3.3 Guideline for Energy Efficiency Improvement and Conservation for Textile Industry, Especially Dyeing and Finishing Process

3.3.1 Basic Items

(1) Introduction

The manufacture of the textile products includes raw materials production, medium material manufacturing and final consumption goods manufacturing. In the long term human history, the materials from natural were the raw material of the textile manufacture firstly. These materials are selected and improved, and then they were divided into natural fabric and other materials and they were shared by the entire world. The 18th century industrial revolution was started from the application of the steam engine into the textile industry. After the industrial revolution, many mechanized devices were invented and used to the natural faber industry. This makes the mass production of the developed high quality textile products possible.

The two world wars obstructed the supply of the natural fabric. This accelerated the appearance of the chemical fiber, which doesn't depend on the natural material. The invention of the artificial fiber that started from the viscose rayon in 1930's enabled the new fiber material to be produced. The various synthetic fibers which appeared after 1960's makes the manufacture process of the textile products very complex. In order to satisfy the vigorous demand for textile goods, until now, the development of the new manufacture equipments are continued in parallel with the invention of new fiber. In Japan, many auto companies were root from the textile equipment manufacturer, and are working as manufactures of the textile equipment until now.

The past textile goods were made by hand and the process needed the help of the natural material. However, after the industrial revolution, it changed into the mechanical industry that makes the coal as energy source. And now, the textile industry becomes a various energy sources industry.

Moreover, the synthetic fiber is produced in the petrochemical plant. That consumed large amount of naphtha as raw material besides using it as energy. The textile industry is response for part of crude oil consumption.

There are several methods to classify the textile industry. As the industry sub-sector classification, it is popular to classify by manufacturing process from the source of material manufacturing to the downstream of final consumption product. The classification is described as follows.

1) Fiber manufacture

It is chemical fiber manufacture such as the viscose rayon which is made by using the wood pulp as the raw material. And also it means the synthetic fiber manufacture that manufactures polyester, nylon, and acrylic fiber from petrochemical making naphtha as raw material. Moreover, the processing that raises the additional value to these artificial fibers is an important industry, too.

2) Spinning

It is the single manufacturing such as the natural fibers with cotton and wool as materials or the mix of natural fibers with the artificial fibers.

3) Weaving

It is the manufacturing of goods (textile) using of the single manufacturing as the above-mentioned industry 1) or 2).

4) Dyeing

It is the processes that gives dyeing, print and function processing to fabric and knitted (including other fibere and yarn, too) manufactured in the above-mentioned industry (3).

5) Sewing

It is the consumption products manufacturing that generally cuts out, and sews textile dyed in industry (4)

The products manufactured in above typical type process are bought and sold as the commodity, sometimes it is also dealt as the international commodity. In these five types process, there are specified manufacturing process matching the material and the usage respectively and the world standard products such as the synthetic fiber and the spinning yarn, But it's share is only several percent of the whole fiber products. The manufacturing method is not the same even in case of the world standard products.

Therefore, there does not defined the energy consumption intensity like the steel and cement industry, etc. However, in order to grasp the macro change, the company and national statistics adopt the energy intensity value of dividing the total energy consumption by total product amount. But when we use this energy intensity in the textile industry, it should be paid attention that multi-products are often manufactured at the same factory, and depend on the product the intensity are quite different.

(Both comparison between similar sub-sector and the estrangement analysis between enterprises are the effective methods to promote the energy conservation in textile industry. However, application of this method is limited, because the data for each manufacturing process is rarely collected and prepared)

(2) Outline and potential technologies on energy consumption of different sub-sector in the textile industry

The energy consumption characteristics of above-mentioned 5 sub sectors are shown in Table 3.3.1-1.

Table 3.3.1-1 Characteristics of Energy Consumption for each Sub Sector in Textile Industry.

	Synthetic F.	Spinning	Weaving	Dyeing	Sewing
Electricity	◎	◎	◎	○	○
Thermal energy	×	×	×	◎	×

For woven fabric, thermal energy for drying is used in sizing process.

From this Table, it can be found that electricity is main energy consumption in all of the processes except for the dyeing. The majority of electricity is consumed by the motor; Part of electricity is used by compressor for air compress.

Large amount of thermal energy is used in the dyeing process, and the factory generally adopts the ventilation fan for air-conditioning. However, in the synthetic fiber, spinning, weaving and sewing processes, the temperature and humidity control is very important to keep the products quality, so the air-conditioning equipments are installed in these process. In Indonesia, the large-scale chiller (electric or thermal absorption type) is prepared for air-conditioning, and the updating of these equipments greatly contributes to the improvement of energy-saving.

1) Energy conservation of the synthetic fiber equipment

In synthetic material manufacture and its yarn processes (Textured yarn), raw material Polymer is melted by an electric heater and extended with slow cooling; an electric heater is also used to maintain the shape of proper drawing of fiber. Because it request 1^0C temperature control accuracy for these heating equipment, the electric heater is the best equipment for such temperature control. In the first generation of synthetic material manufacture, the high purity polymer chip produced firstly, then it was melt again and the yarn processing is done. But now, in order to prevent resin stiffening, after the polymerization, it is warmed in yarn equipment and the yarn extension is also done at the same time. In the yarn processing, it can achieve great energy saving (more than 50%) by cutting the unnecessary resin re-melt energy. In Indonesia, the synthetic fiber company is classified into two types, one is the local joint management with Japan, and the other is the local company. In Japanese company, usually this method has been adopted, but it is not clear weather this manufacturing method is adopted in local company or not. Although the energy saving effect is remarkable, the introduction cost of direct melt spinning is high, the mechanism of the fiscal backup mechanism is necessary to introduce it. Moreover, because the yarn nozzle stiffening and clogging up due to even one second power failure will lead to catastrophic damage, the in-house power generation is a prerequisite in the synthetic material manufacture. Though the in-house power generation has been covered by the crude oil equipment before, it is gradually being replaced by the coal fired or gas engine power generation equipment because of quickly rising crude oil price.

2) Energy conservation of the spinning equipment

The spinning devices manufactured after the 1990's raise the productivity by speeding up rotary motion, therefore, it can reduce the energy intensity. The main improvement points include decreasing motor load by changing heavy metal material (iron or brass) into light material (aluminum or engineering plastic), cutting wasteful kinetic energy by starting and stopping swiftly due to introducing small diameter and improving the yield.

By replacing the belt pulley and V belt rotary control with inverter control, the waste of the power energy in the decelerator is cut, and it contributes to the electricity saving greatly. The improvement of the yield and decreasing of the switch loss time by optimizing the manufacturing condition of each kind product will lead to reduce of energy consumption for lighting and air-conditioning. Although, this will gain about 20% energy saving, the spread of such technology is doubtful, because of the high introduction cost and low electricity price. In Indonesia, this kind of investment had not been done because of cheap electricity price. In spinning industry, The power cut directly occurs the production line stop and defective goods increase, so the in-house crude oil diesel electricity generation is generally adopted. And there are two types of in-house generation. One is supplied all of the manufacture equipment electricity by the in-house power generator. The other is supplied the majority electricity by in-house power generator only when power failure occurred. Although some companies are considering about stopping in-house power generation due to of the skyrocketing crude oil price and convert into electricity purchase from PLN. And some are considering introducing the in-house power generation facilities using the other fuels except crude oil, because the price of PLN electricity is forecasted to rise.

3) Energy conservation of weaving and knitted equipment

a) Energy conservation of weaving equipment
In the weaving process, the non-shuttle loom has been rapidly spread in developed country from the 1980's.

In the past weaving machine, the horizontal yarn is putted into the ship shape case called as shuttle. In weaving mechanism, the shuttle is passed with high speed between warp yarns. Moreover, TOYOTA weaving machine developed by the Initiator of Toyota, TOYOTA SAKICHI, has spread widely worldwide. TOYOTA weaving machine can change the shuttle automatically when the weft yarn in the shuttle has been spend up. In order to move several gram yarns at right angles with warp yarn, about 1kg shuttle should be moved which consumes a lot of useless energy. It is difficult to improve the productivity because of this shortage. After about 20 year's research, the equipment maker developed non-shuttle loom which directly moves the yarn. The productivity increase more than 10 times by introducing non-shuttle loom (It is called as reformation weaving machine). 80% energy saving is achieved per unit products and energy is doubled per unit time. The non-shuttle loom has the following type.

- Griper type (the yarn griped by the small metallic clip called as griper is typed out with high speed)
- Water jet type (the yarn is typed out with the water current that gushed from a thin nozzle. However, it only can be used in the synthetic fiber that doesn't contain moisture)
- Air jet type (the yarn is typed out by using the high pressure air. Moreover, in order to make long distance move, the yarn is moved to the edge with the support of air current.)
- So called "RAPIER" type (the yarn is griped with a long slender metallic stick and moved with the stick. The yarn will be handed over to another metallic stick drawn out from the opposite direction and be transport to opposite edge. The former stick quickly returns to former position. The metallic stick ties to thin needle and repeats a right and left movement)

These non-shuttle loom need high initial cost because it is very expensive compared with the past type shuttle weaving machine. Although it has been spread widely in developed country from the 1980's, the introduction is slow in the developing country. However, the equipment redemption is short because of high productivity and remarkable energy saving effect; it is gradually introduced in many companies.

There is a paste process of the warp yarn in the weaving called sizing. In this process, the yarn is soak in the high viscosity grew, then it need to be dry to make the moisture transpire. In the past sizing equipment, after the yarn soak, the extra grew is scratch. Because of the development of the fluorine polymer chemicals, the scratch type is changed to squeeze type with roller. As results, dry efficiency improves because of a decrease in the amount moisture, and it leads to energy saving.

It is expected that the replacement of the non-shuttle loom in future in Indonesia. Because the restart time of the non-shuttle loom is long and the defective goods will occur when power failure is happened, the in-house generation equipment installation is a prerequisite to introduce this kind machine.

b) Energy conservation of the knitting machine

The knitting machine also is an important machine in the textile industry as well as weaving loom. There are vertical knitted and horizontal knitted machine. The horizontal knitted excellent elasticity that makes the casual shirts including the underwear very comfortable and it becomes the main knitted type. In the horizontal knitted machine, there are horizontal knitting machine using knitted sweater, and circular knitting machine used to manufacture the products with the same cutting method as the woven fabric. The needles of the circular knitting machine is installed in the circular metallic base called as cylinder, the mechanism making the needle called as sinker slipping up and down is rotate surrounding the cylinder. Although the diameter of the circular knitting machine was only 40cm until 1960's, more than 1 meter machine has been mass-produced because of accurate advancing of the metalworking now. Productivity increases in geometrical series times when the diameter grows.

Because 3-4 times production of the machine can be gained with the same motor, about 50% energy saving can be realized.

However, the extremely size of diameter has disadvantage for restriction of manufacture width, except for special usage, the machine of 1.5 meter diameters is widely spreading. The main reason of the increase of the diameter of the circular knitting machine is that it is good for yield of the large width textile during the needlework stage. The energy conservation and high productivity are the sub-effects. Because the large diameter circular knitting machine needs large investment, as for the introduction pattern of it, it was introduced by the big scale company firstly, and then spread into the small and medium scale company.

4) Energy conservation of the dyeing equipment

The dyeing process is the unique process using more thermal energy except electricity in the textile industry. The main thermal source is steam from the boiler. Because of oil price rising, the fuel of the boiler is changing from the crude oil to coal, natural gas and biomass and so on. Especially, the coal, low fineness coal, is the main fuel in Indonesia. In the region where the natural gas can be supplied, the fuel is changing to natural gas. In the typical textile manufacture factory in Indonesia. Co-generation system has been found to be introduced. And it uses coal to generate electricity and the low pressure steam after power generation is used for the thermal source of the manufacture equipment and it uses gas-engine and absorption chiller with hot water collection or waste heat recover. This type system can gain high energy utilization efficiency that makes it more effective of the energy cost reduction compared with China and Thailand where the textile sub-sector is classified same as Indonesia

The electricity is mainly consumed by driving motor in the dyeing (Various size motors are used.). Almost of these motor need velocity control. The old motor control equipment almost used physical velocity control or DC control. As for the amount control of blowing fans and water pomps, the valve and damper was used. In the device manufactured after 2000, both rotation control and flux control use the inverter control. It can gain great electricity consumption reduction. The energy consumption comparison of old and new equipment is described in the next chapter in details.

The poor combustor efficiency of the boiler in dyeing is often pointed out by the boiler expert. However, the consumption steam amount in dyeing always changes greatly and it is impossible to maintain the best air-fuel ratio. In Japan, plural small package boilers are parallelly set, the number of operation boilers is changed with the change of steam pressure. Such system called as decentralized boiler system has been spread. The greater part of companies introduced this system in the region where the city gas supply is received. In addition, because the transportation of LNG becomes possible recently, the introduction of the decentralized boiler system also is increasing in the region without city gas supply. Because of the high combustor efficiency of each operating small boiler, the decentralized boiler system can gain great energy saving. The conversion of the decentralized boiler has not been started in Indonesia.

This decentralized boiler system is also very effective from the view of the carbon dioxide emission reduction. However, the coal boiler is chosen in dyeing considering the economic priority in recent years in Indonesia. Although this is naturally tendency, it is worried.

5) Energy conservation of sewing equipment

The sewing equipment include the plotter for paper pattern, spreading device that spread fabric in the cutting table, cutter that cut fabrics, sewing machine for needlework and embroidery device. The total electricity consumption is small, because almost all of these devices use motor with the capacity lower than 0.25kW. The majority energy consumption in sewing is used for lighting and air-conditioning. Although, the energy conservation method is same as business building, the heat generation from sewing machines and the high population density per floor is different from the commercial building.

(3) Energy conservation potential of each sub-sector in the textile industry

In above paragraph, the general situation of the energy consumption structure for each sub-sector has been described in the textile industry. When just depending on the statistical data, the energy consumption amount for different process can be roughly ordered as (1) dyeing, (2) synthetic fiber, (3) spinning, (4) weaving, and (5) sewing.

Because there has no statistical data about the percentage of energy consumption for different sub-sector in Indonesia, based on the condition of Japan and other country, they were assumed as dyeing (40%), spinning (20%), weaving (15%), synthetic fiber (15%), sewing and others sub-sectors (10%).

Two targets of the energy conservation potential in these sectors is presumed and listed in Table 3.3.1-2. One target is assumed to be achieved without large-scale investment (expected by 2015). The other target is by 2025 target which needs large-scale investment.

Table 3.3.1-2 Estimation of Energy Conservation Potential for Each Sub-sector in Textile Industry

	Dyeing	Spinning	Weaving	Synthetic fiber	Sewing and others	Total
Percentage	40%	20%	15%	15%	10%	100%
	Energy conservation potential for each sub-sector					Total of textile industry
2015	20%	5%	5%	0	0	10%
2025	50%	20%	20%	20%	0	30%

In spinning and weaving sector, the improvement of the energy conservation can be achieved by improvement of air-conditioning facilities and power efficiency with little investment. In addition, the further energy consumption reduction can be gained by introduced the reformation type spinning machine (Jet spinning) and weaving machine (non-shuttle loom) to improve productivity and yield greatly in the mid/long term.

