THE STUDY
ON
RATIONAL USE OF ENERGY
IN
THE REPUBLIC OF HUNGARY

(II)

REFERENCE FOR FORMULATING TECHNICAL GUIDELINE

SEPTEMBER, 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

Contents

1. Character of Guideline

1. CHARACTER OF GUIDELINE

State Authority for Energy Management and Safety (AEEF) is expected to conduct, in a leading position, factory audit and/or education for factory engineers necessary to promote energy conservation activities in Hungary's factories. To support these activities, it is necessary to prepare a guideline which AEEF staff members can rely on.

The materials included in this report summarizes some of the technical issues that AEEF could refer to when preparing the guideline. The following were taken into account for the summarization.

(1) This should be one which can be used as (a) manual for audit instruction, (b) seminar text, or (c) criterion for progress of factory rationalization.

(2) The description should be understandable enough for engineers with 4 to 5 year work experience who are not involved in factories of concerned fields.

(3) The scope of description should be limited to those concerning process at factories investigated this time. It should cover basic items, reference figures, measures and examples of energy conservation in order to reflect the current scene of Hungary's industry.

It is expected that AEEF prepares the guideline in reference of this report and improves it by appending information obtained through its own factory analyses as necessary.

2. General Diagnostic Procedure

2. GENERAL DIAGNOSTIC PROCEDURES

(1) Factory Diagnostic Procedure

The general factory diagnostic procedure is shown in the chart below.

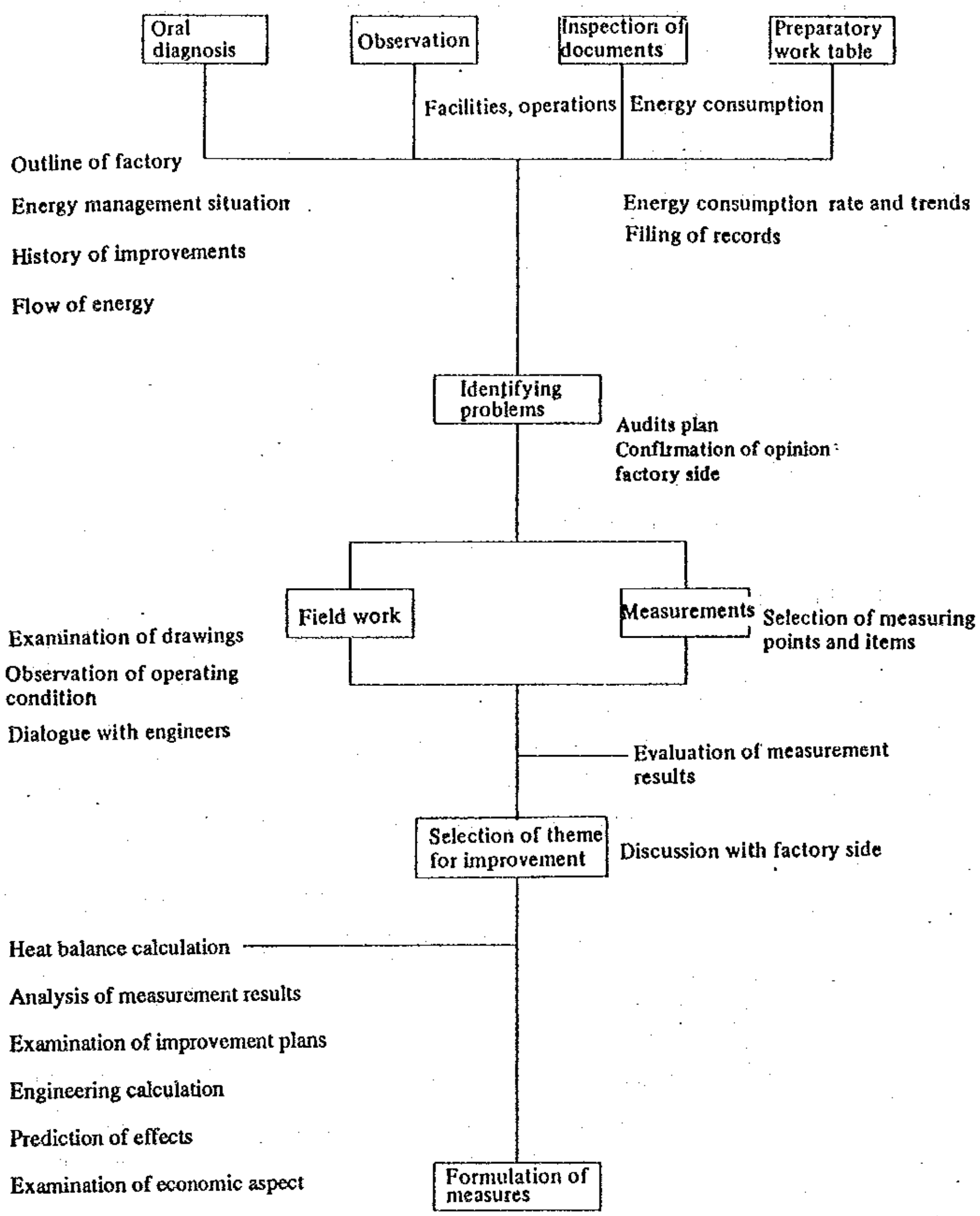


Figure 2.1 Flowchart of Factory Survey

① Acquiring General Information on Factory

The understanding of and enthusiasm about energy conservation on the part of the manager, the steps taken so far for energy conservation, and the problems pointed out by the factory will be determined.

1. Factory outline (name of factory, type of business, capital, sales, number of employees, brief history, market share, and position in the industry)

2. Production of main products in the past 5 years

3. Energy consumption in the past 5 years

4. Production processes of main products

5. Types, capacities, and operating conditions of main energy consuming facilities such as boiler

6. Energy flowchart

7. Electrical one-line diagrams; condition of power receiving facilities

8. Equipment layout

9. Problems pointed out by the factory management and desired to be checked

10. Energy conservation measures taken in the past

11. Energy conservation measures planned for the future

12. Business condition of the industry and the factory, and factors negatively affecting the promotion of energy conservation measures

② Preparing Diagnostic Plan

(a) The factory will be generally inspected while listening to explanations by the factory staff, and information on the following will be obtained by checking the preliminary questionnaire, energy consumption data, and production records.

Problems with the factory equipment and operations

Important diagnostic points

Technical level of the factory

Age and maintenance of the factory equipment

Stability of operating rate

Energy consumption unit and its change with time

(b) A diagnostic plan will be determined.

Equipment or processes requiring primary attention in diagnosis

Measuring points, items, and time

Work assignments

(c) The diagnostic plan will be shown to the factory staff to obtain their understanding of it, and ask for their cooperation in implementing the plan.

Adjustment of the production plan

Making holes for insertion of probes of measuring instruments or taking samples

Preparations for power supply

③ Measuring and Surveying According to Diagnostic Plan as Follows

Selection and arrangement of measuring instruments

Entry of data into measuring instruments to set conditions

Checking whether proper data is obtained

Checking the detailed structure and dimensions of the equipment referring to equipment drawings or by actual measurement

Identifying problems by observation of operation

Hearing from engineers

Checking data (energy prices, fund cost, etc.) required for evaluating the economic effects of the improvement measures

④ When all the measurement results are ready, improvement items to be proposed after analysis of the results to be made later will be worked out, and explained to the factory staff. Then, improvement items to be proposed through a report will be determined.

⑤ Studying Improvement Proposal

On the basis of the data entered in the check list, measurement recording sheets, floppy disk recordings, and drawings, analysis of heat and electricity consumption will be made, involving heat balance calculation, heat transfer calculation, and fluid conveyance power calculation; energy conservation measures with modifications or addition of equipment will be studied; and a proposal best suited to the existing conditions of the factory involved will be prepared.

At the same time, an appropriate cost necessary for the proposed improvements and the expected results will be calculated. On the basis thereof, economic evaluation of each improvement proposed will be made using a common index and procedure, and the practicability and priority of the proposed measures will be specified.

The influence, produced incidental to the implementation of the improvement measures will also be studied, and the points to be borne in mind in their implementation will be presented.

(2) Check Points of Diagnosis

In Japan, the Ministry of International Trade and Industry sets forth the items to be observed by factory operators as criteria in achieving the rational use of energy within technically and economically possible limits.

The Ministry classifies the energy conservation techniques into the 7 following categories, which are not compulsory but serve as guidelines.

I Rationalizing fuel combustion

II Rationalizing heating, cooling, and heat transfer

III Preventing heat loss by radiation, heat conduction, etc.

IV Recovery of waste heat for reuse

V Rationalization by energy conversion from heat to motive power, etc.

VI Preventing electricity loss by resistance, etc.

VII Rationalization by energy conversion from electricity to motive power, heat, etc.

These guidelines will be of help in making energy conservation diagnosis, so the Japanese criteria, quantitative indices and examples of improvement measures taken for rational use of energy are shown for reference as below.

I Rationalization of Fuel Combustion

Optimizing Air Ratio

Standard air ratio

Table 2.1 Boiler (Load factor: 75 to 100%)

Amount of evaporation	Solid fuel	Liquid fuel	Gaseous fuel
Large boiler for electric company	1.2 - 1.3	1.05 - 1.1	1.05 - 1.1
30 tons/h or more	1.2 - 1.3	1.1 - 1.2	1.1 - 1.2
10 to 30 tons/h	—	1.2 - 1.3	1.2 - 1.3
< 10 tons/h	—	1.3	1.3

Table 2.2 Industrial Furnaces (Using liquid and gaseous fuels; 800 MJ/hour or more)

Continuous billet heating furnace	1.25
Metal melting furnace for casting, metal heating furnace, continuous heat treatment furnace, thermal decomposition furnace, reforming furnace, cement kiln, continuous glass furnace	1.3
Gas generating furnace, crude oil heating furnace, alumina kiln, lime kiln	1.4

I-1 Burner selection — Type, Size, Turn down ratio; Maintenance, Cleaning Tip

I-2	Better atomization	Fuel temperature, Viscosity Proportion of atomizing air or Steam to fuel, Fuel pressure Dispersion reagent Emulsified fuel
I-3	Prevention of air intrusion	Furnace pressure control Reduction of opening, Double door, Sealing Shortening door opening time
I-4	Advanced automatic control	Fuel air ratio control by oxygen content in exhaust gas Fuel air ratio control by carbon oxide content in exhaust gas Fuel air ratio cascade control Fuel air ratio cross limit control
I-5	Load levelling	Optimum load sharing Operation unit number control Steam accumulator
I-6	Flame temperature raise	Combustion with enriched oxygen Gas atomized fuel oil combustion Fluid bed combustion
I-7	Lower combustion temperature	Catalystic combustion

II Rationalization of Heating Cooling and Heat Transfer

II-1 Heating in Furnace

II-1-1	Optimum extracting temperature	Setting work standard
II-1-2	Search for best heat pattern	Temperature distribution, Heating velocity Improvement flow of gas in furnace
II-1-3	Optimum load	Optimum load on furnace bed Load sharing to multiple facilities Load levelling
II-1-4	Material charging improvement	
II-1-5	Improvement of furnace shape	

II-1-6	Decrease heat content of furnace body and conveyor	Lighten the weight
II-1-7	Increase of flame emissivity	
II-1-8	Direct heating	Modification to direct firing Submerged combustion Electric resistance heating Far infrared beam heating Microwave heating Induction heating
II-2	Heating by Steam	
II-2-1	Adjusting steam pressure to proper level	
II-2-2	Perfect air purge	
II-2-3	Improvement of direct steaming	
II-3	Heat Transfer	
II-3-1	Decrease of heat transfer resistance	Prevention of scaling, Sludge deposit, Frost Boiler Feed water quality control Reagent injection Optimum blow off of boiler water Tearing off condensate film, Defrostingg Cleaning of heat transfer surface, Soot blowing, Filter cleaning
II-3-2	Improvement of heat transfer coefficient	High-speed gas flow, Jet heating, High-speed burner Fluid bed heat transfer Mist cooling
II-3-3	Heat exchange system	Addition of heat exchanger Minimization of energy loss
II-3-4	Advanced heat exchanger	High heat conductivity material Shape of heat transfer tube Heat exchanger tube arrangement Enlarging heating surface, Fin plate Buffer plate, Turbulence accelerator

II-4 Operation

II-4-1	Start/stop time optimizing	Use of remained pressure of boiler
II-4-2	Decrease of load	Air conditioning (Temperature, Rate of air circulation) Utilization of holding heat of material from previous process Shortening of waiting time between processes Shortening of furnace idling time Lot concentration Distillation (Optimum reflux ratio, selection of feed or extraction tray)

II-5 Process

II-5-1	Controlling method improvement	Decrease of margin
II-5-2	Automation	
II-5-3	Heat utilization as cascade	Multiple effect evaporator, Vapor recompression Increasing distillation tray Plant integration Inter-factory energy pooling
II-5-4	Separation process	Mechanical separator instead of heating process Separation through membrane Adsorption Extraction, Supercritical separation
II-5-5	Improvement of layout	Shortening of transport distance Prevention of complicated transport Decrease of idling time through shortening of transport path
II-5-6	Mildening of operation condition of reactor	Improvement of catalyser Improvement of reagent Bio reactor
II-5-7	Change of product specification	Avoidance of overmuch quality Material not requiring heat treatment in next process

II-5-8	Change of raw material	Recycle
II-5-9	Scale up	Shortening operating time by increasing electric power
II-5-10	Modification of continuous process	
II-5-11	Modification to high speed process	
II-5-12	Simplified process	Hot charge
II-5-13	Use of high-efficiency devices	

III Prevention of Heat Loss caused by Radiation, Conduction etc.

Table 2.3 Standard Furnace Outer Surface Temperature (Ambient temperature 20°C; except rotary furnaces) (Unit: °C)

Internal temperature	Outer ceiling surface	Outer wall surface
1,300	140	120
1,100	125	110
900	110	95
700	90	80

III-1	Prevention of leakage	Inspection and Repair Selection and Maintenance of steam trap Reinforcing seals of rotary parts and joints
III-2	Narrowing heat radiating surface area	Improvement of steam piping route Removing unnecessary pipe Shutting main valve of unused pipe, or Inserting blind plate

III-3 Insulation	Enforcement of insulation at flange and valve Use of heat insulating material of low heat conductivity Lowering emissivity of insulator cover Setting cover, lid Maintenance of insulator Use of lightweight heat insulation material for batch furnace (bulk specific gravity < 1.3)
III-4 Preventing loss of internal gas flow and radiation	Reducing size of openings, closing openings, or mounting doors on openings Shortening door open time
III-5 Optimum boiler water blow	

IV Recovery & Utilization of Waste Energy
Standard Waste Gas Temperature

Table 2.4 Boiler (Load ratio 100%; ambient temperature 20°C) (Unit: °C)

Amount of evaporation	Solid fuel	Liquid Fuel	Gaseous fuel
Large boiler for electric companies	145	145	110
30 tons/h or more	200	200	170
10 - 30 tons/h	—	200	170
<10 tons/h	—	320	300

Table 2.5 Industrial Furnaces (Liquid fuel; air ratio 1.2; ambient temperature 20°C) (Unit: °C)

Furnace outlet exhaust gas temperature	Exhaust gas temperature after waste heat recovery (°C); waste heat recovery ratio (%)					
	> 80 GJ/h		20 - 80 GJ/h		4 - 20 GJ/h	
500 °C	200 °C	(20) %	200 °C	(20) %		
600	290	(20)	290	(20)		
700	300	(30)	330	(25)	370 °C	(20) %
800	370	(30)	410	(25)	450	(20)
900	400	(35)	490	(25)	530	(20)
1,000	420	(40)	520	(30)	570	(25)
>1,000		(40)		(30)		(25)

IV-1 Waste Energy

- Exhaust gas, air
- Waste water, Waste liquor
- Condensate
- Hot solid (hot cokes)
- Mechanical energy (water head)
- Unused pressure (top pressure recovery turbine, fluid coker)
- By-product combustible gas
- Coldness of liquified natural gas
- Natural energy (solar energy, outdoor air temperature)

IV-2 Use

- Heating material
- Heating air for combustion or process
- Preheating boiler feed water
- Preheating fuel (oil, gas)
- Steam generation
- Power generation, Electricity generation
- Air conditioning
- District heating
- Refrigeration
- Fish breeding
- Warming greenhouse
- Snow melting

IV-3 Measures	Heat exchanger, Heat pipe Fluid bed (suspension preheater) Heat pump Heat transport reagent Waste heat boiler, Vacuum evaporation type water heater Turbine (steam, organic reagent) Total enthalpy heat exchanger

V Rationalization of Conversion from Heat to Power

V-1 Elevation of energy efficiency	Steam condition upgrade Combined system Cogeneration Recovery of drive power at low steam pressure
V-2 Operation improvement in power plant	Improvement of turbine, Nozzle shape Vacuum maintenance of condenser (cleaning, water temperature) Optimization of power plant use Variable pressure operation according to load Auxiliary equipment load control, Revolution Optimizing back and extraction pressure Peak shift (Use of electricity during midnight hours and holidays, heat storage as ice)
V-3 Direct electricity	Generation Fuel cell Magnetohydrodynamics
V-4 Improvement of engine efficiency	
V-5 Rational operation of steam ejector	Optimization of number of stages, Steam pressure Substitution to vacuum pump

VI Prevention of Electricity Loss by Resistance

VI-1 Power Transportation

VI-1-1 Higher voltage

VI-1-2 Lower temperature

VI-1-3 Direct current

VI-2 Wiring	
VI-2-1 Minimization of length	Arrangement of receiving facility and load Improvement of wiring route
VI-2-2 Improvement of wiring way	
VI-2-3 Optimization of wire size	
VI-2-4 Balancing loads between 3-phase	
VI-3 Transformer	
VI-3-1 Optimum capacity	
VI-3-2 Load allotment, Adjusting the number of operating units	
VI-3-3 Connection way	
VI-3-4 Cutting off in unused time	
VI-4 Facilities	Minimization of resistance at contact point
VI-5 Improvement of power factor	Installing condenser (Capacitor) Power factor control by synchronous generator Avoidance of low load running of motor
VI-6 Operation	
VI-6-1 Suppression of peak demand	Load levelling Demand control
VI-6-2 Circuit voltage optimizing	
VI-7 Use of low-loss devices	Superconductive

VII Rationalization of Conversion from Electricity to Power, Heat etc.

