REPORT ON THE STUDY ON ENERGY CONSERVATION PROJECT IN THE KINGDOM OF THAILAND

VOL. 3

— PLASTIC & CHEMICAL, FOOD —

JANUARY, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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Contents

I. GENERAL REPORT

1. Objectives of The Third Study

The study conducted this time was carried out in accordance with the Scope of Work for the Study on Energy Conservation Project in the Kingdom of Thailand (hereinafter called "the Scope of Work") which was signed between the National Energy Administration (NEA) of the Kingdom of Thailand and the Japan International Cooperation Agency in March 1982.

The framework of the study agreed upon by "the Scope of Work" is as shown in Fig. 1. The third study implemented this time is a part of the Phase 1 and aimed at the following points:

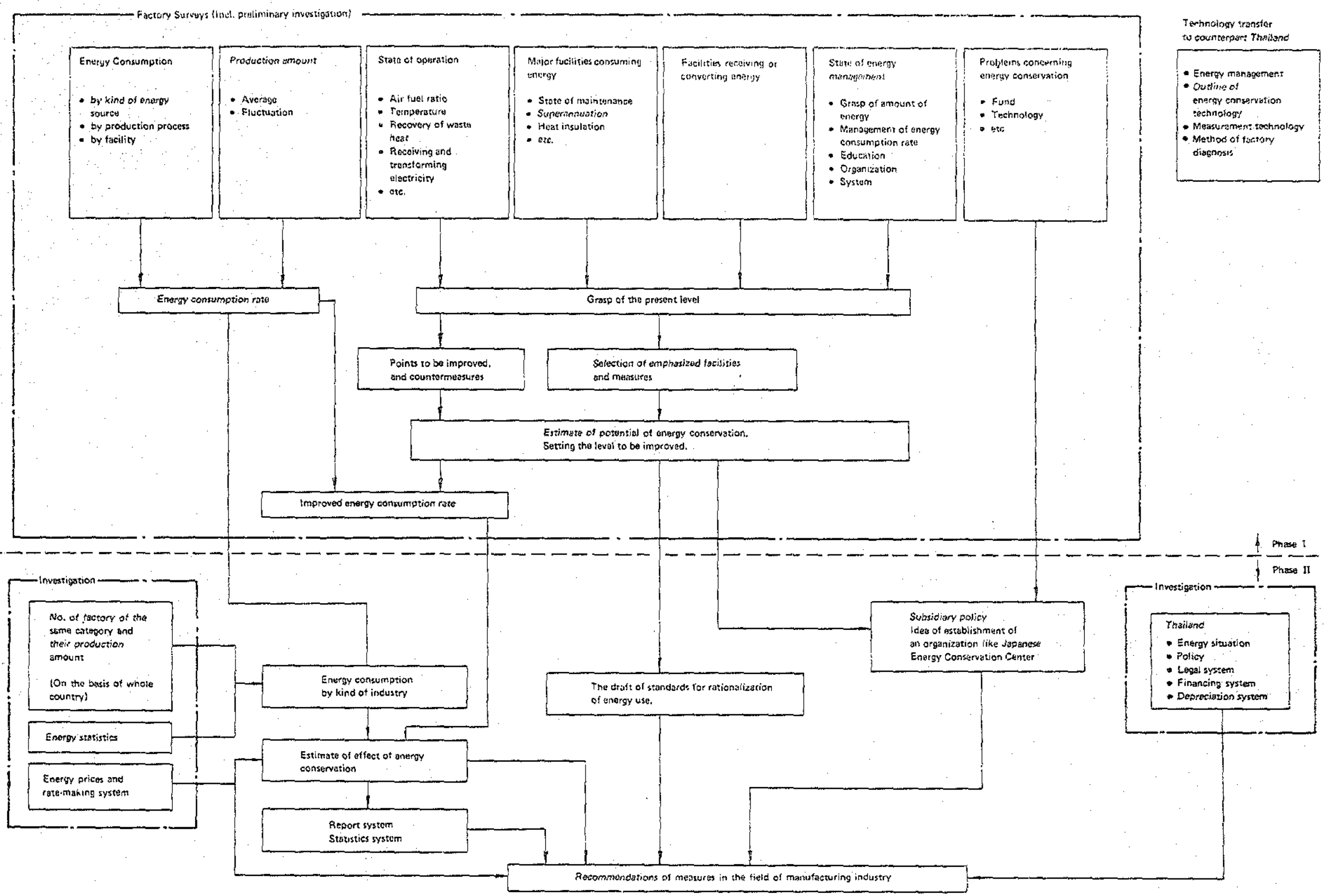
(1) Diagnosis of each 9 factories in the food industry and the plastic/chemical industry.

(2) Transfer of measuring and diagnostic technologies for energy conservation to the counterparts of the Kingdom of Thailand.

(3) Collection of general information related to energy in the Thai industrial field.

The on-site survey was carried out by the members shown in the attached data 1, according to the schedule shown in the attached data 2, for 35 days from June 26, 1983.

Fig. 1 Framework of Thailand's Manufacturing Industry Energy Conservation Investigation



2. Study Method

2.1 Factory Diagnosis

2.1.1 Preliminary Study through Questionnaire

Prior to undertaking the field study, a questionnaire (Attached data 3) was distributed to the factories concerned through the NEA asking that the following items be filled out.

a. Outline of the factory (factory name, address, names of officers, type of industry, capital, annual sales, number of employees and engineers, principal products, and production capacity)

b. Energy consumption (fuel, electric power, and water)

c. Principal energy consuming equipment (name, model, year installed, capacity, fuel used, and operating hours)

d. Production process chart

e. Energy flowchart

f. One-line diagram

g. Factory layout

h. Problems encountered in promoting energy conservation activities

2.1.2 Interviews with Executives and Managers

Referring to the returned questionnaires and energy management check lists (Attached data 4), interviews were held centering on the items shown in the following.

a. Current states of production and sales

b. Energy conservation countermeasures implemented in the past

c. States of energy management

d. Production problems

2.1.3 Overall Inspection of Factory

Overall inspection of the factory was made following the manufacturing processes to grasp the following items.

a. Overall management states

b. Layout

c. Priority facilities for surveys and measurements

2.1.4 Surveys and Measurement

Surveys and measurements were taken on the following items covering the priority facilities in accordance with the items given in the check list.

a. Measurement of facility dimensions

b. Data gathering utilizing factory records and meters

c. Measurement by measuring instruments (Attached data 5)

— Fuel combustion states

— Heating, cooling, and heat transfer states

— States of heat reliese prevention

— States of waste heat recovery

— States of conversion of heat into motive power

— States of electric power losses by resistance, etc.

— States of conversion of electric power into motive power and heat

2.1.5 Discussion

The outline of the survey and measurement results were explained to the executives and managers, and the points that were considered as problems were discussed.

2.2 Technology Transfer to Counterparts

2.2.1 Handling of Measuring Instruments

In the factories diagnosed, the study team showed how to handle the measuring instruments.

2.2.2 Guidance on Diagnostic Techniques

At the begining the study team explained to the conterparts the check list items and their meanings at NEA and thereafter guided them during the factory diagnosis on how to fill in the check list. On the days data were sorted after the factory diagnosis, the processes and diagnostic points for the diagnosed factories were explained to them. Guidance on diagnostic techniques was given through sorting of gathered data and descriptions of information that could be obtained from the data.

2.3 Gathering of Related Information

Information related to energy policies, the energy situation, production state of manufacturing industries, and other items in Thailand was gathered through NEA and the Thai-Japan Technological Promotion Association (TPA).

3. Diagnosed Factories

The diagnosed factories are as shown in Table 1. All of these factories are located in the neighborhood of Bangkok with the farthest one located approx. 130 km away.

Of these factories, two chemical factories and one food processing factory are joint ventures with foreign interest. Two chemical factories and 4 food processing factories belong to Thai enterprise groups.

As regards products, 3 factories are monopolizing the manufacture of specific products in Thailand and 6 factories are in the top group in terms of production scale. The other factories are of the middle or higher production scale.

The chemical and food processing factories are classified as a process industry and are in need of considerations over safety in handling hazardous materials and over sanitation in handling foods. For these reasons, the factories are generally in good order.

Table 1 Factories Diagnosed

Industry Type	Factory	Products	Dates
Chemical	Thai Bones Industry Co., Ltd.	Ossein	6/30~7/1
	Citric Acid Industry Co., Ltd.	Citric acid	7/ 4~ 5
	Custom-Pack Co., Ltd.	Plastic wares	7/ 7~ 8
	Thai Industrial Gases Ltd.	Liquid Oxygen/Nitorogen	7/11~12
	Siam Union Sahamitr Co., Ltd.	Vegetable oil, Soap, Margarin, Glycerin	7/14~15
	Siam Chemical Co., Ltd.	Sulfuric acid, Nitrous oxide, Alum sulfur roll	7/18~19
	Thai Chemical Corporation Ltd.	Formalin, Plasticizer, Adhesive	7/21~22
	Thai Silicate Co., Ltd.	Sodium silicate	7/23
	The Bangkok Chemical Industrial Co., Ltd.	Sulfuric acid, Cupric sulfate, Ferrous sulfate, Alum, Sulfur powder/roll	7/26~27
Food	Sang Som Co., Ltd.	Whisky	7/ 4~ 5
	United Grains Co., Ltd.	Granary	7/ 7~ 8
	Thai Castor Oil Industries Co., Ltd.	Castor oil	6/30~7/1
	Thanakorn Vegetable Oil Products Co., Ltd.	Vegetable oil	7/11~12
	The Unicord Investment (Thailand) Co., Ltd.	Canned sea-food	7/14~15
	Thai Union Manufacturing Co., Ltd.	Canned sea-food	7/21~22
	Union Seri Co., Ltd.	Canned sea-food	7/23
	Star Feedmill Co., Ltd.	Feed	7/18~19
	Central Food Products Co., Ltd.	Feed	7/26~27

4. Results of Factory Diagnosis

4.1 Status of Energy Management

4.1.1 General

The managers of the diagnosed factories are equally highly concerned about energy conservation. Some of the factory general managers with excellent technological background are willing to put technical measures into practice ahead of others. The measures are successful. However, generally, there are only few companies which have reached such a stage that the policy is reflected in the activities of the whole factory.

(1) Setting of Targets and Appeal by the Management

In order to promote energy conservation, the managers should establish concrete targets of achieving energy conservation such as "by when" and "how much percent". Then they should have the employees understand the reason why energy conservation is necessary by indicating the targets to the latter. After these procedures, the managers need to seek cooperation from the employees toward the targets. Based on the targets, the employees will have a clear aim of in which direction each department or an individual should put its efforts, thus enabling them to take concrete steps easily.

Of the diagnosed factories, 2 chemical factories and 4 food processing factories have their targets established. One of these factories has set a ceiling for energy consumption according to a monthly production schedule. This ceiling is made known to the employees for observation.

The appeal by the factory general managers are made to the employees whenever necessary at the meetings centering around the slogans "abiding by the rules and attaching importance to safety." Nevertheless, there has a few appeal regarding mainly to energy conservation or in writing.

(2) State of Enforcement of Measures up to Now

As measures taken for energy conservation, 13 factories have put the following into practice: recovery of condensate, reinforcement of insulation, checkup and repair of traps, utilization of byproduct fuel and utilization of waste heat from boilers and processes. Some of the factories has invested 8 million Bt.(Refer to Table 2.)

Some has actually improved the fuel consumption rate by close to 40% by improving operating condition. On the other hand, some shows a case where, despite investment, equipment has been left unmaintained without confirmation of its results. Thus the equipment has not displayed its function.

Most of the factories consider that the basic investment recovery period is approx. 3 years.

4.1.2 Participation by All Employees

Generally speaking, few factories have a system or organization concerning with energy conservation. Only the factory general manager and a few number of staff members are engaged in working out and implementing measures for energy conservation on equipment.

No factory has a committee solely working under a theme of "energy conservation". However, the factories which deal with the energy problem at a regular meeting of the cost

Table 2 The Energy Saving Measures Carried Out to Date

Measures	Chemical	Food	Total
Rationalization of combustion of fuel			
Preheating of fuel	1	1	2
Rationalization of heating, cooling and heat transfer			
Replacement of boiler	3	1	4
Sale of surplus steam to neighboring factory	1		1
Utilizing of raw material getting higher yield		1	1
Prevention of energy loss by radiation and conduction			
Reinforcement of insulation	3	2	5
Inspection and repair of steam traps		3	3
Recovery and utilization of waste heat			
Combustion of waste oil and gas	1	1	2
Recovery of condensate	3	1	4
Utilization of heat of exhauste gas	1	1	2
Heat recovery in process	1	1	2
Heat recovery in blower and compressor	2		2
Utilization of solar energy	1		1
Prevention of electric loss by resistance			
Cutting off of surplus transformers		1	1
Rationalization of converting electricity to driving power and heat			
Improvement of lighting		3	3
Reduction of power consumption for motors		2	2
Improvement of transport equipment		1	1
Total	17	19	36

committee account for approx. 1/3 of the total diagnosed.

Only one chemical factory is provided with an improvement suggestion system. On the other hand, 6 food processing factories are with the said system. Nevertheless, no suggestion has ever been submitted in both cases, hence the system is not working effectively.

Only one chemical factory and one food processing factory have begun small group activities such as QC circle. Another factory is now preparing for these activities.

There is one exemplary fatory which is conducting energy conservation activities by creating a project team. This factory holds a discussion attended by also foremen once a month and carries out measures to solve problems taken up as themes such as power factor improvement, insulation and trap/valve leakage. The results are reported to the higher-level committee.

4.1.3 Determining the Actual Situation of Energy Consumption

Almost all the diagnosed factories catch daily energy consumption. More than a half of the factories are keeping data by process and facility.

Two chemical factories and 3 food processing factories showed satisfactory results by the following manner.

Based on such data, a fuel consumption rate is calculated and a control chart prepared. If there is any change in the rate, its possible cause is analyzed and properly dealt with. Thus control procedures which are instrumental to the improvement of operation are faithfully taken.

As explained above, generally the level of control through data is high. However, the installation of control instruments is not yet sufficient for proceeding to a stage where the control by process is carried out. For instance, concerning the flow meters for boiler feed water and for fuel oil which are necessary for daily control of the heat management of boiler, 4 units of boiler of the total 13 are not equipped with the former, and 5 units with the latter. In addition, each 2 units are out of order, although equipped. After all, almost half the total units are operated without any control indicator.

4.1.4 Improved of Technical Level

Almost all the factories diagnosed are conserning about employees' education/training. That is, they send their employees to external seminars except 3 chemical factories. Actually, some let the employees participate into the seminar more than 10 times a year. Some sent approx. 20 employees to the seminar a year. Approx. 1/3 of the factories sent the employees for study visits to other industrial facilities.

"Transfer" seminars where the employees who ever participated in external seminars act as instructors, are not held at the factories. It is possible for the instructors to acquire what they learned at the seminar more completely by teaching other people. In addition, technical knowledge acquired by them is not limited to them only, but is spread to other employees, thus contributing to the technical leveling-up of the whole company. In this sense, it is desired that the transfer seminars be held henceforth. As a good example of the case that iternal education is provided satisfactorily, the factory general manager sponsors a seminar twice a week as an instructor. Another example is that the jobs are intentionaly interchanged among the employees so that the technical level of the entire work force may be enhanced.

A few factories are manned by fewer employees than should normally be required or employees lack in technical knowledge. So the factory general manager alone handles everything ranging from daily management to improvement planning. However excellent he may be, he cannot devote himself toward these things all the time, attending to immediate matters occurring around the factory. From this viewpoint, it is urgently needed to bring up capable staffs and man them to such jobs as now being handled exclusively by the general manager.

4.1.5 Items which the Factories consider as Problems in carrying out Energy Conservation (Answers to Questionnaire)

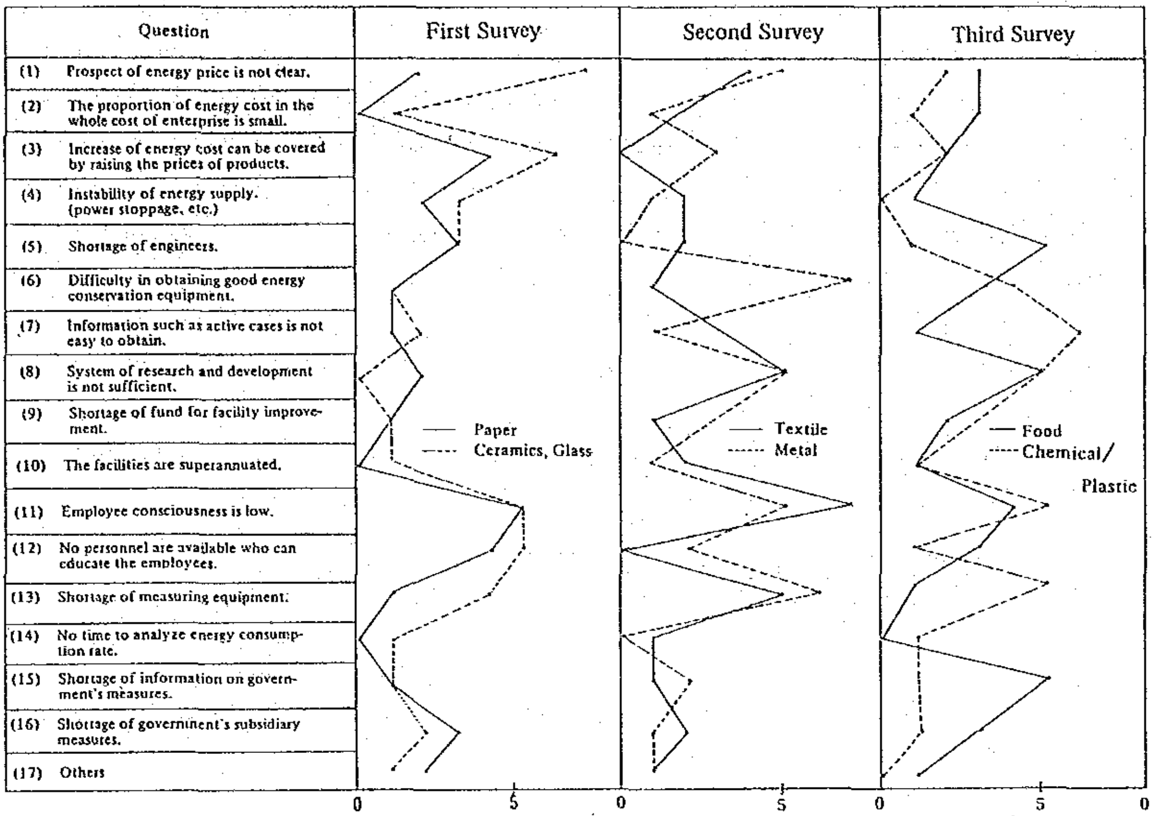
The answers to the questionnaire (attached data 3) handed to the factories in advance are as shown in Table 3. and Fig. 2

Table 3 Replies to Questionnaire "Problems Encountered in The Promotion of Energy Conservation"

(Number of replies 18 factoreis)

Question		Food	Chemical	Total	(Reference) The First study	(Reference) The Second study	Total
(1)	Prospect of energy price is not clear.	3	2	5	9	9	23
(2)	The proportion of energy cost in the whole cost of enterprise is small.	3	1	4	1	3	8
(3)	Increase of energy cost can be covered by raising the prices of products.	2	2	4	10	3	17
(4)	Instability of energy supply. (power stoppage, etc.)	1	0	1	5	3	9
(5)	Shortage of engineers.	5	1	6	6	2	14
(6)	Difficulty in obtaining good energy conservation equipment.	3	4	7	2	8	17
(7)	Information such as active cases is not easy to obtain.	1	6	7	3	4	14
(8)	System of research and development is not sufficient.	5	5	10	2	10	22
(9)	Shortage of fund for facility improvement.	2	3	5	2	4	11
(10)	The facilities are superannuated.	1	1	2	1	3	6
(11)	Employee consciousness is low.	4	5	9	10	12	31
(12)	No personnel are available who can educate the employees.	3	1	4	9	2	15
(13)	Shortage of measuring equipment.	1	5	6	5	11	22
(14)	No time to analyze energy consumption rate.	0	1	1	1	1	3
(15)	Shortage of information on government's measures.	5	1	6	2	3	11
(16)	Shortage of government's subsidiary measures.	3	1	4	5	3	12
(17)	Others	1	0	1	3	2	6
Total		43	39	82	76	83	241

Fig. 2 Replies to Questionnaire "Problems Encountered in The Promotion of Energy Conservation"



The under-mentioned questions collected many answers:

(8) The research and development system is insufficient.

