

Basic Course of Temperature Control Method

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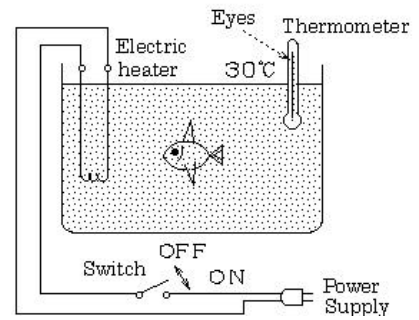
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1. Temperature Control

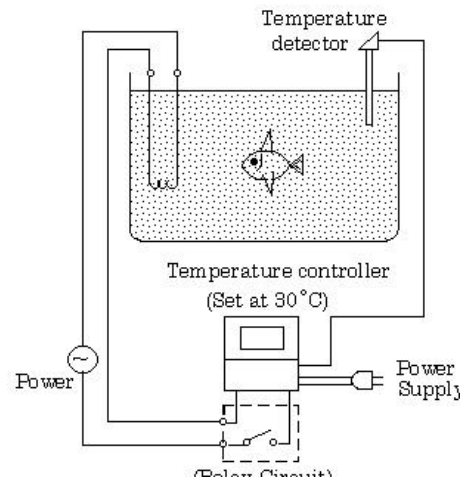
1.1 Temperature control

The optimum water temperature for tropical fish in a water bath is 30°C. Therefore, the temperature must always be maintained at 30°C throughout the year. Maintaining a temperature at a certain level is called “controlling a temperature”. Fig.1 shows a manual control method where the water temperature is understood by reading the thermometer and then the switch is turned ON and OFF to control the temperature.



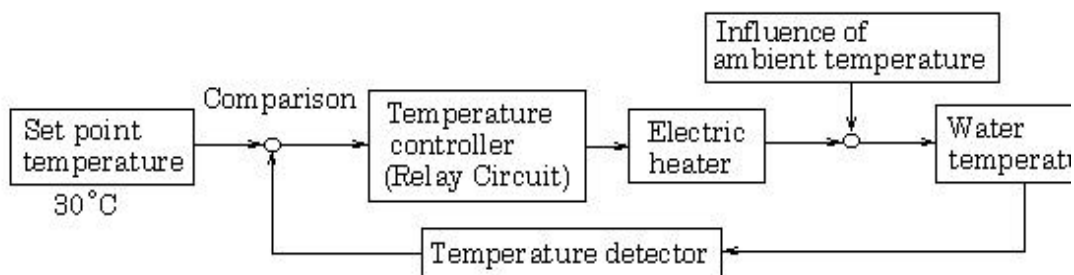
1.2 Automatic temperature control

In automatic control, a temperature controller and temperature detector are used instead of a switch and thermometer. The temperature controller has a set point, which is set at 30°C. The temperature detector detects the water temperature. If the detected temperature is below 30 °C, the relay circuit in the temperature controller closes in order to supply current to the heater. Water temperature is therefore increased by the heater. When the temperature is increased above 30°C, the relay circuit opens in order to stop the supply of current, resulting in decreasing of the water temperature. By repeating this cycle, the water temperature can be maintained at approximately 30°C.



1.3 Feedback loop

The above control can be expressed in the block diagram shown below, called “Feedback Loop”. This type of control is called “feedback control”.



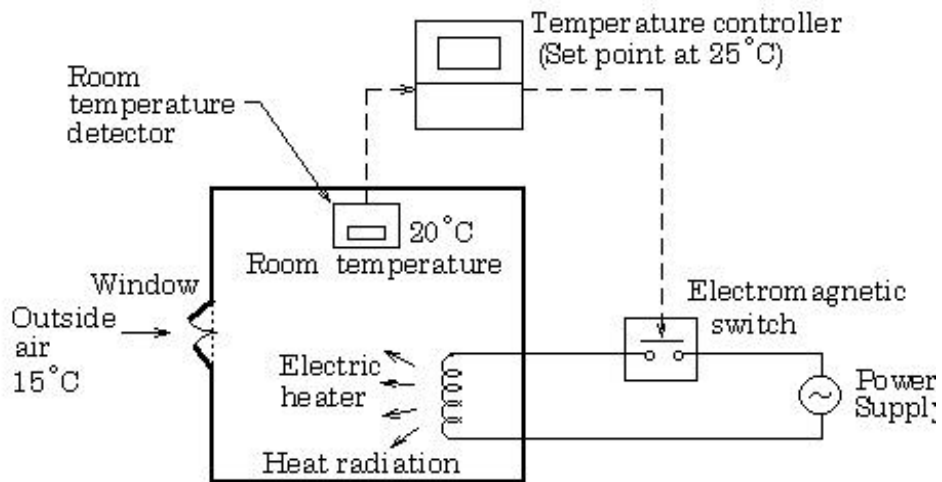
1.4 Influence of ambient temperature

If the ambient temperature of this water bath is very low, for example 20°C, the 30°C water temperature will decrease soon after the heater stops (when it reaches 30°C). If the ambient temperature is 40°C, then the water temperature will naturally increase above the desired 30°C. In this case, a cooler is required instead of the heater. As described above, the water temperature is always influenced by ambient temperature. This influence is called “disturbance” to the control system.

2. Feedback Control

2.1 Room temperature control using a heater

Fig. 1 shows an example of controlling a room temperature using an electric heater. The temperature detector detects the room temperature (20°C), and sends this information to the controller. The temperature controller compares the set point (ex. 25°C) with the detected room temperature, and consequently sends an output signal to an electromagnetic switch to bring the room temperature to the set point. The difference between the set point and the detected temperature is called “differential”. The electromagnetic switch is opened or closed by the output signal of the temperature controller, which turns the heater current ON and OFF. In the above case, the electromagnetic switch is closed, in order to supply power to the heater so as to increase the room temperature up to 25°C. If the window is opened, the outside air enters into the room. Both the heater’s heat and the outside air influence the room temperature. The room temperature detector detects this influenced room temperature, and its signal is sent to the controller. When the room temperature is again increased up to 25°C, the detected temperature becomes the same as the set point, hence the differential becomes zero and the controller output becomes “OFF (zero)”.



2.2 Feedback loop

As a signal in the above control system is circulated, this control method is called “feedback control”.

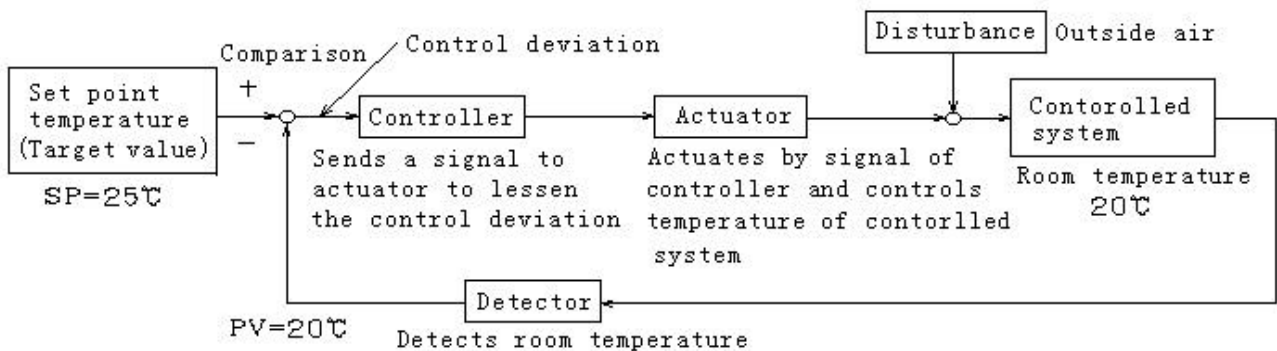


Fig. 2

3. Temperature Control Method

3.1 Water bath temperature control

A solenoid valve or electric control valve is used to manipulate the supply of steam which controls the water temperature. An electric heater can also be used instead of steam.

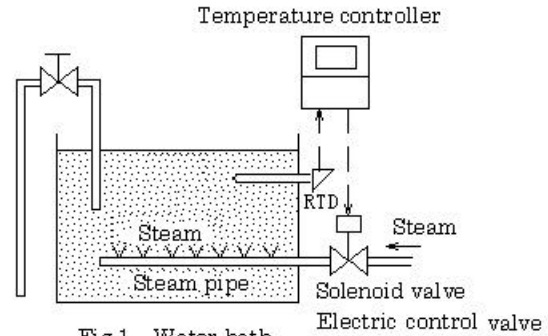


Fig.1 Water bath

3.2 Oven control

An electromagnetic switch is used to manipulate the supply of electric current, which controls the oven temperature. If the oven temperature is high, a refrigerator may be used to decrease the temperature.

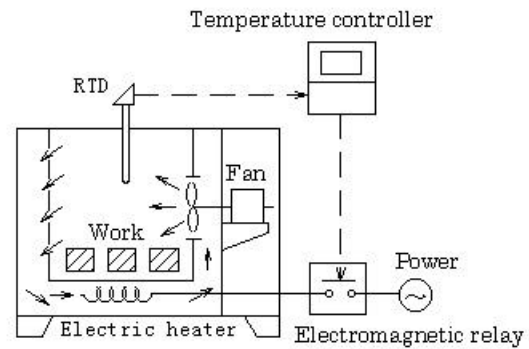


Fig.2 Constant temperature oven

3.3 Electric furnace control

Thyristor (SCR or Triac) having no contact is used in this application to control the oven temperature.

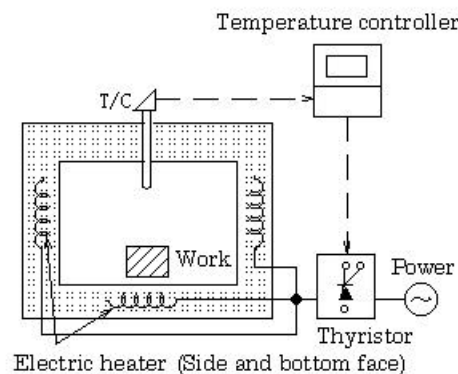


Fig.3 Electric furnace

3.4 Combustion furnace control

An electric control valve or pneumatic control valve is used in this application. In an actual system, FSG (flame safeguard controls system) is used for automatic ignition, flame monitoring and shutoff of valve at flame failure.

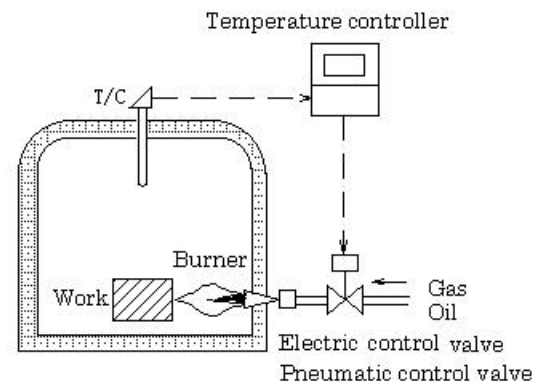


Fig.4 Combustion furnace

3.5 Tunnel oven control

In the case of a continuous furnace, such as a tunnel oven or tunnel furnace, the furnace is divided into several zones for temperature control. The below example shows a 4-zone furnace. The temperature of each zone is independently controlled by the temperature controller, temperature detector (T/C or RTD) and control valve.

(Example) A bread baking tunnel oven is divided into 6 zones at every 20 to 30 m for temperature control. For this type of control, a Venturi type burner is generally used. The control valve controls air supply volume. Zero-governor is used in the piping to reduce the gas pressure to air pressure.

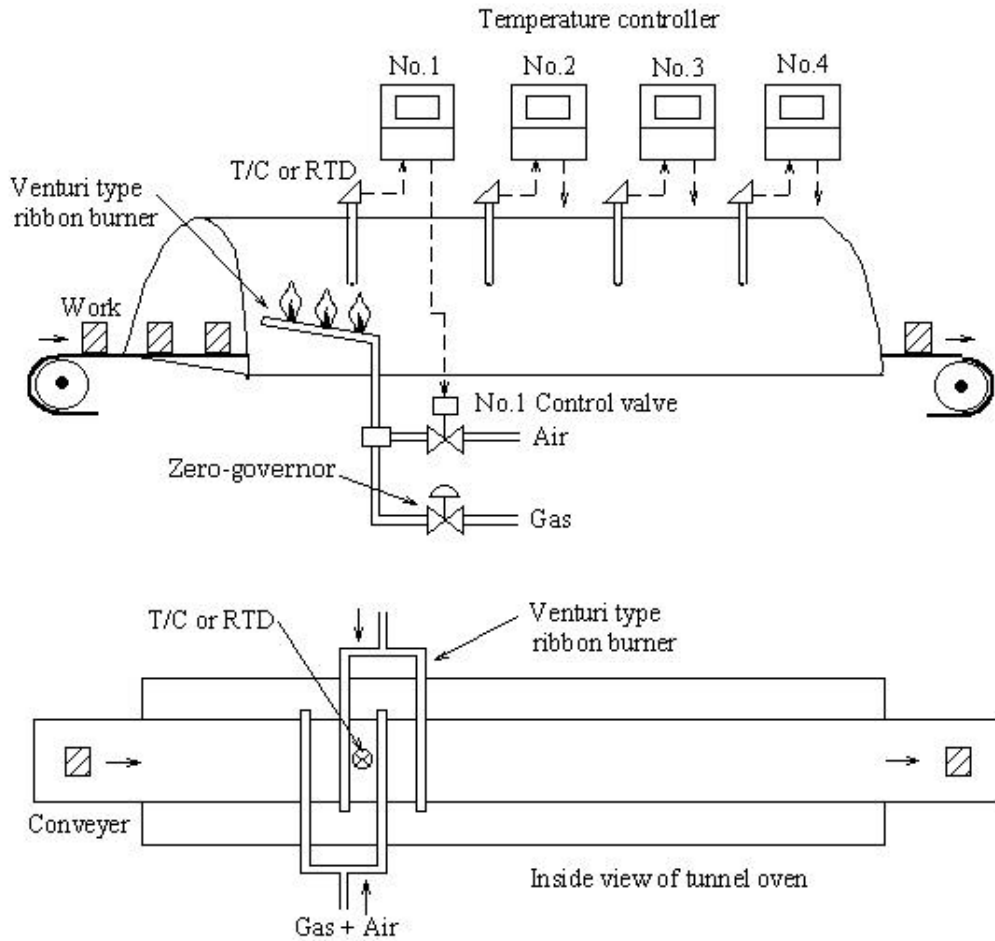


Fig.5 Tunnel oven

As the furnace temperature is not always constant. Zone control enables the profile temperature control, as shown below.

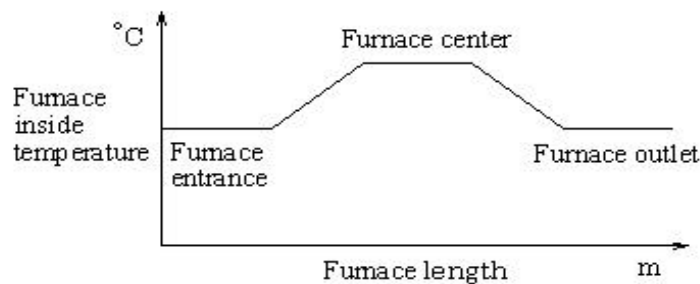


Fig.6

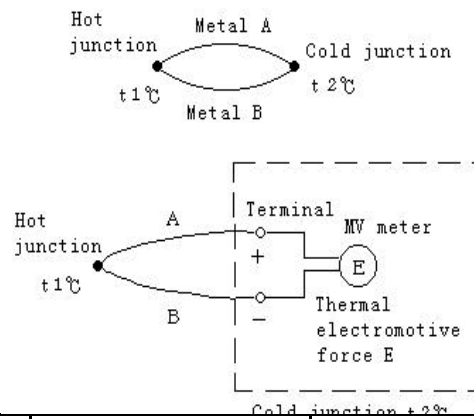
4. Type and Features of Temperature Detectors

Type	Principle	Strong Points	Week Points	Range
Thermocouple (T/C)	Electromotive force (Seebeck effect)	<ul style="list-style-type: none"> ■ Suitable for high temperature ■ Remote measurement possible ■ Quick response ■ High accuracy 	<ul style="list-style-type: none"> ■ Cold junction compensation required ■ Must use compensation wires ■ Not suitable for low temperature (because low electromotive force) 	-180 to 1400° C
Resistance temperature detector (RTD)	Resistance change	<ul style="list-style-type: none"> ■ Suitable for low temperature ■ Remote measurement possible ■ Quick response ■ High accuracy 	<ul style="list-style-type: none"> ■ Not suitable for high temperature 	-50 to 400° C
Liquid expansion type	Liquid expansion (Toluene,silicon,etc)	<ul style="list-style-type: none"> ■ For field instrument (Detector indicator and controller units incorporated in one unit) ■ Low cost ■ Easy to use ■ Easy to operate 	<ul style="list-style-type: none"> ■ Narrow temperature range ■ Not Suitable for remote measurement ■ Slow response ■ Not high accuracy 	-50 to 200° C
Bimetal	Expansion of 2 metals having a different coefficient of thermal expansion	<ul style="list-style-type: none"> ■ Low cost ■ Easy to use ■ Easy to operate 	<ul style="list-style-type: none"> ■ Narrow temperature range ■ Slow response ■ Not high accuracy ■ Not so long life 	-50 to 195° C
Radiation pyrometer	Radiant heat of material (Infrared ray energy)	<ul style="list-style-type: none"> ■ Suitable for higher temperature than T/C ■ Remote measurement possible ■ Quick response ■ Can measure temperature without touching material heated 	<ul style="list-style-type: none"> ■ Need calibration of radiant coefficient depending on material measured ■ High cost ■ Influenced by ambient conditions 	0 to several thousands ° C

Table.1

5. Thermocouple (T/C)

5.1 Two different metals A and B are connected. When different temperatures of t_1 and t_2 are applied to these connected points, a thermal electromotive force is produced in proportion to the temperature differential between t_1 and t_2 (Seebeck effect). The temperature measurement side is called “hot junction”, and the reference side is called “cold junction”.