VII-1 Motor	Advanced type Optimum capacity

VII-2 Power transmission	Improvement of transmission Transmission belt (Material, relaxation degree) Lubrication control
VII-3 Operation	Keeping rated voltage Preventing idling, Intermittent running
VII-4 Fluid transportation	
VII-4-1 Reduction of load	Decrease of flow (Preventing leakage) Reducing pipe resistance (Rationalizing pipe route, cleaning pipes) Lowering suction temperature Selection of transport measures High-efficiency devices, Impellers, Movable blades
VII-4-2 Optimizing equipment capacity	Shape of impeller
VII-4-3 Control	Revolution speed control (VVVF, clutch, pole change) Unit number control
VII-5 Energy recovery	Regenerative braking
VII-6 Electric heating	
VII-6-1 Reduction of load	Hot charge Furnace charging method, Optimum power input pattern Reducing contact resistance
VII-6-2 High-efficiency devices	Modification of frequency convertor Direct heating (Direct electric resistance heating, induction heating, dielectric heating, micro-wave heating, plasma heating)
VII-6-3 Comparative study between electric and combustion heating methods	

VII-7 Air conditioning	Reduction of load Shape, Structure, Direction, Surroundings of building Induction of outdoor air, Total enthalpy heat exchange Prevention of outdoor air invasion (automatic door, curtain) Optimum rate of air circulation Insulation Isolation of heat generating body, Lighting facilities Localized air conditioning Zoning (Setting different condition by zone) Far infrared ray heating
VII-7-1 Ventilation	Filter cleaning Lowering flow resistance in duct Fan rpm control Optimum size of humidifier nozzle
VII-7-2 Control	Return water temperature control
VII-7-3 Operation	Water quality control in cooling tower line Cleaning of heat exchanger
VII-8 Lighting	
VII-8-1 Optimum illuminance	
VII-8-2 Better interior finishment of room	Wall color
VII-8-3 Improving lighting fixture arrangements	
VII-8-4 Utilization of daylight	
VII-8-5 Enforcement of turn-off unnecessary lamps	
VII-8-6 Illumination control	
VII-8-7 Cleaning fixtures	
VII-8-8 Replacing bulbs at proper intervals	

VII-8-9	High efficiency facilities	Lamp, stabilizer
VII-9 Electrolysis		
VII-9-1	Reduction of resistance at contact point	
VII-9-2	Voltage lowering	Lowering overvoltage, Improvement of electrode
VII-9-3	Adjusting hot bath temperature and concentration, inter-electrode distance	
VII-9-4	Others	Electric precipitator intermittent charge

3. Energy Management

3. ENERGY MANAGEMENT

In Hungary, as a shift to the market economy progresses, many of the state-run companies have been privatized and each company is required to be competitive in the international market, in terms of product quality and cost, more than ever. In reducing energy consumption as well as in raising the efficiency and level of production and quality, it is necessary, first of all, to use an equipment appropriate to the purpose and well maintained and to properly operate it. It would be most effective for energy conservation to reduce equipment failures and raise product yield.

Secondly, consider the possibility of improving the present equipment and operating procedures, repeat surveys and operation tests, and thus seek a better way.

To this end, all the employees, not only top-ranking people and engineers in the factory but also on-site operators are required to make an effort through cooperation. It is no exaggeration to say, therefore, that the awareness and willingness of all the factory employees can vitally affect the performance of the factory. Improving factory management to lead the employees in that direction is extremely significant. Energy management can be defined as "an organized effort to achieve energy conservation".

(1) Defining Management Policy

Factory owners and executive have come to have growing interest in energy conservation because of growing awareness of the energy situation and the need for improving the profitability of factory operation. If the factory owner wants to take a step forward from merely having wishes and start a company-wide activity, he must show his policy and his definite attitude to implement it to all the employees. Man tends to take no action unless he is given a clear purpose. Specifically, he must set a quantitative target, specifying the percentage of reducing energy consumption per ton of product and the date of achieving the target; an upper limit of annual investment; and a period in which the investment is to be recovered. When the management defines the direction to proceed, the employees will be able to have confidence in doing work the way the management wants it to be done. Because all the employees will have the same thing in mind, they will be able to cooperate with one another more smoothly than before.

After the management presents a comprehensive factory operation policy, the individual departments set more concrete, specified targets which can be achieved within the scope of their own responsibilities to meet the management policy. Such targets will be shown in a more familiar, understandable form so that the department managers can expect full understanding of the targets and cooperation on the all of the employees.

In formulating such concrete targets by each department, a committee, such as the one mentioned later, must examine their fitness with the company target set forth in the management policy. What's more, it is important to set a higher target for their challenge and to raise competition-minded morale among departments.

(2) Organizing for Promotion of Energy Conservation

In a movement that involves many persons at different levels, such as a movement for energy conservation, some one must be assigned to lead it. In the case of a small factory, a person may be assigned to lead a movement. In the case of a large factory, an organization may be formed for that purpose.

Such an organization, as staff for the factory manager, takes the responsibility of keeping attention to the progress of energy conservation and, if a delay is found, checks for its cause and takes steps to achieve the end.

Specifically, it collects data on energy consumption, compares the acquired data with the plan, seeks ideas for improvement, checks them, distributes the budgets, manages the progress of improvement, formulates education plans, makes preparations for appointing a committee, and undertakes other duties.

A committee is effective for coordinating the different departments—production, sales, material purchase, equipment maintenance, accounting, etc.—to ensure smooth communication among them and satisfactory implementation of the plan. It must examine the effects of the energy conservation measures to be undertaken on the individual departments, and thus confirm that they will not adversely affect the overall earnings of the factory.

The head of a committee must be the factory manager who has responsibilities and authority regarding production, or some one next to him. Otherwise, nothing can be decided or executed.

An energy conservation measure developed from an excellent idea cannot produce a good result if the workers do not adequately understand its meaning or utilize it on their jobs. There are many successful instances of using a QC (quality control) circle (small group activities) for energy conservation. A QC circle improves the human relations on the job, makes use of the willingness inherent in the human beings, and thus lets the workers find their jobs enjoyable. It would be necessary to provide good conditions to facilitate work such as education, incentives until the employees become aware that a QC circle is something good and necessary for themselves. The operators are always face to face with the energy consuming equipment and know best the phenomena arising from changes in the operating conditions. It would be very effective for energy conservation to make use of the information they have and the idea they might to able to offer.

(3) Scientific and Organizational Activities

Accurate information on energy consumption is essential to implementing an energy conservation plan. Without data on consumption rates which may vary with production, equipment, type of product, or kind of material, a plan for concrete measures cannot be drawn up. In other words, it can be said without exaggeration that factory data has countless suggestions for improvement. If you check the data with an awareness of the problems, you'll be able to find such suggestions in the data. Thus, install meters when necessary, record their readings, and periodically process them to find the needed information. Remember that it is important to process the data by mathematical statistics and determine whether differences are significant.

When an improvement plan is implemented, the results must be followed up. Efforts must be made to raise the quality of work according to the PDCA circle advocated by Dr. Deming. The PDCA circle consists of, as shown in Figure 3, (1) "Plan" that draws up a plan about an improvement theme, (2) "Do" that gives practice and implementation of the method, (3) "Check" that checks the result of "Do" and (4) "Action" in which standardization is done based on satisfied results and correction is made if any problem remains. When one step is completed, the PDCA circle takes another step to achieve a higher target. This method is useful for not only energy conservation but also raising work quality in any field.

Figure 3.1 Deming Circle

In the first stage of preparing a plan, points that should be improved tend to be outstanding. Therefore, an improvement proposal system should be made effective use of. Individuals, workshops, QC circles, or staff members should be allowed to present proposals. Once a proposal is offered, don't ignore it, but examine it at a committee, etc. in a short time. Adopt it as much as possible depending on the case, ask the proposer to modify the proposal, and give a reward for it. If the adopted proposal is found effective, commend the proposer so that the other workers will be aware of the importance of taking part in the efforts for energy conservation. If a proposal is found not acceptable, give the reason for it and advice to the proposer.

In the stage of doing or implementing a plan, explain the purpose and the concept of the planned improvement to all the workers and ask them to cooperate in implementing the plan. Let them report anything amiss concerning the work, no matter how minor it may seem, so that it can be carefully dealt with. Otherwise, the plan may end up in a failure.

Conduct a check periodically, report the check results to the committee and factory manager. Also let the workers know them so that they will be more interested in them. It is important to define evaluation criteria first of all. It is undesirable to carelessly change them in the course of implementing the plan.

In the action stage, if good results can be expected by implementing an improvement plan, establish an operation standard to lay down rules to be observed by the workers, and take the necessary measures for the equipment so that the operators will not have to bear excess burdens in usual operation. Such actions are necessary for ensuring lasting volition.

If significant results are consecutively produced by implementing a plan, announce the improving process of it, use it as a reference in other cases, commend the persons involved, and thus encourage others to follow suit.

(4) Providing Education and Information

Employees willing to cooperate cannot make improvements unless they know how. They will be more willing to take part in improvement plans if you not only point out problems but also let them propose their ideas for improvement. Institutional education is important for this purpose. Seminars may be held, or guidebooks may be distributed to this end.

Consequently, intracompany education is thought critical. Such measures may be taken as a training course and distribution of instruction manuals. If the staff cannot share the knowledge obtained from the training course outside the company with other staff members and operators, the effectiveness may be cut half. If ones who have received external training act as lecturers for training within the company and transfers their knowledge to the others, they will be able to improve the overall level of the company and at the same time confirm their own knowledge.

It is also desirable to actively exchange information with others in the same trade, material suppliers, and customers who buy the products. It may help to raise a chance for improvement. Competition among companies is something necessary, but exchanging technical information within a certain scope on a give-and-take basis will be conductive to raising the level of the trade as a whole, strengthening international competitiveness, and enhancing the mutual profit as a result. Announcing data on consumption rates, for example, will help simulate a motive for competition. A different approach to finding problems can be expected by receiving advice or audit from public organizations, consultants or university professors.

4. Energy Conservation in the Dyeing Industry

4. ENERGY CONSERVATION IN THE DYEING INDUSTRY

4.1 Characteristics of use of energy

4.1.1 Production processes at a dyeing factory

The processes at a dyeing factory vary by the working method, but they are as described in Figure 4.1 in general.

(1) Preparatory bleaching

Singeing and degluing ① — Scouring ② — Bleaching ③ — Drying

Each one of ① ~ ③ is followed continuously by chemical immersion, steamer and washing processes.

(2) Mercerization

Chemical immersion — Stabilizing — Washing — Drying

(3) Heat setting

Heat setting

Fibers of polyester type are set with heat of 190 ~ 200°C.

(4) Dyeing

a. Continuous dyeing

Dyeing solution impregnation — Drying — Steaming — Washing — Drying

b. Batch dyeing

Dyeing solution impregnation — Fixing (auxiliaries) — Washing — Drying

c. Textile printing

Screen, roller — Steaming — Washing — Drying

Figure 4.1 Production processes (1/2)

(5) Finishing

a. Gluing, tentering and drying

Finishing agent immersion — Drying

b. Resin working

Resin immersion — Drying and heat treatment — Washing — Drying

(6) Inspection

(7) Shipping

Figure 4.1 Production processes (2/2)

4.1.2 Situations of use of energy

(1) Equipment that use energy

The principal energy used at a dyeing factory are steam used for heating water, steam for fixing dyestuff, and steam or combustion gas heat and electricity required for drying. Washing process, fixing process and drying process are the principal points of use of these energy. It is necessary to eliminate loss and wastefulness of these energy, to recover the heat of waste liquid and exhaust gas for reuse, and to keep the equipment in good conditions for execution of running at high efficiency. For promoting energy conservation, therefore, it is important to make improvement with attention paid to these three processes.

The contents of use of energy are shown in Table 4.1.

Table 4.1 Equipment that use energy and contents of use of energy

Equipment	Purpose of use	Energy
Singeing equipment	To burn the raising portion of textile surface	Gas
Dyeing equipment	To attach various dyestuff and to perform coloring by immersion or alike	Hot water Steam
Washing equipment	To wash off contaminants, dyestuff, chemical solution, etc.	Hot water Steam
Steaming equipment	To fix the color after dyeing	Steam
Drying equipment	Drying, tentering and finishing of the textile	Steam Gas

(2) Energy consumption

The energy consumption varies to a certain extent by differences in the working method, contents of equipment, used chemical, etc. There are two views for management of energy consumption. One is the consumption per equipment (per unit time, per lot). Another is what is called unit consumption, that is, the consumption per unit length, unit weight or per piece of product.

Typical energy consumption in Japan is shown in Table 4.2 for reference.

a. Energy consumption by equipment

Table 4.2 Energy consumption by equipment

Process/equipment	Energy	Consumption
Washing equipment	Water	5 m^3/t-textile
Dyeing process (dyeing, washing, drying)	Steam	2.500 ~ 3,500 kg/h
Bleaching process (steaming, washing, drying)	Steam	5,000 ~ 7,000 kg/h
Steamer 40 ~ 50 m/min, stay for 15 minutes	Steam	450 ~ 600 kg/h
Drying equipment		
Low pressure cylinder dryer	Steam	30 ~ 40 kg/h/Cylinder
Steam pressure 1.5 ~ 1.9 bar(G)		
Textile speed 40 ~ 60 m/min		
Cylinder width 1,500 ~ 2,000 mm		
Frame dryer 40 ~ 50 m/min	LPG	0.016 kg/m-textile

b. Situations of energy unit consumption

The energy unit consumption varies by the production rate, production method, operating hours, production items, etc. and simple comparison cannot be made. But a comparison of energy unit consumption in production processes only between a company in Japan (Company A) and a company in Hungary (Company B) is shown in Table 4.3. The energy consumption at Company B is larger by 50 ~ 60% than Company A.

Table 4.3 Comparison of energy unit consumption

Consumption	Steam unit consumption	Electric energy unit consumption
Company A of Japan	7.9 MJ/m^2	0.13 kWh/m^2
Company B of Hungary	12.6 MJ/m^2	0.23 kWh/m^2

Table 4.4 indicates progress of energy consumption and energy unit consumption at businesses of mechanical dyeing and finishing of textile, etc. that appear in the fiber statistics of Ministry of International Trade and Industry.

Table 4.4 Progress of energy consumption mechanical dyeing and finishing businesses

Year		1973	1975	1980	1985	1987	1989
Worked quantity	Mm^2	7,287	6,940	7,133	7,516	7,130	7,257
Fuel oil	ℓ/m^2	0.216	0.209	0.163	0.125	0.128	0.130
Electric energy	kWh/m^2	0.147	0.156	0.171	0.178	0.189	0.192

4.2 Rationalization of use of energy

4.2.1 How to implement energy conservation measures

(1) Steps for energy conservation

It is recommended that energy conservation measures are implemented in the following steps.

Step 1: To improve the equipment statuses and operating conditions making without large investment.

Step 2: To implement improvement that accompanies investment of a certain amount in addition and improvement of equipment.

Step 3: To implement modification to production equipment, modification to processes and introduction of new equipment that accompany large equipment investment.

To implement energy conservation in steps, it is necessary to judge, based on data, the situations of use of the energy by the current equipment and to promptly seize if the design performance is exhibited. Secular deterioration of equipment is occurring, and energy consumption is increasing at unexpected points.

In the aspect of energy management, it is recommended that management is made by unit consumption. Seize the energy consumption per equipment, energy consumption per process and energy consumption of the whole factory per processed quantity, make comparison by year and by month, and judge if the current situations are satisfactory. If the unit consumption is changing even if energy conservation measures are implemented, it indicates that the equipment operation rate is changing or excess energy is consumed at unexpected points.

(2) Calculation of investment recovery period

In the case where energy conservation investment is made, it is necessary to make calculation of the invested expenses recovery period so as to implement investment of high efficiency. In Japan, the equipment investment recovery period is set as 3 ~ 5 years in general. In usual cases, measures involving investment of short recovery period were implemented first, and measures involving investment of long recovery period were gradually implemented. It is unavoidable that the criteria for the recovery period varies by the nation because circumstances such as prices of energy, fostering in the aspect of policy and interest rate are different.

For calculation of the recovery period, the simple number of years of recovery obtained by simply dividing the investment amount by the increased profit is often used for investment of small scale in Step 1 and Step 2 of energy conservation measures.

$$X = A / B$$

where;

X : Recovery period (year)

A : Amount of investment = Gross amount of investment + Estimated profit or loss from disposal of old equipment

B : Increased annual profit = Increased profit + (Depreciation of new equipment – Depreciation of old equipment)

In Step 3 where the equipment investment is large, however, the method to convert the annual profit into the current price by compound interest calculation and to then compare it with the investment amount is adopted.

4.2.2 Energy conservation measures

To implement Step 1 and Step 2 of energy conservation, examine the feasibility of the energy conservation measures from the aspects of losses, wastefulness, recovery of waste energy for reuse and equipment.

(1) To eliminate "losses"

a. Prevention of heat radiation (execution of heat insulation work)

Heat losses by heat radiation from surfaces of tanks and pipes and also from liquid surfaces cannot be ignored. The radiating heat varies by the flow of air and liquid on the convection heating surfaces and by temperature. With washing equipment and others, the water makes stream and the radiating heat is large.

In general, execution of heat insulation work provides economy if the surface temperature is 50 ~ 60°C or higher. With dyeing machines and water washing machines, heat insulation work was not executed in many cases because large expenses are required for preventing entry of water into the insulators. In the recent years, however, water repelling plastic foam of independent bubble type was developed, and it can be applied by adhesion using adhesive. Insulators now permit use up to the temperature level of about 100°C.

The calorific value of heat radiation from hot water surfaces in hot water storage tanks and so forth is also large. Therefore, it is necessary to insulate the wall surfaces and also to prevent heat radiation from the hot water surface using a floating cover or alike. Measured values of calorific value of heat radiation from hot water surfaces are shown in Figure 4.2.

b. Prevention of leakage

With steam valves, water delivery valves and so forth, flaws are produced on valve seats and leaking losses will occur after use for a long time. Furthermore, steam traps and automatic valves are provided with bypass circuits, but there are cases where the bypass valves are not completely closed and leakage is occurring from the bypass circuit side. It is necessary to execute periodic inspection to find these problems.

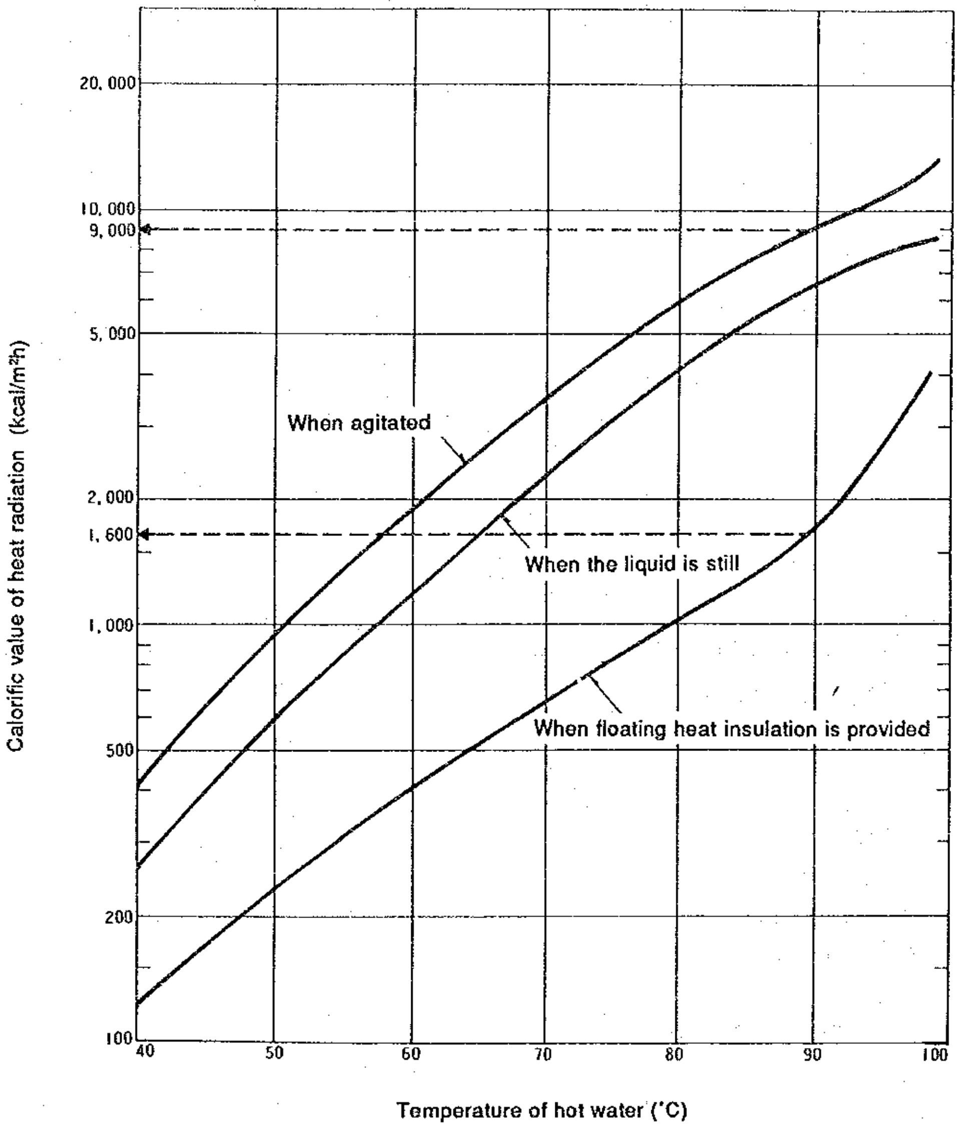


Figure 4.2 Radiation heat from free surface of hot water tank

c. Management of steam traps

The steam traps of optimum type and capacity should be selected in correspondence to the place of use, whether waste heat recovery is made or not, situations of discharge of condensate, etc.

