

CP-D/CP-DR type  
Probe Transmitter  
**Operation Manual**



Read this operation manual before  
using this product.



## Precautions

Please read this operation manual thoroughly and gain an understanding of the contents before using this product. Carefully store this manual in a convenient location at all times for quick and easy reference.



This product should be handled by a person who has sufficient knowledge and skill in safety use.

Safety is not guaranteed for uses that are not intended or prescribed in this manual.

The contents of this manual are subject to change without notice, due to improvements of performance or functions of the product.

Pictures or figures used in this manual may be different from the actual product.

In this manual, safety precautions are classified under the ranks "Warning" and "Caution".

 <b>Warning</b>	Indicates contents that can cause death or serious bodily harm if handled improperly.
 <b>Caution</b>	Indicating contents that can cause injury to persons or physical damage if handled improperly.

## Table of Contents

1	Handling Instructions.....	1-1
2	General Matters.....	2-1
2-1	Introduction.....	2-1
2-2	CP-D and CP-DR Type Probe Transmitter.....	2-1
2-3	Product Warranty.....	2-2
2-4	Precautions for use.....	2-3
2-5	Product Overview.....	2-4
2-6	Principle of the Zirconia Sensor.....	2-5
2-7	Names and Functions of Each Part.....	2-8
3	After Opening the Package.....	3-1
3-1	Checking Accessories.....	3-1
3-2	Temporary Storage of the Product.....	3-1
4	Installation.....	4-1
4-1	Installation Conditions.....	4-1
4-2	How to install.....	4-2
4-3	Piping/Wiring Configuration.....	4-4
4-4	Inspection after Installation.....	4-5
5	Maintenance.....	5-1
5-1	Daily Check.....	5-1
5-2	Regular Check.....	5-1
5-3	Trouble Shooting.....	5-3
5-4	Suspension of Operation, Long-term Storage of the Product.....	5-6
6	References.....	6-1
6-1	Standard Specifications.....	6-1
6-2	Supplemental Chart.....	6-2

# 1 Handling Instructions



## Warning

Do not connect or disconnect the probe transmitter while the furnace is operating, since it may cause injuries such as burns through outbursts of hot furnace gas. If it is necessary to do so, follow the cautions below:

- Keep away from, or do not look into the opening of the attached portion, since hot furnace gas will erupt from the opening.
- Use heat-resistant gloves, etc., since the temperature around the attached portion will become high.
- Attach the product correctly as described in this manual. Improper sealing at the time of attachment may result in danger or outbursts of hot furnace gas.



## Caution

Be careful of the following points when attaching/removing the probe transmitter.

- Attach/remove the probe transmitter with care, since rough handling may damage the internal zirconia sensor.
- When removing from high-temperature places, please pull out the probe transmitter being careful not to apply excessive thermal shock in red-hot areas.
- When cooling the probe transmitter which removed from high-temperature places, please avoid that let the probe transmitter touch the refrigerants such as the forced cooling by fans or the direct floor. The excessive quenching may let a zirconia sensor damage even if superior in heat-resistant impulsiveness.
- Air-cool red-hot areas after removing the product from high-temperature places. Keep the product from touching cooling mediums such as the floor face. Excessive cooling will damage the zirconia sensor, even though the product has superior thermal shock resistance.



## Caution

It is recommended that the probe transmitter be inserted into a furnace with a standard air flow. (If impurities get inside the cell while being stored, a redox status may occur inside the cell, resulting in wear of the electrodes or thermocouples.)



## Caution

When you attach a coupling to the standard air inlet of the probe transmitter, please be careful not to strongly screw it too much. If you strongly screw a coupling too much (more than  $25\text{N} \cdot \text{m}$ ), a standard air inlet turns and the internal plumbing is twisted, and as a result standard air may not flow. When you remove a coupling, please be careful not to turn a standard air inlet together with coupling.

## 2 General Matters

### 2-1 Introduction

The CP-D/CP-DR type probe transmitter inserts its zirconia sensor directly into the furnace atmosphere of the carburizing furnace (each heat-treating furnace) to measure oxygen partial pressures in the furnace by using the furnace temperature, sets the temperature and CO level conditions, and measures the CP (carbon potential) of the furnace atmosphere.

Conversion into the CP value is carried out by the CPM type carbon potential calculator.

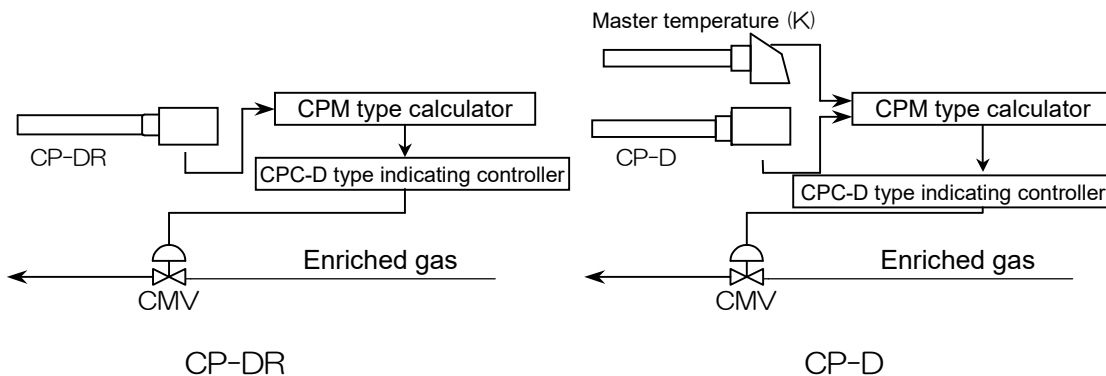
Additionally, the CPC-D type indicating controller is used to control (adjust the additive gas flow rate of) the opening of the control motor valve, etc.

Refer to the operation manual of the separate volumes for the use of the CPM type carbon potential calculator and the CPC-D type indicating controller.

### 2-2 CP-D and CP-DR Type Probe Transmitter

The R-thermocouple is built into the zirconia sensor of the CP-DR type probe, since temperature measuring is indispensable in reading the CP value directly from the zirconia sensor output.

Only the zirconia sensor is built into the CP-D type probe transmitter, and thermocouples are not built into it; therefore, the master temperature (K-thermocouple) signal is used to directly read the CP value by using the CP-D type probe transmitter.



## 2-3 Product Warranty

### 1) Period

One year from the date of purchase

### 2) Conditions

The Energy Support Corporation shall repair, recall, or exchange the product free of charge if there is any problem or abnormality arising from defects in design, craftsmanship, or materials attributed to the company during the above-stated warranty period, provided that the product is properly stored and installed and all appropriate procedures are followed after purchase. (This warranty does not cover consumable supplies and expendable parts.)

Appropriate procedures shall mean:

- Satisfying the use conditions and installation conditions described in this manual.
- Avoiding excessive mechanical shock or vibration to the transmitter.
- Having consumable supplies replaced.
- Checking and maintaining the analysis equipment operation status.

However, the warranty shall not cover the following cases, even during the applicable warranty period:

- Problems resulting from misuse (operations not described in this manual).
- Problems resulting from repair, modification, or disassembling/cleaning by anyone other than the Energy Support Corporation.
- Problems resulting from any naturally occurring event such as fires (including inductive lightning surges).
- Problems resulting from improper storage (storage in locations subject to high temperatures and high humidity) or improper maintenance (generation of mold, etc.).

### 3) Coverage

This warranty applies only to products delivered by the Energy Support Corporation. This warranty shall not cover incidental damages resulting from products delivered by the Energy Support Corporation (damage or lost profits of products which are atmosphere-controlled by the product delivered by the Energy Support Corporation or damage or lost profits of the furnace in which the product is installed).

### 4) Special Notes

Note the following points in order to use the transmitter correctly:

1. Burnout protection should be used in the case of adhesion of soot to the transmitter.
2. Furnace atmosphere should not contain hazardous substances such as Zn, Sn, Pb, P.
3. Furnace atmosphere should not contain halogen compounds (HF, Cl<sub>2</sub>, etc.).
4. Instrument readings of the carbon potential sensor display the logical operation, on the conditions that the furnace atmosphere degrades to a complete equilibrium state and the CO level is constant. In other words, it does not directly measure CP values, but calculates and displays CP values by measuring the O<sub>2</sub> partial pressure and carrying out computation. Therefore, there may be deviations from the actual CP values.

<Major causes of deviations>

- Distribution of furnace atmosphere due to differing installation locations.
- Effects of undecomposed enriched gas (remaining methane).<sup>\*1</sup>
- Fluctuations in the CO concentration in the furnace.<sup>\*2</sup>
- Differences between the sensor temperature and the master temperature.

5. Calculation of CP is performed in the austenite range. Note that the instrument readings in the cementite range are estimated values. Additionally, electrodes and protective tubes of the sensor shall be regarded as consumable supplies if the product is used in the cementite range.

- ※1) Deviations may become more significant in a fiber furnace, or when 13A is used as enriched gas.
- ※2) When used in an N<sub>2</sub> or Nx based atmosphere or an oxidizing or carburizing atmosphere, there may be fluctuations.

#### 5) When Using Carburizing Stop-off Coating

In the case that the sensor is used in an atmosphere in which carburizing stop-off coating is used, the sensor should be attached horizontally, so that the sampling vent at the top will be placed vertically. However, depending on the component that are included in the Carburizing Stop-off Coating, may become abnormal sensor output in a short period of time.

### 2-4 Precautions for use

Please handle the probe transmitter with care when attaching/removing, since rough handling will damage the zirconia sensor inside.

It is recommended that the probe transmitter be inserted into a furnace with a standard air flow.

(If impurities get inside the cell while being stored, a redox status may occur inside the cell, causing wear of the electrodes or thermocouples.)

Use the product in the following environment:

Probe transmitter	Installation location	Indoors
	Ambient temperature	-10~120°C
	Ambient humidity	No more than 85% RH
	Attachment direction	Horizontally, or vertically downward
	Vibration	Little
	Corrosive gases/ hazardous gases	No
Conversion connector cable (optional)	Installation location	Indoors
	Ambient temperature	-10~80°C When installing the CP-DR cable, make sure that there is no difference in temperature between the connectors (within a difference of 5°C)
	Ambient humidity	No more than 85% RH
	Corrosive gases/ hazardous gases	No

Zirconial sensor life may be shortened if corrosive gases or organic gases exist.

Air-cool the probe transmitter after removing it from high temperature places. Keep the transmitter from directly touching cooling mediums such as the floor face. Excessive cooling will damage the zirconia sensor, even though the product has superior thermal shock resistance.

When you attach a coupling to the standard air inlet of the probe transmitter, please be careful not to strongly screw it too much. If you strongly screw a coupling too much (more than 25N • m) , A standard air inlet turns and the internal plumbing is twisted, and as a result standard air may not flow. When you remove a coupling, please be careful not to turn a standard air inlet together with coupling.



## 2-5 Product Overview

The product has superior features such as the following:

### 1) Thermal Shock Resistance

The product can be freely detached from the 960°C furnace into the atmosphere.

### 2) Removal of Soot from the Electrodes

Soot can be removed from the electrodes by regularly carrying out burnout protection.

### 3) Temperature Measurement of the Zirconia Sensor (CP-DR Type Only)

R-thermocouples are built into the zirconia sensor of the CP-DR type probe transmitter, allowing for temperature measurements indispensable for direct reading of CP values.

### 4) No Need for Daily Maintenance

The probe transmitter does not require daily maintenance since it is directly inserted into the furnace (there are no sampling parts).

### 5) Adjustable Insertion Length of the Probe Transmitter

The location of the furnace wall attachment bracket is adjustable, allowing for measurements from a location close to the product.

## 2-6 Principle of the Zirconia Sensor

### 1) Reasons Why Oxygen Partial Pressure can be Measured

Oxygen ions can move around in the crystal structure of stabilized zirconia or partially stabilized zirconia (hereby referred to as zirconia), compounds in which yttria ( $Y_2O_3$ ) dissolves into zirconia ( $ZrO_2$ ) at high temperatures (greater than  $300^\circ C$ ). At this time, an oxygen concentration cell comes to exist, generating voltage due to the differing oxygen concentrations (oxygen pressures) of both sides of the zirconia. The oxygen concentration (oxygen pressure) can be measured using the characteristics of this oxygen ion solid electrolyte.

Generally, atmospheric air is introduced to one side of the zirconia as the standard. Furnace atmosphere is introduced to the other side. The electrical potential (E) caused by this will be explained by the following Nernst's equation:

$$E = - \frac{RT}{nF} \ln \left( \frac{P_{O_2^A}}{P_{O_2^S}} \right)$$

However,

R: gas constant	8.3143 (J/mol • K)
T: zirconia temperature	(K)
N: number of ions x valences	4 (since 2 divalent oxygen ions are generated from one oxygen molecule)
F: Faraday constant	$9.6487 \times 10^4$ (C/mol)
$P_{O_2^A}$ : oxygen partial pressure in the standard atmospheric air	0.206 (atm)
$P_{O_2^S}$ : oxygen partial pressure in the furnace atmosphere	(atm)

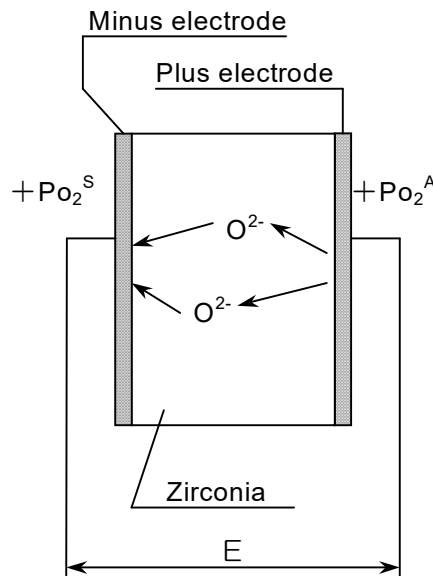
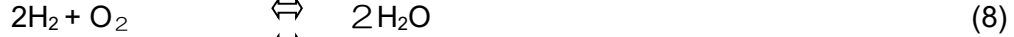


Figure 1. Measurement principle diagram of the Zirconia Type  $O_2$  Analyzer

## 2) Reasons Why CP Values Are Calculated by Measuring Oxygen Pressure

Major equilibrium reactions in the reduction atmosphere furnaces, such as carburizing/quenching furnaces will be explained by the following equations:



Note) (C) is carbon activity.

As described above, reactions occur simultaneously or successively in the furnace, thereby entering into an equilibrium status. If each reaction in the furnace reaches an equilibrium status, the amount of the same element in each equilibrium reaction equation will become the same value, no matter which equilibrium reaction equation is used for calculation. Now, look at equations (1) and (7) from among (1)-(11), and let the equilibrium constants of (1) and (7) be  $K_{p1}$  and  $K_{p2}$  respectively. From there, we obtain:

$$K_{p1} = \frac{(P_{CO})^2}{(C) \cdot P_{CO_2}} \quad (12)$$

$$K_{p2} = \frac{P_{CO} \cdot (P_{O_2})^{1/2}}{P_{CO_2}} \quad (13)$$

And we obtain the following by eliminating  $P_{CO_2}$  from equations (12) and (13):

$$K_{p1} = \frac{(P_{CO})^2 \cdot K_{p2}}{(C) \cdot P_{CO} \cdot (P_{O_2})^{1/2}} = \frac{P_{CO} \cdot K_{p2}}{(C) \cdot (P_{O_2})^{1/2}} \quad (14)$$

Also, we obtain the following by modifying equation (14):

$$(C) = \frac{K_{p2} \cdot P_{CO}}{K_{p1} \cdot (P_{O_2})^{1/2}} \quad (15)$$

When the activity coefficient of carbon activity is 1, then:

$$(C) = \frac{\text{Amount of carbon dissolved in austenite (\%)}}{\text{Amount of saturated carbon in austenite (\%)}} = \frac{A_c}{A_s} \quad (16)$$

And we obtain the following using equations (15) and (16):

$$A_c = A_s \cdot \frac{K_{p_2} \cdot P_{CO}}{K_{p_1} \cdot (P_{O_2})^{1/2}} \quad (17)$$

Furthermore,  $A_s$ , the amount of saturated carbon in austenite, and the equilibrium constants  $K_{p_1}$  and  $K_{p_2}$  can be evaluated as the function of the temperature (T). Therefore, equation (17) will be as follows:

$$A_c = F(T) \cdot \frac{P_{CO}}{(P_{O_2})^{1/2}} \quad (18)$$

In Rx gas based furnaces, the CO level in the furnace is kept constant by the material gas; therefore, the amount of carbon dissolved in austenite  $A_c$  can be evaluated if the temperature and the oxygen partial pressure in the furnace  $P_{O_2}$  can be measured.

### 3) Conversion into CP Values

Conversion into CP values is performed through logical operation, based on the conditions that the furnace atmosphere has degraded into a complete equilibrium state and the CO level is kept constant. In other words, it does not directly measure CP values, but indirectly measures CP values by measuring  $O_2$  partial pressures. For this reason, there may be deviations from the actual CP values.

Reference) The relation between CP and sensor output under each gas condition is shown in the supplementary chart.

<Major causes of deviations>

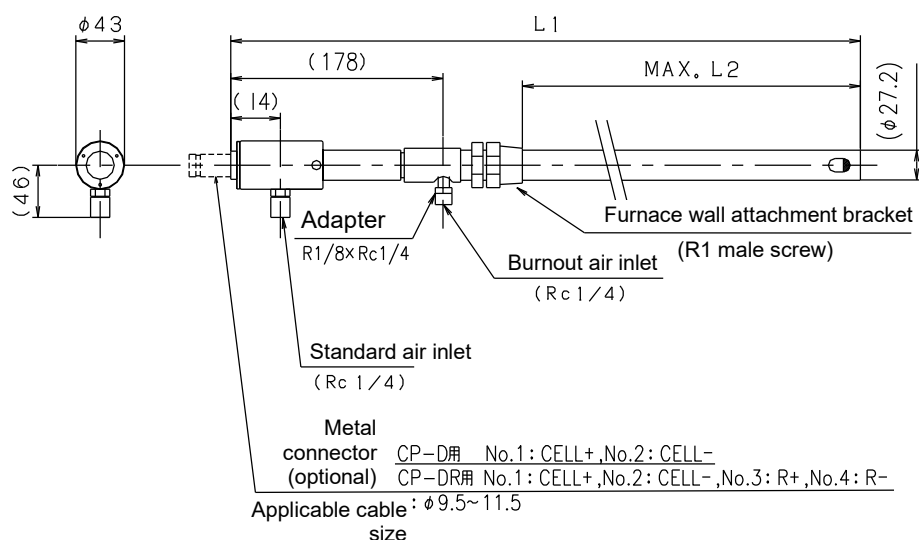
- Distribution of furnace atmosphere due to differing installation locations.
- Effects of undecomposed enriched gas (remaining methane).<sup>※1</sup>
- Fluctuations in the CO concentration in the furnace.<sup>※2</sup>
- Differences in the sensor temperature and the master temperature.

