water.

If you have any questions about this catalog, please contact TML or your local representatives.

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Approval Certificate **ISO9001**
Design and manufacture of strain gauges, strain measuring equipment and transducers

TML STRAIN GAUGES

Stress measurement technologies are indispensable for ensuring the safety and efficiency of all kinds of structures. Since its foundation in 1954, Tokyo Sokki Kenkyujo Co., Ltd. has been a specialized manufacturer of stress measuring instruments including strain gauges and related products. Throughout the history of more than 60 years, the company has striven to take the needs of the times and to provide trustworthy products that can be used with full reliability.
TML Strain Gauges are our main products,and we unveiled the world's first polyester strain gauge in 1956. This new gauge brought about a great improvement in the humidity resistance of gauge backings compared to the strain gauges with paper backings which were popular at that time. Since then, our various technologies represented by the development of foil strain gauges and high temperature strain gauges have enabled reliable measurements under diverse conditions.

About this TML STRAIN GAUGES

This catalog presents the full range of TML standard strain gauges and associated products including bonding adhesives and coating materials manufactured by Tokyo Sokki Kenkyujo Co., Ltd.
It also describes how to find specific strain gauges, introduces typical applications, and defines the most commonly used technical terms.

Each strain gauge series includes its operating temperature and temperature compensation range along with the bar images as shown right.

Each strain gauge series is available with different bonding adhesives. Operating temperature is given along with combination of applicable adhesive, while it may differ from potential temperature of the adhesive itself.

Operating temperature range

-20°C  +80°C

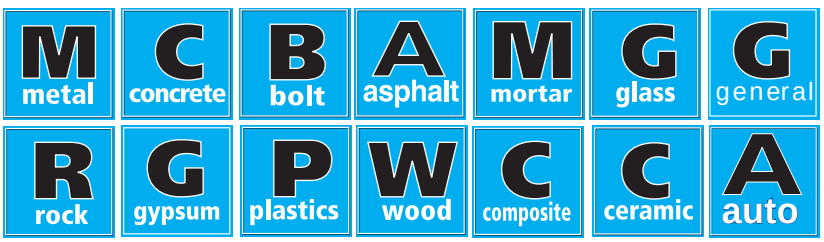
Temperature compensation range

+10°C  +80°C

Compatible adhesive & Operating temperature

CN : 0 ~ +80°C
P-2 : -20 ~ +80°C

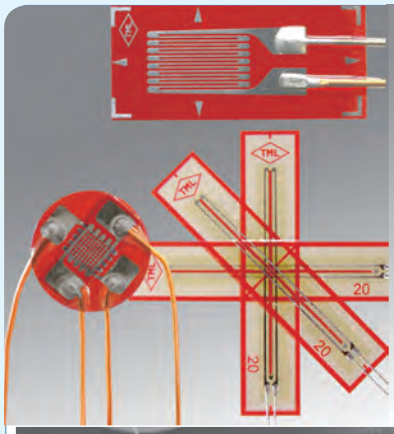
Each strain gauge series is designed for object materials. 14 different materials are shown with pictograms.

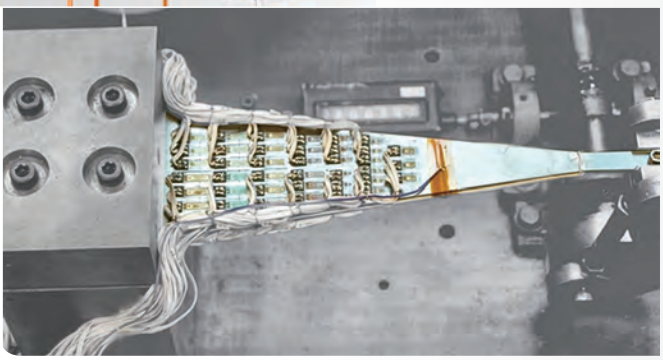


TML STRAIN GAUGES TESTING AND INSPECTION STANDARDS

TML strain gauges are manufactured under a fully integrated system that covers all stages from development to tests and inspections, and the utmost attention is paid to quality management in all processes. Our strain gauges, which we manufacture in the cleanest environment using the best materials available, are tested and inspected according to international standards, most notably NAS 942, the National Aerospace Standard.

TML Strain gauges Testing and Inspection Standards





Testing and Inspection Standards

Visual and Microscopic Inspections
TML Inspection Procedures and Standards

¶ Gauge Resistance
TML Procedures and Inspection Standards

¶ Gauge Factor
ASTM E251, NAS 942 and BS6888

¶ Transverse Sensitivity
ASTM E251 and NAS 942

¶ Temperature Coefficient of Gauge Factor
ASTM E251 and NAS 942

¶ Thermal Output
ASTM E251 and NAS 942

¶ Strain Limits
NAS 942

¶ Fatigue Life
NAS 942

¶ Creep
NAS 942

¶ Drift
NAS 942

Principal standards used for strain gauge calibration and standard test methods

¶ ASTM E251-74
"Standard Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gauges"
Designation: E251-92, ASTM

¶ BSI BS6888
"Methods for Calibration of Bonded Electric Resistance Strain Gauges"
Draft for development 6:1972. BSI

¶ NAS942
"Strain Gauges, Bonded Resistance"
Classification Specification NAS 942, 1963

¶ VDE/VDI Richtlinen NR 2635
"Bonded Electric Resistance Strain Gauges with Metallic Measurement Grids - Characteristics and Testing Conditions"
VDE/VDI-Richtlinen NR 2635 August, 1974

¶ Other standards
JIS Z2300-91 - "Glossary of Terms Used in Nondestructive Testing", Japan Industrial Standard
NDIS 4001:2008 - "Glossary of Terms Relating to Electric Resistance Strain Gauges", NDI, Japan

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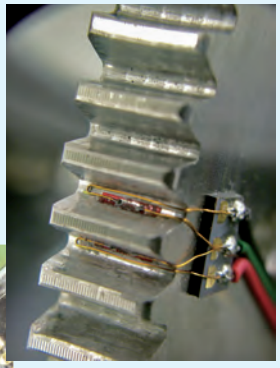
TML STRAIN GAUGE APPLICATIONS

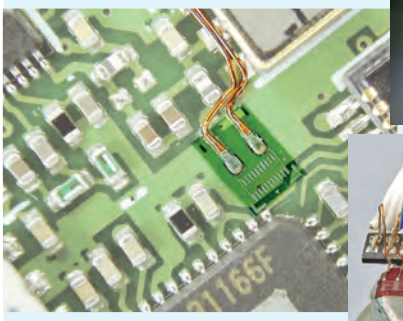
Miniature strain gauges

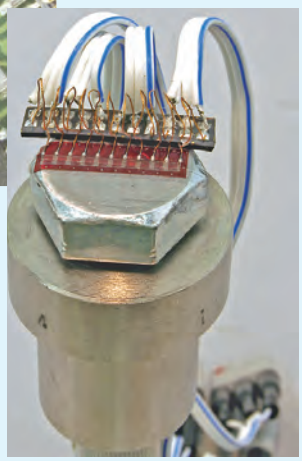
Printed circuit boards and surface mounting parts of automobile, computers and industrial machinery are getting smaller. Miniature strain gauges can be installed in a very limited gauge installatioin space.

Strain gauges in the valley of gear



Strain gauges on printed circuit board

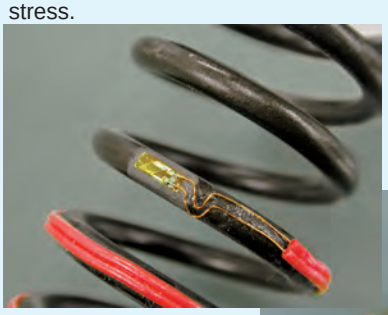


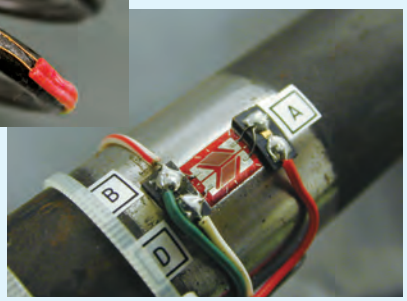


10-element chain type strain gauges on bolt head

Shearing strain and torque measurements

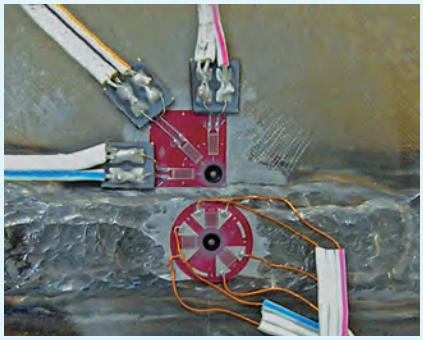
Shearing strains in 45-degree direction generated by shearing stress.





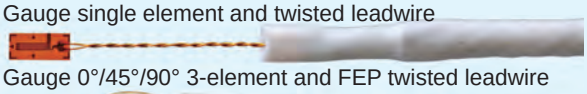
Residual stress measurement

3-element residual stress measurement by center-hole drilling method



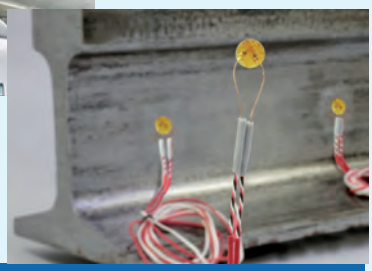
Magnetic field use

Strain Gauge single element and twisted leadwire



Strain Gauge 0°/45°/90° 3-element and FEP twisted leadwire

Strain measurement less influenced by EM noise between pantograph and trolley wire of electrified railway system

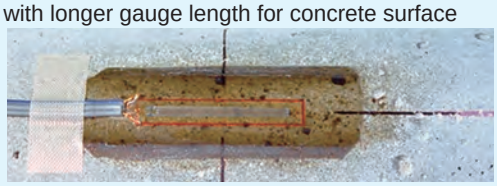


Railway axle load measurement

Concrete/Mortar measurements

Surface strain measurement of concrete and mortar

Strain Gauge with longer gauge length for concrete surface



Strain Gauges with longer gauge length and metal backing for concrete surface

Internal strain measurement of concrete and mortar

Mold strain gauges

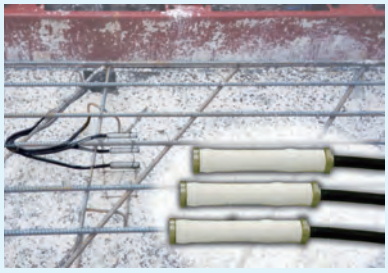
PM series

PMF series available with temperature sensor integrated

Internal strain measurement of concrete for long term

Full bridge Strain Transducer KM series

Before placement of concrete, 3 KM transducers are installed to reinforcing bars.

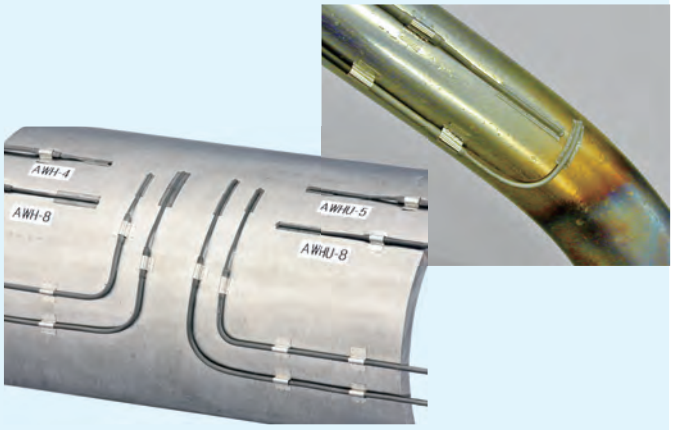


TML STRAIN GAUGES APPLICATIONS

Bolt tensile force by emebedment type gauges

For measurement of tensile strain of bolt. Simply inserted into a pre-drilled hole in the bolt head together with A-2 bonding adhesive. BTM gauge series is recommendable if an ordinary strain gauge cannot be mounted on the bolt surface. Accurate tensile force measurement is possible by calibrating the bolt after installing the bolt gauges.

Weldable strain gauges

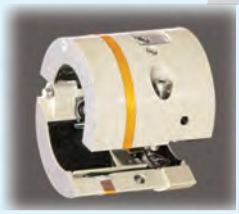


Friction type Strain Checker, Axial Strain Transducer, Torque Transducer

Strain Checker FGMH series for single and 3-directional measurement. Re-usable with installation by magnet.

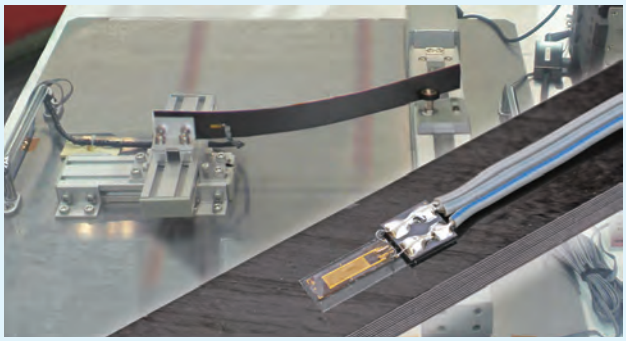
Torque transducer FGDH series applicable to driving shaft with split and cover-up system. With built-in telemetry transmitter, no wiring is required.

Split and cover-up system



Axial Strain Transducer FGAH series applicable to sterling shaft with cover-up system
Different from the above FGDH, wire connection is required.

High Endurance Strain Gauge bonded on composite materials

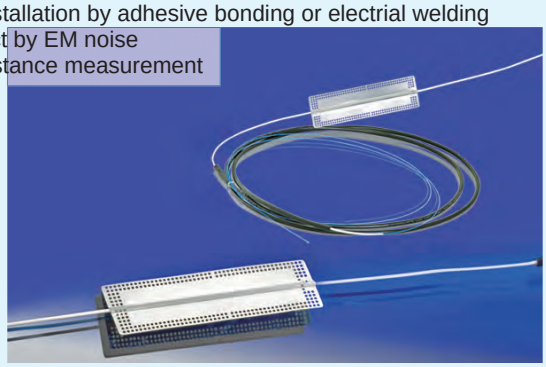


Composite materials on which High Endurance Strain Gauge DSF is bonded are demonstrated for fatigue test over 10^7 cycles at strain level of ±3,000 microstrain.

Optic fiber sensor OLM-60A

Fiber Bragg Grating based strain gauges with optic fiber

- Easy installation by adhesive bonding or electrial welding
- No effect by EM noise
- Long distance measurement



Long term measurement

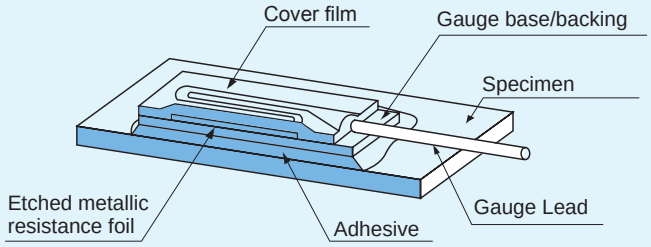
For construction measurement and maintenance.

GENERAL DESCRIPTION

Strain gauges are generally used for one of three reasons:

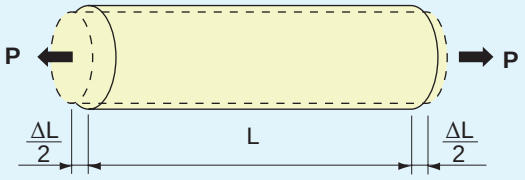
- To ascertain the amount of deformation caused by strain
- To ascertain the stress caused by strain and the degree of safety of a material or of a structural element that uses that material.
- To indirectly ascertain various physical quantities by converting them to strain.

There are a number of ways of measuring strain mechanically and electrically, but the vast majority of stress measurement is carried out using strain gauges due to their superior measurement characteristics.



What is Strain?

External force applied to an elastic material generates stress, which subsequently generates deformation in the material. At this time, the length of the material L extends to L+ΔL if the applied force is a tensile force. The ratio of ΔL to L, that is ΔL/L, is called strain. On the other hand, if a compressive force is applied, the length L is reduced to L−ΔL. Strain at this time is (−ΔL/L).



$$\varepsilon = \frac{\Delta L}{L}$$ where ε : Strain
L : Original length of material
ΔL : Change in lenth due to force P

Example) when a material of 100mm long deforms by 0.1mm in its length, the resulting strain is as follows.

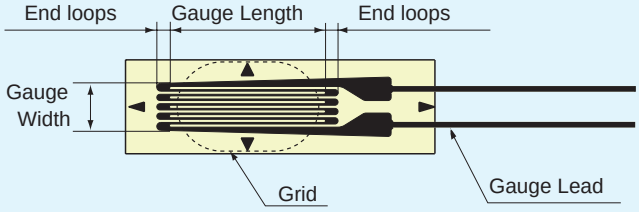
$$\varepsilon = \frac{\Delta L}{L} = \frac{0.1}{100} = 0.001 = 1000 \times 10^{-6}$$

What is Strain Gauge?

The electric resistance of a metal changes proportionally to the mechanical deformation caused by an external force applied to the metal. By bonding a thin metal to a measurement object through a thin electrical insulator, the metal deforms depending on deformation of the measurement object and its electric resistance changes. The strain gauge (electric resistance strain gauge) is a sensor to measure the strain by means of measuring the resistance change.

Strain Gauge Configuration

A strain gauge is constructed by forming a grid made of fine electric resistance wire on photographically etched metallic resistance foil on an electrical insulation base (backing), and attaching gauge leads.



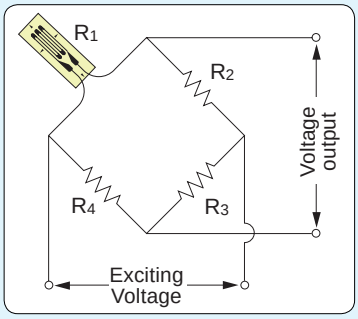
Strain Gauge Principles

When strain is generated in a measurement object, the strain is transferred to the resistance wire or foil of the strain gauge via the gauge base (backing). As a result, the wire or foil causes a resistance change. This change is exactly proportional to the strain as in the equation below.

$$\varepsilon = \frac{\Delta L}{L} = \frac{\Delta R / R}{K}$$

where
ε : Strain measured
L : Original length of material
ΔL : Change in length due to force P
R : Gauge resistance
ΔR : Resistance change due to strain
K : Gauge Factor as shown on package

Normally, this resistance change is very small and requires a Wheatstone bridge circuit to convert to voltage output.



The voltage output of the circuit is given as follows.

$$e = \frac{R_1 R_3 - R_2 R_4}{(R_1 + R_2)(R_3 + R_4)} E$$

,where
e : Voltage output
E : Exciting voltage
R1 : Gauge resistance
R2~R4 : Fixed resistance

Here, if R=R1=R2=R3=R4 the resistance of the strain gauge changes to R+ΔR due to strain. Thus, the output voltage Δe (variation) due to the strain is given as follows.

$$e = \frac{\Delta R}{4R + 2\Delta R} E$$

When ΔR« R,

$$\Delta e = \frac{\Delta R}{4R} E = \frac{E}{4} K\varepsilon$$

When measuring a strain gauge, it is connected to an instrument called strainmeter. The strainmeter configures a Wheatstone bridge circuit and supplies exciting voltage. Measured strain is indicated on a digital display and/or output as analog signals.

Plane Stress and Strain

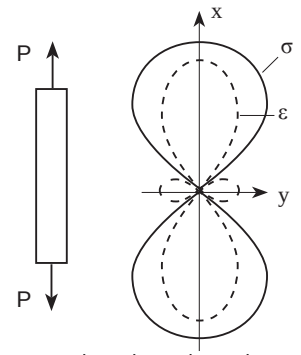
The stress in a material balanced with an applied external force can be considered a combination of more than one simple stress. In other words, these stresses can be divided into simple stress in the respective axial directions; however, measurement with ordinary strain gauges is restricted to the plane strain. In case that the stress exists in uniaxial direction like tension of a bar illustrated below, the following equation are applicable.

$$\varepsilon_x = \frac{\sigma}{E}$$

$$\varepsilon_y = -\nu\varepsilon_x = -\frac{\nu\sigma}{E}$$

, where

σ : Stress
E : Elastic modulus
ε_x : Strain in x direction
ε_y : Strain in y direction
ν : Poisson's ratio

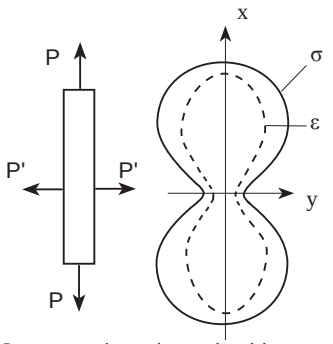


Stress and strain under uni-stress condition

The biaxial stresses generated by pulling the bar in both normal and transversal directions are:

$$\varepsilon_x = \varepsilon_x' - \nu\varepsilon_y' = \frac{\sigma_x}{E} - \frac{\nu\sigma_y}{E} = \frac{1}{E}(\sigma_x - \nu\sigma_y)$$

$$\varepsilon_y = \varepsilon_y' - \nu\varepsilon_x' = \frac{\sigma_y}{E} - \frac{\nu\sigma_x}{E} = \frac{1}{E}(\sigma_y - \nu\sigma_x)$$



Stress and strain under bi-stress condition

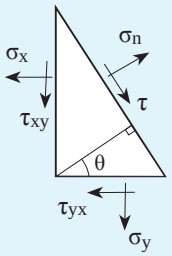
ε_x' : strain in the x direction due to σ_x

ε_y' : strain in the y direction due to σ_y

$$\sigma_x = \frac{E}{1-\nu^2}(\varepsilon_x + \nu\varepsilon_y)$$

$$\sigma_y = \frac{E}{1-\nu^2}(\varepsilon_y + \nu\varepsilon_x)$$

For the stress in other than the crossed biaxial directions, it is shown according to its angle as follows.



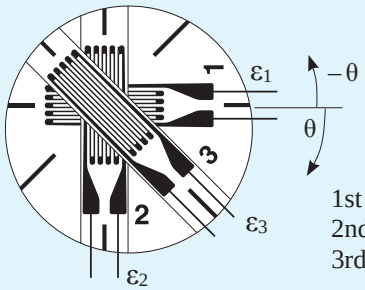
$$\sigma_n = \sigma_x\cos^2\theta + \sigma_y\sin^2\theta + \tau_{xy}\sin 2\theta = \frac{1}{2}(\sigma_x + \sigma_y) + \frac{1}{2}(\sigma_x - \sigma_y)\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau = \frac{1}{2}(\sigma_x - \sigma_y)\sin 2\theta - \tau_{xy}\cos\theta$$

As noted from the above equations, in a certain direction, the maximum value of the resultant stress appears in the uniaxial diretion. The axial direction is called a principal direction of stress and the stress in that direction a principal stress. In this direction, the shearing stress is zero. The maximum value of shearing stress is generated in the direction of 45° against the principal directioin of stress. It can also be applied to the strain. The strain in such a direction is called a pricipal strain.

Measurement of principal strain and stress using 3-element rectangular rosette gauge

When strain is generated in the surface of material and the principal direction of the strain and its extent are unknown, the principal strain, stress and their directions and shearing strain and stress can be obtained by measuring the strains in three directions over the surface. In order to simplify calculation, the relative angle in the three directions are determined as follows.



1st axis : ε_1
2nd axis : ε_2 at 90° position
3rd axis : ε_3 at 45° position

Maximum principal strain

$$\varepsilon_{max} = \frac{1}{2}\left[\varepsilon_1 + \varepsilon_2 + \sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}\right]$$

Minimum principal strain

$$\varepsilon_{min} = \frac{1}{2}\left[\varepsilon_1 + \varepsilon_2 - \sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}\right]$$

Maximum shearing strain

$$\gamma_{max} = \sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}$$

Angle from ε_1 gauge to direction of principal strain

$$\theta = \frac{1}{2}\tan^{-1}\left\{\frac{2\varepsilon_3 - (\varepsilon_1 + \varepsilon_2)}{\varepsilon_1 - \varepsilon_2}\right\}$$

If $\varepsilon_1 > \varepsilon_2$, the angle to the maximum principal strain is rotated by θ clockwise from the 1st axis, and the minimum principal strain is located at θ+90°. If $\varepsilon_1 < \varepsilon_2$, the angle to the maximum principal strain is rotated by θ+90° clockwise from the 1st axis, and the minimum principal strain is located at θ.

Maximum principal stress

$$\sigma_{max} = \frac{E}{1-\nu^2}(\varepsilon_{max} + \nu\varepsilon_{min}) = \frac{E}{2}\left[\frac{\varepsilon_1 + \varepsilon_2}{1-\nu} + \frac{1}{1+\nu}\sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}\right]$$

Minimum principal stress

$$\sigma_{min} = \frac{E}{1-\nu^2}(\varepsilon_{min} + \nu\varepsilon_{max}) = \frac{E}{2}\left[\frac{\varepsilon_1 + \varepsilon_2}{1-\nu} - \frac{1}{1+\nu}\sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}\right]$$

Maximum shearing stress

$$\tau_{max} = \frac{E}{2(1+\nu)}\gamma_{max} = \frac{E}{2(1+\nu)}\sqrt{2\{(\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2\}}$$

NOTE:
The above rosette analysis equations are based on the 3-element strain gauge shown in the diagram. When the order of the axis numbers is different or when the gauge is not a 90° rosette gauge, different equations must be used. Check the axis numbers of applicable strain gauge before performing rosette analysis.

TECHNICAL TERMS

Gauge Length

This dimension represents the actual grid length in the sensitive direction.

Gauge Resistance

The gauge resistance is the electrical resistance of an unbonded gauge at room temperature and subject to no external pressure. The gauge resistance generally used is 120Ω but gauges are also produced with gauge resistance of 60Ω, 350Ω and 1000Ω. High-resistance gauges yield a high bridge output when high voltages are applied but they are also susceptible to noise. The majority of the strain gauges used in the production of transducers have a gauge resistance of 350Ω.

Gauge Factor

The amount shown in the following equation is called the gauge factor. In this equation, ε indicates the strain generated due to uniaxial stress in the direction of the strain gauge axis. ΔR/R shows the ratio of resistance change due to strain ε.

$$K = \frac{\Delta R / R}{\varepsilon}$$

where
K : Gauge Factor
ε : Mechanical strain
R : Gauge Resistance
ΔR : Resistance change

Longitudinal Sensitivity

Longitudinal sensitivity is very similar to the gauge factor and refers to the sensitivity of the gauge when no strain is applied in the direction perpendicular to the gauge axis.

Transverse Sensitivity

The gauge also exhibits sensitivity in the direction perpendicular to the axial direction. The amount shown in the following equation due to the uniaxial strain (εt) in the direction perpendicular to the gauge axis, and the resistance variation generated thereby, is called transverse sensitivity (Kt).

$$Kt = \frac{\Delta R / R}{\varepsilon t} \times 100$$

where
Kt : Transverse Sensitivity
εt : Uniaxial strain perpendicular to the gauge axis

Transverse Sensitivity Ratio

This refers to the ratio of transverse sensitivity to longitudinal sensitivity. This is usually 1% or less and does not usually pose a problem except in high-precision measurement or in locations with biaxial strain.

Gauge Hysteresis

When a strain gauge is bonded to a test specimen and strain is applied, resistance change for identical strain in increase and decrease processes may differ. This difference is referred to as hysteresis. Gauge hysteresis varies depending on factors such as grid configuration, base material, adhesive and temperature.

Thermal Hysteresis

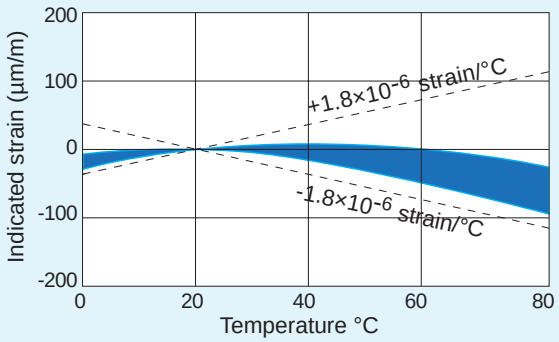
Thermal hysteresis refers to hysteresis that occurs in the heating or cooling cycle such that the respective cycles do not pass through the same point. Thermal hysteresis poses an ongoing problem in strain measurement where temperature change occurs. This hysteresis must be removed by applying heat experience to stabilize the characteristic of the strain gauge and the adhesive.

Gauge Zero Drift with Temperature

At high temperature, effects such as thermal oxidation of the sensing elements in a strain gauge cause the zero point of the gauge in a no-load state to gradually drift. This is one of the characteristics that determine a strain gauge's resistance to heat. Above 200°C, Ni-Cr alloy performs far better than Cu-Ni alloy, and alloys such as Pt-W are used in 500°C to 800°C environments.

Self-Temperature-Compensated Gauges

The ambient temperature change may cause a variation of strain gauge resistance. The variation is ascribable to the thermal expansion of both strain gauge material and specimen, together with the thermal coefficient of resistance of the gauge material. Self-temperature compensated gauges are commonly used to minimize the gauge thermal output when bonded to test specimens having a specific liner thermal expansion coefficient in the specified temperature range. The following graph shows an example of thermal output.

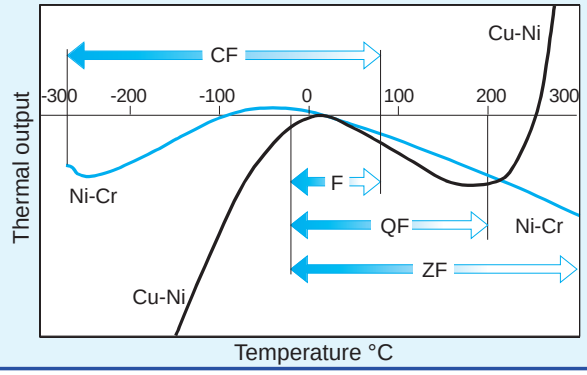


Temperature Compensation Range

This refers to a temperature range in which the thermal output of a self-temperature compensated gauge should be within the given range. Compensation is accurate within approximately ±1.8×10^{-6} strain/°C. For greater accuracy, corrections can be made using the curves for apparent strain vs. temperature which is suplied with each package of gauge.

Operating Temperature Range

This range is the temperature range within which a strain gauge can be used continuously in the appropriate conditions. The figure below shows thermal output characteristics for Cu-Ni and Ni-Cr alloys used for the sensing elements in TML strain gauges. Most strain gauges use Cu-Ni alloy, with Ni-Cr alloy is used in strain gauge series that have a wider operating temperature range.



Gauge Length Selection

Different gauge lengths should be selected depending on specimens. Gauges with short gauge lengths are used to measure local strain, while gauges with long lengths can be used to measure averaged strain over a larger area. For a heterogenous material, a gauge length is required that can average out irregular strain in the material. For example, as concrete is composed of cement and aggregate (gravel or sand, etc.) the length of a gauge used is more than three times the diameter of the aggregate so as to give an averaged evaluation of the concrete.

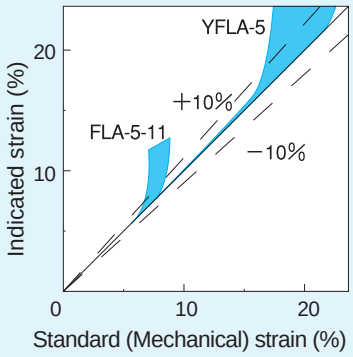
Gauge length (mm)	Gauge Applications
0.2 ~ 1	For stress concentration measurement
2 ~ 6	For metal and general use
10 ~ 20	For mortar, wood, FRP, etc.
30 ~ 120	For concrete

Strain Limit

The strain limit is the maximum amount of strain under which a strain gauge can operate under a given condition without suffering damage. At TML, the strain limit is the smallest value of mechanical strain at which the indicated strain exceeds the mechanical strain by 10%.

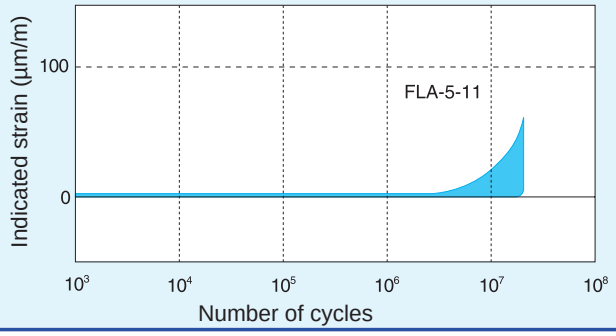
General use strain gauge
F series : FLA-5-11

Post-Yield strain gauge
YF series : YFLA-5



Fatigue Life

When strain is applied repeatedly to a strain gauge, as the amount of strain becomes large, the gauge resistance increases and disconnection or peeling-off of the gauge occurs to make the gauge useless. In general, the fatigue life is determined by the amount of applied strain and speed of cyclic loading and expressed by the number of repetitions. At TML, a constant mechanical strain is applied repeatedly to the bonded strain gauge and the fatigue life is indicated by the number of repetitions at which the indicated strain value without loading exceeds 100×10^{-6} strain. The calibraiton result is exampled below. Even if the number of repetitions is over rthe specified life, the gauges do not always become out of service. Usually, the fatigue life is an extend of 10^6 ~ 10^7 times. At less than 500×10^{-6} strain, the fatigue life extends and can be regarded infinite. Post-yield strain gauges of which sensing element is heat-treated are inadequate for cyclic loading.



Permissible Current (Permissible Volgate)

The current flowing a strain gauge is related to the output voltage of the gauge bridge, and the larger the current, the larger the voltage is obtained. To the contrary, depending upon the material of a specimen and the area of the gauge, Joule's heat is generated by the current to raise the temperature of gauge and as a result apparent strains are produced. In general, a current less than 30mA is recommended for metallic specimens and less than 10mA for wooden and plastic specimens.

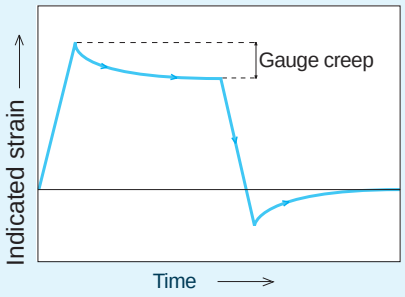
Strain Gauge Frequency Response

The frequency response of a strain gauge is determined by the gauge length and the longitudinal elastic wave speed of the test specimen.

Gauge length (mm)		0.2	1	3	5	10	30	60
Steel	[kHz]	660	530	360	270	170	-	-
Concrete	[kHz]	-	-	-	-	120	50	20

Gauge Creep

A bonded strain gauge subjected to a constant strain will give a decreasing indicated value as time progresses. This phenomenon is referred to as creep. In general, the shorter the gauge length, the greater the gauge creep becomes. Also, this tendency exhibits well if the strain gauge or adhesive absorbs moisture.



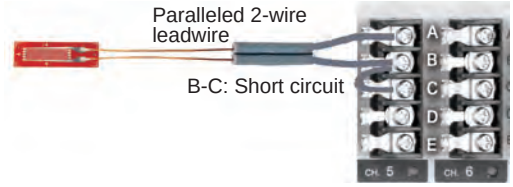
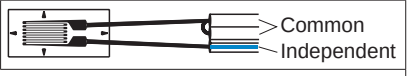
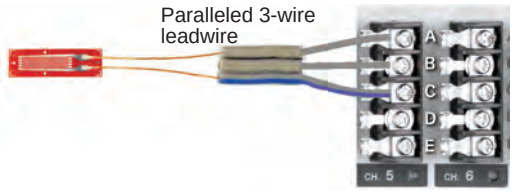
Gauge creep

STRAIN GAUGE MEASUREMENT

Temperature compensation for leadwires in Quarter bridge

For strain gauge measurement, the Wheatstone bridge circuit is used to convert resistance change of the strain gauge into voltage output. The simplest bridge method is quarter bridge method, where one arm is composed of the strain gauge while other three arms are composed of fixed resistors in the instrument. A 2-wire leadwire may be used for connecting the strain gauge to the instrument. However, if the temperature of the leadwire changes, thermal output of the bridge is caused even if there is no change in actual strain. By this reason, the quarter bridge 2-wire method should be used only when temperature change is not expected during the measurement or for a dynamic measurement in which the thermal output can be disregarded. A quarter bridge 3-wire method is available as a method to eliminate the thermal output of the leadwire, where a 3-wire leadwire is used for connection of the strain gauge. In this method, influence of resistance change of the leadwire caused by temperature change is cancelled. In addition, effect of the leadwire on gauge factor is half as large as that of the quarter bridge 2-wire method. The quarter bridge 3-wire method is more recommendable than 2-wire method, especially when temperature change is expected during the measurement and/or comparatively long leadwires are used. Other bridge methods including half bridge and full bridge are also available. Refer to p.15~18 for the details.

Strain Gauge and leadwire connection

Bridge Circuit	Connection
Quarter bridge with 2-wire	
	
Quarter bridge with 3-wire	
	

¶ Thermal output caused by temperature change

In quarter bridge 2-wire method, changes in leadwire temperature cause changes in the leadwire resistance, which result in thermal output. Use the equation below to compensate for this thermal output.

$$\text{Leadwire thermal output} \quad \varepsilon L = \frac{r \cdot L \cdot \alpha \cdot \Delta T}{K \cdot (R + r \cdot L)}$$

where

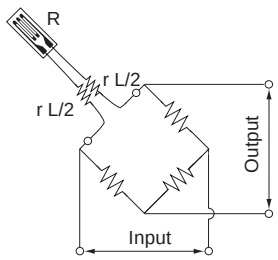
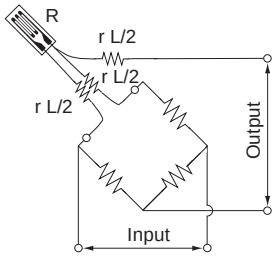
- εL : Leadwire thermal output
- K : Gauge factor indicated on the strain gauge package
- α : Thermal coefficient of resistance of leadwire (3.9×10^{-3}/°C for copper)
- r : Total resistance of leadwire per 1 meter (Ω/m)
- L : Leadwire length (m)
- ΔT : Temperature change of leadwire (°C)

Note)

- Compensation is possible on condition that the temperature change is uniform for whole length of the leadwire.
- In quarter bridge 3-wire method, compensation is not necessary because the influence of change in leadwire resistance caused by temperature change is cancelled.

¶ Gauge Factor (Gauge sensitivity) correction for leadwire connection

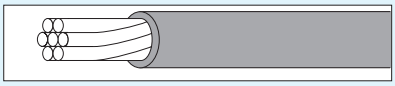
The leadwire resistance between the strain gauge and strainmeter noticeably lowers the gauge factor. Calculation for the correction is required depending on the measurement method and on the leadwire type and length.

Quarter Bridge with 2-wire	Quarter Bridge with 3-wire
	
Correction coefficient of lead-wire : A $A = \frac{R}{R + rL}$ Corrected Gauge Factor : K_0 $K_0 = \frac{R}{R + rL} \quad K = A \cdot K$	Correction coefficient of lead-wire : A $A = \frac{R}{R + \frac{rL}{2}}$ Corrected Gauge Factor : K_0 $K_0 = \frac{R}{R + \frac{rL}{2}} \quad K = A \cdot K$
where R : Nominal gauge resistance in Ω r : Total resistance per meter of leadwire (Ω/m) K : Gauge Factor shown on package L : Length of leadwire in meter	

¶ Total resistance per meter of leadwire

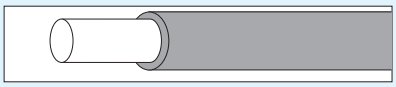
In strain gauge, the leadwire resistance produces a deterioration of gauge sensitivity and thermal drift. The leadwire should be as thick and as short as possible.

Twisted leadwire



Construction core/diameter	7/0.12	10/0.12	7/0.16	7/0.18	12/0.18	20/0.18
Cross section area of lead wire (mm^2)	0.08	0.11	0.14	0.18	0.3	0.5
Total resistance of leadwire per meter (Ω)	0.44	0.32	0.24	0.20	0.12	0.07

Single-core leadwire



Construction	Polyimide wire (0.14mm-dia.)	Polyimide wire (0.18mm-dia.)
Cross section area of leadwire	0.015 mm^2	0.025 mm^2
Total resistance of leadwire per meter	2.5 Ω	1.5 Ω

¶ Setting the Gauge Factor to TML Data Loggers

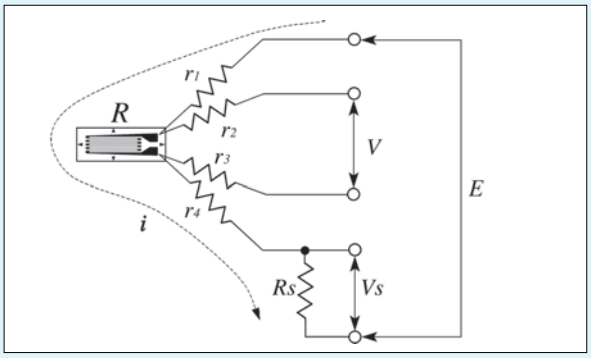
$$Cs = \frac{2.00}{K_0}$$

Cs : Coefficient set
K_0 : Gauge Factor corrected with leadwire attached

1-Gauge 4-Wire Strain measurement method

For strain gauge measurement, the Wheatstone bridge circuits are employed according to the number of strain gauges to be used and measuring purpose. In quarter bridge configuration, three wire method is widely used to remove the effect of temperature to gauge leadwire resistance. However, some measuring error occurs owing to gauge factor correction due to leadwire resistance and variation in the contact resistance of connection part.

Our developed 1-gauge 4-wire strain measurement method does not use the Wheastone bridge circuit, and configures simple series circuit with gauge resistance (R) and reference resistance (Rs) to measure the strain. Find the strain with voltage (V) generated in gauge resistance and voltage (Vs) generated in reference resistance. As the path where the current runs and the path where the voltage is measured are different, it is possible to perform a measurement without being affected by leadwire resistance or contact resistance (r).



where,

R	: Gauge resistance
Rs	: Reference resistance
$r_1 \sim r_4$	: Leadwire resistance and contact resistance
i	: Current flowing in gauge resistance and reference resistance
E	: Excitation voltage
V	: Voltage of gauge resistance
Vs	: Voltage of reference resistance

No Contact resistance

In conventional method, leadwire extension and connection to a measuring instrument are done by soldering or the use of exclusive connector. As the 1-gauge 4-wire method is not affected at all by contact resistance, a modular plug can be used. Because the modular plug makes leadwire extension and connection to the instrument possible by merely plugging in, the efficiency of wiring work and prevention of wiring mistake are achieved and also RoHS-compliant lead free soldering is unnecessary.

Compares Quarter Bridge 3-Wire vs. 1-Gauge 4-Wire

	Quarter Bridge 3-wire (Wheatstone Bridge)	1-Gauge 4-Wire
Plug connection	Not available	Available
Soldering works	Required	Not required
Wiring time	Required	Less
Wiring error	Occurs	None
RoHS-directive	Lead inclusive	Lead free

Using commercial interconnection adapter, leadwire extension can be easily done.

Leadwire resistance

In conventional method, as thick and short leadwires as possible are recommended to keep the resistance of leadwires lower. On the contrary, as the 1-gauge 4-wire method is not influenced at all by the leadwire resistance, it is possible to connect a thin and long leadwires to strain gauges.

Compares Quarter Bridge 3-Wire vs. 1-Gauge 4-Wire

	Quarter Bridge 3-wire (Wheatstone Bridge)	1-Gauge 4-Wire
Size of leadwire	Thick	Thin
Weigt of leadwire	Not less	Less
Different leadwires	Not available	Available
Color of leadwire	Planned	Free
Load to specimen	Not less	Less
Carrying cost	Not less	Less

Strain gauges with leadwires and modular plug

The strain gauges are used in our developed 1-gauge 4-wire strain measurement method. Most of our strain gauges can be supplied with pre-attached leadwires and modular plug (RJ12). As a modular plug is attached to the end of the leadwires, soldering or screwing connectioin to a measuring instrument is unnecessary, but the instrument must be of TML make. The 4-wire leadwires are covered with polypropylene resin which does not generate noxious gas even if disposed by fire.

Single element strain gauge with 4-wire paralleled leadwire

Three-element rectangular rosette strain gauge

With 6-wire paralleled leadwire and modular plug

With 4-wire paralleled leadwire and modular plug

STRAIN GAUGE MEASUREMENT

Complete correction method for strain with Wheatstone Bridge - COMET

COMET: Abbreviation of Complete Compensation Method of Strain

When measuring strain using a strain gauge, quarter bridge method is commonly used. Quarter bridge 2-wire method is the easiest for strain measurement, while quarter bridge 3-wire method has an advantage of eliminating thermal output caused by the temperature change of the lead wire. It is known that there may be some small errors in measured values obtained by these methods, which are caused by initial unbalance and non-linearity of the bridge circuit. Most of our strainmeters already have a function of correcting non-linearity of quarter bridge circuit. However, if we look into the matter more closely, this function is not enough to completely correct the measured values, for example when the initial unbalance of the bridge is significant. Our unique technique “Complete Compensation Method of Strain” is a method which is capable of fully correcting the errors in measured values obtained by quarter bridge method without being influenced by initial unbalance and non-linearity of the bridge circuit. This method is available in our instruments listed below.

Data loggers

TDS-630, TDS-530, TDS-602, TDS-303, TDS-150 TDS-102, TC-31K, TC-32K

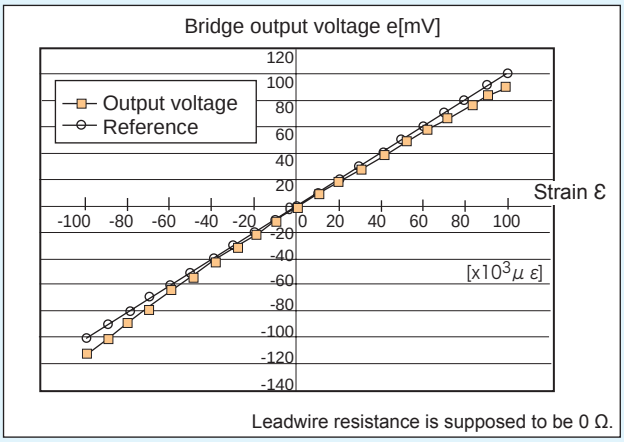
Measurement error is not caused by initial unbalance of bridge

If the resistance of strain gauge and bridge completion resistors is not exactly the same when the strain is zero, an output voltage is yielded. This should more or less occur in actual bridge circuits. The output voltage is treated as an initial unbalance and deducted from the output voltage when strain is applied. However, it causes some error in measured strain values. This error becomes zero by using the Complete Compensation Method of Strain.It is especially effective in cases as follows, in which a large initial unbalance is expected.

- The leadwire is extended during the measurement.
- The strain gauge is mounted on a curved surface.
- Strain gauges having uneven resistance are used.
- Temperature change is large during the measurement.

Non-linearity error of bridge circuit is completely corrected

The relation between the output voltage of bridge circuit and the strain is not exactly linear. Non-linearity error becomes larger with increase of strain. Conventional method for correcting the non-linearity is based on condition that the initial unbalance of bridge is zero. The Complete Compensation Method of Strain works to correct the non-linearity error even when the initial unbalance of bridge is large. It is also effective in the following cases in addition to the cases mentioned in former clause.