That is, if recovery of condensate is made and the back pressure is high, a steam trap of mechanical type should be selected. Select the discharge capacity at about 1.5 ~ 2 times of the condensate generation rate. For a cylinder dryer, however, select a steam trap of discharge capacity that is around 4 ~ 5 times of the condensate generation rate.

Periodically (once or twice a year) inspect the steam traps to check if discharge of condensate is made normally.

In the case where recovery of condensate is made, if the temperature of the recovery tank rises abnormally or if steam is emitted out of the top surface of the tank, it should be considered that abnormality occurred to the operation of the trap.

Examples of selection of steam traps are shown below.

[Example of selection 1] Case of batch type high pressure dyeing machine

Calculation of condensate generation rate

Conditions:	Steam pressure	: 5 bar(G) (Latent heat r = 2,085 kJ/kg)
	Dyeing volume per batch	: 300 kg (Specific Heat C = 1.26 kJ/(kg·°C)
	Dyeing liquid volume	: 1,600 ℓ
	Heat-up time	: Raise the water temperature from 15°C to 100°C in 40 minutes

Condensate generation rate

$$Wp = \frac{(300\,kg \times 1.26\,kJ/(kg\cdot{}^{\circ}C) + 1{,}600\,kg \times 4.186) \times (100 - 15^{\circ}C)}{2{,}085\,kJ/kg} \times \frac{60}{40}$$

$$\fallingdotseq 432\,kg/h$$

When 1.5 times is adopted as the safety factor, the required discharge capacity becomes about 700 kg/h. But because of being large quantity discharge type, divide the heater into two and provide two steam traps.

[Example of selection 2] Case of cylinder dryer

In the case of a low pressure cylinder dryer (steam pressure 2 bar(G) or less, width 1,500 ~ 2,000 mm), the condensate generation rate per cylinder is 30 ~ 40 kg/h. In order to quickly discharge the condensate, provide a steam trap for each cylinder. Determine the trap discharge capacity as 160 kg/h or higher, which is about 4 ~ 5 times of the condensate generation rate.

(2) To eliminate "wastefulness"

a. Reduction of washing water flow

The objective of washing is fully achieved if the water flow used for textile washing is about 4 ~ 5 times of the textile weight. If washing cannot be made unless water of a large volume is used, it is necessary to replace the washing equipment with an equipment of high washing efficiency. Uplift the washing efficiency by the following methods as a rule.

① To increase the number of times of contact of the cloth with the washing water.

② To change the flow direction of the washing water to the cloth from parallel flow to counterflow in the case of multi-stage washing.

③ To apply vibration to the cloth and water.

④ To use water with distinction made between hot water side and cold water side.

Such a method for washing that spray washing is applied to washing by immersion in hot water and the water flow is reduced by increasing the number of times of contact of the cloth with the water is also available as shown in Figure 4.3. The hot water temperature should be kept at a fixed level in this case, but use of liquid-steam mixing devices which are capable of freely controlling the temperature has recently increased.

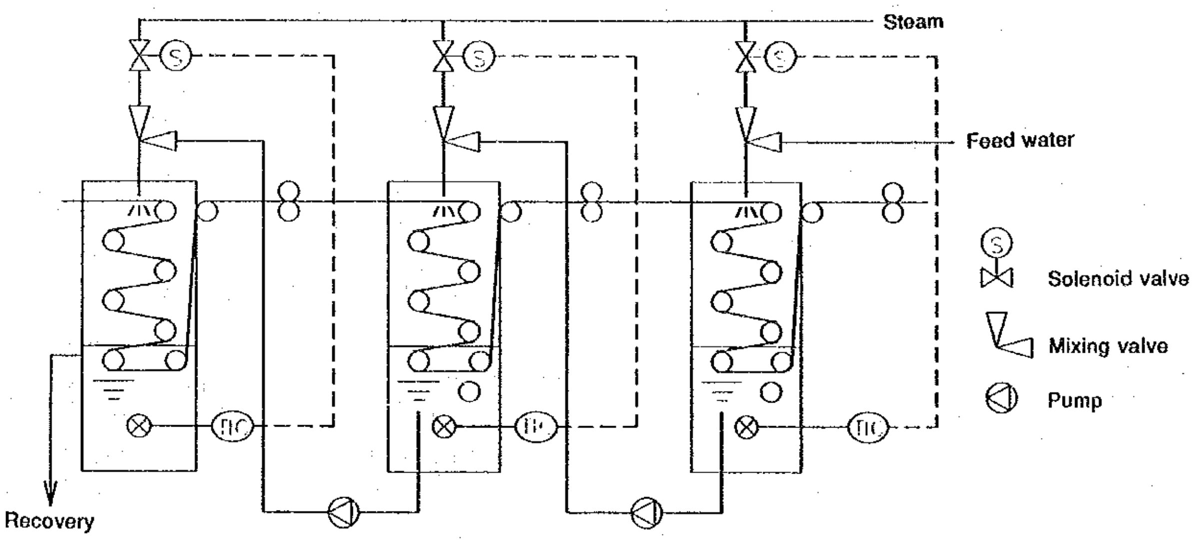


Figure 4.3 Spray type counterflow method

Furthermore, in the case where counterflow multi-stage washing is performed, increase the washing effect by making the water flow and water temperature optimum by the following methods.

① To provide a constant flow valve.

② To provide a relief valve to keep the water delivery pressure at a fixed level.

③ To mount sensors to keep the water level and water temperature in the tank at fixed levels.

It is possible to reduce the water volume to three times or less of the textile weight and to reduce the steam consumption to 50% or less of that of a conventional type by the use of these methods.

b. Reduction of liquor ratio

Water is used by a large quantity in the dyeing process, and in addition, water is used as heated (to 70 ~ 105°C) to improve the dyeing ratio. Saving of water, therefore, leads to saving of thermal energy.

The volume of water (*ℓ*) used for dyeing an object of 1 kg is called liquor ratio. The liquor ratio varies considerably by the dyeing equipment and dyeing method.

As for dyeing machines, various dyeing machines of low liquor ratio type have been developed. Even if the liquor ratio was 1:20 ~ 30 before, it is now reduced to 1:11 or less by improving contact of the cloth with the water by rotating or vibrating the cloth at high speed of 200 m/min or higher. In the batch dyeing in particular, the liquor ratio was reduced to a major extent by changing from dyestuff solution immersion type to dyestuff solution flow type, in an effort to achieve energy conservation. The energy consumption was reduced to 50% or less of conventional types as a result of implementation of these measures.

A comparison of low liquor ratio type and conventional type is shown in Figure 4.4.

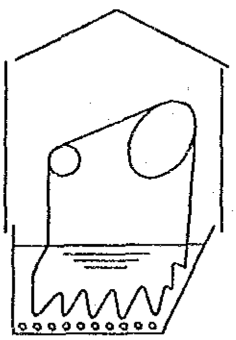
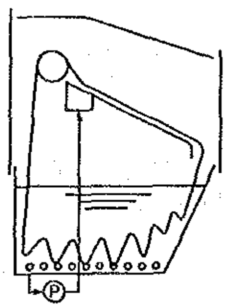
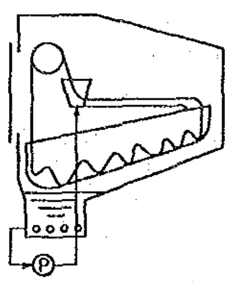
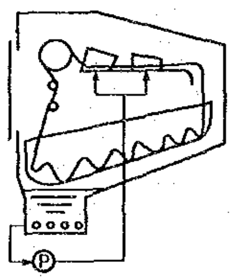
Type	Wince	Liquor flow type wince (winpact)	Liquor flow type wince (dash line)	Liquor flow type wince (super flow)
				
Textile velocity	60 m/min	80 m/min	80 m/min	210 m/min
Liquor circulating cycle	—	60 sec	30 sec	20 sec
Liquor ratio	1:20	1:15	1:10	1:5
Produc-tivity	1 revolution/D	2 revolutions/D	3 revolutions/D	4~5 revolutions/D

Figure 4.4 Reduction of liquor ratio of batch type dyeing machine

Besides, for plain dyeing, such a method that the dyeing solution is added to the textile as converted to small equal foam using air is also available to reduce the liquor ratio to 3 or less.

c. Shortening of dyeing time

The cloth speed can be increased with liquid flow dyeing. Accordingly, the dyeing time becomes short. Even if one turn only was made in a day of 8-hour operation, now four or more turns can be achieved in a day, and the productivity increased to a major extent and space saving and energy conservation were achieved at the same time.

Furthermore, such a method that the capacity of the heater in the water bath is increased to permit quick heating up in the temperature range that does not affect dyeing and to make level dyeing unnecessary was also developed.

Chains and belts were used for power transmission with Smith drum type dyeing machines, but now motor direct drive is applied, the motor is subject to VVVF control, the drum revolution is controlled and reversing is made in addition to uplift the dyeing ratio.

d. Drop of treating temperature

It is possible to reduce the treating temperature of bleaching, dyeing, etc. by changing chemicals, etc. There is a case where the treating temperature was reduced from 98°C to 70°C in the dyeing of Nylon products.

Also with water washing, it is necessary to repeat tests for reducing the temperature so as to reach the optimum temperature.

e. Efficient use of cylinder dryers

Cylinder dryers are often used because their efficiency of heat transfer is better than that of hot air dryers. If management is inferior, however, the cylinder surface temperature drops and insufficient drying will result. Therefore, there are cases where the cylinder dryer is run with the textile speed reduced from 60 m/min, which is a design condition, to 40 m/min.

It is necessary to pay the following attention regarding of handling of steam at a cylinder dryer.

- To increase dryness of the steam so as not to allow entry of condensate into the cylinders.
- To provide a pressure regulator valve so that the steam pressure supplied to the cylinders is kept at a fixed level even when the steam flow rate varies.
- To provide a steam trap for each cylinder so that the condensate generated in the cylinder is completely and quickly discharged. Furthermore, not to neglect maintenance and inspection of the internal siphons.

- To select steam traps of a suitable type so that no steam locking will occur.

f. Prevention of overdrying

Even if fibers are dried beyond a certain limit, moisture absorption occurs to the equilibrium moisture level when shelved in the air. Therefore, to dry beyond the levels shown in Table 4.5 is a loss of energy.

Table 4.5 Equilibrium Moisture Percentage (20°C/65% RH)

Material	Equilibrium Moisture (%)
Cotton	7.0
Polyester	0.4
Nylon	4.5
Viscose	12.5
Wool	16.0
Polyester-cotton blend (2:1)	2.5
Polyester-wool blend (2:1)	5.5

Source F.C. Harbert International Dyer. Vol. 142, No.2, (1972), p102.

g. Use of mangle dehydration

It is recommended that textile is fully dehydrated with a mangle to reduce the energy for drying. Employ rubber sheathed rolls of a suitable hardness level for increasing the dehydration ratio, and make adjustment so that the roll line pressure is equal. Equipment using unwoven cloth rolls and equipment of vacuum type that makes suction through slit are also available as more effective equipment. Such a method that dehydration is made by blowing high speed airflow is also effective. Since the moisture content can be reduced to 25 ~ 50%, the drying speed can be doubled and there is a case where the drying cost was reduced by 17%.

h. Efficient running of hot air dryers

In hot air drying, it is possible to save thermal energy and electric energy when VVVF control is made to the motors of hot air fan, hot air circulation fan and exhaust fan with inverters incorporated in these motors.

Measure the extent of drying of the textile at the dryer outlet using a moisture sensor, and control the drying hot air temperature and/or the hot air circulation rate.

Measure the temperature or humidity of the exhaust on the suction side of the exhaust fan, and implement automatic control of the exhaust rate.

With a dryer of air shrinker system, hot air is blow to the textile at high speed (35 m/s) to increase the drying efficiency.

There is a case where energy conservation by over 20% and uplift of productivity by 20% were achieved by taking such measures that are described above.

i. Reduction of number of times of drying

Immersion in liquid and drying are repeatedly performed in the dyeing process. But there is a case where a method to equally apply finishing agent to wet cloth was developed to reduce the number of times of drying to achieve energy conservation.

(3) To recover and reuse waste heat

a. Situations of generation of exhaust heat

Thermal energy of a large quantity is abandoned at a dyeing factory including exhaust from drying equipment and hot wastewater from washing equipment and dyeing equipment. Typical analysis of thermal energy at a dyeing factory is shown in Table 4.5. It is learned from this table that the ratio of heat abandoned by waste liquid is large. Therefore, there are many cases where heat exchange is made between dyeing wastewater and washing wastewater with feed water or warmed cooling water is used for next feed water.

Table 4.6 Thermal Energy Consumption State (Intermediate Scale Dyeing Factory)

Item	Percentage (%)
Product heating	16.6
Product drying	17.2
Waste liquor loss	24.9
Heat release from equipment	12.3
Exhaust loss	9.3
Idling	3.7
Evaporation from liquid surface	4.7
Unrecovred condensate	4.1
Loss during condensate recovery	0.6
Others	6.6
Total	100.0

The principal sources of generation of exhaust heat and situations of recovery and use of exhaust heat at a dyeing factory are shown in Table 4.7.

Table 4.7 Principal sources of generation of exhaust heat and situations of recovery of heat for reuse (1/2)

Generation source	Situations of exhaust heat	Situations of recovery and use of exhaust heat
① Dyeing and bleaching equipment	Hot wastewater (50~60°C)	Used for heating the dyeing and bleaching water with plate type heat exchangers.
② High temperature and high pressure dyeing machine	(a) Hot wastewater (80~95°C)	Used for heating the dyeing and bleaching water with plate type heat exchangers.
	(b) Hot wastewater (100~120°C)	The low temperature wastewater after heat recovery is timely sprayed to the hot wastewater gathered in the pit to absorb the flash steam, and then recovery and use are made in the manner equal to the above.
	(c) Hot fresh water after passage through cooling coil (50~70°C)	Directly reused as dyeing water.
③ Air compressor	Cooling wastewater (hot fresh water) (30~45°C)	Used as dyeing water or for hot water feed to the bath room.
④ Heat setter	Low temperature exhaust steam (100~120°C) (contains condensate, oil and dust)	Used for heating the dyeing, bleaching and boiler water with plate type heat exchangers after condensation with cooling coil with fan.
⑤ Dryer	(a) Exhaust (70~80°C) (includes cotton dust, etc.)	Used for heating the feed air for drying with a rotary disk type sensible heat exchanger provided in the exhaust duct.
	(b) Exhaust after heat exchange mentioned above (40~50°C)	The latent heat is recovered to the boiler water with a cooling coil without fins located in series with the heat exchanger stated above.
	(c) Exhaust (70~80°C) (in the case of small air-flow)	Used for heating the dyeing and bleaching water with a cooling coil with fins provided in the exhaust system.

Table 4.7 Principal sources of generation of exhaust heat and situations of recovery of heat for reuse (2/2)

Generation source	Situations of exhaust heat	Situations of recovery and use of exhaust heat
⑥ Tenter	LPG (LNG) Combustion exhaust gas (220°C)	Used for heating the combustion air with a rotary disk type sensible heat exchanger.
⑦ Air conditioner	Cooling exhaust heat	Used for heating the dyeing and bleaching water with an absorption type heat pump using the cooling exhaust heat and the heat of dyeing and bleaching water of ① above.
⑧ Washing equipment	Hot wastewater (70 ~ 80°C)	(1) Used as counterflow. (2) The wastewater is recovered in the pit, filtered with a screen and is then used for heating washing water with a plate type heat exchanger.

b. Selection of heat exchangers

The dyeing waste liquid, combustion gas, etc. contain contaminants, oily matter and dust. For making effective recovery of exhaust heat, it is necessary to select heat exchangers upon careful examination of method for recovery (air to air, air to water, water to water or recovery as flash steam), characteristics of heat exchanger (ease of contamination, corrosion resistance, possibility of occurrence of leakage, ease of clean-up, etc.) and achievements of use.

Heat exchangers should be periodically cleaned to prevent drop of the coefficient of overall heat transfer. Plate type heat exchangers are often used from the standpoint of ease of clean-up.

c. Recovery and use of condensate

Recovery and use of condensate is an effective means for energy conservation. The latent heat of steam is effectively used with cylinder dryers, hot water heaters, etc., but sensible heat is discharged without being used. In general, the calorific value that can be recovered as condensate is as much as 20 ~ 30% of the used steam. When its recovery and use is made, 10 ~ 13% of the energy consumed by boilers can be saved.

For use of recovered condensate, use for boiler feed water and process hot water may be made.

Points requiring attention in the recovery and use of condensate are as follows.

- The back pressure of the recovery line should not exceed the level of 40 ~ 45% of the minimum working steam pressure.
- Select steam traps of mechanical type which are hardly affected by the back pressure.
- Apply heat insulation to the recovery line.
- The flash steam, that is generated at the time when the condensate is reduced in pressure to the atmospheric pressure, should not be allowed to scatter.
- In the case where the recovered condensate is led into the liquid in the recovery tank, provide many small holes to allow the condensate to broadly disperse, as vibration and noise are generated when the tank internal temperature is higher than 80°C.

  Furthermore, cool the recovery tank and supply water to the tank so that its internal temperature will not exceed 90°C.

  The method to directly recover the condensate in a boiler without reducing its pressure is most effective for preventing its loss.
- Provide a sight glass along the recovery line to check for steam leakage from the trap.

(4) To draw out the "equipment performance" by 100%

The equipment performance drops due to secular deterioration. In addition, there are cases where the efficiency drops due to the difference in the operation and handling by the operator.

The following points can be raised as what require attention in the management of equipment.

- Increase the operation rate with periodic inspection and repair to the equipment suitably implemented.
- Establish an operation manual so that the equipment handling method will not change even when the operator changes.
- Establish an operation standard so that the temperature, pressure, flow rate, etc. are optimum in correspondence to the specification of the product.

- In the case where linkage between adjacent equipment is made by means of a textile, these equipment should be of the same speed.

- Uplift the quality (dryness) of the steam used for the cylinder dryer.

- Periodically clean the circulation air filter of the dryer to eliminate drying fault caused by the drop in the airflow.

- Adopt VVVF control for rotary equipment if possible.

- With a steaming machine, make contrivances so that the condensate will not attach to the textile.

4.3 Cases of energy conservation measures

Examples of activities implemented as small group activities of operators of factories are introduced below. All of these examples are measures which do not accompany large investment, but they achieved conspicuous effect of energy conservation.

[Example 1] Energy conservation at mercerization and washing equipment

(1) Heat insulation of tank surfaces

Insulators made of water repelling type plastic foam which can be easily worked by adhering with adhesive were made available. Therefore, heat insulation work was executed to Smith drum type and wince type dyeing machines using these insulators. Energy conservation of 50% was achieved as a result of this heat insulation work.