※1) Deviations may become more significant in a fiber furnace, or if 13A is used as enriched gas.

※2) In case of employing under the conditions of the N<sub>2</sub> & N<sub>x</sub> base or the acid sintered carbon, there are some possibilities to cause the deviations.

## 2-7 Names and Functions of Each Part

### 1) Probe Transmitter



Nominal designation	Built-in R-thermocouple	Type	L1	L2	Part number
500	No	CP-D	750	490	KS-164461-B
500	Yes	CP-DR	750	490	KS-164462-B
700	No	CP-D	950	690	KS-164463-B
700	Yes	CP-DR	950	690	KS-164464-B

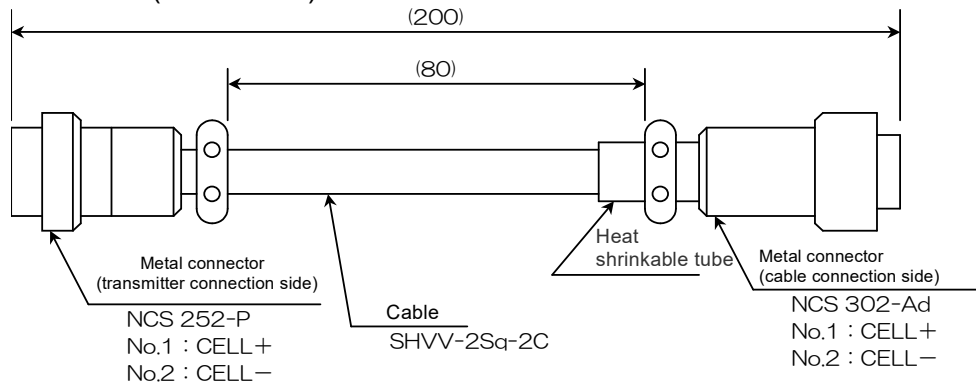
※When you need an optional metal connector, please refer to us.

No.	Name	Function
1	Zirconia sensor	Measures oxygen partial pressures
2	R-thermocouple	Detects temperature inside the furnace (inside the cell) Built only in CP-DR
3	Sample gas inlet	Sample gas inlet or burnout air outlet
4	Furnace wall attachment bracket	A bracket to fix the probe transmitter to the furnace. Insertion length of the probe transmitter is adjustable within the limit of MAX. L2. Wrap with seal tape before attaching.
5	Metal connector	Connects to external wiring Connect external wiring by soldering.
6	Standard air inlet	Inlet for standard air Run 30cc/min. air constantly. ※ Please do not strongly screw a coupling too much. (less than 25N · m)
7	Burnout air inlet	Inlet for burnout air Run 2-5L/min. air regularly to remove soot adhering to electrodes. Note) Burnout air is released into the furnace through the sample gas inlet.

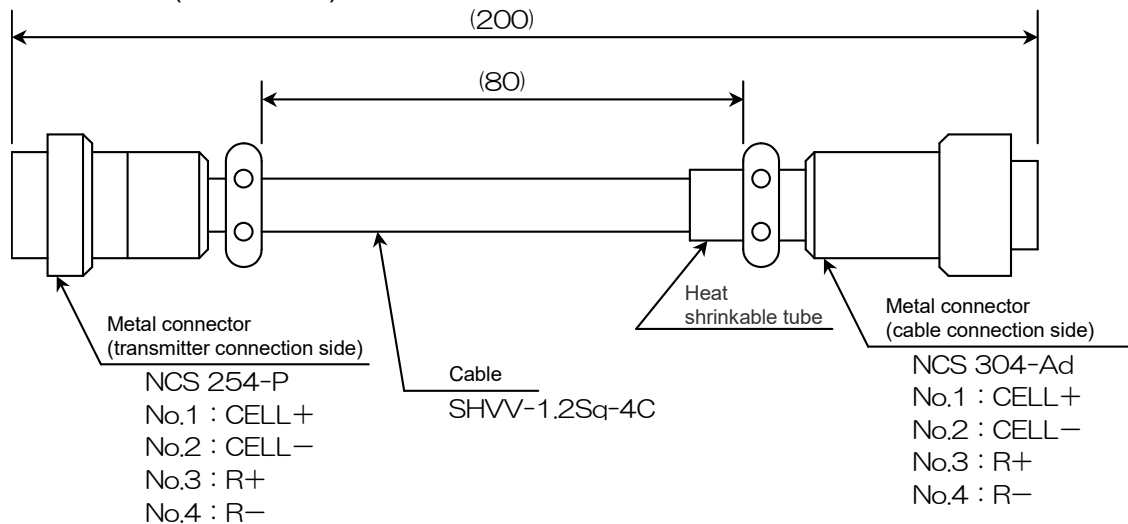
## 2) Conversion Connector Cable (Optional)

This cable is for maintaining compatibility with the connectors of the Old-model probe transmitters. (KS-1644\*\*~1NS)

- For CP-D (KS-164441)



- For CP-DR (KS-164442)



Note) Be sure that there is no temperature difference between both connectors since R-compensating lead wire is not used (keep the temperature difference within 5°C).

## 3 After Opening the Package

### 3-1 Checking Accessories

<Product and accessories list>

Product name	Part number	Quantity	Note
Probe transmitter	KS-16446 *-B	1	* differs between CP-D and DR and according to length. CP-D-L500 : KS-164461-B CP-DR-L500 : KS-164462-B CP-D-L700 : KS-164463-B CP-DR-L700 : KS-164464-B
Connector (optional)	NCS25 *-P (Straight) NCS25 *-LP (L shaped)	1	Accessory *differs between CP-D and DR. In the case of CP-D: NCS-252-(L)P (2P) In the case of CP-DR: NCS-254-(L)P (4P)
Conversion connector cable (optional)	KS-16444*	1	*differs between CP-D and DR. In the case of CP-D: KS-164441 In the case of CP-DR: KS-164442

### 3-2 Temporary Storage of the Product

When temporarily storing the product, follow the instructions below:

- It is desirable for the product to be stored under the original packaging conditions of the Energy Support Corporation (in a cardboard box with the probe transmitter in a fixed location).
- Keep the product indoors, away from rainwater.
- Keep the product in a location with little change in temperature, with 0-40°C ambient temperature and no more than 85% RH humidity.
- Keep the product in a low-dust location.
- Keep the product in a location with little mechanical vibration.
- Keep the product in a location free from corrosive gases or hazardous gases.

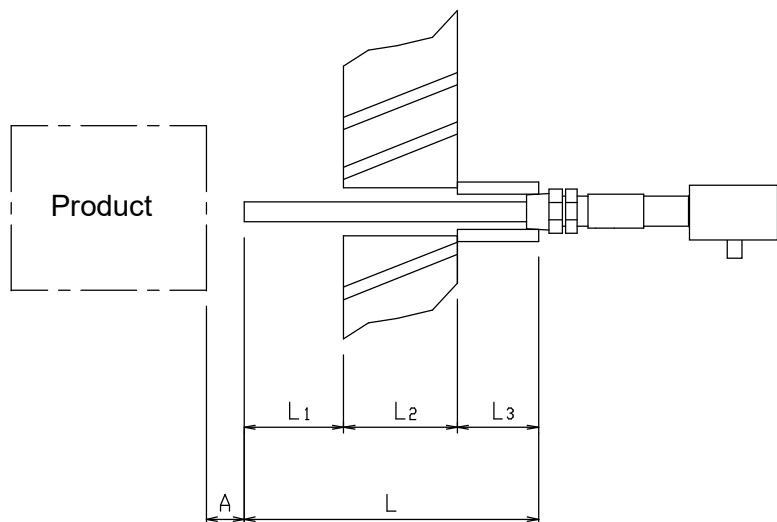
## 4 Installation

### 4-1 Installation Conditions

The probe transmitter will be inserted into a section between radiant tubes horizontally, face down from the ceiling or horizontally, from the side. Choose a location where the following conditions are satisfied:

- Measurement target gas is the representative value.
- A location having few sudden changes in gas values. (Do not install the product in a location such as the vicinity of an enriched gas transfer tube, where the transmitter is directly exposed to undecomposed enriched gas directly touching the transmitter.)
- A location having few sudden changes in gas temperature (pressure).
- Gas temperature is between 800°C and 960°C.
- A location having little vibration or shock.
- A location where maintenance can be easily performed.
- A location where outside air temperature (terminal part) remains 120°C or lower.
- A location with no corrosive gases or hazardous gases.
- A low-dust location.

The apical part of the probe transmitter should also be placed as close as possible to the product.

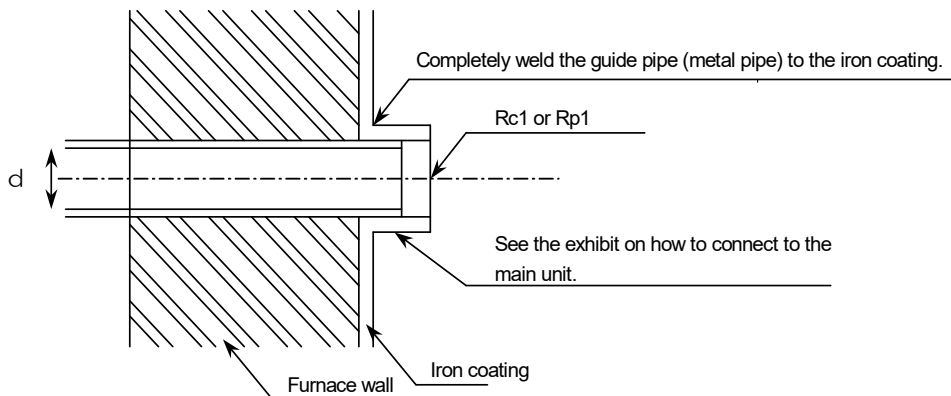


Keep a distance from the product (A) of approximately 50 mm, then take measurements of the furnace interior (L1) and the furnace wall (L2) and decide the measurement of L (L1+ L2 + L3). Choose an attachment location that is not touching piping, etc.

Caution: if the distance from the product (A: approximately 50 mm) is large, the furnace temperature (master temperature) and the CP-DR temperature may not correspond, thus not allowing for accurate CP value calculation. Also, if the temperature of the installation location is low, soot will adhere to the sensor, causing trouble such as abnormal instructions of sensor deterioration, etc.



<Attaching the mount of the probe transmitter>

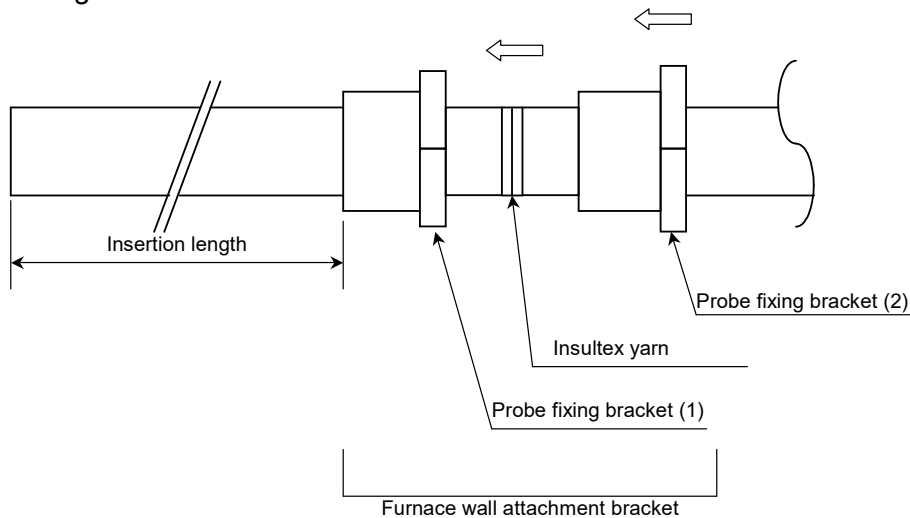


d: More than  $\phi$  32.

## 4-2 How to install

### 1) How to Attach the Probe Transmitter

Wrap the probe fixing bracket (1) of the furnace wall attachment bracket 2 to 3 times with seal tape and attach it to the furnace. The insertion length of the probe transmitter may be adjusted using the furnace wall attachment bracket. Adjust the insertion length to the appropriate length.



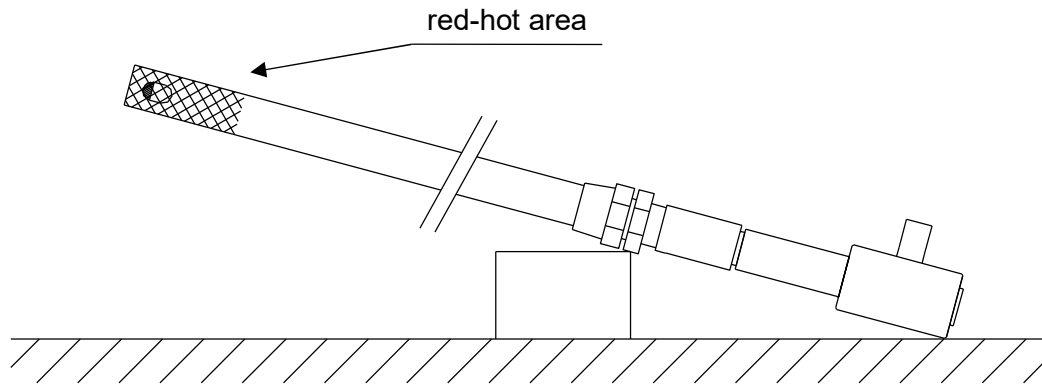
To fix and seal, push the Insultex yarn into the probe fixing bracket (1) and screw the probe fixing bracket in.

Maximum insertion length:  
L 500; 490 mm, L700; 690 mm

### 2) Attachment/Removal of the Probe Transmitter

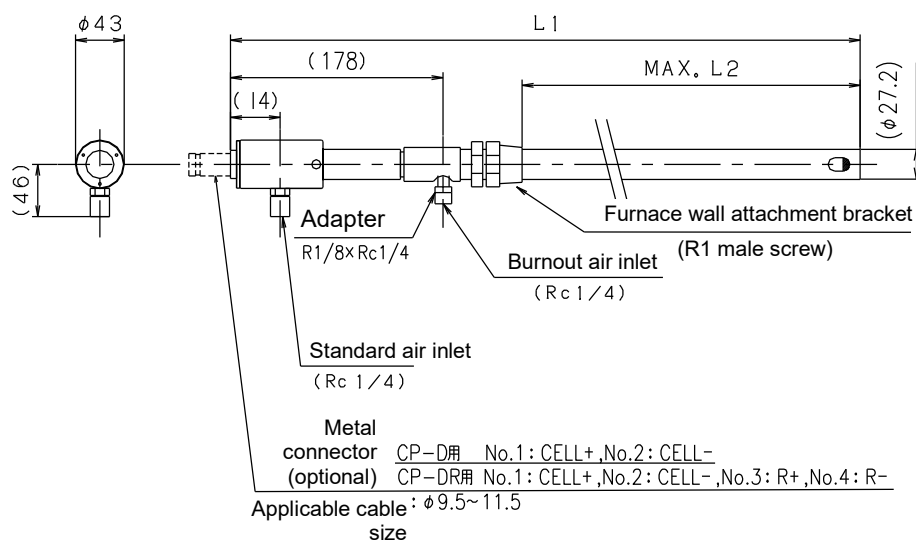
- The zirconia sensor is susceptible to shock. Handle the transmitter with care so as not to hit pipes, etc., when attaching or removing it.
- Be careful of burns, etc., when attaching/removing the transmitter while the furnace is running, since furnace gas will erupt.
- The zirconia sensor made by the Energy Support Corporation has superior thermal shock resistance and can be removed from a furnace with a temperature of 960°C into the outside atmosphere or can be attached to a furnace from the outside atmosphere without restrictions. However, if it is removed from high temperatures, air-cool the red-hot area as described in the figure below. (Do not directly touch cooling mediums such as the floor

face. Excessive cooling may cause damage to the zirconia sensor, even though it has superior thermal shock resistance. Note that the sensor is especially susceptible to water droplet adherence.)



- If the transmitter is attached to a furnace in operation, 30 to 60 minutes will be required for the temperature of the transmitter to stabilize. Note that the output may fluctuate or show abnormal values during this period.

## 4-3 Piping/Wiring Configuration



### 1) Piping

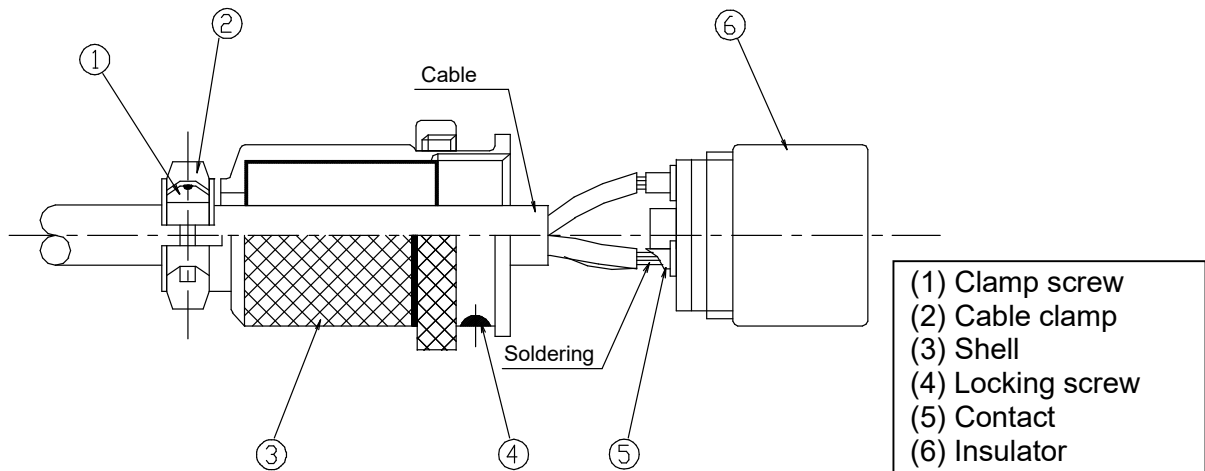
Burnout air	<p>Burnout protection should be performed regularly on the sensor.</p> <p>Batch furnace : supply air from the insertion of processing materials (work) until the temperature recovers (approximately 800°C).</p> <p>Continuous furnace : supply air once a week, for approximately 10 minutes.</p> <p>Air supply quantity : supply a quantity that brings the sensor output down to 100 mV or lower. (Approximately 2-5 L/min.)</p> <p>Note) Sensor output may not become lower than 100 mV if the sensor is located in the vicinity of a fan. Under such circumstances, make 800 mV the target. In this case, stop the fan of the furnace once a week and check if the output shows 100 mV or lower, to make sure that burnout protection is working.</p>
Standard air	<p>Constantly supply 30 cc/min. (supply drained air)</p> <p>※Please do not strongly screw a coupling too much.(less than 25N · m)</p>
Pipe material	<p>Control Copper Tube <math>\Phi 6/4 \sim \Phi 10/8</math> or Teflon Tube <math>\Phi 6/4 \sim \Phi 10/8</math></p> <p>Onetouch joints will allow for easy attachment/removal of piping when attaching or removing the probe transmitter.</p>

### 2) Wiring

Connector pin No.	(1)	(2)	(3)	(4)
CP-D	Sensor +	Sensor -	/	
CP-DR	Sensor +	Sensor -	R-thermocouple +	R-thermocouple -
Wiring material	Ambient temperature: -10~60°C; CVVS ~80°C; HCVVS ~150°C; KGB		R-compensating lead wire Ambient temperature: ~80°C; RX-GS ~150°C; RX-HS	

Note) Output impedance of the sensor is several tens KΩ. Therefore, make sure that the total input impedance of the instrument connected to the sensor is greater than 10 MΩ.