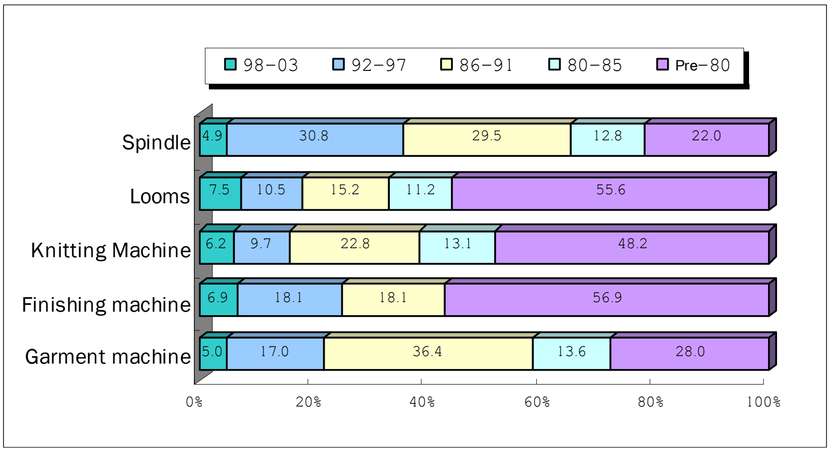
On the other hand, in the dyeing sector with the maximum energy in textile industry, if only to improve the ventilation fan level and not to change the air-conditioning facilities, the energy saving effect can not be desired. Energy saving due to the large capital investment for equipment introduction in dyeing not only need the improvement of yield and the review of manufacture process, but also need negligible remodeling and control devices addition for part equipment.

In Indonesia, the equipment investment in textile industry was actively done until 1992, After that, the investment environment declined remarkably due to the uneasy political situation and the devaluation of exchange rate. That induced the investment decrease especially after 1998. Preparation of an attractive investment situation can or is only able to improve the energy conservation.

○ The average use time of the equipment in textile industry is prolonged, and superannuation progresses greatly. These are the main reason of the deterioration of the productivity and competitiveness.

Spinning:	15 – 35 year	Weaving (shuttle looms):	10 – 25 year
Weaving (shuttle less looms):	5 – 10 year	Knitting machine:	10 – 25 year
Finishing Fabric machine:	15 – 25 year	Sewing machine:	15 – 25 year

Equipment introduction time and shear in each sub-section of textile industry



Source: API

Figure 3.3.1-1 Investment Transition of Textile Sub sector in Indonesia

In the next paragraph, key point for energy conservation is described in details on the highest energy saving potential sector, dyeing.

3.3.2 Key Point for Energy Conservation in The Dyeing

The dyeing includes the manufacturing of various devices combination, such as, end-products, material and the target quality of the final product. These complex combinations can be classified as three kinds of process. They are 1) preparation process, 2) dyeing process and 3) finishing and final process. The content of the three kind of process can be subdivided some sub processes further. The equipment of these sub processes is greatly different according to the manufacture type of the processes, which is done by the continuous dyeing method or by the batch dyeing method. And so, the energy conservation technique is also different.

Though the thermal energy consumption is greatly different because of the different device and manufacture method, the typical process order of the energy consumption is as follow: (1) Washing process, (2) Drying process, (3) Steaming process, and (4) Heat-treatment process

(1) Classification of dyeing

1) Continuous dyeing method

The relation between fabrics and the social stratum was very closely according to the fabrics history of human beings. Because the fabrics color was used to divide the top and bottom stratum in the stratified society, the dyeing technology was an important technology for the statesmen. From prehistoric to the first half of the 20th century, all of the dyeing method was the batch dyeing method. On the other hand, in the latter half of the 20th century, based on the background that the belt conveyer method has been adopted by many industries as a manufacture method of low-cost and mass products because of the remarkable advancement of various machine device and chemical goods, the continuous dyeing method was developed in the dyeing.

Because all of the past dyeing method was batch dyeing method, the dyeing consumed a lot of time and resource. However, the continuous dyeing method can produce high-quality dyeing goods in a short time. In addition, the great energy and water reduction can be realized by using the continuous dyeing method.

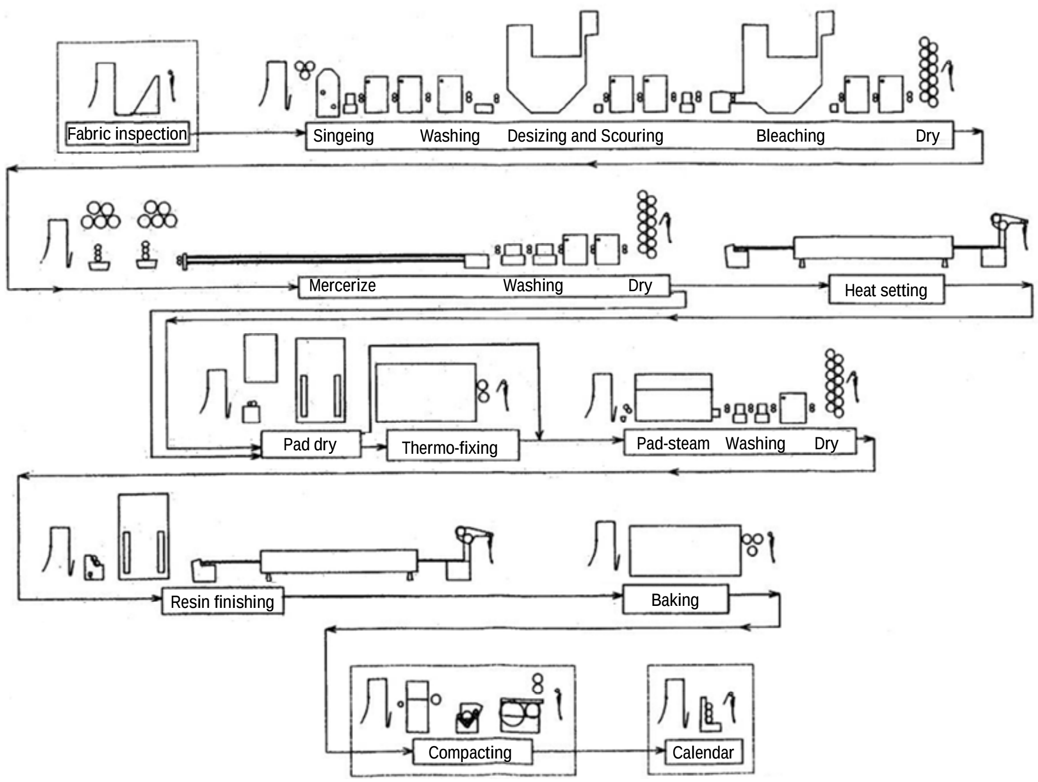


Figure 3.3.2-1 Continuous Dyeing Method Process and Device for cotton and Polyester Mixed Fabric

However, because each process is divided according to the different purpose, the entire device composition becomes complex and large scale in continuous dyeing method. That leads to high investment naturally. However, the equipment redemption of the continuous dyeing method is quickly because of the rationality of processing, and so, the comprehensive economic effect is very larger.

Figure 3.3.2-1 shows the outline of the typical continuous dyeing method of cotton fabric.

Input→[Singeing]→[Desizing *1]→[Scouring*2]→[Bleaching*3]→[Mercerizing*4]→ [Width set]→ [Pad・dry]→ [thermosol]→ [Washing・drying]→ [Width set]→ [Heat-treatment]→ [Shrink proofing] →[Checking]→[Shipment]

The washing and drying equipment is accompanied with the above-mentioned process *1~*4, and the steaming device is equipped in the process of *1~*3.

In a word, the above-mentioned continuous dyeing method is composed of four typical thermal energy consumption processes, (1) washing process, (2) drying process, (3) steaming process, and (4) heat-treatment process.

In addition, the previous 6 processes are the preparation process, the processes from pad and dry to washing and drying are the dyeing process and the finishing and final process are the 4 processes after width set.

2) Batch dyeing method

As above mentioned, the batch dyeing method is the old method. This method also has 1) preparation process, 2) dyeing process and 3) finishing and final process. The further subdivision in each process is not done like the continuous dyeing method. In the extreme case, the dyeing, washing and drying are progressed in the same device when the preparation process ends. Then the finishing and final process and checking are done.

The investment of the batch dyeing method is comparatively small (the processing amount is also little). That make it is easy for the small and medium size company to invest.

However, considering energy and resource consumption, compared with the continuous dyeing method adopting equipment for each processing purpose which makes it can exclude energy useless as much as possible, the batch dyeing method using the same or few devices has much energy and resource useless.

Why the batch dyeing method with so much shortage is also adopted compared with the continuous dyeing method. The reason is that some goods can not be processed by the continuous dyeing method because of the material and structure of it. The materials can not be processed by the continuous dyeing method is listed as follow.

- Materials need pressurizing (more than 100°C) treatment (such as Polyester)
- Yarn and fiber such as case and cheeses excluding fabrics.
- Materials which are transformable with tension like knitted fabric or the fabric which elasticity yarn are knitted.
- Physically weak materials such as silk, wool, and rayon
- The fabric structure is disproportionate like race.
- Cowlick materials such as velvets and corduroy.
- Pile fabric and knitted such as towels

It can be found that the continuous dyeing method is advantageous in the processing of the materials that doesn't easily transform such as shirt fabric, sheet and work wear. But it is unsuitable for the materials which can not be dyed under the normal pressure, weakness for the physical power, easily transformable and swelling. Such materials should be processed by the batch dyeing method basically, and they would consume lots of energy and resource.

However, in order to reduce the energy and resource consumption, some efforts has been done for the batch dyeing method, such as not always using the same device, using the device matching the process purpose according to the material, or adopting part of continuous dyeing method although in the batch dyeing method in process.

a) Processes of polyester filament fabric

Because polyester filament fabric can not be dyed under the normal pressure, it is dyed with 0.5MP pressure. It is a typical batch dyeing method example. The dyeing processes of the filament fabric with 100% polyester are shown in Figure 3.3.2-2.

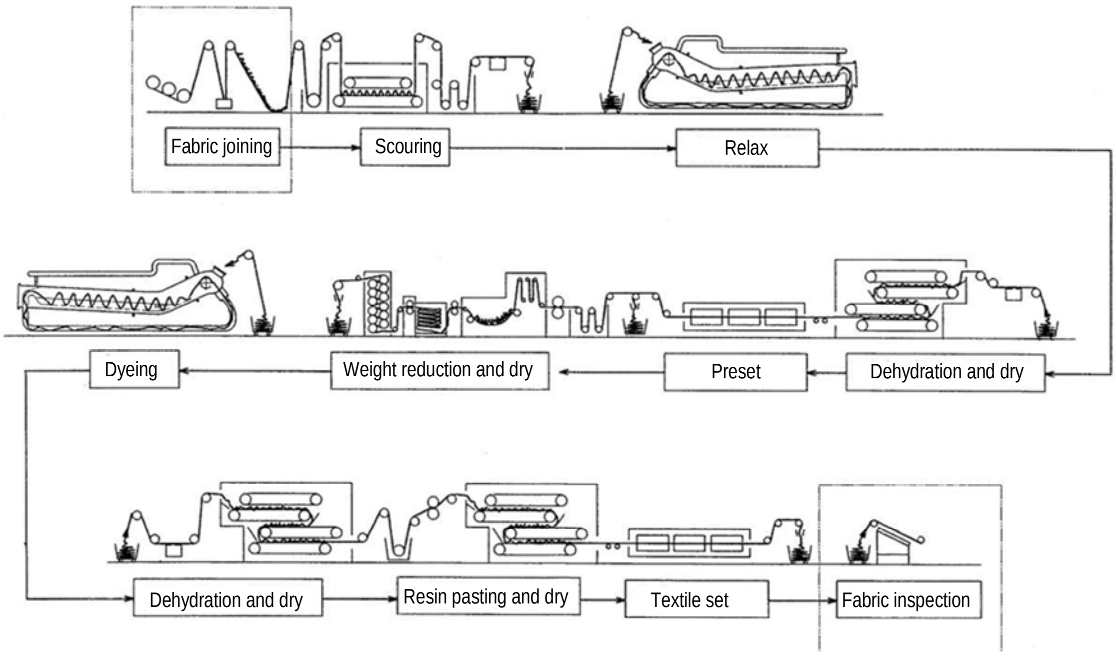


Figure 3.3.2-2 Dyeing Processes of the Filament Fabric with 100% Polyester

In Figure 3.3.2-2, the preparation process includes the processes from fabric joining to weight reduction and dry process. The dyeing, dehydration and drying processes are included dyeing process. The finishing and final procedure is the processes after resin chemical pasting.

In these processes, although the relax process is the batch dyeing method, it is divided into 4 processes by using water, chemicals and energy.

Warm water supply→Hot rinsing→Remaining liquid exhaust→Warm water supply→Soaping→Remaining liquid exhaust→Warm water supply→Hot rinsing→Remaining liquid exhaust→Cold water supply→Rinsing→Remaining liquid exhaust (If there is no warm water to supply, cold water can be supplied and warmed up by steam. If the temperature of the warm water is lower than the required temperature, it also should be warmed by steam.)

In the dyeing process, the following procedure are done. Although the old device of these processes is the manual operation, the latest device is operated by the computerized program controller.

Cold water supply (**Fabric input in dyeing bath** at the same time)→Dyestuff dissolution and injecting into dyeing machine→Warming and temperature rise→High temperature dyeing→Dye liquid cooling (cooling the heat exchanger by the cold water injection.)→Remaining liquid exhaust→Cold water supply→Rinsing→Remaining liquid exhaust→Cold water, reducing agent, and alkali chemicals injection→Temperature rise→Reduction washing→Remaining liquid exhaust→Cold water injection→Temperature rise→Warm rinsing→Remaining liquid exhaust→Cold water injection→Rinsing→**Fabric taking out**→Remaining liquid exhaust

The above-mentioned processes line is an example in Japan. The scouring and the weight reduction processes are done by continuous method. The possibility of these processes is supposed to be done by the batch dyeing method in Indonesia.

b) Cotton and mixed goods knitted fabrics process

In the past, the circular knitted fabric used for underwear and T-shirt is comparatively simply processed with the small-scale processing. But now, it changes into the woven fabric product as a golf shirt and a casual material from the 1990's, and becomes multi-use.

However, because these materials should transform with the lengthwise and crosswise tension, the majority processes of it should select no tension equipment. In addition, the high efficiency drying equipment without tension is necessary because there are a lot of gaps make the materials maintains moisture easily (high water ratio) and not easy to dry. This kind of process just started in Indonesia recently, and most process devices are diverted into the above-mentioned polyester filament fabric device. Because of large difference between polyester and cotton in behavior in dehydration and drying, dyeing materials in dyeing machine and water ratio (polyester is 1:6, cotton knitted is 1:12), much more water used for dyestuffs and steam used for temperature rise are consumed. Moreover, large energy is needed in the drying process, and an efficiency drying equipment is indispensable.