(11) The employees are not highly conscious about energy conservation

(6) It is difficult to obtain effective energy conservation equipment.

(7) It is difficult to gather information such as examples of energy conservation actually carried out.

In comparison with the results of the first and second surveys, it was found that the number of answers to the question "(1) The future energy price trend is unpredictable" had further decreased. This fact reflects a stable crude supply situation. The number of answers to the question "(11) The employees are not highly conscious about energy conservation" is large in every surveys. The answers which were increased in number compared with those to the other surveys were to the questions "(5) The number of technicians is short" and "(15) Available information on governmental measures is insufficient," which were posed to the food processing factories and also to the question "(7) It is difficult to gather information such as examples of energy conservation actually carried out" to the chemical factories." The number of answers to the question "(8) The research and development system is insufficient " was the same as the second survey. This fact is indicative of being conscious about energy conservation of higher level.

4.2 State of Energy Consumption

4.2.1 Fuel Combustion

(1) Load on Boilers

Of the 13 factories diagnosed, 6 factories show a conspicuously low actual load as against the capacity of the boiler. For this reason, the frequency of suspending and starting of the boiler is high. In some worst case, the flame went out. If the said frequency is high, the efficiency tends to become low because of the introduction of cool air for purging when the boiler is fired again.

(2) Maintenance of Burners

Some of the burners checked are lacking in sufficient cleaning and equipped with the nozzles worn out. On account of insufficient atomizing of fuel, they generated smoke or burned in the rear as backfire. With a factory the boiler capacity is reduced, and therefore there happens necessity to operate a stand-by boiler. In addition, due to the fouling of the heat transfer surface, the temperature of exhaust gas is high.

(3) Maintenance of Instruments

The installation state of the feed water flowmeters and the fuel oil flowmeters is as shown in Table 4. Approximately half the total number are in need of installation or maintenance.

These measuring meters are indispensable for the daily monitoring of boiler efficiency after calculation of an evaporation multiple based on the ratio of feed water flow to fuel oil flow. It is desired, therefore, that they be installed and placed under satisfactory maintenance and control.

Some of the boilers is equipped with an instantaneous value indicating meter for steam flow. However, it is difficult to use the meter for the control of the above-mentioned evaporation multiple unless it is of an integrating type.

Table 4 Equipment of Flowmeters for Boilers

	Equipped		Not equipped	Total
	Working well	Out of order		
Flow meters for feed water	7	2	4	13
Flow meters for fuel	6	2	5	13

(4) Air Ratio

The distribution of the air ratio for the boiler is as shown in Fig 3.

Some of the boilers have an extremely high air ratio. One of such boilers is extremely in low load and have to be at a low combustion rate for a long time. On the contrary another boilers emits smoke due to a low air ratio.

(5) Preheating of Fuel Oil

Some of the boilers are without a preheater for fuel oil or with the preheater which, however, is not properly used. Unless the viscosity of fuel oil is kept within an appropriate range by preheating it at a temperature corresponding to the type of fuel oil, a satisfactory atomizing state cannot be achieved.

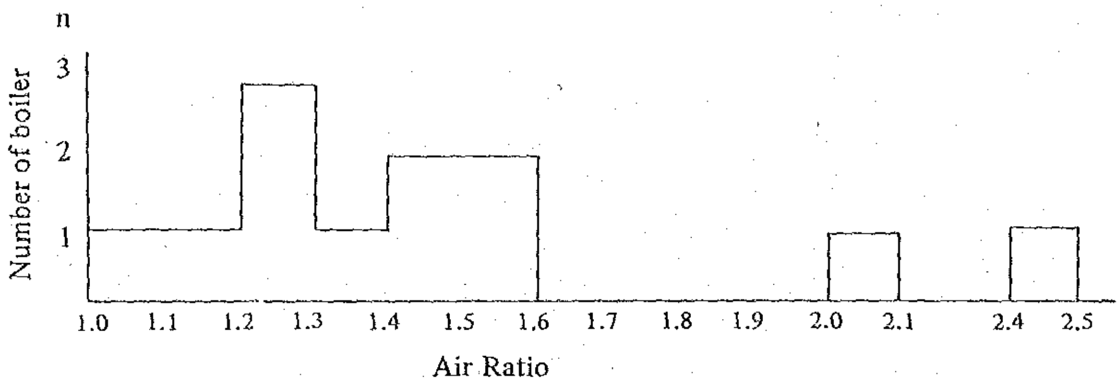


Fig. 3 Air Ratios of Boilers n = 12

4.2.2 Heating, Cooling and Heat Transfer

(1) Improvement of Yield

A considerable amount of energy is already spent until a product was finished whether it be a final or a intermediate product. Therefore, if they are fouled, spilled or lost halfway in the process, that means an enormous loss of energy. During our visit to the factories this time, we noticed a large amount of spillage of molten sulfur, materials for canned food or animal feed on the floor. Even if these materials were recycled into virgin materials, the energy spent for the former could not be recovered.

On the contrary, we noticed a commendable case where, in order to secure raw material castor seed containing a high percentage of oil, some castor oil manufacturing factory selected high-quality seeds and redistributed them to the farmers.

(2) Evaporator

Four factories are equipped with the evaporator units for thickening of solution or solvent removal. The majority of the units are of a double effect type, but a single effect type is also seen. It is the latent heat of vaporization that accounts for a majority of the heat requirements for the evaporator. Therefore, the double effect unit is composed of two evaporation stages, the second stage using the vapor which is generated in the first stage as heat source. Theoretically, it is possible to reduce the required energy by half. Accordingly, the number of the effect for the evaporator can be increased so that energy may be conserved, whenever the energy cost mounts increasingly. The examples of the application of the double effect unit are often seen.

In addition to the above energy conservation-type evaporator, there is another type that utilizes a generated vapor recompressed by the blower as a heat source. It is necessary to select the evaporator after considering the type of finished product, space availability and other points.

(3) Air Purge during Steam Heating

The residual air in the steam heater cannot easily be discharged because of a specific gravity difference between the air and steam or a small vent area. Since the air is a bad conductor of heat, the residual air may possibly cause the following troubles:

a. Temperature rise takes time.

b. The temperature distribution in the steam heater becomes ununiform.

c. A drop of the partial steam pressure results in a decrease of steam temperature, hence the impossibility of heating up to a required temperature.

d. Oxygen in the air accelerates corrosion.

A spot where the air remains is located differently according to the shape of equipment and operating modus. Therefore, it is necessary to improve the design of the steam heater by collecting as much data as possible regarding heating-up period and temperature distribution.

The employees of the factories generally seem to be not much concerned about the harmful effect of air.

(4) *Steam Pressure*

It is a portion equivalent to the latent heat of steam that is effectively used for heating, of the total heat of steam. The lower the steam pressure, the more the latent heat in steam. It is effective for steam conservation to reduce steam pressure as much as possible within a range where a difference in the temperature between the steam and a heated material can be maintained.

There are two factories which should have the steam pressure reduced.

(5) Temperature of Exhaust Gas from Boilers

The distribution of temperatures of exhaust gas from the boilers is as shown in Fig 4. Some of the boilers show an abnormal rise of the temperature of exhaust gas due to soot generated by imperfect combustion or incomplete cleaning of the heat transfer area. Some show a drop in the temperature of exhaust gas on account of a low load. For boilers of this kind, attention needs to be paid to the stack where corrosion might have occurred.

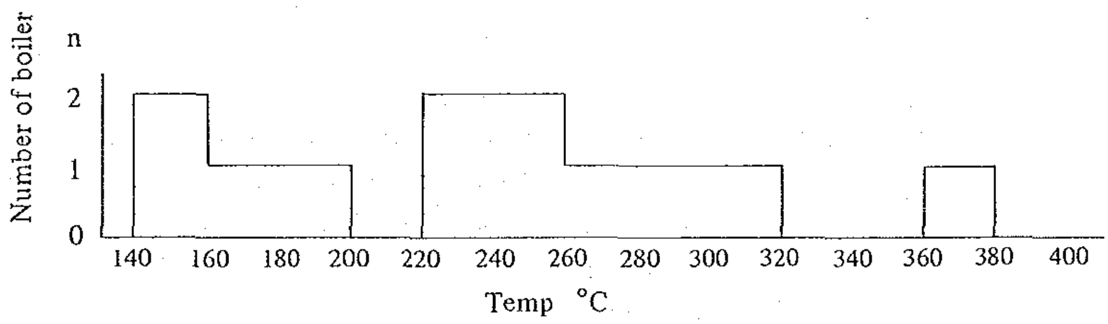


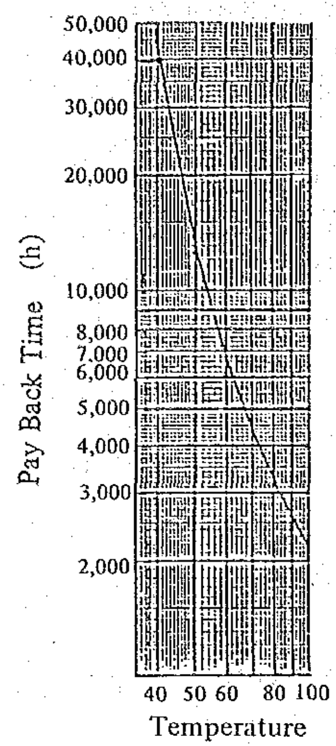
Fig. 4 Exhaust Gas Temperature n = 12

4.2.3 Heat Loss by Radiation, Conduction, etc.

(1) Insulation

Almost all of the equipment and piping are insulated and also the remainder are now being insulated. Nevertheless, there remain a considerable number of parts which require insulation. Almost all of the steam valves are not insulated except those of one factory. The condensate recovery piping are also not insulated. In addition, large-size equipment such as distillation towers or cookers are without insulation.

Following the soaring of energy cost, the economics of insulation has improved more than ever. Fig 5 shows an example of a calculation based on certain established conditions. For the surface of 60° C or higher, insulation cost can be recovered almost within one year.



<Basis of Calculation>

Ambient temperature	35°C
Surface emissivity	0.2
Boiler efficiency	85%
Fuel cost	4.35 Bt/ℓ
Heating value of fuel	9,500 kcal/ℓ
Insulation efficiency	90%
Insulation cost	500 Bt/m²

Fig. 5 Pay Back Time of Insulation Cost

We also noticed other cases where significant effect can be expected by the installation of a cover on the hot water tank or a reduction of emissivity through the change of paint color.

(2) Blow Down Water for Boilers

The distribution of electroconductivity of blow down water for the boiler is as shown in Fig 6. Generally the value is low which is suggestive of a satisfactory state of water treatment or blow-down operation. However, there is a case where the blow-down operation is carried out beyond the limits of necessity.

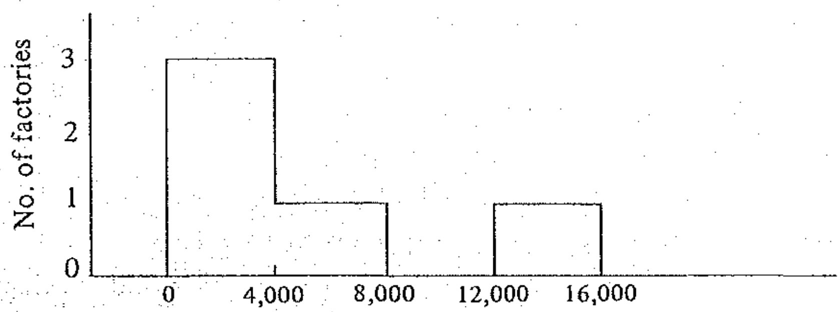


Fig. 6 Conductivity of Boiler Water μS/cm

(3) Check on Traps

There is a case where steam is entrained even into the feed water tank on account of defective traps. Generally it seems that the check and maintenance of traps are unsatisfactory.

4.2.4 Waste Heat Recovery and Reutilization

(1) Recovery of Heat of Process Fluid

In the distillation process, solvent separation process and reactor, parts necessitating heating and cooling of process fluid are provided in a same plant. Therefore, it is important for energy conservation to effectively exchange heat between these fluids. The said process are generally so designed as to attain the level of most economical operation considering costs involved in energy and equipment. However, following the energy price hike, there is a trend that more stress is placed on more efficient heat exchange. As far as the diagnosed factories are concerned, the distillation towers, deodorizing towers and crystallization tanks still can afford to accommodate considerations over heat exchange.

(2) Recovery of Pressure

If a generated steam pressure is higher than a consuming pressure, the pressure difference can be recovered by means of a turbine as an electric power. In the case of water desalting operation by the reverse osmosis, brine equivalent to approx. half the quantity of raw water is discharged as it is in a high pressure state. It is possible to recover the pressure and drive the pump with it. If this process is to be performed in an economical way at all, the pressure difference or the scale should be larger than a level. Some of the diagnosed factories have a potential for the above-mentioned conditions.

4.2.5 Heat Conversion to Motive Power, etc.

Because of unstable power supply from the power company, the power supply failure occurs frequently. On the other hand, some factories do not even allow for a short power supply failure because the process handles dangerous materials. These factories are equipped with a diesel electric generator working always for security purposes. This small-scale electric power generating equipment should be designed to make simultaneous use of the exhaust heat of diesel engines. Otherwise, the efficiency is considered low. Accordingly, it is necessary to provide a power receiving unit based on two power supply sources or recover heat.

4.2.6 Loss of Electric Power by Resistance, etc.

(1) Power Factor

The distribution of power factor and the installation state of condensers at the diagnosed factories are as shown in Fig 7. At the food processing factories, condensers for the improvement of power factor are well arranged. However, some have condensers not working because of defective relays. In the group of chemical factories, a factory having the highest power factor is equipped with a large capacity induction synchronous motor. They maintain the power factor at close to 100% by adjusting the field current.

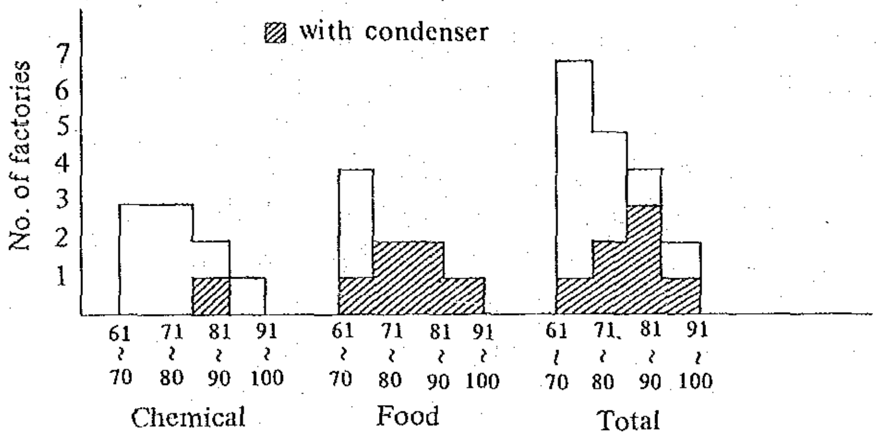


Fig. 7 Distribution of Power Factor by Branches of Industry

(2) Imbalance of 3-Phase Electric Current

Approx. 1/3 of the diagnosed factories suffer a current imbalance. It is necessary to eliminate the imbalance by contriving the connection of the single phase loads such as illumination.

(3) Peak Demand

No factories pay much attention to the restriction of peak demand. It is necessary to look into the causes for peak and work out countermeasures by measuring hourly electric energy and preparing a daily load curve. If the peak is restricted, not only the penalty for peak demand can be reduced but also a resistance loss can be diminished.

(4) Transformers

Generally, the capacity is reasonable. Some factories have disconnected the transformers in surplus. It is desirable to put the transformers considered "extra" out of service during a long annual shutdown or whenever a significant change has occurred in the operation henceforth.

4.2.7 Conversion of Electric Power into Motive Power, Heat, etc.

(1) Service Voltage to Electric Motors

Generally, the service voltage to electric motors is rather high. It is to be noted that the motor efficiency will be improved, if the voltage is adjusted slightly downward during a low load (less than 50%) on the motor.

(2) Illumination

The daylight-color fluorescent lamps are seen used at many factories. It is suggested that they be replaced by the energy conservation-type white-color fluorescent lamps for power conservation.

(3) Conservation of Electric Power for Compressed Air

There is still room for the conservation of electric power for air compressors by preventing a leakage of compressed air, reducing the discharge pressure and stopping an unnecessary release of compressed air.

4.3 Plastic & Chemical Industry

4.3.1 Outline of the Industry and Relative Positions of the Factories Diagnosed

The chemical industry showed an annual growth of close to 12% in 1970s. From a viewpoint of the composition ratio of an added-value amount in the manufacturing industry, the chemical industry accounts for approx. 15% following the foods and textile industries. In addition, the petrochemical complex using natural gas of the Siamese Bay is now under construction. The chemical industry is playing an important role in the manufacturing field of Thailand.

In the factories diagnosed this time, factories of large energy consumption type such as petroleum refiners are not included. In addition, three factories which do not consume fuel oil because of small heat requirement or the availability of a large quantity of credit heat through chemical reaction are also included. For this reason, this energy consumption status might not necessarily reflect the entire situation.

However, comparing with the total energy consumption of the entire Thai industry and that of the factories diagnosed this time, the consumption proportion of heat and electric power is comparatively closer to the value of the entire industry as shown in Table 5.

Table 5 Energy Consumption in Chemical Industry 10^9 kcal/y

	Overall chemical industry (A) 1)	Factories diagnosed (B) 2)	B/A
Fuel	1,724 (69.1%)	68.4 (71.4%)	4.0%
Power	770 (30.9%)	27.4 (28.6%)	3.6%
Total	2,494 (100.0%)	95.8 (100.0%)	3.8%

Note: 1) Expected annual increase of 10% for two years based on UNDP/UNIDO Terminal Report, Annex VII Table B.

2) Equivalent heating values are 9,500 kcal/ℓ for fuel and 860 kcal/kWh for electric power.

The diagnosed factories involve three factories, each occupying the top position in three different products respectively. However, the energy consumption of the diagnosed factories accounts for only 3.8% of the total energy consumption, because the chemical industry involves many factories manufacturing a variety of products or consuming a large amount of energy such as petroleum refiners.

4.3.2 Manufacturing Process

The factories diagnosed this time generally do not have a common process, so their manufacturing processes are omitted. Refer to "Edition for Individual Factories."

4.3.3 States of Energy Consumption

Energy is consumed at the chemical factories in the following forms:

Table 6 Type of Consumption of Energy

Service	Equipment	Kind of Energy
Steam generation	Boiler	Bunker oil, Sulfur
Power generation	Diesel engine	Diesel oil
Chemical reaction	Melting furnace Reactor	Bunker oil, steam, electricity
Drying	Through-circulation dryer Fluid bed Rotary dryer Flash dryer Spray dryer	LPG, steam Diesel oil Diesel oil Steam Steam
Melting	Melter	Steam
Degreasing	Extractor Autoclave	Steam Steam
Evaporation, thickening	Evaporator	Steam
Cooking	Cooker	Steam
Bleaching	Bleaching tank	Steam
Deodorization	Deodorizer	Steam, Heating medium
Air compression	Compressor	Electricity
Fluid transportation	Pump Blower	Electricity
Plastic molding	Molder	Electricity
Chilled water making up	Refrigerator	Electricity
Crushing	Crusher	Electricity
Lighting	Fluorescent lamp	Electricity

4.3.4 Major Points of Energy Management

(1) State of Combustion in the Boiler

The following items are important:

Installation of burners of an appropriate capacity corresponding to a load, periodical cleaning of burner nozzles, keeping of fuel oil temperature at a appropriate level, adjustment of the air ratio, maintenance of a flowmeters and control of the evaporation multiple through their readings.

(2) Temperature of Boiler Exhaust Gas

The boiler needs to be cleaned and removed soot periodically so that the deterioration of heat transfer rate can be prevented. Though the frequency of cleaning the boiler varies according to the quality of feed water, the cleaning should be carried out twice a year in case feed water is not treated. For cleaning of the exterior of the heat transfer area, check on a change in the exhaust gas temperature, and carry out the cleaning at a time when the difference between a temperature daily examined and one showed right after the cleaning.

(3) Yield

The following procedures are necessary: Control a change in the yield by grasping a clear picture of quantities of raw materials, finished products and byproducts, and at the same time, check on the quantities of rejects from the manufacturing process which were thrown away or recycled into virgin materials. Then work out any appropriate procedures so that the rejection ratio may be minimized.

(4) Heat Flow in the Process

Examine the flow and enthalpy of fluid in each part of the process and prepare a heat flow chart. Then look into the feasibility of heat exchange and study more rational remodeling of the process.