- Strain gauge is replaced with a new one when measuring large strain.
- Initial unbalance is readjusted during the measurement.

Descent of sensitivity caused by the leadwire resistance is corrected

The strain gauge sensitivity is influenced by the resistance of the leadwire. In quarter bridge 3-wire method, the lead-wire resistance is measured and the sensitivity is corrected automatically by using a data logger having the Complete Compensation Method of Strain. When measuring multiple points of strain gauges, it is not necessary to use lead wires of the same length for the purpose of simplifying the correction calculation.

Complete Correction of thermal output of strain gauge

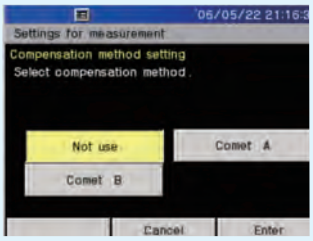
Thermal output of strain gauge is given as data under no strain, and it may somewhat differ under strained condition. The Complete Compensation Method of Strain compensates thermal output by taking the applied strain into consideration. This is especially effective when the thermal output is large. (This compensation is available in TDS-630.)

Correction of error caused by replacement of strain gauge

When measuring a large strain, it is a common practice to replace the strain gauge with a new one when the strain comes close to strain limit of the strain gauge. In this case, accurate strain after the replacement can be known by correcting the measured values referring to the strain value at the time of replacement. The Complete Compensation Method of Strain makes this correction automatically.

Setting of true strain measurement (COMET)

This is the setting for performing a measurement correcting the error of strain value using the function called "COMET".
When the sensor mode is quarter bridge 3-wire method, the measurement value is displayed by implementing non-linear correction even if [Not use] is selected. By selecting Comet, it is possible to obtain more correct strain value.
Half bridge common dummy can be used only for Comet A.



COMET A

This is the correction method to correct the nonlinearity error by initial unbalance of bridge, and this is effective when the initial unbalance value is large. The bridge output voltage e_0 is measured at initial in and memorized internally. The bridge output voltage e when the strain is generated is calculated when the measurement is performed, and the correction calculation below is implemented.

$$\varepsilon_m = \frac{e - e_0}{(1-e) \times (1+e_0)}$$

COMET B (Quarter bridge 3-wire method only)

This is used when correcting the descent of sensitivity by leadwire at the same time as the correction method of Comet A.
The bridge output voltage e_0 at initial unbalance and both-ends voltage of lead wire resistance e_r are measured at initial in, and memorized internally. The bridge output voltage e when the strain is generated is measured at the measurement, and the calculation below is implemented.

$$\varepsilon_m = \frac{e - e_0}{(1-e) \times (1+e_0-e_r)}$$

When Comet B calculation is implemented, the correction calculation that includes initial unbalance value that is recorded at initial in and both-ends voltage of leadwire resistance is implemented from the formula above, so only the measure measurement is available. Be sure to perform the measurement after implementing the initial in at the initial unbalanced status for starting measurement.

Application example of Complete Compensation Method of Strain

Measurements using our data loggers equipped with Complete Compensation Method of Strain have the advantages of the followings.

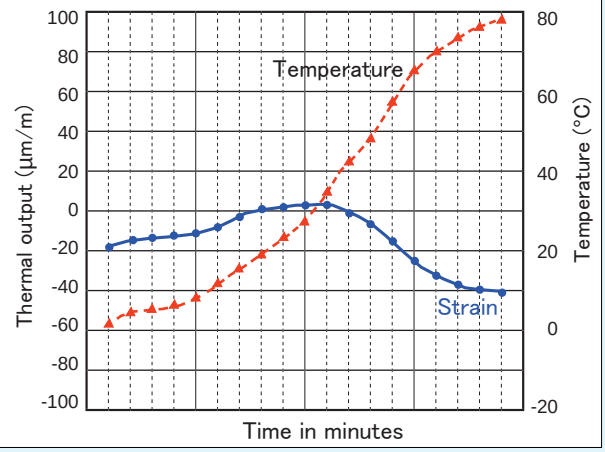
- Complete compensation of non-linearity
- No influence of strain gauge resistance
- No influence of dummy resistance
- No need of using leadwires of the same length saving costs and space for unnecessary leadwires
- No need of correcting sensitivity change caused by leadwire resistance

Accurate strain measurement is possible owing to the features above. Furthermore, measurements as in the following examples become possible by the use of Complete Compensation Method of Strain.

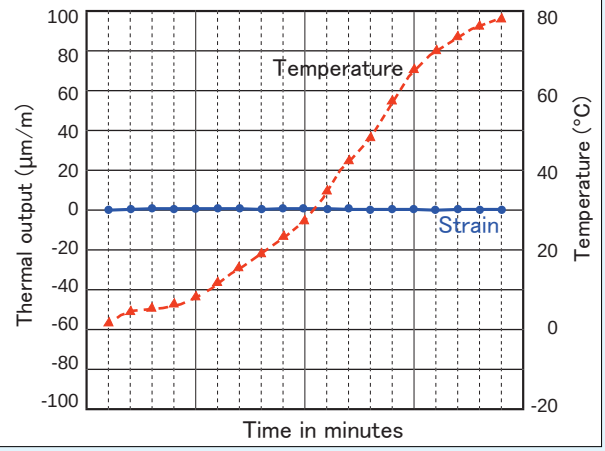
Application example 1:
Compensation of thermal output when using a temperature-integrated strain gauge

Thermal output of strain gauge is automatically compensated when measuring a temperature-integrated strain gauge with data logger TDS-630. A polynomial representing the thermal output is attached to each strain gauge, and coefficients of the polynomial are input to TDS-630 before starting the measurement. Thermal output of the strain gauge caused by the change of environmental temperature is calculated and corrected by the TDS-630 with better accuracy than conventional method.

Real temperature and apparent strain measurement



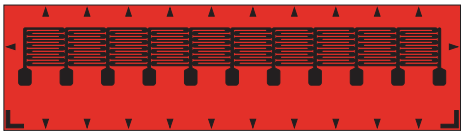
True strain after thermal output correction



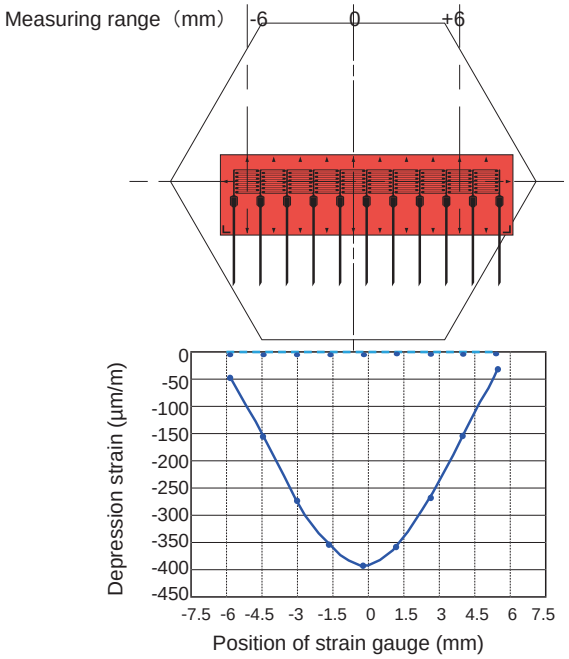
Application example 2:
Measurement of stress concentration gauge CCFXX, CCFYX

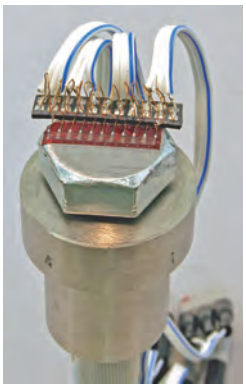
The CCFXX and CCFYX are newly developed strain gauges having 10 grids aligned continuously without interval between each adjoining grids. Different from the conventional stress concentration gauge having individual grids aligned with small intervals, it can measure strain distribution of the specimen more precisely. This strain gauge should be measured using our data logger with Complete Compensation Method of Strain. The number of leadwires are reduced to 11.

CCFXX



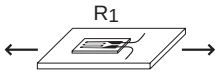
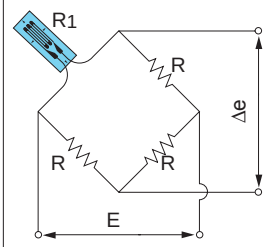
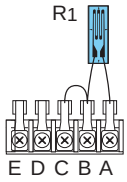
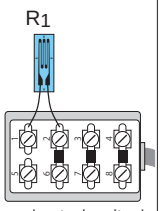
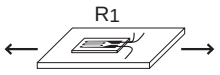
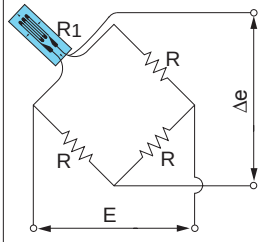
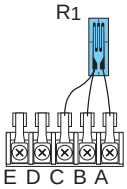
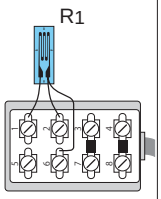
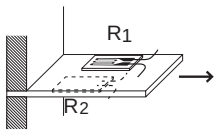
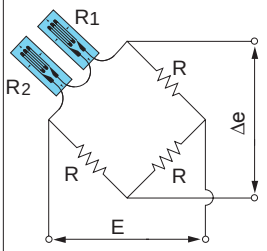
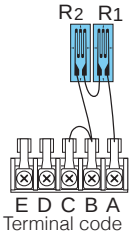
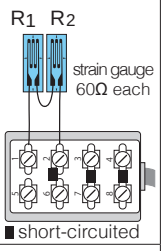
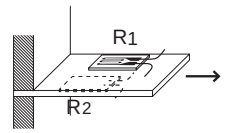
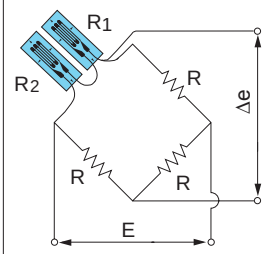
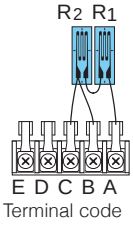
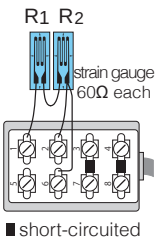
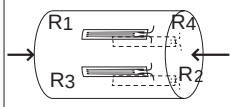
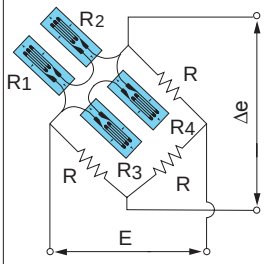
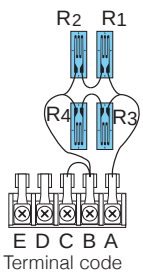
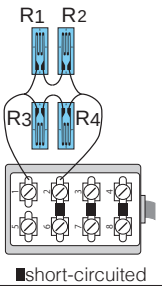
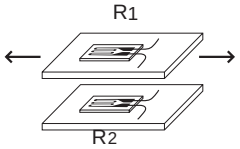
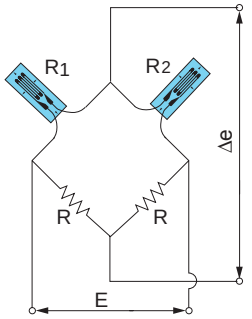
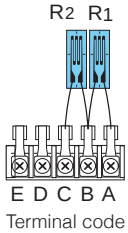
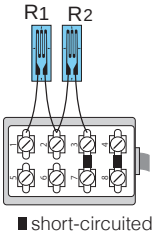
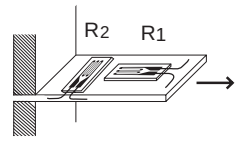
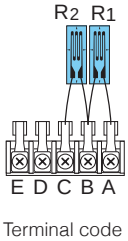
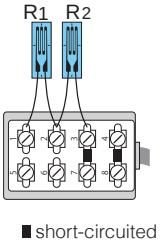
Measurement example
Strain caused by depression of bolt head (M10)





The number of leadwires is 30 which is required for measuring a conventional 10-element strain gauge with quarter bridge 3-wire method. The number is reduced to 11 in CCFXX/CCFYX strain gauge. This is achieved by using one leadwire for measurement of two or three grids. The adjacent grid is connected in series with one leadwire of 3-wire connection. The resistance of this adjacent grid can be ignored by using our data logger with Complete Compensation Method of Strain.

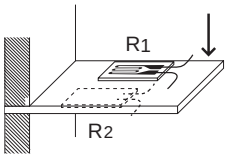
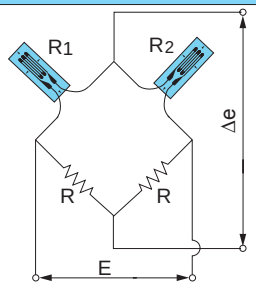
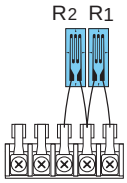
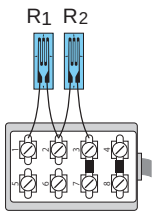
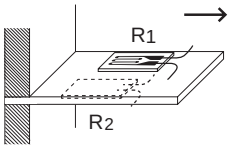
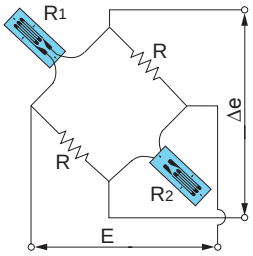
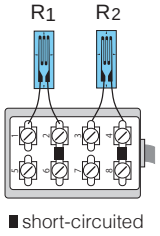
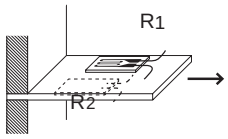
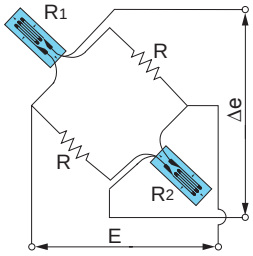
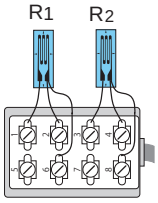
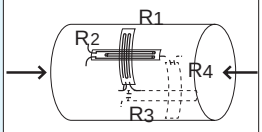
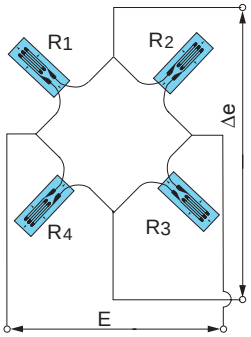
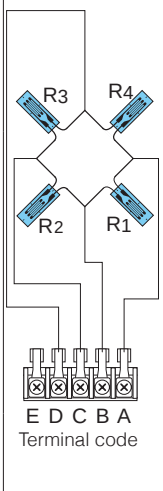
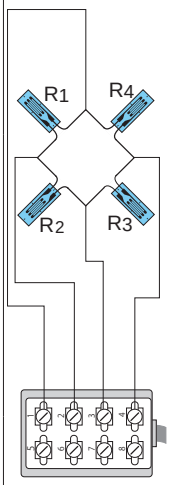
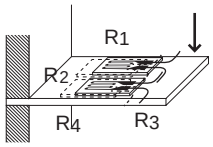
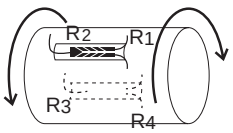
STRAIN GAUGE BRIDGE CIRCUIT

	Measuring mode	Bridge circuit	Wiring connection to Switching Box	Wiring connection to Bridge Box	Bridge Output
1	Quarter bridge (with 2-wire) 				$\Delta e = \frac{E}{4} \times \frac{\Delta R_1}{R} = \frac{E}{4} K \cdot \varepsilon_1 = \frac{E}{4} K \cdot \varepsilon$ Δe : Output voltage due to strain ε_1 E : Excitation voltage K : Gauge Factor of strain gauge R : Fixed resistor ΔR_1 : Resistance change due to strain ε_1 $R_1 = R_0 + \Delta R_1$: Gauge resistance due to ε_1 R_0 : Gauge resistance before strain applied $\varepsilon_1 = \varepsilon$
2	Quarter bridge with 3-wire 				
3	Quarter bridge with two gauges connected in series in one arm, eliminating bending strain 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 + \Delta R_2)}{R} = \frac{E}{4} \cdot K \cdot \frac{(\varepsilon_1 + \varepsilon_2)}{2}$ $= \frac{E}{4} \cdot K \cdot \varepsilon$ R_1 : Strain Gauge resistance = $R_0 + \Delta R_1$ R_2 : Strain Gauge resistance = $R_0 + \Delta R_2$ $R = 2R_0$ R_0 : Gauge resistance before strain applied ΔR_1, ΔR_2 : Resistance change of strain gauge R_1, R_2 ε_1, ε_2 : Strain applied to strain gauge R_1, R_2 R : Fixed resistor
4	Quarter bridge 3-wire with two gauges connected in series in one arm, eliminating bending strain 				
5	Quarter bridge with four gauges connected in series and paralleled in one arm 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4)}{4R}$ $= \frac{E}{4} \times \frac{(\varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4)}{4} = \frac{E}{4} K \cdot \varepsilon$ $\Delta R_1 \sim \Delta R_4$: Resistance change of strain gauge $R_1 \sim R_4$ $\varepsilon_1 \sim \varepsilon_4$: Strain applied to strain gauge $R_1 \sim R_4$ $\varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \varepsilon_4 = \varepsilon$
6	Half bridge with 1-active and 1-dummy gauge 				$\Delta e = \frac{E}{4} \times \frac{\Delta R_1}{R} = \frac{E}{4} K \cdot \varepsilon_1 = \frac{E}{4} K \cdot \varepsilon$ $\varepsilon_1 = \varepsilon$: Axial strain $R_1 = R_0 + \Delta R$: active $R_2 = R_0 = R$: dummy R : Fixed resistor R_0 : Gauge resistance before strain applied
7	Half bridge with two active gauges 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 - \Delta R_2)}{R} = \frac{E}{4} K \cdot (\varepsilon_1 - \varepsilon_2)$ $= \frac{E}{4} (1+\nu) K \cdot \varepsilon$ ν : Poisson's ratio $\varepsilon_1 = \varepsilon$: Strain applied to strain gauge R_1 $\varepsilon_2 = -\nu\varepsilon$: Strain applied to strain gauge R_2 R : Fixed resistor

STRAIN GAUGE BRIDGE CIRCUIT

Temperature-compensated to		Output multiple	Gauge Factor correction due to leadwire resistance	Description
Strain Gauge	Leadwire			
N/A	N/A	x1	$K_0 = \frac{R}{R+r\,L} K$	Ordinary uniaxial strain measurment when infulence of temperatyure change can be disregarded. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
N/A	Available	x1	$K_0 = \frac{R}{R+\frac{r\,L}{2}} K$	Ordinary uniaxial strain measurement Thermal output of leadwire is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
N/A	N/A	x1	$K_0 = \frac{R}{R+r\,L} K$	Uniaxial strain measurement (Mean of two gauges is output) bending strain is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
N/A	Available	x1	$K_0 = \frac{R}{R+\frac{r\,L}{2}} K$	Thermal output of leadwire is cancelled in addition to the above. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
N/A	N/A	x1	$K_0 = \frac{R}{R+r\,L} K$	Uniaxial strain measurement (Mean of four gauges is output.) Bending strain is cancelled. If 3-wire connection is used, thermal output of leadwire is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
Available	Available	x1	$K_0 = \frac{R}{R+r\,L} K$	Uniaxial strain measurement Dummy gauge should be of the same type and lot as the active gauge, bonded on the same kind of material, and placed in the same environment including the leadwire. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
Available	Available	x (1+ν)	$K_0 = \frac{R}{R+r\,L} K$	Axial strain measurement with sensitivity of (1+ν) times. Thermal output of strain gauge and leadwire is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter ν : Poisson's ratio of specimen

STRAIN GAUGE BRIDGE CIRCUIT

	Measuring mode	Bridge circuit	Wiring connection to Switching Box	Wiring connection to Bridge Box	Bridge Output
8	Half bridge with 2 active gauges : Bending strain 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 - \Delta R_2)}{R} = \frac{E}{4} \cdot K \cdot (\varepsilon_1 - \varepsilon_2)$ $= \frac{E}{2} \cdot K \cdot \varepsilon$ E : Excitation voltage K : Gauge Factor of strain gauge ε : Strain due to bending $\varepsilon_1 = -\varepsilon_2 = \varepsilon$
9	Opposite arm Half bridge with 2 active gauges 		N/A		$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 + \Delta R_2)}{R} = \frac{E}{4} \cdot K \cdot (\varepsilon_1 + \varepsilon_2)$ $= \frac{E}{2} \cdot K \cdot \varepsilon$ E : Excitation voltage K : Gauge Factor of strain gauge ε : Uniaxial strain $\varepsilon_1 = \varepsilon_2 = \varepsilon$
10	Opposite arm Half bridge with 3-wire 2 active gauges 		N/A		
11	Full bridge with 4 active gauges : Uniaxial strain 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 - \Delta R_2 + \Delta R_3 - \Delta R_4)}{R}$ $= \frac{E}{4} K (\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4) = \frac{E}{2} (1+\nu) \cdot K \cdot \varepsilon$ E : Excitation voltage K : Gauge Factor of strain gauge ε : Axial strain ν : Poisson's ratio $\varepsilon_1 = \varepsilon_3 = \varepsilon, \quad \varepsilon_2 = \varepsilon_4 = -\nu \cdot \varepsilon$
12	Full bridge with 4 active gauges : Bending strain 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 - \Delta R_2 + \Delta R_3 - \Delta R_4)}{R}$ $= \frac{E}{4} K (\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4) = E \cdot K \cdot \varepsilon$ E : Excitation voltage K : Gauge Factor of strain gauge ε : Strain due to bending $\varepsilon_1 = \varepsilon_3 = \varepsilon, \quad \varepsilon_2 = \varepsilon_4 = -\varepsilon$
13	Full bridge with 4 active gauges : Torque 				$\Delta e = \frac{E}{4} \times \frac{(\Delta R_1 - \Delta R_2 + \Delta R_3 - \Delta R_4)}{R}$ $= \frac{E}{4} K (\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4) = E \cdot K \cdot \varepsilon$ E : Excitation voltage K : Gauge Factor of strain gauge ε : Strain due to torque $\varepsilon_1 = \varepsilon_3 = \varepsilon, \quad \varepsilon_2 = \varepsilon_4 = -\varepsilon$

STRAIN GAUGE BRIDGE CIRCUIT

	Temperature-compensated to		Output multiple	Gauge Factor correction due to leadwire resistance	Description
	Strain Gauge	Leadwire			
	Available	Available	x2	$K_0 = \frac{R}{R+r\,L}K$	Bending a strain measurement with twice sensitivity Axial strain is cancelled. Thermal output of strain gauge and leadwire is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
	N/A	N/A	x2	$K_0 = \frac{R}{R+r\,L}K$	Uniaxial strain measurement (sum of two gauges is output.) Bending strain is cancelled. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
	N/A	Available	x2	$K_0 = \frac{R}{R+\frac{r\,L}{2}}K$	Thermal output of leadwire is cancelled in addition to the above. K_0 : Corrected gauge factor K : Original gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
	Available	Available	x2(1+ν)	$K_0 = \frac{R}{R+r\,L}K$ rL should be of the leadwire for supplying excitation voltage, provided that the leadwire resistance inside the full bridge cirucit is small enough to be neglected.	Uniaxial strain measurement with sensitivity of 2(1+ν) times. Bending strain is cancelled. ν : Poisson's ratio of specimen K : Original gauge factor K_0 : Corrected gauge factor R : Resistance of strain gauge r : Total resistance of leadwire per meter L : Length of leadwire in meter
	Available	Available	x4		Bending strain measurement with sensitivity of 4 times Axial strain is cancelled.
	Available	Available	x4		Measurement of strain due to torque with sensitivity of 4 times Axial strain and bending strain are cancelled.

Connection diagram varies according to strainmeter type.

TML STRAIN GAUGE CODING SYSTEM

F L A - 3 T - 350 - 11 - 3 L T

- **FLA**: Gauge series (see table below)
- **3**: Gauge length in mm
- **T**: Functions (*2) (see table below)
- **350**: Gauge resistance in Ω (standard 120Ω not presented)
- **11**: Pattern configuration (*1) (see table below)
- **3LT**: Pattern image (see below)

Functions (*2)		Applicable gauge
A	Left 45°	QFLT-A
B	Right 45°	QFLT-B
	for shearing strain measurement	
T	Thermocouple	Temperature-integrated

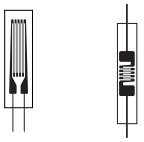
(*2) Not indicated for general model

Pattern configuration (*1)	
L/LA/LK/LX/LG BX/BY	Single
C/CA/LC/CS/CB	2-axis Rosette (0°/90°)
R/LR/RA/RAS/RS	3-axis Rosette (0°/45°/90°)
XV/YV/BXV/BYV	5-element Single
CV	5-element Rosette (0°/90°)
CT	Torque
LT	45° Single

(*1) Not always coded

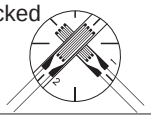
Pattern image

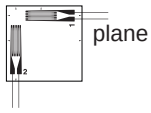
Single



2-element Rosette (0°/90°)

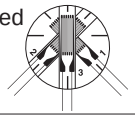
stacked

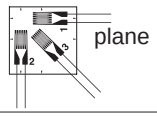




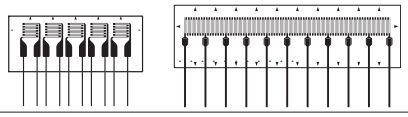
3-element Rosette (0°/45°/90°)

stacked

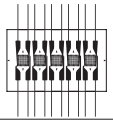




5-element Single 10-element Single

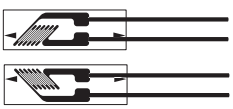


5-element Rosette (0°/90°)



Torque

45° Single



Gauge series	Applications
F/UF	General purpose
WF	Waterproof construction
QF/ZF/EF	High temperature use
CEF	Wide range temperature use
CF	Cryogenic temperature use
AW	Weldable strain gauge
P	Concrete use, Polyester wire gauge
PF	Concrete use, Polyester foil gauge
FLM/WFLM	Concrete use, Metal-backing strain gauge
PM	Concrete use, Embedment type strain gauge
PMF	Concrete use, Embedment type strain gauge
PMFLS	Asphalt use, Embedment type strain gauge
KM	Concrete/Asphalt embedment use, strain transducer
UBF/BF	Composite material use
GF/LF/PFLW	Low elastic material use, Plastics/Gypsum/Wood
MF	Magnetic field use
YEF/YF/YHF	Post-yield strain (Large strain) measurement
DSF	High endurance use, Fatigue test
DD	One-side gauge
FAC	Crack detection gauge
SFA	Stress measurement
TF	Strain gauge type temperature measurement
BTM	Bolt axial strain measurement
FGMH	Friction type Strain Checker
FGAH	Friction type Axial strain transducer
FGDH	Friction type Torque transducer

TML STRAIN GAUGE CODING SYSTEM

Length of leadwire pre-attached

-002	2cm long
-005	5cm long
-1	1m long
-3	3m long
-5	5m long

Compensation mateiral ppm/°C (*3)

3 Composite material	
Ceramic (Si_3N_4)	2.6~3.3
CFRP	3 ~ 5
5 Composite material	
Ceramic (SiC)	4.6
CFRP	3 ~ 5
8 Composite material	
Glass	7.9
Titanium	8.9
Titanium alloy (Ti-6Al-4V)	8.8
11 Mild steel	
Mild steel (0.1~0.2C)	11.8
Hard steel (0.4~0.5C)	11.2
Cast iron	10.5
Hastelloy-276	11.2
Inconel 600	13.3
Inconel 750	12.1
Monel	13.5
SUS 630 (17-4PH)	10.8
SUS 631 (17-7PH)	10.6
Concrete	7 ~ 13
17 Stainless steel/Copper alloy	
SUS 304	16.2
SUS 310	15.8
SUS 316	16.0
SUS 321	16.7
Copper	16.7
Beryllium copper	16.6
Brass	16.7
Bronze	17.0
Constantan	14.9
23 Aluminium	
Aluminium	23.4
Aluminium 2024-T4	23.0
Lead and its alloy	29.0
Gypsum	25.0
Polyimide	20 ~ 30
28 Magnesium	
Magnesium alloy	27.0
50 Plastics	
Epoxy (Cast)	45 ~ 65
70 Plastics	
Acrylics	70
ABS	74
Polyacetal (POM)	80
Polycarbonate (PC)	66 ~ 70
Polystyrene (PS)	60 ~ 80

(*3) Indicated only for self-temperature-compensated gauges
For other materials, contact TML or your local representatives.

Suffix codes of pre-attached leadwires

Thin and lightweight leadwires

-LE :2-wire polyimide coated leadwire, Direct connection
Applicable temperature –269°C~+300°C
Applicable strain gauges series
: F, UF, Q, Z, EF, CEF, CF, P, PF, FLM, UBF, BF, GF, LF, YEF, YF, YHF DSF, FAC

For use in air with room temperature

-L :2-wire paralleled vinyl sheathed leadwire, general purpose
Applicable temperature : –20°C~+80°C
Applicable strain gauges series
: F, UF, EF, P, PF, FLM, UBF, BF, GF, LF, YEF, YF, YHF, DSF, FAC, BTM

-LT :3-wire paralleled vinyl sheathed leadwire, general purpose
Applicable temperature : –20°C~+80°C
Applicable strain gauges series
: F, UF, EF, P, PF, FLM, UBF, BF, GF, LF, YEF, YF, YHF, DSF, FAC, BTM

-LTSA : φ3mm, 3-core shielded vinyl sheathed leadwire
Applicable temperature : –20°C~+80°C
Applicable strain gauges series
: F, UF, EF, P, PF, FLM, UBF, BF, GF, BTM

-LQM : 4-wire paralleled polypropylene
Applicable temperature : –20°C~+100°C
Applicable strain gauges series
: F, UF, EF, P, PF, FLM, UBF, BF, GF, BTM

For use in water with normal temperature

-LRT : 3-wire twisted cross-linked vinyl sheathed leadwire
Applicable temperature : –20°C~+100°C
Applicable strain gauges series
: F, UF, EF, P, PF, FLM, UBF, BF, GF, BTM

For use in steam with hot water

-LJQTA: 3-wire twisted cross-linked polyethylene sheathed leadwire
Applicable temperature : –60°C~+125°C
: F, UF, EF, UBF, BF, GF, BTM

For chemical-resistant

-LXT : 3-wire paralleled special vinyl sheathed leadwire
Applicable temperature : –20°C~+150°C
Applicable strain gauges series
: UF, Q,EF, CEF, CF, UBF, BF

For use in cryogenic and/or high temperature

-6FA-LT : 3-wire twisted fluorinated resin (FEP) sheathed leadwire
Applicable temperature : –269°C~+200°C
Applicable strain gauges series
: Q,Z, EF, CEF, CF, UBF, BF

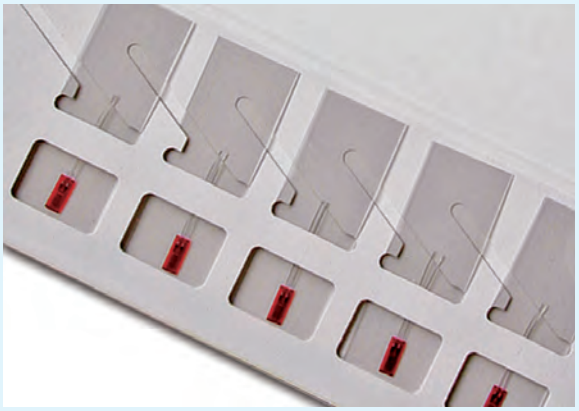
-4FA-LT : 3-wire twisted fluorinated resin (PTFE) sheathed leadwire
Applicable temperature : –269°C~+260°C
Also available upto +300°C for short term
Applicable strain gauges series: Z, EF

For further information on leadwires such as electrical resistance, dimensions, etc., refer to pages 31~36.

PACKAGE DESIGNATION

TML strain gauges are delivered together with TML Strain Gauge Test Data (example shown below). The evaluation methods conform to the National Aerospace Standard NAS942 (modified). For installation, handling and bonding procedures, please see the data sheet.

GAUGE PACKAGE



Batch No.
Production code for procedure and history.

Environment
Temperature in degrees centigrade and relative humidirty in % at which the test data are obtained.

TEST DATA

TYPE FLA-3-11			TEST CONDITION 23°C 50%RH
LOT NO. A502515	BATCH NO. UK32K		GAUGE FACTOR 2.14 ±1%
GAUGE LENGTH	3	mm	
GAUGE RESISTANCE	120±0.3	Ω	TEMP.COMPENSATION FOR 11×10^{-6}/°C
QUANTITY	10		TRANSVERSE SENSITIVITY 0.0 %

Gauge type

Lot No.

Quantity
Number of gauges contained in a package.

Gauge resistance
Electrical resistance of the strain gauge under free conditions at room temperature, unbonded as supplied. Various range (60, 120, 350 or 1000Ω) are available.

Gauge length
This represents the actual grid length in the sensitive direction. Within this length, the measured strain is averaged.

Ratio of transverse sensitivity
The sensitivity in the direction perpendicular to the axial direction is given in percent.

Applicable temperature compensation
Various temperature compensation values are available (3, 5, 8, 11, 17, 23, 50, 70ppm/°C) (Blank is not for temperature compensation.)

Gauge factor with tolerance
This factor is a ratio of the resistance variation to the strain generated due to the uniaxial stress in the direction of the gauge axis.

COLOR CODING FOR TEST SPECIMEN

Colors of package label differ depending on the test specimen material for temperature compensation.

Test specimen	Linear thermal expansion coefficient	Coloring	Gauge type exampled
Mild stee (ferritic)	11ppm/°C	Red	FLA-3-11-5LT
Stainless steel Copper alloy	17ppm/°C	Brown	FLA-3-17-5LT
Aluminium	23ppm/°C	Green	FLA-3-23-5LT
Others	–	Grey	GFLA-3-70-5LT

PACKAGE DESIGNATION

LEADWIRE-INTEGRATED STRAIN GAUGE PACKAGE

TYPE FLA-3-11-5LT	
LOT NO. A510511	GAUGE LENGTH 3 mm
GAUGE FACTOR 2.14 ±1%	
GAUGE RESISTANCE 119.5±0.5 Ω	QUANTITY 10
TEMP.COMPENSATION FOR 11 $\times 10^{-6}$/°C	TEST CONDITION 23°C 50%RH
TRANSVERSE SENSITIVITY 0.0 %	BATCH NO. ZF28T
LEADWIRES 10/0.12 3W 5m	

LEADWIRES
Core number/diameter (or cross section area) Wiring procedure Length of leadwire
Above in column examples 10-core 0.12mm diameter, 3-wire leadwire of 5-meter long

TML STRAIN GAUGE TEST DATA

Test specimen used in thermal output test

Gauge type → GAUGE TYPE : FLA-3-11 | TESTED ON : SS 400

Lot Number → LOT NO. : A502515 | COEFFICIENT OF THERMAL EXPANSION : 11.8 $\times 10^{-6}$/°C ← A linear thermal expansion coefficient of specimen materials in thermal test

Gauge Factor → GAUGE FACTOR : 2.14 ±1% | TEMPERATURE COEFFICIENT OF G.F. : +0.1±0.05 %/10°C ← Temperature coefficient of Gauge Factor with tolerance per 10°C

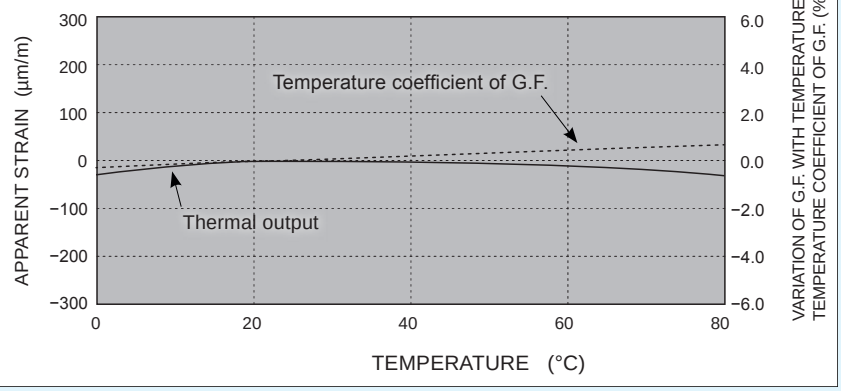
Bonding adhesive used in tests → ADHESIVE : P-2 | DATA NO. : A0312

THERMAL OUTPUT (εapp: APPARENT STRAIN)

$\varepsilon app = -2.94\times10^{1}+2.32\times T^{1}-4.60\times10^{-2}\times T^{2}+1.65\times10^{-4}\times T^{3}+5.00\times10^{-7}\times T^{4}$ (μm/m) ← Quadratic equation of thermal output (apparent strain with temperature)

Allowable tolerance of temperature compensation → TOLERANCE : ±0.85 [(μm/m)/°C], T: TEMPERATURE

Gauge Factor set on strainmeter → (INSTRUMENT G.F. SET :2.00) ——— APPARENT STRAIN - - - - GAUGE FACTOR



Example of curved data on thermal output

GAUGE FACTOR OF LEADWIRE-INTEGRATED STRAIN GAUGES

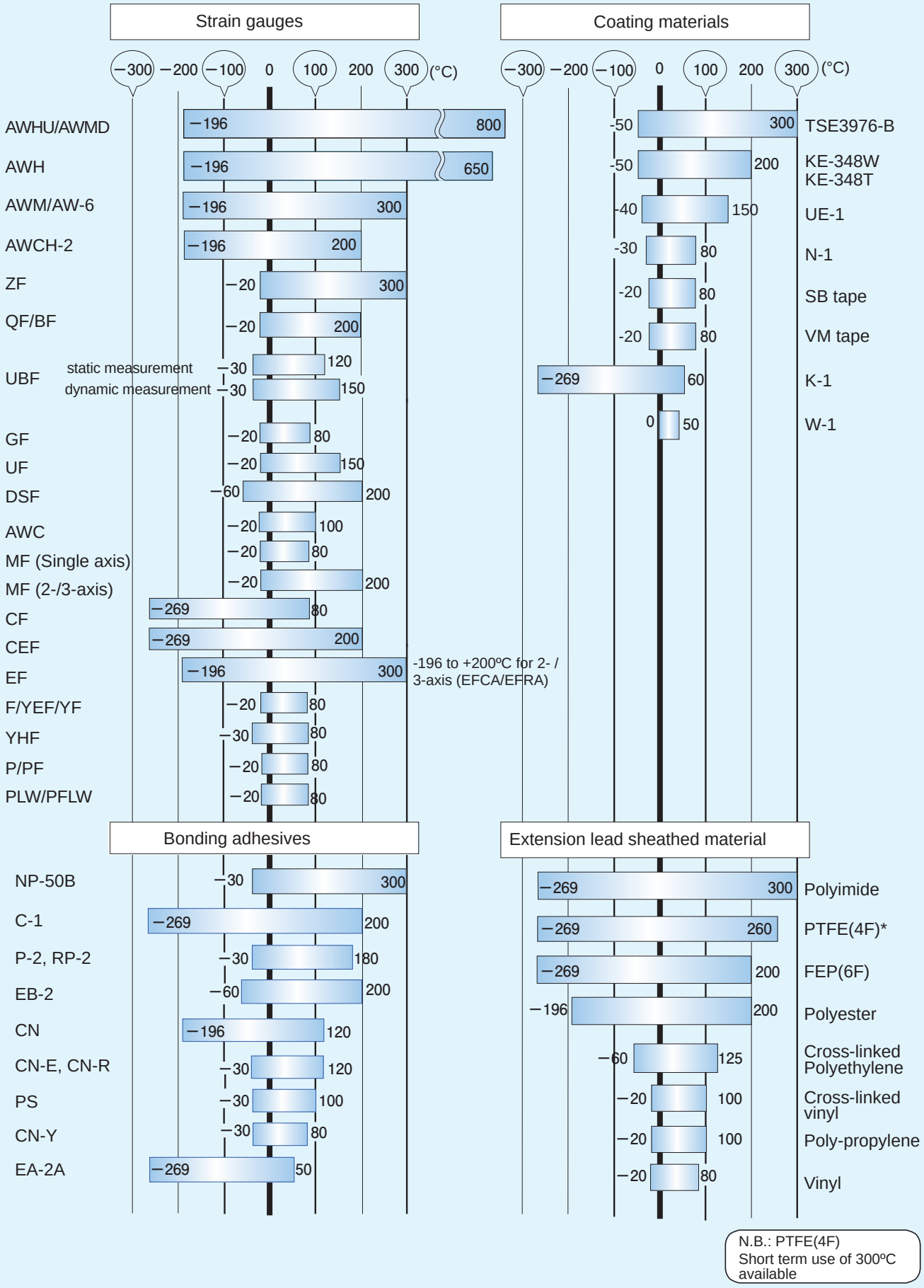
Gauge factor of leadwire-integrated strain gauges given in the supplied TML STRAIN GAUGE TEST DATA is of the strain gauge itself, which is not corrected with attached leadiwre. Refer to the test data sheet in which Gauge Factor Correction due to Leadwire attachment is given.

TML STRAIN GAUGES SELECTION

Measuring purpose

Material - Purpose	Gauges series & Operating temperature (°C)	Bonding adhesive	Coating materials	Code of extension wire recommended
Metal				
General use Normal	−20 F/PF +80	CN/P-2/EB-2	W-1/N-1/SB tape	-LE, -L, -LT
Under water	0 WF +80	CN/P-2	W-1/N-1/SB tape	-L, -LT
General use Mid-high temperature	−20 UF +150	CN/P-2/EB-2	W-1/N-1/SB tape	-LE, -L, -LT, -6FA-LT
High temperature	−20 QF +200	CN/C-1/NP-50B	KE-348	-6FA-LT
High temperature	−20 ZF +300	CN/C-1/NP-50B	Consult TML	-4FA-LT
Miniature, High	−196 EF(Single) +300	CN/EB-2/C-1 NP-50B	KE-348	-6FA-LT, -4FA-LT
Miniature, High	−196 EF(2-/3-axis) +200			
Wide range temp.	−269 CEF +200	EA-2A/CN/C-1	K-1	-6FA-LT
Cryogenic temp.	−269 CF +80			
Spot welding	−196 AWM (Quarter with 3-wire) +300	Spot welding (Welder W-50RB)	Consult TML	MI cable
	−196 AWMD (Full bridge) for dynamic +800			
	−196 AWH (Full bridge) for static +600 for dynamic +650			
	−196 AWHU (Full bridge) +800			
	−196 AW-6 (Quarter with 3-wire) +300			-LT(4FA-LT)
	−20 AWC +100			-LQ, -LT
	−196 AWCH +200			-LQ
Long-term	−20 ZF +80	C-1/NP-50B/EB-2	W-1 SB tape	Vinyl/Cross-linked vinyl/PTFE(4F)
	−196 AW-6 +80	Spot welding		
Stress concentration	−20 F +80	CN/P-2/EB-2	W-1/SB tape	-L, -LT
	−20 QF +200	CN/C-1/NP-50B	KE-348	-6FA-LT
Residual stress	−20 F +80	CN/P-2/EB-2	W-1/SB tape	-L, -LT
Torque	−20 FCT +80	CN/P-2/EB-2	W-1/SB tape	-L, -LT
	−20 QFCT +200	CN/C-1/NP-50B	KE-348	-6FA-LT
Shear strain	−20 FLT +80	CN/P-2/EB-2	W-1/SB tape	-L, -LT
	−20 QFLT +200	CN/C-1/NP-50B	KE-348	-6FA-LT
One-side gauge	−10 DD +70	CN/P-2	—	-L, -LT
Bolt axial strain	−10 BTM +80	A-2/CN	—	-L, -LT
Large strain	−20 YEF/YF +80	CN/CN-Y	SB tape	-L, -LT
	−30 YHF +80			
Metal or Concrete				
Magnetic field use	−20 +80 MF(Single axis)	CN/CN-E/RP-2	W-1/SB tape	-L, -LS
	−20 MF(2-/3-axis) +200	CN/NP-50B EB-2/C-1	KE-348	-6FD-LTS
Concrete or Mortar				
Surface strain	−20 P/PF +80	CN-E/RP-2/PS	W-1/SB tape	-L, -LT
	−20 +80 FLM/WFLM	PS		-LT
Internal strain	−20 +60 PM/PMF	Embedment	—	-LT
Asphalt				
Internal strain	−20 +60 PMFLS	Embedment	—	Special
Plastics				
	−20 GF +80	CN	W-1/N-1/SB tape	-L, -LT
Composite				
General purpose	−20 BF +200	CN/NP-50B/EB-2	W-1/SB tape	-L, -LT, -6FA-LT
	−30 UBF for static +120 for dynamic +150	CN/EB-2		
Fatigue test	−60 DSF +200	CN/C-1/EB-2	—	-L, -LT, -6FA-LT
Printed circuit board				
General purpose	−196 EF (Single axis) +300	CN/NP-50B/EB-2	—	-L, -LT, -6FA-LT, -4FA-LT
	−196 EF (2-/3-axis) +200			
Wood long-term/Gypsum				
General purpose	−20 +80 PFLW/PLW/LF	PS/CN-E	W-1/N-1/SB tape	-L, -LT
General use				
Temperaute	−20 TF +200	CN/C-1/NP-50B	W-1/SB tape	-L, -LT, -6FA-LT

Operating temperature (°C)



N.B.: PTFE(4F)
Short term use of 300ºC available

TML STRAIN GAUGES SELECTION

GENERAL USE

¶ F series Foil strain gauges

P.39

These gauges employ Cu-Ni alloy foils for the grid and epoxy resin for the backing. The epoxy resin backing exhibits excellent electrical insulation performance, and is color-coded to identify the objective material for self-temperature-compensation. Various types of strain gauges such as for residual stress measuremenent and are available in addition to general use gauges.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN/P-2/EB-2	Epoxy	Cu-Ni	5%(50,000)

General use P.39
Residual Stress measurement P.40
Shearing strain measurement P.40
Torque measurement P.40
Glass/Ceramic materials P.41
Stress concentration measurement P.41,42

¶ UF series strain gauges

P.45

These strain gauges utilize Cu-Ni alloy foils for the grid and polyimide-amide resin for the backing. It enables the strain gauges to be used in 150°C at the maximum. The backing features excellent flexibility, thus allowing easy adhesion even on a curved surface and providing excellent stability in thermal characteristics of the strain gauges. The backing is color-coded to identify the objective material for self-temperature-compensation in the same manner as the F series.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+150°C	+10~+100°C	CN/P-2/EB-2	Polyimide amide	Cu-Ni	5%(50,000)

WATERPROOF CONSTRUCTION

WF series strain gauges

P.43

These gauges eliminate the need for a moisture-proofing coating, which is sometimes troublesome in a field test. These have an integral vinyl leadwire, and whole area of the strain gauge and the leadwire junction are coated with epoxy resin. The coating is transparent and flexible, so the positioning and bonding works are very easy. By merely bonding the gauge with CN or P-2 adhesive, outdoor or underwater measurement for a short-term becomes possible. These gauges are also effective in eliminating the primary coating in case of applying a multi-layer coating.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
0~+80°C	+10~+80°C	CN/P-2	Epoxy	Cu-Ni	3%(30,000)

TEMPERATURE-INTEGRATED

FLA-T and QFLA-T series Strain Gauge

P.44

These are strain gauges having a thermocouple integrated with the pre-attached leadwire. One core of the three-core parallel leadwire is made of Cu-Ni wire while other two cores are made of ordinary copper wire. A type T thermocouple is composed of the Cu-Ni wire and the copper wire. Simultaneous measurement of strain with quarter bridge 3-wire method and temperature with type T thermocouple is possible by using TML data loggers. The QFLA-T uses FEP sheathed leadwire to withstand high temperature up to 200°C.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
F : -20 ~+80°C QF: -20~+200°C	+10~+80°C	CN/P-2 NP-50B	Epoxy Polyimide	Cu-Ni Cu-Ni	5%(50,000) 3%(30,000)

HIGH TEMPERATURE USE

P.47

¶ QF series strain gauges

These are foil strain gauges having a polyimide resin backing, which exhibits excellent performance in high temperature up to 200°C. Stress concentration measurement gauges and shear stress measurement gauges are also available in this series.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+200°C	+10~+100°C	CN/NP-50B/C-1	Polyimide	Cu-Ni	3%(30,000)

HIGH TEMPERATURE USE

¶ ZF series strain gauges

P.49

These strain gauges are designed for measurement in high temperature up to 300°C. They utilize specially designed Ni-Cr alloy foil for the grid and polyimide resin for the gauge backing. Owing to the construction, these strain gauges are successfully used for measurement in high temperature.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+300°C	+10~+100°C	CN/NP-50B/C-1	Polyimide	Ni-Cr	1%(10,000)

¶ EF Series strain gauges

P.50

Polyimide backing strain gauges for high temperature use. The gauges have a miniature grid pattern required as strain gauges to measure the mechanical properties of printed circuit boards and mounting parts which are getting smaller.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal*	Compensation*		Backing	Grid	
Single element (EFLA)					
-196~+300°C	+10~+150°C	CN/EB-2 NP-50B/C-1	Polyimide	Ni-Cr	1%(10,000)
2-/3-element (EFCA/EFRA)					
-196~+200°C	0~+150°C	CN/EB-2 NP-50B/C-1	Polyimide	Ni-Cr	1%(10,000)

HIGH & LOW TEMPERATURE USE

CEF series strain gauges

P.50

These are strain gauges utilizing polyimide resin for the gauge backing and special alloy foil for the grid. These feature a wide range of operating temperature from cryogenic temperatue to +200°C. This series is available only in single axis configuration with gauge length of 1,3 and 6mm.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-269~+200°C	-196~+80°C	CN/EA-2A C-1	Polyimide	Special	1%(10,000)

CRYOGENIC TEMPERATURE USE

CF series strain gauge

P.51

These are foil strain gauges with epoxy backing designed for measurement under cryogenic conditions. These are available in single element, rectangular 2-element and rectangular 3-element configurations with 350Ω resistance. The specially selected and heat treated grid of these gauges shows very small zero shift under cryogenic temperature compared to conventional strain gauges.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-269~+80°C	-196~+80°C	CN/EA-2A C-1	Epoxy	Special	1%(10,000)

WELDABLE TYPE

AW series strain gauges

P.53

These strain gauges have strain sensing elements fully encapsulated in corrosion-resisting metal tubes made of stainless steel or Inconel (except AW-6-350). The strain gauge backings are also made of the same material, and the gauges are installed by spot welding to metal specimens using a dedicated spot welder. The maximum operating temperatue is 800°C for the AWHU. These gauges are suited to measurement in high temperature, harsh environments such as underwater or gas-filled atmosphere, or for long term. The AWC-2B and AWCH-2 adopt 1-gauge 4-wire strain measurement method.

