HANDY MANUAL

PLASTIC FORMING INDUSTRY

Output of a Seminar on
Energy Conservation
in Plastic Forming Industry

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India  Pakistan
The conservation of energy is an essential step we can all take towards overcoming the mounting problems of the worldwide energy crisis and environmental degradation. In particular, developing countries are interested in increasing their awareness of inefficient power generation and energy usage in their countries. However, usually only a minimum of information on the rational use of energy is available.

The know-how on modern energy saving and conservation technologies should, therefore, be disseminated to government and industrial managers, as well as to engineers and operators at the plant level in developing countries. It is particularly important that they acquire practical knowledge of the currently available energy conservation technologies and techniques.

In December 1983, UNIDO organised a regional meeting on energy consumption as well as an expert group meeting on energy conservation in small- and medium-scale industries for Asian countries. The outcome of these promotional activities prompted UNIDO to initiate a new regional programme designed to increase the awareness and knowledge of government officials and industrial users on appropriate energy saving processes and technologies. In 1991, the first project, Programme for Rational Use of Energy Saving Technologies in Iron and Steel and Textile Industries in Indonesia and Malaysia (US/RAS/90/075), was approved and financed by the Government of Japan.

The successful completion of this project prompted UNIDO to request the financial support of the Government of Japan to carry out similar projects under this programme in other developing countries. Since 1992, under continuous support of the Government of Japan, two other projects have successfully been completed: Rational Use of Energy Saving Technologies in Pulp and Paper and Glass Industries in the Philippines and Thailand (US/RAS/92/035); and Rational Use of Energy Saving Technologies in Ceramic and Cement Industries in Bangladesh and Sri Lanka (US/RAS/93/039).

This year the programme is being implemented in India and Pakistan, targeting two energy intensive industrial sub-sectors; namely, plastic forming and food processing industries.
In the plastic forming industry, a substantial amount of energy is consumed. Excessive use of energy is usually associated with many industrial plants worldwide, and plastic forming plants are no exception. Enormous potential exists for cost-effective improvement in existing energy-using equipment. Also, application of good housekeeping measures could result in appreciable savings in energy. Therefore, it is imperative to introduce and disseminate information about modern energy saving technologies among the parties concerned in government and especially, at plant level, in industries.

In order to achieve the objectives of this programme, the following strategy is being used:

1. Conduct surveys of energy usage and efficiency at plant level, to establish the required energy saving measures.
2. Prepare handy manuals on energy management and energy conservation techniques and technologies, based on the findings of the above surveys.
3. Present and discuss the content of the handy manuals at seminars held for government officials, representatives of industries, plant managers and engineers.
4. Disseminate the handy manuals to other developing countries for their proper utilization and application by the target industrial sector.

The present Handy Manual for the plastic forming industry was prepared by UNIDO, with the cooperation of experts from the Energy Conservation Center (ECC) Japan, on energy saving technologies in the framework of the above-mentioned UNIDO programme. It is designed to provide an overview of the main processes involved in food processing, and present a concise guideline for the recommended energy saving measures.

Appreciation is expressed for the valuable contribution made by the following institutions to the successful preparation and publication of this manual:
- Ministry of Petroleum and Natural Gas, India;
- Ministry of Water and Power, Pakistan;
- Ministry of International Trade and Industry (MITI), Japan; and
- The Energy Conservation Center (ECC), Japan.

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Contents

1. Production process of plastic forming ............................................. 1

1.1 History of plastic forming process ............................................. 1

1.2 Production process of plastic forming ......................................... 2

1.2.1 Injection molding process ..................................................... 2

1.2.2 Extrusion molding process .................................................... 4

1.2.3 Blow molding process .......................................................... 5

1.2.4 Classification of plastic materials ........................................... 8

2. Characteristics of energy consumption in plastic forming ...... 8

3. Promotion of energy conservation technique ......................... 10

3 steps of energy conservation

3.1 Raw material process ............................................................. 11

3.2 Molding process ................................................................. 12

3.3 Finishing process ................................................................. 30

3.4 Mold design .......................................................... 33

3.5 Production control ............................................................... 37

3.6 Utilities .......................................................... 38

3.7 Energy conservation in equipment ........................................... 40

4. Conclusion ............................................................................. 43
1. Production process of plastic forming

1.1 History of plastic forming process

The word “plastic” means substances which have plasticity, and accordingly anything that is formed in a soft state and used in a solid state can be called a plastic. Therefore, the origin of plastic forming can be traced back to the processing methods of natural high polymers such as lacquer, shellac, amber, horns, tusks, tortoiseshell, as well as inorganic substances such as clay, glass, and metals. Because the natural high polymer materials are not uniform in quality and lack mass productivity in many cases, from early times it has been demanded in particular to process them easily and into better quality and to substitute artificial materials for natural high polymers. Celluloid, synthetic rubber, ebonite, and rayon are these artificial materials.

Presently, it is defined that the plastics are synthesized high polymers which have plasticity, and consequently substances made of these natural materials are precluded.

The history of plastic forming started together with the development of phenol resin in the beginning of the 20th century. Originally, plastics were not produced as plastic materials but derived from improvement of natural materials, and therefore, their processing methods also progressed on the extended line of conventional processing methods.

Several years after the industrial production of phenol resin, the production of vinyl chloride resin started, and then the production of styrene-based resins started. By the end of the first half of the 20th century, almost all main materials of synthetic resins were developed.

As to the forming methods, it is said that the first injection molding machine was put to use in Germany in 1921; however, it can be said that this machine is an extension of the die-cast machine. All basic methods using pressing machines, rolling machines and extrusion machines had already existed since early days. The development and prevalence of plastic forming as shown today can be ascribed to the characteristics of materials, prices, and good processability arising from the uniformity of artificial materials and, in addition, their mass produceability and allowance for cost reduction.

An industry does not develop until there are demands and supply for the demands. The plastic industry is an exemplar model to meet these demands. This exemplar model, however, could cause unexpected harmful influences if the long-term perspective of plastics is not taken into consideration. One of them is the problem of treatment of wastes and
another is the problem deriving from excessive consumption of energy.

1.2 Production process of plastic forming

There are two types of plastics. One is called thermosetting resin which does not soften again once it is formed and hardened, and the other is called thermoplastic resin which becomes soft or hard when its temperature rises or falls.

Although thermosetting resin has an older history, the majority of the presently used plastics are made of thermoplastic resins. The main plastic forming methods are shown in Table 1.