(2) Counterflow washing

The water consumption is 3,000 ℓ/h and the washing temperature is 80°C. The washing effect was uplifted by such a setup that counterflow of water flow and textile flow occurs as shown in Figure 4.5.

A temperature sensor is mounted in the water tank, and the temperature of the washing water can be controlled by steam indirect heating using a pipe type heat exchanger.

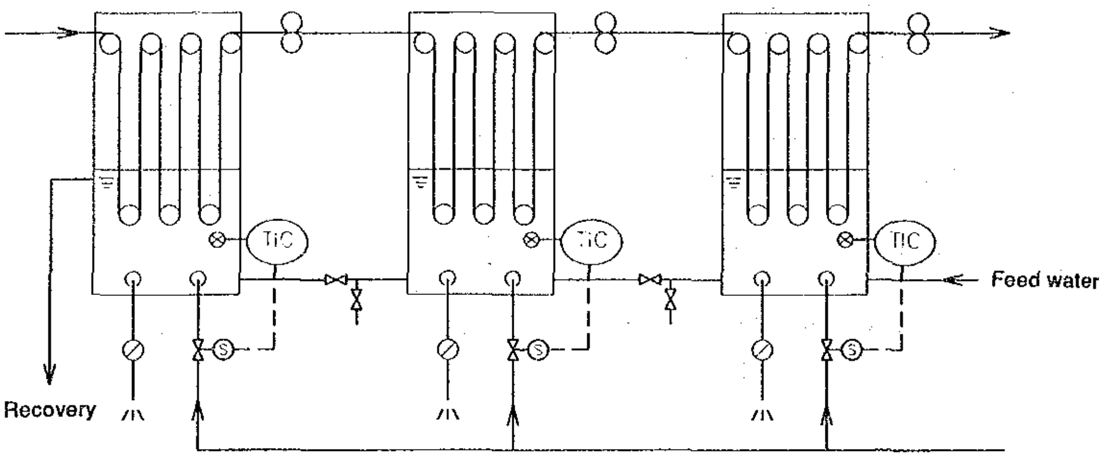


Figure 4.5

(3) *Recovery of washing wastewater waste heat and recovery of steam condensate*

As the washing wastewater contains waste yarn and other foreign matter, they are removed with a natural flow type filter screen of around 30 mesh. A plate type heat exchanger of large coefficient of overall heat transfer was adopted for heat recovery from hot wastewater. (K = 6,300 ~ 6,700 kJ/(m^2·h·°C))

Furthermore, steam condensate is directly recovered to the boiler feed water tank with a recovery line provided.

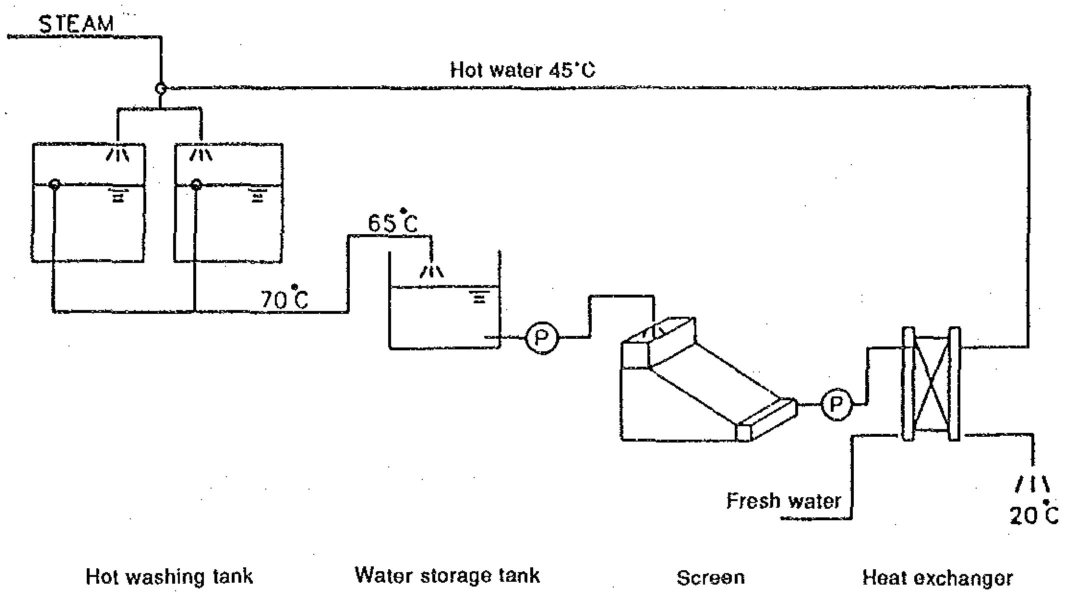


Figure 4.6 Flow of hot water exhaust heat recovery

(4) *Standardization of water usage*

Large differences as 6,000 ~ 12,000 ℓ/h were observed in the water consumption at the scouring process, bleaching process and mercerization process, and the following points were found as a result of the survey of the cause for such large differences.

a) The water delivery pressure is not constant ··· The water pressure drops when multiple water consuming equipment are connected to a line.

b) The opening of the water delivery valves of each tank is not fixed.

c) Decision of the water delivery rate varies by the operator.

In order to obtain stable washing effect, the operation should not vary by the operator. Therefore, the standard washing water flow was determined for each kind of materials as follows.

Material	: Cotton textile
Unit weight	: *150 ~ 200 g/m²*
Textile width	: 1,500 mm
Textile input speed:	45 m/min

When the necessary water flow is assumed as five times of the weight of the textile to be washed, the standard water flow in this case is 4,500 ~ 5,000 ℓ/h. But 5,500 ℓ/h was determined with a margin of 10% taken into account.

(5) Improvement of equipment

a) The valve handle was changed from round type to lever type so that the valve opening can be easily identified.

b) An orifice plate was installed so that the mangle water delivery rate becomes constant.

c) A relief valve was installed along the water delivery mains so that the pressure becomes constant.

d) A float type flow indicator was installed along the water delivery mains.

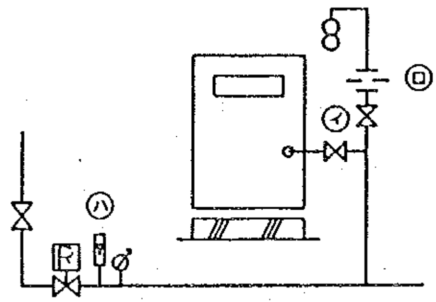


Figure 4.7 Standardization of washing water flow

[Example 2] Energy conservaiton at cylinder dryer

It was found that the textile treating speed dropped to 45 m/min and faulty drying is also occurring at occasions at the cylinder dryer, and troubleshooting was executed. The following matters were found as a result.

a) The steam pressure is varying ··· 1.4 ~1.6 bar(G) (maximum working pressure 1.9 bar(G))

b) Some thermodynamic type steam traps are malfunctioning.

The piping trapping method is as shown in Figure 4.8.

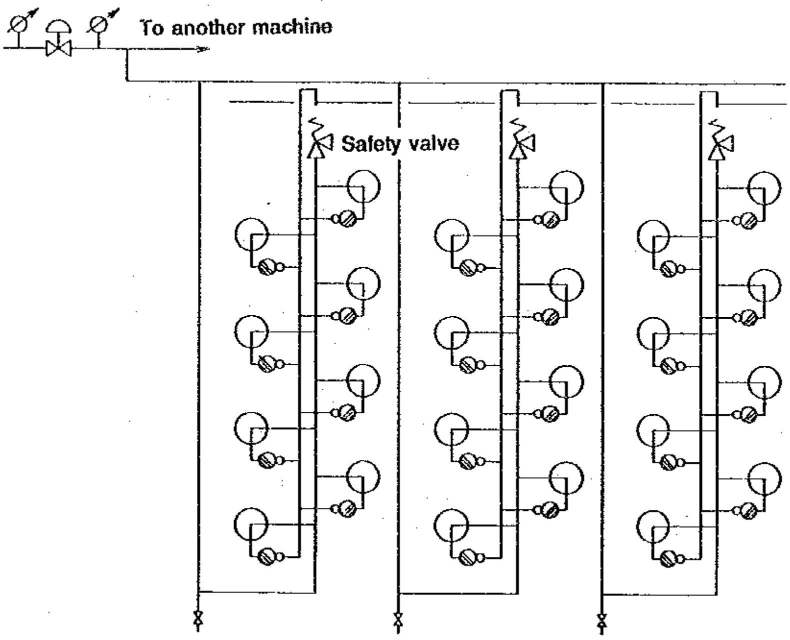


Figure 4.8 cylinder dryer before Improvement

Accordingly, the following improving measures were implemented.

a) A condensate separator was added to uplift the dryness of the steam and not to allow entry of the condensate into the dryer.

b) A reducer valve dedicated to the cylinder dryer was added to keep the steam pressure for the cylinder dryer at a fixed level, so that variation of pressure as affected by running of other machines will not occur.

c) Thermodynamic type steam traps were changed to mechanical type steam traps to prevent malfunction of steam traps due to back pressure.

The conditions before and after improvement are shown in Figure 4.8 and Figure 4.9.

Drying can be made after improvement even when the cylinder dryer speed is increased to 65 m/min. Furthermore, the steam pressure became stable, the dryness became constant, and the steam unit consumption dropped.

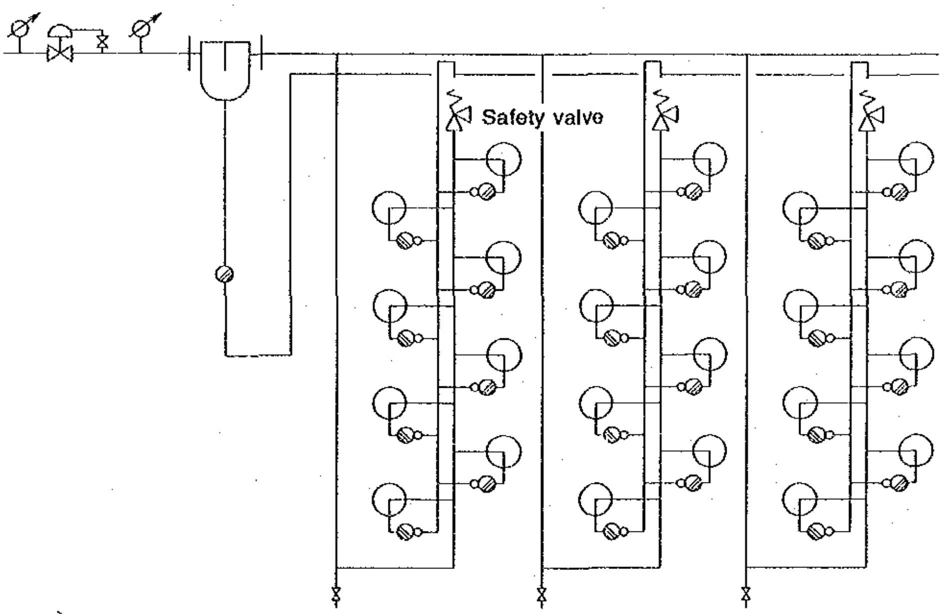


Figure 4.9 cylinder dryer After Improvement

[Example 3] Energy conservation at shrink dryer

This is an example of energy conservation measures applied to a shrink dryer for finish drying of cotton fabrics.

A shrink dryer is shown in Figure 4.10.

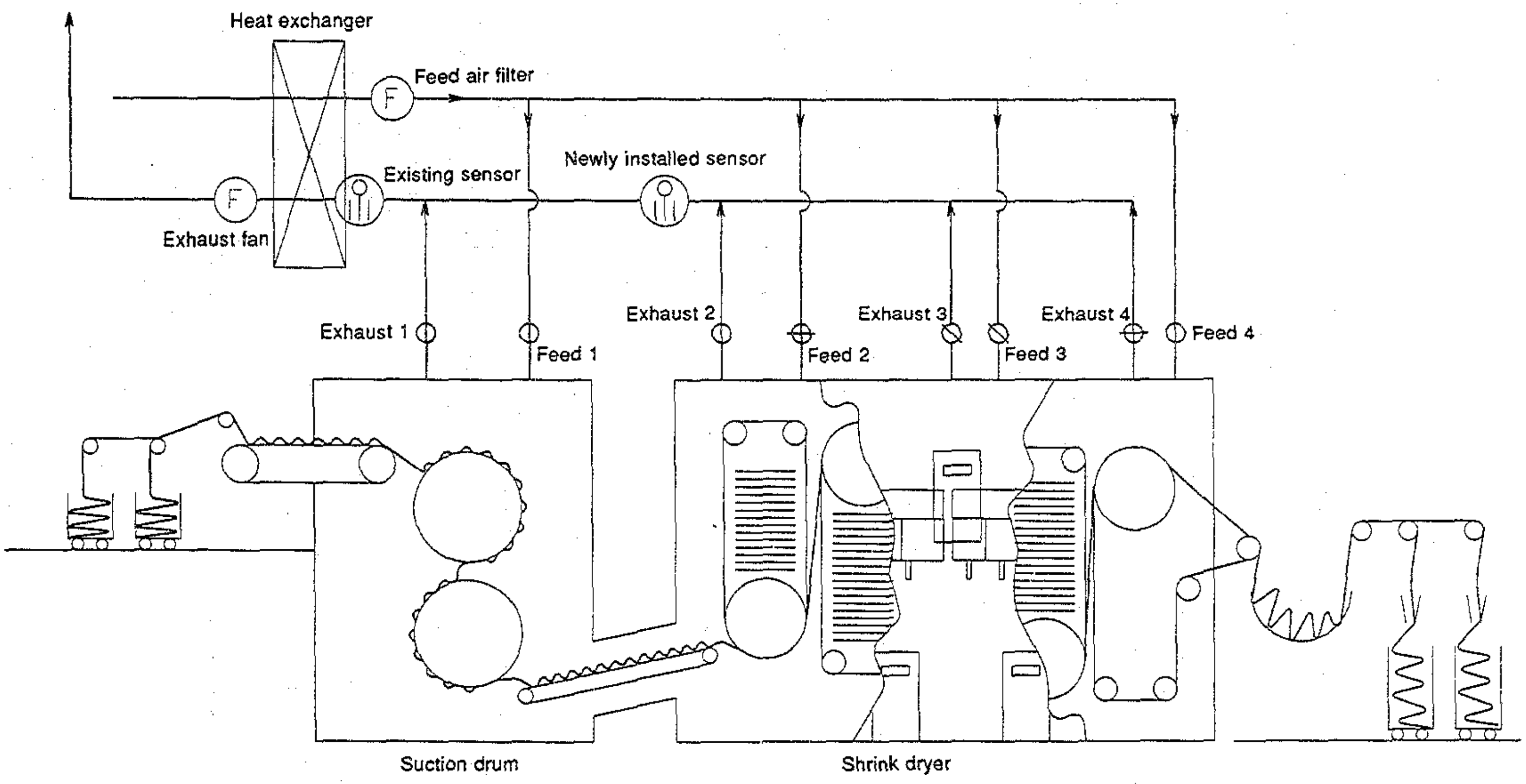


Figure 4.10 Shrink dryer

Large energy of as much as 30% of the entire energy consumption at a dyeing factory is consumed for drying of the textile, and the majority is discharged as exhaust.

- Improvement 1: Installation of rotary disk type sensible heat exchanger

A rotary disk type sensible heat exchanger was mounted along the exhaust line of the dryer. The rotor is of honeycomb structure made of metal, and the revolution is 6 ~ 10 rpm. The situations of intake and exhaust at the heat exchanger are shown in Table 4.8.

Table 4.8 Situations of Intake and exhaust at heat exchanger

		DB ˚C	WB ˚C	kcal/kg	x kg/kg'	Q kg/min
Exhaust	Inlet side	88	49	61.5	0.063	199
	Outlet side	50	41	42.0	0.048	199
Intake	Inlet side	35	24	17.0	0.014	260
	Outlet side	83	39	37.0	0.027	260

The heat recovery rate is 59% as follows from Table 4.8.

$$\frac{(37-17)\times 260}{(61.5-17)\times 199}=0.59$$

However, the actual heat recovery rate is around 50% due to leakage at sealed portions and partial mixture of intake with exhaust.

Furthermore, a cooling coil was inserted to the exhaust system after this heat exchanger to recover the latent heat for the boiler feed water. The total heat recovery rate with both heat exchangers is about 70% in this case.

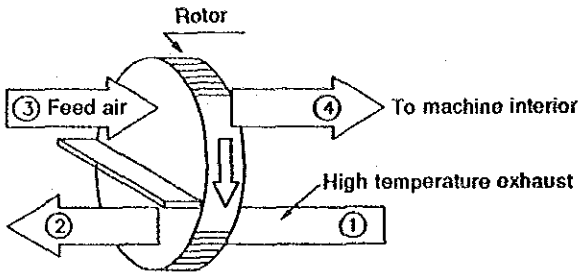


Figure 4.11 Rotary disk type sensible heat exchanger

- Improvement 2: Control of revolution of exhaust fan (VVVF control)

The exhaust from the suction drum (for preparatory drying) and the shrink dryer is led to the integrated duct. A humidity sensor was installed before the inlet to the rotary disk type sensible heat exchanger and exhaust fan revolution control (VVVF control) was made so as to keep the exhaust temperature at a fixed level.

With this scheme, however, the exhaust rates of the suction drum and of the shrink dryer fluctuate by the rate ratio, and the dryness degree became different by the article. Improvement 3 was implemented in order to solve this problem.

- Improvement 3: Feed/exhaust damper automatic control system

The dew-point temperature in the machine changes as drying of the textile makes progress from the suction drum to the shrink dryer. Therefore, it was determined to mount a dedicated temperature sensor in the shrink dryer exhaust system and to automatically control the opening of the feed (exhaust) damper 2 ~ 4 shown in Figure 4.10 by the program in which the relation between the encoder angle and the airflow is input in advance (Figure 4.12).

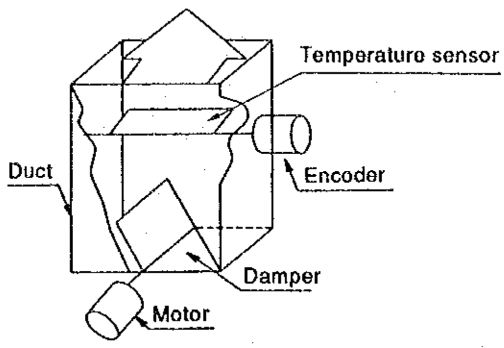


Figure 4.12 Damper control

[Example 4] Energy conservation by recovery of wastewater heat in dyeing process

The wastewater from the dyeing factory was gathered in the set tank as in Figure 4.14 and was fed to the wastewater treatment plant (activated sludge treatment + coagulation/ sedimentation treatment) to treat BOD, COD, SS, color, etc. before discharge to a river.

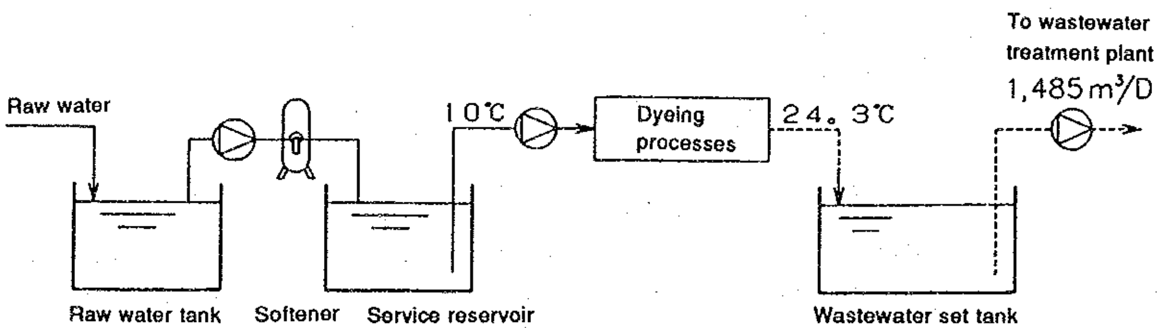


Figure 4.13 Flow sheet before improvement

- Improvement 1: Recovery of exhaust heat with counterflow plate type heat exchanger

  The dyeing wastewater is divided into two systems, i.e., hot wastewater and cold wastewater. Although the cold wastewater is fed as it is to the wastewater treatment plant, the hot wastewater is fed through a plate type heat exchanger to recover the heat to be used for heating the dyeing water.

