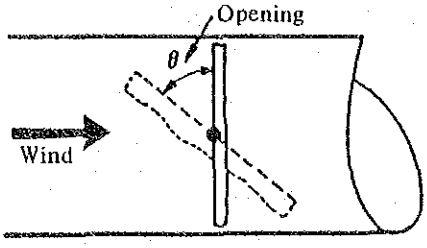
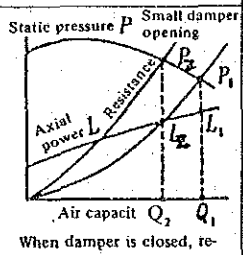
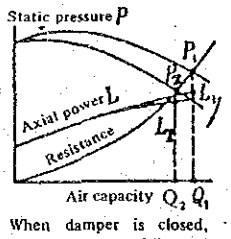
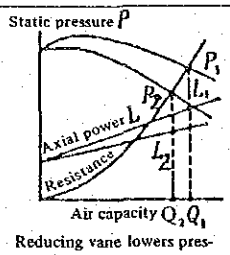
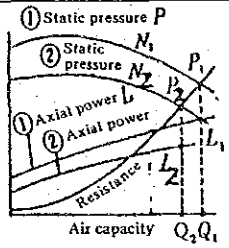



Fig. III–8–42 Principle of damper adjustment

Table III–8–28 Damper, vane opening adjustment

| Method | Discharge damper opening adjustment | Intake damper opening adjustment (discharge side piping) | Intake vane control | Changing the rotating speed |
|---|---|---|---|---|
| Principle | Change blower resistance curve by intentionally increasing resistance of the piping system. | Since damper resistance is provided on intake side, it serves as a negative pressure and pressure curve slightly changes. Axial power curve also changes slightly. | Reduce the impeller work done by intentionally changing gas flowing angle against blower impellers, thus changing the pressure and power curves at the same time. | Air capacity is in proportion to the rotating speed, the pressure to square of the rotating speed, and the axial power to cube of the rotating speed. |
| Diagram of principle |   When damper is closed, resistance increases and operating point changes from ($P_1$, $L_1$, $Q_1$) to ($P_2$, $L_2$, $Q_2$). Note; Operating point is a point of intersection of pressure and resistance curves. |   When damper is closed, pressure curve falls and operating point changes from ($P_1$, $L_1$, $Q_1$) to ($P_2$, $L_2$, $Q_2$). |   Reducing vane lowers pressure and axial power curves. Operating point changes from ($P_1$, $L_1$, $Q_1$) to ($P_2$, $L_2$, $Q_2$). Reduction in axial power is far larger than damper opening adjustment. |   Changing the rotating speed from $N_1$ to $N_2$ shifts the pressure and axial power curves from (1) to (2), and the operating point from ($P_1$, $L_1$, $Q_1$) to ($P_2$, $L_2$, $Q_2$). |
| Special features | 1) Surging area is wide and effective air capacity control cannot be performed.<br>2) Axial power does not lower much even in low air capacity area. | 1) Surging area is narrower than for discharge damper.<br>2) Axial power lowers almost in proportion to air capacity. | 1) Same as at left.<br>2) Axial power lowers almost in proportion to air capacity and tends to lower much more than the intake damper. | Axial power lowers most and this is the best method for electric power conservation. |

d. Change in rotating speed (change of motor or diameter of pulley)

Assuming the rotating speed of blower as N,

$$Q \propto N$$

$$P \propto N^2 \quad \cdots\cdots (6)$$

$$L \propto N^3$$

Since there is the above relation, when it is possible to replace with a motor with lower rotating speed, energy can be greatly saved. However, in this case, once it is changed, it cannot be easily returned to the original position unlike the damper adjustment. Therefore, carefully investigate the resistance curve of load, etc. and be careful so that the air flow is not insufficient after replacement. Also, in the case of belt-drive, it is an effective method to lower the rotating speed by changing the diameter of the pulley.

e. Variable types

In variable control systems of air flow, there are various systems as shown in

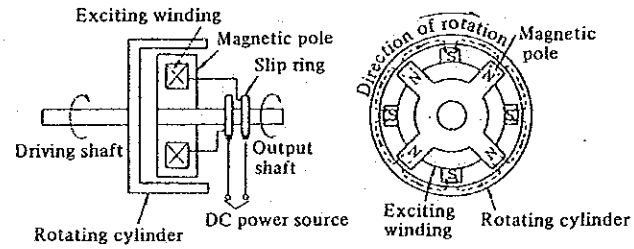
Table III-8-29, of which we will describe the eddy current joint control and Scherbius control.

Table III–8–29 Method to control air capacity (Variable system)

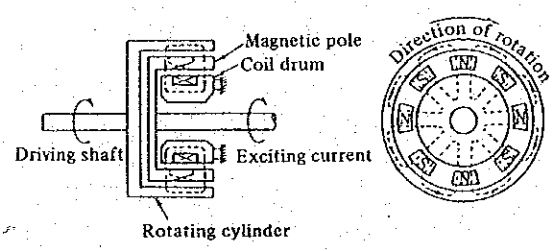
| | |
|---|---|
| Discharge damper control (Variable) | Intake damper control(Variable) |
| Intake vane control (Variable) | Change in number of poles |
| Eddy current joint control | Secondary resistance control |
| VVVF control | Scherbius control |
| | Others |

f. Eddy current joint control

This eddy current joint control is a method to change the rotating speed in the following method: while a prime mover (motor) is running at a specified rotating speed, an eddy current joint is direct-coupled to the prime mover output shaft and the slip of the rotating speeds of the input and output shafts is altered to change the rotating speed. Fig. III-8-43 (a) shows a principle diagram of the eddy current joint. The salient magnetic pole equipped with the exciting winding inside is direct-coupled to the output shaft, outside of which the rotating cylinder is provided across a small clearance. This rotating cylinder is direct-coupled to the output shaft of the prime mover and while the cylinder is rotating at a specified rotating speed, the magnetic flux generated by the exciting winding is cut and, as such, eddy current flows. Electromagnetic force working between this eddy current and magnetic flux generates transfer torque and the magnetic pole direct-coupled to the load rotates in the same direction as the rotating cylinder.




(a) With slip ring




(b) Slip ring-less

Fig. III–8–43 Principle of eddy current joint

The exciting current is supplied through the slip ring because the magnetic pole is a rotor. However, the slip ring can be eliminated by equipping the stator side with the exciting winding and providing the salient magnetic pole across the small clearance as shown in (b).

Since the amount of the generated torque varies with the amount of the exciting current, changing the exciting current changes the output torque or the speed optionally. The outside rotor has high-slip characteristics as shown in Fig. III-8-44.

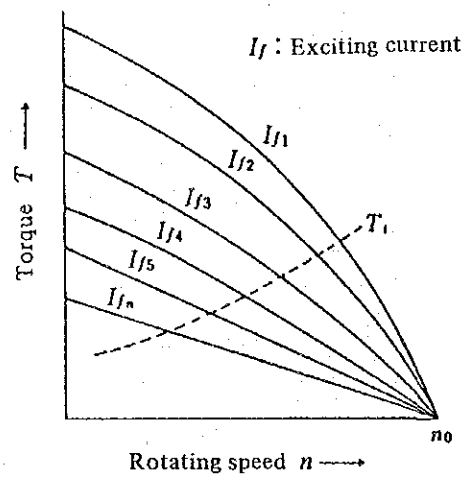



Fig. III–8–44 Torque characteristic of eddy current joint

Fig. III-8-45 shows a distribution diagram of rotating speed control when an induction motor is used for the prime mover. For this control, first turn on switch 88 and operate the induction motor before operating the load. If the desired speed is set with the automatic control operated by means of the presetter SRH, the speed standard signal $e_{sr}$ and speed feedback signal $e_{sf}$ are compared and amplified by the speed control circuit and the control angle $\alpha$ of thyristor conversion is controlled through the phase control circuit. The rotating speed can be controlled by controlling the exciting current of the eddy current joint. For the eddy current joint, assuming the slip between the input and output shafts as S, and efficiency of the prime mover as $\eta_m$, the system efficiency $\eta_s$ will be quite the same as the secondary rheostatic control of the induction motor, and the efficiency in the low-speed area remarkably lowers.

$$\eta_s = (1 - S)\eta_m \times 100\ (\%) \quad \cdots\cdots (7)$$

Since the slip generates heat as eddy current loss within the rotating cylinder, the water cooled type is generally adopted for of more than 55 kW.

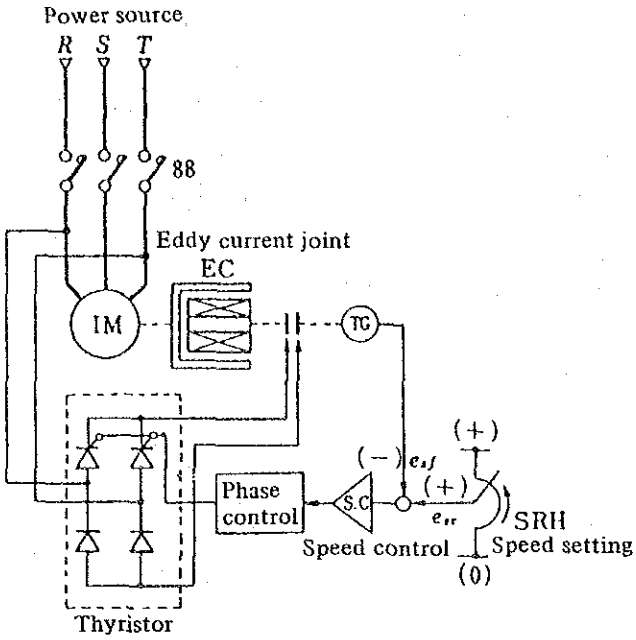



Fig. III–8–45 Distribution diagram of rotaing speed control by means of eddy current joint

g. Scherbius control

Assuming the induced electromotive force on the secondary as $E_2$, the secondary winding resistance per phase as $\gamma_2$ and reactance when slip s = 1 as $x_2$, the secondary current of the wound-rotor type induction motor $I_2$ (A) is

$$I_2 = \sqrt{\frac{sE_2}{\gamma_2^2 + (sx_2)^2}} \quad \cdots\cdots (8)$$

If electromotive force Ec with the same phase and frequency is supplied to the secondary winding from the outside,

$$I_2 = \sqrt{\frac{sE_2 + E_c}{\gamma_2^2 + (sx_2)^2}} \quad \cdots\cdots (9)$$

Here, $E_2$ is constant and if the load is constant, $I_2$ will be constant. Accordingly, changing $E_c$ will change the slip s speed. This is the principle of Scherbius control. Fig. III-8-46 shows a principle diagram. In the diagram, electric power corresponding to the secondary copper loss is taken out through the slip ring and returned to the power source by means of a DC-AC converter through a transformer. Adjusting the return power changes the speed.

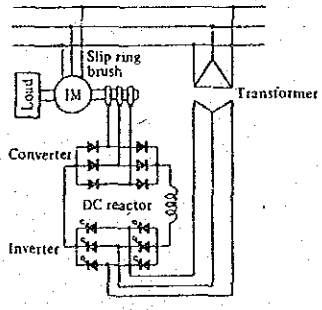



Fig. III–8–46 Principle of scherbius control

The secondary rheostatic control system is of control with low efficiency because electric power corresponding to the secondary copper loss is consumed at the external resistance. This Scherbius control system recovers that electric power and, therefore, becomes a variable control system with very high efficiency. Fig. III-8-47 shows motor input (%) of various variable air flow control methods specified in Table III-8-29.

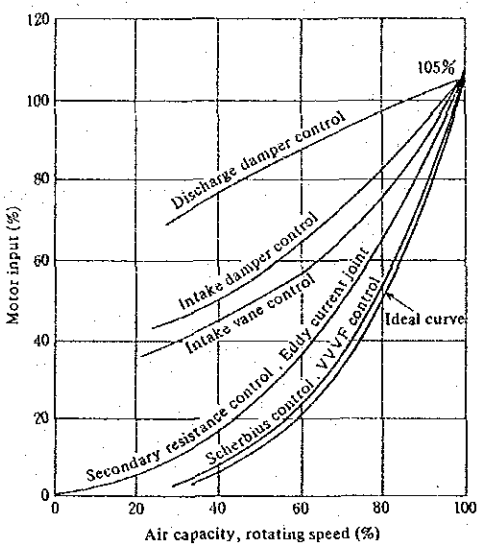



Fig. III–8–47 Comparison of blower motor's input

8.6 Lighting

8.6.1 Factory lighting

(1) Purpose of factory lighting

Good lighting facilitates various visual operations and has the following effects:

A) Improved operation efficiency

Proper illuminance diminishes nerve strain, reduces defective products and improves the operation efficiency.

B) Improved operation safety

Since things can be clearly seen and the visual range is widened, employees are careful for their operation and any disasters due to mistakes, etc. can be prevented.

C) Thorough shop management

It becomes easier to point out any defects in the operation and shop, morale for proper arrangement and environmental hygiene is enhanced, and management for the operation and equipment, etc. can be thoroughly achieved.

D) Improved operation efficiency

A shop with a well-ordered working environment including lighting enhances the employees' pride and responsibility for their appointed tasks, and excites their desire to work.

(2) Good factory lighting

Good factory lighting has the following factors:

- Proper illuminance and illuminating distribution
- Free from flickering and glare

- Color rendering properties of light source should not be exceedingly improper.
- Good economical efficiency

For proper illuminance, the necessary value is determined by content of the operation, size of the object and color, etc. Values specified in Table III-8-30 are recommended as illuminance standard values in Japan. For the aged, these standard values should be somewhat increased.

Also, flickering and glare cause eye fatigue, hindering the operation and lowering the efficiency. Color rendering properties may also hinder some operations.

Table III–8–30 Illumination standard

| Illumination[lx] | Place | Operation |
|---|---|---|
| 3,000<br>2,000 | o Instrument panel and control panel in control room, etc. | Exceedingly fine visual operation in manufacture of precision machines and electronic parts, printing factory, etc., such as o assembly a, o inspection a, o test a, o selection a, o design, o drawing. |
| 1,500<br>1,000 | Design and drawing rooms | Fine visual operation in selection and inspection in textile mills, typesetting and proofreading in printing factory, analysis, etc. in chemical industry, such as o assembly b, o insepction b, o test b, o selection b. |
| 750<br>500 | Control room | Ordinary visual operation in general manufacturing processes, etc., such as o assembly c, o inspection c, o test c, o selection c, o packing a, o desk work in warehouses. |
| 300<br>200 | Electricity room and air conditioning machine room | Rough visual operation such as o packing a, o wrapping b, o restricted operation |
| 150<br>100 | Entrance/exit, corridor, passage, warehouses involving operation, staincases, lavatories | Very rough visual operation such as o wrapping c, o packing b, o restricted operation |
| 75<br>50 | Indoor emergency staircases, warehouses, outdoor power equipment | Operation such as o loading, unloading, load transfer, etc. |
| 30<br>20<br>10 | Outdoor (for passage and safety guard within compound) | — |

(Remarks)

1. Similar operation are divided into the following three according to the object to view and nature of the operation:
   (1) a in the above table indicates fine, dark colored, weak-contrasted, specially expensive, hygiene-related ones and when high precision is required or when long working hours are required, etc.
   (2) b in the above table indicates an intermediate between (1) and (3).
   (3) c in the above table indicates coarse, light-colored, strong-contrasted, robust, not so expensive ones.
2. For dangerous operation, double above shall be required.
3. For places for operation marked o, this illumination may be obtained by local lighting. It is desirable that illumination for general lighting in this case is more than 1/10 of illumination by local lighting.

8.6.2 Energy conservation for lighting

As an equation for general lighting in a factory and office, the following equation is well-known.

$$E = \frac{N \times F \times U \times M}{A} (lx) \quad \cdots\cdots (1)$$

Where E : Illuminance (lx)

A: Area of room ($m^2$)

N: Number of lamps

F: Luminous flux emitted from one lamp (*l*m)

U: Utilization factor (See Note 1)

M: Maintenance factor (See Note 2)

Note 1: Utilization factor U is the ratio of luminous flux applied to the working plane against the full luminous flux from the lamp, and varies with luminous intensity of the luminaire, installed position, room condition, etc.

Note 2: Maintenance factor is the predicted lowering rate (figure) of initial illuminance with lapse of the working time. This varies with how well the equipment will be maintained, which is determined at the design stage.

Determining the energy required for lighting by transforming equation (1),

$$W \cdot H = \frac{N \times F}{\eta} \times t = \frac{A \times E \times t}{U \times M \times \eta} [Wh] \quad \cdots\cdots (2)$$

Where W·H: Watt-Hour

$\eta$: Lamp efficiency

t: Lighting time (hour)

Since the actual electric power consumed for lighting contains the distribution line loss for lighting added to this equation (2), the following can be considered for energy conservation for lighting:

- Reduce the lighting time.
- Reduce the distribution line loss.
- Keep the illuminance proper.
- Use high-efficient luminaires.
- Improve the utilization factor.
- Improve the maintenance factor.

8.6.3 Concrete measure for energy conservation

(1) Reduce the lighting time

Concrete measures are:

a. Lights-out while unnecessary, including noon recess

b. Individual lights-out near windows

c. Provide many switches for individual lights-out.

d. Lights-out in quiet areas

e. Adopt automatic switches or timer switches for outdoor lamps, etc.

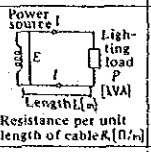
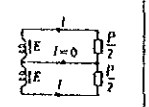
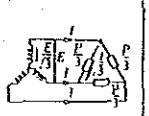
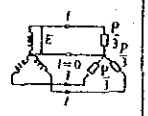
In any case, these countermeasures much depend upon the employees' consciousness and therefore, it is necessary to endeavour to enhance it.

(2) Reduce the distribution line loss

Since the distribution line loss greatly varies with the distribution system (See Table III-8-31), it is desirable to compare and study well for determination when establishing new equipment. Besides, to increase voltage in the distribution line and to

improve of power factor, etc. must be studied.

Table III–8–31 Comparison of loss by wiring system

| Wiring system | Connection | Loss calculation | Loss ratio |
|---|---|---|---|
| Single phase two wire system |  | $P=EI\times10^{-3}$ [kVA]<br>Loss $W=I^2\times 2LR_1=\left(\frac{P}{E}\times10^3\right)^2\times 2LR_1=\frac{2P^2LR_1}{E^2}\times10^6$ [W] | 100% |
| Single phase three wire system |  | $\frac{P}{2}=EI\times10^{-3}$ [kVA]<br>$W=2I^2LR_1=\left(\frac{P}{2E}\times10^3\right)^2\times 2LR_1=\frac{P^2LR_1}{2E^2}\times10^6$ [W] | 25% |
| Three phase three wire system |  | $\frac{P}{3}=E\times\frac{I}{\sqrt{3}}\times10^{-3}$ [kVA]<br>$W=3I^2LR_1=\left(\frac{P\times10^3}{\sqrt{3}E}\right)^2\times 3LR_1=\frac{P^2LR_1}{E^2}\times10^6$ [W] | 50% |
| Three phase four wire system |  | $\frac{P}{3}=EI\times10^{-3}$ [kVA]<br>$W=3I^2LR_1=3\left(\frac{P\times10^3}{3E}\right)^2\ LR_1=\frac{PLR_1}{3E^2}\times10^6$ [W] | 16.7% |

NOTE: Each cable size is same

(3) Keep the illuminance proper

Although it is of course important to secure illuminance required for the operation, it is important for energy conservation to reexamine the lighting level and provide with local lighting for passages, places where persons do not much enter and outdoor lighting, etc.

Also, when establishing a new factory, adoption of natural daylight should be positively considered.

(4) Use high-efficient luminaires

Luminaires here mean stabilizers, lamps and light reflectors. Table III-8-32 shows one example of stabilizers' characteristics. To diminish the distribution line size, the current when starting should be smaller, and to reduce the distribution line loss, the power factor should be higher. However, the weight and cost increase in inverse proportion to these and, therefore, it is necessary for selection of kinds of luminaires to study the economical efficiency.

Table III-8-33 and Table III-8-34 show features and general applications of various lamps.

Table III–8–32 Example of stabilizer characteristic (For 400W Mercury lamp)

| | | Non-dimming type | | | Dimming type | | | |
|---|---|---|---|---|---|---|---|---|
| | | Low power factor type | High power factor type | Constant power type | Constant power type | | General type | |
| Input voltage (V) | | 200 | 200 | 200 | 200 | | 200 | |
| Voltage tap (V) | | 200, 220 | 200, 220 | 200 | 200 | | 200, 220 | |
| Input current (A) | | | | | Normal | Dimmed | Normal | Dimmed |
| | When starting | 5.7 | 4.0 | 2.3 | 2.3 | – | 3.8 | – |
| | When stabilized | 3.3 | 2.3 | 2.3 | 2.3 | 1.3 | 2.4 | 1.3 |
| Input power (W) | | 425 | 425 | 435 | 435 | 255 | 432 | 255 |
| Power factor (%) | | 64 | 90 | 95 | 95 | 95 | 90 | 95 |
| Weight (kg) | | 4.6 | 5.2 | 10.0 | 13.5 | | 7.0 | |
| Volume ratio (%) | | 100 | 160 | 270 | 340 | | 220 | |
| Price ratio (%) | | 100 | 150 | 240 | 310 | | 260 | |

## Table III–8–33 Special features and applications of various lamps

| Class of lamps | Special features | Scope of size (W) | Main performance of standard quality | | | | Applications |
|---|---|---|---|---|---|---|---|
| | | | Efficiency (lm/w) | Color temperature (K) | Color rendering index (Ra) | Life | |
| Incandescent lamp | • Stable light color<br>• Possible to light as-is.<br>• Instantaneous lighting high luminance | Several W ~ Several kW | 100W | | | | Residence, store, office |
| | | | 15 | 2,850 | 100 | 1,000 | |
| Tungsten halogen lamp | Small-size, high efficiency and long life lamp | Several 10W~ Several kW | For general use 500W | | | | For floodlamp, for automobiles, for projection, for photography, for copying machine, studio |
| | | | 21 | 3,000 | 100 | 2,000 | |
| Fluorescent lamp | • High efficiency and long life<br>• A wide variety of light colors<br>• Little glare | 4~ 220W | White 40W | | | | Residence, office, store |
| | | | 82 | 4,500 | 69 | 10,000 | |
| Mercury lamp | High efficiency, long life, high luminance lamp | 40~ 2kW | 400W | | | | For floodlamp (baseball ground, golf course) |
| | | | 51 | 5,800 | 23 | 12,000 | |
| Fluorescent mercury lamp | Mercury lamp with luster improved | 40~ 1kW | 400W | | | | Roads, factory, street lighting, arcade lighting |
| | | | 56 | 4,100 | 44 | 12,000 | |
| Choreless mercury lamp | Mercury lamp requiring no stabilizer | 160,250 500W | 500W | | | | For works, stores |
| | | | 27 | 3,000 | 42 | 6,000 | |
| Halide lamp | Higher efficiency and lustrous lamp than mercury lamp | 250~ 1kW | 400W | | | | Gymnasium, factory, shopping street, open space, park |
| | | | 80 | 4,500 | 65 | 9,000 | |
| High lustrous halide lamp | High lustrous, high luminous lamp | 250~ 400W | 400W | | | | Cymnasium, lobby, hall |
| | | | 50 | 5,000 | 92 | 6,000 | |
| Low pressure sodium lamp | Highest efficiency, yellow, luminous lamp | 35~ 180W | 180W | | | | Tunnel, high-way, switch-yard |
| | | | 175 | – | – | 9,000 | |
| High pressure sodium lamp | Highest efficiency, luminous lamp for general lighting | 150~ 1,000W | | | | | Gymnasium, high-ceiling factory, warehouse, roads, open space |
| | | | 120 | 2,100 | 29 | 12,000 | |

Note: Efficiency of fluorescent and mercury lamps is of 100 hrs value.

