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20363

**HANDY MANUAL**  
**TEXTILE INDUSTRY**



**Output of a Seminar on Energy  
Conservation in Textile Industry**

*Sponsored by*  
**United Nations Industrial Development Organization  
(UNIDO)**

*and*  
**Ministry of International Trade and Industry  
(MITI), Japan**

*Hosted by*

<b>Ministry of Energy, Telecommu- nications and Post, Malaysia</b>	<b>Ministry of Mines and Energy, Indonesia</b>
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*Organized by*  
**The Energy Conservation Center (ECC), Japan**

**1992**

**Malaysia**

**Indonesia**

## *Preface*

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

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

In December 1983, UNIDO organized a Regional Meeting on Energy Consumption as well as an Expert Group Meeting on Energy Conservation in small- and medium-scale industries for Asian countries. During these meetings, it was brought out that, for some energy intensive industries, savings up to 10% could be achieved through basic housekeeping improvements, such as auditing and energy management.

The rational use of energy calls for a broad application of energy conservation technologies in the various industrial sectors where energy is wasted. One of these energy intensive industrial sectors to be considered to improve efficiency through the introduction of modern energy conservation technologies is the textile industry.

In the textile industry, appreciable amounts of energy could be saved or conserved by regulating the temperature in the steam pipes, adjusting the air/fuel ratio in the boilers, and installing heat exchangers using warm waste water.

Currently, UNIDO, with the financial support of the Japanese Government, is carrying out a regional programme on the promotion and application of energy saving technologies in selected Asian developing countries. This programme aims at adopting these innovative energy conservation technologies, developed in Japan, to the conditions of developing countries.

In this programme, we are considering that the transfer of these technologies could be achieved through:

- (i) Conducting surveys of energy usage and efficiency at the plant level;
- (ii) Preparing manuals on energy management and energy conservation/saving technologies, based on the findings of the above survey;

- (iii) Presenting and discussing the manuals at seminars held for government officials, representatives of industries, plant managers and engineers;
- (iv) Disseminating the manuals to other developing countries for their proper utilization and application by the industrial sector.

The experience obtained through this programme will be applied to other programmes/projects which involve other industrial sectors as well as other developing countries and regions.

UNIDO has started this programme with the project US/RAS/90/075 — Rational Use of Energy Resources in Steel and Textile Industry in Malaysia and Indonesia.

The present Handy Manual on Textile Industry was prepared by UNIDO, with the cooperation of experts from the Energy Conservation Center (ECC) of Japan, on energy saving technologies in the framework of the above mentioned UNIDO project. It is based on the results of the surveys carried out, the plant observations and the recommendations and suggestions emanating from the Seminars on Energy Conservation in the Steel and Textile Industries, held under the same project in January 1992 in Jakarta, Indonesia, and Kuala Lumpur, Malaysia. The manual will not only be interesting for government and representatives from industry, but it is, in particular, designed for plant-level engineers and operators in developing countries as a help to improve energy efficiency in the production process.

Appreciation is expressed for the valuable contribution made by the following institutions to the successful preparation and publication of the manual mentioned above:

Ministry of Mines and Energy, Indonesia

Ministry of Energy, Telecommunications and Posts, Malaysia

Ministry of International Trade and Industry (MITI), Japan

The Energy Conservation Center (ECC), Japan

June 1992

# CONTENTS

1. Characteristics of the Manual .....	1
2. Characteristics of Energy Consumption .....	1
2.1 Types of energy used in the textile industry .....	1
2.2 Production process and energy use for each specialized technical field.....	2
2.2.1 Fiber production.....	3
2.2.2 Spinning.....	4
2.2.3 Twisting .....	4
2.2.4 Textured-yarn production.....	5
2.2.5 Weaving .....	5
2.2.6 Knitting .....	6
2.2.7 Dyeing and finishing.....	6
2.2.8 Clothing manufacturing.....	11
3. Promotion of Energy Conservation Technologies.....	12
3.1 Energy conservation management technologies.....	12
3.1.1 Organizational rationalization .....	12
3.1.2 Improving efficiency of electricity use .....	12
3.1.3 Improvements in efficient fuel use .....	13
3.1.4 Improvement in efficient use of steam.....	14
3.1.5 Utilization of heat exchanger .....	15
3.1.6 Measuring instruments and automatic control .....	15
3.2 Energy use and rational use of energy in process-specific technologies.....	15
3.2.1 Fiber production.....	16
3.2.2 Spinning.....	17
3.2.3 Textured-yarn production .....	18
3.2.4 Weaving .....	19
3.2.5 Knitting .....	20
3.2.6 Dyeing and finishing.....	20
3.2.7 Clothing manufacturing.....	35

4. Actual Conditions of the Textile Industry in Japan .....	35
5. Structures of Textile Markets .....	42
5.1 Basic clothing.....	42
5.2 Fashion clothing.....	44
5.3 World's total textile demand and production base distribution.....	45
5.4 Characteristics of textile market.....	47
6. Conclusions .....	51

## **1. Characteristics of the Manual**

In order to promote energy conservation in the textile industry, this manual analyzes in detail the actual conditions of energy consumption in each field. Thus, it has been compiled to serve as reference material for the practical application of these techniques which are always kept available for the engineers. A step-by-step description is included as to how to implement the energy conservation measures, specifically in the area of the dyeing and finishing process, where many small- to medium-sized companies are operating. We strongly hope that this manual will be used as a guide to promote energy conservation in the textile industry and to rationalize the management.

## **2. Characteristics of Energy Consumption**

### **2.1 Types of energy used in the textile industry**

In general, energy in the textile industry is mostly used in the forms of: electricity, as a common power source for machinery, cooling and temperature control systems, lighting, office equipment, etc.; oil as a fuel for boilers which generate steam; liquified petroleum gas; coal; and city gas. Table 1 compares the energy consumption shares of various specialized technical fields and it can be seen that energy consumption is relatively high in the fields of dyeing and finishing, fiber production, spinning, weaving and clothing manufacturing. Table 2 summarizes recent trends in the use of various energy sources in the fiber production and dyeing and finishing divisions of the textile industry, where the energy consumption ratio is relatively high.

**Table 1 Energy Consumption Share of Each Specialized Technical Field in the Japanese Textile Industry**

Specialized Technical Field	Unit: million Yen			
	Fuel	Electricity	Total	Share
Fiber production	32,551	21,498	54,049	21.0%
Spinning	3,224	44,262	47,480	18.4
Twisting	219	1,660	1,879	0.7
Textured-yarn production	120	1,543	1,663	0.6
Weaving	4,467	24,848	29,315	11.4
Knitting	4,059	11,709	15,858	6.1
Dyeing	37,661	28,412	66,073	25.0
Clothing manufacturing	8,240	15,420	23,660	9.2
Others	5,959	12,000	17,959	7.0
<b>Total</b>	<b>96,500</b>	<b>161,442</b>	<b>257,942</b>	<b>100.0</b>

Note: Calculated from the Tabulated Industrial Statistics (Industry Volume)

**Table 2 Types of Energy Sources Used in the Textile Industry**

Technical Field	Fiscal Year	Electricity (10 <sup>7</sup> kWh)	Kerosene (Kt)	Gas Oil (Kt)	Fuel Oil A (Kt)	Fuel Oil B (Kt)	Fuel Oil C (Kt)	Liquefied Petroleum Gas (t)	Coal (t)	City Gas (10 <sup>7</sup> m <sup>3</sup> )	Total (10 <sup>7</sup> kcal)
Fiber Production	1986	3,839,760	4,067	10	6,182	16	719,547	712	517,177	134	15,631,924
	1987	3,889,582	5,587	17	2,221		635,941	609	706,302	116	15,884,930
	1988	3,882,074	3,821	14	12,209		622,291	727	788,698	132	16,012,279
	1989	3,887,386	2,736	3	28,520		544,848	656	838,810	155	15,458,822
	1990	4,066,002	3,571	5	35,503		539,098	662	871,265	177	15,458,854
Dyeing	1986	1,325,692	21,250	300	39,770	11,751	876,942	3,678	7,387	46,881	12,103,482
	1987	1,351,231	22,565	306	50,351	11,006	806,477	87,978	40,064	41,835	12,322,368
	1988	1,433,959	21,879	332	97,509	12,323	775,313	95,439	37,846	41,902	12,670,598
	1989	1,497,260	21,370	371	180,880	10,507	708,562	104,125	37,580	45,111	12,706,610
	1990	1,498,127	20,702	614	199,846	10,068	678,942	109,281	32,827	51,294	12,724,916

Note: Calculated from the Annual Report on Textile Statistics. Dyeing represents the dyeing process including finishing, for both woven and knitted materials.

## 2.2 Production process and energy use for each specialized technical field

The major operations and sources of energy use involved in the production process of each specialized technical field, as a necessary component of the overall production of apparel goods, as illustrated in Figure 31, are schematically summarized as follows:



## 2.2.1 Fiber production

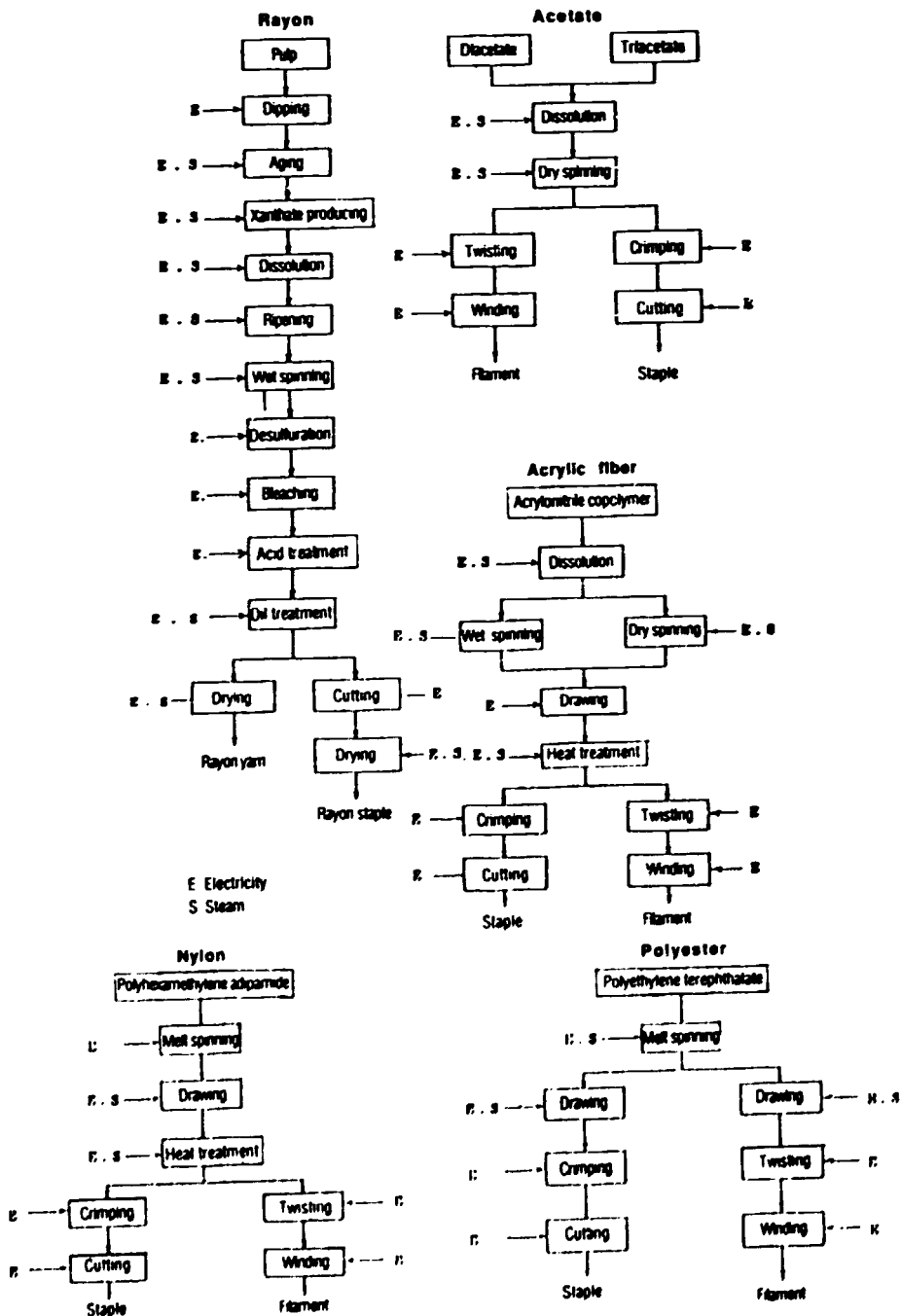


Figure 1 Examples of Production Processes and Energy Use for Major Fiber Types

## 2.2.2 Spinning

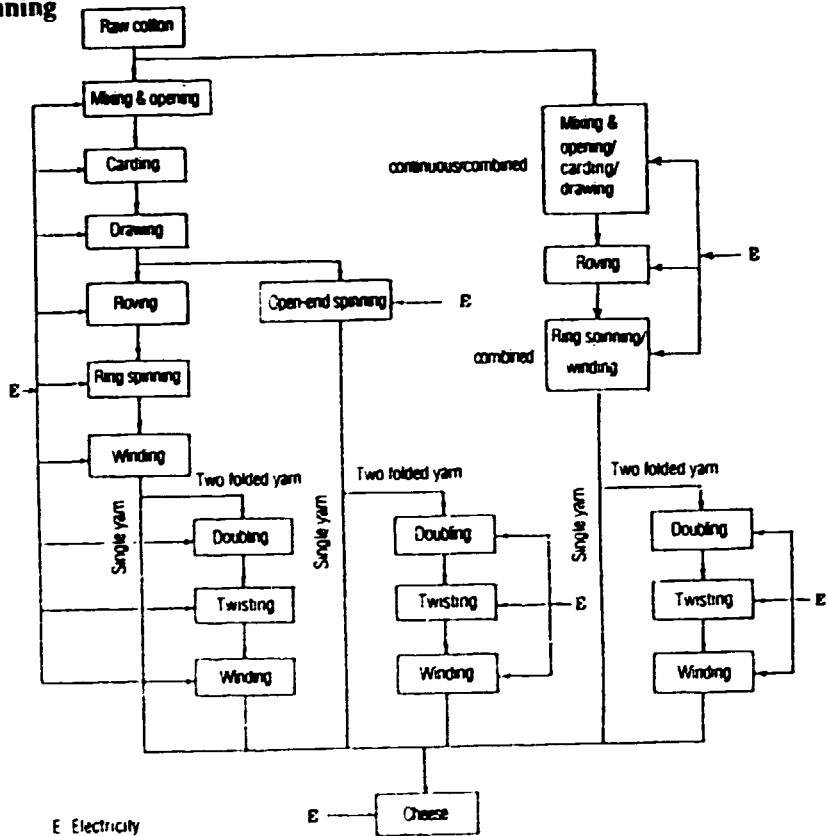


Figure 2 Example of Typical Spinning Processes and Energy Use

## 2.2.3 Twisting

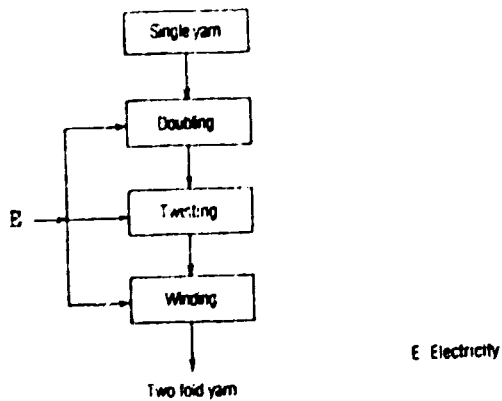


Figure 3 Twisting Process and Energy Use

## 2.2.4 Textured-yarn production

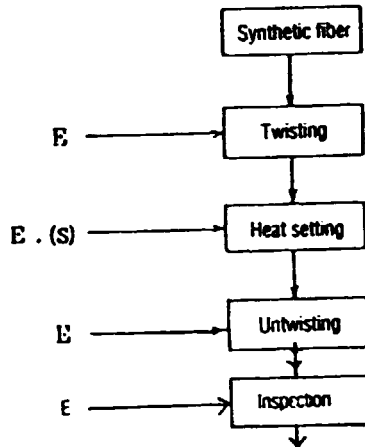


Figure 4 Textured-yarn Production Process and Energy Use

## 2.2.5 Weaving

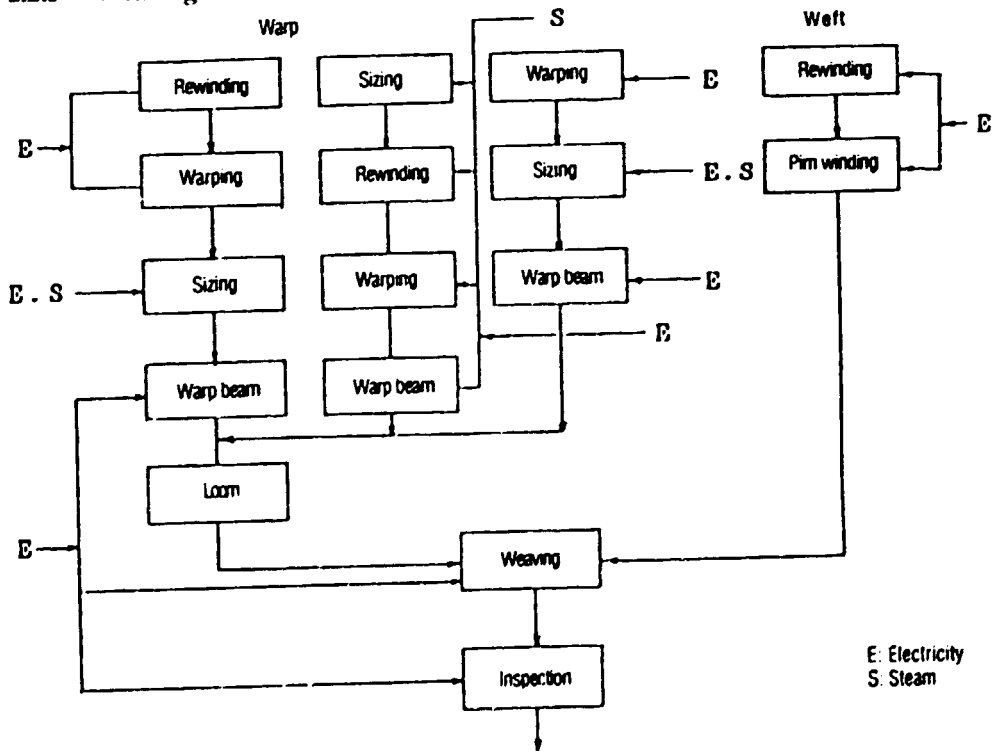


Figure 5 Weaving Processes and Energy Use

## 2.2.6 Knitting

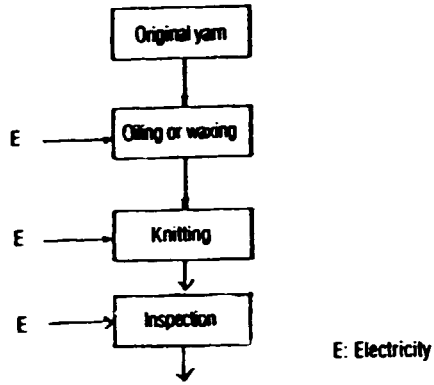


Figure 6 Knitting Processes and Energy Use

## 2.2.7 Dyeing and finishing

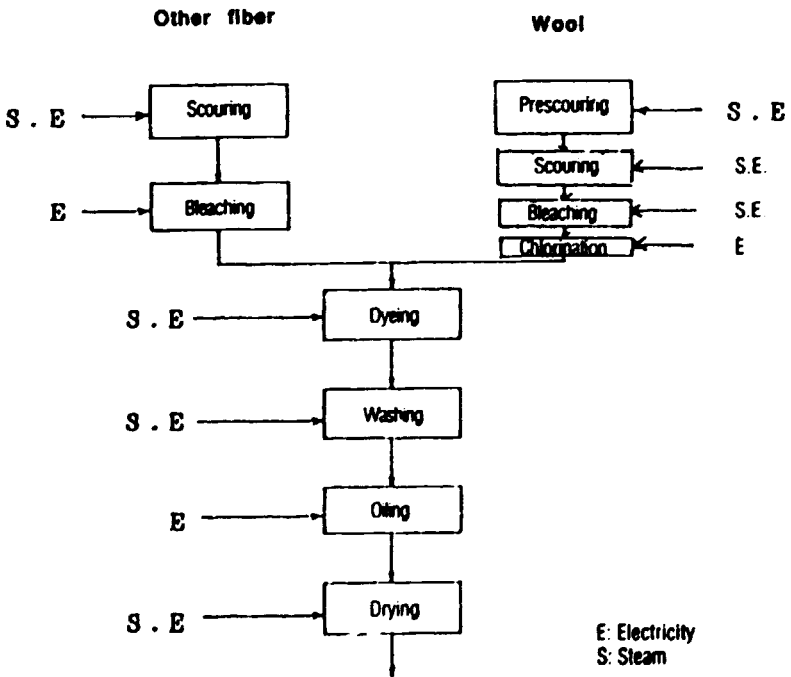


Figure 7 Fiber and Yarn Dyeing Processes and Energy Use

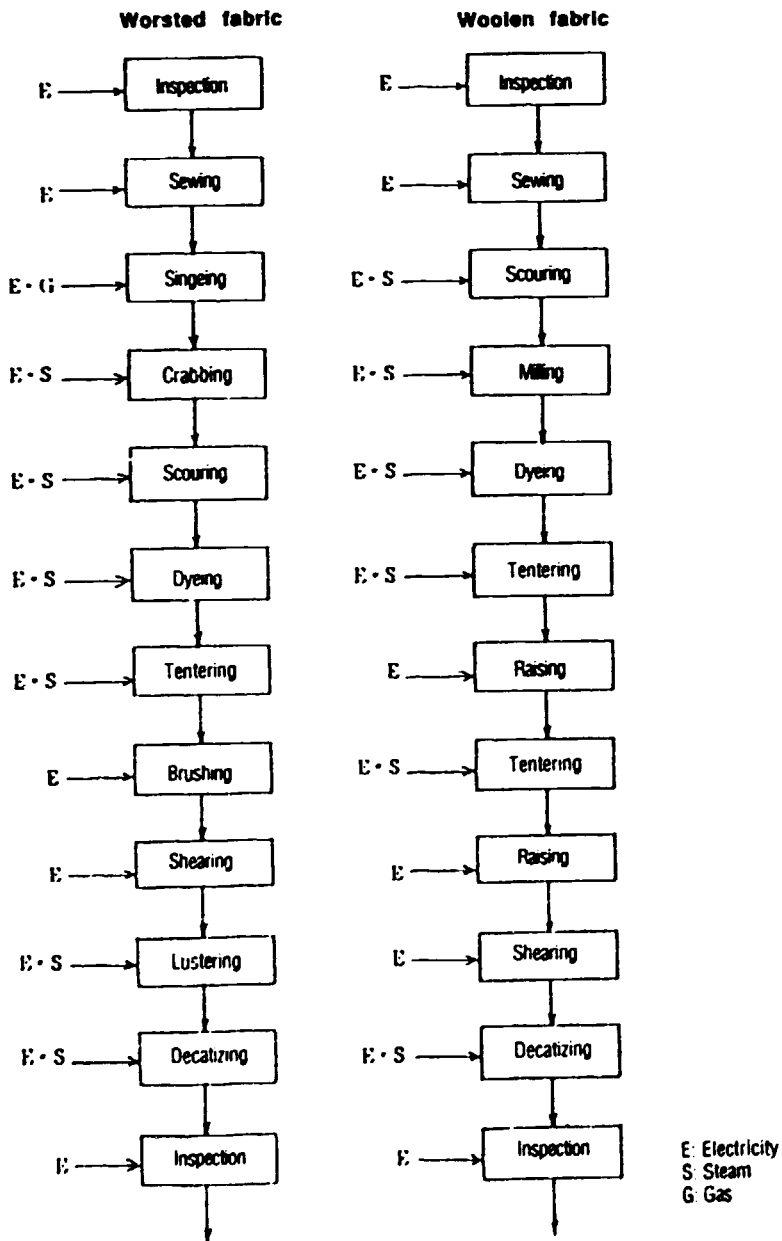


Figure 8 Typical Dyeing Processes and Energy Use for Woolen Fabric

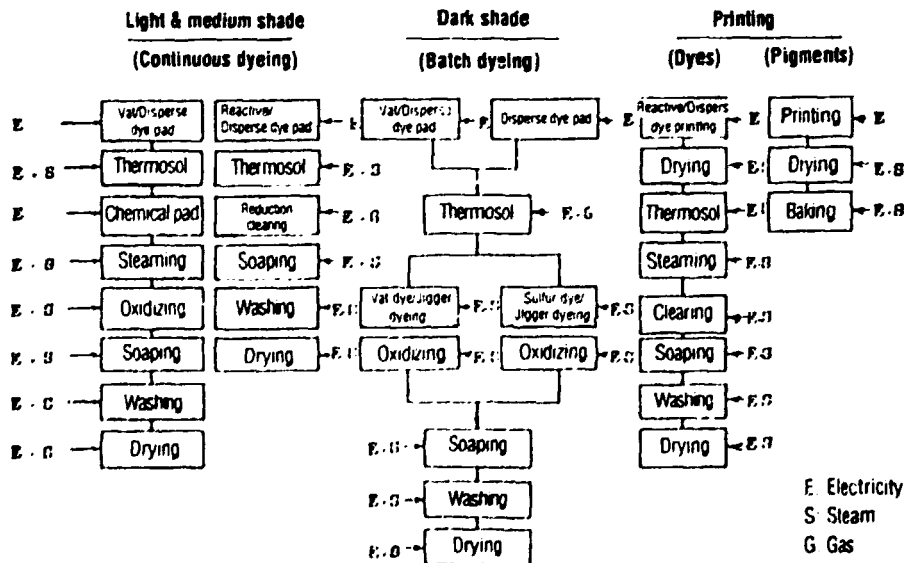
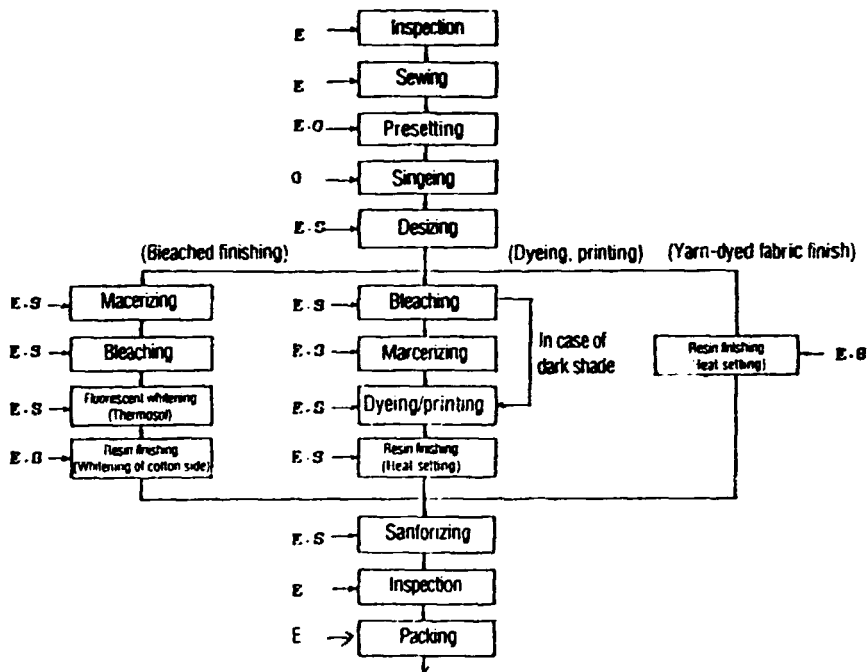


Figure 9 Typical Dyeing Processes and Energy Use for Cotton Fabric

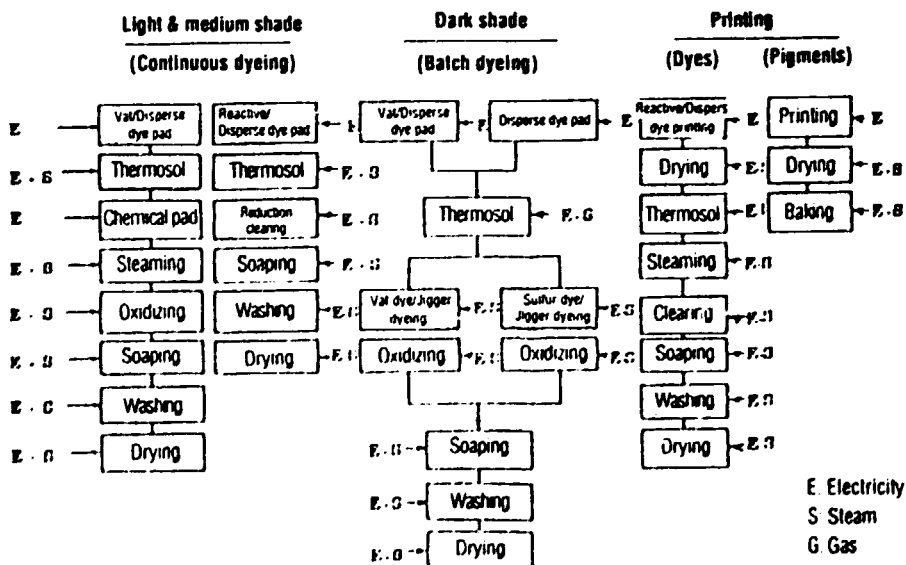
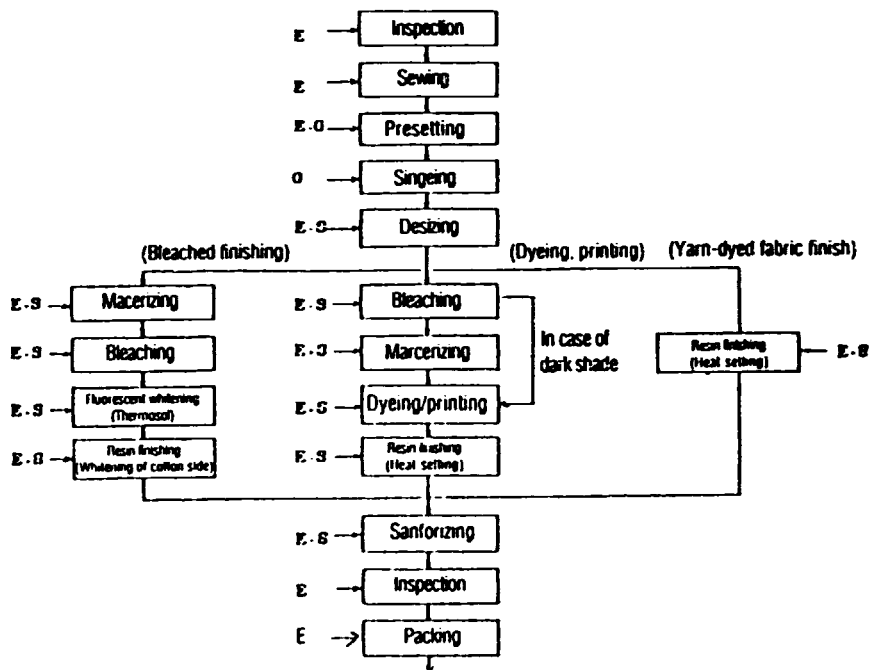


