SEMINAR ON ENERGY CONSERVATION IN RUBBER INDUSTRY

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PREFACE

The conservation of energy is an essential step we can all take toward overcoming the mounting problems of the worldwide energy crisis and environmental degradation. Although developing countries and countries with economies in transition are very much interested in addressing the issues related to the inefficient power generation and energy usage in their countries, only a minimum amount of information on the rational use of energy is available to them. Therefore, distributing the available information on modern energy saving techniques and technologies to government and industrial managers, and to engineers and operators at the plant level in these countries is essential.

In December 1983, UNIDO organized a regional meeting on energy consumption and 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 Asian countries. Since 1992, under continuous support of the Government of Japan, three 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); in Ceramic and Cement Industries in Bangladesh and Sri Lanka (US/RAS/93/039); and in Plastic Forming and Food Industries in India and Pakistan (US/RAS/94/044).

This year UNIDO is carrying out the programme in China and Vietnam, targeting two energy intensive industrial sub-sectors: iron casting and rubber industries.

Rubber industry consumes a substantial amount of energy. Excessive use of energy is usually associated with many industrial plants worldwide, and rubber plants are no exception. Enormous potential exists for cost-effective
Improvements in the existing energy-using equipment. Also, application of good housekeeping measures could result in appreciable savings in energy. Therefore, it is imperative to introduce and distribute information on modern energy-saving techniques and technologies among the parties concerned in government and especially, at plant level, in industries.

To achieve the objectives of this programme, UNIDO has adopted the following strategy.

1. Conduct plant surveys to characterize energy use and to identify measures to improve energy conservation at the plants.

2. Prepare handy manuals on energy management and on applicable energy conservation techniques and technologies.

3. Organize seminars to discuss the content of the handy manuals and the findings of the plant surveys with government officials, representatives of industries, plant managers and engineers.

4. Distribute the handy manuals to other developing countries and countries with economies in transition for their proper use by the targeted industrial sectors.

UNIDO prepared this handy manual for the rubber industry, with the cooperation of experts from the Energy Conservation Center, Japan (ECCJ), on energy saving technologies in the framework of this UNIDO programme. It is designed to provide an overview of the main processes involved in manufacturing of rubber, and to present a concise outline of the applicable energy saving measures.

Appreciation is expressed to the following institutions for their valuable contribution to the successful preparation and publication of this manual:

The State Economic and Trade Commission of the People's Republic of China;
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Outline of Rubber Industry

It was some 500 years ago that natural rubber was discovered by Columbus. Since then, the use of crude rubber has gradually spread in Europe and the U.S. as we see in rubber-coated cloth today. With the advance in the method of processing rubber as well as in scientific research, Charles Goodyear succeeded in discovering "heat curing method" in 1839, a process in which crude rubber is heated with sulfur to yield "vulcanized rubber", highly elastic and more resistant to heat than crude rubber. Soon in England Hancock followed suit, who developed various methods of vulcanization after perceiving the essence of this process. This heralded a start of the modern rubber industry.

During the Industrial Revolution from 1930's through 1840's, bicycles and automobiles were invented along with the opening of railway traffic, and the necessity to meet the needs of the times has led to the invention and later to the spread of pneumatic tires.

In 1845 R. W. Thomson in England tried to develop pneumatic tires for trucks to replace the tires mounted on iron wheels or solid tires prevalent in those days. Later in 1888, Dunlop (J. B. Dunlop) in England succeeded in developing pneumatic tires for bicycles and tricycles with solid tires. The pneumatic tires invented by Dunlop were adopted in the bicycle race in 1889, and went so far as to be used for automobiles until finally they were standardized in around 1905 after various improvements. Later studies of improving durability, comfortableness of riding, driving force, braking force, and swirling force have brought about drastic changes in shape, structure, and members used of tires, and further in the method of testing tires.

A remarkable progress has also been witnessed in the process and equipment of manufacturing pneumatic tires. The manufacture of tires requires the largest equipment in comparison with that of other rubber products, accompanied by the consumption in large quantities of rubber materials, electric power, coal, oil, and gas.

After outlining the general process of manufacturing tires, I would like to propose for your consideration my concept and several examples of energy conservation.
1. **Tire Manufacturing Processes**

Process flow diagram (Fig. 1) represents general tire manufacturing processes, giving the flow of work ranging from the preparation of intermediate products (members) from various raw materials to the completion of tires by a combination of those members, along with the outlines of all the equipment used for respective processes. The processes consist mainly of mix formulation, compounding, molding, vulcanization, and finishing, accompanied further by the processes of manufacturing tire cords and bead wires.

![Tire manufacturing process flow diagram](image)

**Fig. 1 Tire manufacturing process flow diagram**

1.1 **Characteristics of Manufacturing Tires**

The tire manufacturing processes consist of:

1) preparing intermediate products (members) utilizing the fluidity and plasticity of crude rubber,
2) laminating the members covered with crude rubber utilizing the
tackiness of the covering crude rubber,
3) assembling the members to make raw tires, and
4) vulcanizing them at the final stage to produce chemically stable and
elastic tires.

Since green rubber is unexpectedly stiff, it is generally sheeted or
extruded with a large-capacity motor after it has been softened by heating.
The tire manufacturing industry is therefore classified as a large energy
consuming industry.

The plasticity of rubber is greatly influenced by the quality of raw
material elastomers, the methods of compounding and hysteresis of rubber,
and working conditions of respective processes. Tackiness also varies widely
depending on the kinds of rubber and the formation of a thin coating on the
surface of rubber, called blooming.

The degree of blooming depends largely on the kinds of compounding
ingredients, moisture when rubber was compounded, length of time and
temperature after compounding, and stimulation by rubbing. In an extreme
case, rubber does not adhere at all. It is impossible to eliminate the variance
resulting from the fluidity of rubber and accompanying movement of cords
even in the process of thermal vulcanization.

The variance in plasticity and tackiness makes it inevitable to largely
rely on manual work even today when automation is highly advanced in the
molding process in which raw tires are assembled. Given this situation,
elimination of variance can contribute a great deal to energy conservation,
to say nothing of the improvements in quality and productivity.
1.2 Preparation of Materials

The manufacture of tires begins with preparing materials for rubber compounding, and for pretreatment and subsequent rubber-coating of cords (to wrap them in rubber) so that various raw materials processed can be used for the later processes of making intermediate products (members).