Table III–8–34 Selection of lamps from standpoint of typical applications

| Class of lamps | | Incandescent lamp | | | Fluorescent lamp | | | Mercury lamp | | | | Halide lamp | | Sodium lamp | | Xenon lamp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | General lamp | Reflector lamp | Halogen lamp | General fluorescent lamp | High color rendering properties | High output type | Transparent mercury lamp | Fluorescent mercury lamp | Reflector mercury lamp | Stabilizer built-in type | General type | High lustrous type | High pressure | Low pressure | |
| Residence | | ◎ | ○ | △ | ◎ | ○ | × | × | × | × | × | × | × | × | × | × |
| Office | General office | △ | △ | △ | ◎ | △ | ○ | × | × | × | × | △ | △ | × | × | × |
| | High-ceiling office, lobby | ○ | ○ | ○ | ○ | △ | ○ | × | ○ | ○ | △ | ◎ | ○ | × | × | △ |
| | Single room, drawing room | ○ | ○ | △ | ◎ | ○ | × | × | △ | × | × | △ | △ | × | × | × |
| Store | General stores | ◎ | ◎ | ○ | ◎ | ◎ | ○ | × | ○ | △ | △ | △ | △ | × | × | × |
| | High-ceiling stores | ○ | ○ | ○ | ○ | ○ | ◎ | × | ○ | ○ | ○ | ◎ | ○ | △ | × | △ |
| | Exhibits, showcase | ◎ | ◎ | ◎ | ◎ | ◎ | ○ | × | △ | △ | ○ | ○ | ○ | × | × | △ |
| Factory | Low-ceiling factory | △ | △ | ○ | ◎ | ○ | ○ | × | △ | △ | △ | △ | △ | △ | × | × |
| | High-ceiling factory | △ | △ | ○ | △ | △ | ◎ | × | ◎ | ○ | ○ | ◎ | ○ | ○ | × | △ |
| | Warehouse | ○ | △ | ○ | ◎ | △ | ○ | △ | ◎ | ○ | ○ | ○ | △ | ○ | × | × |
| School | Class room | △ | △ | △ | ◎ | ○ | △ | × | △ | × | × | △ | △ | × | × | × |
| Hospital | Operating room | ○ | ○ | △ | ◎ | ◎ | △ | × | × | × | × | × | × | × | × | × |
| Theater, hall | Spectator's seats | ◎ | ◎ | ◎ | ◎ | ○ | △ | × | △ | △ | △ | ○ | ○ | × | × | △ |
| | Stage | ◎ | ◎ | ◎ | ◎ | ○ | ○ | × | △ | △ | △ | △ | △ | × | × | △ |
| Art museum, museum | General | ◎ | ◎ | ○ | ○ | ◎ | △ | × | △ | △ | △ | ○ | ○ | × | × | △ |
| | Exhibits | ◎ | ◎ | ○ | ○ | ◎ | △ | × | × | × | × | ○ | ○ | × | × | △ |
| Roads | Automobiles exclusive roads | × | × | × | △ | × | × | △ | ◎ | × | × | △ | × | ○ | ○ | △ |
| | Automobiles exclusive tunnel | × | × | × | △ | × | × | △ | ○ | × | × | △ | × | ○ | ◎ | × |
| | Streets | △ | × | × | ○ | × | × | △ | ◎ | △ | △ | △ | △ | ○ | △ | × |
| | Shopping streets | ○ | × | ○ | ○ | △ | ◎ | × | ◎ | △ | △ | ◎ | △ | ○ | × | × |
| | Roads in resident area | ○ | × | × | ○ | × | × | △ | ◎ | △ | × | △ | × | ○ | × | × |
| Parking zone | Indoor | △ | △ | △ | ◎ | × | ○ | × | ○ | △ | △ | △ | △ | ○ | × | × |
| | Outdoor | △ | △ | △ | ○ | × | × | △ | ◎ | ○ | △ | △ | △ | ○ | △ | △ |
| Open space, park, garden | | ○ | △ | △ | ○ | △ | × | △ | ◎ | △ | △ | ○ | △ | ○ | × | △ |
| Floodlight lighting | Structure | ○ | ○ | ○ | × | × | × | △ | ◎ | ◎ | ○ | ○ | ○ | ○ | △ | ○ |
| | Advertisement, signboards | ○ | ◎ | ◎ | ○ | ○ | ○ | △ | ◎ | ◎ | △ | ○ | ○ | △ | × | ○ |
| Sports | Indoor | ○ | ○ | ◎ | ○ | ○ | ○ | △ | ◎ | ○ | △ | ◎ | ○ | △ | × | △ |
| | Outdoor | ○ | ○ | ○ | × | × | × | △ | ◎ | ○ | △ | ◎ | ○ | ◎ | × | ○ |

(5) Improving utilization factor

Table III-8-35 shows an example of the utilization factor table. Room index RI in this table is calculated in the following equation:

Table III–8–35 Example of coefficient of utilization table

| Ceiling | 80 % | | | | | | | | | 50 % | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wall | 60 % | | | 30 % | | | 10 % | | | 60 % | | | 30 % | | | 10 % | | |
| Floor surface | 40 % | 20 % | 10 % | 40 % | 20 % | 10 % | 40 % | 20 % | 10 % | 40 % | 20 % | 10 % | 40 % | 20 % | 10 % | 40 % | 20 % | 10 % |
| Room index | Coefficient of utilization | | | | | | | | | | | | | | | | | |
| 0.60 | .45 | .42 | .40 | .31 | .30 | .30 | .26 | .25 | .25 | .41 | .39 | .38 | .30 | .29 | .29 | .25 | .25 | .25 |
| 0.80 | .56 | .51 | .49 | .41 | .39 | .38 | .35 | .34 | .33 | .51 | .48 | .47 | .39 | .38 | .37 | .34 | .33 | .33 |
| 1.00 | .63 | .57 | .55 | .47 | .45 | .44 | .41 | .40 | .39 | .57 | .53 | .52 | .45 | .44 | .43 | .40 | .39 | .38 |
| 1.25 | .71 | .63 | .60 | .55 | .52 | .50 | .48 | .46 | .45 | .64 | .59 | .57 | .52 | .50 | .49 | .46 | .45 | .44 |
| 1.50 | .76 | .68 | .64 | .61 | .56 | .54 | .54 | .51 | .50 | .68 | .63 | .61 | .57 | .54 | .53 | .52 | .50 | .49 |
| 2.00 | .85 | .75 | .70 | .71 | .65 | .62 | .64 | .59 | .57 | .76 | .70 | .67 | .66 | .62 | .60 | .60 | .58 | .56 |
| 2.50 | .91 | .79 | .74 | .78 | .70 | .66 | .71 | .65 | .62 | .80 | .73 | .70 | .71 | .67 | .65 | .66 | .63 | .61 |
| 3.00 | .95 | .82 | .76 | .83 | .74 | .70 | .77 | .69 | .66 | .84 | .76 | .73 | .76 | .70 | .68 | .71 | .67 | .65 |
| 4.00 | 1.01 | .86 | .80 | .91 | .79 | .75 | .85 | .76 | .71 | .88 | .80 | .77 | .28 | .75 | .72 | .78 | .72 | .70 |
| 5.00 | 1.09 | .88 | .82 | .96 | 3.8 | .77 | .91 | .79 | .78 | .91 | .82 | .79 | .88 | .78 | .78 | .82 | .76 | .73 |
| 10.00 | 1.13 | .93 | .86 | 1.08 | .90 | .84 | 1.05 | .89 | .82 | .97 | .87 | .83 | .94 | .85 | .81 | .92 | .84 | .80 |

Light output ratio: 83% Light source: FL 40 SW 3,400 lm Fluorescent lamp reflector used

$$RI = \frac{W \times L}{H\,(W + L)} \quad \cdots\cdots (3)$$

Where W: Width of room (m)

L: Depth of room (m)

H: Height of light source from the working plane (m)

The room index has a higher value when it is a square room. And the utilization factor will be higher with the higher reflectivity of the inner wall and floor and the higher room index.

(6) Improving maintenance factor

To improve the maintenance factor, first adopt luminaires with less lowering of luminous flux with lapse of the working time and secondly periodically clean the luminaires and replace the lamps. However, under the actual circumstances of the factory with much expenditures in labor cost, it will be unavoidable to replace the lamps and clean the luminaires when the lamps are burnt out. Therefore, the first countermeasure is to use luminaires with less lowering rate.

Fig. III-8-48 and Fig. III-8-49 show the lowering tendency of the luminous flux of lamp itself and the lowered luminous flux when dirt accumulates on luminaires respectively.

(7) Others

Other precautions for lighting are not to fluctuate the supply voltage. Although motors, etc. are capable of operating smoothly even at ± 10% fluctuation, lamps are manufactured to perform their best functions and ensure the longest lives at the rated voltage. Therefore, it is desirable to separate illuminating circuits from motor circuits and also to restrict the voltage fluctuation with ± 5%.

Also for ambient temperatures, it is important not to deviate from the manufacturer's specified value.

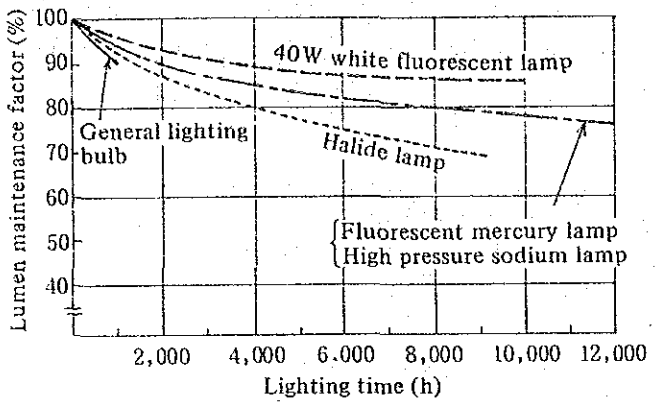



Fig. III–8–48
Lumen maintenance characteristic of various light source

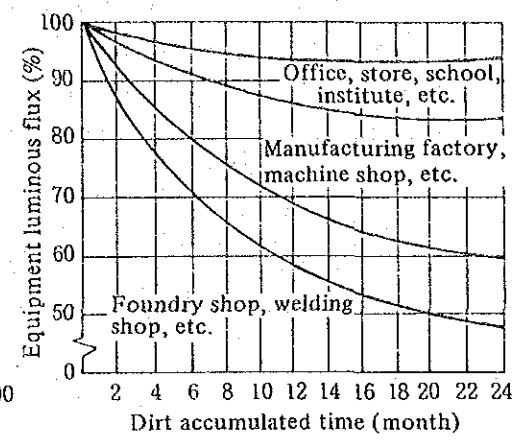



Fig. III–8–49
Lowered lumen when dirt accumulated on lamp and lighting equipment

8.7 Electric heating

8.7.1 Class of industrial heaters

There are various methods to classify industrial heaters, which are classified by heating systems as follows:

(1) Arc furnaces

These heat an object by heat generated by arc and there are arc furnaces for steel manufacturing and vacuum arc furnaces, etc.

(2) Induction furnaces

These heat an object directly or indirectly utilizing Joule heat generated by electromagnetic induction and it is classified into high-frequency and low-frequency furnaces by power source frequency.

(3) Resistance furnaces

These heat an object by Joule heat generated in a resistor and have two systems; one is to heat an object indirectly by making a current flow through a heating unit and the other is to heat by directly making a current flow through an object.

(4) Infrared heating ovens

Thermal energy is transferred mainly by infrared radiation and this is used to heat at comparatively low temperatures or for paint drying.

(5) Dielectric heating ovens

These heat by dielectric loss in an alternating field. High frequency is used for the power source and the capacity is comparatively small.

In this proposal, we will describe the infrared heating of these, above all far infrared heating which is especially watched in recent years.

8.7.2 Special features of far infrared rays

(1) Infrared rays

Infrared rays are electromagnetic waves ranging from 0.75$\mu$m to 1,000$\mu$m, namely having a wavelength longer than visible light and shorter than microwaves. Infrared rays are further divided into near infrared rays for 0.75$\mu$m to 4$\mu$m and far infrared rays for 5.6$\mu$m to 1,000$\mu$m as shown in Fig. III-8-50.

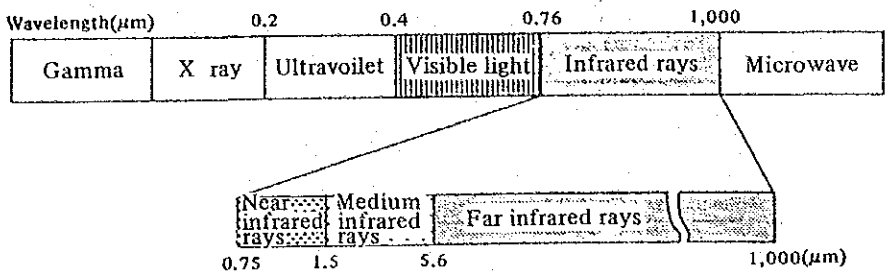



Fig. III–8–50 Position of infrared light in electromagnetic wave spectrum

(2) Principles of infrared heating

A substance is heated by other heat sources in three ways; convection, conduction and radiation. As the infrared rays are electromagnetic waves, the transfer of heat is by radiation. That is, infrared rays emitted from a heat source are directly absorbed by an object to transfer heat.

Various molecules of which a substance is composed have respective peculiar vibrations and rotary frequencies by difference in kinds of its atoms and binding power in the molecules. When the frequency of incident infrared rays coincides with these vibrations or rotary inherent frequencies, the molecule absorbs energy from the infrared rays, and these vibration or rotation gets harder, generating heat. This phenomenon is known as resonance absorption.

When the incident infrared wavelength is not within the absorption wave range, the infrared rays pass through molecules and no heat is generated. Fig. III-8-51 shows infrared absorption spectrum of vinyl chloride resin and there is a strong absorption wave range mostly in far infrared areas though there is also a portion of absorption wave range which is in the 3.5$\mu$m medium infrared areas.

For organic matters of macromolecular and a portion of inorganic matters, a greater part of the absorption wave range is in medium and far infrared areas and there is almost no absorption wave range in near infrared areas in most cases.

Far infrared heating is effective for high-molecular compounds, enable to heat for a short time, and energy can be saved as compared to the use of an infrared ray lamp having an energy peak near infrared areas.

Fig. III-8-52 shows one example of spectral radiation characteristics of infrared ray lamps and far infrared heaters, from which superior emission characteristics of the far infrared heaters in long wave areas are well understandable.

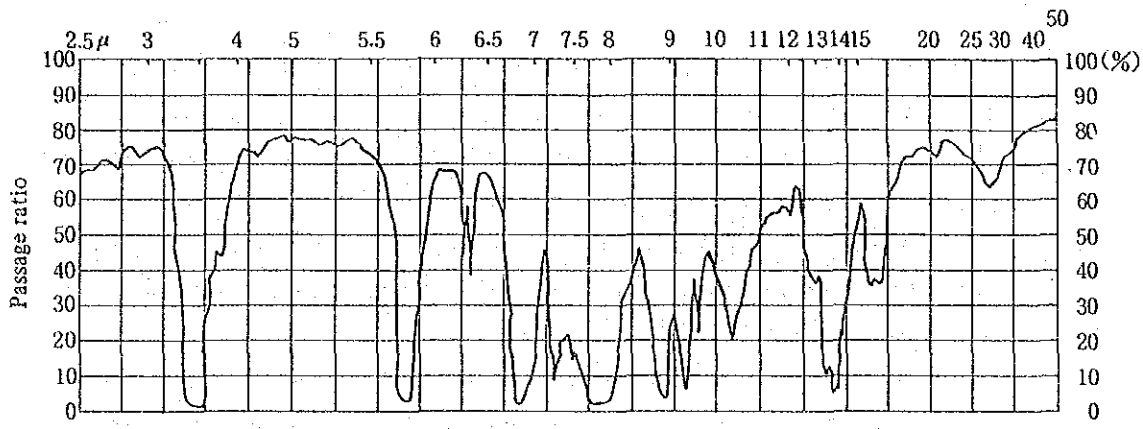



Fig. III—8—51 Vinyl chloride infrared absorption spectrum

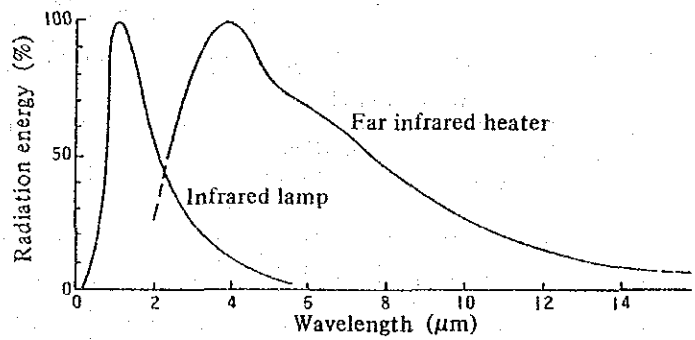



Fig. III—8—52 Spectral radiation characteristic of infrared lamp and far infrared heater (Example)

(3) Features of far infrared heating

Points, in which infrared heating is considered to be more advantageous than other methods such as hot air heating, high frequency heating, etc. are as follows:

a. It is simple to operate.

b. No medium is required to transfer heat, and the object can be directly heated: therefore, response is quick and energy can be saved.

c. It is easy to heat and control.

d. Much space is not required, and it is comparatively easy to move.

e. Equipment cost is low.

f. The object to be heated is easy to monitor.

Also, points the which far infrared heating is considered to be superior to conventional infrared heating are as follows:

A) Drying finish is good.

Since the far infrared heater uniformly heats up the inside of a substance by long wavelength, it is not necessary to heat the substance surface more than required, and the dried substance obtains superior physical properties. Accordingly, in the case of paint drying, no foaming is caused and internal hardening of the coat is also good.

B) Heating unevenness does not occur due to difference in color.

C) Heat-treating time is shortened and energy can be saved.

D) Life is long.

Since the far infrared heater heating unit is sealed and contact with air is shut off, the performance is not lowered much.

Even if it is located at a place exposed to waterdrops or with severe vibration, it is not likely to be damaged and can hold a life of more than several years.

(4) Precautions for application of the far infrared heating

Precautions for application of the far infrared heater are as follows:

A) Selection of effective object

The object to be processed must be of suitable material for the far infrared absorption characteristics and it is important to get an accurate absorption characteristics by literature or experiments beforehand.

B) Construction of equipment

It is necessary, as much as possible not to project a shadow on the object. To do this, it is advisable to avoid an object with a complicated construction. However, somewhat of the shadow can be supplemented by arrangement of the heater or arranging a reflector on the inner wall surface of oven.

C) Ventilation in the ovens

Generally, natural ventilation is enough. When, however, steam or carbon dioxide gas is produced in large quantities, forced ventilation is required. When forced ventilation is performed, it is necessary not to lower the heater temperature.

D) Temperature measurement

It should be noted that the temperature of the object may often exceed the atmosphere temperature in the furnace.

E) Light reflectors

Dirty or damaged light reflectors remarkably lower the reflection efficiency. When dirty, clean by spraying air, etc. so that they are not damaged.

F) Re-examination of irradiation conditions

Heating efficiency lowers due to long-term use or change in the reflection efficiency, etc. even if the object remains unchanged. When any change is recognized in disposal conditions, it is important to investigate the causes and adjust the irradiation conditions such as irradiation distance, heater voltage, conveyor speed, etc.

9.7.3 Application of far infrared equipment to industry

As already described, in far infrared heating, the heater itself is an energy-saving heat source, unlike convection and conduction heating, and research and development are expected to advance increasingly and its applicable fields are considered to be enlarged in the future. Table III-8-36 shows applicable examples in industrial fields considered at present and Table III-8-37 shows examples of practical use in various industries. This indicates how great the energy conservation effect of the far infrared rays is.

Table III--8--36 Applicable industrial fields of far infrared rays heating

| Type of industry | Examples of applications |
|---|---|
| Manufacture of machinery and appliances | Automobile body paint drying, Motorcycle marking drying, Automobile frame primer drying, Casting paint drying, Home electrical appliances paint drying, Transformer case paint drying, Injection molding heating, Furnitures paint baking, Dental cream tube and beer can print drying, Condenser paint drying, Pulverulent body paint drying |
| Chemical industry | Printed circuit board drying, Vinyl chloride resin gelatinization, Chemicals drying, Acrylic sheet softening, Printing ink drying |
| Lumber, wooden product, building material, paper pulp | Furniture and batt plywood drying, Plywood adhesive drying and hardening, Lacquer ware drying, Half-split chopsticks drying, Plywood paint drying, Gypsum board drying, Slate roofing primer and finish coat drying, Mirror surface letters baking, Fire board resin processing, Laminated paper baking and drying, Wall paper processing and drying |
| Textile industry | Sizing and drying, Printing and drying, False twister |
| Food manufacture and processing | Boiled fish paste, a kind of fish paste baking and drying equipment, Rice cake baking, Ripening SAKE, Frozen food thawing, Meets drying, Smoked fish drying. |
| Agricultural and marine products | Heating for pig breeding, Brooder, incubation, Plant forcing culture, Raising (Laying eggs acceleration, frys breeding, baits multiplication) |

# Table III–8–37 Example of practical use of far infrared rays heating

| Classification | Name of process | a. Conventional heat source | Outline of processing | b. Effect of application of far infrared rays (b/a) | | | | Scale of practical use |
|---|---|---|---|---|---|---|---|---|
| | | | | Consumed energy (%) | Fuel cost (%) | Processing time (%) | Others | |
| Textiles-related | Narrow fabrics manufacture | LPG direct flame | Sizing, finishing and drying of narrow fabrics containing rubber in use for training ware, trousers and underwares. | 46 | 73 | 100 | Improved quality, Omission of water washing process | 16.8 kW × 14 unit |
| | Resin treatment of textile products | Schwung burner for LPG | Heat and set vinyl chloride on gloves, socks, entrance mats, car seat, etc. and provide non-slip processing | 43 | 85 | 67 | Improvement of operating circumstance, homogenizing and quality improvement of products | 154 kW |
| | Yarn-dyeing woven textile | Infrared lamp | Sizing and drying fabric yarn (nylon) for umbrellas | 71 | 71 | 100 | Preventing damage to bulbs, etc. Improvement of equipment and operation safety | 8 kW × 2 unit |
| | Sewing and dyeing | Quartz pipe heater | Athletic shirts print drying | 32 | 32 | 67 | Improvement of operational circumstances | 1.5 kW × 3 unit |
| | Crepe dyeing | Schwung burner for LPG | Crepe 80% dyeing (brushing) drying | 71 | 68 | 100 | Improvement of operational circumstances | 6 kW |
| | Manufacture of printing screen | Kerosene warm air | Drying after coating high class printing screen with developing solution | 16 | 27 | 20 | Quality improvement | 12 kW |
| | Manufacture of insect screening | Fuel oil steam warm air | Heat set of vinyl chloride, polypropylene insect screening | 60 | 56 | 100 | Improvement of operational circumstances | 16 kW |
| | Sizing, woven textile | Infrared lamp | Beaming process, sizing and drying of woven textile warp (polyester) | 24 | 24 | 33 | Improvement of operational circumstances | 2 kW |
| Electric and construction machinery, home appliances, others | Manufacture of construction machine parts | Fuel oil steam warm air | Cast iron products paint drying | 50 | 80 | 33 | Reduced equipment area 1/4 | 26 kW |
| | Water heater, hot water feeding machine manufacture | Schwung burner for LPG | Armored portion paint drying | 20 | 28 | 25 | Reduced equipment area 1/3<br>Quality improvement | 25.2 kW |
| | Manufacture of large-sized crests and nameplates | Fuel oil steam or natural | Drying ground of hard porcelain and large-sized crests before calcination | • Natural drying 30 to 40 days, steam drying 20 days → Far infrared 3 to 4 days<br>• Fuel cost for drying process unknown | | | Yield 30 → 100%<br>Improvement of operational circumstances | 1.5 kW × 3 unit |
| | Manufacture of aluminum home appliances | Electrial heat | Heating in glazing process of aluminum pans and kettles, etc. | 14 | 23 | 38 | Furnace efficiency 30 → 78%<br>Equipment capacity 37%<br>Improvement of operational circumstances | 16.5 kW × 3 unit |
| | Sale of herb | Natural | Drying to keep harb from getting moldy during storing herb | — | — | (3 ~ 5 minutes) | Quality improvement<br>Preventing occurrence of mold and insects | 12 kW |

## 8.8 Air conditioning

### 8.8.1 What is air conditioning?

Air conditioning means to control so that the air conditions in a room are kept at an optimum, according to the use application or purpose of the room or factory.

Air conditions in a room to be controlled have the following four factors:

(1) Temperature

Control the dry-bulb temperature to the specified value by cooling or heating air in the room.

(2) Humidity

Control air in the room to the specified comfortable relative humidity.

(3) Cleanness

Remove dust in the air and, at the same time, maintain so that the concentrations for smoke, carbon dioxide gas, odor, poisonous gas, etc. do not exceeded the limit.

(4) Distribution

Prepare moderate air flow so that conditioned air is distributed in the room and make temperature and humidity conditions at each point in the room constant.

The purpose of air conditioning is mainly divided into two; one is A) health air conditioning, and the other is B) process air conditioning.

A) Health air conditioning

This is to hold air in the room at air conditions fit for persons in the room or operators in the room, and the two main factors to control optimum air conditions are temperature and humidity. Fig. III-8-53 shows the comfort zone in summer and winter in Japan.

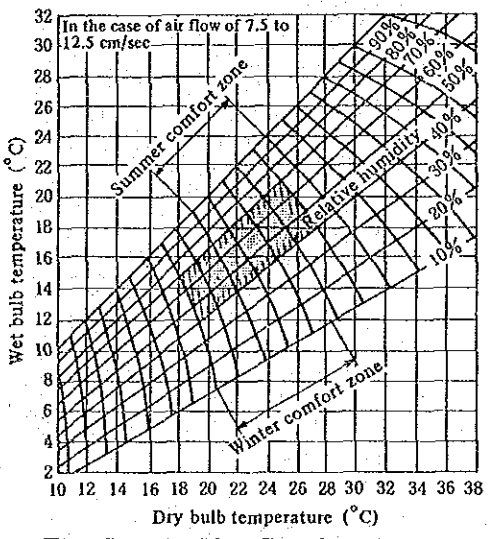



Fig. III–8–53 Comfort zone

Separately from this diagram, to eliminate shock from air-conditioning, it is said to be preferable to keep temperature difference between indoors and outdoors small, and humidity low. The temperature difference between outdoors and indoors is said to be proper at 5 to 7° C.

B) Process air conditioning

Many of various industrial production processes require individually peculiar conditions for temperature and humidity of ambient air and cleanness in each process from raw material to completion of the products.

Table III-8-38 shows typical design air conditioning conditions for each industrial process. However, values on this table are only for the standard and, therefore, it is necessary to investigate well for determination when individually designing.