Figure 10 Typical Dyeing Processes and Energy Use for Polyester & Cotton Blend Fabric

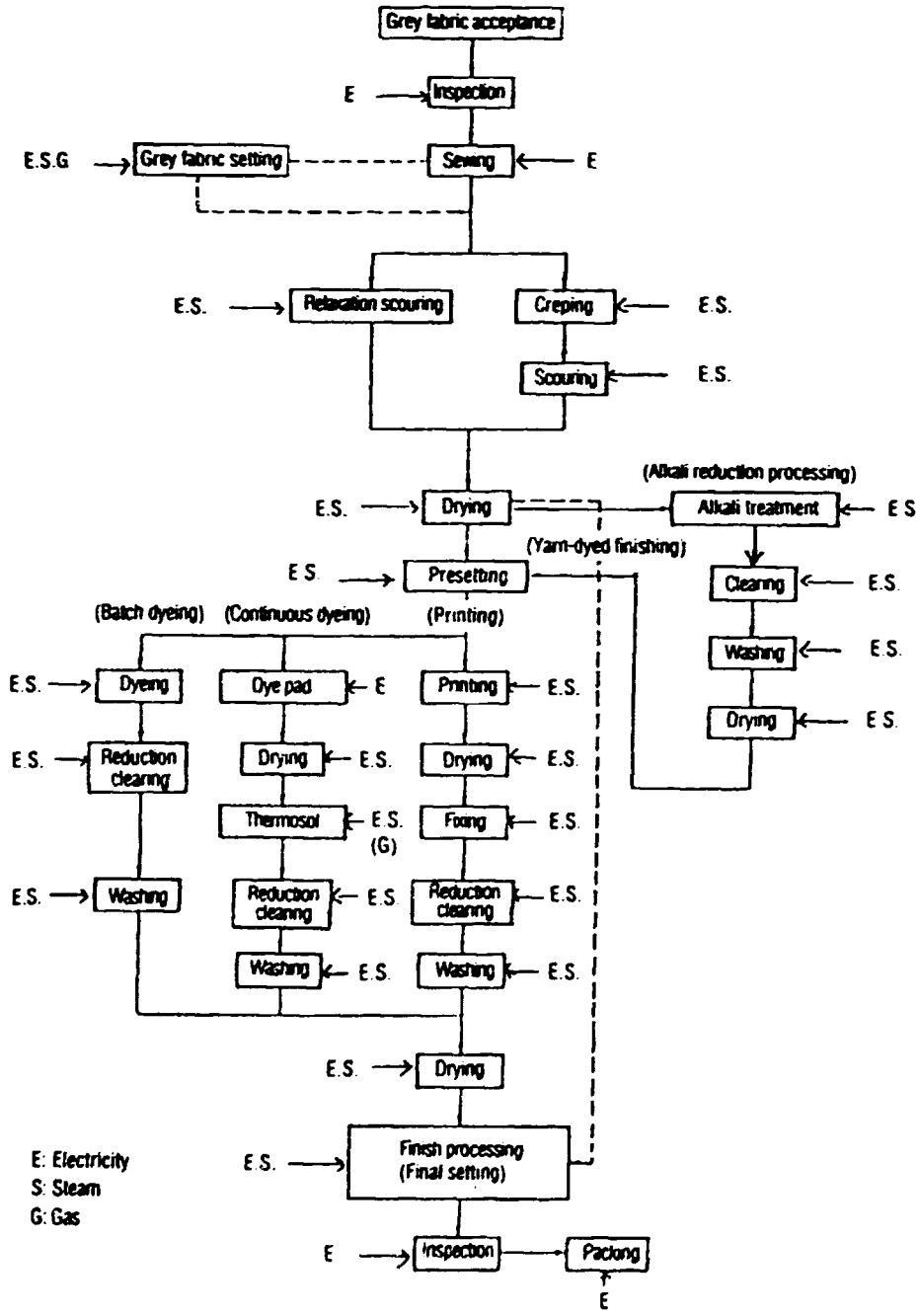


Figure 11 Typical Dyeing Processes and Energy Use for Polyester Textured-Yarn Fabric



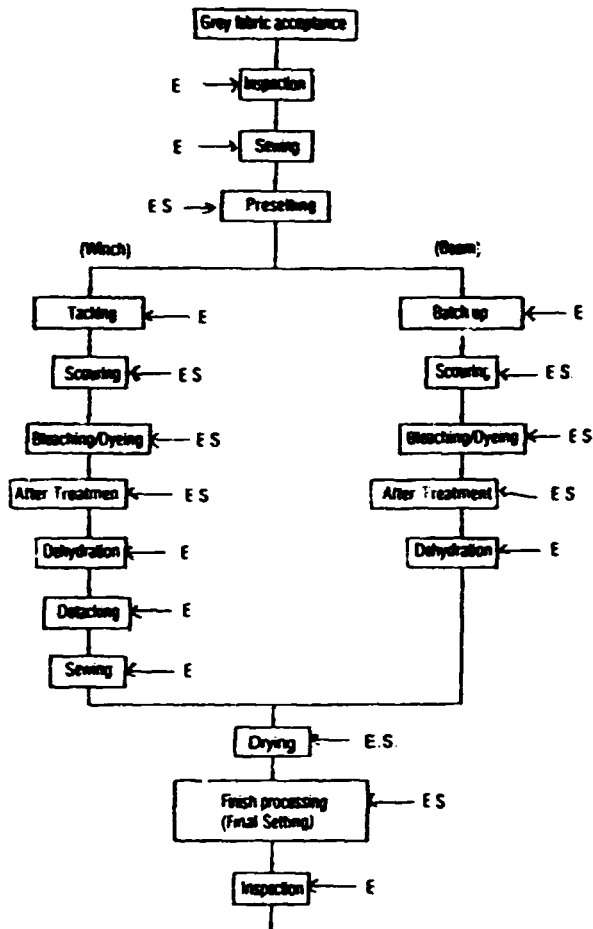


Figure 12 Dyeing Processes and Energy Use for Nylon Tricot

### 2.2.8 Clothing manufacturing

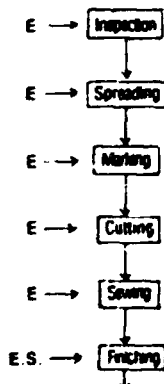


Figure 13 Sewing Processes and Energy Use

### **3. Promotion of Energy Conservation Technologies**

While the significance of energy conservation awareness is relatively easily understood at home, when a program is introduced into a factory to promote it, its thorough implementation tends to be delayed at an early stage. Therefore, for its actual course of implementation, it is desired to devise company-wide coordinated measures similar to QC activities at factories. Also, in order to promote energy saving measures efficiently, it is found to be effective to separately consider general management techniques for "rational use of energy" and process-specific techniques to be developed in each specialized technical field.

#### **3.1 Energy conservation management technologies**

##### **3.1.1 Organizational rationalization**

Since energy management is relevant to a wide range of departments within a company, it is necessary to enhance the awareness, improve the knowledge and obtain the participation and cooperation of everybody involved in the production process. Therefore, while it is necessary for engineers and technicians with specialized technical knowledge to play a central role in energy conservation efforts, the implementation of an energy conservation program itself should not be left to a handful of specialists or specialized sections. Rather, it is desirable to address the task company-wide, for example by setting up an 'Energy Management Committee'.

##### **3.1.2 Improving efficiency of electricity use**

###### **(1) Lighting**

Due to its nature of operations, the share of lighting in electricity use is relatively high. After the switch from tungsten bulbs to fluorescent lamps achieved considerable electricity savings, electricity-saving fluorescent lamps have been developed and marketed for further improvements, including those capable of reducing electricity use by several percent for the same level of illumination.

In general, the effectiveness of illumination is influenced by various factors, such as the intensity of light source, the reflection coefficient and shape of the reflective fitting (lamp shade), the layout of the room to be illuminated, interior finish, color and the distance from the light source. Therefore, it is important to

re-examine whether the light source is utilized in the most efficient way and take electricity saving measures, if necessary, such as reducing the number of lamps in use by switching from global lighting to local lighting as much as possible.

**(2) Electric motor**

The textile industry uses a vast number of relatively small electric motors. Notably, while a conventional machine was driven by a single motor with the generated mechanical power transmitted to various parts of the machine in a collective manner, many modern machines utilize multiple motors with a control board controlling the movement of each motor, which is directly coupled to a machine part to drive it independently from others. This is also a rationalized feature in terms of energy saving. However, regarding the selection of each motor, emphasis has been placed on mechanical performance, resulting in a motor with an excessive capacity. This leaves considerable room for re-examination from an energy conservation point of view.

**(3) Electric heating**

In the textile industry, electric heating has largely been replaced by other methods (steam, gas heating, or direct or indirect fired heating) for some time in order to achieve cost reductions. However, since electric heating only requires a small initial investment as a result of convenience and simplicity in equipment construction, it is still used for small capacity local heating purposes. Therefore, it is desirable to conduct a comparative investigation into alternative heating methods, such as far-infrared radiation heating, high frequency dielectric heating and microwave heating.

**3.1.3 Improvements in efficient fuel use**

**(1) Selection of fuel**

As is described before, fuels utilized in the textile industry have already gone through a switch-over from coal to oil. More recently, efficient energy use is under investigation, including the revival of coal on the way to a further move from oil to liquefied and city gases, while reflecting various fuel prices. In selecting fuels, those with good flue gas characteristics in addition to high calorific value and ease of combustion are desired, so that air pollution can be prevented as much as possible.

## **(2) Selection of boiler**

By and large, boilers used in the Japanese textile industry have experienced a change from Lancastrian- or Scotch-type tubular or smoke tube to water-tube boilers (natural circulation and forced circulation water-tube boilers and once-through boilers). As a result, boiler efficiency has improved from the conventional 60's to 70's of percentage points to as high as the 90's. Since high performance boilers are prone to a rapid growth of scales inside their water tubes, feed water management becomes important. Furthermore, these boilers have small amounts of retained water and high evaporation speeds so that many aspects of their operation are automated, including feed water and combustion management.

### **3.1.4 Improvement in efficient use of steam**

#### **(1) Piping**

The noted feature of steam use in the textile industry is that the amount of steam involved is not so large but the locations where steam is required are widespread so that steam losses due to heat radiation from steam transportation pipes and pressure drops are considerable.

Therefore, for steam transportation over long distances, high pressure and small-diameter rather than low pressure and large-diameter piping is desired, with pressure reducing valves placed as necessary to regulate the steam pressure at the point of use, thereby curbing heat losses. Also, as pressure losses around bends are great, it is desirable to make their radii large. In order to prevent steam leaks from joints due to the thermal expansion of the pipe, expansion joints should be placed where required. Furthermore, in order to maintain the temperature inside the valve, tank and treatment tank as well as the piping, it is necessary to install them heat-insulated, using appropriate heat insulating materials, so as to efficiently use steam while preventing heat losses.

#### **(2) Steam accumulators**

Since live steam is often used in dyeing factories, fluctuations in steam use during working hours are large. On the other hand, since high performance water tube boilers and once-through boilers are designed such that water retained inside the boiler is very little, the boiler cannot react to momentary and sudden

load changes, while responding to automatically controlled slow load changes is not a problem. In such a case, a steam accumulator can be installed midway through the heat transporting pipe, between the boiler and the heat consuming load, in order to store excess steam when the load is light by transforming it to heated water. This then transforms the heated water back to steam when the load is heavy in order to reinforce supply to the load. This allows the boiler to continuously operate with the average load and is quite advantageous in view of energy saving.

### **(3) Recycling of drain**

So far, after its heat energy is consumed, steam has been drained off. However, in view of energy saving, it is necessary to collect and recycle the heat energy carried by the drain water.

### **3.1.5 Utilization of heat exchanger**

In each production process of the textile industry, the heating and cooling of gases and liquids as media of heat are frequently required. This is done through heat exchange between different fluids, and in order to avoid contamination or chemical reaction due to their direct contact, heat exchangers are used to carry out indirect heating and cooling. It is important to use the right heat exchanger for the intended purpose.

### **3.1.6 Measuring instruments and automatic control**

Energy saving is an operation to grasp the actual situation of energy use in a factory precisely and quantitatively and to carry out improvement measures in order to rationalize and economize on it. While measuring instruments are needed to obtain quantitative data, it will become more and more important to investigate the use of sophisticated measuring instruments based on recent developments in mechanical and electronic engineering, combined with automatic control systems.

## **3.2 Energy use and rational use of energy in process-specific technologies**

Progress in production rationalization is achieved through the implementation of a comprehensive set of measures, including energy conservation technologies as the

centerpiece measure, along with time management, labor saving, natural resources saving and space saving. It has been frequently pointed out that, along with management techniques described earlier, the improvement and development of process-specific techniques on energy conservation greatly contribute to the rationalization of production. Here, process-specific techniques relating to energy saving are summarized for each specialized technical field.

### 3.2.1 Fiber production

Exhibiting relatively large-scale structural forms in the textile industry, this division has already reached a high level of production rationalization, as seen from Figure 24; as is well known, it is technologically aiming at diversification into such high value-added goods as super extra-fine fiber and inorganic functional fiber, commonly referred to as *shingosen*. In particular, the following techniques relate to energy saving:

#### (1) Raw material production process

Implementation of energy saving through **improvements in the process and reaction conditions**

#### (2) Polymerization process

**Reduction in polymerization time** by means of high efficiency catalysts, polymerization methods, etc.

#### (3) Spinning process

Promotion of energy saving through combining the POY (Pre-oriented Yarn: Yarn with some stability with its molecules partially having gone through orientation) and DTY (Draw Textured Yarn: **false twisted yarn produced while drawing POY yarn**) methods and **an expanded use in multi-folded spinning yarn.**

#### (4) Newly built factories

The factories built during the high growth period have large margins and allowances for production increase so that high losses would result if production decreased. Therefore, suitably sized factories should be constructed.

### 3.2.2 Spinning

Regarding technological trends in spinning, moves towards high speed and large package size have been investigated in order to achieve labor saving through as much automation as possible. As a result, energy consumption has been gradually increasing, as shown in Figure 24. However, in view of price competition with overseas companies, further labor saving as well as energy saving is desired.

Table 3 compares a modern and a traditional factory in terms of electricity consumption for each plant/operation.

**Table 3 Electricity Consumption per 1000 Spindles for Each Plant/Process**

Factory		Modern Factory		Traditional Factory	
Electricity Consumption		KWh/1000 spindles	%	KWh/1000 spindles	%
Spin- ning plant	Mixing/Opening	16.7	7.5	4.2	6.0
	Carding	17.7	8.0	4.9	7.0
	Combing	10.9	5.0	2.2	3.0
	Drawing/Roving	9.1	4.0	2.8	4.0
	Ring Spinning	66.1	30.0	34.5	48.0
	Finishing	14.7	6.5	4.7	6.0
Subtotal		135.2	61.0	53.3	74.0
Air-conditioning plant		85.9	39.0	18.7	26.0
Total		221.1	100	71.9	100

(Mikio Uno: Textile Engineering Vol.28 No.5 (1975))

Namely, it can be seen that a modern factory as a means of achieving production rationalization requires approximately three times as much electricity as a traditional one, with electricity consumption particularly increasing in the air-conditioning plant. In terms of processing operations, fine spinning, as the main operation of the spinning process, consumes a large amount of electricity. Thus, energy saving measures are required in these fields.