Table 1. Plastic molding process

<table>
<thead>
<tr>
<th>No.</th>
<th>Molding process</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Extraction molding</td>
<td>Pipe, etc.</td>
</tr>
<tr>
<td>2.</td>
<td>Injection molding</td>
<td>Bucket, housing of office automation equipment</td>
</tr>
<tr>
<td>3.</td>
<td>Blow molding</td>
<td>Container, bottle</td>
</tr>
<tr>
<td>4.</td>
<td>Vacuum forming</td>
<td>Packcase for egg (thin film product)</td>
</tr>
<tr>
<td>5.</td>
<td>Pressure forming</td>
<td>Suitcase (thick sheet product)</td>
</tr>
<tr>
<td>6.</td>
<td>Rotation (Roto) molding</td>
<td>Bottle, doll</td>
</tr>
<tr>
<td>7.</td>
<td>Inflation process</td>
<td>Film, sack</td>
</tr>
<tr>
<td>8.</td>
<td>Calender process</td>
<td>Film, sheet</td>
</tr>
<tr>
<td>9.</td>
<td>Fluidized bed process</td>
<td>Tub</td>
</tr>
<tr>
<td>10.</td>
<td>Compression molding</td>
<td>Electric parts: plug, switch box</td>
</tr>
<tr>
<td>11.</td>
<td>Transfer molding</td>
<td>Package molding for integrated circuit</td>
</tr>
<tr>
<td>12.</td>
<td>Pull trusion mold bar</td>
<td></td>
</tr>
</tbody>
</table>

Among the methods mentioned above, 3 main methods are explained below.

1.2.1. Injection molding process

Fig. 1 shows the forming process. Figs. 2 and 3 show injection machines.

(1) In general, material arrangement and coloring are carried out in separate process.

(2) The drying process may be required for some plastics but not required by others.

(3) Materials are supplied to a molding machine from a hopper.

(4) Materials are heated to be plasticized with a heating cylinder. There are various methods for this process. The most popular method is as follows: The screw in-line feeds materials forwards while the screw itself goes rearwards, and when a specified volume of plastic material for plasticity is completed, the screw is moved forwards
Figure 1 Injection molding process

Figure 2 Plunger type Injection equipment

Figure 3 Screw type injection equipment (In-line screw system)
and a plastic resin is injected and charged into a closed die to mold a shape.

(5) The resin that has filled up the inside of the cavity of die is cooled in the die and becomes solid.

(6) The die is opened to take out molded products. Parts other than products (spure, runner, fin, defective products, etc.) which are produced by this process are regarded as non-conforming products and they can be used again as molding materials.

1.2.2 Extrusion molding process

Fig. 4 shows an extrusion molding process.

Fig. 5 shows an extrusion machine. Although there is no difference from the injection molding until a material is supplied, when the material is heated plastic in the heating cylinder, the position of screw is fixed, in general. Therefore, a resin which is made plastic is discharged continuously from the die. The discharged resin is molded into the basic shape and finally formed with the sizing die and cooled and solidified. The receiving equipment serves an auxiliary function to receive extruded products.

The products are cut or wound up according to their characteristics and purpose of use.

This molding method is most suitable for molding pipes, sheets, and films with uniform cross sections.

![Figure 4 Extrusion molding process](image)
1.2.3. Blow molding process

There is no difference from the injection molding and extrusion molding until a material is carried into the hopper. The blow molding is a method which clamps a cylindrical material called “parison” with split molds and blows air inside to blow it up and press it onto the inner wall of the die. Fig. 6 shows the blow molding process.

The parison is a word which is used only for the blow molding and indicates a material in the form of a tube, pipe (bottomless or bottomed) or a pair of sheets before the material is blown up during the blow molding.

There are 2 molding methods for this parison; one is the direct blow method as shown in Fig. 7, in which the material is pushed out in the form of a pipe from the extrusion molding machine and the other is the injection blow method as shown in Fig. 8, in which an injection molding machine is used to form the material into a bottomed parison like a test tube.

In the case of the injection blow, the method called “extension blow”, in which the material is blown up not only in lateral direction but also in longitudinal direction for improvement in physical properties, as shown in Fig. 9 is often used.
Figure 6 Blow molding conceptual drawing

Figure 7 Direct blow conceptual drawing
Figure 8 Conceptual drawing of injection blow molding machine

Figure 9 Conceptual drawing of extension blow molding process
1.2.4 Classification of plastic materials

Plastic materials consist of the thermosetting type and the thermoplastic type. Fig. 10 shows a classification of plastic materials and the production amount of plastic materials in Japan in 1994. The thermosetting materials account for less than 20% of all plastic materials, and the majority of them are used as coating agents and adhesives. Therefore, almost all plastic products are thermoplastic. Engineering plastic does not yet account for 20% of all plastics.

Therefore, almost all of plastics forming products are thermoplastics resin. Engineering plastics which are PET(polyethylene telephthalare)bottles and polyester film does not yet account for 20% of all plastics.

Accordingly, most of the materials for plastics forming products are vinyl cride, polystyrene and polyolefine.

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**Figure 10 Amounts of plastics production in Japan (1994)**

2. Characteristics of energy consumption in plastic forming

The production systems using plastic molding machines are shown in Fig. 11. The state of energy consumption in each system is as follows:

1) Molding machine: Consumes energy to melt and extrude material pellets.
2) Material supplying system: Consumes energy to operate the material supplying conveyors and to dry materials. There are 2 cases where scraps and runners of product are crushed and used again as materials and where they are crushed and melted again and regenerated as material pellet with an extruding machine, and energy is consumed for crushing, remelting and pelletization.

3) Die exchange system: Consumes energy necessary for preparation and machining of die, and also, consumes energy to regulate temperature of die (cooling).

4) Product taking out system: Consumes energy to cool products when they are taken out. After runners are taken out, they are crushed and used as material again. Crushing them also consumes energy.

5) Physical distribution system: Consumes energy for vehicles and cranes to transport and store products.

6) Information control system: Energy is consumed by monitors and computers for setting conditions and information control.

Among the above-mentioned systems, it is the forming machines that consume the most energy.