1.2.1 Rubber compounding (mix formulation and compounding)

A variety of raw material elastomers and various compounding ingredients are used for tires by mixing and compounding them for use in respective members. In former days, this compounding was carried out with open rolls, and naturally the working site was made terribly dirty due to the scattering of carbon black and other chemicals. Today, intensive mixers, including internal and Banbury mixers, are widely used. This intensive mixer is of enclosed type and computer-controlled so that raw material elastomers, various compounding ingredients, and oil are automatically fed, and compounded. This has resulted in reducing dirt to a considerable degree. Fig. 2 shows this process schematically.

Since the properties of rubber, uncured and cured, vary greatly depending on various factors as described below, attention has been focused on producing rubber compounds to specifications with a slight variance by computer control. The various factors include the kind, quantity, order and time of feeding, the extent to which ingredients are mixed evenly, compounding time, and temperature of raw material elastomers and compounding ingredients.

In this process, high-capacity motors are used. This inevitably involves large power consumption, which accounts usually for 35 to 55% of the total power consumption of the factory. It is a common practice to recycle cooling water used in large quantities.
1.2.2 Pretreatment of cords

Pretreatment of tire cords and canvas is a very important process aiming not only at processing fibrous materials and rubber for good adhesion, but also at modifying the properties of fibers, particularly synthetic fibers, including nylon, polyester, and rayon, into ones fit for tire cords. It is a process in which cords are dipped in adhesives, and, at the same time, subjected to a great tension at high temperature so that they are made not to be readily stretched out and thermally stable to be best fit for tire cords. This process requires a large equipment in which dipping and drying can be carried out simultaneously.

1.2.3 Calendering

Calendering, also called rolling, is a process in which coating operation is carried out by covering treated textile fabric or steel cords with thin rubber layers on both sides so that materials to be used for sandwiched plies and belts can be made. The quality and thickness of rubber layers depends on respective applications.

The important point in this process lies in the accuracy of thickness in both directions of length and width. Inaccurate thickness leads to the
poor performance of tires and further to vibration due to increased imbalance. Accuracy is therefore required to 1/100 mm. A calender with three or four rolls is generally used. The temperature of rolls and gauges are computer-controlled. Figs 3 and 4 show respectively a schematic drawing for textile fabric cords and a conceptual drawing for steel cords.

In addition to the use for coating cords and canvas, a calender is also used for preparing various kinds of rubber sheets, squeegees (belt-like rubber sheets for reinforcing plies), and strips (strings), and one of the important equipment at the rubber factory. It also consumes much electric power.

![Fig. 3 Calendering process flowsheet](image)

![Fig. 4 Steel cord calendering process flowsheet](image)
1.3 Preparation of Members

In the later sections on the processes of preparing necessary members according to respective sizes of various tires, the forming of a bead, cutting of rubberized cords including plies and belts, and extrusion of a tread and a sidewall will be described.

1.3.1 Rubber coated cord cutting

The operation is called "cutting", in which rubber coated cords and canvas are cut to the angle and width according to respective kinds and applications of tires.

The machine used is called "a bias cutter", classified into two types: one is a cutter as used for press-cutting paper or thin steel sheets in principle, while the other is a ring cutter that runs at high speed along the beam used for checking the cutter and cords. Two types are available for cutting devices: one is a vertical one with which coated materials, wound off the roll and suspended vertically, are cut after they have been held down, while the other is a horizontal one with which coated materials, wound off the roll onto the conveyor for horizontal lamination, are cut while they are held down. Since the width and the angle of cutting are required to be accurate at present, a horizontal type is more widely used. Fig. 5 shows the conceptual drawing of a horizontal bias cutter.

![Steel cords are cut to a given width and angle according to respective applications of tires (a steel cord cutter).]

**Fig. 5 Process flowsheet of cutting steel cords**
1.3.2 Extrusion of Treads and other Moldings

An extruder is used for preparing rubber members with definite cross-sections, such as treads and sidewalls. Fig. 6 shows a schematic drawing of this operation. Rubber for treads, compounded in the Banbury mixer, is softened by kneading through the hot rolls, fed to the extruder, forced through the tread die with a given cross-section, and cut to a desired length after cooling.

![Tread extrusion process flowsheet](image)

Rubber made belt-like (through the hot rolls) → Tire tread rubber forced out (through the tread extruder) → Cooled (in the cold water bath) → Cut to a length equal to that of one tire (with the tread skiver)

The process of extruding treads is one of the most important ones in the manufacture of tires, the uniformity of which is strictly required, because the tread, accounting for nearly half of the total weight of a tire, tends to cause trouble when imbalanced. It is therefore important that the extruded and cooled tread is cut to a correct and uniform length, thickness, shape, and weight.

Various extruders are used for tread extrusion depending on respective discharges, and multi-layer extruders aiming at the simultaneous extrusion of the combination of various kinds of rubbers have come to be used widely in recent years.

The multi-layer extruder extrudes the compound, fed from more than two extruders in respective quantities required, to a desired shape. Two types of extruders are available, hot and cold types, as described earlier. The
former requires heating, whereas the latter does not. Electric power is required in large quantity for softening rubber with a screw.

1.3.3 Bead molding

Beadwires, arranged at a given interval and in given number, are rubber coated and extruded to a flat bead, which, in turn, is wound around the core drum, with an inside diameter given according to respective kinds and sizes of tires, by the number of steps required. This is a process most commonly used. Fig. 7 shows a schematic drawing. Usually, thin rubberized fabric tape, called bead covering tape, is wound further with apex rubber attached thereon.

This process is carried out by another equipment.

Fig. 7 Bead making process flowsheet
1.4 Manufacture of Green Tires

Green tires are made by the molding process, in which various members, prepared through the processes described earlier, are laminated. Two methods are available for molding: one is used for bias tires, and the other for radial tires, each differing in carcass structure.

Fig. 8 shows this process.

![Diagram of molding methods]

(a) Core lamination

(b) Flat former lamination

(c) Crown former lamination

(d) 1st stage in radial tire molding

(e) 2nd stage in radial tire molding

Fig. 8 Conceptual drawing of molding methods

The flat former lamination in Fig. 8 (b) is a method by which all members, including a ply, a bead, a breaker, and a tread, are laminated on a cylindrical
former, also called a drum, with a diameter slightly larger than that of a tire rim, to make a cylindrical green tire. A carcass is inflated, a process called shaving, during vulcanization to make a doughnut-shaped tire. Then, the interval between cords widens to lead to a decrease in pressure resistance. The flat lamination is therefore a method of molding tires for low pressure use to be used for small automobiles, light trucks, and agricultural machines.