#### (1) Ring spinning operation

For the fine spinning operation, electricity is consumed in driving the spindles, packaging, spinning, drafting, and operating the lifting and cleaning mechanisms. It is desired to curb the increase of electricity consumption as much as possible by setting an optimal condition for each of these electricity usages.

## (2) Air-conditioning

Although as an ideal working environment a room temperature less than 30°C is desirable, in cases where the working environment has been drastically improved in most other aspects with work load also reduced, a slightly increased room temperature may be permitted. As has been reported, there was a case where raising the regulated temperature from 30°C to 32 °C resulted in a reduction in the electric power demand of a carrier **with a contract demand of some 8,000 kW by 190 kW**. Also, there are many instances of seasonal switch-over from a damper to a pulley as a means of readjusting the blown air volume; this is in order to recycle the air sucked from the processing machine for each operation through a filter back to the same room, and it is therefore necessary to recheck the locations of fans for suction and returning.

### 3.2.3 Textured-yarn production

While synthetic-fiber textured-yarn is mostly produced with false twisting machines, its history of rationalization is characterized by challenges for high speed operation. As their operating speeds increased, driving and heat-curing motors and other peripheral equipment became larger, accompanied by an inevitable increase in electricity consumption. Although this may be acceptable as long as the production improvement resulting from a high speed operation covers the increase in electricity costs, reductions in energy cost would surface as an avoidable urgent task, should a sharp increase in electricity charge occur. It can reasonably be said that the major form of energy consumed in the production of synthetic finished-yarn is electricity (Ref Figure 26). Although the amount of electricity consumed in each piece of equipment varies with factory scale and the type of false twist machine, and therefore cannot be treated in a standardized manner, generally accepted average values may be taken as 3.5 kWh/kg for a single heater system and 5.0 kWh/kg for a double heater system—as one report suggests. Of all the energy consumed in finished-yarn production, 70% is accounted for by false twist machines. Table 4 shows a breakdown of this energy consumption:



**Table 4 Example of False Twisting Machine and Electricity Consumption (kWh)**

Processing Machine Equipment	Single Heater (192 spindles)		Double Heater (216 spindles)	
	Capacity	Utilized	Capacity	Utilized
Main motor	15.0	8.0	13.5	9.5
Exhaust gas motor	1.5	1.0	2.2	1.5
Yarn sucking motor	2.2	1.5	—	—
No.1 heater	32.0	16.0	15.0	7.5
No.2 heater	—	—	11.0	6.0
Total	50.7	26.5	46.7	24.5

(Edited by JTCC: Energy Conservation Techniques in Textile Industry, p.68, 1981)

As is seen from Table 4, 60% of all energy consumption by a false twist machine occurs in the heater. Therefore, **improvements in the heat insulation of the heater and the lowering of heater temperature** may be considered as energy saving measures. Since the latter has implications in the characteristics of the finished-yarn, whether or not it is adopted should be examined on such occasions as in the development of a new product.

Since air-conditioning plants are designed based on the conditions applicable at the time of installation, it is desirable that they be re-examined against the present conditions.

### 3.2.4 Weaving

As is shown in Figure 24, rationalization in fabric production is such that while various improvements in machinery aimed at high speed operation and labor saving have been carried out, the amount of energy use per unit of the product has gradually increased. Regarding loom design, high productivity shuttleless looms such as water jet, rapier and gripper types have successfully been introduced, with air jet models put in practice in the production area of industrial fabric material. The amount of energy consumed by each loom during its weaving operation can be estimated from the motor capacity and weaving speed.

Conventional shuttle looms are based on the weft-insertion method, incorporating a shuttle zooming to and fro with a large inertia mass (approx. 400) and mounted with extra weft, and they also use energy consuming pirns as an integral part of the machine. For this reason, the shuttleless looms' contribution to energy saving cannot be regarded as too high.

On the other hand, as a large amount of energy is consumed in sizing, as one of the preparatory operations for weaving, **the introduction of foam and solvent sizing operations are being investigated.** Furthermore, **long fiber fabrics using nonsizing filaments have been developed,** eliminating the sizing process altogether. In a reported example, **the introduction of a new heat exchanger into a sizing machine with a very poor sealing capability achieved more than 40% of energy saving.**

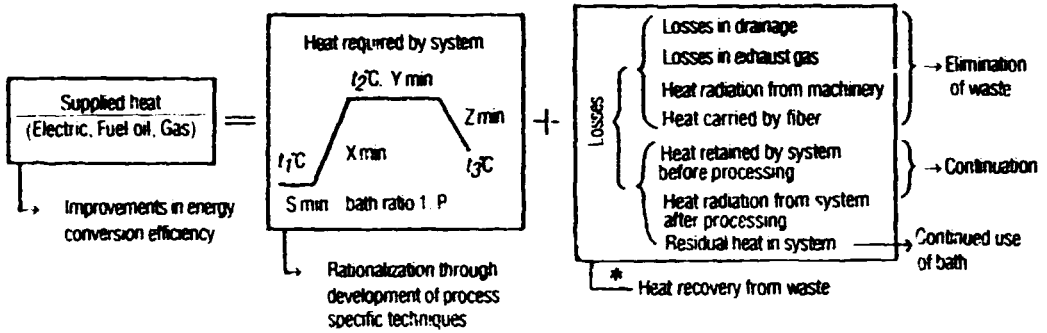
### 3.2.5 Knitting

As is shown in Table 13, the share of energy cost in the total cost of production is not necessarily high for the knitting process. However, of the main production facilities for this process, knitting machines have also been undergoing a shift towards high speed and large capacity and fine gauge features; the current industry trend is for high added-value goods and multi-line, small-volume production based on advanced systems such as computer-controlled pattern making mechanisms. Therefore, a potential tendency for increased energy consumption should be taken into account. As a result, it is **desirable to conduct a comprehensive re-examination of the production schedule along with the implementation of actual energy conservation measures in order to reduce or restrain the share of energy cost in the total production cost.**

### 3.2.6 Dyeing and finishing

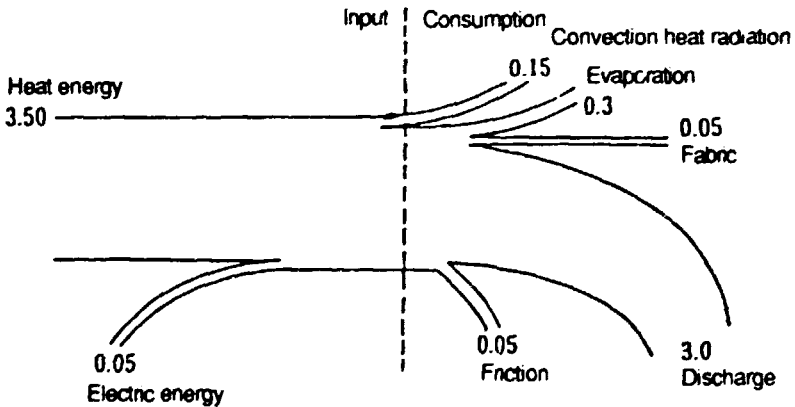
**It is very important to advance energy conservation in the dyeing and finishing field,** which has a high energy consumption share in terms of both the amounts of money and energy used, as shown in Table 1 and Figure 24.

As is illustrated in Figures 7 to 12, the dyeing and finishing process consists of many interwoven unit operations, and it is well known that the process generally goes through repeated wet and dry operations. The heat balance of a unit operation can mainly be considered as the difference between the total supplied heat on the one hand and the sum of the heat required by the system and various forms of heat losses on the other. Figure 14 graphically summarizes the major factors in a thorough implementation of energy savings. Figure 15 shows an example of heat balance in a continuous water cleansing machine.



**Figure 14 Heat Balance in Unit Operation**

(Kazuo Shiozawa: Textile Wet Processing Technology, p.118 Chijin Shokan, 1991)



**Figure 15 Example of Energy Balance in Typical Continued Washing Machine**

(E P Dempsey & C.E. Vellings, Heat Transfer Printing p.46, Interprint 1975)

This clearly illustrates the importance of the development and utilization of process-specific techniques, apart from the already-described management technologies. Table 5 shows that the implementation of production rationalization eventually relates to energy conservation. The following are brief explanations of typical examples.

**Table 5 Relationship between Production Rationalization Techniques and Energy Savings**

Production Rationalization Technique	Mechanism	Effect
Time saving	(1) High speed processing of unit operations (2) Reduction in waiting time between unit operations (3) Elimination or merger of unit operations	Reductions in energy use per unit operation through an improvement in productivity
Labor saving	(1) Implementation of automation (2) Strengthening colorimetric management	Reductions in the frequency of reprocessing through a reduction in the failure rate
Energy saving	(1) Reduction in bath ratio (2) Reduction in treatment time (3) Reduction in margin of temperature rise (4) Re-examination of drying method (5) Switch to non-water-based operations	Reductions in energy cost
Conservation of natural resources	(1) Utilization of continuous bath	Utilization of system's residual heat
Space saving	(1) Construction of modern factories	Improvements in factory-wide energy saving effects

**(1) High speed processing of unit operations**

As the processing machines become faster they also become larger. This means the energy consumption per unit length of time will increase, but generally it will accompany a reduction in energy consumption for the treatment of a unit amount of fabric. Table 6 shows an example of this situation. Therefore, it follows that, as long as the product turnout is maintained, **continuous processing with a large machine will be more effective in achieving energy conservation.**

**Table 6 Length of Mercerizing Machine and Productivity and Energy Consumption**

Total machine length (m)		38	47	56
Treating speed (m/min)		40	60	80
Treating time (sec/m <sup>2</sup> )		1.5	1	0.75
Product turnout (m)	1 hour (Operation rate 100%)	2,400	3,600	4,800
	8 hours (Operation rate 85%)	19,200 (16,300)	28,800 (24,500)	38,400 (32,600)
	16 hours (Operation rate 90%)	38,400 (34,500)	57,600 (51,800)	76,800 (69,000)
	24 hours (Operation rate 95%)	57,600 (54,700)	86,400 (82,000)	115,200 (110,000)
Con- sumption rate	Water (m <sup>3</sup> )	10.5	14.0	19.0
	Steam (kg)	1,075 (82,69l)	1,500 (115,38l)	1,850 (142,31l)
	Electricity (AC motor) (kWh)	21.0	38.0	50.0
	NaOH (30°Be) (l)	288	432	576
Energy and raw material required for treating m <sup>2</sup> of fabric	Water	0.0044	0.0039	0.0040
	Steam	0.4479 (0.034l)	0.4167 (0.032l)	0.3854 (0.030l)
	Electricity	0.0088	0.0106	0.0104
	Amount of energy (kcal)	337.2	322.0	302.8
	NaOH	0.12	0.12	0.12

- Notes
1. The bracketed entries under Production Turnout show approximate figures which would result from the respective operation rates.
  2. The bracketed entries under Steam show equivalent fuel consumption figures which would be needed if a boiler with a evaporation ratio (= evaporation/fuel consumption) of 13 was used.
  3. The energy values were obtained from Figure 24.

(Kazuo Shiozawa: Textile Wet Processing Technology, p.48, Chijin Shokan, 1991)

## (2) Elimination or merger of unit operations

The currently employed dyeing techniques are based on unit operations which have been developed and established for use with natural fiber. For this reason, the traditional standard treatment steps are often applied to blended yarn fabrics as a matter of principle. However, **through omitting or merging some of the unit operations according to the usage of the product and considering the characteristics of the coexisting synthetic fibers, it becomes possible to achieve energy conservation. Table 7 shows an example.**

**Table 7 Unit Operations in Preparatory Process of PE/C Blended Fabric and its Processing Characteristics**

Combination and Ordering of Operations	Number of Units	Processing Characteristics
Singeing → Desizing → Drying → Heat setting → Scouring → Drying → Bleaching → Drying → Mercerizing → Drying	10	(1) Cumulative Method (2) Strict Control (3) Excessive Drying operations
Singeing → Desizing → Scouring → Bleaching → Drying → Mercerizing → Drying → Heat setting	8	(1) Fewer drying operations (2) Difficulty in controlling scouring and bleaching (3) Great number of wrinkles from processing
Heat setting → Singeing → Desizing → Scouring → Bleaching → Drying → Mercerizing → Drying	8	(1) Difficulty in desizing (2) Insufficient effectiveness in processing (3) Wrinkles from processing prevented
Singeing → Desizing → Scouring → Bleaching → Drying → Heat setting → Mercerizing → Drying	8	(1) Satisfactory desizing (2) Fewer drying operations (3) Caution against wrinkles from processing
Singeing → Mercerizing → Desizing → Scouring → Bleaching → Drying → Heat setting	7	(1) Fewest drying operations (2) Difficulty in desizing (3) Small mercerizing effect

(Kazuo Shiozawa: Textile Wet Processing Techniques, p.50, Chijin Shokan, 1991)

### (3) Reduction in processing bath ratio

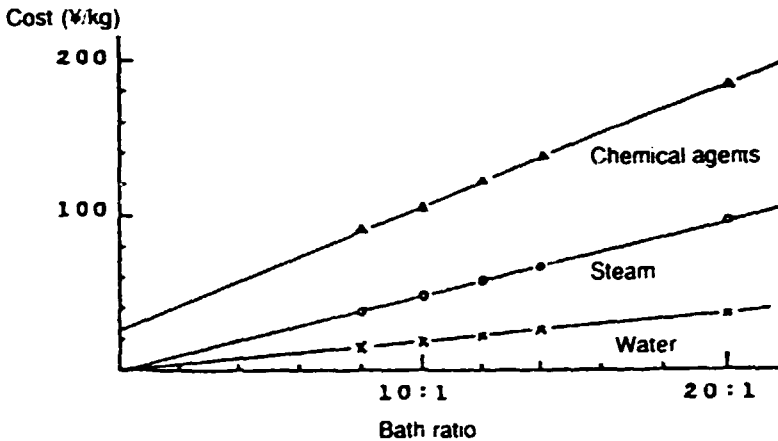
It is easy to understand that a **reduction in water use will contribute to energy conservation in the dyeing process** which consists of various wet treatment and drying unit operations. It is especially desirable to curb the water consumption because it is linked to the overall water supply cost including that of drainage.

For the reduction of the processing bath ratio, it is necessary to investigate the following measures:

#### (a) Treatment with low bath ratio

In general, dyeing and finishing methods are classified into the batch and continuous processing methods, and it is recommended to use the latter method where a low bath ratio is desired. However, depending on the details of processing requirements, there are often instances in which the batch method has to be employed. In such cases, batch processing machines which allow

lower bath ratios such as the jigger, wince, beam, pad roll and jet flow types should be selected as far as the circumstances permit. Figure 16 graphically shows the relationship between the bath ratio and the production cost for the wince dyeing of a cotton fabric with a reactive dye (bright red, medium shade). It is easy to see that the bath ratio has a direct influence on the production cost.