Table III–8–38 Example of process air conditioning

| Classification | Process | Temperature (°C) | Relative humidity (%) |
|---|---|---|---|
| Color printing | Bronze plating room | 24~27 | 45~50 |
| | Plate preparation | 24 | " |
| | Printing room | 24~27 | " |
| Printing | Book binding | 21~24 | 45 |
| | Form | 24~27 | 45~50 |
| | Printing room | " | " |
| | Web press | " | 50~55 |
| | Paper storage | 20~23 | 50~60 |
| | Photographic printing | 21~23 | 40~50 |
| Optics | Melting room | 24 | 45 |
| | Abrading room | 27 | 80 |
| Plywood | Manufacture | – | 55~60 |
| | Gluing | – | " |
| Rubber | Storage | 14~24 | 40~50 |
| | Cementing | 27 | 25~30 |
| | Dipping | 24~27 | " |
| | Manufacture | 32 | – |
| | Sulfurization | 26~28 | 25~30 |
| Laboratory | Animal laboratory | 24~27 | 40 |
| | General analysis room | 23 | 50 |
| Photograph | Manufacture of ordinary film | 23~24 | 24~40 |
| | Printing | " | 65~70 |
| | Finished product storage | 16~27 | 45~50 |
| | Developing | 21~24 | 60 |
| Bakery | Base mixing | 24~27 | 45~55 |
| | Base fermentation | 27 | 70~80 |
| | Bread cooling | 21 | " |
| | Bread wrapping | 18~24 | 50~65 |
| | Powder storage | 21~27 | 50~60 |
| | Cake freezing | " | 45~50 |
| Precision machinery | Gear cutting | 24~27 | 45~55 |
| | Precision parts | 24 | " |
| | Precision assembly | 20~24 | 40~50 |
| | Precision test room | 24 | 45~50 |
| Pharmacy | Capsuling | 24~27 | 35~40 |
| | Colloid | 21 | 30~50 |
| | Deliquescene salt | 27~32 | 15~40 |
| | Gelatin capsule | 26 | 40~50 |
| | Powder product | 24~27 | 5~35 |
| | Tablet forming | 21~27 | 35~40 |
| | Tablet finish coating | 24~27 | " |
| | Serum | 23~26 | 45~50 |
| | Powder material drying | 54~71 | 20 |
| | General pharmacy room | 21~27 | 10~50 |
| Electricity | Manufacture of thermostat | 24 | 50~55 |
| | Manufacture of insulating material | 24 | 65~70 |
| | Assembly of electron tubes | 20 | 40 |
| | Cable insulation | 40 | 5 |
| | Transformer coil winding | 16~24 | 15~35 |
| Food | Manufacture of butter | 16 | 60 |
| | Coffee substitute | 24~27 | 40~45 |
| | Milling | – | 60 |
| | Macaroni | 21~27 | 38 |
| | Mayonnaise | 24 | 40~50 |
| | Mushroom growing room | 14~27 | 75 |
| Brewing | Storage of grains | 16 | 35~40 |
| | General manufacture | 16~24 | 45~65 |
| | Aging room | 18~22 | 50~60 |
| | Beer fermentation room | 3~ 4 | 50~70 |
| | Beer malthouse | 10~15 | 80~85 |
| Confectionery | Chewing gum — Cooling | 22 | 50 |
| | Chewing gum — Drying | 49~60 | 50 |
| | Chewing gum — Wrapping and storage | 21~24 | 45~60 |
| | Candy — Manufacture | 18~27 | 35~50 |
| | Candy — Cooling | 24~27 | 40~45 |
| | Candy — Product storage | 16~24 | 45~55 |
| | Candy — Dry fruits storage | 10~13 | 50 |
| | Chocolate — Bar manufacture | 18 | 45~50 |
| | Chocolate — Center cream manufacture | 24~29 | 50 |
| | Nougats | 18 | 50 |
| | Starch room | 24~29 | 50 |
| | Wrapping | 18 | 50 |
| | Product storage | 16~24 | 40~50 |
| Tobacco | Cigarette — Raw material storage | 27 | 75~78 |
| | Cigarette — Cutting | 24~27 | 80 |
| | Cigarette — Cut tobacco storage | 27~29 | 60~65 |
| | Cigarette — Manufacturing room | 21~27 | 55~65 |
| | Cigarette — Wrapping room | 27~29 | 50 |
| | Cigarette — Truck removing room | 27 | 70~75 |
| | Cigarette — Sweating | 49 | 80 |
| Cotton spinning | Roving | 21~24 | 50~55 |
| | Spinning | " | 55~65 |
| | Drawing | " | 55 |
| | Picker | " | 45~50 |
| | Roving | " | 50~60 |
| | Warp spinning | 24~27 | 50~65 |
| | Weft spinning | " | " |
| | Cotton reel | " | 60~70 |
| | Twister | 21~24 | 65 |
| | Woven textile | 24~27 | 70~85 |
| | Fabric storage | 24~27 | 65~75 |
| Jute spinning | Fabric conditioning room | 24~27 | 90~95 |
| | Spinning | 24~27 | 60 |
| | Woven textile | 26~27 | 80 |
| | Preparation | 18~20 | 80 |
| | Roving and spinning | 24~27 | 60 |
| Match | Manufacture | 22~27 | 45~50 |
| | Storage | 15 | 50 |

8.8.2 Setup of air conditioning system

Air conditioning is generally performed by blowing air at a suitable temperature with moderate humidity and cleanness from diffusers into a room. Accordingly, to accomplish this,

there are various methods considered. Fig. III-8-54 shows a setup example of a comparatively large-scale air conditioning system, on the basis of which we will describe with an eye to cooling.

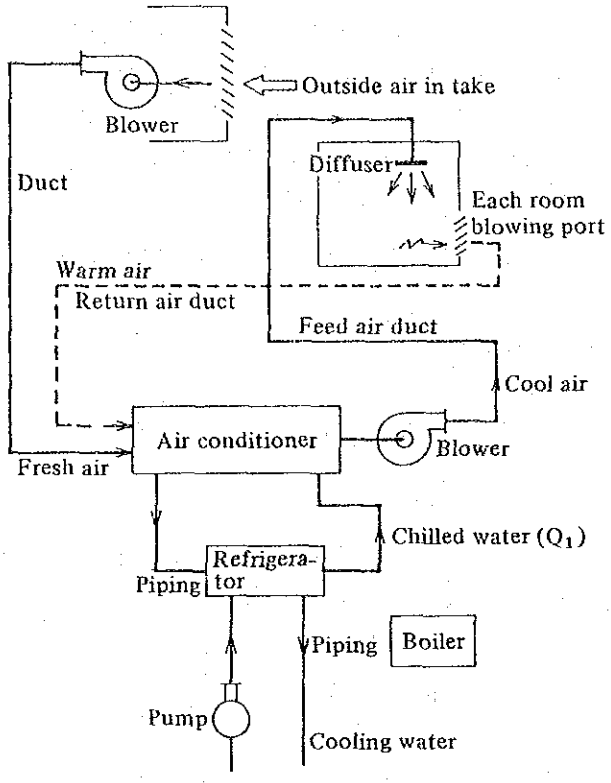



Fig. III–8–54 Composition example of large scale air conditioning system (during cooling)

(1) Heat source equipment (Refrigerator)

This feeds hot water (heating medium) or cold water (refrigerant) to an air conditioner. A boiler, heat storage tank, heat pump, etc. prepares the heating medium and a refrigerator feeds the refrigerant. In addition, there are heat exchanger and pumps, blowers, pipings, etc. for the auxiliary equipment.

(2) Air conditioners

Air conditioners are used to make the feed air to the room suitable temperature, humidity and cleanness.

Accordingly, air conditioners contain various apparatus to achieve functions such as air cleaning, cooling, dehumidification, heating, humidification, blast, etc.

(3) Transport equipment

Transport equipment is used to transport liquid and gas and consists of blower and fan, pump, duct, piping equipment, etc. For example, feed air conditioned by an air conditioner is fed through a duct into the room for cooling by a blower. Also, warmed air in the room is sucked by negative pressure in the blower and enters the air conditioner.

(4) Air distributors

Air distributors consists of diffuser, intake port, muffler, damper, etc. and are

installed at outlets and inlets of the transport equipment.

(5) Switchboard, control panel, monitor panel

These are electric equipments to operate, control and monitor an air conditioning system.

The above equipments are not always separately installed. According to the scale of an air conditioning system, 1 unit may be composed of several equipments and also 1 unit may be composed of each equipment, like package type air conditioners.

Capacity of each apparatus in Fig. III-8-54 is as follows:

A) Capacity of intake air blower (Q)

Assuming sensible heat load in a room as $q_s$ (kcal/h),

$$Q = \frac{q_s}{\text{Air specific weight (kg/m}^3) \times \text{Air specific heat (kcal/kg·°C)} \times (t_1 - t_2)}$$

$$= \frac{q_s}{1.2 \times 0.24\,(t_1 - t_2)}$$

$$= 3.47 \frac{q_s}{t_1 - t_2} [\text{m}^3/\text{hr}] \quad \cdots\cdots (1)$$

Where $t_1$ (°C): Indoor dry-bulb temperature (preset temperature)

$t_2$ (°C) : Diffuser dry-bulb temperature

B) Cooling capacity of air conditioner (q)

$q$ = Air specific weight $\times$ Q $\times$ $(i_1 - i_2)$

$= 1.2\,Q\,(i_1 - i_2)$ (kcal/hr) $\cdots\cdots (2)$

Where $i_1$ (kcal/hr): Air enthalpy at air conditioner inlet

$i_2$ (kcal/hr): Air enthalpy at air conditioner outlet

C) Capacity of refrigerators

Amount of cooling water $Q_1$ fed from the refrigerator to the air conditioner to achieve the above cooling capacity q is, assuming thermal efficiency of the air conditioner as $\eta_1$,

$$Q_1 = \frac{q \times 10^{-3}}{\eta_1\,(tw_1 - tw_2)} [\text{m}^3/\text{hr}] \quad \cdots\cdots (3)$$

Where $tw_1$ , $tw_2$: Temperature of cooling water at inlet and outlet of the air conditioner (°C)

Also, power of the compressor P is, assuming the compressor efficiency as $\eta_2$, and coefficient of performance of the refrigerator as $\epsilon$,

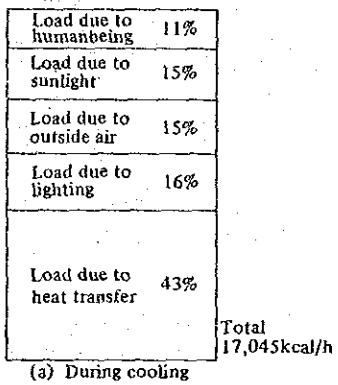
$$P = \frac{q}{860\,\eta_2 \cdot \epsilon} [\text{kW}] \quad \cdots\cdots (4)$$

8.8.3 Energy conservation for air conditioning

To install an air conditioner, the planner determine the load to be air conditioned and select a suitable air conditioner and system for this load. Accordingly, for energy conservation for an air conditioning, it is important to reduce the cooling load as the first step, and to select or improve to an energy-saving air conditioner or system for the cooling load as the second step.

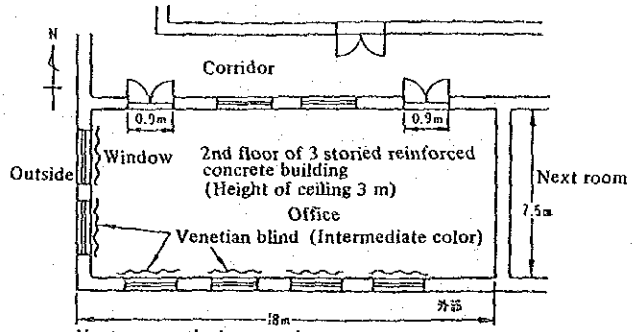
(1) Class of cooling loads

Table III-8-39 shows loads for cooling. Total cooling load is a sum of these loads. Fig. III-8-55 shows an example of cooling load for a factory office. Their building construction is shown in Fig. III-8-56. This indicates that the load due to heat conduction is the highest, followed by outside air, lighting, solar radiation and the human body in sequence.




(a) During cooling

Fig. III–8–55
Example of air conditioning load in factory office




Next rooms, the lower and upper floors have no cooling and heating system.

Fig. III–8–56 Example of office

(2) Methods for energy conservation

A) Reduction of outside air load and intensification of heat insulation

Outside air load has two loads: load due to draught $q_i$ and fresh air load $q_0$.

Load due to draught $q_i$ is due to natural ventilation when the outside air at higher temperatures enters through the window and door clearance and by the opening and shutting and is expressed generally by the following equation:

$q_i$ = Sensible heat load + Latent heat load (kcal/hr)

$$\fallingdotseq 0.29\ NV\ (t_1 - t_2) + 720\ NV \times (x_1 - x_2) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5)$$

Where N (times/hr) : Number of times for natural ventilation (See Table III-8-40)

$V(m^3)$: Volume of a room

$t_1$, $t_2$ (°C): Outdoor, indoor temperature

$x_1$, $x_2$ (kg/kg) : Outdoor, indoor absolute humidity

Table III–8–40 Number of times for natural ventilation (N)

| Class of room | n |
|---|---|
| 1 wall surface facing outside air and having window or door | 1 |
| 2 walls surface facing outside air and having window or door | 1.5 |
| 3 walls surface facing outside air and having window or door | 2 |
| 4 walls surface facing outside air and having window or door | 2 |
| Room without window facing the outside air or door | ½ ~ ¾ |

For air-tight window, ½ of this table shall be used. However, n shall be more than ½ in any case.

## Table III–8–39 Class of cooling load

<table>
<tr><th>Main classification</th><th>Sub-classification</th><th>Outline</th></tr>
<tr><td>Indoor acquisition heat capacity</td><td>Heat capacity from wall by heat transfer qW (kcal/h)</td><td>This is infiltration heat capacity from wall by heat transfer and varies according to thickness of the wall, the material, inner wall, outer wall, etc.<br>$qw = Aw \cdot K \cdot \Delta t$<br>Where Aw : Area of wall ($m^2$), K : Heat once-through factor ($kcal/m^2 \cdot h \cdot °C$),<br>$\Delta t$ : Equivalent temperature difference (°C)<br>Note (1) Difference between wall surface temperature and indoor side temperature is called "Equivalent temperature difference".<br>(2) Heat once-through factor varies according to material of wall (Ceiling, floor, side wall, window, etc.), combination and thickness.</td></tr>
<tr><td></td><td>Infiltration heat capacity from window glass qg (kcal/h)</td><td>(1) qgr : Radiation heat capacity = Radiation amount passing through glass ($kcal/m^2 \cdot h$) x Shielding coefficient x Area of window ($m^2$) x Radiation decrease ratio for double glass<br>(2) qgc : Heat capacity infiltrating from inner surface of glass by convection (including heat transfer) = Convection heat capacity coefficient ($kcal/m^2 \cdot h$) x Area of glass window ($m^2$)<br>$qg = qgr + Qgc$</td></tr>
<tr><td></td><td>Load due to draught (Infiltrating outside air), qi (kcal/h)</td><td>This has sensible load (qis) and latent load (qil).<br>qis = 0.29 x Amount of draught ($m^3/h$) x Difference between inside and outside temperature (°C) = 0.29 x nV x Difference between inside and outside temperature (°C)<br>Where n : Number of times for ventilation hourly<br>V : Volume of room ($m^3$)<br>qil = 720 x Amount of draught ($m^3/h$) xDifference between inside and outside absolute humidity (kg/kg)</td></tr>
<tr><td></td><td>Heat capacity from human body qh (kcal/h)</td><td>This varies according to his or her age, distinction of sex, operating conditions, indoor temperature and humidity, etc. Heating capacity of a Japanese adult male during rest at normal temperature is 45 in sensible heat and 35 in latent heat, totaling 80 kcal/h, and in the case of a clerk in an office, 50 in sensible heat and 45 in latent heat, totaling about 95 kcal/h. For female and the aged or little one, their heat capacity are assumed as 80 to 90%, and 50 to 80% respectively. Total heat capacity is obtained by multiplying by the number.</td></tr>
<tr><td></td><td>Heating capacity from indoor appliances, qe (kcal/h)</td><td>This is heat capacity from various appliances such as lighting appliances, electric heater, appliances for motor, production equipment and appliances for cooking, etc.<br>Heat capacity from lighting appliances = kW number of All lighting (Stabilizer input base) x 860 x Use ratio of lighting appliances x Net heat release ratio*1 of lighting appliances (kcal/h)<br>Heat capacity from motor = Motor rated output (kW) x Load factor x Following coefficient*2<br>*1 This is used when a portion of heat capacity has been arranged not to discharge inside the room (for example, it is purged from the ceiling).<br>*2
<table>
<tr><th>Place of Motor</th><th>Place of Machine</th><th>Coefficient</th></tr>
<tr><td>Inside air-cooled room</td><td>Inside air-cooled room</td><td>1/motor efficiency</td></tr>
<tr><td>Outside " </td><td>" "</td><td>1</td></tr>
<tr><td>Inside "</td><td>Outside "</td><td>(1−motor efficiency)/motor efficiency</td></tr>
</table></td></tr>
<tr><td>Fresh air load</td><td>Acquisition heat capacity from intake outside air (forced intake), qo (kcal/h)</td><td>Sensible heat load qos = 0.29 x Amount of intake outside air ($m^3/h$) x (Outside temperature − Indoor temperature) (°C) (kcal/h)<br>Latent heat qol = 720 x Amount of intake outside air ($m^3/h$) x (Outside absolute humidity − Indoor absolute humidity (kg/kg) (kcal/h)<br>In general air conditioning, this load is not necessary when the required fresh air is sufficiently supplemented by draught.<br>Amount of intake outside air = Number of times for ventilation hourly x Volume of room ($m^3$) ($m^3/h$)</td></tr>
<tr><td>Miscellaneous heat</td><td></td><td>This means once-through heat load receiving from the outside when feed and return ducts are passing through the place where are not cooled, and exothermic heat from fan and compressor, etc. are included, and it shall be 3 to 7% of the indoor acquisition heat capacity.</td></tr>
<tr><td>Others</td><td></td><td>When some allowance is considered for cooling capacity, it shall be 8 to 20% of the total load.</td></tr>
</table>

To reduce the draught load, it is advisable to shut the doors tightly and reduce the number of times for opening and shutting by adopting automatic doors as much as possible. When, however, outdoor temperature lowers more than the room temperature at night, $t_1 - t_2$ becomes negative, which means reduced cooling load. In this case, induce outdoor air by opening the window and door, of course resulting in a better cooling effect. As fresh air load $q_0$ is due to forced ventilation, assuming the amount of intake fresh air as Q ($m^3$/hr), $q_0$ is determined by replacing NV with Q in equation (5). Amount of ventilation Q is provided for mainly from human safety and hygiene and the required amount of fresh air per person in room will be about 30 $m^3$/hr assuming an allowable carbon dioxide gas concentration of 0.1%.

To reduce the outdoor air load in any case, it is important to reduce the number of times for ventilation as much as possible to the extent that the carbon dioxide gas concentration as 0.1% is not exceeded.

When there is a return air system as shown in Fig. III-8-57, it is better to circulate air as much as possible to reduce the intake of outdoor air. To be more specific, make the damper opening of the return air system larger to increase the amount of return air and at the same time, make the damper opening of the outdoor air intake system smaller to reduce the amount of outdoor air intake.

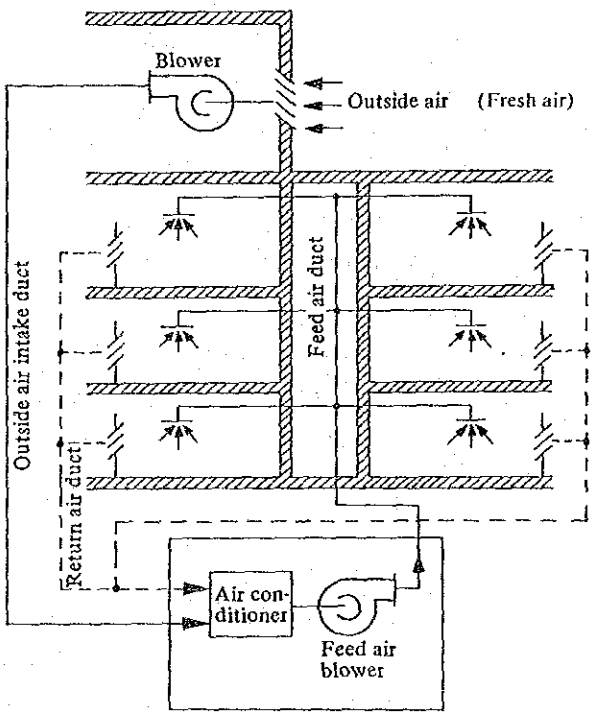



Fig. III–8–57 Air conditioning system when return air is available

For a precaution at this case, when the amount of return air is too much, the pressure in the room becomes negative against the outdoors, and dust is liable to enter the room. Therefore, it is desirable to keep the pressure in the room 0.1 mmAq to 1 mmAq higher than the outdoor.

For reducing load by heat conduction, it is of course important to intensify the heat insulation of the building, for which, see the other technical books.

Heat insulation for piping and duct for cooling is particularly important. In the case of heat insulation, condensation does not occur since the temperature of the fluid in the piping is higher than the dew point temperature of ambient air. However, in the case of cold insulation, condensation occurs when the surface temperature of the insulator is lower than the dew point temperature of ambient air, since the temperature of the fluid in the piping is low. Once condensation occurs, the cold insulator absorbs moisture and the heat conductivity increase more and more, expediting condensation. Care should be taken.

B) Relief of indoor preset temperature

Raising the preset temperature during cooling greatly reduces the cooling load because heat conduction from wall surfaces is in proportion to the temperature difference between indoors and outdoors. In the example shown in Fig. III-8-55, raising the preset temperature from 26° C to 27° C causes the cooling load by about 100 kcal/hr.

In equation (1), $q_s$ decreases and $t_1$ increases and if $t_2$ is assumed constant, the amount of feed air can be reduced and, therefore, the blower axial power can be reduced. Thus, it is also possible to reduce the compressor output and temperature of cooling water.

C) Reduction of heating value of indoor appliances

Except when circumstances compel it, it is desirable not to place any heat-generating appliances in air conditioned rooms. Fig. III-8-55 shows that lighting load accounts for 15% of the total load. As the countermeasure for it, it is desirable to save electric power by adopting efficient lighting, and to ventilate the heat portion of the luminaires collectively by a separate duct.

D) Re-examination of humidity

In an air conditioner with dehumidifying capacity, releasing the humidity condition effectively saves electric energy. In a trial calculation example, changes in air conditioning load when temperature and humidity is changed respectively are shown in Fig. III-8-58.

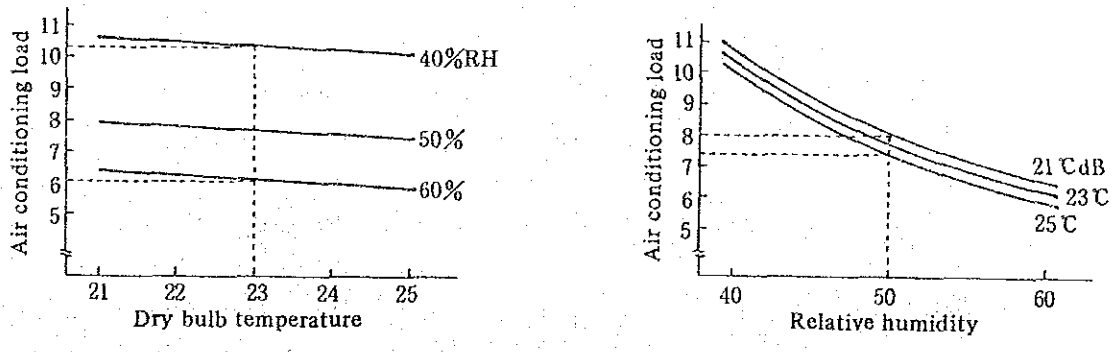



Fig. III–8–58 Energies required for temperature and humidity changes (Trial calculation on a certain conditions)

According to this diagram, when humidity is released from 40% RH to 60% RH at a temperature of 23°C, the load is reduced by about 4.2 kcal/hr. Also, when the temperature is released from 21°C to 25°C at 50% relative humidity, the load is reduced by only about 0.7 kcal/hr and humidity releasing is about six times advantageous in energy conservation. However, it should be noted that excessively high humidity gives human beings discomfort and affects the product quality.

E) Improved control methods

As shown in equation (1) and equation (3), heat load carried by refrigerant is in proportion to the flow rate and temperature difference. For controlling heat load there are two methods; one is to change the flow rate, and the other is to change the refrigerant temperature under constant flow rate. The former is greater in reduction in amount of air flow and pump power and more energy can be saved. As for fluid control methods, there are damper control, vane control and various variable speed controls as described already and each consumed power is in the following order: Discharge damper control > Inlet vane control > Variable speed control. Therefore, the system with the best efficiency should be selected within the allowable conditions. Especially, the variable speed control by means of VVVF can be easily installed on the existing motor equipment and is very effective when large flow change is often occured. So it is advisable to study this first when modifying the existing equipment. See the items "Motor" and "Blower" for details.

F) Periodic maintenance and control

a. Cooling water piping

Adherence of scale and sludge to the piping system causes increased resistance, thus increasing the pump output to feed the same flow rate. If the water quality is improper, naturally scale and sludge adhere heavily. Accordingly, it is necessary to control water quality. Reference values for water control standards are shown in Table III-8-41.

b. Heat exchangers

In evaporators and condensers, scale, sludge and germs occur from cooling water, adhere and accumulate, lowering the heat exchange efficiency and increasing the consumed power per refrigerating ton. Therefore, it is necessary to clean periodically.

c. Air ducts

When a filter is used for air purification, periodic cleaning is necessary. Needless to say, filter clogging increases the pressure loss, reducing the air flow and lowering the cooling capacity. Since air conditioners in improper environmental conditions are quickly contaminated, it is desirable to clean once a week.