5.2 Types of thermocouples

Symbol	Old symbol	Sheath color	side(red)	side(white)	Temperature range in normal application	Max. operating temperature range
T	CC	Brown	Copper	Constantan*1	-180 to 300° C	-250 to 350° C
J	IC	Yellow	Iron	Constantan*1	0 to 600° C	-200 to 1000° C
E	CRC	Purple	Chromel*2	Constantan*1	0 to 700° C	-250 to 1000° C
K	CA	Blue	Chromel*2	Almel*3	0 to 1000° C	-200 to 1300° C
R	PR	Black	Platinum rhodium Pt87Rh13	Platinum	0 to 1400° C	0 to 1600° C
S	PR	black	Platinum rhodium Pt90Rh10	Platinum		

*1 Constantan - Copper and Nickel based alloy Cu55 Ni45

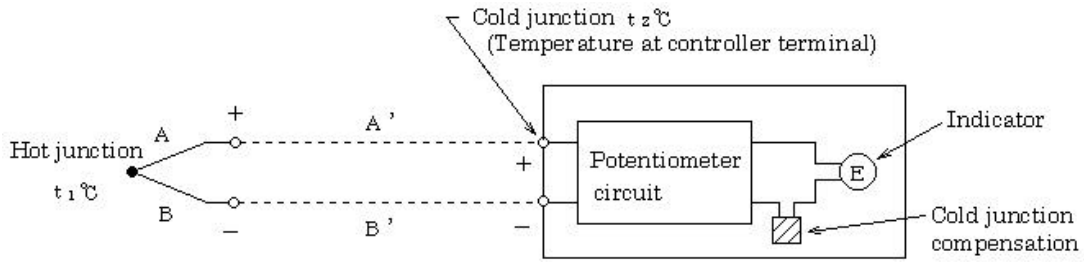
*2 Chromel - Nickel and Chromium based alloy Ni90 Cr10

*3 Almel - Nickel, Aluminum and Manganese based alloy Ni95 Mn2 Al2

5.3 Features of thermocouples

Types	Features
T : Copper - Constantan	• Low cost, better linearity and large thermal electromotive force
J : Iron – Constantan	• Low cost, better linearity and large thermal electromotive force • Applicable to reducing gases (H ₂ , CO)
E : Chromel - Constantan	• Better linearity and large thermal electromotive force • Used more than J type
K : Chromel - Alumel	• Better linearity and large thermal electromotive force • Largely used in industrial applications, but weak to reducing gases
R : Platinum Rhodium – Platinum	• Not so large thermal electromotive force and poor linearity, but stable performance, small aging and high measurement accuracy. • Strong to oxidization gases but weak to reducing gases
PR6-30 : Pt70Rh30 - Pt94Rh6	• T/C for high temperature application, usable up to 1800° C (normal use temperature: 1650° C) • Better linearity in the range above 1,000° C • Weak to free carbon
Ir-Ir60 Rh40 : Iridium - Iridium - Rhodium	• Usable up to the highest temperature in an oxidizing environment • Usable up to 2,000° C (normal use temperature: 1,800° C max.)
W-W74 Re26 : Tungsten - Tungsten - Rhenium	• T/C for high temperature application • Usable up to 2,800° C (normal use temperature: 2,300° C max.) • Weak to oxidation, therefore used in Nitrogen gas or inactive gases
Cu-Co Au : Copper-Gold Cobalt	• Better linearity in low temperature range, therefore used for detecting very low temperatures • Operating range: -273 to +20° C
PT31 : Platinel Au3Pd83Pt14 - Au65	• Same as K, but having no such magnetism as available in K.

5.4 Temperature measurement circuit using thermocouple



[T/C] [Compensation wires] [Temperature indicator] Fig 2

5.5 Compensation wire

Wiring between thermocouple and controller must be made by compensation wires dedicated for each type of thermocouple. The purpose is to compensate the error caused by temperature change at the terminal area of thermocouple.

Compensation wire has characteristics almost same as each thermocouple at room temperature. In case of low cost thermocouples such as T and J types, same material is used as compensation wires. But, for high cost ones like K and R types, the same expensive material cannot be used, and instead low cost materials having similar characteristics are used.

5.6 Types of compensation wires

Types	Symbol	side(red)	side(white)	Sheath color	Total electric resistance in both ways
T : General purpose	WCC-G	Copper	Constantan	Brown	0.5 O/m max.
T : Heat resistant	WCC-H				
J : General purpose	WIC-G	Iron	Constantan	Yellow	0.50/m max.
J : Heat resistant	WIC-H				
E : General purpose	WCRC-G	Copper	Constantan	Purple	1.00/m max.
E : Heat resistant	WCRC-H	Chromel	Constantan		
K : General purpose Normal grade	WCA-G	Copper	Constantan	Blue	1.50/m max.
K : General purpose Precision grade	WCA-GS				
K : Heat resistant Normal grade	WCA-H	Iron	Cu and Ni alloy		
K : Heat resistant Precision grade	WCA-HS				
R : General purpose	WPR-G	Copper	Cu and Ni alloy	Black	0.070/m max.
R : Heat resistant	WPR-H				

5.7 Cold junction compensation

Thermal electromotive force is the value when the temperature of cold junction (reference contact) t_2 is 0°C . But, as a controller is used at approx. room temperature, t_2 does not become 0°C . Therefore, the temperature amount of t_2 becomes error. In order to deny this amount, the separate electromotive force of same direction (same amount as room temperature t_2) is applied to produce electrically the same status as that the t_2 is 0°C . This is called cold junction compensation. In case of a thermocouple-input type controller, generally it has a cold junction compensation.

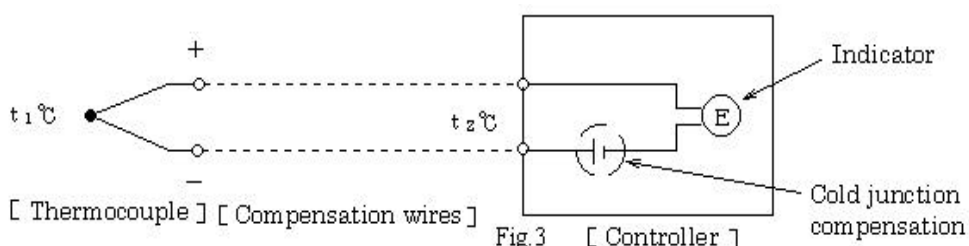
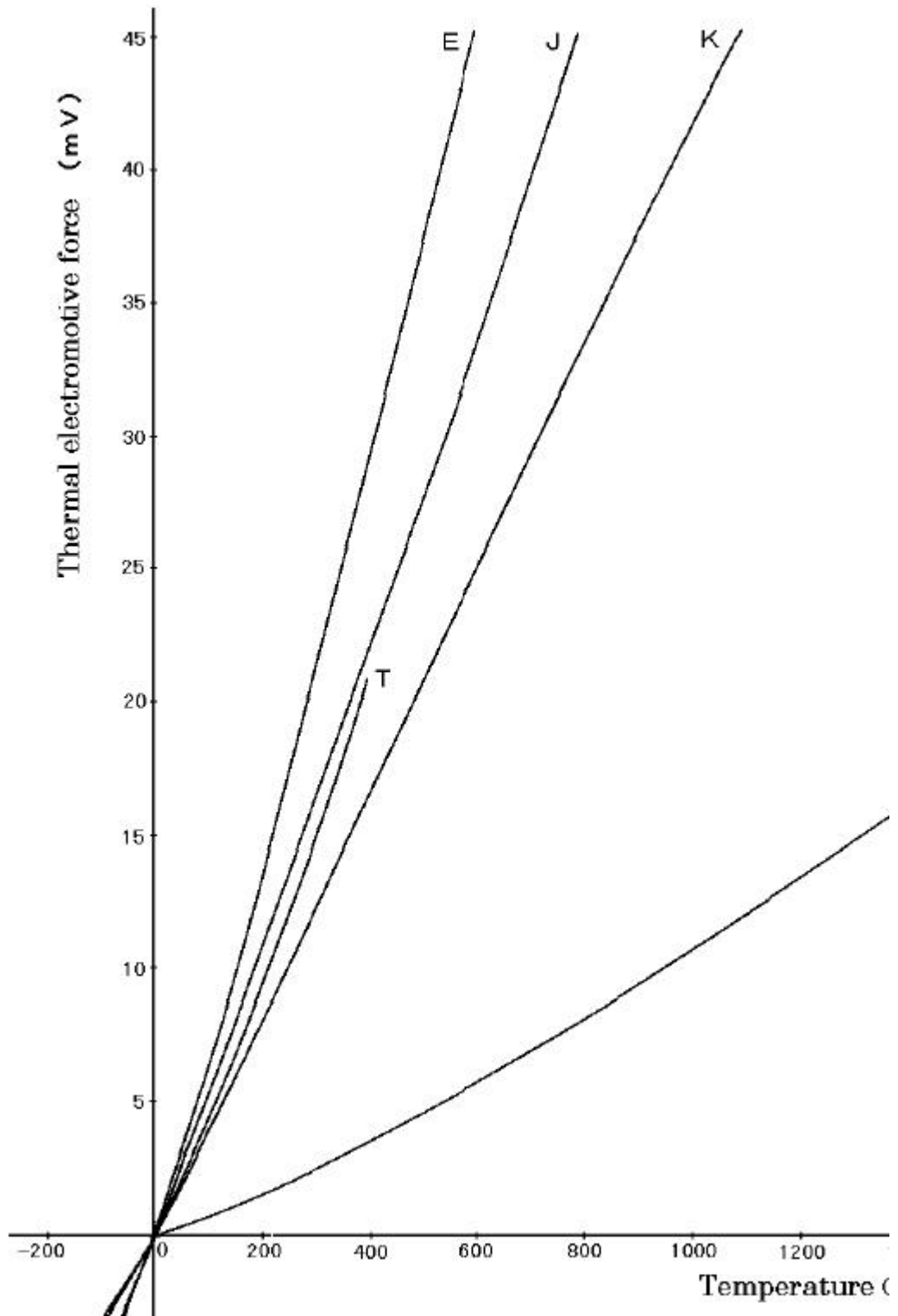


Fig 3 [Thermocouple] [Compensation wires] [Controller]

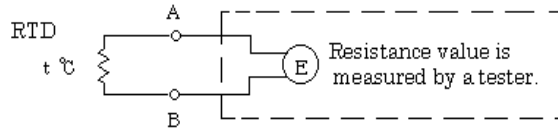
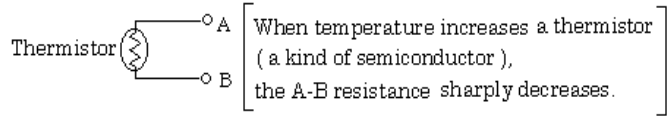
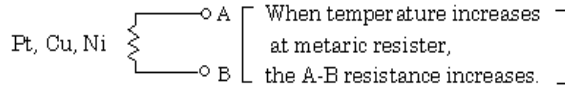
5.8 Temperature characteristics table of thermal electromotive force



6. Resistance Temperature Detector (RTD)

6.1 Principle of RTD

- (1) Metal wire such as Pt, Ni or Cu has characteristics that its resistance increases with temperature increase. Thermistor which is a kind of semiconductor has different characteristics that resistance steeply reduces with temperature increase.
- (2) RTD utilizes this type of resistance change by temperature.
- (3) Generally in low temperature areas (particularly lower than 100°C), as the thermal electromotive force of thermocouple is low resulting in difficulty of high accuracy measurement, RTD is much used.
- (4) But, in high temperature area, as the life of RTD becomes remarkably short, thermocouples are generally used.
- (5) RTD has some merits in comparison with thermocouple that a cold junction compensation is not required, and compensation wires are not required.



$$R_t = R_0 (1 + \alpha t + \beta t^2)$$

[α and β are constant values of metal.
 R_0 is a resistance at 0°C.
 R_t is a resistance at t°C.]

6.2 Types and features of RTD

Types		Max. operating temperature range	Temperature range in normal use	Features	
Metal wires	Platinum	JIS Pt 500	-200 to 100°C	<ul style="list-style-type: none"> Although temperature coefficient is not large, repeatability and stability are very superior. As a uniform material can be easily made, Pt type is widely used. JIS 0.15 type, 0.3 type, (0.5 type) This Ni type is low in cost and large in temperature coefficient. But, making a uniform material is comparatively difficult. Linearity is good. But, as the measurement temperature range is narrow, this type is not so used when compared with Pt and Ni types. Measurement temperature range is wide. But, as it is hard and brittle, W type RTD cannot be easily manufactured. 	
		JIS Pt 1000			Middle temperature types : 0 to 350°C High temperature types : 0 to 500°C
	Nickel	Ni508.40 Yamatake standard	-50 to 250°C		-50 to 150°C
	Copper Cu				0 to 120°C
	Tungsten W				
Semiconductor	Thermistor *		-50 to 300°C	<ul style="list-style-type: none"> As the temperature coefficient is very large (10 times metal wires), high sensitivity measurement can be made. But, although there are some defects as such that a uniform material cannot be easily manufactured, it has an aging characteristic, and the performance does not have a linearity, the response speed is the highest. 	

* : Oxides such as Co, Ni, Mn, and Fe are mixed and sintered.

6.3 Temperature measurement circuit using RTD

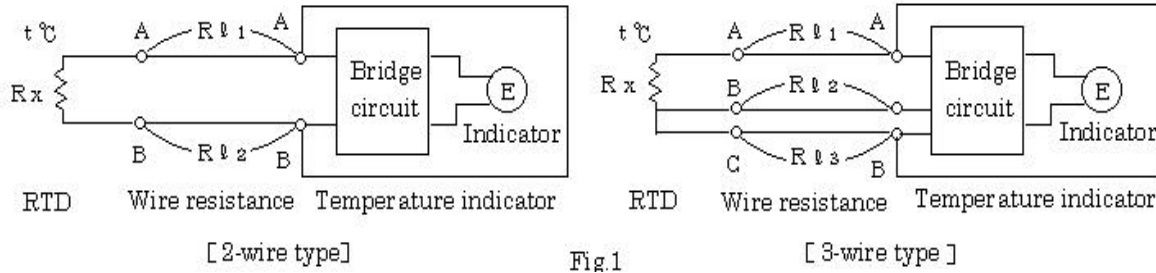


Fig.1

6.4 Bridge circuit (Wheatstone bridge)

- Power E is applied between (a) and (d) in this Wheatstone bridge circuit.
- By Kirchhoff's law, the balancing condition of bridge:

$$R(1) \times R(3) = R(2) \times R(X) \quad [1]$$

- In this case, as the electric potential of (b) is the same as (c), electric current does not flow between (b) and (c).

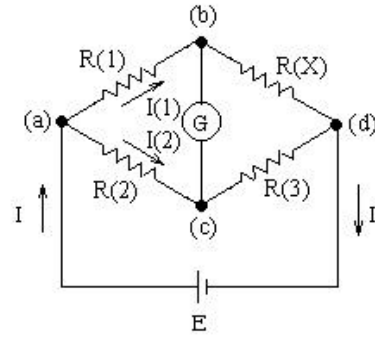


Fig.2

6.5 2-wire type

RTD resistance: $R(X)$

Wire resistance: $Rl(1) = Rl(2) = Rl$

Balancing condition of bridge:

$$R(1) \times R(3) = R(2) \times \{Rl(1) + R(X) + Rl(2)\} \\ = R(2) \times \{R(X) + 2Rl\} \quad [2]$$

Under this condition, as an electricity does not flow between (b) and (c), the same electric current $I(1)$ as that between (a) and (b) flows between (b) and (d). In addition, same current $I(2)$ as that between (a) and (c) flows between (c) and (d).

As $2Rl$ is added to the balancing condition as can be seen from the formula, the voltage drop of $I(1) \times 2Rl$ occurs in electric wire, which becomes an error.

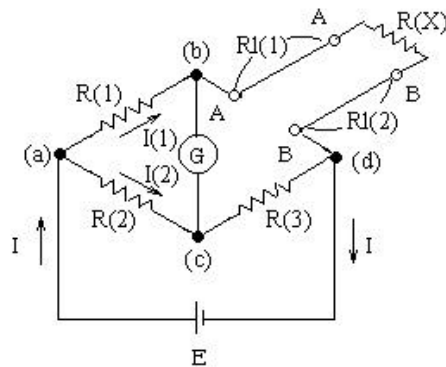


Fig.3

6.6 3-wire type

RTD resistance: $R(X)$

Wire resistance: $Rl(1) = Rl(2) = Rl(3) = Rl$

Balancing condition of bridge:

$$R(1) \times \{R(3) + Rl(2)\} = R(2) \times \{Rl(1) + R(X)\} \quad [3]$$

When the bridge is balanced, electric current $I(1)$ flows in $Rl(1)$, and $I(2)$ in $Rl(2)$.

When $I(1) = I(2)$, the voltage drop $I(1) \times Rl(1)$ by $Rl(1)$ is same value as that of $I(2) \times Rl(2)$ by $Rl(2)$ except the direction is reverse. Both mutually works so as to deny each other.

As the voltage drop $I \times Rl(3)$ by $Rl(3)$ is present in power supply circuit, it does not have any relation to the balancing condition of bridge.