AWM-8	Quarter bridge with 3-wire system	: -196 ~ +300°C
AWMD-5, AWMD-8	Full bridge for dynamic measurement	: -196 ~ +800°C
AWH-4, AWH-8	Fulll bridge for static measurement	: -196 ~ +600°C
	Fulll bridge for dynamic measurement	: -196 ~ +650°C
AWHU-5, AWHU-8	Fulll bridge for static & dynamic	: -196 ~ +800°C
AW-6-350-11-01LT	Quarter bridge with 3-wire system	: -196 ~ +300°C
AWC-2B-11-3LQ	1-Gauge 4-Wire	: - 20 ~ +100°C
AWC-8B-11-3LT	Quarter bridge with 3-wire system	: - 20 ~ +100°C
AWCH-2-11-05LQ	1-Gauge 4-Wire	: -196 ~ +200°C

TML STRAIN GAUGES SELECTION

CONCRETE MATERIAL USE

¶ P series Polyester wire strain gauges

P.59

C concrete M mortar R rock

These are wire strain gauges utilizing a transparent plastic backing impregnated with polyester resin. The gauge length is available in 3 steps of 60, 90 and 120mm, so it is sutited to the measurement of concrete strain. Since the backing is transparnt, the bonding position can easily be checked in the installation works.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN-E/RP-2	Polyester	Cu-Ni wire	2%(20,000)

¶ PF series Polyester foil strain gauges

P.59

C concrete M mortar R rock

These are foil strain gauges utilizing a polyester resin backing which is the same as the P series. The gauge length is available in 3 steps of 10, 20 and 30mm, so it is suited mainly to strain measurement on concrete or mortar. The backing is transparent and the installation is easy.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN/RP-2	Polyester	Cu-Ni	2%(20,000)

¶ FLM/WFLM series Metal backing strain gauges

P.60

C concrete M mortar

These strain gauges have thin stainless steel backings which prevent the penetration of moisture from the reverse sides. These constructions are aimed for successful strain measurement on concrete surface. The WFLM gauges have moisture proofing over-coating and integral leadwire in addition to the stainless steel bakcing. These are intended for long term measurement or measurement on underwater-curing conctrete.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	PS	SUS 304	Ni-Cr	0.5%(5,000)

¶ PM series Mold strain gauge Embedment type

P.60

C concrete M mortar

These gauges are designed exclusively for the measurement of internal strain of concrete or mortar under loading test. These are embedded into the measurement position when the concrete or mortar is placed. These gauges have a construction of the sensing element sealed into the backing made of acrylic resin for waterproofing.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+60°C	Not applicable	Embedment	Special pla	Cu-Ni	N/A

¶ PMF series Mold strain gauge Embedment type

P.62

C concrete M mortar

These gauges are designed for the measurement of internal strain of concrete or mortar under loading test. These can also be used for short-term measurement of the behavior of concrete. These are embedded into the measurement position when the concrete or mortar is placed. These employ super engineering plastics as the backing for sealing the sensing element, which provides excellent waterproofing. A tempraturte-integrated type PMFL-T is available for measurement of both strain and temperature using our data loggers.

*For long-term mearuement of concrete structures, the use of Strain Transdujcer KM is recommended.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+60°C	Not applicable	Embed-ment	Super engin-eering plastic	Cu-Ni	N/A

CONCRETE MATERIAL CIVIL ENGINEERING USE

¶ KM Strain Transducer

P.63

C concrete M mortar

The KM series are embedment type transducers designed for measurement of internal strain of materials such as concrete and synthetic resin not only in their hardened state but also in curing process. The apparent elastic modulus is as low as approx. 40N/mm², and they are idealy suited to strain measurement during the very early stage of curing (except KM-A and KM-AT). They are totally impervious to moisture absorption producing excellent stability for long-term strain measurement. The KM-100B and KM-100BT are also applicable to measurement of surface strain of steel or concrete structures by using optional collars for surface installatiion.

ASHPHALT USE, EMBEDMENT TYPE

¶ PMFLS series Asphalt Mold strain gauges

P.62

A asphalt

The gauges are embedded in asphalt and used for strain measurement in loading test such as rolling compaction. The material of the backing is super engineering plastics featuring high temperature resistivity and waterproofing performance. The gauges withstand a high temperature up to 200°C during placement of asphalt, while the operating temperature range is –20 to +60°C.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+60°C	Not applicable	Embed-ment	Special plastic	Cu-Ni	N/A

ASPHALT PAVEMENT CIVIL ENGINEERING USE

P.64

A asphalt

¶ KM-HAS Strain Transducer

This transducer is embedded into asphalt for measurement of the internal strain. It has flanges with reinforcing bars on its both ends for good fixatiohn to asphalt pavement materials. The operational temperature range of the transucer is –20 to +180°C, and it has a fully waterproof construction.

COMPOSITE MATERIAL USE

¶ UBF series Composite strain gauges

P.65

C composite

These are strain gauges developed for measurement on composite materials. These have a specially designed grid pattern to reduce the stiffening effect of the strain gauge. In addition, owing to the development of gauge backing with better compliance, the number of repetition in thermal cycling test and the creep characteristics have been significantly improved compared to conventional strain gauges.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-30~+150°C	Not applicable	CN/EB-2	Polyimide-amide	Cu-Ni	3%(30,000)

¶ BF series Composite strain gauges

P.65

C composite C ceramic

These are foil strain gauges designed for measurement on composite mateirals. These have a specially designed grid pattern to enable small stiffening effect and excellent peformance in strain measurement up to 200°C. This series is available with self-temperature-compensation for a material having coefficient of thermal expansion of 3,5 or 8×10^{-6}/°C. This series is recommended for use on ceramic, carbon and composite materials.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+200°C	+10~+80°C	CN/NP-50B EB-2	Polyimide	Cu-Ni	3%(30,000)

TML STRAIN GAUGES SELECTION

LOW ELASTIC MATERIAL USE

¶ GF series strain gauges for plastics P.66

P plastics

These gauges are suited for the measurement on materials such as plastics, which have low elastic modulus compared to metal. These specially designed grid reduce the stiffening effect of the strain gauges to the specimen material, and also reduce the effect of Joule heat in the strain gauges. This series is available with self-temperature-compensation for the material having coefficient of thermal expansion of 50 or 70×10^{-6}/°C.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN	Epoxy	Cu-Ni	3%(30,000)

¶ LF series strain gauges for wood gypsum P.67

W wood G gypsum

These are foil strain gauges for the measurement on materials having low elastic modulus such as wood or gypsum. These specially designed grid reduce the stiffening effect of the strain gauges to the specimen material. They have a backing made of epoxy resin, which is compliant to the strain on the specimen. These gauges are temperature-compensated for the material having coefficient of thermal expansion of 11×10^{-6}/°C

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN-E	Epoxy	Cu-Ni	3%(30,000)

WOOD MATERIAL USE FOR LONG TERM OF PERIOD

¶ PFLW and PLW series strain gauges P.67

W wood

These gauges are specially designed for long term measurement on wood. It has a metal foil lined on the back of the PFL or PL strain gauge. The metal foil is effective to protect the strain gauge from the influence of moisture in the wood.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	PS	Polyester	Cu-Ni	2%(20,000)

MAGNETIC FIELD USE

¶ MF series strain gauges P.68

M mortar C concrete M metal

These gauges are designed for strain measurement in the magnetic field. The gauges have a sensing element material which exhibits low magnetoresistance. In addition, the sensing element consists of two identical grids with one grid folded back on another. This construction makes the strain gauges less sensitive to the influence of the alternating field. These gauges have a twisted leadwire pre-attached which is also effective to avoid the influence of the alternating field. The 2-element and 3-element gauges of this series are usable in high temperature up to 200°C.

Single element with twisted Vinyl leadwire of 1m

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	+10~+80°C	CN/CN-E/RP-2	Epoxy	Ni-Cr	1%(10,000)

2- /3-axis element Rosette, stacked
with 3-wire twisted Fluorinated (FEP) resin leadwire of 1m

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+200°C	+10~+100°C	CN/CN-E/RP-2 NP-50B	Polyimide	Ni-Cr	1%(10,000)

POST-YIELD (Large strain) MEASUREMENT

¶ YEF series Post-yield strain gauges P.69

M metal

These gauges are applicable to the measurement of large strain up to 10~15%. Also they withstand the repeated strain in elastic range (at strain level ±1500×10^{-6} strain) like as ordinary strain gauges. However, these are not applicalble to the measurement of repeated strain in a large range.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	N/A	CN/CN-Y	Special plastics	Cu-Ni	YEF: 10~15%

¶ YF series Post-yield strain gauges P.69

These gauges are applicable to the measurement of large strain up to 15 to 20%. The gauges are not applicable to the measurement of repeated strain in elastic range as well as in large range.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+80°C	N/A	CN/CN-Y	Special plastics	Cu-Ni	YF :15~20%

¶ YHF series Post-yield strain gauges P.69

These gauges are developed for the measurement of very large strain up to 30~40%. These are not applicable to the measurement of repeated strain in elastic range as well as in large range.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-30~+80°C	N/A	CN/CN-Y	Special plastics	Special	YHF: 30~40%

HIGH ENDURANCE STRAIN GAUGE

¶ DSF series strain gauge P.71

C composite M metal

These gauges are designed for fatigue test in high stress level. The gauges satisfy the fatigue life over 10 million times at a strain level of ±3000με. These are available for use in cyclic loading test of composite materials.

Operating temperaturee		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-60~+200°C	N/A	CN/EB-2/C-1	Polyimide	Special	N/A

ONE-SIDE STRAIN MEASUREMENT

¶ DD series One-side strain gauges P.71

M metal

These gauges are intended for measuring the bending and tensile strains separately by simply bonding the gauges on one side of a plate or beam. These work on the assumption that the strain distribution in the section of the specimen is linear along the height of the section when the section is subjected to both tensile and bending stress. These gauges are effectively used for the measurement of a box construction in structures such as bridges or pressure vessels, where the reverse side of the measurement object is not accessible for strain gauge installation.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-10~+70°C	N/A	CN, P-2	Acrylic	Cu-Ni	0.15%(1,500)

CRACK DETECTION GAUGE

¶ FAC series Crack detection gauges P.72

C concrete M metal

These gauges are designed to measure the propagation speed of fatigue crack in a metal specimen. The gauges are bonded with an adhesive on the position where the crack is initiated or the crack initiation is expected. The grids of the gauges, which are aligned with interval of 0.1mm or 0.5mm, are disconnected one by one with the propagation of the crack. The gauges are used together with the crack gauge adaptor CGA-120B, and the disconnection of one grid is measured as the change of approx. 45 or 40×10^{-6} strain by a strainmeter.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-30~+80°C	N/A	CN, RP-2	Epoxy	Cu-Ni	N/A

TML STRAIN GAUGES SELECTION

STRESS GAUGE

¶ SF series Stress gauges

P.72

These gauges are intended to measure the stress in an optional direction of the specimen in plane stress field. The gauges are sensitive not only in their axial direction but also in their transverse direction, and the sensitivity ratio of the transverse direction to the axial directions is equal to the Poisson's ratio of the specimen material. In addition, the gauges are not sensitive to the shearing strain. Accordingly, the output of the gauges is proportional to the stress in the axial direction. The gauges are available in three types depending on the Poisson's ratio of the specimen material.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+200°C	+10~+100°C	CN/NP-50B C-1	Polyimide	Cu-Ni	N/A

BOLT AXIAL STRAIN MEASUREMENT EMBEDMENT TYPE

¶ BTM series Bolt strain gauges

P.75

These gauges are used for measurement of tensile strain of bolt. These are simply inserted into a pre-drilled hole in the bolt head together with A-2 bonding adhesive and cured. The gauge series is recommendable if an ordinary strain gauge cannot be mounted on the bolt surface. Accurate tensile force measurement is possible by calibrating the bolt after installing the bolt gauges.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-10~+80°C	N/A	A-2	Special plastics	Cu-Ni	0.5%(5,000)

¶ BTMC series Bolt strain gauges

P.75

The BTMC series is also available for measurement of tensile strain of bolt, while it is designed with round shape sensing element to be easily bonded by fast-room-temperature curing CN adhesive. Accurate tensile force measurement is possible by calibrating the bolt after installing the bolt gauges.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-10~+80°C	N/A	CN	Special plastics	Cu-Ni	0.5%(5,000)

TRANSDUCER-SPESIFIC STRAIN GAUGES

P.73

TML strain gauges are used not only for the purpose of knowing strain/stress but also as sensors for strain gauge type transducers. A strain gauge type transducer converts physical quantity such as load, pressure or displacement into mechanical strain on the strain generating body (elastic body), and the mechanical strain is converted into electrical output using strain gauges mounted on the elastic body. We offer various types of transducer-specific strain gauges featuring highly reliable and stable performance.

TEMPERATURE GAUGE

¶ TF series Temperature gauge

P.77

These gauges are bonded on the specimen surface like as ordinary strain gauges, and measure the surface temperature. By combining with the dedicated temperature gauge adaptor (TGA-1A or TGA-1B), actual temperature can be measured easily using a strainmeter.

Operating temperature		Bonding adhesive	Materials		Strain limit (με)
Normal	Compensation		Backing	Grid	
-20~+200°C	N/A	CN/NP-50B C-1	Polyimide	Ni alloy	N/A

FRICTION TYPE STRAIN TRANSDUCER/CHECKER

¶ FGAH-1A Axial Strain Transducer

P.84

This is a transducer to measure the axial strain of the steering tie-rod of a car or the tension rod of a structure. Since frictional strain gauges are used in this transducer, installation is completed and it gets ready for measurement by merely pinching the tie-rod with the transducer, without detaching the tie-rod. In addition, there is no need of technical skill and complicated works for attaching strain gauges on the tie-rod.

¶ FGDH Frictional Torque Transducer (Digital telemetry)

P.85

This is a transducer to measure torque on the drive shaft of a car. Frictional strain gauges are used as sensing elements, and the installation is completed by merely pinching the shaft with the transducer. There is no need of detaching the shaft nor bonding and wiring strain gauges for the installation. In addition, since a telemetry transmitter with battery is built in the transducer, measured data are transferred to an exclusive receiver by wireless and output as analog signals. The transducer is applicable to shafts having diameter of 20mm to 30mm using spacers together, which are available as optional items. For wireless transmission, the FGDH-2A uses 315MHz band extremely low power radio wave while the FGDH-3A uses 2.4GHz band advanced low power radio communication system.

¶ FGMH series Strain Checker

P.87

An ordinary strain gauge picks up the strain generated in the specimen through the adhesive layer. The Strain checker FGMH picks up the strain through the frictional force working on the contact surface of the frictional strain gauge by pressing the gauge against the structure with magnetic force. The checker can be easily fixed on the position of interest and immediately get ready for strain measurement. The FGMH-1B is a standard type of small and lightweight construction. The FGMH-2A features measurement in a narrow place such as near a welding point. These are for single axis measurement. The FGMH-3A is a 3-element type of 0°/45°/90° rectangular rosette configuration.

PRIMARY INSTALLATIONS - Bonding strain gauges

When bonding the strain gauges, the most suitable adhesive should be selected for each application. A typical installation procedure is described below using the fast-curing adhesive CN.

1. Preparation

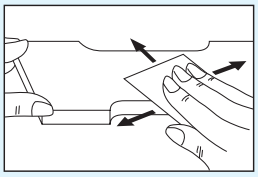
The following items are required for bonding and leadwire connection: Strain gauges, bonding adhesive, connecting terminals, test specimen, solvent, cleaning tissue for industrial use, soldering iron, solder, abrasive paper (120 -320 grit), marking pencil, scale, tweezers, extension leadwire, polyethylene sheet, nippers.

2. Positioning

Roughly determine the location on the test specimen where the strain gauge is to be bonded.

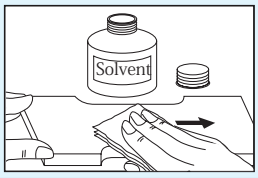
3. Surface preparation

Before bonding, remove all grease, rust, paint, etc., from the bonding area. Sand an area somewhat larger than the bonding area uniformly and finely with abrasive paper. Finish the surface with #120 to 180 abrasive paper for steel, or #240 to 320 for aluminium.



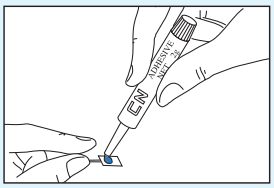
4. Fine cleaning

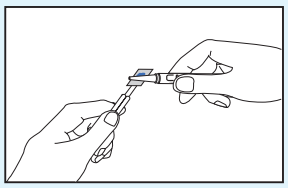
Clean the bonding area with industrial tissue paper or cloth soaked in a small quantity of chemical solvent such as acetone. Continue cleaning until a new tissue or cloth comes away completely free of contamination. Following the suface preparation, be sure to attach the gauge before the surface becomes covered with an oxidizing membrane or becomes newly contaminated.



5. Applying bonding adhesive

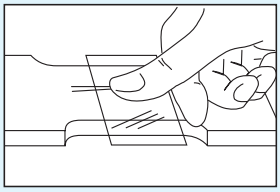
Drop the proper amount of adhesive onto the back of the gauge base. Usually one drop of adhesive will suffice, but you may increase the number of drops according to the size of the gauge. Use the adhesive nozzle to spread the adhesive over the back surface thinly and uniformly.





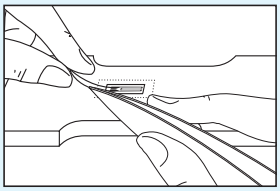
6. Curing and pressing

Place the gauge on the position, place a plyethylene sheet onto it and press down on the gauge constantly using your thumb or a gauge clamp. This should be done quickly as the curing process is completed very fast. The curing time varies depending on the gauge, test specimen, temperature, humidity and pressing force. The curing time under normal conditions is 20-60 seconds.



7. Raising the gauge leads

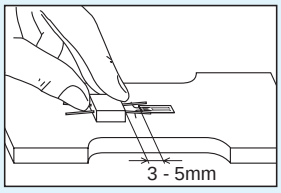
After completely curing the adhesive, remove the polyethylene sheet, and raise the gauge leads with a pair of tweezers. Raise the gauge leads as far as and a little way onto the gauge base. Hold down the gauge leads anchor points on the gauge base with a pair of tweezers to ensure that you do not break the gauge leads.



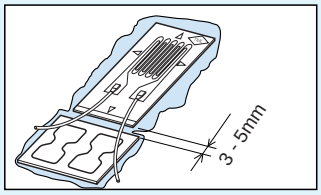
8. Bonding connecting terminals

Bond the connecting terminal in the same manner as bonding the strain gauge, apart from the strain gauge by 3 to 5mm.

Bond the connecting terminal in the same manner as bonding the strain gauge, closely to the strain gauge.



Cubic type connecting terminals

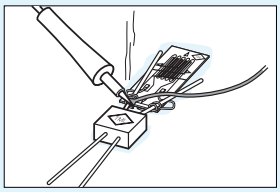


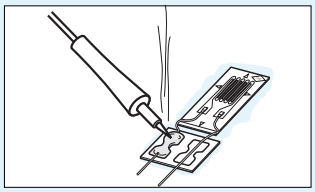
Foil type connecting terminals

9. Soldering the gauge leads

Wrap the gauge leads 2 or 3 times around the connecting terminal wires allowing a little slack in the gauge leads, and apply solder.

Lay the gauge leads over the connecting terminal allowing a little slack in the gauge leads, and apply solder. Twist the excess gauge leads off with a pair of tweezers.



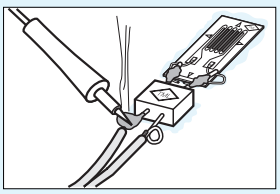


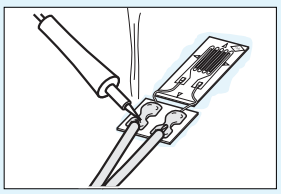
10. Soldering extension leadwires

It is recommended to plate the exposed core wires of the extension leadwire with solder preliminarily.

Solder the extension leadwire to the terminal leadwires on the opposite side of the connecting terminal. Then clip off excess gauge leads and leadwires with a pair of nippers.

Solder the extension leadwire to the connecting terminal. Take care not to apply too much heat as this can cause the metal foils of the connecting terminal to peel off.





PRIMARY INSTALLATIONS - Overcoating strain gauges

Water- and Moisture-proofing with SB tape and VM tape

Requirement in strain gauge coatings

- Excellent resistance to moisture and water and good electrical insulation
- Good adhesion to the strain gauge, leadwires and test specimen surafce
- No constriction of the test specimen

Both of the SB and VM tapes are butyl rubber tape generally referred to as pressure-sensitive adhesive. These coating tapes are applied by being pressed onto the test specimen, and they provide excellent resistance to moisture and water.

SB tape

Buthyl rubber
Temperature : -30 to +80°C
Contents : 10mm×3mm
5m long/roll

VM tape

Buthyl rubber
Temperature : -20 to +80°C
Contents : 38mm×1mm
6m long/roll

Example for leadwire integrated strain gauge

First coating with SB tape

Trimming the SB tape

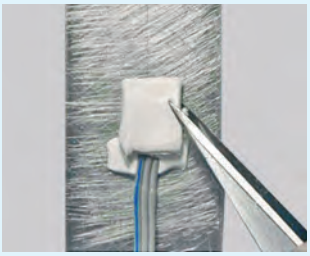
With scissors, cut off one piece of tape large enough to cover the coating area and another piece 5mm to 10mm in length to fit under the leadwires.

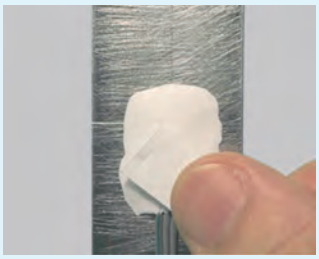
Under-laying

Lift up the leadwires and press the smaller piece of tape onto the test specimen surface under the leadwires.

Overall coating

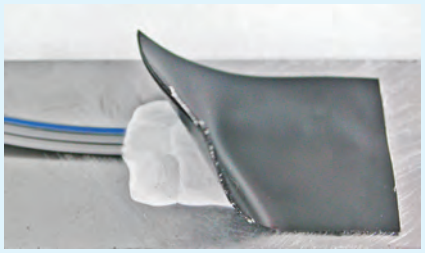
Press the leadwires back down onto the piece of SB tape and then press the larger piece of coating tape down onto the strain gauge.





Finish coating with VM tape

Cut a piece of VM tape slightly larger than the layer of SB tape coating and press it down onto the place so that the first coating is fully covered by the VM tape.



STRAIN GAUGE EXTENSION LEADWIRES

Strain gauges are connected to strain measuring instruments using extension leadwires. We offer various types of leadwires to be selected depending on the usage conditions. In addition, most of TML strain gauges are available with extension leadwires preattached at our factory. Those leadwire-integrated strain gauges greatly save the leadwire connection works during the strain gauge installation. Please feel free to contact TML or local representatives for the extension leadwires and the leadwire-integrated strain gauges.

Standard leadwire length for leadwire-integrated strain gauges

The standard lengths of our integral leadwires are 1m, 3m and 5m except enamel leadwires. The standard lengths of enamel leadwires are 0.3m, 0.5m and 1m. Other lengths than the standard lengths may be available on request. Enamel leadwires are not available in a length more than 1m.

Leadwire selection

¶ Vinyl leadwires

Vinyl leadwires are widely used as strain gauge leadwires, and are available in a variety of types. Because the vinyl sheath can be colored, these wires allow color-coding for rosette gauges. The stranded core wires are flexible and easy to handle, and allow easy wire connection and terminal attachment.

·Small diameter vinyl wires : -LH, -LHT

These leadwires feature a thin vinyl sheath and small diameter core wires to achieve an outside diameter of 0.4mm. They are used for wiring in tight spaces. The stranded wires are flexible and minimize breakage due to repeated bending.

·Shielded vinyl wires : -LTSA, -LTSB

These are 3-core wires with shield made of aluminium foil or braided copper wire. The outer sheaths are made of vinyl. These leadwires offer a noise shielding function.

Leadwire type	Core/Diameter (cross section)	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.08mm² paralleled vinyl lead wire	7/0.12 (0.08mm²)	-20 ~+80°C	0.44Ω/m	1.1 x 2.2mm	200m*2	-L(for UF) -LJB	Red, White, Green, Black, Yellow Blue, Red-White
0.08mm² 3-wire paralleled vinyl leadwire				1.1 x 3.3mm		-LJBT -LT(for UF)	White, One wire with Blue, Red or Orange stripe*3
0.08mm² twisted vinyl leadwire	7/0.12 (0.08mm²)	-20 ~+80°C	0.44Ω/m	ϕ 1.6mm		-LJA	Red, Green, Yellow
0.08mm² 3-wire twisted vinyl leadwire				ϕ 1.9mm		-LJAT	Red-Green-Yellow, Red-Green-Blue, Red-Green-White
0.11mm² paralleled vinyl lead wire	10/0.12 (0.11mm²)	-20 ~+80°C	0.32Ω/m	1.4 x 2.8mm	200m	-L, -LJC(for UF)	Grey
0.11mm² 3-wire paralleled vinyl leadwire				1.4 x 4.2mm	100m	-LT -LJCT(for UF)	Grey, One wire with Blue stripe*3
0.3mm² paralleled vinyl leadwire	12/0.8 (0.3mm²)	-20 ~+80°C	0.12Ω/m	1.9 x 3.8mm	200m	-LJD	Grey
0.3mm² 3-wire paralleled vinyl leadwire				1.9 x 5.7mm	100m	-LJDT	White, One wire with Red stripe*3
0.5mm² paralleled vinyl leadwire	20/0.8 (0.5mm²)	-20 ~+80°C	0.07Ω/m	2.5 x 5.0mm	100m	-LJG	Grey
0.5mm² 3-wire paralleled vinyl leadwire				2.1 x 6.3mm		-LJGT	White, One wire with Blue stripe*3
0.02mm² Twisted vinyl leadwire	5/0.07 (0.02mm²)	-20 ~+100°C	1.8 Ω/m	ϕ 0.8mm		-LH	Red, Green, White
0.02mm² 3-wire twisted vinyl leadwire				ϕ 1.0mm		-LHT	Red-Green-White
3mm-dia. 3-core shielded vinyl leadwire	7/0.12 (0.08mm²)	-20 ~+80°C	0.44Ω/m	ϕ 3mm	200m	-LTSA	Outer sheath: Red, White or Green Core wire sheath: Red-Black-White
5mm-dia. 3-core shielded vinyl leadwire	7/0.26 (0.3mm²)	-20 ~+80°C	0.1 Ω/m	ϕ 5mm	200m	-LTSB	Outer sheath: Black Core wire sheath: Red-Black-White
0.08mm² polypropyrene 4-paralleled leadwire	7/0.12 (0.08mm²)	-20 ~+100°C	0.44Ω/m	0.9 x 4.0mm	200m	-LQM	White, One wire with Red, Blue or Black stripe*3
0.08mm² polypropyrene 6-paralleled leadwire	7/0.12 (0.08mm²)	-20 ~+100°C	0.44Ω/m	0.9 x 6.0mm	100m	-LHM	White, One wire with Red stripe*3

N.B.: *1 : Lead wires are supplied by one roll each *2 : For Red only, 400m for the other colors
*3 : Stripe is for distinction of independent wire in quarter bridge.

¶ Enamel leadwires

Enamel leadwires have a single core covered with a resin sheath. Heat resistance and handling methods vary depending on the sheath type. Because the wire mass and diameter are small, enamel leadwires are used for strain measurement of rotating specimens and/or measurement of multiple points located in close proximity. Since the enamel leadwire contains one core covered with a thin sheath, it must be handled with care.

·Polyurethane leadwires (-LP, -LJP, -LJPT)

Polyurethane leadwires allow easy post-processing because the sheath can be removed with a soldering iron. The sheath is not strong, therefore, polyurethane wires must be handled with special care.

·Polyester leadwires : -LU, -LJU, -LJUT

Polyester leadwires have a stronger sheath than polyurethane wires, it cannot be removed with a soldering iron.

·Polyimide leadwires : -LE, -LJE, -LJET

Polyimide leadwires have a stronger sheath than polyester wire. A soldering iron cannot be used for post-processing.)

Leadwire type	Core/Diameter	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.14mm-dia. Polyurethane leadwire	1/0.14	-10 ~+120°C	2.5Ω/m	ϕ 0.16mm		-LP, -LJP -LJPT	
0.18mm-dia. Polyurethane leadwire	1/0.18		1.5Ω/m	ϕ 0.20mm			
0.14mm-dia. Polyester leadwire	1/0.14	-196 ~+200°C	2.5Ω/m	ϕ 0.16mm		-LU, -LJU -LJUT	
0.18mm-dia. Polyester leadwire	1/0.18		1.5Ω/m	ϕ 0.20mm			
0.14mm-dia. Polyimide leadwire	1/0.14	-269 ~+300°C	2.5Ω/m	ϕ 0.16mm		-LE, -LJE -LJET	
0.18mm-dia. Polyimide leadwire	1/0.18		1.5Ω/m	ϕ 0.20mm			

¶ Cross-linked Vinyl sheathed leadwires : -LJRA, -LJRTA, -LRT, -LT

The cross-linked vinyl sheath provides improved resistance against environmental elements. It is often used for underwater measurement in ordinary temperature.

¶ Cross-linked Polyethylene sheathed leadwires : -LJQTA, -LT

The cross-linked polyethylene sheath offers higher durability than the cross-linked vinyl sheath. Cross-linked polyethylene sheathed leadiwres can be used in steam, warm water and concrete with virtually no insulation degradation.

Leadwire type	Core/Diameter (Cross section)	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.14mm² 2-wire twisted cross-linked vinyl sheathed leadwire	7/0.16 (0.14mm²)	-20 ~+100°C	0.24Ω/m	ϕ 3.0mm		-LJRA	White
0.09mm² 3-wire twisted cross-linked vinyl sheathed leadwire	7/0.127 (0.09mm²)		0.4Ω/m	ϕ 2.0mm	200m	-LJRTA -LRT, -LT	Red-Green-Black
0.09mm² 3-wire twisted cross-linked polyethylene sheathed leadwire	7/0.127 (0.09mm²)	-60 ~+125°C	0.4Ω/m	ϕ 2.0mm		-LJQTA -LT	Red-Yellow-Black, Red-Yellow-Blue, Red-Yellow-White

N.B.: *1 : Lead wires are sold by one roll each

¶ Fluorinated resin sheathed leadwire : -6FA, -6FB, -6FC, -4FA, -4FB

With a fluorinated resin sheath, these leadwires can be used in a wide range of temperature from extremely low to high temperatures. Fluorinated resin resists most chemicals. Surface treatment (tetra-etching) is required for some coatings.

Leadwire type	Core/Diameter (Cross section)	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.18mm² 3-wire twisted fluorinated resin (FEP) sheathed leadwire	7/0.18 (0.18mm²)	-269 ~+200°C	0.2Ω/m	ϕ 2.0mm	100m	-6FA-_LT*2	Red-Green-Blue
0.09mm² 3-wire twisted fluorinated resin (FEP) sheathed leadwire	1/0.2 (0.09mm²)		1.2Ω/m	ϕ 1.1mm		-6FB-_LT	Red-Green-Blue
0.04mm² 3-wire twisted fluorinated resin (FEP) sheathed leadwire	7/0.08 (0.04mm²)	-269 ~+200°C	1.1Ω/m	ϕ 1.0mm		-6FC-_LT	Red-Black-White
0.14mm² 3-wire twisted fluorinated resin (PTFE) sheathed leadwire	7/0.16 (0.14mm²)	-269 ~ +260°C*3	0.24Ω/m	ϕ 1.9mm	100m	-4FA-_LT*4	Red-Grey-White
0.2mm-dia. 3-wire twisted fluorinated resin (PTFE) sheathed leadwire	1/0.2		1.05Ω/m	ϕ 1.1mm		-4FB-_LT*4	Red-Black-White
						-LT (for AW-6-11)	

N.B.: *1 : Leadwires are sold by one roll each *2 : _LT is filled with required length *3 : PTFE leadwire is available in 300ºC for short-term use. *4 : Suffix code LT (CT) is provided with connecting terminal joint, and another LT(TA) with insulation film

¶ Special leadwire for temperature-integrated gauge : -LT, -6FB

Special leadwire for temperature-integrated gauge consists of 2-core copper and 1-core constantan. To extend this wire, the exclusive leadwire should be applied properly.

Leadwire type	Core/Diameter (Cross section)	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.08mm² 3-wire paralleled vinyl leadwire	7/0.12 (0.08mm²)	-20 ~+80°C	0.44Ω/m	1.2x3.6mm		-_LT*1	Red-White-Blue
0.2mm-dia. 3-wire twisted fluorinated resin (FEP) sheathed leadwire	1/0.2	-269 ~+200°C	1.05Ω/m	ϕ 1.1mm		-6FB-_LT*1	Red-White-Blue

N.B.: *1 : _LT is filled with required length

¶ Special 3-wire paralleled leadwire : -LXT

Leadwire type	Core/Diameter (Cross section)	Applicable temperature	Total resistance of leadwire	Outer sheath dimensions	Length per roll*1	Suffix code of leadwire	Colors
0.08mm² 3-wire paralleled special vinyl sheathed leadwire	7/0.12 (0.08mm²)	-20 ~+150°C	0.44Ω/m	0.9x7.2mm		-_LXT*1	Red-Black-White

N.B.: *1 : _LXT is filled with required length

HOW ARE INTEGRAL LEADWIRES JOINTED

Most TML strain gauges are available with extension leadwires preattached for the customer convenience. We have several methods for connecting leadwires to be chosen depending on conditions such as the type of strain gauge and leadwire, measurement environments, and so on.

Different joints

·Integral type

A vinyl leadwire is jointed to the polyimide sheathed gauge leads of a strain gauge. The solder joints are covered with the vinyl sheath of the leadwire. This is our standard method of integral leadwire attachment.

·Heat-shrinkable tubing

The soldered joint between the gauge leads and the leadwire is protected with a heat shrinkable tube. The heat shrinkable tubes are available in three temperature ratings of 80°, 200°C and 260°C.

·Connecting terminals joint type

The gauge leads and the leadwire are jointed using a foil shape connecting terminal. Measurement in high temperature is possible by using a high temperature solder with melting point of 300°C or more for the joint.

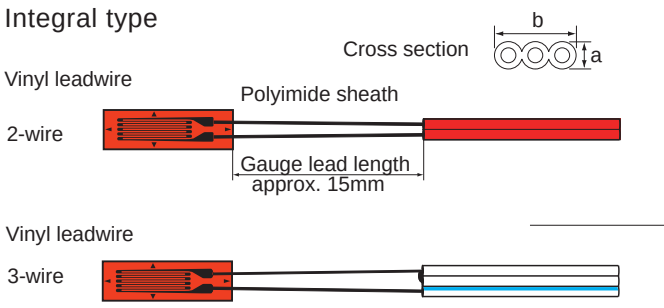
·Insulation film type

The soldered joint between the gauge leads and the leadwire is covered with an insulation film of glass cloth base. The film is resistive to heat up to 300°C, so this method is suited to measurement in high temperature.

·Direct type

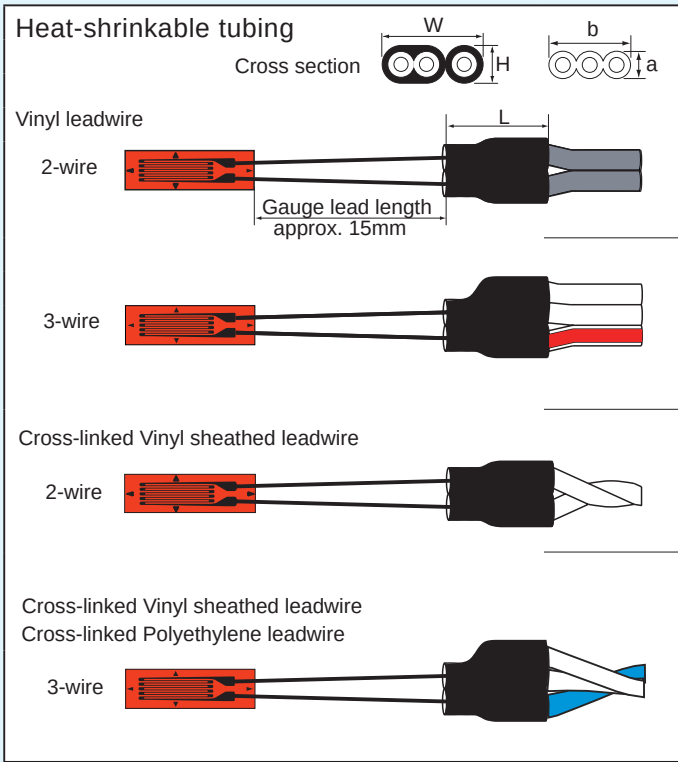
A vinyl leadwire is jointed directly to the gauge leads, which are made of nickel plated copper. The solder joints are covered with the vinyl sheath of the leadwire up to the end of the gauge base.

Integral type



Leadwire				
Construction		Dimension a	Dimension b	Code to order
2-wire paralleled	7/0.12	1.1	2.2	-L, -LJB
	10/0.12	1.4	2.8	-L, -LJC
2-wire twisted	7/0.12	0.8	-	-LJA
	5/0.07	0.4	-	-LH
3-wire paralleled	7/0.12	1.1	3.3	-LT, -LJBT
	10/0.12	1.4	4.2	-LT, -LJCT
3-wire twisted	7/0.12	0.8		-LJAT

Heat-shrinkable tubing



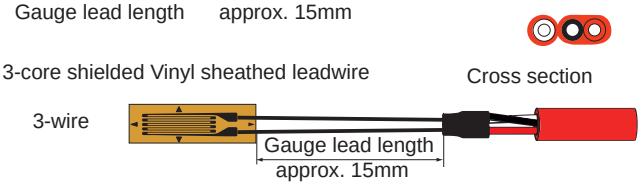
Leadwire				Heat-shrinkable tube			Code to order
Construction		Dimension a	Dimension b	Dimension L	Dimension H	Dimension W	
2-wire paralleled	12/0.18	1.9	3.8	11	3	6	-LJD
	20/0.18	2.5	5.0	12	3.5	7	-LJG
3-wire paralleled	12/0.18	1.9	5.7	11	3	7	-LJDT
	20/0.18	2.1	6.3	11	3	7	-LJGT
3-wire twisted	5/0.07	0.4	-	5	0.8	1.6	-LHT
Cross-linked vinyl 2-wire twisted	7/0.16	0.9	-	11	2	4	-LJRA
Cross-linked vinyl 3-wire twisted	7/0.127	0.9	-	11	2	4	-LJRTA -LRT -LT
Cross-linked polyethylene 3-wire twisted	7/0.127	1.0	-	11	2	4	-LJQTA -LT

HOW ARE INTEGRAL LEADWIRES JOINTED

Heat-shrinkable tubing

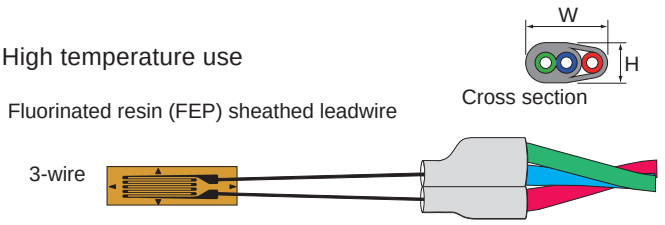
Gauge lead length approx. 15mm

3-core shielded Vinyl sheathed leadwire



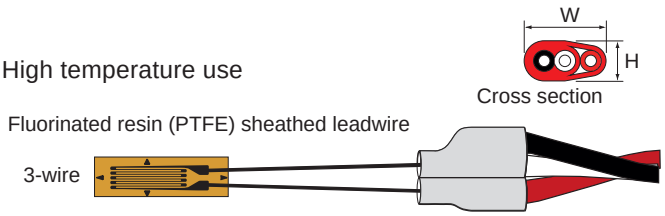
High temperature use

Fluorinated resin (FEP) sheathed leadwire



High temperature use

Fluorinated resin (PTFE) sheathed leadwire



Leadwire			Heat-shrinkable tube			Code to order
Construction		Dimension	Dimension			
			L	H	W	
3-wire twisted	7/0.12	ϕ 3.0	10	2	4	-LTSA
	7/0.26	ϕ 5.0	12.5	3	6	-LTSB
FEP (Fluorinated-ethylene-propylene) 3-wire twisted	1/0.2	ϕ 1.1	11	2	2	-6FB
	7/0.18	ϕ 2.0	11	3	4	-6FA
PTFE (Polytetra-fluoroethylene) 3-wire twisted	1/0.2	ϕ 1.1	11	2	2	-4FB
	7/0.16	ϕ 1.9	11	2.5	4	-4FA

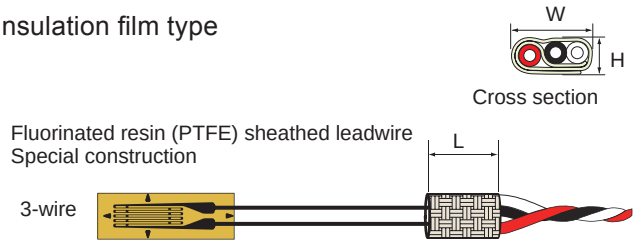
Connecting terminals joint type

Fluorinated resin (PTFE) sheathed leadwire
Special construction

Leadwire			Code to order
Construction		Dimension	
PTFE(Polytetra-fluoroethylene) 3-wire twisted	7/0.16	ϕ 1.9	-4FA-LT (CT)
PTFE(Polytetra-fluoroethylene) 3-wire twisted	1/0.2	ϕ 1.1	-4FB-LT (CT)

Insulation film type

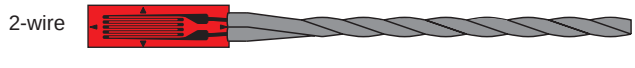
Fluorinated resin (PTFE) sheathed leadwire
Special construction



Leadwire			Film			Code to order
Construction		Dimension	Dimension			
			L	H	W	
PTFE(Polytetra-fluoroethylene) 3-wire twisted	7/0.16	ϕ 1.9	13	1.5	4	-4FA-LT (TA)
PTFE(Polytetra-fluoroethylene) 3-wire twisted	1/0.2	ϕ 1.1	13	1.5	4	-4FB-LT (TA)

Direct type

Vinyl leadwire



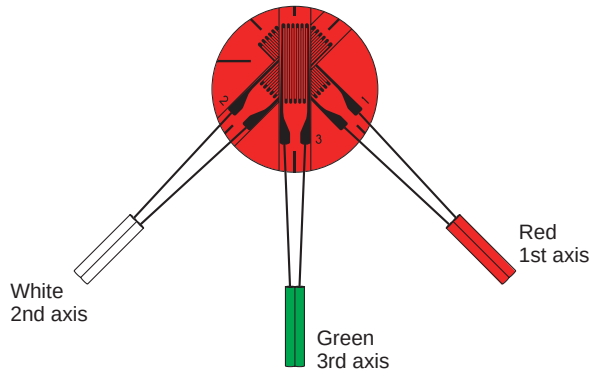
Leadwire			Code to order
Construction		Dimension	
Vinyhl leadwire 2-wire twisted	7/0.12	ϕ 1.6	-LD

The figures in the Leadwire construction column show "Number of cores/ Diameter of one core in mm". For example, "7/0.12" represents "7core / 0.12mm diameter for one core". All dimensions of the Leadwire Heat-shrinkable tube and Film are approximate values in mm.