The crown former lamination process in Fig. 8 (c) is a method generally used for molding green tires, for which resistance to high pressure is required, to be used for trucks, buses, construction machinery, and aircraft, because in this process the degree of inflating a green tire to a finished one is comparatively low thus enabling to secure a required strength in addition to the ease of molding a bead part even if the number of plies increases when necessary. In this process, the so-called crown drum is used with a large space for laminating cords within a range allowable for the operation of narrowing plies down toward the bead part.

When the crown drum is used, several plies are pre-laminated in a ring form, called a band, in consideration of the operation of narrowing plies down, and fitted to the drum so that the plies can be narrowed down toward the bead part. Since another machine, called a band builder, is used for making a band, a combination of a molding machine and a band builder is commonly employed. Needless to say, a breaker, a tread, and a sidewall are also laminated in process (c) besides those in the above figure.

When canvas was used for a tire ply, it required much labor in the core lamination in process (a) when molding a tire. A tire was not formed then unless pleats, made from a sidewall through to a bead, were folded. The invention of cords, however, has led to a higher productivity because it has enabled to make green tires almost cylindrical in shape by molding processes (b) and (c).

On the other hand, in the process of molding a radial tire, in which
the belt part is so made as not to extend in the circumferential direction, it is impossible to inflate a tire after it has been molded flatly unlike a bias tire.

It therefore becomes inevitable to apply a belt and a tread after inflating a laminate close to a finished tire in shapes described later. The molding operation is therefore carried out usually in two stages: an inner liner, a carcass ply, a bead assembly, and a sidewall are laminated on the easy-to-operate flat drum in first stage shown in Fig. 8 (d) because those rubberproducts can be easily shaved. And a belt and a tread are applied after the resulting laminate has been inflated close to a finished tire in size in second stage shown in Fig. 8 (e).

In the tire molding factory, green tires cylindrical in shape are bias tires, laminated on the flat drum, for use under low pressure, while radial tires are close to finish tires in shape. Fig. 9 shows how green tires differ from each other in shape when used for radial and bias tires of passenger cars.

(a) Bias  (b) Radial

Fig. 9 Shapes of green tires
1.5 Vulcanization of Tires

Molded tires are fed to a mold (a metal mold with a tread pattern, a side pattern, a marking, and a trademark carved thereon) of the specified vulcanizer, pressed against the inside of the mold from the inside, and heated simultaneously from both sides, internal and external, with heating media, such as steam and hot water, so that, after a given period, vulcanization proceeds throughout the entire tire. Thus, a finished tire with a vulcanized rubber structure is elastic and stable.

Automatic vulcanizers, such as BAG-O-MATIC® and AUTOFORM®, are widely used. With these machines, insertion of green tires, and taking out and transfer of cured tires are carried out completely automatically with no one attending. Operators have only to prepare green tires and watch the process.

Since synthetic fibers shrink by nature if left standing when hot, hot tires after vulcanization diminish in size when left standing. A device (a post-cure inflator) is therefore provided, with which bias tires in which synthetic fibers are used are inflated by applying air pressure immediately after vulcanization, and cooled in an inflated state.

Two types of molds are used for molding tires: one is a full mold that splits into upper and lower parts, and mainly used for molding bias tires, while the other is a split mold widely used for molding radial tires. The split mold is one that splits into 6 to 9 segments along its perimeter. Fig. 10 shows conceptual drawings of a vulcanizer and a split mold in use.
The process of vulcanization consumes more steam than any other processes for making tires. Since fuel consumption of the factory is greatly influenced by this process, it is very important to think up how to save energy for this process, which usually accounts for 60 to 90% of the total steam consumption of the factory.
1.6 Finishing of Tires

When finishing tires, a vent hole, drilled right through a metal mold, is used for discharging air from the space between the tire and the mold. An excess rubber is forced out and forms hair-like vent spew in the vent holes and other shape of spews at the split parts of upper and lower molds and joint parts between mold segments. These spews should be removed in terms of good appearance. Automatic finishing machines have recently been introduced for this purpose in the most of factories. The finished tires are subjected to 100% inspection including that of appearance (a sensory test by an inspector) for rejection of defective units. Those for use in passenger cars, trucks, buses, and aircraft are subjected further to a balancing test to screen unbalanced units. A uniformity machine is also incorporated in the production line for measurement of uniformity of tires for use in passenger cars, trucks, and buses.

Supplement:

Names of tire parts

Fig. 11 (a) is a cross-section of the steel-belt radial tubeless tire for passenger cars, and Fig. 11 (a) shows the appearance and the internal structure of both bias and radial tires for better understanding.
Names of tire parts

Tread: That portion of a rubber layer which contacts the road surface. The tread pattern is so engraved on the surface as to give the property of a nonskid.

Side: A portion between the tread and the bead. The surface rubber layer only of this portion is sometimes called a sidewall.

Bead: A portion made to suit the rim, with a circular assembly of steel wires wrapped with plies.

Shoulder: An interval between the tread part and the side part. The boundary is not definitely defined.

Carcass: A portion constituting the structure of a tire composed mainly of ply and bead parts, including a belt. In some case, it includes a breaker. Ply is a thin layer of rubberized fabric.

Breaker: One to several layers of textile material, inserted between the tread and the carcass of a bias tire to protect the carcass from a road shock or from external damage.

Belt: In a radial tire, it is placed in the same position with a breaker, with textile material, durable and hard to stretch out, arranged almost
circumferentially around the tire to give a hoop effect.

Interliner: In a tubeless tire, it is a thin butyl rubber layer, made gas tight to hold air pressure, and used for lining a carcass. In a tire with an inner tube, the tire is lined only with an ordinary rubber layer since the tube itself is made of highly gas tight butyl rubber.

Apex: Apex stands for the uppermost peak of a triangle. It is a hard rubber member with a triangle-shaped cross-section, sometimes added onto bead wires to put the bead part in shape as well as to give rigidity. It is called "Apex", and sometimes "Bead Filler" or "Stiffener". This member is an essential for supporting a radial structure with a low degree of carcass rigidity since a ply cord has no angle, and used for truck tires of bias type that carry heavy loads.
1.7 Rubber products manufacturing and energy consumption

Among rubber products manufacturing processes, the rubber materials milling process, the extruding process and the rolling process have a relatively higher electric power consumption which is more than 50% of the total consumption, and the vulcanizing process have 80% more or less of the total consumption.

It is most important to take countermeasures for energy conservation, but it should be also important to improve the yield in manufacturing processes. The yield rate is the ratio of the amount of a rubber product completed to the amount of rubber materials consumed when the rubber materials are processed.