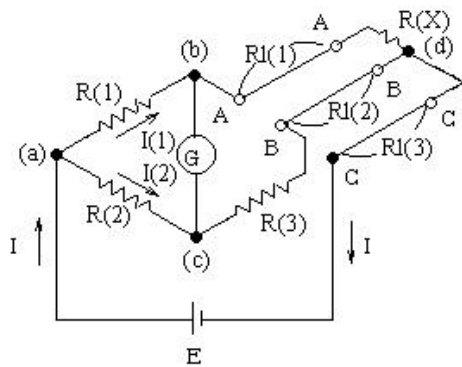
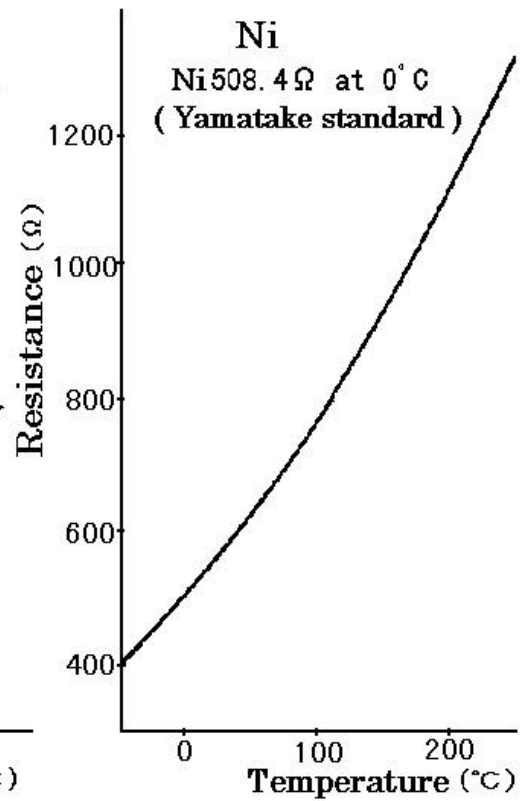
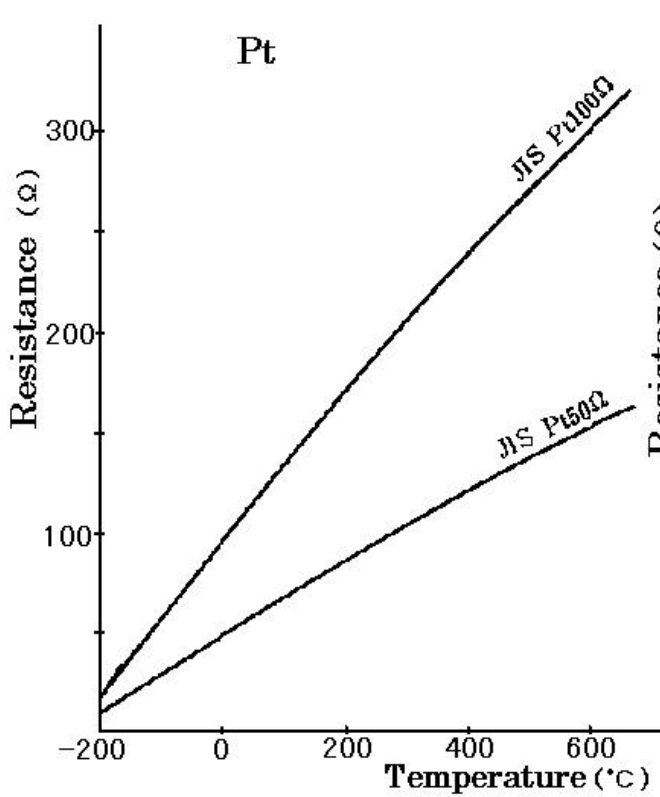
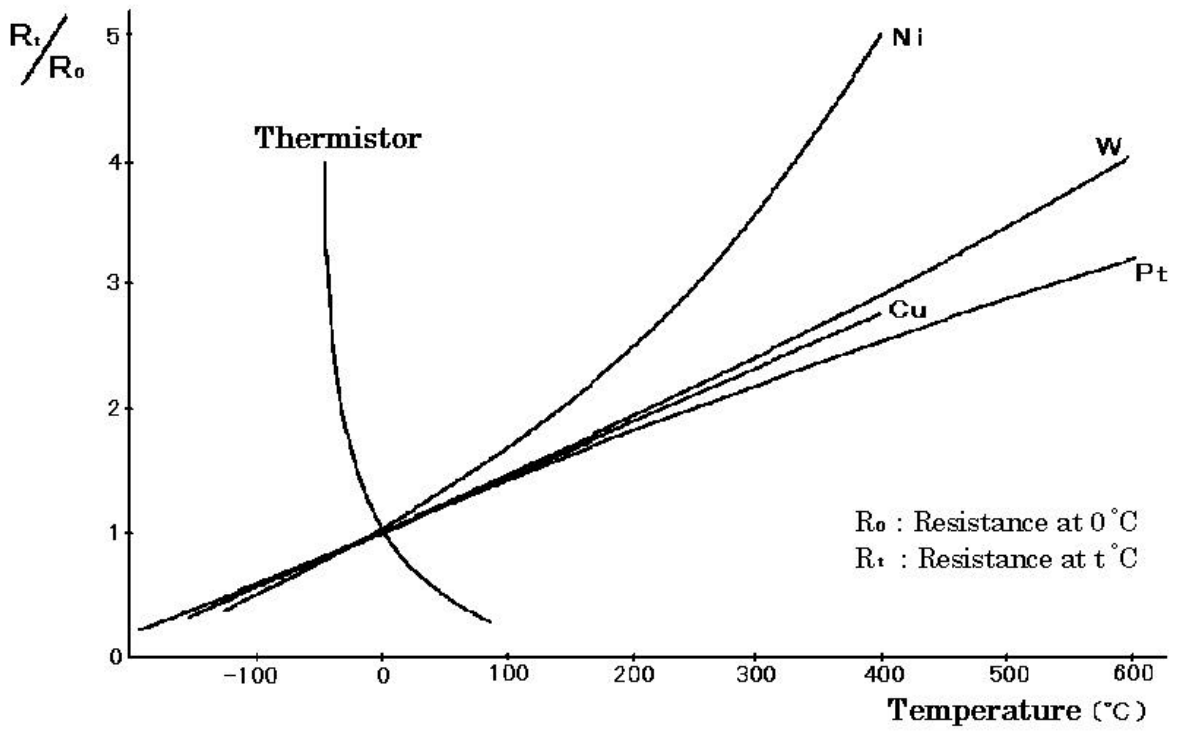


Fig.4

6.7 Temperature characteristics table



6.8 Temperature detectors other than T/C and RTD

‡ Liquid expansion type

(1) Principle

?Volume of material is increased when temperature is increased (thermal expansion). The temperature can be measured by utilizing this phenomenon.

?A liquid expansion type is a model using toluene or silicon liquid.

(2) Features

?As a liquid expansion type controller is generally incorporated with an indication/control unit and a detection unit, this model is used as a field instrumentation type controller.

?As the length of a capillary tube which connects a sensing element with an indication/control unit is within 5 or 6m, this model cannot be used for temperature measurements and control applications where the load is located at a distance of 500 or 600 meters.

?Shortcomings are narrow temperature range, slow response and low accuracy.

?Advantages are low cost and easy-to-use. Therefore, this controller is widely used for many applications where high accuracy is not required.

‡ Bimetal type

(1) Principle

?Thermal expansion of solid metal is utilized.

?A bimetal consists of two different metals of which thermal expansion coefficient is different. When temperature is increased, the bimetal is bent toward a metal of which thermal coefficient is larger resulting in switch contacts to make off.

?When temperature is decreased, the bimetal is bent toward a metal of which thermal coefficient is small resulting in the switch contacts to make on.

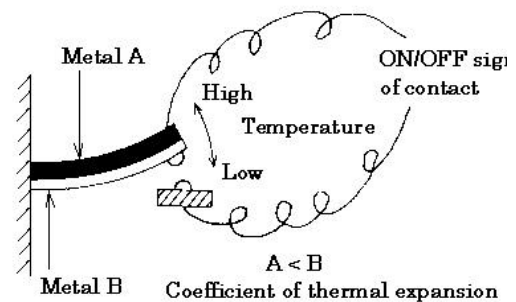
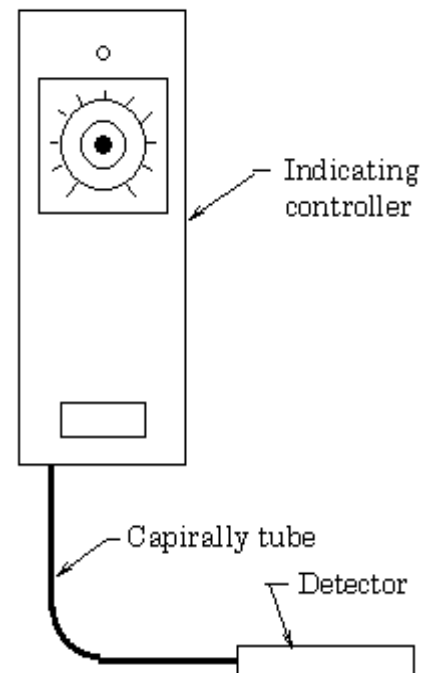
?Bimetal is widely used in various thermostats for residential houses, offices, flashing lamps or heaters.

(2) Features

?T/C, RTD and liquid expansion type detectors can be used for industrial applications. On the other hand, the bimetal type detector is used for residential houses and offices.

?Advantages of this detector are low cost, easy-to-use and easy-to-operate.

?Shortcomings are slow response and low accuracy when compared with T/C and RTD temperature detectors.

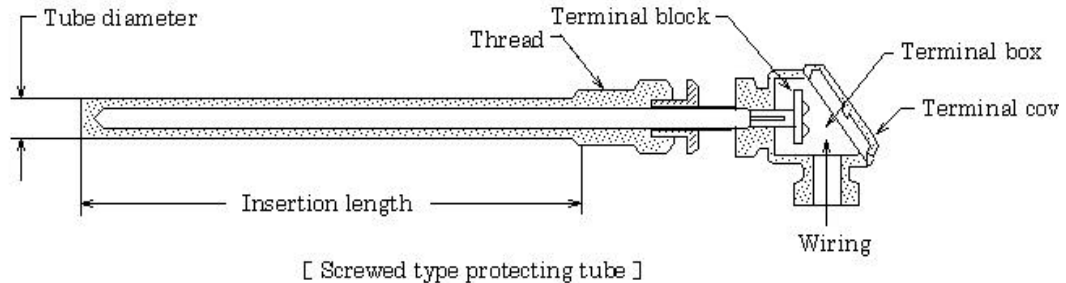


7. Protecting tube of sensing element

7.1 Purpose to use

A T/C or RTD type temperature detector has a good performance of high response without a protecting tube. But in an actual application, depending on some mechanical vibration, shock or corrosive environment, the life is considerably shortened. Therefore, a protecting tube is used to protect the sensing element.

7.2 Shape



7.3 Protecting tube type, material and operating temperature

Type		Symbol	Material	Max. operating temperature	Overheated temperature	Feature
Metal protecting tube	Stainless steel	SUS304	Fe,Cr18,Ni8	750°C	850°C	General application.
		SUS316	Fe,Cr17,Ni13, Mo2 ~ 3	850°C	950°C	General application. High corrosion resistance.
		SUS316L	Fe,Cr17,Ni14, Mo2 ~ 3	850°C	950°C	
		SUS310S	Fe,Cr25,Ni20	950°C	1050°C	High heat resistance.
		SUS347	Fe,Cr18,Ni17, Nb,Ta	850°C	750°C	High corrosion resistance.
	High chromium steel pipe	P4	Fe,Cr27, Mn1.5	1000°C	1125°C	High heat resistance. Resistance to gas containing S.
		907	Fe,Cr27	1000°C	1125°C	
	Kantal	A-1	Fe,Cr24,Al5.5	1100°C	1350°C	High heat resistance. Acid resistance.
	Inconel	In	Ni76,Cr15.8, Fe7.2	1100°C	1200°C	High heat resistance. High corrosion resistance.
	Hastelloy	Has X	Ni,Cr122,Mo9,Fe18.5,W0.6	1090°C	1250°C	High heat resistance. Chemical resistance.
Non-metal protecting tube	Hard glass	GT-0		500°C	600°C	Acid resistance.
	High purity aluminum	PT-0	AL2O3 99.5%	1650°C	1750°C	High heat resistance. (Type JIS 0)
	Aluminum ceramic	PT-1	AL2O3 55% SiO2 41%	1500°C	1550°C	High heat resistance. (Type JIS 1)
		PT-2	AL2O3 48% SiO2 47%	1350°C	1400°C	High heat resistance. (Type JIS 2)
	Translucent quartz tube	QT	SiO2	1100°C	1200°C	Resistant to rapid heating/cooling.
	Non-translucent quartz tube	QT	SiO2	1000°C	1050°C	
	Teflon	TF		205°C	250°C	High resistance to acid, alkali and chemicals.
	Zirconia	ZR	ZrO2 91% CaO 6%	1800°C	2200°C	High erosion resistance to glass, metal and slab.

7.4 Double elements

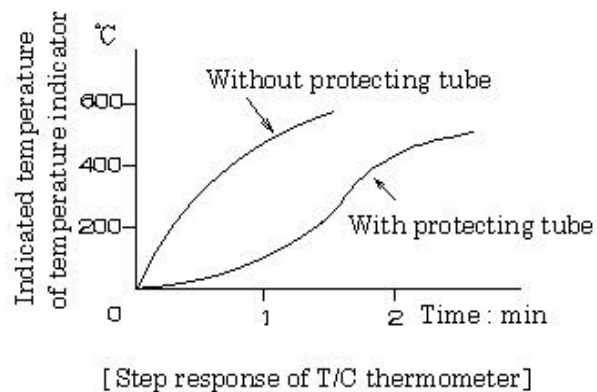
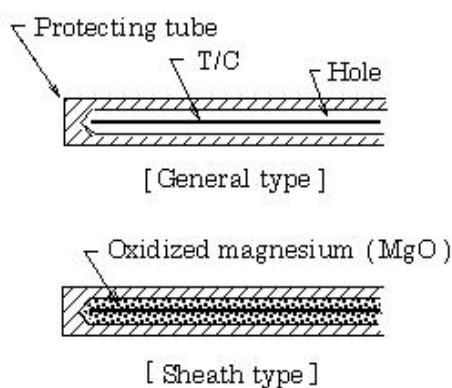
Generally, one T/C or RTD temperature sensing element is enclosed in a protecting tube. However, when a recorder or an instrument for alarming or monitor monitoring the indication in the field is additionally used, two or three elements are enclosed in one protecting tube. Such a detector having two elements in one protecting tube is called double element type detector.

7.5 Time delay (response delay)

When a T/C or RTD temperature detector is used with a protecting tube, it may cause some temperature response delay when compared with direct use of such a sensing element without a protecting tube. The time delay is different in accordance with the material, configuration shape (external dimensions, insertion length, tube thickness or internal space) or mounting method.

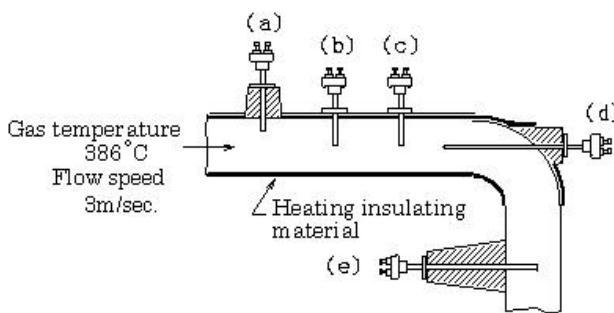
Method to eliminate time delay:

- (1) Providing large contacting area of a protecting tube against the temperature to detect.
- (2) Using a sheath type tube (containing higher heat conduction of MgO in the protecting tube)



7.6 Error difference based on mounting dimensions

The difference between b-type and c-type examples is a diameter. If the insertion length is same, a longer protecting tube is better. As a-type is shorter in the insertion length, its error is larger. The e type is mounted at the location where no heat insulation material is provided.



Error by mounting location

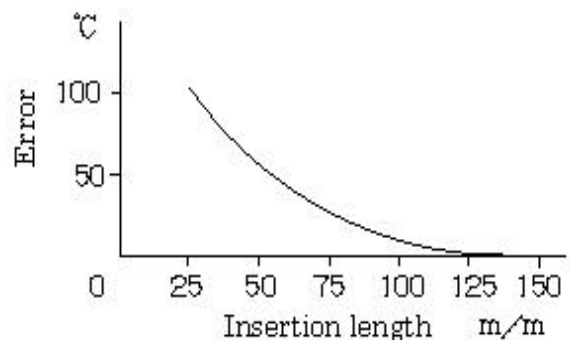
Mounting location	Error (°C)
a	-15°C
b	-2°C
c	-1°C
d	0°C
e	-45°C

7.7 Error difference by insertion length

The insertion length for a protecting tube is described to be 15 to 20 times the diameter.

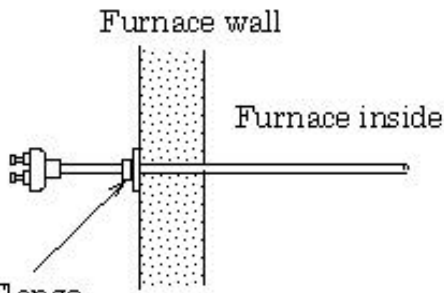
A graph shown at the right side is the test data obtained from an incineration furnace.