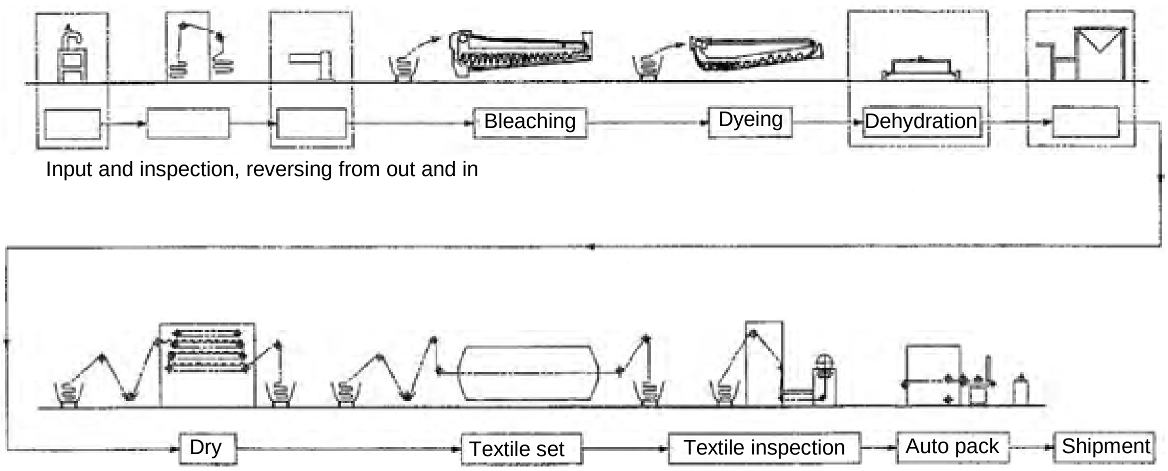


Figure 3.3.2-3 Dyeing Process and Device of Cotton Knitted Fabrics

Only compared by the number of the above-mentioned processes, the process of the cotton knitted fabric is easier than that of the polyester filament. However, the process load and the processing time of cotton knits are greatly larger than that of the polyester filament fabrics. Especially, for the situation of 100% cotton, dyeing is one process; however, the mixed and the cotton with polyester filament has two processes; but because the polyester is dyed under high pressure, the cotton dyeing under normal pressure need more process load and long time.

For example, 12 hours are required in two dyeing machines for same amount polyester/cotton knits dyeing, though 250kg polyester filament fabric can be dyed in 4 hours. Energy and water consumption amount is about 5 times per unit. The per unit energy consumption naturally increases, if the polyester dyeing decreases and the cotton knitted dyeing increases in Indonesia in the future. It forecast that the polyester processing is being shifted to India and the knits processing with a higher additional value increases in Indonesia.

Finally, if the composition of these commodities is changed, the contradiction cannot be resulted between energy consumption increasing due to the material change with energy consumption decrease by introducing the energy conservation equipment.

Similar contradiction was seen in Japan 15 years ago.

c) Other factors to prevent energy conservation in the dyeing industry

The dyeing industry is one that is the combination of color, feel and function. The technological level of this industry is evaluated by whether the dyed goods can match the market request color and be shipped by the delivery date.

However, the color matching is unexpectedly difficult. Human's eyes are the sharpest in five senses, the colorimetric machine, and its sensitivity is higher than man's eyes, has been developed recently. The color according to the customer request is analyzed with the colorimetric machine, and then the numerical value is calculated by the computer. Using these values, the combination of the best dyestuffs are selected, and the goods are dyed. If the absorption percentage of the dyestuff is 100%, it is easy to match the color request. However, even all of the condition is in the optimum, the 100% absorption can not be obtained; and there will have several percent to several ten percent dyestuff can not be dyed in the goods.

Moreover, these values are different with a slight condition change. Additionally, joining the artificial error and other reasons, the accurate color is difficult to realize. About 90 times accurate color can get in 100 times dyeing. The re-processing should be done if not matching color occurred. In some situation, the bleaching process also should be done. The energy consumption of the re-processing is about 2~3 times of that of normal process.

Therefore, physical and immediate energy conservation, yield improvement and productivity improvement are necessary for energy conservation in the dyeing at the same time. There has the impression that the physical energy conservation in the dyeing enterprise is late. The reason is that the change of the process will cause a slight change in color. There are companies that do efforts on the eradication of the re-processing because it is expected that no re-processing is the largest energy saving.

Table 3.3.2-1 Energy Conservation Measures in Each Dyeing Processes (Short-term~Medium-term Target) (Each Item Described in Paragraph in Details)

No.	Item	Energy conservation measure	Energy saving effect	Cost factor	Note
1	Continuous scouring and bleaching	Thermal insulation of the Steamer (excluding Mercerize)	10% reduction of consumption amount	Thermal insulation work、	
2	(Mercerize)	Counter flow washing for rinsing machine	20%~50% together with the water amount reduction.	Water current work(pump, filter and water meter ad so on	
3	(Continuous dyeing)	Water amount control of rinsing machine			
4		Temperature management of rinsing trough	gain 10% by putting cover	Automatic temperature control, cover construction	
5		Thermal recover from exhaust water	30~50%	One set of heat exchanger	
6		Management of drying equipment	5%	Daily maintenance	
7		Prevention of over drying	5~15%	Moisture amount controller	
8		Thermal insulation of cylinder drying device	20%	Insulation material, construction expenses	
9		Recover of condensed water	5%	Steam trap and piping	
10	Mercerize	Neutralizing of rinsing trough	5%	Automatic chemical solution injection device	
11	Width set	Introduction of fan inverter	Electricity 40% reduction	Making to inverter	
12	(Resin finishing)	Exhaust air sensor and moisture control	5%	One set of control device	
13	(drying machine)	Temperature sensor of fabric and speed controller	5%	One set of control device	
14		Filter clean	5%	Daily maintenance	
15		Dehydration by vacuum system	10%(Polyester 100% fabric)	Vacuum type	
16		Thermal insulation board and joint strengthening	5%	Construction materials	
17		Prevention of over drying	5~15%	Moisture control device	
18	Waste water treatment	DO management	10% of electricity	One set of DO control device	

(2) Energy conservation by minimum investment

1) Energy conservation of the continuous dyeing process

The outline of the continuous dyeing process is described in Figure 3.3.2-1 Based on this rough sketch, the small-scale energy conservation measures of existing devices are described as follows.

a) Continuous scouring and bleaching process

a. Energy conservation of steamer

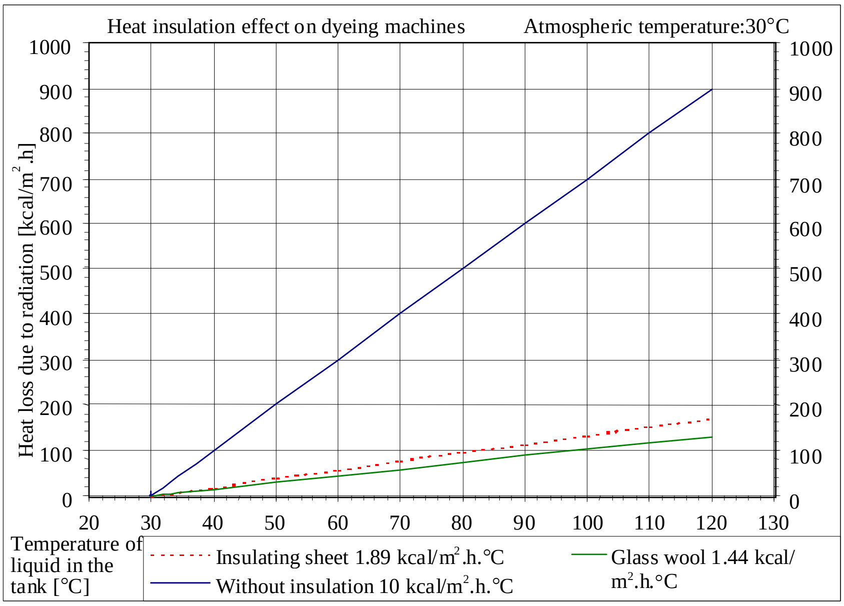


Figure 3.3.2-4 Thermal Diffusivity from Surface of Heated Device and the Thermal Insulation Effect

The souring and bleaching processes is the preparation processes removing impurities from the natural fabric such as cotton before dyeing.

The fabric is permeated in the different chemical solution corresponding to the purpose of the fabric, in the steaming process, chemical reaction happened between impurities and chemical. Generally, The fabric is made to stay in the steaming equipments that are the big box in stainless plate (called as Ageing device or Steamer) with 100℃ temperature about 30-45 minutes. The fabric is delivered into the equipment and piled up on the conveyer uniformly. Then it s carried to the equipment exit by the movement of the conveyer. The stream can not leak from the water-sealed entrance and exit of the steaming equipment. Although about 50% of the steamer box is insulated for the existing of the peephole and the roller shaft, the entire impossible insulation area is 80m^2 with 10m × 2m = 20m^2 in one side.

The energy saving amount can be read from the following insulation graph.

Outside temperature: 40°C , inside temperature: 100°C;

No insulation

Heat loss: 600 kcal/m^2/hr

80 m^2 × 600 kcal = 48,000 kcal/hr
With insulation,
Heat loss: 100 kcal/ m^2/hr
80 m^2 × 100 kcal = 8,000 kcal
The difference is, 48,000 kcal – 8,000 kcal = 40,000 kcal/hr
(167.5 MJ/hr)

b Energy conservation of rinsing trough

After the steaming process, the continuous scouring and bleaching equipment advances the rinsing process for the removal of impurities. The rinsing process composed by 5-10 troughs filling with water or warm water. The structure of each trough is shown in Figure 3.3.2-5.
There are squeezing rolls (Mangle) in the entrance and exit of the trough, and the impurities are discharged into water while moving the fabric up and down in the water or warm water. Especially, because the impurities pushing out effect of the squeezing rolls is important, it is paid attention to the pressure condition of the roller, smoothness of roller (the upper part is made of rubber and it is stainless in the lower part), stiffening of rubber roller and abrasion. Because washing effect with high temperature water is higher for lot of impurities, the entire trough need to be covered as the right figure in Figure 3.3.2-5 considering the energy saving and operation environment. Moreover, as the right figure in Figure 3.3.2-5 shown, the washing water utilization efficiency is improved by staying the impurities as most as possible in the same trough.

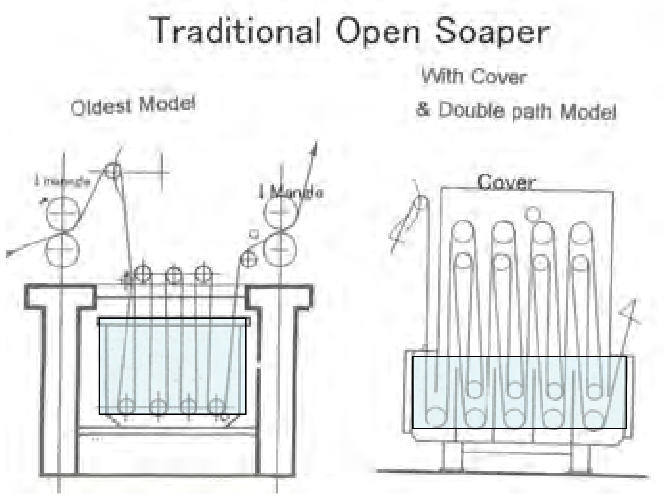


Figure 3.3.2-5 The Old Type Rinsing Trough

c. Water amount control and counter flow washing

The speed of these kinds of continuous washing devices depends on the ability of drying equipment. The hydrophilic materials and heavy fabric (cotton, hemp, and rayon) are difficult to dry; the hydrophobic Synthetic materials and thin fabric drying easily.

Generally, because the washing speed in the washing machine of the thick fabric and heavy one including lots of impurities is slow, the treatment speed should slow down. In this device, the fresh water keeps supplied, and a large amount of steam is used to raise the temperature.

- Judgment of pollution

The energy conservation of this device will be gained from the largest washing effect with a little steam that will be realized by the water supply amount control corresponds to the pollution level of the washing trough. In past, the pollution was check with human sense, and it was thought that if much more water was supplied, the problem can not happen. With this past method, the more water and steam using for temperature rising would be consumed than they were needed.
As for the judgment of the pollution, the turbid meter, spectrum brightness and COD measure device are used, generally. However, because various inorganic chemicals are used in dyeing process, the measurement result of the pollution judgment by using the conductivity meter is acceptable. According to the monitor, this method is cheap and easily maintenance. The number of washing troughs changes greatly by the combination with the following drying equipment, and the number is usually 5-10.

- Counter flow washing

Although water supply entrance and outlet of the washing trough were set respectively in the past, these troughs were connected, and the counter flow washing method that the water is supplied from the counter direction of the fabric moving has been adopted. Therefore, it is normal practice that the position of the trough near dryer is highest and that of the trough ahead (fabric entrance side) is lowest, and then the natural flow occurs due to height difference. For the long line of the device, the pump is installed in the line medium to get entire height balance.
However, because not all of the troughs is the washing trough and there are special function troughs, such as neutralizing troughs and oxidation troughs, there is no reason to explain that the simply connection and counter flow washing is good. In addition, even the counter flow washing is adopted, the setting of water supply amount is more important.

- Setting of the water supply amount

The Energy conservation point of these washing troughs is that the control to make the water supply amount matching the pollution of the final washing trough and the management of water temperature. Great energy saving realization is possible by the combination of water valves introducing conductivity meter and flux control device.
The following data is a comparison example between the counter flow washing introducing contamination management and non-introducing management.

Weight of fabric: 0.25gr/m, process speed: 60m/min, water amount: 50 times of fabric weight, the highest water temperature: 90°C, Supplied water temperature: 30°C (90-30) × 0.25 × 60 × 50 × 60min = 2,700,000 cal = 2,700 kcal/hr (11.3 MJ) (Water amount 45 m^3/hr)

If controlling the water amount to 25 times of fabric weight, the energy consumption will be 1/2 of the above-mentioned.

(90-30) × 0.25 × 60 × 25 × 60min = 1,350 kcal/hr (5.7MJ) (Water amount 22.5 m^3/hr)

As a result, the high energy saving ratio 50% is obtained.

Great energy saving becomes possible by remodeling the now situations that not or partial introduce counter flow washing and neither pollution measure nor the flux control are adopted.

The typical flux adjustment device is shown in Figure 3.3.2-6.

The flux control method basing on the conductivity of the final trough is comparatively easy. However, because the rinsing process is a very important process influencing the quality of products in dyeing and printing, the flux setting should consider the product's wet fastness degree.

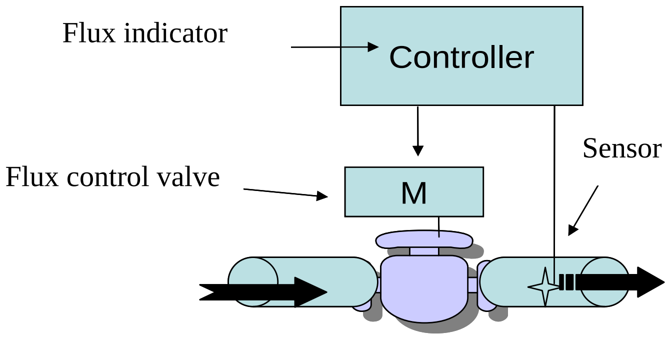


Figure 3.3.2-6 Flux Control Valve Chart of Washing Water

- Temperature management of washing trough

Temperature management of washing trough is an important factor for energy saving. If the fiber can not be damaged by high temperature washing, the washing effect is good under higher temperature (It is unlimited and near 100°C). Especially, in the cotton fabric and blended fabric of polyester and cotton dyestuffs using continuous dyeing method, most of the reactive dyestuffs is used, that make large amount water and energy is consumed in the washing process. There are cases that try to raise the washing effect by using rinsing agent, too. There is no the time misgiving as it in batch dyeing method for temperature rising, it is good to raise high temperature in the continuous dyeing method. However, the temperature rising method that blowing steam directly is adopted in many washing troughs, the steam energy not contribute to raise water temperature, but used to diffuse large amount steam when becoming high temperature.