Presently almost all molded plastics are thermoplastic products. The basic method to form thermoplastic pellets is to “set a thermoplastic material in plastic state by heating” and form into “a desired shape” and then “cool and solidify it.” The basic forming process is as follows: Heating for plasticity --> forming --> cooling and solidifying.
3. Promotion of energy conservation technique

Energy conservation in industrial sectors starts from the software including operation control and process control, then extends into the hardware including equipment improvement and process improvement. Generally, energy conservation efforts can be classified into the following three steps:

Step 1 - Good housekeeping

Energy conservation efforts, made without much equipment investment, include elimination of the minor waste, review of the operation standards in the production line, more effective management, improvement of employees’ cost consciousness, group activities, and improvement of operation technique.

For example, such efforts include management to prevent unnecessary lighting of the electric lamps and idle operation of the motors, repair of steam leakage, and reinforcement of heat insulations.

Step 2 - Equipment improvement

This is the phase of improving the energy performance of the equipment by minor modification of the existing production line to provide waste heat and pressure recovery equipment or by introduction of efficient energy conservation equipment, including replacement by advanced equipment. For example, energy conservation efforts in this step include effective use of the waste heat recovery in combustion furnaces and introduction of the waste pressure recovery device and waste heat recovery generator in the steel and iron works and cement plant.

Step 3 - Process improvement

This is intended to reduce energy consumption by substantial modification of the production process itself by technological development. Needless to say, this is accompanied by a large equipment investment. However, this is linked to modernization of the process aimed at energy conservation, high quality, higher added value, improved product yield and manpower saving.

The following Table 2 shows the classification of energy conservation techniques in the plastic forming industry:
Table 2 Three steps of energy conservation in the plastic forming

<table>
<thead>
<tr>
<th>Raw material process</th>
<th>Molding process</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st step</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Quality control</td>
<td>1) Suitable</td>
<td>1) Reduction in preparation time at start</td>
</tr>
<tr>
<td>of raw material</td>
<td>plasticity method</td>
<td>2) Reduction in time for change of products</td>
</tr>
<tr>
<td></td>
<td>2) Suitable heater connection</td>
<td>3) Improvement of yield</td>
</tr>
<tr>
<td></td>
<td>3) Increase in forming speed</td>
<td>4) Improvement of power factor of transformer</td>
</tr>
<tr>
<td></td>
<td>4) Suitable forming method and equipment</td>
<td>5) Emission of non-conforming products</td>
</tr>
<tr>
<td></td>
<td>5) Hydraulic operating fluid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6) Compressed air leakage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7) Suitable cooling system</td>
<td></td>
</tr>
<tr>
<td>2nd step</td>
<td>1) Heat insulation of heating cylinder</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd step</td>
<td>1) Change of driving system</td>
<td></td>
</tr>
</tbody>
</table>

3.1 Raw material process

3.1.1 Quality control of materials

The forming materials have unexpectedly large non-uniformity of quality. Although the non-uniformity of quality of general purpose materials which are supplied continuously may not be very conspicuous, it should be assumed that this non-uniformity of engineering plastics is very large in batch production. Therefore, control of products and material lots should always be made.

Although the non-uniformity of quality may not be a serious problem for injection molding, it is an important factor for extrusion molding and blow molding.

The sizes of pellets also influence the forming property significantly. In particular, when pellets are used in the flake form, attention should be paid as much as possible to the uniformity of size and mixing ratio.

Coloring is generally conducted in a separate process. However, when the coloring quantity is large, coloring may be carried out by mixing coloring pigment with the screw (hopper blending).

Quantity of coloring with the master batch may not require much attention, but when a dry color or a liquid color is used, then it is necessary to take the color change procedure into account.

If pellets in the form of flake or pellet of extremely different sizes are transferred with the hopper loader or the dryer by combined use of the hopper loader, there is a possibility of causing separation of pellets resulting in defective molding.
3.1.2 Return control of scrap

There are many cases where scraps are put to a batch control. However, properties of scrap differ greatly in quality depending on their origin. For example, spure and runner as well as films under production which are just ejected remain utterly clean, therefore, it is required to return them on the spot. For example, polyester family resins (PET resin, etc.) which need sufficient drying are not humid immediately after forming. Hence, no re-drying is necessary if they are returned dry. Accordingly, it is utterly useless to stock them, allow them to absorb humidity, dry them for extrusion, or to soak them in water to let them absorb humidity.

In comparison, scraps which were generated after the finishing process as well as scraps which have fallen on the floor are extremely fouled. In general, the former can be flaked and returned again without any further treatment, while the latter should be melted and pelletized to remove rubbish and other contamination. For this purpose, automation of the finishing process should be progressed, equipment which can prevent scraps from falling on the floor should be prepared, and finish of the floor should be improved. (At least, the floor should be finished to lustering polish cement which allows cleaning with a mop.)

Moreover, to regard various scraps which are so different in quality and to mix them together will reduce the quality of returned materials and push up the returning cost (energy cost in various meanings).

It is important to control the origin of occurrence of scraps. It is against the principle to remove contamination at the step of molding machine operation. The net of molding machine is provided in order to improve the mixing effect and to eliminate contamination, although their effects are not outstanding.

3.2 Molding process

3.2.1. The insulation of heat cylinders

As a rule, thermoplasticity is provided at the heating cylinder. A thermal medium such as oil may sometimes be used for heating. In general, however, this process is carried out only with an electric heater that uses resistance heat generation. What is important in this context is the insulation of the heating cylinder.

The insulation of the heating cylinder does not simply mean to surround the heating cylinder with a heat insulating material so as to keep heat inside the heating
cylinder. It is true that plasticity of resin is provided by heating the heating cylinder externally, the pieces of resin sufficiently rub against each other while they are transferred with the screw and they are heated by friction with the internal wall of the heating cylinder and by shearing force. And so, heating with the heater is the principle, but cooling is also required sometimes. In general, heating is carried out using an incomplete cover (without any cover in some cases) to provide air cooling on a constant basis.

Fig. 12 shows an example of a good cover in order to prevent heat radiation from heating cylinder (Fig. 13). The cover is specified to have a dual wall, and a heat insulating material such as rock wool is inserted inside. A window is provided in a suitable portion, and it is opened and shut automatically in proportion to the rise of temperature. It is better if a blower is provided to it. The inside and outside of the cover and the heater holding bands need to be made of stainless steel or an equivalent which has a metallic luster and is free from rusting. If these improvements are not available, provide a cover which can fully enclose the heating cylinder, at least.