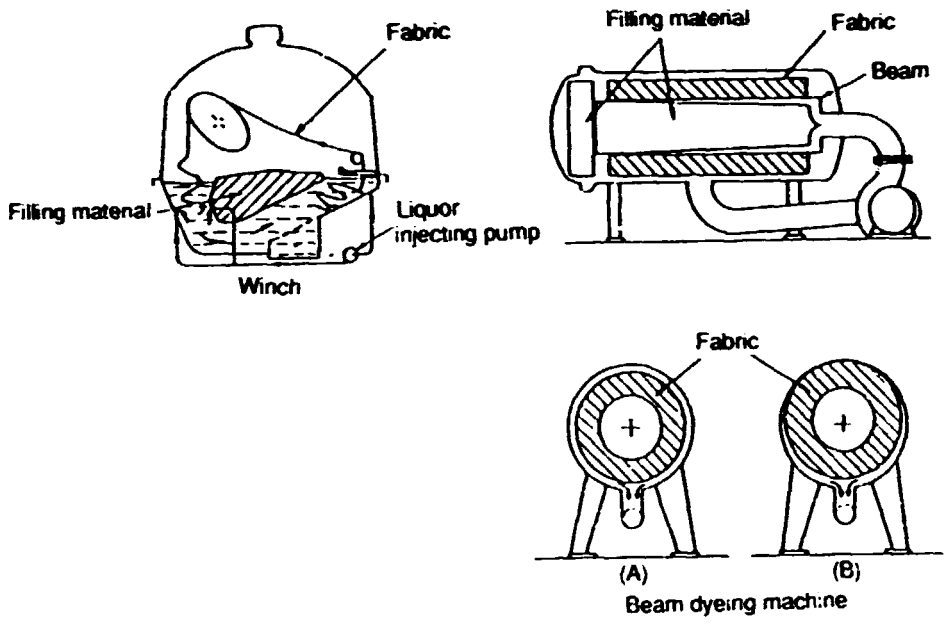


**Figure 16 Relationship between Bath Ratio and Production Cost in Reactive Dyeing**

(Kazuo Shiozawa: Science of Textile Consumption, p.24. Otsuka Textile Design School)

**(b) Utilization of low bath ratio processing equipment**

In order to use a lower bath ratio with the existing machinery intact, a method to insert a filling material inside the processing equipment, as shown in Figure 17, has been proposed. It has been reported that with this method, the bath ratio of a wince could decrease from 25:1 to 17:1, and for a beam a reduction was possible from 15:1 to 12.5:1, or even down to as low as less than 10:1 where the axis of the beam was made off center with respect to the container body, thus increasing the batch-up volume as shown in (B). More recently, low bath ratio processing machines which are built in with the above mechanisms have been developed and put on the market.



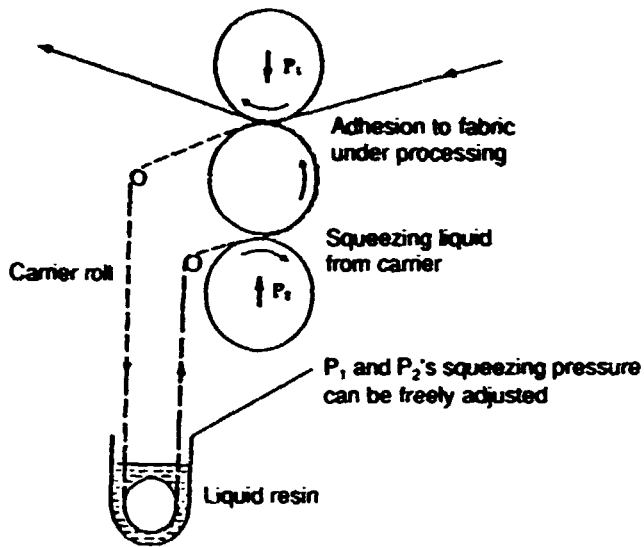
**Figure 17 Example of Low Bath Ratio Operation of Existing Processing Equipment through Insertion of Filling Material**

(D H SQUIRE. J. Soc Dyers Colourists. 92 109 (1976) )

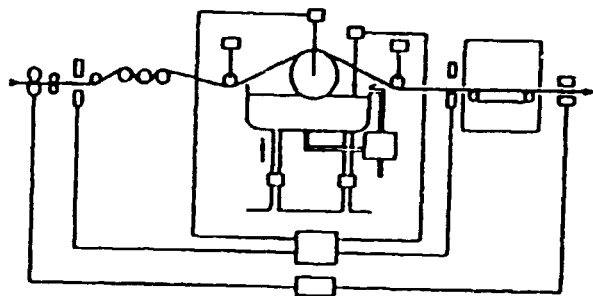
**(c) Utilization of low add-on equipment**

Several types of processing equipment with a mechanism to uniformly apply the fabric with a minimum amount of liquid necessary in semi-continuous and continuous processing systems are known to be typical examples of energy conservation techniques. Those in Figure 18 are typical of them.

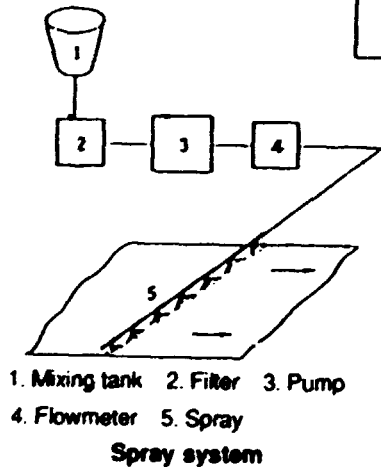




**Transfer padding mangle**



**Triatex MA system**



**Figure 18 Typical Low Add-on Machines**

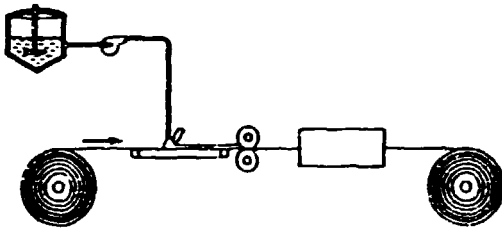
(Transfer Padding Mangle: P.F.Greenwood, Dyer, 153 25 (1975))

(Triatex MA System: P.T. Nordan: Am. Dyestuff Reporter, 69 35 (Aug. 1980))

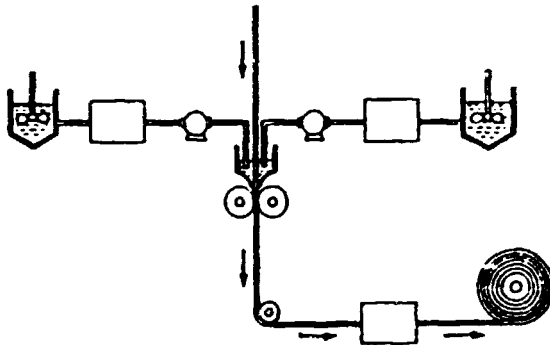
(Spray System: H.B.Goldstein.H.W. Smith, T C C, 12 49 (1980))

**(d) Extension of foam processing technique**

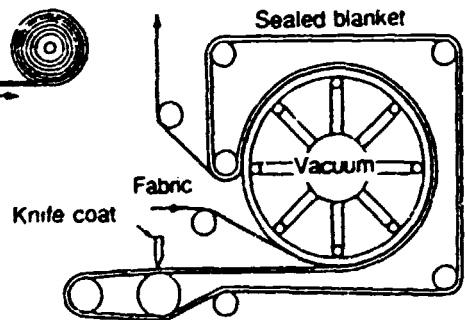
Figure 19 is a typical example of foam processing liquid applying equipment. The foam processing technique is used for the preparatory, dyeing, textile printing and finishing processes, with confirmed effects of promoting energy conservation, but it is desirable to examine details of usage and other practical conditions prior to application.



**a) Example of knife coat applying equipment**



**b) Horizontal pad applying equipment**



**c) Vacu-foam equipment (Montforts make)**

**Figure 19 Typical Foam Applying Equipment**

(a & b) T.F. Cooke: T C C, 15 13 (May 1983)

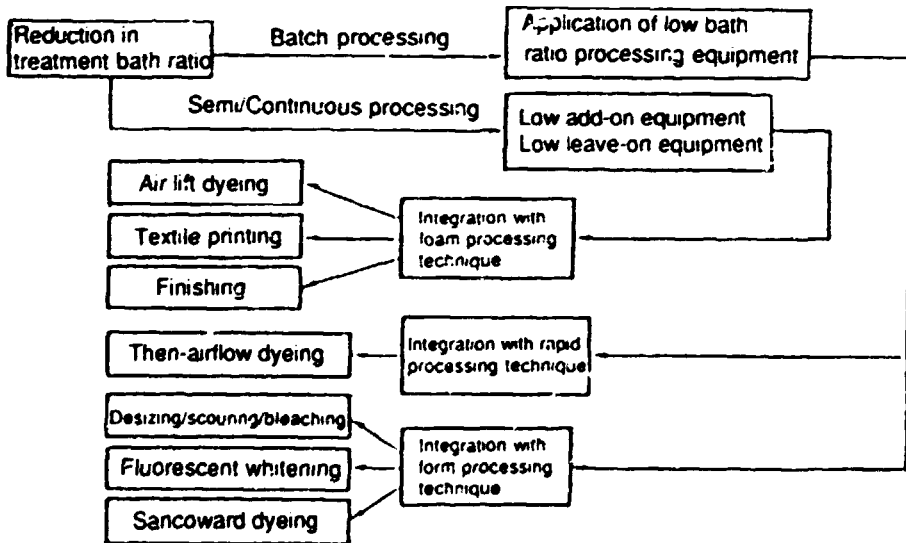
(c) R.D. Leah: J. Csc. Dyers Colourists, 98 422 (1982)

**(4) Reduction of processing time**

As has been pointed out, being a time saving technique aimed at improving productivity, continuous operation with an increase in the size of the processing machine can also further energy conservation. Likewise, for **batch processing**, the number of technical fields is increasing where the promotion of energy conservation is desired through a reduction in processing time. This tendency becomes more pronounced as the needs of the market become sophisticated. Techniques to accelerate the processing effect with rapid dyeing and plasma treatment are typical examples.

**(a) Rapid Dyeing**

Rapid dyeing which can drastically reduce the dyeing time and achieve remarkable time savings can also achieve great energy conservation effects when applied to polyester. In order to attain these effects, it is necessary to select dyes with assistants and provide appropriate dyeing equipment. Combined with the foam processing technique, the rapid dyeing technique may also have a potential of leading up to the development of new practical dyeing techniques. Figure 20 shows the position of the dyeing technique in the overall processing bath ratio reduction technique.



**Figure 20 Situation of Dyeing Technique in Processing Bath Ratio Reduction Technique**

(Kazuo Shiozawa: Textile Wet Processing Technologies, p.50, Chijin Shokan, 1991)

**(b) Accelerating techniques for processing effects**

Aiming at a reduction of processing time, the combined use of a number of new techniques are being studied and it has been reported that processing with plasma, ultrasound, magnetism and radioactive rays accelerates processing effects. Various methods are being investigated to reduce processing time through accelerating processing effects using these techniques in preprocessing, postprocessing, simultaneous processing, etc.

**(5) Reduction in temperature rise margin**

In many cases, unit operations of the dyeing process are carried out at high temperature. Therefore, to reduce the required margin of temperature rise from heating is very important in view of achieving fundamental energy conservation along with reductions in processing time. These measures need to be addressed from the following two viewpoints:

**(a) Raising temperature of inlet water**

If the temperature of the inlet water to be used in the dyeing process becomes relatively higher, the amount of energy to be consumed in raising it to the predetermined value will be reduced. For that purpose, cooperation within a company, or that involving more than one company (using low temperature inlet water at the dyeing factory for cooling purposes, and the high temperature discharge from the cooling system for dyeing purposes) should be investigated, as well as the utilization of natural resources (for example, geothermal and solar energy)

**(b) Development and introduction of low temperature processing techniques**

It is important to continue with technological development aimed specifically at lowering the processing temperature along with raising the inlet water temperature. It would naturally involve the integration of this method with the processing speed acceleration techniques described in (4) (b). Low temperature scouring, bleaching, dyeing and curing techniques are some of the practical examples of this.

**(6) Re-examination of drying method**

An important consideration along with the reduction of the processing bath ratio is a re-examination of drying operations. A drying operation is, in principle, inserted after every other unit operation and is an important operation which not only determines drying efficiency as such but also has a direct influence on the morphological stability and texture of the final product. For this reason, various types of drying equipment have been selected and put to practical use, depending on the fiber material and form involved. In view of implementing energy saving measures, it is particularly important to investigate the following three items:

**(a) Reduction of drying operations in number**

As can be seen from Table 7, a detailed study of typical preparatory process configurations reveals that drying operations are involved in relatively high numbers, ranging from one to four units or 14% to 40% of all unit operations in the entire process. Therefore, combinations of unit operations should be sought after such that drying operations between standard unit operations can be eliminated as much as possible. It is especially necessary to cut down on drying operations in preparatory processes which will not directly affect the product's performance or appearance quality. However, an operation which would have come after an eliminated drying operation would have to treat wet fabrics, thereby necessitating special measures that would enable wet on wet treatment.

**(b) Improvements in drying efficiency**

It is desirable to investigate possible improvements in the drying efficiency in terms of efficiencies of both the dewatering and drying steps. While it is well known that the most efficient methods of dewatering and drying are by means of a mangle and a cylinder dryer, methods which have been practiced for a long time, they are also known to have limitations in terms of applicable fiber materials and forms. It is necessary to investigate new drying methods (high frequency drying, microwave heating, far infrared radiation heating, etc.) together with other measures such as utilizing vacuum liquid removal, adding a drying-facilitating organic solvent to the treatment liquid, and combining foam treatment systems with non-foam ones.

(c) **Recovery of heat energy**

Along with active energy saving measures, it is important to carry out the collection and recycling of the energy used in unit operations. The collection of heat energy should start with thoroughly grasping the basic energy balance of each unit operation (eg. Ref. Figure 15).

(7) **Shift to solvent processing**

In the dyeing process, although water has been used as the only abundant and cheap resource so far, it is becoming difficult to obtain high quality water in large quantities at a low cost. The worsening of river pollution coinciding with an increase in population density is inevitably creating a situation where the cost of water will gradually increase, including the investment for improvements in waste-water treatment facilities. In addition, although dry-system processing has been contemplated for a long time due to the fact that most energy is consumed in the heating and evaporating operations, it has to date only been applied to a specific area on a limited scale. However, it is a technique which deserves attention as a promising process in the mid- to long-term future. This technique has the following two variations:

(a) **Organic solvent processing**

While the solvents to be used for dyeing processing are categorized into four main groups—halogenated hydrocarbons, petroleum derivatives, aromatics and oxygen-containing solvents—halogenated hydrocarbons are generally recommended as they do not cause a fire or explosion (provided that thorough countermeasures to groundwater pollution are taken). **It is well known that in terms of energy conservation, these solvents have an advantage over water-based ones in all of these aspects:** specific heat, latent heat for evaporation, heat needed for evaporation and evaporation speed. There are a number of proposals for solvent scouring, solvent dyeing and solvent finishing, including those already put to practical use as a differentiating technique.

**(b) Inorganic solvent processing**

Liquid ammonia is one of the agents being considered for dyeing applications as a inorganic solvent. Of its typical processing techniques, liquid ammonia mercerizing and liquid ammonia dyeing are given particular attention.