  The flow sheet is shown in Figure 4.14, and the effect of improvement is shown in Table 4.9.

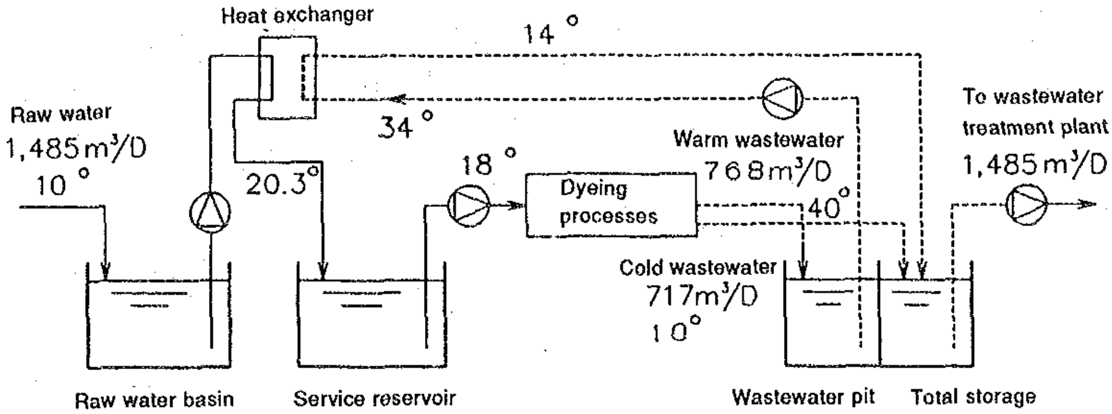


Figure 4.14 Flow sheet of heat recovery with heat exchanger

Table 4.9 Effect of investment for heat recovery with heat exchanger

Heat recovery amount	2,210 kFt/y	Steam unit price 860 Ft/t
Additional working expenses	200 kFt/y	Power rate + administration expenses
Equipment investment amount	4,150 kFt/y	Excluding interest
Number of years for recovery of investment	2 years	

- Improvement 2: Heat recovery by the use of absorption type heat pump

Heat recovery from hot wastewater to dyeing water was implemented with a heat exchanger in "Improvement 1". But it was found that heat recovery from wastewater of lower temperature can be made when an absorption type heat pump is used. At the same time, provisions were made to recover the cooling waste heat, which was discharged to the atmosphere through the chiller and cooling tower before, for use for heating water. In addition, automatic cleaning system was adopted for the strainer.

The flow sheet after improvement is shown in Figure 4.15, and the effect of improvement is shown in Table 4.10.

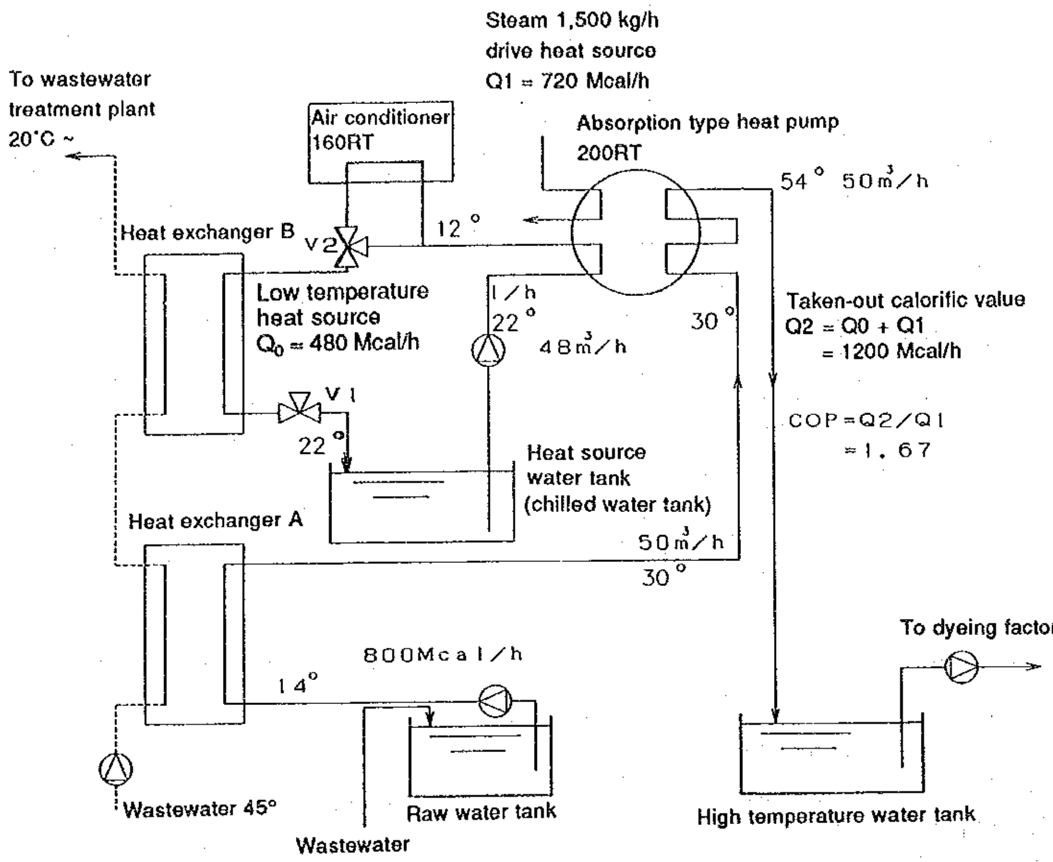


Figure 4.15 Flow sheet of absorption type heat pump system

Table 4.10 Effect of investment for heat recovery with heat pump

Fuel oil saved quantity	170 kℓ/year	2,550 kFt/year
Lowering of contracted power	170 kW	1,700 kFt/year
Power rates saved amount	360 MWh	3,600 kFt/year
Total		7,850 kFt/year

[Example 5] Energy conservation by recovery of the condensate

Since the condensate possesses the energy that is equivalent to 20~30% of the steam energy, it was recovered as boiler feed water.

Contents of equipment

Boiler:
20 t/h boiler of 7 bar(G), 1 unit (natural circulation type water tube boiler)
16 t/h boiler of 7 bar(G), 1 unit (natural circulation type water tube boiler)

Batch type dyeing machine:
Water holding volume 500 ~ 1,000 ℓ/tank, 35 units (wince type, Smith drum type)

Finish dryer:
Steam consumption 250 kg/h/unit, 30 units

- Improvement 1: Recovery of condensate to feed water tank (Figure 4.16)

The recovered energy became 15,000 ℓ/h × (95°C – 20°C) × 4,186 kJ/kg = 4,709 MJ/h, and the boiler fuel was saved by about 150 ℓ/h.

What become problems in this case are that the water in the feed water tank reaches the boiling point, steam is relieved to the atmosphere by a considerable rate from the tank top and vibration noise is produced in the tank.

- Improvement 2: Direct recovery of the condensate to the boiler (Figure 4.17)

Considerable calorific value was relieving as flash steam from the top of the feed water tank with "Improvement 1". To improve this situation, a pump was installed in the condensate system only for the finish dryer, to make direct recovery to the boiler.
With the condensate of the dyeing machine, however, open recovery is made as before because there is a fear of entry of the dye liquor.

The energy recovered in the feed water tank is 2,198 MJ/h, the energy directly recovered to the boiler by a recovery pump is 4,709 MJ/h, and the fuel consumption was reduced by 219 ℓ/h.

The amount of saving of fuel expenses brought by this improvement is as shown in Table 4.11.

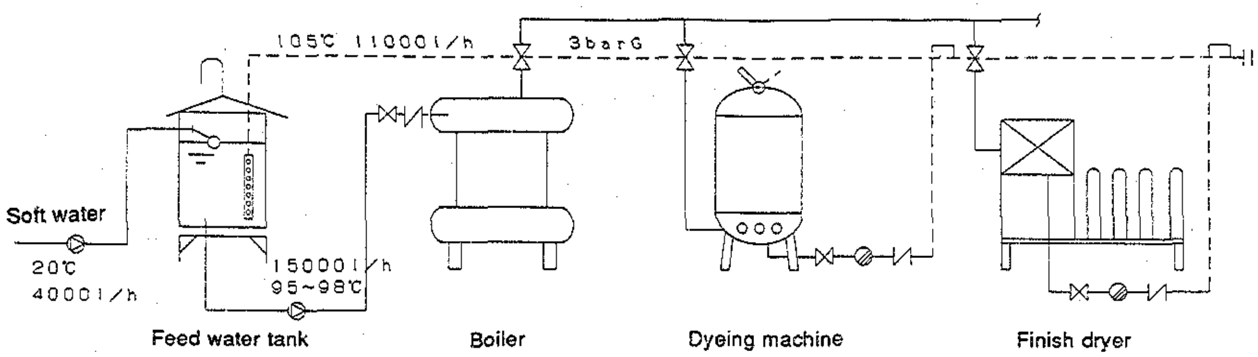


Figure 4.16 Condensate recovery system (open system)

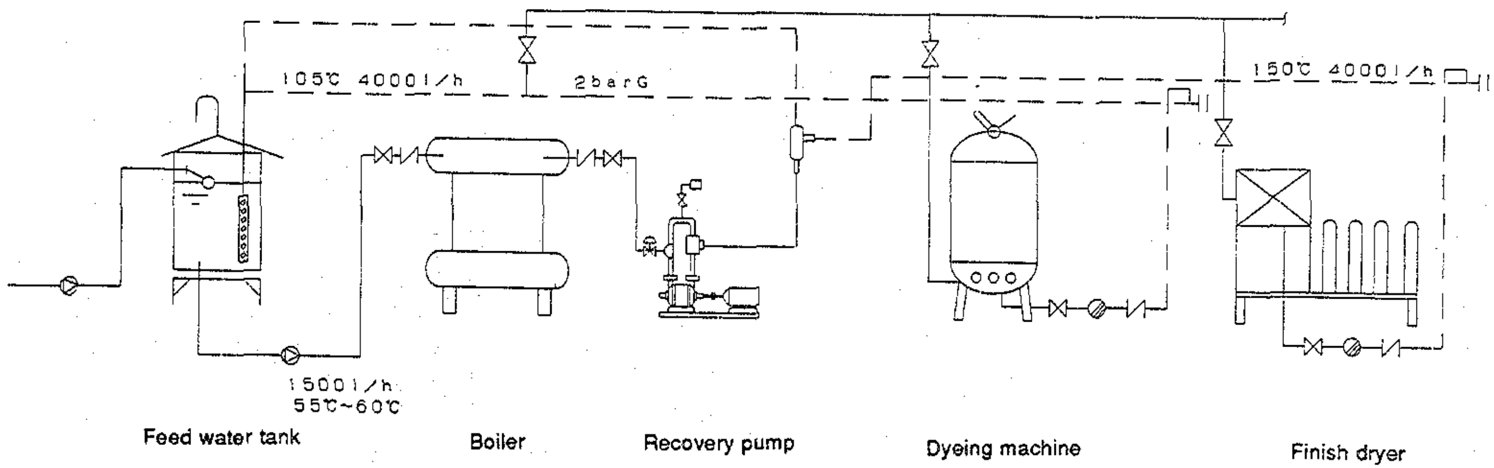


Figure 4.17 Condensate recovery system (open system + closed system)

Table 4.11 Fuel expenses saved amount

	Fuel oil saved volume	Saved amount
Improvement 1	300 kℓ/y	4.5 MFt/y
Improvement 2	438 kℓ/y	6.6 MFt/y

Note: Fuel oil unit price 15,000 Ft/kℓ
Operating hours 2,000 h/y

[Example 6] Reduction of fuel oil heating energy

The outline of fuel storage and transfer equipment is as shown in Figure 4.18. The used fuel is of heavy type (kinematic viscosity 200 cts or higher, pour point 2°C), and the fuel requires heating for transfer. Even if it was scheduled that running of the boiler is suspended on Saturday and Sunday, but in winter it was necessary to run the boiler in order to keep the temperature of the fuel oil in the tank and pipeline at 30 ~ 40°C. The following measures were implemented in order to suspend running of the boiler on holidays.

① The fuel oil storage tank was heat insulated with glasswool insulator (thickness 30 mm).

The drop in the oil temperature during holidays was reduced to 7 ~ 10°C.

② The fuel oil service tank was heat insulated with glasswool insulator (thickness 30 mm), and a tape heaters (3kW) that operates when the fuel oil temperature drops to 30°C or less was installed.

③ The fuel oil pipeline was heat insulated with glasswool insulator (thickness 25 mm), and tape heaters (3kW) that operate when the fuel oil temperature drops to 40°C or less were installed. Tape heaters of such a type that the current decreases as the temperature rises were selected for safety.

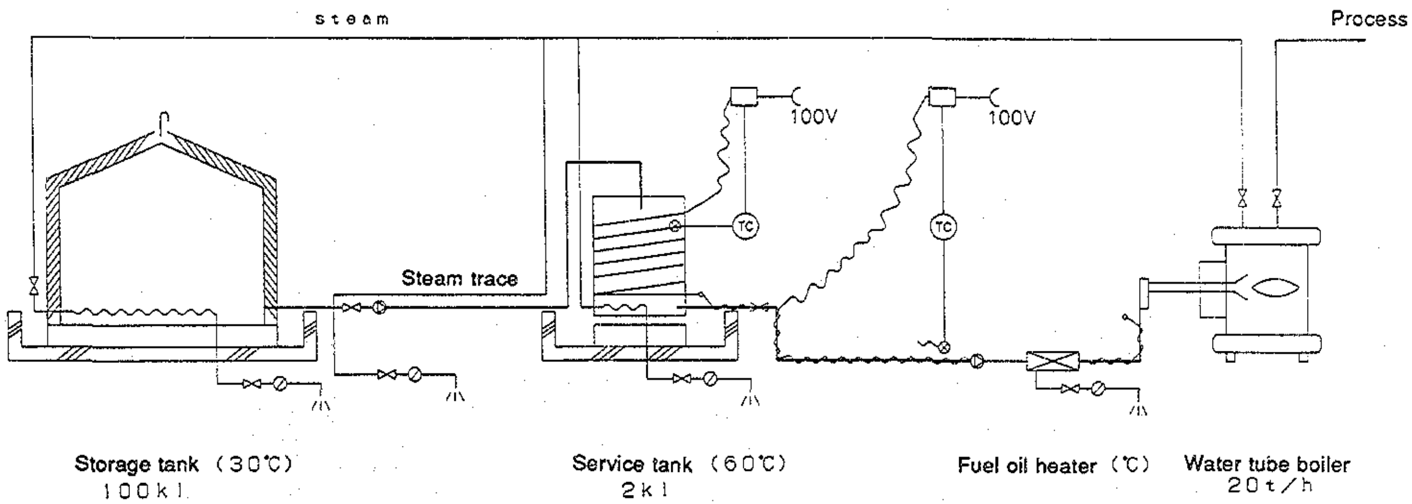


Figure 4.18 Fuel oil storage and transfer equipment

5. Energy Conservation in the Tyre Industry

5. ENERGY CONSERVATION IN THE TYRE INDUSTRY

5.1 Evolution of energy conservation activities in the tyre industry

The industrial world of Japan faced an oil crisis two times in the 1970's. In order to overcome these difficulties, every industry of Japan endeavored to solve the problems. Japan has little resources and is almost entirely dependent on imported energy as well as imported raw materials required for production. These imported resources and materials are processed to produce products. Although the majority of these products are consumed domestically, a part of them are exported to earn foreign currency.

The degree of dependence of raw materials and fuel on imported resources varies to a certain extent by the category of business. The tyre industry depends for its raw materials on petroleum resources by about 70%, and resources conservation and energy conservation are a critical issue that affects the very existence of the business. As Japan was driven to the last extremity because of lack of resources, the industries made every effort in the energy conservation. As a result, Japan achieved superior energy conservation among nations in the world. The tyre industry is not exceptional. It is considered that the energy unit consumption of the tyre industry of Japan is of the world's top level.

The progress of prices of imported crude oil in the past years is shown in Figure 5.1. The progress of unit consumption of fuel oil and electric energy in the tyre industry is shown in Figure 5.2 and Table 5.1.

The energy conservation activities in the mean time started with "elimination of wastefulness", and by way of improvement by the use of "problem solving technique", the activities were finally implemented with the step of "improvement of processes". The method for implementation is based on the policy management of TQC, which is the management technique that is adopted by almost all the principal businesses in Japan. The yearly target and allotment of roles to departments were clarified for implementation.