(5) Steam Pressure

Study if it is possible to further decrease the working pressure of steam. If there is any process which needs to be used at high pressure for unavoidable reasons, consider the recovery and utilization of flash steam from the condensate.

(6) Insulation

Study the reinforcement of insulation by measuring the surface temperature of each part of a plant. For the existing insulation, maintain and inspect it so that it may not be broken or wet.

(7) Steam Traps

Attach a serial number to the steam traps, examine their operating condition periodically and record the results in the log.

(8) Feed Water for the Boiler and Quality of Boiler Water

Check on the quality of the feed water for the boiler and the boiler water periodically so that blow-down quantity may be maintained at a proper level.

(9) Recovery of Condensate

Try to increase the condensate recovery rate as far as circumstances allow and make efficient use of the whole quantity of recovered condensate. If possible, it is desirable that, in addition to a feed water flowmeter, a soft water flowmeter be installed on the boiler to enable an easy determination of recovered condensate quantity. Further, make sure that the condensate recovery piping and the feed water tank be insulated.

(10) Power Factor

Study the installation of a condenser for improving the power factor. For the existing condensers make sure that the relays are sufficiently maintained and controlled.

(11) Peak Demand

Measure a hourly electric energy and prepare a daily load curve. Then examine the causes for peak demand generation and try to restrict the peak demand.

(12) Service Voltage to Electric Motors

Be careful about a service voltage to the electric motor and keep it at an appropriate value. Set the said voltage at a slightly lower value when the load is less than 50%.

(13) Electric Power for the Pumps and Air Compressors

Examine the working state of fluid such as cooling water or compressed air and try to reduce the quantity or pressure.

(14) Illumination

Make sure that the utilization of daylight be maximized, unnecessary lighting lamps be switched off and the existing lamps be switched to high-efficiency illumination lamps.

4.3.5 Targets for Improvement and Projected Effects

(1) Targets for Improvement

With regard to the major points, we established target values for the under-mentioned items as ones whose targets can set quantitatively:

Air ratio of boiler	1.3 max.
Temperature of boiler exhaust gas	250° C max.
Surface temperature of steam using facilities and piping	60° C max.
Power Factor	85% min.

(2) Projected Effect

We totaled the values of practicable measures proposed to the diagnosed factories individually. The expected results are as follows:

(1) Fuel Conservation

Item	Expected Conservation Quantity (Heavy oil equivalent kl/year)	Ratio to Consumption (%)
Improvement of Air Ratio	44.2	0.6
Reinforcement of Insulation	344.3	4.8
Installation of Liquid Surface Cover	67.9	0.9

Shortening of Piping	2.5	---
Recovery of Condensate	46.3	0.6
Recovery of Waste Heat	296.4	4.1
Total	801.6	11.1

Total of Fuel Consumption 7,201 kl/year(excluding fuel for power generation)

(b) Electric Power Conservation

Item	Expected Conservation Quantity (× 10^3kWh/year)	Ratio to Consumption (%)
Insulation of Electric Heaters	119.0	0.4
Recovery of Exhaust Pressure	791.7	2.5
Disconnection of Transformer	44.0	0.1
Improvement of Power Factor	72.5	0.2
Adjustment of Motor Voltage at Correct Level	73.9	0.2
Rationalization of Illumination	21.9	0.1
Conservation of Electric Power for Pumps and Air Compressors	264.7	0.8
Total	1,387.7	4.3

Total Consumption of Electric Power 31,874 × 10^3kWh/year

The total energy consumption of the diagnosed factories accounts for approx. 3.8% of the total energy consumption of all the chemical factories. Assuming that this percentage represents the entire situation, the following conservation is estimated in terms of the entire Thai chemical industry:

Fuel approx. 21,100 kl/year

Electric Power approx. 36,500 × 10^3kWh/year

4.4 Food Industry

4.4.1 Outline of the Industry and Relative Positions of the Factories Diagnosed

In Thailand, the food industry is an industry which accounts for 30% or higher of the added value amount of the domestic manufacturing industry and thus carries most significant weight.

The sugar industry which is typical in the food manufacturing field was excluded from our visit schedule, because it was then in the non-operating season.

The canning industry shows a rapid growth rate of 30% or higher per year, and as such is now capable of competing favorably in the international market. Therefore, much can be expected of the industry in export activities. The total production capacity of the three factories diagnosed this time reaches approx. 23,600 tons/year or and estimated share of approx. 1/3 of the whole market in Thailand.

We visited two animal feed factories. The Thai livestock industry is rapidly expanding, following a sharp increase of broiler export quantity. The production of animal feed is increasing year by year and is now estimated at slightly less than 2 million tons per year. The total production of the diagnosed factories is approx. 300,000 tons or approx. 15% of the total output of the entire industry.

One of the two fat and oil manufacturing factories occupies a 40% share of the total edible oil production. One factory, a grain terminal, is treating approx. 1/6 of the total corn production in Thailand. In this way, the diagnosed factories have a considerable figure in share each in the respective product markets. In the food industry, other items such as sugar refining, dairy goods, beer and tobacco are included. From a viewpoint of energy consumption, the diagnosed factories consume fuel equivalent to only 6.2% and electric power to only 1.7% of the respective total energy consumptions of said industry as shown in Table 7.

Table 7 Energy Consumption in Food Industry 10^9 kcal/y

	Overall food industry (A) 1)	Factories diagnosed studies (B) 2)	B/A
Fuel	2,065 (58.3%)	127.5 (83.7%)	6.2%
Power	1,475 (41.7%)	24.8 (16.3%)	1.7%
Total	3,540 (100.0%)	152.3 (100.0%)	4.3%

Note: 1) Expected annual increase of 10% for two years based on UNDP/UNIDO Terminal Report, Annex VII Table B.

2) Equivalent heating values are 9,500 kcal/ℓ for fuel and 860 kcal/kWh for electric power.

4.4.2 Manufacturing Process and Outline of Facilities

(1) Canned Sea-food Products

A considerable number of retorts are insulated but precookers are not insulated at all. Generally, the equipment are relatively new.

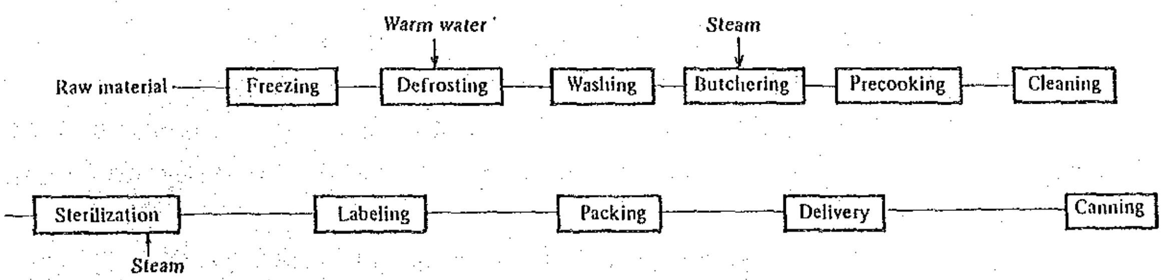


Fig. 8 Process for Seafood Canning

(2) Manufacture of Vegetable Oils

The equipment are new and the major facilities are well insulated.

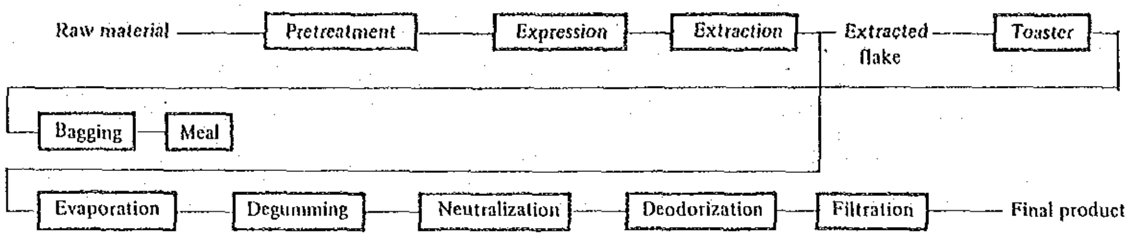


Fig. 9 Process for Vegetable Oil Manufacturing

(3) Manufacture of Animal Feeds

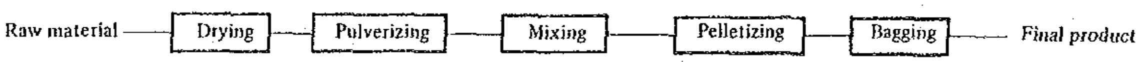


Fig. 10 Process for Feed Manufacturing

4.4.3 States of Energy Consumption

(1) Canned Sea-food Products

The state of energy consumption is as shown in Fig 11. Fuel is exclusively consumed by the boilers for steam generation. Steam is used almost entirely for precooking and sterilization. Although the fuel consumption rate varies according to the kind of fish, the rate variations such as 48, 63 and 106 l/ton are noticed. One factory shows an extremely high figure.

The electric power consumption for the refrigerators is proportionately large, so the total power consumption makes much difference depending on them.

The power consumption rate for the refrigerators is 143 to 164 kWh/t. On the other hand, the power consumption rate for the other uses is 59,75 and 124 kWh/t.

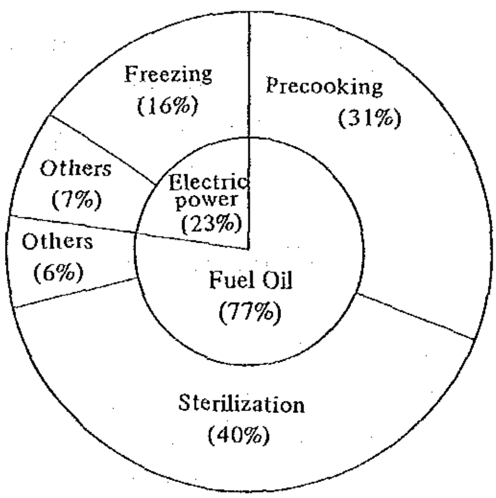


Fig. 11 Energy Consumption Rate in Seafood Canning

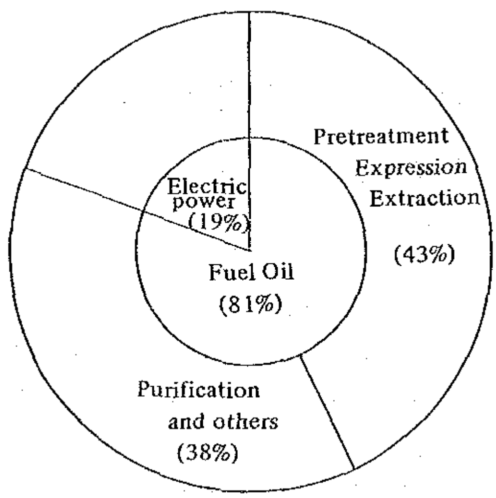


Fig. 12 Energy Consumption Rate in Vegetable Oil Manufacturing

(2) Manufacture of Vegetable Oils

The state of energy consumption is as shown in Fig 12. Fuel is consumed exclusively by the boilers for steam generation. Steam is used almost entirely for the extraction process and refining process. The fuel and electric power consumption rates vary significantly according to the oil content of raw materials.

(3) Manfacture of Animal Feeds

Fuel is used for hot air drying of maize and for heating of the pelletizers by steam. At the factories provided with these two processes, half of the fuel are consumed for each process. The fuel consumption rate for pelletizing process is 2.8~2.9 l/t, and for drying process 4~8 l/t, although this value varies according to the percentage of moisture in raw materials. The estimated power consumption rate is approx. 15 kWh/t for each process.

4.4.4 Major Points of Energy Management

(1) State of combustion in the Boiler

The following items are important:

Installation of burners of an appropriate capacity corresponding to a load, periodical cleaning of burner nozzles, keeping of fuel oil temperature at appropriate level, adjustment of the air ratio, maintenance of a flowmeters and control of the evaporation multiple through their readings.

(2) Temperature of Exhaust Gas from the Boiler

For the boilers, remove soot and clean periodically, so that the deterioration of the heat transfer rate may be prevented. Although the frequency of cleaning the boiler varies according to the quality of feed water, it is necessary to carry out the cleaning approx. twice a year in case the feed water is not treated.

As to the cleaning of the external heat transfer area, examine a change in the exhaust gas temperature and clean it at the time when the difference in temperature is remarkable in comparison with the temperature checked right after the cleaning.

(3) Production Control

It is necessary t monitor the ratio of raw material quantity to finished product quantity all the time. At the same time, grasp a clear picture of the quantity of rejects from the manufacturing process which were thrown away or recycled into virgin materials, and then try to minimize the quantity.

Further, prepare a production schedule in such a manner that the operation may be continuous, and work out preventive measures for reducing a heat loss resulting from a repeated shut-down.

(4) Study on Process Heat Flow or Heating Method

Examine the flow and enthalpy of fluid in each part of the process and prepare a heat flow chart. Then look into the feasibility of heat exchange between different fluids and study the remodeling of the process to a rational type.

In addition, select the best location of a steam injection inlet for heating and contrive an effective steam injection method so that the most suitable operating method for smooth air discharge and quick heating-up rate and lower steam consumption may be discovered.

(5) Steam Pressure

It is advantageous to use steam at as low a pressure as possible, as far as a temperature differential required for the process can be obtained. Make sure that the pressure is not higher than actually required. If a high-pressure steam has to be used for unavoidable reasons, study means to utilize flash steam from the condensate.

(6) Insulation

Study the reinforcement of insulation by measuring the surface temperature of each part of a plant. For the existing insulation, it is necessary to maintain and inspect it so that it may not be broken or wet. Select a surface color with as low emissivity as possible.

(7) Steam Leakage

Attach a serial number to steam traps, examine their operating condition periodically and record it in the log. If a leakage from the steam valve or flange is left along, it will become larger. So take remedial procedures as early as possible.

(8) Quality of The Boiler Feed Water and Boiler Water

Check on the quality of the boiler feed water and the boiler water periodically so that the blow down quantity may be kept at an appropriate level.

(9) Recovery of Condensate

Increase the condensate recovery rate as far as circumstances allow. In addition, prevent the temperature of recovered condensate from becoming low and try to make effective use of its whole quantity. If possible, install a soft water flowmeter in addition to a feed water flowmeter for the boiler, so that the quantity of recovered condensate may always be made known.

(10) Power Factor

Study the installation of a condenser for improvement of the power factor. For the existing condensers, make sure that the relays are sufficiently maintained and controlled.

(11) Peak Demand

Measure hourly electric energy and prepare a daily load curve. Then examine the causes for peak demand generation and try to restrict it.

(12) Transformers

When the transformers have a surplus capacity, some of them shall be disconnected or integrated so that a iron loss may be reduced.

(13) Imbalance of Electric Current

Be careful about the connection of a single-phase load to a transformer so that an imbalance current may not be generated.

(14) Service Voltage to Electric Motors

Make sure that service voltage to the electric motors be kept at an appropriate level. If the load is low, it will be advantageous to set voltage at a rather lower level.

(15) Electric Power for Pumps, Air Compressors and Refrigerators

Try to decrease the quantity and pressure of fluid transfered and also prevent its leakage. In addition, maintain equipment so that an internal leakage may be prevented. As to refrigerating load, prevent a refrigeration loss in the refrigerator and also make sure that the cooling water is kept at an appropriate temperature and the equipment be kept clean.

(16) Illumination

Make the best use of daylight and make sure that lights are off whenever unnecessary. Also use high-efficiency illumination lamps instead of the existing power-consuming lamps.

4.4.5 Targets for Improvement and Projected Effects

(1) Improvement Targets

With regard to major points, we selected the following items as ones having targets which can be established quantitatively. Then we set the target values as follows:

Air ratio of boiler	1.3 max.
Temperature of exhaust gas from boiler	250°C max.
Surface temperature of steam using facilities and piping	60°C max.
Power factor	85% min.

(2) Projected Effects

We totaled the values of items proposed as practicable measures for the diagnosed factories individually and obtained the following projected effects:

(a) Fuel Conservation

Items	Expected Energy Conservation Quantity (Heavy Oil Equivalent kl/year)	Ratio to Consumption (%)
Improvement of Air Ratio and Lowering of Temperature of Boiler Exhaust Gas	1,026.0	7.6
Production Control, Improvement of Heating Method	212.8	1.6
Reinforcement of Insulation	364.1	2.7
Lowering of Emissivity of Surface	9.6	0.1

Installation of Liquid Surface Cover	5.9	--
Prevention of Steam Leakage	7.9	0.1
Adjustment of Blow Down Water Quantity at Boiler	8.7	0.1
Recovery of Condensate	35.5	0.3
Utilization of Flash Steam	45.2	0.3
Utilization of Boiler Exhaust Heat	10.6	0.1
Recovery of Heat of Fluid in the Process	279.6	2.1
Total	2,005.9	14.9
Total Fuel Consumption	13,420 kl/year	

(b) Electric Power Conservation

Item	Expected Energy Conservation Quantity (10^3kWh/year)	Ratio to Consumption (%)
Improvement of Power Factor	31.5	0.1
Disconnection, Integration of Transformers	75.5	0.3
Adjustment of Service Voltage to Electric Motors at Proper Level	472.9	1.6
Power Conservation for Pumps, Air Compressors and Refrigerators	287.3	1.0
Improvement of Illumination	25.9	0.1
Total	893.1	3.1

Total Electric Power Consumption 28,877 × 10^3kWh/year

The total fuel consumption of the factories diagnosed this time accounts for 6.2% of that of all the food processing factories. The total electric power consumption of the former accounts for 1.7% of that of the latter. Assuming that the above percentages represent the whole situation, it is estimated that the energy conservation of the whole Thai food industry will amount to the following:

Fuel approx. 32,400 kl/year

Electric Power approx. 52,500 × 10^3kWh/year

Ⅱ. SEPARATE REPORT ON THE INDIVIDUAL FACTORIES

— PLASTIC & CHEMICAL, FOOD —

CONTENTS

Report No. 1: Plastic & Chemical

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— Thai Bones Industry Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Thai Bones Industry Co., Ltd. —

1. Outline of the Factory

Address	Muh 5, Tambol Klongnueng, Amphur Klongluang, Palumthanee	
Capital	4 Million Bt	
Type of industry	Chemical	
Major products	Ossein, Dicalciumphosphate (D.C.P.)	
Annual product	Ossein 1,800 ton, D.C.P. 3,600 ton	
No. of employees	280	
Annual energy consumption	Electric Power	2,678 x 10^3 kWh
	Fuel	Bunker C 1,944 kℓ, Diesel oil 330 kℓ, LPG 336,000 kg
Interviewees	Personnel Manager Mr. Prasert Technical Staff Mr. Pansert Technical Adviser Mr. Chroon	
Date of diagnosis	June 30 ~ July 1, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

This company is an organization established with a capital paid up by the Kingdom of Thailand 30 years ago. It is an only manufacturer of ossein in the country. All the product produced by the company is being exported to Japan. In order to assure quality control, one engineer dispatched by a Japanese buyer is now working at the factory as an instructor of manufacturing technology.

The existing equipment was installed 20 years ago and was partly expanded 10 years ago. Since the equipment is now obsolete, the replacement work of the existing boiler is before long put in practice. In addition, the partial replacement and expansion of the principal facilities are now underway. The factory is manufacturing calcium phosphate, bone feed and raw material for soap as by products. Almost all the raw material is processed into the finished product without wasting it under a system of resources conservation-type production.

From a viewpoint of raw material collection, cost and handling, the production of ossein is considered beneficial to the Kingdom of Thailand in the international trade. However, the climate of pollution control is now becoming severe. For this reason, it seems that the company has difficulty in expanding its existing production capacity and the newcomers of the same industry also find the problem to be an obstacle to the commencement of business.

It is considered that the position and responsibility of the company as a manufacturer of the international product in the Thai industry are very important.