- Protecting tube diameter: 7mm
- Actual temperature: Approx. 700°C
- Furnace wall temperature: 150°C



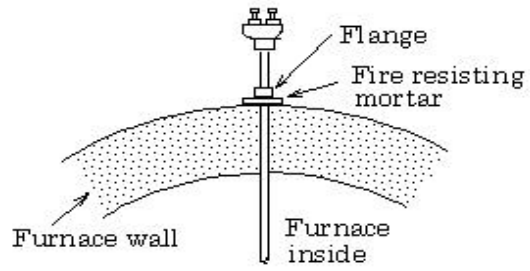
8. Mounting method of detector

8.1 Vertical mounting through furnace wall .

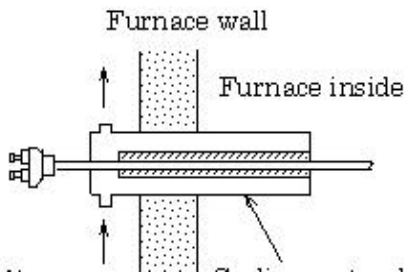


8.3 Flange inside temperature .

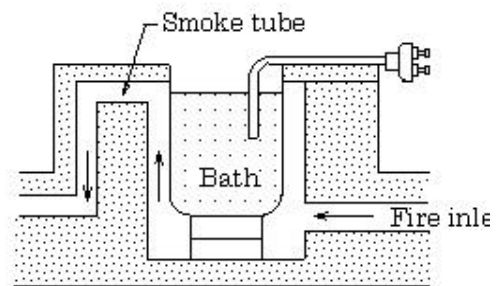
8.2 Vertical mounting from top.



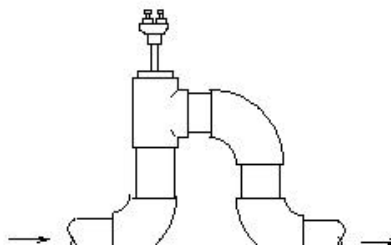
8.4 Bath inside temperature measurement.



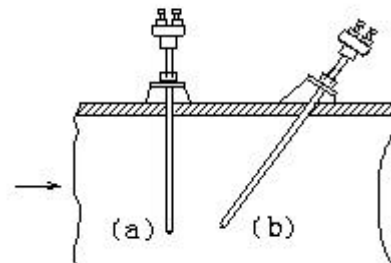
8.5 Pipe



8.6 Large diameter tube (b better than a)

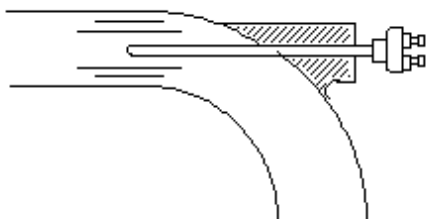


8.7 Gas supply pipe

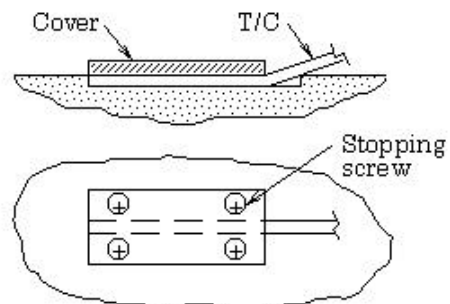


8.8 Surface temperature measurement

When the difference between pipe wall temperature and gas temperature is large, the mounting of a heat radiation cover is recommended.



A T/C is directly creped on the surface of temperature measurement material. If a groove can be made, mount the T/C in it and use a cover on it



9. SDC control modes and actuators

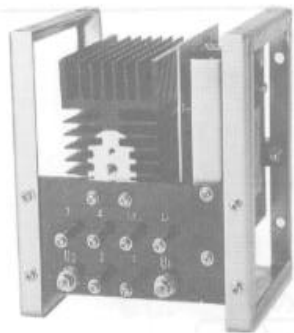
When selecting a control mode of the controller, first confirm if it is heater control or flow control.

Then, select an actuator depending on whether a slight cycling operation in temperature control is acceptable or not.

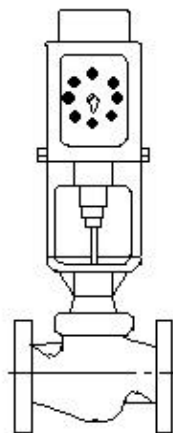
Model NO.	Control mode	Output	Heater control			Flow control						
			Electromagnetic relay	Solid state relay	Thyristor unit	Modutrol motor		Motor driver RN796A / M6284 M904	I/P converter/air driving valve	Solenoid valve	Selection point	
						Contact driving M6284 M904	4 ~ 20mA driving M7284				Cycling operation	
0D	Time proportioning PID	Relay	O	---	---	---	---	---	---	O	Heater control	Middle
6D	Time proportioning PID	Voltage	---	O	---	---	---	---	---	---	Heater control	Small
5G	Continuous proportioning PID	Current 4 ~ 20mA	---	---	O	-	---	---	---	---	Heater control	Very Small
					---		O	O	O		Flow control by various actuator	
2G	Position proportioning PID	Relay	---	---	---	O	---	---	---	---	For modutrol motor driving	



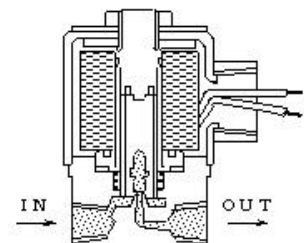
Electromagnetic relay



Solid state power relay



Modutrol motor



Solenoid valve

10. ON/OFF control

10.1 ON/OFF control

When a heater temperature reaches the set point, the heater is automatically turned off or on.

The temperature between ON and OFF points is called a “differential”.

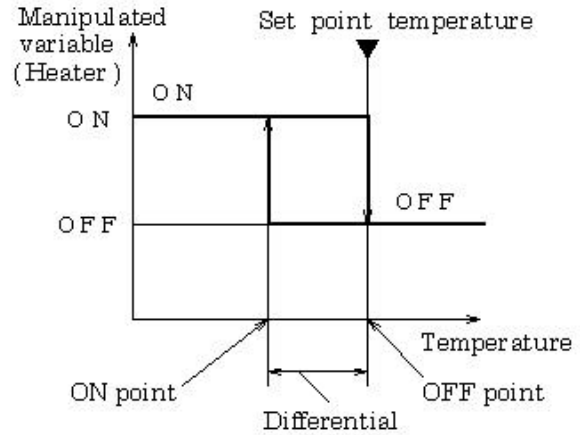


Fig.1

10.2 ON/OFF control result

Fig.2 shows a heater which is turned off at the set point A and is turned on at the set point B. The actual temperature at the control result is expected to be somewhere between A and B points. However, the actual temperature may increase beyond the set point A or decrease below the set point B due to the sensing delay in the detector, heat conduction delay in the equipment, difference in the heat capacity etc. This is called “dead time”. The former is called “overshooting”. The temperature change in the wave form is called “cycling”. Particularly, a large cycling mode which is unfavorable for controlling is called “hunting”.

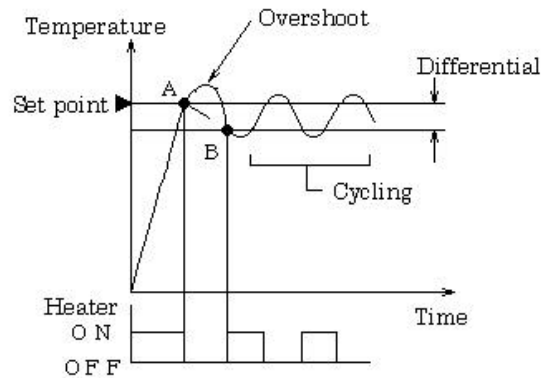


Fig.2

10.3 Actual ON/OFF control

A controller having relay contacts is generally used for ON/OFF control. Electromagnetic relay or valve is used as an actuator. The former is used for ON/OFF control of electric heaters, the latter is used for the control of fluids (water, steam, gas, etc.). When the differential is narrower, an ON/OFF cycling will be repeated resulting in obtaining better control although the differential width differs depending on the equipment (controlled system).

Too narrow differential will shorten the life of electromagnetic relay or solenoid valve, or will cause a hunting problem. When the electric heater capacity is large or the solenoid valve size is large, the hunting problem will occur.

Therefore, the differential should be set wide. When this control is used as an alarm function, the differential should be generally set wide.

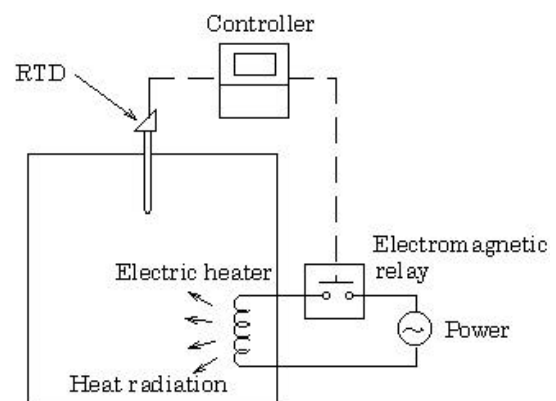


Fig.3

10.4 ON/OFF control and actuator

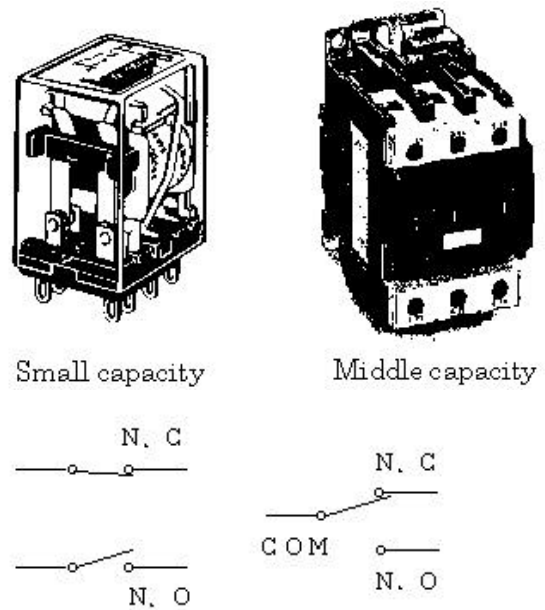
The following is an application example of electromagnetic relays and solenoid valves in ON/OFF controls:

(1) Electromagnetic relay

In this operation, the relay is closed (energized) or opened (de-energized) when electricity is applied or disconnected. The contact arrangement of SPST (single pole single throw) or SPDT (single pole double throw) is generally used.

N.C. (normally closed) contact is closed when the solenoid coil is de-energized, and is opened when the coil is energized. N.O. (normally open) contact is opened when the coil is de-energized, and is closed when it is energized.

As there are many models ranging from small to large capacities, an appropriate model can be selected in compliance with the capacity of load (like an electric heater).



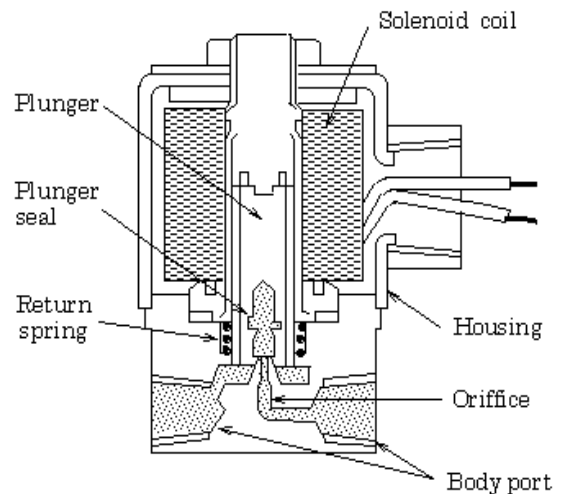
[Contact arrangement]

(2) Solenoid valve

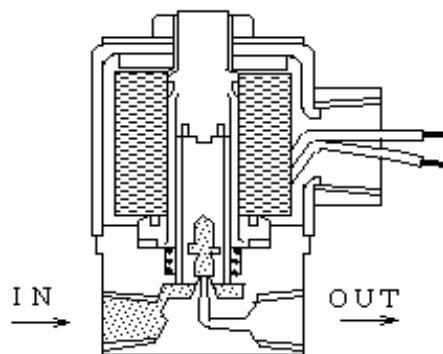
Solenoid valve is a control valve in which the solenoid coil is used as a driving unit. When the electricity is applied to the solenoid coil, the magnetic power generated will pull a plunger to open or close the valve. When the electricity is applied (energized) to the solenoid coil of N.C. type valve, the valve is opened.

When the electricity is out off (de-energized) from the solenoid coil of N.O. type valve, the valve is opened. There are 2-port and 3-port solenoid valves depending on the number of ports. For fluid application, a general purpose, heat resistance, chemical resistance or other specific model can be selected to meet the type of fluid.

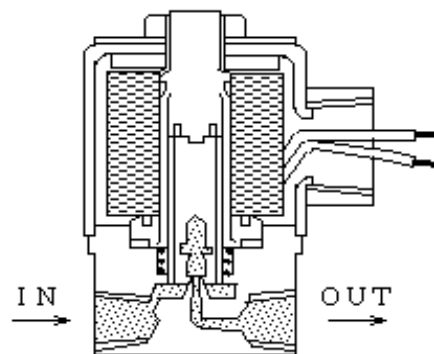
A splash-proof or a high pressure explosion-proof type can be selected depending on the place of its application.



[2 port valve construction]



[De-energized]



[Energized]

11. Proportioning control

11.1 Shortcomings in ON/OFF control

In ON/OFF control, the manipulated variable is 100% or 0%. In addition, when the sensing delay is added, the overshooting will be larger. Because of this reason, the control will be repeating the cycle operations.

Fig.1 shows a steam control by an ON/OFF-control controller and a solenoid valve. In case of the control which deals with the movement of a controlled target such as water, there may exist a time delay between the point (where the manipulated variable begins to change) and the point (where the control variable begins to change). Therefore, the control result is much higher than the set point at 100% manipulated variable, but much lower than the set point at 0% manipulated variable. Therefore, in case of this kind of control pattern, hot water or cold water will be alternatively generated. As described above, ON/OFF control has some inconveniences to the expectation of the stable control.

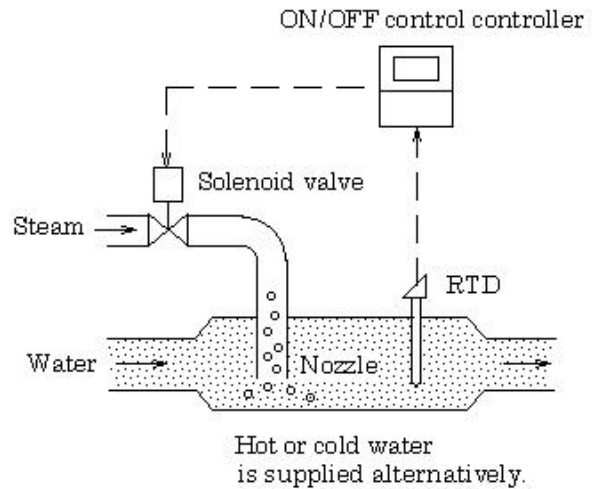


Fig.1 Flow control by ON/OFF control

11.2 Proportioning control

To solve the above-mentioned inconveniences to be caused by only two manipulated variables of 0 or 100%, the proportioning control method can be used. In the proportioning control method, the manipulated variable is linearly changed between 0 to 100% in proportion to the amount of change in process temperatures (control variables) within a certain temperature range.

A stable controlling can be obtained by this proportioning control method.

The controlled-target like moving water as shown in Fig.1 can be controlled.

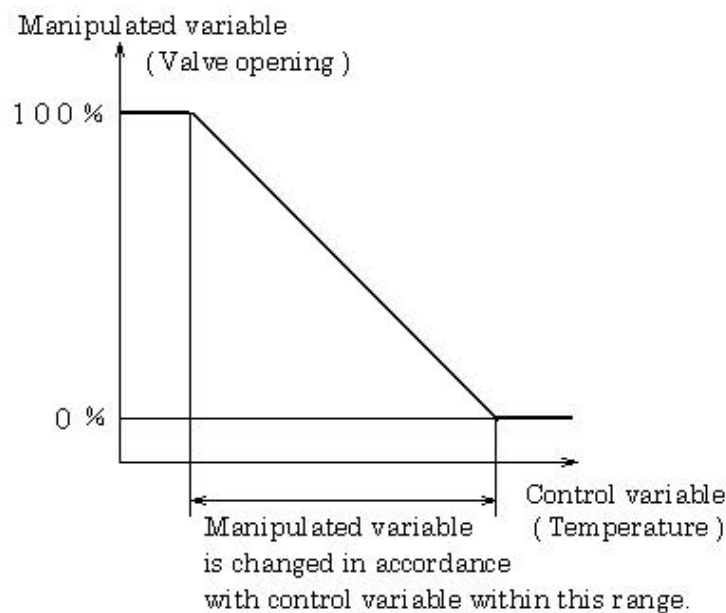


Fig.2 Proportioning control concept

11.3 Terms in proportioning control

(1)Proportional band

Proportional band is the width of control variable (temperature, pressure, etc.) required to change the manipulated variable between 0 and 100%.

When the proportional band is narrow, the manipulated variable will be largely changed against small change in control variable. As a result, the sensitivity is increased, but the stability is decreased. When the proportional band is extremely narrow, the control will be similar to the ON/OFF control. On the contrary, when the proportional band is wide, the changing rate of manipulated variable will be small against the change in control variable. As a result, the sensitivity is decreased, but the stability is better. Because of this control method, the width of proportional band must be adjusted to execute the optimum control in the proportioning control.

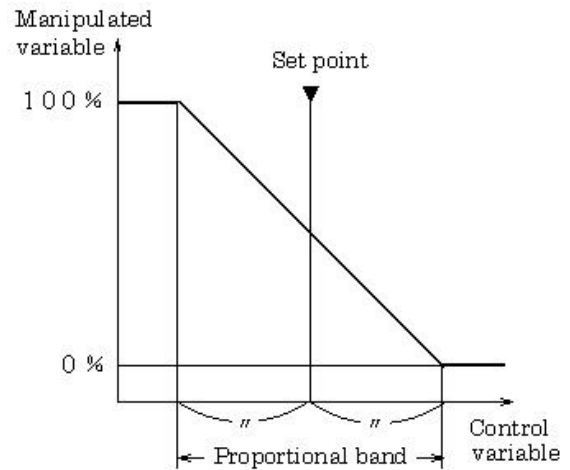


Fig.4 Proportional band

(2)Set point

Set point in the proportioning control must be set at the center of proportional band as shown in Fig.4. As an example, if set point is changed from 200°C to 300°C, the proportional band is changed to the new one in which the new set point of 300°C is the center of the proportional band.