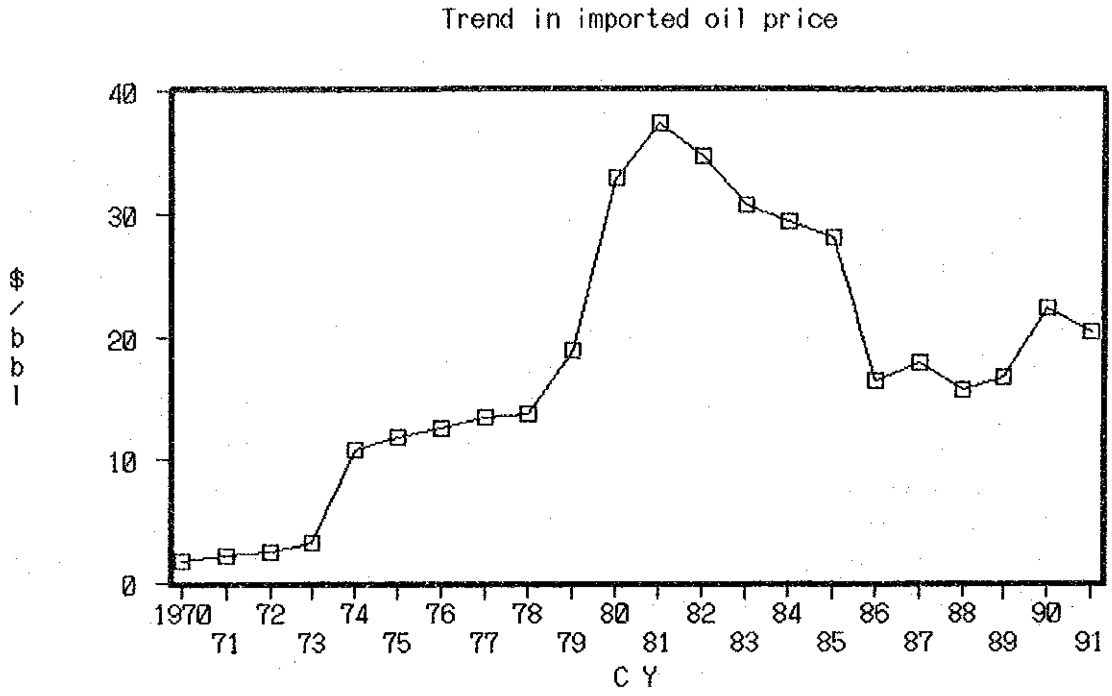


Figure 5.1 Trend in Imported Oil Price

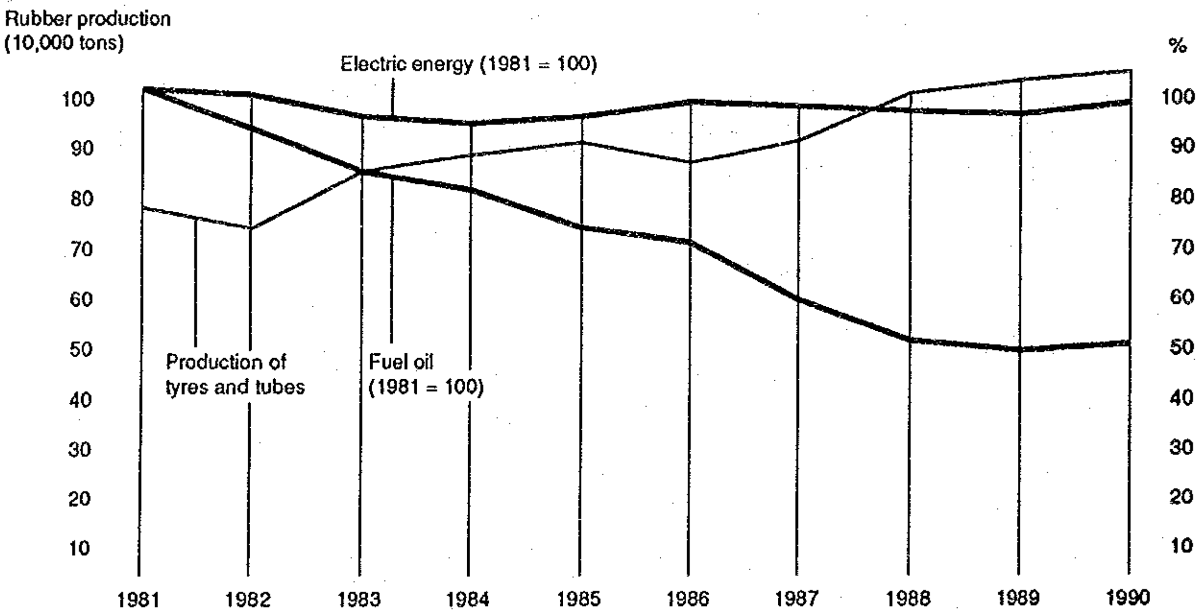


Figure 5.2 Progress of production of automotive tyres and tubes and of effect of promotion of energy conservation

Table 5.1 Effect of energy conservation in automotive tyre industry

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Electric energy (kWh)	Consumption	1,270,852	1,165,667	1,258,042	1,332,984	1,350,021	1,330,549	1,387,538	1,512,952	1,590,516	1,636,352
	Unit consumption	1.659	1.633	1.555	1.541	1.544	1.596	1.579	1.552	1.556	1.587
	Unit consumption index	100.0	98.4	93.7	92.9	93.1	96.2	95.2	93.6	93.8	95.7
	Unit consumption compared to previous year	99.5	98.4	95.2	99.1	100.2	103.4	98.9	98.3	100.2	102.0
Fuel (kℓ)	Consumption	260,762	226,575	228,514	229,641	211,032	194,437	194,313	189,001	192,058	197,081
	Unit consumption	0.340	0.317	0.283	0.268	0.241	0.233	0.221	0.194	0.188	0.191
	Unit consumption index	100.0	93.0	83.2	78.8	70.9	68.5	65.0	57.1	55.3	56.2
	Unit consumption compared to previous year	91.2	93.2	89.3	94.7	89.9	96.7	94.8	87.8	96.9	101.6
Productioh of automotive tyres and tubes (ton)		766.160	713,791	808.876	858,433	874,304	833,454	878,808	974,817	1,022,325	1,031,099

Source: JATMA

5.2 Energy conservation of elimination of wastefulness and economy type

"Wastefulness" means that energy is not used effectively for its objective. When the tyre curing process is used as an example, leakage of steam and air and heat loss due to faulty heat insulation belongs to this category. To eliminate this "wastefulness" is the origin for effective use of energy regardless of how highly production technology made advancement, and it is what should be constantly and continuously implemented in the routine management. It should be implemented with the attitude of "deeds, not words" without taking so seriously, so as to take corrective measures upon recheck of "wastefulness" which tends to be overlooked. In general, it is not expensive. It is satisfactory if implemented briskly.

What requires attention, however, is not to have preconception or determinedness, but it is necessary to have the attitude to make observation candidly based on facts. Furthermore, it is desirable to ask for participation and cooperation of as many people as possible rather than problem finding by single manager or expert staff. It is because such a style "I am the one who uses energy and you are the one who manages energy" will not bear good fruits because buck-passing to other departments tends to occur.

It is more concrete and the appealing power is large if "wastefulness" is indicated as converted into a monetary value, in order to ask for participation of more people and to call attention of more people. An example used at a factory in Japan is shown in Figure 5.3.

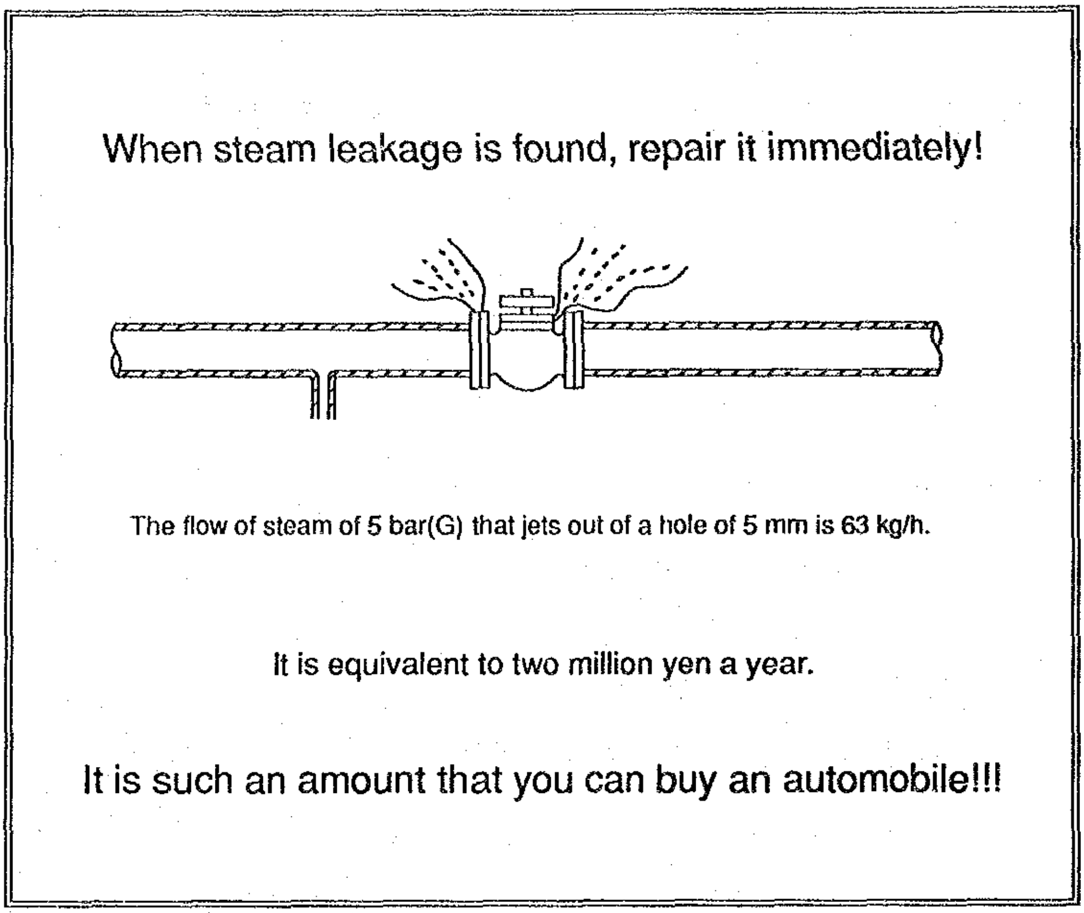


Figure 5.3 Typical poster to appeal to employees

Typical steam leakage and typical heat radiation from a bare pipe are shown below for reference.

A) Steam leakage rate in the case where a hole of diameter 1 mm is located along a steam line of pressure 5 bar(G)

The steam leakage rate through a hole of area A m² is expressed by the following equation.

$$G = 71.64 \times 10^4 \times A \times \sqrt{P / V''}$$

where;

G :	Steam leakage rate	kg/h
A :	Area of leaking hole	m^2
P :	Absolute pressure of steam $P = P_1 \times 1.0197 + 1.033$	kg/cm^2 abs
P_1 :	Steam pressure in the line	bar (G)
V'':	Steam specific volume in the line	m^3/kg

The rate of leakage of steam of 5 bar(G) through a hole of diameter 1 mm is as follows.

$$\therefore G = 71.64 \times 10^4 \times 0.785 \times 0.001^2 \times \sqrt{\frac{5 \times 1.0197 + 1.033}{0.3213}}$$

$$= 2.5\ kg/h$$

B) Heat loss in the case where heat insulation is incomplete and bare pipe is exposed (Figure 5.4)

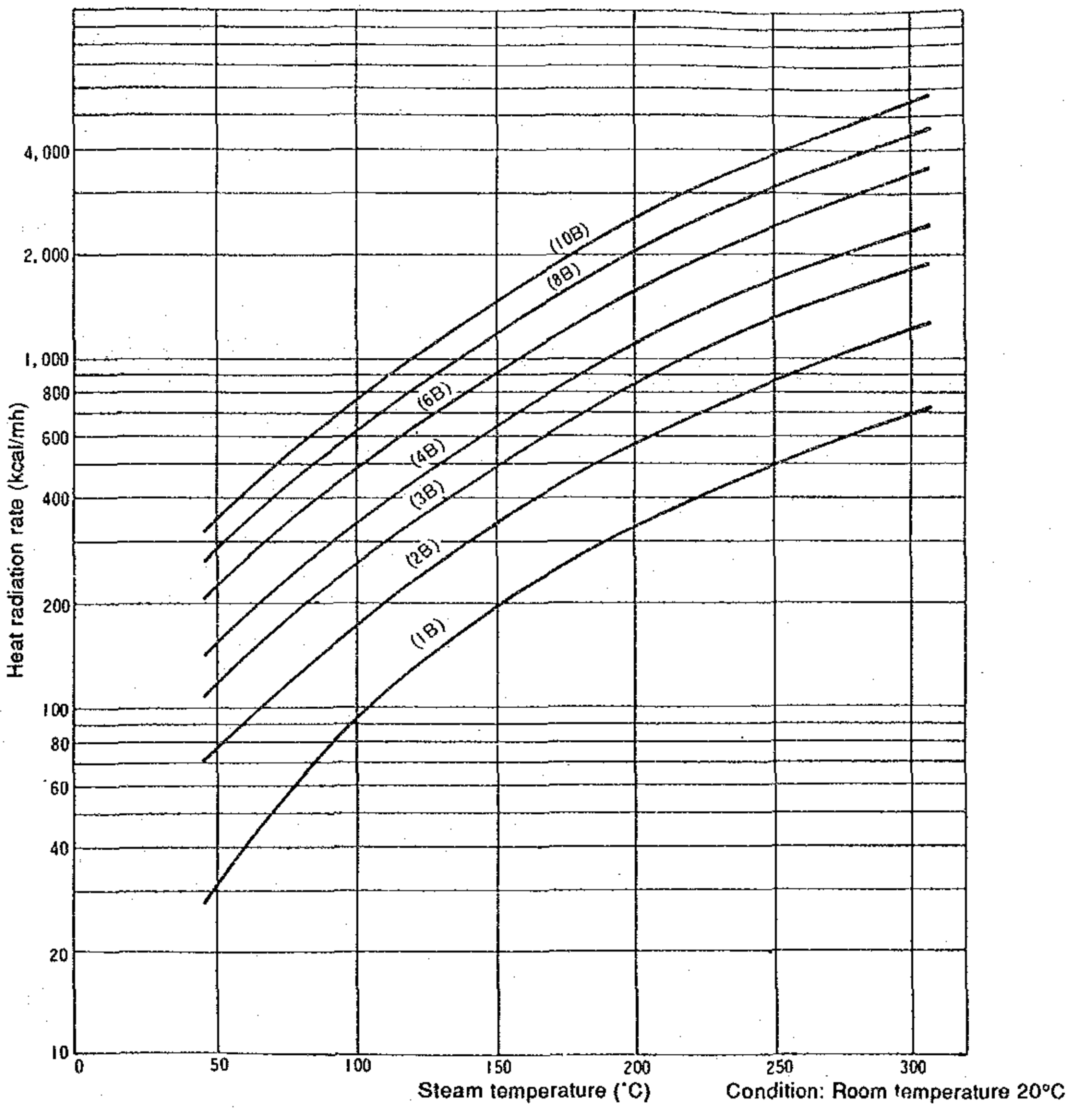
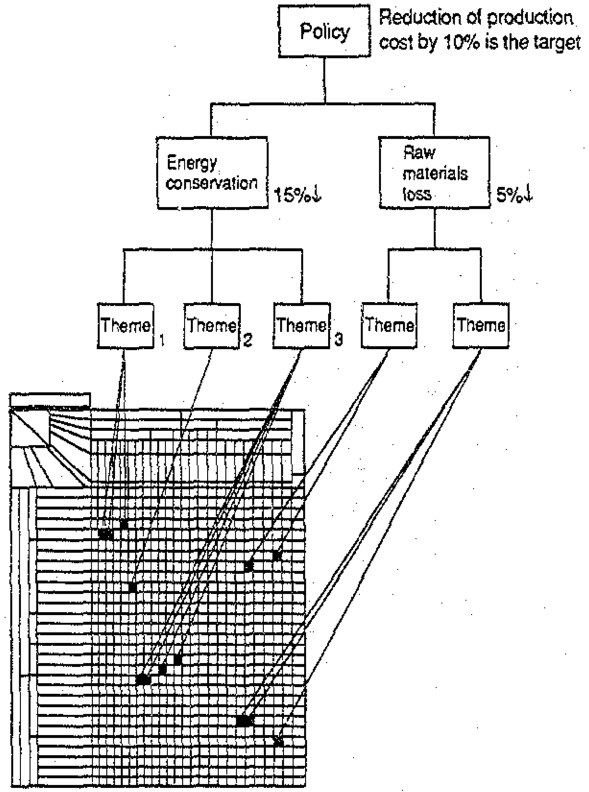


Figure 5.4 Heat radiation from bare steam line

5.3 Use of problem solving technique

To find losses and wastefulness rearby and to take corrective measures were described in the preceding section. A number of problem solving techniques such as MAP technique have been put into practical use with the objective to broadly and systematically implement the move. When the case where the MAP technique is applied to energy conservation is observed, a chart that covers all the aspects and equipment where energy is used is prepared, the situations of use of energy are checked with each one of them, whether use of the energy is really necessary or not and entry is made in the chart. As its name suggests, it is more like observation of a map. This technique is characteristic in that the whole and details are illustrated and understanding is easy. It is a technique that is effective for seizing problems as faces and for implementing various improvement activities. On the other hand, some technical knowledge or some measurement is required as the case may be for drawing such a MAP. It may be considered that "heat balance chart" that is often used for examination and analysis of energy conservation is located along the extension of or a part of this MAP technique. Its conceptional form is shown in Figure 5.5. The guideline and policy for the target item are entered along the vertical axis and the applicable process or equipment is entered along the horizontal axis.

A MAP in the stage of project planning is indicated as an example, but in the stage of execution, identical MAP's are prepared for further details.



Each case is classified and indicated by the following items.

① "Viewpoint/attack"
② Classification of application of the energy
③ "Guideline for excavation"
④ Excavated "issue"
⑤ "Theme name"
⑥ Amount of expected effect
⑦ "Direction of improvement", which is the content of the red mark

<Case 1>

① Substitution of utility
② Heating/cooling energy
③ "If it is possible to reduce the unit price by changing steam to hot water or alike"
④ Steam is currently used for preheating the boiler air. But it may be substituted by combustion exhaust gases.
⑤ To review the boiler air preheating source for reducing the unit price
⑥ Steam: 8.3 million yen per year
⑦ To combine combustion exhaust gases and steam

<Case 2>

① Change to contract scheme
② Heating/cooling energy
③ "If it is possible to reduce the high unit price by changing contract based on the master pressure"
④ Even if pressure loss is involved between the steam supply source and the factory inlet, payment is made based on the unit price at the master pressure.
⑤ To review the contract of the steam accepting unit price for reducing the unit price
⑥ Steam: 3.1 million yen per year
⑦ Unit price contract scheme, examination of pipeline system with little pressure loss

<Case 3>

① Change to production method
② Power energy
③ "If it is possible to reduce excessive electric energy by changing to a production method of less power consumption"
④ Kneading and blending are made by roll system, and the power consumption is excessive.
⑤ To change to a kneading scheme of less power consumption to reduce the consumption
⑥ Electric power: 3.39 million yen per year
⑦ Change from roll system partially to kneader system

Figure 5.5 Typical application of MAP technique

5.4 Energy conservation by improvement of process and equipment

Corrective measures are sequentially taken for each of the issues excavated as a result of the activities described in sections 5.2 and 5.3. But there are cases where improvement of equipment or development of production technology is requested for implementation of fundamental measures. Equipment investment or examination period that corresponds to such a request is naturally required in such a case.

With the tyre curing process, the typical case is the steam inert gas curing process. The history of tyre curing indicates that the curing method took the following course.

Air
H & L 2 Way Steam
Steam Air
Hot Water
Steam Inert Gas (CO_2 N_2)

Under such conditions that high pressure of around 20 bar is required on one hand, and there are restrictions related to thermal deterioration of physical properties of rubber and fibers on the other hand, and also when the energy efficiency is taken into account, nothing is superior to the steam inert gas curing process. A period of over ten years has elapsed since this curing process began to penetrate into the rubber industry, and inert gas suppliers are consolidated these days. Microwave curing process has been examined by some businesses for over ten years, but it still is in the stage of trial.

The gas produced by burning propane or butane and by then removing the residual oxygen from the combustion gas was mainly used as the inert gas in the early days, but today inert gas suppliers such as L'air Liquide Group have consolidated the supply scheme including required equipment. The following methods are available for supply of N_2 gas used for tyre curing. Suitable method may be selected in correspondence to the scale of use.