The yield rate would be decreased due to a loss of weight during processing, an occurrence of defective units and so. Since any occurrence of the defective units consumes their ration of materials, energy and labor expense, it results in directly increasing in the cost. Therefore, attention should be paid to the following points for managements.

1. Management of rubber materials: checking of the raw rubber, compounding ingredients and so, checking of characteristics of the milling rubber.
2. Management of materials other than the rubber: as regards the tire, checking of the strength of tire cord, checking of the binding wire.
3. Management of manufacturing conditions of equipments in each process: checking of operating conditions, checking of process specifications.
4. Management of inspection: checking whether or not various conditions are correspond to the drawings and standards for the manufacturing factory.
2. Tire Manufacturing and Energy Conservation

2.1 Concept of Energy Conservation

There is not such a factory that consciously wastes fuel, electric power and so. But it is the subject how cleverly the factory consumes these energy sources.

The fact which we have become aware of through our inspecting on the rubber factories carried out this time is that the amount of energy consumed was being recorded in almost all factories and controlled further by CPU in some factories. However, it is necessary to take the following two points into consideration, that is, (1) the numerical values recorded in each factory are made the best use of them from the viewpoint of energy conservation, and (2) a receptible cooperation from the posts other than the post in charge is obtained in carrying out the energy conservation activities.

Viewed at this angle, we will refer to some basic conceptions at the time of promoting the energy conservation.

2.1.1 Understanding of current situation

First of all, the amounts of both materials and energy to be consumed which are most important items in manufacturing products should be soundly seized. In the case of the fuel, items to be controlled are as follows.

Amount of fuel consumption/Production amount (Weight of mixing rubber) →

Fuel consumption per unit weight of mixing rubber

(Coal) Weight of coal consumption (t)/(t); per 1 ton of mixing rubber
(Heavy oil) Weight of heavy oil consumption (kl)/(t); per 1 ton of mixing rubber
(Gas) Amount of gas consumption (Nm³)/(t); per 1 ton of mixing rubber

Since the calorific value of each fuel is already known, the unit of
kcal/t can be also controlled.

In the case of the electric power, it should be as follows.

Electric power consumption/Weight of mixing rubber → Electric power consumption per the unit weight of mixing rubber

\[
\frac{(kWh)}{(t)} \quad ... \text{per 1 ton of mixing rubber}
\]

\[
\downarrow
\]

\[
860 \text{ (kcal/kWh)} \times \text{Electric power consumption (kWh)} \text{ kcal/t}
\]

Such a "unit requirement" or "energy consumption rate" is the basic numerical value in executing countermeasures for the energy conservation. When carrying out the energy conservation activity until finishing it up to its index 100, there will go by some stages having a respective index value. Therefore, by confirming at each stage to what degree the index has been reduced, the effectiveness of the energy conservation could be ascertained. And as the result of it, the effectiveness in terms of money might be calculated.

The numerical values of the unit consumption should be hopefully confirmed once in a month at least, also from the viewpoint of factory management.

Further, in order to seize the present situation, if the specifications of main equipment in factories and the wiring and piping installations are ready to be clearly shown, this makes it convenient to select the subjects of the energy conservation activity and to analyze the present situation.

Fig. 12 through Fig. 14 are examples showing the schematic diagrams of the piping or wiring systems for steam, electricity and cooling water.
Fig. 12 Schematic diagram of the factory steam piping

Fig. 13 Schematic diagram of the factory electric wiring
2.1.2 Selection of themes

Carrying out the energy conservation activity means reducing in the unit consumption, in other words. However, there are another measures to reduce in the energy cost, that is, utilizing the fuel and electric power of a lower cost, or making all employees present any proposals for a remedy of the energy conservation through leveling up their consciousness on it. Fig. 15 shows methods and countermeasures for reducing in the energy cost. In the case of the rubber manufacturing factory, the electric power and the fuel are the main items to be controlled.
Fig. 15 Methods and countermeasures for reducing in the energy cost
2.1.3 Organization for the energy conservation activity

In the case that the subject of worker's activity is either on the quality control or the cost down, almost of all workers are consciously tackling with it, but in the case that it is on the "energy conservation", those members of a driving group (engineering group) tend to set to work unexpectedly. To be noted here, however, the people who are operating the manufacturing equipment are the workers in the manufacturing field. Once when the course for the energy conservation has been shaped and presented by the top classes including the plant manager, the managers should explain this course to the workers in a way to make them facilitate the understanding of it, and present concrete measures or subjects to ask for the worker's cooperation in all its aspects. Since these workers are operating the same equipment and machines every day, they well enough hit upon ideas of improving the pertinent subjects.

It is important that an organization which promotes the energy conservation activity should be established by the driving group, with a strong cooperation of the manufacturing group and under the top class's understanding. This is needed because, when a new machine is required to be introduced with the purpose of improving the productivity or of carrying out the energy conservation activity, a considerable investment may be required. The top of the factories should make the activity executed after checking and confirming an existence of the effectiveness of investment.

There seems to be a difference in estimating the revulsion of investment between countries, but, in case of Japan, a recovery within three to five years is the target generally aimed.
2.2 Energy Conservation in the Tire Manufacturing Factories

2.2.1 Energy consumption at tire manufacturing factories

Table 1 below shows an example of the state of energy usage in the tire manufacturing factories.

Table 1 State of the energy usage by processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Fuel (heavy oil)</th>
<th>Electric power</th>
<th>Air</th>
<th>Industrial water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing</td>
<td>9.7%</td>
<td>32.8%</td>
<td>○</td>
<td>Submergence, and cooling water</td>
</tr>
<tr>
<td>Extruding</td>
<td>0.8</td>
<td>17.0</td>
<td>○</td>
<td>Cooling water</td>
</tr>
<tr>
<td>Sheeting</td>
<td>0.5</td>
<td>4.9</td>
<td>○</td>
<td>(Cooling water)</td>
</tr>
<tr>
<td>Cutting</td>
<td>0.2</td>
<td>5.7</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Beading</td>
<td>0.1</td>
<td>0.1</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Forming</td>
<td>0.1</td>
<td>4.7</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Vulcanization</td>
<td>81.1</td>
<td>4.3</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Finishing and Testing</td>
<td>0.9</td>
<td>2.2</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Driving</td>
<td>1.9</td>
<td>17.0</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4.0</td>
<td>10.4</td>
<td>○</td>
<td></td>
</tr>
</tbody>
</table>

2.2.2 Energy conservation at tire manufacturing factories

From the above Table, the process which consumes lots of fuel is the curing process, and both the refining section and the driving section consume the electric power prominently. The key points to improve the manufacturing processes from the viewpoint of carrying out the energy conservation are as follows.