### 3) How to Connect the Cable to the Metal Connector



#### [Order]

- 1) Remove (4) to take out (6).
- 2) Loosen (1) so that the cable can enter.
- 3) Perform appropriate end treatment on the cable and pass it through (3).
- 4) Solder the conductors of the cable to (5).
- 5) Screw (3) onto (6), match the tap location, and screw in (4) to fix it.
- 6) Tighten (1) sufficiently to fix the cable.

Applicable cable size:  $\Phi 9.5 \sim 11.5\%$

Applicable cable size when using the optional conversion connector cable:  $\Phi 11 \sim 13$

### 4) Pre-operation Inspection

Confirm that the piping and wiring is installed correctly, and measure the insulation resistance between the terminals.

Between sensor+ and the case	100 kΩ or higher (DC500V)
Between R- thermocouple and the case	100 kΩ or higher (DC500V)
Between sensor+ and R- thermocouple+	100 kΩ or higher (DC500V)

### 4-4 Inspection after Installation

#### <Cross-checking transmitter output>

Conduct a cross-check of the furnace atmosphere under all operation conditions after installing the transmitter

Use the Resistance Carbon Potential Sensor (Hot wire), CO<sub>2</sub> sensor, or DP sensor to conduct cross checking.

The output value of the transmitter will have some draft due to causes such as deterioration of electrodes or soot adherence. There also exist some differences among transmitters. The above stated cross check value will allow for adjustments when correcting such draft or differences.

Reference) The supplementary chart shows relations between carbon potential and CO<sub>2</sub>/DP values under each gas condition.

## 5 Maintenance

### 5-1 Daily Check

- Check that the standard air is running at 30~50 cc/min. (Once a day.)
- Check that there are no abnormalities in instrument readings or the operational gas flow rate (valve-opening), as compared to normal values. (Once a day.)
- Conduct a cross check of the instrument readings to confirm that the values are within  $\pm 0.05\%C$  of the default value of the CP conversion value. (Once every 2 weeks.)  
Note) If a value exceeds  $\pm 0.05\%C$ , correct the setting value, etc., so that the cross check value will be within  $\pm 0.05\%C$ . Additionally, if the correction value is greater than  $\pm 0.15\%C$  of the default value, see Trouble Shooting for resolutions. Corrections can be made using the CPM type carbon potential calculator.
- Conduct burnout protection on the transmitter (when the furnace temperature is 750°C or higher) and check that the output value is 100 mV or smaller, using the digital voltmeter. (Once every 2 weeks.)

### 5-2 Regular Check

1. Soot adhering to the inside and the electrode of the transmitter is removable through the performing of burnout protection on the transmitter; however, soot adhering to the outside cannot be removed. If a large amount of soot adheres to the outside of the transmitter, the soot will cause the output to become high (less carburizing). In such a case, conduct burnout protection on the transmitter entirely within a high temperature (750~960°C) oxidizing atmosphere to remove the soot adhering to the outside.  
Note) Never expose the transmitter to rapid heating by burners, etc. It will cause damage to the transmitter.
2. When using the transmitter in a furnace where a large amount of carburizing stop-off coating is used, adherence of the coating to the heat insulator (Kao wool) placed at the end slit part of the transmitter will weaken the output responsiveness and lower the output (excessive carburizing). In such cases, remove the heat insulator and replace with a new heat insulator.
  - Use 1 g of heat insulator (Kao wool).
  - Replace the heat insulator when the sensor temperature drops below 100°C.
  - Generally, the heat insulator does not need to be replaced.
3. The zirconia sensor output may be weakened from damage caused by excessive thermal shock, mechanical shock, etc. (excessive carburizing). Follow the steps below for inspection.
  1. Manually operate the (furnace) atmosphere and measure the output between pins 1 and 2 of the metal connectors of the transmitter (measurement value 1).
  2. Next, stop the standard air and measure the output, as above, 5 minutes later (measurement value 2).
  3. If (measurement 1) - (measurement 2) is 10 mV or greater, the zirconia sensor is damaged; replace the transmitter.  
Note) See Trouble Shooting for solutions if it is less than 10 mV.  
Note) Measure the output using a voltmeter with an input impedance greater than 10 MΩ.

4. The degree of the transmitter's electrodes can easily be checked by measuring the output impedance of the transmitter. Follow the steps below to check:

1. Manually operate the (furnace) atmosphere and measure the output of the transmitter between pins 1 and 2 of the metal connector (voltage 1).
2. Next, measure the output between pins 1 and 2, with the known resistance (resistance value R) connected parallel (voltage 2).
3. Calculate the output impedance (Z) of the transmitter from the results, using the following equation:

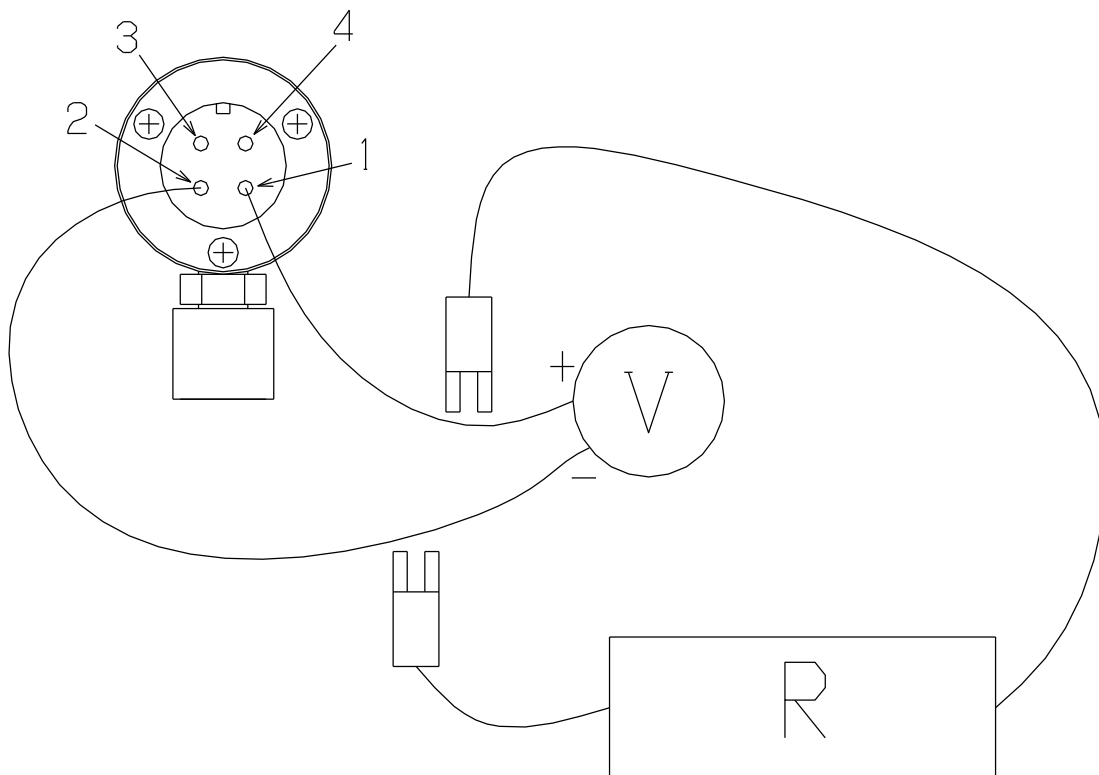
$$Z = (\text{voltage 1} - \text{voltage 2}) \times R / \text{voltage 2}$$

If the value of Z is 100 kΩ or greater, the electrodes have reached the end of their lifespan; replace the transmitter.

Note) Measure the output using a voltmeter with an input impedance of 10 MΩ or greater.

Note) Use a known resistance of 50~1000 K.

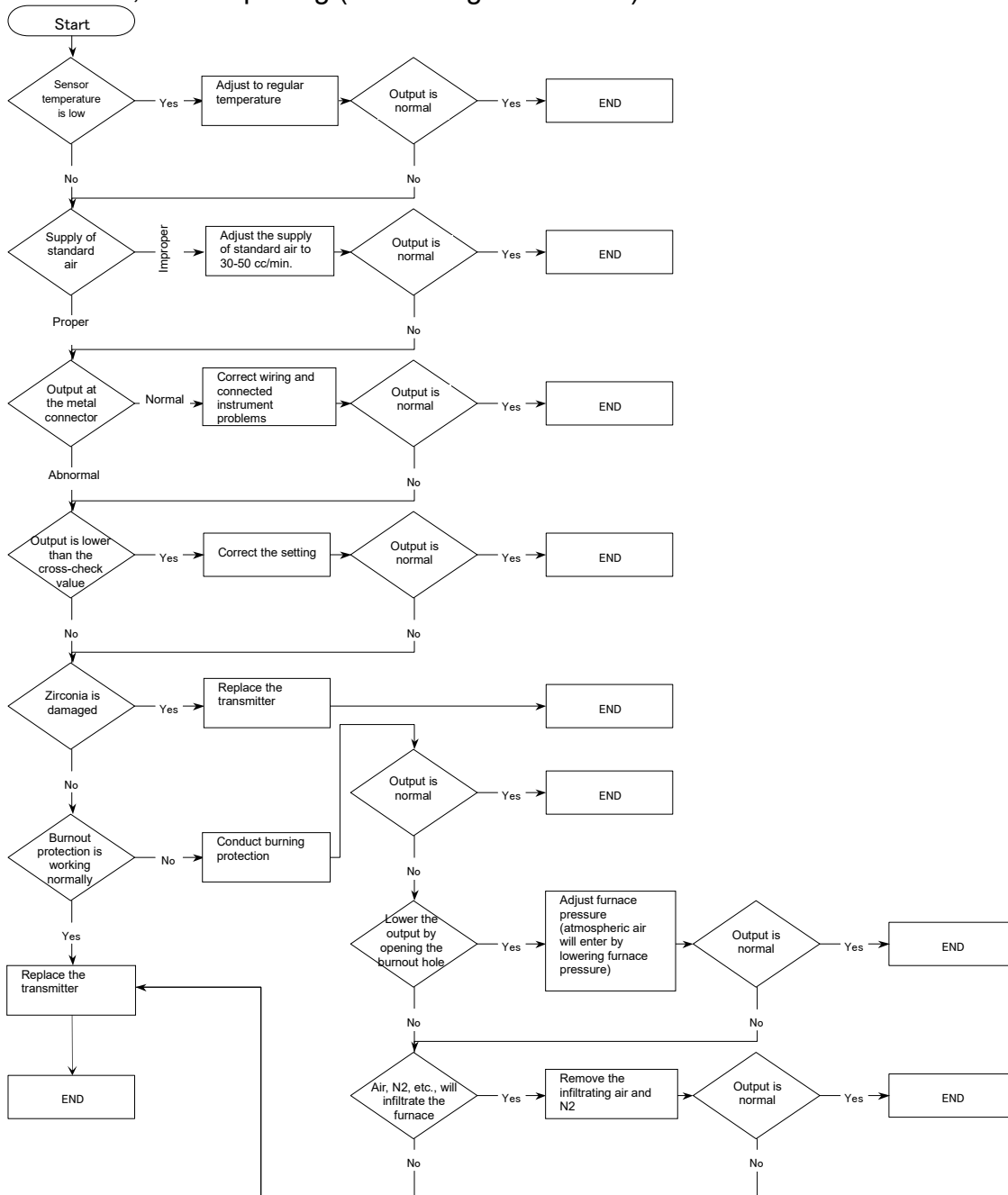
Note) Although the output impedance of the transmitter changes according to temperature, it is normally several kΩ below 930°C and several tens kΩ below 850°C.



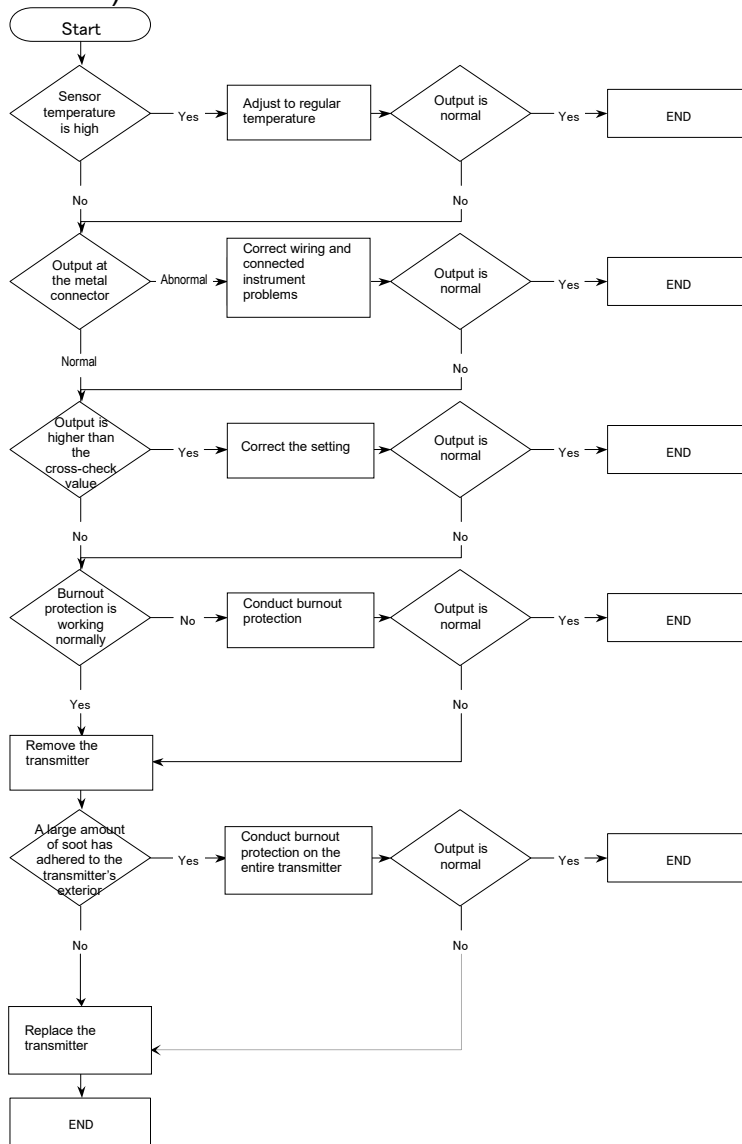
### 5-3 Trouble Shooting

Use the following trouble shooting tips as solutions if problems occur while using the Carbon Potential Sensor.

- 1) Output is low; Output does not begin; Start-up is slow; Excessive carburizing occurs; Valve-opening (enriched gas flow rate) exceeds the normal value

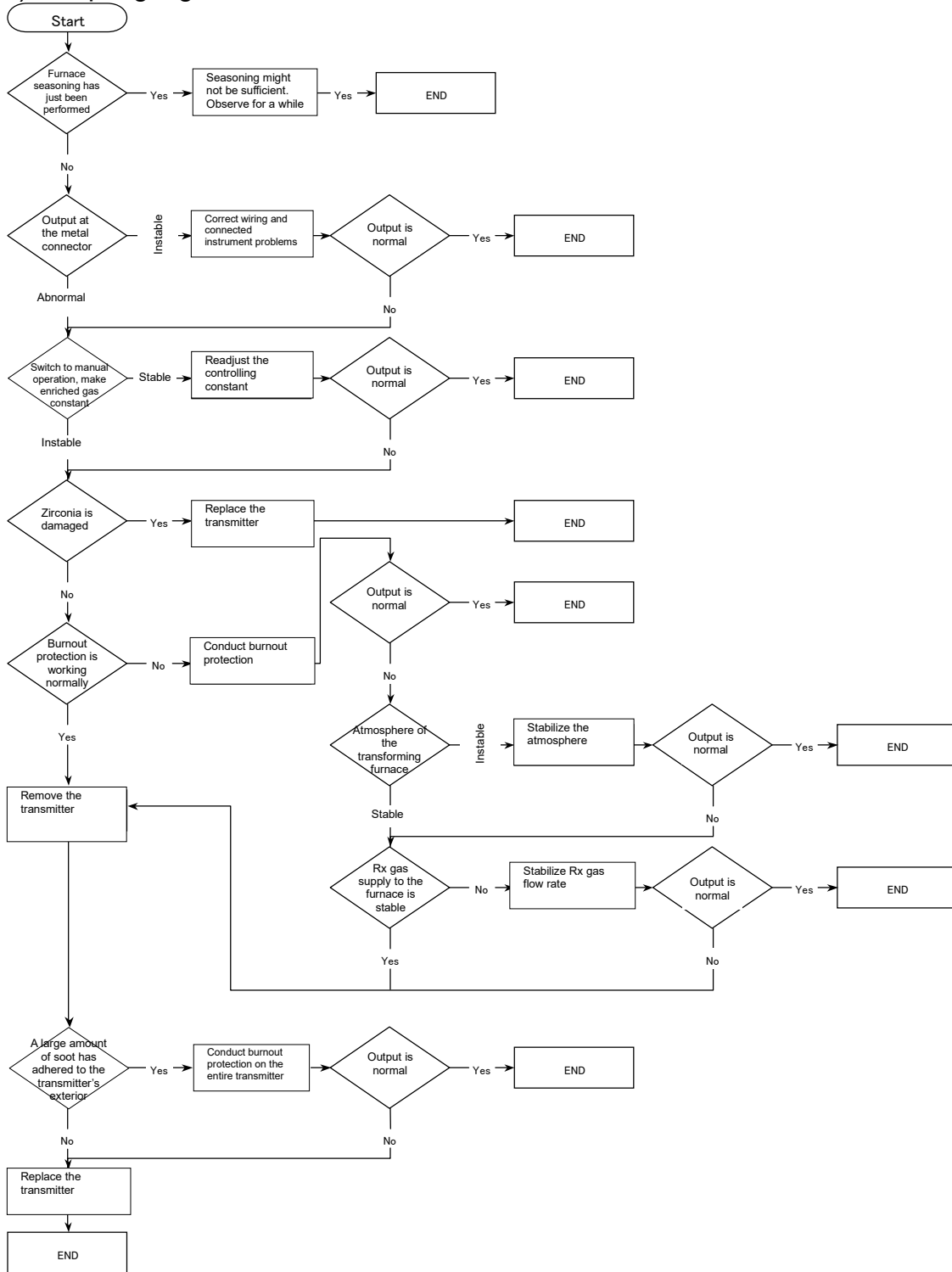


2) Output is high; Insufficient carbureting occurs; Valve-opening (enriched gas flow rate) is less than the normal value





### 3) Output gauge oscillates; Difficult to control



## 5-4 Suspension of Operation, Long-term Storage of the Product

1. If suspending operation, conduct burnout protection before suspending in order to remove soot adhering to the electrodes.
2. If keeping the product in storage for an extended period of time, follow the instructions below:
  - It is desirable for the product to be stored under the original packaging conditions of the Energy Support Corporation (in a cardboard box, with the probe transmitter in a fixed location).
  - Keep the product indoors, away from rainwater.
  - Keep the product in a location with little change in temperature, with 0-40°C ambient temperature and no more than 85% RH humidity.
  - Keep the product in a low-dust location.
  - Keep the product in a location with little mechanical vibration.
  - Keep the product in a location free from corrosive gases or hazardous gases.
3. When restarting operation, note the following:
  - It is recommended that the probe transmitter be inserted into the furnace with a standard air flow. (If impurities get inside the cell while being stored, a redox status may occur inside the cell, resulting in wear to the electrodes or thermocouples.)
  - Conduct burnout protection when the interior furnace temperature increases, to remove soot adhering to the electrodes.