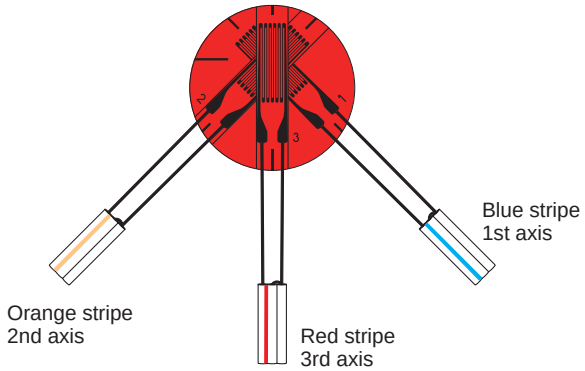
HOW ARE INTEGRAL LEADWIRES JOINTED

Sheath colors of 3-element Rosette strain gauge lead wires

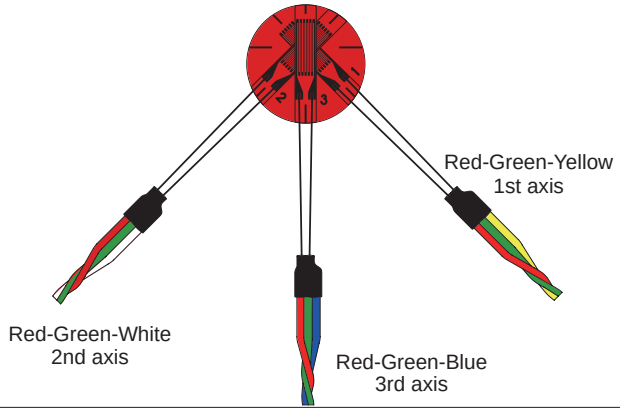
7/0.12 (0.08mm^2) Paralleled vinyl leadwire
Suffix code : -L, -LJB



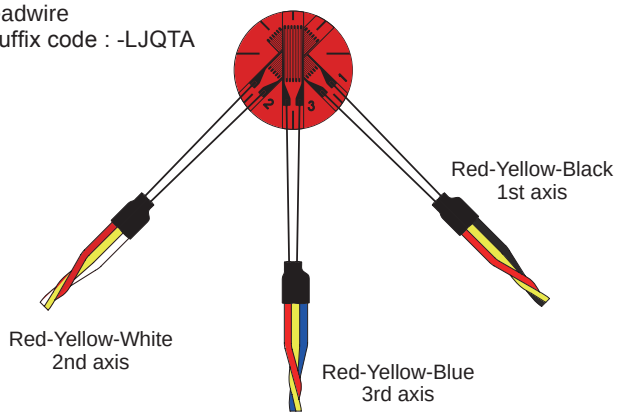
7/0.12 (0.08mm^2) 3-wire Paralleled vinyl leadwire
: -LT, -LJBT



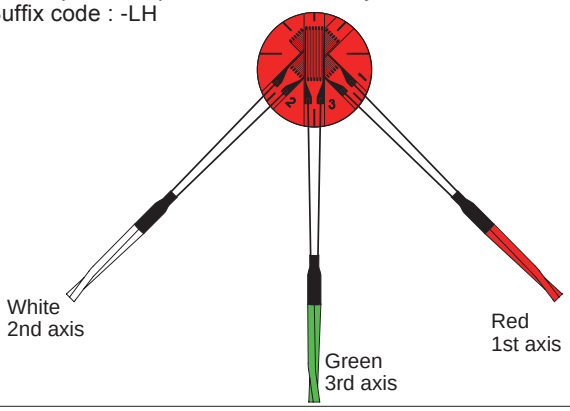
7/0.12 (0.08mm^2) 3-wire twisted vinyl leadwire : -LJAT



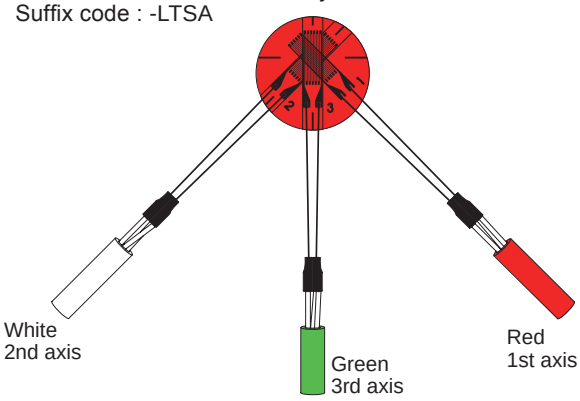
7/0.127 (0.09mm^2) 3-wire twisted cross-linked polyethylene leadwire
Suffix code : -LJQTA



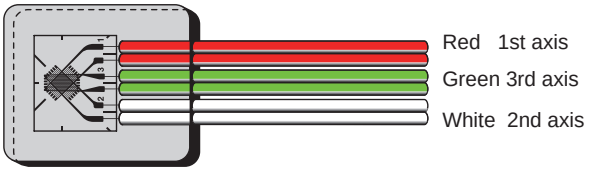
5/0.07 (0.02mm^2) 2-wire twisted vinyl leadwire
Suffix code : -LH



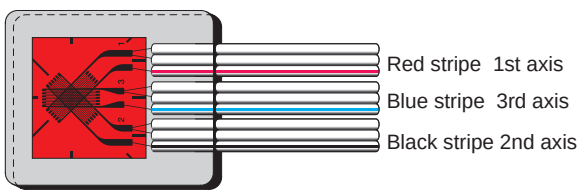
3mm-dia. 3-core shielded vinyl leadwire
Suffix code : -LTSA



7/0.12 (0.08mm^2) Paralleled vinyl leadwire
Suffix code : -L Waterproof strain gauge



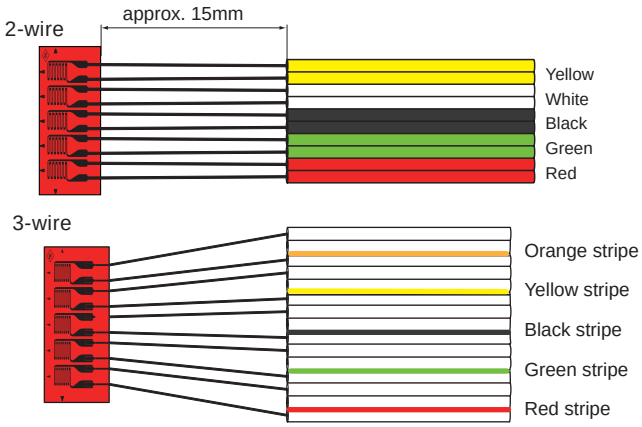
7/0.12 (0.08mm^2) 3-wire Paralleled vinyl leadwire
Suffix code : -LT Waterproof strain gauge



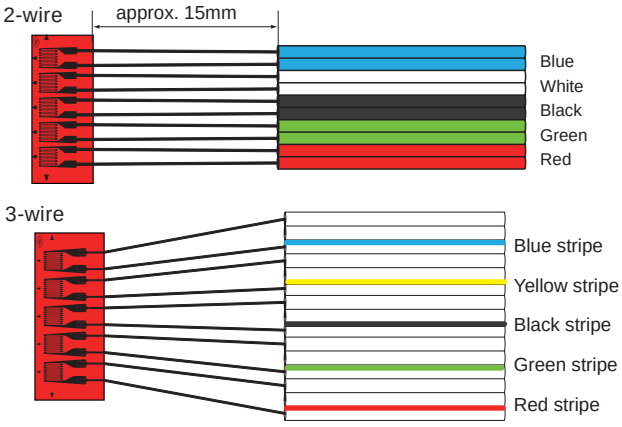
HOW ARE INTEGRAL LEADWIRES JOINTED

Sheath colors of leadwires

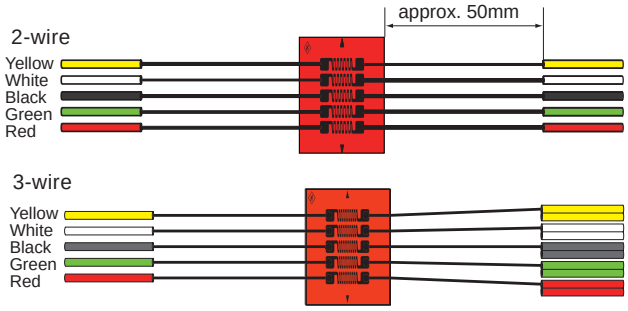
Stress concentration measurement use
FXV 5-element single axis integrated



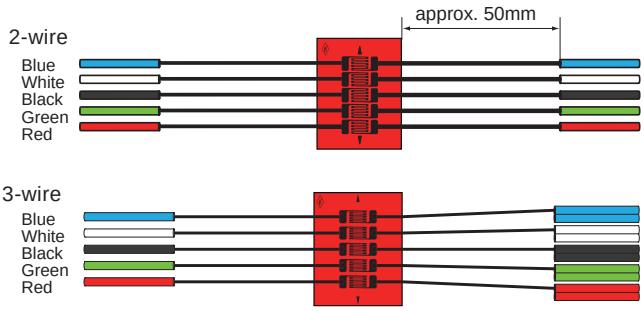
Stress concentration measurement use
FYV 5-element single axis integrated



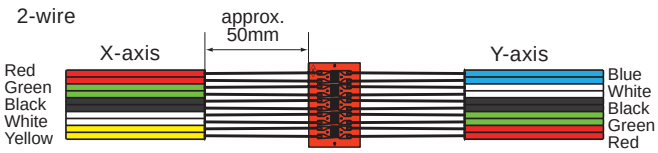
FBXV 5-element single axis integrated

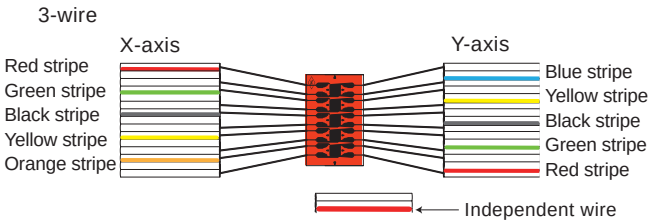


FBYV 5-element single axis integrated

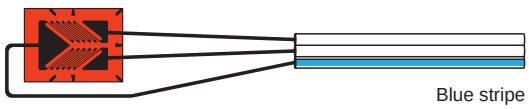


Stress concentration measurement use
FCV 10-element 2-axis cross integrated





Torque measurement use (Integral type)



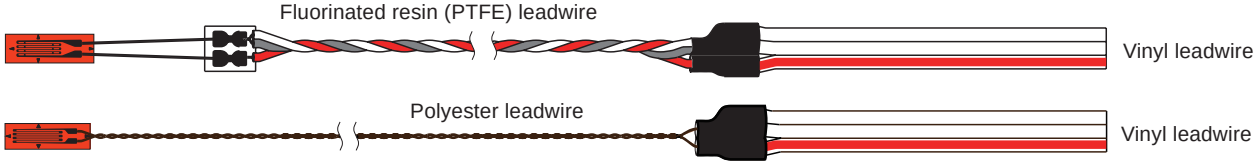
Torque measurement use (Direct type)

Temperature gauge
TFL (Connecting terminal joint type)

Color of leadwire sheath may vary depending on the leadwire type.

Single element strain gauge with different leadwire

Color of leadwire sheath may vary depending on the leadwire type.

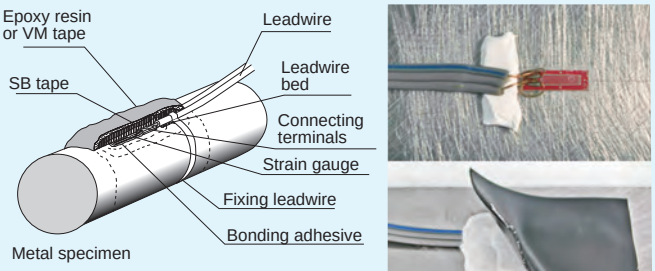


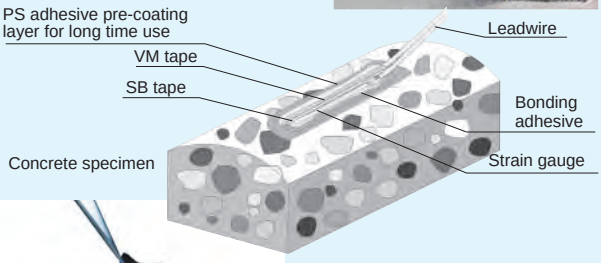
STRAIN GAUGE INSTALLATION

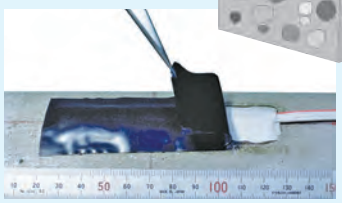
TML strain gauge series are roughly classified into 4 types depending on the method of installation.

1. Adhesive bonding type

In general, most of strain gauges are installed on surface of test specimen with adhesive. Measurement is possible as far as the specimen material is bondable with adhesive. This method can be applied to various materials including metal, concrete, wood and composite material. After installation, coatings should be applied to protect the strain gauges and leadwires from various environmental conditions. The availability of this bonding type depends on the operating temperature of adhesive. The maximum operating temperature is 300°C.



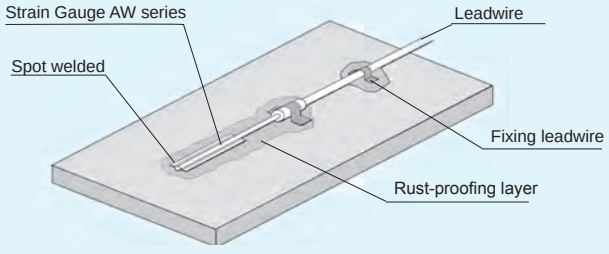


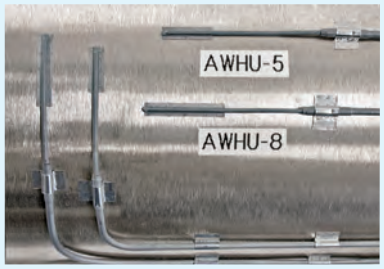


SB tape (white) and VM tape (black) applied on concrete specimen

2. Electrical Spot weldable type

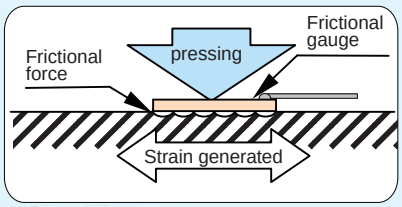
The strain gauge of this type is fully encapsulated in a corrosion-resisting metal tube for use in various conditions, such as gas-filled and underwater environments. It is constructed heat resistive, and the installation is made by electrical spot welding which maintains excellent adhesion even in high temperature. The operating temperature range is from -196°C to +800°C. The spot welder W-50RB is developed exclusively for installation of strain gauges of this type, and it can be used without any qualifications or special skills. Naturally, the specimen material must be a metal which allows electrical spot welding.





3. Frictional gauge type (Re-usable type)

This gauge consists of a soft rubber layer on its contact surface and a magnet which presses the strain gauge against the specimen surface by magnetic force. It measures strain by friction which is caused betwen the contact surface of strain gauge and the measurement surface of the metal specimen. It has the advantage of being usable repeatedly because it is attached by magnetic force without using adhesive. Since the measurement point can be moved easily, it is useful for preparatory or supplemental measurement. The maximum operating temperature is 60°C because of adopting magnetic force.



Strain Checker FGMH Series

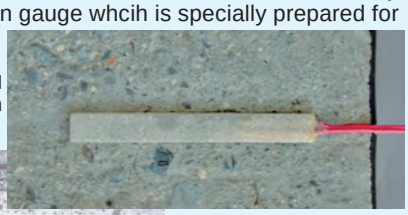
Axial Strain Transducer FGAH Series

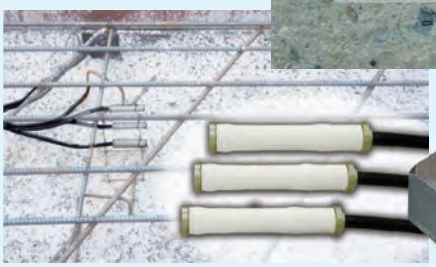
Torque Transducer FGDH Series

4. Internal strain measurement using embedment type

The strain gauges of the above three types measure surface strains of test specimen. The strain gauge of this type measures internal strain of concrete, mortar or asphalt by embedded into the material before its hardening. Measurement can be started in the early stage of hardening of the material. Some series of this type are applicable to measurement in asphalt in high temperature of 200°C. We also have a method to measure axial force of a bolt by embedding a bolt strain gauge whcih is specially prepared for this purpose.

Mold strain gauges PM and PMF series for use in concrete and mortar





Strain Transducers KM for use in concrete and KM-HAS for use in asphalt pavement

Bolt gauge BTM series installed into bolt with bonding adhesive

STRAIN GAUGE RELATED PRODUCTS

STRAIN GAUGE INSTALLATION TOOL KIT "KIT-51"

The KIT-51 provides all of the necessary tools for bonding strain gauges from surface preparatioin upto complete wiring, in a single tool box.

■Tools contained

Tool box/ Sponge cusion/ Screwdriver/ Drafting tape/ Tweezers/ Polyethylene sheet/ Nipper/ Solder (melting point 180°C) / Radio pinchers/ Paste for solder/ Measruing tape (2-meter length)/ Numbering plate/ Stainless steel scale/ Fine abrasive paper/ Mending tape/ Protractor/ Wire stripper/ Soldering tip cleaner/ Connecting terminals/ Cutter/ Marking pencil/ Soldering iron/ Compasses/ Scissors/ Acute swab (cotton)/ Heat gun/ AC plug/ Vinyl tape/ Brush for coating works, etc.

TML STRAIN GAUGE USERS' GUIDE
TML STRAIN GAUGE PERFORMANCE CHARACTERISTICS

A wide range of TML strain gauges are available to match diverse measuring conditions. Since strain gauges provide their designed functions only when they are attached to specimens, it is important to select the most appropriate gauge type in consideration of the specimen material type, operating temperature, measurement environment and installation dimensions. The Strain Gauge Users' Guide provide inexperience users with comprehensive information on strain gauges, covering various subjects ranging from step-by-step strain gauge installation instructions to cautions in handling strain gauges. The Strain Gauge Performance Characteristics compile a guide to the technology of current strain gauge for use in consideration of a limit in detection with regard to the materials and size of a test specimen, humidity, the amount of strain, speed, fatigue, environments, etc.

FOIL STRAIN GAUGES series F

Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Applicable adhesives

CN	–20 ~ +80ºC
P-2	–20 ~ +80ºC
EB-2	–20 ~ +80ºC

GENERAL USE

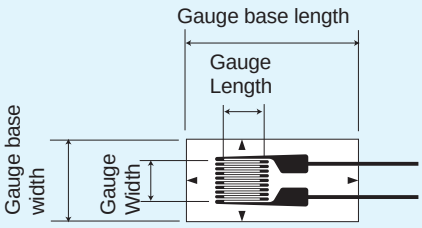
These gauges employ Cu-Ni alloy foils for the grid and epoxy resin for the backing. The epoxy resin backing exhibits excellent electrical insulation performance, and is color-coded to identify the objective material for self-temperature-compensation. Various types of strain gauges such as for residual stress measuremenent and are available in addition to general use gauges.

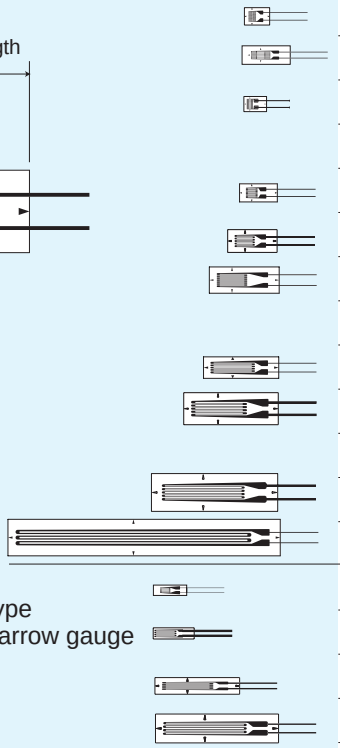
L : length W : width (Unit:mm)

M metal G general

Single element : FLG/FLA/FLK

Each package contains 10 gauges.



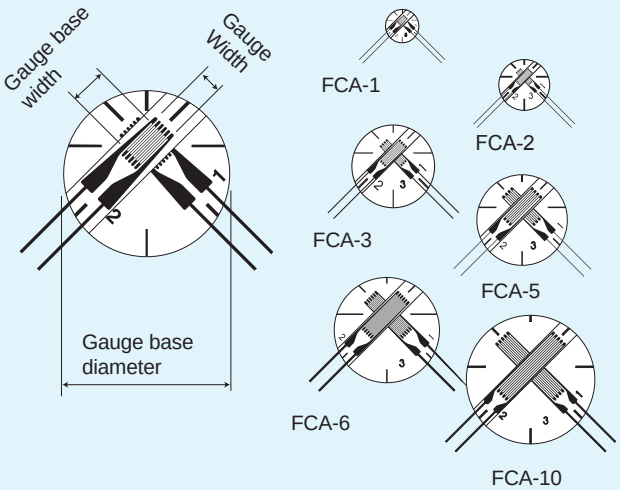


FLK type with narrow gauge width

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
FLG-02	0.2	1.4	3.5	2.5	120
FLG-1	1	1.1	6.5	2.5	120
FLA-03	0.3	1.4	3.0	2.0	120
FLA-05	0.5	1.2	5.0	2.2	120
FLA-1	1	1.3	5.0	2.5	120
FLA-2	2	1.5	6.5	3.0	120
FLA-3	3	1.7	8.8	3.5	120
FLA-3-60	3	1.2	8.0	3.0	60
FLA-5	5	1.5	10.0	3.0	120
FLA-6	6	2.2	12.5	4.3	120
FLA-6-1000	6	4.6	13.5	7.0	1000
FLA-10	10	2.5	16.7	5.0	120
FLA-30	30	2.0	36.1	5.1	120
FLK-1	1	0.7	4.5	1.4	120
FLK-2	2	0.9	5.5	1.5	120
FLK-6	6	1.0	11.2	2.2	120
FLK-10	10	1.6	16.2	3.8	120

0°/90° 2-element Rosette Stacked: FCA

Each package contains 10 gauges.



FCA-1	1	0.7	ϕ 4.5	120
FCA-2	2	0.9	ϕ 7.0	120
FCA-3	3	1.7	ϕ 11.0	120
FCA-5	5	1.9	ϕ 12.0	120
FCA-6	6	2.4	ϕ 14.0	120
FCA-10	10	2.5	ϕ 17.0	120

FOIL STRAIN GAUGES series F

M metal G general

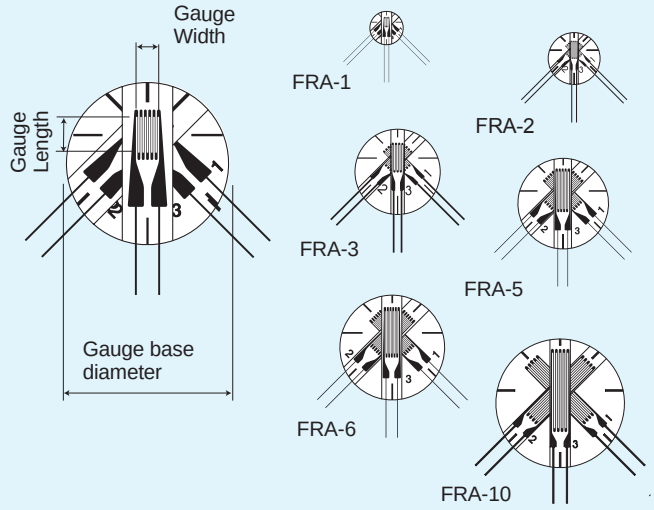
Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

Applicable adhesives

CN	–20 ~ +80ºC
P-2	–20 ~ +80ºC
EB-2	–20 ~ +80ºC

GENERAL USE

0°/45°/90° 3-element Rosette Stacked: FRA



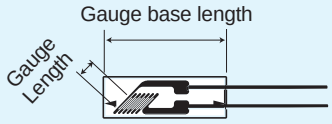
Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing Diameter	Resistance Ω
FRA-1	1	0.7	ϕ 4.5	120
FRA-2	2	0.9	ϕ 7.0	120
FRA-3	3	1.7	ϕ 11.0	120
FRA-5	5	1.9	ϕ 12.0	120
FRA-6	6	2.4	ϕ 14.0	120
FRA-10	10	2.5	ϕ 17.0	120

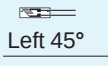
SPECIAL USE

L : length W : width (Unit:mm)

Shearing strain measurememt : FLT

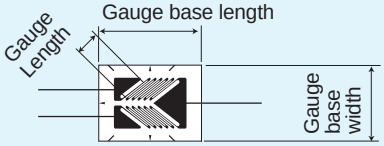


Each package contains 10 gauges.

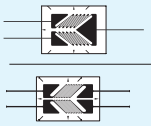


Basic type	Gauge size L	Gauge size W	Backing Diameter		Resistance Ω
FLT-05A	0.5	0.66	4.0	1.3	120
FLT-05B	0.5	0.66	4.0	1.3	120

Torque measurememt : FCT

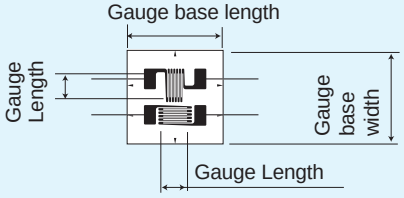


Each package contains 10 gauges.

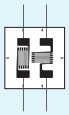


Basic type	Gauge size L	Gauge size W	Backing Diameter		Resistance Ω
FCT-2	2	1.5	8.7	6.5	120
FCT-2-350	2	1.5	7.6	5.3	350

0°/90° 2-element Rosette Plane : FCB

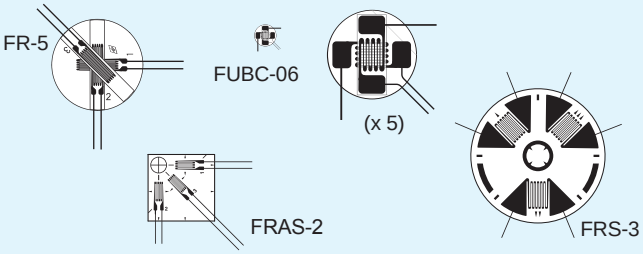


Each package contains 10 gauges.



Basic type	Gauge size L	Gauge size W	Backing Diameter		Resistance Ω
FCB-2	2	1.5	8.2	8.0	120
FCB-6-350	6	2.0	10.0	13.0	350

Residual stress measurement : FR/EUBC/FRS



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing Diameter		Resistance Ω
FR-5	5	1.5	ϕ 12		120
EUBC-06	0.6	0.7	ϕ 2.4		120
FRAS-2	2	1.1	9.0	9.0	120
FRS-2	1.5	1.3	ϕ 9.5		120
FRS-3	3	2.6	ϕ 17.5		120

FOIL STRAIN GAUGES series F

Suffix code for temperature compensation materials
-8: Glass, Ceramic

For ordering, the above suffix code should be specified after basic gauge type.

G glass C ceramic

Operating temperature range
–20°C — +80°C
Temperature compensation range
+10°C — +80°C

Applicable adhesives

CN	–20 ~ +80ºC
P-2	–20 ~ +80ºC
EB-2	–20 ~ +80ºC

GLASS, CERAMIC

Single element : FLA

FLA-5-8 (x 2)

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	L : length	W : width (Unit:mm)			
FLA-2	2	1.5	6.5	3.0	120
FLA-5	5	1.5	10.0	3.0	120

0°/90° 2-element Rosette stacked: FCA

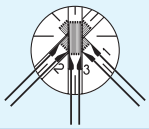
FCA-2-8

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
FCA-2	2	0.9	ϕ 7.0		120
FCA-5	5	1.9	ϕ 12.0		120

0°/45°/90° 3-element Rosette stacked: FRA

FRA-5-8



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
FRA-2	2	0.9	ϕ 7.0		120
FRA-5	5	1.9	ϕ 12.0		120

STRESS CONCENTRATION MEASURMENT

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

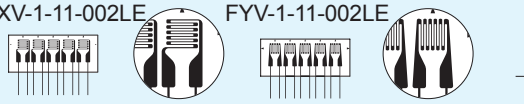
For ordering, the above suffix code should be specified after basic gauge type.

M metal

Operating temperature range
–20°C — +80°C
Temperature compensation range
+10°C — +80°C

5-element Single-axis : FXV/FYV/FBXV/FBYV

FXV-1-11-002LE FYV-1-11-002LE



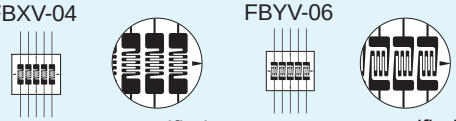
X-axis magnified Y-axis magnified

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	L : length	W : width (Unit:mm)			
Gauge pitch 2mm					
FXV-1-002LE	1	1.3	5.0	12.0	120
FYV-1-002LE	1	1.4	5.0	12.0	120

-002LE: Polyimide sheathed gauge lead of 2-cm pre-attached

FBXV-04 FBYV-06



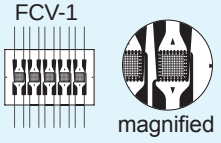
magnified magnified

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Gauge pitch 1mm					
FBXV-04-005LE	0.4	1.3	5.4	7.4	120
FBYV-06-005LE	0.6	0.8	5.3	7.0	120

-005LE: Polyimide sheathed gauge lead of 5-cm pre-attached

10-element 2 axes : FCV

FCV-1



X and Y axes
Y-axis leadwire is marked for identification.
magnified

Each package contains 10 gauges.

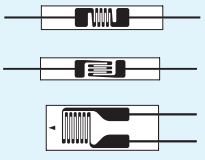
Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Gauge pitch 2mm					
FCV-1-005LE	1	1.4	7.5	12.0	120

-005LE: Polyimide sheathed gauge lead of 5-cm pre-attached

Single element : FBX/FBY/FLX

Single element cut away from the above Stress Concentration gauge.

FBX-04 (x 3)
FBY-06 (x 3)
FLX-1 (x 3)



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
FBX-04-005LE	0.4	1.3	5.4	1.0	120
FBY-06-005LE	0.6	0.8	5.3	1.0	120
FLX-1-002LE	1	1.3	5.0	2.0	120

-005LE: Polyimide sheathed gauge lead of 5-cm pre-attached
-002LE: Polyimide sheathed gauge lead of 2-cm pre-attached

FOIL STRAIN GAUGES series F

M metal

Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

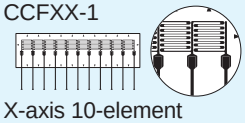
Applicable adhesives

CN	–20 ~ +80ºC
P-2	–20 ~ +80ºC
EB-2	–20 ~ +80ºC

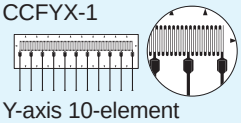
STRESS CONCENTRATION MEASURMENT

Chain Strain Gauges CCFXX, CCFYX

CCFXX-1 X-axis 10-element



CCFYX-1 Y-axis 10-element



Gauge pitch 1.5mm

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
		L : length		W : width (Unit:mm)		
	Each package contains 10 gauges.					
CCFXX-1	CCFXX-1-002LE	1	1.5	16.4	4.5	120
CCFYX-1	CCFYX-1-002LE	1	1.5	16.4	4.5	120

These gauges are specially designed to use Complete correction method for strain and need our Data Logger TDS-530 with built-in the method. For the details, contact TML.

Example of type number designation.

FLA-5 -11 -3L/-3LT (2-wire/3-wire)

- -3L/-3LT: Length in meter and type of integral leadwire (*1)
- -11: Self-temperature-compensation number (*2)
- FLA-5: Basic strain gauge type

*1: Not mentioned for gauges without integral leadwire.

*2: Following numbers are available for F-series gauges
-11: Mild steel (11ppm/ºC)
-17: Stainless steel, Copper alloy (17ppm/°C)
-23: Aluminium (23ppm/°C)
- 8: Composite, Glass (8ppm/°C) *3
*3 Available only for gauges specified accordingly

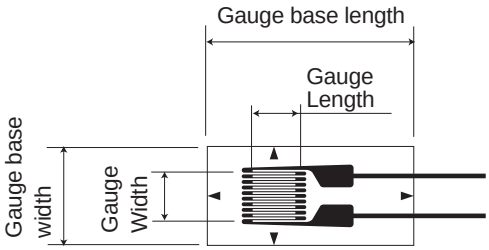
Point

Gauge size

The location of strain gauge installation and the material on which the strain gauge is installed impose restrictions on the strain gauge size. In addition, because leadwires are connected to connecting terminals and coating materials are applied for moisture-proofing, the space required for them must also be considered.

- **Gauge length**

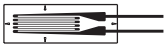
  Strain gauges with short gauge lengths are used to measure localized strain, while strain gauges with long gauge lengths can be used to measure averaged strain over a large area.



- **Gauge width**

  Strain gauges with the same gauge lengths are also available in narrower gauge widths in FLK types. Use the FLK types for strain measurement in axial direction of thin specimens such as cylindrical pipes, rods, etc.

FLK type



FLA type

WATERPROOF STRAIN GAUGES series WF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

M metal

Operating temperature range
0°C +80°C

Temperature compensation range
+10°C +80°C

Applicable adhesives

CN	0 ~ +80ºC
P-2	0 ~ +80ºC
EB-2	0 ~ +80ºC

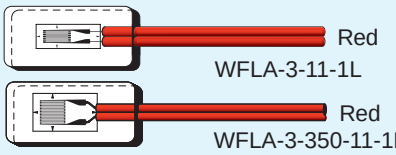
WATERPROOF STRAIN GAUGES

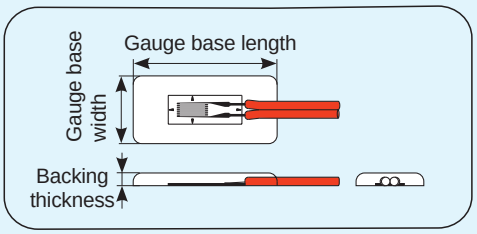
These gauges eliminate the need for a moisture-proofing coating, which is sometimes troublesome in a field test. They have an integral vinyl leadwire, and whole area of the strain gauges and the leadwire junction are coated with epoxy resin. The coating is transparent and flexible, so the positioning and bonding works are very easy. By merely bonding the gauges with CN or P-2 adhesive, outdoor or underwater measurement for a short-term becomes possible. These gauges are also effective in eliminating the primary coating in case of applying a multi-layer coating.

Single element : WFLA

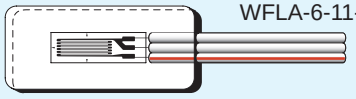
0.08mm² integral vinyl leadwire
Total leadwire resistance per meter : 0.44Ω

2-wire system



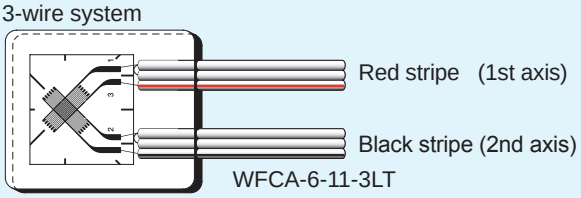


3-wire system



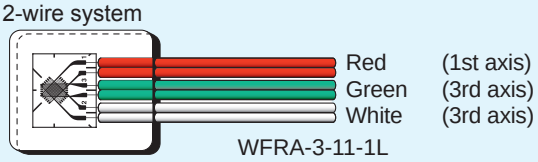
0°/90° 2-element Rosette Stacked: WFCA

3-wire system

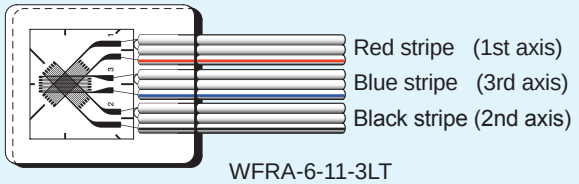


0°/45°/90° 3-element Rosette Stacked: WFRA

2-wire system



3-wire system



L : length W : width T: thickness (Unit:mm)

Basic type		Gauge size L	Gauge size W	Backing L	Backing W	Backing T	Resistance Ω
2-wire system							
Single element							
WFLA-3	-1L	3	1.7	17.0	8.0	1.5	120
WFLA-3-350	-3L	3	3.2	17.0	8.0	1.5	350
WFLA-6	-5L	6	2.2	25.0	11.0	1.5	120
0°/90° 2-element Rosette Stacked							
WFCA-3	-1L -3L	3	1.7	19.0	16.0	1.5	120
WFCA-6	-5L	6	2.3	25.0	21.0	1.5	120
0°/45°/90° 3-element Rosette Stacked							
WFRA-3	-1L -3L	3	1.7	19.0	16.0	1.5	120
WFRA-6	-5L	6	2.3	25.0	21.0	1.5	120

Minimum order is 10 gauges or more.

3-wire system

Quarter bridge 3-wire system is usable to avoid an unexpected effect of resistance change with temperature.

Slingle element							
WFLA-3	-3LT	3	1.7	17.0	8.0	1.5	120
WFLA-6	-5LT	6	2.2	25.0	11.0	1.5	120
0°/90° 2-element Stacked							
WFCA-3	-3LT	3	1.7	19.0	16.0	1.5	120
WFCA-6	-5LT	6	2.3	25.0	21.0	1.5	120
0°/45°/90° 3-element Rosette Stacked							
WFRA-3	-3LT	3	1.7	19.0	16.0	1.5	120
WFRA-6	-5LT	6	2.3	25.0	21.0	1.5	120

Minimum order is 10 gauges or more.

Temperature-integrated STRAIN GAUGES

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

M metal

Operating temperature range
Series F
–20°C +80°C
Series QF
–20°C +200°C

TEMPERATURE-INTEGRATED STRAIN GAUGES

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω

These are strain gauges having a thermocouple integrated with the pre-attached leadwire. One core of the three-core parallel leadwire is made of Cu-Ni wire while other two cores are made of ordinary copper wire. A type T thermocouple is composed of the Cu-Ni wire and the copper wire. Simultaneous measurement of strain with quarter bridge 3-wire method and temperature with type T thermocouple is possible by using TML data loggers. The QFLA-T uses FEP sheathed leadwire to withstand high temperature up to 200°C.

L : length W : width (Unit:mm)

Series F Applicable adhesives	CN	–20 ~ +80ºC
	P-2	–20 ~ +80ºC
Series QF Applicable adhesives	CN	–20 ~ +120ºC
	C-1	–20 ~ +200ºC
	NP-50B	–20 ~ +200ºC

Single element

Minimum order is 10 gauges or more.

Series F
0.08mm² integral vinyl leadwire
Total leadwire resistance per meter : 0.44Ω

Blue : Cu
White : Cu-Ni
Red : Cu
(independent)

FLA-2T-11-3LT

FLA-1T		1	1.3	5.0	2.5	120
FLA-2T	-3LT*	2	1.5	6.5	3.0	120
FLA-5T		5	1.5	10.0	3.0	120

* : -3LT Exclusive 3-wire paralleled vinyl leadwire of 3m

Single element

Minimum order is 10 gauges or more.

Series QF
ϕ 0.2mm² integral fluorinated resin (FEP) sheathed leadwire of 3m
Total leadwire resistance per meter : 1.05Ω

Blue : Cu
White : Cu-Ni
Red : Cu
(independent)

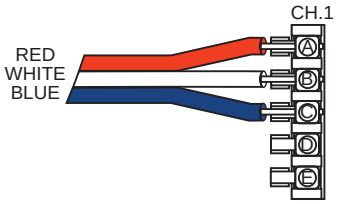
QFLA-2T-11-6FB-3LT

QFLA-1T		1	1.3	5.0	2.5	120
QFLA-2T	-6FB-3LT*	2	1.5	6.5	3.0	120
QFLA-5T		5	1.5	10.0	3.0	120

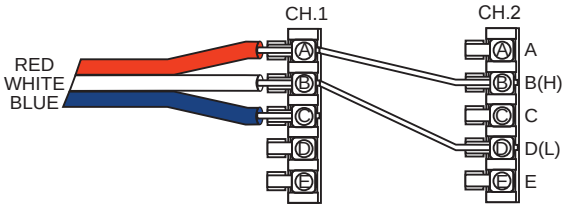
* : -3LT Exclusive 3-wire twisted fluorinated resin (FEP) leadwire of 3m

• CONNECTION METHOD

A: For TDS-530 / TDS-630 using one channel



B: For TDS-303/TDS-601/TC-32K/TDS-150 using serial two channels



Ch. 1: Strain measurement with quarter bridge 3-wire
Ch. 2: Temperature measurement with T-type thermocouple

When extending the leadwire, use exclusive leadwires and connect appropriately.
Refer to the operation manual of the instrument for connection method.

FOIL STRAIN GAUGES series UF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Operating temperature range
–20°C +150°C

Temperature compensation range
+10°C +100°C

Applicable adhesives

CN	–20 ~ +120ºC
NP-50B	–20 ~ +150ºC
EB-2	–20 ~ +150ºC

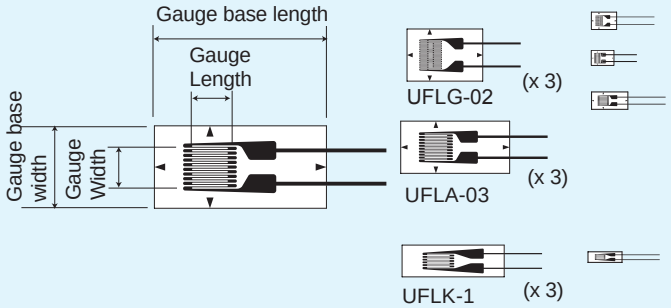
GENERAL PURPOSE

These strain gauges utilize Cu-Ni alloy foils for the grid and polyimide-amide resin for the backing. It enables the strain gauges to be used in 150°C at the maximum. The backing features excellent flexibility, thus allowing easy adhesion even on a curved surface and providing excellent stability in thermal characteristics of the strain gauges. The backing is color-coded to identify the objective material for self-temperature-compensation in the same manner as the F series.

L : length W : width (Unit:mm)

G general | M metal | G glass | C concrete

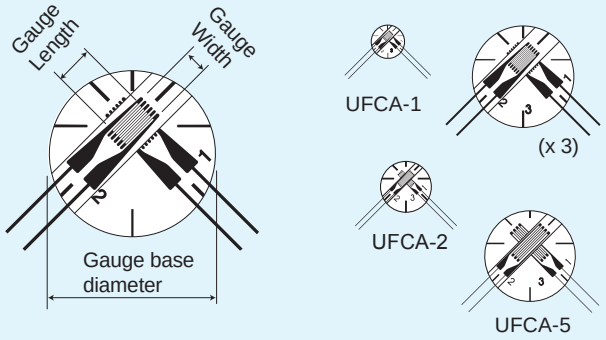
Single element : UFLG/UFLA/UFLK



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
UFLG-02	0.2	1.4	3.5	2.5	120
UFLA-03	0.3	1.4	3.0	2.0	120
UFLA-1	1	1.3	5.0	2.5	120
UFLA-2	2	1.5	6.5	3.0	120
UFLA-5	5	1.5	10.0	3.0	120
UFLK-1	1	0.7	4.5	1.4	120
UFLK-2	2	0.9	5.5	1.5	120

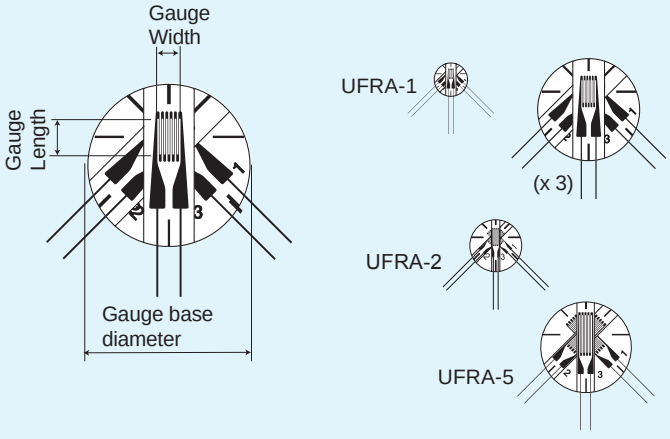
0°/90° 2-element Rosette stacked: UFCA



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
UFCA-1	1	0.7	ϕ 4.5		120
UFCA-2	2	0.9	ϕ 7.0		120
UFCA-5	5	1.9	ϕ 12.0		120

0°/45°/90° 3-element Rosette stacked: FRA



Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
UFRA-1	1	0.7	ϕ 4.5		120
UFRA-2	2	0.9	ϕ 7.0		120
UFRA-5	5	1.9	ϕ 12.0		120

FOIL STRAIN GAUGES series UF 350Ω

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Operating temperature range
–20°C +150°C

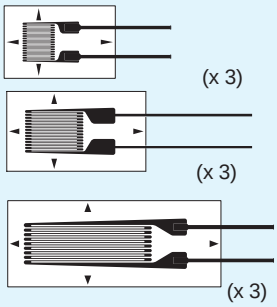
Temperature compensation range
+10°C +100°C

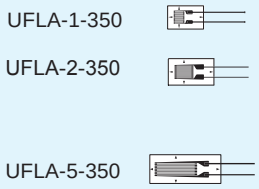
Applicable adhesives

CN	–20 ~ +120ºC
NP-50B	–20 ~ +150ºC
EB-2	–20 ~ +150ºC

GENERAL PURPOSE

Single element





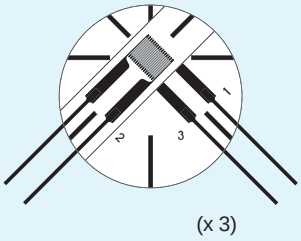
Each package contains 10 gauges.

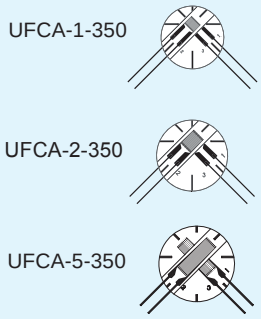
L : length W : width (Unit:mm)

G general M metal G glass C concrete

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
UFLA-1-350	1	1.6	4.6	3.0	350
UFLA-2-350 *3	2	1.9	6.1	3.5	350
UFLA-3-350	3	1.6	7.2	3.0	350
UFLA-5-350 *3	5	1.8	9.4	3.8	350

0°/90° 2-element Rosette stacked: UFCA

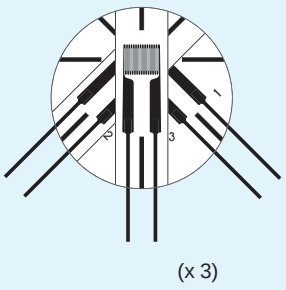


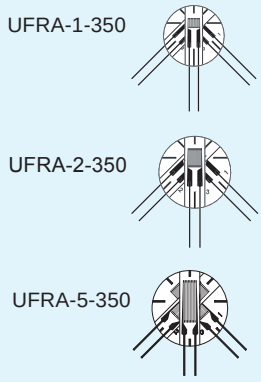


Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing	Resistance Ω
UFCA-1-350	1	1.6	ϕ 8.0	350
UFCA-2-350 *3	2	1.9	ϕ 9.5	350
UFCA-3-350	3	2.0	ϕ 10.0	350
UFCA-5-350 *3	5	1.8	ϕ 10.0	350

0°/45°/90° 3-element Rosette stacked: UFRA





Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing	Resistance Ω
UFRA-1-350	1	1.6	ϕ 8.0	350
UFRA-2-350 *3	2	1.9	ϕ 9.5	350
UFRA-3-350	3	2.0	ϕ 10.0	350
UFRA-5-350 *3	5	1.8	ϕ 10.0	350

Refer to pages 19~20 for appllicable integral leadwires.