G) Others

On each season, it is desirable to re-examine the air conditioning zone by studying whether there is any unbalance due to supercooling and overheating in each room and whether the air conditioning level is proper in each corridor, etc., in order to reduce the air conditioning load as much as possible.

When establishing a new air conditioning system, it is necessary to carefully study the advisability of installation of a heat storage tank, of waste heat utilization, and selection of the most effective air conditioning duct system, etc., with an eye to reducing operation cost.

Table III–8–41 Quality standard of cooling water

(Japan Refrigeration and Air Conditioning Industrial Association Standard)

| | Item | | Standard value for makeup water | Standard value for cooling water*1 | Tendency*3 | |
|---|---|---|---|---|---|---|
| | | | | | Corrosion | Scale |
| Standard item | PH (25°C) | | 6.0~8.0 | 60~8.0 | O | O |
| | Conductivity | (μv/m) | 200 or less | 500 or less (1,000 or less) | O | |
| | Chlorine ion Cl | (ppm) | 50 or less | 200 or less | O | |
| | Sulfuric acid iron $SO_4^{2-}$ | (ppm) | 50 or less | 200 or less | O | |
| | Total iron Fe | (ppm) | 0.3 or less | 1.0 or less*2 | O | O |
| | M Alkalinity $CaCO_3$ | (ppm) | 50 or less | 100 or less | | O |
| | Total hardness $CaCO_3$ | (ppm) | 50 or less | 200 or less | | O |
| Reference item | Sulfur ion $S_1$ | (ppm) | Not be detected | Not be detected | O | |
| | Ammonium iron $NH_4$ | (ppm) | Not be detected | Not be detected | O | |
| | Silicon oxide $SiO_2$ | (ppm) | | 50 or less | | O |

*1. Cooling water means water passing through condenser for both transient and circulation systems.
*2. Standard value for plastic piping shall be 0.5 ppm or below.
*3 Mark O in "Tendency" column indicates a factor concerning either corrosion or scale tendency.

III. Guideline for Rationalization of Energy Use

9. Process Measurement

Contents

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1.1.1 Kinds of thermometers ..... III-9-1
1.2 Measurement of flow ..... III-9-10
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## 9 Process Measurement

When promoting energy conservation, it is basic for energy control to grasp the status of energy consumption. This principle used to be emphasized thus far. In addition, it is of course, impossible to grasp the status of energy consumption without measuring the process variables. In this section, an explanation is made of the process measurement method used generally for routine energy control.

### 1.1 Temperature measurement

#### 1.1.1 Kinds of thermometers

The kinds and characteristics of the thermometers used in the industry are shown in Table III-9-1.

(1) Thermocouple thermometer (Table III-9-1)

(Principle)

When two different kinds of metal A and B are bonded together, an electromotive force $E_{AB}(\theta)$ will be generated according to the temperature $\theta$ of a bonded point as shown in Fig. III-9-1. Further, if both ends of two different kinds of metal are bonded as shown in Fig. III-9-2, an electromotive force E will be generated between both contact points A and B according to a difference in the temperatures $\theta_1$ and $\theta_2$ of the said contact points. The way two different kinds of metal bonded together is called "thermocouple." E is determined only by the kind of metal constituting the thermocouple and the temperature of both bonded points. Whatever the size or the intermediate part temperature may be, there will be no change in the electromotive force.

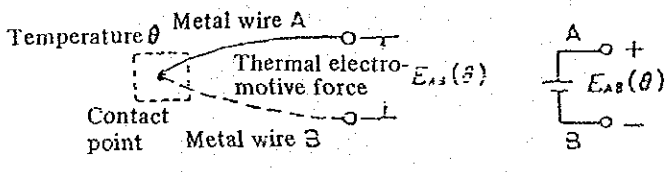



Fig. III–9–1 Thermal electromotive force

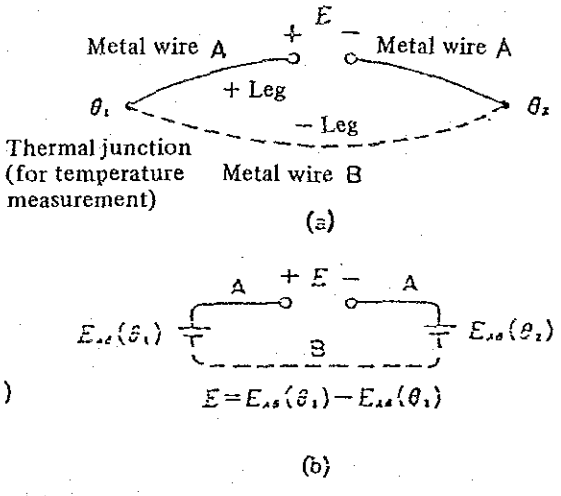



Fig. III–9–2 Thermocouple circuit

If $\theta_2$ is maintained at a known temperature (standard contact point) and E is measured, it is possible to determine the temperature $\theta_1$ (measurement contact point) of the other contact point.

In case the distance between a location where a thermocouple is to be installed

and a standard contact point is long, it is actually covered by a low cost compensating wire as a substitute. It is necessary that the thermal electromotive force of the compensating conductor have a value close to that of the thermocouple at lower than the temperature of the compensating contact point (contact points between the thermocouple and the compensating wire).

Table III–9–1 Kind and characteristics of working thermometer

| Kind | | Temp. range (°C) | Accuracy (%) | Advantages | Shortcomings |
|---|---|---|---|---|---|
| Thermocouple thermometer | Precious metal<br>Base metal | 200~1,600<br>−200~1,100 | 0.2~0.5<br>0.4~1.0 | 1. Temp. of small place can be measured.<br>2. Time-lag can be minimized.<br>3. Highly vibration and impact-resistant.<br>4. Convenient for temp. difference measurement.<br>5. Influence of deterioration of the contact point for temp. measurement is insignificant.<br>6. The cost of base metal wire is low.<br>7. Various kinds are available, so suitable materials can be used at appropriate parts. | 1. Standard contact point is required.<br>2. Error due to the difference between standard contact point and compensating conductor need to be considered.<br>3. High accuracy canot be obtained because of parasitic thermal electromotive force and the effect of heterogenous quality.<br>4. Sensitivity of the movable coil-type instrument is low, so that it is apt to be influenced by a change in resistance. |
| | Sheath-type | same as above. | same as above. | In addition to the above, convenient for use, highly durable and high shielding effect against electro-magnetic force. | In addition to the avove, slightly low accuracy and costly. |
| | Consumption-type | 1,100~1,800 | 0.2~0.5 | Easy maintenance and no degradation due to high temp. | Impossible to check the total quantity and also to measure continuously. |
| Resistance thermometer | Platinum | −260~600 | 0.1~0.3 | 1. High accuracy and sensitivity.<br>2. If the ratio meter is used, this type is comparatively durable and cheap. | 1. Large temp. measureing part, so it is impossible to measure a spot.<br>2. Be careful about self-heating and the influence of conductor.<br>3. The instrument needs a power supply.<br>4. Unless a special make, this type can not be used at high temp.<br>5. Vulnerable against mechanical shock. |
| | Copper | 0~180 | 0.1~0.3 | | |
| | Nickel | −50~300 | 0.2~0.5 | | |
| | Sheath-type | −260~600 | 0.1~0.3 | Compact and responsive quickly so that this type is convenient for use. | |
| 1 | Thermister | −50~350 | 0.3~1.5 | 1. The sensor is small in size and time lag is insignificent.<br>2. The influence of conductor is insignificant.<br>3. Highly sensitive and durable. | 1. An aging change is rather significant and interchange-ability, is low.<br>2. Be careful about self-heating.<br>3. The linearity of graduation, is unsatisfactory.<br>4. Might be broken by mechanical shock. |
| Radiation thermometer | Thermopile-type | 200~2,000 | 1 | 1. An object is not disturbed by noncontact. This type is suitable for the measurement of a moving object.<br>2. Quick response.<br>3. Possible to measure high temperature.<br>4. Possible to measure a small object.<br>5. This type is suitable for the measurement of temp. distribution. | 1. True temperature can not be obtained unless effective emissivity is known.<br>2. As far as a solid is concerned, only its surface temp. can be obtained.<br>3. Susceptible of the impact of external turbulence (stray light, dust).<br>4. Rather difficult to calibrate. |
| | Thermister bolometer-type | −50~3,200 | | | |
| | Narrow-band type | 0~3,500 | | | |

| Kind | | Temp. range (°C) | Accuracy (%) | Advantages | Shortcomings |
|---|---|---|---|---|---|
| | Optical pyrometer | 700~3,000 | 1 | Simple in design and the impact of emisivity is low. | Unsuitable for automation. |
| | Color thermometer-type | 800~3,500 | 1 | The impact of emissivity and reduced luminous intensity is slightly small. | Characteristics vary according to manufacturer. Corrective data for emissivity are not sufficiently available. |
| Glass thermometer | Mercury-sealed | −50~650 | 0.1 | 1. High accuracy<br>2. Easy to handle and low-priced. | 1. Breakable easily.<br>2. Unsuitable for remote reading and difficult to read. |
| | Other than mercury-sealed | −200~200 | 1 | | |
| Pressure-type thermometer | Liquid-filled | −30~600 | 1 | 1. Built firmly and highly vibration-resistant.<br>2. Suitable for remote reading or automatic recording.<br>3. Low-priced. | 1. The sensor is large in size.<br>2. If the temp. range is erroneous, reading might be wrong.<br>3. Some of this type is influenced by atmospheric pressure, temperature and altitude.<br>4. The vapor pressure-type has an uneven scale between gradations. |
| | Vapor Pressure-type | −20~350 | | | |

Performance and Characteristics of the thermocouple generally used in industry is shown in Table III-9-2.

A) Structure of Industrial Thermocouple

a. Thermocouple with protective tube

This device is inserted into the heating furnace or equipment for measurement. An element introduced through a heat-resistant insulation tube, is housed in a protective tube of appropriate quality with a terminal. (Fig. III-9-3)

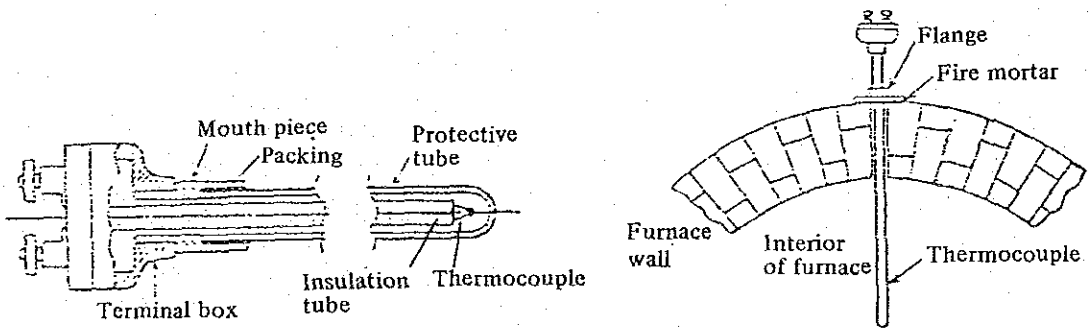



Fig. III—9—3 Thermocouple with protective tube

b. Sheathed thermocouple

Wire for thermocouple is tightly sealed in a metal sheath with an insulating filler such as magnesia. It is highly flexible, heat-resistant, vibration-proof, and favable characteristic in response. (Fig. III-9-4)

Select proper sheathing materials according to the temperature and atmosphere of the place where they are used. The wire ranges from 0.25 to 12.7 mm in diameter and is characteristic of being bent to a radius of curvature equivalent to approx. two times the diameter.

## Table III–9–2 Performance and characteristics of thermocouple

| Kind | Wire Dia. and normal limits | Class and tolerance** | Characteristics |
|---|---|---|---|
| Copper/Constantan<br>(IEC: T type)<br>(JIS: CC) | 0.32φ –200~200(250)°C<br>0.65 –200~200(250)<br>1.0 –200~250(300)<br>1.6 –200~300(350) | Class 0.75:<br>0~200°C<br>±1.5°C<br>200°C~ normal limits<br>±0.75% | Low-price, satisfactory cold characteristic and high homogeneity.<br>Suitable for reductive atmosphere.<br>Significant thermal conduction error. |
| Iron/Constantan<br>(IEC: J type)<br>(JIS: IC) | 0.65φ –200~400(500)°C<br>1.0 –200~450(550)<br>1.6 –200~500(650)<br>2.3 –200~550(750)<br>3.2 –200~600(800) | Class 0.75:<br>0~400°C ±3°C<br>400°C~normal limits<br>±0.75%<br>Class 1.5:<br>0~400°C ±6°C<br>400°C~normal limits<br>±1.5% | Low-priced, slightly large thermoelectric power.<br>High linearity of electromotive force.<br>Suitable for reductive atmosphere.<br>Low homogeneity.<br>Some of this type is significantly different from standard.<br>Uneven quality, becomes rusty easily and changeable hysteresis at high temp. |
| Chromel/Constantan<br>(IEC: E type)<br>(JIS: CRC) | 0.65φ –200~450(500)°C<br>1.0 –200~500(550)<br>1.6 –200~550(650)<br>2.3 –200~600(750)<br>3.2 –200~700(800 | Class 0.75:<br>0~400°C ±3°C<br>400°C~normal limits<br>±0.75% | Cheaper than CA and high thermoelectric power.<br>Higher corrosion resistance than IC and slightly changeable hysteresis in non-magnetism.<br>High resistance value but small temperature change. |
| Chromel/Alumel<br>(IEC: K type)<br>(JIS: CA) | 0.65φ –200~650(850)°C<br>1.0 –200~750(950)<br>1.6 –200~850(1,050)<br>2.3 –200~900(1,100)<br>3.2 –200~1,000(1,200) | Class 0.4:<br>0~400°C ±<br>±1.6°C<br>400°C~normal limits<br>±0.4%<br>Class 0.75:<br>0~400°C ±3°C<br>400°C~normal limits<br>±0.75% | High linearity of electro-motive force.<br>Suitable for oxidative atmosphere.<br>Highly resistant against metallic vapor.<br>Slightly changeable historically. |
| Platinum/Rhodium 10/Platinum<br>(Pt · Rh 10-Pt)<br>(IEC: S type)<br>Platinum/Rhodium 13/Platinum<br>(Pt · Rh 13-Pt)<br>(IEC: R type)<br>(JIS: PR) | 0.5φ 0~1,400(1,600)°C | Class 0.25:<br>0~600°C<br>±1.5°C<br>600~1,600°C<br>±0.25% | Highly stable and suitable for standard.<br>Suitable for oxidative atmosphere.<br>Vulnerable against hydrogen and metallic vapor.<br>Low thermoelectric power and slightly changeable historically.<br>Large error of compensating conductor. |
| Platinum/Rhodium 30/ Platinum/Rhodium 6<br>(Pt·Rh30–Pt·Rh6)<br>(IEC: B type) | 0.5φ 300~1,550(1,800)°C | Higher than 300°C<br>±0.5% | Normal temperature thermoelectric power is extremely low.<br>Some of this type is significantly different from standard.<br>Same as PR in other respect. |

* ( ) means the working limits for overheating.

** For those not specified by JIS, the accuracy of the commercial-grade will apply.

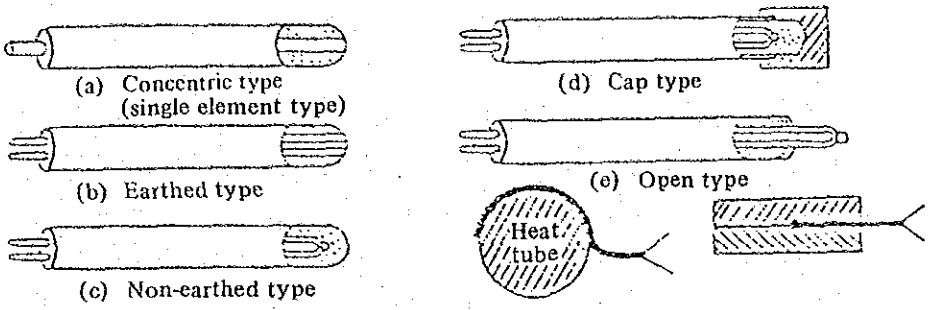



Fig. III–9–4 Sheathed thermocouple and examples of application

B) Standard Contact Point

In the standard use method, the standard contact point of the thermocouple is kept at 0° C. However, at temperatures other than 0° C, it is important to compensate by a mechanical or an electric method. The following are procedures for such a compensation.

a. Freezing point system standard contact point

A temperature of 0° C is created by using broken ice and clean water. This unit is selling on the market.

b. Constant temperature/constant room temperature system standard contact point

The temperature of the standard contact point is kept at a constant level either by fixing the room temperature, by a thermostat, or by any other means. Then a thermal electromotive force equivalent to the temperature of the standard contact point, is added to the normal thermal electromotive force to obtain a thermal electromotive force at 0° C standard.

c. Compensating standard contact point

The effect of the standard contact point's temperature is automatically compensated for by a bimetal or an electric means (utilization of a difference in the resistance temperature coefficient between two different kinds of metal or the temperature characteristics of silicon diode in a normal direction).

d. Heat/electricity converter

When converting a detected signal to a unified signal and sending it to a measuring instrument, it is a common practice that compensation of contact point for the standard is automatically carried out in the converter concurrently.

(2) Resistance thermometers

The principle of the resistance thermometer is to measure a temperature by utilizing the constant relationship between the electric resistance of a metal or a semi-conductor and the temperature. The required characteristics of the element are as follows: simple and as linear a relationship as possible between resistance and temperature, high temperature coefficient, simple manufacture, high interchangeability, reproducibility and stability, as extensive an application range as possible, less susceptibility to influences other than temperature, and qualitative deterioration. The

only materials which can meet the above conditions are pure metallic wire and thermistor.

A) Metallic wire resistance thermometers

Platinum, having high interchangeability and temperature characteristics, is most extensively used as the wire material. Nickel or copper is rarely used. The standard measurement range is −200 to 600° C. The normally adopted resistance value of wire at 0° C is 50 and 100 ohms. From the viewpoint of structure, the protective tube type and the sheathed type are available. (Fig. III-9-5)

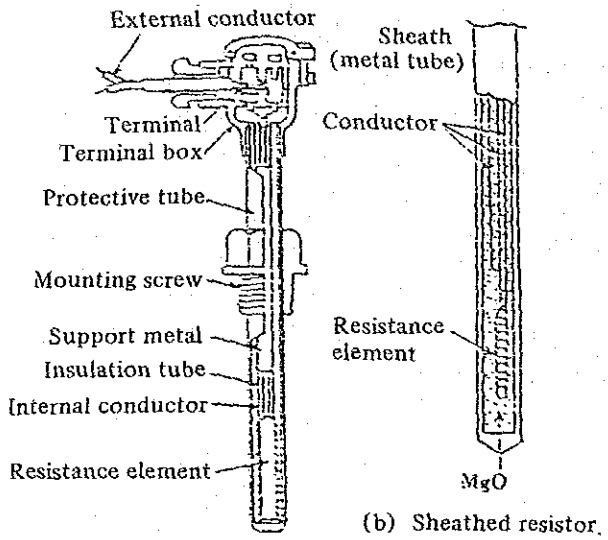



Fig. III−9−5 Resitance thermometer

As a simple model, the double conductor system is used. However, in order to reduce the effect of conductor resistance, the tri-conductor system is used for general industrial applications and the tetra-conductor system for precision work.

B) Thermistor thermometers

The thermistor is a semi-conductor manufactured by mixing and sintering metal oxides such as nickel, manganese and cobalt at high temperatures. In addition, the thermistor has a large negative temperature coefficient and also a high specific resistance. The characteristics of the thermometer are that it is provided with a small sensor, so its manufacturing cost is low and its response is quick. The working temperature range is approx. −50 to 300° C. Therefore, the thermometer is not suitable for measuring a wide temperature range, but is suitable for measuring a microdifference of temperatures.

(3) Radiation thermometers

(Principle)

Every body emits or absorbs energy in the form of electromagnetic waves according to its temperature. The radiant energy value is determined by the temperature and quality of body. It is the principle of the radiation thermometers to measure the surface temperature of an object through the measurement of the said

radiant energy. The thermometers have characteristics of not being contacted to high temperatures, quick responsiveness, and does not disturb the thermal condition of a measured object. For these characteristics, the thermometers are extensively used for industrial purposes. The energy value $W_B$ which is emitted from the perfect black body at a temperature of T (K) is expressed by the following equation:

$$W_B = \sigma T_b^4 (W/m^2)$$

Here

$\sigma = 5.67 \times 10^{-8}\ W/m^2K_o^4$ $T_b$ is to be identified by measuring $W_B$. However, the true temperature T(K) of a measured object is represented by the equation $T = T_b/\epsilon_o^{1/4}$.

Where,

$\epsilon_o$ is effective emissivity and is determined by the surface emissivity and the shape of an object, ambient thermal condition, the existence of gas, measuring direction, the wave length of radiant rays, etc.

A) Optical pyrometer (Fig. III-9-6)

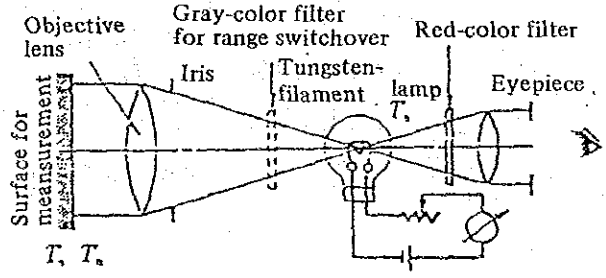



Fig. III–9–6 Principle of filament vanishing-type pyrometer

This thermometer uses a thermal emission of a wave length range close to monochrome in the visible zone. It is possible to precisely measure (± 1%) the temperature range of 0 to 3,500° C with the naked eye. An image of the measured surface is formed on a tungsten filament through an objective lens and the electric current is adjusted so that the brightness of the filament may match that of the image. Thus the temperature of a measured surface can be determined by the relationship between filament current and brightness temperature $T_b$.

B) Photoelectric-type optical pyrometer

This thermometer provided with a photoelectric-type multiplication tube or a detector such as Si or PbS instead of the naked eye, uses a narrow wave length band combined with a proper optical system. If the infrared ray band is utilized, the pyrometer can measure temperature to below 120° C.

C) Total radiation thermometer

This thermometer uses a wide radiant wave length band. A thermopile, a bolometer (film-type temperature measuring resistor), etc. are used as detection elements. Fig. III-9-7 shows the principle of the most ordinary type.

For measurement of the furnace temperature, a transmitter with a cooler or an air blow-in tube is often used (Fig. III-9-8).

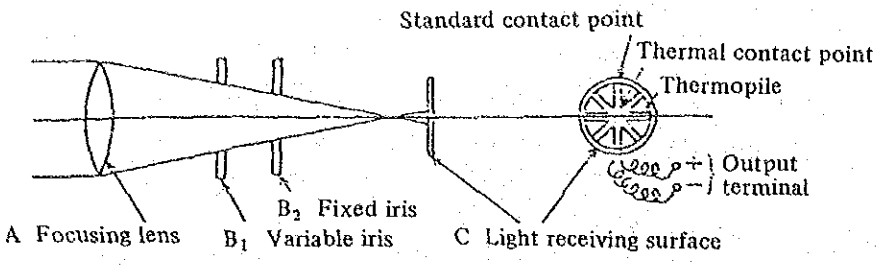



Fig. III–9–7 **Principle of transmitter for total radiation thermometer (Lens light focusing-type)**

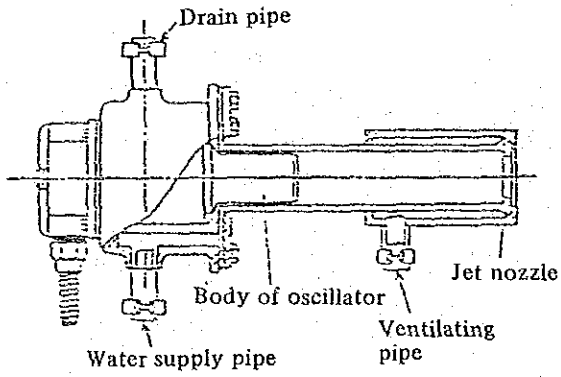



Fig. III–9–8 **Transmitter with water-cooling pipe and air blow-in pipe**

(4) Other thermometers

These thermometers are: the fluid-filled glass thermometer using the thermal expansion of a liquid sealed in a glass tube, the bimetal thermometer indicating a temperature with a pointer which receives a deflection of a bimetal sheet consisting of two different kinds of metal plate attached together with each having a different thermal expansion factor, and the pressure-type thermometer indicating a temperature by converting a volume change in the gas filled in the sensor by its temperature, to a pressure.

(5) Caution in temperature measurement

A) Error by thermal radiation

When measuring the temperature of a gas flowing through the interior of a duct with a thermometer inserted into the duct, the sensor reaches a balanced temperature where the heat received from a gas by convective heat transfer and the heat given to the duct wall by radiant heat transfer are equal. As a result, the thermometer indicates a lower value than the true temperature of the liquid. This difference amounts to over 100° C as the case may be. In order to eliminate this error, a thermometer is shielded with as many layers of the thin cylinders of low emissivity, or a thermometer of suction-type which make the fluid velocity in the sensor high is used (Fig. III-9-9).