## 6 References

### 6-1 Standard Specifications

Measurement rangedetector cell electromotive force: 1000~1200 mV (austenite range)

Sampling method – direct insertion

Response time --- 90% response No more than 10 seconds

Measured gas conditions

		Measured gas conditions of your company	Measured gas conditions of our company
Material gas			
Furnace conditions	Pressure	kPa	±5
	Temperature	°C	800~960
	Dust quantity	mg/Nm <sup>3</sup>	No greater than 500
Measured gas conditions	CO	%	20~25
	CO <sub>2</sub>	%	0.1~1.0
	H <sub>2</sub>	%	20~50
	Dew point	°C	-15~15
	Remaining CH <sub>4</sub>	%	(MAX)No greater than 4 (Regular)No greater than 2
	N <sub>2</sub>	%	Remaining

Supplied air

Standard air      30 cc/min  
Burnout air      2~5 L/min.

## 6-2 Supplemental Chart

Relationship of CP-CO<sub>2</sub>%

CO=20.7%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05	14.230	12.498	10.999	9.699	8.569	7.585	6.727	5.978	5.321	4.746	4.240	3.794	3.402	3.055	2.748	2.476	2.235	2.020
0.10	7.035	6.177	5.434	4.791	4.232	3.745	3.321	2.951	2.627	2.342	2.093	1.873	1.679	1.508	1.357	1.222	1.103	0.997
0.15	4.637	4.070	3.579	3.155	2.786	2.465	2.186	1.942	1.729	1.541	1.377	1.232	1.105	0.992	0.893	0.804	0.726	0.656
0.20	3.437	3.016	2.652	2.337	2.063	1.825	1.618	1.438	1.279	1.141	1.019	0.912	0.818	0.735	0.661	0.596	0.538	0.486
0.25	2.718	2.384	2.095	1.846	1.639	1.441	1.278	1.135	1.010	0.901	0.805	0.720	0.646	0.580	0.522	0.470	0.424	0.384
0.30	2.238	1.962	1.724	1.519	1.340	1.185	1.051	0.933	0.830	0.740	0.661	0.592	0.531	0.477	0.429	0.387	0.349	0.316
0.35	1.896	1.661	1.459	1.285	1.134	1.003	0.889	0.789	0.702	0.626	0.559	0.500	0.449	0.403	0.363	0.327	0.295	0.267
0.40	1.639	1.436	1.261	1.110	0.979	0.865	0.767	0.681	0.606	0.540	0.482	0.432	0.387	0.348	0.313	0.282	0.255	0.230
0.45	1.439	1.260	1.106	0.973	0.858	0.759	0.672	0.597	0.531	0.473	0.423	0.378	0.339	0.305	0.274	0.247	0.225	0.202
0.50	1.279	1.119	0.982	0.864	0.762	0.673	0.597	0.530	0.471	0.420	0.375	0.336	0.301	0.270	0.243	0.219	0.198	0.179
0.55	1.148	1.005	0.881	0.775	0.683	0.604	0.535	0.475	0.422	0.376	0.336	0.301	0.270	0.242	0.218	0.197	0.178	0.161
0.60	1.039	0.909	0.797	0.701	0.617	0.545	0.483	0.429	0.381	0.340	0.304	0.272	0.244	0.219	0.197	0.178	0.160	0.145
0.65	0.947	0.828	0.726	0.638	0.562	0.496	0.439	0.390	0.347	0.309	0.276	0.247	0.222	0.199	0.179	0.162	0.146	0.132
0.70	0.868	0.758	0.664	0.584	0.514	0.454	0.402	0.357	0.317	0.283	0.252	0.226	0.203	0.182	0.164	0.148	0.133	0.121
0.75	0.799	0.698	0.611	0.537	0.473	0.417	0.369	0.328	0.291	0.260	0.232	0.208	0.186	0.167	0.151	0.136	0.123	0.111
0.80	0.739	0.645	0.565	0.496	0.437	0.385	0.341	0.303	0.269	0.240	0.214	0.192	0.172	0.154	0.139	0.125	0.113	0.102
0.85	0.686	0.599	0.524	0.460	0.405	0.357	0.316	0.280	0.249	0.222	0.198	0.177	0.159	0.143	0.129	0.116	0.105	0.095
0.90	0.639	0.558	0.488	0.428	0.376	0.332	0.294	0.261	0.232	0.206	0.184	0.165	0.148	0.133	0.120	0.108	0.098	0.088
0.95	0.597	0.521	0.455	0.399	0.351	0.310	0.274	0.243	0.216	0.192	0.172	0.154	0.138	0.124	0.112	0.101	0.091	0.082
1.00	0.559	0.487	0.426	0.373	0.328	0.289	0.256	0.227	0.202	0.180	0.160	0.144	0.129	0.116	0.104	0.094	0.085	0.077
1.05	0.525	0.457	0.399	0.350	0.308	0.271	0.240	0.212	0.189	0.168	0.150	0.134	0.121	0.108	0.098	0.088	0.080	0.072
1.10	0.494	0.430	0.375	0.329	0.289	0.255	0.225	0.199	0.177	0.158	0.141	0.125	0.113	0.102	0.092	0.083	0.075	0.068
1.15	0.466	0.405	0.353	0.309	0.272	0.239	0.212	0.187	0.167	0.148	0.132	0.118	0.106	0.096	0.086	0.078	0.070	0.064
1.20	0.439	0.382	0.333	0.292	0.256	0.225	0.199	0.176	0.157	0.140	0.125	0.112	0.100	0.090	0.081	0.073	0.066	0.060
1.25	0.416	0.361	0.315	0.275	0.242	0.213	0.188	0.166	0.148	0.132	0.117	0.105	0.094	0.085	0.076	0.069	0.062	0.056
1.30	0.393	0.341	0.297	0.260	0.228	0.201	0.177	0.157	0.139	0.124	0.111	0.099	0.089	0.080	0.072	0.065	0.059	0.053
1.35	0.373	0.323	0.282	0.246	0.216	0.190	0.168	0.148	0.132	0.117	0.105	0.094	0.084	0.076	0.068	0.061	0.056	0.050
1.40	0.354	0.307	0.267	0.233	0.204	0.180	0.159	0.140	0.125	0.111	0.099	0.089	0.080	0.071	0.064	0.058	0.053	0.048
1.45	0.336	0.291	0.253	0.221	0.194	0.170	0.150	0.133	0.118	0.105	0.094	0.084	0.075	0.068	0.061	0.055	0.050	0.045
1.50	0.320	0.277	0.240	0.210	0.184	0.161	0.142	0.126	0.112	0.100	0.089	0.080	0.071	0.064	0.058	0.052	0.047	0.043

Unit: %

6-2

Relationship of CP-DP°C

CO=20.7%, H<sub>2</sub>=37.8%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05																		
0.10										33.90	32.39	31.01	29.69	28.19	26.83	25.59	24.32	22.99
0.15					34.23	32.57	31.07	29.63	28.02	26.57	25.26	23.81	22.42	21.17	20.02	18.65	17.39	16.24
0.20		33.82	32.11	30.58	28.96	27.33	25.87	24.43	22.91	21.53	20.29	18.89	17.53	16.30	15.18	13.92	12.72	11.62
0.25	31.36	29.80	28.02	26.42	24.99	23.35	21.87	20.53	19.11	17.68	16.38	15.20	13.88	12.62	11.48	10.44	9.31	8.12
0.30	27.96	26.32	24.80	23.12	21.61	20.25	18.72	17.27	15.96	14.71	13.33	12.08	10.95	9.89	8.60	7.43	6.36	5.39
0.35	25.23	23.50	21.90	20.47	18.93	17.41	16.04	14.76	13.33	12.04	10.87	9.74	8.43	7.24	6.15	5.16	3.99	2.88
0.40	22.67	21.11	19.63	18.00	16.53	15.21	13.75	12.38	11.15	10.03	8.66	7.41	6.28	5.25	4.07	2.91	1.85	0.89
0.45	20.62	19.01	17.40	15.95	14.57	13.08	11.74	10.53	9.25	7.90	6.69	5.60	4.46	3.24	2.12	1.11	0.19	-0.91
0.50	18.66	17.04	15.60	14.12	12.64	11.31	10.12	8.70	7.38	6.19	5.12	3.84	2.64	1.56	0.57	-0.45	-1.59	-2.62
0.55	16.89	15.44	13.89	12.40	11.06	9.82	8.36	7.04	5.86	4.72	3.41	2.23	1.16	0.18	-0.97	-2.08	-3.10	-4.03
0.60	15.42	13.83	12.31	10.96	9.66	8.18	6.85	5.66	4.44	3.13	1.95	0.88	-0.11	-1.33	-2.44	-3.44	-4.36	-5.27
0.65	13.93	12.37	10.98	9.64	8.13	6.78	5.57	4.31	2.98	1.79	0.72	-0.35	-1.57	-2.67	-3.68	-4.59	-5.59	-6.64
0.70	12.55	11.11	9.77	8.21	6.82	5.59	4.29	2.95	1.76	0.65	-0.47	-1.70	-2.81	-3.83	-4.74	-5.80	-6.86	-7.82
0.75	11.36	10.02	8.41	6.97	5.69	4.39	3.01	1.77	0.65	-0.48	-1.74	-2.87	-3.89	-4.82	-5.92	-6.99	-7.96	-8.84
0.80	10.31	8.73	7.22	5.89	4.60	3.16	1.88	0.73	-0.41	-1.69	-2.85	-3.89	-4.84	-5.96	-7.04	-8.03	-8.92	-9.74
0.85	9.16	7.57	6.17	4.91	3.41	2.08	0.89	-0.24	-1.57	-2.76	-3.83	-4.80	-5.93	-7.03	-8.03	-8.94	-9.77	-10.75
0.90	8.03	6.55	5.24	3.75	2.35	1.11	0.00	-1.37	-2.60	-3.71	-4.70	-5.83	-6.96	-7.99	-8.91	-9.76	-10.75	-11.76
0.95	7.03	5.63	4.19	2.72	1.41	0.25	-1.09	-2.37	-3.52	-4.55	-5.67	-6.83	-7.88	-8.84	-9.70	-10.70	-11.73	-12.66
1.00	6.12	4.74	3.17	1.79	0.56	-0.73	-2.08	-3.28	-4.35	-5.44	-6.64	-7.73	-8.71	-9.60	-10.58	-11.64	-12.60	-13.48
1.05	5.30	3.73	2.25	0.95	-0.29	-1.70	-2.97	-4.10	-5.14	-6.40	-7.53	-8.54	-9.46	-10.42	-11.51	-12.49	-13.39	-14.21
1.10	4.39	2.81	1.41	0.18	-1.25	-2.59	-3.78	-4.84	-6.09	-7.27	-8.33	-9.28	-10.21	-11.33	-12.35	-13.27	-14.11	-14.88
1.15	3.47	1.96	0.64	-0.72	-2.14	-3.40	-4.52	-5.72	-6.95	-8.06	-9.06	-9.96	-11.10	-12.16	-13.11	-13.98	-14.77	-15.70
1.20	2.62	1.19	-0.08	-1.60	-2.95	-4.14	-5.27	-6.58	-7.75	-8.79	-9.73	-10.83	-11.92	-12.92	-13.82	-14.63	-15.53	-16.50
1.25	1.84	0.49	-0.97	-2.42	-3.70	-4.82	-6.14	-7.38	-8.48	-9.46	-10.50	-11.65	-12.68	-13.62	-14.46	-15.33	-16.33	-17.24
1.30	1.13	-0.23	-1.80	-3.18	-4.39	-5.63	-6.94	-8.11	-9.15	-10.12	-11.32	-12.40	-13.38	-14.26	-15.08	-16.12	-17.06	-17.92
1.35	0.46	-1.07	-2.57	-3.87	-5.03	-6.44	-7.68	-8.79	-9.78	-10.94	-12.08	-13.10	-14.03	-14.86	-15.87	-16.85	-17.74	-18.55
1.40	-0.22	-1.85	-3.28	-4.52	-5.85	-7.19	-8.37	-9.42	-10.51	-11.71	-12.79	-13.76	-14.63	-15.59	-16.60	-17.53	-18.37	-19.13
1.45	-1.02	-2.58	-3.94	-5.17	-6.62	-7.89	-9.01	-10.01	-11.29	-12.43	-13.45	-14.36	-15.26	-16.33	-17.29	-18.16	-18.95	-19.67
1.50	-1.76	-3.26	-4.56	-5.95	-7.33	-8.54	-9.61	-10.80	-12.01	-13.09	-14.06	-14.93	-16.01	-17.01	-17.92	-18.75	-19.50	-20.27