Mixing: Heating up the crude rubber, Investigating on the peptizer, Investigating on milling conditions, Circulating the warm water, Exhausting fan.

Extruding: Temperature of the warming sheets, Investigating on the roll size (face length and number of roll), Heating the mouth rings,
Controlling the remolding amount, Narrowing the width of cooling conveyer.

Sheeting: Same with extruding.

Vulcanization: Controlling the outgoing radiation, Improving the curing method, Preheating the die assembly, Shortening the time for exchanging the die assembly, Investigation on the blowing air, Improving the ventilation fan.

Driving: Rising the temperature of boiler feeding water, Drain recovery, Jointing the steam and the warm water systems, Miniaturizing the boiler, Withdrawing the disused pipings, Reducing in the number of air compressor.

Others: Natural illumination, Controlling the steam and air leaks, Reducing in the idling time, Inspecting the optimum capacities of equipment and motors, Installing the instruments and gauges.

In the case of the mixing process among the above said processes, the relationship between the internal mixer and the power load is shown in Fig. 16.

![Fig. 16 Internal mixer and the power load](image)
In order to reduce in the electric power for milling process, followings are the items to be noted, as enumerated also in the keypoints for improving processes. Reducing in the idling time should be important, too.

1) Heating up the green rubber. (resulting in minimizing the peak electric power)
2) Investigating on the peptizer. (resulting in shortening the masticating time)
3) Investigating on the milling conditions. (resulting in shortening the cycling time and so)

Further, almost all amount of the fuel or steam used is consumed in the curing process. Table 2 shows problems and courses of measures for improving them.

Table 2 Problems and courses of measures for improving them

<table>
<thead>
<tr>
<th>Problems</th>
<th>Loss</th>
<th>Reasons</th>
<th>Measures for improving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big loss of boiler heat</td>
<td>10%</td>
<td>High temperature of the exhaust gas</td>
<td>Recovery of exhaust heat</td>
</tr>
<tr>
<td>Big loss of outgoing heat in the vulcanization process</td>
<td>55%</td>
<td>Insufficient heat insulation</td>
<td>Complete thermal insulation</td>
</tr>
<tr>
<td>Big loss of the waste heat in the vulcanization process</td>
<td>20%</td>
<td>Big un-recuperated heat</td>
<td>Recovery of waste gas</td>
</tr>
<tr>
<td>Big amount of indistinct parts (unable to measure)</td>
<td>25%</td>
<td>Many leaks</td>
<td>Prevention of leaks</td>
</tr>
<tr>
<td>Small amount of recovered heat from the pre-process</td>
<td>18%</td>
<td>Big un-recuperated outgoing heat</td>
<td>—</td>
</tr>
</tbody>
</table>

From the table, it should be noted that thermal insulation or adiabatic measures, recovering the waste gas, and preventing the leaks, should be further paid attention to. Especially main energy saving point are in the vulcanization process.
3. **Examples of the Energy Conservation**

There are many differences in the views of the energy conservation between countries or companies (factories) including difference of the production amount and the types of equipment. Here, some leading tire manufactures in Japan are selected, and their activities on reducing in the driving power of equipment and the effectiveness of the energy conservation activity are described.

3.1 **Reduction of Electric Power for Driving Equipment**

**Outline of factory (one of the factories of A company)**

Production item: Tires for automobile

Number of employees: 1,150

**Energy consumption**

- Heavy oil (A, C): For boiler 8,316 kl/Y
- Kerosene: For private power generation 8,858 kl/Y
- Electric power: Purchased 74,906 MWh/Y
  - Private power generation 20,186 MWh/Y

**Outline of the subject of the energy conservation activity**

With regard to the electric power consumption of the driving equipment, which accounted for a big ratio among the equipment in factories, a 3% reduction in the electric power unit consumption was set as the target, which was also the whole company's target to be aimed, and thus the activity for the energy conservation was started. As the results, an effectiveness was obtained mainly by both improving the nitrogen gas generating equipment and improving the equipment for factory cooling water.
Period for executing the activity and its members

November, 1992 through July, 1994, Driving group; 13 workers

Reasons for the selection of the subject

The electric power consumed by the driving equipment in the factories accounted for comparatively a high figure of 16.2% of the total, and most of the power was the fixed one to be consumed regardless of an increase or decrease in production amount. In order to attain the target of the 3% reduction in the electric power unit consumption, the equipment was reviewed and a plan was established to improve them. Fig. 17 shows the ratios of the electric power consumption by processes recorded in fiscal 1992.

Fig. 17 Ratios of the electric power consumption by processes in fiscal 1992
Seizing of the present state and analysis of it

(1) Seizing of the present state

The driving equipment managed and controlled by members were those of a compressor, a cooling water equipment, a drainage system, a treating equipment and so. The ratios of the electric power consumption of each equipment are shown in Fig. 18.

Fig. 18 Ratios of the electric power consumption of equipment

(2) Analysis of the present state

With regard to the compressors which consumed the biggest amount of electric power, some countermeasures had already been taken, such as automating the operation by a pressure switching, controlling the number of compressors, reducing in the blasting pressure, reducing in the air leaks and so. Therefore, the activity was directed to the equipment for cooling
Progress of the activity for the electric power conservation

(1) System of the activity

Since more than half of the members of the driving group were working in the three-shift duty, it was made arrangements that;
   a) problems should be pointed out by all workers,
   b) countermeasures for the electric power conservation should be planned by the respective worker in charge,
   c) executing the countermeasures and testing should be carried out by the regular daytime workers, and then, according to the results, the above a) through c) would be repeated.

(2) Establishment of the target

Since the target of the whole company was the "3% reduction in the electric power unit consumption", the driving group accordingly established the same target as the 3% reduction in the electric power unit consumption per production for the driving equipment.

(3) Problems

The production of factories had been decreased by 20% or more comparing with the past.

3.1.1 Improvement of nitrogen gas generators

(1) Role of the nitrogen gas in the tire manufacturing processes

   a) The nitrogen gas was used in the tire curing process as a pressing source for pushing a crude tire to a die from the inside of the tire in the curing machine through a rubber bag.
   
   b) The nitrogen gas absorbs air and separates it. The nitrogen gas was
generated by the nitrogen generating equipment and pressured by the high pressure compressor to send it to the curing machine.

c) In order to prevent a deterioration of the rubber bag, the residual concentration of oxygen gas existing in the nitrogen gas should be made as lower as possible.