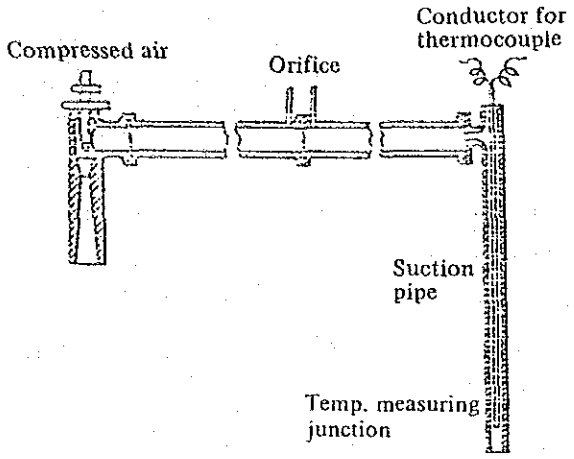



Fig. III–9–9 Suction-type thermocouple

B) Error by thermal conduction

The sensor, besides contacting an object measured for temperature, is in contact with the outside. If a sufficiently large thermal capacity representing "heat sink" exists outside, the temperature of the sensor will be different from the temperature of an object measured on account of the thermal conduction.

As a means to prevent this phenomenon, it is said that the protective tube should be inserted into a depth 15 to 20 times larger than its diameter. The installation way for the sensor also has something to do with the error. Therefore, attention needs to be given to this point (refer to Fig. III-9-10).

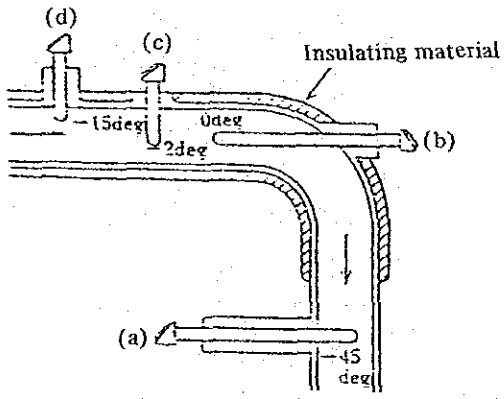



Fig. III–9–10 Error by thermocouple mounting ways

C) Error of the radiation thermometer

Generally, the radiation thermometer is calibrated at black body temperature by black body radiation. As the surface of an object to be measured is, in most cases, not a black body. It is possible to correct measurements, if the emissivity is known. Otherwise, measure as close to black body conditions as possible (make a hole, measure a cavity or use a peep pipe for insertion in the case of fluid).

In addition, the solar ray, electric light, reflection from another object and the effect of an absorptive material would cause an error.

1.2 Measurement of flow

The flow measuring instruments are roughly classified as the flow meter which directly or indirectly measures the volume per unit time of fluid flowing through a certain cross-section, and the current meter which determines the volume of fluid flowing through a certain cross section by measuring the average velocity of fluid.

(1) Flow meters

A) Volumetric flow meter

The typical volumetric flow meter is classified as the Oval gear type and the Roots type as shown in Fig. III-9-11.

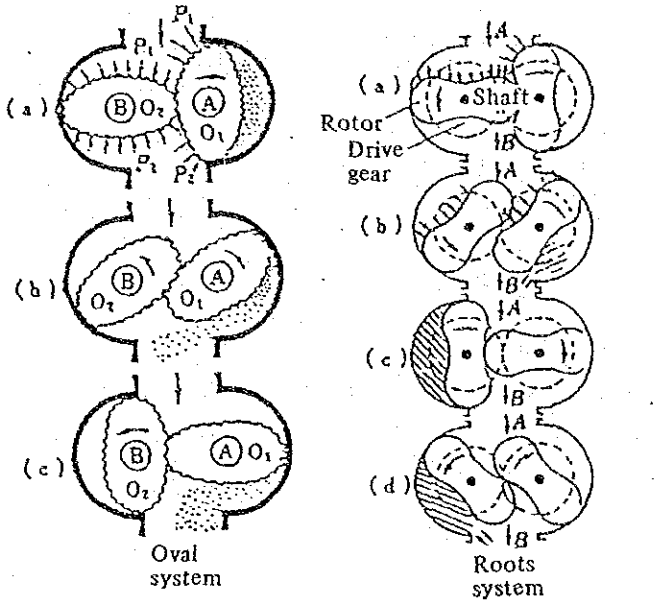



Fig. III–9–11 Rotor-type flow meter

Two pieces of rotor closely contacting to each other in the casing are rotated through the differential pressure between the inlet side and the outlet side without a dead point. The volume of fluid surrounded by the rotors and the casing is subjected to measurement. It is possible to minimize the leakage between the rotor and the casing by virtue of precision fabrication and assembly, and to carry out highly accurate measurements over an extreme flow range. One of the characteristics of this flow meter is that it is barely affected by the influence of fluid density, viscosity and current velocity distribution.

B) Area-type flow meters

If a float is provided in the tapered tube and fluid is caused to flow in direction from bottom to top, it becomes stationary at position where the sum of the differential pressure generated between above and under the float and the bouyancy of the float matches the weight of the float.

These flow meters use this principle. The area-type flow meters are classified into the following two types:

a. Glass tube (or plastic tube) area-type flow meter

Since the tapered tube is transparent, the movement of the float is visible.

Accordingly, it is possible to read the flow directly by a scale provided on the tapered tube. However, because of its short mechanical strength, the flow meter must be installed carefully and be protected against a sharp change in temperature and flow.

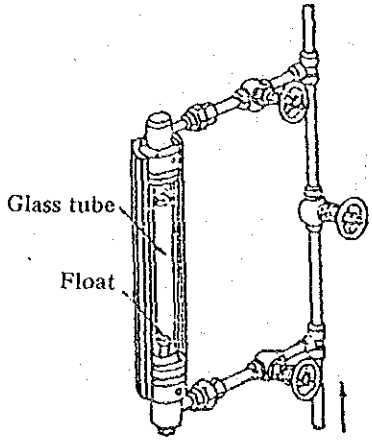



Fig. III–9–12 Glass tube area-type flow meter

b. Metallic tube area-type flow meter

A tapered tube of stainless steel is used and the position of the float is detected by a magnet. In addition, the detected value is transmitted after being converted to air and electricity through a linking mechanism. Because of it being of the metal tube type, the flow meter is characteristic of withstanding high temperature and high pressure. It is also used for measuring the flow of heavy oil.

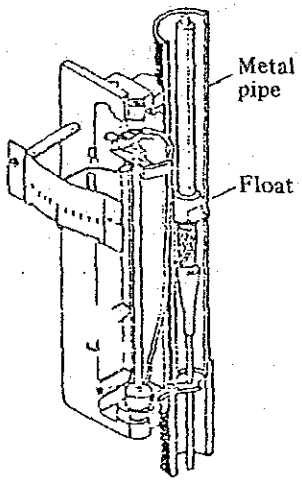



Fig. III–9–13 Metal pipe area-type flow meter

C) Flow measurement by the throttle mechanism

The Bernoulli's theorem "the differential pressure generated before and after a throttle provided in the duct is proportional to the square of the velocity of fluid passing through the throttle", is used for measurement of flow measurement.

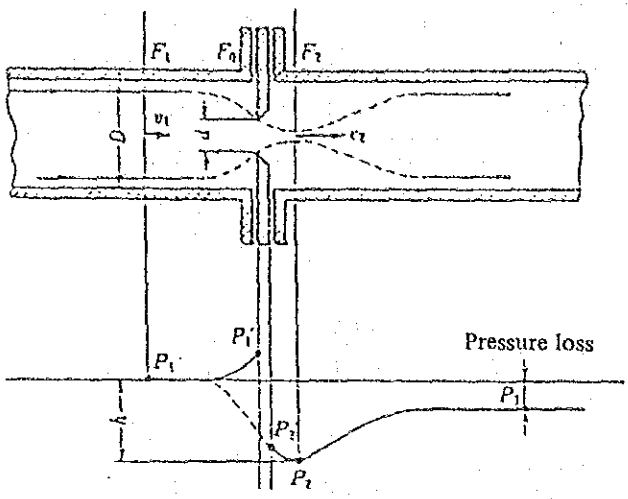



Fig. III–9–14 Differential pressure generation mechanism

Generally, this device is composed of a throttle mechanism such as orifice plate and venturi tube, and a differential pressure transmitter which converts the differential pressure received to an air pressure or an electric signal. Many countries maintain the standards for the shape of throttle, dimensional error, finish, differential pressure outtake system, etc. It is also necessary to consider the provision of a sufficient straight tubular length in the upstream part of the location where this device is installed to eliminate error caused by an insufficient current velocity distribution. The characteristic of this device is that regardless of whether it be gas or liquid of the range of pressure and temperature, it is possible to measure the flow within a certain range of accuracy—if the device meets the specified requirements of throttle mechanism.

D) Turbine meters

An impeller installed in the current rotates almost in proportion to velocity. The turbine meter measures flow, using this principle. The turbine meters are classified as the tangential flow-type impeller flow meter having an impeller shaft installed at a right angle with the current (Fig. III-9-15) and the axial flow-type impeller flow meter provided with an impeller shaft mounted in parallel with the current (Fig. III-9-16).

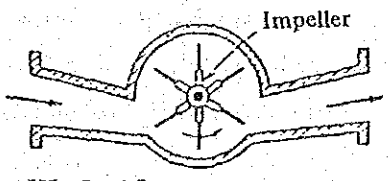



Fig. III–9–15
Tangential water impeller-type flow meter

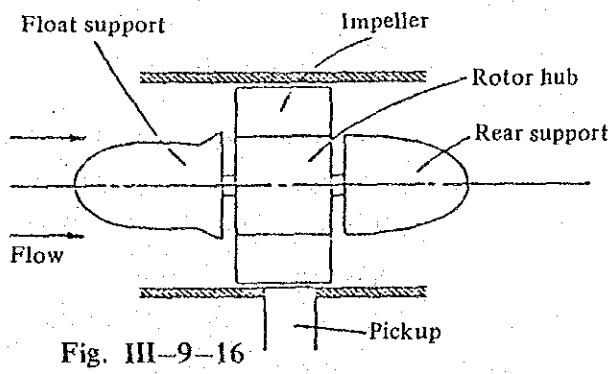



Fig. III–9–16
Principle mechanism of turbine meter

The tangential flow type is of a simple structure, but often develops leakage and shows low measurement accuracy. In most cases, it is used as a city water meter. The axial flow-type can minimize mechanical and hydrodynamic friction comparing driving force, thus making high-precision flow measurement possible. The type generally called "turbine meter" refers to the high-precision industrial flow meter (precision 0.2%) possible. The rotation of the impeller is detected in the form of electromagnetic induction or inductance changes. These changes are then processed into signals by means of a preamplifier and transmitted distantly.

The turbine meters are characteristic of having a proportional relationship between the number of rotations and the flow over an extensive flow range. This relationship is affected by the viscosity of fluid, so the meter needs to be calibrated by the same fluid as fluid to be measured. Besides, a straight part approx. 10 times the diameter of pipe must be provided at the upstream side. The installation angle and position of the meter would adversely affect the characteristics of flow. Therefore, attention should be given to this point.

E) Electromagnetic flow meter

If an electroconductive fluid runs at right angles in the AC magnetic field, an electromotive force will occur between both ends of the conduit section. This is Faraday's law of electromagnetic induction. This flow meter uses the principle "electromotive force is proportional to the average flow velocity." (Fig. III-9-17)

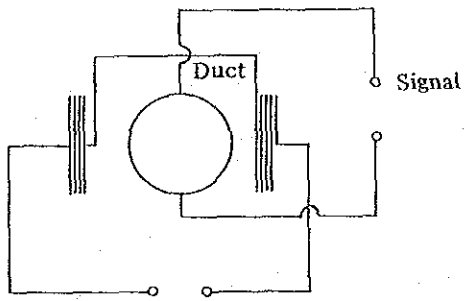



Fig. III–9–17 Principle of electromagnetic flow meter

The generated electromotive force is weak, so it is amplified to be processed into a signal and this signal is transmitted.

The detector has no movable part and accordingly almost no fluid resistance. Even if admixture were present, the flow meter would not develop trouble. This is a characteristic of the electromagnetic flow meter. Further, if any appropriate materials are used for lining and electrodes, it is possible to measure the flow of highly corrosive liquid or slurry. It is also possible to measure the flow in both normal and reverse directions. From the viewpoint of principle, gas and oil cannot to be measured with this flow meter. When installing the flow meter, a straight length approx. 5 times the diameter of pipe is required at the upstream side.

F) Supersonic flow meter

This flow meter uses the principle "the velocity of sound transmitted in the fluid

varies according to the velocity of fluid". The flow meter is of such a design that a set of wave senders/receivers capable of sending and receiving the supersonic waves installed across the duct, switch sending and receiving operations alternately every predetermined period. The flow meter counts the number of supersonic pulses during such a switchover action and obtains the flow by the difference in the count (Fig. III-9-18).

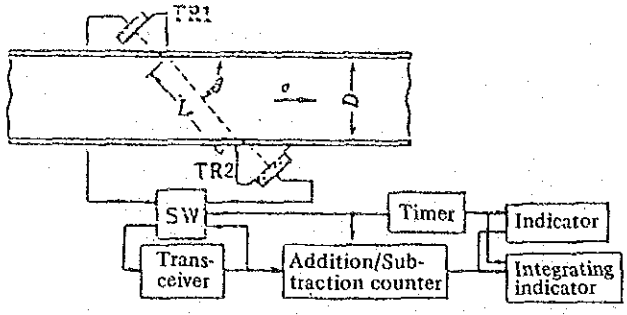



Fig. III-9-18 Principle of supersonic flow meter

The supersonic pulse is transmitted by $TR_1$ and then is received by $TR_2$, passing through the fluid. If the system is so designed that this pulse may be detected and amplified by the transceiver and such an amplified pulse may be transmitted by $TR_1$ again, the pulse will be oscillated at a frequency related to the velocity of fluid flowing through the duct. The same is true about the case where the supersonic waves are transmitted by $TR_2$ and received by $TR_1$. Based on the difference in the frequency of pulses in a predetermined time between the aforementioned two cases, it is possible to measure the flow with the help of an addition and subtraction counter and a digital/analog converter. This instrument is extensively used as a large-caliber flow meter for city water systems.

G) Vortex flow meter

If a column is set in the current, a stable vortex (Kármán vortex) is generated at a steady position in the downstream part by the exfoliation of a boundary film. The number of vortexes generated in a unit time is proportional to the current velocity. This flow meter adopts this principle. (Fig. III-9-19)

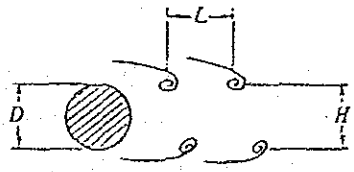



Fig. III-9-19 Karman's vortex street

The generated vortex is accompanied by a pressure variation, so this pressure variation is received by the semi-conductor strain gauge. The electric resistance variation of the strain gauge is converted to a voltage change, and this voltage change is amplified and waveshaped, and then transmitted. This flow meter has characteristics of wide measurement range and having no movable part provided. However, if the fluid used is corrosive or contains an adhesive material, the shape of the vortex

generator becomes abnormal, resulting in the change in the relationship between the velocity and the frequency for vortex generation. Therefore, the flow meter is not suitable for such a kind of fluid. In addition, since it is of a principle to utilize vibration phenomenon, the flow meter shall not be set at a place where mechanical vibration occurs. The vortex flow meter is extensively used for whatever materials, liquid, or gas.

(2) Current meters

A) Pitot tube

This tube is designed to measure the current velocity by utilizing the principle "the differential pressure between the total pressure shown by the tube with a perpendicular opening to the current and the static pressure shown by the tube perforated parallel the flow is in proportion to the square of the velocity. However, the differential pressure generated is so low as to be only 6.5 mm $H_2O$ at an air velocity of 10 m/s. Therefore, the high-sensitivity differential pressure gauge is required.

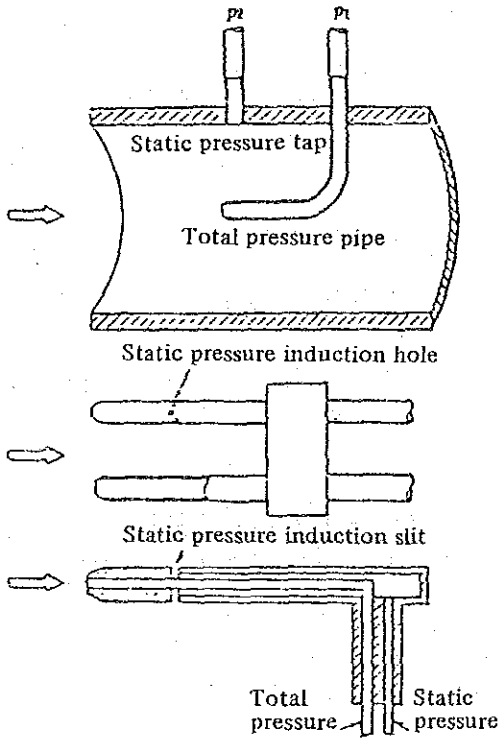



Fig. III–9–20 Various types of Pitot pipe

When using this tube, attention shall be given to the following:

① Match the axis of the tube with the direction of the current perfectly (the position where the differential pressure is maximum), ② arrange so that the Pitot tube inserted may not cause any current turbulence to an allowable maximum extent and ③ provide the Pitot tube with as small a diameter as possible compared with a pipe for fluid to be measured.

B) Hot wire anemometers

If a constant electric current is made on an electric hot wire arranged at a right

angle with the current, the electric power input and the quantity of heat transferred to fluid will be balanced. These anemometers use a constant relationship existing between the temperature of electric hot wire and the fluid velocity under the abovementioned balanced condition. For temperature detection, the thermocouple, resistance thermometer, thermistor, etc. are used. The anemometers whose heaters itself detect temperatures are called "direct heating types" and those whose heaters are separated from the temperature detection function are called "side heating types". The thermocouple is used in the latter. The basic circuitry and characteristics of the hot wire anemometer are shown in Fig. III-9-21. In addition to the above types, the direct heating types with platinum hot wires contained in the bridge which are automatically balanced for making the temperatures of hot wires constant, and the types for balancing $\theta$-$\theta_o$ constantly are available.

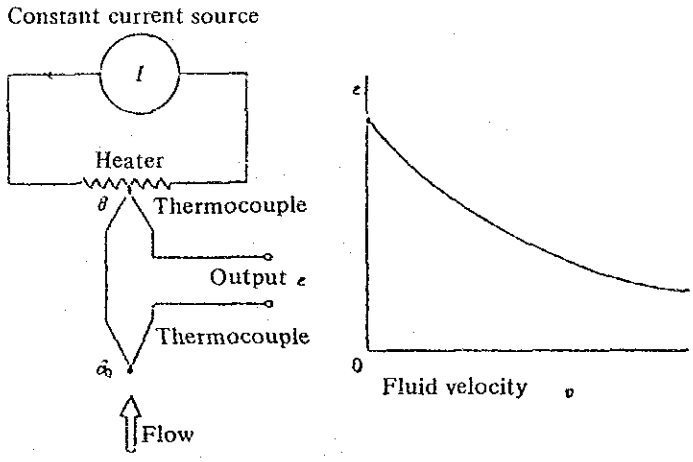



Fig. III–9–21 Thermocouple-type constant current anemometer

1.3 Pressure measurements

(1) Primary manometer (absolute measurement)

If pressure desired to be measured are induced to both ends of the U-tube or the single tube containing water, mercury, etc., the differential pressure between these ends can be measured by the difference in the heights of liquid columns. This manometer is called "liquid column manometer." (Fig. III-9-22)

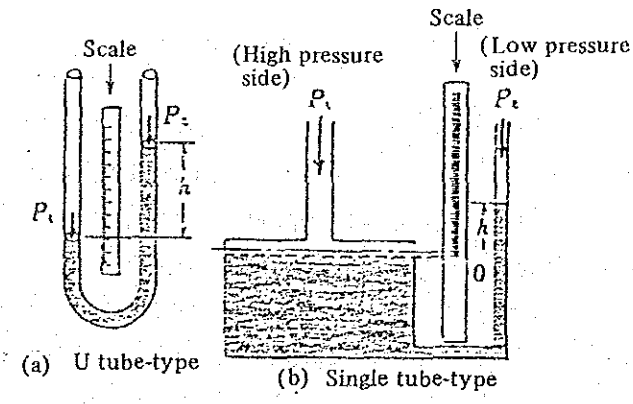



Fig. III–9–22 Liquid column manometer

In case the differential pressure is insignificant, if the inclined single tube is used, the length of the liquid column is enlarged, making the measurement feasible (capable of measuring the differential pressure of up to 0.01 mm $H_2O$ over the measurement range of 50 mm $H_2O$).

This manometer can easily develop errors under the influence of direct sunlight or thermal radiation or contaminated tube wall. Therefore, attention needs to be given to this point.

(2) Secondary manometer (relative measurement; Fig. III-9-23)

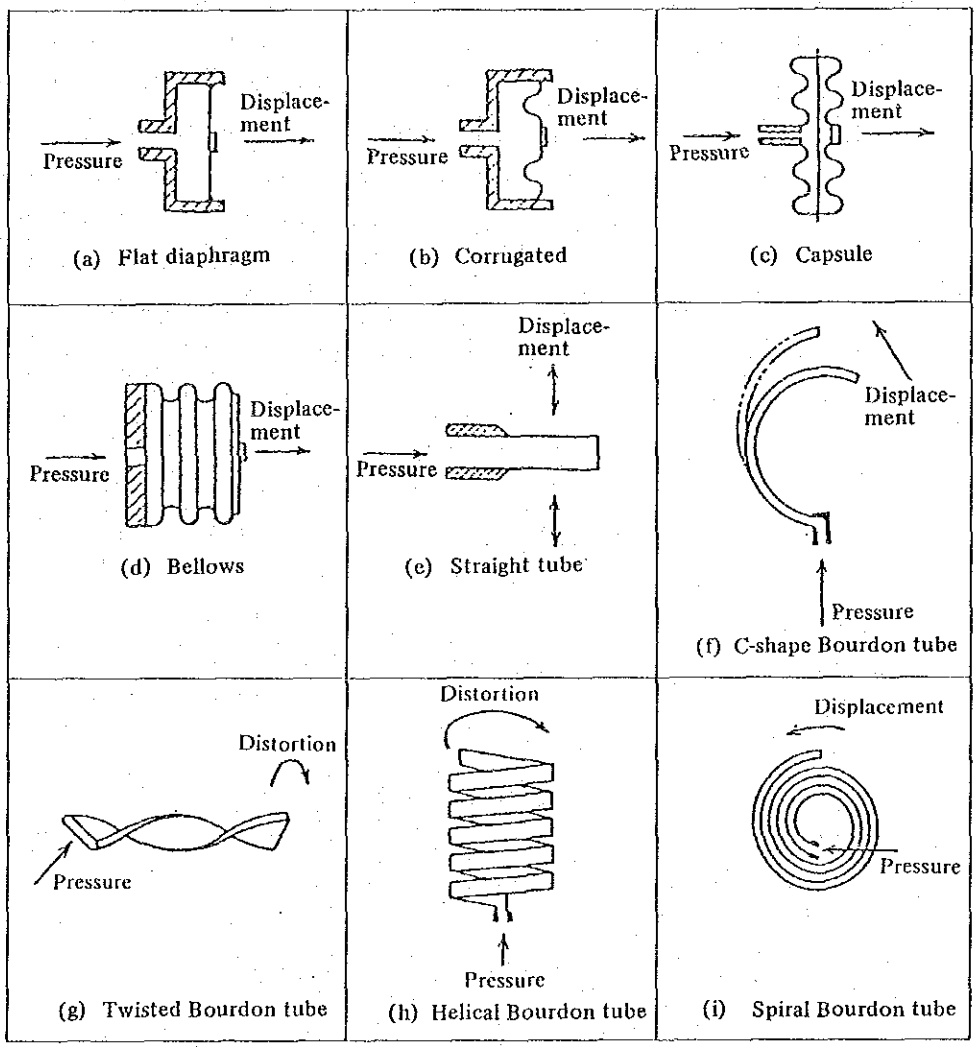



Fig. III–9–23 Elastic pressure-sensitive elements

This manometer uses physical properties such as elastic deformation of body, electric resistance, piezo-electricity etc, and various types of manometer are available. Explanation is made of the typical types for industrial use here.

A) Bourdon tube manometer

If pressure is applied through a fixed opening of an archwise bended tube which has cross section shaped ellipse or oval and has the end sealed, the sealed end is displaced as a free end. This manometer adopts this principle. Phosphor bronze, beryllium steel, etc. are generally used as materials for the Bourdon tube. Corrosion-

resistant stainless steel tube, special steel drawn pipe for high pressure use, fused quartz tube for low pressure precision measurement, etc. are available.

The accuracy is approx. 0.5 to 3% depending on structure.

B) Diaphragm manometer

This manometer uses the pressure deformation of a circular sheet with the periphery fixed. The diaphragm is corrugated or flat. The former has an increased effective area and stiffness. Accordingly, it is possible to manufacture various types of diaphragm manometer having different pressure and deflection characteristics. Materials used for this manometer are almost the same as those for the Buldon tube. However, when specially high corrosion resistance is required, tantalum, hastelloy, monel metal, etc. are employed. When a deflection is secondarily converted by a transducer, it is possible to electrically amplify or transmit the signal.

When fluid to be measured is at high temperatures, mixed with a solid, highly viscous or corrosive, the diaphragm is used as a partition, and silicon oil (working temperature: 40 to 230° C) or mercury (−330° C) is filled between the diaphragm and the sensor. Thus pressure is measured indirectly. Some types use this principle.

The accuracy of the diaphragm manometer is 0.2 to 2%.

C) *Corrugated capsule manometer*

Two pieces of corrugated diaphragm are plied back to front with the periphery welded together. If pressure is applied, each diaphragm receives the same pressure, thus producing a deflection twice as much as when a single diaphragm is used. In order to multiply the deflection, the diaphragm can be made multi-stage. In such a case, the multiplication is equivalent to the number of diaphragms provided. The capsule manometer welded and sealed in vacuum is used for low pressure measurement or as a barometer.