2. Manufacturing Process

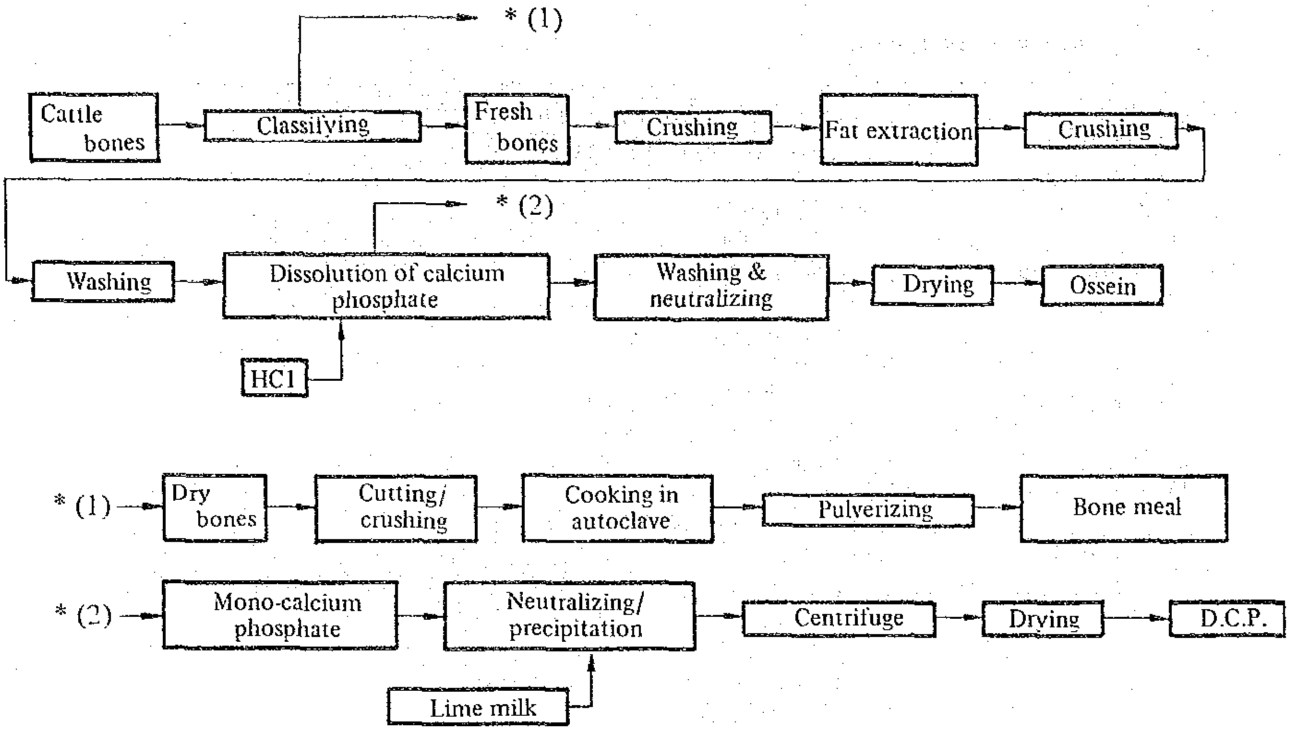


Fig. 1–1

3. Major Equipment

3.1 Major Equipment

Table 1–1

Name	No. of units installed	Type, etc.
Fat extracter	1	Open square tank, with mixer/conveyer
Crusher	2	Heavy knife 1, Fine knife 1
Calciumphosphate dissolution tank	3 units	7 tanks/unit, open square concrete tank
Ossein dryer	3 units	Bed dryer
Chiller unit	2 units	R-22 refrigerater
Neutralizing/precipitation tank	3	D.C.P. precipitation
Flash dryer	1	D.C.P. drying
Autoclave	3	
Boiler	2	4 ton/h x 10 kg/cm^2
Boiler	1	(under construction)

3.2 Layout

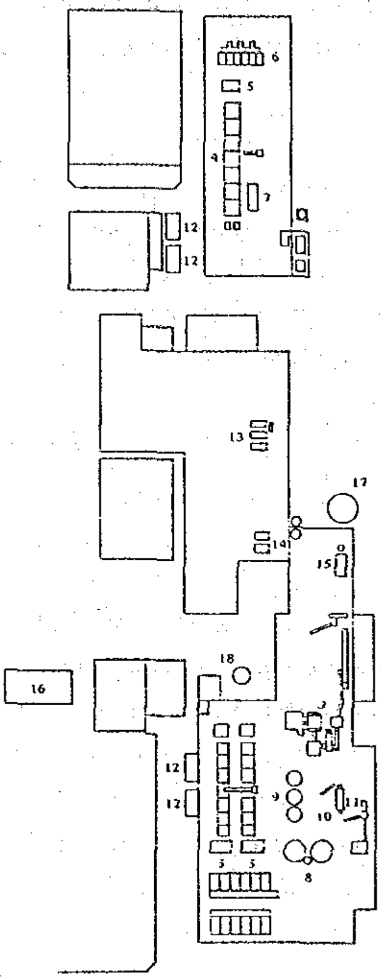


Fig. 1–2

4. State of Energy Management

4.1 Policy for Energy Conservation

The company is highly interested in energy conservation. The company invested in the boiler water heating unit using a solar heat collector (invested amount: 200,000 Bt) several years ago and the facilities for the utilization of exhaust heat generated by the refrigerator condenser to dry ossein (100,000 Bt) a couple of years ago. However, on account of insufficient maintenance and control, the former is not fully utilized (at the time of our survey, the unit was still idling). On the other hand, due to lack of design considerations, the latter has turned out to be of such a structure as to be unable to utilize all of the exhaust heat. Despite their novel concept, these units have not achieved the originally projected aims. Thus the precious investment is not fully utilized. We felt it regretable to see this state.

Further, as mentioned later, the company has not yet determined the operating conditions quantitatively, so that the performance of the equipment and the amount of conserved energy are still unknown. This fact makes the analysis of investment effect difficult.

For the above reasons, the factory continues to operate without recognition of the technical and economic effect in spite of the measures enforced for energy conservation. In addition, the company has particularly not set a payback time for investment. This is considered one of the reason why the economic effect is not confirmed.

Steam condensate from the air heater for the ossein dryer is recovered into the hot well and utilized for processing purpose.

4.2 Participation by All Employees

The company has neither voluntary control activities such as QC circle nor work improvement suggestion and commendation systems. The job classification of staff members and workers is definitely defined. During the visit of staff members to the workshop, they are ready to point out any defects in the operation or their correction to the workers whenever found.

The factory general manager appeals to the staff members alone whenever there are problems yet to be resolved.

4.3 Control through Data

At the factory, installed instruments required for the quantitative management of operation, and adjustment or control devices are almost not seen. Although some of the units are equipped with instruments, most of them are defective because of insufficient maintenance and management. Generally speaking, the operation is carried out by the empirical knack of the workers. Therefore, data required for operation are only for the dissolution of calcium phosphate which is essential to the assurance of product quality and specific conditions for the drying of ossein. Neither measurement nor recording is performed.

The fuel and electric power consumption is known only through a purchase slip which indicates a quantity required throughout the entire factory for one month. At the entrance of the factory, a truck scale is provided, and the purchased quantity of raw material, secondary material and fuel is actually measured for confirmation. This system is well controlled. A wattmeter for incoming power attached to the transformer is not used at all. We recommend that the said wattmeter be used for constant reading for recording (hourly, daily and weekly) and also for the analysis of relations between operation and power consumption as a substitute of the wattmeter. It is also suggested that the said wattmeter be utilized for reduction of the unit power consumption and supression of the peak demand.

As to the energy consumption by process, nothing is known because no measuring instrument is provided except for LPG and diesel oil use. The boiler is not provided with the feed water flowmeter nor the fuel flowmeter. Therefore, it is impossible to calculate the heat balance. In addition, there is provided no steam flowmeter, thus making calculation of a unit steam consumption rate per process (or per finished product) impossible.

On each refrigerator, an ammeter for the motor is not provided. In addition, some of the pressure gauge and thermometers for suction and discharge are defective, so that the state of load and action cannot be determined and consequently the number of water coolers cannot be controlled with ease.

According to those whom we interviewed, the quality of raw material changes significantly and therefore, operating conditions and the consumption of secondary material and energy vary conspicuously. For this kind of process, the rational control of operation by instrument is all the more important.

4.4 Education and Training, Level-Up of Employees

No participation by the employees in the internal and external seminars has ever taken place except for those concerned with the boiler. However, the manager-class employees and staff members are highly interested in energy conservation technology, and are trying their best to obtain both demestic and foreign information.

There is no special committee for energy conservation. Measures for energy conservation are planned and implemented by the factory general manager. And the staff members are behind him.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil C	1,944 kl/year (consumed by two boilers)
Diesel oil	330 kl/year (consumed by D.C.P. dryer)
LPG	336 t/year (consumed by ossein dryer)

Steam generated by boiler ┬ Fat extracter (1)
├ Ossein dryer (2)
└ Autoclave (3)

The quantity of (3) (manufacture of bone feed) is far larger than the combined total quantity of (1) and (2).

The fuel consumption rate is as follows:

Fuel oil C:	1.08 kl/t-ossein
LPG:	186.7 kg/t-ossein
Diesel oil:	91.7 l/t-D.C.P.

5.2 Heat Balance of Boiler

As to the heat balance of boiler, we dispensed with measurements because renovation of the boiler was scheduled before long.

6. Problems in Heat Control and Potential Solutions

6.1 Boiler

In addition to two units of the boiler presently in operation, one unit of second-hand boiler is set anew and under trial run for adjustment. Specially the existing two boilers are obsolete with its insulation becoming defective (missing or deteriorated). These matters reminded us about the necessity of improvement for the management of equipment and operation. As we were informed of renovation of the boiler facilities before long, we describe here necessary matters for the management of equipment and operation in connection with the installation of new boilers instead of recommendations on the improvement of the existing boilers. We solicit your cooperation in putting the undermentioned suggestions into practice as far as circumstances allow.

6.1.1 Installation of Instruments for the Control of Operation

When the boiler feed water flowmeter and oil flowmeter are installed, please keep in your mind that they are important for the execution of appropriate control and measures for energy conservation through calculation of an evaporation multiple and determination of a boiler heat efficiency.

In additon, the periodical checkup of exhaust gas temperature enables you to grasp the state of fouling on the heat transfer surface of the boiler tube. We recommend that a thermometer for exhaust gas be installed. If the fouling becomes serious, the exhaust gas temperature rises from the level of the temperature measured right after the cleaning of the tube, resulting in the occurrence of a heavy heat loss. It is suggested that you regard this temperature rise as a guideline for the performance of a periodical checkup. What is important in connection with the installation of these instruments for the control of operation is the maintenance and checkup of instruments. Their periodical maintenance and checkup are also necessary.

6.1.2 Control of Boiler Operation

It is important for the improvement of boiler efficiency to assure the precise balance of an oil combustion amount and a combustion air amount at the burner. In order that the oxygen concentration of combustion exhaust gas is kept approx. 4.8% or less, it is necessary to throttling the air volume by adjust the combustion device within the limit such an extent that a black smoke does not come out. The ratio of the actually fed air volume against the theoretically required air volume for combustion is called "air ratio" (m). The precise air ratio of the small boiler is 1.3 or less as a recommendable value. The relationship between the air ratio and the oxygen concentration of the exhaust gas is shown by the following equation:

$$m = \frac{21}{21 - O_2}$$

In order that the equipment may always be operated at a precise value of the air ratio, it is required to periodically measure the oxygen concentration of combustion exhaust gas and readjust the combustion device. For realizing this purpose, it is necessary to keep in custody and manage the set data of air volume per every load stage of the performance test and the trial run result table at the time of boiler installation. At the same time, it is necessary to carry out a comparative checkup of the values.

It is also important to place the routine operation of boiler under close management by the operator. The operator should make it a rule to enter into the log operation data such as feed water quantity, recovered condensate quantity, make-up water quantity and fuel consumption at least twice a day. Based on these values, it is possible to calculate an evaporation multiple which is a substitute characteristic value of the boiler efficiency everyday. And by checking up the said multiple, the level of the operation of the boiler can be heightened, thus reminding the employees of energy conservation. The evaporation multiple can be obtained by the following equation:

$$\text{Evaporation multiple} = \frac{\text{Feed water quantity} - \text{Blow water quantity}}{\text{Fuel consumption}}$$

6.1.3 Control of Feed Water Quality

The feed water is only natural water which has not undergone either filtration or softening. However, it is desirable to set up a water softening unit during the introduction of new facilities.

The boiler water is blown down three times a day (15 seconds each time) and the whole boiler water is replaced once every month. Now, there is particularly no problem. However, if the boiler water is softened, the whole boiler water need not be replaced once a month and at the same time, the heat loss also can be prevented. At present, the analysis of feed water and the boiler water are not put into practice. So it is desired that a periodical measurement be carried out. The standard pH value of boiler water quantity is 11.0 to 11.8 and the electric conductivity 6,000 μS/cm or less.

6.1.4 Recovery of Condensate and Raising up of the Feed Water Temperature

As things stand, recovery of the condensate as a boiler feed water does not take place at all, so that the feed water is at room temperature. This need be improved.

The most easily recoverable condensate is those generated on the heater for the heavy oil service tank and on the ossein dryer. However, condensate generated on the ossein dryer is recovered into the hot well tank and utilized for washing.

Steam is mostly used for direct injection, so the recovery of condensate is limited. It is desired that, for raising the temperature of feed water, the solar heat collector presently in trouble be repaired and used again. For recovering the boiler exhaust heat, the installation of an economizer in the flue will be effective. Judging from the sulfur content of the fuel now used, it is necessary to keep the exhaust gas temperature at 200° C or higer so that the corrosion of the recovery device may be prevented. When using the solar heat collector and an economizer together, the economy of heat recovery by the economizer is reduced by the amount of temperature raise. But it is still the effective way to improve the boiler efficiency.

6.2 Improvement of Ossein Dryer using Condensation Heat of Refrigerator

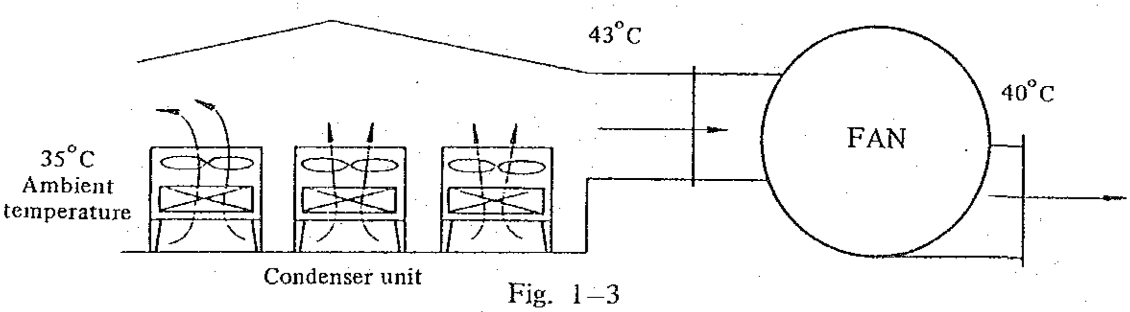


Fig. 1-3

The device for using an exhaust heat generated by the refrigerator condenser as a heat source for the ossein drying bed is a very excellent idea for energy conservation. However, the existing system is of such a structure that all of the warm air from the condenser cannot easily be sucked by the blower. Therefore, condensation heat which should otherwise be utilized is wasted. It is desired that the warm air be trapped by applying measures such as providing an outer wall for the condenser chamber. In order to keep the drying bed in efficient operating condition, you are kindly requested to check up the air temperature and uniform air flow distribution.

6.3 Other Improvements of Heat Utilizing Equipment

6.3.1 Improvement of LPG-Burnt Hot Blast Drying Floor for More Effective Combustion

It is recommended that the burners of LPG combustion unit be converted to such a type that the switchover of combustion to the high or low level can be controlled according to heat requirements. In this way, the combustion efficiency will be improved.

It is also important to adjust the amount of hot air to each drying bed, so you are kindly requested to adjust and maintain the damper with utmost care.

6.3.2 Prevention of Steam Leakage and Installation of More Effective Insulation

Significant steam leakage is noticed in steam valves around the fresh bone washer. Therefore, please carry out their maintenance services. We suggest that the action of the steam trap be checked up at a frequency of once or more a month so as to prevent a heavy loss resulting from the steam leakage.

Insulation of the autoclave body for dry raw bones is very old and the lid is uninsulated. Please repair or reinforce the insulation.

Insulation for the main steam piping, flange and valves are seen partly missing and old. Some stretch 27 m or longer 3" piping is still uninsulated. Be sure to apply insulation on the said part. The estimated quantity of conserved heavy oil resulting from the insulation of bare piping and valves will be 19.3 kl/year according to Table 1-2. This means 19,300 × 4.3 Bt/l = 82,990 Bt/year in value.

Table 1-2

Piping & valves	Rate of heat loss	Heat loss kcal/h	Heat recovery by insulation
3" x 27 m	450 kcal/mh	12,150	Insulations efficiency 80%
Valve 20 pieces	550 kcal/h. piece	11,000	18,520 kcal/h
Total		23,150	

$$\text{Fuel saving, } \frac{18{,}520 \times 24 \times 358}{9{,}700 \times 0.85} = 19.3 \text{ k}\ell\text{/year}$$

The estimated cost of installing insulation is approx. 14,500 Bt, so this cost can be recovered in a couple of months. The fat extractor is operated through the manual adjustment of steam injection so that the temperature may be maintained at 80°C. However, on account of the liquid surface of the tank being exposed to the atomosphere and the tank body being uninsulated, the fat extractor has significant heat release. As remedial measures for this defect, it is recommended that a stainless steel lid be installed to prevent the heat release from the liquid surface of the tank and insulate the whole tank wall. This measure will bring about the following advantage:

Assuming that the heat release from the liquid surface could be held down to 80%, the amount of energy conservation is calculated in terms of boiler fuel as follows:

$$\frac{7{,}000\ \text{kcal/m}^2\text{h} \times 0.8 \times 9.6\ \text{m}^2}{9{,}700\ \text{kcal/l} \times 0.85} \doteqdot 6.5\ \text{l/h}$$

If the effect of heat release prevention by the insulation of the tank body is calculated in the same way, the results will be as follows:

$$\frac{(411 - 100)\ \text{kcal/m}^2\text{h} \times 37.2\ \text{m}^2}{9{,}700\ \text{kcal/l} \times 0.85} \doteqdot 1.4\ \text{l/h}$$

Consequently, the estimated fuel conservation on an annual basis will be as follows:

$(6.5 + 1.4) \times 24 \times 358 \doteqdot 67.9$ kl/year

The estimated cost of carrying out the above-mentioned remedial measures will be 61,200 Bt which will be recoverable in approx. 2.5 months.

6.3.3 Introduction of More Effective Centrifugal Dehydration of D.C.P.

The D.C.P. are dryed in two stages. However, it seems that the dehydration efficiency of the rotary dryer is extremely inferior. There are the possibilities that the pneumatic dryer alone might be capable of drying operation by adding a centrifugal dehydrator of more efficient performance.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	500 kW
Power Consumption	:	2,678,000 kWh/year
Load Factor	:	62.3 %
Penalty Fee	:	37,770 Bt/year
Power Factor	:	64 % to 70 %
Transformers	:	1ϕ 167 kVA × 3
		1ϕ 100 kVA × 3 2 Banks
Power Consumption Rate	:	1,488 kWh/t

7.2 One Line Diagram

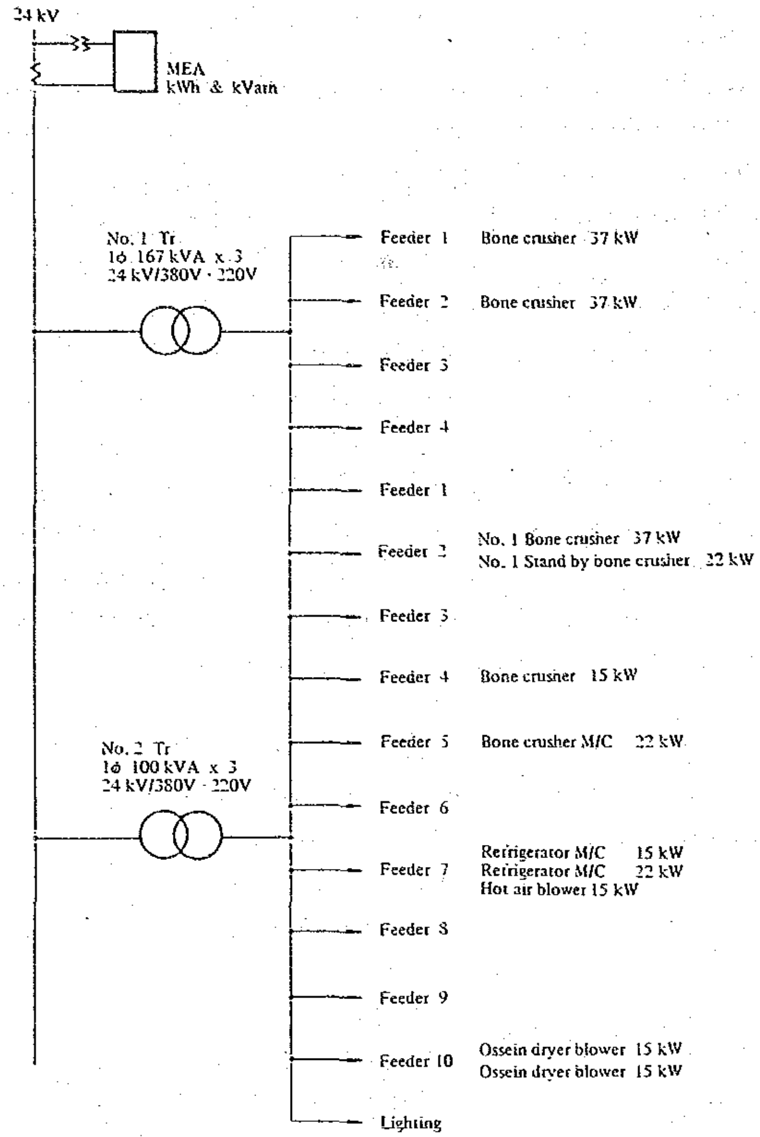


Fig. 1–4

8. Problems of Power Control and Potential Solutions

8.1 Maintenance of Electric Instruments

On the primary and secondary, instruments such as voltmeter, ammeter, wattmeter and power factor meter are uninstalled or not well maintained. For this reason, it is impossible to obtain the overall evaluation of a load state of the factory. Neither is it possible to grasp the loaded condition of each transformer.