In order to prevent such energy waste, the rinsing water should be heated with indirect heating device; the washing trough also should be heated using indirect heating pipe. The automatic temperature control device installation is a precondition for these temperature holding equipments.

Generally, the cold water is supplied into the final washing trough and squeeze roller (Mangle). However, considering the effect of squeezing and drying, it will leads to opposite effect using cold water, the warm water should be supplied.

The last mangle in washing trough has influence on the load of the drying equipment, and then it is necessary to always exclude the squeezing rate influencing factor.

- Thermal recovery from exhaust water

Highest polluted washing water is exhausted from the front trough in the counter flow washing, sometime the temperature of it will reach to more than 90°C. Large energy saving effect can be expected by recover this thermal energy from exhaust water. If assuming that the exhaust water temperature is 85°C and supply water temperature is 35°C, then the temperature difference is 50°C, as result, 75°C hot water can be gained by using the heat exchanger considering the heat exchange temperature difference is 10°C. The heat recover rate is about 50%. The waste thermal recover from exhaust water will be described in paragraph 3.3.2 (2) 2) a). in details.

d. Energy conservation of drying device

The drying device is attached to the washing device usually. Generally, the cylinder dryer is used though there are lots kinds of devices. As the mechanism of the cylinder drying device, the stainless cylinder is heated by the thermal energy of the pressurizing steam filled in the cylinder, then the fabric contact with the cylinder outside surface is heated and the moisture of it is transpired (refer to Figure 3.3.2-7).

The wet fabric is contact directly the surface of the cylinder and the temperature of fabric is raised by the conduction thermal and the moisture is transpired in this device. Generally, pressure of the steam is limited to 0.2MP and the surface temperature is limited to 122°C. The number of cylinder is about 20-40, though it is changed with the composition and weight of washing fabric. These cylinders are arranged in the vertical direction usually. Considering the space, there also exist the horizontal arrangements.

Ventilation should be considered above the drying device for large amount of steam radiate from the drying process.

Because this drying device using large amount steam same as former washing process, the energy saving effect will be great difference depending on management. The energy conservation point of the cylinder dryer is as follows.

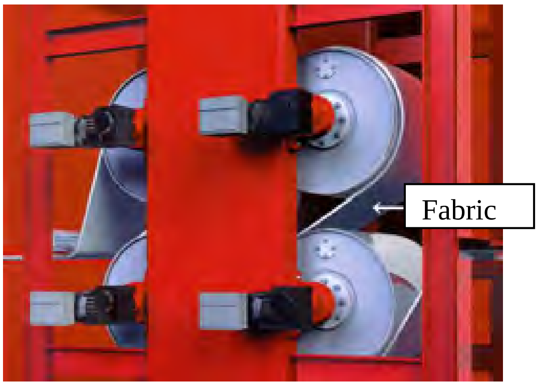


Figure 3.3.2-7 Cylinder Drying Device

- Steam inflow route and condensed water exhaust

The latent heat of steam is used to make dry in cylinder dryer. Therefore, steam should be introduced into the cylinder efficiently, and the steam discharging the latent heat becomes condensed water also should be exhausted outside the cylinder efficiently. The rotation speed of the cylinder is about several ten times per minute, that make it is a little complex to inject steam and exhaust condensed water at the same time.

However, if the mechanism is not understood, it is impossible to check and maintain. That will lead to steam waste because of steam leak and condensed water stay in the cylinder.

It is needless to say like the maintenance of steam leak of the letdown valve and the frequency using on-off valve before the steam entering into cylinder. Figure 3.3.2-8 shows the section of the cylinder dryer.

The pressurizing steams pass from the rotary joint and are discharged in the inside and outside layer thought outside of the double pipe then inject into the cylinder. The condensed water staying the bottom of the cylinder is sucked up from the siphon tube locating in the bottom of cylinder, and then discharged from the cylinder via the inside of the same double pipe and the rotary joint (Figure 3.3.2-9).

The construction of rotary joint is a little complex. The construction is that the scrape of the bush (10) made of graphitized happen between rotary joint and cylinder. The steam leak is caused when the bush is worn out. Moreover, if the condensed water stays in the cylinder causing by transformation and dropout of siphon tube, the fabric will be cooled and the rotation of cylinder will becomes heavy. That will leads to extremely electricity consumption.

The condensed water is exhausted by the steam trap installed in the outside of the cylinder. The number of this trap is about 20-40 for it was attached in each cylinder. Most of the trap is thermal differential type, so it is necessary to check them because the defective operation happens easily for this type trap.

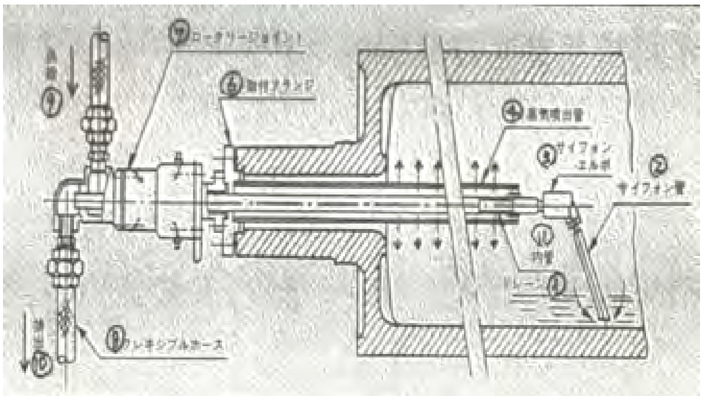


Figure 3.3.2-8 Section of the Cylinder Dryer

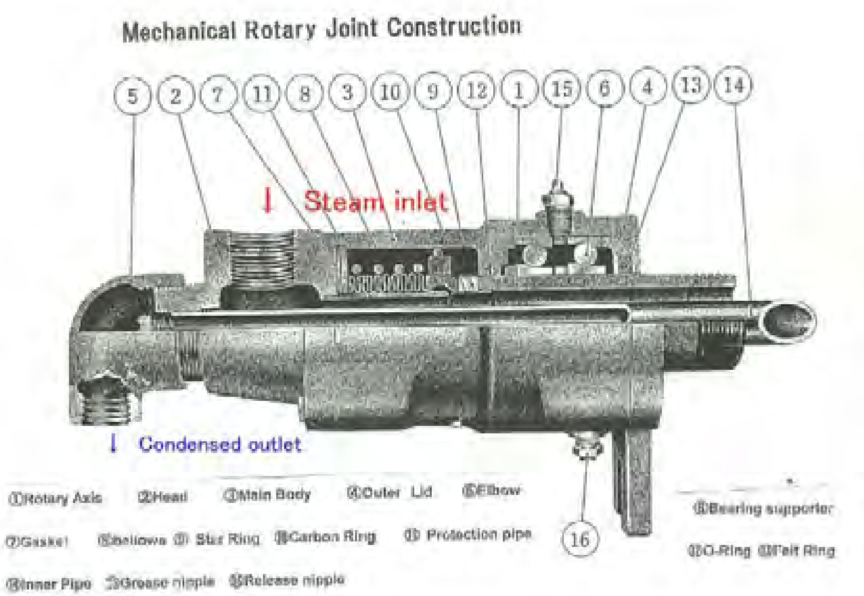


Figure 3.3.2-9 The Section of the Rotary Joint of Cylinder Dryer

➢ Prevention of over drying

The energy conservation point of all of the drying equipment (not only limited to the cylinder dryer) in the dyeing is prevention from over drying. We know well that fabric drying as the house laundering is not necessary to keep under higher temperature. Moisture of atmosphere is less than 100%, fabric or garments should be get to dry.

The water transpiration is that moisture will transpires gradually into atmosphere when the relative humidity in atmosphere is less than 100%. In order to make quick drying, the transpiration speed is accelerated by putting the wet fabric into the environment that the temperature is high more than 100°C, boiling point of water. However, because moisture exists in the fabric, the temperature of the wet fabric can not reach to more than100°C in any case that how many degree of the contact surface temperature. (Refer to Figure 3.3.2-10).

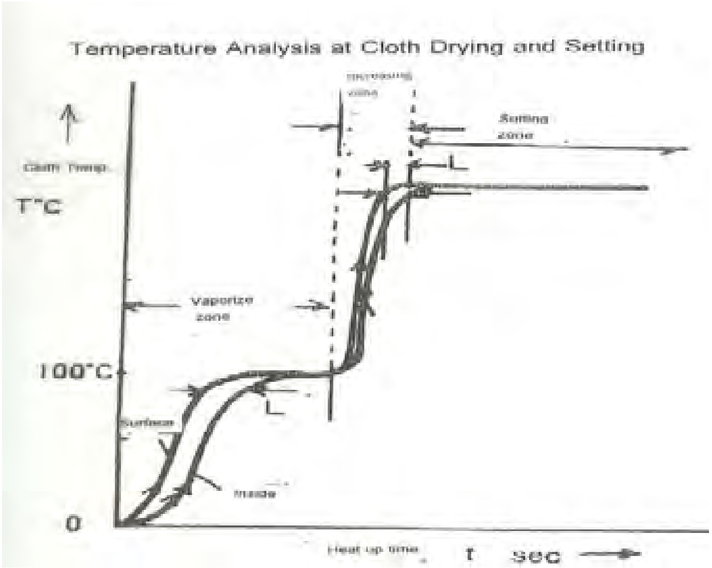


Figure 3.3.2-10 Temperature Analysis at Cloth Drying and Setting

The fabric temperature will keep to 100^0C until the fabric is dried in any case some temperature difference between the fabric surface and inside is happened.

But the fabric temperature will rise rapidly up to the setting temperature after the drying finish in this zone, the moisture in the fabric is 0, and it was called over drying. On the other hand, the fabric has certain moisture keep ability. The moisture keep amount is called water ratio. The water ratio of each fiber is listed in Table 3.3.2-2 after leaving 24 hours under 65% humidity and 20°C temperature environment.

The water ratio is higher than these values in high temperature and humidity country, like Indonesia.

Table 3.3.2-2 The Moisture Ratio of Typical Fibers

Type of fabric	Cotton	Hemp	Rayon	Nylon	PET
Moisture ratio	7%	7~10%	12~14%	3.5~5%	0.4~0.5%

It can be found from this table that the moisture contained in the fabric is not 0, and it is good that the drying is finished at the condition that the moisture amount containing of fabric is keep in fabric. If the moisture ratio less than these values, extra energy will be consumed because the fabric will absorb moisture from air in the process.

Therefore, 7% energy saving in cotton process and 12% energy saving in rayon process can be obtained. The energy conservation technology for this is setting the humidity sensor in the finishing part of drying process to control the steam supply amount supplied to the several end cylinders (on-off or proportion control) . (Refer to Figure 3.3.2-11 and Figure 3.3.2-12).

The more simply method is that replacing the steam valve with electromagnetic valve to control the surface temperature of fabric exit from the end cylinder keep 98°C by continually measuring using the infrared rays radiation thermometer.

The same energy saving technique using moisture ratio sensor to control drying can be used to various drying equipment applied in the continuous and batch dyeing method. Although, it is become a normal recognition that such moisture control function is added in the recent drying process device, the control measurement is attached later for the device before 1990's.

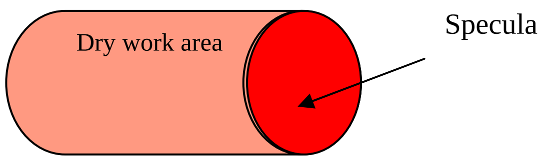
It can achieve more energy saving by promptly stopping the steam supply to drying device and washing device via adopting the interlock mechanism with the electromagnetic valve when the machine stops to switch the processing materials.

Figure 3.3.2-11 Partial Contact Type Moisture Sensor

Figure 3.3.2-12 All Width Traverse Type Moisture Sensor

- Thermal insulation of the cylinder machine

In the cylinder drying device, the dry work is done by making the fabric contact with cylinder surface. But the part called as "Specula" on both sides is the cast iron disk. Because this part is not contact with wet fabric, the temperature of it is higher than the dry area. Most of the heat is diffused from this part for it always rotates.



The diameter of this part is about 65cm. It can be insulated excluding the center. There is 12m^2 thermal insulation areas for 24 cylinders with 0.25m^2 × 2 in both side for one cylinder, when insulating it by resin or strong laminate lumber in hemicycle.

Temperature of Specula: 120°C, Environment temperature: 40°C Diffuse energy: 800kcal/hr/ m^2, Thermal insulation effect: 100kcal/hr m^2,

Energy saving amount: 12 m^2 × (800-100kcal/hr/ m^2) × 20hr/day x 300days =

50.4Mcal = 1,206MJ/Y

- Condensed water exhausted from cylinder drying device

All of the steam supplied to cylinder dryer turn to condensed water with more than 90°C temperature, finally.

In order to make energy saving, this condensed water is used as boiler supply water. And so the pipe also should be insulated.

b) Mercerize process and related energy saving

The Mercerize processing is the specific processing done to the cotton fiber. Especially, it is an indispensable processing method of cotton and the blended yarn and fabrics. Firstly, the caustic soda solution with a concentration of 25% is used to soak the fabric. Then draw the fabric by length and breadth simultaneously. After the fabric is soaked in the caustic soda solution for about 60 seconds, use the cold water to pour it just like a small waterfall. In order to stimulate the substitution between caustic soda and water, the decompression suck devices are used to absorb water from the back of fabric. Afterwards, in order to brush off the remaining caustic soda, the fabric should be washed in the boiled trough. The caustic soda is very appetent to the cotton fiber, large amount of water and steam is needed for the washing. In order to make it easier, it is better to use the acid to neutralize the caustic soda. The organic acids such as acetic acids and formic acids and inorganic acids such as hydrochloric acid can be used. Because the remaining acid will weaken the strength of the fabric, it is important to adjust the pH value of the washing trough. Although the washer and drier are used similar to the process of refinement and the bleaching, the point of operation management is greatly different. The concentration of caustic soda after dilution is about 5%. Sometimes, a concentration device is set to decompress and heat the solution to get a concentration of about 25%. Steam is used for heating the device indirectly. The condensate water from the process is sent back to the boiler as the feed water which leads to large energy saving.

c) Continuous dyeing process

The continuous dyeing process is composed of two separate processes: the Pad-Dry process which spreads the dyestuff on the fabric evenly; and the Pad-Steam process which made the dyestuff fix to the fabric.

a. Energy conservation of dryers in Pad-Dry process

After soaking the fabric in the dyestuff liquid and squeezing it in the width direction using the mangle, the fabric is led to the intermediate dryer. Before reaching the guide roll in the dryer of the main body, in order to transpire the moisture on the fabric's surface, the infrared rays heating device using gas or electric heater can be introduced. In the drying equipment which has a main body called roller dryer, the heat sources such as gas, steam and hot wind are used to dry the fabric. The moisture from the inside of the dryer is discharged outside with the exhaust fan. In the dryer and tender which will be introduced in the next section, the structure in which hot wind blows from the nozzle at a high speed is composed. However, in the dryer of Pad-Dry process, drying the fabric's surface rapidly will lead to the migration phenomenon, the spots of dyestuffs will generate. Therefore, during this dry process, it is necessary to operate in an environment with no temperature irregularity. The efficiency of this drying equipment is not very good.