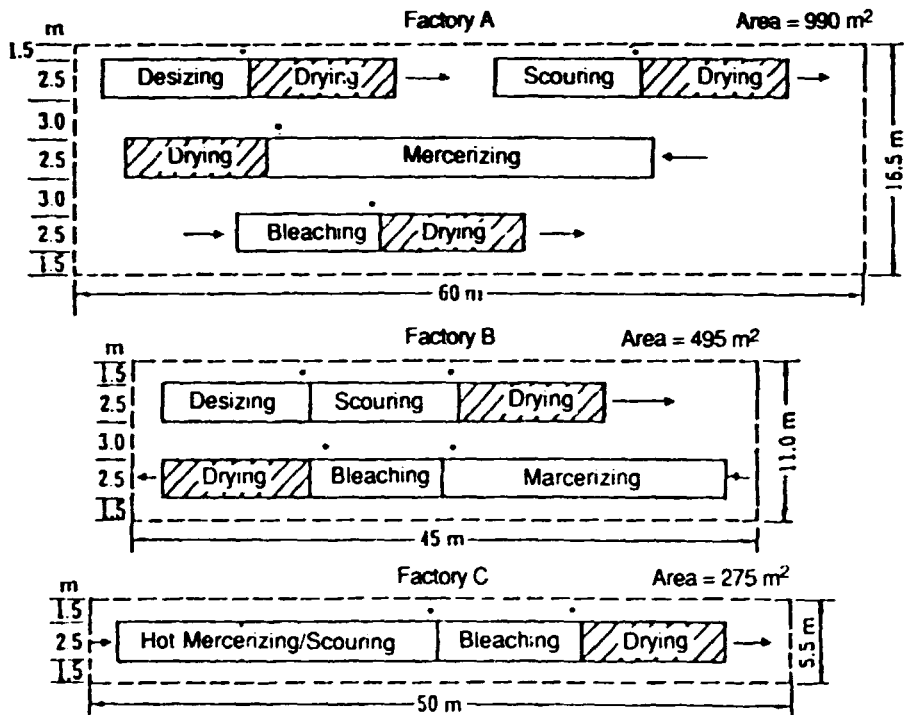
**(8) Use of continuous bath**

While textile manufacturing techniques which promote the conservation of natural resources include grease refinement from raw wool, the collection and recycling of warp sizing agents, and the re-use of alkaline waste liquid arising from the mercerizing process in a scouring bath, **in terms of energy conservation the use of continuous baths which utilize the residual heat of the system are particularly important in view of energy conservation.**

If the continuous use of a processing bath is introduced with the necessary conditions being met, thus allowing only those materials consumed in the dyeing process to be replenished, in particular with the unit operations designed for the batch method, it will greatly contribute to the recycling of heat energy in addition to achieving the conservation of natural resources and the rationalization of countermeasures to water waste. In the dyeing process with a high heat consumption, **the use of the continuous bath deserves particular attention as a technique whose practical application is an urgent task to help implement the remaining rationalization measures.**

**(9) Space saving**

With an expansion in the practical use of knit mercerizing and ammonia mercerizing, the characteristics of the hot mercerizing technique is also attracting attention. It has been pointed out that, since poor uniformity associated with the traditional mercerizing due to the hydrophobic nature of cotton grey fabric is dissolved in hot mercerizing which uses heated sodium hydroxide, the rationalization of the preparatory process can be greatly advanced. Figure 21 shows an example of comparing some space saving effects achieved by the introduction of hot mercerizing. Table 8 compares operating conditions of the same three factories. At the time a new space-efficient factory is being built, it is possible to incorporate a program to introduce such facilities as to be complete with factory-wide energy conservation measures.



Note Factory A: Although it has the same types of machines as Factory B, it has introduced a drying operation for each unit operation, emphasizing flexibility.  
 Factory B: Considers the production rationalization resulting from continuous processing.  
 Factory C: It has the same production capability as Factory B, but has reduced the preparatory process related to mercerizing

**Figure 21 Space Saving Resulting from Introduction of Hot Mercerizing**

(C. Duckworth, L. M. Wrennall, Soc. Dyers Colour Colourists, 93 407 (1977))

**Table 8 Comparison of Actual Operating Conditions of Three Factories**

Factory	Investment	Area (m <sup>2</sup> )	Workers (person)	Electric Power (kW)	Steam (kg/hour)	Water Supply (l/hour)	Waste Water (l/hour)
A	109%	990 (200%)	14 (155%)	242 (114%)	5,727 (130%)	14,535 (100%)	14,535 (100%)
B	100%	495 (100%)	10 (100%)	216 (100%)	4,386 (100%)	14,535 (100%)	14,535 (100%)
C	67%	275 (55.5%)	5 (50%)	114 (52%)	2,500 (57%)	7,785 (54%)	7,785 (54%)

(C. Duckworth, L. M. Wrennall; J. Soc. Dyers Colour Colourists, 93 407 (1977))



### **3.2.7 Clothing manufacturing**

The energy consumption share of the clothing manufacturing division which consists of large numbers of small-sized companies and their employees in the overall textile industry is not necessarily low, as seen from Table 1, but the ratio of energy cost to the total cost is relatively low, as can be deduced from Figure 25. However, the energy cost forecast is inevitably a gradual increase under circumstances where the production of high value-added goods is required, along with the implementation of labor saving measures, as a result of the challenging market environment characterized by personalized and diversified consumer needs, high demand for quality goods, short product cycles, etc. Therefore, it is desirable that a comprehensive rationalization program be investigated apart from reductions in energy consumption.

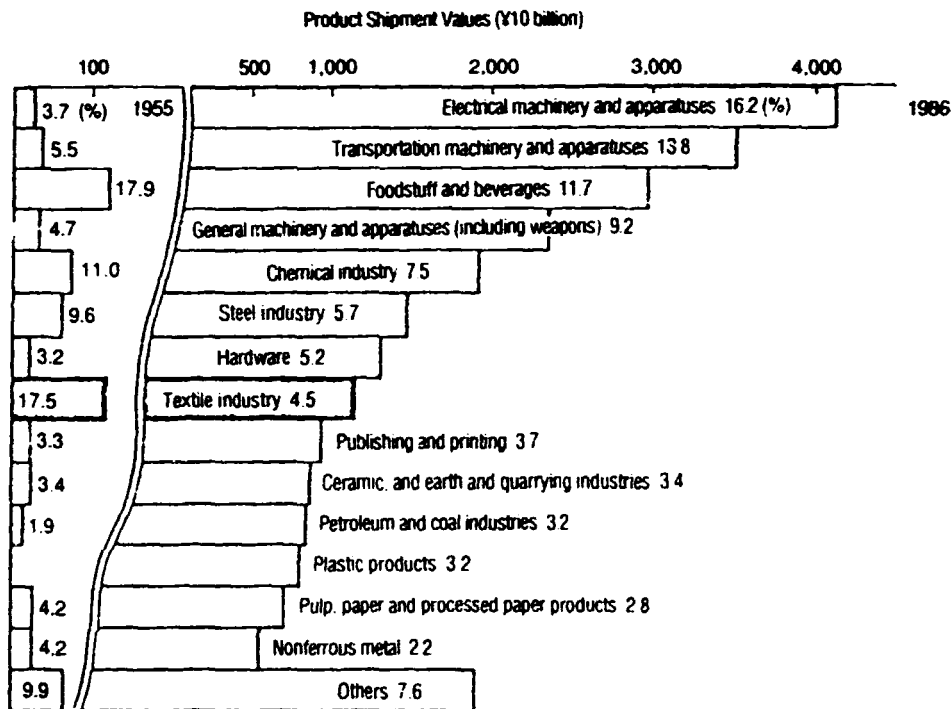
## **4. Actual Conditions of the Textile Industry in Japan**

(1) It is widely acknowledged that as a result of tireless rationalization efforts made by all companies involved, the textile industry has increased its production value by 10 times since 1955 (when it recorded the largest share in total shipment value as a bright star in the entire range of export industries), with a gradual decline in its share over the same period (Ref. Figure 22), though maintaining a stable growth as a mature industry.

### **(2) Structural changes in textile industry**

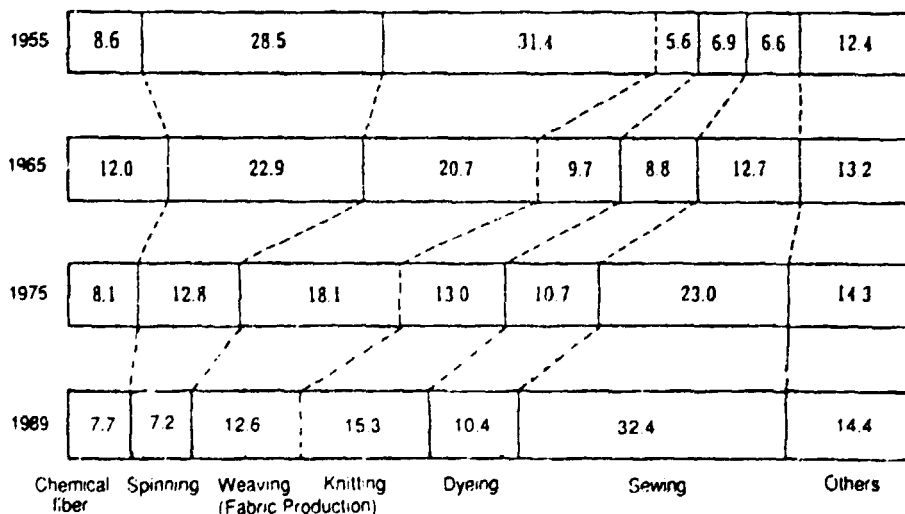
It can be seen that large structural changes occurred in the industry as the domestic companies carried out measures to overcome severe competition from overseas, in addition to the already intense competition among themselves. Figure 23 shows a typical example of this situation.

The shares in shipment value of major subdivisions in the textile industry have undergone drastic changes, such as a rapid fall in the fiber production and weaving divisions and a fast growth in the knitting and sewing divisions, reflecting the conditions surrounding the international as well as domestic textile markets.



Notes 1. The graphs were drawn using data from the Tabulated Industrial Statistics.  
 2. Figures inside the bar graphs represent shares for the respective fiscal years.

**Figure 22 Changes in Product Shipment Values for Various Industries**



Note Graphs were drawn using data from the Industrial Statistics Table Sewing combines various textile manufacturing including clothing manufacturing.

**Figure 23 Structural Changes in Textile Industry**

### (3) Progress in production rationalization

Table 9 compares and summarizes the progress made in production rationalization by some typical subdivisions of the textile industry.

**Table 9 Progresses in Production Rationalization by Typical Textile Industry Subdivisions**

Subdivision	Unit	Fiscal Year		1955	1960	1965	1970	1973	1975	1980	1985	1990
Fiber Production	kg/person/month			507	672	1,035	2,097	2,759	2,237	4,776	6,021	8,264
	¥10,000/person/month			14.2	24.7	42.4	90.8	106.8	101.9	231.9	286.1	326.5
Spinning	kg/person/month			294	375	479	613	734	726	1,166	1,419	1,655
	¥10,000/person/month			14.9	18.1	24.0	36.2	60.1	64.9	110.2	134.6	131.0
Fabric Production	m <sup>2</sup> /person/month			917	1,073	1,215	1,603	1,900	1,703	2,464	2,943	3,337
	¥10,000/person/month			8.8	9.7	12.8	25.3	41.8	47.7	74.3	91.4	137.7
Dyeing and Finishing	m <sup>2</sup> /person/month			4,907	5,450	7,569	7,431	9,379	9,964	12,028	15,424	16,502
	¥10,000/person/month			7.0	11.3	15.1	27.1	42.6	57.3	82.4	104.0	119.3

- Notes
1. Since quantities and sums were taken from the Annual Report on Textile Statistics and the Tabulated Industrial Statistics, respectively, they do not necessarily correspond to each other.
  2. Fabric only represents woven materials and does not include knitted ones.
  3. 1973 is the year when the oil shock broke out and as a result textile consumption reached its maximum.
  4. Sums for 1990 are the actual results for 1989.

Despite a strong tendency towards multi-line small-volume production in response to requirements for high value-added products from the fashion market, there is a marked growth in both per capita monthly production volume and product value. Regarding future trends, while the latter is difficult to estimate as it depends on the goods' prices, which are in turn to be determined by a balance between demand and supply, the former may be more easily foreseen as continuing with its increasing trend as a result of advances in the sophistication of production equipment, if profitability is ignored. However, due to the high level of rationalization already incorporated in such equipment, it will be reasonable to expect that attempts to achieve further improvements in this respect will inevitably meet with considerable difficulty.

#### (4) Changes in energy consumption

Table 10 shows changes in the average amount of energy required to make a unit quantity of each textile product over time. It illustrates the course of events as oil replaced coal as the dominant energy source supporting the backbone of society, with the textile industry actively introducing the fluid energy revolution amid high economic growth. This took place against the background of a low level stabilization policy for oil prices made possible by ample oil supplies, including the discovery of large-scale oil fields, as well as oil's convenience in transportation and utilization. It can also be seen that a shift in emphasis from oil with its sky-rocketing price to electricity occurred as a result of energy saving measures introduced after 1973. More recently, energy saving has been advanced, while a rationalized use of diversified energy sources is being pursued with a global view taking the oil market price etc. into consideration.

**Table 10 Changes in Amount of Energy Required for Unit Production**

Production Field	Fiber Production (t)			Spinning (t)	Fabric Production (1000 m <sup>2</sup> )	Dyeing and Finishing (1000 m <sup>2</sup> )			
	Electricity (kWh)	Coal (kg)	Fuel Oil (t)	Electricity* (kWh)	Electricity* (kWh)	Electricity (kWh)	Coal (kg)	Fuel Oil (t)	Gas (m <sup>3</sup> )
1955	2.905	—	—	1,795	37	48	—	11	—
1960	2.942	2,404	248	2,099	156	60	134	73	—
1965	3.029	660	1,200	2,138	196	76	33	144	—
1970	2.771	96	1,375	2,459	247	121	8	210	—
1973	2.762	—	1,362	2,851	301	147	—	205	—
1975	3.174	—	1,493	2,944	337	156	—	199	—
1980	2.367	—	890	2,865	339	171	—	155	—
1985	2.145	205	461	2,802	366	178	1	119	16
1990	2.244	481	313	3,125	395	201	5	127	23

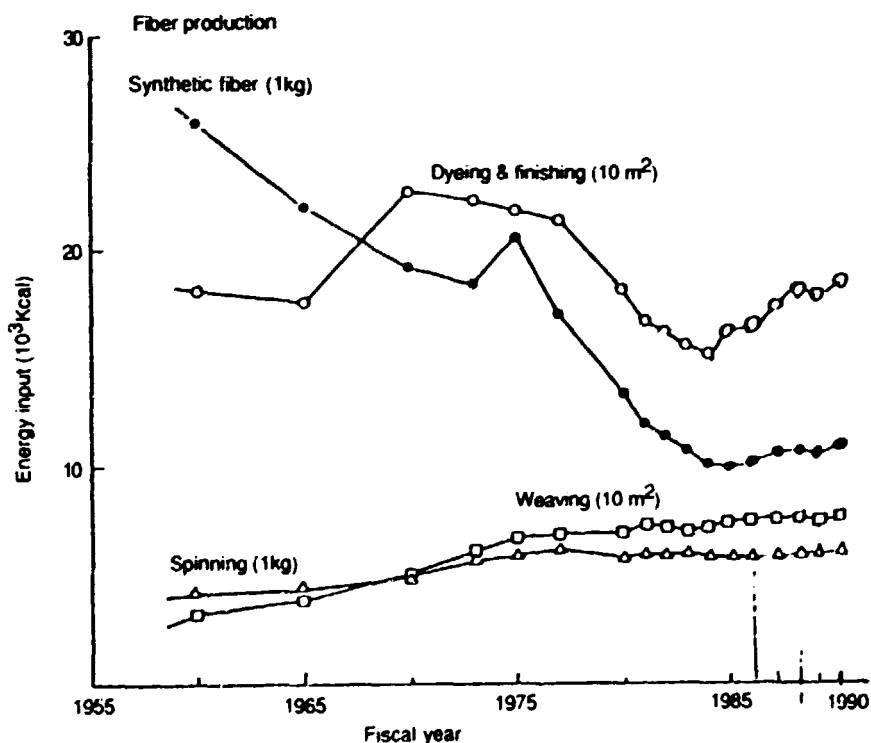
Notes 1. Data were taken from the Annual Report on Textile Statistics

2. \* shows categories which have alternative entries in the Tabulated Textile Statistics, such as 18.9% and 33.1% for spinning and fabric production for Fiscal 1980 as the ratio of fuel cost to the total energy cost respectively, but omitted from this table as their corresponding figures for absolute energy consumption are not known.