Example of type number designation.

UFLA-5-350 -11 -3L/-3LT (2-wire/3-wire)

- UFLA-5-350: Basic strain gauge type
- -11: Self-temperature-compensation number (*2)
- -3L/-3LT: Length in meter and type of integral leadwire (*1)

*1: Not mentioned for gauges without integral leadwire.
*2: Following numbers are available for UF-series gauges
-11: Mild steel (11ppm/ºC)
-17: Stainless steel, Copper alloy (17ppm/°C)
-23: Aluminium (23ppm/°C)
-3 : Composite (3ppm/°C) *3
-5 : Composite (5ppm/°C) *3
-8 : Composite (8ppm/°C) *3
*3 Available only for gauges with this marks.

HIGH TEMPERATURE STRAIN GAUGES series QF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -28: Magnesium

Operating temperature range
–20°C — +200°C
Temperature compensation range
+10°C — +100°C

Applicable adhesives

CN	–20 to +120ºC
NP-50B	–20 to +200ºC
C-1	–20 to +200ºC

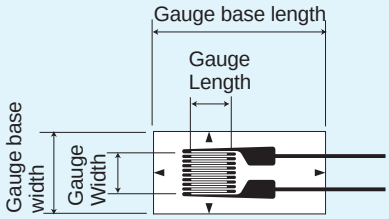
GENERAL PURPOSE/SHEARING STRESS MEASUREMENT

These are foil strain gauges having a polyimide resin backing, which exhibits excellent performance in high temperature up to 200°C. Stress concentration measurement gauges and shear stress measurement gauges are also available in this series.

L : length W : width (Unit:mm)

M metal C ceramic

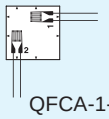
Single element : QFLG/QFLA/QFLK

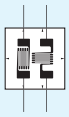


Each package contains 10 gauges.

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
General purpose	QFLG-02-11	0.2	1.4	3.5	2.5	120
	QFLA-1-11	1	1.3	5.0	2.5	120
	QFLA-2-11	2	1.5	6.5	3.0	120
	QFLA-3-11	3	1.7	8.8	3.5	120
	QFLA-5-11	5	1.5	10.0	3.0	120
	QFLA-6-11	6	2.2	12.5	4.3	120
FLK type with narrow gauge base	QFLK-1-11	1	0.7	4.5	1.4	120
	QFLK-2-11	2	0.9	5.5	1.5	120
for Magnesium	QFLK-2-28	2	0.9	5.5	1.5	120
High gauge resistance	QFLA-1-350-11	1	2.0	5.0	4.0	350
	QFLA-2-350-11	2	1.9	6.1	3.5	350
	QFLA-3-350-11	3	3.2	8.5	5.0	350
	QFLA-6-350-11	6	2.6	12.5	4.5	350
	QFLA-6-1000-11	6	4.6	13.5	7.0	1000

0°/90° 2-element Rosette Plane : QFCA

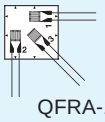

QFCA-1-11


QFCB-2-11

Each package contains 10 gauges.

QFCA-1-11	1	1.3	7.2	7.2	120
QFCA-3-11	3	1.7	11.0	11.0	120
QFCB-2-11	2	1.5	8.2	8.0	120

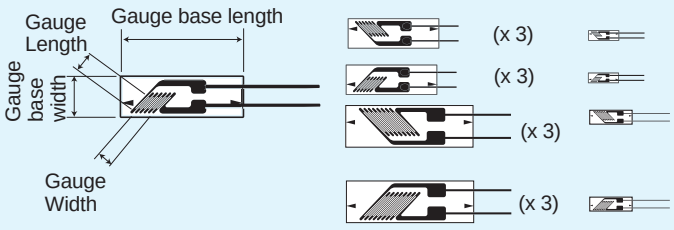
0°/45°/90° 3-element Rosette Plane : QFRA


QFRA-1-11

Each package contains 10 gauges.

QFRA-1-11	1	1.3	7.2	7.2	120
QFRA-3-11	3	1.7	11.0	11.0	120

Single element
Shearing strain measurement



Each package contains 10 gauges.

QFLT-05A-11-002LE	0.5	0.66	4.0	1.3	120
QFLT-05B-11-002LE	0.5	0.66	4.0	1.3	120
QFLT-1A-11-002LE	1.2	1.1	5.7	2.0	120
QFLT-1-350A-11-002LE	1	1.1	5.7	2.0	350
QFLT-1B-11-002LE	1.2	1.1	5.7	2.0	120
QFLT-1-350B-11-002LE	1	1.1	5.7	2.0	350

N.B. -002LE: Polyimide sheathed joints of 2-cm pre-attached

HIGH TEMPERATURE STRAIN GAUGES series QF

M metal C ceramic

Operating temperature range
–20°C ——— +200°C
Temperature compensation range
+10°C | ——— +100°C

Applicable adhesives

CN	–20 to +120ºC
NP-50B	–20 to +200ºC
C-1	–20 to +200ºC

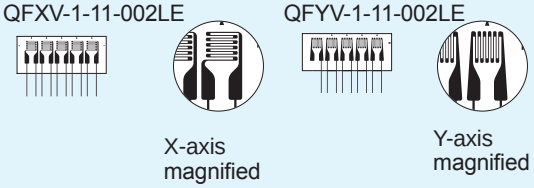
STRESS CONCENTRATION MEASURMENT

L : length W : width (Unit:mm)

5-element single-axis : QFXV/QFYV/QFBXV/QFBYV

Each package contains 10 gauges.

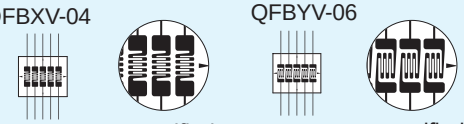
QFXV-1-11-002LE QFYV-1-11-002LE



	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Gauge pitch 2mm	QFXV-1-11-002LE	1	1.3	5.0	12.0	120
	QFYV-1-11-002LE	1	1.4	5.0	12.0	120

N.B. -002LE: Polyimide sheathed joints of 2-cm pre-attached

QFBXV-04 QFBYV-06



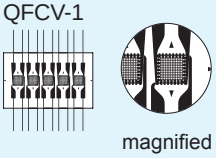
	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Gauge pitch 1mm	QFBXV-04-11-005LE	0.4	1.3	5.4	7.4	120
	QFBYV-06-11-005LE	0.6	0.8	5.3	7.0	120

N.B. -005LE: Polyimide sheathed joints of 5-cm pre-attached

10-element 2 axes : QFCV

Each package contains 10 gauges.

QFCV-1



X and Y axes
Y-axis leadwire is marked for identification.

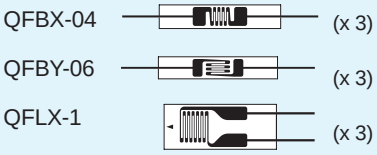
	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Gauge pitch 2mm	QFCV-1-11-005LE	1	1.4	7.5	12.0	120

N.B. -005LE: Polyimide sheathed joints of 5-cm pre-attached

Single element : QFBX/QFBY/QFLX

Single element cut away from the above Stress Concentration gauge.

Each package contains 10 gauges.

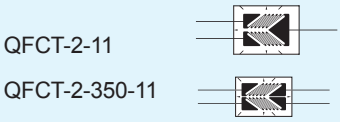


Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
QFBX-04-11-005LE	0.4	1.3	5.4	1.0	120
QFBY-06-11-005LE	0.6	0.8	5.3	1.0	120
QFLX-1-11-002LE	1	1.3	5.0	2.0	120

N.B. -005LE: Polyimide sheathed joints of 5-cm pre-attached
N.B. -002LE: Polyimide sheathed joints of 2-cm pre-attached

Torque measurememt : QFCT

Each package contains 10 gauges.



Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
QFCT-2-11	2	1.5	8.7	6.5	120
QFCT-2-350-11	2	1.7	7.6	5.3	350

Example of type number designation.

QFLA-5 -11 -6FA-3L/-3LT (2-wire/3-wire)

- -6FA-3L/-3LT (2-wire/3-wire): Length in meter and type of integral leadwire (*1)
- -11: Self-temperature-compensation number (*2)
- QFLA-5: Basic strain gauge type

*1: Not mentioned for gauges without integral leadwire.

*2: QF-series gauges are available for self-temperature-compensation with -11 (Mild steel of 11ppm//°C)

For the following numbers, contact TML or your local representatives.
-17: Stainless steel, Copper alloy (17ppm/°C)
-23: Aluminium (23ppm/°C)

Refer to pages 19~20 for appllicable integral leadwires.

HIGH TEMPERATURE STRAIN GAUGES series ZF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic)

Operating temperature range
–20°C ——— +300°C
Temperature compensation range
+10°C | ——— +100°C

Applicable adhesives

NP-50B	–20 ~ +300ºC
C-1	–20 ~ +200ºC
CN	–20 ~ +120ºC

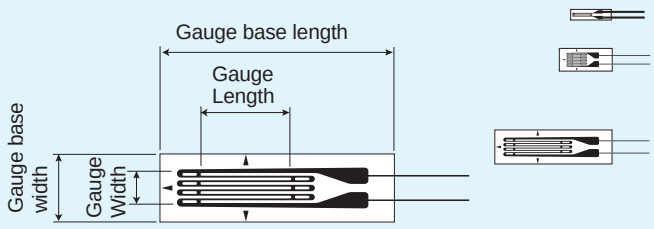
HIGH TEMPERATURE USE

These strain gauges are designed for measurement in high temperature up to 300°C. It utilizes specially designed Ni-Cr alloy foil for the grid and polyimide resin for the gauge backing. Owing to the construction, the strain gauges are successfully used for measurement in high temperature.

M metal C ceramic

L : length W : width (Unit:mm)

Single element : ZFLA



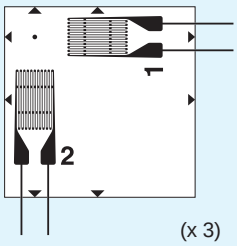
Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
ZFLK-2-11	2	0.5	5.4	1.4	120
ZFLA-1-11	1	1.8	7.0	3.0	120
ZFLA-3-11	3	1.8	10.5	3.5	120
ZFLA-6-11	6	2.5	15.5	4.5	120
ZFLA-3-60-11	3	0.7	7.7	2.6	60
ZFLA-1-350-11	1	1.7	6.6	3.2	350
ZFLA-3-350-11	3	3.2	10.2	5.2	350
ZFLA-6-350-11	6	2.8	16.0	5.3	350

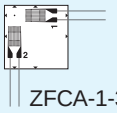
0°/90° 2-element Rosette

Plane : ZFCA
Stacked : ZFCAL

ZFCA-1-350-11



(x 3)



ZFCA-1-350-11

ZFCAL-1-11

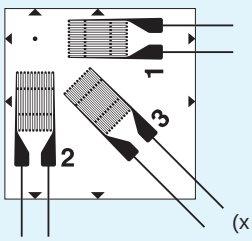
Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Plane type					
ZFCA-1-350-11	1	1.7	8.5	8.5	350
ZFCA-3-350-11	3	1.4	10.5	10.5	350
Stacked type					
ZFCAL-1-11	1	1.1	ϕ 5.4		120

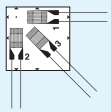
0°/45°/90° 3-element Rosette

Plane : ZFRA
Stacked : ZFRAL

ZFRA-1-350-11



(x 3)



ZFRA-1-350-11

ZFRAL-1-11

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Plane type					
ZFRA-1-350-11	1	1.7	8.5	8.5	350
ZFRA-3-350-11	3	1.4	10.5	10.5	350
Stacked type					
ZFRAL-1-11	1	1.1	ϕ 5.4		120

Example of type number designation.

ZFLA-5 -11 -4FA-3L/-3LT (2-wire/3-wire)

- -4FA-3L/-3LT (2-wire/3-wire): Length in meter and type of integral leadwire (*1)
- -11: Self-temperature-compensation number (*2)
- ZFLA-5: Basic strain gauge type

*1: Not mentioned for gauges without integral leadwire.

*2: ZF-series gauges are available for self-temperature-compensation with -11 (Mild steel of 11ppm//°C)

For the following numbers, contact TML or your local representatives.
-17: Stainless steel, Copper alloy (17ppm/°C)
-23: Aluminium (23ppm/°C)

Refer to pages 19~20 for applicable integral leadwires.

HIGH TEMPERATURE STRAIN GAUGES series EF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic)

Applicable adhesives

CN	–196 ~ +120ºC
EB-2	–60 ~ +200ºC
C-1	–196~ +200ºC
NP-50B	–20 ~ +300ºC

HIGH TEMPERATURE USE, MINIATURE

These gauges have a small grid pattern required for measurement of printed circuit boards and surface mounted devices, which are getting smaller and smaller. The backing of the gauges is made of polyimide resin. The maximum operaing temperature is +300°C for single element gauges and +200°C for two and three elements gauges. The lowest operating temperature is –196°C for both gauges.

M metal C ceramic

L : length W : width (Unit:mm)

Each package contains 10 gauges.

Single element

Operating temperature range –196°C ~ +300°C
Temperature compensation range +10°C ~ +150°C


EFLK-02-11 (x3)

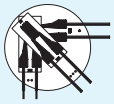

EFLX-02-11 (x3)

Single element

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	EFLK-02-11	0.2	0.8	1.6	1.2	120
	EFLX-02-11	0.2	0.8	1.8	1.2	120

0°/90° 2-element Rosette
0°/45°/90° 3-element Rosette

Operating temperature range –196°C ~ +200°C
Temperature compensation range 0°C ~ +150°C


EFRA-05-11 (x3)

0°/90° 2-element Rosette
0°/45°/90° 3-element Rosette

Stacked type

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	EFCA-05-11-002LE	0.2	0.8	1.6	1.2	120
	EFRA-05-11-002LE	0.2	0.8	1.8	1.2	120

N.B. -002LE: Polyimide sheathed joints of 2-cm pre-attached

Refer to pages 19~20 for applicable integral leadwires.

HIGH & LOW TEMPERATURE STRAIN GAUGES series CEF

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Applicable adhesives

EA-2A	–269 ~ +50ºC
CN	–196 ~ +120ºC
C-1	–269 ~ +200ºC

HIGH & LOW TEMPERATURE USE

These are strain gauges utilizing polyimide resin for the gauge backing and special alloy foil for the grid. It features a wide range of operating temperature from cryogenic temperature to +200°C. This series is available only in single axis configuration with gauge length of 1,3 and 6mm.

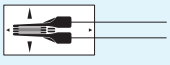
M metal C ceramic

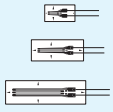
L : length W : width (Unit:mm)

Operating temperature range –269°C ~ +200°C
Temperature compensation range approximately –196°C ~ +80°C

Each package contains 10 gauges.

Single element


CEFLA-1 (x3)



Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	CEFLA-1	1	0.5	4	2.2	120
	CEFLA-3	3	0.6	6.9	2.8	120
	CEFLA-6	6	1	10.6	3.1	120

Refer to pages 19~20 for applicable integral leadwires.

Cryogenic temperature STRAIN GAUGES series CF

Operating temperature range
–269°C ~ +80°C

Temperature compensation range approximately
–196°C ~ +80°C

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Applicable adhesives

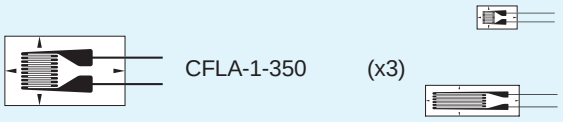
EA-2A	–269 ~ +50ºC
CN	–196 ~ +80ºC
C-1	–269 ~ +80ºC

CRYOGENIC TEMPERATURE USE

Gauge pattern

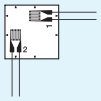
These are foil strain gauges with epoxy backing designed for measurement under cryogenic conditions. They are available in single element, rectangular 2-element and rectangular 3-element configurations with 350Ω resistance. The specially selected and heat treated grid of thw gauges shows very small zero shift under cryogenic temperature compared to conventional strain gauges.

Single element : CFLA



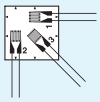
CFLA-1-350 (x3)

0°/90° 2-element Rosette : CFCA Plane



CFCA-1-350

0°/45°/90° 3-element Rosette Plane



CFRA-1-350

Refer to pages 19~20 for appllicable integral leadwires.

Basic type

M metal C ceramic

L : length W : width (Unit:mm)

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Each package contains 10 gauges.					
CFLA-1-350	1	1.4	5.4	3.2	350
CFLA-3-350	3	1.7	8.8	3.5	350
CFLA-6-350	6	2.2	12.5	4.3	350
Each package contains 10 gauges.					
CFCA-1-350	1	1.3	7.2	7.2	350
CFCA-3-350	3	1.7	11.0	11.0	350
Each package contains 10 gauges.					
CFRA-1-350	1	1.3	7.2	7.2	350
CFRA-3-350	3	1.7	11.0	11.0	350

Strain measurement in High- and Low-temperature environments

In situations where heating or cooling occurs, as in engines, turbines, nuclear reactors, chemical plants, etc., the mechanical and thermal stresses in the structural materials are measured. Strain measurement in high- or low-temperature environments differs from measurement in normal temperature (room temperature up to +80°C) in that a problem of thermal output can no longer be ignored, and the key factor is technique used to eliminate or compensate for this thermal output.

Actual strain measurement at high and low temperatures

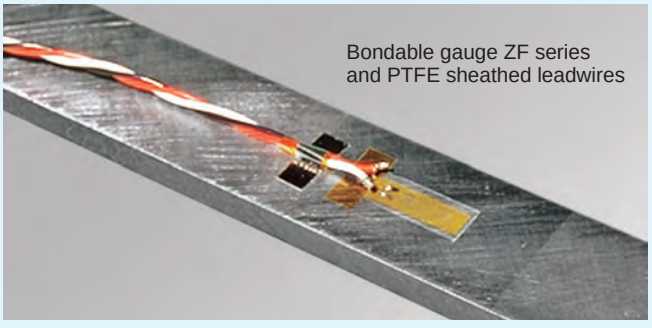
Material combination chart

Test temperature	High-temperature atmosphere to 300°C	High-temperature atmospher to 800°C	Cryogenic temperature atmosphere to -269°C
Strain Gauge	ZF series	AWHU (Weldable type)	CF series
Bonding adhesive	NP-50B	Resistance welding	EA-2A, C-1
Connecting terminals	Not used	-	TPF
Leadwire	PTFE-sheathed	MI cable	FEP-theathed
Coating materials	TSE3976-B	-	K-1

PTFE : Polytetrafluoroethylene 4F
FEP : Tetrafluoroethylene-hexafluoropropylene copolymer

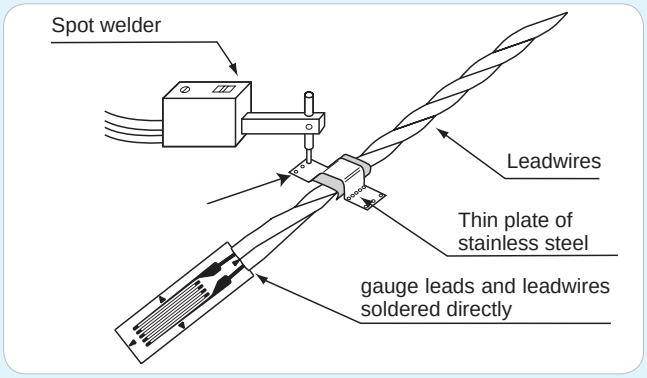
Wire connection

At temperature above 200°C, ordinary adhesive-bonded connecting terminals cannot be used. Connect the gauge leads and leadwires directly using high-temperature solder. In this case, the best method is to use thin stainless steel plates to be welded to a test specimen to secure the leadwire. The same installation method can also be used in low temperature environments, and connecting terminals can also be used as a relay.



Bondable gauge ZF series and PTFE sheathed leadwires

Strain measurement in High- and Low-temperature environments



Coating

Materials that are flexible in normal temperatures become rigid and brittle in very low temperatures, and care should be taken of the thickness of such coatings. K-1 is a coating with excellent hardeness and peel strength in low temperatues. However, if the coating applied is thicker than necessary, it tends to constrain the section of the test specimen on which the strain gauge is installed so that accurate measurements cannot be performed. Note that this constraint effect is particularly pronounced when the test specimen is a thin plate.

Curing

To eliminate characteristic fluctuations resulting from repeated temperature cycles, strain gauge and adhesive must be stabilized. Exposing an adhesive that hardens at room temperature to a temperature slightly higher than the test temperature stabilizes the strain gauge and adhesive, thereby improving the reproducibility of the thermal output. For mechanical structures, perform repeated break-in trial runs prior to strain measurement to subject the strain gauge to the temperature and other loads.

Measurement correction and causes of errors

Effects of leadwire temperature

With quarter bridge 2-wire system, changes in leadwire temperature cause changes in the leadwire resistance which in turn generate thermal output. The following equation is to compensate for such thermal output.

$$\varepsilon = \frac{r \times L \times \alpha \times \Delta T}{K \times (R + r \times L)}$$

where,
K : Indicated Gauge factor
R : Strain gauge resistance (Ω)
r : Total resistance per meter of leadwire (Ω/m)
L : Leadwire length (m)
Ɛ : Leadwire thermal output
α : Thermal coefficient of resistance of leadwire
ΔT : Leadwire temperature change (°C)

The leadwire temperature has no effect on thermal output for quarter bridge measurement with 3-wire system.

Thermal output (Apparent strain with temperature)

If there is temperature change in the strain gauge installed on the test specimen, thermal output will be generated even when there is no strain caused by external force. As a result, if external force is applied along with a change in temperature, the thermal output must be subtracted from the indicated value on the measuring device as shown in the following equation.

Equation $\varepsilon_C(\Delta T) = \varepsilon(\Delta T) - \varepsilon_{app}(\Delta T)$

where, ΔT : Temperature change at the strain gauge
$\varepsilon_C(\Delta T)$: Value minus thermal output (corrected value)
$\varepsilon(\Delta T)$: Indicated value on strainmeter
$\varepsilon_{app}(\Delta T)$: Thermal output with temperature change

The strain gauge thermal output is shown on the data sheet supplied with the strain gauge in the form of a graph and as a quadratic equation (as a variable of the temperature). This thermal output is the value with the strain gauge installed on the test specimen given on the data sheet. This data is also formulated based on a standard temperature of 20°C and a gauge factor of 2.00. To check the thermal output, read the value from the graph or substitute the temperature into the quadratic equation.

Gauge factor change with temperature

Because the gauge factor of a strain gauge also changes with temperature, the gauge factor should be corrected when this change is large. The gauge factor change with temperature is given in the data sheet supplied with the strain gauge in the form of a graph and as a temperature coefficient per 10°C. The gauge factor shown on the strain gauge package is a reference value at room temperature.
Use Equation K_T as below to obtain a gauge factor with a temperature change using the indicated gauge factor and the temperature coefficient.

Equation $K_T = K \times \{ 1 + C_K \times (t - 20) / 10 \}$

Where, K_T : Gauge factor at T°C
K : Gauge factor at room temperature
C_K : Gauge factor temperature coefficient (%/10°C)
T : Strain gauge temperature (°C)

Also, in case measurement at T°C is performed using the normal temperature gauge factor, Equation ε_G corrects the indicated value.

$$\text{Equation } \varepsilon_G = \frac{K}{K_T} \times \varepsilon_T$$

ε_G : Strain following correction of the gauge factor for temperature
ε_T : Indicated strain for T°C

If strain is measured when external force is applied at the same time as a temperature change, perform the thermal output and gauge factor corrections described above. Use the following equation to correct the indicated strain on the measuring device and obtain the strain due to the external force.
From Equations $\varepsilon_C(\Delta T)$ and ε_G,

$$\text{Equation } \varepsilon(\Delta T) = \{ \varepsilon_i(\Delta T) - \varepsilon_{app}(\Delta T) \} \times \frac{K}{K_T}$$

Where, ΔT : Temeperature change experinced by the strain gauge
$\varepsilon(\Delta T)$: Strain due to external force
$\varepsilon_i(\Delta T)$: Indicated strain on the measuring device
$\varepsilon_{app}(\Delta T)$: Thermal output due to temperature change
K : Gauge factor at room temperature
K_T : Gauge factor at T °C

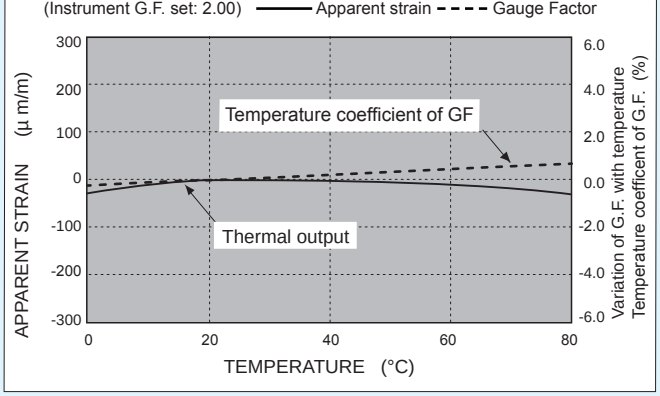
STRAIN GAUGE TEST DATA

GAUGE TYPE	: FLA-3-11	TESTED ON	: SS 400
LOT NO.	: A502515	COEFFICIENT OF THERMAL EXPANSION	: 11.8 x10^{-6}/°C
GAUGE FACTOR	: 2.14 ±1%	TEMPERATURE COEFFICIENT OF G.F.	:+0.1±0.05 %/10°C
ADHESIVE	: P-2	DATA NO.	: A0312

THERMAL OUTPUT (Ɛ app: APPARENT STRAIN)

$\varepsilon_{app} = -2.94\times10^{1}+2.32\times T^{1}-4.60\times10^{-2}\times T^{2}+1.67\times10^{-4}\times T^{3}+5.00\times10^{-7}\times T^{4}$ (μ m/m)

Tolerance : ±0.85 [(μ m/m)/°C], T : Temperature



High temperature WELDABLE STRAIN GAUGES series AW

M metal

AWM / AWMD / AWH / AWHU / AW / AWC / AWCH

These strain gauges have strain sensing elements fully encapsulated in corrosion-resisting metal tubes made of stainless steel or Inconel (except AW-6-350). The strain gauge backings are also made of the same material, and the gauges are installed by spot welding to metal specimens using a dedicated spot welder.

The maximum operating temperatue is 800°C for the AWHU. These gauges are suited to measurement in high temperature harsh environments such as underwater or gas-filled atmosphere, or for long term. The AWC-2B and AWCH-2 adopt 1-gauge 4-wire strain measurement method.

AWM –196 ~ +300°C Quarter bridge 3-wire

AWM-8-1A Base materials : Inconel 600
AWM-8-1B Base materials : SUS304

AWMD –196 ~ +800°C for dynamic strain Full bridge

AWMD-5

AWMD-8

AWH –196 ~ +600°C for static strain Full bridge
–196 ~ +650°C for dynamic strain Full bridge

AWH-4-7A/AWH-8-7A Gauge base: Inconel 600
AWH-4-7B/AWH-8-7B Gauge base: SUS321

AWHU –196 ~ +800°C Full bridge

AWHU-5

AWHU-8

AW-6 –196 ~ +300°C Quarter bridge 3-wire

AW-6-350-11-01LT

AWC –20 ~ +100°C

AWC-2B-11-3LQ 1-Gauge 4-Wire
AWC-8B-11-3LT Quarter bridge 3-wire

AWCH –196 ~ +200°C 1-Gauge 4-Wire

AWCH-2-11-05LQ

AW series coding system

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AWM	-8-	1	B		-2		-17.0
AWMD	-5-		A	KM	-2	(6F)	-1.6Hz*
AWMD	-8-		A		-2		-1.6Hz*
AWH	-8-	7	A		-2		-11.0
AWHU	-5-	9	A	KM	-2	(6F)	-12.7

*: High-pass filter only for AWMD Either one available among 1.6, 7.2 or 16Hz.

(1) Type	(2) Gauge length	(3) Temperature compensation range	(4) Gauge base*1	(5) Option
AWM : static/dynamic 300°C	8: 8mm	0 : –196°C ~ RT 1 : RT ~ +300°C 2 : RT ~ +350°C 3 : RT ~ +400°C 4 : RT ~ +450°C 5 : RT ~ +500°C 6 : RT ~ +550°C 7 : RT ~ +600°C 8 : RT ~ +650°C 9 : RT ~ +800°C 10 : Others NB1: Dynamic use AWMD is not applicable. NB2: RT Room temperature	A: Inconel 600 Applicable thermal expansion coefficient of 11ppm/°C or closer B: AWH SUS321 AWM SUS304 Applicable thermal expansion coefficient of 17ppm/°C or closer	E: Ground earth F: Compression fittings K: Narrow gauge width W=3mm (5mm standard) M: Small junction type of sleeve B ϕ 2.0mm L=20mm AWHU and AWMD-5 are normally provided with small junction P: NDIS type plug attached*2 R: Bend of gauge backing or pipe Z: Filter-less (AWMD)
AWMD : dynamic only 800°C	5: 5mm 8: 8mm			
AWH : static 600°C : dynamic 650°C	4: 4mm 8: 8mm			
AWHU : static/dynamic 800°C	5: 5mm 8: 8mm			

*1: Select code A for thermal expansion coefficient of 11ppm/°C or closer, or B for coefficent of 17ppm/°C
*2: For option code P, NDIS plug with ϕ 3mm shielded chloroprene cable of 2m is positioned to Temperature-compensation board or High-pass filter. Available with AWMD-8/AWH/AWHU

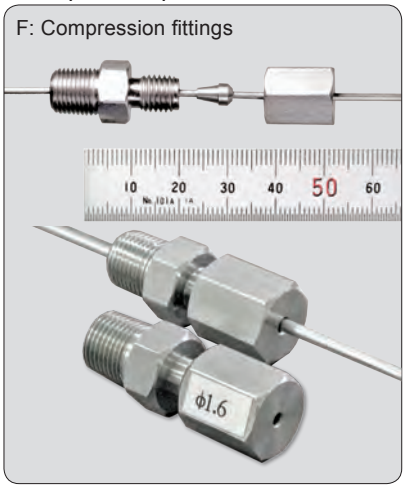
High temperature WELDABLE STRAIN GAUGES series AW

AWM / AWMD / AWH / AWHU / AW / AWC / AWCH

(6) MI cable	(7) Supplied cable length	(8) Temperature compensation materials or High-pass filter
2: ϕ 1.6mm 2m Core cable of heat-resistive copper	No marks: ϕ 4.1mm shielded vinyl cable of 0.5m Except for standard length, required length is given in bracket Example: 4.5m long to (4.5)	Materials available for temperature-compensation 10.9: SUS430 or equivalent 11.0: Mild steel (ferritic) or equivalent 12.7: INCONEL 600 or equivalent 17.0: SUS304 or equivalent
	(6F): ϕ 1.6mm shielded fluoroethylene propylene cable (FEP) of 0.5m for AWHU-5/-8, AWMD-5 Except for standard length, required length is given after suffix 6F. Example: 4.5m long to (6F4.5)	High-pass filter for only AWMD 1.6: 1.6Hz 7.2: 7.2Hz 16 : 16Hz

Examples of option

F: Compression fittings

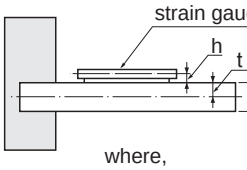


R: Bend of gauge backing or pipe

Weldable gauge AWHU and MI cable

Correction for strain gauge height

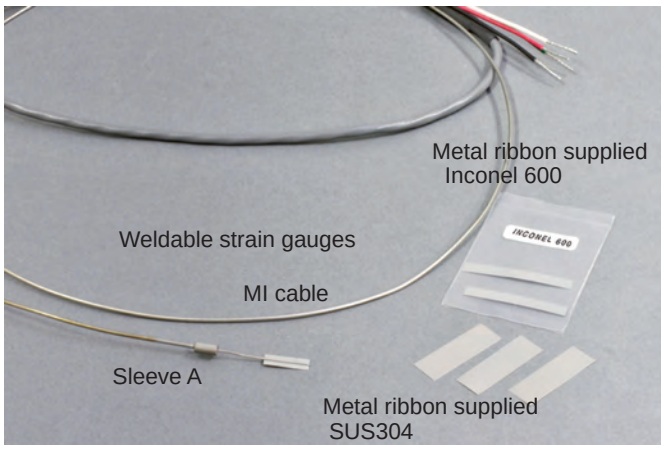
Unlike adhesive-bonding strain gauges, the sensitive elements in weldable strain gauges sit some distance above the test specimen surface. As a result, the sensitivity to torsion and bending is different. Particularly in bending tests for thin boards, the following equation must be used to correct the sensitivity.



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

where,
h : height of the strain gauge sensitive element
t : test specimen thickness
K_b: Gauge factor due to bending
K : Indicated gauge factor

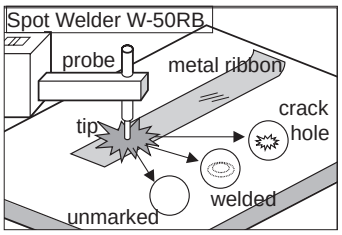
Using resistance welding to install weldable strain gauges



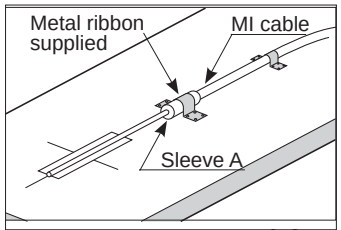
Weldable strain gauges include Metal ribbon of Inconel 600 and/ or SUS304 for trial welding and securing sleeve A and MI cable. To install weldable strain gauges, use special-purpose gauge welder Spot Welder W-50RB along with the metal ribbon.

Metal ribbon supplied :
Inconel 600 2 pcs. 30~50 x 5 x 0.08mm
SUS304 3 pcs. 32 x 11 x 0.08mm

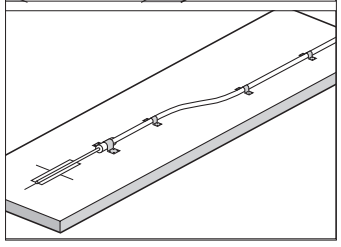
Trial Welding
The metal ribbon is used to adjust the welding power of the Spot Welder. If cracks or a hole appear in the ribbon, reduce the power. If the ribbon is unmarked, increase the power.



Securing Sleeve A
Align the center of the strain gauge with the marks and press down on the gauge so that it is flush against the test specimen. Sleeve A is secured using the metal ribbon as illustrated.



Securing MI cable
To avoid load being placed on secured sleeve A, secure the MI cable with the metal ribbon.
To avoid undue strain on the MI cable, secure the cable between the gauge and connecting terminal in a gentle curve.



High temperature WELDABLE STRAIN GAUGES series AW

Weldable Strain Gauges AWM / AWMD

AWM-8 Quarter bridge with 3-wire method

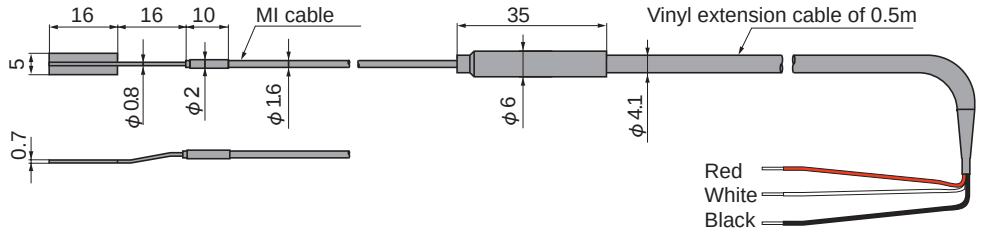
Minimum order is 1 gauge or more.

The AWM is usable up to 300°C for both static and dynamic strain measurement. The backing material is available in Inconel 600 or SUS304 which should be selected according to the test specimen material.

Operating temperature range
–196°C ——— +300°C
Temperature compensation range
RT | ——— +300°C

Type		Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Resistance in Ω
			Dimension(mm)	Materials		
Static/Dynamic strain measurement 300°C	AWM-8-1A-2-11.0	8	16x5	Inconel 600	–196~+300°C <Room-temperature ~ +300°C>	120
	AWM-8-1B-2-17.0			SUS304		

AWM-8



AWMD-5 / AWMD-8 for dynamic strain measurement only Full bridge

Minimum order is 1 gauge or more.

The AWMD is applicable up to 800°C and it is dedicated to dynamic strain measurement. A high pass filter is a standard accessory. Using the high pass filter, unnecessary direct current component or low frequency component (thermal output, drift etc.) in the measurement signal can be neglected. The DC exciting Dynamic Strainmeter (DC-96A/-97A) or the Smart Dynamic Strain Recorder DC-204R, Multi-Recorder TMR-200 should be used for measurement.

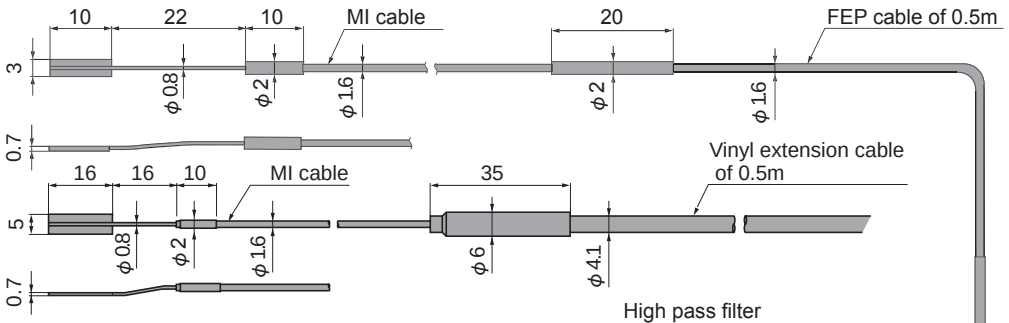
Operating temperature range
–196°C ——— +800°C
Temperature compensation range Not available

Type		Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Resistance in Ω
			Dimension(mm)	Materials		
Dynamic strain measurement 800°C	AWMD-5-AKMS-2(6F)-1.6Hz*	5	10x3	Inconel 600	–196~+800°C < N/A >	60
	AWMD-8-A-2-1.6Hz*	8	16x6	Inconel 600		120

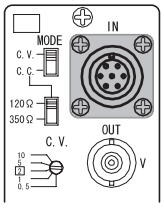
*: High-pass filter only for AWMD Either one available among 1.6, 7.2 or 16Hz.

AWMD-5

AWMD-8



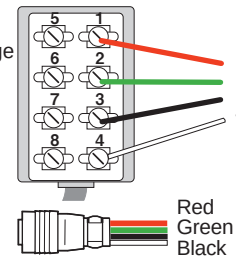
Plug-in NDIS connector of TML Dynamic Strainmeter



TML Bridge Box Full bridge wiring

or

NDIS plug connector



Red
Green
Black
White

Red
Green
Black
White

Option code P for NDIS plug connector available with AWMD/AWH/AWHU attached to Temperature-compensation board or High-pass filter

High temperature WELDABLE STRAIN GAUGES series AW

Weldable Strain Gauges AWH / AWHU

AWH-4 / AWH-8 Full bridge

Minimum order is 1 gauge or more.

The backing material is available in Inconel 600 or SUS321 which should be selected according to the test specimen material. Although it has a half bridge construction consisting of active and dummy gauges, the measurement is made by the full bridge method using the supplied temperature compensation circuit board. The maximum operating temperature is 600°C for static strain measurement and 650°C for dynamic strain measurement.

Operating temperature range

Static strain measurement
–196°C ——— +600°C

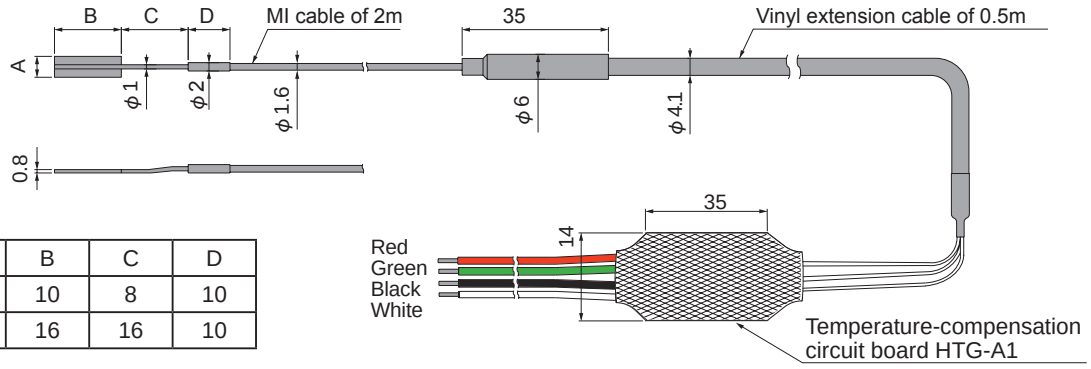
Dynamic strain measurement
–196°C ——— +650°C

Temperature compensation range

Static strain measurement
RT | ——— +600°C

Dynamic strain measurement
RT | ——— +650°C

Type	Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Test specimen	Resistance in Ω
		Dimension(mm)	Materials			
AWH-4-7A-2-11.0	4	10x3	Inconel 600	For static use –196~+600°C <Room-temperature ~ +600°C>	Mild steel or equivalent	60
AWH-4-7B-2-17.0			SUS321		SUS304 or equivalent	
AWH-8-7A-2-11.0	8	16x5	Inconel 600	For dynamic use –196~+650°C < N/A >	Mild steel or equivalent	120
AWH-8-7B-2-17.0			SUS321		SUS304 or equivalent	



Type	A	B	C	D
AWH-4	3	10	8	10
AWH-8	5	16	16	10

AWHU-5 / AWHU-8 Full bridge

Minimum order is 1 gauge or more.

These gauges are usable up to 800°C for both static and dynamic strain measurement. Although it has a half bridge construction consisting of active and dummy gauges, the measurement is made by the full bridge method using the supplied temperature compensation circuit board. The gauge base, junction part and cable of these gauges are constructed small as a standard specification and it is suited for being mounted on a narrow or a curved part.

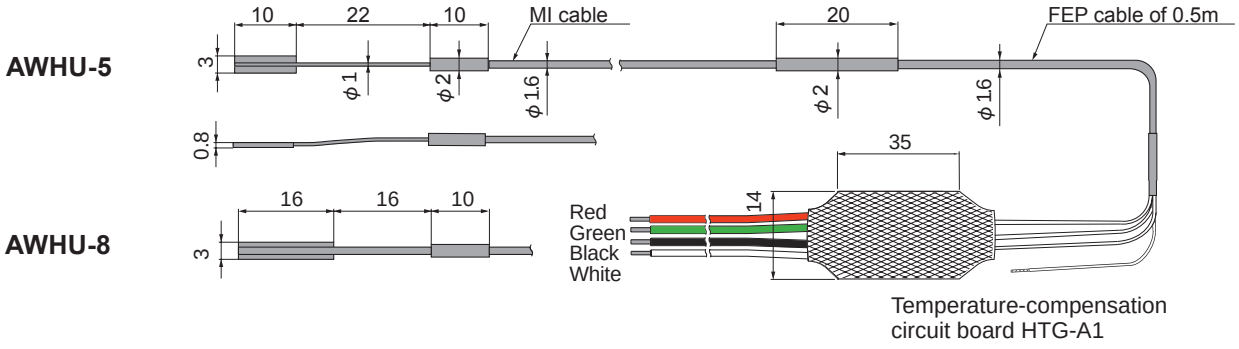
Operating temperature range

–196°C ——— +800°C

Temperature compensation range

RT | ——— +800°C

Type		Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Resistance in Ω
			Dimension(mm)	Materials		
Static/Dynamic measurement 800°C	AWHU-5-9AKM-2(6F)-12.7	5	10x3	Inconel 600	–196~+800°C < N/A >	60
	AWHU-8-9AKM-2(6F)-12.7	8	16x3			120



High temperature WELDABLE STRAIN GAUGES series AW

Weldable Strain Gauges AW / AWC

These gauges have corrosion-resisting stainless steel backing with thickness of 0.08mm. They are easily installed by using dedicated spot welder W-50RB.

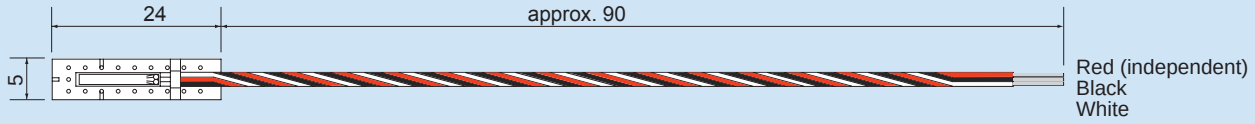
AW-6-350-11-01LT Quarter bridge with 3-wire method

Minimum order is 5 gauges or more.

These gauges are suited for strain measurement in high temperature up to 300°C, for measurement of specimen to which adhesion is not applicable or for long term measurement.

Operating temperature range
–196°C +300°C
Temperature compensation range
+10°C +100°C

Type	Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Test specimen	Resist-ance in Ω
		Dimension(mm)	Materials			
AW-6-350-11-01LT	6	24x5	SUS304	–196~+300°C <Room-temperature ~ +100°C>	Mild steel	350



Extension leadwire : ϕ 0.2mm fluorinated resin sheath (PTFE) of 0.1m standard

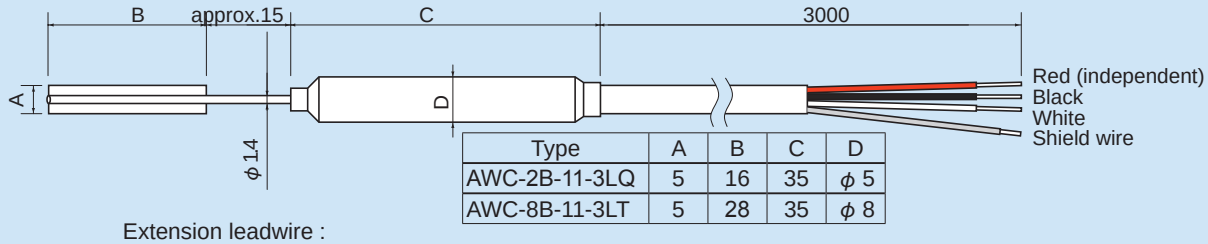
AWC-2B-11-3LQ 1-Gauge 4-Wire system
AWC-8B-11-3LT Quarter bridge 3-wire method

Minimum order is 1 gauge or more.

These gauges are fully encapsulated in a stainless steel tube. It enables long term strain measurement in harsh environment.