6-9

Unit: %

Relationship of CP-EMF  
CO=20.5%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990
0.05	961.7	963.0	964.4	965.9	967.3	968.7	970.2	971.7	973.2	974.6	976.1	977.6	979.2	980.7	982.2	983.7	985.2	986.8	988.3	989.9
0.10	994.2	995.9	997.7	999.4	1001.1	1002.9	1004.7	1006.4	1008.2	1010.0	1011.8	1013.6	1015.4	1017.3	1019.1	1020.9	1022.7	1024.6	1026.4	1028.2
0.15	1013.5	1015.4	1017.3	1019.2	1021.2	1023.1	1025.1	1027.0	1029.0	1031.0	1033.0	1035.0	1036.9	1038.9	1040.9	1042.9	1044.9	1047.0	1049.0	1051.0
0.20	1027.3	1029.4	1031.4	1033.5	1035.6	1037.7	1039.7	1041.8	1043.9	1046.1	1048.2	1050.3	1052.4	1054.5	1056.7	1058.8	1060.9	1063.0	1065.2	1067.3
0.25	1038.2	1040.4	1042.5	1044.7	1046.9	1049.1	1051.3	1053.5	1055.7	1057.9	1060.1	1062.3	1064.6	1066.8	1069.0	1071.2	1073.5	1075.7	1077.9	1080.1
0.30	1047.2	1049.4	1051.7	1054.0	1056.3	1058.5	1060.8	1063.1	1065.4	1067.7	1070.0	1072.3	1074.6	1076.9	1079.2	1081.5	1083.8	1086.1	1088.5	1090.8
0.35	1054.9	1057.2	1059.6	1061.9	1064.3	1066.6	1039.0	1071.4	1073.7	1076.1	1078.5	1080.9	1083.2	1085.6	1088.0	1090.4	1092.7	1095.1	1097.5	1099.9
0.40	1061.6	1064.0	1066.5	1068.9	1071.3	1073.8	1076.2	1078.6	1081.1	1083.5	1085.9	1088.4	1090.8	1093.2	1095.7	1098.1	1100.5	1103.0	1105.4	1107.8
0.45	1067.6	1070.1	1072.6	1075.1	1077.6	1080.1	1082.6	1085.1	1087.6	1090.1	1092.6	1095.1	1097.6	1100.1	1102.6	1105.0	1107.5	1110.0	1112.5	1115.0
0.50	1073.0	1075.6	1078.2	1080.8	1083.3	1085.9	1088.4	1091.0	1093.6	1096.1	1098.6	1101.2	1103.7	1106.3	1108.8	1111.3	1113.9	1116.4	1118.9	1121.4
0.55	1078.0	1080.7	1083.3	1085.9	1088.6	1091.2	1093.8	1096.4	1899.0	1101.6	1104.2	1106.3	1109.4	1111.9	1114.5	1117.1	1119.7	1122.2	1124.8	1127.4
0.60	1082.6	1085.3	1088.0	1090.7	1093.4	1096.1	1098.7	1101.4	1104.0	1106.7	1109.3	1112.0	1114.6	1117.2	1119.8	1122.4	1125.0	1127.7	1130.3	1132.9
0.65	1086.9	1089.7	1092.5	1095.2	1097.9	1100.7	1103.4	1106.1	1108.8	1111.4	1114.1	1116.8	1119.5	1122.1	1124.8	1127.4	1130.1	1132.7	1135.3	1138.0
0.70	1091.0	1093.8	1096.6	1099.4	1102.2	1104.9	1107.7	1110.5	1113.2	1115.9	1118.6	1121.3	1124.0	1126.7	1129.4	1132.1	1134.8	1137.5	1140.1	1142.8
0.75	1094.8	1097.7	1100.5	1103.4	1106.2	1109.0	1111.3	1114.6	1117.4	1120.1	1122.9	1125.6	1128.4	1131.1	1133.8	1136.5	1139.2	1141.9	1144.6	1147.3
0.80	1098.4	1101.3	1104.2	1107.1	1110.0	1112.9	1115.7	1118.5	1121.3	1124.2	1126.9	1129.7	1132.5	1135.2	1138.0	1140.7	1143.5	1146.2	1148.9	1151.6
0.85	1101.8	1104.8	1107.8	1110.7	1113.6	1116.5	1119.4	1122.3	1125.1	1128.0	1130.8	1133.6	1136.4	1139.2	1142.0	1144.7	1147.5	1150.3	1153.0	1155.7
0.90	1105.1	1108.1	1111.1	1114.1	1117.1	1120.1	1123.0	1125.9	1128.8	1131.6	1134.5	1137.3	1140.2	1143.0	1145.8	1148.6	1151.4	1154.1	1156.9	1159.7
0.95	1108.2	1111.3	1114.4	1117.4	1120.5	1123.4	1126.4	1129.3	1132.3	1135.2	1138.1	1140.9	1143.8	1146.6	1149.5	1152.3	1155.1	1157.9	1160.7	1163.4
1.00	1111.3	1114.4	1117.5	1120.6	1123.7	1126.7	1129.7	1132.7	1135.6	1138.6	1141.5	1144.4	1147.3	1150.1	1153.0	1155.8	1158.7	1161.5	1164.3	1167.1
1.05	1114.2	1117.4	1120.5	1123.7	1126.8	1129.9	1132.9	1135.9	1138.9	1141.9	1144.8	1147.7	1150.6	1153.5	1156.4	1159.3	1162.1	1165.0	1167.8	1170.6
1.10	1117.0	1120.3	1123.5	1126.7	1129.8	1132.9	1136.0	1139.0	1142.1	1145.1	1148.0	1151.0	1153.9	1156.8	1159.7	1162.6	1165.5	1168.3	1171.2	1174.0
1.15	1119.7	1123.0	1126.3	1129.5	1132.7	1135.9	1139.0	1142.1	1145.1	1148.2	1151.2	1154.1	1157.1	1160.0	1162.9	1165.8	1168.7	1171.6	1174.5	1177.3
1.20	1122.4	1125.8	1129.1	1132.3	1135.6	1138.8	1141.9	1145.0	1148.1	1151.2	1154.2	1157.2	1160.2	1163.1	1166.1	1169.0	1171.9	1174.8	1177.7	1180.5
1.25	1125.0	1128.4	1131.8	1135.1	1138.4	1141.6	1144.8	1147.9	1151.0	1154.1	1157.2	1160.2	1163.2	1166.2	1169.1	1172.1	1175.0	1177.9	1180.8	1183.7
1.30	1127.5	1131.0	1134.4	1137.8	1141.1	1144.3	1147.6	1150.8	1153.9	1157.0	1160.1	1163.1	1166.2	1169.2	1172.1	1175.1	1178.0	1181.0	1183.9	1186.7
1.35	1130.0	1133.5	1137.0	1140.4	1143.7	1147.0	1150.3	1153.5	1156.7	1159.8	1162.9	1166.0	1169.1	1172.1	1175.1	1178.1	1181.0	1183.9	1186.8	1189.7
1.40	1132.4	1136.0	1139.5	1143.0	1146.4	1149.7	1153.0	1156.2	1159.5	1162.6	1165.8	1168.8	1171.9	1175.0	1178.0	1180.9	1183.9	1186.9	1189.8	1192.7
1.45	1134.8	1138.4	1142.0	1145.5	1148.9	1152.3	1155.6	1158.9	1162.2	1165.4	1168.5	1171.6	1174.7	1177.8	1180.8	1183.8	1186.8	1189.7	1192.7	1195.6
1.50	1137.1	1140.8	1144.4	1148.0	1151.5	1154.9	1158.2	1161.6	1164.8	1168.0	1171.2	1174.4	1177.5	1180.5	1183.6	1186.6	1189.6	1192.6	1195.5	1198.4

Unit: mV

G-4

Relationship of CP-CO<sub>2</sub>%  
CO=23.1%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05	17.721	15.565	13.698	12.079	10.672	9.447	8.378	7.444	6.627	5.910	5.280	4.725	4.237	3.805	3.422	3.084	2.783	2.516
0.10	8.761	7.692	6.768	5.966	5.270	4.664	4.136	3.675	3.271	2.917	2.606	2.333	2.091	1.878	1.890	1.522	1.374	1.242
0.15	5.774	5.068	4.458	3.929	3.470	3.070	2.722	2.419	2.153	1.920	1.715	1.535	1.376	1.236	1.112	1.002	0.904	0.818
0.20	4.281	3.756	3.303	2.910	2.569	2.273	2.016	1.790	1.593	1.421	1.269	1.136	1.019	0.915	0.823	0.742	0.670	0.605
0.25	3.385	2.969	2.610	2.299	2.029	1.795	1.591	1.413	1.258	1.122	1.002	0.897	0.804	0.722	0.650	0.586	0.529	0.478
0.30	2.787	2.444	2.148	1.891	1.669	1.476	1.309	1.162	1.034	0.922	0.824	0.737	0.661	0.594	0.534	0.481	0.435	0.393
0.35	2.361	2.069	1.818	1.600	1.412	1.249	1.107	0.983	0.874	0.780	0.696	0.623	0.559	0.502	0.452	0.407	0.368	0.332
0.40	2.041	1.788	1.570	1.382	1.219	1.078	0.955	0.848	0.755	0.673	0.601	0.538	0.482	0.433	0.390	0.351	0.317	0.287
0.45	1.792	1.569	1.378	1.212	1.069	0.945	0.837	0.743	0.661	0.590	0.527	0.471	0.423	0.380	0.342	0.308	0.278	0.252
0.50	1.593	1.394	1.224	1.076	0.949	0.839	0.743	0.660	0.587	0.523	0.467	0.418	0.375	0.337	0.303	0.273	0.247	0.223
0.55	1.430	1.251	1.097	0.965	0.851	0.752	0.666	0.591	0.526	0.469	0.419	0.375	0.336	0.302	0.272	0.245	0.221	0.200
0.60	1.294	1.132	0.992	0.873	0.769	0.679	0.602	0.534	0.475	0.423	0.378	0.338	0.303	0.273	0.245	0.221	0.200	0.181
0.65	1.179	1.031	0.904	0.794	0.700	0.618	0.547	0.486	0.432	0.385	0.344	0.308	0.276	0.248	0.223	0.201	0.182	0.164
0.70	1.081	0.944	0.827	0.727	0.640	0.566	0.501	0.444	0.395	0.352	0.314	0.281	0.252	0.227	0.204	0.184	0.166	0.151
0.75	0.995	0.869	0.761	0.669	0.589	0.520	0.460	0.408	0.363	0.324	0.289	0.259	0.232	0.208	0.188	0.169	0.153	0.138
0.80	0.921	0.804	0.704	0.618	0.544	0.480	0.425	0.377	0.335	0.299	0.267	0.239	0.214	0.192	0.173	0.156	0.141	0.128
0.85	0.855	0.746	0.653	0.573	0.504	0.445	0.394	0.349	0.310	0.277	0.247	0.221	0.198	0.178	0.160	0.145	0.131	0.118
0.90	0.796	0.694	0.607	0.533	0.469	0.414	0.366	0.325	0.289	0.257	0.230	0.205	0.184	0.166	0.149	0.135	0.122	0.110
0.95	0.744	0.648	0.567	0.497	0.437	0.386	0.341	0.303	0.269	0.240	0.214	0.191	0.172	0.154	0.139	0.125	0.113	0.103
1.00	0.697	0.607	0.530	0.465	0.409	0.361	0.319	0.283	0.251	0.224	0.200	0.179	0.160	0.144	0.130	0.117	0.106	0.096
1.05	0.654	0.569	0.497	0.436	0.383	0.338	0.299	0.265	0.235	0.210	0.187	0.168	0.150	0.135	0.122	0.110	0.099	0.090
1.10	0.615	0.535	0.467	0.410	0.360	0.317	0.280	0.248	0.221	0.197	0.176	0.157	0.141	0.127	0.114	0.103	0.093	0.084
1.15	0.580	0.504	0.440	0.385	0.338	0.298	0.264	0.234	0.207	0.185	0.165	0.148	0.132	0.119	0.107	0.097	0.088	0.079
1.20	0.547	0.476	0.415	0.363	0.319	0.281	0.248	0.220	0.195	0.174	0.155	0.139	0.125	0.112	0.101	0.091	0.082	0.075
1.25	0.518	0.450	0.392	0.343	0.301	0.265	0.234	0.207	0.184	0.164	0.146	0.131	0.118	0.106	0.095	0.086	0.078	0.070
1.30	0.490	0.425	0.371	0.324	0.284	0.250	0.221	0.196	0.174	0.155	0.138	0.124	0.111	0.100	0.090	0.081	0.073	0.067
1.35	0.464	0.403	0.351	0.307	0.269	0.237	0.209	0.185	0.164	0.146	0.131	0.117	0.105	0.094	0.085	0.077	0.069	0.063
1.40	0.441	0.382	0.332	0.290	0.255	0.224	0.198	0.175	0.155	0.138	0.123	0.111	0.099	0.089	0.080	0.073	0.066	0.060
1.45	0.419	0.363	0.315	0.275	0.241	0.212	0.187	0.166	0.147	0.131	0.117	0.105	0.094	0.084	0.076	0.069	0.062	0.056
1.50	0.398	0.345	0.299	0.261	0.229	0.201	0.177	0.157	0.139	0.124	0.111	0.099	0.089	0.080	0.072	0.065	0.059	0.053

Unit: %

Relationship of CP-DP°C

CO=23.1%, H<sub>2</sub>=30.8%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05																	34.99	33.54
0.10									33.70	32.18	30.80	29.40	27.91	26.55	25.31	23.96	22.65	21.44
0.15				34.16	32.48	30.96	29.47	27.85	26.40	25.08	23.57	22.18	20.92	19.71	18.34	17.08	15.94	14.86
0.20	33.84	32.10	30.55	28.89	27.25	25.77	24.28	22.75	21.37	20.11	18.66	17.30	16.07	14.93	13.62	12.42	11.33	10.33
0.25	29.82	28.01	26.39	24.93	23.26	21.76	20.42	18.95	17.50	16.20	15.02	13.64	12.38	11.24	10.20	8.99	7.80	6.72
0.30	26.34	24.80	23.09	21.56	20.18	18.61	17.15	15.83	14.53	13.14	11.89	10.75	9.61	8.33	7.16	6.10	5.12	3.97
0.35	23.53	21.90	20.45	18.87	17.33	15.95	14.63	13.18	11.88	10.71	9.52	8.20	7.00	5.92	4.91	3.69	2.57	1.56
0.40	21.15	19.65	17.98	16.49	15.15	13.66	12.27	11.02	9.86	8.47	7.22	6.08	5.05	3.79	2.64	1.59	0.63	-0.34
0.45	19.06	17.41	15.94	14.52	13.01	11.65	10.44	9.10	7.75	6.53	5.42	4.22	3.00	1.88	0.87	-0.07	-1.23	-2.29
0.50	17.09	15.62	14.11	12.60	11.26	10.05	8.59	7.25	6.05	4.96	3.63	2.43	1.35	0.36	-0.75	-1.88	-2.91	-3.85
0.55	15.49	13.92	12.39	11.03	9.76	8.27	6.94	5.74	4.55	3.23	2.04	0.97	-0.01	-1.23	-2.35	-3.36	-4.29	-5.18
0.60	13.90	12.34	10.96	9.63	8.12	6.77	5.57	4.30	2.98	1.79	0.72	-0.35	-1.57	-2.68	-3.68	-4.60	-5.60	-6.66
0.65	12.43	11.01	9.65	8.11	6.73	5.50	4.20	2.86	1.66	0.57	-0.56	-1.78	-2.89	-3.90	-4.81	-5.89	-6.94	-7.90
0.70	11.18	9.82	8.22	6.81	5.54	4.21	2.85	1.62	0.52	-0.65	-1.89	-3.01	-4.03	-4.95	-6.08	-7.14	-8.10	-8.97
0.75	10.09	8.46	6.99	5.68	4.34	2.93	1.68	0.55	-0.64	-1.91	-3.05	-4.08	-5.01	-6.18	-7.25	-8.22	-9.10	-9.90
0.80	8.82	7.27	5.90	4.58	3.12	1.82	0.65	-0.54	-1.84	-3.01	-4.06	-5.01	-6.20	-7.29	-8.27	-9.16	-9.97	-11.03
0.85	7.67	6.22	4.93	3.40	2.04	0.83	-0.35	-1.69	-2.89	-3.98	-4.95	-6.15	-7.26	-8.26	-9.17	-9.99	-11.07	-12.06
0.90	6.64	5.29	3.78	2.35	1.08	-0.06	-1.46	-2.71	-3.86	-4.84	-6.03	-7.17	-8.19	-9.12	-9.97	-11.05	-12.06	-12.98
0.95	5.73	4.27	2.75	1.41	0.22	-1.15	-2.46	-3.63	-4.67	-5.84	-7.02	-8.07	-9.03	-9.90	-10.98	-12.01	-12.94	-13.80
1.00	4.87	3.25	1.82	0.57	0.76	-2.13	-3.36	-4.45	-5.59	-6.81	-7.90	-8.89	-9.78	-10.85	-11.91	-12.87	-13.74	-14.54
1.05	3.86	2.33	0.99	-0.27	1.73	-3.02	-4.17	-5.26	-6.54	-7.68	-8.71	-9.63	-10.67	-11.76	-12.75	-13.64	-14.46	-15.29
1.10	2.94	1.49	0.22	-1.24	2.61	-3.82	-4.91	-6.20	-7.40	-8.47	-9.43	-10.43	-11.56	-12.58	-13.51	-14.35	-15.16	-16.16
1.15	2.10	0.73	-0.65	-2.12	3.41	-4.56	-5.80	-7.06	-8.19	-9.19	-10.14	-11.32	-12.38	-13.34	-14.21	-15.00	-16.02	-16.96
1.20	1.33	0.03	-1.54	-2.93	4.15	-5.32	-6.66	-7.85	-8.91	-9.86	-11.02	-12.13	-13.13	-14.03	-14.84	-15.84	-16.80	-17.68
1.25	0.62	-0.85	-2.35	-3.67	4.83	-6.18	-7.45	-8.57	-9.57	-10.67	-11.83	-12.87	-13.81	-14.66	-15.62	-16.62	-17.52	-18.35
1.30	-0.05	-1.68	-3.11	-4.36	5.63	-6.98	-8.17	-9.24	-10.26	-11.47	-12.58	-13.56	-14.45	-15.35	-16.39	-17.33	-18.19	-18.97
1.35	-0.89	-2.44	-3.80	-4.99	6.44	-7.72	-8.85	-9.86	-11.08	-12.23	-13.27	-14.20	-15.05	-16.13	-17.11	-18.00	-18.81	-19.54
1.40	-1.67	-3.15	-4.45	-5.80	7.18	-8.40	-9.47	-10.62	-11.84	-12.93	-13.90	-14.79	-15.83	-16.85	-17.78	-18.62	-19.38	-20.11
1.45	-2.39	-3.81	-5.07	-6.57	7.88	-9.04	-10.08	-11.39	-12.55	-13.58	-14.51	-15.49	-16.56	-17.52	-18.40	-19.19	-19.91	-20.84
1.50	-3.07	-4.43	-5.85	-7.28	8.53	-9.63	-10.86	-12.10	-13.21	-14.19	-15.09	-16.22	-17.24	-18.15	-18.98	-19.73	-20.60	-21.52