Unless the load on each transformer is grasped, it happens that the capacity of the transformer may easily be increased when equipment is expanded, because it is difficult to decide which transformer has an extra capacity.

At the factory, although the voltmeter and ammeter are attached to the low voltage side, the needle of an ammeter of the 167 kVA transformer is not on working. In view of this situation, it is necessary to keep the existing voltmeter and ammeter in good working condition and install the wattmeter and power factor meter so as to determine the actual load condition of each transformer.

In addition, in order to proceed with energy conservation, it is desirable that each feeder be rearranged and Watt-hour meters be installed to facilitate calculation of a unit electric power consumption per finished product.

8.2 Power Factor

Because of low power factor, the company paid a penalty fee of 37,770 Bt during the period from January through December, 1982 as shown in Paragraph 7.1. Among the peak demand Pd, the amount subjected to penalty Pn and the peak reactive power P_R, the under-mentioned relationship exists. When the amount of maximum reactive power exceeds 63% of the peak demand, the penalty must be paid.

$$P_R = 0.63\ Pd + Pn \quad \text{.......... (8.1)}$$

$$\cos\phi = \frac{Pd}{\sqrt{P^2d + P^2_R}} = \frac{Pd}{\sqrt{P^2d + (0.63Pd \times Pn)^2}} \quad \text{.......... (8.2)}$$

Table 1–3 Peak Demand and Power Factor

Month	Peak demand kW	Peak Demand x0.63 kVar	Penalty kVar	Peak reactive power kVar	Apparent power kVar	cos ϕ
1 1982	390	246	224	470	611	0.638
2	430	271	189	460	630	0.683
3	440	277	173	450	629	0.700
4	430	271	209	480	644	0.667
5	410	258	192	450	609	0.673
6	410	258	202	460	616	0.666
7	440	277	193	470	644	0.683
8	410	258	212	470	624	0.657
9	400	252	238	490	633	0.632
10	450	284	256	540	703	0.640
11	500	315	195	510	714	0.700
12	450	284	236	520	688	0.654

Judging from the peak demand and the penalty indicated in a monthly electric power bill, the power factor represents 70% or less as shown in Table 1-3. The limit for exoneration of the penalty is represented as Pn to be O according to the equation of (8.2):

$$\frac{1}{\sqrt{1 + 0.63^2}} = 0.846$$

The readings of the kWh meter and the kVarh meter of MEA on the day of our diagnosis are shown in Table 1-4. The power factor is almost the same as that of Table 1-3

Table 1–4 Record by Meter of MEA

Date / Time	Power kWh/h = kW	Reactive power kVarh/h = kVar	Apparent power kVA	cos ϕ	Remark
6–30 3:18 PM	450	500	673	0.669	from 2:18 PM to 3:18 PM
4:18 PM	346	462	577	0.6	
7–1 10:40 AM	300	400	500	0.6	from 9:40 AM to 10:40 AM
11:40 AM	300	300	424	0.707	

Next, the readings of the portable meter and the calculated power factor on the secondary of two banks of transformers are shown in Table 1-5 and Table 1-6. The load of No.2 transformer was light on July 1, so the records of June 30 would be used for study.

Table 1–5 Instantaneous Value of Secondary Circuit for No. 1 Transformer (1ϕ 167 kVA x 3)

Date / Time	Measured value			Calculated value		
	Voltage V	Current A	Apparent power kVA	Power kW	Power factor	Reactive power kVar
6–30 2:20 PM	400	525	364	225	0.618	286
3:20 PM	400	470	326	220	0.675	241
7–1 9:45 AM	397	550	378	259	0.685	275
10:45 AM	397	487	335	179	0.534	283

Power factor = Power / apparent power

Reactive power = $\sqrt{(\text{apparent power})^2 - (\text{power})^2}$

Table 1–6 Instantaneous Value of Secondary Circuit for No. 2 Transformer (1ϕ 100 kVA x 3)

Date / Time	Measured value			Calculated value		
	Voltage V	Current A	Apparent power kVA	Power kW	Power factor	Reactive power kVar
6–30 2:20 PM	420	265	193	140	0.725	133
3:20 PM	415	321	231	160	0.693	167
7–1 9:45 AM	423	76.4	56	29	0.518	48
10:45 AM	422	90.1	66	46	0.697	47

The composite electric power as viewed from the 24 kV side is as shown in Table 1-7.

Table 1–7

Date / Time	Active power kW	Reactive power kVar	Apparent power kVA	Power factor
6–30 2:20 PM	365	419	556	0.656
6–30 3:20 PM	380	408	558	0.681

Even in this case, almost the same power factor is shown. If the power factor when the 300 kVar capacitor has been conditionally inserted is sought, the results will be as shown in Table 1-8. The power factor will be improved to 90% or higher without exception.

Table 1–8

	Present state %	After condensers installed %
Month showing the lowest power factor in 1982 (September)	63	90
Month showing the highest power factor in 1982 (November)	70	92
PM 2:20 on June 30th (diagnosised day)	66	95
PM 3:20 on June 30th (diagnosised day)	68	96

The example of calculation in the case of June 30,3 o'clock 20 minutes

$$\frac{380}{\sqrt{380^2 + (408 - 300)^2}} = 0.96$$

Next, we studied the best way how to divide the 300 kVar capacitor to No. 1. transformer and No.2 transformer. Based on Table 1-5 and Table 1-6, six units of the 30 kVar capacitor were distributed to No. 1 transformer and four units of the 30 kVar capacitor to No. 2 transformer. All of these capacitors were connected to the secondary of the transformers. As a result, the power factor was improved as shown in Table 1-9.

Table 1–9 Improvement of Power Factor for Each Transformer

Date / Time	No. 1 Bank				No. 2 Bank				Overall power factor
	Power kW	Reactive power	Apparent power kVA	Power factor	Power kW	Reactive power	Apparent power kVA	Power factor	
6–30 2:20 PM	225	286–180 106 kVar	249	0.904	140	133–120 13 kVar	141	0.996	0.951
3:20 PM	220	241–180 61	228	0.965	160	167–120 47	167	0.959	0.962
7–1 9:45 AM	259	275–180 95	276	0.938	29	50– 30 20	35	0.829	0.929
10:45 AM	179	283–180 103	207	0.865	46	47– 30 17	49	0.939	0.882

The transformers of No.2 bank have a intermittent load and sometimes become low load as shown in the case of July 1. It is suggested that the capacitors be so arranged that only the required number may be put to use. If the power factor is improved, the penalty will be nothing and the load loss (copper loss) of the transformer and the resistance loss of wiring will be reduced. The copper loss of the transformer is calculated, as follows:

Given data for calculation

(1) Annual average electric power 312 kW

(2) It is assumed that power is distributed to No.1 and No.2 banks according to the capacity ratio.

(3) Average power factor 64.4%

(4) Load loss of the transformer at the rated capacity

1ϕ 167 kVA 2.5 kW

1ϕ 100 kVA 1.7 kW

Table 1–10

No. of banks	Before power factor improved			After power factor improved		
	Power kW	Reactive power kVar	Apparent power kVA	Reactive power kVar	Apparent power kVA	Power factor %
No. 1	195	232	303	52	202	97
No. 2	117	139	182	19	119	98

Amount of Reduction of Load Loss

No. 1 $2.5\ \text{kW} \times 3 \times \{(\frac{303}{167 \times 3})^2 - (\frac{202}{167 \times 3})^2\} \times 8{,}592\ \text{h/year} = 13{,}095\ \text{kWh/year}$

No. 2 $1.7\ \text{kW} \times 3 \times \{(\frac{182}{100 \times 3})^2 - (\frac{119}{100 \times 3})^2\} \times 8{,}592\ \text{h/year} = 9{,}233\ \text{kWh/year}$

Total 22,328 kWh/year

Next, since the capacitors are connected to the secondary of transformers, a cable loss from where they are connected to the secondary terminal of the transformer is reduced.

Table 1–11

Transformers	No. 1 1ϕ 167 kVA x 3	No. 2 1ϕ 100 kVA x 3
Cable		
Size	200 mm^2	100 mm^2
Number of cables	2 rolls	2 rolls
Length	20 m	30 m
Resistance (20°C)	0.0922 Ω/km	0.1800 Ω/km
Current		
Before power factor improved	$\frac{303}{\sqrt{3} \times 0.40} = 437$ A	$\frac{182}{\sqrt{3} \times 0.42} = 250$ A
After power factor improved	$\frac{202}{\sqrt{3} \times 0.40} = 292$ A	$\frac{119}{\sqrt{3} \times 0.42} = 164$ A

Given data for calculation

Temperature coefficient of resistance 0.00393Ω/°C (at 20°C)

Temperature of wire 33°C

Reduction of cable loss

No. 1 $3 \times (437^2 - 292^2) \times 0.0922 \times 10^{-3} \times \{1 + 0.00393(33 - 20)\} \times 0.5 \times 20 \times 8{,}592 \times 10^{-3} = 2{,}640\ \text{kWh/year}$

No. 2 $3 \times (250^2 - 164^2) \times 0.1800 \times 10^{-3} \times \{1 + 0.00393\ (33 - 20)\} \times 0.5 \times 30 \times 8.592 \times 10^{-3} = 2{,}604\ \text{kWh/year}$

Total 5,244 kWh/year

The total reduction of the loss due to improvement of the power factor will amount to 22,328 + 5,244 = 27,572 kwh/year which means 39,979 Bt/year in value.

If the penalty of 37,770 Bt/year not to be paid for is added to the above total amount, the total advantage will be 77,749 Bt/year. The estimated combined total cost of the capacitors and switches to be installed for the improvement of the power factor will be approx. 150,000 Bt. This cost will be recovered in approx. one year and 11 months.

8.3 The load of the Electric Motor is considerably lower than the rated.

The usage, rated ouput and actual load of the electric motor are shown in Table 1-12. If the power factor of a load on the transformer is low, the causes are as follows:

(1) Many small electric motors are used.

(2) The load of each electric motor is exceedingly low compared with the rated output.

For the above reasons, it is important to select the electric motor of a rating such as to be suitable to the load machine. It is suggested that a list of electric motors be prepared, spare motors be kept in orderly storage and if any spare motors are available, the electric motors numbered 1 ~ 3,5 and 6 on Table 1-12 be replaced by the 11 kW electric motors, the 22 kW be changed to the 11 kW and the 37 kW electric motor of crusher to the 15 kW.

Table 1–12 Actual Load for Each Motor

	Using for	Rated out put kW	Measuring in put kW	Rated voltage V	Measuring voltage V	Rated current A	Measuring current A	Power factor %
1.	Ossein gas blower	15	7.5	380	390	*	16.3	68
2.	Ossein gas blower	15	10.6	380	394	*	19	82
3.	Hot air blower	15	9.1	380	407	30	20.6	63
4.	Bone crusher	37	13.3	380	377	70	26.1	68
5.	Hot air blower	15	11	380	394	30	20.8	77
6.	Hot air blower	15	11	380	394	30	20.8	77
7.	Cooling unit	15	13	380	366	*	25.6	80
8.	Bone crusher	37	12.4	380	394	70	22.8	70
9.	Unit 1. compressor	22	9.9	380/220 Tr 220	242	*	31.6	75
10.	Bone crusher	37	13.3	380	377	70	26.1	78
11.	Unit 2 No. 2 compressor	*	6.5	380	394	*	21.4	45
12.	No. 3 compressor	*	13.1	380	393	*	22.6	82
13.	No. 4 compressor	*	11.9	380	394	*	23.5	74
14.	No. 5 compressor	*	7.4	380	394	*	24.6	44
15.	No. 6 compressor	*	7.8	380	394	*	23.2	49

* *Unknown*

The load of each electric motor is low. Therefore, if the voltage supplied to the electric motor is reduced by approx. 5% compared with the rated voltage, the exciting current will be decreased, the power factor improved and the loss diminished by approx. 2%

Energy conservation rate $2,678 \times 10^3 \times 0.02 = 53.6 \times 10^3$ kWh/year

8.4 Improvement of Illumination

The daylight-color fluorescent lamp is used now. This lamp should be replaced by the energy conservation-type fluorescent lamp. The latter will help conserve the energy as follows: Assuming that approx. 150 lamps are on throughout the whole factory for 10 hours a day, the following results will be obtained:

$$5W \times 150 \times 10 \times (358) \times 10^{-3} \times \frac{1}{2} = 1{,}342 \text{ kWh/year}$$

We noticed that sixteen 40W fluorescent lamps were on, on the ossein tank in day time. However, if more daylight were introduced into the factory and the said lamps were off, the results would be as follows:

$$40 \times 16 \times 10 \times (358) \times 10^{-3} = 2{,}291 \text{ kWh/year}$$

The total electric power consumption of 3,633 kWh or the cost of 5,268 Bt will be saved.

Assuming that a transparent plastic sheet is installed for introduction of daylight, the estimated required cost will be approx. 5,440 Bt based on the calculation of 340 Bt/m^2 $\times$ 16m^2. This cost will be recovered in 2.4 years.

8.5 Supression of Peak Demand

Although the annual load factor of 62.3% is not low, the intermittent load represented by the bone crusher and continuous operating load exist. Therefore, it is recommended that the peak demand be supressed by measuring the values of kWh and kVarh every hour, checking up the change in the load and power factor and improving the operating method. In this way, the capacity of transformer need not be increased if new equipment is installed, and at the same time, the demand charge can be reduced. If the values of November and March, 1982 are compared according to Fig. 1-5, it can be found the possibility to supress the peak demand to 440 kW by improving the operating method.

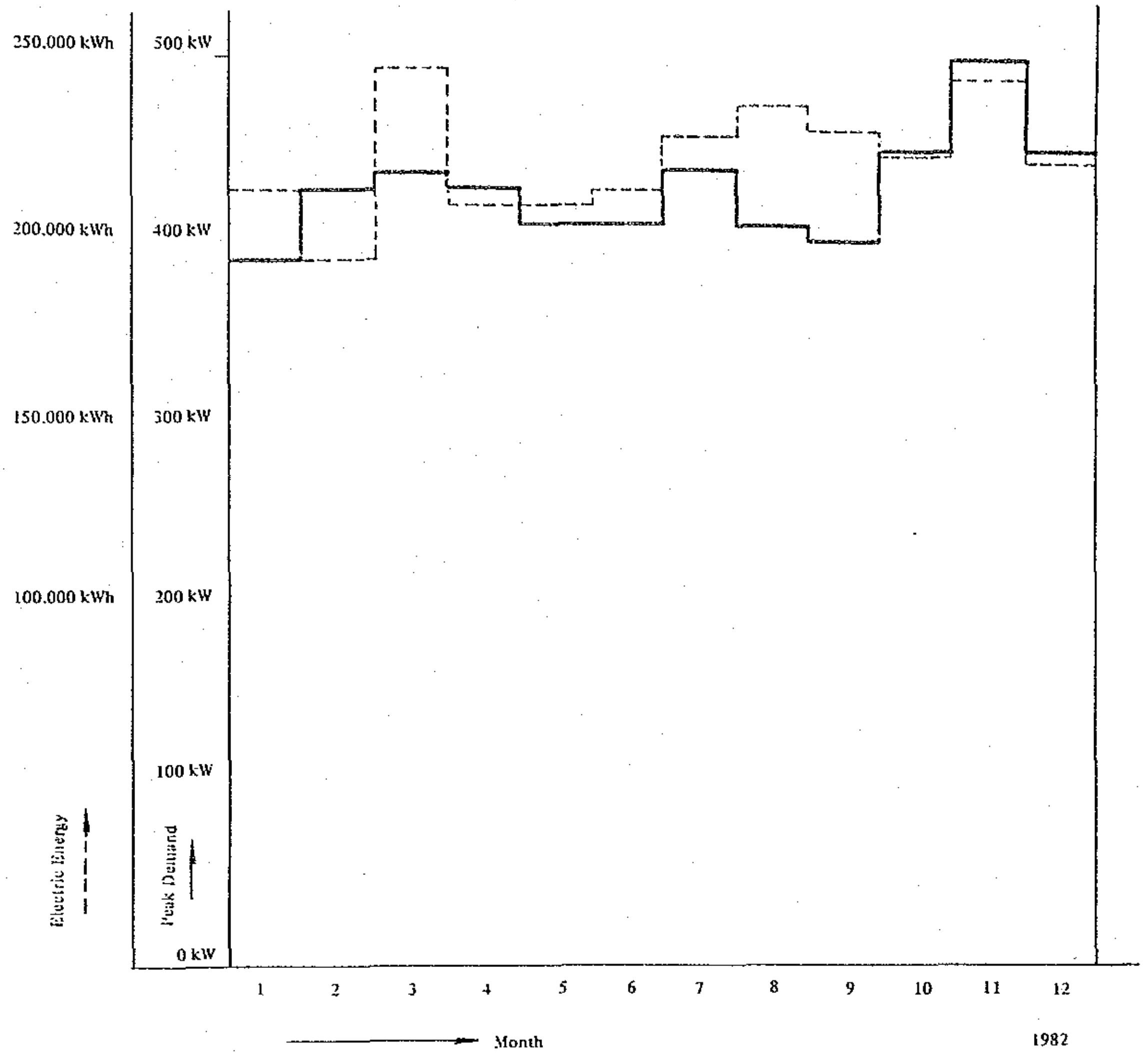


Fig. 1–5 Peak Demand & Electric Energy for Every Month

9. Summary

The above-mentioned improving measures, if actually taken, will bring about energy conservation effects as shown under:

	(Oil equivalent) kl/year	%
Reinforcement of Insulation	19.3	1.0
Installation of Lid of Fat Extractor and Insulation	67.9	3.5
Subtotal	87.2	4.5
	10^3kWh/year	%
Improvement of Power Factor	27.6	1.0
Reduction of Voltage for Electric Motor	53.6	2.0
Improvement of Illumination	3.6	0.1
Subtotal	84.8	3.1

Report No. 2: Plastic & Chemical

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

— Citric Acid Industry Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Citric Acid Industry Co., Ltd. —

1. Outline of the Factory

Address	Bangpoo Industrial Estate 231, Sukhumvit Road Phraeksa, Muang District Samutprakarn	
Capital	87 Million Bt	
Type of industry	Chemical	
Major products	Citric acid	
Annual product	1,500 ton	
No. of employees	190	
Annual energy consumption	Electric power	2,103 x 10^3 kWh
	Fuel	Bunker C 1,600 kℓ
Interviewees	Factory Manager Mr. Nopadol Production Manager Mr. Chaiwat	
Date of diagnosis	July 4 ~ 5, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

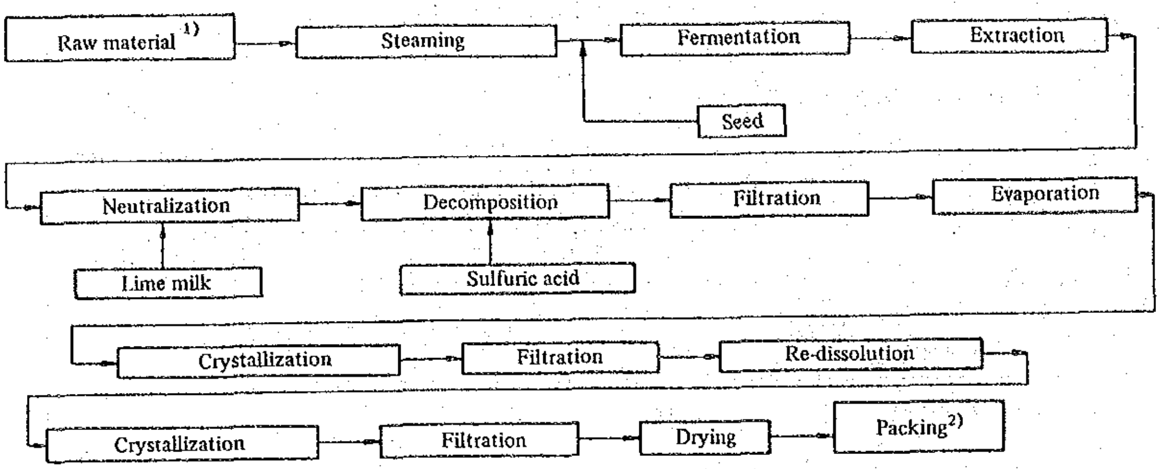
The company is the only citric acid production company in Thailand. The company supplies about 80% of the domestic demand and exports the rest. The quantity of 20% out of the whole domestic demand is the quantity contained in the material imported as an intermediate for food and drink goods. Accordingly, almost the whole quantity of the actual domestic demand is supplied by the company. The company is an enterprise capitalized with 100% Thailand. The company carried initially the business of only an import and domestic selling of citric acid and then started the production of citric acid with tapioca as a raw material existing plenty at home, three years ago. The manufacturing facility was designed and fabricated by Taiwan technology and as to the manufacturing technique, the company received the instruction of Taiwanese engineers.