Operating temperature range
–20°C +100°C
Temperature compensation range
0°C +100°C AWC-2B-11-3LQ
+10°C +100°C AWC-8B-11-3LT

Type	Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Test specimen	Resist-ance in Ω
		Dimension(mm)	Materials			
AWC-2B-11-3LQ	2	16x5	SUS304	–20~+100°C <0 ~ +100°C >	Mild steel	120
AWC-8B-11-3LT	8	28X5		–20~+100°C <+10 ~ +100°C >		



Type	A	B	C	D
AWC-2B-11-3LQ	5	16	35	ϕ 5
AWC-8B-11-3LT	5	28	35	ϕ 8

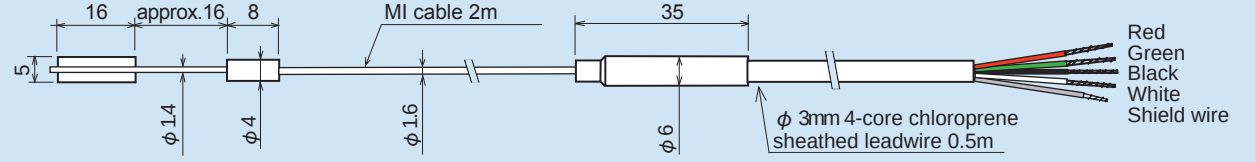
Extension leadwire :
AWC-2B-11-3LQ ϕ 3mm 0.05mm² 4-core shielded chloroprene sheathed leadwire of 3m standard
AWC-8B-11-3LT ϕ 5mm 0.3mm² 3-core shielded viny sheathed leadwire of 3m standard

AWCH-2-11-MI-2L-05LQ 1-Gauge 4-Wire system

These gauges are fully encapsulated in compact size of stainless steel tube. These are designed for only 1-Gauge 4-wire system and can measure up to 200°C.

Operating temperature range
–196°C +200°C
Temperature compensation range
0°C +150°C

Type	Gauge length (mm)	Gauge base		Operating temperature <Temperature compensation range>	Test specimen	Resist-ance in Ω
		Dimension(mm)	Materials			
AWCH-2-11-MI-2L-05LQ	2	16x5	SUS304	–196~+200°C <0 ~ +150°C >	Mild steel	120



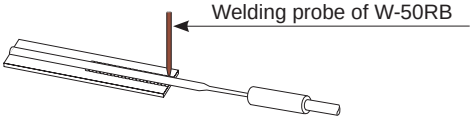
High temperature WELDABLE STRAIN GAUGES series AW

SPOT WELDER W-50RB

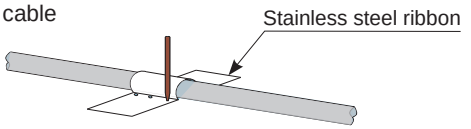
This is a capacitive charge spot welder used for installing weldable strain gauges and fixing leadwires. The welding energy is controlled in 2 ranges of 1~10/5~50 watt second continuously, and a stabilizing circuit cancels the effect of changes in the power source voltage. Projecting parts such as electrical cables are packed inside, these are extremely convenient for field applications.

Examples of installation

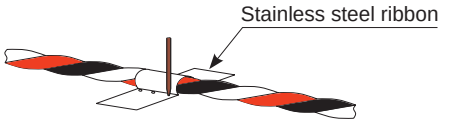
Installing a weldable gauge



Fixing a MI cable



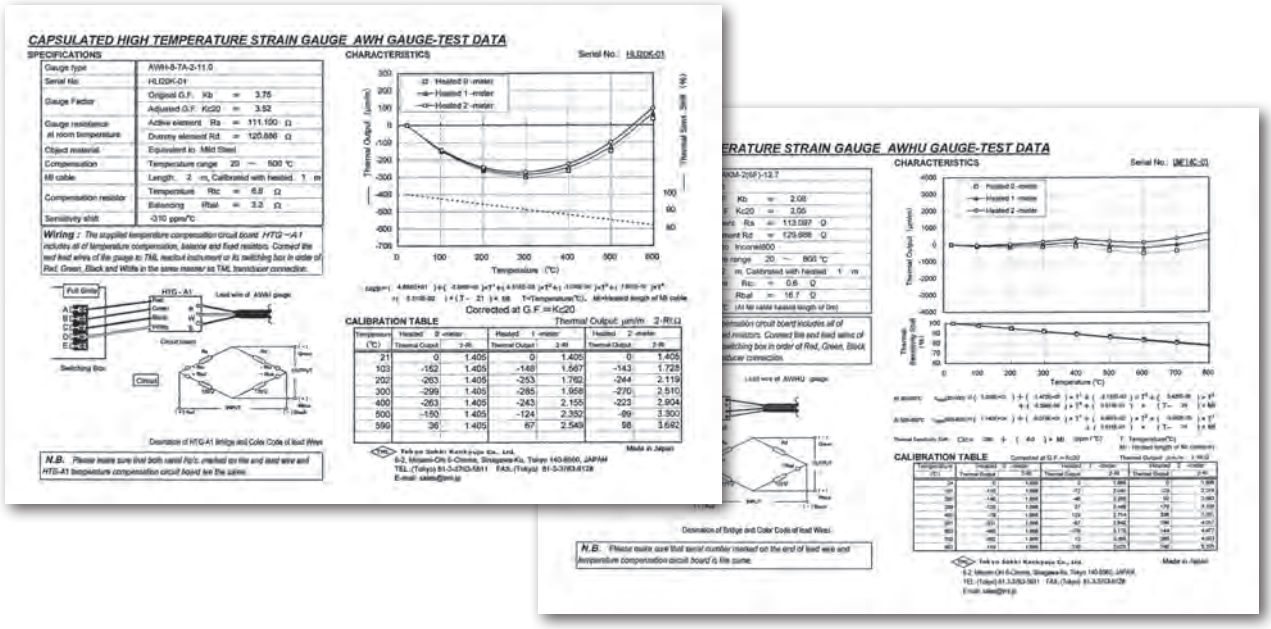
Fixing a fluorinated sheathed cable



SPECIFICATIONS	
Welding energy	1~10 watt sec./5~50 watt sec. continuous 60 watt sec. Max. (110Vac 50Hz)
Output voltage	approx. 32V Max.
Output pulse width	approx. 5 msec.
Repetition use	2 welds/sec. at 50 watt sec.
Rated output	20 min./1.5 welds/sec. at 50 watt sec.
Weldable probe	III type probe
Welding force	4.9~19.8N
Welding tip	Arm ϕ 3mm, Nose ϕ 1mm
Cable length	2m
Operation environment	0~+50°C 85%RH or less (no condensation allowed)
Power source	90~110Vac., 50/60Hz 550VA peak(160msec.), 210VA/2 welds/sec.
Dimensions	300(W) x 195(H) x 195(D) mm
Weight	13kgs.
Standard accessory	
Operation manual ..... 1 AC power cable (CR-01) ..... 1 Welding tip ..... 3 Protective cap..... 2 Abrasive paper (#400) ..... 5 Carrying belt ..... 1 Hexagon head wrench 1	

INDIVIDUAL TEST DATA

AWM, AWH and AWHU are always examined and supplied with individual test data including serial number, gauge factor, thermal output curve, bridge configuration, etc.



POLYESTER STRAIN GAUGES series P/PF

Operating temperature range
–20°C ——— +80°C
Temperature compensation range
+10°C | ——— +80°C

C concrete M mortar R rock

Applicable adhesives

CN-E	–20 ~ +80ºC
RP-2	–20 ~ +80ºC
PS	–20 ~ +80ºC

STEEL, CONCRETE, MORTAR MATERIAL USE

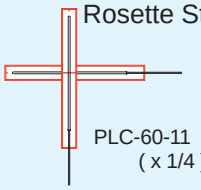
series P

These are wire strain gauges utilizing a transparent plastic backing impregnated with polyester resin. The gauge length is available in 3 ranges of 60, 90 and 120mm, so it is suited to the measurement of concrete strain. Since the backing is transparent, the bonding position can easily be checked in the installation works.

Single element

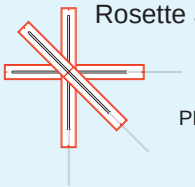
PL-60-11

0°/90° 2-element Rosette Stacked



PLC-60-11 (x 1/4)

0°/45°/90° 3-element Rosette Stacked



PLR-60-11 (x 1/4)

Refer to pages 19~20 for applicable integral leadwires.

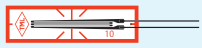
L : length W : width (Unit:mm)

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Single-element	Each package contains 10 gauges.					
	PL-60-11	60	1	74	8	120
	PL-90-11	90	1	104	8	120
	PL-120-11	120	1	134	8	120
	Each package contains 10 gauges.					
0°/90° 2-element Rosette Stacked	PLC-60-11	60	1	74	74	120
0°/45°/90° 3-element Rosette Stacked	PLR-60-11	60	1	74	74	120

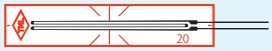
series PF

These are foil strain gauges utilizing a polyester resin backing which is the same as the P series. The gauge length is available in 3 steps of 10, 20 and 30mm, so it is suited mainly to strain measurement on concrete or mortar. The backing is transparent and the installation is easy.

Single element



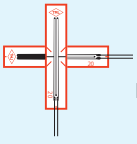
PFL-10-11



PFL-20-11

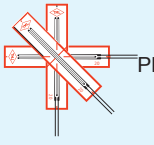
PFL-30-11

0°/90° 2-element Rosette Stacked



PFLC-20-11 (x 1/2)

0°/45°/90° 3-element Rosette Stacked



PFLR-20-11 (x 1/2)

Refer to pages 19~20 for applicable integral leadwires.

Single element	Each package contains 10 gauges.					
	PFL-10-11	10	0.9	17.5	5	120
	PFL-20-11	20	1.2	28	6	120
	PFL-30-11	30	2.3	40	7	120
	Each package contains 10 gauges.					
0°/90° 2-element Rosette Stacked	PFLC-20-11	20	1.2	28	28	120
	PFLC-30-11	30	2.3	40	40	120
0°/45°/90° 3-element Rosette Stacked	PFLR-20-11	20	1.2	28	28	120
	PFLR-30-11	30	2.3	40	40	120

Example of type number designation.

PL-60 -11 -3L/-3LT (2-wire/3-wire)

- PL-60: Basic strain gauge type
- -11: Self-temperature-compensation number (*2)
- -3L/-3LT: Length in meter and type of integral leadwire (*1)

*1: Not mentioned for gauges without integral leadwire. Integral leadwire is not available for PLC-60 and PLR-60.

*2: P and PF series gauges are available for self-temperature-compensation with -11(Mild steel of 11ppm/°C)

METAL BACKING STRAIN GAUGES series FLM/WFLM

Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

Suffix code for temperature compensation materials
-11: Mild steel (ferritic)

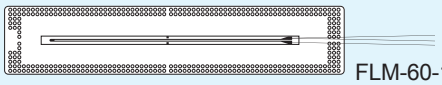
Applicable adhesives

PS	–20 ~ +80ºC

CONCRETE, MORTAR MATERIAL USE

These strain gauges have thin stainless steel backings which prevent the penetration of moisture from the reverse sides. This construction is aimed for successful strain measurement on concrete surface. The WFLM gauges have moisture proofing over-coating and integral leadwire in addition to the stainless steel backing. It is intended for long term measurement or measurement on underwater-curing conctrete.

Single element



FLM-60-11 (x 1/2)

Refer to pages 19-20 for applicable integral leadwire.

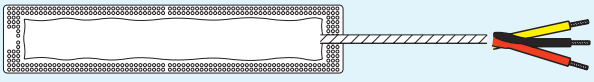
L : length W : width (Unit:mm)

C concrete M mortar

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Backing T	Resistance Ω
Single element	Each package contains 10 gauges.					
FLM-30-11	30	0.5	60	18	0.12	120
FLM-60-11	60	0.7	90	18	0.12	120

WATERPROOF TYPE
Single element

0.09mm² integral crosslinked polyethylene sheath leadwire of 2m standard
Total leadwire resistance per meter : 0.4Ω



WFLM-60-11 (x 1/2)

Integral leadwire length longer than 2m are available.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Backing T	Resistance Ω
Single element	Each package contains 10 gauges.					
WFLM-30-11-2LT	30	0.5	60	18	4	120
WFLM-60-11-2LT	60	0.7	90	18	4	120

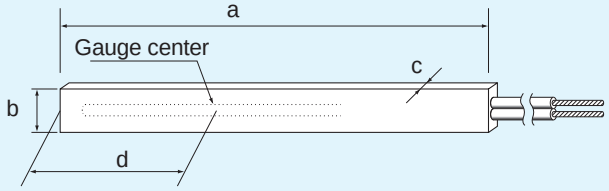
MOLD STRAIN GAUGES series PM

Operating temperature range
–20°C +60°C

C concrete M mortar

CONCRETE, MORTAR MATERIAL USE

These gauges are designed exclusively for the measurement of internal strain of concrete or mortar under loading test. These are embedded into the measurement position when the concrete or mortar is placed. The gauges have a construction of the sensing element sealed into the backing made of acrylic resin for waterproofing.



Integral leadwire length longer than 2m are available.

L : length W : width (Unit:mm)

For long-term measurement of concrete structure, use Strain Transducer KM (refer to page 63).

Basic type		Gauge size L	Gauge size W	Backing a	Backing b	Backing c	Backing d	Resistance Ω
Single element		Each package contains 5 gauges.						
PML-60	-2L	60	1	125	13	5	40	120
PML-120	-2LT	120	1	180	13	5	65	120

Strain Gauge Installation on Concrete, Mortar

Three methods for installing strain gauges on concrete and mortar are introduced.

Test Condition and Applicable Strain Gauges

Test Conditions	Strain Gauge	Strain Gauge Adhesive
Immediate testing indoor	PF or P series	CN, CN-E, P-2
Somewhat prolonged testing outdoors	PF or P series	RP-2
Long term testing outdoors	WFLM series	PS

If the strain gauge is used only for short-term loading test performed indoors, coating over the strain gauge is not required. In this case, if the surface of the mortar or concrete is smooth and fully dry, precoating is also not required.

Concrete or Mortar surface preparation

1. Preparing

Remove any laitance, paint or other soiling from gauge installation area on the test specimen to provide a clean contact surface. Because the adhesive may not harden if the gauge installation area on the test specimen is wet, use TML surface preparation agent AC-1 to remove any moisture.

2. Sanding

Evenly sand an area 20mm to 30mm larger than the strain gauge to be installed with abrasive paper. Depending on the test specimen material, grade 80 to 120 abrasive paper should be used to finish the surface.

3. Cleaning

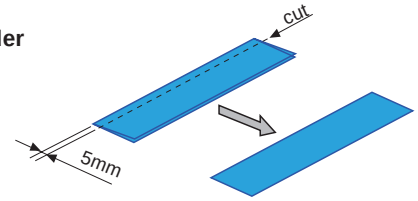
Clean the abraded surface with industrial tissue or cloth dampened with a small amount of a solvent such as acetone.

Precoating with PS adhesive

The purpose of precoating is, firstly, to render the surface of the mortar or concrete flat and provide surface to which the strain gauge will readily bond, and secondly, to act as a barrier against any dampness that is exuded from the surface of the concrete or mortar, thereby preventing absorption of moisture by the underside of the strain gauge. A special purpose PS adhesive is used as the precoat.

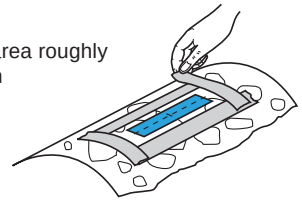
1. Cutting gauge binder

Cut the gauge binder supplied with the strain gauge about 5mm in from the fold.



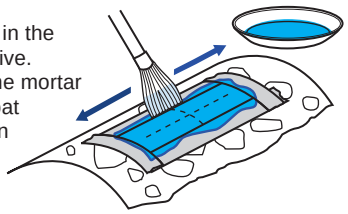
2. Masking

Use packing tape to mask an area roughly 10mm larger on each side than the cut piece of gauge binder.



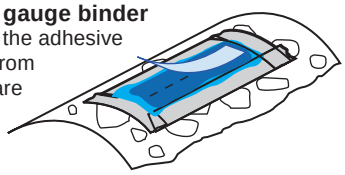
3. Applying PS adhesive

Following the procedure given in the instructions, mix the PS adhesive. Brush the adhesive fully into the mortar or concrete. Apply another coat of the PS adhesive to the strain gauge installation surface so that a layer 0.5mm to 1mm thick is formed.



4. Finishing surface with the gauge binder

Lay the cut piece of binder onto the adhesive pressing it into place gradually from one end so that no air bubbles are trapped under the binder. Press down lightly on the piece of gauge binder to expel any excess adhesibve and air bubbles. Once the adhesive has hardened, peel off the piece of gauge binder and install the strain gauge.



For a laboratory load test on a mortar specimen

Example of Installation using CN-E adhesive

Test specimen	Mortar aged 2 months (ϕ 100x200mm)
Strain Gauge	PFL-30-11-3LT
Strain Gauge Adhesive	CN-E, CN
Leadwire	10-core/ ϕ 0.12mm, vinyl-covered Quarter bridge 3-wire system, 3m

Use CN-E adhesive to attach the strain gauge to a surface precoated with PS adhesive. Secure the leadwires with vinyl tape.

When bonding a strain gauge having long gauge backing with CN-E adhesive, position the strain gauge to the measuring point and fix the top of the gauge (opposite side to the gauge leads) with adhesive tape. Then lift the strain gauge from the gauge leads side, apply the adhesive to the back of the gauge, and return the gauge to the original measuring point. Cover the strain gauge with a polyethylene sheet and apply finger pressure from the center of the gauge toward both ends so as to squeeze out air bubbles.

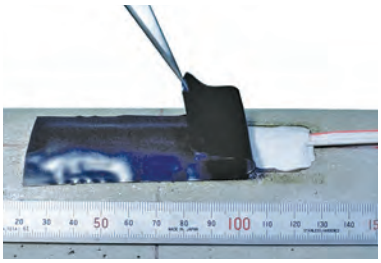
For outdoor test with a measurement period of 2 weeks

Example of Installation using RP-2 adhesive

Strain Gauge	PL-60-11
Strain Gauge Adhesive	RP-2
Connecting terminals	TFY-2M
Leadwire	ϕ 5mm, 3-core shielded vinyl cable
Coating materials	W-1 + SB tape + VM tape

Mix the RP-2 adhesive as described in the adhesive instructions. Apply a thin layer of the adhesive uniformly over the back of the strain gauge and the strain gauge installation area on the precoated surface. Place the strain gauge onto the installation position, and apply a pressure of 0.05~0.3MPa until the adhesive hardens. Once the adhesive hardens, install the connecting terminal using CN-E adhesive. Coat the strain gauge and the connecting terminal with W-1. Solder leadwires to the connecting terminal, then secure the leadwires with a cut SB tape.

If any metal portions of the leadwires or connecting terminal are not covered by the coating, reapply the W-1 and SB tape. Cut a piece of VM tape slightly larger than the layer of SB tape coating and press it down into place.

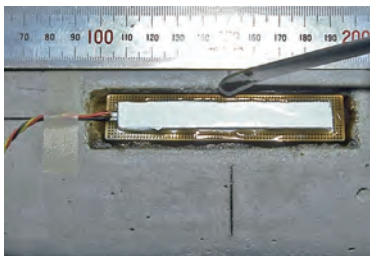


For a long term outdoor measurement

Example of Installation using PS adehsive

Strain Gauge	WFLM-60-11-2LT
Strain Gauge Adhesive	PS

Position a strain gauge WFLM-60-11-2LT on PS-adhesive-precoated area and secure the leadwire temporarily with cellophane tape. Turn the WFLM strain gauge over and apply a generous amount of mixed PS adhesive to the underside of the gauge base and the precoated surface. Return the gauge to its previous installation position. Press lightly down on the WFLM strain gauge, working from the center out to the edges expel any excess PS adhesive and air bubbles. To bond firmly, the metal base of the WFLM strain gauge should be fully enveloped from above and below by the PS adhesive.



MOLD STRAIN GAUGES series PMF

Operating temperature range
–20°C +60°C

CONCRETE, MORTAR MATERIAL USE

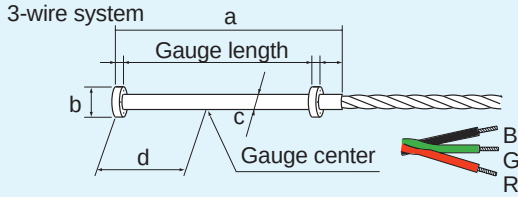
Gauge pattern

These gauges are designed for the measurement of internal strain of concrete or mortar under loading test. These can also be used for short-term measurement of the behavior of concrete. These are embedded into the measurement position when the concrete or mortar is placed. The gauges employ super engineering plastics as the backing for sealing the sensing element, which provides excellent waterproofing. A temperature-integrated type PMFL-T is available for measurement of both strain and temperature using our data loggers.

Single element

0.09mm² integral cross-linked vinyl sheath leadwire of 2m standard
Total leadwire resistance per meter : 0.4Ω

3-wire system



C concrete M mortar

For long-term measurement of concrete structure, use Strain Transducer KM (refer to page 63).

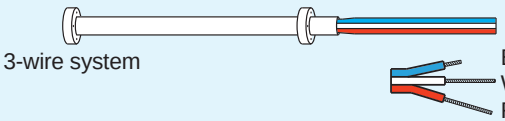
Each package contains 10 gauges.

Basic type		Gauge length (mm)	a	b	c	d	Backing	Resistance Ω
PMFL-50	-2LT	50	60	φ8	φ4	27		120
PMFL-60	-2LT	60	70	φ8	φ4	32		120

Integral leadwire length other than 2m are available.

Temperature sensor integrated

0.08mm² integral cross-linked vinyl sheath leadwire of 3m standard
Total leadwire resistance per meter : 0.44Ω



Each package contains 10 gauges.

Basic type		Gauge length (mm)	a	b	c	d	Backing	Resistance Ω
PMFL-50T	-3LT	50	60	φ8	φ4	27		120
PMFL-60T	-3LT	60	70	φ8	φ4	32		120

Asphalt Mold STRAIN GAUGES series PMFLS

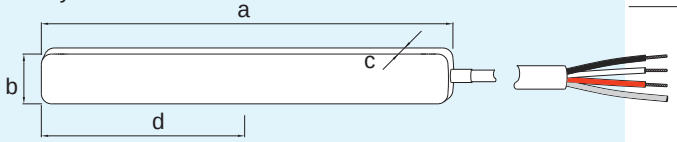
Operating temperature range
–20°C +60°C

ASPHALT PAVEMENT USE

Gauge pattern

The gauges are embedded in asphalt and used for strain measurement in loading test such as rolling compaction. The material of the backing is super engineering plastics featuring high temperature resistivity and waterproofing performance. The gauges withstand a high temperature up to 200°C during placement of asphalt, while the operating temperature range is –20 to +60°C.

3-wire system



A asphalt

Minimum order is 1 gauge or more.

Basic type	Gauge length (mm)	a	b	c	d	Backing	Resistance Ω
PMFLS-60-50-2LT	50	60	φ8	φ4	27		120

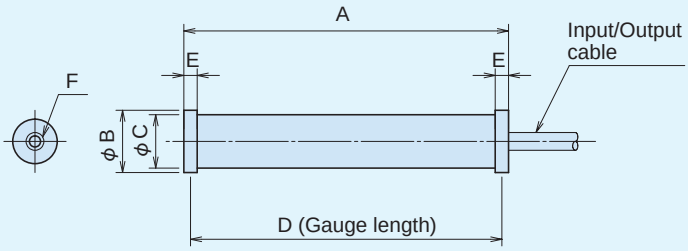
Civil Engineering use STRAIN TRANSDUCERS series KM/KM-HAS

C concrete A asphalt

Operating temperature range
–20°C +180°C

STRAIN TRANSDUCER KM

The KM series are embedment type transducers designed for measurement of internal strain of materials such as concrete and synthetic resin not only in their hardened state but also in curing process. The apparent elastic modulus is as low as approx. 40N/mm², and they are idealy suited to strain measurement during the very early stage of curing (except KM-A and KM-AT). They are totally impervious to moisture absorption producing excellent stability for long-term strain measurement. The KM-100B and KM-100BT are also applicable to measurement of surface strain of steel or concrete structures by using optional collars for surface installatiion.



Unit: mm

TYPE	Dimensions (mm)						Weight (g)
	A	B	C	D	E	F	
KM-30	34	12	10	31	3	M3 Depth 4	12
KM-50F	54	20	17	50	4	M3 Depth 6	45
KM-100A KM-100B	104	20	17	100	4	M3 Depth 6	75
KM-100HB	104	20	17	100	4	M3 Depth 6	80
KM-200A	205	28	23	200	5	M5 Depth 8	220
KM-100AT KM-100BT	104	20	17	100	4	M3 Depth 6	75
KM-200AT	205	28	23	200	5	M5 Depth 8	220

■ SPECIFICATIONS

Type	KM-30	KM-50F	KM-100A	KM-100B	KM-100HB	KM-200A	KM-100AT	KM-100BT	KM-200AT
Capacity	±5000 x 10^{-6} strain								
Gauge length	31mm	50mm	100mm			200mm	100mm		200mm
Rated output (approximately)	2.5mV/V (5000 x10^{-6})	4mV/V (8000 x10^{-6})	2.5mV/V (5000 x10^{-6})			5.0mV/V (10000 x10^{-6})	2.5mV/V(5000 x10^{-6})		5.0mV/V (10000 x10^{-6})
Non-linearity	1%RO								
Apparent elastic modulus	40N/mm²		1000N/mm²	40N/mm²		1000N/mm²		40N/mm²	1000N/mm²
Integral temperature	N/A		*1Strain gauge (350Ω Quarter bridge 3-wire method :50x 10^{-6} strain/°C)				*2 Thermocouple T		
Temperature range	–20~+60°C	–20~+80°C			–20~+180°C	–20~+80°C			
Input/Output	120Ω Half bridge	350Ω Full bridge							

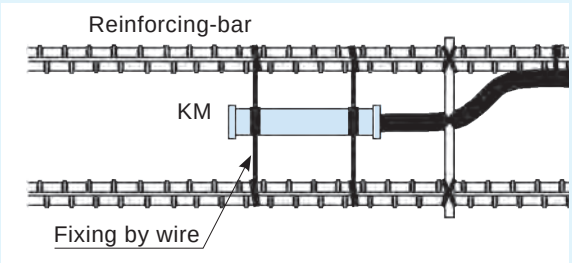
*1 Relative temperature measurement possible
*2 Real temperature measurement possible

Input/Output cable

KM-30	ϕ 2.4mm	0.04mm²	3-core shielded Vinyl cable	2m cable-end free
KM-50F	ϕ 6mm	0.35mm²	4-core shielded Chloroprene cable	2m cable-end free
KM-100A/-100B	ϕ 9mm	0.3mm²	5-core shielded Chloroprene cable	2m cable-end free
KM-100HB	ϕ 6mm	0.3mm²	5-core shielded Fluoroplastic cable	2m cable-end free
KM-200A	ϕ 11.5mm	0.5mm²	5-core shielded Chloroprene cable	2m cable-end free
KM-100AT/-100BT	ϕ 9mm	0.3mm²	4-core shielded T-thermocouple compound cable	2m cable-end free
KM-200AT	ϕ 11.5mm	0.5mm²	4-core shielded T-thermocouple compound cable	2m cable-end free

For use of internal strain measurement

The KM Strain Transducers make possible strain measurement in materials such as concrete which undergo a transition from a compliant state to a hardened state. Various strains are produced by external force, ambient temperature, drying shrinkage, materials creep, etc. the KM is designed to measure such strains. Applicable gauge length should require three times the diameter of the gravel pieces so as to give an averaged evaluation of the concrete.
As illustrated right, attach wires to KM body at 2 points, then position the KM to marked points of reinforcing bar in advance .



Civil Engineering use STRAIN TRANSDUCERS series KM/ KM-HAS

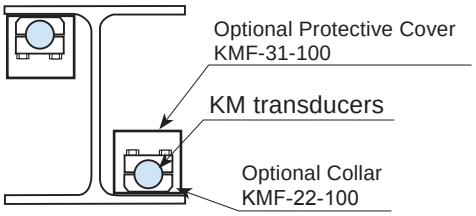
Operating temperature range
–20°C +180°C

For use of surface strain measurement

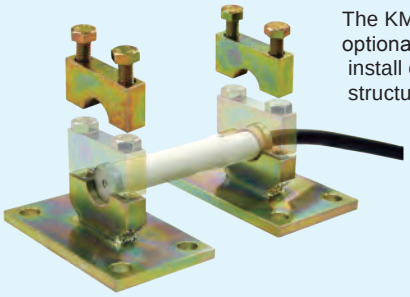
Surface strain measurement onto steel and concrete structures is available with KM-100B or KM-100BT. (Optional fittings such as Spacer and Collar are available for fixing the model and positioning gauge length.

An installation onto surface of steel structure

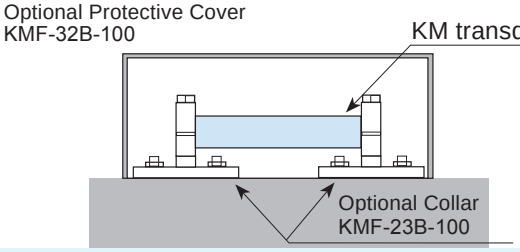
The KM model is combined with optional Collar KMF-22-100 to install onto surface of steel by welding.



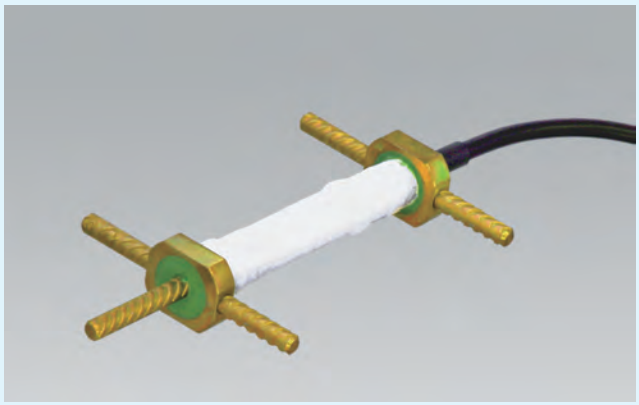
An installation onto surface of concrete structure



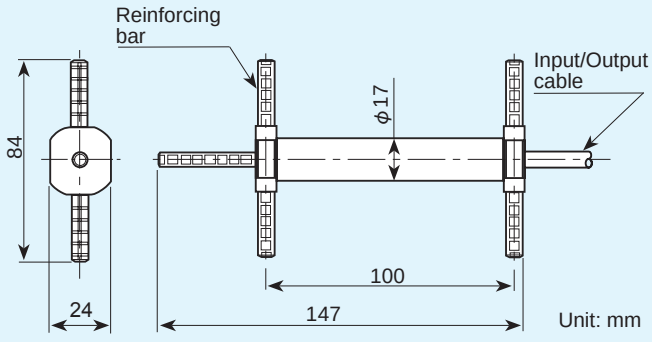
The KM model is combined with optional Collar KMF-23B-100 to install onto surface of concrtete structure with anchor bolts.



STRAIN TRANSDUCERS for asphalt pavement KM-HAS



These transducers are embedded into asphalt for measurement of the internal strain. They have flanges on reinforcing bars on its both ends for good fixation to asphalt pavement materials. The operating temperature range of the transducers is –20 to +180°C, and they have fully waterproof construction.



■ SPECIFICATIONS

Type	KM-100HAS
Capacity	±5000 x 10^{-6} strain
Gauge length	100mm
Rated output	Approx. 2.5mV/V (5000 x10^{-6})
Non-linearity	1%RO
Apparent elastic modulus	Approx. 40N/mm²
Integral temperature	350Ω Full bridge : strain measurement Quarter bridge 3-wire method : temperature measurement
Temperature range	–20~+180°C
Bridge excitation	Recommended 1~2V, Allowable 10V
Input/Output cable	φ 6mm 0.3mm² 5-core shielded Fluoroplastic cable, 2m

COMPOSITE USE STRAIN GAUGES series UBF

These strain gauges are not self-temperature-compensated. These may be necessary to measure the thermal output using a dummy specimen prior to the measurement.

Operating temperature range

–30°C ——— +150°C

Static measurement : –30 ~ +120°C
Dynamic measurement : –30 ~ +150°C

Applicable adhesives

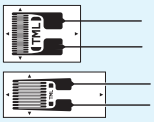
CN	–20 to +120ºC
EB-2	–30 to +150ºC

COMPOSITE MATERIALS USE

Gauge pattern

These are foil strain gauges developed for measurement on composite materials. They have a specially designed grid pattern to reduce the stiffening effect of the strain gauges. In addition, owing to the development of gauge backing with better compliance, the number of repetition in thermal cycling test and the creep characteristics have been significantly improved compared to conventional strain gauges.

Single element



UBFLA-03 (x 3)

UBFLA-1 (x 3)

Refer to pages 19~20 for applicable integral leadwires.

Basic type

C composite

L : length W : width (Unit:mm)

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
UBFLA-03	0.3	1.9	3.4	2.5	120
UBFLA-1	1	1.3	4.5	2.0	120

Point

Composite materials consisting of plastic matrix and fibers such as glass fibers (GFRP), carbon fibers (CFRP) or aramid fibers (AFRP) have different elastic modulus and linear thermal expansion coefficient depending on their fiber orientation. For strain measurement, consideration of materials property and fiber orientation should be taken.

COMPOSITE USE STRAIN GAUGES series BF

Suffix code for temperature compensation materials
-3, -5 or -8 : composite materials

For ordering, the above suffix code should be specified after basic gauge type.

Operating temperature range

–20°C ——— +200°C

Temperature compensation range

+10°C | ——— +80°C

Applicable adhesives

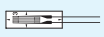
CN	–20 to +120ºC
NP-50B	–20 to +200ºC
EB-2	–30 to +150ºC

COMPOSITE MATERIALS USE

Gauge pattern

These are foil strain gauges designed for measurement on composite materials. They have a specially designed grid pattern to enable small stiffening effect and excellent peformance in strain measurement up to 200°C. This series is available with self-temperature-compensation for a material having coefficient of thermal expansion of 3,5 or 8×10^{-6}/°C. This series is recommended for use on ceramic, carbon and composite materials.

Single element



BFLA-2

0°/90° 2-element Rosette Plane

BFCA-2-3

0°/45°/90° 3-element Rosette Plane

BFRA-2-3

Refer to pages 19~20 for applicable integral leadwires.

Basic type

C composite

L : length W : width (Unit:mm)

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Single element					
BFLA-2	2	0.9	7.6	2.5	120
BFLA-5	5	1.5	12.3	3.3	120
0°/90° 2-element Rosette Plane					
BFCA-2	2	1.3	8	8	120
BFCA-5	5	1.5	11.5	11.5	120
0°/45°/90° 3-element Rosette Plane					
BFRA-2	2	1.3	8	8	120
BFRA-5	5	1.5	11.5	11.5	120

Point

Composite materials consisting of plastic matrix and fibers such as glass fibers (GFRP), carbon fibers (CFRP) or aramid fibers (AFRP) have different elastic modulus and linear thermal expansion coefficient depending on their fiber orientation. For strain measurement, consideration of materials property and fiber orientation should be taken.

LOW ELASTIC STRAIN GAUGES series GF

Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

Suffix code for temperature compensation materials
-50, or -70 : Plastics

For ordering, the above suffix code should be specified after basic gauge type.

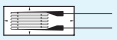
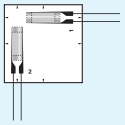
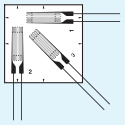
Applicable adhesives | CN | –20 to +80ºC

PLASTICS USE

These gauges are suited for the measurement on materials such as plastics, which have low elastic modulus compared to metal. These specially designed grid reduces the stiffening effect of the strain gauges to the specimen material, and also reduces the effect of Joule heat in the strain gauges. This series is available with self-temperature-compensation for the material having coefficient of thermal expansion of 50 or 70×10-6/°C.

L : length W : width (Unit:mm)

Each package contains 10 gauges.

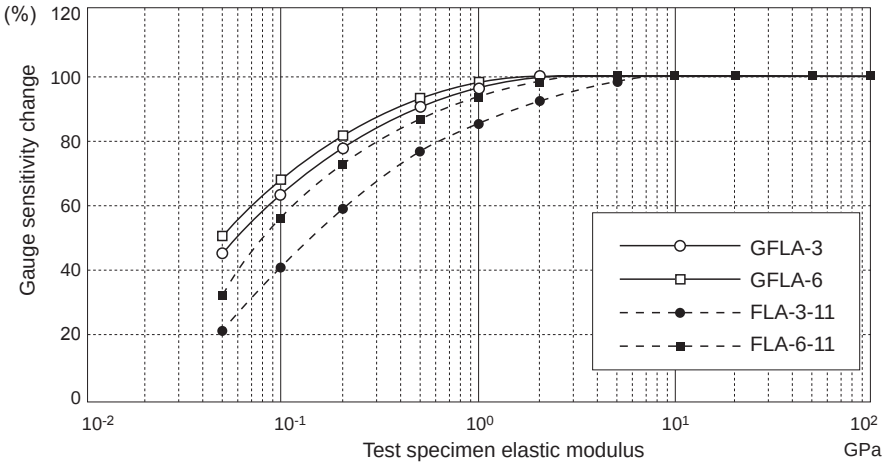
Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Single element						
 GFLA-3	GFLA-3	3	2.3	9.5	4.0	120
Single element	GFLA-6	6	2.5	14.0	5.0	120
	GFLA-3-350	3	2.9	10.0	5.0	350
	GFLA-6-350	6	2.7	15.0	5.0	350
0°/90° 2-element Rosette Plane						
 GFCA-3	GFCA-3	3	1.4	10.5	10.5	120
0°/90° 2-element Rosette Plane	GFCA-3-350	3	2.9	15.0	15.0	350
0°/45°/90° 3-element Rosette Plane						
 GFRA-3	GFRA-3	3	1.4	10.5	10.5	120
0°/45°/90° 3-element Rosette Plane	GFRA-3-350	3	2.9	15.0	15.0	350

Refer to pages 19~20 for applicable integral leadwires.

Point

Effect of low elastic modulus of specimen

When a strain gauge is installed on materials such as plastics that have low elastic modulus, the stiffness of the strain gauge causes to disturb the stress distribution around the strain gauge, thus resulting in reduced strain sensitivity. This is referred to as the strain gauge stiffening effect and it gets larger as the elastic modulus of specimen gets smaller. For materials with an elastic modulus of 2.9GPa (approx. 300kgf/cm²) or less, a preparatory test must be conducted to correct the gauge factor.



Gauge sensitivity change due to Elastic Modulus of test specimen

Effect of Joule heat

The GF series gauges have a specially designed grid to reduce the effect of Joule heat. Though an allowable current is 30mA or less for metallic specimens in general, a current of 10mA or less is recommended for plastic specimen.

LOW ELASTIC STRAIN GAUGES series LF

Suffix code for temperature compensation materials
-11: Wood

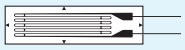
Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

Applicable adhesives | CN-E | –20 to +80ºC

WOOD, GYPSUM USE

Gauge pattern

These are foil strain gauges for the measurement on materials having low elastic modulus such as wood or gypsum. These specially designed grid reduces the stiffening effect of the strain gauges to the specimen material. They have a backing made of epoxy resin, which is compliant to the strain on the specimen. These gauges are temperature-compensated for the material having a coefficient of thermal expansion of 11×10^{-6}/°C.



Refer to pages 19~20 for applicable integral leadwires.

Basic type

W wood G gypsum

L : length W : width (Unit:mm)

Single element	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	Each package contains 10 gauges.				
LFLA-10-11	10	3.1	18.5	5.3	120

WOODEN MATERIAL USE FOR LONG TERM STRAIN GAUGES Series PFLW/PLW

Suffix code for temperature compensation materials
-11: Wood

Operating temperature range
–20°C +80°C
Temperature compensation range
+10°C +80°C

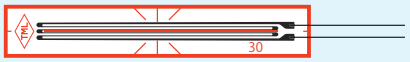
Applicable adhesives | PS | –20 to +80ºC

COMPOSITE MATERIALS USE

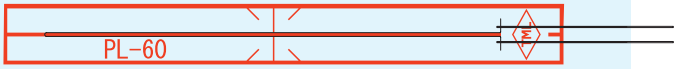
Gauge pattern

These gauges are specially designed for long term measurement on wood. They have a metal foil lined on the back of the PFL or PL strain gauges. The metal foil is effective to protect the strain gauges from the influence of moisture in the wood. These gauges should be bonded with PS adhesive to make the best of their performance.

Single element



PFLW-30-11



PLW-60-11

The PFLW and PLW series are available with an extension leadwire in 2-wire parallel (suffix code -L) or 3-wire parallel (suffix code -LT) vinyl leadwires.

Basic type

W wood

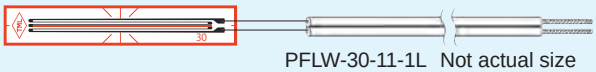
L : length W : width (Unit:mm)

Single element	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	Each package contains 10 gauges.				
PFLW-30-11	30	2.3	40	7	120
PLW-60-11	60	1	74	8	120

Single element

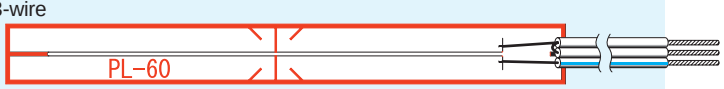
0.11mm² integral vinyl sheath leadwire
Total leadwire resistance per meter : 0.32Ω

2-wire



PFLW-30-11-1L Not actual size

3-wire



PLW-60-11-3LT

Blue stripe (independent)

Single element		Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
		Each package contains 10 gauges.				
PFLW-30-11	-1L -3L	30	2.3	40	7	120
PLW-60-11	-5L -3LT -5LT	60	1	74	8	120

Refer to pages 19~20 for applicable integral leadwires.

MAGNETIC FIELD STRAIN GAUGES series MF

Suffix code for temperature compensation materials approximately
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

For ordering, the above suffix code should be specified after basic gauge type.

Applicable adhesives for single element

CN-E	–20 ~ +80ºC
RP-2	–20 ~ +80ºC
RP-2	–20 ~ +80ºC

Applicable adhesives for 2-/3-element

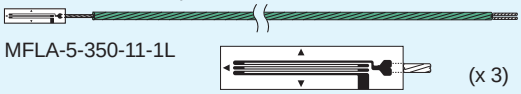
CN-E	–20 ~ +120ºC
NP-50B	–20 ~ +200ºC

MAGNETIC FIELD USE

These gauges are designed for strain measurement in magnetic field. The gauges have a sensing element material which exhibits low magnetoresistance. In addition, the sensing element consists of two identical grids with one grid folded back on another. These construction makes the strain gauges less sensitive to the influence of the alternating field. The gauges have a twisted leadwire pre-attached which is also effective to avoid the influence of the alternating field. The 2-element and 3-element gauges of this series are usable in high temperature up to 200°C.

Single element

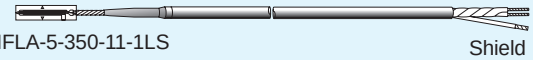
0.08mm² integral stranded vinyl leadwire of 1m
Total leadwire resistance per meter : 0.44Ω



MFLA-5-350-11-1L (x 3)

Shielded leadwire

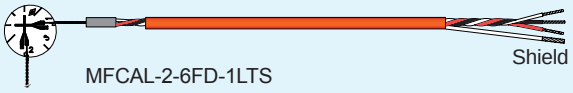
ϕ 3.2mm 2-core shielded stranded vinyl leadwire of 1m
Total leadwire resistance per meter : 0.44Ω



MFLA-5-350-11-1LS Shield

0°/90° 2-element Rosette Stack

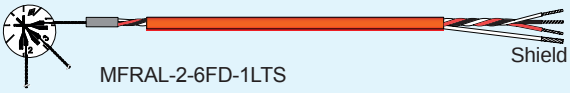
ϕ 1.5mm 0.04mm² 3-wire twisted fluorinated resin sheathed lead-wire of 1m
Total leadwire resistance per meter : 1.1Ω



MFCAL-2-6FD-1LTS Shield

0°/45°/90° 3-element Rosette Stack

ϕ 1.5mm 0.04mm² 3-wire twisted fluorinated resin sheathed lead-wire of 1m
Total leadwire resistance per meter : 1.1Ω



MFRAL-2-6FD-1LTS Shield

Concrete structure use

Temperature-compensation is not available.

0.08mm² integral stranded vinyl leadwire of 1m
Total leadwire resistance per meter : 0.44Ω

MFLA-60-350-1L

Shielded leadwire

ϕ 3.2mm 2-core shielded stranded vinyl leadwire of 1m
Total leadwire resistance per meter : 0.44Ω

MFLA-60-350-11-1LS

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
	L : length	W : width (Unit:mm)			
Single element					
MFLA-2-350-11 -1L	2	0.5	4.7	1.9	350
MFLA-5-350-11 -1LS	5	0.5	7.9	1.9	350

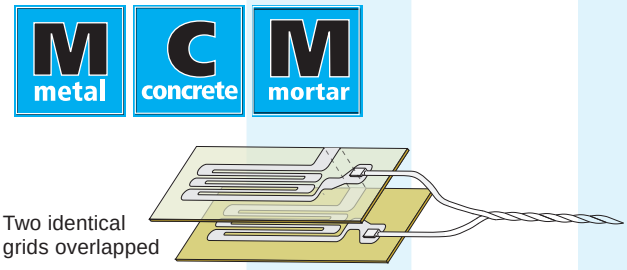
Integral leadwire lengths longer than 1m are available for single element gauges. For 2-element and 3-element rosette gauges, no other length than 1m is available.

2-element Rosette/3-element Rosette

Basic type	Gauge size L	Gauge size W	Backing	Resistance Ω
0°/90° 2-element Rosette Stack				
MFCAL-2-6FD-1LTS	2	0.1	ϕ7	120
MFCAL-2-350-6FD-1LTS	5	0.2	ϕ7	350
0°/45°/90° 3-element Rosette Stack				
MFRAL-2-6FD-1LTS	2	0.1	ϕ7	120
MFRAL-2-350-6FD-1LTS	5	0.2	ϕ7	350

Single element

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
MFLA- 60-350 -1L -1LS	60	0.1	64	5	350



Two identical grids overlapped

Single element
Operating temperature range –20°C +80°C
Temperature compensation available only for mild steel
+10°C +80°C

Minimum order is 10 gauges or more.

2-element Rosette/3-element Rosette
Operating temperature range
–20°C +200°C
Temperature compensation range approximately
+10°C +100°C

Minimum order is 10 gauges or more.

Minimum order is 10 gauges or more.

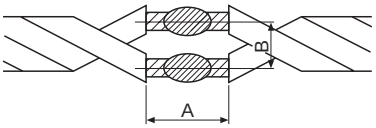
Point

Countermeasure againt Noise interference in magnetic field

If you are not using magnetic field strain gauge, use a strain gauge with a narrow gauge width. A narrow gauge width reduces the induced voltage on the gauge leads and is preferable to a wide strain gauge.
The parallel leadwires used in normal strain measurement are affected by induction. Always use twisted wires. The interwining of twisted wires cancels out the induced voltage that is generated. Using shielded leadwires also prevents interference from noise.

Connection

If you extend the leadwires, locate the connection as far as possible from the magnetic field. Bridge boxes should also be placed as far as possible from the magnetic field. If you do connect the wires inside the magnetic field, keep the length of the connecting wire (A) short and the distance between the leads (B) small.