Unit: °C

9-9



Relationship of CP-EMF  
CO=23%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990
0.05	956.3	957.7	959.0	960.4	961.8	963.2	964.6	966.0	967.4	968.9	970.3	971.8	973.2	974.7	976.2	977.7	979.1	980.6	982.1	983.6
0.10	988.9	990.6	992.2	993.9	995.6	997.3	999.0	1000.8	1002.5	1004.2	1006.0	1007.8	1009.5	1011.3	1013.1	1014.8	1016.6	1018.4	1020.2	1022.0
0.15	1008.2	1010.0	1011.9	1013.8	1015.7	1017.6	1019.5	1021.4	1023.3	1025.2	1027.1	1029.1	1031.0	1033.0	1034.9	1036.9	1038.8	1040.8	1042.8	1044.7
0.20	1022.0	1024.0	1026.0	1028.0	1030.1	1032.1	1034.1	1036.2	1038.2	1040.3	1042.4	1044.4	1046.5	1048.6	1050.6	1052.7	1054.8	1056.9	1059.0	1061.1
0.25	1032.9	1035.0	1037.1	1039.2	1041.4	1043.5	1045.7	1047.8	1050.0	1052.1	1054.3	1056.5	1058.6	1060.8	1063.0	1065.2	1067.3	1069.5	1071.7	1073.9
0.30	1041.9	1044.1	1046.3	1048.5	1050.7	1053.0	1055.2	1057.5	1059.7	1061.9	1064.2	1066.4	1068.7	1071.0	1073.2	1075.5	1077.7	1080.0	1082.2	1084.5
0.35	1049.5	1051.8	1054.1	1056.5	1058.8	1061.1	1063.4	1065.7	1068.0	1070.4	1072.7	1075.0	1077.3	1079.6	1082.0	1084.3	1086.6	1088.9	1091.3	1093.6
0.40	1056.3	1058.7	1061.0	1063.4	1065.8	1068.2	1070.6	1073.0	1075.3	1077.7	1080.1	1082.5	1084.9	1087.3	1089.7	1092.0	1094.4	1096.8	1099.2	1101.6
0.45	1062.3	1064.7	1067.2	1069.6	1072.1	1074.6	1077.0	1079.4	1081.9	1084.3	1086.8	1089.2	1091.7	1094.1	1096.5	1099.0	1101.4	1103.8	1106.3	1108.7
0.50	1067.7	1070.3	1072.8	1075.3	1077.8	1080.3	1082.8	1085.3	1087.8	1090.3	1092.8	1095.3	1097.8	1100.3	1102.8	1105.3	1107.7	1110.2	1112.7	1115.2
0.55	1072.7	1075.3	1077.9	1080.5	1083.0	1085.6	1088.2	1090.7	1093.3	1095.8	1098.4	1100.9	1103.5	1106.0	1108.5	1111.0	1113.6	1116.1	1118.6	1121.1
0.60	1077.3	1080.0	1082.6	1085.3	1087.9	1090.5	1093.1	1095.7	1098.3	1100.9	1103.5	1106.1	1108.7	1111.2	1113.8	1116.4	1118.9	1121.5	1124.0	1126.6
0.65	1081.6	1084.3	1087.0	1089.7	1092.4	1095.1	1097.9	1100.4	1103.0	1105.7	1108.3	1110.9	1113.5	1116.2	1118.8	1121.4	1124.0	1126.5	1129.1	1131.7
0.70	1085.6	1088.4	1091.2	1093.9	1096.7	1099.4	1102.1	1104.8	1107.5	1110.1	1112.8	1115.5	1118.1	1120.8	1123.4	1126.0	1128.7	1131.3	1133.9	1136.5
0.75	1089.4	1092.3	1095.1	1097.9	1100.7	1103.4	1106.2	1108.9	1111.7	1114.4	1117.1	1119.8	1122.5	1125.1	1127.8	1130.5	1133.1	1135.8	1138.4	1141.1
0.80	1093.1	1095.9	1098.8	1101.7	1104.5	1107.3	1110.1	1112.9	1115.6	1118.4	1121.1	1123.9	1126.6	1129.3	1132.0	1134.7	1137.4	1140.0	1142.7	1145.4
0.85	1096.5	1099.4	1102.3	1105.2	1108.1	1111.0	1113.8	1116.6	1119.4	1122.2	1125.0	1127.7	1130.5	1133.2	1136.0	1138.7	1141.4	1144.1	1146.8	1149.5
0.90	1099.8	1102.8	1105.7	1108.7	1111.6	1114.5	1117.4	1120.2	1123.1	1125.9	1128.7	1131.5	1134.3	1137.0	1139.8	1142.5	1145.3	1148.0	1150.7	1153.4
0.95	1102.9	1106.0	1109.0	1112.0	1114.9	1117.9	1120.8	1123.7	1126.6	1129.4	1132.2	1135.1	1137.9	1140.7	1143.4	1146.2	1149.0	1151.7	1154.5	1157.2
1.00	1105.9	1109.0	1112.1	1115.1	1118.2	1121.1	1124.1	1127.0	1129.9	1132.8	1135.7	1138.5	1141.4	1144.2	1147.0	1149.8	1152.5	1155.3	1158.1	1160.8
1.05	1108.9	1112.0	1115.1	1118.2	1121.3	1124.3	1127.3	1130.2	1133.2	1136.1	1139.0	1141.9	1144.7	1147.6	1150.4	1153.2	1156.0	1158.8	1161.6	1164.3
1.10	1111.7	1114.9	1118.1	1121.2	1124.3	1127.3	1130.4	1133.4	1136.3	1139.3	1142.2	1145.1	1148.0	1150.9	1153.7	1156.5	1159.4	1162.2	1165.0	1167.7
1.15	1114.4	1117.7	1120.9	1124.1	1127.2	1130.3	1133.4	1136.4	1139.4	1142.4	1145.3	1148.3	1151.2	1154.1	1156.9	1159.8	1162.6	1165.4	1168.3	1171.0
1.20	1117.1	1120.4	1123.7	1126.9	1130.1	1133.2	1136.3	1139.4	1142.4	1145.4	1148.4	1151.3	1154.3	1157.2	1160.1	1162.9	1165.8	1168.6	1171.5	1174.3
1.25	1119.7	1123.0	1126.4	1129.6	1132.8	1136.0	1139.2	1142.3	1145.3	1148.4	1151.4	1154.3	1157.3	1160.2	1163.1	1166.0	1168.9	1171.7	1174.6	1177.4
1.30	1122.2	1125.6	1129.0	1132.3	1135.6	1138.8	1142.0	1145.1	1148.2	1151.2	1154.3	1157.3	1160.3	1163.2	1166.1	1169.0	1171.9	1174.8	1177.6	1180.5
1.35	1124.7	1128.1	1131.6	1134.9	1138.2	1141.5	1144.7	1147.9	1151.0	1154.1	1157.1	1160.2	1163.2	1166.1	1169.1	1172.0	1174.9	1177.8	1180.6	1183.5
1.40	1127.1	1130.6	1134.1	1137.5	1140.8	1144.1	1147.4	1150.6	1153.7	1156.9	1159.9	1163.0	1166.0	1169.0	1171.9	1174.9	1177.8	1180.7	1183.6	1186.4
1.45	1129.5	1133.0	1136.6	1140.0	1143.4	1146.7	1150.0	1153.3	1156.4	1159.6	1162.7	1165.8	1168.8	1171.8	1174.8	1177.7	1180.7	1183.6	1186.5	1189.3
1.50	1131.8	1135.4	1139.0	1142.5	1145.9	1149.3	1152.6	1155.9	1159.1	1162.3	1165.4	1168.5	1171.6	1174.6	1177.6	1180.5	1183.5	1186.4	1189.3	1192.2

Unit: mV

Relationship of CP-CO<sub>2</sub>%  
CO=23.5%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05	19.340	16.108	14.176	12.501	11.044	9.777	9.671	7.704	6.858	6.116	5.464	4.891	4.385	3.938	3.542	3.192	2.880	2.604
0.10	9.067	7.961	7.004	6.175	5.454	4.827	4.281	3.803	3.386	3.019	2.697	2.414	2.164	1.944	1.749	1.576	1.422	1.286
0.15	5.376	5.245	4.613	4.066	3.591	3.178	2.818	2.503	2.228	1.987	1.775	1.589	1.424	1.279	1.151	1.037	0.936	0.847
0.20	4.430	3.887	3.419	3.012	2.659	2.353	2.086	1.853	1.649	1.471	1.314	1.176	1.054	0.947	0.852	0.768	0.693	0.627
0.25	3.503	3.072	2.701	2.379	2.100	1.858	1.647	1.463	1.302	1.161	1.037	0.928	0.832	0.747	0.672	0.606	0.547	0.495
0.30	2.885	2.529	2.223	1.957	1.728	1.528	1.354	1.203	1.070	0.954	0.853	0.763	0.684	0.614	0.553	0.498	0.450	0.407
0.35	2.443	2.141	1.881	1.656	1.461	1.232	1.145	1.017	0.905	0.807	0.721	0.645	0.578	0.520	0.467	0.421	0.380	0.344
0.40	2.112	1.850	1.625	1.430	1.262	1.116	0.999	0.878	0.781	0.696	0.622	0.557	0.499	0.448	0.403	0.364	0.328	0.297
0.45	1.854	1.624	1.426	1.255	1.106	0.978	0.867	0.768	0.684	0.610	0.545	0.488	0.437	0.393	0.354	0.319	0.288	0.260
0.50	1.648	1.443	1.066	1.114	0.882	0.868	0.769	0.683	0.607	0.541	0.484	0.433	0.388	0.349	0.314	0.283	0.255	0.231
0.55	1.480	1.295	1.136	0.999	0.981	0.778	0.689	0.612	0.544	0.485	0.433	0.388	0.348	0.312	0.281	0.253	0.229	0.207
0.60	1.339	1.171	1.027	0.803	0.796	0.703	0.623	0.553	0.492	0.438	0.391	0.350	0.314	0.282	0.254	0.229	0.207	0.187
0.65	1.220	1.067	0.935	0.922	0.724	0.640	0.566	0.503	0.447	0.398	0.356	0.319	0.286	0.257	0.231	0.208	0.188	0.170
0.70	1.119	0.977	0.856	0.752	0.663	0.595	0.518	0.460	0.409	0.364	0.325	0.291	0.261	0.235	0.211	0.191	0.172	0.156
0.75	1.030	0.900	0.799	0.692	0.610	0.538	0.476	0.423	0.376	0.335	0.299	0.268	0.240	0.216	0.194	0.175	0.158	0.143
0.80	0.853	0.932	0.728	0.639	0.563	0.497	0.440	0.390	0.347	0.309	0.276	0.247	0.222	0.199	0.179	0.162	0.146	0.137
0.85	0.885	0.772	0.676	0.593	0.522	0.461	0.407	0.361	0.321	0.286	0.256	0.229	0.205	0.184	0.166	0.150	0.135	0.123
0.90	0.824	0.719	0.629	0.552	0.485	0.429	0.379	0.336	0.299	0.266	0.238	0.213	0.191	0.171	0.154	0.139	0.126	0.114
0.95	0.770	0.671	0.597	0.515	0.453	0.399	0.353	0.313	0.279	0.248	0.221	0.198	0.178	0.160	0.144	0.130	0.117	0.106
1.00	0.721	0.629	0.548	0.481	0.423	0.373	0.330	0.293	0.260	0.232	0.207	0.185	0.166	0.149	0.134	0.121	0.110	0.099
1.05	0.677	0.589	0.515	0.451	0.397	0.350	0.309	0.274	0.244	0.217	0.194	0.173	0.156	0.140	0.126	0.114	0.103	0.093
1.10	0.637	0.554	0.484	0.424	0.372	0.328	0.290	0.257	0.228	0.204	0.182	0.163	0.146	0.131	0.118	0.107	0.096	0.087
1.15	0.600	0.522	0.455	0.399	0.350	0.309	0.273	0.242	0.215	0.191	0.171	0.153	0.137	0.123	0.111	0.100	0.091	0.082
1.20	0.567	0.492	0.429	0.376	0.330	0.291	0.257	0.228	0.202	0.180	0.161	0.144	0.129	0.116	0.105	0.094	0.085	0.077
1.25	0.536	0.465	0.406	0.355	0.311	0.274	0.242	0.215	0.191	0.170	0.152	0.136	0.122	0.109	0.099	0.089	0.080	0.073
1.30	0.507	0.440	0.384	0.335	0.294	0.259	0.229	0.203	0.180	0.160	0.143	0.128	0.115	0.103	0.093	0.084	0.076	0.069
1.35	0.481	0.417	0.363	0.317	0.278	0.245	0.216	0.191	0.170	0.151	0.135	0.121	0.109	0.098	0.088	0.079	0.072	0.065
1.40	0.456	0.395	0.344	0.301	0.264	0.232	0.205	0.181	0.161	0.143	0.128	0.114	0.103	0.092	0.083	0.075	0.068	0.062
1.45	0.433	0.375	0.326	0.285	0.250	0.220	0.194	0.172	0.152	0.136	0.121	0.108	0.097	0.087	0.079	0.071	0.064	0.058
1.50	0.412	0.357	0.310	0.270	0.237	0.208	0.194	0.163	0.144	0.128	0.115	0.103	0.092	0.083	0.075	0.067	0.061	0.055

Unit: %

8-9

Relationship of CP-DP°C

CO=23.5%, H<sub>2</sub>=29.4%

(°C)

G-9

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05																	34.41	33.00
0.10								34.79	33.16	31.68	30.33	28.84	27.39	26.07	24.84	23.44	22.16	21.00
0.15				33.60	31.97	30.49	28.91	27.34	25.92	24.54	23.06	21.71	20.49	19.18	17.85	16.63	15.52	14.36
0.20	33.29	31.60	30.09	28.34	26.75	25.32	23.75	22.26	20.92	19.61	18.16	16.84	15.64	14.43	13.15	11.99	10.93	9.94
0.25	29.25	27.49	25.92	24.38	22.76	21.31	20.00	18.44	17.04	15.77	14.51	13.17	11.95	10.84	9.77	8.52	7.37	6.32
0.30	25.87	24.25	22.59	21.10	19.70	18.11	16.69	15.41	14.03	12.69	11.47	10.36	9.13	7.88	6.74	5.71	4.68	3.52
0.35	23.02	21.44	20.03	18.37	16.87	15.53	14.13	12.73	11.46	10.32	9.03	7.75	6.59	5.54	4.43	3.24	2.16	1.18
0.40	20.71	19.12	17.50	16.05	14.68	13.19	11.84	10.63	9.37	8.02	6.80	5.69	4.58	3.35	2.22	1.20	0.27	-0.80
0.45	18.55	16.95	15.52	14.03	12.56	11.24	10.06	8.62	7.31	6.13	5.06	3.76	2.57	1.49	0.51	-0.53	-1.66	-2.70
0.50	16.64	15.21	13.63	12.16	10.86	9.57	8.13	6.83	5.67	4.48	3.19	2.02	0.97	0.01	-1.19	-2.29	-3.30	-4.21
0.55	15.08	13.44	11.96	10.64	9.27	7.82	6.53	5.37	4.08	2.80	1.65	0.60	-0.48	-1.67	-2.75	-3.73	-4.63	-5.62
0.60	13.42	11.91	10.56	9.14	7.67	6.37	5.19	3.84	2.56	1.40	0.36	-0.81	-1.99	-3.07	-4.05	-4.93	-6.03	-7.06
0.65	12.00	10.61	9.16	7.66	6.33	5.13	3.74	2.44	1.27	0.22	-1.01	-2.20	-3.28	-4.25	-5.20	-6.32	-7.34	-8.27
0.70	10.78	9.32	7.77	6.40	5.17	3.75	2.43	1.24	0.17	-1.10	-2.31	-3.39	-4.38	-5.38	-6.50	-7.52	-8.46	-9.31
0.75	9.62	8.00	6.57	5.30	3.88	2.51	1.29	0.19	-1.09	-2.32	-3.43	-4.43	-5.46	-6.60	-7.63	-8.57	-9.43	-10.30
0.80	8.35	6.85	5.52	4.11	2.69	1.43	0.29	-0.99	-2.25	-3.39	-4.41	-5.46	-6.62	-7.67	-8.62	-9.49	-10.40	-11.44
0.85	7.25	5.83	4.45	2.97	1.64	0.47	-0.81	-2.11	-3.28	-4.33	-5.38	-6.57	-7.64	-8.61	-9.50	-10.43	-11.48	-12.44
0.90	6.24	4.90	3.33	1.95	0.71	-0.53	-1.89	-3.10	-4.19	-5.23	-6.45	-7.55	-8.55	-9.45	-10.39	-11.46	-12.44	-13.33
0.95	5.35	3.81	2.33	1.03	-0.17	-1.59	-2.86	-3.99	-5.00	-6.27	-7.41	-8.44	-9.36	-10.29	-11.39	-12.39	-13.30	-14.13
1.00	4.39	2.82	1.43	0.21	-1.21	-2.54	-3.73	-4.79	-6.02	-7.20	-8.27	-9.23	-10.13	-11.27	-12.29	-13.22	-14.07	-14.84
1.05	3.41	1.92	0.62	-0.73	-2.15	-3.40	-4.51	-5.71	-6.94	-8.05	-9.05	-9.95	-11.09	-12.15	-13.11	-13.98	-14.77	-15.70
1.10	2.51	1.11	-0.17	-1.67	-3.00	-4.18	-5.32	-6.62	-7.78	-8.82	-9.76	-10.86	-11.96	-12.95	-13.85	-14.66	-15.58	-16.55
1.15	1.70	0.37	-1.10	-2.53	-3.78	-4.90	-6.23	-7.45	-8.54	-9.52	-10.58	-11.72	-12.75	-13.68	-14.52	-15.41	-16.41	-17.32
1.20	0.95	-0.43	-1.96	-3.31	-4.50	-5.76	-7.06	-8.21	-9.24	-10.24	-11.43	-12.51	-13.47	-14.35	-15.20	-16.23	-17.17	-18.03
1.25	0.26	-1.30	-2.75	-4.03	-5.22	-6.60	-7.83	-8.92	-9.89	-11.09	-12.22	-13.23	-14.14	-14.97	-16.02	-16.99	-17.87	-18.68
1.30	-0.51	-2.10	-3.48	-4.70	-6.06	-7.37	-8.53	-9.56	-10.69	-11.88	-12.94	-13.90	-14.76	-15.77	-16.77	-17.69	-18.52	-19.28
1.35	-1.33	-2.84	-4.16	-5.43	-6.84	-8.09	-9.19	-10.23	-11.49	-12.61	-13.61	-14.52	-15.47	-16.52	-17.47	-18.33	-19.12	-19.83
1.40	-2.09	-3.53	-4.79	-6.23	-7.57	-8.75	-9.79	-11.04	-12.23	-13.29	-14.24	-15.13	-16.23	-17.22	-18.12	-18.93	-19.67	-20.51
1.45	-2.79	-4.17	-5.51	-6.97	-8.25	-9.37	-10.52	-11.78	-12.91	-13.92	-14.82	-15.89	-16.93	-17.87	-18.72	-19.49	-20.28	-21.22
1.50	-3.45	-4.77	-6.27	-7.66	-8.88	-9.94	-11.28	-12.48	-13.55	-14.51	-15.51	-16.61	-17.59	-18.48	-19.28	-20.02	-20.99	-21.88