3. Gas combines the liquefied petroleum and city gases represented separately in Table 2, and shows their total in volume.

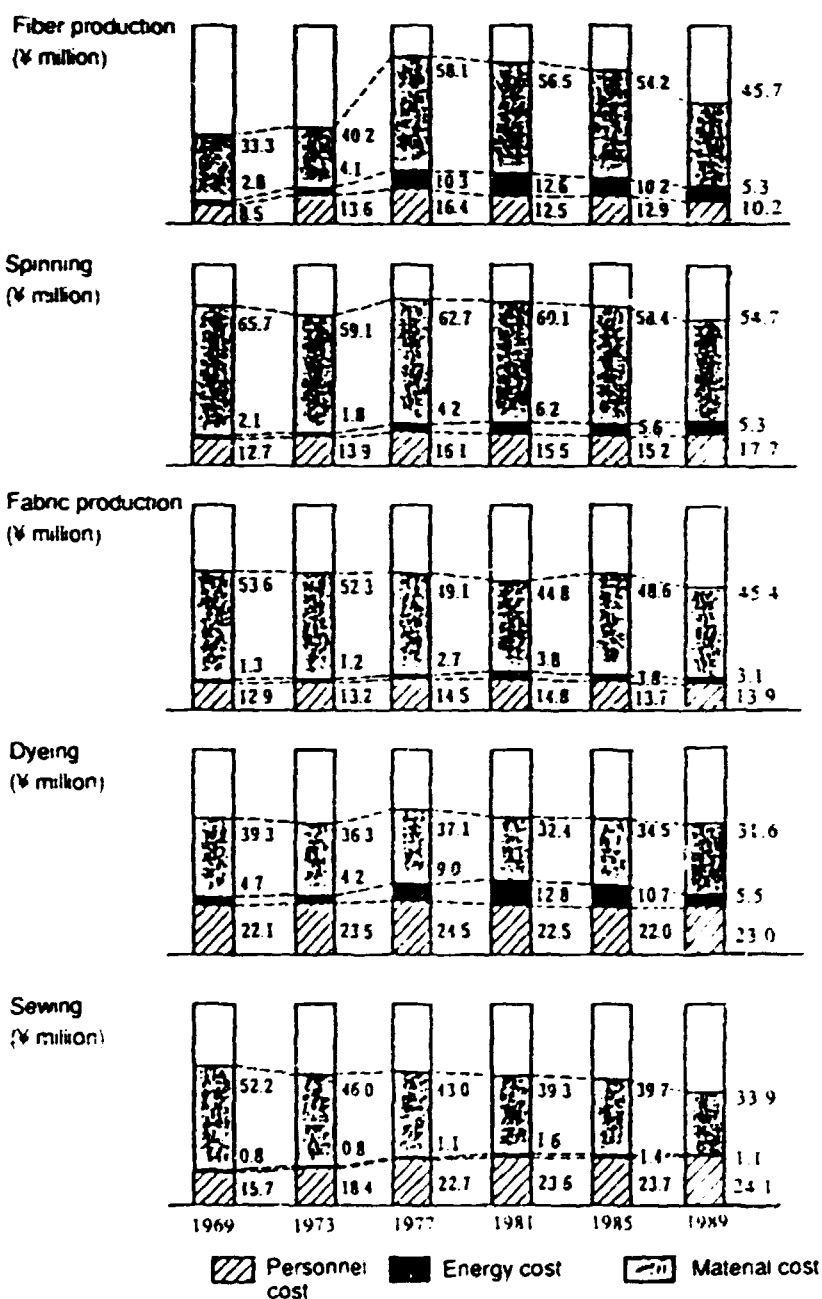
Converting each form of energy use required to produce a unit quantity of the product, as shown in Table 9, to its corresponding calorific value. Figure 24 graphically illustrates changes over time of the total of these values. It can be seen from the graph that while the oil shock which took place in 1973 encouraged a move away from oil and increased a relative dependence on electricity, comprehensive energy saving measures were also successfully implemented.

Although the achievement of significant energy saving can be observed in the fiber production and dyeing divisions, where energy consumption ratios are particularly high, it is also apparent that their energy consumption has actually been on the increase since 1985.



- Notes
1. The graphs were drawn using data from the Annual Report on Textile Statistics
  2. Energy was calculated with the following conversion ratios:  
 Electricity: 2,000 Kcal/KWh  
 Coal: 7,400 Kcal/kg  
 Fuel Oil: 9,400 Kcal/l  
 Gas: 9,900 Kcal/m<sup>3</sup> as the average of the following:  
 Natural gas: 9,800 Kcal/m<sup>3</sup>; City gas: 10,000 Kcal/m<sup>3</sup>.
  3. 10 m<sup>2</sup> of 100 g/m<sup>2</sup> Weight shirting can be woven from 1kg of yarn.

**Figure 24 Changes in Amount of Energy Required for Unit Production**



Notes 1. The graphs are drawn using data from the Tabulated Industrial Statistics.  
 2. Figures for Fiscal Years 1969 and 1973 involve businesses with 20 or more employees, with the rest covering those with 30 or more employees

**Figure 25 Changes in Cost Composition Ratios for Textile Products**

Given this phenomenon along with the steadily increasing energy use in the spinning and weaving fields, it can reasonably be assumed that rationalization efforts are reaching their limits in view of the current production structure designed to cater for the needs for multi-line, small-volume production from the fashion clothing market. Figure 25 summarizes and graphically illustrates changes in cost compositions for the production of major textile products, as shown in Table 13, after the oil shock. It can easily be seen that the influence of the energy component on the total production cost has been more pronounced after 1973, while at the same time effects of energy saving efforts are also noticeable. The gradual increase in energy consumption in spinning and fabric production and the upward trends after 1985 in fiber production and dyeing as shown in Figure 24 are both translated into a decrease in terms of the ratio of energy cost to the total, illustrating that comprehensive energy saving efforts have been made by the companies concerned.

**(5) Assessment of production rationalization level**

Although it is generally difficult to assess the level of production rationalization in the textile manufacturing industry in absolute terms, the dyeing and finishing subdivision is often put under scrutiny as a typical specialized technical field with a number of unknown factors. It consumes large quantities of energy carrying out multi-line processing tasks within short periods of time in order to directly reflect the market's needs. Table 11 shows the results of calculations to find the levels of productivity which could be obtained from dyeing operations assumed to have been conducted in a planned manner at some ideal factories, comparing them with the corresponding average figures for actual Japanese companies.

Since productivity drastically changes with the texture or structure of the original fabric and the details of processing, polyester-cotton blend fabric (shirting of approx 100 g/m<sup>2</sup> assumed), which is more likely to be processed in a uniform manner, was used as the material for this scenario. The table shows that the latest figure of average per capita productivity for Japanese companies is already comparable to those for hypothetical model plants, highlighting the fact that with the current level of technological development Japan has also reached a considerable level of production rationalization.

**Table 11 Example of Productivity Comparison for Hypothetical Model Plants**

Factory	Model A	Model B	Model C	Actual Result	
				Av of 11 Comps*	Av of 7 Comps**
Processing Details	Textile Printing	Bleaching/ Dyeing and Finishing	Bleaching/ Dyeing/ Textile Printing	Bleaching/ Dyeing/ Textile Printing	Bleaching/ Dyeing/ Textile Printing
Processing Quantities (10,000 m/year)	2,400	3,000	2,730	9,578	13,598
Number of Employees	225	205	207	992	941
Product Quantities (10,000 m/person/month)	0.8889	1.2195	1.0990	0.8046	1.2042

Note: \* and \*\* mean 1977 and 1988 averages of figures for companies specializing in dyeing with listed shares.

(Kazuo Shiozawa: Textile Wet Processing Technology, p.30, Chijin Shokan, 1991)

## 5. Structures of Textile Markets

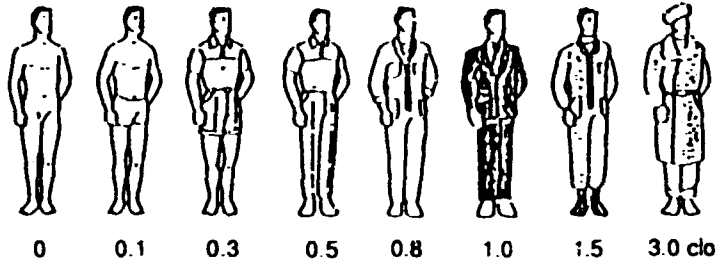
In general, it is well known that the developmental process of a textile market moves from a product-oriented stage, where all goods produced are sold to a consumer-oriented stage where the desired goods are only those which will satisfy the consumer's demand, comprising his wants and purchasing power. This is via a mass-consumption stage which is supported by a mass-production system. The characteristics of textile products demanded in the markets in these different developmental stages may be classified into price-sensitive mass-production type basic clothing, which applies to the earlier stages, and multi-line, small-volume production type fashion clothing which pertains to the last stage and needs to satisfy each individual consumer's taste.

### 5.1 Basic clothing

Assuming the amount of fabric necessary for people to live a physically comfortable life in a given environment can be derived from the weight of clothes which is enough to keep a certain level of body temperature, given such factors as air temperature, humidity and wind velocity prevalent in the region, basic clothing can be regarded as a cumulative total of such clothes. Figure 26 summarizes the relationship between some clo values



and examples of the corresponding clothes. Table 12 shows the results of calculations to find the weight of clothes required under average climatic conditions in summer and winter in three Japanese cities.



**Figure 26 Typical Relationship between Clothing and Clo Value**  
(P.O.Fanger: "Human Requirements to Indoor Climate" (1983))

**Table 12 Example of Effect of Climatic Conditions on Clo Value and Weight of Clothing**

Region	Season	Temperature (°C)	Humidity (%)	Wind Velocity (m/sec)	Clo Value	Required Weight of Clothing (g)
Sapporo	Jan	-4.9	74	2.3	4.1	4005
	Aug	21.3	79	2.7	1.2	1189
Tokyo	Jan	4.7	53	3.1	3.1	3034
	Aug	26.7	75	3.0	0.6	607
Fukuoka	Jan	5.7	67	3.7	3.0	2937
	Aug	27.3	76	2.9	0.6	607

- Notes
1. The clo values are shown assuming an average skin temperature of 33.5°C.
  2. One unit of clo value is 0.155°C/W/m<sup>2</sup>.
  3. The required weight values are calculated with Hanada's formula for female clothing:  

$$Y = 0.00103W - 0.025$$

Where Y: Clo Value

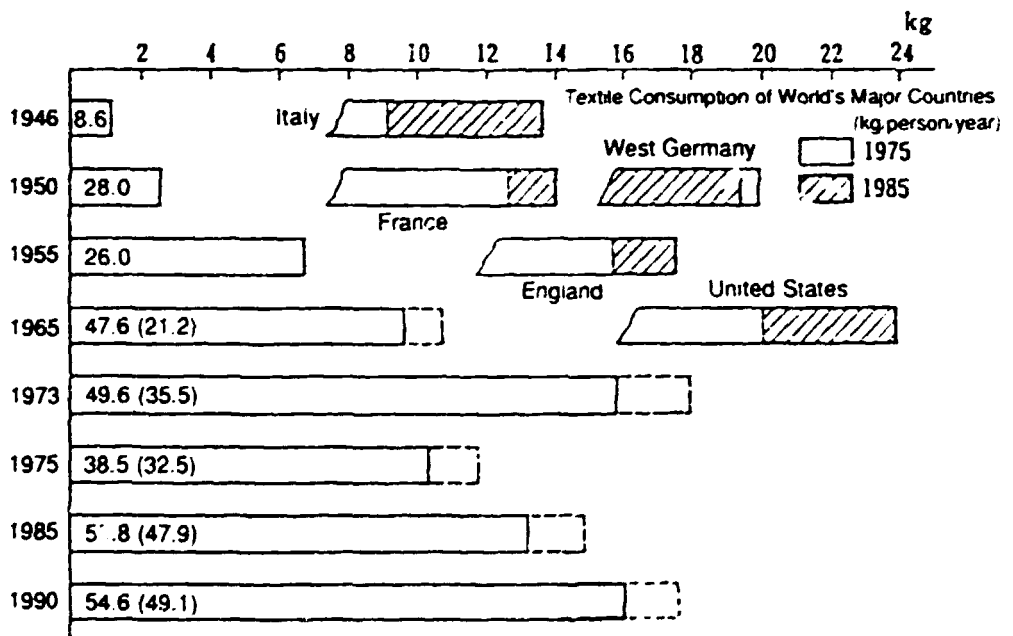
W: Total Weight of Clothing

(Japan-Korea Committee for the Investigation and Research of Industrial Structures: 'Consulting Engineer' May 1991 Special Edition, p. 35)

Although the ultimately required quantity is difficult to determine, the per capita annual textile consumption (kg/person) can be estimated through multiplying the above weight by coefficient *a* (obtained from the service life of a textile product and its number of units demanded per annum).

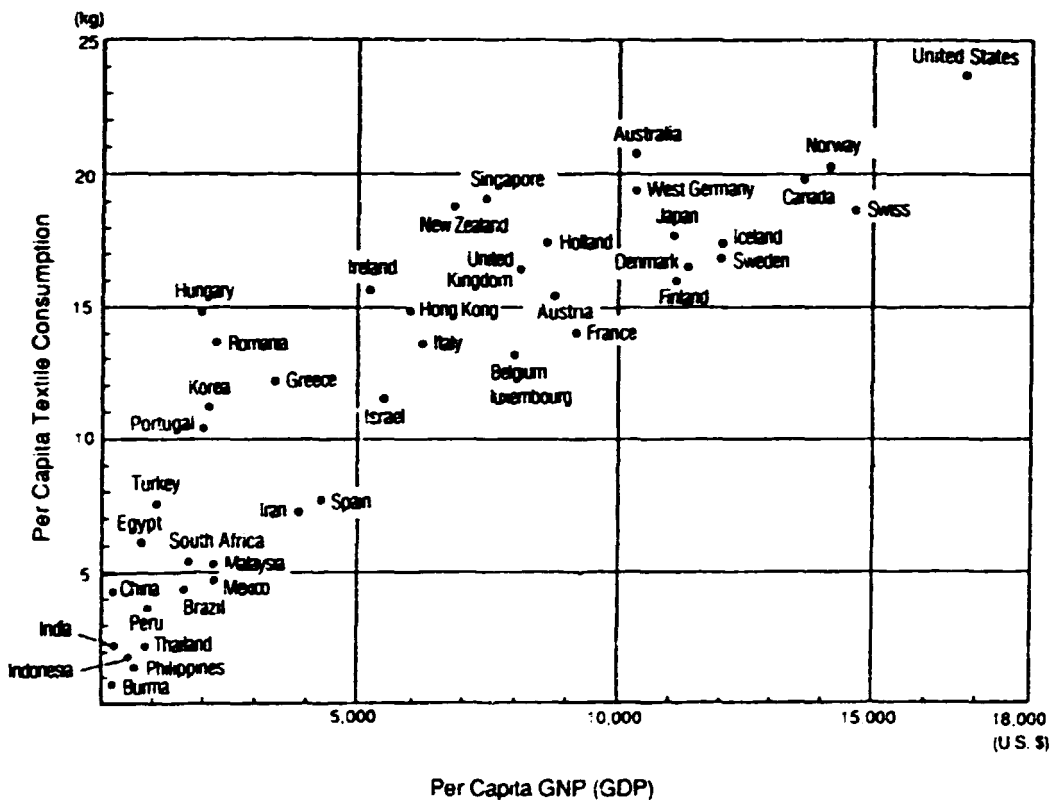
## 5.2 Fashion clothing

Although it is even more difficult to define the amount of fabric consumed in fashion clothing, a market which has satisfied the demand for minimum basic clothes has a tendency to shift its emphasis towards textile products with stronger fashion overtones and grow rapidly. This is illustrated by Figure 27, showing chronological changes in textile consumption in Japan and the world's major countries, and Figure 28, a graphically expressed correlation between per capita textile consumption and GNP.