POST-YIELD (Large strain) MEASUREMENT STRAIN GAUGES series YEF/YF/YHF

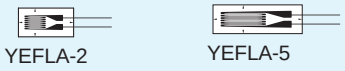
Self-temperature-compensation : Not available

LARGE STRAIN MEASUREMENT

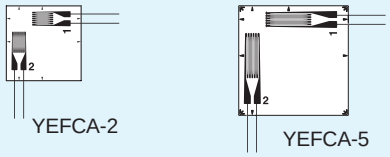
series YEF

These gauges are applicable to the measurement of large strain up to 10~15%. Also these withstand the repeated strain in elastic range (at strain level ±1500×10^{-6} strain) like ordinary strain gauges. However, these are not applicalble to the measurement of repeated strain in a large range.

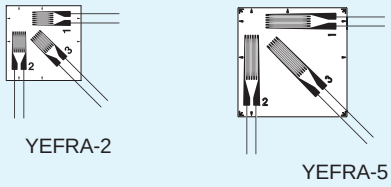
Single element



0°/90° 2-element Rosette Plane



0°/45°/90° 3-element Rosette Plane



L : length W : width (Unit:mm)

Operating temperature range –20°C +80°C

Applicable adhesives	
CN	–20 ~ +80ºC
CN-Y	–20 ~ +80ºC
Strain limit in room-temperature	10 ~ 15%

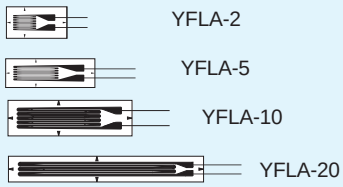
Each package contains 10 gauges.

Gauge pattern	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
Single element	YEFLA-2	2	1.8	7.5	4.0	120
	YEFLA-5	5	1.9	12.0	4.0	120
0°/90° 2-element Rosette	YEFCA-2	2	1.8	10.0	10.0	120
	YEFCA-5	5	2.0	14.5	14.5	120
0°/45°/90° 3-element Rosette	YEFRA-2	2	1.8	10.0	10.0	120
	YEFRA-5	5	2.0	14.5	14.5	120

series YF

These gauges are applicable to the measurement of large strain up to 15 to 20%. These are not applicable to the measurement of repeated strain in elastic range as well as in large range.

Single element



Operating temperature range –20°C +80°C

Applicable adhesives	
CN	–20 ~ +80ºC
CN-Y	–20 ~ +80ºC
Strain limit in room-temperature	15 ~ 20%

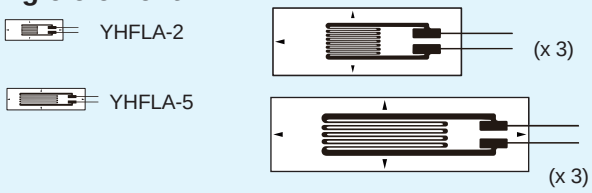
Each package contains 10 gauges.

Single element						
	YFLA-2	2	1.8	7.5	4.0	120
	YFLA-5	5	1.9	12.0	4.0	120
	YFLA-10	10	2.6	16.6	4.9	120
	YFLA-20	20	1.8	26.0	3.7	120

series YHF

These gauges are developed for the measurement of very large strain up to 30~40%. These are not applicable to the measurement of repeated strain in elastic range as well as in large range.

Single element



Operating temperature range –30°C +80°C

Applicable adhesives	
CN	–30 ~ +80ºC
CN-Y	–30 ~ +80ºC
Strain limit in room-temperature	30 ~ 40%

Each package contains 10 gauges.

Single element						
	YHFLA-2	2	1.5	8	2.7	120
	YHFLA-5	5	1.7	11	3	120

Refer to pages 19~20 for applicable integral leadwires.

Point

Performance of YEF/YF/YHF

Series	Strain measurement	Fatigue limit at room temperature*1	Self-temperature compensation	Change of apparent strain due to cyclic loading of large strains*2	Applications
YEF	10~15%	5 x 10^5 cycles	Not available	2000 x 10^{-6} strain/10 cycles	Measurement of repeated strain in elastic range.
YF	15~20%	1 x 10^2 cycles	Not available	2000 x 10^{-6} strain/10 cycles	
YHF	30~40%	2 x 10^4 cycles	Not available	Not available	
F	5%	1 x 10^6 cycles	Effective	400 x 10^{-6} strain/10 cycles	Measurement of repeated strain in elastic range.

*1 : The number of repetitions at which the indicated strain value changes by 100x10^{-6} strain or more by applying repeated strain of approx. ±1,500x10^{-6} strain at 15Hz

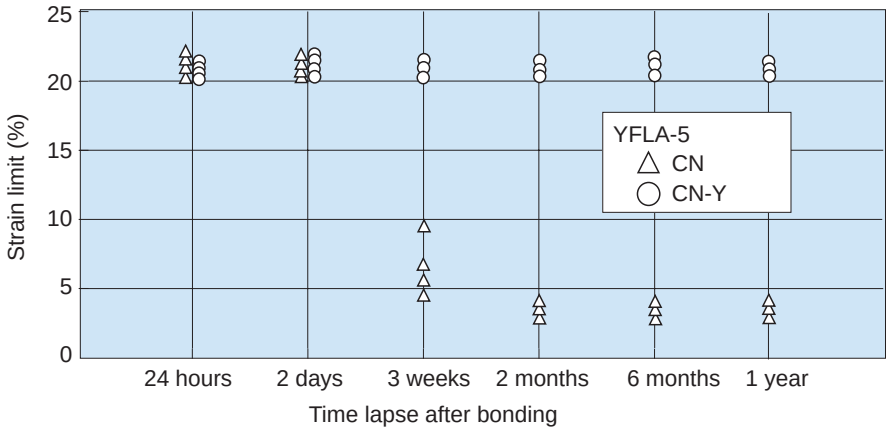
*2 : Change of indicated strain by applying a repeated strain of approx. ±10,000x10^{-6} strain at a speed of 4 minutes per cycle.

Adhesive for YEF/YF/YHF series gauges

These strain gauges should be bonded with CN or CN-Y adhesive. If measurement is made a few days or longer after the strain gauge bonding, the CN-Y should be used. Measurement of large strain is possible even after one year of bonding the strain gauge with the CN-Y adhesive, provided that the specimens are stored at room temperature without any unfavorable conditions (moisture, direct sunlight, etc.).

CN adhesive variation with time

Though CN adhesive is normally used for large elongation strain measurement, the strain limit gradually decreases with the number of days following strain gauge installation. This variation with time occurs as a consequence of exposure to direct sunlight (UV), temperature and humidity, as well as the number of days since installation. The following shows an example of the results of testing performed by TML for the effects of adhesive variation with time. While these results show marked differences due to the exposure conditions of the test specimens (temperature and humidity), they also show that the strain limits for strain gauges decrease as time passes after installation. While this does not pose a problem in ordinary strain measurement, TML recommends that the measurement ends in 1 or 2 days after installation in the case of large elongation strain measurement. If the strain gauge is to be left for a long period after being installed, use the CN-Y adhesive.



Countermeasure in case there is a span between gauge installation and start of measurement

Store the test specimen with the attached strain gauge in a cool, dark and dry location.
Use the CN-Y adhesive. (Refer to the instructions provided).

Repeatability of Post-Yield strain gauges

Post-Yield strain gauges can be used to measure large elongation strain once, but cannnot be used for measurement of repeated large elongation strain. When repeated testing is performed in a strain range exceeding 5000x 10^{-6} , the strain gauge experiences zero drift. Note that the amount of drift varies depending on factors such as the type of strain gauges and the level and frequncy of strain.

HIGH ENDURANCE STRAIN GAUGES series DSF

Operating temperature range
–60°C +200°C

These strain gauges are not self-temperature-compensated. It may be necessary to measure a thermal output using a dummy specimen prior to the measurement.

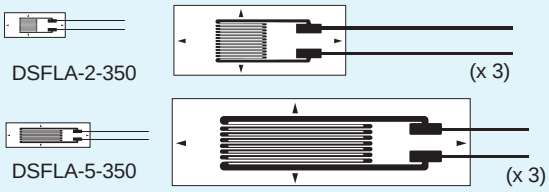
Applicable adhesives

CN	–60 ~ +120ºC
C-1	–60 ~ +200ºC
EB-2	–60 ~ +200ºC

HIGH STRESS FATIGUE TEST

Gauge pattern

These gauges are designed for fatigue test at high stress level. The gauges satisfy the fatigue life over 10 million times at a strain level of ±3000x10^{-6} strain. It is available for use in cyclic loading test of composite materials.



Integral leadwire is available.
Refer to pages 19~20 for applicable integral leadwires.

Basic type

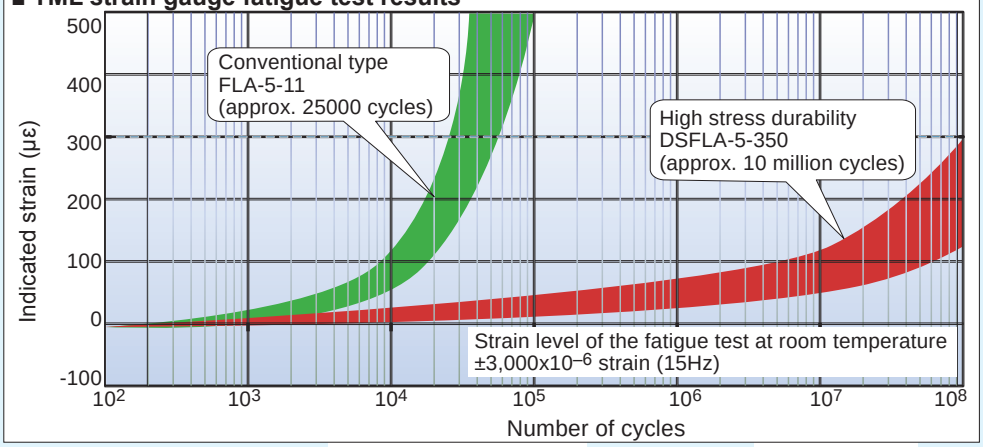
M metal

L : length W : width (Unit:mm)

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
DSFLA-2-350	2	2	8	3.3	350
DSFLA-5-350	5	2	11	3.2	350

■ TML strain gauge fatigue test results



Fatigue Limit

This number is determined as the number of cycles in case a mechanically repeated strain of ±3000x10^{-6} strain is applied to the strain gauge before the indicated strain changes by ±300x10^{-6} strain.

ONE-SIDE STRAIN GAUGES series DD

Operating temperature range
–10°C +70°C

These strain gauges are not self-temperature-compensated. It may be necessary to measure a thermal output using a dummy specimen prior to the measurement.

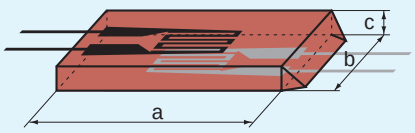
Applicable adhesives

CN	–10 ~ +70ºC
P-2	–10 ~ +70ºC

ONE-SIDE STRAIN GAUGES

Gauge pattern

These gauges are intended for measuring the bending and tensile strains separately by simply bonding the gauges on one side of a plate or beam. It works on the assumption that the strain distribution in the section of the specimen is linear along the height of the section when the section is subjected to both tensile and bending stress. The gauges are effectively used for the measurement of a box construction in structures such as bridges or pressure vessels, where the reverse side of the measurement object is not accessible for strain gauge installation.



Basic type

M metal

L : length W : width (Unit:mm)

Each package contains 5 gauges.

Thickness of applicable specimen (mm)	Basic type	Gauge size L	Gauge size W	Backing a	Backing b	Backing c	Resistance Ω
Approx. 5 or less	DD-1-15	3	2.9	15	7	1	350
Approx. 5~10	DD-2-30			30	7	2	

CRACK DETECTION GAUGES series FAC

Operating temperature range
–30°C +80°C

Applicable adhesives

CN	–30 ~ +80ºC
RP-2	–30 ~ +80ºC

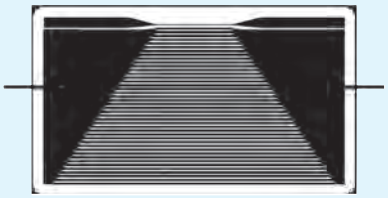
CRACK PROPAGATION MEASUREMENTS

Gauge pattern

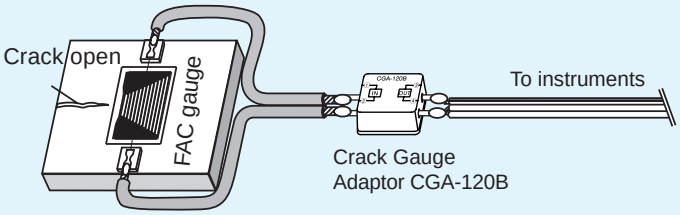
These gauges are designed to measure the propagation speed of fatigue crack in a metal specimen. The gauges are bonded with an adhesive on the position where the crack is initiated or the crack initiation is expected. The grids of the gauges, which are aligned with interval of 0.1mm or 0.5mm, are disconnected one by one with the propagation of the crack. The gauges are used together with the crack gauge adaptor CGA-120B, and the disconnection of one grid is measured as the change of approx. 45 or 40×10^{-6} strain by a strainmeter.

Crack Gauges

FAC-5



FAC-20



metal

CRACK GAUGES — Each package contains 10 gauges.

Gauge type	FAC-5	FAC-20
Measuring range	4.5mm	20mm
Gauge resistance	approx. 1Ω	
Grid interval	0.1mm	0.5mm
Number of grids	46	41
Output per grid	approx. 45 με	approx. 40 με
Operating temperature	-30 ~ +80°C	
Backing size	28 x 5mm	43 x 25mm

Crack Gauge Adaptor CGA-120B
Minimum order is 1 piece or more.

Measuring point	1
Allowable temperature	-30 ~ +80°C
Bridge connection	Quarter bridge 3-wire method 120Ω
Dimension	20(W) x 15(H) x 15(D) mm (except projection parts)
Weight	5g

Crack Gauge Adaptor CGA-120B

STRESS GAUGES series SF

Operating temperature range
–20°C +200°C
Temperature compensation range
+10°C +100°C

Applicable adhesives

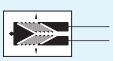
NP-50B	–20 ~ +200ºC
C-1	–20 ~ +200ºC
CN	–20 ~ +120ºC

Suffix code for temperature compensation materials
-11: Mild steel (ferritic) -17: Stainless steel -23: Aluminium

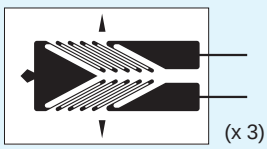
AXIAL STRESS MEASUREMENT

Gauge pattern

These gauges are intended to measure the stress in an optional direction of the specimen in plane stress field. The gauges are sensitive not only in these axial direction but also in these transverse direction, and the sensitivity ratio of the transverse direction to the axial directions is equal to the Poisson's ratio of the specimen material. In addition, the gauges are not sensitive to the shearing strain. Accordingly, the output of the gauges is proportional to the stress in the axial direction. The gauges are available in three types depending on the Poisson's ratio of the specimen material.



SFA-285



(x 3)

metal

Each package contains 10 gauges.

Poisson's ratio of specimen	Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
0.285	SFA-285-11	4	3	9	6	120
0.305	SFA-305-17					
0.330	SFA-330-23					

Integral leadwire is available.
Refer to pages 19~20 for applicable integral leadwires.

TRANSDUCER-SPECIFIC STRAIN GAUGES

TML strain gauges are used not only for the purpose of knowing strain/stress but also as sensors for strain gauge type transducers. A strain gauge type transducer converts physical quantity such as load, pressure or displacement into mechanical strain on the strain generating body (elastic body), and the mechanical strain is converted into electrical output using strain gauges mounted on the elastic body. We offer various types of transducer-specific strain gauges featuring highly reliable and stable performance.

- Force transducers (Load Cells)
- Pressure transducers
- Acceleration transducers
- Displacement transducers
- Torque transducers

VARIOUS TYPE OF TML TRANSDUCER-SPECIFIC STRAIN GAUGES

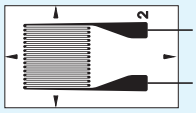
GAUGE SHAPE AND GAUGE LENGTH

Single, Rectangular 2-element, Torque (Shearing) strain measurement.

Pattern	Gauge length (mm)
Single-element	2, 3
0°/90° 2-element	2, 3, 6
Torque (Shearing strain) use	2

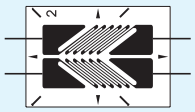
Pattern

Single-element



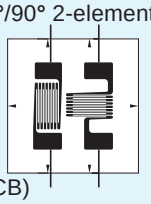
(LA)

Torque



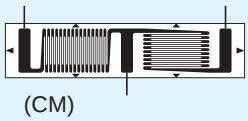
(CT)

0°/90° 2-element



(CB)

0°/90° 2-element



(CM)

2 types of 0°/90° 2-element gauge are lined-up with different pattern of gauge tab. CM-type has half-bridge configuration.

GAUGE RESISTANCE

Pattern	Gauge resistance (Ω)
Single-element	350, 1000
0°/90° 2-element	120, 350
Torque (Shearing strain) use	350

Please note that 1000Ω gauge has less power consumption in bridge circuit comparing to 350Ω gauge's and limits Joule's heat generation.

GAUGE BACKING MATERIALS

Unlike stress measurement gauges, the gauge backing materials for transducer-specific strain gauge cannot be determined based solely on the operating temperature and bonding method. To ensure maximum transducer performance, it is necessary to test various combinations using different stress-generating bodies (elastic bodies) to select the most suitable backing mateirals.

OPERATING TEMPERATURE

Operating temperature range differs from heat-resistive temperature's. F series gauge (with epoxy backing) is also available for use of heat-curing type bonding adhesives. Refer to pages 79 and 80 for the details.

Gauge series	Gauge backing materials	Operating temperature
F	Epoxy resin	-20 ~ +80°C
QF	Polyimide resin	-20 ~ +200°C
EF	Polyimide resin	-20 ~ +200°C

CREEP ADJUSTMENT

The creep characteristic is particularly important in force transducers. The most common compensation system uses the material creep (+) of the stress-generating body (elastic body) and the gauge creep (–) to cancel each other. Various TML strain gauges are available for creep adjustment and are selectable by creep code.

Creep code

Gauge creep	Large ————> Small
Creep code	C2>C4>C6>C8

TEMPERATURE SENSITIVITY COMPENSATION

Elastic modulus of strain-generating body (elastic body) varies with temperature variation. In the same manner, as ambient temperature around the strain-generating body varies, resulting in change of apparent strain. To reduce such temperature influence, sensitivity compensation resistor is assembled in bridge circuit.

Coding system of Transducer-specific strain gauges

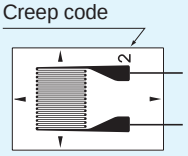
FLA-2-350-C2-11

- 2: Gauge length
- C2: Creep code
- 11: Mild steel
- 17: Stainless steel
- 23: Aluminium

●Single element

FLA-2-350-C2

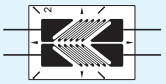
Creep code



Not actual size shown

●Torque (Shearing strain) measurement

FCT-2-350-C2



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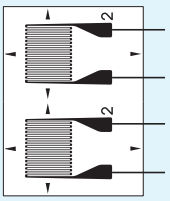
●Single axis 2-element

FLA-2-350-C2-2H

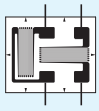


Not actual size shown

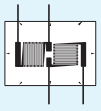
●0°/90° 2-element

FCB-2

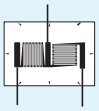
FCB-3-350



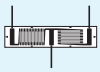
FCB-6-350



FCB-2.8-350

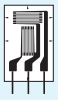


FCM-2.8-350



EFCM-2-350

EFCMX-3-350



EFCMY-3-350

Basic type			Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
			L : length		W : width (Unit:mm)		
FLA-2-350- (QF)	C2 C4 C6 C8	-11 -17 -23	2	2.9	6.8	4.6	350
FLA-3-350- (QF)	C2 C4 C6 C8	-11 -17 -23	3	3.2	8.5	5.0	350
FLA-3-1000- (QF)	C2 C4 C6 C8	-11 -17 -23	3	4.2	9.2	5.8	1000
FCT-2-350- (QF)	C2 C4 C6 C8	-11 -17 -23	2	1.5	7.6	5.3	350
FLA-2-350- (QF)	C2-2H C4-2H C6-2H C8-2H	-11 -17 -23	2	2.9	6.8	9.2	350
FLA-3-350- (QF)	C2-2H C4-2H C6-2H C8-2H	-11 -17 -23	3	3.2	8.5	10.0	350
FCB (QF)	-2	-11 -17 -23	2	1.5	8.2	8.0	120
	-3-350		3	3.2	10.5	9.1	350
	-6-350		6	2.0	10.0	13.0	350
	-2.8-350		2.8	2.8	12.0	8.5	350
FCM-2.8-350			2.8	2.8	12.0	8.5	350
EFCM-2-350-11			2.5	1.4	3.0	12.2	350
EFCMX-3-350-11			3	1.6	8.0	7.5	350
EFCMY-3-350-11			3	1.6	10.0	6.5	350

BOLT STRAIN GAUGES series BTM/BTMC

These gauges are used for measurement of tensile strain of bolt. They are simply inserted into pre-drilled hole in the bolt with exclusive adhesives. This method is recommendable when an ordinary strain gauges can not be mounted on the bolt surface. Accurate tensile force measurement is possible by calibrating the bolt after installing the bolt gauges.

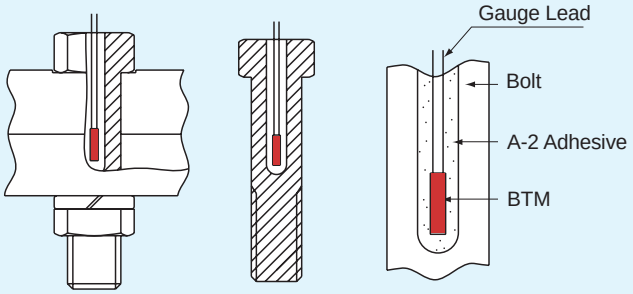
Operating temperature range
–10°C +80°C

Temperature compensation range
Not available

BOLT AXIAL STRAIN MEASUREMENT

series BTM

The BTM bolt gauges use heat-curing A-2 adhesive for installation, which provides better long-term stability.



B bolt

Applicable adhesives: A-2 | –10 ~ +80ºC

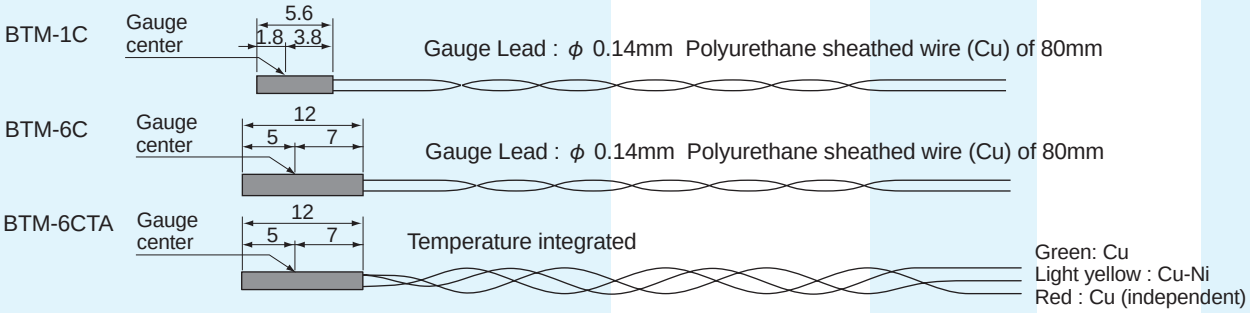
L : length W : width (Unit:mm)

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
BTM-1C Hole drilled: ϕ 1.6mm	1	0.7	5.6	1.4	120
BTM-6C Hole drilled: ϕ 2.0mm	6	1.0	12.0	1.7	120
BTM-6CTA Hole drilled: ϕ 2.0mm	6	1.0	12.0	1.7	120

Temperature integrated applicable in -10~+80°C

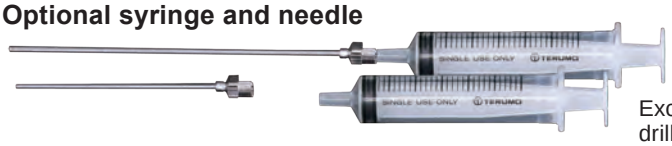
NB : Polyurethane sheath of the gauge leads is easily removed by heat of soldering iron, while Polyester sheath is removed by chemical solvent.



Gauge Lead: ϕ 0.14mm Polyurethane sheathed wire (Cu) of 80mm
ϕ 0.12mm Polyester sheathed wire (Cu-Ni) of 80mm

Unit: mm

Optional syringe and needle

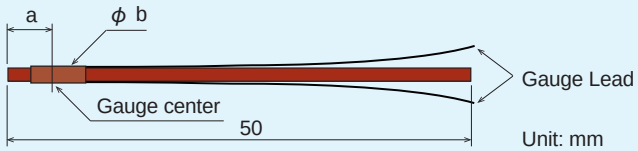


Applicable to	Needle diameter	Needle length
BTM-1C	1.5mm-dia.	60mm
BTM-6C	1.8mm-dia.	100mm

Exclusive syringe for injecting A-2 adhesive into the pre-drilled hole before BTM-1C or -6C gauge is embedded.

series BTMC

The BTMC gauges have a tube shape sensing element, and they are installed with fast-curing CN adhesive. The installation is easily made at room temperature.



Unit: mm

B bolt

Applicable adhesives: CN | –10 ~ +80ºC

Basic type	Gauge Length (mm)	Gauge Center a (mm)	Backing diameter ϕ b (mm)	Resistance Ω
BTMC-05-D10-003LE Hole drilled: ϕ 1.0mm	0.5	5	ϕ 0.9	120
BTMC-1-D16-003LE Hole drilled: ϕ 1.6mm	1	5	ϕ 1.5	120
BTMC-3-D20-006LE Hole drilled: ϕ 2.0mm	3	10	ϕ 1.9	120

Gauge Lead: ϕ 0.1mm Polyimide sheathed of 30mm for BTMC-05 and BTMC-1, 60mm for BTMC-3

Bolt strain gauge installation/calibration service

Currently, bolts are used in various fields for connecting structural members. Confirmation and management of the fixing condition are possible by measuring axial force applied to the bolt in machine structures, cars, airplanes, expressways, bridges, fixing of segments, and so on. Also the axial force measurement is useful for knowing the strength of bolt and designing the bolt connection.

TML offers strain gauging service for measurement of axial force acting on bolts. The service includes drilling a hole, fixing the gauge, connecting the cable, and applying load calibration to the bolt supplied by the customer. Strain gauge installation service for high temperature is also available.

Processing method

There are two methods in strain gauge installation service. One is embedding, and the other is bonding.

Embedding BTM series

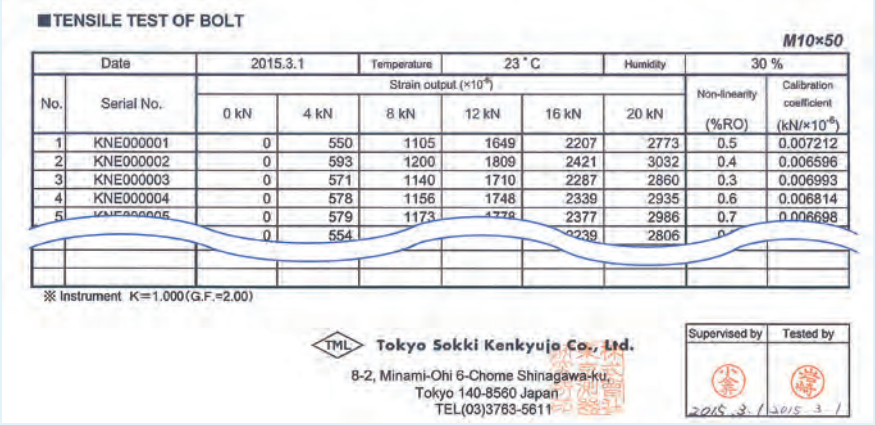
A hole of 1.6mm or 2mm in diameter is drilled in the center of the bolt. The strain gauge is inserted into the hole and embedded with an exclusive adhesive. This method has the advantage of avoiding the gauge being damaged by a washer, etc. while fastening the bolt.

Bonding F, QF, ZF, CF series

Two strain gauges are bonded on both sides of the bolt shaft in axially symmetric positions to cancel the influence of bending. It is required to slightly scrape off the surface of the bolt shaft where the strain gauges are bonded, for the purpose of avoiding strain gauges being damaged while fastening the bolt or by contact of a washer. Choose strain gauges according to the usage conditions including temperature.

Calibration service

In order to achieve accurate measurement, we offer calibration service that the bolt is calibrated with specified load. Instruments and calibration machines used for the calibration service are periodically calibrated and inspected by public institutions traceable to the national standards.



■TENSILE TEST OF BOLT

M10×50

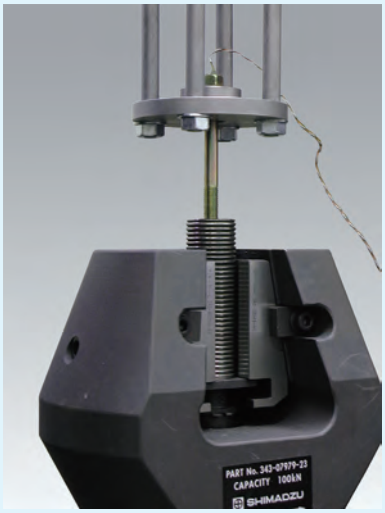
Date	2015.3.1	Temperature	23 ˚C	Humidity	30 %

No.	Serial No.	Strain output (×10⁻⁶) 0 kN	4 kN	8 kN	12 kN	16 kN	20 kN	Non-linearity (%RO)	Calibration coefficient (kN/×10⁻⁶)
1	KNE000001	0	550	1105	1649	2207	2773	0.5	0.007212
2	KNE000002	0	593	1200	1809	2421	3032	0.4	0.006596
3	KNE000003	0	571	1140	1710	2287	2860	0.3	0.006993
4	KNE000004	0	578	1156	1748	2339	2935	0.6	0.006814
5	KNE000005	0	579	1173	1778	2377	2986	0.7	0.006698
		0	554			2239	2806		

※ Instrument K=1.000(G.F.=2.00)

TML Tokyo Sokki Kenkyujo Co., Ltd.
8-2, Minami-Ohi 6-Chome Shinagawa-ku,
Tokyo 140-8560 Japan
TEL(03)3763-5611

Supervised by	Tested by
2015.3.1	2015.3.1



TEMPERATURE GAUGES series TF

Operating temperature range

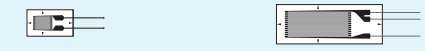
–20°C ——— +200°C

Applicable adhesives

NP-50B	–20 ~ +200ºC
C-1	–20 ~ +200ºC
CN	–20 ~ +120ºC

TEMPERATURE GAUGES

Gauge pattern	Basic type	Sensitivity (Ω / ℃)	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
			L : length	W : width (Unit:mm)			
These gauges are bonded on the specimen surface like as ordinary strain gauges, and measures the surface temperature. By combining with the dedicated temperature gauge adaptor (TGA-1A or TGA-1B), actual temperature can be measured easily using a strainmeter.	TFL-2-60	0.34 approx.	2	1.9	6.1	3.5	60
	TFL-3-60	0.34 approx.	3	3.2	8.5	5.0	60
	TFL-6-60	0.34 approx.	6	2.6	13.0	4.5	60
	TFL-8	0.68 approx.	8	3.5	14.0	5.4	120



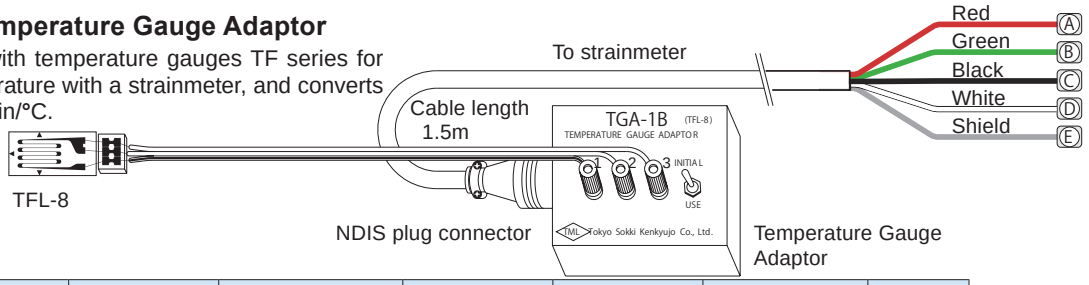
TFL-2-60

TFL-8

Integral leadwire is available. Refer to pages 19~20 for applicable integral leadwires.

TGA-1A/TGA-1B Temperature Gauge Adaptor

This adaptor is used with temperature gauges TF series for direct reading of temperature with a strainmeter, and converts output to 100x10^{-6} strain/°C.



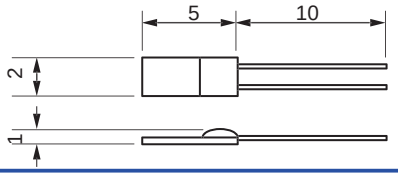
Type of Adaptor	Applicable gauge	Temperature °C	Sensitivity (x10^{-6} strain/°C)	Accuracy (°C)	Bridge mode	Dimensions W x H x D(mm)	Weight
TGA-1A	TFL-2-60	-20~+200	100	±1 or less	Full bridge	100 x40 x 70	370g
	TFL-3-60						
	TFL-6-60						
TGA-1B	TFL-8	-20~+200	100	±1 or less	Full bridge	100 x40 x 70	370g

PLATINUM RTD

PLATINUM RTD (Pt 100)

The Platinum RTD is mounted on a specimen and connect to a data logger to measure temperature. Easy measurement of temperature by bonding to specimen with strain gauge adhesive. Units equipped with leadwire are also available upon request.

Type	Rated current	Base size (mm)	Resistance	Operating temperature
CRZ-2005	1mA or less	5.0x2.0x1.1	100Ω (at 0°C)	–40 ~ +400ºC



Unit: mm

THERMOCOUPLE

A thermocouple configures the closed circuit in which a small electric current flows in the circuit composed of a pair of dissimilar conductors, and measures temperature using thermoelectric effect produced at both ends of conductors in different temperatures.

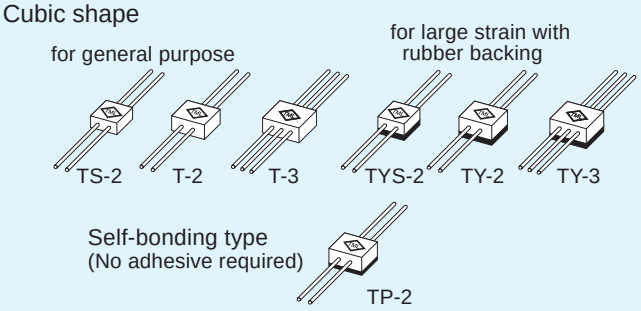
Type	Thermo-couple	Core diameter (mm)	Outer dimension (mm)	Sheath materials	Sheath color: Insulator +	Sheath color: Insulator –	Sheath color: Outer sheath	Heat-resistive temperature (ºC)	Length per roll (m)	Remarks
0.32x1P T-G	T	0.32	2.1x3.2	Heat-resistive vinyl	Red	White	Brown	approx.100	100	
0.65x1P T-G	T	0.65	2.6x4.0	Heat-resistive vinyl	Red	White	Brown	approx.100	100	
0.32x1P T-6F	T	0.32	1.0x1.6	Fluoroethylene propylene	Red	White	Brown	approx.200	100	
0.65x1P T-6F	T	0.65	1.5x2.5	Fluoroethylene propylene	Red	White	Brown	approx.200	100	
0.65x1P T-GS	T	0.65	ϕ 7.2	Heat-resistive vinyl	Red	White	Brown	approx.100	100	Shielded
0.32x1P K-H	K	0.32	1.4x2.3	Glass fiber	Red	White	Blue	approx.350	100	
0.65x1P K-H	K	0.65	2.0x3.4	Glass fiber	Red	White	Blue	approx.350	100	

CONNECTING TERMINALS

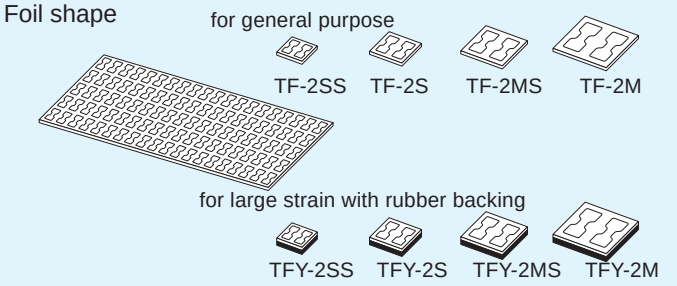
TML Connecting Terminals provide convenient junction points to connect strain gauges to instrumentation leadwires.

T series is made of a cubic plastic and two or three wires of approximately 0.8mm diameter are fixed to the cube. TY is laminated with rubber sheet and suitable for large strain measurement. TP-2 is a self-bonding terminal with two wires. TF is made of a 0.03mm thick copper foil and a glass-epoxy insulation base of approx. 0.15mm thick. TFY is laminated with rubber sheet approx. 0.8mm thick over the back side of TF series terminals.

Cubic shape



Foil shape



Cubic type

Type	Dimensions (mm)	Operating temperature (°C)	Quantity (pcs/box)
T-2	10x10x5	–20~+90	100
T-3 (3-wire method)	10x10x5	–20~+90	100
TS-2	7.5x7.5x5	–20~+90	100
TYS-2	7.5x7.5x7	–20~+90	100
TY-2	10x10x7	–20~+90	80
TY-3 (3-wire method)	10x10x7	–20~+90	80
TP-2	10x10x6	–20~+60	100

Foil type

Type	Dimensions (mm)	Operating temperature (°C)	Quantity (pairs/sheet)
TF-2SS	4.6x3.8x0.2	–196~+180	50
TF-2S	6 x5.3x0.2	–196~+180	50
TF-2MS	8 x7.2x0.2	–196~+180	50
TF-2M	10x9.2x0.2	–196~+180	50
TFY-2SS	4.6x3.8x0.8	–20~+120	50
TFY-2S	6 x5.3x0.8	–20~+120	50
TFY-2MS	8 x7.2x0.8	–20~+120	50
TFY-2M	10x9.2x0.8	–20~+120	50
TPF-2SS	4.6x3.8x0.2	–196~+200	50
TPF-2S	6 x5.3x0.2	–196~+200	50
TPF-2MS	8 x7.2x0.2	–196~+200	50
TPF-2M	10x9.2x0.2	–196~+200	50
TPFH-2SS	4.6x3.8x0.1	–269~+350	50
TPFH-2S	6 x5.3x0.1	–269~+350	50
TPFH-2MS	8 x7.2x0.1	–269~+350	50

NB: TPFH series are heat-resistive connecting terminals with polyimide resin backing to TPF. It allows high temperature measurement using QF/ZF series gauges and bonding repetition on the terminals.

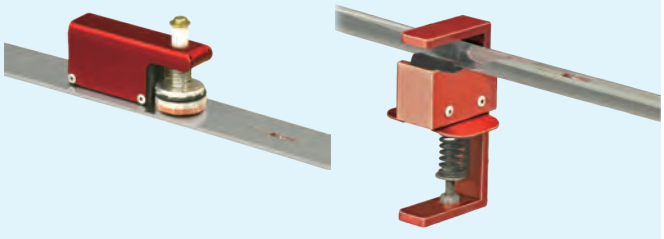
STRAIN GAUGE CLAMP

Gauge Mate GMR-S/GMA-S

When bonding a strain gauge, a fixing pressure should be applied to the gauge until curing is completed. This can be easily done using the TML Gauge Mate, which is a gauge clamp device consisting of a coil spring and a permanent magnet. For use on specimens of different shapes, two types are available. Model GMA-S is for flat specimens, and model GMR-S is for round specimens. Both can be used with room-temperature curing type bonding adhesives.

GMA-S
for flat specimen of 1mm thick or more

GMR-S
for round specimen of 6~32mm-dia.



Pressing jig PRESSEE PM-19

PRESSEE is a pressing jig capable of not only pressurizing the strain gauge but also checking adhesion status from the clear pressing part with eyes. The use of PRESSEE saves time to keep pressing the strain gauge with your finger in the bonding work. In addition, since the PRESSEE can apply a constant pressure to the strain gauge, bonding quality is expected to be higher than a finger pressure.

Applicable strain gauge	Gauge length of 6mm or less and backing dimension of ϕ 15mm or less
Applicable adhesive	CN/CN-R/CN-Y, P-2, NP-50B, EA-2A, EB-2
Pressing method	Magnetic method by permanent magnet
Object to be bonded	Flat surface of magnetic body
Dimensions	ϕ 29mm x Approx. 30mm height

Pressure area of ϕ 19mm for flat specimen.

STRAIN GAUGE ADHESIVES

STRAIN GAUGE ADHESIVES

Type		Contents	Component	Applicable specimen	Operating temperature	Curing temperature and time	
CN	Single component Room-temperature-curing	Single 2g x 5	Cyanoacrylate	Metal, Plastics Composite	–196~+120°C	Room temperature 20sec.~1 min. (thumb pressure)	
CN-E	Single component Room-temperature-curing	Single 2g x 5	Cyanoacrylate	Concrete Mortar, Wood	–30~+120°C	Room temp. 40sec.~2 min. (thumb pressure)	
CN-R	Single component Room-temperature-curing	Single 2g x 5	Cyanoacrylate	Metal, Plastics Composite	–30~+120°C	Room temp. 10~30sec. (thumb pressure)	
CN-Y	Single component Room-temperature-curing	Single 2g x 5	Cyanoacrylate	Metal, Plastics Composite	–30~+80°C	Room temperature 60 sec.~2 min. (thumb pressure)	
P-2	Two-component Room-temperature-curing Mixing ratio: 2~6%	A: 25g B: 3g	Polyester	Metal	–30~+180°C	Room temperature Pressure 50~300kPa 2~3 hrs.	
RP-2	Two-component Room-temperature-curing Mixing ratio: 2~4%	A: 25g B: 3g	Polyester	Concrete Mortar	–30~+180°C	Room temperature Pressure 50~300kPa 2~3 hrs.	
PS	Two-component Room-temperature-curing Mixing ratio: 2~4%	A: 25g B: 3g	Polyester	Concrete Mortar Wood	–30~+100°C	Room temperature 2~3 hrs.	
NP-50B	Two-component Room-temperature-curing Mixing ratio: 3~4%	A: 25g B: 3g	Polyester	Metal Composite	–30~+300°C	Room temperature Pressure 50~300kPa 16 hrs.	
C-1	Single component Heat-curing	Single 25g	Phenol	Metal	–269~+200°C	Pre-curing at 130°C 1 hr., pressure 200~300kPa. Post-curing at 200°C 1 hr. without pressure	
EA-2A	Two-component Room-temperature-curing Mixing ratio: 2:1	A: 25g B: 15g	Epoxy	Metal, Concrete Composite	–269~+50°C	Pressure at 50~300kPa. Room temperature 1 day, or at 50°C 2 hrs.	
EB-2	Two-component Room-temperature-curing Mixing ratio: 10: 3	A: 10g x3 B: 3g x3	Epoxy	Metal Composite	–60~+200°C	Room temperature 1 day Pressure 50~200kPa.	
A-2	Two-component Heat-curing Mixing ratio: 10: 1	A: 25g B: 5g	Epoxy	Bolt	–30~+100°C	Room temperature 12 hrs. and 140°C 3 hrs.	

NB: Shelf life

Effective storing duration on condition that the adhesive is properly kept in a cool dry and dark place such as a refrigerator (+5~+10°C, do not store in a freezer).

Thumb pressure 100~300kPa

For two-component adhesives, use the supplied mixing vessles.

Mixing vessles: Polyethylene make
75mm-diameter, 10mm depth

Point

- In general, curing time of an adhesive called "room temperature curing type" is largely affected by environmental conditions such as temperature and humidity. Referring to the curing conditions described in the supplied operation manual, it is recommended to carry out a "test curing" on the site.
- A trace of water in the air is requreid to cure the CN adhesive (cyanoacrylate). Therefore the curihng time is largely affected by humidity rather than temperature.

	Shelf life	Applications
	6 months	Single component adhesive for strain gauges. The time required to bond the gauge is extremely short and handling is very easy. The thin bonding layer allows adhesion to plastic objects as well as metal. Curing time under normal conditions is 20~60 seconds.
	6 months	Single component adhesive featuring high viscosity for bonding strian gauges to porous materials such as concrete and mortar. Curibng time under normal conditions is 40~120 seconds.
	3 months	Single component adhesive for accelerating cures in lower ambient temperature, or lower relative humidity. Curing time under normal conditions is 10~30 seconds.
	6 months	Single component adhesive designed exclusively for use on post-yield strain gauge. Offers minimum degradation in bonding performance (peel strength) due to aging. Suitable when a large strain measurement is made after a few days or more of bonding the strain gauge. Curing time under normal conditions is 60~120 seconds.
	6 months	Two-component room-temperature-curing polyester adhesive for bonding PF, P and F series strain gauges. Put the necessary quantity of drug A in the supplied mixing vessel, then add drug B by drops to total 2~6% in weight of drug A. Use the mixed adehsive within 5~15 minutes.
	3 months	Two-component room-temperatuere-curing polyester adhesive for bonding PF and P series strain gauges. The mixing procedure is the same as above for P-2 adhesive. Put the necesary quantity of drug A in the supplied mixing vessel, then add drug B by drops to total 2~4% by weight of drug A. Use the mixed adhesive within 10~20 minutes.
	3 months	Two-component room-temperature-curing polyester adhesive. Used as a surface precoating agent for bonding P and PF series gauges to concrete and also as an adhesive for WFLM series gauges. The special filler contained exhibits alkali resistance and effectively shuts off moisture and gas from inside of the concrete. Its high viscosity enables use on vertical walls or ceilings. Put the necessary quantity of drug A in the supplied mixing vessel, then add drug B by drops to total 2~4% by weight of drug A.
	6 months	Two-component room-temperature-curing polyester adhesive for bonding QF, ZF and BF series strain gauges. Put the necessary quantity of drug A into the supplied mixing vessel then add drug B by drops to total 3~4% by weight of drug A. Use the mixed adhesive within 5~20 minutes.
	3 months	Single-component heat-curing type adhesive. For use on strain gauges that are suited to heat curing. Enables reliable measurement for long periods and in high temperature up to 200°C.
	3 months	Two-component room-temperature-curing epoxy adhesive for bonding CF series strain gauges for use in temperature from cryogenic (–269°C) up to 50°C. Mix the necessary quantity of drugs A and B at the weight ratio of 2 to 1.
	3 months	Two-component room-temperature-curing epoxy adhesive for bonding strain gauges for use in temperature from –60 to +150°C. Enables stable measurement for a long period of time. Mix the necessary quantity of drugs A and B at the weight ratio of 10 to 3.
	3 months	Two-component heat-curing epoxy adhesive for bonding BTM strain gauges. Mix the necessary quantity of drugs A and B at the weight ratio of 10 to 1, then pour the mixed adhesive into a hole drilled on the bolt in which the gauge is inserted. Keep at room temperature for 12 hours, then cure at 140°C in furnace for 3 hours.