Unit: °C

Relationship of CP-EMF  
CO=23.5%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990
0.05	955.4	956.7	958.0	959.4	960.7	962.1	963.5	964.9	966.4	967.8	969.2	970.7	972.1	973.6	975.1	976.5	978.0	979.5	980.9	982.4
0.10	987.9	989.6	991.2	992.9	994.6	996.3	998.0	999.7	1001.4	1003.2	1004.9	1006.7	1008.4	1010.2	1011.9	1013.7	1015.5	1017.3	1019.0	1020.8
0.15	1007.2	1009.0	1010.9	1012.7	1014.6	1016.5	1018.4	1020.3	1022.2	1024.1	1026.1	1028.0	1029.9	1031.9	1033.8	1035.7	1037.7	1039.6	1041.6	1043.5
0.20	1021.0	1023.0	1025.0	1027.0	1029.0	1031.1	1033.1	1035.1	1037.2	1039.2	1041.3	1043.3	1045.4	1047.4	1049.5	1051.6	1053.7	1055.7	1057.8	1059.9
0.25	1031.9	1034.0	1036.1	1038.2	1040.3	1042.5	1044.6	1046.8	1048.9	1051.1	1053.2	1055.4	1057.5	1059.7	1061.9	1064.0	1066.2	1068.4	1070.5	1072.7
0.30	1040.9	1043.1	1045.3	1047.5	1049.7	1051.9	1054.2	1056.4	1058.6	1060.9	1063.1	1065.4	1067.6	1069.8	1072.1	1074.3	1076.6	1078.8	1081.1	1083.3
0.35	1048.5	1050.8	1053.1	1055.4	1057.7	1060.0	1062.3	1064.7	1067.0	1069.3	1071.6	1073.9	1076.2	1078.5	1080.8	1083.2	1085.5	1087.8	1090.1	1092.4
0.40	1055.3	1057.6	1060.0	1062.4	1064.8	1067.1	1069.5	1071.9	1074.3	1076.7	1079.0	1081.4	1083.8	1086.2	1088.5	1090.9	1093.3	1095.7	1098.0	1100.4
0.45	1061.3	1063.7	1066.2	1068.6	1071.1	1073.5	1076.0	1078.4	1080.8	1083.3	1085.7	1088.1	1090.6	1093.0	1095.4	1097.8	1100.3	1102.7	1105.1	1107.5
0.50	1066.7	1069.2	1071.8	1074.3	1076.8	1079.3	1081.8	1084.3	1086.8	1089.3	1091.7	1094.2	1096.7	1099.2	1101.7	1104.1	1106.6	1109.1	1111.5	1114.0
0.55	1071.7	1074.3	1076.9	1079.4	1082.0	1084.6	1087.1	1089.7	1092.2	1094.8	1097.3	1099.8	1102.3	1104.9	1107.4	1109.9	1112.4	1114.9	1117.4	1119.9
0.60	1076.3	1079.0	1081.6	1084.2	1086.9	1089.5	1092.1	1094.7	1097.3	1099.8	1102.4	1105.0	1107.6	1110.1	1112.7	1115.2	1117.8	1120.3	1122.9	1125.4
0.65	1080.6	1083.3	1086.0	1088.7	1091.4	1094.0	1096.7	1099.3	1102.0	1104.6	1107.2	1109.8	1112.4	1115.0	1117.6	1120.2	1122.8	1125.4	1128.0	1130.5
0.70	1084.7	1087.4	1090.2	1092.9	1095.6	1098.3	1101.0	1103.7	1106.4	1109.1	1111.7	1114.4	1117.0	1119.7	1122.3	1124.9	1127.5	1130.1	1132.7	1135.3
0.75	1088.5	1091.3	1094.1	1096.9	1099.6	1102.4	1105.1	1107.9	1110.6	1113.3	1116.0	1118.7	1121.4	1124.0	1126.7	1129.3	1132.0	1134.6	1137.3	1139.9
0.80	1092.1	1094.9	1097.8	1100.6	1103.5	1106.3	1109.0	1111.8	1114.6	1117.3	1120.0	1122.8	1125.5	1128.2	1130.9	1133.5	1136.2	1138.9	1141.5	1144.2
0.85	1095.5	1098.4	1101.3	1104.2	1107.1	1109.9	1112.8	1115.6	1118.4	1121.1	1123.9	1126.7	1129.4	1132.1	1134.8	1137.6	1140.3	1142.9	1145.6	1148.3
0.90	1098.8	1101.8	1104.7	1107.7	1110.6	1113.4	1116.3	1119.2	1122.0	1124.8	1127.6	1130.4	1133.2	1135.9	1138.7	1141.4	1144.1	1146.8	1149.5	1152.2
0.95	1101.9	1105.0	1108.0	1110.9	1113.9	1116.8	1119.7	1122.6	1125.5	1128.3	1131.2	1134.0	1136.8	1139.6	1142.3	1145.1	1147.8	1150.6	1153.3	1156.0
1.00	1104.9	1108.0	1111.1	1114.1	1117.1	1120.1	1123.0	1126.0	1128.9	1131.7	1134.6	1137.4	1140.3	1143.1	1145.9	1148.6	1151.4	1154.2	1156.9	1159.6
1.05	1107.9	1111.0	1114.1	1117.2	1120.2	1123.2	1126.2	1129.2	1132.1	1135.0	1137.9	1140.8	1143.6	1146.5	1149.3	1152.1	1154.9	1157.6	1160.4	1163.2
1.10	1110.7	1113.9	1117.0	1120.2	1123.2	1126.3	1129.3	1132.3	1135.3	1138.2	1141.1	1144.0	1146.9	1149.7	1152.6	1155.4	1158.2	1161.0	1163.8	1166.6
1.15	1113.4	1116.7	1119.9	1123.0	1126.2	1129.3	1132.3	1135.3	1138.3	1141.3	1144.3	1147.2	1150.1	1152.9	1155.8	1158.7	1161.5	1164.3	1167.1	1169.9
1.20	1116.1	1119.4	1122.6	1125.9	1129.0	1132.2	1135.2	1138.3	1141.3	1144.3	1147.3	1150.2	1153.2	1156.1	1158.9	1161.8	1164.7	1167.5	1170.3	1173.1
1.25	1118.7	1122.0	1125.3	1128.6	1131.8	1135.0	1138.1	1141.2	1144.3	1147.3	1150.3	1153.2	1156.2	1159.1	1162.0	1164.9	1167.7	1170.6	1173.4	1176.2
1.30	1121.2	1124.6	1128.0	1131.3	1134.5	1137.7	1140.9	1144.0	1147.1	1150.2	1153.2	1156.2	1159.1	1162.1	1165.0	1167.9	1170.8	1173.6	1176.5	1179.3
1.35	1123.7	1127.1	1130.5	1133.9	1137.2	1140.4	1143.6	1146.8	1149.9	1153.0	1156.0	1159.1	1162.0	1165.0	1167.9	1170.9	1173.7	1176.6	1179.5	1182.3
1.40	1126.1	1129.6	1133.1	1136.5	1139.8	1143.1	1146.3	1149.5	1152.7	1155.8	1158.8	1161.9	1164.9	1167.9	1170.8	1173.8	1176.7	1179.5	1182.4	1185.3
1.45	1128.5	1132.0	1135.6	1139.0	1142.4	1145.7	1149.0	1152.2	1155.4	1158.5	1161.6	1164.7	1167.7	1170.7	1173.7	1176.6	1179.5	1182.4	1185.3	1188.1
1.50	1130.8	1134.4	1138.0	1141.5	1144.9	1148.3	1151.6	1154.8	1158.0	1161.2	1164.3	1167.4	1170.5	1173.5	1176.5	1179.4	1182.3	1185.2	1188.1	1191.0

Unit: mV

G-10

Relationship of CP-CO<sub>2</sub>%  
CO=33.3%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05	36.826	32.345	28.466	25.101	22.177	19.631	17.411	15.470	13.772	12.282	10.973	9.820	8.804	7.907	7.113	6.409	5.784	5.228
0.10	18.206	15.986	14.064	12.399	10.952	9.694	8.596	7.638	6.799	6.063	5.417	4.848	4.346	3.903	3.512	3.164	2.856	2.582
0.15	12.000	10.532	9.264	8.165	7.211	6.381	5.658	5.027	4.474	3.990	3.564	3.190	2.860	2.569	2.311	2.083	1.880	1.700
0.20	8.896	7.806	6.864	6.048	5.340	4.725	4.189	3.721	3.312	2.953	2.638	2.361	2.117	1.902	1.711	1.542	1.392	1.259
0.25	7.034	6.170	5.423	4.778	4.218	3.731	3.308	2.938	2.615	2.331	2.083	1.864	1.671	1.501	1.351	1.217	1.099	0.994
0.30	5.793	5.079	4.463	3.931	3.469	3.069	2.720	2.416	2.150	1.917	1.712	1.533	1.374	1.234	1.111	1.001	0.904	0.817
0.35	4.906	4.300	3.778	3.326	2.935	2.595	2.300	2.043	1.828	1.621	1.448	1.296	1.162	1.044	0.939	0.847	0.764	0.691
0.40	4.241	3.716	3.263	2.872	2.534	2.241	1.985	1.763	1.569	1.399	1.249	1.118	1.003	0.901	0.811	0.731	0.660	0.597
0.45	3.724	3.261	2.863	2.519	2.222	1.965	1.740	1.545	1.375	1.226	1.095	0.980	0.879	0.790	0.711	0.641	0.579	0.523
0.50	3.310	2.898	2.543	2.237	1.973	1.744	1.545	1.371	1.220	1.088	0.972	0.870	0.780	0.701	0.631	0.569	0.513	0.465
0.55	2.972	2.600	2.281	2.006	1.769	1.563	1.384	1.229	1.093	0.975	0.871	0.779	0.699	0.628	0.565	0.510	0.460	0.416
0.60	2.690	2.353	2.063	1.814	1.599	1.412	1.251	1.110	0.988	0.880	0.786	0.704	0.631	0.567	0.510	0.460	0.416	0.376
0.65	2.451	2.143	1.878	1.651	1.455	1.285	1.138	1.010	0.898	0.801	0.715	0.640	0.574	0.516	0.464	0.419	0.378	0.342
0.70	2.246	1.963	1.720	1.511	1.331	1.176	1.041	0.924	0.822	0.732	0.654	0.585	0.525	0.472	0.425	0.383	0.346	0.313
0.75	2.069	1.807	1.583	1.390	1.225	1.081	0.957	0.849	0.755	0.673	0.601	0.538	0.483	0.434	0.390	0.352	0.318	0.288
0.80	1.914	1.671	1.463	1.285	1.131	0.998	0.884	0.784	0.697	0.621	0.555	0.497	0.445	0.400	0.360	0.325	0.294	0.266
0.85	1.777	1.551	1.357	1.191	1.048	0.925	0.819	0.726	0.646	0.575	0.514	0.460	0.413	0.371	0.334	0.301	0.272	0.247
0.90	1.655	1.444	1.263	1.108	0.975	0.860	0.761	0.675	0.600	0.535	0.478	0.428	0.384	0.345	0.310	0.280	0.253	0.229
0.95	1.546	1.348	1.179	1.034	0.909	0.802	0.710	0.629	0.559	0.498	0.445	0.398	0.357	0.321	0.289	0.261	0.236	0.214
1.00	1.448	1.262	1.103	0.967	0.850	0.750	0.663	0.588	0.523	0.466	0.416	0.372	0.334	0.300	0.270	0.244	0.221	0.200
1.05	1.360	1.184	1.034	0.907	0.797	0.703	0.621	0.551	0.489	0.436	0.389	0.349	0.313	0.281	0.253	0.229	0.207	0.187
1.10	1.279	1.113	0.972	0.852	0.748	0.660	0.583	0.517	0.459	0.409	0.365	0.327	0.293	0.264	0.238	0.215	0.194	0.176
1.15	1.206	1.049	0.915	0.801	0.704	0.620	0.548	0.486	0.432	0.385	0.343	0.307	0.276	0.248	0.223	0.202	0.182	0.165
1.20	1.138	0.989	0.863	0.755	0.663	0.584	0.516	0.457	0.406	0.362	0.323	0.289	0.260	0.233	0.210	0.190	0.172	0.156
1.25	1.076	0.935	0.815	0.713	0.626	0.551	0.487	0.431	0.383	0.341	0.305	0.273	0.245	0.220	0.198	0.179	0.162	0.147
1.30	1.019	0.884	0.771	0.674	0.591	0.521	0.460	0.407	0.362	0.322	0.288	0.258	0.231	0.208	0.187	0.169	0.153	0.139
1.35	0.966	0.838	0.730	0.638	0.559	0.492	0.435	0.385	0.342	0.304	0.272	0.243	0.218	0.196	0.177	0.160	0.145	0.131
1.40	0.917	0.794	0.691	0.604	0.530	0.466	0.411	0.364	0.323	0.288	0.257	0.230	0.207	0.186	0.168	0.151	0.137	0.124
1.45	0.871	0.754	0.656	0.573	0.502	0.442	0.390	0.345	0.306	0.273	0.243	0.218	0.196	0.176	0.159	0.143	0.130	0.118
1.50	0.828	0.717	0.623	0.544	0.476	0.419	0.369	0.327	0.290	0.258	0.231	0.207	0.185	0.167	0.150	0.136	0.123	0.112

G-11

Unit: %

Relationship of CP-DP°C

CO=33.3%, H<sub>2</sub>=66.7%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970
0.05																		
0.10																		
0.15																		33.82
0.20														33.90	32.47	31.17	29.98	28.56
0.25											33.99	32.49	31.13	29.86	28.38	27.03	25.80	24.58
0.30									33.46	31.95	30.59	29.15	27.68	26.34	25.13	23.75	22.45	21.27
0.35							33.57	32.00	30.59	29.10	27.58	26.21	24.96	23.51	22.19	20.99	19.87	18.55
0.40					34.19	32.51	31.01	29.54	27.94	26.49	25.19	23.72	22.35	21.10	19.95	18.59	17.34	16.20
0.45				33.45	31.81	30.34	28.71	27.14	25.74	24.32	22.85	21.52	20.32	18.98	17.66	16.47	15.37	14.20
0.50		34.85	33.01	31.37	29.88	28.16	26.61	25.22	23.69	22.25	20.94	19.69	18.28	16.99	15.83	14.70	13.45	12.31
0.55	34.65	32.79	31.14	29.56	27.83	26.28	24.87	23.28	21.84	20.55	19.18	17.78	16.52	15.37	14.13	12.91	11.79	10.77
0.60	32.77	31.08	29.45	27.69	26.13	24.65	23.04	21.60	20.30	18.85	17.46	16.20	15.06	13.73	12.52	11.41	10.40	9.29
0.65	31.18	29.52	27.72	26.11	24.60	22.96	21.49	20.18	18.68	17.27	16.00	14.81	13.47	12.26	11.15	10.14	8.94	7.80
0.70	29.77	27.89	26.23	24.69	23.01	21.51	20.17	18.63	17.20	15.91	14.68	13.33	12.10	10.99	9.97	8.71	7.56	6.52
0.75	28.21	26.48	24.93	23.19	21.64	20.26	18.70	17.24	15.92	14.66	13.29	12.04	10.91	9.85	8.58	7.42	6.37	5.41
0.80	26.85	25.24	23.49	21.88	20.44	18.89	17.37	16.02	14.75	13.33	12.06	10.91	9.83	8.54	7.36	6.30	5.32	4.24
0.85	25.66	23.92	22.22	20.71	19.18	17.61	16.20	14.93	13.47	12.16	10.98	9.89	8.57	7.37	6.29	5.30	4.19	3.08
0.90	24.48	22.68	21.09	19.58	17.93	16.47	15.16	13.69	12.34	11.12	10.02	8.68	7.45	6.34	5.33	4.21	3.08	2.04
0.95	23.26	21.57	20.08	18.36	16.82	15.45	14.00	12.59	11.32	10.19	8.86	7.59	6.45	5.42	4.29	3.14	2.08	1.12
1.00	22.16	20.57	18.90	17.26	15.82	14.39	12.91	11.59	10.41	9.11	7.80	6.62	5.55	4.44	3.25	2.17	1.19	0.29
1.05	21.16	19.55	17.81	16.27	14.88	13.32	11.93	10.69	9.43	8.07	6.84	5.73	4.64	3.42	2.30	1.29	0.38	-0.64
1.10	20.26	18.47	16.82	15.37	13.82	12.35	11.04	9.83	8.40	7.12	5.97	4.91	3.64	2.49	1.45	0.50	-0.50	-1.59
1.15	19.25	17.47	15.91	14.41	12.84	11.46	10.22	8.80	7.46	6.25	5.17	3.91	2.72	1.64	0.66	-0.31	-1.43	-2.46
1.20	18.25	16.56	15.08	13.43	11.95	10.64	9.29	7.87	6.60	5.46	4.24	3.00	1.88	0.86	-0.08	-1.24	-2.29	-3.25
1.25	17.33	15.73	14.13	12.53	11.13	9.85	8.34	7.00	5.80	4.64	3.33	2.16	1.10	0.15	-0.99	-2.08	-3.08	-3.98
1.30	16.48	14.94	13.22	11.70	10.37	8.90	7.47	6.20	5.07	3.73	2.49	1.39	0.39	-0.71	-1.84	-2.87	-3.80	-4.65
1.35	15.70	14.02	12.37	10.94	9.55	8.02	6.67	5.46	4.18	2.88	1.72	0.67	-0.38	-1.56	-2.62	-3.59	-4.48	-5.38
1.40	14.96	13.16	11.59	10.22	8.66	7.20	5.92	4.70	3.32	2.09	0.99	0.00	-1.23	-2.34	-3.35	-4.27	-5.14	-6.19
1.45	14.08	12.36	10.86	9.40	7.83	6.44	5.22	3.84	2.53	1.36	0.32	-0.85	-2.02	-3.08	-4.03	-4.90	-5.94	-6.94
1.50	13.26	11.61	10.18	8.55	7.05	5.73	4.42	3.03	1.79	0.68	0.42	-1.65	-2.76	-3.76	-4.66	-5.67	-6.70	-7.64

G-12

Unit: °C

Relationship of CP-EMF  
CO=33%

(°C)