![Figure 12 Heating cylinder cover](image1)

![Figure 13 Heat radiation from heating cylinder](image2)
Neat loss from the heating cylinder is caused by conduction, convection and radiation from the contacting portions of the machine proper and others. Apart from conduction, we calculate heat radiation volume by convection and radiation. Assuming that:

- Outer diameter of heating cylinder: 20 cm
- Length of heating cylinder: 1.5 m; Surface area = 0.942 m² = 0.2 x 3.14 x 1.5
- Surface temperature of heating cylinder: 277°C (550°K)
- Room temperature: 27°C
- Wall surface temperature: 17°C (290°K)

Then, the heat conduction volume, q, (heat radiation volume) by natural convection per unit time and unit area is expressed by the following equation:

\[ q = \alpha \Delta T \]

\( \alpha \) is a conduction rate by natural convection, which is approximately 5 W/m².k and approximates 10 W/m².k when the temperature is near 300°C. Consequently, the heat radiation volume by natural convection, \( q_i \), is calculated as follows:

\[ q_i = 10 \times (277 - 27) \times 0.942 \approx 24 \text{ kW} \]

When no cover is provided thereto, the heat radiation volume \( q_2 \) (where only one machine is installed in a large room) is expressed as follows:

\[ q_2 = \varepsilon \times 5.67 \times 10^8 \times (T_1^4 - T_2^4) \]

\( \varepsilon \) is a radiation rate which is 0.1 for metallic lustrous surface and 0.9 for a black surface. \( T_1 \) and \( T_2 \) are absolute temperatures of the heating cylinder and the circumferential wall, respectively. Therefore, the maximum radiation loss is calculated as follows:

\[ 0.9 \times 5.67 \times 10^8 \times \{(273 + 277)^4 - (273 + 17)^4\} \times 0.942 = 4 \text{ kW} \]

In consequence, the heat radiation without a cover is the addition of 2.4 + 4 = 6.4 kW

The calculation expression (where there is not enough space from walls to install a cover) is expressed as follows:

\[ q'_2 = \frac{5.67 \times 10^8 \times (T_1^4 - T_2^4)}{(1/\varepsilon_1 + 1/\varepsilon_2 - 1)} \]

Assuming that \( \varepsilon_1 \) and \( \varepsilon_2 \) are 0.1 when heat insulating material is added, and that the temperature of the inner wall is 207°C and the temperature of the outer wall is 87°C where the natural convection heat conduction rate is 6 kW/m².k, and in the case where no heat
insulating material is added and the temperature of the inner wall is 207°C and the temperature of the outer wall is 197°C where the natural convection heat conduction rate is 8 kW/m².k, then the heat loss volume is calculated as follows:

Heat insulating material is installed:

- Between heating cylinder and inner wall $\approx 0.11$ kW
- Between the outer wall of cover and room wall $\approx 0.03$ kW
- Heat radiation by natural convection $\approx 0.36$ kW
- The total loss of heat $\approx 0.5$ kW

Where a cover is installed without any heat insulating material, the heat loss is calculated as follows:

Only a cover is installed:

- Between heating cylinder and inner wall $\approx 0.11$ kW
- Between the outer wall of cover and room wall $\approx 0.13$ kW
- Heat radiation by natural convection $\approx 1.5$ kW
- The total loss of heat is 1.74 kW.

Comparing this value with the heat loss of 6.4 kW where no cover is provided, it can be said that there is a considerable energy saving volume.

1. Be sure to install a cover on the heating cylinder in order to prevent natural convection.
2. Replace the heating cylinder cover (in general, presser of the band heater) and the inside/outside of the cover with metallic and lustrous plates such as stainless steel plate (silver coating color, at least). Provide heat insulation so that the surface temperature of these covers can be restricted as low as possible.
3. Repaint the walls and ceiling of workshop to a bright color (white color has the lowest radiation rate).

### 3.2.2 Heater temperature control

The basis of temperature control is feedback control. Detect the heater temperature of extruder with a thermocouple and convert it into an electric volume and compare this as a feedback volume with a set value. If there is a deviation, determine the operation volume of the deviation and operate the electromagnetic relay so that the heater temperature can be the same value as the set value.
Turning ON/OFF the electromagnetic relay turns heater electricity ON and OFF and permits regulating and maintenance of the heater temperature at a set temperature.

Figs. 14 and 15 show a drawing and a block diagram of the heater circuit of an extruder.

There are the following signal volumes for the temperature controlling system:
(1) Control volume (controlled variable): A target volume of control (e.g., heater temperature)
(2) Operation volume (manipulated variable): A volume added to the control target to perform control. Modifying this variable makes it possible to keep the controlled variable constant. (e.g., volume of electric current inputted to the heater)
(3) Deviation (error): A volume obtained by subtracting a detected value from a set value as target temperature. Normally, control is performed to eliminate this deviation volume.
(4) Measured value (process variable): Value which is converted from a detector (e.g., electromotive force of thermocouple)

When it is desired to operate a heating cylinder at 200°C, as shown in Fig. 16, the supplied power is controlled in proportion to the degree of temperature between a point of temperature below 200°C (assumed to be 190°C in this context) and a point over 200°C (assumed to be 210°C).
This regulation is necessary, because overheating tends to occur if the supplied power is not decreased; moreover, calories are always consumed, and it is impossible to stop supplying electricity when a target value is obtained. Thus, this zone is called the proportional band to control the supplied power in proportion to the degree of temperature. When the temperature goes up further and exceeds the upper limit (210°C in this case), then it becomes necessary to cool down the heating cylinder. A blower is often used for this cooling; however, there are many cases where only radiation by natural convection is employed. As explained above, it is a total waste of energy to excessively use cooling equipment. The supplied power decreases when temperature falls to the proportional band. There are various methods to decrease the supplied power; one method is to regulate voltage and another method is to supply power on an intermittent basis, and there are some more methods. What is introduced next is a method to decrease the basic supplied power by changing over connection of electric wires.
In general, thermal plasticity is obtained by transmitting pellets with the screw in the heating cylinder. The heat that is involved in the plasticity can be classified into the following 3 categories:

(1) Heat that is generated by pellet friction
(2) Heat that is generated by shearing of melted resin
(3) Heat that is added externally.

Category (1) i.e., use of frictional heat, is reported to be effective for energy savings, however, reports on numeric values only are not made yet. Category (2) (use of shearing heat) is utilized very effectively depending on products and kinds of material, however, a suitable design of the screw for this utilization is required, and there has been no report on energy only.

In contrast, there have been case studies on the category (3) (external addition of heat) indicating that a greater result was obtained by changing the electric wire connecting method. These case studies commonly relate to the extrusion molding machine, and basically the method can be applied to the injection molding machine as well.