D) Bellows manometers

These manometers are provided with metallic bellows serving as pressure receivers. So they are characteristic of showing a significant deflection for a small effective area. The same materials used for the Bourdon tube or the disphragm are employed for the bellows manometers. The measurable pressure range is 0 to 10 $kg/cm^2$. Some types use a spring as an auxiliary part to improve the characteristics, because the linearity between pressure and deflection is not satisfactory.

E) Pressure transducers

Pressure is converted to deflection by means of elastic element and this is further converted to an electric signal. Explanation is made of the most popular types below:

a. Strain gauge

This gauge utilizes the principle "the electric resistance of metal wire is changed by strain". The deformation or deflection of an elastic body is converted to a change of electric resistance. The semi-conductor also shows a resistance value change by strain caused by an external force, so it is used for the strain gauge.

b. Capacitor types

A condenser formed between one of flat sheet-type metal diaphragm as one

electrode and one or two of corresponding fixed electrodes is assembled into a resonance circuit. Then a change in the resonant state when the diaphragm is deflected, is took out in the form of voltage or current signal.

c. Induction types

The deflection is converted to a change in the inductance and then it is took out in the form of a change in the frequency of the resonance circuit. Generally, a change in the inductance is made by a method to change magnetic permeability. In this method, a core of high magnetic permeability inserted into the coil is displaced or a magnetic diaphragm in the proximity of an iron core coil is displaced.

1.4 Level measurements

The classification and gain/loss of various level meters are shown in Table III-9-3.

(1) Gauge glass

A tube of transparent material such as glass is provided outside a vessel and the level of liquid contained inside is read on a scale. The gauge glass is classified as transparent types and reflection types from a structural point of view. It is of simple structure, and is heat- and pressure-resistant, so that it is extensively used for boilers or high-pressure tanks.

However, the glass gauge is vulnerable to thermal shock or a difference of the thermal expansion coefficient from that of metal results in breakage. Attention must be given to these points.

(2) Float types

The vertical shift of a float restricted by a guide rope on the surface of liquid is took out by a stainless steel tape or a steel wire, and read by the indication mechanism using a gear train, or read by the level of a scale. This method is extensively used for storage tanks at atmospheric pressure.

(3) Displacement types (Fig. III-9-24)

If a cylindrical displacer with a constant cross-section area is set in the liquid, it receives a buoyancy equivalent to the volume submerged in the liquid. Therefore, it is possible to measure the level of liquid by detecting the weight of the displacer. The below listed three types of measurement mechanisms using a variation of buoyancy are available:

a. Balance type:

Bellows, diaphragm, bending tube, etc. are used for detection.

b. Torque tube type:

Twist generated in the torque tube is used for detection.

c. Spring type

The expansion value of spring generated by applying force to the spring through a rod linkage is took out by solenoid.

The variation of buoyancy detected is processed by the force balance method or the mechanical displacement method into air pressure signal or electric signal, and transmitted. This type is of compact structure and durable against high temperatures

and pressures. For these reasons, it is extensively used at refinery and chemical plants.

Table III–9–3 Classification of level meters and characteristics comparison

| System | | | Accuracy | Characteristics | | Applicable to | Service |
|---|---|---|---|---|---|---|---|
| | | | | Shortcomings | Advantages | | |
| Measuring scale system | | | 1 ~ 5 mm (Individual difference exists) | Simple, highly accurate and low-priced. | Labor is required. Impossible to measure a sealed tank, danger is involved and impossible to transmit signals. | Liquid and powder | General open tank, silo, bunker and hopper |
| Gauge glass system | | | 0.5 ~ 1 mm (Changes by surface tension) | Simple, highly accurate and low-priced. | If fouled, difficult to read, glass might be broken and impossible to transmit signals. | Liquid | General tank, boiler and spherical tank. |
| Conductivity-type level switch | | | 1 ~ 50 mm (Varies according to sensitivity) | Simple to mount/handle, low-priced, no movable part and highly durable. | Can be used only for conductive liquid and the conductive and insulated part are fouled. | Liquid (powder) and border between 2 liquids. | Water facilities and boiler |
| Electrostatic capacity | Level meter | | 1 ~ 2% (Excluding a change in dielectric constant) | Simple, low-priced, no movable part, highly corrosion-resistant, and can be used for liquid and powder. | Change in dielectric constant (change in temp. and moisture), attachment to probe and less assurate. | Liquid, powder and border between 2 liquids. | General and border surface measurement. |
| | Level switch | | (Varies according to condition for mounting) | Simple, low-priced, no movable part, highly corrosion-resistant and can be used for liquid and powder. | Change in dielectric constant (change in temp. and moisture) and attachment to probe. | Liquid, powder and border between 2 liquids. | General and border surface measurement. |
| Float system | Level meter | | 1.5 ~ 3 mm (Excluding various problems involved in mounting) | Highly accurate, simple to handle, possible to transmit signals and alarm. | Movable part and structure are required in tank and less corosion resistant. | Liquid and border between 2 liquids. | Inventory control for petroleum products and general of others |
| | Level switch | | 2 ~ 10 mm | Simple, easy to handle and low-priced. | Movable part exists in tank. Less corrosion-resistant. | Liquid and border between 2 liquids. | General |
| Displacement system | Level meter | | 0.5 ~ 1.5% (Excluding a change in specific gravity) | Durable against high pressure, highly responsive and possible to transmit signals. | Costly, error might occur due to a change in specific gravity, and unsuitable for high viscosity liquid. | Liquid and border between 2 liquids. | On-site level control and minor span level measurement |
| | Level switch | | 2 ~ 10 mm | Durable against high pressure, no shaft and low-priced. | Less corrosion-resistant. | Liquid and border between 2 liquids. | General |
| Differential pressure system | Level meter | | 0.5 ~ 1.5% (Excluding a change in specific gravity) | Durable against high temp. and pressure, possible to transmit signals and highly corrosion-resistant. | Error might occur due to a change in specific gravity. Consumes gas (bubble system). | Liquid and border between 2 liquids. | On-site level control and general |
| | Level switch | | (Varies according to specific gravity and span) | Simple and easy to maintain safety. | Low accuracy, and error might occur due to a change in specific gravity. Be careful about viscosity and a solid. | Liquid and powder. | General |
| Supersonic system | Level meter | | 1 ~ 2% | No relationship with physical property, no contact and no structure is required in tank. | Correction of temp. is required. Be careful about the effect of wind and noise. | Liquid, powder and border between 2 liquids. | Tanker's tank level measurement, food storage tank and silo for lump products |
| | Level switch | Beam | 50 ~ 100 mm | No relationship with physical property, and no structure is required in tank. | Be careful about the effect of wind, reflection and noise. | Powder | Silo level control for lump products and cake level control |
| | | Vibration diaphragm | 1 ~ 2 mm | No movable part, compact and no relationship with physical property. | Unsuitable for high viscosity, be careful about attachment and error in action due to bubble. | Liquid | Food storage tank level control and small-capacity tank |
| | | Tuning fork | (According to the condition of powder surface) | No movable part, highly sensitive and no relationship with physical property. | Vibrates and powder attaches. | Powder and border between liquid and powder. | Powder and granule silo, hopper and border surface control for liquid and powder. |
| Radiant ray system | Level meter | | (Depending on a condition) | No structure is required in tank, less influence of physical property and durable against high temp. and pressure. | Responsible person for radiant ray is required. | Liquid and powder. | Reactor, cupola and high-temp. and high-pressure tank. |
| | Level switch | | (Depending on a condition) | No structure is required in tank, influence of physical property and durable against high temp. and pressure. | Responsible person for radiant ray is required. | Liquid and powder. | Reactor, cupola and high-temp. and high-pressure tank. |

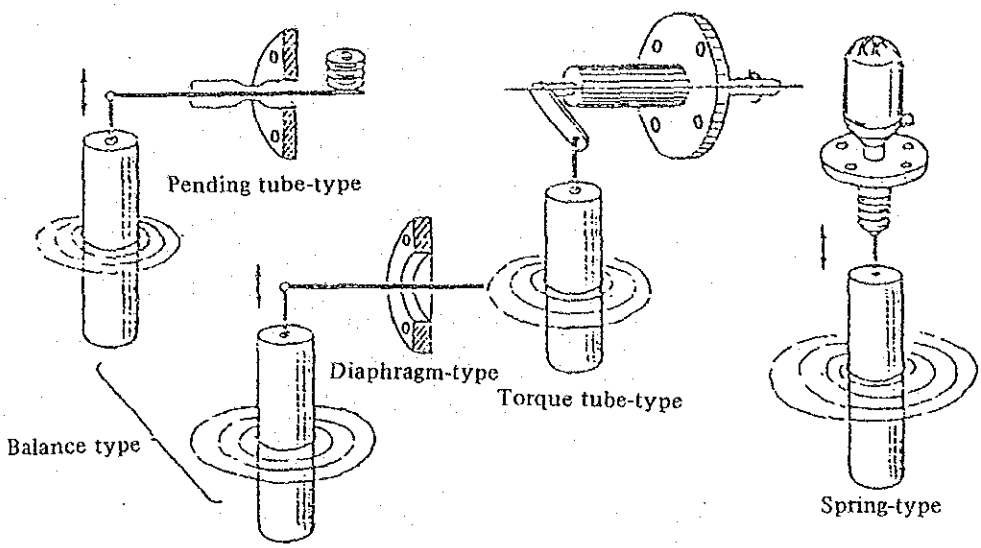



Fig. III–9–24 Displacement system

(4) Differential pressure types

Since the static pressure under the liquid level is proportional to the depth of liquid, it is possible to determine the level by measuring the differential pressure between a point at the liquid bottom and the upper space. There are the following four different means of measuring the differential pressure:

a. Bourdon tube manometer

This is the simplest design used for storage tankage and vessels of atmospheric pressure specification. (Fig. III-9-25)

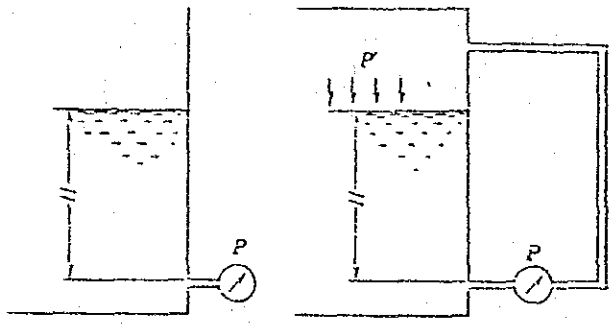



Fig. III–9–25 Differential pressure measurement method

b. Bubble type

If bubbles are released into the liquid from the tip of the pipe introduced to a depth close to the bottom of a liquid storage tank by sending air into the pipe, the back pressure in the pipe will be equal to the static pressure of liquid at the tip of the pipe. In the case where the storage tank contains internal pressure, if the same quantity of air is injected into the upper space, it is possible to measure the static pressure of liquid by a differential pressure between both parts. (Fig. III-9-26)

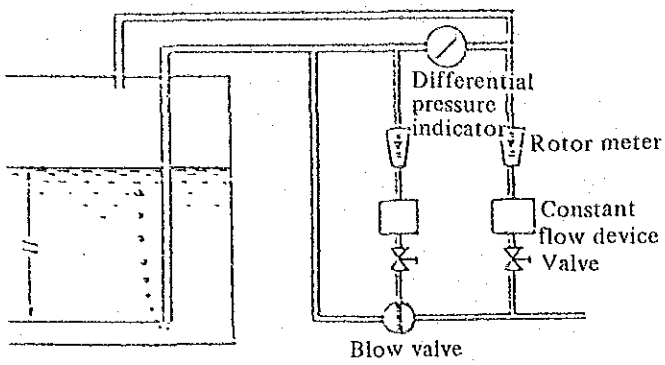


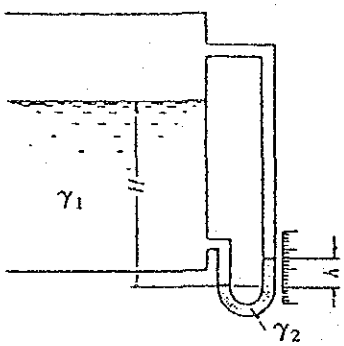

Fig. III–9–26 Bubble system

The detection accuracy can be heightened by maintaining a constant air release and minimizing the release resistance of bubbles. In the case where air release is dangerous, use an inert gas such as nitrogen. As this type has no movable part or mechanism, it is suitable for the use of corrosive liquids.

c. U-shape types (Fig. III-9-27)

The mechanisms of these types are similar to those shown in Fig. 25(b) of the Bourdon tube manometer. That is, the pressure is measured by the manometer.

Based on the relationship $H\gamma_1 = h\gamma_2$, H can be measured.




$\gamma_1$: Weight per unit volume of measured fluid (gf/cm$^3$), $\gamma_2$: weight of unit volume of fluid sealed in the manometer (gf/cm$^3$), (H): level in tank. h: level difference between the primary and the secondary side of manometer.

Fig. III–9–27 U-shape tube-type

d. Force balance types

Pressure or differential pressure is received by the diaphragm or bellows and then is converted to an electric signal or an air signal by mechanisms such as force balance and mechanical displacement. It is also possible to measure the level of liquid in the high-pressure tank or the level of highly viscous liquid with this type. The force balance types have high precision and quick response.

(5) Capacitor types

The static capacity between two pieces of mutually opposed electrodes is proportional to the area of electrodes board, the dielectric constant of charged substances and the reciprocal of the space between electrodes. These types use the principle that the body of a storage tank and a probe inserted into the former constitute the electrodes and a variation in the level of the storage tank content changes the static capacity. These types are comparatively low-priced and simple to install. Besides, they have no movable parts and high durability, so they can be used

for liquids and powders as well as for the surfaces between two different kinds of liquids.

Accordingly, their applications are extensive. However, an error may occur due to the change of the dielectric constant resulting from the variations of temperature, density, and composition of the object to be measured, or matter sticking to the probe. For this reason, be careful when these types are used.

The surface of some electrodes for the probe is coated with insulating materials such as teflon, nylon, polyethylene and PVC. However, select whichever may be appropriate according to the corrosiveness and adhesiveness of the object to be measured.

(6) Supersonic types

Traveling time during the supersonic pulse is sent from a transmitter installed on the top of a storage tank into the gas, and returns to the sensor reflected on the liquid surface or powder surface is measured. In this way, the level of liquid or powder is measured. (Wave transmission in gas type as shown in Fig. III-9-28(1).) Other devices: the wave transmission in liquid types having a sensor provided of the bottom of a storage tank as shown in Fig. III-9-28(2); and the wave transmission in solid types having a metal rod inserted into the storage tank, as medium as shown in Fig. III-9-28(3), are available.

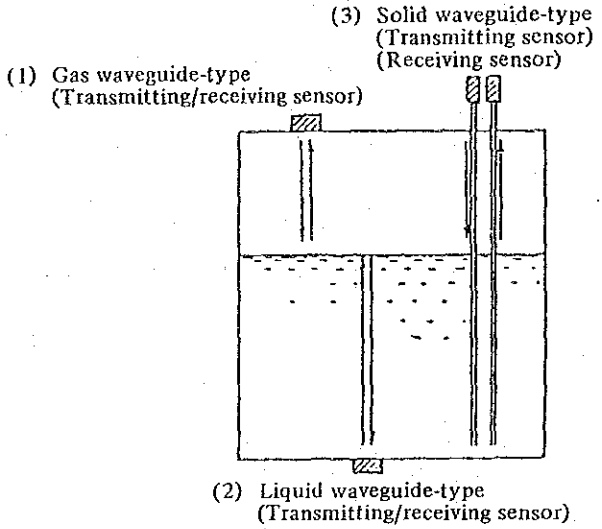



Fig. III–9–28 Supersonic-type level meter

1.5 Oxygen meters

It was often stressed that the $O_2$ concentration in combustion exhaust gas has an important relationship with thermal efficiency. It is indispensable to measure the $O_2$ concentration. The zirconia ceramic oxygen meter used extensively in Japan is described below:

Principle: Stabilized zirconia containing $ZrO_2$ with CaO or $Y_2O_3$ is an excellent oxygen ion conductor at high temperatures. Porous platinum electrodes are attached on both sides of the diaphragm of zirconia ceramic at high temperatures, thus making an electric cell (Fig. III-9-29). If gasses of varying oxygen partial pressure are allowed to contact each

platinum electrode, the potential difference according to the ratio of partial pressure is generated between the electrodes based on the principle of a concentration cell. When the $O_2$ partial pressure on one electrode is known,the $O_2$ partial pressure on the other, i.e. the $O_2$ concentration can be determined by measuring the potential difference.

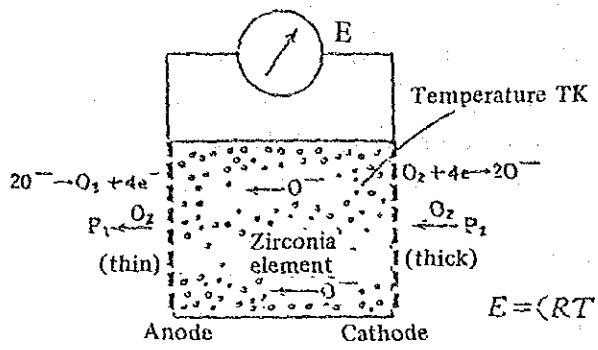



Fig. III–9–29 Principle of potential difference generation

In the actual instrument structure, the zirconia tube (detection cell) accommodated in the heater is built into the probe, and a standard gas is introduced into one side of the diaphragm, while a sample gas passing through the filter comes into contact the other, the potential difference detected is operated inside the receiver and is indicated at $O_2$ or convented to an electric signal. It is possible to make high-precision measurements ranging extensively from 50 to 60 ppm to the order of percent by selecting the proper concentration of standard gas.

When using this meter, attention should be given to the following:

(1) Error would occur because of the consumption of oxygen in the detection cell, if reductive components such as CO, and $H_2S$ exist in the gas.

(2) If dust adheres to the platinum electrode, the sensitivity becomes low.

(3) Unless the flow of sample gas is retained as specified, the drift point shift might occur.

## IV. Recommendation of Measures to Promote Energy Conservation in the Field of Manufacturing Industry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# 1. Introduction

## 1.1 Meaning of energy conservation

In studying how to promote energy conservation in the field of manufacturing industry, it is necessary, first of all, to make clear what energy conservation implies.

The word "energy conservation" is used in many ways case by case.

Here, "energy conservation" is used in the meaning of rationalization of energy use. More specifically, energy conservation implies not simply reducing energy consumption but rationalizing the use of energy so that minimum energy may be exploited in producing maximum output.

Therefore, the government's energy conservation measures are not to restrict production activities of industry or improvements in the national standards of living, rather they are steps to make use of energy most effectively, satisfying various social demands such as development of national economy and improvement of living standards, by saving waste of energy at each stage of consumption.

Reduction in energy consumption through the government's direct compulsory measures — for example, steps to compulsorily reduce energy consumption to a given level by adopting ration scheme — will involve, if implemented, more or less sacrifices in the form of lower production levels and lower living standards for people.

Also, when these measures are carried out, it would become unavoidable in many cases for the government to opt for a specific social value, and there is the possibility of problems of social impartiality cropping up as a result.

Viewed in this light, it may be said that such steps to control energy consumption directly should be justified only in emergencies.

Though Thailand has several problems in the field of energy, on the whole it does not seem that the energy situation in the country is alarming.

In some cases "energy conservation" is used even to denote reduction in oil consumption by developing non-conventional energy sources or oil substitutes, but in this report rationalization covering all kinds of energies is adopted as the subject.

## 1.2 Coverage of the Study~manufacturing industry

(1) Covered by the Study is energy conservation in the manufacturing industry, more strictly, more efficient use of energy in the production process at manufacturing factory.

In Thailand at present, the industrial sector is the second largest energy consumer next to the transport sector. It is expected that the industrial sector's share in total energy consumption will steadily augment, from now on, parallel to the rapid industrialization of the Thai economy. Also, compared with other sectors, energy-consuming place is less diffusive in the industrial sector (number of registered factory in Thailand: about 67,700). Besides, in this sector energy user is enterprise which primarily aims at profit-making. Enterprises are relatively well aware of the need to reduce energy costs and conserve energy, and their internal systems are relatively well-kept to that end. Because of this, the industrial sector may be expected to react

swiftly to the government's energy conservation measures.

For the abovementioned reasons, the manufacturing industry sector that appears most hopeful in bringing the results of energy conservation effectively, is chosen as the subject of the Study.

In Thailand, much energy is consumed also in transport, residential-commercial and energy industry sectors. Energy conservation efforts in these sectors too would be important in the future. Experience gained in the manufacturing industry might serve as a good reference for energy conservation in these sectors.

(2) Viewed from the macroeconomic standpoint, structural changes within the industrial sector exert substantial influence on energy conservation. In fact, as a result of oil-price rises over the past decade, production in the energy-intensive material industry has continued leveling off in many countries. On the contrary, production share of the processing and assembly industry or the service industry which are less energy-intensive and high added value type, has gone up, contributing a great deal to energy conservation on a nationwide level. However, in only few instances the industrial structure policy is regarded as the mean of attaining energy conservation.

Since industrial structure changes usually over a long periods, reflecting various economical and social needs such as optimum exploitation of national resources, securing employment and export promotion, it is thought inappropriate to decide on a course of industrial structure only from the viewpoint of energy conservation.

In other words, changes in the industrial structure can lead to energy conservation, but it should be considered carefully to take up them as the means of attaining energy conservation.

Rather, it is proper, in designing the measures, to aim firstly at energy conservation on the individual enterprise level, regarding industrial structure change as a postulate.

1.3 Relations between government and enterprises

(1) Energy conservation in the field of manufacturing industry is carried out by individual enterprises (factories). Actions which directly results in more efficient use of energy are taken by energy-consuming enterprises. The methods for these actions to be taken by enterprises has been stated minutely in Part III (Guideline).

Here, measures the government should adopt to promote energy conservation efforts of enterprises are taken up.

(2) The role to be fullfilled by the government in energy conservation lies in promoting the interests of enterprises in energy conservation, supporting and encouraging their energy conservation activities, and creating an environment conducive to energy conservation. The chief means to this end is providing information and incentives to enterprises.

Energy conservation is considered in many countries an important pillar of their energy policies. It seems that the influence government measures would have on results of energy conservation by enterprises is extremely great, especially under the

circumstances where the private sector has not amassed adequate technical information, talent and funds required to promote energy conservation. Hence the positive initiative of government is essential.

(3) Energy conservation has its own merits for both the government and enterprises, though the objectives each seeks to attain through energy conservation are not necessarily identical. Although the way emphasis is placed on differs according to countries, governments' objectives are economic development, security of national economy, and eradicating deficits in the balance of international payments, etc. The objective of enterprises is, on the other hand, realizing maximum profits through energy-cost reduction.

Therefore, there is inevitably a gap in perceiving priority for and importance of energy conservation between the government and enterprises.

Because of this, there is an absolute need for government and enterprises to communicate and cooperate as much as possible with each other to fill up such a perception gap in formulation and implementation of energy conservation measures.

Without understanding and cooperation on the part of enterprises, no tangible results can be expected.

The first prerequisite to the success of the government's energy conservation measures would be for the government to fully recognize the needs and interests of enterprises.

(4) In the case of energy conservation, the government's measures, as stated in the foregoing, evolve mainly around assistance and guidance. Accordingly, aside from formulation of the basic policy, there is necessarily no need for central government agencies to hold themselves responsible directly for all phases in implementing energy conservation measures; there are more than a few cases in which neutral semi-governmental organs can be entrusted with the task of implementing such measures.

In this report, therefore, the word "government" is used in a broad sense to include semigovernmental organs.

1.4 Results of energy conservation and its evaluation

(1) Energy conservation is considered, in many countries, as one of the major items of their energy policies, but it is rather an unattractive task compared with other items of energy policies, such as those concerning energy supplies, i.e., development of oil substitutes and investment in boosting oil- and power-production capacities.

This is largely ascribed to the fact that energy conservation is itself a countermeasure in the aspect of energy demand and that, even in the manufacturing sector where the consuming places are less diffusive, energy is consumed in many separate places. The results of energy conservation efforts made per energy-consuming workshops are negligible compared with the nationwide energy demand, thus attracting little attention.

However, if summed up, the results will bring on an unexpectedly large accumulation of substantial achievements in due time.

A simple calculation based on energy forecast made by NEA shows that the reduction in energy consumption to be attained during the forecasting period—through lowering the average annual increase rate of energy consumption from 7.1 percent (1973–1982) to 5 percent (1982–1991)—might reach about 20 million kl of crude oil equivalent, which surpasses the total quantity of lignites produced in Thailand during the period and corresponds to 50 percent of total natural gas production.

Hence, viewed from the macroscopic standpoint, energy conservation is definitely worth a considerable amount of funds and manpower.

(2) However, it is not easy to grasp precisely on a macroeconomic level to what extent the government's measures has contributed to energy conservation.

On an individual enterprises level, on the contrary, it is relatively easy to grasp the results of energy conservation efforts by comparing the production with the amount of energy consumed. It may happen that the energy consumption rate is affected, with the elapse of time, by factors such as changes in production methods, products and the rate of operation. Even in this case, data concerning such factors can readily be obtained within the enterprise. Therefore, it is possible for them to grasp the results of their own energy conservation efforts by supplementing the effects based on these factors and comparing the energy consumption rates at all times under the same conditions.