The general role of the nitrogen gas generating equipment is shown in Fig. 19.

(2) Seizing of the present state

The nitrogen gas generating equipment was consisted of three mechanisms, that is, one atmospheric regenerator and two vacuum regenerators, and the former consumed a less electric power.

The average amount of nitrogen gas used is at present less than the corresponding capacity of one mechanism, but taking the fluctuation of
flow amount into consideration, the said two vacuum regenerators were continuously being operated. Table 3 shows the nitrogen gas generating equipment by mechanisms.

Table 3 Mechanisms of the nitrogen gas generating equipment

<table>
<thead>
<tr>
<th>Type of regenerator</th>
<th>Vacuum regenerator</th>
<th>Atmospheric regenerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regenerator</td>
<td>1, 2</td>
<td>3</td>
</tr>
<tr>
<td>Regenerating capacity</td>
<td>300Nm³/h</td>
<td>300Nm³/h</td>
</tr>
<tr>
<td>pressure</td>
<td>3.5kg/cm²</td>
<td>5.5kg/cm²</td>
</tr>
<tr>
<td>desorbing method after absorbing</td>
<td>Using a vacuum pump</td>
<td>Atmosphere relief with the raw air</td>
</tr>
</tbody>
</table>

A flowchart of the nitrogen gas equipment and the curing equipment is shown in Fig. 20.
(3) Analysis of the present state

The reasons for operating two vacuum regenerators were because of coping with the fluctuations of the gas amount to be treated and to stabilize the oxygen content in the nitrogen gas. If these were dealt with satisfactorily by operating the only one regenerator, its effects would produce satisfactory results.

(4) Contents of countermeasures

a) The whole of recovery gas was let flow to the side of the high pressure compressor. (Improvement 1)

b) In the case of the above, since the oxygen pressure would rise when the standby high pressure compressor started its operation in response to a fluctuation of loading, one nitrogen generating equipment was let start automatically to dissolve it.

c) The pressure controlling method for the nitrogen gas in the generating equipment was altered to a (flow + pressure) controlling method. (Improvement 2)

d) The high pressure compressor automatically started in response to a pressure in the high pressure receiver tank, but the generating equipment was let start automatically before it. (Improvement 3)

As the results, it had been made possible to cope with the fluctuation of the gas amount and to stabilize the oxygen content, resulting in obtaining the effectiveness of the energy conservation, through adopting the practice that the one atmospheric regenerator was normally let operate, and, when the loading was fluctuated, the one vacuum regenerator was let operate in the on-off mode.

Fig. 21 shows a flowchart of integrated improvements, and Fig. 22 shows the equipment effectiveness of the nitrogen generating equipment.
Fig. 21 Flowchart of integrated improvements

Fig. 22 Electric power unit consumption
3.1.2 Improvement of cooling water pumps at factories

(1) Seizing of the present state

The factory cooling water was used for cooling the rolling machines, various hydraulic units and compressors, for cooling the extruding process, and so.

The cooling water was supplied at 1.5 kg/cm² for directly cooling the rubber in a shower condition in which any pressure was not needed, and 3 kg/cm² for the other usage.

A flowchart of the factory cooling water is shown in Fig. 23.

![Flowchart of the factory cooling water](image)

*Fig. 23 Flowchart of the factory cooling water*

(2) Analysis of the present state

a) Cooling of the milling machine and the hydraulic units could be carried out by the cooling water with a lower pressure.

b) The pressure of the compressor should not be lower than 3 kg/cm² from the viewpoints of protecting machines and their performance. However,
if these points could be improved, the pressure in the 3 kg/cm² - designed pipelines could be reduced, resulting in reducing the electric power to be consumed for pumps.

(3) Contents of countermeasures

Aiming at reducing in the pressure of cooling water from 3 kg/cm² to 2 kg/cm², some countermeasures were carried out.

a) The cooling water system for compressors was let separate from the factory side to be a dedicated system.

b) Since it was anxious that the cooling performance was degraded when lowering the pressure of the cooling water, the pressure was let gradually lower with the close cooperation of manufacturing workers and respective maintenance workers in charge, and problems were pointed out each time to establish countermeasures.

(4) Results

a) The prospect of 2 kg/cm², the target of the cooling water pressure for factories, had been acquired, and the pumps were so remodeled, resulting in reducing in the electric power consumption.

Fig. 24 shows the course of tests for decreasing the supplying pressure of the factory cooling water, which were carried out in 1992.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.00K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.75K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.50K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.25K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.00K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Results</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td></td>
<td>Having come to the present</td>
</tr>
</tbody>
</table>

Fig. 24 Tests for decreasing the supplying pressure of the factory cooling water
b) By making the cooling water for compressors dedicated, the water treatment could have been easily carried out, resulting in improving the heat exchanging effectiveness. Fig. 25 shows the effectiveness of supplying the factory cooling water.

![Figure 25: The factory cooling water supplying effectiveness](image)

3.1.3 Reduction of electric power for the boiler equipment

(1) Seizing of the present state

The boiler with a capacity of 50t/h was being operated, but the actual loading had been reduced by about 30% owing to the countermeasures of the energy conservation for the secondary system.

(2) Analysis of the present state

The forced draft fan was operated through controlling the revolving speed, but the exhaust gas recirculating fan for a countermeasure against NO₂ was still being operated by a tamper controller regardless of the lower loading which had been attained, and further there were many cases of a "closed" condition.

(3) Contents of countermeasures

Based on the control standard values of the Air Pollution Control Act and the present condition of loading, it was judged that there would
not be any problems even if the exhaust gas recirculating fan was closed, and accordingly the combustion air damper was regulated and the operation of fan was stopped.

(4) Results

There was almost none of changing in the amount of NOx, resulting in conserving the electric power for the exhaust gas recirculating fan. Fig. 26 shows a schematic diagram of the relation between the exhaust gas recirculating fan and the boiler.