CPWT %	800	810	820	830	840	850	860	870	880	890	900	910	920	930	940	950	960	970	980	990
0.05	939.7	940.8	942.0	943.2	944.5	945.7	947.0	948.2	949.5	950.8	952.1	953.4	954.7	956.0	957.3	958.6	960.0	961.3	962.6	964.0
0.10	972.2	973.7	975.2	976.8	978.3	979.9	981.4	983.0	984.6	986.2	987.8	989.4	991.0	992.6	994.2	995.8	997.4	999.1	1000.7	1002.3
0.15	991.5	993.2	994.9	996.6	998.3	1000.1	1001.8	1003.6	1005.4	1007.1	1008.9	1010.7	1012.5	1014.3	1016.1	1017.9	1019.7	1021.5	1023.3	1025.1
0.20	1005.3	1007.2	1009.0	1010.9	1012.7	1014.6	1016.5	1018.4	1020.3	1022.2	1024.1	1026.0	1027.9	1029.8	1031.8	1033.7	1035.6	1037.5	1039.5	1041.4
0.25	1016.2	1018.1	1020.1	1022.1	1024.1	1026.0	1028.0	1030.0	1032.0	1034.0	1036.1	1038.1	1040.1	1042.1	1044.1	1046.1	1048.2	1050.2	1052.2	1054.2
0.30	1025.2	1027.2	1029.3	1031.4	1033.4	1035.5	1037.6	1039.7	1041.8	1043.9	1045.9	1048.0	1050.1	1052.2	1054.3	1056.4	1058.5	1060.6	1062.7	1064.9
0.35	1032.8	1035.0	1037.1	1039.3	1041.4	1043.6	1045.8	1047.9	1050.1	1052.3	1054.4	1056.6	1058.8	1060.9	1063.1	1065.3	1067.4	1069.6	1071.8	1073.9
0.40	1039.6	1041.8	1044.0	1046.3	1048.5	1050.7	1053.0	1055.2	1057.4	1059.6	1061.9	1064.1	1066.3	1068.6	1070.8	1073.0	1075.3	1077.5	1079.7	1081.9
0.45	1045.6	1047.9	1050.2	1052.5	1054.8	1057.1	1059.4	1061.7	1064.0	1066.2	1068.5	1070.8	1073.1	1075.4	1077.7	1080.0	1082.2	1084.5	1086.8	1089.1
0.50	1051.0	1053.4	1055.8	1058.1	1060.5	1062.9	1065.2	1067.6	1069.9	1072.2	1074.6	1076.9	1079.3	1081.6	1083.9	1086.2	1088.6	1090.9	1093.2	1095.5
0.55	1056.0	1058.5	1060.9	1063.3	1065.7	1068.1	1070.5	1073.0	1075.3	1077.7	1080.1	1082.5	1084.9	1087.3	1089.6	1092.0	1094.4	1096.7	1099.1	1101.5
0.60	1060.6	1063.1	1065.6	1068.1	1070.6	1073.0	1075.5	1078.0	1080.4	1082.8	1085.3	1087.7	1090.1	1092.5	1094.9	1097.4	1099.8	1102.2	1104.6	1106.9
0.65	1064.9	1067.5	1070.0	1072.6	1075.1	1077.6	1080.1	1082.6	1085.1	1087.6	1090.1	1092.5	1095.0	1097.4	1099.9	1102.3	1104.8	1107.2	1109.6	1112.1
0.70	1069.0	1071.6	1074.2	1076.8	1079.3	1081.9	1084.5	1087.0	1089.5	1092.1	1094.6	1097.1	1099.6	1102.1	1104.5	1107.0	1109.5	1112.0	1114.4	1116.9
0.75	1072.8	1075.4	1078.1	1080.7	1083.4	1086.0	1088.6	1091.1	1093.7	1096.3	1098.8	1101.4	1103.9	1106.4	1108.9	1111.4	1113.9	1116.4	1118.9	1121.4
0.80	1076.4	1079.1	1081.8	1084.5	1087.2	1089.8	1092.5	1095.1	1097.7	1100.3	1102.9	1105.5	1108.0	1110.6	1113.1	1115.7	1118.2	1120.7	1123.2	1125.7
0.85	1079.8	1082.6	1085.3	1088.1	1090.8	1093.5	1096.2	1098.8	1101.5	1104.1	1106.7	1109.3	1111.9	1114.5	1117.1	1119.7	1122.2	1124.8	1127.3	1129.8
0.90	1083.1	1085.9	1088.7	1091.5	1094.3	1097.0	1099.7	1102.4	1105.1	1107.8	1110.4	1113.1	1115.7	1118.3	1120.9	1123.5	1126.1	1128.6	1131.2	1133.8
0.95	1086.2	1089.1	1092.0	1094.8	1097.6	1100.4	1103.2	1105.9	1108.6	1111.3	1114.0	1116.7	1119.3	1122.0	1124.6	1127.2	1129.8	1132.4	1135.0	1137.5
1.00	1089.2	1092.2	1095.1	1098.0	1100.8	1103.7	1106.5	1109.2	1112.0	1114.7	1117.4	1120.1	1122.8	1125.5	1128.1	1130.7	1133.4	1136.0	1138.6	1141.2
1.05	1092.2	1095.2	1198.1	1101.1	1103.9	1106.8	1109.6	1112.5	1115.2	1118.0	1120.7	1123.5	1126.2	1128.9	1131.5	1134.2	1136.8	1139.5	1142.1	1144.7
1.10	1095.0	1098.0	1101.1	1104.0	1107.0	1109.9	1112.7	1115.6	1118.4	1121.2	1124.0	1126.7	1129.4	1132.1	1134.8	1137.5	1140.2	1142.8	1145.5	1148.1
1.15	1097.7	1100.8	1103.9	1106.9	1109.9	1112.8	1115.7	1118.6	1121.5	1124.3	1127.1	1129.9	1132.6	1135.3	1138.1	1140.8	1143.4	1146.1	1148.8	1151.4
1.20	1100.4	1103.5	1106.7	1109.7	1112.7	1115.7	1118.7	1121.6	1124.5	1127.3	1130.1	1132.9	1135.7	1138.5	1141.2	1143.9	1146.6	1149.3	1152.0	1154.6
1.25	1103.0	1106.2	1109.4	1112.5	1115.5	1118.5	1121.5	1124.5	1127.4	1130.3	1133.1	1135.9	1138.7	1141.5	1144.3	1147.0	1149.7	1152.4	1155.1	1157.8
1.30	1105.5	1108.8	1112.0	1115.1	1118.2	1121.3	1124.3	1127.3	1130.2	1133.2	1136.0	1138.9	1141.7	1144.5	1147.3	1150.0	1152.7	1155.5	1158.1	1160.8
1.35	1108.0	1111.3	1114.6	1117.8	1120.9	1124.0	1127.1	1130.1	1133.0	1136.0	1138.9	1141.8	1144.6	1147.4	1150.2	1153.0	1155.7	1158.4	1161.1	1163.8
1.40	1110.4	1113.8	1117.1	1120.3	1123.5	1126.7	1129.8	1132.8	1135.8	1138.8	1141.7	1144.6	1147.4	1150.3	1153.1	1155.9	1158.6	1161.4	1164.1	1166.8
1.45	1112.8	1116.2	1119.6	1122.9	1126.1	1129.3	1132.4	1135.5	1138.5	1141.5	1144.4	1147.4	1150.2	1153.1	1155.9	1158.7	1161.5	1164.2	1167.0	1169.7
1.50	1115.1	1118.6	1122.0	1125.3	1128.6	1131.8	1135.0	1138.1	1141.2	1144.2	1147.2	1150.1	1153.0	1155.9	1158.7	1161.5	1164.3	1167.1	1169.8	1172.5

Unit: mV

G-13

## Thermal Electromotive Force of R-Thermocouple

Unit:  $\mu\text{V}$ 

Temp. (°C)	0	1	2	3	4	5	6	7	8	9	Temp. (°C)
400	3407	3418	3428	3438	3449	3459	3470	3480	3490	3501	400
410	3511	3522	3532	3543	3553	3563	3574	3584	3595	3605	410
420	3616	3626	3637	3647	3658	3668	3679	3689	3700	3710	420
430	3721	3731	3742	3752	3763	3774	3784	3795	3805	3816	430
440	3826	3837	3848	3858	3869	3879	3890	3901	3911	3922	440
450	3933	3943	3954	3964	3975	3986	3996	4007	4018	4028	450
460	4039	4050	4061	4071	4082	4093	4103	4114	4125	4136	460
470	4146	4157	4168	4178	4189	4200	4211	4222	4232	4243	470
480	4254	4265	4275	4286	4297	4308	4319	4329	4340	4351	480
490	4362	4373	4384	4394	4405	4416	4427	4438	4449	4460	490
500	4471	4481	4492	4503	4514	4525	4536	4547	4558	4569	500
510	4580	4591	4601	4612	4623	4634	4645	4656	4667	4678	510
520	4689	4700	4711	4722	4733	4744	4755	4766	4777	4788	520
530	4799	4810	4821	4832	4843	4854	4865	4876	4888	4899	530
540	4910	4921	4932	4943	4954	4965	4976	4987	4998	5009	540
550	5021	5032	5043	5054	5065	5076	5087	5099	5110	5121	550
560	5132	5143	5154	5166	5177	5188	5199	5210	5221	5233	560
570	5244	5255	5266	5278	5289	5300	5311	5322	5334	5345	570
580	5356	5368	5379	5390	5401	5413	5424	5435	5446	5458	580
590	5469	5480	5492	5503	5514	5526	5537	5548	5560	5571	590
600	5582	5594	5605	5616	5628	5639	5650	5662	5673	5685	600
610	5696	5707	5719	5730	5742	5753	5764	5776	5787	5799	610
620	5810	5821	5833	5844	5856	5867	5879	5890	5902	5913	620
630	5925	5936	5948	5959	5971	5982	5994	6005	6017	6028	630
640	6040	6051	6063	6074	6086	6098	6109	6121	6132	6144	640
650	6155	6167	6179	6190	6202	6213	6225	6237	6248	6260	650
660	6272	6283	6295	6307	6318	6330	6342	6353	6365	6377	660
670	6388	6400	6412	6423	6435	6447	6458	6470	6482	6494	670
680	6505	6517	6529	6541	6552	6564	6576	6588	6599	6611	680
690	6623	6635	6647	6658	6670	6682	6694	6706	6718	6729	690
700	6741	6753	6765	6777	6789	6800	6812	6824	6836	6848	700
710	6860	6872	6884	6895	6907	6919	6931	6943	6955	6967	710
720	6979	6991	7003	7015	7027	7039	7051	7063	7074	7086	720
730	7098	7110	7122	7134	7146	7158	7170	7182	7194	7206	730
740	7218	7231	7243	7255	7267	7279	7291	7303	7315	7327	740
750	7339	7351	7363	7375	7387	7399	7412	7424	7436	7448	750
760	7460	7472	7484	7496	7509	7521	7533	7545	7557	7569	760
770	7582	7594	7606	7618	7630	7642	7655	7667	7679	7691	770
780	7703	7716	7728	7740	7752	7765	7777	7789	7801	7814	780
790	7826	7838	7850	7863	7875	7887	7900	7912	7924	7937	790
800	7949	7961	7973	7986	7998	8010	8023	8035	8047	8060	800
810	8072	8085	8097	8109	8122	8134	8146	8159	8171	8184	810
820	8196	8208	8221	8233	8246	8258	8271	8283	8295	8308	820
830	8320	8333	8345	8358	8370	8383	8395	8408	8420	8433	830
840	8445	8458	8470	8483	8495	8508	8520	8533	8545	8558	840
850	8570	8583	8595	8608	8621	8633	8646	8658	8671	8683	850
860	8696	8709	8721	8734	8746	8759	8772	8784	8797	8810	860
870	8822	8835	8847	8860	8873	8885	8898	8911	8923	8936	870
880	8949	8961	8974	8987	9000	9012	9025	9038	9050	9063	880
890	9076	9089	9101	9114	9127	9140	9152	9165	9178	9191	890



Temp. (°C)	Unit: $\mu\text{V}$										Temp. (°C)
	0	1	2	3	4	5	6	7	8	9	
900	9203	9216	9229	9242	9254	9267	9280	9293	9306	9319	900
910	9331	9344	9357	9370	9383	9395	9408	9421	9434	9447	910
920	9460	9473	9485	9498	9511	9524	9537	9550	9563	9576	920
930	9589	9602	9614	9627	9640	9653	9666	9679	9692	9705	930
940	9718	9731	9744	9757	9770	9783	9796	9809	9822	9835	940
950	9848	9861	9874	9887	9900	9913	9926	9939	9952	9965	950
960	9978	9991	10004	10017	10030	10043	10056	10069	10082	10095	960
970	10109	10122	10135	10148	10161	10174	10187	10200	10213	10227	970
980	10240	10253	10266	10279	10292	10305	10319	10332	10345	10358	980
990	10371	10384	10398	10411	10424	10437	10450	10464	10477	10490	990
1000	10503	10516	10530	10543	10556	10569	10583	10596	10609	10622	1000
1010	10636	10649	10662	10675	10689	10702	10715	10729	10742	10755	1010
1020	10768	10782	10795	10808	10822	10835	10848	10862	10875	10888	1020
1030	10902	10915	10928	10942	10955	10968	10982	10995	11009	11022	1030
1040	11035	11049	11062	11076	11089	11102	11116	11129	11143	11156	1040
1050	11170	11183	11196	11210	11223	11237	11250	11264	11277	11291	1050
1060	11304	11318	11331	11345	11358	11372	11385	11399	11412	11426	1060
1070	11439	11453	11466	11480	11493	11507	11520	11534	11547	11561	1070
1080	11574	11588	11602	11615	11629	11642	11656	11669	11683	11697	1080
1090	11710	11724	11737	11751	11765	11778	11792	11805	11819	11833	1090
1100	11846	11860	11874	11887	11901	11914	11928	11942	11955	11969	1100
1110	11983	11996	12010	12024	12037	12051	12065	12078	12092	12106	1110
1120	12119	12133	12147	12161	12174	12188	12202	12215	12229	12243	1120
1130	12257	12270	12284	12298	12311	12325	12339	12353	12366	12380	1130
1140	12394	12408	12421	12435	12449	12463	12476	12490	12504	12518	1140
1150	12532	12545	12559	12573	12587	12600	12614	12628	12642	12656	1150
1160	12669	12683	12697	12711	12725	12739	12752	12766	12780	12794	1160
1170	12808	12822	12835	12849	12863	12877	12891	12905	12918	12932	1170
1180	12946	12960	12974	12988	13002	13016	13029	13043	13057	13071	1180
1190	13085	13099	13113	13127	13140	13154	13168	13182	13196	13210	1190
1200	13224	13238	13252	13266	13280	13293	13307	13321	13335	13349	1200
1210	13363	13377	13391	13405	13419	13433	13447	13461	13475	13489	1210
1220	13502	13516	13530	13544	13558	13572	13586	13600	13614	13628	1220
1230	13642	13656	13670	13684	13698	13712	13726	13740	13754	13768	1230
1240	13782	13796	13810	13824	13838	13852	13866	13880	13894	13908	1240
1250	13922	13936	13950	13964	13978	13992	14006	14020	14034	14048	1250
1260	14062	14076	14090	14104	14118	14132	14146	14160	14174	14188	1260
1270	14202	14216	14230	14244	14258	14272	14286	14301	14315	14329	1270
1280	14343	14357	14371	14385	14399	14413	14427	14441	14455	14469	1280
1290	14483	14497	14511	14525	14539	14554	14568	14582	14596	14610	1290
1300	14624	14638	14652	14666	14680	14694	14708	14722	14737	14751	1300
1310	14765	14779	14793	14807	14821	14835	14849	14863	14877	14891	1310
1320	14906	14920	14934	14948	14962	14976	14990	15004	15018	15032	1320
1330	15047	15061	15075	15089	15103	15117	15131	15145	15159	15173	1330
1340	15188	15202	15216	15230	15244	15258	15272	15286	15300	15315	1340
1350	15329	15343	15357	15371	15385	15399	15413	15427	15442	15456	1350
1360	15470	15484	15498	15512	15526	15540	15555	15569	15583	15597	1360
1370	15611	15625	15639	15653	15667	15682	15696	15710	15724	15738	1370
1380	15752	15766	15780	15795	15809	15823	15837	15851	15865	15879	1380
1390	15893	15908	15922	15936	15950	15964	15978	15992	16006	16021	1390

## Thermal electromotive force of K-thermocouple

Unit:  $\mu\text{V}$ 

Temp (°C)	0	1	2	3	4	5	6	7	8	9	Temp (°C)
700	29128	29170	29212	29254	29296	29338	29380	29422	29464	29505	700
710	29547	29589	29631	29673	29715	29756	29798	29840	29882	29924	710
720	29965	30007	30049	30091	30132	30174	30216	30257	30299	30341	720
730	30383	30424	30466	30508	30549	30591	30632	30674	30716	30757	730
740	30799	30840	30882	30924	30965	31007	31048	31090	31131	31173	740
750	31214	31256	31297	31339	31380	31422	31463	31504	31546	31587	750
760	31629	31670	31712	31753	31794	31836	31877	31918	31960	32001	760
770	32042	32084	32125	32166	32207	32249	32290	32331	32372	32414	770
780	32455	32496	32537	32578	32619	32661	32702	32743	32784	32825	780
790	32866	32907	32948	32990	33031	33072	33113	33154	33195	33236	790
800	33277	33318	33359	33400	33441	33482	33523	33564	33604	33645	800
810	33686	33727	33768	33809	33850	33891	33931	33972	34013	34054	810
820	34095	34136	34176	34217	34258	34299	34339	34380	34421	34461	820
830	34502	34543	34583	34624	34665	34705	34746	34787	34827	34868	830
840	34909	34949	34990	35050	35071	35111	35152	35192	35233	35273	840
850	35314	35354	35395	35435	35476	35516	35557	35597	35637	35678	850
860	35718	35758	35799	35839	35880	35920	35960	36000	36041	36081	860
870	36121	36162	36202	36242	36282	36323	36363	36403	36443	36483	870
880	36524	36564	36604	36644	36684	36924	36764	36804	36844	36885	880
890	36925	36965	37005	37045	37085	37125	37165	37205	37245	37285	890
900	37325	37365	37405	37445	37484	37524	37564	37604	37644	37684	900
910	37724	37764	37803	37843	37883	37923	37963	38002	38042	38082	910
920	38122	38162	38201	38241	38281	38320	38360	38400	38439	38479	920
930	38519	38558	38598	38638	38677	38717	38756	38796	38836	38875	930
940	38915	38954	38994	39033	39073	39112	39152	39191	39231	39270	940
950	39310	39349	39388	39428	39467	39507	39546	39585	39625	39664	950
960	39703	39743	39782	39821	39861	39900	39939	39979	40018	40057	960
970	40096	40136	40175	40214	40253	40292	40332	40371	40410	40449	970
980	40488	40527	40566	40605	40645	40684	40723	40762	40801	40840	980
990	40879	40918	40957	40996	41035	41074	41113	41152	41191	41230	990
1000	41269	41308	41347	41385	41424	41463	41502	41541	41580	41619	1000
1010	41657	41696	41735	41774	41813	41851	41890	41929	41968	42006	1010
1020	42045	42084	42123	42161	42200	42239	42277	42316	42355	42393	1020
1030	42432	42470	42509	42548	42586	42625	42663	42702	42740	42779	1030
1040	42817	42856	42894	42933	42971	43010	43048	43087	43125	43164	1040
1050	43202	43240	43279	43317	43356	43394	43432	43471	43509	43547	1050
1060	43585	43624	43662	43700	43739	43777	43815	43853	43891	43930	1060
1070	43968	44006	44044	44082	44121	44159	44197	44235	44273	44311	1070
1080	44349	44387	44425	44463	44501	44539	44577	44615	44653	44691	1080
1090	44729	44767	44805	44843	44881	44919	44957	44995	45033	45070	1090
1100	45108	45146	45184	45222	45260	45297	45335	45373	45411	45448	1100
1110	45486	45524	45561	45599	45637	45675	45712	45750	45787	45825	1110
1120	45863	42900	45938	45975	46013	46051	46088	46126	46163	46201	1120
1130	46238	46275	46313	46350	46388	46425	46463	46500	46537	46575	1130
1140	46612	46649	46687	46724	46761	46799	46836	46873	46910	46948	1140
1150	46985	47022	47059	47096	47134	47171	47208	47245	47282	47319	1150
1160	47356	47393	47430	47468	47505	47542	47579	47616	47653	47689	1160
1170	47726	47763	47800	47837	47874	47911	47948	47985	48021	48058	1170
1180	48095	48132	48169	48205	48242	48279	48316	48352	48389	48426	1180
1190	48462	48499	48536	48572	48609	48645	48682	48718	48755	48792	1190



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