Case Study: Improvement of extruder heater heating method

(1) **Heat balance of extruder and thermal efficiency**

Product: Vinyl covered wire

Thermal efficiency = (Product output heat / input heat) x 100 (%)

extruder:

Heater capacity = 40 kW; driving electric motor capacity = 45 kW

Fig. 17 shows an extruder.
Figure 17 Extruder in water cooling system

<table>
<thead>
<tr>
<th>Input heat:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>17,500 kcal/h (56.3%)</td>
<td></td>
</tr>
<tr>
<td>Heater</td>
<td>13,600 kcal/h (43.7%)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31,100 kcal/h (100%)</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output heat:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>11,300 kcal/h (36.3%)</td>
<td></td>
</tr>
<tr>
<td>Cooling water</td>
<td>11,900 kcal/h (38.3%)</td>
<td></td>
</tr>
<tr>
<td>Radiation</td>
<td>2,900 kcal/h (9.3%)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>5,000 kcal/h (16.1%)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31,100 kcal/h (100%)</strong></td>
<td></td>
</tr>
</tbody>
</table>

Thermal efficiency = \( \frac{11,300}{31,100} \times 100 = 36.3\% \)

Mean heater electricity consumption = 15 kWh/h

(2) Improving method

Thermal efficiency lowers due to repetition of heating and cooling. If the speed of temperature rise is lowered, useless heating can be prevented and less cooling is required. As the heater connection is the A connection, if the heater connection is changed for Y connection in order to decrease the heater capacity, then the capacity can be reduced to \( \frac{1}{3} \). This case study succeeded in decreasing the heater capacity by specifying the heater connection to be the Y-A connection and the Y connection is employed only during motor operation. Nevertheless, the PID (Proportional, Integrating and Differential) control is more suitable for temperature regulator of extruder in air-cooling system.

(3) Effects

**Thermal efficiency before improvement:** 30～40%
Mean heater power consumption: 15 kWh/h

**Thermal efficiency after improvement:** 40～50%
Mean heater power consumption 8.4 kWh/h
Comparison: approx. 130% and 56%

Figs. 18 and 19 show the A connection and Y connection. Figs. 20 and 21 show temperature changes before and after the improvement.

Figure 18 Δ connection

Figure 19 Y connection

Figure 20 Transition of temperature before improvement
3.2.3 Driving the molding machine

The driving unit of the molding machine is mainly composed of the injection (extrusion) mechanism and the clamping (receiving) mechanism. The receiving mechanism of the extrusion molding machine used to apply electric power in early days, and in those days no hydraulic system was applied. As to other components, both systems were applied for various reasons. When judged from the viewpoint of energy saving, however, it is obvious that the direct motor driving system is superior to the hydraulic system in which hydraulic power is generated with a driving motor and so the direct motor driving system is applied in many molding machine recently. To take an example from the injection molding, the electric-powered servo machine is defined to be a machine whose injection system employs a servo motor and the clamping employs a toggle system. The toggle machine is defined to be an injection machine which applies a hydraulic system and the clamping employs a toggle system. The straight hydraulic machine is defined to be a machine in which both systems are operated by hydraulic power. Table 3 shows a comparison of power consumption volumes between an electric-powered servo machine and a straight hydraulic machine manufactured by the same maker, according to the same standard.

The straight hydraulic machine of this maker is equipped with a hydraulic mechanism for pressure holding independent of the main driving mechanism, and owing to these mechanisms, this energy saving type does not consume much electric
Table 3. Comparison of power consumption volumes between electric-powered servo machine and straight pressurizing machine

<table>
<thead>
<tr>
<th></th>
<th>Standard power consumption/h</th>
<th>Yearly power consumption</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric-powered servo machine</td>
<td>2.94 kW</td>
<td>21,168 kWh</td>
<td></td>
</tr>
<tr>
<td>Straight hydraulic machine</td>
<td>4.30 kW</td>
<td>30,960 kWh</td>
<td></td>
</tr>
</tbody>
</table>

Yearly operating hours 24 h/day x 25 days/month x 12 months = 7,200 h

power. Still the difference in power consumption is shown in table 3. Power consumption of the toggle machine falls between them.

With respect to minimization of power consumption, it is desired for hydraulic fluid of the hydraulic mechanism to have as low a viscosity in the lubrication of cylinder. However, an excessively low viscosity of the fluid will hinder machine operation. The viscosity of the hydraulic fluid is heavily affected by ambient temperature. It is, therefore, effective to change the types of hydraulic fluid according to temperatures in summer and winter. Accumulated leakage of air and water will result in a vast waste of electric power in the long run.

3.2.4 Increase in forming speed

The major themes of energy savings during the forming process consist in restricting electric power consumption while maintaining the production volume and in increasing the production volume without much increase in electric power consumption, because the latter will result in reduction of energy cost per product.

The basic process of forming thermoplastics is to form thermoplastic material and to take it out after cooling and solidifying it. The majority of energy is used for providing plasticity to the material, and this energy does not change very much by material volumes so long as the plasticity is provided continuously with the same machine. That is to say, even if the production volume per unit time is increased by 50% or 100%, the energy that is consumed for plasticity remains almost the same. For the purpose of energy savings, therefore, it is important to increase the forming speed by improving dies and ancillary equipment and thereby to decrease the energy cost per product.
(1) Extrusion molding by reducing useless friction

In the case where one kind of resin is extruded with one machine, the discharge volume of resin changes to a large extent depending on the pressure applied to the resin. Although the discharge volume changes greatly, the total electric power consumption changes little. In the case of extrusion molding, the resistance (pressure) of the die to the resin is effective for manufacturing products, however, most of the resistance (pressure) that is applies to the resin in the previous steps of the die is useless. Therefore, filtration of contamination at the breaker of the molding machine should be restricted as an ancillary preparation. Basically, the role of net of the breaker plate is to assure the mixing effect.

(2) Extrusion molding: Continuous exchange device of contamination filtrating net

There are devices, such as the extruder net of the pelletizer for recycling whose purpose is to eliminate contamination. The net used to be exchanged by shutting down the machine operation once, or 2 nets and 2 passages were provided to change over the 2 passages by checking for pressure, and the net of the changed over passage was exchanged or cleaned. Recently, however, nets in the form of a belt or a disk are shifted sequentially to carry out exchange of a net without greatly changing the discharge volume while continuing to operate extrusion process. Such equipment has been manufactured.