![Schematic diagram of the exhaust gas recirculating fan and the boiler](image)

**Fig. 26 Schematic diagram of the exhaust gas recirculating fan and the boiler**

**3.1.4 Effects after taking countermeasures**

The abovementioned countermeasures taken for the energy conservation in the three fields had the following effects shown in Table 4.
### Table 4 Effects of countermeasures

<table>
<thead>
<tr>
<th>Item</th>
<th>Effects (¥1,000/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement on the nitrogen gas generating equipment</td>
<td>6,900</td>
</tr>
<tr>
<td>Improvement on the factory cooling water pumps</td>
<td>2,200</td>
</tr>
<tr>
<td>Stoppage of the fans for the boiler exhaust gas</td>
<td>980</td>
</tr>
</tbody>
</table>

As the results that the countermeasures had been carried out with the target aimed at the 3% reduction in the electric power unit consumption, a 3.8% reduction had been attained regardless of the decrease in the factory production by 20% or more, if the fixed electric power consumption was excepted.
3.2 Reduction in the Fuel Unit Consumption in Rubber Factories

Outline of the factory

Production item: Tires and tubes for bicycle, V-belts and so
Number of workers: 420
Amount of fuel consumption: Heavy oil; 2,854 kl/Y

Outline of the subject on the reduction in the fuel unit consumption

If the index of the fuel unit consumption in 1973 was made at 100, it in 1976 was decreased to 77.9 owing to the energy conservation activities, but it in 1977 was increased to 84.4 in contrast. The activities for the energy conservation in 1977 were such as repairing leaks, performing a heat insulation on pipes and so without much investments. Since it was felt that such activities would not produce any excellent results, new activities of improving equipment and of introducing new instruments were taken up together with a measure of investments.

Term of the activities: 1978 through 1981
Members: Four workers of the driving brackish water group

3.2.1 Analysis of the present state

(1) Fig. 27 shows a transition of the index of the fuel unit consumption, in which it is noted that the fuel unit consumption in 1977 was raised.
The fuel unit consumption had made progress in good shape from 1973 through 1976, and improvements which had born full fruit were as follows.

1) A thorough heat insulation with 35 mm to 70 mm in thickness on the curing machine, the hot water piping installment, the hot water equipment, the steam piping installation and so on.

2) Recovery of the drain from both the curing machine and the hot water piping installation.

3) Adjustment and integration of both the steam piping and the hot water piping installations.

4) Rising the temperature of the boiler supplying water

5) Improvement in the effectiveness of the hot water equipment by changing its type.

6) Rationalization of operating conditions for the hot water circulating installment.

7) Reduction in the cycle time through rationalizing the curing conditions.

Fig. 27 Transition of the index of the fuel unit consumption
(2) Cause and effect diagram

Fig. 28 shows the results of confirming where the energy losses were existing.

**a) Piping**

There were many complex piping parts and naked pipes by installations.

**b) Traps**

There were some traps having an excessive discharging capacity against the loading, resulting in generating an energy loss. Further, such traps were located at a place where the inspection work was hard to carry out, and their actuation was sometimes difficult to be judged.

**c) Heat insulation**

The main pipes were fairly heat-insulated, but some of flange valves, pressure reducers and covers of the curing cans were not.

**d) Loading equipment**

1) The loading might be light in the case of operating the one machine,
but its fluctuation became violent in the case of operating the multi-equipment in parallel at the same time. Therefore, the boiler loading sometimes got 18t/h at the maximum against its capacity of 10t/h, resulting in decreasing the boiler pressure and in interfering with the production.

2) There were some curing equipment which threw away the steam each time when the curing processing was finished.

3) There were leaks of the steam.

e) Valves

There were marked leaks from the ground parts of valves for a high pressure and from the parts of bonnets.

3.2.2 Contents of activities and scheduled term

Since the range of the activities for the energy conservation was wide, a long plan was established before carrying out the activities. Table 5 shows the contents of the activities and their scheduled term.

Table 5 Contents of the activities and their scheduled term.

<table>
<thead>
<tr>
<th>Item</th>
<th>Contents</th>
<th>Fiscal year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>Boiler</td>
<td>Heat recovery from the exhaust gas</td>
<td>○</td>
</tr>
<tr>
<td>Boiler</td>
<td>Low oxygen combustion</td>
<td>○</td>
</tr>
<tr>
<td>Piping system</td>
<td>Rationalization of the piping for the tire curing machine</td>
<td>○</td>
</tr>
<tr>
<td>Trap</td>
<td>Improvement on the capacity of the tube heater trap</td>
<td>○</td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Recovery of the exhaust heat from the pot heater</td>
<td>○</td>
</tr>
<tr>
<td>Trap</td>
<td>Improvement on the type of dryer trap</td>
<td>○</td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Countermeasures for leaks from the piston valves</td>
<td>○</td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Equalization of loads (installing of an accumulator)</td>
<td>○</td>
</tr>
<tr>
<td>Heat insulator</td>
<td>Thorough heat insulation</td>
<td>○</td>
</tr>
<tr>
<td>Valve</td>
<td>Countermeasures for outside leaks</td>
<td>○</td>
</tr>
</tbody>
</table>
(1) The target for the fiscal 1978

The 5% reduction in the unit consumption index of the fiscal 1977.

(2) Problems and countermeasures for these

a) Heat recovery from the boiler exhaust gas

Temperature of the exhaust gas was 250°C at the exit of the economizer, the gas thus being exhausted at a higher temperature. In order to lower this temperature, a preheater for the supplying water was installed at a place between the economizer and the chimney as shown in Fig. 29, to supply water to the feed tank and to devise to recover the heat.

b) The boiler had been operated with the oxygen content of about 3.7% in the exhaust gas from the boiler. However, in order to reduce in the holding heat of the exhaust gas, a low oxygen combusting equipment was installed to enable to make the boiler operated at 2.5% oxygen content in the exhaust gas.

c) Rationalization of piping installation for the tire curing machine
The piping installations for jacketing the tire curing machine were much complex and their total length amounted to 7m, almost of which were composed of naked pipes. The complexity was because the piping had a structure in which two pipes enabled to cure the tire at the same time, and therefore even if one of them got out of order, the other alone enabled to cure it through closing the opposite valve. However, since there had not been actually such a one-pipe curing operation, the piping installation was altered as shown in Fig. 30, in which the piping was shortened to 4m and was thoroughly heat-insulated to reduce in the heat loss due to an outgoing radiation.