Methods for supply of N_2 gas for tyre curing

1) To purchase liquefied nitrogen

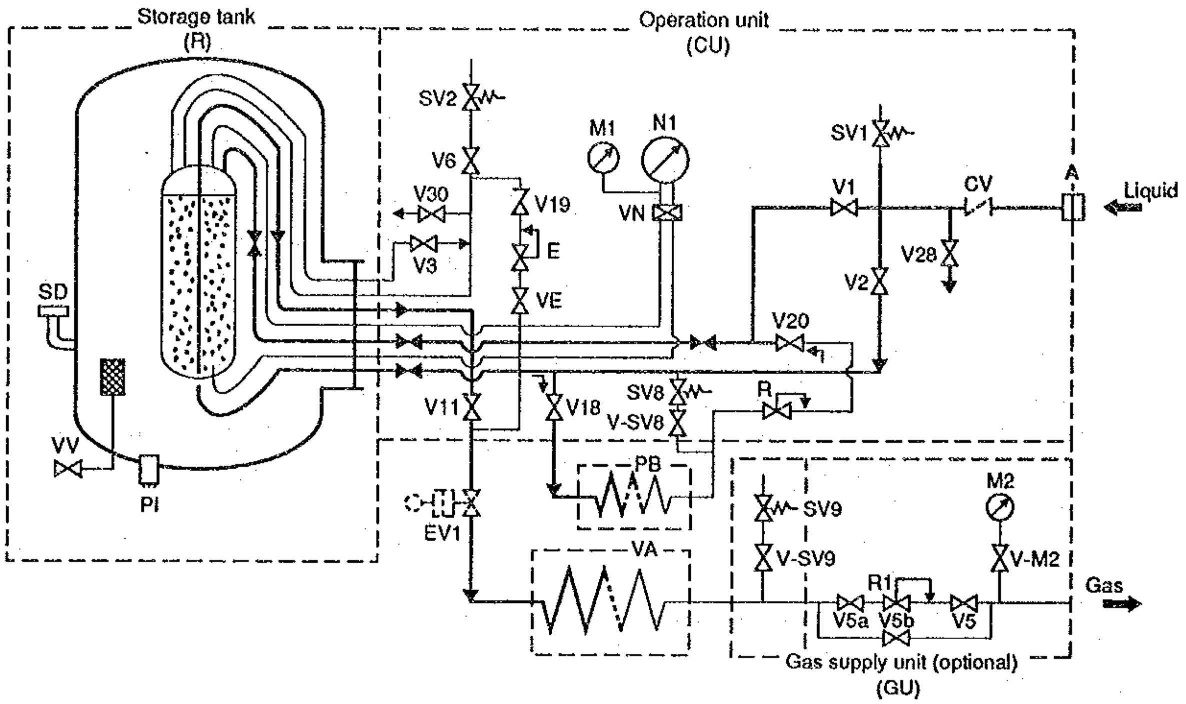
2) To operate N_2 gas generator (raw material: butane)

3) To operate PSA (pressure swing absorption) nitrogen generator

4) N_2 gas generator + liquefied nitrogen (for backup)

5) To operate small size nitrogen production plant

A rough plan of N_2 gas supply system using liquefied nitrogen is shown in Figure 5.6.



A Charge port
V1 Upper charge valve
V2 Lower charge valve
V3 Liquid level metering valve
V5 Gas supply valve
V5a Changeover valve
V5b Bypass valve
V6 Storage tank safety valve master valve
V11 Siphon liquid take-out valve
V18 Pressurizer master valve
V20 Pressurizing valve
V28 Charge unit drain valve
V30 Storage tank gas discharge valve
VN Liquid level gauge master valve
SV1 Charge unit safety valve
SV2 Storage tank safety valve
SV8 Pressurizing evaporator safety valve
SV9 Evaporator safety valve
V-SV8 Safety valve master valve
V-SV9 Safety valve master valve
R Automatic pressurizing valve
R1 Reducer valve
N1 Liquid level gauge
M1 Storage tank pressure gauge
M2 Supply unit pressure gauge
V-M2 Pressure gauge master valve
E Automatic delivery gas valve
VA Evaporator
PB Pressurizing evaporator
PI Pirani vacuum gauge measuring element
SD Safety device
VV Vacuum suction valve
V19 Automatic delivery gas valve master valve
VE E auxiliary valve

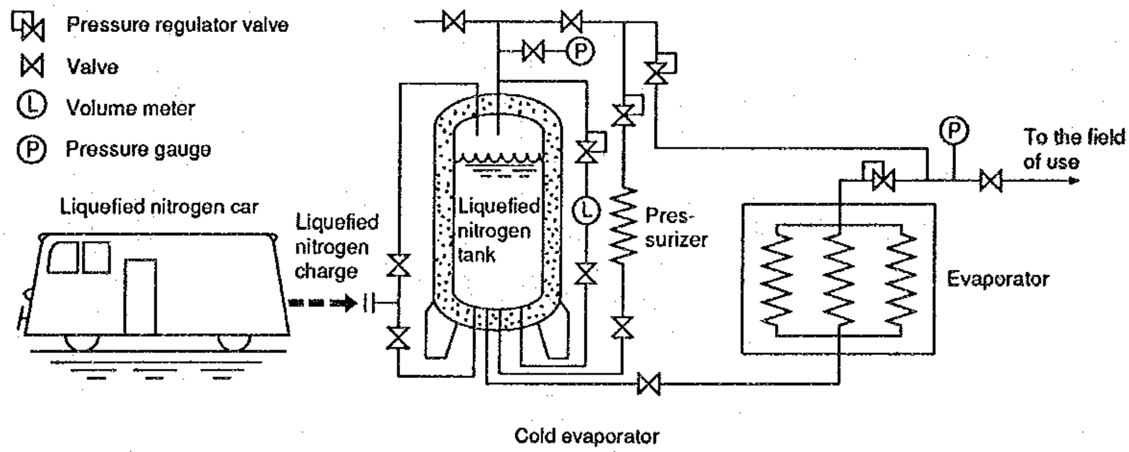


Figure 5.6 Rough plan of N_2 gas supply system

5.5 Items of implementation of energy conservation measures in the curing process

The outline of the method for implementation of energy conservation activities was described with focus on the curing process. The items of implementation of energy conservation measures in the curing processes of type factories in Japan for over ten years are enumerated in Table 5.2. Since about 70% of the thermal energy used in a tyre factory is consumed in the curing process, this curing process naturally is the focus of activities related to thermal energy.

As for electric energy, since about two thirds are consumed in the rubber blending, tread extrusion and calender processes, electric energy conservation is the main subject at these processes. The method for implementation of energy conservation activities at these processes is identical to that of thermal energy except for the issues belonging to the category of inherent technology.

Table 5.2 Contents of implementation of energy conservation measures in the curing processes of tyre factories

- Repair and strengthening of heat insulation for curing press and pipelines
- Check and prevention of steam and air leakage
- Maintenance and inspection of steam traps
- Integration and rearrangement of steam lines
- Shortening of machine open-shelving time
- Recovery and use of waste heat (used for other processes, boiler feed water, etc.)
- Modification to small size curing press (dome type to platen type)
- Reduction of temperature difference between upper and lower molds of curing press
- Reduction of dispersion of proportioning rubber blow point (shortening of curing time)
- Review of heat insulation of molds and uncured tyres
- Review of mold blow method
- Review of water cooling and vacuum suction
- Maintenance and control of the room temperature for the winter season
- Expansion of employment of N_2 gas curing

Announced cases of energy conservation activities implemented at tyre factories are described below for reference.

Cases of implementation of energy conservation activities at tyre curing process

[Case 1] Challenge to elimination of heat radiation by heat insulation of dome (1982; at Tokyo Factory of Bridgestone Tire Co. Ltd.)

1) Outline of the factory

- Production item : Bias tyres (for trucks, buses, small size trucks, construction machinery, agricultural machinery)
  Steel radial tyres (for passenger cars)

- No. of employees : 2,300 persons

- Production capacity : 730,000 tyres per month (largest scale in the Orient)

- Fuel consumption : 29,000 kℓ/y

2) Background of activities

With establishment of "Promotion of energy conservation activities participated by all" as the basic policy of the factory as the opportunity, Energy Committee was organized. With slogan "Let's break the existing concept and challenge what are new" put up, energy conservation activities were implemented with attention paid to "temperature, pressure, time, heat radiation and leakage" and with any minor matter picked up. The case introduced here is what was implemented as a part of these activities.

3) Implementers of improvement activities

A group of 21 operators in the curing process

4) Selection of theme

The steam consumption of the curing process occupies about 70% of the consumption in the whole factory. The curing press has been heat insulated, but it has been pointed out that the heat insulation has been deteriorated and heat radiation loss is large. Furthermore, because of inferior heat insulation, the workshop environment was inferior because the room temperature rose to as high as 45°C at maximum.

Since prevention of heat radiation is the largest theme of energy conservation activities which can be made by their own hands if they have will and patience, it was picked up as a theme of the activities.

5) Progress of activities

a. The situations of heat radiation were picked up with an infrared camera to make everybody visually recognize the situations.

b. The condensate generation rate by type was checked.

c. Heat insulation was implemented to a model curing press. (An idea contest by team was held.)

d. Trial calculation of expenses and man-hour for implementation of heat insulation was made.

e. The effect was checked using an infrared camera and by checking the condensate generation rate.

f. Implementation of heat insulation was extended to all curing press.

6) Examination of method for heat insulation (Table 5.3, Table 5.4, Figure 5.7, Figure 5.8, Figure 5.9)

6-1 Dome

Table 5.3

Subject	Plan	Result	Adopted or not
Shape of insulator	To sew as large cushion.	Gaps are observed narrow portions.	No
	To make large and small cushions of a number of types.	Good.	Yes
Method for fixing insulator	To bind using wires.	Difficult	No
	To tap to existing insulator using an automatic screwdriver.	Working is easy.	Yes

Total required man-hour: 1,192 hours

6-2 Top beam

Table 5.4

Subject	Plan	Result	Adopted or not
Shape of insulator	To make large and small cushions of a number of types.	Sewing is troublesome.	Yes/No
	To put the insulation into the concave portion of the top beam and to cover it up with galvanized sheet iron.	The galvanized sheet iron becomes hot and major heat radiation occurs.	No
	To put the insulation into the concave portion of the top beam and to cover it up with belts.	The quantity of the abandoned conveyor belts is insufficient. It is necessary to weld the lock bolts.	No
	To envelope the insulator with wire nets. Figure 5.7	Fabrication is easy, as no sewing is required. Mounting/dismounting is easy.	Yes
Method for fixing insulator	To make holes in the insulator for pressure gauges and lubricators.	To make holes in the insulator is troublesome.	No
	To weld flat steel plate to the top beam in a horizontal position, to move instruments on the plate and to fix insulator by the flat steel.	Large man-hour is required to move of instruments. Heat radiation is minor if a gap is provided between the top beam and the insulator. Figure 5.8	Yes

Total required man-hour: 588 hours

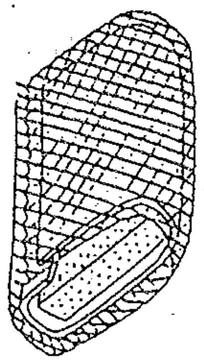
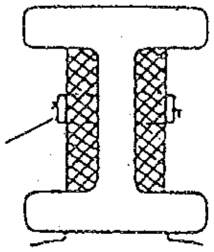


Figure 5.7 Form of Insulator



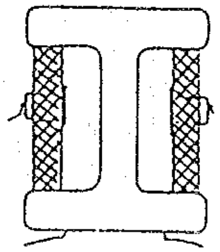


Figure 5.8 Mounting of Insulator to top beam

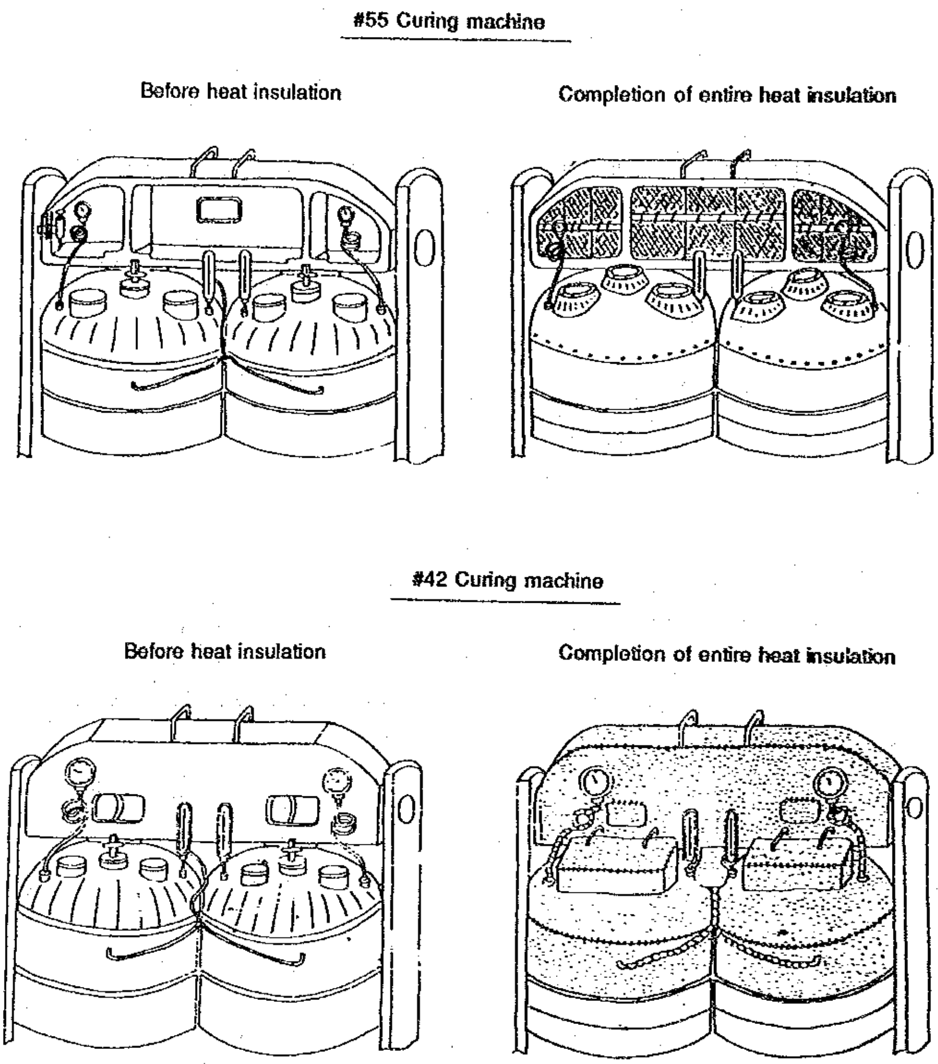


Figure 5.9 Overall heat Insulation drawing

7) Result and effect

Heat radiation loss	44% → 30%
Condensate discharge rate	Reduction by 11%
Steam saving amount	31 M¥/y

[Case 2] Energy conservation activities in the process for production of tyres for industrial vehicles (1990; Kakogawa Factory of Sumitomo Rubber Co.)

1) Outline of the factory

Production item : Tyres for industrial vehicles, tennis balls, ocean products, printing goods, rubber tubes, floor materials, etc.

No. of employees: 322

Fuel consumption: Fuel : 2,208 kℓ/y

Electric energy: 6,337 MWh/y

2) Background of activities

"Energy conservation activities participated by all with importance attached to the field and actual goods" is the basic policy at this factory. It has become necessary to increase the production of tyres for industrial vehicles, and "to achieve the production increase program with minimum equipment investment in the limited space without worsening the energy unit consumption" was instructed by the superintendent.

3) Implementers of improvement activities

12 persons in charge of tyre equipment

4) Selection of theme

Enhancement of productivity that leads to energy conservation was adopted as the theme in accordance with the instructions of the superintendent.

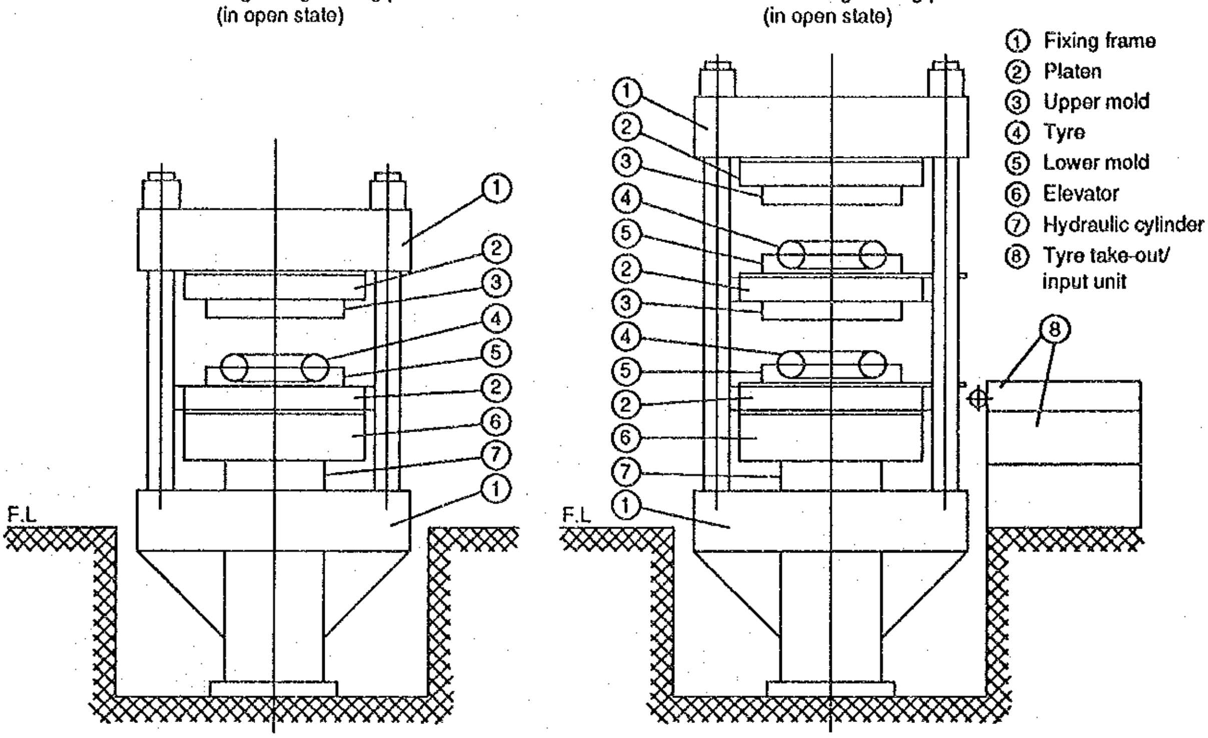
It was learned as a result of examination of equipment capacity by process of blending, rolling, construction, curing and finish inspection that the curing process becomes the bottleneck for increasing the production. To install additional curing presses, however, was judged to be difficult because it involves the space problem, it requires large equipment investment and increase of personnel and it also involves increase of energy consumption. Under these circumstances, "implementation of dual stage curing" to cure two tyres at a time with one curing press was picked up as the theme.

5) Problems and countermeasures

A single stage type curing press and a dual stage type curing press are shown in Figure 5.10.

Outline of single stage curing press
(in open state)

Outline of dual stage curing press
(in open state)



Single stage curing

Platen 2
Tyre 1

Dual stage curing

Platen 3
Tyre 2

Figure 5.10 Single stage type curing press and a dual stage type curing press

a. Modification to the curing press

Modification was made to the frame and so forth because the height of the curing press was insufficient.

b. Addition of tyre take-out unit

As the tyre take-out position becomes high, the operation becomes difficult and it takes time. Therefore, an automatic tyre take-out unit was newly installed to shorten the cycle time. The press open time was also shortened accordingly, and the heat radiation loss from molds was reduced.

Furthermore, a jig for alignment was contrived and installed, as alignment of upper and lower molds became necessary because the tyre is taken out together with the lower mold.

c. Strengthening of heat insulation

The heat insulation was strengthened in general, and such a heat insulation curtain of automatic roll-up type that is shown in Figure 5.11 was installed at the moving portion of the main unit.