(3) Injection molding: Balancing or eliminating the internal stress

It is important to arrange the gate position and geometry so that deformation by internal distortion does not occur in the cooling step.

Speed up of solidification leads to reduction in die temperature more often than not, and this forms an orientation layer of resin on the surface of the product, leading to its internal distortion. Since the internal distortion causes deformation, it is necessary to install the gate in a position where the stress by this internal distortion does not generate (i.e., deformation). As shown in Fig. 22, for example, it is known that in the case where a product is a wide and thin bottle lid, deformation appears easily when a side gate is provided and the shot cycle is sped up, however this deformation does not appear easily where a three-plate mold (die) and a center gate are installed. Depending on product shapes, the shape of the gate also exerts influence.
In some cases, positive elimination of the orientation layer is also attempted. Plate-formed products tend to bend in one direction. The orientation layer mentioned before shrinks when it is cooled, but its shrinkage does not occur uniformly; as a result, the layer tends to bend in the direction where shrinkage is greater. The orientation layer characteristic by disappears when it receives a force applied at right angles to it. Therefore, as shown in Fig. 23, the bend will disappear by adopting a die structure which press-fits a compaction core in a manner to cut the orientation layer. The press-fitting of the core is possible by both hydraulic pressure and pneumatic pressure.
(4) Blow molding: Accumulator head

In an operation of an extruding machine with a single die head, the driving motor steps every time of pavison pushing. Basically, however, such molding should be avoided.

If the accumulator type die head as shown in Fig. 24 is adopted, the molding can be continued without stopping the motor. This adoption makes it possible to achieve twice the yield with the same energy in the same time. Intermittent operation of the motor would incur various problems such as occurrence of peak current, wear of switch, and damage to the machine. There is also a method which installs a double head for changeover of valves, as shown in Fig. 25.

![Figure 24 Accumulator system](image1)
![Figure 25 Conceptual drawing of double-head type](image2)

3.2.5 Standard for selection of molding machine

There are various and diversified forming methods for plastics, and there are suitable forming machines for each method. Even if some forming machines are classified into one group of forming method and called by the same name, there may be large differences in content. And so, an excellent forming machine cannot manufacture good products if it is not suitable for a specified product. Accordingly, it is important to select a forming machine which is suitable for the products to be manufactured. In a factory
where forming machines are already installed, it is important to choose orders of products by checking whether or not the forming machines match the ordered products. Next, mismatch of products and forming machines as well as the standard for selection of injection molding machines and blow molding machines is as follows:

(1) Injection molding machine

There are various types of injection molding machines. It does not necessarily mean that it is better to use expensive machines for manufacture of better quality products. Ordinary injection molding products can be classified into the following 4 groups. It is recommended to use an exclusive-use machine for special molding such as 2-color molding. Inappropriate molding process will make product quality lower and will lead to occurrence of accident. Please select a suitable molding machine, making sure of the group to which the products to be manufactured belong. If molding machines are already installed, select products which match the existing machines. (Table 4)

<table>
<thead>
<tr>
<th>Molding</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Molding</td>
<td>Molding of general molded products including appearance products: Select molding machine according product capacity.</td>
</tr>
<tr>
<td>Low Deformation Molding</td>
<td>Molding thick-wall molded products such as lenses that prohibit internal deformation.</td>
</tr>
<tr>
<td>High Transcription</td>
<td>Molding of molded products which demand to accurately transcribe the surface of die to the surface of products such as compact disk and models of flowers and insects.</td>
</tr>
<tr>
<td>Precision Molding</td>
<td>Molding of molded products of which demand on dimensional precision for mechanism parts is strict.</td>
</tr>
<tr>
<td>Special Molding</td>
<td>Injection compression molding, 2-color molding, sandwich molding, gas injection molding, etc.</td>
</tr>
</tbody>
</table>
(2) Blow molding

In the case of blow molding, it is obvious whether a blow molding machine matches or does not match products more so than it with injection molding machines. Fig. 26 systematically shows blow forming methods. This distinction applies to even the simplest containers which are manufactured by blow molding.

a) Some products are suitable for direct blow molding, and others need to be manufactured by injection blow molding.

b) The injection blow is classified into no-extension blow and extension molding.

c) Depending on quantity, appropriateness of the cold parison method or the hot parison method should be selected.

In the field of the function blow, specialization of machines has progressed for productivity of manufacture in the same manner as the special molding field. Table 5 shows the relation between products and molding machines in the field of blow molding.
Figure 26 Systematic table of blow molding methods
<table>
<thead>
<tr>
<th>Classification by quantity</th>
<th>Forming machine to be used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large-sized container</strong> Large-size irregular shaped container Irregular-shaped product</td>
<td>Larger than 10 liters  Mainly for capacity up to 200 liters  May mold greater than 200 liters</td>
</tr>
<tr>
<td><strong>Middle-sized container</strong> Middle, Medium size irregular shaped container (with a handle, etc.) Accumulator system only Possible to mold irregular-shaped products</td>
<td>Applicable from 1 to 10 liters  Sometimes up to 20 liters</td>
</tr>
<tr>
<td><strong>Small container</strong></td>
<td>1 liter or less  Sometimes up to 2 liters</td>
</tr>
</tbody>
</table>
3.3 Finishing process and others (Finishing and Printing)

After formed products are taken out of a forming machine, they necessarily enter some subsequent process.

What is important in the subsequent process is that manual modification or correction should be avoided as much as possible, because such manual modification or correction will increase non-uniformity of quality and lead to an increase of defective products.

In the field of injection molding, various kinds of in-mold automatic cutting equipment are contrived. Various contrivances are also made in the field of the direct blow molding where trimming is indispensable. And, in any forming method, taking out and arranging products need to be carried out, which should also be performed without using manual modification or correction as much as possible. Printing, adhesion, and jointing are important factors in the subsequent process.

3.3.1 Trimming (similar to overall pinch off) of large-sized product

Much difficulty follows trimming (similar to overall pinch off) of a large-sized product. If the cutting-off portion of the molding die is sharpened, the jointing portion will be torn and if the cutting-off portion of the molding die is made dull, the finishing process takes much labor. And if fins of the jointing portion are not removed, deformation necessarily occurs, resulting in molding defective products. In general, the wall of these products is thick, and the shot cycle cannot be shortened easily. In such a case, it is recommended to prepare a finishing die in addition to the molding die.