The citric acid products have the two types of anhydrous and monohydrate. The facility has been designed according to the specification for a production of the latter.

The raw materials are dregs of tapioca and rice bran and these can be procured in large quantities for a low cost. Accordingly, the product manufactured by the company has a strong cost-competitiveness in the international market.

The factory was once offered for an occasion of case study by academic circles and study for energy conservation was conducted on one occasion under provision of funds by the Australian government.

2. Manufacturing Process



Note: 1) Tapioca waste, rice bran, and rice skin.
2) Citric acid – monohydrate and/or – anhydrous.

Fig. 2–1

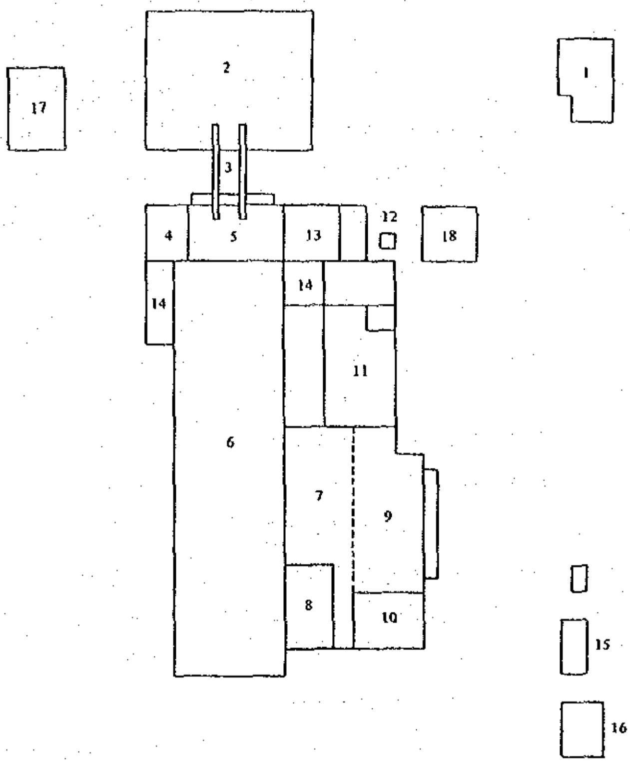
3. Major Equipment

3.1 Major Equipment

Table 2–1

Name	No. of units installed	Type, etc.
Cooker	12	3 t/unit
Fermenter	60 rooms	10 t/day
Extracter	14	16 m^3/unit
Neutralizer	6	8 m^3/unit
Decomposer	3	4.5 m^3/unit
Evaporater	8	5 m^3/unit
Crystallizer	14	3 m^3/unit
Centrifuge	7	0.4 – 1 t/h unit
Dryer	1	500 kg/h
Refrigerater	1	R-22, 60 HP
Boiler	2	5 t/h,
Waste water treatment plant	1	

3.2 Layout



1. Office
2. Raw material storage
3. Belt conveyers
4. Boiler room
5. Steaming room
6. Fermentation chamber
7. Calcium citrate refinery
8. Decomposition
9. Citric acid refinery
10. Calcium citrate storage
11. Citric acid drying/storage
12. Transformer
13. Laboratory
14. Tray cleaning room
15. Lime milk preparation
16. Work shop
17. Waste water treatment plant
18. Canteen

Fig. 2–2

4. State of Energy Management

4.1 Policy for Energy Conservation

With advices of the academic world, the company has very positively wrestled with the study for energy conservation.

Since the plant manager and the staffs have now taken a priority to the rationalization of production as the urgent subject, the countermeasure with the sole object of energy conservation has an inclination to somewhat delay. With the appointment of one person as a utility supervisor, the energy management has been served by him.

The target of energy conservation is set as 15% in this year and its equipment investment is budgeted with 2,000,000 Bt. The pay back time to the investment is set as a standard three years or less.

So far, the investment has not been taken only for the energy conservation but taken together with the rationalization. The six water ejectors for the cooker have been reduced to three ejectors through integration of them in order to promote a simplification of the operation and a reduction of the power consumption by the pumps. Since some equipments stop at nighttime, the boiler is operated with the pressure dropped down to the pressure necessary for the operation process at night for the energy conservation.

The steam condensate in the evaporator is recovered to exchange the heat with the feed water for boiler and then utilized as the process water for seeding.

4.2 Participation by All Employees

There is no self-control activity such as a QC circle and also no suggestion system and no commendation system.

Upon the service regulation, the division of duties between the staff and the operator is divided definitely. An improvement of operation and an investigation of rationalization are limited to the duties of the plant manager and the staff.

The energy conservation has been appealed as occasion demands from the plant manager to the general employees.

4.3 Control through Data

The consumptions of fuel and power are computed every week from the quantities of purchase and inventory and from the reading of the companie's watt-hour meter respectively, and relations to the operation are analyzed by these computed data. The fuel and power consumption rates and the energy cost are computed every month.

The numerical control is relatively easy becaue the whole processes are a batch operation. With the standardization of charge, operating condition and operating time, the operation is performed exactly. The product is put under a severe quality control to be in conformity with the standards of Japan, U.S and Britain.

However, as the flowmeters for steam are not provided for every major process, the steam consumption cannot be grasped by process. Then, a rough allotment is estimated from the engineering calculation and the data at the individual operation of each equipment and these estimated values are regarded as a reference of the operating data analysis. Also the power consumption is estimated on the basis of the reading of ammeter and the operated time because of no wattmeter. The fuel flowmeter of one boiler and the ammeter of 60HP motor for the refrigerator in the chiller unit were out of order. The maintenance of the meters for such major equipment should not be neglected.

4.4 Education and Training for Leveling-Up of Employees

Although a systematic energy conservation committee is not organized, a system to examine the energy conservation measures is organized with three persons of the plant manager, the production manager and the utility supervisor. The technical materials such as the design drawings of plant and equipment and the engineering data are preserved and arranged in a regular manner. An attitude of respect for a technology is evinced. Some staffs are dispatched to the seminars held by outsiders three or four times per year. Observation visit for study is not conducted.

5. State of Fuel Consumption

5.1 Fuel Consumption

The fuel consumption in 1982 is as follows:

Fuel oil C 1,600 kl/year

All of fuel oil C is consumed for generation of steam in the boiler. The generated steam is consumed in each process of citric acid as shown in Fig.2-3.

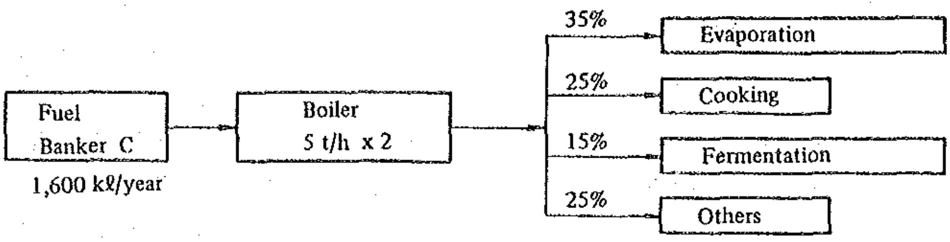


Fig. 2–3

One boiler is operated for nine hours from A.M. 5 o'clock to P.M. 2. Other boiler is operated at the pressure of 4 to 6 kg/cm^{2}G for the hours from morning to P.M. 4 and at the pressure of 2.5 to 4 kg/cm^{2}G at night.

5.2 Fuel Consumption Rate

Assuming that the citiric acid production in last year is 1,500 t/year, the annual average fuel consumption rate is as follows:

$$\text{Fuel consumption rate} = \frac{1{,}600 \times 10^3 \text{ l/year}}{1{,}500 \text{ t/year}} = 1{,}067 \text{ l/t}$$

5.3 Heat Balance of Boiler

The heat balance based on the data of the operating daily report for No.1 boiler is as shown in Table 2-2:

Table 2–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	1,468.8	99.7	Heat of steam	1,112.6	75.5
Sensible heat of fuel	5.1	0.3	Heat loss in exhaust gas	185.7	12.6
			Heat loss in blow water	7.4	0.5
			Heat release from boiler body, others	168.1	11.4
Total	1,473.9	100.0	Total	1,473.9	100.0

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil C
Fuel consumption	(F)	153 kg/h
Heat content of fuel (low value)	(Hl)	9,600 kcal/kg
Specific gravity of fuel	(SG)	0.975
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	104°C
Reference temperature	(To)	30°C
Oxygen content in exhaust gas	(O_2)	7.5%

Temperature of exhaust gas	(Tg)	255°C
Quantity of blow down water	(B)	49 kg/h
Temperature of blow down water	(Tb)	154°C
Quantity of feed water	(W)	1,899 kg/h
Temperature of feed water	(Tw)	55°C
Steam pressure	(P)	4.2 kg/cm^{2}G
Quantity of steam (S = W − B)	(S)	1,850 kg/h
Enthalpy of steam	(Es)	656.4 kcal/kg
Enthalpy of feed water	(Ef)	55 kcal/kg

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) $1{,}468.8 \times 10^3$kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 5.1×10^3kcal/h

$Qs = F \times Cp(Tf - To)$

Output

Heat of steam (Qv) $1{,}112.6 \times 10^3$kcal/h

$Qv = S \times (Es - Ef)$

Heat loss in exhaust gas (Qe) 185.7×10^3kcal/h

$Qe = S \times (Es - Ef)$

Theoretical amount of air (Ao)

$Ao = 0.85\ Hl/1{,}000 + 2.0 = 10.16\ Nm^3/kg$

Theoretical amount of exhaust gas (G_o)

$Go = 1.11\ Hl/1{,}000 = 10.66\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.56$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 16.35\ Nm^3/h$

Heat loss in blow down water (Qb) 4.9×10^3kcal/h

$Qb = B(Tb - Tw)$

Heat release from body and others (Qr) 170.7×10^3kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Boiler

6.1.1 Improvement of Combustion

With the analysis of the past operating data, the quantity of steam is 1.86 t/h based on the feed water per one boiler. This is an average load of 37% to the maximum evaporation capacity of 5 t/h in the boiler specification. As the peak load in the factory is estimated as 3.7 t/h, the operation of one boiler can sufficiently cover the load. As a matter of fact, two boilers are usually operated.

The reason that two boilers must be operated can be estimated to be the following factors.

According to the heat balance of boiler, the value of 11.4% to the heat release of body plus other heat loss is abnormally larger. This can be judged to be definitely the loss due to unburned fuel with the causes of a deterioration of the burner tip and its improper size. Observing the boiler operating condition, the abnormal combustion of unburned fuel was recognized at the rear section in the boiler flue such as the explosion door clattered. The continuation of such incomplete combustion is a serious problem for the safety, and the flue and the smoke tube may become terribly dirty. Without loss of time, the burner must be checked and arranged and the furnace tube must be cleaned up.

The link of the damper which adjust the quantity of air for combustion came loose. It is required to adjust the link with re-checking of a proper damper position at each step of combustion load. In a large fluctuating load, the pressure jet type burner is improper and an air atomizing burner is preferable.

The reading of the exhaust gas thermometer located in the flue is lower by 20° C. Re-adjustment is required. Without regard for a low load, the higher exhaust gas temperature of 240 to 250° C is caused by the dirt of flue due to incomplete combustion. The burner must be first all arranged and an improvement to a proper air ratio (m = 1.3 or less) and the cleaning of flue must be taken as a preference. Still, when the exhaust gas temperature is higher, then the recovery of heat should be investigated.

The oxygen content in exhaust gas of No. 1 boiler is 7.5% in a high degree. The oxygen content is desirable to be kept within 4% by arrangement of the burner and adjustment of the air damper.

When the oxygen content is improved to the proper value of 4.0%, the consumption of fuel is possible to be reduced by 2.8% (calculation on the basis of the boiler heat balance).

The fuel reduction through this combustion improvement is as follows:

Fuel consumption in No. 1 boiler:

1,600 kl/year × 0.7 = 1,120 kl/year

Reduced quantity of fuel per year:

1,120 × 0.028 ≒ 31.4 kl/year

This results in the cost down of 134,850 Bt/year.

6.1.2 Maintenance of Flowmeters for Feed Water and Fuel Oil

The flowmeters for feed water and fuel oil are provided to each boiler but either get out of order as much as to cannot measure the flow. To check of evaporation multiple as a index of the boiler efficiency, these two meters should be used usually with arrangement.

$$\text{Evaporation multiple} = \frac{\text{Feed water} - \text{Blow down quantity}}{\text{Fuel consumption}}$$

This value is to be referred for the maintenance and the operation of boiler with the calculation of every day and the entry in the daily log sheet because the value gets a typical index for the boiler efficiency.

6.1.3 Control of Boiler Feed Water

The qualities of boiler feed water and softened water are checked every day. These analyzed values show generally a good control as shown in Table 2-3.

Table 2–3

	Soft water	No. 1 Boiler water	No. 2 Boiler water
PH.	7.75	11.10	11.40
Electric conductivity μS/cm	800	2,720	4,720

The concrete feed water tank has crack and a lot of softened water is leaked. The tank should be immediately repaired or a new iron steel tank is required.

6.2 Adoption of Multiple-effect Evaporator

A great portion of heat supplied to the evaporator through the steam is discarded to the outside as vapor generated. To utilize effectively the generated vapor, if the evaporator is provided with multiple stages as shown in Fig.2-4 and the boiling point in the second stage becomes to a lower temperature than the condensing temperature of the generated vapor in the first stage by reduction of pressure, the generated vapor in the first stage can be utilized to heating the second stage.

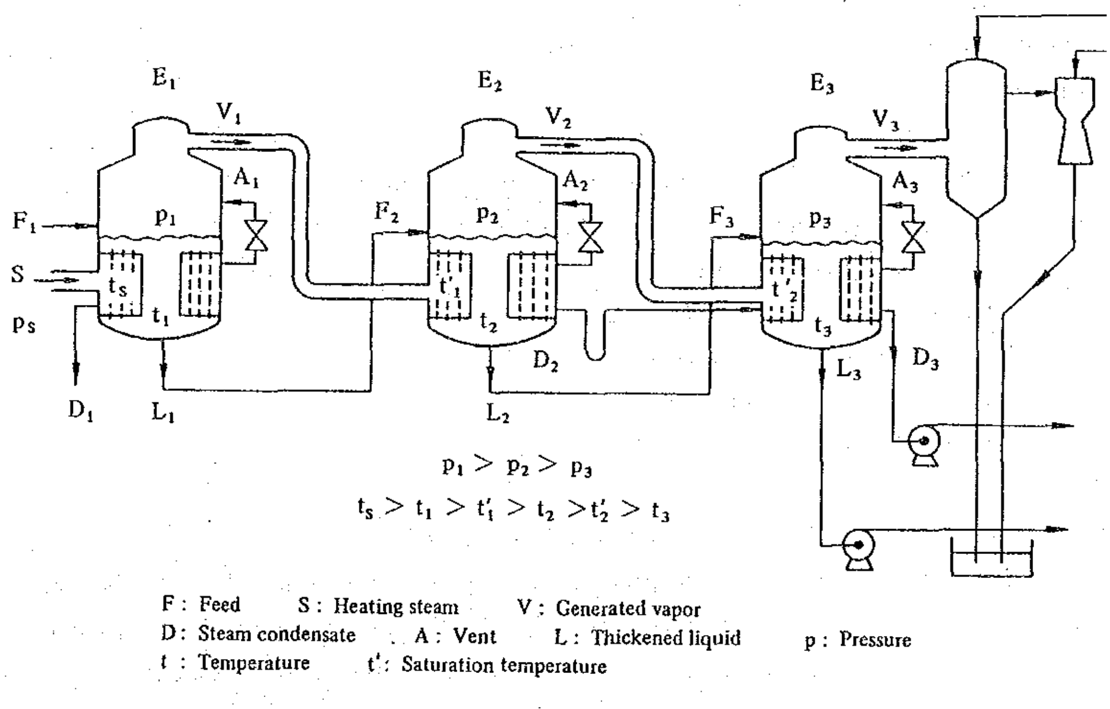


Fig. 2–4 Triple Effect Evaporation System

Thus, the evaporation is carried by the generated vapor in steps only with supply of the steam to the first stage. Compared with the single stage evaporation, this system will consume extremely less steam. This is the characteristic and advantage of a multi-effect evaporator.

Theoretically when the number of effects in N, the steam for heating results in 1/N of the single stage evaporation and a larger N is advantageous on the heat economy. In practice, the cost of installation and operation increase together with an increase of N. Accordingly, an economically optimum value of N exists. In the citric acid plant, most of the plants have adopted a multi-effect evaporator. In these days that the energy cost has been rising by a large margin, there is a strong probability that the adoption of this system brings profit.

It is recommendable to investigate an adoption of the multi-effect evaporator with an detail estimation of the costs of installation energy and operation with help of the manufacturer.

Beside this, there is a vapor compression type evaporator which utilize the generated vapor after compression by a blower as a heat source. This evaporator should be also examined because it has obtained good results to the energy conservation.

6.3 Improvement of Condensate Recovery

Although an installation is provided for the recovery of steam condensate in the evaporator which is the largest steam consumption process in the citric acid production, the recovered condensate is not utilized sufficiently by the following incomplete installation.

(1) The recovered condensate is fed to an indirect heat exchanger in the boiler room to provide heat to the boiler feed water and then the condensate is utilized as a process water for seeding. In the existing piping system, however, the condensate is not utilized in the time when the process water is not used for seeding. When we visited for the diagnosis, the condensate was discarded through overflow from the condensate recovery tank for the evaporator. When the process water is unnecessary, the condensate should be utilized as boiler feed water directly. For this purpose, a direct piping from the condensate recovering pipe to the boiler feed water tank should be provided.

If the condensate of 50% is utilized to rise the temperature of boiler feed water, the recovery merit can be calculated as shown in the following.

(i) Assuming that 35% of the total steam quantity is consumed in the evaporator, its heat is as follows:

$1,600 \text{ kl} \times 0.35 \times 0.755 \times 9,600 \times 0.975 \times 10^3 = 3,957 \times 10^6$ kcal/year

(ii) The heat of the steam condensate generated in the evaporator is $152.3/656.0 = 0.23$ as the steam pressure of $4kg/cm^2G$. In other words, the heat of condensate is 23% of the heat of steam. However, the pressure of the condensate is reduced to atmospheric pressure, the heat of 41% in the condensate is released to an atmosphere as a flash steam. The remained heat in the condensate is as follows:

$3,957 \times 10^6 \times 0.23 \times (1 - 0.41) = 537 \times 10^6$ kcal/year

(iii) If the quantity of condensate discarded so far is taken as 50%, its heat is as follows:

$537 \times 10^6 \times 0.5 = 268 \times 10^6$ kcal/year

Assuming that this heat is recovered and is utilized effectively to rise the temperature of boiler feed water of 35°C, when the final available heat equivalent to fuel oil is as shown in the following,

$$\frac{268 \times 10^6 \times (65/100)}{9{,}600 \times 0{,}975 \times 0.755} = 24.7 \text{ kl/year}$$

This can be calculated as the energy conservation effect of 1.5% to the annual fuel oil consumption.

6.4 Intensification of Insulation

All the steam piping were insulated sufficiently. And the valves were also insulated. But since the collection piping for the steam condensate, the recovery tank and the recovery piping to the boiler room were not insulated, these piping should be insulated.