However, it is not easy to grasp precisely the results of energy conservation on a macroeconomic level, for instance the industrial sector as a whole, by supplementing the aforementioned factors.

Furthermore, it is extremely difficult to evaluate how much the government's measures has contributed to the results of energy conservation attained by the enterprises.

1.5 Recommendation items

Based on the abovementioned considerations, we think, in order to promote energy conservation in the field of Thai manufacturing industry, it is necessary to take up firstly the following three items as targets for government's measures and recommend details in the following section.

(A) Motivating entrepreneurs to carry out energy conservation;

(B) Improving energy conservation technical level of enterprises;

(C) Providing conditions necessary for investment in energy saving equipment.

As regards the establishment of a private organ for expediting energy conservation, the Thai project made marked progress during the study period and it was decided that a new energy conservation center be set up under the joint cooperation of the government and the private sectors. Since the outline of project for the energy conservation center has already been formulated, here, we will make some comment on the Thai project.

2. Motivating Entrepreneurs to carry out Energy Conservation

Energy conservation in the manufacturing industry sector is undertaken by enterprises (factories) which carry out energy conservation on their own responsibility and under their own judgment, as part of their profit-seeking activities.

Therefore, entrepreneur's interest in or will toward energy conservation are the major premise for the promotion of energy conservation. No matter how excellent may be the energy conservation plans formulated by the technical staff of enterprises, there is little possibility of such plans working successfully unless they are supported by the management. Indeed, whether enterprises succeed in energy conservation depends entirely on the commitment of the management.

Of the factories covered by the Study, private enterprises, family companies or small-sized enterprises whose management systems are not well-ordered occupied a fairly large percentage. In the case of these enterprises, it seems that "the top-down type" management where important decisions on business management are left entirely up to the discretion of the top management or owners is predominant.

Since such a trend appears common, more or less, to the industrial community in Thailand, the importance of motivating entrepreneurs to carry out energy conservation may be all the greater in Thailand.

At the factories we visited we found that the management were on the whole interested in energy conservation and well aware of the necessity of it.

However, taking into account that the purpose of the visits were to see energy conservation status there and the factories covered might be selected from among those originally having interest in energy conservation, it may be a bit rash to analogize the whole immediately out of a part.

The problem lies rather in the fact that in most factories the management's interest is confined only to personal level and not bearing fruit in the form of factorywide organized energy conservation activities based on the leadership of the top management.

Following are the points many factories have in common, which we found through interviews with the factory management and other people concerned:

A) The paucity of specialized technical information and technicians that are indispensable for implementing energy conservation;

B) The difficulty of raising funds for investment in energy saving equipment;

C) What should be done to push for energy conservation within factory is not well understood;

D) Not sure of the prospect about profits which will be realized through energy conservation;

Also, some people set forth the following opinions:

E) Information on the government's energy conservation measures is not fully provided;

F) Prospect for energy prices is not clear.

G) Energy conservation is the government's task and enterprises have only to follow government instructions.

H) There is no much need of energy conservation because a large quantity of natural gas will be developed in Thailand in the near future.

I) It is the government's responsibility to provide an adequate supply of energy.

J) It is advisable for enterprises to take action after the government works out good subsidy policy. Too early action would be disadvantageous to enterprises in the event the ration scheme be adopted in the future.

The abovementioned points prevent the management from giving energy conservation high priority among their management problems and tackling energy conservation with lasting interest.

In order to put energy conservation activities on the right track, there is the need for the government to implement the following measures to eradicate those points.

Of the aforementioned items, mention will be made separately of A) and B).

2.1 Energy conservation campaigns aimed at entrepreneurs

(1) There is the need for the government to keep entrepreneurs informed of the need for energy conservation and its will to promote energy conservation, to enlist their cooperation, and to listen to the views from enterprises.

Though in Thailand these attempts have been made more than once at meetings of the Joint Public/Private Sector Consultative Committee chaired by the prime minister or the management seminars, it is desirable to develop a more powerful campaign, considering a large number of factories which cover a diversity of types and scales.

(2) The major contents of information to be supplied to entrepreneurs are as follows:

A) The energy situation and its impact on the Thai economy

B) Prospects for energy demand and energy prices

C) The government's energy conservation measures, including aid to enterprises, and expectations on the industrial circles concerned

D) Factory energy management methods

E) Profits accruing from energy conservation

(3) The problem lies rather in how to communicate information. For instance, the following methods are conceivable:

A) To begin with, to make maximum use of all the opportunities for entrepreneurs to get together, such as meetings of economic and business organizations, and seminars for management. To this end, there is the need to keep in touch closely with organizations sponsoring such events.

B) To hold a national energy conservation conference regularly, for instance once a year, to be attended by entrepreneurs, concurrently with an energy conservation exhibition or a dissemination convention of successful cases, and taking this opportunity, for the high-ranking government officials to appeal personally to them.

C) Other conceivable methods include the use of publications, TV and radio broadcasting programs designed for entrepreneurs, direct mail, and permanent display rooms in the heart of Bangkok.

(4) In any of the abovementioned cases, it is necessary to take care to arrange necessary information concisely and plainly in order to attract the keen interest of entrepreneurs having many management problems on hand, in energy conservation.

The following are points to which attention must be given in supplying information to entrepreneurs:

A) As regards energy management methods and profits to accrue from energy conservation, priority should be given to easily workable methods centering around concrete and successful cases. In any case, it is necessary to clarify how much profit energy conservation will bring to entrepreneurs.

B) It must be emphasized that the government's energy conservation measures will not stand in the way of industrial activities but will serve to make enterprises more competitive and to ensure larger profits for them, and that enterprises with little interest in energy conservation will suffer loss and lag behind.

C) The interest of entrepreneurs in energy conservation can be killed if the possibility of developing oil-substitute or non-traditional energies is overemphasized.

2.2 Recording and reporting schemes

(1) The first step toward expediting energy conservation in factory would be to record precisely how much energy is used per consuming place.

Effective energy conservation steps cannot be formulated unless data on energy use are accumulated and comparative analysis is made of such data in series or per production process to clarify fluctuation factors.

Though most of the factories we visited had kept records, by and large, on the energy they used, the extent to which such records were kept differed variously. Factories where adequate records were sufficiently prepared constituted only a negligible percentage and even in these factories, only few of them made effective use of data for energy conservation.

(2) The following is an outline of the recording and reporting scheme:

A) The government designates factories where more than a given amount of energy is used.

B) Designated factories are obligated to continuously keep detailed records on the energy used.

C) Designated factories are obligated to report periodically to the government on the energy used, results of energy conservation efforts, future energy conservation target values and plans designed to attain these values.

This scheme has been adopted in several countries. Also in Thailand, a plan for this scheme has been taken up as one of the major energy conservation measures in the Fifth Plan. But it has not been enforced yet.

(3) The scheme has three purposes, that is:

A) Motivating entrepreneurs to enforce energy management based on data and target setting for energy conservation habitually.

B) Enabling the government to grasp, from a macroscopic standpoint, the energy

use situation, the progress of energy conservation activities in the manufacturing industry sector and the future possibility of energy conservation through reports submitted by enterprises, so that the government may decide on a course for future measures.

C) Based on the reports, the government's evaluating the energy management situation of the individual enterprises, commending excellent cases and making them public. Also sending "energy audit" teams to extend guidance and advice for improvement where energy conservation efforts by enterprises have failed to produce tangible results.

(4) There is the need to pay attention to the following points in implementing the scheme:

A) To keep enterprises well informed, in advance, of the following:

a. The prime objective of the scheme lies in encouraging energy management based on data.

b. Information obtained by the government through the scheme, specifically information on an individual enterprise level, is used solely for energy conservation, not for any other purpose such as energy ration scheme, disciplinary steps against enterprises exerting little conservation efforts, and tax investigations. Also, the information will be by no means leaked to other enterprises.

B) The government should not impose heavy burden upon enterprises at least at the outset of the scheme. It would be advisable, for example:

a. To confine the recording items to basic ones.

b. To exclude the items which are readily available through existing statistics or reports, from being reported.

It would also be advisable to collect necessary information at the time when licenses for factory operation are renewed every three years according to the factory law.

c. To collect reports once or twice a year.

Several years after the inauguration of the scheme it would be appropriate to gradually expand the scope of the recording or reporting items, studying to what extent the scheme has taken root.

C) The government should effectively exploit information obtained through the scheme.

It would not be easy to check one by one, sum up and analize a large amount of data submitted simultaneously by many factories. Hence it is necessary for the government to set up adequate data-processing systems before initiating the scheme.

Furthermore, in order to ensure effective and continuous maintenance of the scheme, the government is advised to periodically make public the results of analysis or successful case, showing its effective use of the reports, and to feed back the fruits of the scheme to enterprises.

(5) The scheme is a highly effective means for the government to grasp the actual state of energy use in industry, which is necessary to formulate effective energy

conservation measures. It is desirable that such a scheme be adopted at the earliest possible date in Thailand.

When the scheme takes solid root and data are accumulated in the future, there would be the possibility of the scheme being exploited in making demand forecasts, grasping the effects of energy conservation measures, or setting up standards for energy use.

2.3 Commendation of factory excellent in energy conservation

(1) Energy conservation contributes a great deal to the rationalization of business management and the stability of the national economy, yet it has attracted little attention from the general public. Therefore, if the government commends enterprises whose energy conservation efforts have attained tangible results, it will serve to expedite energy conservation.

The commendation system, if introduced, will serve not only to boost the morale of entrepreneurs and people engaging in energy management but also to demonstrate the government's willingness toward energy conservation to industry.

(2) Those to be commended by the government for their admirable energy conservation efforts may be classified into two categories: individuals (entrepreneurs, plant managers and energy managers); and organizations (enterprises, factories and workshop groups). It seems that the tangible results of energy conservation efforts are usually attained not so much through individuals' activities as with the cooperation of many people concerned. Therefore, it would be advisable to start commendations on an organizational level. This will make it easier for the government to make choice from among the candidates.

(3) There is a need to give attention to the following matters in introducing the commendation system:

A) To make the presence of this system widely known to the industrial community and to hold commendations regularly, once a year, under the same formula.

B) To hold the commendation ceremony in public and to make the prize winners known to the public each time through mass media such as newspapers and magazines.

C) The name under which commendations are made and the amount of prize, which may be decided in consideration of other similar systems, is regarded as an index of the government's interest in energy conservation. It is desirable that commendations are made in the name of a Cabinet minister.

D) This kind of system will not be sustained for long without the confidence of the industrial community. Therefore, it would be important to assure the impartiality and authority in screening. To this end, there is the need, at least, to lay down screening rules, set up a screening committee comprising unbiased men of learning and experience, and conduct spot surveys.

(4) The problem is how to select excellent factories or groups. Naturally, it would be impossible to select from among all the factories in Thailand. Because of this, the most

realistic method would be to invite candidates publicly and make the selections from among the entrants.

It would also be advisable to make the selections from among the factories which have submitted reports to the government under the aforementioned recording and reporting scheme.

(5) The outline of commendation systems in Japan will be introduced for reference as follows:

Commendation of Workshop Groups

A) Purpose

a. Enhancement of energy conservation consciousness in industries

b. Spread of energy conservation technology

c. Promotion of technical interchanges between enterprises

B) Promotor

The Energy Conservation Center (Incorporated Foundation)

Supported by the Ministry of International Trade and Industry

C) Subjects of screening

Workshop groups which have entered into the dissemination convention of successful cases sponsored by the Energy Conservation Center.

D) Screening

a. Items to be mentioned in the application papers

① Name and number of the group, theme

② Outline of the factory and facilities

③ Reason for choosing the theme

④ Understanding and analysis of the present situation

⑤ Progress of activities

- Target setting
- Problems and countermeasures

⑥ Effect of countermeasures

Money saved, rate, consumption rate, etc.

⑦ Future plans and tasks

b. Screening committee

The committee consist of representatives from the government agencies concerned, research institutes, the academic circles, and the Energy Conservation Center.

c. Screening method

Screening is made on the following items:

- Originality — Whether new method, new technology and new idea are original
- Universality — Whether it can be applied to any type of industry and equipment
- Effectiveness — How effective for conserving energy
- Efforts Made — Whether adequate efforts have been made theoretically and practically

E) Commendation

a. Kinds and number of prizes

The following prizes (testimonial and extra prize) are awarded to each group (up to 50 groups) which have been judged excellent.

① Minister of International Trade and Industry Prize (three groups or less)

② Agency of Natural Resources and Energy Director General's Prize (five groups or less)

③ International Trade and Industry Ministry Regional Bureau Director's Prize (16 groups or less)

④ Energy Conservation Center President's Prize (25 groups or less)

b. Date for commendation

Once every year, at an open awarding ceremony, during the Energy Conservation Campaign Month (February)

F) Announcement

Announcements are made through the Energy Conservation Center's organ and newspapers.

Commendation of Factories

A) Purpose

To encourage further energy conservation by commending model factories which have obtained excellent results from their constant efforts to rationalize energy use and contribute to the effective use of fuel resources.

B) Promotor

Ministry of International Trade and Industry (MITI)

C) Subjects of screening

Factories which have attained excellent results concerning each of the following items and have been recommended by directors of regional bureaus of MITI, the Energy Conservation Center and other relevant organizations.

a. Energy management organization and its operation

b. Measures taken to rationalize the use of energy at the factory.

c. Training of energy management engineers.

d. Actual results of rationalization of the use of energy.

D) Screening

a. Items to be mentioned in the application papers (Items with a "*" represent data for the past three years.)

① Outline of the factory

Number of certified energy manager, number of employees, main products and their output, etc.

② Production facilities

- Flow chart of manufacturing process
- Energy balance
- Kinds of energies and amounts of their use
- Principal energy consuming equipment

- *Energy consumption rate for each of the main products and reasons for their increase or decrease

③ Energy management organization and its operation
- Chart of organization for energy management
- *Basic policy and goal for energy conservation
- Priorites in energy conservation
- Implementation of events conserning energy conservation
- Number of persons making up the energy management organization
- Sessions of the energy conservation committee

④ Training of energy management engineers and their activities outside the factory
- *Employees' participation in the national training course and the examination for energy managers
- *Employees' participation in outside seminars
- *Education in the company

⑤ Actual results of rationalization of the use of energy
- *Number of cases of improvement and energy conservation effect
- Details of cases of major improvement

⑥ Measures taken for rationalization of the use of energy (for each equipment)
- Establishment of standards for management
- Implementation of measuring and recording
- Implementation of maintenance and inspection
- *Measures for improvement

b. Methods of screening

In addition to judgment based on documents, on-the-spot survey is made.

E) Commendation

a. Kinds and number of prizes

The following prizes (testimonial and extra prize) are awarded to the factories (thermal and electrical sectors, respectively) which have been judged excellent.

① Minister of International Trade and Industry Prize (11 factories or less for each sector)

② Agency of Natural Resources and Energy Director General's Prize (16 factories or less for each sector)

③ International Trade and Industry Ministry Regional Bureau Director's Prize (less than 2 percent of the number of designated factories in each bloc)

b. Date for commendation

Once every year, at an open awarding ceremony during the Energy Conservation Campaign Month (February)

F) Announcement

Announcements are made through the Energy Conservation Center's organ and newspapers.

2.4 Energy prices

As is widely known, energy prices are considered in many countries to be the most important factor in the formulation and implementation of energy and energy conservation policies.

Enterprises usually are sensitive to changes in energy prices; and, therefore, market mechanism and the government's administrative guidance through prices proves highly effective in making entrepreneurs energy conservation-minded and pushing for energy conservation in the industrial sector.

As a matter of fact, the phenomenal improvement attained in major industrialized countries in energy efficiency after the second oil crisis would have been inconceivable without the sharp rise in energy prices.

In this connection, it was found in process of the Study that there exist systems which are problematical from the standpoint of energy conservation, such as the declining block rate system in power rate for industry. However,

(1) In Thailand, the need to adjust energy prices to an appropriate level based on international energy prices is repeatedly mentioned in the Fifth plan and price adjustment steps have so far been carried out on several occasions.

(2) Changes in the energy price structure have far-flung impacts not only on energy conservation but on the economic world as a whole. Rising energy prices in the industrial sector, for instance, are feared to weaken the international competitiveness of enterprises and adversely affect the export promotion policy which the Thai government is currently pushing.

(3) Accordingly, the government's intervention in energy prices must be decided on with utmost prudence not only from the viewpoint of energy conservation but after an overall comparative study of the priorities of many policies such as industrial, trade and general price policies, which the Thai government now confronts.

Viewed in this light, we will not dwell further on energy prices.

3. Improvement in Energy Conservation Technical Level of Enterprises

It goes without saying that factories should have technical staff well versed in energy conservation technology to carry out smooth and effective energy conservation activities.

It seems that such energy conservation activities which will not entail much investment, as improvement in operational management and production process control, are also highly important to Thai enterprises, particularly to smaller enterprises. In conducting such activities, it is important, first and foremost, that plant workers in general, who are always at their work areas where energy is used and who know well how energy is used, should take part vigorously in energy conservation efforts.

Many of the factories we visited send their technical staffers to external seminars, but our impression is that many factories are plagued by a shortage of experts on energy conservation and that the technical levels of their technical staffs are still inadequate. Also, there are few cases in which factories provide educational training to their employees or in which technical staffers who have attended external seminars serve as lecturers for in-company training. Likewise, there are hardly any cases in which employees are participating voluntarily in energy conservation activities.

We addressed questionnaires to entrepreneurs on the occasion of our visits to the factories about issues involved in furthering energy conservation. Most of the answers said that workers' awareness of the need of energy conservation is quite low, reflecting, most likely, the situation mentioned above.

Meanwhile, many of the technical staffers we met exhibited great interest in information concerning energy management technology, while entrepreneurs also expressed strong hope that the government would sponsor seminars on energy conservation for technical staffers.

Therefore, it is apparently a pressing need for the government to take the following steps in effectively communicating information on energy conservation technology, energy management and relevant know-how to the plants' technical staffers.

Basically, steps such as these ought to be carried out by enterprises themselves, but they are not yet prepared to take such steps, with the exception of big businesses and foreign-capital enterprises.

3.1 Appointing an energy manager

(1) First it is important to post an engineer at each factory who can play the central role in energy conservation activities, and to train him emphatically.

For that purpose an energy manager system is adopted in several countries.

These systems are basically designed to expedite the formation of an organization which is to be the core of energy conservation efforts, and to smooth the flow of energy conservation-related information, by encouraging or obligating the appointment of energy manager for factories where more than a given amount of energy is used.

Furthermore, the energy manager systems, by putting energy management services in the limelight, contribute to elevate the status of persons engaging in such services, and to uplift their morale.

Such systems, meanwhile, also help the government in grasping precisely information channels to major factories, hence the government can expect to vitalize the exchange of information by taking up, for instance, the following steps:

A) To obligate or encourage energy managers to periodically attned government-sponsored seminars on energy conservation technology.

B) To take the initiative in organizing an association of energy manager which through periodical meetings serves as an arena for exchanges of experience and for mutual training.

C) To collect information on the actual status of energy conservation efforts within enterprises and grasp points at issues involving such efforts, through energy managers.

(2) It seems effective to adopt this system in Thailand. In this case, it would be necessary for the government to communicate the following points to the management of enterprises and to solicit their understanding:

A) In order to ensure the effective operation of such systems, the management should provide full support to the energy manager.

B) The basic role played by energy manager lies in the overall coordination of energy conservation activities at each division of the factories, and the energy manager is not responsible directly for all phases of energy conservation activities.

The functions of the energy manager differ according to the size of factories and how energy is used. The following is a typical instance of their function.

Energy Manager — Specific Responsibilities

—To maintain summaries of energy purchases, stocks and consumption. To review regularly energy utilization performance.

—To be the focal point for departmental records of energy use.

—To co-ordinate the efforts of all energy users, and set targets. To give technical advice on energy saving equipment and techniques, or identify sources of guidance.

—To identify where major energy waste is occurring, to quantify the losses. To put forward practical recommendations for reducing them.

—To generate and sustain interest in energy conservation.

—To identify areas of activity which require more detailed study and maintain a record of all in-depth studies and to review progress.

—To provide a basic manual or handbook of good energy practices.

—To give specialist advice to purchasing, planning, production and other functions on the longer-term aspects of energy conservation.

—To ensure that, in making improvements, health and safety are not jeopardised.

—To liaise with committees and working groups within his own industry and to exchange ideas on cost-cutting techniques and performance figures in similar processes.

—To maintain contact with research organizations, equipment manufacturers and professional bodies so that he remains up-to-date on all significant developments in energy conservation.

—To remain up-to-date on world and national energy developments and generally advise senior management on energy matters. (Source: IEA)

3.2 Reinforcement of seminars on energy conservation technology

(1) In Thailand at present, itinerant service teams of NEA are extending vigorous energy audit service to individual factories. This is certainly one of the effective means of communicating information. But there is a limit to the scope within which the government can provide information services through such direct methods.

Though ordinary it is, the most effective and sure method to disseminate technical information necessary for energy conservation to the broad spectrum of industries in a relatively short time would be mass education in the form of seminars.

(2) In Thailand, too, many government and private organizations have so far held such events. Details on these seminars were not available to us, but considering their themes and frequency it does not seem that they, except those sponsored by TPA, have been held on a continual, planned and systematic basis.

The Electric Technician Training Center attached to NEA was recently re-organized into an Energy Training Center. But it appears more time is needed before training activities related to overall energy management and energy conservation technology at the reorganized center will get on the right track.

(3) The government should sponsor seminars or back up seminar activities of private organs so that energy conservation technology seminars may be held more often and be better programed. It is desirable that due attention be given to the following points in boosting the educational effects of such seminars:

A) For the organs concerned, under the initiative of NEA, to work out annual seminar schedules through cnsultations so that seminars may be held on a systematic and planned basis; to listen to the views of leading technical experts in the industrial sector when preparing such schedules' to grasp educational needs; to keep enterprises well informed, in advance, of schedules for the opening of seminars.

B) Upon classifying seminars into ones designed to elevate the technical levels and ones aimed at enlightenment or motivation, to give precedence to the former.

To restrict seminar themes to a specific technical topic; to hold a series of seminars for regular participants as the theme demands (for example, techniques for effective utilization of steam 1, 2, 3, and so on).

C) To place empahsis, for the time being, on training key persons (for instance, energy managers) who will become the core of energy conservation activities at the factories.

To limit the number of participants per seminar to 50 at the most, and also to provide courses classified by technical level to make the level of participant of a seminar as uniform as possible.

D) Not merely to give lectures, but to prepare elaborate textbooks; to use as many audiovisual aids, such as videotapes and slides, as possible.

To incorporate visits to excellent factories and on-the-spot energy audit training

into the curriculums.

To replenish training facilities (especially, those for effective utilization of fuel and heat) of the NEA-operated Energy training Center at the earliest opportunity.

To enlist the cooperation of other government-related industrial educational organizations so that their facilities may be utilized.

E) To asses the effectiveness of a seminar upon its termination, through questionnaires, so that the participant's views and needs can be reflected in the subsequent seminar programs.

To keep a name list of participants so as to utilize it for the follow-up trainings and the formation of communication channels between the government and enterprises.

Though it brings no tangible results immediately in energy consumption, manpower building is the corner stone of energy conservation. In Japan monthly seminars on energy conservation technology have a constant stream of participants. It is highly hoped that steady efforts toward technical training will be accumulated.

3.3 Distribution of printed matters on energy conservation technology

(1) This is the easiest method of disseminating information. Besides, its necessity and effectiveness seem to be all the greater especially in a country like Thailand where special books on energy conservation are not published in many copies on the commercial basis.

As in the case of seminars, several organizations in Thailand have so far prepared pamphlets on energy conservation technology for distribution to factories etc., but the printings are not so many.

(2) Though preparation and distribution of such pamphlets by various organizations on the basis of themes selected from their respective positions will serve to expand the information channels to the factories, we would like to advise that emphasis be placed first on the following two points:

A) One is to foster an all-round energy conservation technology magazine which is published periodically (monthly or bi-monthly), and fulfills the role of major information channels linking the government organizations in charge of energy conservation and the factory engineers directly.

A major portion of articles of this magazine would be devoted, of course, to information on energy conservation technology, but it is advisable that it also carries comments on the government's energy policies, schedules for various seminars on energy conservation technology, factory management methods, and other relevant information. This would perhaps help enabling such magazines to win many regular readers.

As regards a concrete method for this, it would be mroe realistic to foster steadily the "News Letter" issued periodically at present by NEA's Energy Conservation Center.

B) The other is to introduce successful energy conservation cases in domestic and overseas factories.

For factory engineers, knowledge of concrete instances of fruitful conservation efforts at other factories would serve to stimulate their efforts to improve the energy-use situation at their own factories and also help them acquire new ideas toward better energy conservation.

It would also be attractive and effective to collect and introduce, if possible, unsuccessful cases with their cause of failure.

(3) As in the cases of seminars, cooperation among the organs concerned is of special importance to information service activities.

As already mentioned, in Thailand many governmental and private organizations are pushing independently for the dissemination of energy conservation-related information. This is problematical from the standpoint of efficiency, though instrumental to widening the scope of information service activities.

As seen in the case of some seminars, it is desirable that cooperation among the relevant organizations be further stepped up by, for instance, the following methods:

A) To set up a planning committee of working-level representatives of the relevant organs so that the committee may hold meetings regularly to exchange information and to study the possibility of co-sponsoring seminars or jointly editing pamphlets.

B) For the relevant organizations to push for mutual utilization of the sources of information (including experts), channels for communication of information, seminar rooms, and other facilities they own.

C) If possible, to specialize the functions of the relevant organizations by gradually determining their respective fields of special activities.