The difference between the forming die (mold) and the finishing die is that the cutting-off portion is made sharp although their shapes are exactly the same. Molding is performed with the forming die (mold), and when the shape of a product is almost completed in its mild state, the product is transferred to the finishing die. Then, air is blown again and pressure is applied to perform closing sufficiently. This method permits finishing of the product without incurring any cut at the jointing portions. Such use of 2 pieces of dies is also applicable to the shot cycle.

3.3.2 Trimming of the mouth of narrow bottles

In the case of the cut-off type molding machines, it is possible to automate the trimming process for the mouth of narrow bottles by introducing a two-step closing system as shown in Fig. 27 and by slightly rotating the insertion inner diameter.
3.3.3 Joining in the secondary process

The insert molding, in which a single product member is inserted in a die, hinders not only the shot cycle but also tends to incur unexpected troubles such as dropping or biting of the member. In such a case, it is advantageous more often than not to perform jointing in a separate process although one process is added.

1) Process a prepared hole in advance prior to the forming, and press-fit parts such as a nut to be inserted by using an ultrasonic vibrator in the secondary process. Then, the press-fit parts are heated and deposited by the effect of the ultrasonic vibrator. It is, however, required to provide a preventive measure such as cutting with a knurling tool to the outer periphery of the inserted parts.

Depending on shapes of parts, it is possible to employ a screw mechanism of self-tap type. When press-fitting metallic parts, there is a method to press-fit by heating the metallic parts with high-frequency waves without using the ultrasonic vibrator.

2) If a member is in the shape of a pin, in most cases it is only required to process a prepared hole followed by simple press-fitting. In such cases, it is needed to provide a preventive measure by cutting the jointing part with a knurling tool or by crushing the joint.

3.3.4 Surface treatment

When performing printing or adhesion, it goes without saying that it is required to clean the surface to be processed. However, there are many kinds of materials such as polyolefine resin and others that require more measures for a satisfactory finish. In such cases, it is needed to provide a treatment which activates the surface. The representative
cases are the corona discharge treatment used mainly for films, the flame treatment for formed products, and the corona discharge treatment for formed products. Since the primer treatment is easy, this treatment is applied for many purposes.

### 3.3.5 Printing

Printing to the product is indispensable for the subsequent process of molding in order to show value and use of product. Fig. 28 shows the kinds of printing systematically.

Among these kinds of printing, it is flexographic printing that is used for printing of sheet and film of plastic products, silk screen printing that is used mainly for bottles, pad printing that is mainly used for injection molding products, and the hot stamp for metallic luster.

Except in the hot stamp printing, ink drying becomes the biggest problem in the printing process. Natural drying used to be the main method. Presently, printed products are passed through a drying furnace, or an ultraviolet ray hardening ink is used for improvement in efficiency.

![Figure 28 Types of printing](image)

**Figure 28 Types of printing**
3.4 Mold design
3.4.1 Product shapes and die structures

What is important for the design of injection molding products is to make the wall thickness uniform and to allow sufficiently for the draft. The undercut should be strictly avoided.

Forced pulling must be avoided in any case. Be sure to provide a large roundness to each edge as much as possible. This also applies to blow molding and other methods. In addition, the basis of shaping by blow molding is the “slender shoulder and shrunk bottom.” As to the arrangement of the cooling water pipe in the mold, the distance to the cavity surface needs to be slightly longer than the pitch of the cooling water pipes. If there is a portion which cannot be cooled easily, more cooling water pipes are required. In the case of the blow die, the cooling water pipes are arranged to have uniform space to one another. If it is difficult to install cooling water pipes or there is a fear of water leakage from the built-block type die, it is effective to use heat pipes. It is often employed to combine die materials such as combination of steel material and copper alloy or aluminum material of which heat conductivity and heat capacity are not the same.

If requirement for product quality is high, it becomes important to improve technology of deairing and degassing. Natural exhaust of air or gas from die and die material is not sufficient, therefore, exhaust is forced using a vacuum. Although vacuum pumps were used before as the vacuum equipment, such pumps had problems of cost and handling. Recently, therefore, vacuum equipment which uses a compressor is used mainly. The exhaust hole used to be prepared by longitudinally arranging thin plates, but recently, the equipment called bent chip, as shown in Fig. 29, is available commercially. This bent chip has a high porosity with longitudinal arrangement of fine wire.
3.4.2 Examples of injection molding

The spureless die is often used. In the case of die structure of injection molding, the runner and the gate are indispensable elements for the structure, but the spure is not necessary. The spure has secondary drawbacks such as waste of material, difficulty in product taking out due to unsolid spure while product is solidified already.

It is possible to decrease the cross section of the runner by eliminating the spure. In general, it is possible to reduce the size of spure to approximately 1/5. Fig. 30 shows an example of improvement in yield by use of a spureless die. This example shows that a die using a 15-g spure and a 15-g runner to make a 70 g product is changed for a spureless die. Then, a simple calculation shows that a 70% yield can be improved to a 96% yield by reducing the spure to 0 g and the runner to 1/5 (3 g). Fig. 31 shows a conceptual drawing of an ordinary die and a spureless die. There are many methods to eliminate the spure. The most popular method is to employ an extension nozzle.

![Diagram of spureless die and suction equipment](image)

**Figure 29 Gas bent chip and suction equipment**
3.4.3 Example of inflation process

Sacks which are manufactured by the inflation process need to have enough strength. The strength of the bag is determined by the strength of the thinnest portion. Therefore, forming of uniform wall thickness is important. There are many methods to ensure uniformity of wall thickness. Fig. 32 shows one example thereof. That is to say, in this example, thickness is measured (circumference is always measured) immediately before winding and cold air is blown into the resin discharging port when a portion of thin thickness appears.
3.4.4. Examples of blow molding

In the same manner as the inflation process, the main attention is given to preventing differences in thickness. The countermeasures are uses of the accumulator (see Fig. 33) to avoid draw down and the parison controller (see Fig. 34) for molding irregular shaped products.
3.5 Production control

3.5.1 Improvement in yield

Calculation expression of yield has quantity of product (weight) as the numerator and the total quantity of materials inputted into the hopper or the total quantity of materials discharged from nozzle as the denominator. That is to say, in connection to the expression of $A$ (virgin materials) + $B$ (in-house reproduction) $\longrightarrow C$ (conforming products) + $D$ (fins, scraps and non-conforming products), the yield is expressed as follows:

$$\text{Yield} = \frac{C}{A + B} \text{ or } \frac{C}{C + D}$$

(Conforming products) \\
(Total forming amount)

The materials consumed for die exchange, restart, color change and material change are to be evaluated individually and accounted as cost. In any case, energy for moving and crushing of return material is necessary.