The energy conservation quantity converted to fuel oil based on the intensification of insulation is as shown in Table 2-4 and the cost of insulation and its pay back time are respectively as follows:

(1) Piping

Insulation cost approx. 70,800 Bt

Pay back time 0.94 years

(2) Tank

Insulation cost approx. 400 Bt

Pay back time 0.17 years

And a falling-off of the insulation on the dish plate in the lower part of the evaporator was found.

Table 2–4 Effect of Insulation

(1) Condensate piping

Piping	Rate of heat loss kcal/mh	Heat loss kcal/h	Insulation effect
Piping 2" x 20 m Piping 2½" x 140 m Total	151 125	3,000 17,500 20,500	20,500 x 0.8 = 16,400 kcal/h

Fuel saving $\frac{16{,}400 \times 24 \times 312}{9{,}600 \times 0.975 \times 0.755}$ = 17.4 kℓ/year

Fuel cost saved 17,400 x 4.3 = 74,800 Bt/year

(2) Condensate recovery tank

Specification	Rate of heat loss $kcal/m^2h$	Heat loss kcal/h	Insulation effect
Surface area of tank $7.4 m^2$/unit x 2 unit	810	11,990	9,590

Fuel saving $\frac{9{,}590 \times 24 \times 312}{9{,}600 \times 0.975 \times 0.755}$ = 10.2 kℓ/year

Fuel cost saved 10,200 x 4.3 = 43,860 Bt/year

6.5 Repairing of Cold Insulation in the Crystallization Process and Improvement of Chiller Unit Operation

In the crystallization process, cooling and crystallization are worked in the jacket tank through the chilled water of 9°C fed from the chiller unit. Accordingly a reliable cold insulation is required to improve the cooling efficiency all over the tank and to prevent dewing of the moisture in air on the tank surface. In the current condition, the polystyrene foam of cold insulator is exposed and deteriorated or fallen of ever so much, and a bare part of the tank is found. In such a condition, air enters into the inner part of cold insulator, the moisture in air dews on the tank surface and the cold insulation effect decreases extremely. Consequently the load of chilled water goes to larger and it results in an increase of the chiller unit load. The hints of the work is that the cold insulator must be to fix firmly on the body not to be a gap and to protect air-tightly on the surface by a airtight material such as mastic for prevention of an air entry.

The necessity of repairing and intensification of the cold insulation is not only to the crystallizer but also to the piping for chilled water, the chiller unit and the chilled water tank. Repairing and intensification of the insulation for these all equipment must be performed by all means. These countermeasures are expected to reduce the quantity of electric load in the chiller unit by larger margin (10 to 20%).

The cold of the filtrate in the crystallization process is not utilized at all. When the cold is recovered and utilized to cooling of the mother liquor by heat exchange, the load of the chiller unit is much more reduced. The re-utilization of cold should be investigated.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	550 W
Power Consumption	:	2,103,000 kWh/year
Load Factor	:	51.1%
Penalty Fee	:	26,265 Bt/year
Power factor	:	73%
Transformer	:	1,250 kVA 1bank
Power Consumption Rate	:	1,752.5 kWh/t
Power cost	:	1.73 Bt/kWh

7.2 One Line Diagram

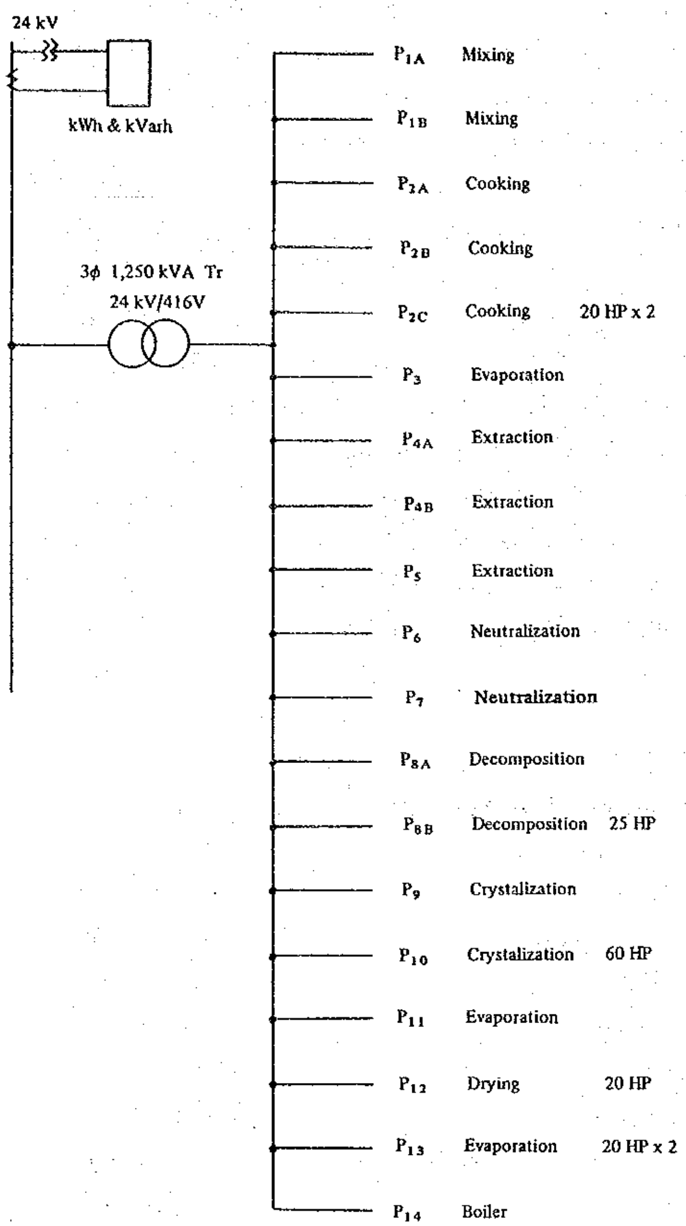


Fig. 2–5

8. Problems of Power Control and Potential Solutions

8.1 Power Factor

Because there are many small motors in the factory, the power factor is low. The record calculated from the monthly power bill is shown in Table 2-5. In January no penalty was paid and so the power factor was not recorded.

The maximum value of penalty in other eleven months was 232 kVar in February. In the case, if a condenser of 250 kVar is connected to the secondary side of the transformer, the power factor will be as follows:

Table 2–5　From Peak Demand to Power Factor

Month	kWh	Peak demand kW	Average power kW	P.D x 0.63 kVar	Penalty kVar	Peak reactive power kVar	Apparent power kVA	Cos. ϕ
1982								
1	55,000	220	199		–	–	–	–
2	151,000	520	230	328	232	560	764	0.68
3	202,000	550	307	347	143	490	737	0.746
4	176,000	530	268	334	146	480	715	0.741
5	167,000	520	255	328	152	480	708	0.734
6	199,000	520	303	328	142	470	701	0.742
7	191,000	490	291	309	171	480	686	0.714
8	185,000	520	282	328	192	480	708	0.734
9	205,000	530	312	334	146	480	715	0.741
10	197,000	520	300	328	142	470	701	0.742
11	215,000	530	327	334	136	470	708	0.749
12	160,000	510	244	321	149	470	694	0.735

Annual Average Power = 281 kW

$$\cos\varphi = \frac{\text{Peak demand}}{\text{Apparent power}} = \frac{520}{\sqrt{520^2 + (560-250)^2}} = 0.859 \quad \text{.............(8.1)}$$

In March of the maximum peak demand, the power factor is improved as follow.

$$\cos\varphi = \frac{550}{\sqrt{550^2 + (490-250)^2}} = 0.917 \quad \text{..............................(8.2)}$$

The average power factor from February to December is 0.733 by the following equation.

$$\cos\varphi = \frac{\Sigma \text{ Peak demand}}{\sqrt{(\Sigma \text{ peak demand})^2 + (\Sigma \text{ Peak reactive power})^2}} = 0.733 \quad \text{.........(8.3)}$$

The average power is 281kW. The apparent power is 281/0.733 = 383 kVA. In the case, the reactive power is as follows:

$$383 \times \sqrt{1 - 0.733^2} = 261 \text{ kVar} \quad \text{..(8.4)}$$

By the condenser of 250kVar, the apparent power and the power factor will be as follows:

$$Pa = \sqrt{281^2 + (261-250)^2} \doteqdot 281.2 \text{ kVA} \quad \text{.............................(8.5)}$$

$$\cos\varphi = 281/281.2 = 0.999 \quad \text{..(8.6)}$$

If the copper loss on a rated load of the 1,250 kVA transformer is taken as 17.5 kW, the reduction for a year of the copper loss due to the power factor improvement is as follows:

$$17.5 \times \{(\frac{383}{1,250})^2 - (\frac{281.2}{1,250})^2\} \times 24 \times 312 = 5,671 \text{ kWh} \quad \text{..................(8.7)}$$

The reduction of the resistance loss in the wiring from the secondary of the 1,250 kVA transformer can be calculated as the following. Assuming that the conductor (325 mm^2) resistance is 0.0565 Ω/km at 20°C, the four conductors are mounted per one phase and each the length is 25m, the conductor's temperature is average 33°C and the resistance temperature factor is 0.00398, the conductor resistance is as follows:

$$0.0565 \times \frac{1}{4} \times \frac{25}{1,000} \times \{1 + 0.00393 \times (33-20)\} = 0.0003712\ \Omega \quad \text{............(8.8)}$$

Accordingly, the reduction of the resistance loss in the wiring is as follows:

$$3 \times \left(\frac{383}{\sqrt{3} \times 0.38}\right)^2 - \left(\frac{281.2}{\sqrt{3} \times 0.38}\right)^2 \times 0.0003712 \times 24 \times 312 \times 10^{-3}$$

$= 1{,}302$ kWh/year. . . . . (8.9)

The losses in the transformer and the conductors are reduced by 6,973 kWh/year totally.

This results in the reduction of 10,111 Bt/year. Added with the penalty fee, this results in the reduction of 36,376 Bt/year. The installation cost of the condenser 250 kVar including the switchgear and the relay is estimated as 125,000 Bt. This is possible to be amortized with about five months and three years.

8.2 Service voltage at the motor is higher by 12V to 17V to rated voltage (See Table 2-6).

In a low load of the motor (less than 50% load), when the service voltage is lower than the rated voltage, both the power factor and the efficiency are improved in comparison with the case of rated voltage.

Table 2–6 Actual Load for Each Motor

Using for	Rated out put HP	Measuring in put kW	Rated voltage V	Measuring voltage V	Rated current A	Measuring current A	Power factor	No. of pole	Rated R.P.M.
Compressor 50 ton	60 (45)	20.6	380	392	86	43.3	0.7	4	1,475
Cooling water pump	20 (15)	5.8	380	393	29	12.1	0.7	4	1,455
Cooling water pump	20 (15)	10.6	380	394	29	19.4	0.8	4	1,455
Dust collector	25 (18.5)		No working						
Cooling water pump	20 (15)	3.6	380	397	29	11.2	0.47	4	1,455
Water pump	20 (15)		No working						
* Burner for boiler	20 (15)	7	460	389	23	13.4	0.78	2	3,520
* Burner for boiler	20 (15)		No working						

* Mark is for 60 Hz. Inside ( ) is kW.

Generally, in the case of 50% load for an induction motor, when the service voltage is lowered by 5% of the rated voltage, the efficiency is higher by about 2%. In the factory, the loads of motors of 20HP(15kW) or more, excepting one motor of 20HP (input: 10.6kW), are less than 50%. If the service voltage is decreased by 5%, the energy conservation is as follows:

$(20.6 + 5.8 + 3.6) \times 0.02 \times 312 \times 24 = 4{,}493$ kWh/year . . . . (8.10)

Accordingly, this is the merit of 6,514 Bt/year.

For the motor of 60Hz, 460V and 20HP rated, the core loss in a condition of 390V and 50Hz is proportional to V^2/f. Accordingly, the core loss decreases but the load current and the copper loss increase. And the revolutions goes down below the rated value and the cooling effect is reduced. Taking a chance, the motors should be replaced to one of 50Hz, 380V and 11kW.

8.3 The Peak demand is large and the expenditure of the fee is too much. Table 2-7 is the values measured a momentary voltage, current and power factor in each branch by the meters

Table 2–7 Load for Motor (Instantaneous value)

		7 – 4 1.40 ~ 2.40 PM				7 – 4 2.45 ~ 3.45 PM				
		V	I	Cos. ϕ	kW	V	I	Cos. ϕ	kW	Remark
		V	A			V	A			
P–2C	Cooking	396	131.5	0.8	72.2	395	111.7	0.79	60.7	
P–13	Evaporation	395	185.3	0.8	101.4	396	186	0.8	102.1	
P–5	Extraction	395	21.4	0.6	8.8	396	15.5	0.6	6.4	
P–8A	Decomposition	395	10.5	0.48	3.4	395	24.1	0.5	8.2	
P–C	Office	395	39.5	0.87	23.5	395	41.3	0.86	24.3	
P–3	Evaporation	396	72.3	0.81	40.2	396	57.2	0.84	32.9	
P–14	Boiler	395	53	0.78	28.3	395	69.8	0.7	33.4	
Spare	Shop	395	14.6	0.54	5.4	396	15.3	0.52	5.5	
P–1A	Mixing		No working				No working			
P–1B	Mixing		No working				No working			
P–4B	Extraction	395	8.5	0.6	3.5	395	14.8	0.4	14	
P–4A	Extraction	396	23.8	0.83	13.6	395	25.6	0.84	14.7	
P–6		396	1.8	0.39	0.5	395	3.3	0.4	0.9	
P–D	Lighting & mixing		No working				No working			
P–7	Neutralization	395	4	0.5	1.4	395	8.4	0.49	2.8	
P–12	Drying		No working			395	21.1	0.66	9.5	
P–2A	Cooking	395	13	0.44	4	395	12.2	0.65	5.4	
P–2B	Cooking	396	36	0.68	16.8	395	32.9	0.74	16.7	
P–A	Lighting	395	23	0.93	14.6	395	26.3	0.74	13.3	
P–11	Evaporation	396	4.9	0.45	1.5	395	10.4	0.46	3.3	
P–8B	Decomposition	396	5	0.74	2.5	395	5.1	0.46	1.6	
P–9	Crystallization	395	15.7	0.42	4.5	395	22.4	0.4	6.1	
P–10	Crystallization	396	102.1	0.79	55.3	395	101.5	0.78	54.2	
1,250 kVA Secondary		395	860	0.748	440	396	800	0.729	400	

brought by us. The loads in the following five branches are larger. An improvement of the operating procedure to these loads is possible to suppress the peak demand.

P2C Cooking
PC Office
P10 Crystallization
P13 Evaporation
P3 Evaporation

If the peak demand is suppressed, the peak demand fee not only reduced but also the losses in the transformer and the wiring are possible to reduce. In all the places installed with an watt-hour meter as well as the watt-hour meter of MEA, with recording the every hour power consumption, preparing the load curve and finding a tendency of the load change, the causes of the peak demand may be found out. Thus, the peak demand must be suppressed. In Fig 2-6, the peak demand in March was higher than in November which had the higher average load. This fact indicates that there is a room for improvement.

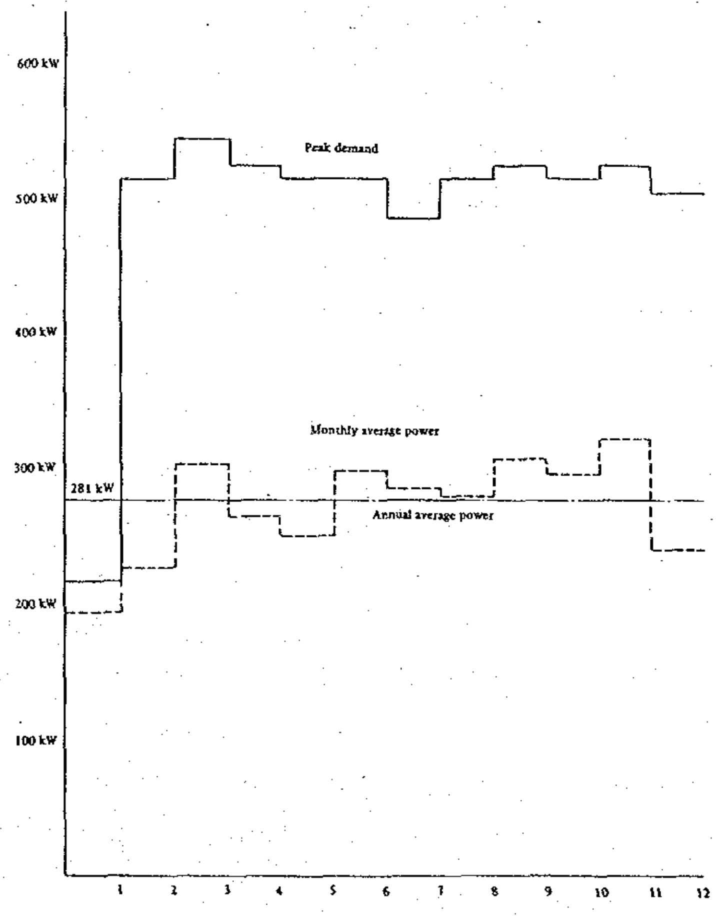


Fig. 2–6 Peak Demand & Average Power

8.4 About 100 daylight fluorescent lamps are used out of total about 500 fluorescent lamps used in the factory. By the replacement of the 100 lamps to an energy conservation type white fluorescent lamps with a good luminous efficacy, the following energy conservation can be made.

$$5W \times 100 \times 10H \times 312 \times 10^{3} = 1{,}560 \text{ kWh/year} \qquad (8.12)$$

8.5 The indications of the power-factor meter on the incoming panel and of the ammeter on the 60HP compressor panel are out of order. These meters are desirable to put effectively to practical use by calibration for the right indication.

8.6 It is said that there are many burning troubles in the motors. However, these troubles may be avoided if the motors used to mixing, cooking, fermentation and seeding in the condition of a high temperature and humidity or a bad atmosphere, are replaced by corrosion-proof type motors. On the other hand, since the service voltage is only 5% higher than the rated voltage, the voltage cannot be the cause of motor burning.

9. Summary

The effect, when the above measures are taken, is as follows:

	(Fuel oil equivalent) kl/year	%
Improvement of air ratio in boiler	31.4	2.0
Improvement of utilization rate of condensate	24.7	1.5
Intensification of insulation	27.6	1.7
Subtotal	83.7	5.2

	10^{3}kWh/year	%
Improvement of power factor	7.0	0.3
Lowering of service voltage in motor	4.5	0.2
Higher efficiency of lighting	1.6	0.1
Subtotal	13.1	0.6

Report No. 3: Plastic & Chemical

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Custom-Pack Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Custom-Pack Co., Ltd. —

1. Outline of the Factory

Address	150/1 Soi Tesbal 4 Sukumvit Road A, Muang Smutprakan	
Capital	25 Million Bt	
Type of industry	Plastics	
Major products	Plastic containers	
Annual product	840 ton	
No. of employees	300	
Annual energy consumption	Electric power	$2,844.4 \times 10^3$ kWh
	Fuel	
Interviewees	General manager Mr. Mana Technical staff Mr. Niran	
Date of diagnosis	July 7 ~ 8, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

This company belongs to the White Group consisting of six companies with capitalization of Thailand. The other five companies are trading firms handling mainly export and import business. It is only this company that is manufacturing products.

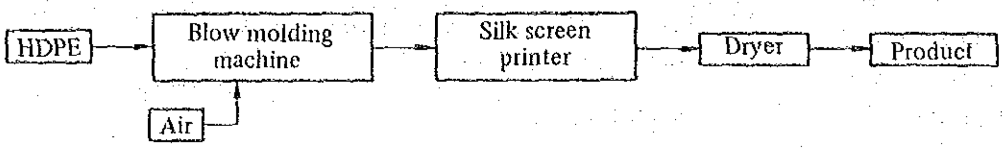
Originally, the company was fabricating steel products, but later began repacking of liquid products such as oils, chemicals and detergents into plastic containers under a contract with the leading manufacturers of the mentioned products. This was an opportunity for the company to have ever been involved in the plastic industry. During the early stage of their operation, the company used to purchase plastic containers and repack the products into the containers. However, fourteen years ago, they initiated container-forming as they are doing it now. They also began manufacturing containers other than those for repacking. At the beginning, they were manufacturing blow-molding plastic containers and then introduced thermoforming machinery at the factory. Further, the company expanded the factory equipment gradually according to the increasing business activities, and is now maintaining this expanded business scale. Because of their continued receipts of orders for repacking into the containers, the company is still handling the repacking operation but to the minimum extent.

In Thailand, there are at present approx. 1,400 plastic molders. Custom-Pack Co., Ltd. is one of the Big 5 in terms of production scale and especially is only a company that is manufacturing thermoforming plastic products in Thailand.