As an energy saving method, by inspecting the relative humidity in the exhaust duct, the rotation speed of the exhaust motor can be controlled using the inverter control system device.

b. Energy conservation of washing and drying equipments in the Pad-steamer process

In the drying process, the dyestuff is adhered to the fabric only, its means fiber and dyestuffs is not fixed perfectly. Therefore in this process, dyestuffs on the fiber are fixed in the steamer.

Not all the dyestuff is adhered to the fabric, some is omitted. The washing equipment is used to wash off the unfixed dyestuffs on the fabrics. Sometimes, the drying equipment is included. The above equipments are similar to that of continuous refinement and bleaching equipment. But the detention period of the fabric is about 30 minutes in the refinement and bleaching equipments, the streamer of dyeing device is about 90 seconds. The volume of the steamer is also very small. To prevent the dyeing irregular caused by fluctuated temperature, the insulated structure is used for the main body of streamer, no heat insulation is necessary. However, because of the large amount of washing troughs compared with that of refinement and bleaching devices, there will be big difference if the idea of energy conservation is or not taken into consideration. The dying equipment is very similar to the scouring and bleaching process which can be used as a reference.

c. Electricity saving

Among the total electricity consumption of continuous scouring and bleaching equipment, the mercerize device, and the continuous dyeing device, the roller for fabric transportation and the motor for drive of the cylinder drying device take up more than a half. In the devices before the 1990's, Ward-Leonard system was synchronously driven by direct current. Therefore, the AC motor and the DC generator are driven in the series. By conversed into DC using the semiconductor, the speed control is operated using the variable resistor which connected to the DC motor series.

In the latest devices, because of the use of inverter for conversing to AC, the electricity loss is decreased during speed control. However, the control related electricity is necessary for the entire equipment, not much electricity is saved.

d) Heat setting and resin finishing equipments

The main energy consumption (electricity and heat) equipments in dyeing process are tenter m/c m/c. This equipment is mainly used in heat setting and resin finishing processes.

Heat setting is a process executed before dyeing. In order to correct the wrinkles and uneven of width of the fabric with 100% cotton, it is socked in the water. Using the tenter m/c in the preliminary dry room, after 30% moisture is transpired, the width arrangement is done with tenter m/c.

In the fabric and knitted including polyester, in order to level the temperature of the polyester fiber, it is spread for about 45 seconds under a high temperature of about 190°C. Without soaking, the fabric is dried directly in the tenter m/c.

Similar equipment is also used in the resin finishing process.

In the resin finishing process after the dyeing process, the chemicals is melted by water and some water is evaporated in the preliminary drying process, then tenter m/c processing is executed. The heating zone of the tenter m/c is an old device less than 15m, the heat treatment time after the resin finishing cannot be taken enough. Therefore, sometimes a baking device is included for heat treatment. If too strong heat treatment is not necessary, or the processing room has a length more than 15m, the heat treatment can be operated in the tenter m/c with a entire set temperature of about 165°C (Recently, this methods is widely used).

a. Heat source of the tenter m/c

Much combustion energy is necessary for the tenter m/c during heating setting and resin finishing processes. Therefore, the selection of heat source when the device is installed is the main point of energy conservation. When the city gas, natural gas and LPG are used, warming the air with burners is always adopted. If using crude oil, kerosene, coal and biomass etc., warming and circulating the heat medium is a common method. Sometimes this method (indirect method) is also employed when gas is used. Because of the rise of oil price in the Asia countries, the shift towards coal is accelerated. Compared with the indirect method using heat medium, the gas direct burning method can improve the efficiency by about 20%. From the viewpoint of atmospheric pollution in our country, using LNG and city gas is preferred to refer to the global warming issues.

When there are many tenter m/c, the switch is frequent. It is difficult to control the combustion of heat medium why using the heat medium heating method based on coal. This is a serious problem of shifting towards the coal which has a price of about 1/4 to 1/5 of the oil fuel.

Figure 3.3.2-13 Inverter for Tenter m/c and Dryer Fan

b. Energy conservation with inverter

Much power is consumed for transporting the fabric and circulation fan with tenter m/c. In this device, according to the materials, different running speed and wind velocity are necessary. Pulley method was formerly used for the changing of running speed, since the 1980’s, the inverter method was often used. On the other hand, the Paul change motor was used partially for the speed changing mechanism of the circulation fans. The motor and the fan were driven with V belt, and the adjustment of wind amount is executed by using a damper control. Since the 1990’s, the inverters were gradually introduced. The wide spread may be realized by the 2000’s when the price is lowed down. The air temperature is relatively low while starting, large impetus is needed for the tenter m/c and fans of driers. As the rise of air temperature, the air is becoming lighter. The energy consumption is reduced even with a usual induction motor. However, because the rotational speed is always the same, the velocity and amount of the wind sprayed on the fabric tend to be excessive. Therefore, the damper is installed for the adjustment of wind volume by 1/4 or 1/2. When the rotational speed of the circulation fan is reduced by about 1/4 to 1/2, the power consumption can be decreased by about 1/4. Existing motor is used for the inverter, less investment is necessary. Even the inverter has already been adopted, it is necessary to reduce the energy consumption by dropping the rotational speed.

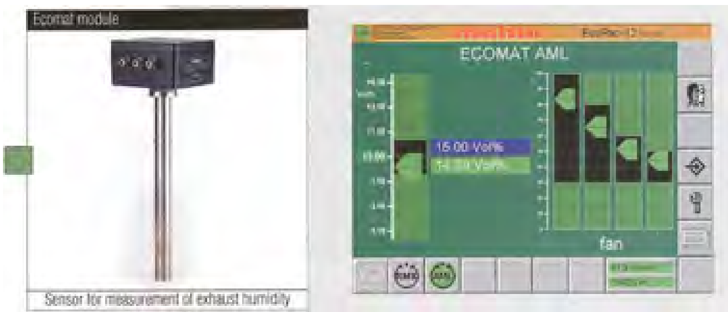


Figure 3.3.2-14 Exhaust humidity Sensor and Monitor (From Mahlo Co. ltd.)

c. Energy conservation with tenter m/c

- Treatment for heat setting

As the preprocessing of the continuous dyeing of the cotton fabric, the heat setting is used as the drying equipment. In order to avoid the irregular dyeing, although it is necessary to soak it absolutely in the water, it is important to decrease the water amount by spray and surface wetting methods. If the temperature is set to 140-150°C, wind volume is increased and the damper is used (about 45 Hz in the inverter). If the preliminary dry equipment is installed, it is the same.
Speed and heat control according to the amount measurement of fabric moisture and exhaust motor control according to exhaust humidity sensor are executed (about 10-15% energy saving is possible).

- Treatment of heat set

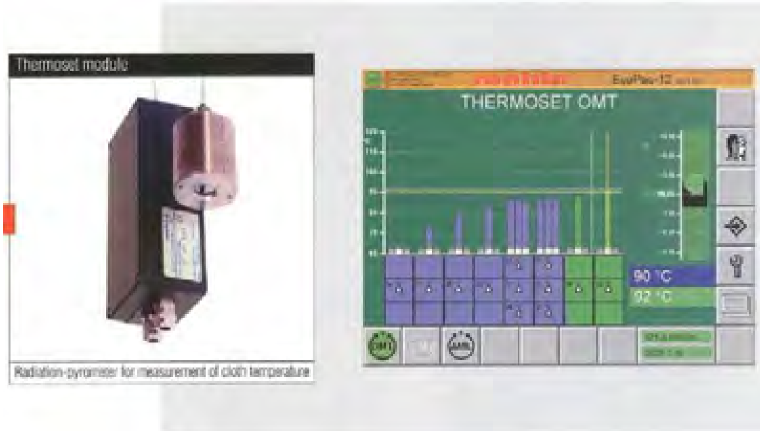
For the 100% polyester and mixed goods, although the temperature is set to 190-200°C, on the fabric after refinement and bleaching, no oil is occurred in the tenter m/c from the fabric because no chemicals is mixed. (However, while treating the unprocessed fabric such as stretch fabric, it is necessary to consider as in the resin finishing process.)
At this time the tenter m/c should be operated under a situation that the fabric is at the set surface temperature and the detention period is 20s, the exhaust fan is closed mostly (if having a inverter, it is under low speed with 20 Hz). If the inverter control is introduced for the circulation fan, it should also be under a low speed (about 30Hz). The speed should adjust the processing zone to about 20 seconds in order to make the surface temperature of fabric be 190°C. However, the temperature in the chamber is measured by the setting temperature and the rise of fabric's temperature may have some delay. Therefore, the speed should be a little slower according the experience. If the temperature of the fabric is actually gotten, for example, the processing speed should be 45m/minute (three times of the chamber) for a chamber of 15m. In order to measure the fabric's surface temperature, three sensors should be installed in the ceiling of the tenter m/c. Furthermore, the proportion control should be introduced to control the speed.

- Resin finishing

The following three functions are necessary for the resin finishing (prevention, water-repellent processing, etc.) with tenter m/c.
- Soak the fabric with resin liquid
- Vaporize moisture from the fabric
- Cause the cross-linking reaction on the resin chemicals clung to the fabric

Therefore, old type tenter m/c with a processing room of 15 m is not enough. A processing room of 20 m is preferred. Especially, in order to cause the crosslinking reaction in the back part of the tenter m/c, a heat treatment of 150°C for more than

30 seconds is necessary. So the accrual temperature measurement of the fabric surface is necessary. For this purpose, a measure and control mechanism as shown in Figure 3.3.2-15 is preferred. These equipments are necessary for the purpose of energy conservation.



(From Mahlo Co. ltd.)

Figure 3.3.2-15 Fabric Surface Thermometer (Tenter Ceiling Installation Type)

2) Energy conservation of batch dyeing processing (Polyester fabric)

As well as the continuous dyeing method introduced above, the batch dyeing method is also important. Figure 3.3.2-3 shows the outline of the processing process. The continuous dyeing method is appropriate for fabric dyeing processing method of large lot, much energy potential is expected.

The energy consumption efficiency of batch method is not higher than a continuous method. However, it necessary to save the resources including water and energy, some other methods which are different from the continuous method should be considered. Especially, batch dyeing processing is needed for the polyester knitted fabrics because high pressure is necessary for the dyeing processing. The dyeing processing of polyester fabrics is introduced in sp3-109. The energy intensive processes which also have great potential of energy conservation are explained.

a) Energy conservation in relaxation process

This process is not suitable for all the polyester fabrics. Although the relaxation process is detached from the refinement process as introduced in this paper, they can also be operated continuously.

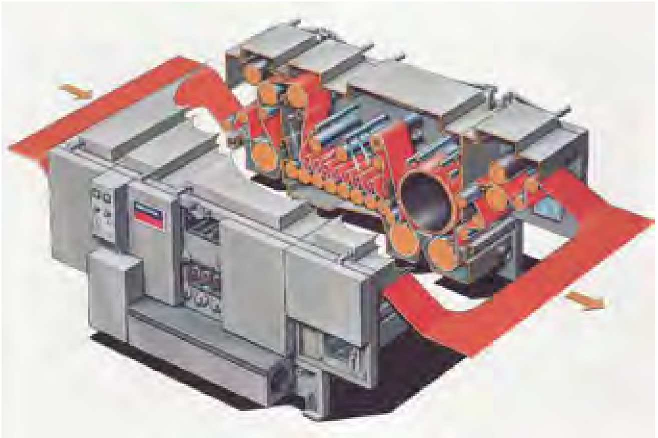
- Coating with heat insulation materials

The processing trough made of stainless steel is used for both batch and continuous method. Better effect may be reached if insulation material is used in the trough.

Surface temperature of the device: 95°C.
Outside temperature: 35°C.

Heat radiation area: 8 m^2.

As shown in Figure 3.3.2-4, (650-50kcal) × 8 m^2 × 12hr = 57,600 kcal = 241 MJ ／day



(From the BENNINGER Co. Ltd.,)

Figure 3.3.2-16 Continuous Refinement and Relaxation Device

- Heat recovery from wasted hot water

The high and low temperature drain is separated. The energy conservation from heat recovery of high temperature drain is expected. The heat exchanger used here is made of several stainless sheets which are recognized as plate type. Although the exchange efficiency is good, a lot of fibers and thread craps may float in the drains of fiber factory. This will block the space between plates and stop the flow of drains. Therefore, using the type called spiral type in the drain of fiber factory is expected. (Figure 3.3.2-18 illustrates the image of heat exchanger)

In the inlet and exit sides of the heat exchanger, thermometer and adjustment valve, as well as flux meter are necessary. The installation of pressure gauge is preferred.

The relaxation process is operated under a temperature of about 100°C and the temperature of drain may reach 90°C. However, because the washing with cold water is executed in the end, it is necessary to distinguish between the warm water and cold water. About 50% of the necessary steam energy for heat recovery can be reduced. The soft water for the boiler is used for the supply water while recovering heat. Recovered water can be used for washing the boiler.

