Cryogenic temperature STRAIN GAUGES series CF

Operating temperature range

–269°C — +80°C

Temperature compensation range approximately

–196°C — +80°C

Applicable adhesives

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

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

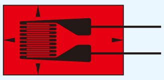
For ordering, the above suffix code should be added to the basic gauge type.

CRYOGENIC TEMPERATURE USE

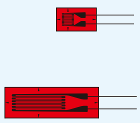
These are foil strain gauges with epoxy backing designed for measurement under cryogenic conditions. They are available in single element, rectangular 2-element and rectangular 3-element configurations with 350Ω resistance. The specially selected and heat treated grid of the gauges shows very small zero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

M metal C ceramic

Single element : CFLA

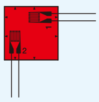


CFLA-1-350 (x3)



Each package contains 10 gauges.

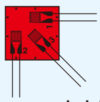
0°/90° 2-element plane Rosette CFCA



CFCA-1-350

Each package contains 10 gauges.

0°/45°/90° 3-element plane Rosette CFRA



CFRA-1-350

Each package contains 10 gauges.

Basic type	Gauge size L	Gauge size W	Backing L	Backing W	Resistance Ω
CFLA-1-350	1	1.6	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
CFCA-1-350	1	1.3	7.2	7.2	350
CFCA-3-350	3	1.7	11	11	350
CFRA-1-350	1	1.3	7.2	7.2	350
CFRA-3-350	3	1.7	11	11	350

Recommendable integral leadwire for CF series

Application	Leadwires	Operating temperature (°C)	Leadwire code exampled
High temperature	3-wire twisted FEP 6FA_LT-F (No Tetra-Etch required for surface) 3-wire twisted FEP 6FB_LT-F	-269~ +200	CFLA-1-350-11-6FA3LT-F CFLA-1-350-11-6FB3LT-F
	3-wire twisted PTFE 4FA_LT-F 3-wire twisted PTFE 4FB_LT-F	-269~ +260	CFLA-1-350-11-4FA3LT-F CFLA-1-350-11-4FB3LT-F

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

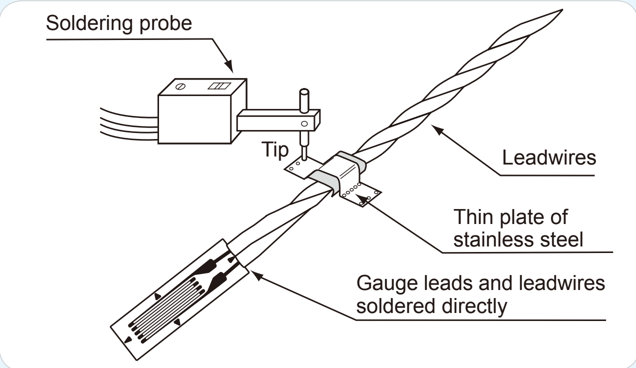
Test temperature	High-temperature atmosphere to 300°C	High-temperature atmosphere to 800°C	Cryogenic temperature atmosphere to -269°C
Strain Gauge	ZF series	AWHU (Weldable type)	CF series
Bonding adhesive	NP-50B	Resistance welding	EA-2A, C-1
Connecting terminals	Not used	-	TPF
Leadwire	PTFE-insulated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

Strain measurement in High- and Low-temperature environments



Coating

Materials that are flexible in normal temperature become rigid and brittle in very low temperature, and care should be taken in the thickness of such coatings. K-1 is a coating with excellent hardeness and peel strength in low temperature. However, if the coating is applied 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 the 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 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 normal temperature gauge factor, Equation ε_G corrects the indicated value.

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 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,

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

Where ΔT : Temperature change experienced 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 the 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)

$\varepsilon_{app} = -2.94 \times 10^1 + 2.32 \times T^1 - 4.60 \times 10^{-2} \times T^2 + 1.67 \times 10^{-4} \times T^3 + 5.00 \times 10^{-7} \times T^4$ (μ m/m)

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