![Fig. 30 Rationalization of piping installation for the tire curing machine](image)

As the result of investigating the discharging capacity of the tube heater traps, it was found that some traps had an excessive discharging capacity against the loading. Hereupon, the traps manufactured by three makers were compared and tested, the results of which is shown in the Table 6.
Table 6 Results of comparing and testing on the traps manufactured by three makers

<table>
<thead>
<tr>
<th>Maker</th>
<th>Amount of discharging</th>
<th>Temperature of die</th>
<th>Unit price</th>
</tr>
</thead>
<tbody>
<tr>
<td>M maker</td>
<td>5.7kg/h</td>
<td>175°C</td>
<td>¥8,000</td>
</tr>
<tr>
<td>Y maker</td>
<td>9.5kg/h</td>
<td>175°C</td>
<td>¥8,000</td>
</tr>
<tr>
<td>T maker</td>
<td>11.2kg/h</td>
<td>175°C</td>
<td>¥8,000</td>
</tr>
</tbody>
</table>

From the above results, traps manufactured by M maker which showed the most small amount of discharging were adopted to replace the existing traps of a hundred in number.

e) Recovery of the exhaust heat from the pot heater

The steam was thrown away from the pot heater each time when the curing processing was finished. This steam was made a heat source for the bath through installing a heat exchanger in the way of the exhausting piping as shown in Fig. 31.

![Fig. 31 Recovery of the exhaust heat from the pot heater](image-url)
(3) The target for the fiscal 1979

The 5% reduction of the actual results of the fiscal 1978

(4) Problems and countermeasures for them

a) Reviewing and changing of the type of dryer traps

Since the traditional traps were located at a place where the inspection work was difficult to carry out and they were of a continuously discharging type, it had been hard to judge their actuation. Therefore these traps were replaced by those of an intermittent type.

b) Countermeasures for leaks from piston valves of the tire curing machine

With regard to the amount of steam used for the curing machine, the difference in its amount was great, between its actual usage indicated by the flow meter and the discharged amount of drain measured by the tire curing model machine. The measuring method is shown in Fig. 32.

![Diagram of drain measuring method by the tire curing model machine](image)
Results of the actually measured amount of steam and the indicated value by the flow meter were 42.8 kg/h and 71.8 kg/h, respectively, resulting in showing a loss of 29 kg/h. As the result of an investigation, it had been found that there was a leak at the high pressure piston valve. Thereupon, the valve was replaced. After that, the flow meter indicated 52.6 kg/h.

C) Equalization of loads (installing of an accumulator)

The said multi-and-parallel equipment operation got a heavy loading, even if each loading of them was light, resulting in a drop of the boiler pressure. Therefore, the reserved boiler had been usually operated for 15 minutes at the time of preheating in the morning, and thus a two-boiler operation had been carried out. In order to solve this problem, an accumulator was installed. As its result, the loading have not exceeded 10t/h, there have not been any pressure drops, and the two-boiler operation have been disused.

D) Thorough heat insulation

Since the heat insulation had not been fully applied on those in factories such as the valves, flanges, pressure reducers and curing can covers, it had been executed on all of those. Further, it had been also executed on the traps which were already changed in the preceding fiscal year.

E) Countermeasures for leaks to the outside of valves

Since there had been marked leaks from the ground parts of valves for a high pressure and the parts of bonnets, some components were replaced and, in case that any repair on the old ones was difficult, they were renewed. By taking the countermeasures, all problems of fifty leaks in number have been solved.
3.2.3 Effects after taking countermeasures

The countermeasures for improving the fuel unit consumption in the rubber factories had been carried out for two years, and satisfactory effects rising the original target were produced, the results of which are shown in the following Table 7, and the transition of the index of the fuel unit consumption shown in Fig. 33.

Comparing the investments with the effectiveness in terms of money shown in Table 6, the table shows that the energy conservation activities carried out that time had obtained satisfactory results even from the viewpoint of the return on investment.

<table>
<thead>
<tr>
<th>Item</th>
<th>Contents</th>
<th>Expected effects</th>
<th>Fiscal 1978</th>
<th>Fiscal 1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>Heat recovery from the exhaust gas</td>
<td>224</td>
<td>1,286</td>
<td></td>
</tr>
<tr>
<td>Boiler</td>
<td>Low oxygen combustion</td>
<td>619</td>
<td>1,857</td>
<td></td>
</tr>
<tr>
<td>Piping system</td>
<td>Rationalization of piping for the tire curing machine</td>
<td>263</td>
<td>394</td>
<td></td>
</tr>
<tr>
<td>Trap</td>
<td>Improvement on the capacity of the tube heater traps</td>
<td>4,866</td>
<td>4,521</td>
<td></td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Recovery of exhaust heat from the pot heater</td>
<td>216</td>
<td>1,295</td>
<td></td>
</tr>
<tr>
<td>Trap</td>
<td>Improvement on the type of the dryer traps</td>
<td>116</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Countermeasures for leaks at the piston valves</td>
<td>3,799</td>
<td>8,989</td>
<td></td>
</tr>
<tr>
<td>Loading equipment</td>
<td>Equalization of loads (installing of the accumulator)</td>
<td>412</td>
<td>2,708</td>
<td></td>
</tr>
<tr>
<td>Heat insulation</td>
<td>Thorough heat insulation</td>
<td>1,269</td>
<td>1,666</td>
<td></td>
</tr>
<tr>
<td>Valve</td>
<td>Countermeasures for the outside leaks from the valves</td>
<td>1,282</td>
<td>2,219</td>
<td></td>
</tr>
<tr>
<td>Effectiveness in terms of money</td>
<td></td>
<td>13,066</td>
<td>9,353</td>
<td>15,645</td>
</tr>
<tr>
<td>Investment</td>
<td>-</td>
<td>2,540</td>
<td>20,050</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 33 Transition of the index of the fuel unit consumption
4. Conclusion

The rubber industry including the tire manufacturing has a history of more than a hundred and ten years, and it has especially grown remarkably in its last half. At the same time, the energy consumption has been increased rapidly with its growth. Under this situation, the activities on the energy conservation have been carried out positively in every factories.

In carrying out the energy conservation, the main points which have been already described are listed once again as follows.

(1) The energy consumption rate at present should be seized and recorded by all means.

(2) The specifications of the main equipment and the wiring and piping installations in factories should be shown clearly.

(3) As shown in Fig. 15, the methods and countermeasures for reducing in the energy costs should be fully investigated into, and then they should be started.

(4) The cooperation of workers affords a great support.

(5) The top classes should exhibit understanding of the workers in charge of the energy conservation activities, and, at the same time, should ascertain the effectiveness of the investment in the case of costing a great deal.

One of the subjects for the international problems to be solved in parallel with the energy conservation is at present the establishment of countermeasures for the environmental problems. In the process that the earth warming is advancing, various subjects of such as reducing in carbon dioxide and so are being discussed. We believe that the clean earth can be regenerated only when we use effectively the valuable energy. Therefore, the countermeasures for the energy conservation and for the earth warming should not be separately considered and discussed.