3.4 Securing sources of technical information

(1) In order to effectively provide energy conservation technology information services to enterprises, the government must establish a system whereby it can grasp precisely and make full use of the present situation and future trends in various energy conservation technology.

Fortunately, in the field of energy conservation, know-how on energy management and various pieces of technical information are more openly available than expected. Because of this, there is hardly any problem in acquiring information.

Furthermore, most of the energy conservation technologies are far less sophisticated than what they call high technologies and do not need advanced technical knowledge.

(2) However, energy conservation technology has the following characteristics which make its dissemination difficult:

A) Though forming a relatively new technical domain, energy conservation technology is, so to speak, interdisciplinary technology based on combined and applied use of various technical knowledges. Hence the basic knowledges to a broad spectrum of relevant technical fields are needed.

B) Because most of the energy conservation technologies are applied technologies, it is exceedingly important that persons have work experience at factories in order to acquire adequate understanding of such technologies and master them.

C) Even limited to the industrial sector alone, the places and the ways of energy utilization are extremely diversified. Because of this, coverage of energy conservation technology ranges over a wide fields.

D) Deriving from the aforementioned characteristics of energy conservation technology, few country has enough experts who are capable of playing a leading role in disseminating energy conservation technology, fully armed with such technology and with abundant experience in factory..

At all the organizations concerend which we visited in Thailand, the shortage of experts is considered one of the crucial problems.

(3) The following methods are regarded as being helpful in establishing the sources of information and securing technical experts:

A) First, to create an information providing system (for instance, the energy conservation information center), through which the government collects both foreign and domestic energy conservation-related information classifies on a systematic basis and makes available whenever necessary.

Accumulating an adequate amount of information may take time, but the stock of elaborately filed technical information, though limited at first, constitutes the essential prerequisite for information services. The center referred to above appears to serve a great deal as the core of the network of experts and industrial technical staffers, of which mention will be made later.

The proposed center may also become a service window for information inquiries from outsiders, by free-of-charge telephone.

B) Exploiting foreign technical information and experience leads to saving of time and funds. Necessary information will be readily obtained from abroad if proper channels are established by permanent cooperative relations with energy conservation promotion agencies overseas.

C) It is difficult and inefficient for the government to hire all the experts it needs.

The government's role lies in devising a mechanism to link the outside expert's information and know-how to its information services effectively and putting this mechanism into work.

For example,

a. To grasp information on experts in the service of big businesses, academic circles, and research institutes, such as their specialities and activities, and to systematically file such information as part of the information stock mentioned above.

b. For the government to take the initiative in organizing a circle of technical experts with the cooperation of organizations to which they belong. This circle will fulfill the role of an advisory committee on the government's energy conservation measures and serve simultaneously as an arena for exchanging research results and information among technical experts.

c. Technical experts taking part in this circle will cooperate with the government, on the part-time base and with proper fee, in lecturing at seminars, writing for the magazine, preparing pamphlets and audiovisual aids, and extending energy audit services to smaller enterprises, insofar as such part-time activities do not interfere with their regular assignments.

If this mechanism works successfully, it would be possible to recruit outside expertise from a broad spectrum of the circles concerned.

3.5 Exhibition and dissemination convention of successful cases

(1) Energy conservation exhibition

There are many kinds of exhibitions ranging from those featuring products of a single maker to large-scale fairs. Yet all exhibitions are similar in that they serve as ideal opportunities to communicate information to many people simultaneously, enabling the visiting public to have a direct approach to the kinds of information they need, and to opt for the information most appropriate for them.

In this way, exhibitions are an effective means of diffusing technical information, and it is desirable that such events be held as often as possible.

In Thailand, as in other countries, the makers have so far sponsored the equipment shows, but similar events have rarely taken place under the auspices of the government.

It may be difficult for the government to sponsor the exhibitions, but it is desirable that the government at least support the exhibitions sponsored by makers, especially in the case of energy conservation where the intentions of the government and makers are the same.

It goes without saying that the exhibitions supported by the government are more dependable to the visiting public than those held by enterprises on their own.

Besides, the energy conservation exhibitions provide capital opportunities for the government's information service activities, attracting many people with keen interest in energy conservation.

If the government, making use of this opportunity, holds lecture meetings with such themes as trends in energy conservation technology, taxation or loan systems designed to promote investment in energy-saving equipment, or if it exhibits information panels, projects video films or distributes pamphlets, it will apparently help attract many visitors as well as enlighten them on the importance of energy conservation.

(2) Dissemination convention of successful cases

Technology and facilities constitute vital factors in furthering energy conservation efforts at factories. However it would be impossible to give full play to technologies and facilities unless the workers who operate and maintenance them daily, are armed with an awareness of energy conservation, no matter how excellent they may be.

Hence, it is important that all the plant workers take interest in energy

conservation and take part in energy conservation efforts by organizing small group activities in their work areas.

Only in a few of the factories we visited had started small group activities, but they have not yet attained tangible results in the field of energy conservation.

In order to encourage small group activities dedicated to energy conservation, it is advisable for the government to hold a dissemination convention of successful cases attained by small group activities, regularly, for instance once a year, on a nationwide level. Such an event is expected to be highly instrumental not only in activating small group activities but also in furthering exchanges of energy conservation technology among enterprises and in diffusing such technology.

If, as stated, the government commends the best selections from among the cases presented, it will make the event all the more effective.

Considering the present situation in Thailand, such an event, if organized, would start on a small scale at the outset. In Thai industries, however, it appears that QC circle activities have been spreading rapidly in recent years, and energy conservation is an ideal theme for such activities. From these, tangible results are expected to be produced in the near future.

3.6 Fostering the consultants

In case an enterprise intends to improve or install facilities in order to enhance energy efficiency, the management would make the final judgement based on the opinion of its own technical staff. But if no reliable staff having a sufficient knowlegde on facilities and technology is found within the enterprise, the external specialist (consultant) would paly the role instead.

At present, in Thailand, organs like NEA, IFCT, etc. are conducting, free of charge, consulting activities like energy audit and guidance in financing affairs, etc., by sending teams composed of 2-3 experts to factories, and considerable merit is allegedly obtained.

On the other hand, in the private sector, the number of consultants and consultant firms is not significant yet, and only some manufacturers are conducting consulting activities through affiliated company.

The consulting activities on the part of manufacturers are certainly significant, but in this case, users are apt to regard it as propaganda for sales promotion, and from the standpoint of users, the available information is limited to one from a certain manufacturer, resulting in the drawback of not being able to choose the optimum from among a lot of informations. Accordingly, it is desirable that the government install, for example, a system to officially qualify the consultant recognized to be competent, after examination or training, from among those having specific knowledge and experience, in order to foster a number of consultants who will advise enterprises from a neutral standpoint.

Upon registration of the qualified person with the government, the government is to introduce the appropriate consultant at the request of the user intending to invest in energy saving equipment.

Once the advice of neutral consultants which are guaranteed, by the government, of a

certain technical level are readily available, the decision-making and execution of investment in energy saving equipment will be accelerated.

Furthermore, it will be effective to prepare for a chance of an additional series of training and to conduct the examination for the renewal of qualification, in order that the qualified consultants would not be outpaced by the newer progresses in technology.

3.7 Itinerant energy audit service

As stated earlier, in Thailand, the energy conservation center of NEA plays the central role in providing free energy audit and guidance services to mediam- and small-size enterprises.

More than 100 factories have been extended these services with considerable achievements as seen in clarification of points requiring improvement. During the 5th Plan period, a total of 600 factories are planned to be audited.

In the program to set up an Energy Conservation Center anew in the future a more elaborate factory energy audit service is considered the main business of the organization.

If the Center operates successfully, it will contribute greatly to the improvement of enterprise's technical levels.

Allow us to hope that these programs will develop successfully.

4. Providing Conditions for Investment in energy saving equipment

The following three stages may be considered in the manufacturing industries' efforts for conservation of energy.

A) Improvement in operation control, process control, etc.

This is mainly done by the so-called "saving campaign," and requires no large equipment investment and hardly any expense.

B) Introduction of additional equipment contributory to energy conservation

At this stage, the existing equipment or production processes are partially replaced, and equipment useful for energy conservation, such as heat exchanger or speed controller, is added.

C) Improvement of production equipment proper, production processes or manufacturing methods

This requires large amounts of equipment investment and highly advanced technology, but is highly effective for energy conservation.

Most of the factories we visited still remain in the above stages A) or B), although there are some differences from factory to factory in regard to energy conservation measures. Our impression was that energy conservation efforts through equipment investment had just started.

As already noted, the following factors may be regarded as reasons for the rather slow progress of energy saving equipment investment.

a. Difficulty in raising funds for equipment investment

b. Shortage of technicians and technical information

In addition, the following factors are also conceivable:

c. There is anxiety about the recovery of invested funds, because of lack of firm confidence in the effectiveness of energy conservation measures.

d. Generally speaking, entrepreneurs tend to follow a policy of earning profits through the short-term operation of funds and thus to avoid getting funds fixed in the form of equipment for a long time.

Energy conservation measures through equipment investment can be expected to be more effective than other measures, such as the improvement in operation control, and make it possible to recover invested funds in two or three years for the most part.

It is considered absolutely necessary to encourage investment in energy saving equipment through incentives regarding tax and financing, and other measures.

Tax and financial incentives aim firstly at promoting energy conservation efforts of enterprises and, at the same time, it serves to stimulate and guide production and sales activities of energy saving equipment manufacturers and importers, thus to foster such industries.

4.1 Preferential tax systems for energy conservation

(1) Two types of tax incentives may be considered for the promotion of energy saving equipment investment—namely, tax deduction and accelerated depreciation.

A) Tax deduction

This is a system whereby certain percentage of the cost of installing specified energy saving equipment is deducted from taxes at a time. This system may be applied to such taxes as import duties, corporate income tax and business tax.

Already, since last year concerning the import of some energy saving equipment and materials, Thailand has taken steps for tariff reduction or exemption, and these steps are expected to produce tangible results. However, it is deemed desirable to strengthen incentives for investment in energy saving equipment by expanding the scope of equipment covered by the above steps and newly creating a preferential tax system for investment in domestically produced energy saving equipment and materials.

B) Accelerated depreciation

This is a system whereby a certain amount (special depreciation), calculated on the basis of the cost of acquiring specified energy saving equipment, is allowed as depreciation in addition to the ordinary amount of depreciation during the early periods of the legal life of the equipment.

The special depreciation results in increasing the amount of losses or necessary expenses, which are deductible from profit, and thereby decreasing the amount of taxable profit during the period.

However, as the system naturally brings about a decline in the amount of depreciation after the end of that period accelerated depreciation is tantamount to postponement of a tax imposition. This spells additional funds reserved within the corporation, which in turn serves to reduce its burden of interest payments and thus to improve the economical efficiency of investment in energy saving equipment.

The establishment of the accelerated depreciation system is considered one of the effective measures to promote investment in those energy saving equipment and materials which are considered necessary in light of the government policy.

(2) In adopting the preferential tax measures for investment in energy saving equipment, a decision should be made regarding the following points on the basis of a comprehensive analysis of such factors as the state of the national treasury, importance of investment in energy saving equipment, the state of corporate earnings, and the state of production, import, and installment of such equipment:

—Which should be adopted, tax deductions or accelerated depreciation, or whether enterprises should be left free to adopt either of the two steps.
—Which tax should be chosen in the case of tax deductions.
—The scope of energy saving equipment to be covered.
—The rates of tax reductions or special depreciation
—The scope of enterprises and industries to be covered.
—The length of the period of application.

Under the existing tariff reduction or exemption system of Thailand, energy saving equipment and materials covered by the system seem to be determined on a case-by-case basis.

However, in the case of a system of this type, it is absolutely necessary to clearly specify the scope of equipment covered in advance and to get the industrial circles fully acquainted with the scope. This will serve to increase enterprises which utilize the system, and also to ensure impartiality among those utilizing the system and to simplify and speed up the procedures involved.

Moreover, after the lapse of a certain period following the enforcement of the system, it is desirable to reexamine the scope of the equipment covered, in light of the progress of energy conservation technologies and the state of dissemination of such equipment.

(3) Japan's preferential tax system for investment in energy saving equipment, the scope of equipment covered, and the principle for selection of the equipment are outlined below for reference.

Tax System for Promotion of Investment for Efficient Use of Energy

◎ Equipment covered

A) Types of equipment

a. Equipment conducive to the efficient use of heat, etc.

This is an equipment which contributes markedly to the efficient use of heat (including fuel as heat source) or motive power, and consists of the following two types:

① High-performance manufacturing equipment using heat, etc.

This is a production equipment proper consuming thermal energy, which is marked by sharply increased efficiency compared to conventional models as a result of the improvement of the manufacturing function, or the manufacturing and processing methods through such steps as automation and continuous operation in the manufacturing stages.

Introduction of such equipment has started to get into high gear recently, and is expected to contribute greatly to the progress of energy conservation in future.

② Heat reutilization equipment, etc.

This means newly developed or markedly improved machines and devices for rationalizing fuel combustion, recovering and using waste heat, and preventing thermal loss. A case in point is equipment added to various energy-consuming facilities for the purpose of enhancing the energy efficiency.

Several such machines and devices were introduced relatively early as a means of promoting energy conservation.

b. Equipment conducive to the efficient use of electricity

This is an equipment which contribute markedly to the efficient use of electricity. There are two types, as follows:

① High-performance manufacturing equipment using electricity

This is a production equipment proper which uses electrical energy. This corresponds

to the equipment mentioned in the above a.①

② Equipment for efficient use of electricity, etc.

This means machines and devices newly developed or markedly improved so as to rationalize the conversion of electricity into motive power and heat, and to prevent the loss of electricity.

These equipment correspond to the equipment mentioned in the above a.②

c. Equipment for medium and small-scale enterprises

These equipment are roughly the same as the equipment mentioned in the above a. and b. But medium- and small-scale enterprises are generally lagging behind big businesses in equipment investment for energy conservation because of a shortage of technical know-how, information, technicians and financial resources. This being the case, limitations on equipment capacity and manufacturing methods are relaxed in the selection of individual machines and devices to be covered by the incentive tax system. Therefore, a wider scope of equipment is covered here.

Regarding all the equipment mentioned above, only equipment newly manufactured are covered by the system.

B) Names of equipment covered

Shown in the equipment list later.

C) Principles for selection of equipment

The equipment, the installation of which needs to be promoted from the government's point of view, are selected by taking into account of such factors as the energy conservation effect, the length of the period for recovery of invested funds, the state of dissemination, and the unit price.

First, the energy conservation effect brought by the equipment must be above 25 percent. Moreover, as to equipment for general industry, the unit price must be ¥10 million or more in principle. The reason is that in view of the capability of equipment investment, the government sees no necessity of assistance regarding small-scale equipment. But this principle is not applied to equipment for medium- and small-scale enterprises.

Likewise, there is little need for governmental aid with respect to equipment which are expected to come into wide use even without assistance, equipment which has already spread to a considerable extent, and equipment which enable an early recovery of investment. Therefore, the extent of dissemination and the recovery period of investment are taken up as factors to be considered in the selection of equipment.

Table IV-1 Standards for Selection of energy-saving Equipment (The following standards must all be met in principle.)

| Standards | Underlying concepts |
|---|---|
| Energy conservation effect of 25% or more | Equipment with an energy conservation effect necessary for attaining energy conservation by about 15% through 1990 |
| Long period for recovery of investment | Equipment with a long recovery period of investment which is left over because of an uncertain economic outlook |
| Equipment which is not in wide use but is expected to be installed by a good many enterprises | Excepted is equipment which is already in fairly wide use, or which is expected to be installed only by particular enterprises. |
| Unit price of ¥10 million or more | Equipment which is too expensive to install under current circumstances |

◎ Preferential tax measures

A) When the equipment mentioned above is acquired within two years from April 1984, and put to use for corporate activity within one year after that, the enterprises which has installed the equipment can choose either of the following two steps:

a. Tax deductions

A sum equivalent to 7 percent of the standard acquisition price of the equipment involved is deducted from the corporate tax (income tax) (up to the limit of 20 percent of the taxable amount).

b. Special depreciation (accelerated depreciation)

In addition to the ordinary depreciation, a sum equivalent to 30 percent of the standard acquisition price of the equipment involved can be included, as depreciation, in the necessary expenses or losses.

The standard acquisition price is, in principle, the price paid for the aquisition of the equipment. But in the case of high-performance manufacturing equipment, it is 75 percent of the price paid for acquisition of the equipment.

The reason is that since high-performance manufacturing equipment is essentially designed for rationalization of production or expansion of production capacity, it is considered inappropriate to have the entire amount of its acquisition price covered by this incentive system.

When the amount of tax deductions exceeds 20 percent or when the amount of special depreciation falls short of 30 percent, the application of the system may be held over into the next year.

B) Permission to choose either tax deductions or special depreciation is intended to enable each enterprise to select a method more favorable to it in consideration of the characteristics of the respective methods, with a view to facilitating effort for energy conservation.

A basic difference between the two methods is that tax deductions are an absolute tax exemption whereas special depreciation represents the postponement of taxation.

In the case of special depreciation, the total amount of depreciation remains the same, when it comes to the entire length of the legally-fixed depreciation period, regardless of whether the special depreciation method is used. Therefore, the tax amount will increase in later years by the same sum that is deducted in earlier years.

On the other hand, there will be no such tax increase in later years in the case of tax deductions.

As to which is more favorable to enterprises, the merit of special depreciation is 1.9 times that of tax deductions insofar as the amount of taxes cut in the first year is concerned. But when seen from the viewpoint of the entire period of depreciation, it cannot be simply determined which is more favorable, since the amount of tax cuts differ according to various factors, such as depreciation method, yield of funds, and the length of the depreciation period.

The tax deduction hardly benefits enterprises in deficit. However, even such enterprises can benefit from the special depreciation because, if they choose special depreciation, they are allowed to defer the loss for five years.

○ Individuals and corporations that can seek application of the preferential system

a. Equipment conducive to the efficient use of heat, etc. (power)

All individuals and corporations (excluding electric utilities)

b. Equipment for medium- and small-scale enterprises

Medium-and small-scale enterprises (individuals with 1,000 full-time employees or less on the payroll, corporations capitalized at ¥100 million or less)

◉ Equipment list covered by the system

I. Equipment for general industry

(1) High performance manufacturing equipment using heat etc. (7 system and 28 equipment)

1. High performance reactor

a. High performence naphtha cracking equipment

b. High performance polyethylene manufacturing equipment

c. High performance polyprophylen manufacturing equipment

d. High performance copolymerization polypropylene manufacturing equipment

e. Carbon monoxide selecting oxidation equipment

f. High concentration phosphoric acid liquid manufacturing equipment

g. High performance urea manufacturing equipment

h. Pipe reactor system compound fertilizer manufacturing equipment

2. High performance separator
   a. Falling film evaporator
   b. Steam reusing vacuum evaporator
   c. Steam recompression system evaporator
   d. Steam recompression system distillation tower
3. High performance baking equipment
   a. Enamel resin baking furnace
   b. Paint baking oven
4. High performance dyeing and finishing equipment
   a. Low bath ratio dyeing equipment
   b. Chemicals padding equipment
   c. Counterflow type washer
5. Vessel propulsion shaft power utilizing generator
   a. Vessel propulsion shaft power utilizing generator
   b. Fishing boat propulsion shaft power utilizing equipment
6. Continuous manufacturing equipment
   a. Improved type continuous casting equipment
   b. Direct feeding rolling mill
   c. Continuous annealing equipment
   d. Automatic controll system plate cooling equipment
   e. Aseptic filling equipment
   f. Continuous digestion unit
   g. Coutinuous kiln
   h. Continuous polymerization spinning equipment
7. High performance forklift

(2) Heat reutilization equipment (13 systems and 22 equipment)

1. Heat exchanger
   a. Equipment for preheating of air for combustion
   b. Equipment utilizing liquified natural gas cold heat
   c. All heat exchanger
2. Waste heat utilizing boiler
   a. Waste heat boiler
   b. Energy efficiency utilizing type boiler
3. Intermediate and low temperature utilizing generator
4. Waste heat utilizing heater
   a. Vacuum type waste heat recovery equipment
   b. Flash dryer
5. Waste pressure recovery equipment
6. Heat efficiency utilization type industrial furnace
   a. Raw material preheating type
   b. Furnace with waste heat utilizing degreasing equipment
   c. Thermal insulation type

d. Furnace with automatic controller for air-fuel ratio
c. Jet impact heating type
7. Cold box mold moulding machine
8. Storage tank heat insulation wall
9. Improved type double usage absorption type cold water equipment
a. Refrigerating capacity: 30,000 Kcal/h or more
b. Equipment number control type
10. Class II absorption type heat pump system heat source equipment
11. High performance radiation type heating equipment
12. Heat/power co-generator
13. Diesel engine for vessel

(3) High performance manufacturing equipment using electricity (10 systems and 23 equipment)

1. Electrical efficient utilization type electric furnace
a. High frequency melting furnace
b. High frequency induction heating equipment
c. High sensitive response arc furnace
d. High performance electrolytic furnace
e. Paint baking oven
2. Electrical efficiency utilization type moulding machine
a. Extruder
b. Foaming machine
c. Thermoforming machine
d. Compression moulding machine
3. High performance separator
a. Sizing machine with high pressure squeezing roller
b. Ultrafilter
c. Demineralizer
d. Ion exchange membrane method electrolytic equipment
4. Liquified natural gas coild heat utilization type air liquefying separator
5. High performance yarn manufacturing machine
a. Automatic yarn winder
b. Friction type drawing false twister
c. High performance yarn twisting machine
d. High speed multi yarn stripes reeling apparatus
6. Incombusible gas utilization arc welder
7. Direct contact system refrigeration unit
8. Friction type continuous extruder
9. High performance pulp washer
10. Substitution bleaching equipment

(4) Equipment for efficient use of electricity (4 systems and 6 equipment)

1. Heat pump system heat source equipment

a. Rated power consumption: 30kW or more
b. Equipment number control type

2. Floor heating equipment
3. Power load adjustment equipment
   a. Control unit for number of revolution
   b. Charging adjustment unit for electric precipitator
4. Surface pressure dehydrator

II. Equipment for medium and small scale enterprises (108 systems and 186 equipment)

1. Heat exchanger (4 types)
2. Waste heat utilization heating equipment (2 types)
3. Automatic combustion control unit
4. Energy efficiency utilizing type firing equipment
5. Automatic temperature controller
6. Power factor improvement unit
7. Power load controller
8. Heat pump system heat source equipment
9. Energy efficiency utilizing type antipollution device (2 types)
10. Energy efficiency utilizing type boiler (2 types)
11. Speed control system fluid equipment
12. Energy efficiency utilizing type industrial furnace (5 types)
13. Energy efficiency utilizing type electric furnace (5 types)
14. High performance separator (3 types)
15. High performance dehydrator (2 types)
16. Energy efficiency utilizing type dryer (4 types)
17. Submerged arc welder
18. Heat pipe system packer
19. Hydraulic lifter
20. Power feeding system metal machine tool
21. energy efficiency utilizing type press (4 types)
22. Vacuum type heating equipment of pretreatment liquid for painting
23. Energy efficiency utilizing type bottle washer (2 types)
24. Cnetrifugal dehydrating dryer of plastic container for transportation
25. Process saving combined type meat chopper
26. Mass treatment type ham slicer
27. Energy efficiency utilizing type automatic smoking apparatus
28. Belt system concentrated liquid vacuum dryer
29. Energy efficiency utilizing type flash sterilizer
30. Energy efficiency utilizing type refrigerated mincedfresh thawing equipment
31. Centrifugal filtration type all fruits squeezing machine
32. Energy efficiency utilizing type fruit juice centrifugal separator.
33. Gyro dryer

34. Continuous cooker
35. Energy efficiency utilizing type rice cooker (3 types)
36. Continuous cooking and cooling equipment
37. Automatic temerature control type fermenter
38. Filter press with automatic controller
39. Energy efficiency utilizing type roasting machine
40. Energy efficiency utilizing type sifter
41. High efficiency pneumatic conveyer
42. Steam control type automatic bean cooker
43. Energy efficiency utilizing type noodle manufacturing machine (3 types)
44. Steam heat exchange type frying machine
45. Energy efficiency utilizing type burning equipment (4 types)
46. Energy efficiency utilizing type bread baker
47. Hot water circulating type bottle warming machine
48. Steam agitation type low-class distilled spirits still
49. Automatic temperature control type malt manufacturing equipment
50. Steam dryer
51. Heat exchangetype solvent recovery equipment
52. Agitated heat conduction heater
53. High speed percussion crusher
54. Energy efficiency utilizing type heating agitator
55. Energy efficiency utilizing type pressure kettle
56. Vertical type automatic continuous steaming apparatus
57. Higher vacuum sealing device
58. Energy efficiency utilizing type raw silk manufacturing apparatus (3 types)
59. Energy efficiency utilizing type yarn manufacturing machine (12 types)
60. Pneumatic bleece conveyor
61. Energy efficiency utilizing type warp sizing machine (3 types)
62. Energy efficiency utilizing type dyeing and finishing equipment (9 types)
63. Non shuttle type automatic loom
64. Energy efficiency utilizing type circular knitting machine (2 types)
65. Energy efficiency utilizing type non-woven fabric manufacturing machine (2 types)
66. Rign-barker for small size timber
67. Energy efficiency utilizing type ogalite moulder
68. Energy efficiency utilizing type timber treating chopper
69. Energy efficiency utilizing type single board dryer (2 types)
70. Energy efficiency utilizing type pulper
71. Energy efficiency utilizing type refiner
72. Screw press type dehydrator
73. Energy efficiency utilizing type paper made container manufacturing equipment (3 types)