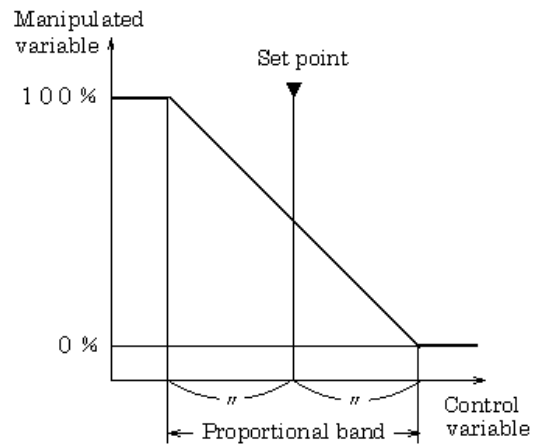


Fig.4 Proportional band

Direct and reverse operation

Direct operation is to increase the manipulated variable in proportion to the increase in control variable as shown in Fig.5. This is generally used for cooling control. On the contrary, the reverse operation is to decrease the manipulated variable against the increase in control variable. This is generally used for a heating control.

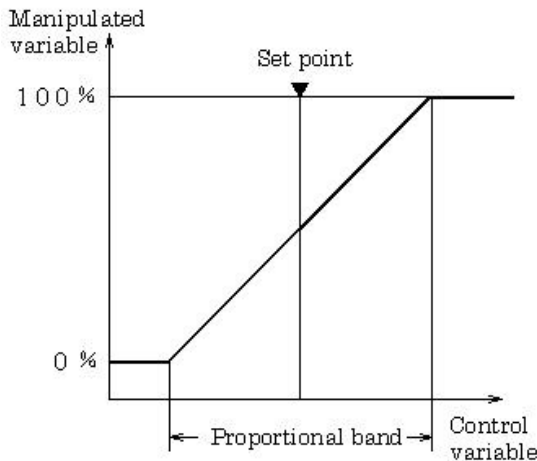


Fig.5 Direct operation

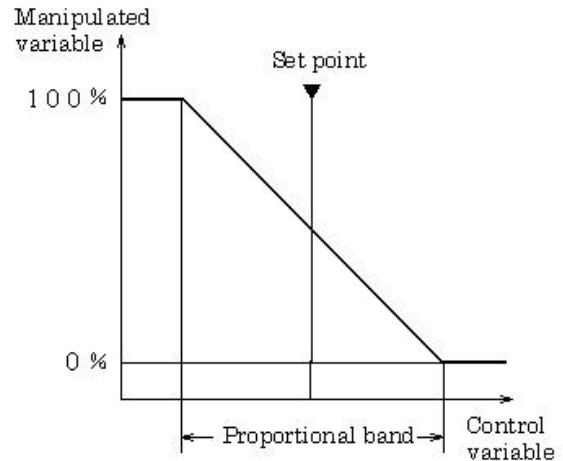


Fig.6 Reverse operation

11.4 Relation between deviation and manipulated variable

?Deviation is the difference between control variable and set point.

?Fig.8 shows the proportional control for the steam quantity by the combination of a proportional control controller and an electric control valve (Modutrol motor / 2-way valve).

In a proportioning control, the manipulated variable which is proportional to the deviation will make corrective action as shown in Fig.10.

When set point becomes the same value as the control variable in proportioning control, the manipulated variable of just 50% is applied. Manipulated variable is corrected in accordance with the amount of deviation where the manipulated variable of 50% is a reference value.

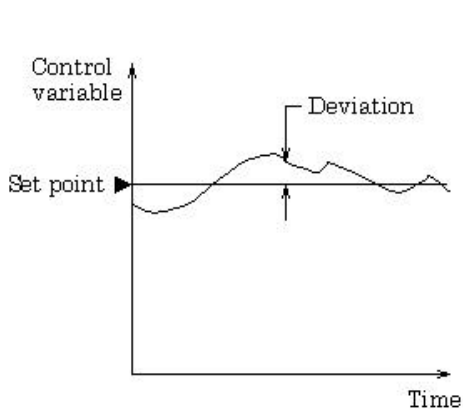


Fig 7 Deviation

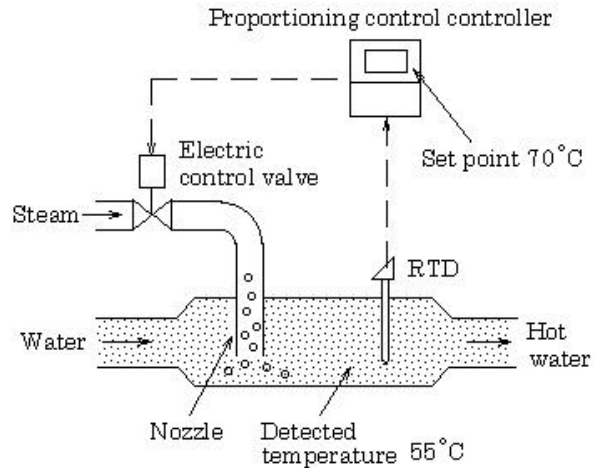


Fig 8 Water temperature control by steam

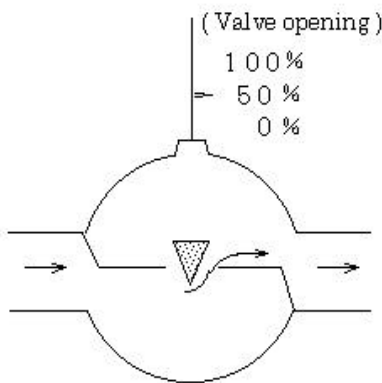


Fig 9 Electric control valve

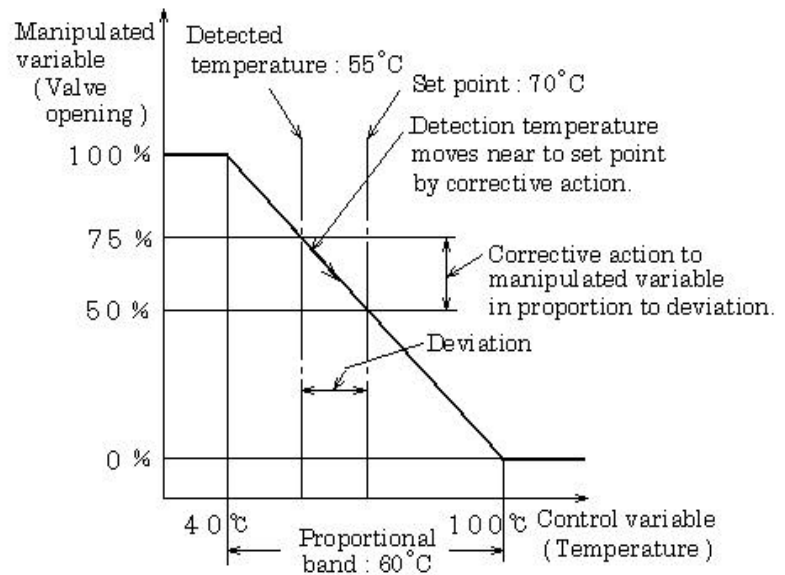


Fig 10 Proportioning control

12. Time proportioning control

12.1 Time proportioning control

Time proportioning control is a proportional control having an ON/OFF control mode. In a proportional band of which center is a set point, the ON and OFF time length is changed in proportion to the amount of deviation.

Time of one ON/OFF cycle which is called “cycle time” is constant.

When this cycle time is 10 seconds, the status is always ON within the temperature range lower than the proportional band. Within the proportional band, the ratio of ON and OFF time length is changed in accordance with the change in temperatures. For example, when a temperature is lower than the set point, ON and OFF timings are 7 and 3 seconds respectively showing that ON time is longer. When the control temperature reaches the set point, both ON and OFF period become 5 seconds each. Table 1 shows the above-mentioned control status.

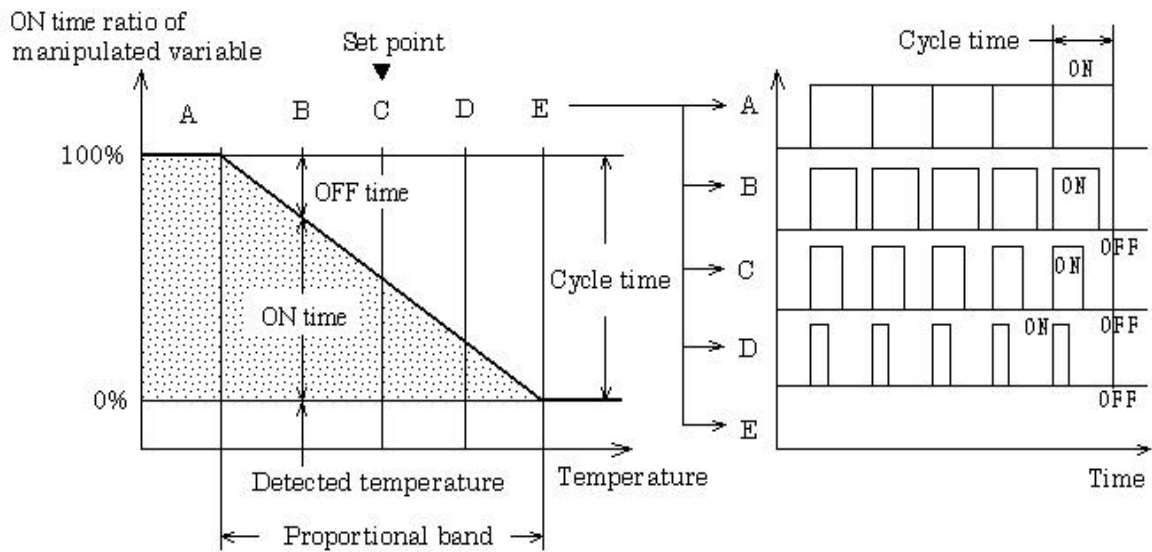


Fig.1

Actual (detected) temperature		Manipulated variable
Temperature lower than proportional band		Continuously ON
Within proportional band	Temperature lower than set point	ON time long and OFF time short.
	Set point temperature	On and OFF time same in length.
	Temperature higher than set point	ON time short and OFF time long.
Temperature higher than proportional band		Continuously OFF

Table 1 Time proportioning control status

12.2 Control result of time proportioning control

Control result of time proportioning control and ON/OFF control is described below. Fig.4 shows an example of temperature control by an electric heater. In case of ON/OFF control, the switch is turned on or off at the set point. Therefore, the amount of overshooting is large due to the temperature sensing delay.

However, for the time proportioning control, when the temperature enters in the proportional band, the ON and OFF time ratio changes in accordance with the amount of deviation. As shown in Fig.2, the overshooting amount is small when compared with the ON/OFF control.

However, the time proportioning control does not execute a smooth change in the manipulated variable when compared with proportioning control. As the control style is to repeat ON/OFF operations, the control result is not so good if the heating capacity of an electric heater is larger than furnace or the cycle time is larger. Therefore, the overshooting amount will be large.

Time proportioning control has relay output and voltage output. The former is used with an electromagnetic relay. The latter is used with an solid state relay (SSR).

The cycle time of relay output is variable and is generally 10 to 60 seconds. If the cycle time is too short, the contact life of the electromagnetic relay will become much shorter.

The cycle time of voltage output is short in the fixed value of 2 to 4 seconds. If a non-contact SSR is used, there is no problem in the contact life. The control result can be better.

Therefore, very important keys to obtain better control result in the time proportioning control are a correct capacity and a cycle time setting.

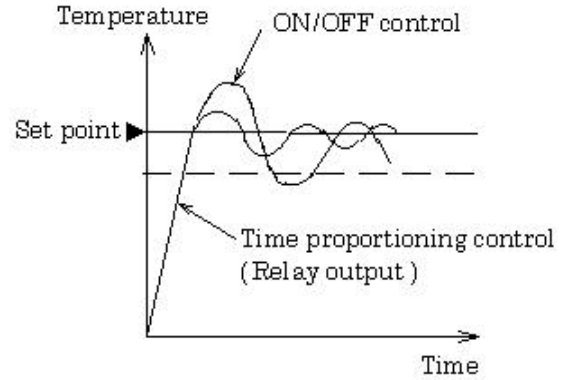


Fig. 2

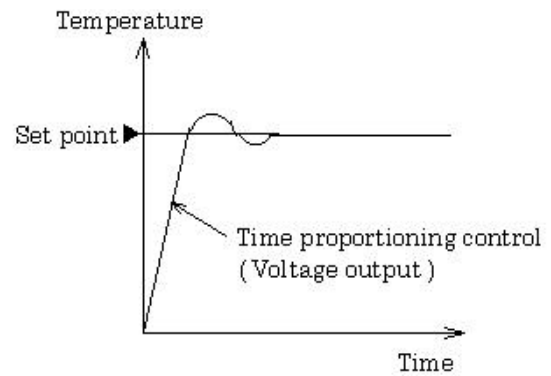


Fig. 3

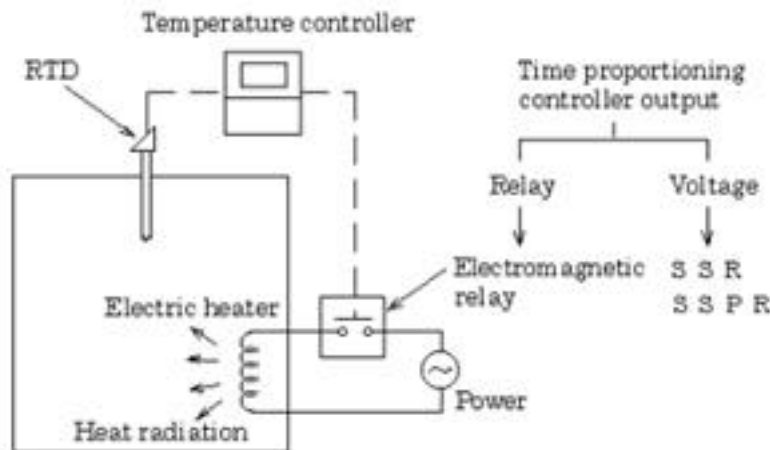


Fig. 4

12.3 Time proportioning control and actuators

Solid state (power) relay which is used with a time proportioning control voltage output type controller is described below.

(1) Solid state relay (SSR)

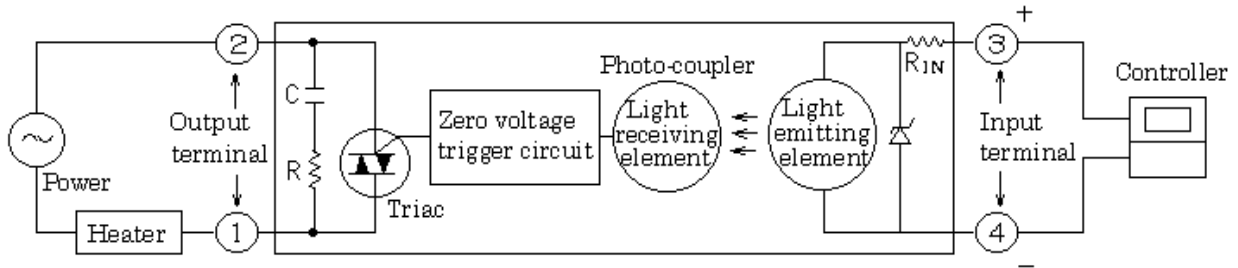


Fig.1 SSR

[SSR operation]

Fig.1 shows a popular photo-coupler insulation type and an AC zero-cross type.

The voltage (24Vdc) input from a controller is inputted in SSR input terminal and then is further sent to the zero-voltage trigger circuit through the photo-coupler (light emitting element / light receiving element).

When the AC current and voltage become just zero, a trigger pulse voltage input is given from the zero voltage trigger circuit to a non-contact switching element which is called a Triac (see “thyristor” on next page) for the alternative current to open or close the electric heater circuit.

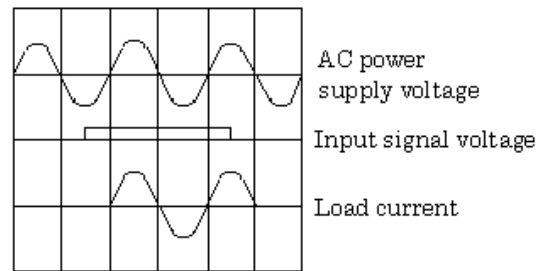


Fig.2 SSR operation wave form

[Maximum load current]

When SSR executes switching of the alternative current, heat is generated. Therefore, the allowable maximum load current differs depending on the ambient temperature or a cooling device for the heat dissipation.

Generally, the maximum load current is specified for the cooling fins to dissipate the generated heat.

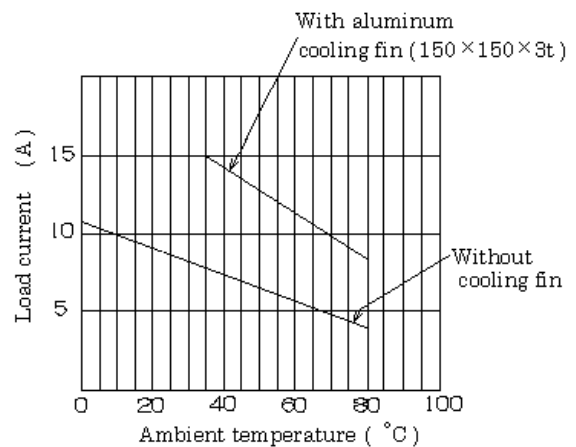


Fig.3 Load current - ambient temperature.