MSDS : Material Safety Data Sheet

TML supplies MSDS for all its strain gauge adhesives and coatings. Contact your TML supplier for more information.

COATING MATERIALS

COATING MATERIALS

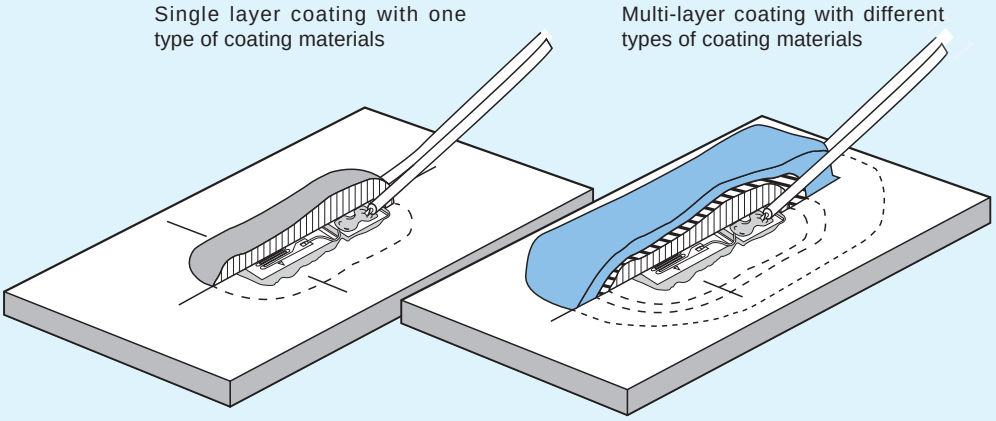
Type	Materials	Color	Contents	Operating temperature	Curing conditions	
W-1	Microcrystalline wax solid	Light yellow	Single 500g	0~+50°C	Hot melting +100~+120°C Hardening in room temperature	
N-1	Chloroprene rubber based solvent thinned	Light yellow	25g	–30~+80°C	Air-drying A half day in room temperature	
K-1	Special rubber based solvent thinned	White	25g	–269~+60°C	Air-drying A half day in room temperature	
UE-1	Special rubber based solvent thinned	Brown	25g	–40~+150°C	Air-drying A half day in room temperature	
SB tape	Buthyl rubber	White	10mm(wide)x3mm (thick) 5m long/roll	–30~+80°C	Pressure sensitive	
VM tape	Buthyl rubber	Black	38mm(wide) x1mm (thick) 6m long/roll	–20~+80°C	Pressure sensitive	
KE-348W	Silicone rubber	White	100g	–50~+200°C	Air-drying A half day in room temperature	
KE-348T		Transparent	100g			
TSE3976-B	Silicone rubber	Black	100g	–50~+300°C	Air-drying One day in room temperature	

MSDS : Material Safety Data Sheet

TML supplies MSDS for all its strain gauge adhesives and coatings. Contact your TML supplier for more information.

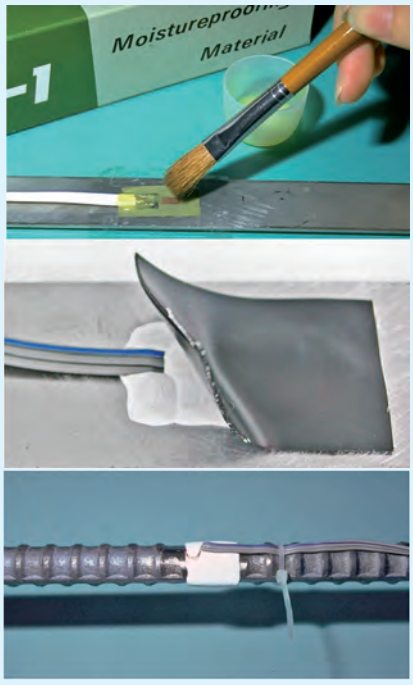
Coatings in special substances

For use in special substances such as acids, alkalis and alcohols, contact TML or your local representatives.

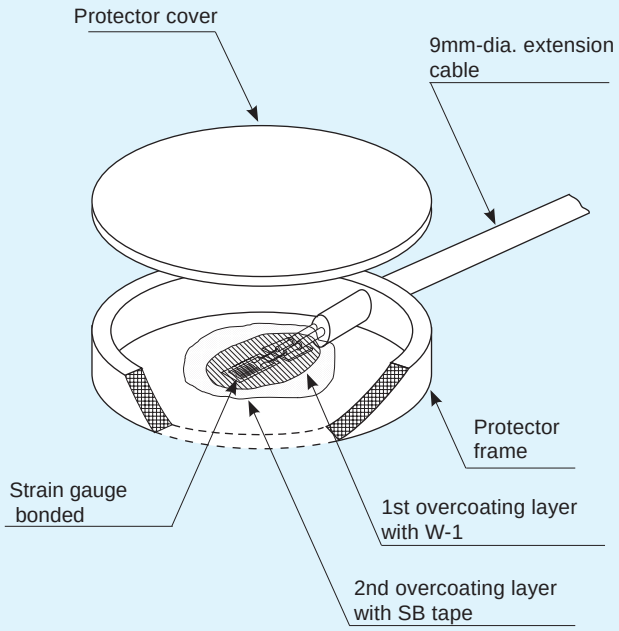


The type of coating required and the application method differ depending on the environment in which the strain gauge is used. In general, if one type of coating is not sufficient, multiple coatings can be combined to protect the strain gauges. At TML, the coating applied directly to the surface of the strain gauge is referred to as the first coating with subsequent coating layers referred to sequentially as the second coating, third coating, etc. Multi-layer coatings offer better strain gauge protection.

	Purpose	Applications
	Moisture- and water- proofing coating for laboratory and field requirements where mechanical protection is not needed, or used as a first coating for multi-layer coating.	The solid W-1 is put into a heating appratus (temprarure-regulated oil bath is recommended) and completely melted at 100 to 120°C. The hot melted W-1 is applied over the area to be coated with a brush. The W-1 cools and turns into solid as soon as the application. It is usually applied repeatedly till the cooled W-1 forms an adequate thickness.
	Moisture- and water- proofing coating for laboratory and less severe field requirements where mechanical protection is not needed.	A layer of N-1 is applied directly from the tube or with a brush over the area to be coated. Curing time is about half a day in room temperature, but it depends on conditions such as the specimen material, temperature, and so on. If the coating layer is too thin, apply another layer to make an adequate thickness.
	Moisture-proofing coating from cryogenic to room temperature for laboratory requirements. Does not provide a high degree of mechanical protection.	A layer of K-1 is applied directly from the tube or with a brush over the area to be coated. Curing time is about half a day in room temperature, but it depends on conditions such as the specimen material, temperature, and so on. If the coating layer is too thin, apply another layer to make an adequate thickness.
	Oil-resistant coating for laboratory and field requirements. Does not provide a high degree of mechanical protection.	A layer of UE-1 is applied directly from the tube or with a brush over the area to be coated. Curing time is about half a day in room temperature, but it depends on conditions such as the specimen material, temperature, and so on. If the coating layer is too thin, apply another layer to make an adequate thickness.
	Moisture- and water-proofing coating for laboratory and field requirements where mechanical protection is not needed, or used as a first coating for multi-layer coating. Offers excellent moisture and water resistant characteristics and is very convenient for use.	The SB tape is cut in an appropriate length and applied over the area to be coated. The application is completed by pressing down the SB tape fimly with a spatula or your finger covered with the separating paper. It is also applied under the leadwire prior to the overcoating.
	Used as a second coating or later for multi-layer coating. Offers excellent moiture and water resistant characteristics. Very convenient for use.	The VM tape is cut in an appropriate length and applied over the area to be coated with finger pressure. The VM tape must not be applied directly over a strain gauge as a first coating.
	Suitable for laboratory requirements with high temperature conditions where high degree of mechanical protection is not needed.	The KE-348 is applied directly from the tube over the area to be coated. Curing time is about one day in room temperature, but it depends on conditions such as temperature, humidity, and so on.
	Suitable for laboratory requirements with high temperature conditions where high degree of mechanical protection is not needed.	The TSE3976-B is applied directly from the tube over the area to be coated. Curing time is about one day in room temperature, but it depends on conditions such as temperature, humidity, and so on.



GAUGE PROTECTOR

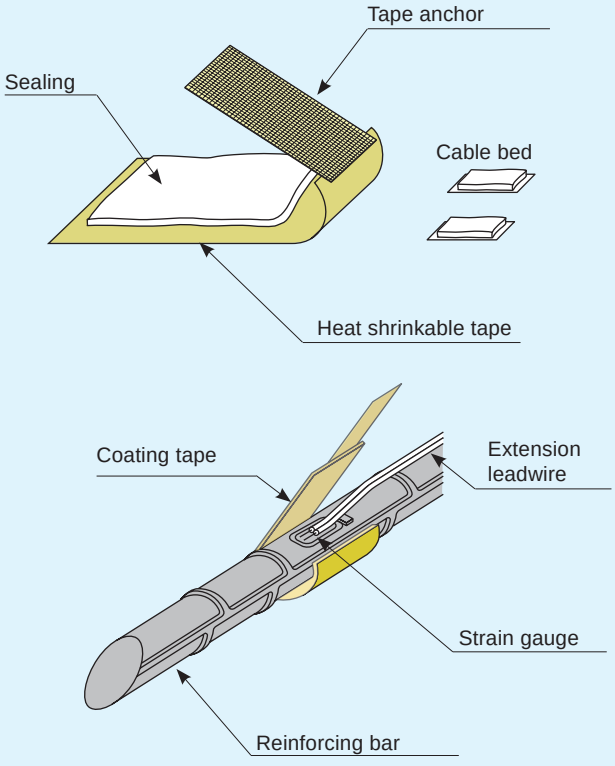


This rubber protector is designed to protect gauges which are bonded onto metal surface from the environment for long-term measurement. The strain gauge is packed inside together with the applied adhesive and overcoating materials. The protector is also provided with a hole for cable intake. It allows the entire area to be isolated from ambient conditions which may affect reliable measurement, and further increases the coating performance.

Specifiction

Dimensions	Frame: ϕ 100mm (Inner ϕ 92mm) x 15mm (Height) Cover: ϕ 100mmx 3mm (Thick)
Operating temperature	–20 ~ +80°C
Extension cable	ϕ 9mm cable recommendable

COATING TAPE for reinforcing bar



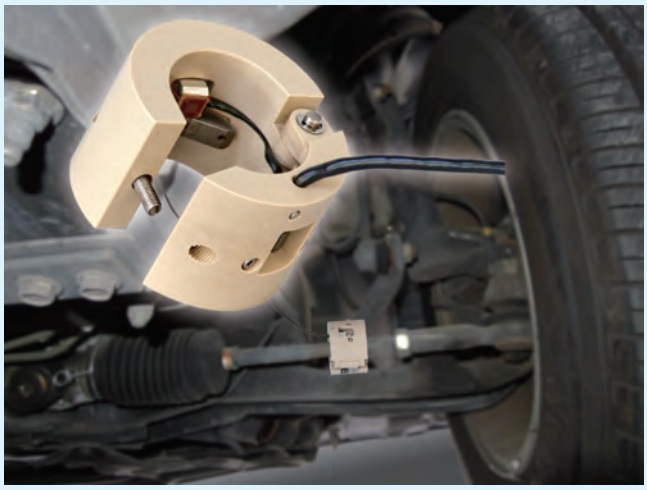
This tape is specially designed for use as a waterproof coating for stain gauges bonded onto reinforcing bars or other cylindrical surfaces. Coating is achieved by simply taping it onto the surface, saving considerable time in comparison with coventional procedures. (A heat gun is required for application.)

Specifications

Operating temperature: –20~+80°C

Type	Applicable reinforcing bar	Qty. per box	Strain gauges	Size finish (example)	
				Reinforcing bar	Dia. x Width (mm)
CT-D04	D4	10	FLK-2-11	D4	ϕ 10x21
CT-D06	D6	10	FLK-2-11	D6	ϕ 12x21
CT-D10	D10	10	FLK-2-11	D10	ϕ 15x21
CT-D13	D13	10	FLA-3-11	D13	ϕ 19x26
CT-D16	D16	10	FLA-3-11	D16	ϕ 21x26
CT-D25	D19~D25	10	FLA-3-11	D25	ϕ 31x31
CT-D35	D29~D35	10	FLA-3-11	D32	ϕ 37x35

Axial Strain Transducer FGAH-1A



This is a transducer to measure axial strain of steering tie-rod of a car. It is also suited to measure axial strain of a tension rod used in aseismic reinforcement structure or in steel frame structure. Since frictional strain gauges are used in this transducer, installation is completed and it gets ready for measurement by merely pinching the rod with the transducer, without detaching the rod. There is no need of technical skill and complicated works for attaching strain gauges on the rod.

NB:
- Frictional strain gauges are consumable parts.
  Applicable type of frictional strain gauges is CBFC-2 (option).

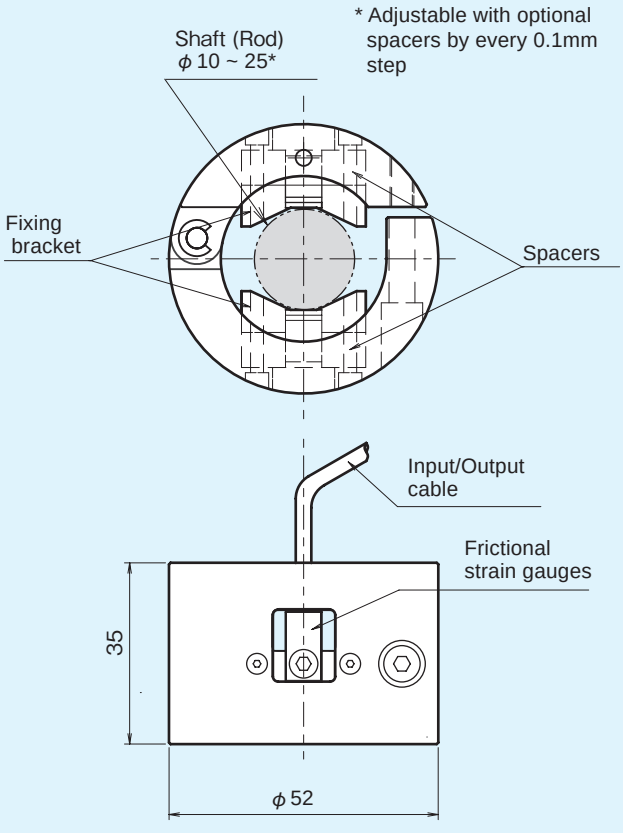
Applicable not only for tie-rod of motor cars but also for tension rod of architectural structures

- Easily installed by just clamping-on without detaching the existing tie-rod
- Tensile force management of rod between sheet piles or in architectural structures is easily achieved – The transducer can be used repeatedly
- Applicable rod diameter is 10 to 25mm (Optional spacers are required)
- Small and light construction which allows installation in a narrow space

■Specifications

Type	FGAH-1A
Applicable shaft diameter	ϕ 10 ~ 25mm
Capacity	±1000×10^{-6} strain
Rated output	Approx. 2600×10^{-6} strain
Non-linearity	1%RO
Allowable temperature range	-30 ~ +60°C (no dew condensation)
Frequency response	Approx. 6.5kHz
Input/output resistance	1000Ω±3%
Dimensions	Approx. ϕ 52x35mm
Weight	Approx.55g(excluding spacers and cable)
Protection rating	Equivalent to IP51
Recommended exciting voltage	2V
Allowable exciting voltage	5V
Input/output cable	ϕ 3.2mm 0.08mm² 4-core shielded vinyl cable 5m

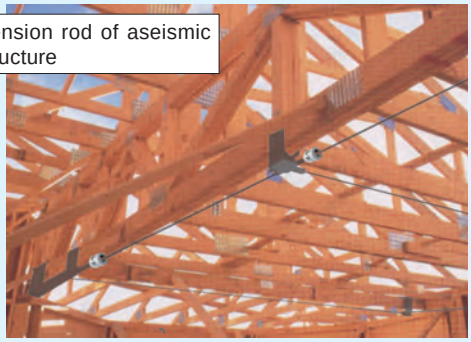
■Dimensions



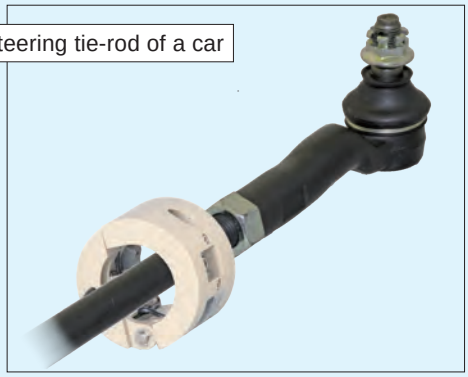
Unit : mm

■Installation image

Installation on tension rod of aseismic reinforcement structure

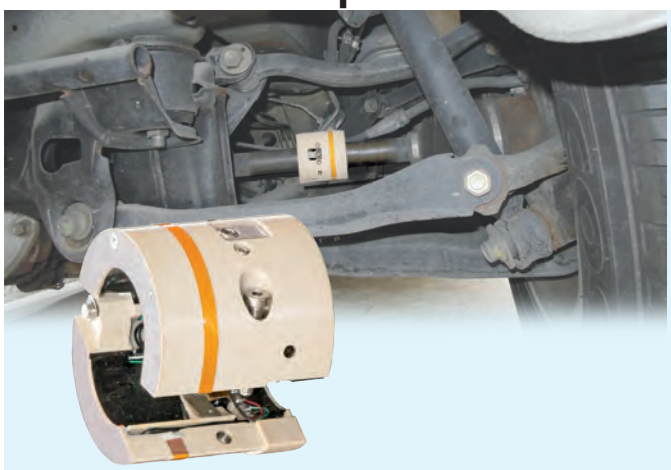


Installation on steering tie-rod of a car



Turnbuckle part

Frictional type Torque Transducer FGDH-2A

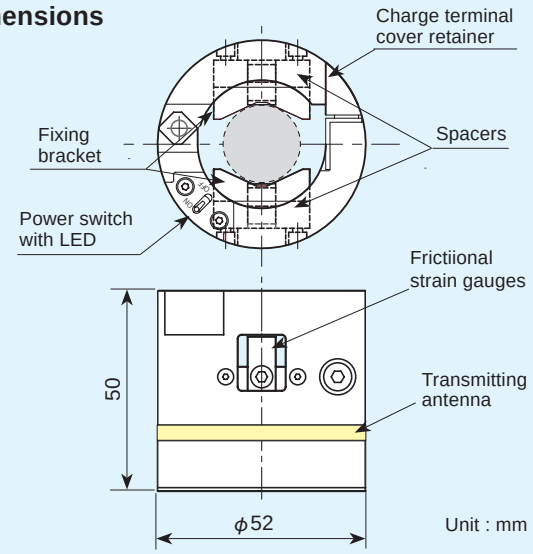


Features

- Easily installed by just clamping-on without detaching the drive shaft
- No bonding is required because frictional strain gauges are used
- Wireless transmission of measured data – no wiring is required
- Noise resistant measurement by the use of digital telemetry system
- Applicable shaft diameter is 20 to 30mm (optional spacers are required)
- Battery is rechargeable with the sensor installed on the shaft

This is a transducer to measure torque on the drive shaft of a car. Frictional strain gauges are used as sensing elements, and the installation is completed by clamping the torque sensor onto an existing shaft and securing it with a screw. There is no need of detaching the shaft nor bonding and wiring strain gauges for the installation. The transducer is applicable to shafts having diameter of 20mm to 30mm using spacers together, which are available as optional items. A digital telemetry transmitter is built in the sensor, and measured data are transmitted to an exclusive receiver DT-041R-1 by wireless and output as analog signals. For wireless transmission, 315MHz band extremely low power radio wave is used.

■Dimensions



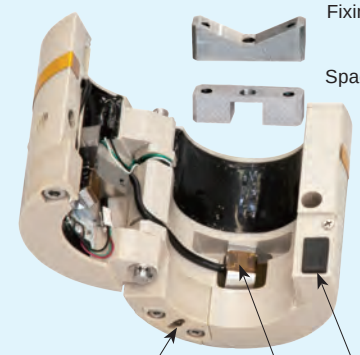
■Specifications

Type	FGDH-2A
Applicable shaft diameter	ϕ20.0 ~ 30.0mm
Capacity	Depends on the diameter (outer/inner) and material of the shaft
Output	Depends on the diameter (outer/inner) and mateiral of the shaft However, within ±16000x10^{-6} strain including initial unbalance of ±2000x10^{-6} strain
Non-linearity	1%RO
Allowable temperature	–20 ~ +60°C (no dew condensation)
Sampling frequency	10kHz
Frequency response	Approx. 1.1kHz
Carrier frequency	315 ~ 321MHz
Number of wireless channels	4
Dimensions	ϕ52 x 50mm
Weight	Approx. 85g (excluding spacer)
Protection rating	Equivalent to IP51
Continuous operating time	Approx. 8 hours (23±5°C)
Power source	Lithium secondary battery
Accessory	USB charger

NB:

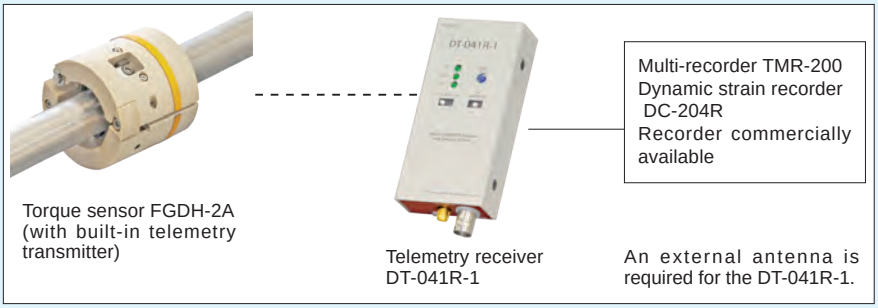
- FGDH-2A uses 315MHz band extremely low power radio wave for wireless transmission.
- This system is not approved for use outside Japan.
- Frictional strain gauges are consumable parts.
  Applicable type of frictional strain gauge is CBFTC-2 (option).
- A torque driver is required for installation of FGDH-2A.

■Name of each part



Spacers FGDHF-41-X
(X shows the thickness of the spacer)
FGDH-2A is applicable to shaft diameter of Φ20.0 ~30.0mm by replacing the spacers. The spacer is available by every 0.1mm step.

■Measuring system



Frictional type Torque Transducer FGDH-3A

This is a transducer to measure torque on the drive shaft of a car. Frictional strain gauges are used as sensing elements, and the installation is completed by clamping the torque transducer onto an existing shaft and securing it with a screw. There is no need of detaching the shaft nor bonding and wiring strain gauges for the installation. The transducer is applicable to shafts having diameter of 20mm to 30mm using spacers together, which are available as optional items. A digital telemetry transmitter is built in the sensor, and measured data are transmitted to an exclusive receiver DT-182R by wireless and output as analog signals. For wireless transmission, 2.4GHz band advanced low power data communication system is used.

Features

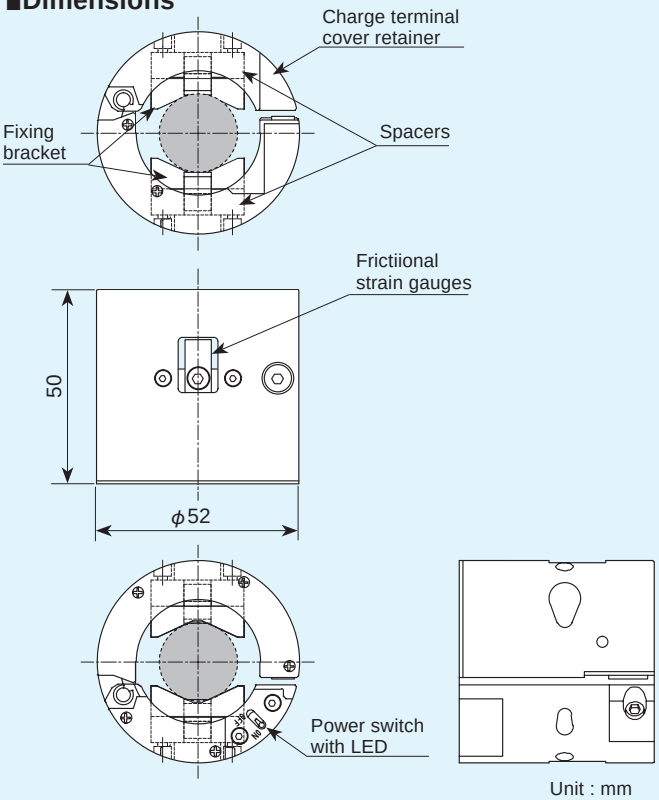
- Easily installed by just clamping-on without detaching the drive shaft
- No bonding is required because frictional strain gauges are used
- Wireless transmission of measured data – no wiring is required
- Globally standardized 2.4GHz band data communication system is used for noise resistant digital transmission
- Applicable shaft diameter is 20 to 30mm (optional spacers are required)
- Battery is rechargeable with the transducer installed on the shaft
- Power saving function provided

■Specifications (Toque transducer)

Type	FGDH-3A
Applicable shaft diameter	ϕ20.0 ~ 30.0mm
Capacity	Depends on the diameter (outer/inner) and material of the shaft
Output	Depends on the diameter (outer/inner) and mateiral of the shaft However, within ±16000x10^{-6} strain including initial unbalance of ±2000x10^{-6} strain
Non-linearity	1%RO
Allowable temperature	–20 ~ +60°C (no dew condensation)
Sampling frequency	5kHz
Frequency response	1kHz
Wireless specifications	Conforms to 2.4GHz band advanced low power data communication system
Number of wireless channels	16
Dimensions	ϕ52 x 50mm
Weight	Approx. 85g (excluding spacer)
Protection rating	Equivalent to IP51
Continuous operating time	Approx. 6 hours (23±5°C)
Power source	Lithium secondary battery
Accessory	USB charger

NB:
- This system is approved for use in Japan, People's Republic of China, and EU. Please contact us for other countries.
- Frictional strain gauges are consumable parts.
  Applicable type of frictional strain gauge is CBFTC-2-005CT. (option).
- A torque driver is required for the installation of FGDH-3A

■Dimensions

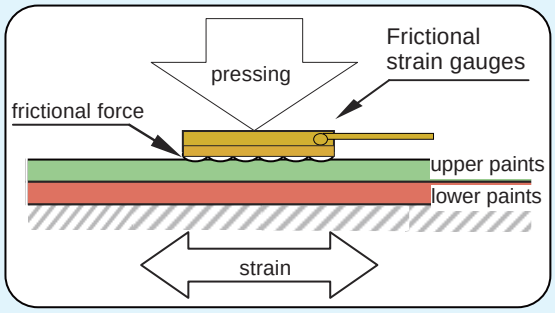


■Specifications (Receiver)

Type	DT-182R
[Wireless part]	
Number of reception	1
Wireless specifications	Conforms to 2.4GHz band advanced low power data communication system
Number of wireless channel	16 channels (Set by wave channel switch)
Antenna connecting terminal	SMA connector
[Volage output part]	
Number of voltage output	Either 1 of received strain value or transmitter battery voltage (BNC)
Strain measurement	±5V FS (at ±16000x10^{-6} strain input, 5kΩ load)
Transimitter battery voltage measurement	+1.3 ~ +3.9V (5kΩ load)
Voltage output accuracy	±0.5%FS (Entire system)
Stability on zero	±0.55mV/°C (Entire system)
Stability on sensitivity	±0.05% FS/°C (Entire system)
SN ratio	47dB
Calibration output level	±5V
Low-pass filter	100Hz, 500Hz, PASS(1kHz)(–3dB±1dB)
Balancing range	±6000x10^{-6} strain
Balancing accuracy	±5mV
Display/Operation	LED for output level, Low-pass filter selection switch, Calibration output selection switch, Balancing switch
[General Specifications]	
Power source voltage	DC9~16V
Current consumption	80mA Max. (when DC12V is supplied at +23°C ±5°C)
Connector	HOSHIDEN HEC3800 (Compatible plug : ϕ5.5x3.3 PIN ϕ1mm)
Operating environment	0 ~ +50°C, 85%RH or less (no dew condensation)
External dimensions	48(W) x 23.5(H) x 100(D) mm (except projecting parts)
Weight	Approx. 140g
Standard accessory	BNC coaxial cable (CR-31) DC power cable (CR-062) Receiving antenna (AA2402RSPU)

NB:
- Coaxial cable for the extension of receiving antenna is required.
  C3RSPJ-EXT-1M (1m long), C3RSPJ-EXT-3M (3m long), C3RSPJ-EXT-5M(5m long)

Frictional type Strain Checker FGMH series

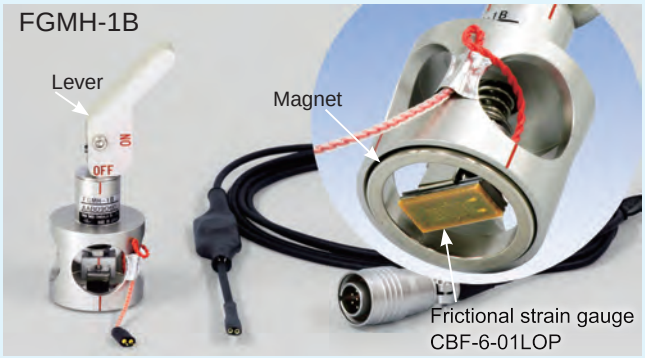


The Strain checker FGMH series measures strain using frictional force working on the contact surface of the frictional strain gauge by pressing the gauge against the structure with magnetic force. Unlike bondable strain gauges, surface preparation and bonding works are not required for this series, thus the works required for strain measurement are largely reduced. In combined use with a handheld type strainmeter, the strain checker can easily measure strains on steel materials such as bridges by changing measurement point one after another. It is the most suited to preparatory measurements before starting a long term measurement.
In the FGMH series, three types are available. They are FGMH-1B and FGMH-2A both for single axis measurement and FGMH-3A for 0°/45°/90° three-axis measurement.

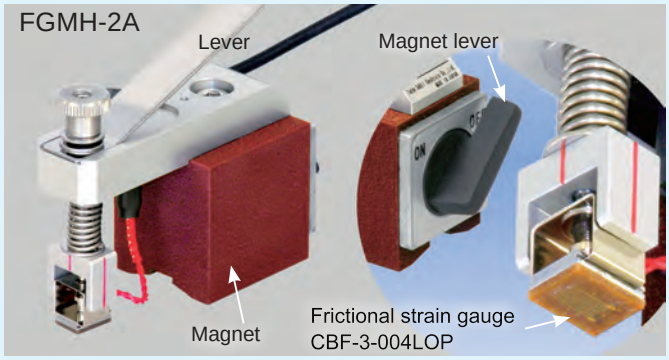
No bonding is required for strain measurement on steel

- Easily mounting and detaching by the lever operation
- Paint removal, grinding, bonding and curing are not necessary
- Can be used repeatedly
- Strain measurement in three directions (FGMH-3A)

Single axis measurement FGMH-1B/FGMH-2A

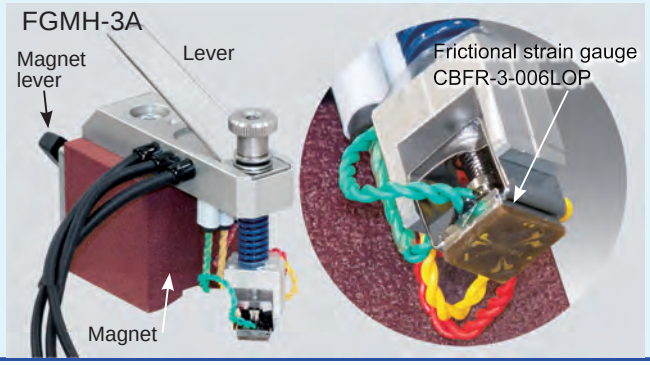


The FGMH-1B is a strain checker constructed small and light. The frictional strain gauge is set to on, off and replacing position by the operation of lever, thus allowing easy handling of the strain checker. The frictional strain gauge is a consumable part. If it is stained, deteriorated or damaged, replace it with a new one.
Option: Applicable frictional strain gauge CBF-6-01LOP



The FGMH-2A is a strain checker especially designed for measurement on a small area such as the vicinity of a welded part. It can be easily attached to and detached from the measurement object by the operation of magnet lever. In addition, a lever is provided on the upper part to slightly lift the frictional strain gauge from the measurement surface by pushing the lever downward. It enables easy adjustment of the direction of the strain gauge. The frictional strain gauge is a consumable part. If it is stained, deteriorated or damaged, replace it with a new one.
Option: Applicable frictional strain gauge CBF-3-004LOP

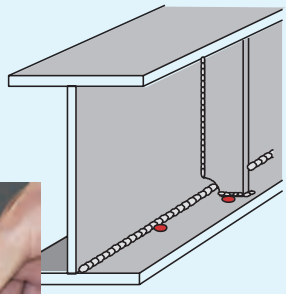
Three-axis measurement 0º/45º/90º FGMH-3A



The FGMH-3A is a strain checker for three-axis measurement in 0°/45°/90°. Principal stress (principal strain) and its direction are known by applying rosette analysis calculation to the measured strain values in three directions. It is applicable to measurement in the vicinity of weld bead like as the FGMH-2A. Also similarly as the FGMH-2A, it can be easily attached to and detached from the measurement object by the operation of magnet lever. Another lever is provided for easy adjustment of the direction of the strain gauge.
The frictional strain gauge is a consumable part.
If it is stained, deteriorated or damaged, replace it with a new one.
Option: Applicable frictional strain gauge CBFR-3-006LOP

Application examples

- Preparatory measurement of bridge which will undergo a long term measurement
- Investigation of neutral axis position of composite girder bridge
- Stress direction of structural member of bridge on which fatigue crack is initiated
- Stress measurement of newly built bridge where paint removal is not available.



Strain measurement in a narrow area

Stress concentration is caused in the vicinity of weld bead, which is deposit of welded materials along the welding pass. The strain checker FGMH-2A/FGMH-3A is capable of strain measurement in a narrow area such as the vicinity of weld bead because it is easily attached and detached by ON/OFF operation of the magnet lever. Strain in three directions can be measured simultaneously by the use of FGMH-3A.

■Specifications

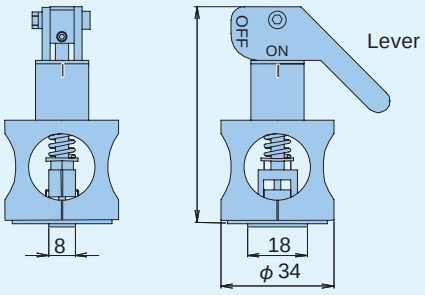
Type	FGMH-1B	FGMH-2A	FGMH-3A
Number of axes	Single axis		Three-axis
Gauge length	6mm	3mm	
Operating temperature	0 ~+60ºC		
Compensated temperature range	0 ~+60ºC		
Objective material	Metal, Steel (Coefficient of thermal expansion 11ppm/ºC)		
Input/Output resistance	120Ω		
Gauge factor	Approx. 2		
Measurement mode	Full bridge		
Input/Output cable	–	ϕ 3mm 0.05mm² 4-core shielded chloroprene cable of 2m NDIS 7-pin plug attached	
Supplied cable	Leadwire with bridge circuit board 2m, NDIS 7-pin plug attached	–	
Weight (excluding cable)	Approx. 60g	Approx. 260g	

Note:

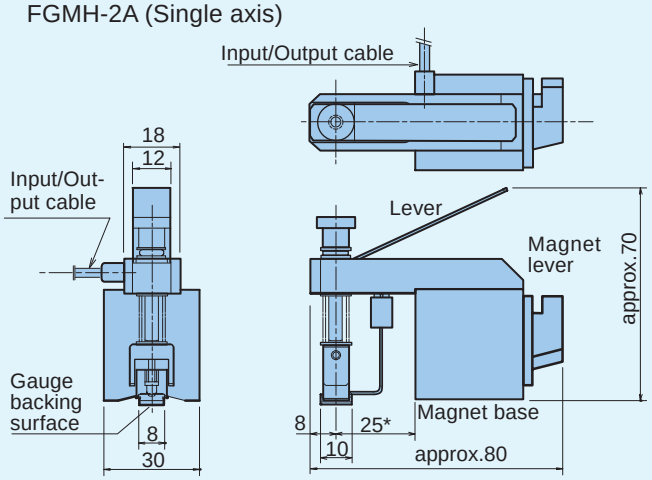
- The strain checker is installed on the measurement object by magnetic force. It is not applicable to the measurement on non-magnetic materials.
- The strain checker is not applicable to the use on a curved on uneven surface.
- If the vicinity of the strain checker is hit strongly with a hammer or an equivalent, a shift in the measured value may be caused.
- Correct measurement may not be possilble by the strain checker on a machine or structure experiencing strong vibration.
- For more precise measurement, it is recommended to remove the paint and to bond an ordinary strain gauge on the basic metal surface.

■Dimensions

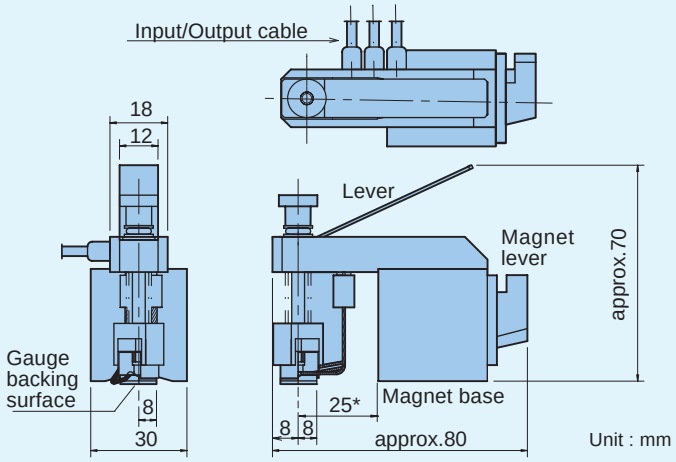
FGMH-1B (Single axis)



FGMH-2A (Single axis)



FGMH-3A (0º/45º/90º Three-axis)



*: When the gauge backing surface is in parallel with the magnet base. (FGMH-2A, FGMH-3A)

TML Strain measuring instruments

Highly reliable and multi-functional
High performance Data Logger TDS-630

This is a high performance data logger featuring high speed, highly reliable and multi-functional measurement as well as excellent ease of use. Strain measurement of 1000 points in 0.1 seconds is possible in combined use with IHW-50H high speed switching boxes. The distance between every two switching boxes is extendable up to 100 meters using exclusive cables.

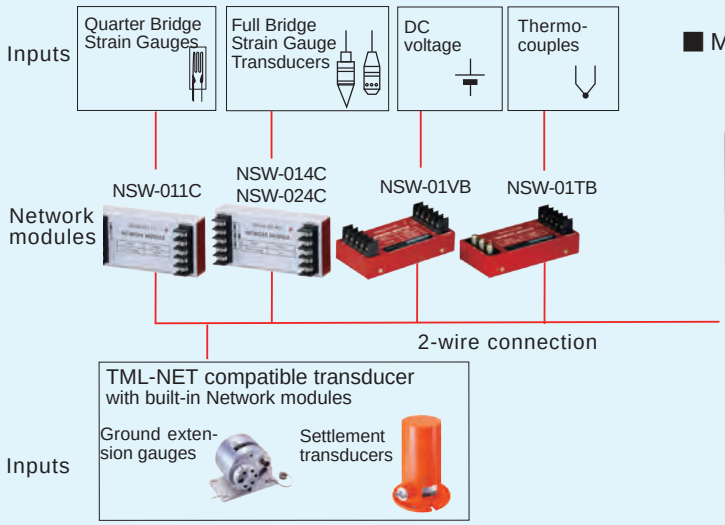
High speed Swtiching Box
IHW-50H

Measuring range and resolution	±4000x10^{-6} strain, 0.1x10^{-6} strain (high resolution mode) ±640000x10^{-6} strain, 16x10^{-6} strain (normal resolution mode)
Measuring accuracy	±0.05%rdg + 1 digit (at 23±5°C)
Input	Strain : Quarter, Half and Full bridge Thermocouple : 7 types Voltage
Measuring speed	1000 points/0.1 seconds (at the fastest, ADC parallel processing)
Calculation function	Four arithmatic operations, Trigonometrical functions, Rosette analyses, Others
Optional software TDS-7130v2	On this software, visual monitor, vector monitor of principal stress, and other monitor graphs are avilable.

Field measurement
Network Measurement System TML-NET

TML-NET is a data acquisition network for strain measurement to perform measurement control and data transfer using two-wire cable. Unlike ordinary analog measurement system, there is no influence of sensitivity drop due to cable extension and insulation lowering, so long term and stable measurement is achieved.

Connection between measurement modules can be made by star type or ring type, wiring easily done as the case may be and wires saved to reduce cost.



■ Monitoring System Controller MD-111

- Output contact functions to bulid an alarm system
- Measurement with sleep interval function
- RS-232C interface available
- 100 modules use with external DC input
- Data recording on SD card
- Total cable extension up to 1,000 meters

ALARM outputs — Revolving light

Pulse count — Tipping bucket rain gauge

Dynamic Strainmeter
Easy sensitivity adjustment by digital method

High precision Carrier type
DA-18A, DA-38A

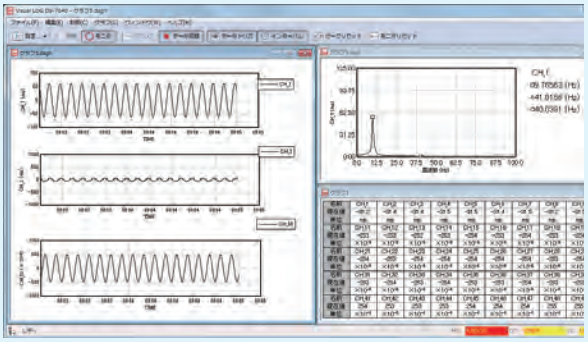
High response DC type
DC-96A, DC-97A

Bridge Boxes

Type	DA-18A/DA-38A	DC-96A/DC-97A
Gauge resistance	60~1000Ω	60~1000Ω
Bridge excitation	2 or 0.5Vrms 5kHz:DA-18A/20kHz:DA-38A	DC0.5,1,2,5,10V
Measuring range	±50,000×10^{-6} strain	±100,000×10^{-6} strain
Sensitivity	1V (5kΩ load) *1	1V (5kΩ load) *1
Output	±10V (5kΩ load)	±10V (5kΩ load)
Frequency response	DC~2.5 kHz: DA-18A DC~ 10 kHz: DA-38A (-3dB±1dB)*2	DC~ 200kHz: DC-96A DC~ 500kHz: DC-97A (-3dB±1dB)*2
SN ratio	60dBp-p or more :DA-18A *3 56dBp-p or more :DA-38A *3	34dBp-p or more : DC-96A *3 30dBp-p or more : DC-97A *3
Stability On zero	±0.1×10^{-6} strain/°C *3 ±0.5×10^{-6} strain/24h *3	±0.5×10^{-6} strain/°C *3 ±5×10^{-6} strain/24h *3
On Span	±0.05%/FS/°C ±0.2%/FS/24h	±0.01%/FS/°C ±0.05%/FS/24h

at Bridge excitation voltage 2Vrms (DA-18A/DA-38A), DC2V(DC-96A/DC-97A)
*1 at SENS=50×10^{-6} strain
*2 at PASS of lowpass filter, DC coupling
*3 at SENS=100×10^{-6} strain、RO=1.0V、LPF=PASS

Simple and economical
Multi-channel Dynamic Strainmeter DS-50A



This is a multi-channel dynamic strainmeter for exclusive use in on-line measurement with a PC. The number of measurement points is 50 for one set of DS-50A, and 20 sets can be connected for simultaneous measurement of 1000 points at the maximum. Sampling speed is 1kHz at the fastest when one set is used. The distance between every two sets is extendable up to 100 meters using connection cables. A large-scale dynamic strain measurement is realized at much lower cost than the use of conventional instruments.

Input (Strain unit)	Quarter bridge 3-wire 120Ω, 350Ω, Half bridge, Full bridge
Sampling speed	1kHz at the fastest (When 1 set is used. Increases by 1msec. every time when 1 set is added.)
Measuring range	±25000x10^{-6} strain
Accuracy	±0.05% FS (at 23±5°C)
When using Optional DS-7640	
Automatic measurement	Data trigger, Time interval
Alarm output	Upper and lower limits are settable for each point
Calculation	Four arithmatic operations, Trigonometrical functions, Rosette analyses, Others
Low-pass filter	1Hz to 100Hz (Settable by every 1Hz)
Monitor	X-Y, Spectrum, Bar graph, Pie chart, Vector, Arrow

Small yet versatile and multi-inputs
Multi-Recorder TMR-200 Series

Number of channels : 80
Sampling speed :
Max 100kHz
Recording media :
CF card
(Max.32GB)
Interface : LAN, USB

This is a multi-functional data acquisition system capable of inputting various sensors. It is suited to vehicle onboard measurement with its small and vibration-tolerant construction. It is also equipped with functions of data recovery against power source interruption and measurement restart after the power source recovery. A long term measurement is possible by using a large capacity CF card. Furthermore, real time histogram analysis is possible by adding the optional histogram analysis library.

Measuring units

Strain Full bridge unit TMR-221

Voltage/Thermocouple unit TMR-231

CAN/VOICE/GPS unit TMR-251

Strain 1G2G4G unit TMR-222

Voltage Output unit TMR-241

Digital I/O unit TMR-253

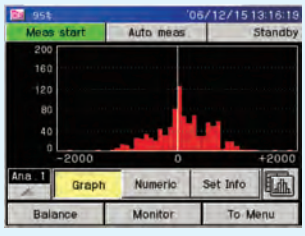
Carrier type Strain unit TMR-223

Telemetry I/F unit TMR-252

Charge amplifier unit TMR-261

OPTION
Histogram analysis library TMR-211-01

By installing the TMR-211-01 software in the control unit TMR-211, the function of a histogram recorder can be added to the TMR-200 system.



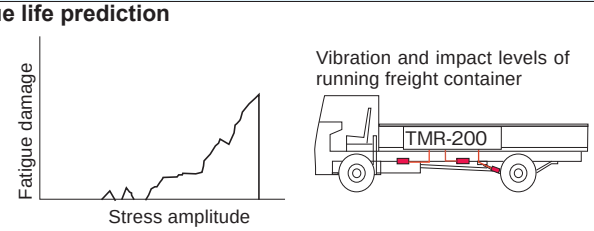
■Histogram recording in applications

It is well known that the majority of structures involve parts subjected to cyclic loads, resulting in structural failure, and such failure includes a correlation between stress and cycles. A random stresses usually take place in structural parts of vehicles, machinary and architecture. Understanding of failure mechanism due to such stresses as above is very important. For cyclic stresses in random, fatigue failure is typically characterized with the processed stress amplitude and its cycles by the Rain-flow counting method.

Frequency analysis TMR-7630H

Indication of various graphs such as monitor graphs in wave-forms, numerical values and X-Y, history graphs, spectrums and histograms.
Automatic measurement and data acquisition using interval, data trigger external trigger, free run, data comparator, and program
Histgoram analysis:
Peak/Valley, MAX/MIN, AMP, TIME, LEVEL, Rain Flow

●Fatigue life prediction



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