3.5.2 Production control and inventory control

After all specifications are satisfied and products are completed, the products should be sold as the final step. If the products do not sell, they are not different from defective products. In particular, products sold in kits need to have counterpart components to be sold as a commodity. Lids without bottles cannot be a commodity.
3.6 Utilities

3.6.1 Improvement of power factor

The power factor of a transformer should be improved by performing measurements on a regular basis at a factory. The electric power that the factory receives is three phase, as a rule. This three phase electricity is often used as single-phase electricity for electric heat. Therefore, a balance between three-phase and single-phase is extremely important. The operating state of machines and change in their condition could also change the power factor.

The equipment, beginning with motors of which rush current is big, needs to restrict the peak current with capacitors; moreover, such equipment with big rush current should positively be replaced with equipment with small rush current. The rush current does not contribute towards production, but increases power consumption; moreover, it places a big burden on the power supplier -- more than superficial numerical values indicate.

3.6.2 Cooling

In forming thermoplastics, the plastic process by heating and the solid process by cooling are both important. In terms of quality and cost of products, it can be said that the solid process by cooling is more important than the former. Fig. 35 shows the cooling equipment of an injection molding machine. The process of cooling can be divided into the

![Figure 35 Cooling equipment of injection molding machine](image)
components ancillary to the forming machine such as the die cooling component and the cooling water treating components such as the cooling tower and the temperature regulator.

(1) Maintenance of die cooling water channels

The cooling water channel of die should always be dried and provided with rust preventing treatment after the forming process is terminated. If rust is generated, the rust should be removed neatly. The channel needs to be cleaned from time to time because lime deposits and water scale tend to attach to it. Observation of these points will exert surprisingly outstanding effects.

Although cooling of the sizing die in the extrusion molding is the same basically, it is recommended to increase the cooling effect by reducing pressure to the cooling tank, if any, and to improve the showering effect by rotation in back and forth strokes.

(2) Maintenance of cooling tower

After passing through the cooling water channel, the cooling water is either cooled in the cooling tower, or its temperature is regulated with the temperature regulator. Maintenance of the temperature regulator conforms to the maintenance instruction manual without serious troubles, in general. The cooling tower tends to have algae and moss or mud, its discharge port tends to be clogged up with these substances, various kinds of rubbish might remain in the tower, and some part of it may remain broken. These points should be checked. A part of cooling water always evaporates in the cooling tower. Accordingly, supply of water alone rather increases solid contents on a gradual basis and therefore some cooling water always needs to be discharged (5 to 10% depending on water quality) constantly so as to maintain the good quality of water.

3.6.3 Cooling and Pressurization of the forming factory

Good products are manufactured in a good environment.

Therefore, it is extremely important to maintain a good environment in the forming factory. Fig. 36 shows an example at cooling of the forming factory. Cool air goes down and warm air goes up. Space without workers can be left hot. It is a waste of energy to cool the whole of a high-ceiling factory attached with fans on the ceiling for cooling.

A working place which manufactures precision products, products of neat appearance, and sanitary products should be enclosed tightly and the indoor pressure should be set higher than outdoor ambient pressure for the purpose of preventing dust and
insects from entering. Consequently, on account of the higher indoor pressure, air flows constantly out of the factory. At such a working place, the entrance and exit have dual doors so that the air in the working place should not mingle directly with the outdoor air. And then, what is important next is that workers at such working places are required to wear suitable working uniforms.

![Figure 36 Example of cooling and pressurization at forming factory](image)

3.7 Explanation of energy conservation equipment
(Effective use of equipment and tools)

We have explained already that there is a vast difference in consumption of electric power between the hydraulic drive system and the electric drive system. The electric drive system gets power directly from motors (one-step drive), whereas the hydraulic drive system converts the power of a motor into hydraulic power (two-step power). This difference in effectiveness is obvious. For some decent reasons the explanation had to make a detour.

The servo motors that are presently put to use restrict the starting torque at a low value so as to avoid occurrence of unnecessary rush current, and inverters are used to perform electric current control according to required output. In addition, frequency control adjusted to motor speed is employed. Through these improvements, the required functions are exerted.
As to the heating control system, the phase control system and the zero cross control system are becoming the mainstream. The phase control system, as shown in Fig. 37, is a method which changes the phase angle of A.C. voltage applied to a load and thereby controls continuously the electric power supplied to the load. Basically, a thyristor element is employed to control the timing to apply trigger voltage.

Subsequently, as to the zero cross control system, as shown in Fig. 38, this is a method in which trigger voltage is applied to the thyristor element when A.C. voltage is 0 V so as to adjust electric power. The points at which the thyristor element is turned ON or OFF are located in the vicinity where voltage is 0 V and therefore there is no fear of noise occurrence. Because there is no mechanical changeover of contact points, there is no worry about the mechanical service life of the contact point. If the heating and cooling control system is employed jointly, it is reported that the electric power consumption (for heating only) can be reduced to 30% (energy saving by 70%) in comparison with the conventional ON-OFF system.

We have already mentioned the temperature control by the proportional band to some extent. At present the main control methods is PID (Proportional Integrating and Differential) control method. Using this method, the heating side is quickly reach and in stabilized at a target temperature, and at the same time, ventilation volume is adjusted to perform natural cooling or forced cooling by blower when temperature exceeds the target temperature. It is so designed that the equipment can be operated in an intermediate zone called dead band as much as possible. In the dead band, as shown in Fig. 39, the output is regulated to 0 both on the heating side and on the cooling side.
If stabilization is achieved at Point B, by providing a dead band, the energy is reduced to 0.
4. Conclusion

As explained before, the energy saving technology in a plastic forming process can be divided into two aspects. The first is the technology for reducing the electric power used for heaters of the plastic heating process and the second is the technology to improve the quality and yield of products thereby increasing the production quantity of the first class goods. The technological improvement in the latter especially brings about a greater energy saving.

Considerations to be given in the actual forming site.

1) Maintenance / servicing of the production facilities and peripheral equipment.
2) Improvement activities for plastic forming methods and conditions.
3) Increase in plastic forming speed; pay attention to the cooling conditions of metal mold and the product unloading speed.
4) Yield improving activities.

How to effectively make use of limited resources and energy is directly related to how to make us happy.