(2) Solid state power relay (SSPR)

The operation principle of SSPR is same as that of SSR. However, the maximum load current of SSPR is larger than SSR. (The maximum load current of SSR is only 15A.) Various models are available up to 130A. As shown in pictures, the size of cooling fins for the heat dissipation differs depending on the maximum load current.

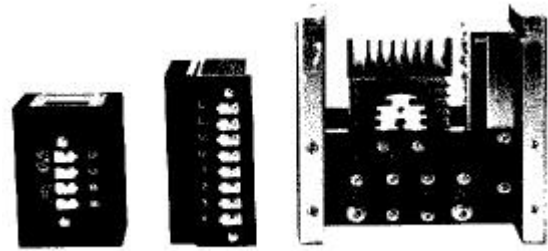


Fig.1

[Thyristor]

Thyristor is a semiconductor element having PN junction. General types are a reverse-blocking 3-terminal thyristor and a bi-directional 3-terminal thyristor.

The former is called a silicon controlled rectifier (SCR). The latter is called Triac.

SCR allows current to flow only to one direction (from anode to cathode). Therefore, when SCR is used for the alternative current, two units should be connected in the reverse/parallel way. However, as Triac has a similar construction as such that 2 SCRs are connected in the reverse/parallel way, Triac can be used for the alternative current as it is. Both SCR and Triac allow currents to flow from the anode to cathode when the trigger voltage is applied to the gate. In order to stop the flow of this current, the gate voltage must be removed and also the load circuit must be disconnected.

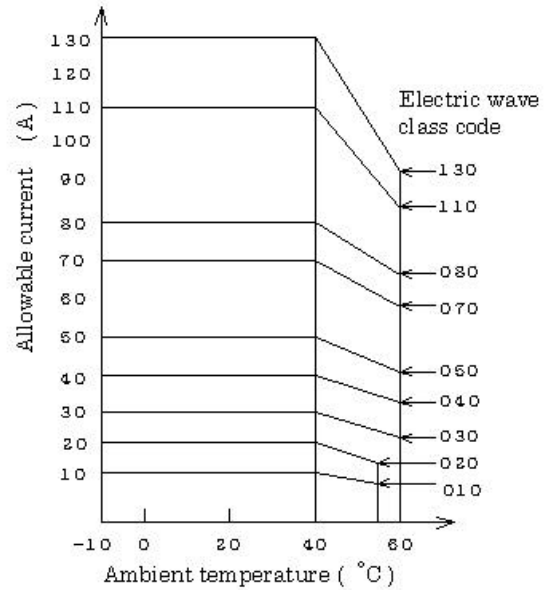


Fig.2 Load current - ambient temperature.

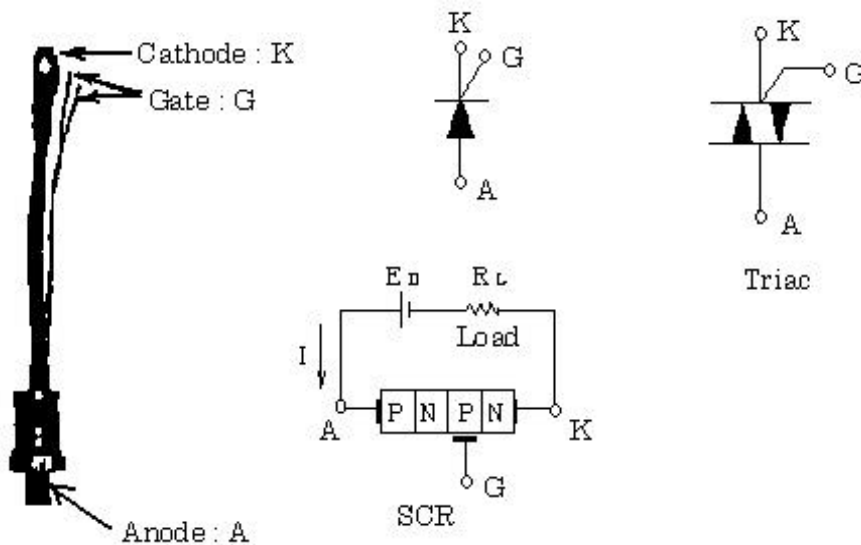


Fig.3

13. Continuous proportioning control

13.1 Continuous proportioning control (current output) is a control mode with the output currents of 4 to 20mA continuous in accordance with the amount of deviation. This current is sent to the actuator called thyristor to control the electric heater. This input is also sent to an I/P positioner (current/pressure converter) to convert the current signal into the air-pressure signal to control a pneumatic control valve.

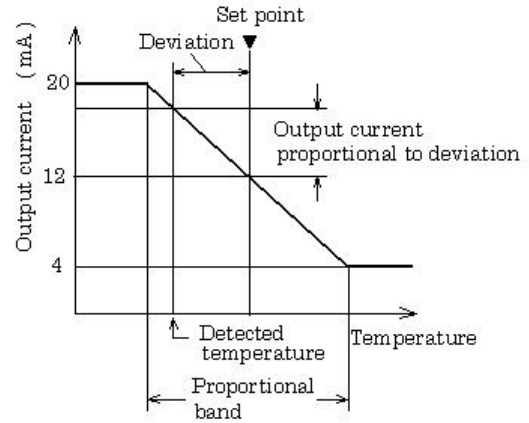


Fig.1 Continuous proportioning control characteristics

13.2 Unified signals

There are two types of unified signals of 0.2 to 1.0kg/cm² pneumatic pressure and 4 to 20mA dc current. Humidity, pressure and flow controls are conducted at large plants in addition to temperature control. In these cases, if many different control systems and various models of controllers are used in mixed conditions, they create much inconvenience in the actual applications.

In addition, such a situation may cause a problem in the signal transmission.

To solve these problems, various converters are prepared and a unified signal is used for the input and output of controllers, recorders and other devices.

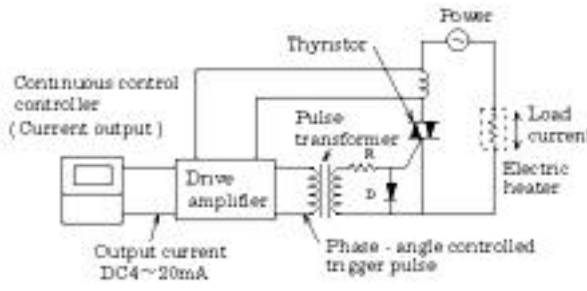


Fig 2 Phase-angle control by thyristor unit

13.3 Continuous proportioning control and electric heater control by thyristor (phase angle control)

Fig 2 shows an example of electric heater control by the phase angle control method using a thyristor. A trigger pulse generates from a drive amplifier in meeting with the phase angle of load electric power by the output current of controller (phase angle control). When this pulse is applied to the gate circuit of the thyristor (Triac), the thyristor is turned on. This thyristor keeps the conductive condition until the load electric power is changed to zero.

As described above, the thyristor changes proportionally the location (time) at which the trigger pulse is generated in accordance with the amount of deviation, and continuously controls the load current flowing into the electric heater.

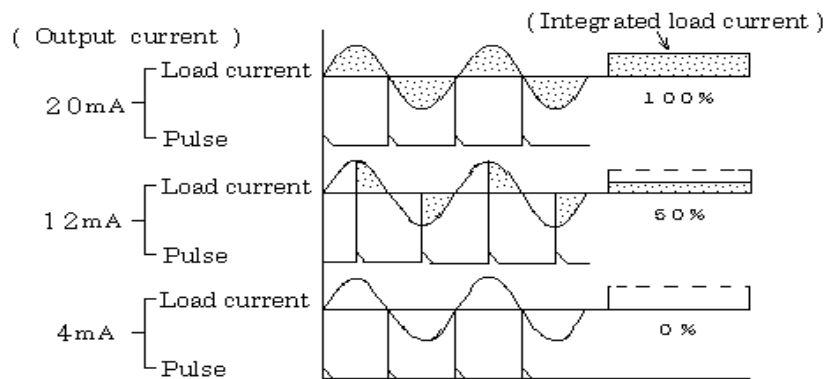


Fig.3

14. Position proportioning control

14.1 Position proportioning control

This is a control mode that the manipulated variable is proportional to the deviation (difference between detected temperature and set point). The electric control valve (Modutrol motor + Control valve) is opened or closed by the output of this controller to control the gas or heavy oil combustion furnace.

Fig.2 shows the example of this operation. When the set point is 700°C and the proportional band is within the range of set point values of $\pm 100^\circ\text{C}$ (600 to 800°C), the motor opening is 100% (full open) when the temperature detected by thermocouple is lower than the proportional band (600°C or lower).

When the temperature increases to the point more than 600°C and enters into the proportional band, the manipulated variable which is proportional to the deviation starts working. For example, when the detected temperature is 650°C, the motor opening is 75%. When the temperature reaches the set point where the deviation is zero, the motor opening is 50%. When the temperature exceeds the set point, the motor closes gradually.

When the temperature becomes more than 800°C, the opening is set to be 0% (full open). As the Mudutrol motor rotates from 0 to 160° range, the motor opening is 80° at 50% manipulated variable.

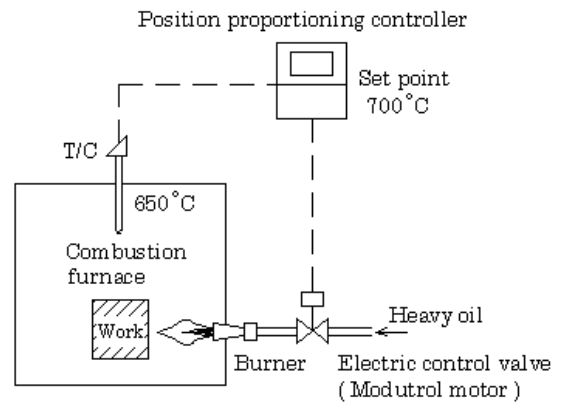


Fig.1 Control example on combustion furnace

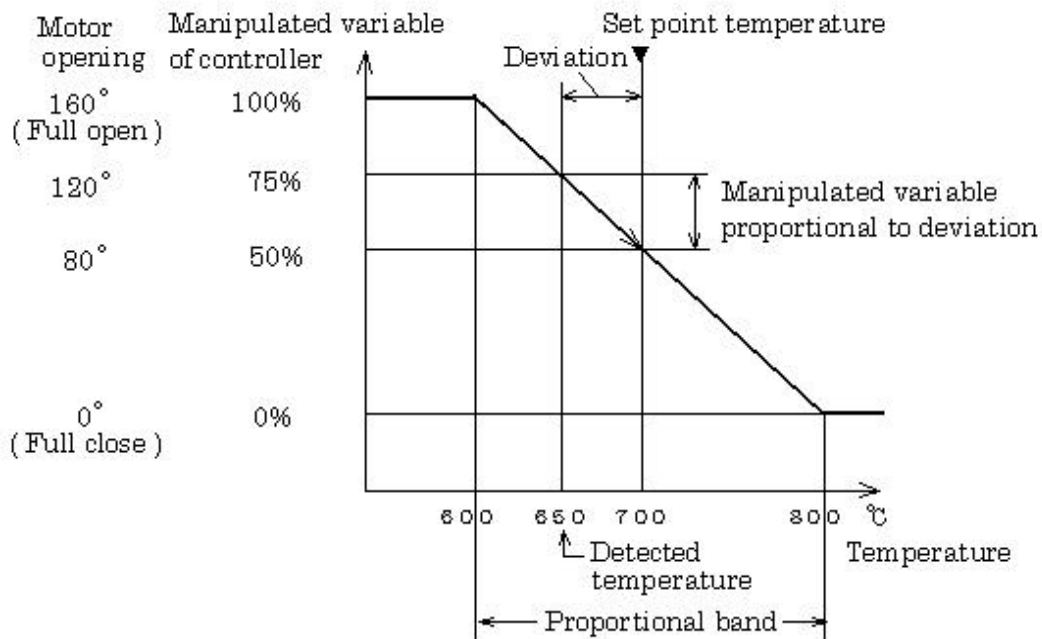


Fig.2 Position proportioning control

14.2 Modutrol motor driving by the position proportioning control

This section will describe the motor driving by the position proportioning control (2 relay contact outputs of a controller) and a Modutrol motor (relay contact inputs).

Fig. 3 shows the relay contacts in the control circuit where the relay (bridge circuit) is balanced. Both K1 and K2 balancing relay contacts become open and the motor stops.

- (1) When a temperature gets lower, the input decreases. And then, the balanced condition of bridge circuit is broken. The relay contact K2 closes and the voltage is applied across the motor terminals(1)and(2). Finally, the motor starts to rotate clockwise in view from the main output shaft (power end). In accordance with the motor rotation, the wiper of a feedback potentiometer moves toward such a direction to make the bridge circuit balance again. When the rotation continues with the temperature drop, the bridge circuit makes balance again. In this case, the relay contact K2 becomes open and then the motor stops at the position.
- (2) When the temperature increases, the input also increases. And then, the balanced condition of bridge circuit is broken. The relay contact K1 closes and voltage is applied across the motor terminals(1)and(3). Finally, the motor starts to rotate counterclockwise. At the same time, when the motor rotates with the temperature drop, the bridge circuit is again balanced. In this case, the relay contact K1 opens and then the motor stop

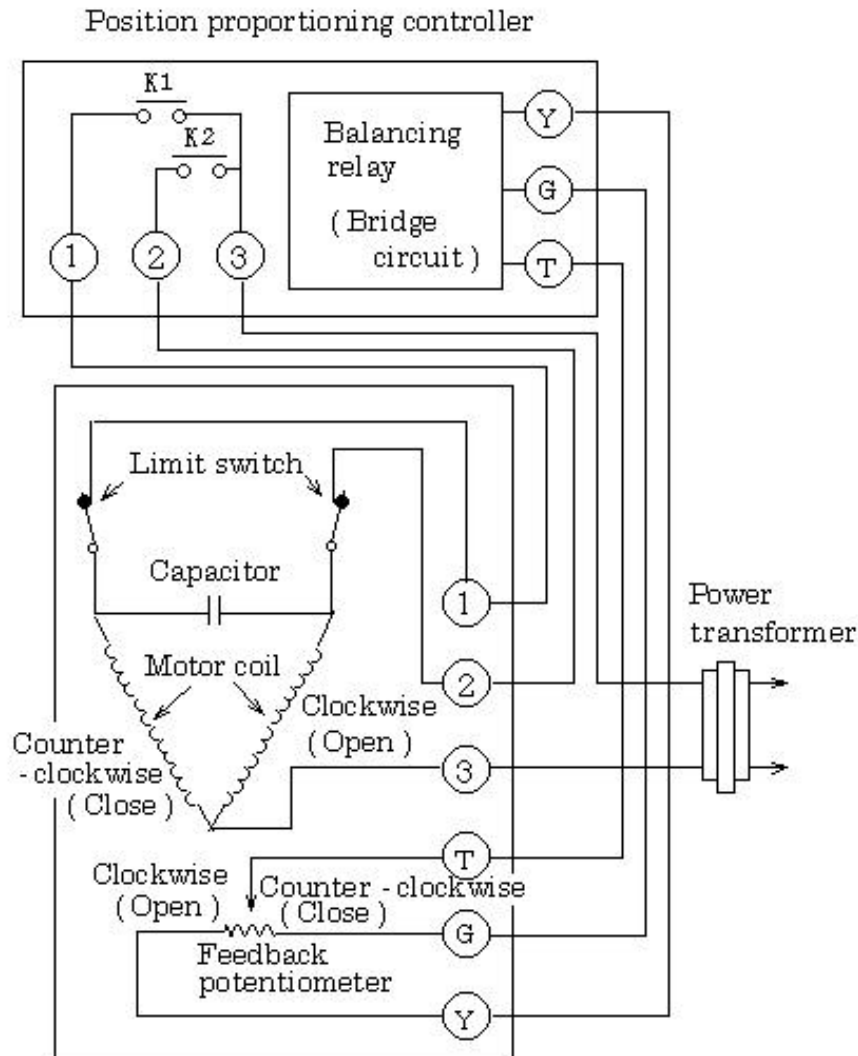


Fig. 3 Motor driving position proportioning control

14.3 Motor resolution

Fig.4 step-type graph shows that the motor is closed by β , when the detected temperature is changed by a . When the amount of temperature change is smaller than a , motor does not start the corrective action. This a is determined by the effective number of turns of the motor feedback potentiometer. When the turns are larger, the resolution is better. (The resolution differs with the proportional band width.)

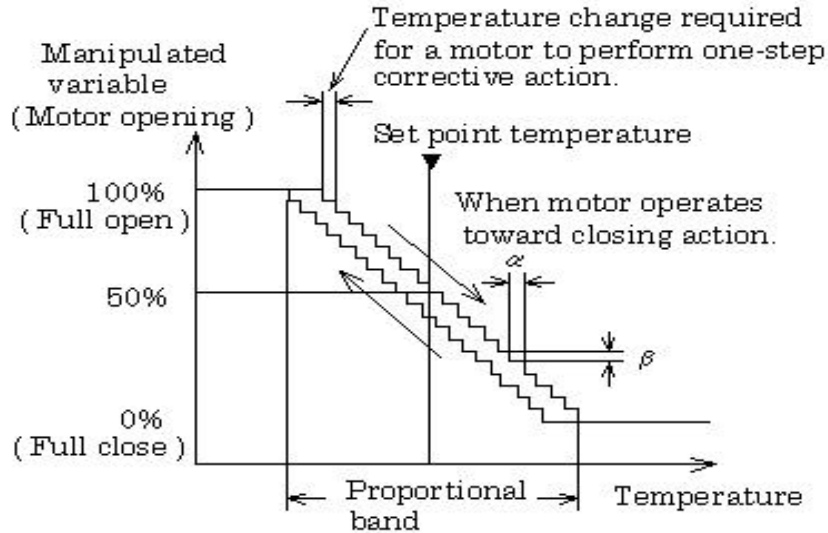


Fig.4 Operation of control motor.