6) Effect

Type production rate : Doubled

Energy unit consumption : Reduced by 20%

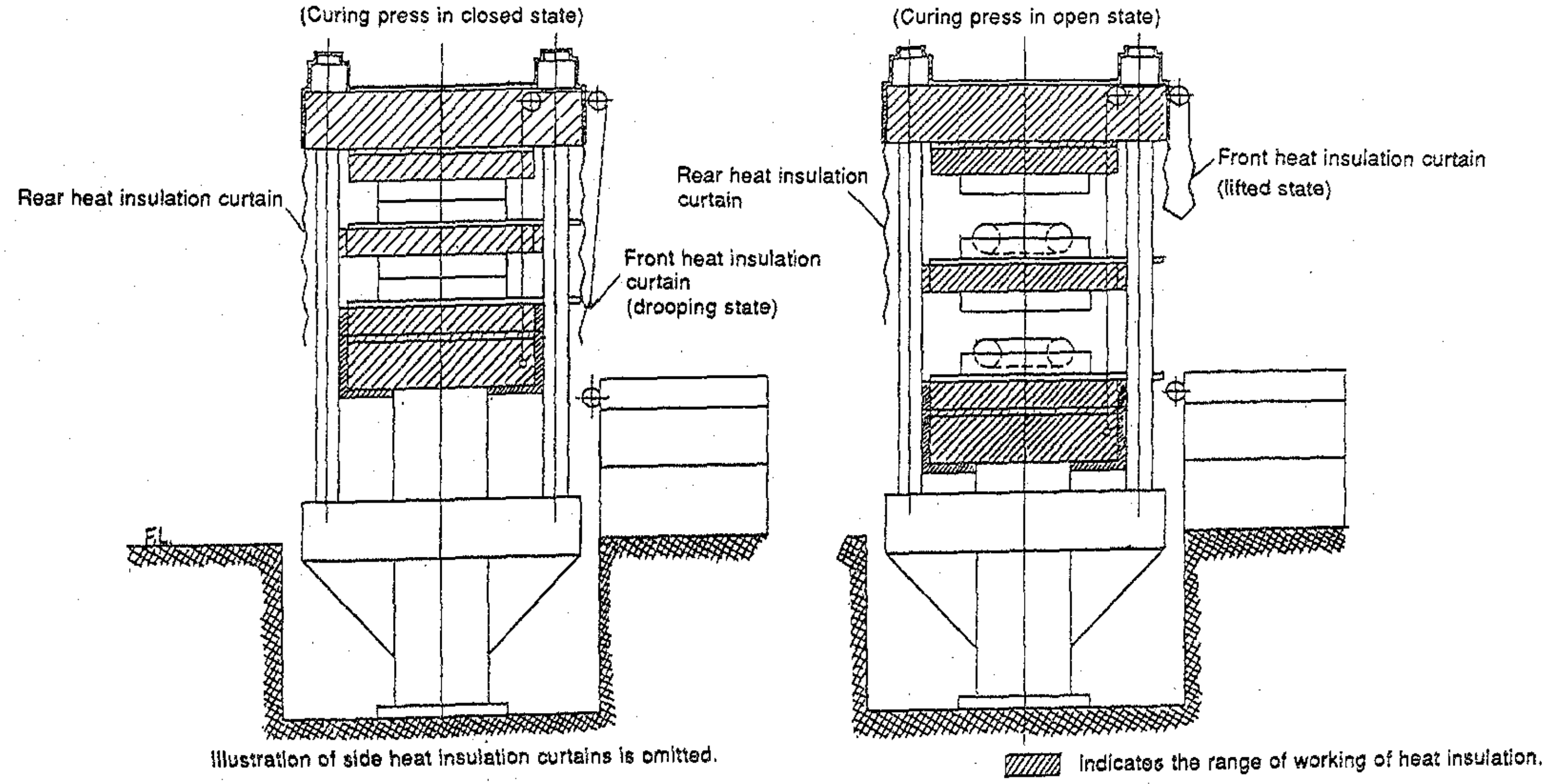


Figure 5.11 Automatic heat insulation curtain

6. Energy Conservation in the Alumina Industry

6. ENERGY CONSERVATION IN THE ALUMINA INDUSTRY

6.1 Characteristics of energy use

6.1.1 Outline of alumina production processes

The majority of alumina production factories in the world currently employ Bayer's process, and the situation is also the same in Hungary. Bayer's process is the process contrived by Karl Bayer, a chemist of Austria, in 1881. It is a wet process that uses alkali solution as described below.

a. The alumina component in bauxite is dissolved in alkali solution to produce sodium aluminate solution.

$$Al_2O_3 + 2NaOH = 2NaAlO_2 + H_2O$$

b. Silicic acid in bauxite is also dissolved in alkali. It then makes reaction with the alkali component and alumina component in the solution and becomes sodalite type compound ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot H_2O$), and it is then separated from the sodium aluminate solution as digestion residue together with insoluble components such as iron oxide and titanium oxide.

c. Crystal of aluminum hydroxide is crystallized by hydrolysis of sodium aluminate.

$$NaAlO_2 + 2H_2O = NaOH + Al(OH)_3$$

d. Water is caused to evaporate by calcinating aluminum hydroxide, and alumina (Al_2O_3) is obtained.

Calcination by case is made to α alumina or to intermediate alumina that is produced at a temperature level that is lower than that of α alumina. Intermediate alumina is mixture of γ alumina and α alumina, and it provides large capacity to adsorb hydrogen fluoride in the exhaust gas of aluminum electrolytic furnaces. γ alumina means alumina other than α alumina. The calcination temperature is 1,200°C for α alumina and about 1,050°C for intermediate alumina.

The quality required of the alumina used for aluminum electrolysis is that the chemical purity should be high, should be well soluble in cryolite bath, should hardly scatter, should provide large hydrogen fluoride gas absorbing capacity, should be of constant bulk specific gravity so as to facilitate handling with alumina automatic feeder of the electrolytic furnace and that the mobility is good.

Bauxite is what was created by chemical weathering action of rock, and its components are alumina, ferric oxide, silicon dioxide (silica), titanium dioxide, etc. Alumina often formulates boehmite ($Al_2O_3 \cdot H_2O$), which is a single hydrate, and gibbsite ($Al_2O_3 \cdot 3H_2O$), which is a triple hydrate. The ore in Hungary also contains diaspore ($H \cdot AlO_2$). What is important next to alumina from the standpoint of economy evaluation among the components of bauxite is silicon dioxide.

It is because silicon dioxide generates sodalite, becomes insoluble digestion residue and causes loss of sodium dioxide and alumina.

In the initial stage, the Bayer's process was developed with the bauxite in Europe having boehmite as the principal component. In Europe, soda of high concentration is used and aluminum hydroxide of a large quantity per unit liquid volume is crystallized, and accordingly, the particle size of aluminum hydroxide is small. Therefore, scattering easily occurs when it is converted to alumina, and in order to prevent it, mineralizer (fluoride) of a small quantity is added at the time of calcination, so that the α alumina content becomes 80% or higher. What is thus obtained is called floury alumina.

In U.S.A. and Canada where bauxite produced in Jamaica, Surinam, etc. having gibbsite as the principal component is used, the aluminum hydroxide crystallization rate per unit liquid volume is made relatively small using soda solution of low concentration, and obtain aluminum hydroxide of coarse and equal particle size. In this case, since scattering of dust is minor even if calcination is not made well, intermediate alumina with small α alumina content is produced. Since this alumina is of sandy form and is of good mobility, it is called sandy alumina. As such a system that the hydrogen fluoride contained in the exhaust gas of electrolytic furnace is adsorbed by the supplied alumina is penetrating to the industry, use of sandy quality of large hydrogen fluoride adsorbing capacity tends to increase. There are cases where factories producing floury alumina before converted to production of semi-sandy alumina or sandy alumina.

The principal quality characteristic values of alumina for aluminum electrolysis are shown in Table 6.1.

Table 6.1 Principal quality characteristic values of alumina for aluminum electrolysis

Type	Ignition Loss (%)	Particle size		Angle of repose (°)	Specific surface area (m^2/g)	α Al_2O_3 (%)
		(%) - 44μ	Mean μ			
Sandy Alumina	0.40 - 1.50	5 - 15	60 - 100	30 - 35	30 - 100	1 - 30
Floury Alumina	0.05 - 0.15	20 - 50	45 - 70	30 - 45	0.5 - 7.0	80 - 95

The values of ignition loss are of 300 ~ 1,100°C.

6.1.2 Situations of energy cycle system

The energy cycle system in the Bayer's process is shown in Figure 6.1. The sodium aluminate solution is circulated as ① → ② → ④ → ⑤ → ① in the process, the alumina component in the bauxite is extracted into the liquid at ①, extracted residue (red mud) is separated at ②, with saturated sodium aluminate solution obtained, seeds of aluminum hydroxide are added and crystallization of aluminum hydroxide is made at ④. The sodium aluminate solution from which aluminum hydroxide was separated at ⑤ is again fed to ①. The aluminum hydroxide separated at ⑤ is classified. The fine particle portion is returned as seeds to ④, and the coarse portions are washed and then become alumina as calcined at ⑥.

Of the silicic acid component of the bauxite, the silicic acid (reactive silica), which is mainly contained in clayey minerals, is dissolved in liquid, makes reaction with alumina component and soda component and creates insoluble sodalite compound ($Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2{\cdot}xH_2O$ desiliconizing product).

Red mud is a mixture of iron oxide, titanium oxide, quartz, etc., which are insoluble components of bauxite, and this desiliconizing product. Therefore, the soda component and alumina component in the desiliconizing product becomes a loss accompanying disposal of red mud. The volume of aluminum hydroxide crystallized at ④ is about 40 ~ 50% of the alumina component in the supersaturated sodium aluminate solution supplied to ④. The alumina component equivalent to the component crystallized at ④ is added at ① to the sodium aluminate solution that made exit from ⑤.

Water is added to the liquid circulation system at various points. Diluting water, red mud washing water, aluminum hydroxide washing water, water attached to bauxite, condensed water in the case where steam is directly blown in for digestion at ① and so forth. The concentration process of ⑦ is provided to discharge to the exterior such water added to the system.

What is of the highest temperature level in the liquid circulation system is digestion process ①. It is about 250°C when the alumina component in the bauxite is boehmite or about 150°C when it is gibbsite. The temperature of process ② is not higher than the boiling point (about 106°C) under normal pressure. As the liquid that goes out of ⑤ should be heated again to the temperature of ①, the heat of ① → ②, ② → ④ is used for preheating the liquid of ⑤ → ①. When it is necessary to reduce the liquid temperature, the liquid is caused to generate steam (flash steam), this steam is led to the heat exchanger, and heat is recovered by preheating the liquid of ⑤ → ①. Furthermore, the condensed water may be used as washing water at ③ and ⑤. The Bayer's process makes recovery of heat by combining these processes.

Calcination process ⑥ is the process to vaporize the moisture attached to the aluminum hydroxide and decomposition produced water.

Of the Bayer's process, ② → ④ and ⑤ → ⑦ → ① are processes to handle liquid. Other processes handle slurry, mud, lumps and powder. Various contrivances have been made in the handling of these substances. Typical alumina production processes are shown in Figure 6.2.

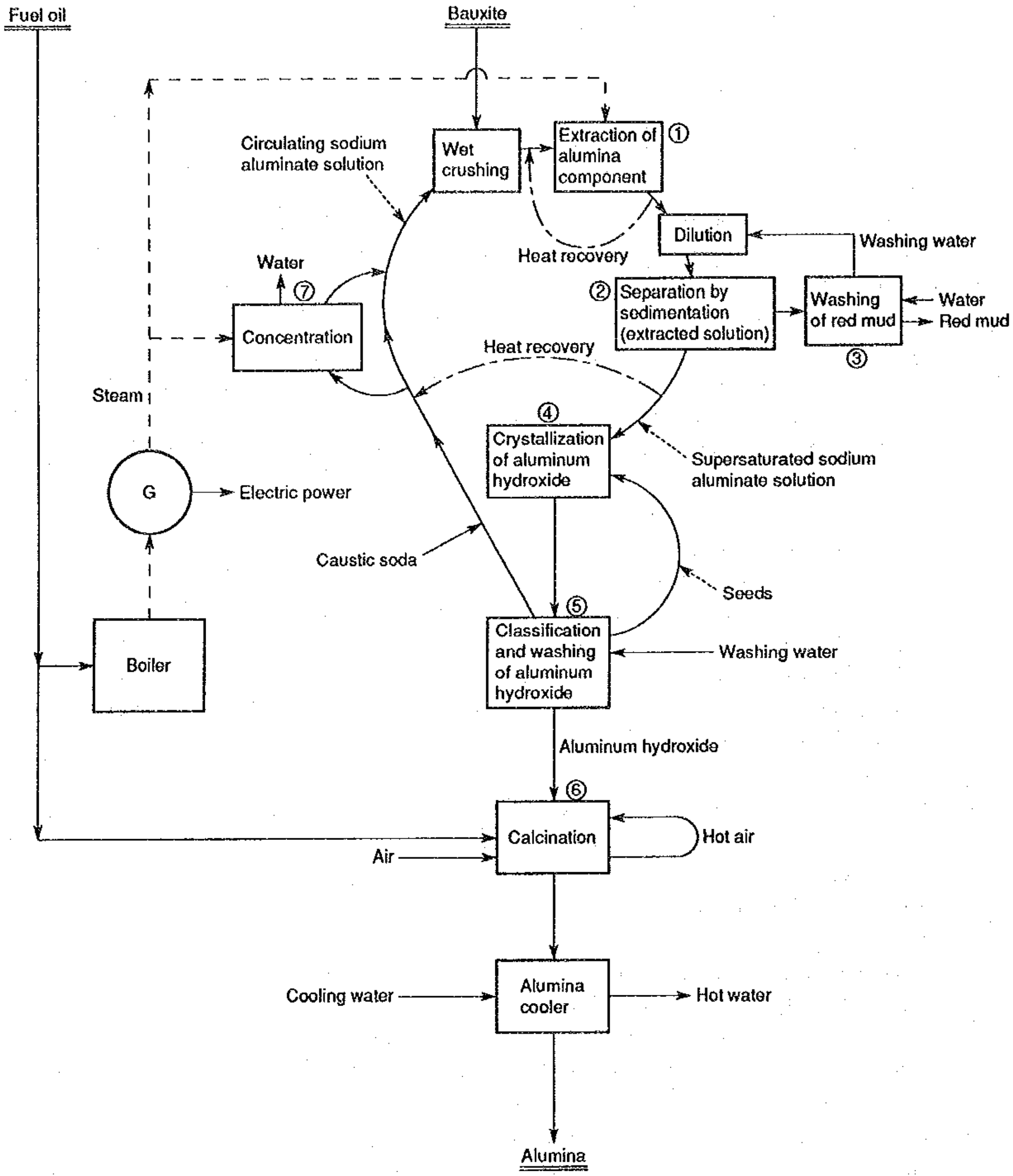


Figure 6.1 Energy cycle system in the Bayer's process

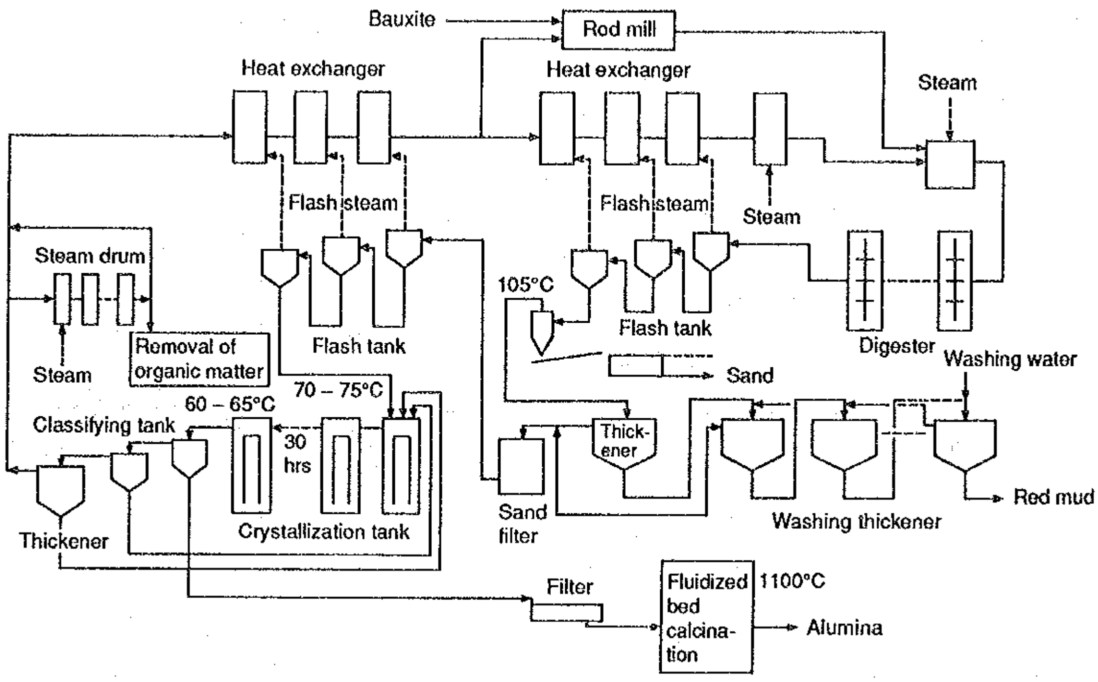


Figure 6.2 Typical alumina production processes

The energy applied to the alumina production processes can be roughly classified as follows. The % value in the parenthesis indicates typical ratio to the total energy consumption.

a. Steam applied to the digester for digestion of alumina component from bauxite (33%)

b. Steam used for concentration of diluted liquid to make recycled use of the sodium aluminate solution after crystallization of aluminum hydroxide (22%)

c. Fuel oil for calcination (24%)

d. Electric energy, etc. (21%)

6.1.3 Production processes in practice of Bayer's process

(1) Digestion process

Digestion of alumina component in the bauxite, desiliconization and recovery of heat from the circulating liquid are made in the digestion process. The digesting conditions (soda concentration, digestion temperature, mole ratio of Na_2O and Al_2O_3 after digestion) are determined by the form of the alumina component in the bauxite. The balancing solubility of various alumina components to the reaction solution is shown in Figure 6.3. The actual operation is performed in the condition that is closed to the equilibrium. The digestion time is determined by the desiliconizing time rather than the dissolving reaction of the alumina component.

A number of agitation tanks connected in series (there are cases where some tanks are without agitators) are usually used as the digesters. But tube digesters are also used in addition to usual digesters of autoclave type in the case where digestion of bauxite containing boehmite and diaspore is made because high soda concentration and high temperature are required. Method to preheat and heat the solution only and to then mix the solution with wet crushed bauxite slurry before introduction to the digester as shown in Figure 6.2 and the method to perform preheating and heating after mixing the bauxite slurry with the solution at low temperature are available.

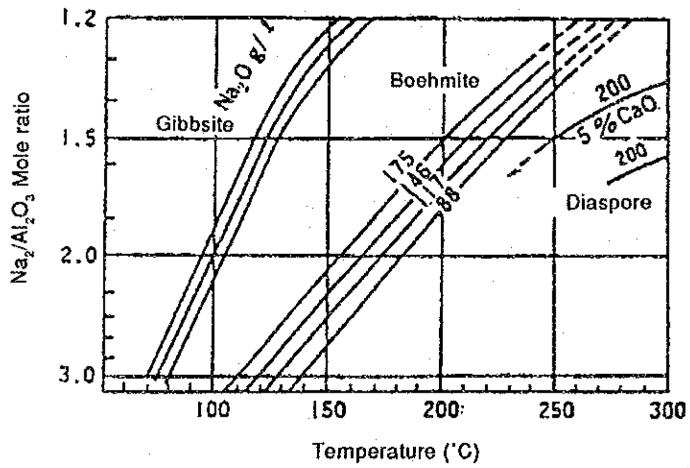


Figure 6.3 Equilibrium solubility of gibbsite, boehmite and diaspore to the reaction solution

The heat recovered from the liquid circulation system and the steam generated at a boiler are used as the heat source to supply the sensible heat and reaction heat up to the digestion temperature. It is the simplest to perform heating by directly blowing steam into slurry. But since water is input to the liquid circulation system and it is necessary to expel this water to outside of the system in the concentration process when this method is used, selection of the method between direct steam blow and indirect heating should be made through comparison of the economy.