- Notes
1. The figures inside the bar graphs with and without brackets are the shares of chemical and synthetic fibers in the total consumption, respectively.
  2. The broken-line portions of bar graphs represent the consumption of textile goods to be used as industrial materials.
  3. The sources are the Annual Statistics on Textile Goods for Japan and FAO data for other countries, respectively.

**Figure 27 Changes in Textile Consumption of Japan and World's Major Countries**  
(Kazuo Shiozawa Textile Wet Processing Technology, p.33. Chijin Shokan, 1991)



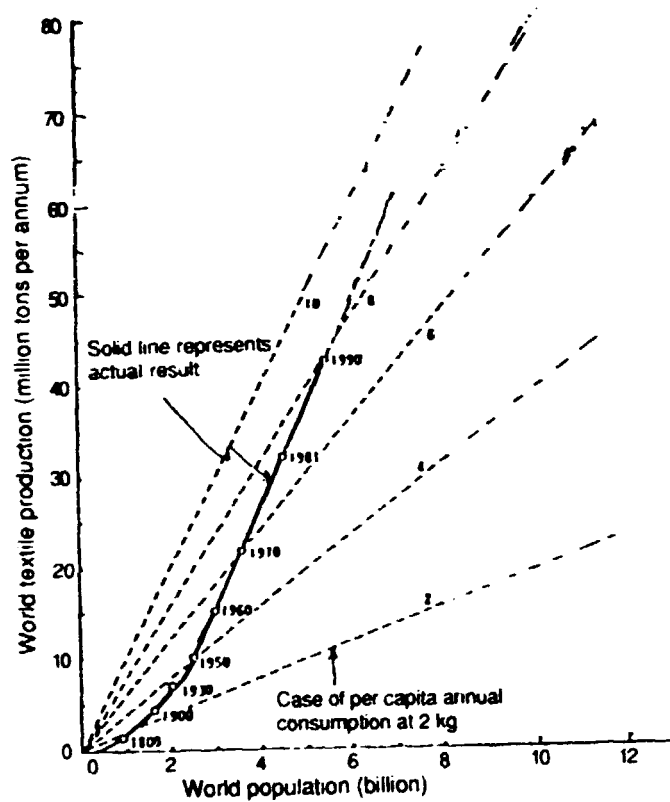
- Notes 1. Data on developed and developing countries are for 1985 and 1984, respectively  
 2. Entries for Japan, the United States, the United Kingdom, France and Italy reflect per capita GNP, while those for China and other countries are based on per capita income and per capita GDP, respectively.

**Figure 28 Correlation between Per Capita Textile Consumption and GNP (GDP)**

(Apparel Handbook, p 193, 1988 Ed, Society for Structural Reform in Textile Industry)

### 5.3 World's total textile demand and production base distribution

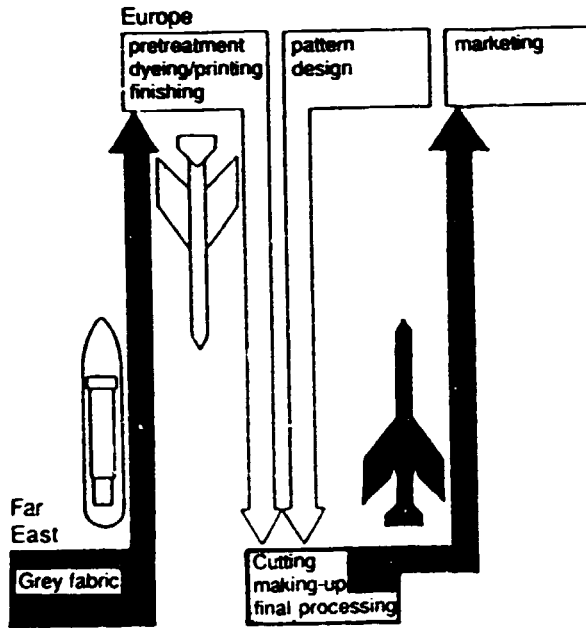
Figure 29 shows the relationship between world population and the total textile demand. Assuming a global environment in which world population will grow from the present 5.4 billion to 10 billion in 2050, and further to 11.6 billion in 2150 when it is expected to reach a static state, the total textile consumption is forecast to double, even using the current figure of per capita annual average textile consumption (8kg/person).



**Figure 29 Relationship between World Population and World Textile Consumption and Production**

(Kazuo Shiozawa: Science of Textile Consumption, p.24, Otsuka Textile Design School)

The textile industry is traditionally regarded as a typical labor intensive industry developed on the basis of abundant labor supply and has a tendency to expand to overseas markets once the domestic demand is satisfied, as illustrated by examples of the established textile industries of many developed countries. For this reason, even when the textile industry of a specific country is to be examined, it is widely recognized that a business strategy taking into consideration the global textile industry setup is very important. Figure 30 shows an example of the schematic representation of such a global setup of textile industries.



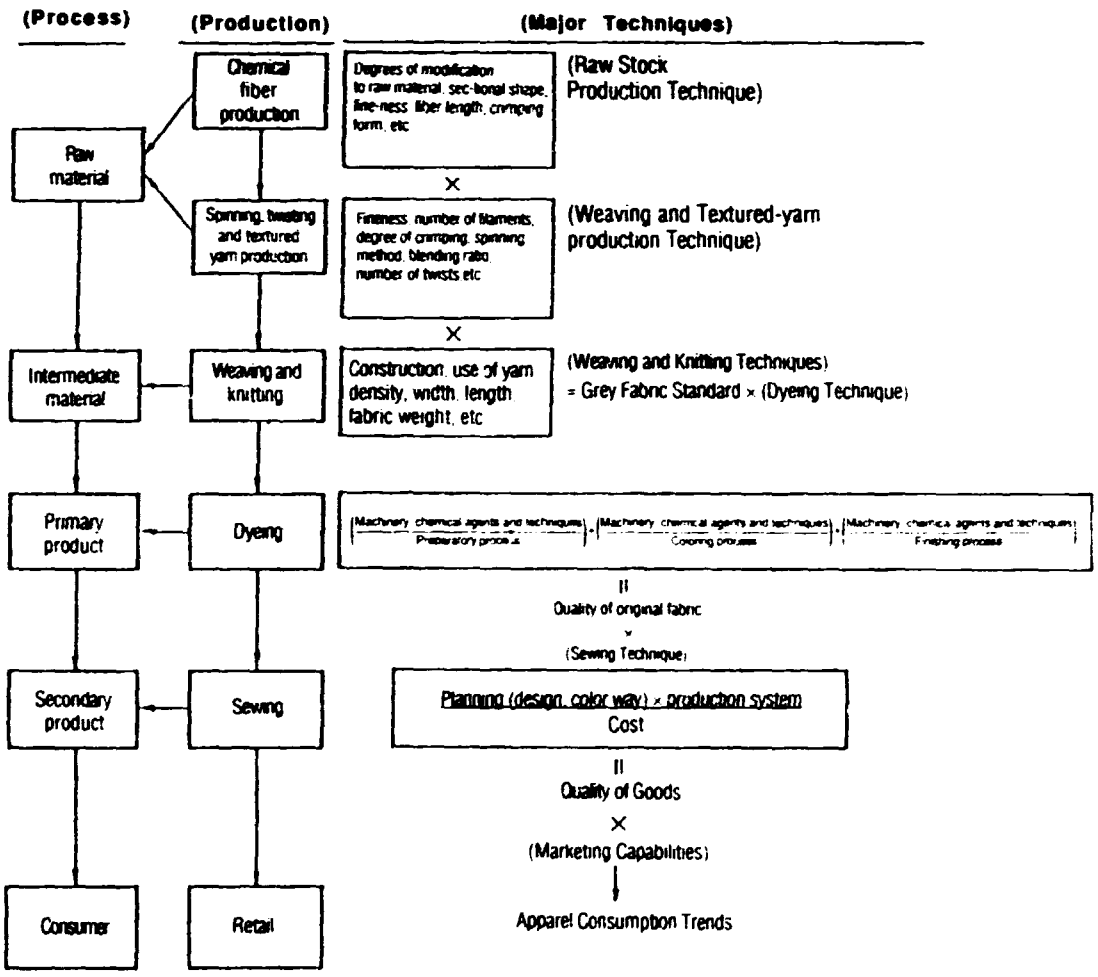
**Figure 30 Example of Schematic Representation of World Textile Industry**  
 (ADR Staff: Am. Dyestuff Reporter, 71.36 (Aug 1982))

#### 5.4 Characteristics of textile market

Most textile consumption takes place in apparel products, and the general tendency is that where further expansion is intended, it will be carried out through the development of industrial applications in which textile products are used as production materials (ranging from fishing nets, tire cords and canvas cloth to geotextile). Therefore, in order to study the textile manufacturing industry, it is generally sufficient to consider the production of apparel goods.

##### (1) Specialized techniques necessary for apparel goods production

There are a number of intertwined technical factors involved in various sub-processes or specialized technical fields which make up the overall production process that fabricates and reshapes the raw fiber material into the final textile product to be used by the consumer. Figure 31 summarizes typical examples.



**Figure 31 Specialized Techniques Necessary for Apparel Production**  
(Kazuo Shiozawa: Textile Wet Processing Technology, Chijin Shokan, 1991)

**(2) Comparison of characteristics of specialized technical fields**

In Fiscal Year 1989, the textile industry had a share of 4.4% in shipment value (19.2% in Fiscal 1955), 14.8% in the number of businesses (20%), and 10.4% in the number of employees (23.3%) in the overall Japanese manufacturing industries, characterized by a gradual decline in relative share, although in terms of absolute shipment value it has actually expanded to 1,053% of the Fiscal 1955 level.

As has been frequently pointed out throughout its development, the Japanese textile industry has a unique organizational structure consisting of groups of independent companies where all companies in a group belong to one of the above-mentioned specialized technical fields and operate in a horizontal specialization configuration. Table 13 shows a comparison and summary of the major indices of these company groups, classifying them in accordance with their specialized technical fields.

From these indices, common company characteristics for each group may emerge.

Namely, in terms of business size, the fiber production and spinning subdivisions are in contrast with the rest of the textile industry where relatively large numbers of small businesses coexist. In addition, these groups of small companies can only stay in business by relying on the supply of abundant cheap labor, exhibiting a legacy of the textile industry's past as a labor intensive industry, even on its path towards modernization. Table 1 compares the energy consumption shares of various specialized technical fields and it can be seen that energy consumption is relatively high in the fields of dyeing and finishing, fiber production, spinning, weaving and clothing manufacturing.

As for water consumption, the share of the textile industry in the entire manufacturing industries is 5.2% for fresh water and 1.1% for sea water. Considering the fact that most of this water is used for easy-to-recycle temperature control and cooling purposes, the industry's total water consumption cannot necessarily be regarded as high. However, as is widely accepted, the dyeing and finishing division is placed in a special position in that its water consumption is mainly for processing and washing purposes.

Table 13 Summary of Major Indices for Japanese Textile Industry (1989)

Technical Field	Fiber Production	Spinning	Twisting	Finished Yarn Production	Weaving	Knitting	Dyeing	Clothing Manufacturing	Others	Total
Number of Businesses <sup>a</sup>	91	693	2,463	122	8,040	9,681	4,546	31,094	5,531	62,261
Number of Employees	26,155	60,995	19,572	2,299	101,330	178,755	96,484	573,385	84,783	1,143,758
Average of Above	287	88	8	19	13	18	21	18	15	18
Total Shipment Value <sup>b</sup>	1,024,885	959,033	187,224	33,318	1,673,848	2,036,186	1,381,077	4,298,456	1,450,055	13,044,082
Average of Above	11,262	1,384	76	273	208	210	304	138	262	210
Total Wages <sup>b</sup>	131,055	175,264	35,535	6,447	251,456	370,973	349,686	1,057,493	242,537	2,621,342
Equivalent Monthly Wages	0.42	0.24	0.15	0.23	0.21	0.17	0.30	0.15	0.24	0.19
Cost Composition <sup>c</sup>										
Raw Material	45.7%	54.7%	48.1%	42.3%	45.4%	43.1%	31.6%	33.9%	54.0%	42.2%
Personnel	10.2	17.7	14.5	19.1	13.9	17.7	23.0	24.1	14.4	18.7
Fuel	3.2	0.4	0.4	0.6	0.5	0.3	3.7	0.4	0.6	1.1
Electricity	2.1	4.0	3.1	7.9	2.6	1.0	2.8	0.7	1.3	0.6
Subcontract	1.0	4.2	13.3	6.2	14.4	17.3	8.9	16.3	5.9	11.0
Business Ratio <sup>d</sup>	68.1	46.5	2.3	13.9	6.2	13.9	13.7	13.3	8.6	12.1
Total Water Consumption <sup>e</sup>	(m <sup>3</sup> /day)									
Fresh Water	3,996,255	1,277,963	15,519	13,132	460,498	113,927	1,182,986	68,935	103,248	7,232,441
Sea Water	413,534	1,050								414,584
Recycled Water	54.6%	35.5%	3.4%	0.3%	19.5%	0.7%	7.4%	1.9%	19.9%	39.2%
Main Usage	Cooling (66.4%) Temp Control (16.6%) Processing (12.3%)	Temp Control (33.5%) Cooling (4.7%) Processing (4.1%)	Temp Control (68.8%) Processing (10.6%) Cooling (4.3%)	Temp Control (42.8%) Processing (30.7%) Boiler (9.2%)	Temp Control (63.0%) Processing (17.2%) Cooling (7.5%)	Temp Control (41.0%) Processing (24.1%) Cooling (10.3%)	Processing (73.3%) Cooling (7.4%) Temp Control (6.7%)	Boiler (23.2%) Temp Control (16.4%) Processing (11.5%)	Processing (40.1%) Cooling (28.1%) Temp Control (15.3%)	Cooling (41.5%) Temp Control (29.7%) Processing (21.5%)
Average Water Consumption	71,126	3,762	272	691	898	84	1,881	17	223	1028

Notes: The data were taken from the Tabulated Industrial Statistics (Industry and Land, Water Volumes)

a) Businesses with four or more employees are covered.

b) Sums are shown in units of million Yen.

c) Cost compositions are based on data for businesses with 30 or more employees.

d) The Business Ratio is the ratio of those with 30 or more employees in all businesses with 4 or more employees.

e) The statistics for water consumption are shown after calculating from the 1989 data (businesses with 30 or more employees)



## 6. Conclusions

- (1) There is no panacea for achieving energy conservation in the textile manufacturing industry.
- (2) With the actual implementation of an energy conservation program, it is important to grasp the current level of energy consumption and its actual conditions in detail, set goals (energy consumption and corresponding cost), and achieve the goals through a company-wide effort as far as possible.
- (3) In the textile manufacturing industry, it is important to thoroughly understand that, depending on the trend of the market, the company is targeting, consumer requirements for the textile products to be supplied differ, thereby urging the implementation of energy conservation measures which are relevant to the production of the goods that suit the market.
- (4) Therefore, it is necessary to expect that, when multi-line, small-volume production type high value-added goods are produced, energy consumption may increase rather than decrease with production rationalization, in contrast with mass-production type goods.
- (5) When differentiated goods are produced, the share of energy costs in the overall production cost should be given importance rather than energy consumption.
- (6) It is reasonable to consider that ultimately desired energy conservation promoting techniques will depend on the development and practical application of innovative technologies in each specialized technical field.