14.4 Setting of dead zone

The dead zone is a range within which the actuator does not operate even if the input is changed. This dead zone is the amount of input change required to cause corrective action of the motor from open to close or close to open positions (a and a' of Fig.5).

When the dead zone is set narrow, the motor will frequently cause the corrective action to open or close the valve even at a small temperature change. In this case, higher control accuracy can be obtained. On the contrary, when the dead zone becomes wider, the motor does not frequently cause the corrective action until the change of detected temperature becomes large.

Generally, if the dead zone is narrow, the control ability is better. However, if it is too narrow, the control will cause a hunting, thus resulting in shortening the life of motor feedback potentiometer. Therefore, the dead zone must be set at a level where such a hunting does not occur.

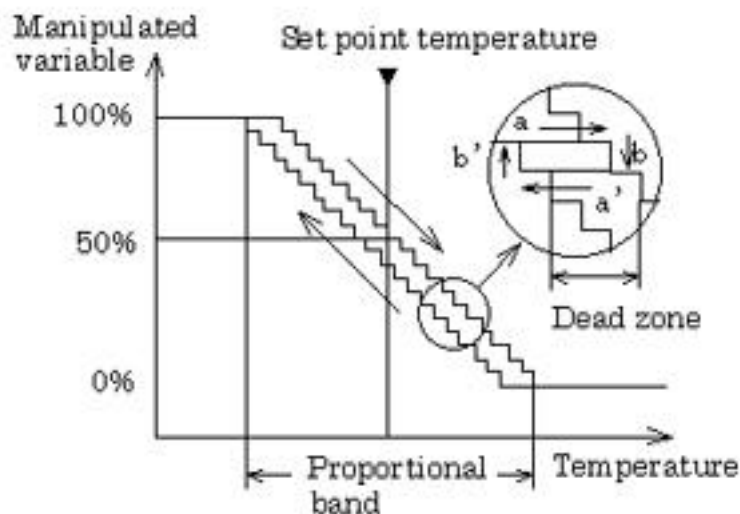


Fig.5 Dead zone

15. Proportioning control in actual application

15.1 Equipment

Fig.1 shows an example of actual proportioning control. This is an equipment to produce hot water by applying steam into the water which is supplied to the equipment at a certain rate. The water temperature is detected by an RTD temperature sensor. Temperature controller executes the proportioning control of the electric control valve.

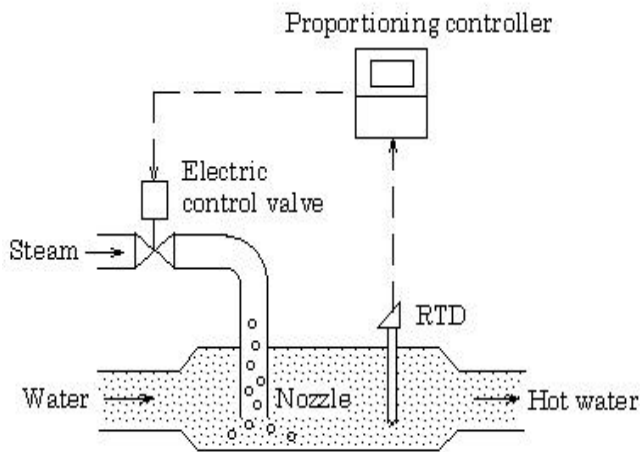


Fig.1 Equipment

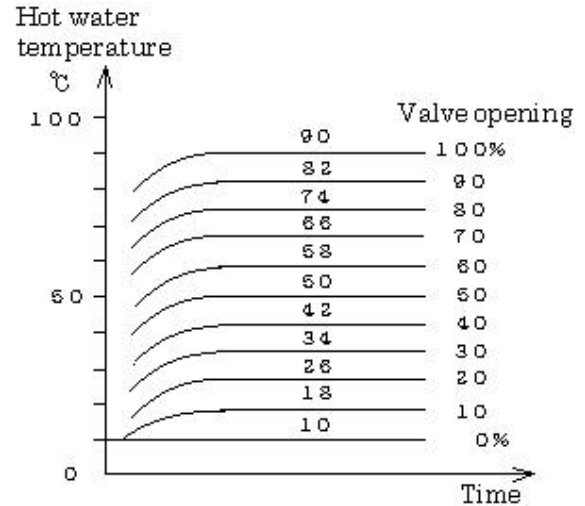


Fig.2 Hot water temperature at a certain valve opening

15.2 Load characteristics

Fig.2 is a graph showing the temperature at which the hot water temperature is saturated when the opening level of electric control valve gradually increases at 10% increment from 10% to 20%, and then finally up to 100%.

Fig.3 shows a load characteristics graph of the valve opening levels vs. hot water temperature. Fig.4 shows a different load characteristics graph in which the vertical line and horizontal line are replaced each other. The line shown in this graph is called load characteristics line.

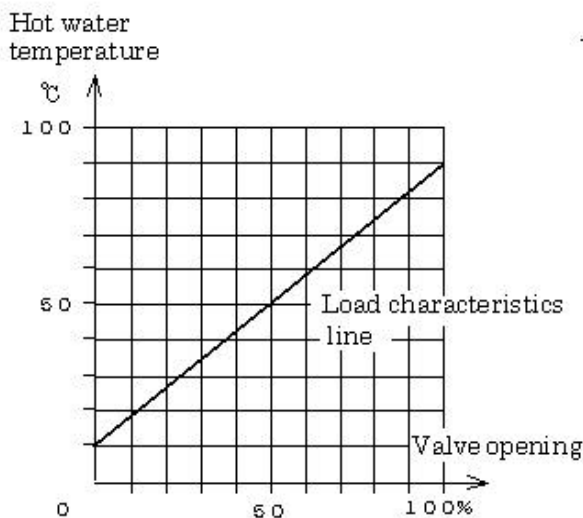


Fig.3 Load characteristics

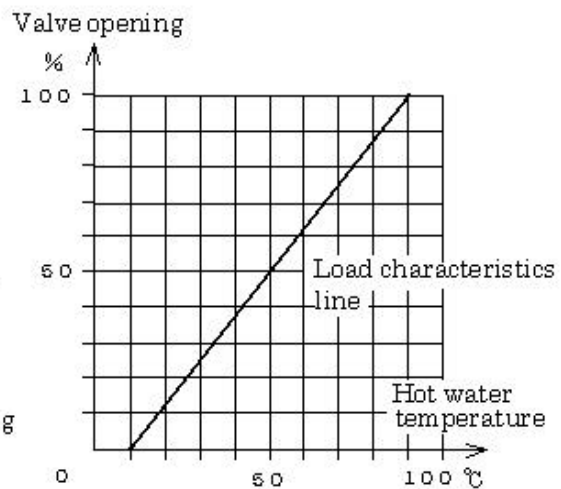


Fig.4 Load characteristics

15.3 Control characteristics

Fig.5 shows a control characteristics graph with the set point of 70°C for the hot water equipment is and the proportional band is of 60°C.

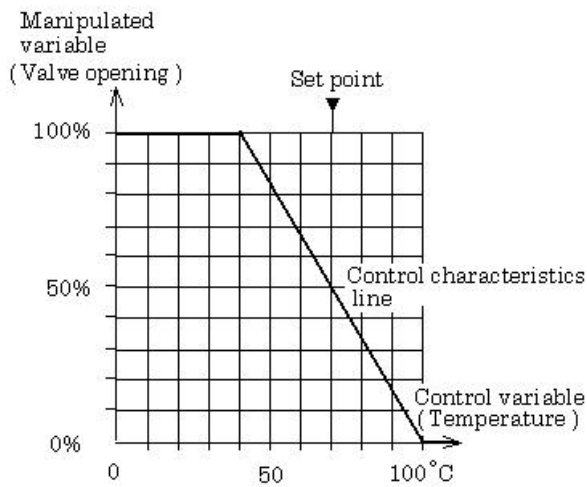


Fig.5 Control characteristics

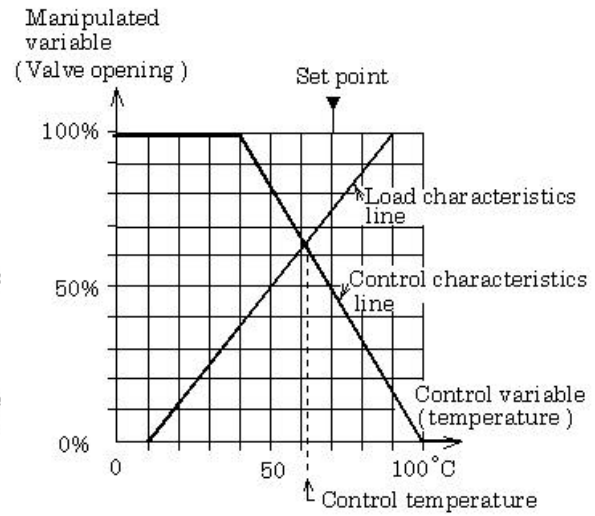


Fig.6 Control temperature by proportioning control

15.4 Proportioning control in actual application

Fig.4 and Fig.5 graphs are produced on the same hot water equipment.

Therefore, both graphs must be satisfied at the same time. The control temperature becomes stable at the cross point of two characteristics lines as shown in Fig.6.

15.5 Proportioning control action

Proportioning action (P) is an action to apply a manipulated variable which is proportional to the amount of deviation within the proportional band.

When P action causes offset, I (integration) action should be added so as to execute PI action (or PID action). A recommended P value is 2 to 10% for an electric heater control although it differs depending on the equipment.

16. Offset

16.1 Offset

Offset is a difference between the set point and the controlled temperature which continuously exists at a constant value while controlling the process.

When the proportioning control is performed, this offset occurs in accordance with the load change or the intrinsic characteristics of the equipment.

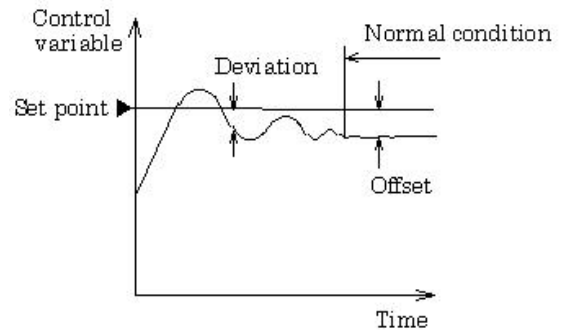


Fig.1 Offset

16.2 Cause of offset occurrence

Fig.2 shows a graph where the cross point of the load characteristic line and the control characteristics line does not exist on the set point line. Therefore, the offset exists against the set point.

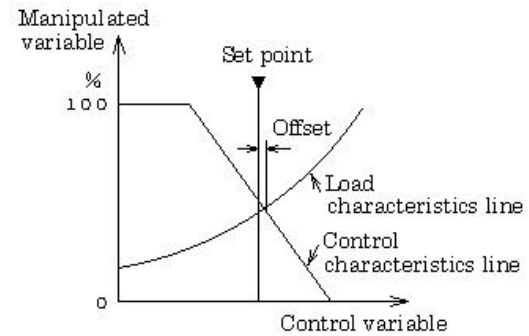


Fig.2 Cause of offset

16.3 Offset occurrence in actual applications

(1) At load change

A. When a large load is applied rather than ideal one, the heat to be used by this large load increases. Therefore, the detected temperature is 790°C.

B. In case of a small load, the result will be reversed.

(2) At the ambient temperature change for combustion furnace

A. When the ambient temperature becomes low in winter, the heat to be used will increase. Therefore, the detected temperature is 790°C.

B. In case of summer, the result will be reversed.

(3) At set point change

A. When the set point is higher than 800°C for the combustion furnace designed for 800°C, the detected temperature is lower than set point.

B. In case of the set point lower than 800°C, the result is reverse.

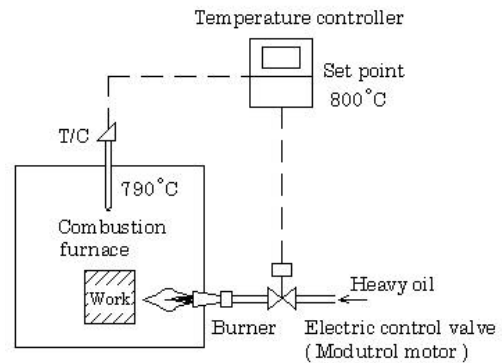


Fig.3 Combustion furnace

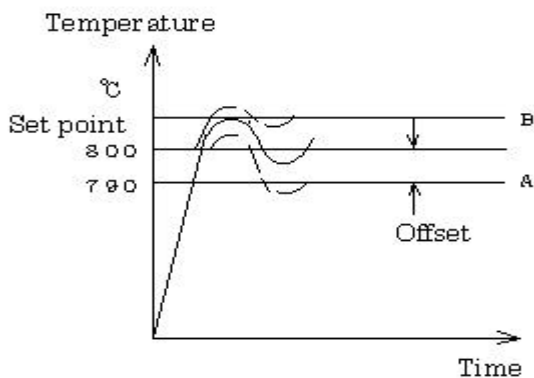


Fig.4

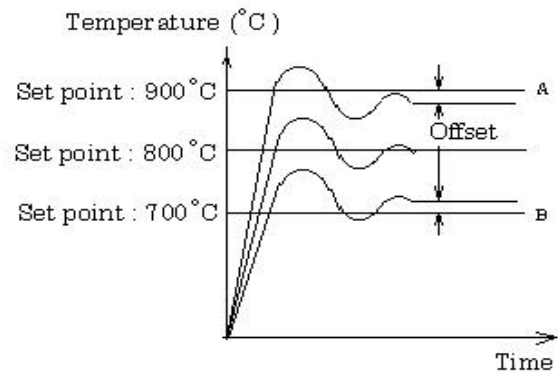


Fig.5

17. Manual reset of set point

Manual reset is a method to adjust the output in application field.

When offset occurs at lower side of set point as shown in the graph below, a potentiometer is turned toward “+” side for the analog controller.

In case of digital controller, the parameter is set to the value larger than 50%.

Manual reset is suitable for an application where the adjustment is required for only several times. For an application where the load is frequently changed, I (integral) action described in the next item is suitable.

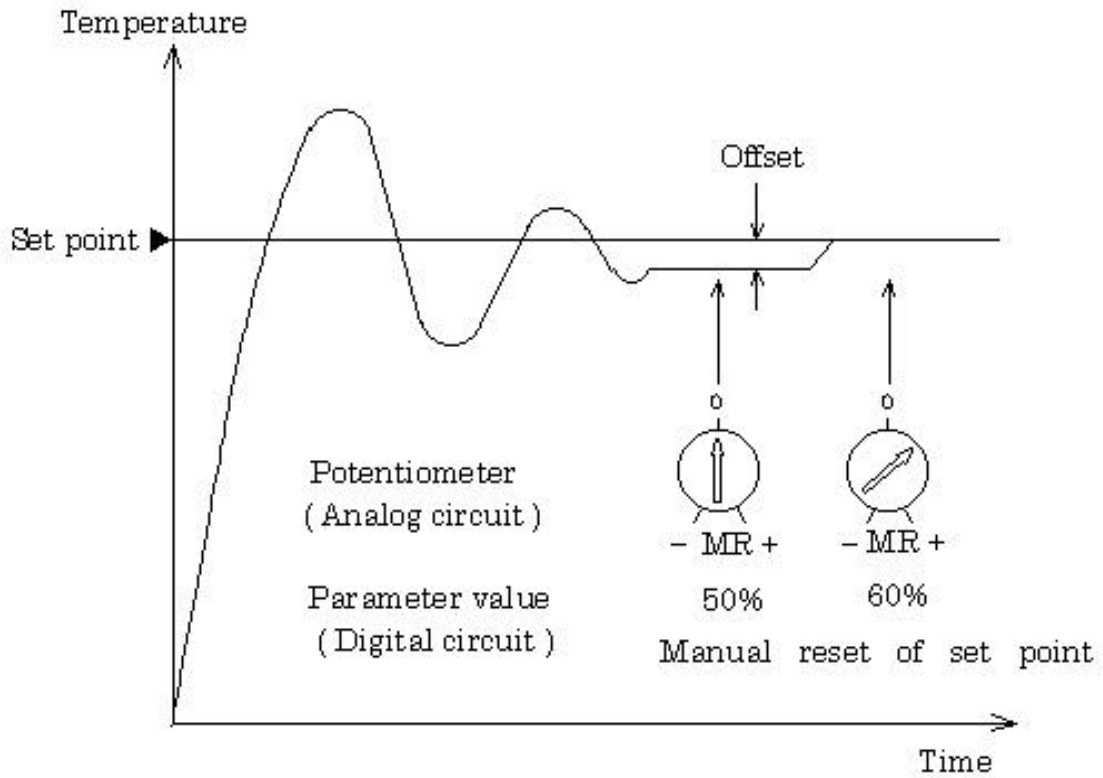


Fig.1

18. Integral action

I (integral) action is called “reset action” which will change the manipulated variable so as to eliminate the offset whenever it occurs.

Fig.1 shows an application where the set point is 800°C with offset of 10°C below set point.

Fig.2 shows that the control is balanced at “A” point (cross point of control and load characteristics lines in P action). The valve opening is 60%.

When I action is added to execute PI action, an additional output is given in the progress of time.

In other words, the control characteristics line is shifted toward right direction in parallel.