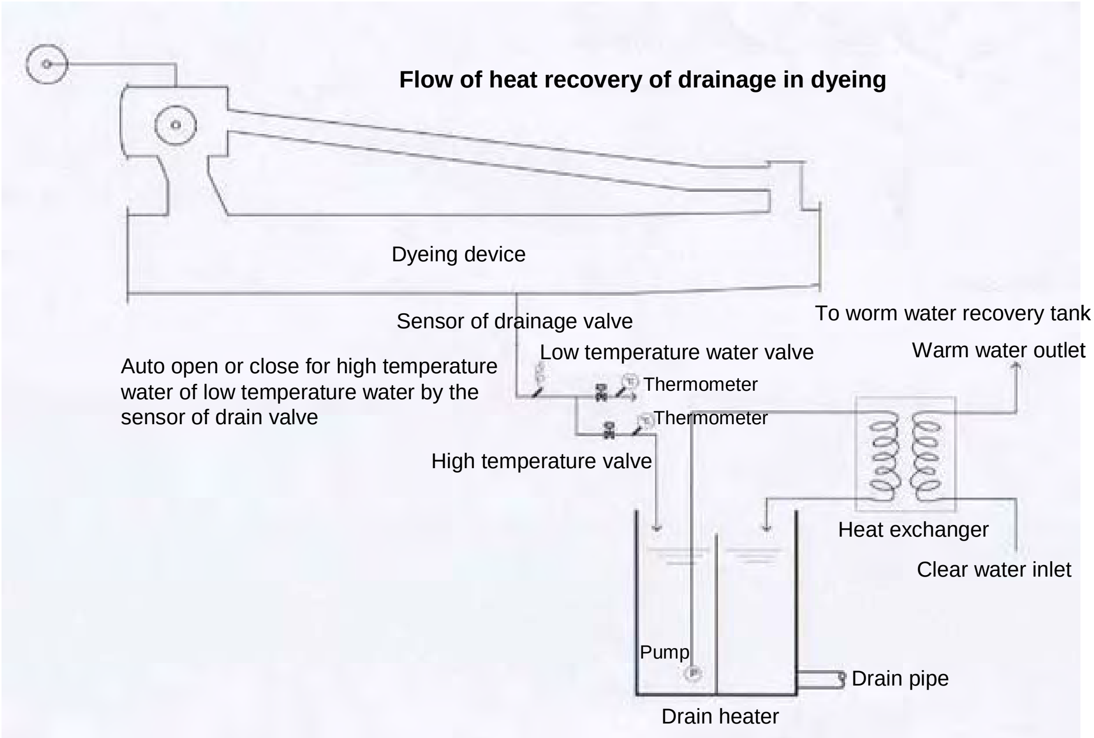


Figure 3.3.2-17 Heat Recovery System from High Temperature Wastewater

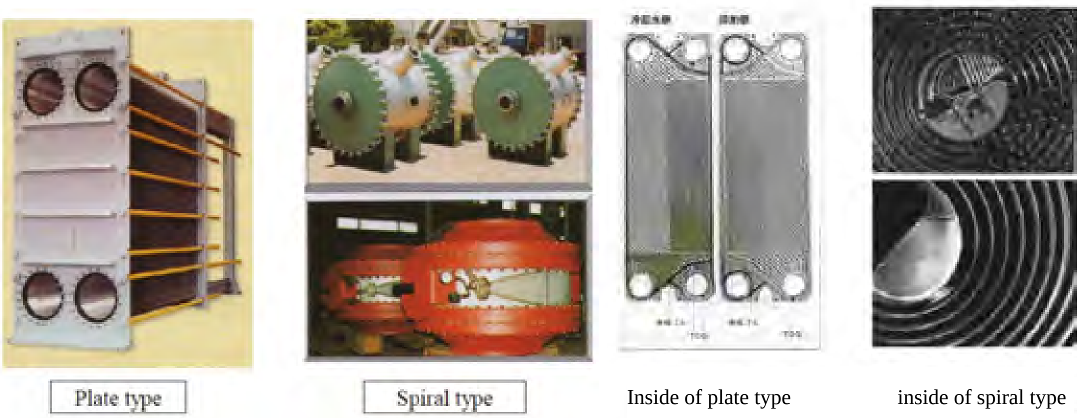


Figure 3.3.2-18 Externals and Internal Structure of Two Heat Exchanger

- Electricity saving

If relaxing is operated using a batch high pressure Jet method, the fabric is circulated under the Jet flow of warm water. The pump for jet flow is connected directly with the induction motor. The changing of jet flow speed is adjusted by controlling the valves to change the warm water volume into the jet nozzle. However, by using the inverter for changing the speed of the motor, much electricity can be saved. (Electricity consumption can be reduced to 40% or less) A 30 kW motor is operated for a processing amount of about 500 kg. The main pump is almost at full load when adjusting the flow rate with valves. The electricity consumption of 150 kWh is necessary for a batch process of about 5 hours. About 40% electricity consumption (90 kWh) can be reduced.

b) Energy conservation in drying process

The main different equipment between continuous and batch method is the dryer that accompanying the refinement, bleaching and dyeing processes. Cylinder drying device is adopted for the continuous method which is mainly for cotton fabric, and various drying equipments are used for the batch method. The loop drying device and conveyer transportation drying device are introduced here. Just like drying laundries using a washing pole, in the loop drying device, the fabric is continuously multiplied in an atmosphere where hot wind is circulated slowly. With the mechanism that the bar is rotating gradually, as the fabric goes to the exit, the chain which maintaining the bar comes back to the underside of the device. In the entrance, the new fabric is put on the bar. (Figure 3.3.2-19)

On the other hand, in the net conveyer method, the fabric is put on the transportation conveyer while forming small webs. Hot wind is accelerated with a strong circulation fan and sprayed from the slit on the fabric at a high speed. The fabric on the net conveyer falls form up to down and is carried out in the end. (See Figures 3.3.2-20 and 3.3.2-21)

Currently, almost all the drying equipments of batch type dyeing processing have been replaced by the net conveyer method in Japan. However, in some Asian countries, the dying equipments which transport the fabric on the felt are used.

In this kind of drying equipment and tenter m/c, because cotton dust generates, and some trouble may encounter when hot wind duct and heat exchanger stick. The filter which collects cotton dust in the hot wind circulation system is installed. However, if the filer is buried with cotton dust, the ventilation is reduced and drying efficiency is decreased. Therefore, rinsing of the filter is the first step for energy conservation. Recently the equipment which can clean the cotton fly periodically has been installed. The inverter control of exhaust fans for heat recovery and exhaust sensor is necessary for the purpose of energy conservation.

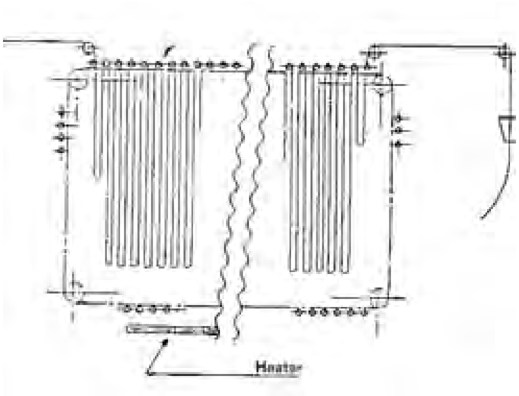


Figure 3.3.2-19
Image of Loop Drying Device

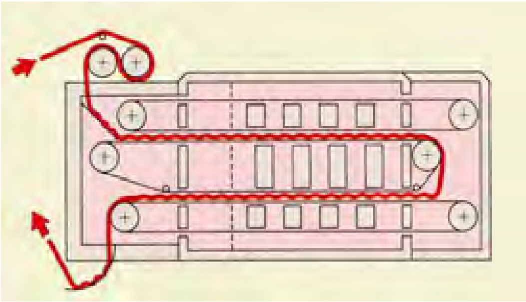


Figure 3.3.2-20
Image of Net Conveyer Drying Device

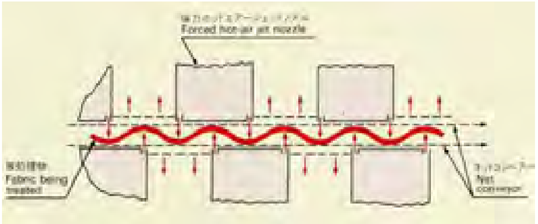


Figure 3.3.2-21
Image of Hot Air Dry in Net Conveyer

c) Energy conservation in presetting process

About this process, please refer to the continuous dyeing method (p3-126), the treatment of a heat set with heat setting and resin finishing equipments.

d) Energy conservation in weight reduction and drying processes

Weight reduction is mainly for the process of fabric with 100% or near 100% polyester. The polyester is made to react with thick caustic soda and decomposed. Then the polyester fiber becomes thin and soft which is easy for process. The amount of loss is about 20%. The loss ratio is proportional to the molar ratio of caustic soda. This method was developed in Japan and was operated in a batch method at the early time. Although batch method is still used in some small scale factory, by introducing from the large scale factories, now consecutive type is used in almost all factories.

As the continuous refinement device, energy conservation can be also reached for this equipment. However, the batch method is still used in many factories in some countries; much investment is needed to transfer to a consecutive type. Similar to the relaxation process, some energy saving methods is adopted for the factories using batch method.

e) Energy conservation in batch dyeing devices

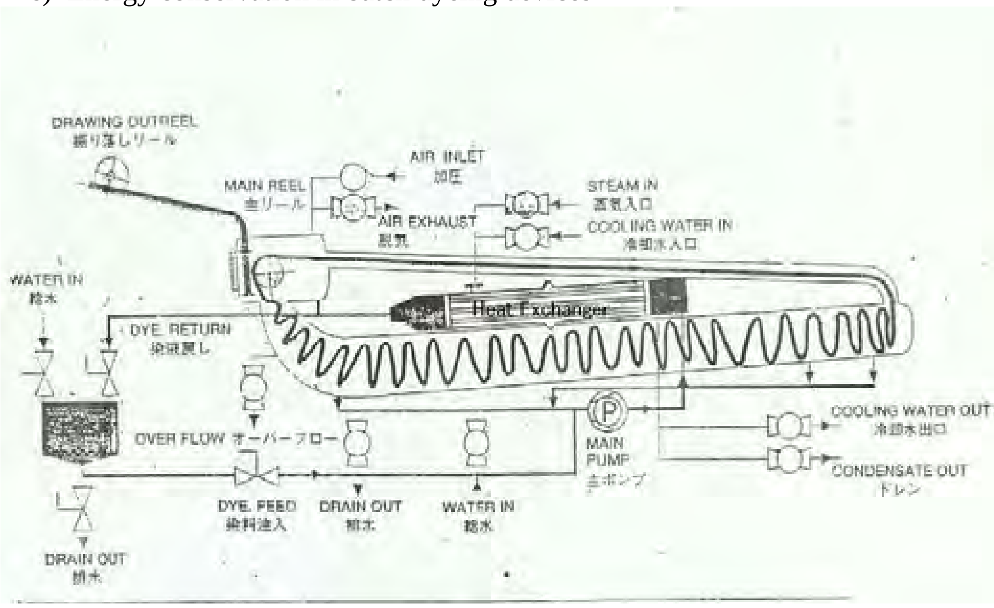


Figure 3.3.2-22 Image of Typical High-pressure Jet Dyeing Machine

Much power and steam is necessary for the batch dyeing method. It is mainly used for the equipments called Jet dyeing machine / high-pressure Jet dyeing machine. (See Figure 3.3.2-22)

Because batch method is used for the dyeing operation, put the fabric in the dyeing machine, the temperature of the dyeing rises gradually and reaches 135°C under the high pressure. The temperature is increased through heat exchange with the steam from boiler in the heat exchanger of the dyeing machine. The dyed fabric is circulated in the dyeing machine at a high speed. As that of relaxing, for the transportation of fabric, in the nozzle of dyeing machine, by using the gush power from high power pump, the mechanism for circulating the fabric with water current is necessary.

The ratio of fabric and dyestuffs solution is called water ratio. The smaller the ratio, less energy is needed for heating and circulation of dyestuffs solution because of reduced dyestuffs solution and rinse water. However, if dyeing circulation is too little, the fabric may not be transported well and the irregular dyeing may generate because of incomplete soak of fabric. Therefore, a limit must be set for the specific dyeing machine. This history of batch dyeing machine is also the history of reducing the ratio. Today, the water ratio of polyester is limited to 1:6. The value is 1:10 in the 1980’s.

After the dyeing, in order to reduce the dyeing machines to a normal pressure, cold water is imported into the heat exchanger to reduce the temperature of vessel to about 80°C, and dyestuffs solution is let out. The following steps can be executed according that introduced in the processing of polyester filament fabric (p3-110).

As the core of energy conservation of this device, the reduction of water ratio can be reached through the development of inverter for changing the Jet flow flexibly, which can also lead to the reduction of electricity consumption. Although some energy saving may reached by adding the inverter to existing main motor of dyeing machines, in order to get the best result, it is necessary to have a good match between the heating of dyestuffs solution and the speed of Jet flow. A computer based on programmatic control is necessary for this. It is most important for those mass devices. The energy conservation of existing devices can refer to that has been introduced for relaxing process.

f) Energy conservation in dehydrating and drying processes

The dyed and washed fabric is dehydrated in the dewatering centrifuge. After spread in the scattcher, it is let into the drying process, which is the same as that in the relaxation process.

g) Energy conservation in finish setting

According to the handled material and productivity, the combination of devices may have various variations in this process. There is tenter m/c in the centre of the device and it is necessary to input the chemicals matching the used material. The drying machine which is set behind the mangle is used for drying. Then the bridge construction is operated between width set and the resin chemicals. Energy conservation in the above processes is the same as that in heat setting and resin processing (p3-123). When inputting the chemicals, for the synthetic fiber, moisture cannot be absorbed by the material; some moisture is resorted in the fabrics construction because of capillary action. On this situation, sucking in vacuum may be better than in mangle. As one of the means of energy conservation, it is important to determine more dehydration can be reached in materials or fabrics constructions.

3) Energy conservation in batch dyeing processing

Another main material of the batch dyeing processing is the knitted. Figure 3.3.2-3 shows the image of processing.

Most of he knits before 1980's were dyed in a yarn, and then sent to the washing and drying processes. One of which is sweater knitted with only horizontal knits, the other is the T-shirt etc. which having circular knits.

As the development of larger scale and high-speed circular knitted devices and dyeing processing devices, the knitted materials are used in the sport shirts and sweat shirts. The use of interior material in the cars is after the 1980's and has a short history. Especially, for some countries, the integrated production system of the fabric has been rooted since early time, using the knitted instead of fabric may lead to large investment. Therefore few enterprises intended to introduce. However, for those countries, although advanced technology is necessary, since 2000, many enterprises started the conversion because of the high added-value of the knitted material. Especially, by reconstructing the dyeing and drying machines of polyester fabric to the knitted is popular. Recently the introduction of knitted only devices has begun. (Besides effect energy conservation, the investment in this field may also promote the spread of commodities to the world market. Therefore, since 2007, under the cooperation of NEDO and the Industrial Ministry, the comparison of energy consumption between existing devices and new modern devices has begun through “Proof project of model plant”.)

The knitted material is composed of cotton and its mixed goods, as well as 100% polyester. The former is mainly used as the casual material for sports fabrics; the later is mainly used for the interior material of cars. The following discussion focuses on the dyeing processing of cotton and its mixed goods. However, from the view point of energy conservation, it is the same for the 100% polyester materials.

a) Energy conservation in bleaching and dyeing processes

The circular knitted has a cylindrical form which is different from the fabric. Therefore, although it is likely to do the whole processing in a cylindrical state, it can also be incised after drying and then be processed in a flat state of a cylindrical state. Especially, for the knitted fabrics construction, incising will curl the ear chopsticks and is done in the end.

The bleaching of knitted of cotton material can be operated in the specific large scale device before dyeing or after dyeing. Recently, for the factories with lot of white things, the large scale bleaching devices are preferred. The colored fabrics are often processed in the devices which are similar to dyeing devices. It may take as long as 10 hours from bleaching until dyeing. Especially, for the polyester mixed goods, two dyeing processes are necessary for both cotton and polyester and much time may take. Though the energy conservation method can be applied as introduced in “Energy conservation of batch dyeing method (p3-127)”, there is much difference of the moisture ratio compared with the 100% polyester fabric.