Finally, when the cross point “B” of the control and load characteristics lines comes to the set point, the control is balanced. At this time, the valve opening is 70%.

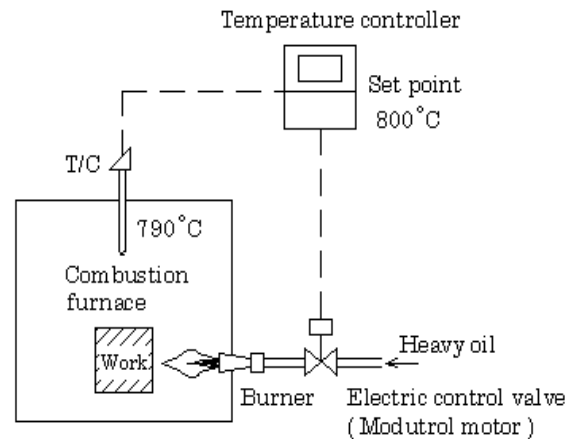


Fig.1

18.1 Integral action

If I action is executed when deviation is present, the controller output is changed at a certain speed in accordance with the amount of deviation. The output continuously changes until the deviation is completely eliminated.

18.2 Definition of integral time

Fig.3 shows the reset time ($T_2 - T_1$) of a controller which executes PI action. When a step input is applied at the time T_1 , the reset time is the difference between T_1 and T_2 where the amount of output change by P action is the same as that of I action.

18.3 Reset time and corrective output

When the reset time is short (for example, $T_3 - T_1$ is shorter than $T_2 - T_1$), a stronger integral action must be applied thus causing a quick corrective action against the deviation.

18.4 Recommended reset time

A recommended reset time is 100 to 150 sec for an electric heater control although it differs depending on the equipment.

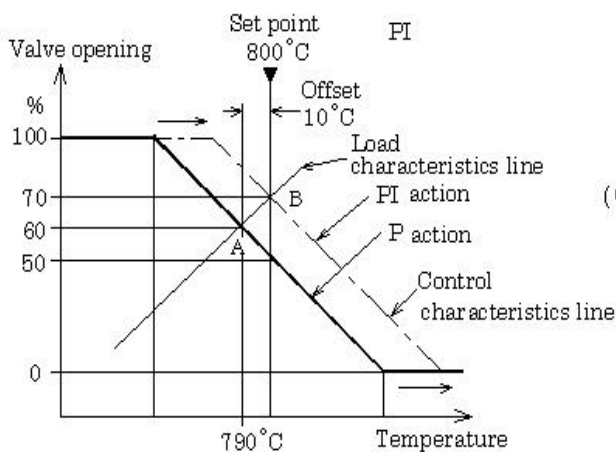


Fig.2 Integral action

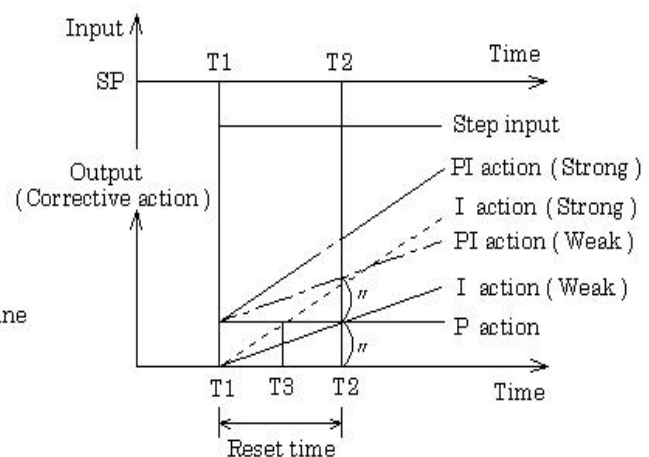


Fig.3 Definition of reset time

19. Derivative action

19.1 Derivative action

Derivative action is called “D action” or “rate action”. When the detected temperature begins to change by disturbances, this derivative action will execute large corrective action while the deviation is still small and prevents large change of the controlled temperature.

19.2 Room temperature control by steam

Fig.1 shows an application where the room temperature is controlled by steam. Cold air suddenly enters into the room from an air intake causing sudden room temperature to drop.

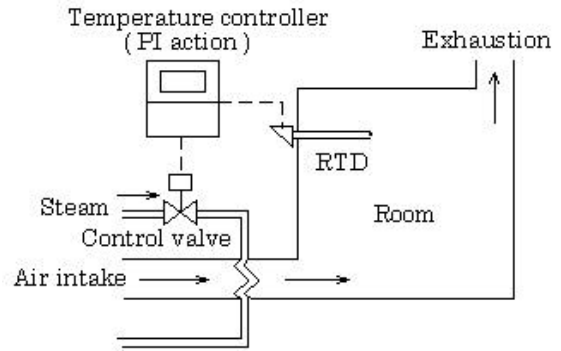


Fig.1 Room temperature control by steam

As shown in Fig.2, when cold air enters into the room at the time T_1 , the affected room temperature is detected at T_2 after a certain response delay. The time difference ($T_2 - T_1$) is called “dead time”.

When the temperature sensor detects a temperature gradually dropping, the controller will send a corrective output signal by following the temperature change with PI control action.

But, as this control always has the $T_2 - T_1$ dead time, the room temperature will excessively drop toward a considerably low temperature.

When a derivative action is applied to this control, the controller will detect the course of this temperature drop (temperature change per unit time) and will make large corrective action by assuming the predicted temperature pattern.

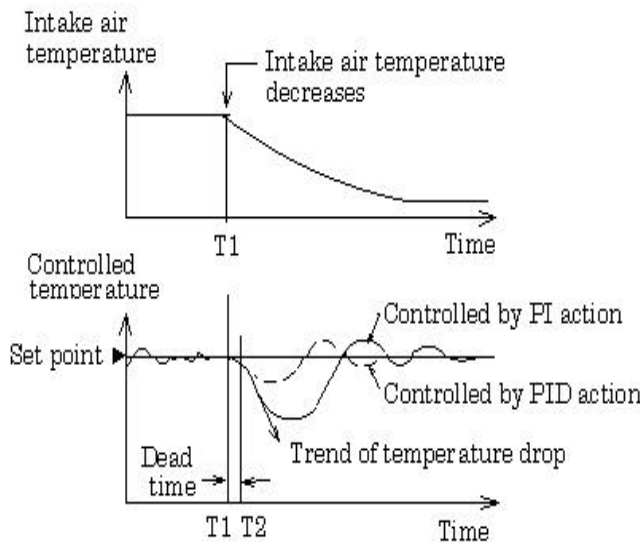


Fig.2

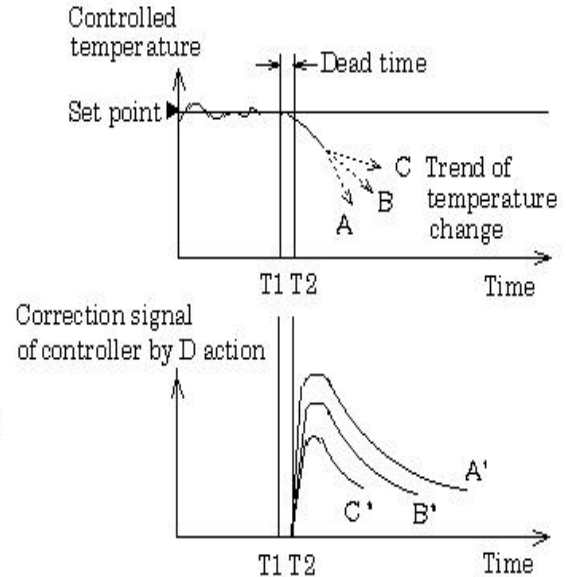


Fig.3

19.3 Corrective output by derivative action

In Fig.3, when the detected temperature begins to drop from the set point at the time T_1 , the temperature sensor detects the changing temperature at the time T_2 . In this case, the controller judges this course (amount of change) and sends a corrective output signal to the motor in accordance with the amount of change. For example, if the trend of temperature change is “A”, the corrective output is “A’ “. For “B” the output is “B’ “.

19.4 Definition of rate time

Fig.4 shows a rate time of a controller which executes PI action. When the input is continuously changed from the time T_1 at a certain speed, the amount of output by P action increases to the same level as that of output by D action. The time difference (T_2-T_1) is called “rate time”.

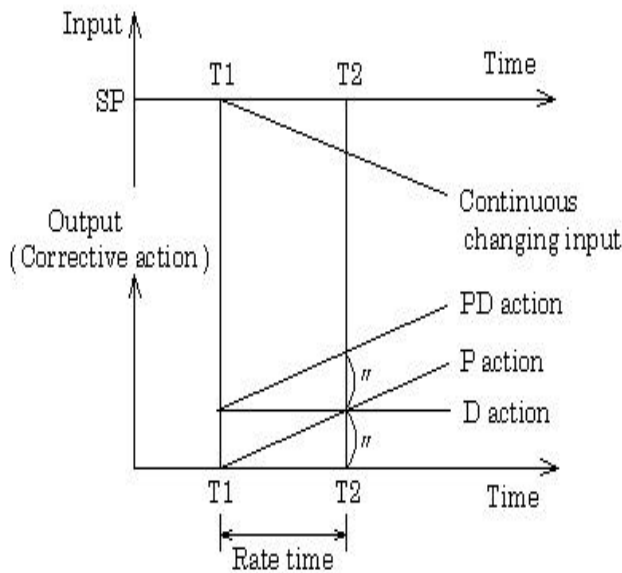


Fig.4 Definition of derivative action

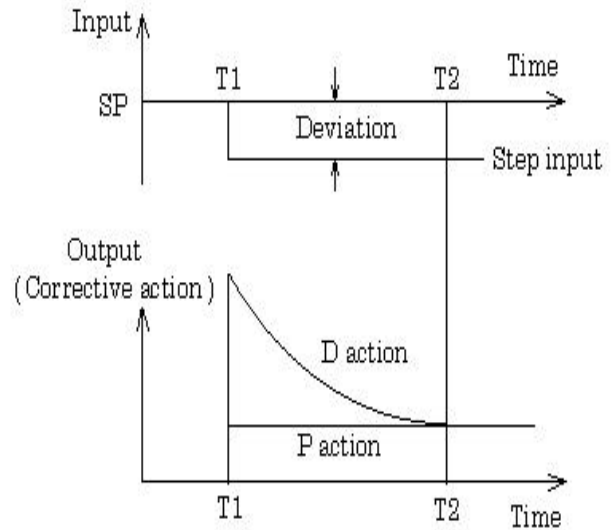


Fig.5 Derivative action at step input

19.5 Derivative action at step input

In Fig.5, when an step input is applied at the time T_1 , the P action output changes in the step configuration. D action instantaneously generates the maximum output.

When the deviation becomes constant, the output immediately begins to drop. At the time T_2 , the amount of output change by P action becomes the same level as that of D action. This time difference (T_2-T_1) is “rate time”.

19.6 Recommended rate time

When the rate time becomes longer, the D action will be stronger.

When the rate time is excessively long, the D action will be excessively strong against even small deviation resulting in causing a cycling or hunting. Shorter rate time is recommended for the initial setting. A recommended rate time is 10 to 50 sec. for an electric heater control although it differs depending on the equipment.

Note: The above example is explained for a PD action controller. But in actual application, the PID action is applied to avoid occurrence of the offset which will be caused by the load change in case of PI action only.

20. PID autotuning

20.1 Much experience is required to set the optimum PID values. But if PID autotuning function is used, the optimum PID values can be easily set.

20.2 Autotuning at start-up

If autotuning is executed at the start-up point, an AT point is calculated from PV and SP values.

At this point, the output of the controller will cycle twice in such a way as “ 0% 100% 0% 100% “.

The amplitude and cycle time (dead time) of PV wave form are calculated to obtain the optimum PID values which are automatically written in the PID constant value items.

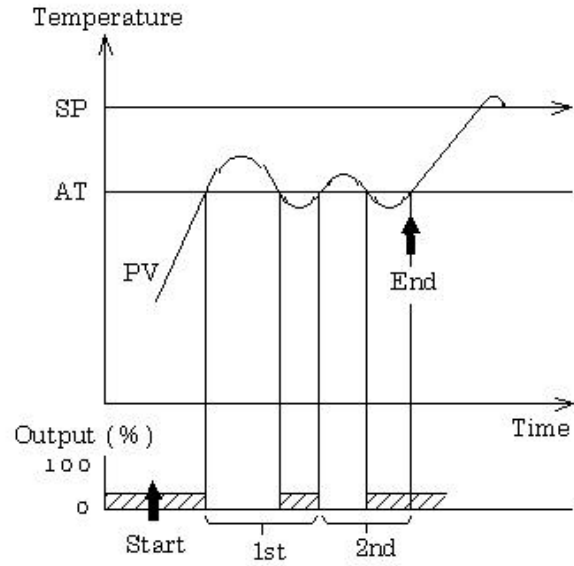


Fig.1 Heating control

20.3 Autotuning at constant value control

Even when performing a constant value control, the autotuning can be executed to set new PID values for better control.

In this case, the ON/OFF output operation is repeated twice at the set point area to calculate new PID values which can be used for new PID setting.

Whether the initial operation is on or off is determined depending on PV and SP values at this point.

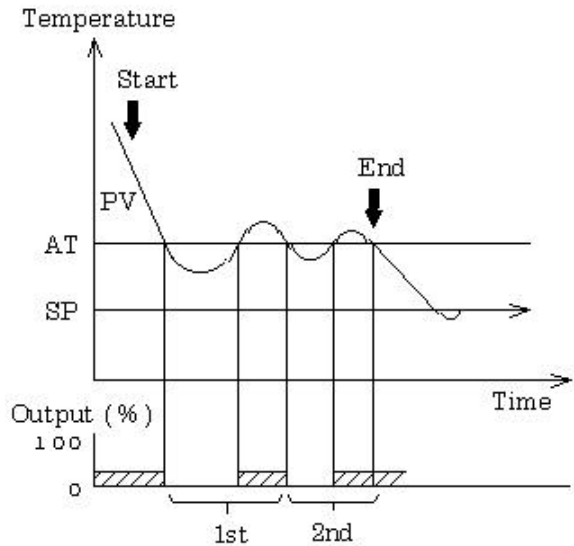


Fig.2 Cooling control

20.4 Autotuning mode selection

There are two autotuning modes of AT=1 and AT=2 which are selected depending on the equipment or the purpose of control.

(1)AT=1

General control constant values can be automatically set.

Slight overshooting may occur. This mode is used when the time to reach the set point is important.

(2)AT=2

This mode is used when the overshooting is large or when the overshooting suppression is required.

In case of this mode, the overshooting can be suppressed. But the rising time may be longer.

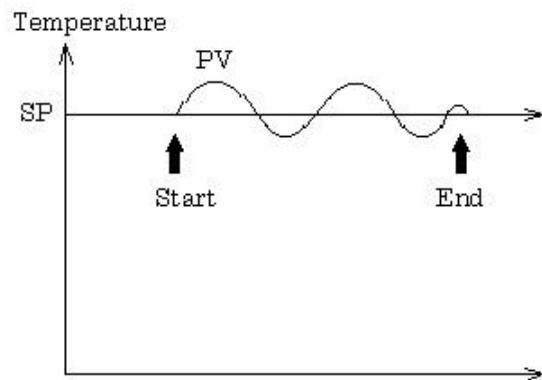


Fig.3 Constant value control

21. Abbreviated terminology related to controllers

Abbreviated letters used for controllers are explained below.

AT: (Auto Tuning)

Automatically calculating and setting the optimum PID values

AUX: (Auxiliary) output

4 auxiliary outputs (PV, SP, DEV and RSP) are available

A/M: (Auto Manual)

Automatic operation and manual operation

DEV: (Deviation)

Difference between process variable (PV) and set point (SP)

DISP: (Display)

Changing a digit of 4-digit display by depressing a DISP key

EV: (Event) signal

ON-OFF signal outputs in accordance with control conditions

Used as alarm, control or time event

EV1: (Event 1) signal

Same as EV

EV2: (Event 2) signal

Same as EV

EV3: (Event 3) signal

Same as EV

LSP: (Local Set Point)

Set point value to be set by keys on front panel

MAN: (Manual) operation

Manual operation in a range of 0 to 100% output values

MV: (Manipulated Variable)

Signal to be sent to actuator (ex. 4 to 20mA)

OL: (Output Low): Output (manipulated variable) low limit

Setting a low limit output value

OH: (Output High): Output (manipulated variable) high limit

Setting a high limit output value

OT1: (Output 1)

ON-OFF output signals in ON-OFF control or time proportioning control

Used as either heating or cooling output in heating and cooling controls

OT2: (Output 2)

Used as either heating or cooling output in heating and cooling controls

OUT: (Output)

Indication example is -10.0 to 110.0% for 4 to 20mA output.

PARA: (Parameter) variable

Parameter setting at a desired value

PID: P(proportioning) action

I (integral) action or reset action

D (derivative) action or rate action

PV: (Process Variable)

Measured value based on T/C, RTD or linear input

RDY: (Ready)

Stand-by condition before startings operation (but without any control output)

Executing setup and parameter setting under this condition

READY: (Ready)

Same as RDY

REM: (Remote) setting input or external setting input

External 4 to 20mA input to be used as a set point without using a set point which is set at the front panel of controller

RSP: (Remote Set Point)

Same as REM

RUN: (Running)

Operating condition under the controlling
Reverse word of "Ready"

R/L: (Remote Set Point/Local Set Point)

Setting by external set point inputs and front keys

SET UP: (Set Up)

Initial setting of direct or reverse action, input range, etc.

SP: (Set Point)

Set point example is a value to control a temperature.

SW1: (Remote Switch 1)

External switch 1

SW2: (Remote Switch 2)

External switch 2

SW3: (Remote Switch 3)

External switch 3