The moisture ratio of polyester fabric is about 1:6. However, the fabric cannot be moved into the dyeing machine unless the value reaches 1:12 for the cotton knitted. Therefore, few fabrics can be input into the device for dyeing the polyester fabric, the efficiency is very low. It is necessary to introduce a special machine for this processing. In addition, much steam energy is necessary for heating the stain solution and rinse water, and the drain is also increased. The dyeing of only cotton knitted can be done using either high-pressure Jet dyeing machine or a normal pressure one. However, for some countries, polyester mixed goods occupy the main parts and high-pressure dyeing machines are generally used. So the normal pressure dyeing is sometimes operated in the high-pressure devices for the cotton knits.

The energy conservation in bleaching and dyeing processes is applied to the polyester fabric and the bleaching of cotton is operated in the hydrogen peroxide. If the hydrogen peroxide is not removed completely after bleaching, irregular color may occur in the dyeing process. Much steam energy is necessary for removing the hydrogen peroxide. Recently, the enzyme (peroxidase) which can decompose the hydrogen peroxide is used in our country. Although it is effective from the view point of energy saving, the possibility of adoption in some countries is uncertain because of the costs.

Much reactive dyeing is necessary for the dyeing process. It is widely used in the world for the fiber based on cotton and cellulose and has a lot of merits. The minor point of those reactive dyestuffs are the low fixing rate. 80% reactive dyestuffs are fixing to the fiber and the other 20% remains on the fiber without fixing or in the dyestuffs liquid. Especially, if the remaining reactive dyestuffs on the fiber are not washed clearly, the customer will complain about the products. Much hot water is needed to wash off the dyestuffs remained on the fiber. By the way, although the dyeing temperature is 60°C, the hot water of about 90°C is necessary for the washing off. Although the washing temperature doesn't change in the consecutive type washing flow, the water and energy are used effectively because the fresh water is supplied continuously. However, for the batch method, the preparation of hot water is necessary because the washing water is always abandoned. Therefore, in the dyeing of knitted fabric, the collection of washing flow can get much energy saving because a lot of energy is spent on the hot water for washing. More than 40% heat recovery is possible through the following two methods: heat collection and insulation of the condensate of steam; the combination of heat exchanger and pits of the washing water.

b) Energy conservation in drying and finishing processes

The circular knitted fabric is dyed in a cylindrical state, dehydrated in the dewatering centrifuge and then dried in the drier after straightening. Various drying equipments are considered for the difficult drying because of the double fabric. Net conveyer drying devices are the main consideration now.

Because a lot of cotton fly is let out from the knitted fabric, it is necessary to clean the filter from the view point of energy saving and maintenance of drying efficiency. In order to let out the large amount of moisture from the drier, the combination of humidity sensor and inverter control exhaust fan are necessary. The tenter m/c is also used for the finishing process. The fabric soaking in finishing chemicals is squeezed in mangle and then dried in the tenter m/c. Sometimes, the tenter m/c is enlarged because of the cross-linking reaction. When a operation of about 30m tenter m/c, in order to get the most energy conservation, it is necessary to operate the convection fan in the optimal conditions where based on the combination of thermometer, moisture meter and humidity sensor.

In addition, the tenter m/c of knitted fabrics is wide and long; the heat radiation from the heat insulation board should be taken into consideration. Especially, it is important to understand the insulation situation of the ceiling, add the insulation material and prevent the heat radiation from the gaps of the heat insulation board. Compared with the other fabric, the breadth of the knitted fabric is wide and has some variation. If operating the narrow fabric in a wide tenter m/c, the hot wind is supplied to the parts without fabric and heat loss is induced. Therefore, the wide and narrow tenter m/c should be used separately.

Much energy conservation can be obtained if the width of hot wind can be changed according to the width of the fabric. Recently, the mechanism like the retractile nozzle is paid much attention (see 3.3.2 (3) 4)).

4) Energy conservation of waste water treatment equipments

In the fiber dyeing enterprises, besides energy, a lot of water is consumed. The waster water treatment equipments are installed. In many enterprises, the aerobic activated sludge method is used for waste water treatment. Energy conservation in this process is also very important.

Figure 3.3.2-23 Aeration Tank of Waste Water Treatment of Dyeing Enterprises in Bandung Outskirts

a) Cooling tower

In most dyeing enterprises, the hot water is let out without heat recovery. Generally, the treatment should be operated under 40°C. However, in some countries, the bacteria is still active in 45°C. Anyhow, it is necessary to introduce the cooling tower or blow the air to the storage land. The electricity can be saved if heat recovery is included.

b) Management of Dissolved oxygen (DO)

Figure 3.3.2-24 Input Pipe to the Aerating Tank of the Dyeing Enterprise in Bandung Outskirts

DO is an important factor concerning the waster water treatment based on activated sludge method. If DO is not enough in the waste water treatment process, the bacteria die out and the processing place may be confused.

In few enterprises, DO is managed by sending large amount of air to the block. It keeps sending large amount of air randomly. Much electricity can be saved by controlling the blower for oxygen and ventilation using the DO automatic measurement devices. The temperature from evening until next morning is very low in lot of Bandung districts with the fiber enterprises. The low temperature makes the taken of DO easier. Therefore, in this period, the operation control of blower is feasible.

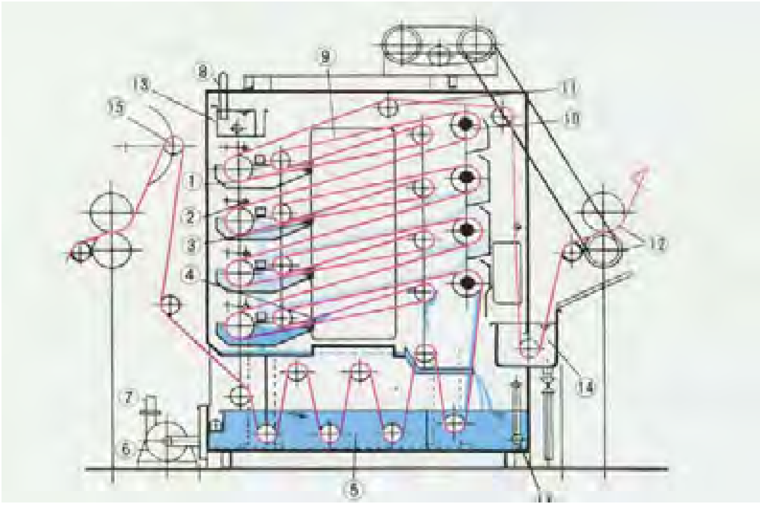
(3) Energy conservation technologies when replacing or establishing new equipments

In chapter 3.3.2 (2), many energy conservation technologies have been introduced. In the following, some feasible energy conservation technologies will be illustrated when replacing existing equipments or establishing new equipments.

1) Washing equipment

As the main energy consumer in dyeing processing, various improvements of the washing equipments have been proposed.

Several washing troughs are installed in the box and the rinsing water can be collected in the downward. By multiplying the fabric in the horizontal direction, the amount of fabric possession is increased. In this way, single trough can be used as several troughs and much energy and water are saved.



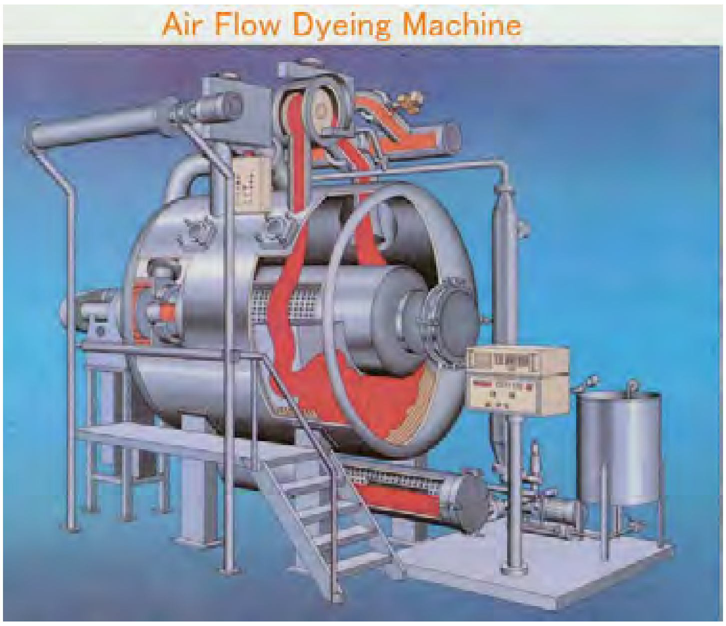
(From the Wakayama Ironworker)

Figure 3.3.2-25 Poly-stream Washing Equipment

2) Dyeing equipment

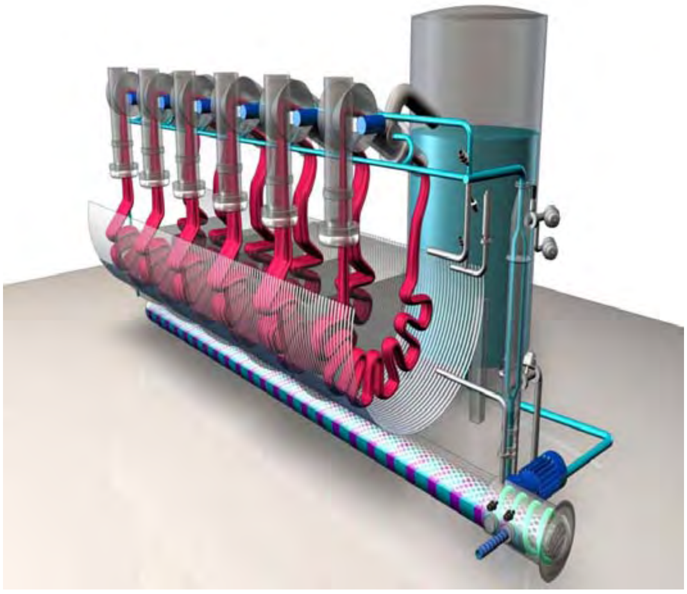
In the past batch dyeing equipment, water flow is used for circulating the fabric. Minimum water is necessary for the dyeing of fabric, and new system is the fabric circulation being done in the air flow. Water ratio can reach 1:3 for the polyester fabric.

In the equipment as shown in Figure 3.3.2-25, heat exchanger is installed in the drain pipes and the obtained warm water can be stored in the back trough. In addition, in order to make the fabric circulate smoothly, the slider of the fabric is set and also the mechanism which can reduce the water ratio is included.



(From the Thies Co. Ltd.,)

Figure 3.3.2-26 Air-Flow Dyeing Devices

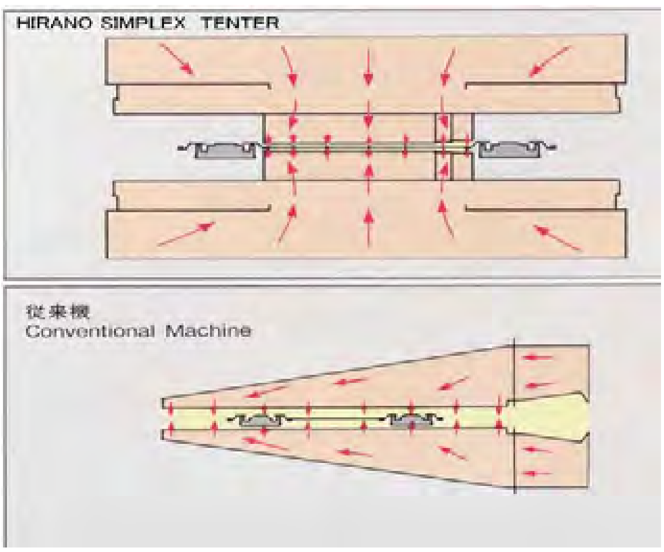


(From the FONG Co. Led.,)

Figure 3.3.2-27 Dyeing Machine Including Conservation of Energy Mechanism

3) Dryers

Large amount of cotton fly generated from the dryer is supplemented with the filter. The filter should be cleaned periodically.



(from Hiranoentec)

Figure 3.3.2-28 Wide Expandable Nozzle and Tenter m/c

4) Tenter m/c

The equipment adjusts the width of the nozzle according to the width of the fabric (Figure 3.3.2-28). Besides the exclusion of loss in the width, through let the hot wind blowing nozzle approach the fabric, the dry ability is improved.

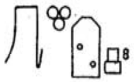
5) Calculation of the energy conservation effect for the feasible technologies at replacement or new establishment

In the year 2025 which is the decrease target year of energy elasticity rate, the following calculation is based on the assumption that the new equipments including that is shown in chapter 3.3.2 (3) have been spread. Besides including the inverters in all equipments, the energy conservation potential is described.

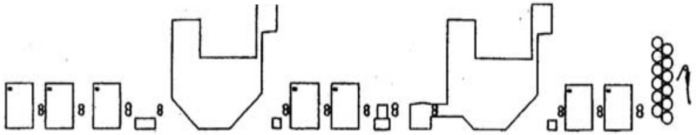
By including the general energy conservation equipments, such as co-generation, boiler, pumps, and compressors, etc., much energy conservation is expected.

Energy conservation potential by investing in new continuous dyeing process of cotton and blended fabric (1/2)

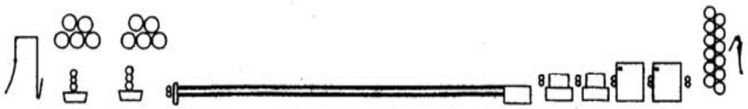
Gas singeing



Desizing, scouring and bleaching



Mercerizing



Heat setting

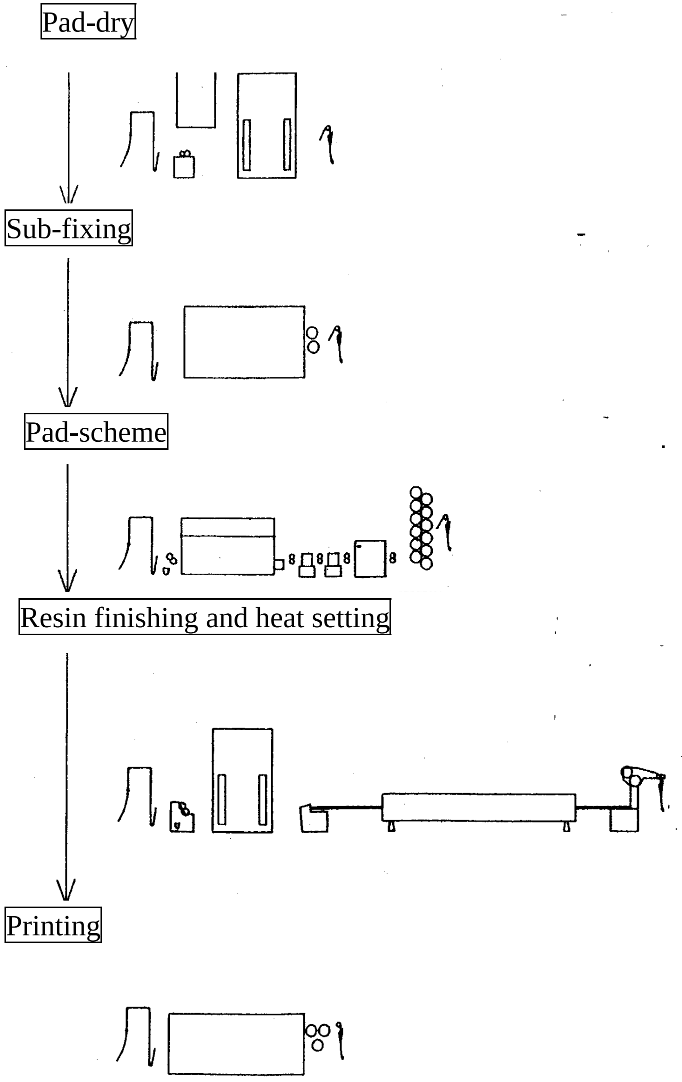
Scouring and bleaching	Water (ton/hr)	Steam (t・hr)	Electricity kWh	Energy saving ratio
Past device	61.0	5.0	115.0	Per time
New device	35.0	3.0	125.0	36.55％

1. High efficient washing device
2. Monitor for flow volume of washing device and inputted steam volume
3. Installation of over drying prevention device
4. Heat recovery device

Mercerize	Water (ton/hr)	Steam (t・hr)	Electricity kWh	Energy saving ratio
Past device	24.0	2.6	145	Per time
New device	10.0	1.5	159	34.4％

1. High efficient washing equipment
2. Monitor for flow volume of washing device and inputted steam volume
3. Installation of over drying prevention device
4. Automatic device for control of chemicals solution density
5. Heat recovery device

Energy conservation potential by investing in new continuous dyeing process of cotton and blended fabric (2/2)



Pad-Dryer	Water (ton/hr)	Gas (Mcal)	Electricity kWh	Energy saving ratio
Past device	1.9	542	6.0	Per time
New device	0.9	345	6.3	44.8%

1. Exhaust control with humidity sensor
2. Over drying prevention mechanism
3. Automatic control of temperature of dryer

Used as heat set

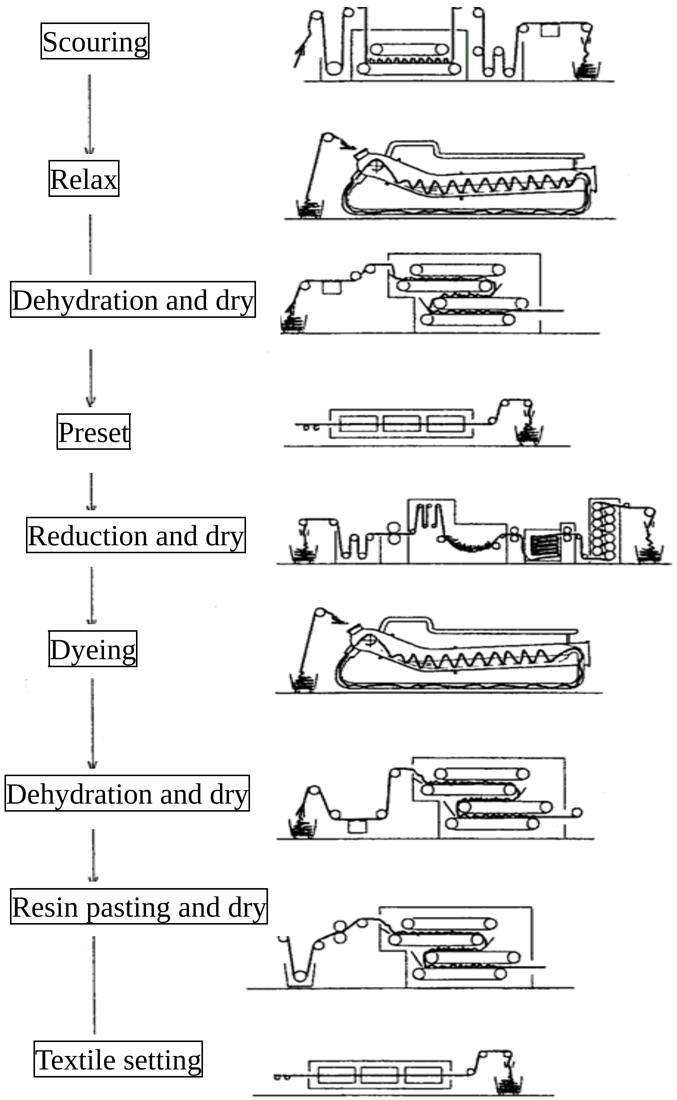
Pad-Steamer	Water (ton/hr)	Steam (t/hr)	Electricity kWh	Energy saving ratio
Past device	16.6	3.24	31.2	Per time
New device	8.5	2.07	26.2	35.8%

Used as finishing dryer

Tenter m/c	Water (ton/hr)	Gas (Mcal)	Electricity kWh	Energy saving ratio
Past device	1.50	400	91	Per time
New device	1.35	243	66	36.3%

Tenter m/c	Water (ton/hr)	Gas (Mcal)	Steam (t/hr)	Electricity kWh	Energy saving ratio
Past device	1.5	1085	0.637	152	Per time
New device	1.35	751	0.446	110	34.6%

Energy conservation potential by investing in new dyeing process of 100% polyester fabric（1/2）



Relaxation process
1. The trough structure for steady run of fabric and low water ratio
2. Setting of optimal processing time for the numerical control of computers
3. Total heat recovery

Dehydration, opening and dry process
1. Improvement of dehydration ability by using vacuum dehydration device
2. Decrease in thermal capacity by the compact of equipments
3. Uniformity of heat distribution by the compact of equipments
4. Reduce of heat loss by the compact of equipments

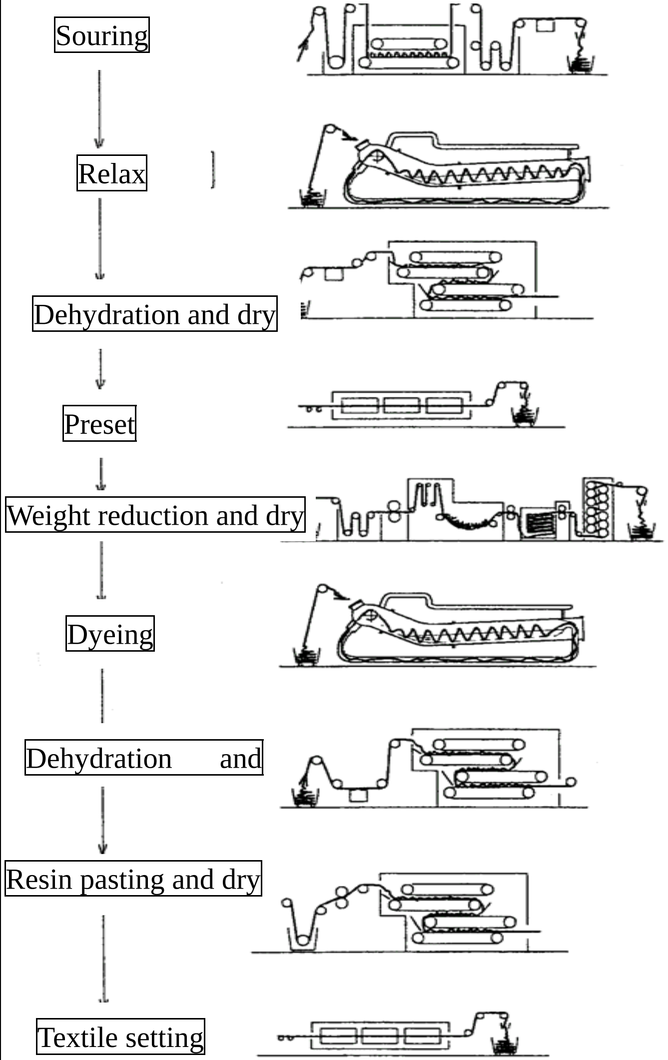
Preset process
1. Improvement of thermal efficient with width-follow hot air nozzle
2. Relative rise of wind speed of width-follow hot air nozzle
3. Heat recovery with heat recovery device
4. High rate operation with automatic filter

Weight reduction and dry process
1. Energy conservation based on continuous weight reduction
2. Control of water supply
3. Control of temperature

Dyeing process
1. The tank structure for steady run of fabric and low water ratio
2. Setting of optimal processing time for the numerical control of computers
3. Heat recovery system (High temperature drain system)

Finish set process
1. Improvement of thermal efficient with width-follow hot air nozzle
2. Relative rise of wind speed of width-follow hot air nozzle
3. Heat recovery with heat recovery device
4. High rate operation with automatic filter

Energy conservation potential by investing in new dyeing process of 100% polyesterfabric（2/2）



Relaxation	Water (ton/hr)	Steam（ton)	Electricity kWh	Energy saving ratio
Past device	42.3	2.34	121	Per Batch
New device	22.5	0.55	141	63.5%

Dehydration and drying	Water (ton/hr)	Steam（t/hr)	Electricity kWh	Energy saving ratio
Past device	0	0.95	75.5	Per time
New device	0	0.35	09.7	45.2%

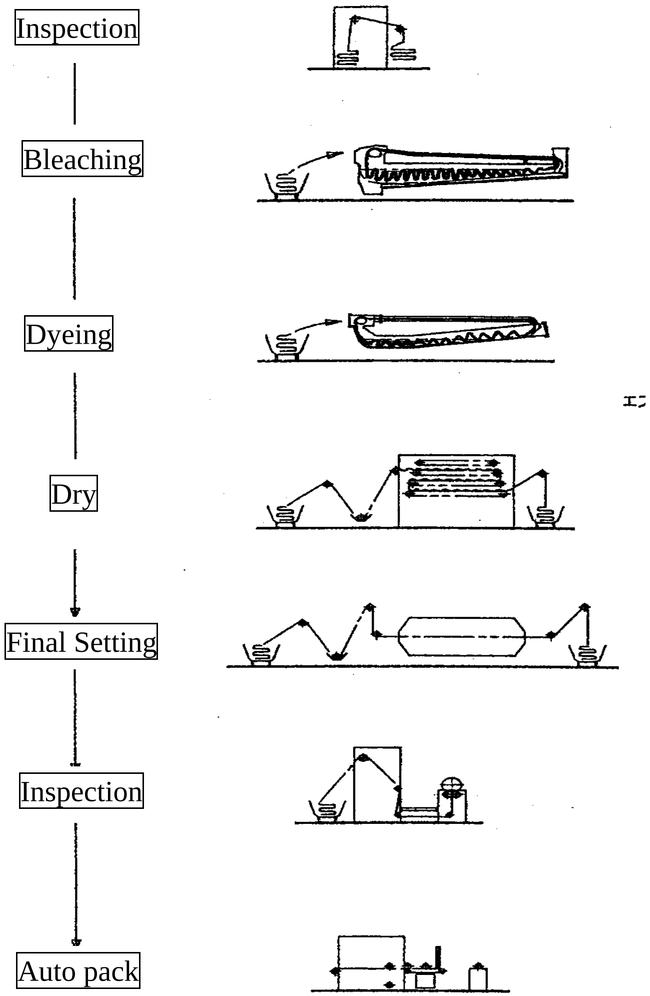
Preset	Water (ton/hr)	Gas（Mcal)	Electricity kWh	Energy saving ratio
Past device	0	390	62.3	Per time
New device	0	220	70.4	28.6%

Weight reduction and dry	Water (ton/hr)	Steam（ton)	Electricity kWh	Energy saving ratio
Past device	50	6.3	2.0	Per Batch
New device	4.5	2.2	48.1	62.3%

Dyeing	Water (ton/hr)	Steam（ton)	Electricity kWh	Energy saving ratio
Past device	53.8	2.34	423	Per Batch
New device	28.8	0.65	282	57.9%

Finishing set	Water (ton/hr)	Gas（Mcal)	Electricity kWh	Energy saving ratio
Past device	0	400	81	Per time
New device	0	280	91	28.0%

Energy conservation potential by investing in new dyeing process of cotton and blended knitted Fabrics (1/2)



Bleaching and dyeing process

1. Machine structure for low water ratio
2. Standardization of heat recovery system
3. Setting of optimal processing time for the numerical control of computers
4. Securing of yield by inputting chemicals automatically

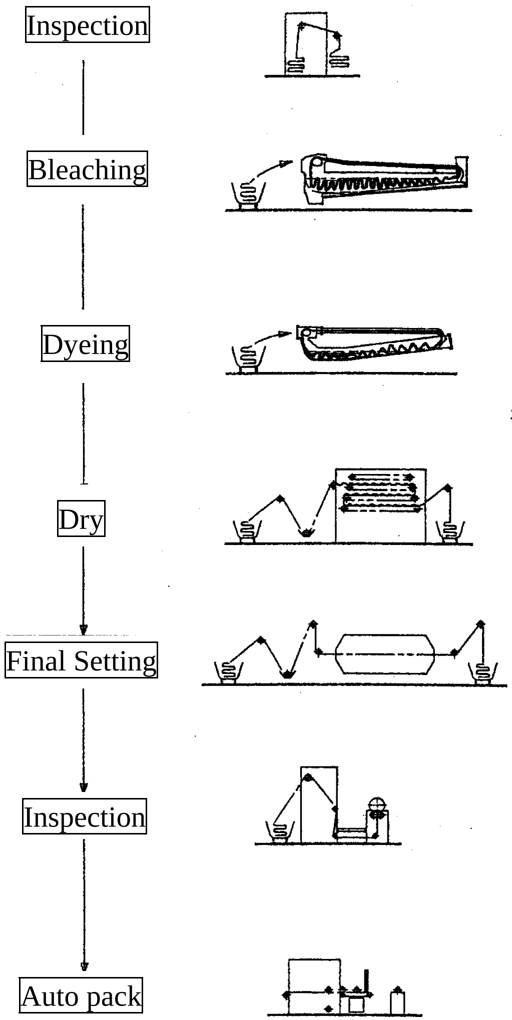
Dry process

1. Decrease in thermal capacity by the compact of equipments
2. Decrease of heat loss accompanying compact
3. Installation of automatic filter
4. Automatic control of fabric moisture
5. Monitoring of exhaust humidity and adjustment of exhaust

Final Setting

1. Strengthen of heat insulation board
2. Installation of automatic filter
3. Heat recovery filter
4. Interlock of fan motor
5. Monitoring of exhaust humidity and adjustment of exhaust

Energy conservation potential by investing in new dyeing process of cotton and blended knitted Fabric (2/2)



Bleaching	Water (ton/hr)	Steam（ton)	Electricity (kWh)	Energy saving ratio
Past device	15.8	1.3	84.2	Per Batch
New device	22.1	0.69	22.1	51.0%

Dyeing (cotton)	Water (ton/hr)	Steam（ton)	Electricity (kWh)	Energy saving ratio
Past device	10.5	0.79	30.6	Per Batch
New device	5.6	0.34	21.4	53.0%

Dyeing(T/C)	Water (ton/hr)	Steam（ton)	Electricity (kWh)	Energy saving ratio
Past device	17.3	1.24	80.5	Per Batch
New device	9.2	0.53	52.5	54.0%

Dry	Water (ton/hr)	Steam（ton/hr)	Electricity (kWh)	Energy saving ratio
Past device	0	0.92	68.0	Per time
New device	0	0.56	60.0	33.8%

Finishing (Set)	Water (ton/hr)	Gas（Mcal)	Electricity (kWh)	Energy saving ratio
Past device	0	500	60.0	Per time
New device	0	320	65.0	32.5%