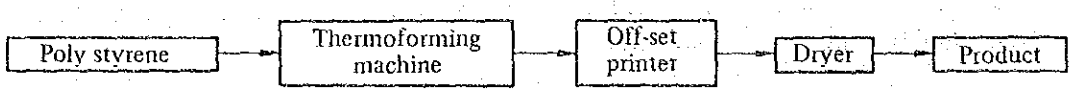
The company is now acting as secretary to the Association of Plastic Molders.

2. Manufacturing Process

Blow molding



Thermoforming



Injection molding

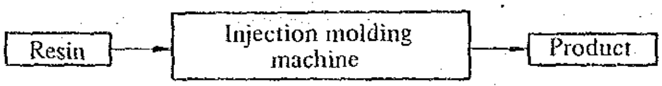


Fig. 3–1

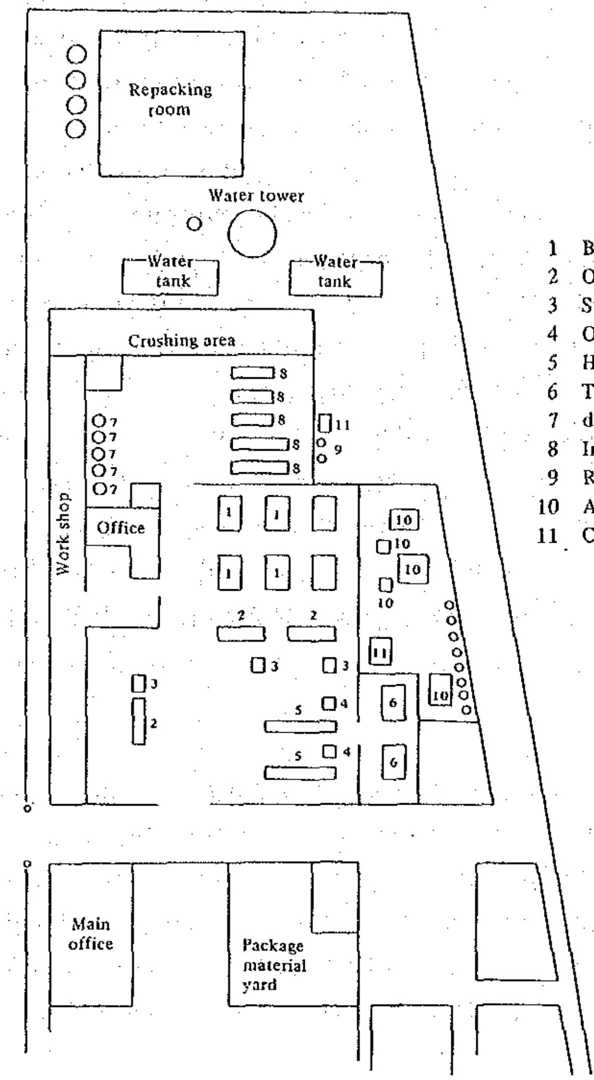
3. Major Equipment

3.1 Major Equipment

Table 3–1

Name	No. of units installed	Type, etc.
Blow molding machine	6	Bekum, W. Germany
Thermoforming machine	2	Illig, W. Germany
ditto	5	
Injection molding machine	5	
Silk screen printer	3	
Off-set printer	2	
Oven type dryer	3	
Heater band dryer	2	
Air compressor	5	40 kW x 1 unit, 37 kW x 2 unit, 2.2 kW x 2 unit
Refrigerater	10	

3.2 Layout



1 Blow molding machine
2 Oven type dryer
3 Silk screen printer
4 Off-set printer
5 Heater band dryer
6 Thermoforming machine
7 ditto
8 Injection molding machine
9 Refrigeraters
10 Air compressor
11 Chilled water tank

Fig. 3–2

4. State of Energy Management

4.1 Policy for Energy Conservation

In view of the frequent occurrence of labor casualties, the company has continued concentrating their efforts to the prevention of such casualties as one of their most important management points. In so doing, they anticipated to see the realization of cost reduction and increased productivity. Since the end of last year, their efforts began bearing fruit after a long time. This year, they have not yet seen even a single case of casualty. As measures for energy conservation, the company has not invested in even a single equipment, but has a few projects of investment under study. The criterion of payback time is two years or less. The company now pays approx. 400,000 Bt per month for their power consumption. However, they aim to reduce this power bill to 300,000 Bt.

The plastic molding machine takes approx. four hours before it could be ready for operation. Therefore, from a viewpoint of productivity and energy conservation, operating pattern such as work by day and stop at night is extremely inefficient. For this reason, the company makes it a rule to operate the machine for 24 hours a day and continue its operation throughout the year without a stop. In the plastic forming, if operating conditions were slightly changed, they are apt to be immediately reflected on the quality of a finished product. Therefore, measures for energy conservation need to be deliberately studied and implemented on a long-range basis. As to insulation for the electric heater of the plastic extruder, they are carefully studying it because the temperature pattern might possibly change and its resultant effect upon the quality of a finished product is yet to be determined. As practicable energy conservation measures, the utilization for the dryer of an exhaust gas from the air compressor cooler and the replacement of a band heater with an infrared ray lamp are conceivable.

The layout of the factory facilities appears to be such that they are based on cumulative expansions. Therefore, it is presumed that when the factory was originally designed, a rational layout including a consideration over possible future expansions was not worked out. For instance, cooling air for the refrigerator condenser is mixed with high-temperature air, because the air-cooled air compressor and the refrigerator are installed in the same room. Thus the cooling efficiency is prevented. In addition, possibly because of the additions of equipment each time the expansion was required, numerous units of small capacity are arranged.

4.2 Participation by All Employees

The QC circle activities are conducted, but are mainly aimed at labor safety and disaster prevention. These aims are well aligned to the afore-mentioned management policy. In the meantime, following the appearance of the direct effects of the said activities on the production side such as the significant improvement of finished product shipping efficiency, it is considered that the activities will be fully utilized for future energy conservation.

As things stand, the factory general manager has not yet appealed to the employees for energy conservation.

4.3 Control through Data

The factory consumes only electric power as energy, but not fuel. The electric power consumption is determined only by a bill sent from a power company every month, and no private wattmeter is installed. In addition, a wattmeter attached to the receiving transformer is not utilized at all. Therefore, it is suggested that reading of this wattmeter used as a substitute of private wattmeter be recorded at a prearranged time (hourly, daily or weekly) and utilized for the analysis of relationship between operation and power consumption and also for the control of peak demand.

It is impossible to determine an energy consumption by process because no wattmeter for each equipment is provided on the power board. An automation mechanism which operate or stop heater and pump according to a prearranged temperature or oil pressure, is built in each equipment. Nevertheless, no means to determine an energy consumption will be available, if it is desired that a energy consumption rate be improved in future by changing operating conditions or any other ways. Therefore, it is recommended that a wattmeter be installed for each equipment or each major process.

The majority of main units are utilizing compressed air. However, its consumption cannot be determined because no flowmeter is provided. Since an electric power consumption for air compression is fairly much, it is suggested that a flowmeter be installed at the important branches of air piping for monitoring an air consumption. In this way, it will be possible to eliminate useless expense and maintain a correct number of air compressors in actual running.

4.4 Education and Training, Leveling-Up of Employees

The company has not established "Energy Conservation Committee", but makes it a rule to take up energy conservation related problems if there at a weekly meeting presided over by the factory general manager as a chairman.

So far, the employees were encouraged to participate in the external seminars and visit the factories of the other companies at a rate of more than 10 times a year. This reflects the management policy that the education of employees should be preferential to investment.

The company intends to raise the technical level of the factory as a whole by increasing the frequency of assigning different jobs to staff members and workers on a rotary basis.

The Plastic Industrial Association is not so much contributing toward technical improvement, because it mainly deals with general information exchange.

5. State of Electric Power Consumption

5.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	490 kW
Power Consumption	:	2,844.4 $\times 10^3$ kWh/year
Load Factor	:	73.7 %
Penalty Fee	:	19,965 Bt/year
Power Factor	:	72.1% ~ 80.6%
Transformer	:	3ϕ 500 kVA, 1ϕ 167 kVA $\times$ 3
Electric Power Consumption Rate	:	Average 3,386 kWh/t
Overall Power Cost	:	1.63 Bt/kWh

7.2 One Line Diagram

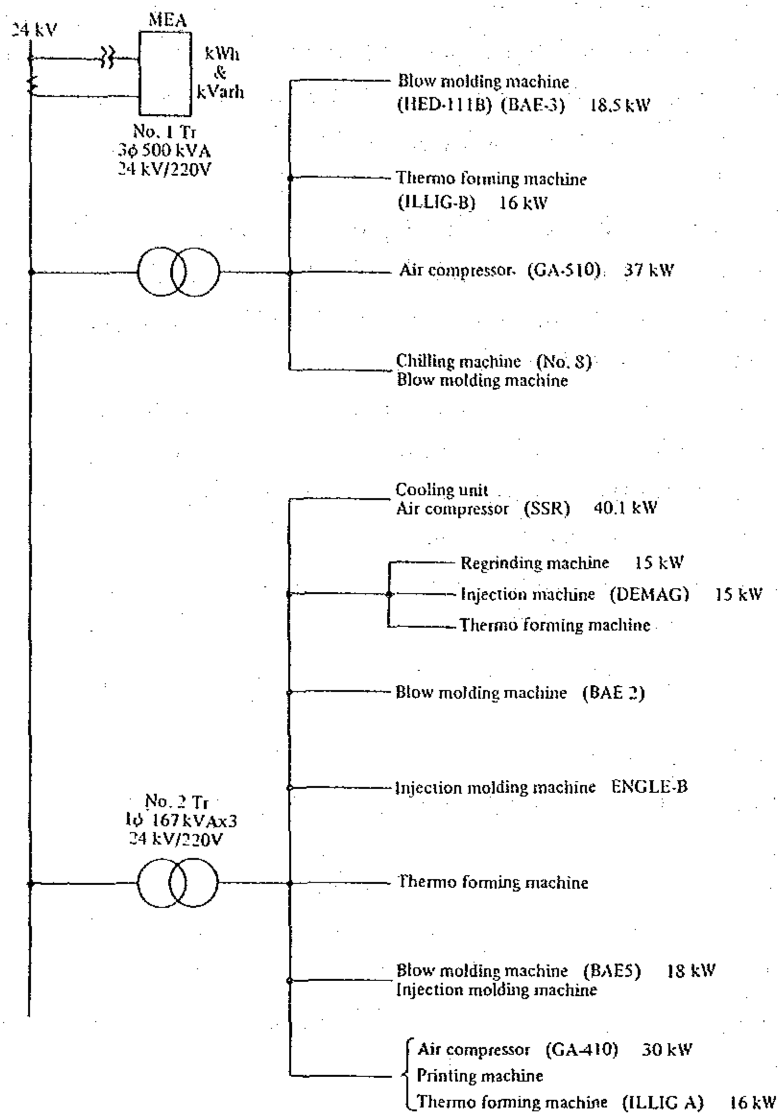


Fig. 3–3

6. Problems of Power Control and Potential Solutions

6.1 Integration of Transformers

There are two banks of transformers, one unit capable of 3ϕ 500 kVA and three units capable of 1ϕ 167 kVA at the factory. Yet, a load on the transformers is low. There are possibilities that if the transformers are integrated, the loss would be reduced. Therefore, we studied the best way of integration. Table 3-2 shows the figures calculated from the monthly power bill. Table 3-3 shows the figures recorded for 24 hours from July 7 and 8 under the cooperation with the factory side.

The maximum apparent electric power of Table 3-2 is 609 kVA and that of Table 3-3 707 kVA.

The buildings of the factory stand leaving almost no space left in its site. Therefore, considering that there would be no more significant increase of power consumption than the present level, it is suggested that facilities suitable to the maximum apparent power of 750 kVA be provided with some allowance.

Table 3–2 Apparent Power and Power Factor

Month	kWh	Average power kW	Peak demand kW	Peak demand x 0.63 kVar	Penalty kVar	Peak reactive power kVar	Peak apparent power kVA	Power factor
1982								
6	255,000	394	440	277	83	360	568.5	0.774
7	235,500	352	435	274	116	390	584	0.745
8	206,000	308	410	258	112	370	552	0.743
9	201,000	310	425	268	127	395	580	0.733
10	222,500	332	415	261	64	325	527	0.787
11	218,000	336	415	261	134	395	573	0.724
12	211,500	316	415	261	134	395	573	0.724
1983								
1	232,500	346	405	255	135	390	562	0.721
2	232,000	384	435	274	121	395	588	0.74
3	289,500	432	450	284	126	410	609	0.739
4	266,950	412	440	277	128	405	598	0.736
5	274,000	409	490	309	51	360	608	0.806
Total	2,844,450				1,331			

Penalty fee 15 x 1,331 = 19,965 Bt/year

Maximum Peak Demand 490 kW

Maximum Apparent Power 609 kVA

Table 3–3 Transformer

Time	3ϕ 500 kVA Transformer					1ϕ 167 kVA x 3 Transformer				
	V V	I_R A	I_S A	I_T A	Apparent power kVA	V V	I_R A	I_S A	I_T A	Apparent power kVA
7–7 2 PM	222	404	430	450	165	219	996	1,005	1,015	381
7–8 10.15 AM	218	364	415	458	157	215	998	1,067	1,078	397
11.50 AM	224	449	418	377	162	214	925	926	846	343
1.30 AM	221	431	458	440	168	214	1,097	964	1,040	385

Remark: V: Secondary line voltage
I_R, I_S, I_t: Each line current
Average apparent power for 3ϕ 500 kVA = 163 kVA (30%)
Average apparent power for 1ϕ 167 kVA x 3 = 377 kVA (70%)

The one line diagram of integrated transformers is shown in Fig. 3-4. It is suggested that the 750 kVA transformer be installed slightly ahead of the position of the existing No.2 bank of transformers and the existing two circuits be connected to the transformer as they are. The estimated advantages of the integration of two banks into a 3ϕ 750 kVA transformer are as follows:

Annual average power is estimated as 361 kW from peak demand 490 kW and annual load factor 73.3%. Average power factor calculated based on Table 3-4: 0.788.

Accordingly, the average apparent power is 361/0.788 = 458 kVA.

If this average apparent power is divided at a ratio shown in Table 3-3, the estimated average apparent power consumed by the 3ϕ 500 kVA transformer is 138 kVA and that by three units of the 1ϕ 167 kVA transformer is 320 kVA.

Table 3–4　24 Hour's Data　July 7th ~ 8th

Time	kWh/h	kVarh/h	kVA	cos φ	Time	kWh/h	kVarh/h	kVA	cos φ
7th 1 PM	400	300	500	0.800	8th 1 AM	400	300	500	0.800
2	400	300	500	0.800	2	500	500	707	0.707
3	400	300	500	0.800	3	400	300	500	0.800
4	500	400	640	0.781	4	300	300	424	0.707
5	400	300	500	0.800	5	500	300	583	0.858
6	400	300	500	0.800	6	300	300	424	0.707
7	400	300	500	0.800	7	400	300	500	0.800
8	400	400	566	0.707	8	400	300	500	0.800
9	400	400	566	0.707	9	500	300	583	0.858
10	400	400	566	0.707	10	500	400	640	0.781
11	400	200	447	0.895	11	400	300	500	0.800
12	400	300	500	0.800	12	500	300	583	0.858

Average power = 417 kW　　Average reactive power = 325 kVar

Maximum power = 500 kW

Daily load factor = $\frac{417}{500}$ = 0.834　83.4%

Maximum apparent power = 707 kVA (Power factor = 0.707)

Minimum apparent power = 424 kVA (Power factor = 0.707)

Average apparent power = 529 kVA

Average power factor = 0.788

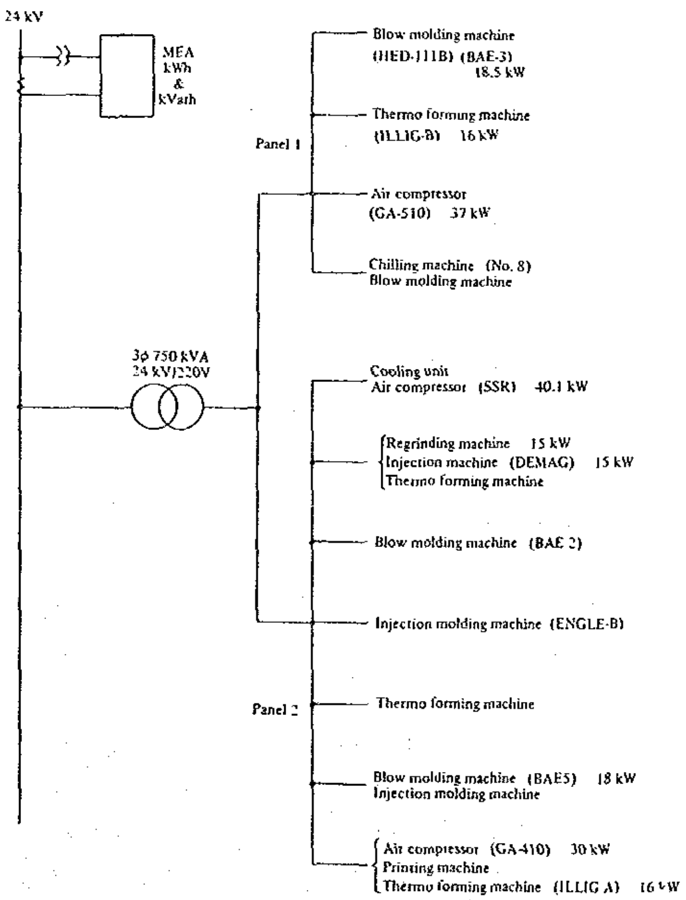


Fig. 3–4

Next, the estimated loss is as follows:

3ϕ 500 kVA transformer	iron loss 1.1 kW, copper loss 5.5 kW (test report)
1ϕ 167 kVA transformer	iron loss 0.6 kW, copper loss 2.5 kW
3ϕ 750 kVA transformer	iron loss 1.5 kW, copper loss 8.5 kW

The decrease in the iron loss is represented by the following equation:

$$\{(1.1 + 0.6 \times 3) - 1.5\ \text{kW}\} \times 8,760\ \text{h} = 12,264\ \text{kWh/year} \quad \cdots\cdots (8.1)$$

Next, the decrease in the copper loss is represented by the following equation:

$$\{5.5 \times (\frac{138}{500})^2 + 2.5 \times 3 \times (\frac{320}{167 \times 3})^2 - 8.5 \times (\frac{458}{750})^2\}$$
$$\times 8,760 = 2,706\ \text{kWh/year} \quad \cdots\cdots (8.2)$$

The total loss decrease is 14,970 kWh/year or 21,707 Bt/year in amount. If the existing transformers are sold, the estimated sale value will be 125,000 Bt or half the total value of new transformers. On the other hand, the estimated cost of a 750 kVA transformer including its installation is 187,500 Bt. The difference is 62,500 Bt which can be depreciated in approx. 2 years 10 months.

6.2 Improvement of Power Factor

Based on the average electric power of 361 kW and the average power factor of 0.788, the reactive electric power is represented by the following equation.

$$361 \times \frac{\sqrt{1 - 0.788^2}}{0.788} = 282\ \text{kVar} \quad \cdots\cdots (8.3)$$

Of the monthly peak reactive power values shown in Table 3-2, the maximum value is 410 kVar and the minimum value is 325 kVar. On the other hand, Table 3-4 indicates that the maximum value of reactive power is 500 kVar and the minimum value is 200 kVar. Accordingly, if a 200 kVar condenser is connected to the secondary side of 750 kVA, no penalty need be paid. The improved power factor in January, 1983 when the paid penalty was the highest is represented by the following equation:

$$\cos\varphi = \frac{405}{\sqrt{405^2 + (390 - 200)^2}} = 0.905 \quad \cdots\cdots (8.4)$$

The improved power factor, if the peak demand is at the maximum level, is as follows:

$$\cos\varphi = \frac{490}{\sqrt{490^2 + (360 - 200)^2}} = 0.951 \quad \cdots\cdots (8.5)$$

The apparent power during the average power consumption is reduced from $\sqrt{361^2 + 282^2} = 458$ kVA to $\sqrt{361^2 = (282 - 200)^2} = 370$ kVA.

Consequently, the copper loss will be reduced as follows:

$$8.5 \times \{(\frac{458}{750})^2 - (\frac{370}{750})^2\} \times 8,760 = 9,645\ \text{kWh/year} \quad \cdots\cdots (8.7)$$

As to wiring laid to a panel for installing a condenser, it is assumed that three single core (1C) cable ($250mm^2$) per phase presently connected to each panel from one unit of the 3ϕ 500 kVA transformer and three units of the 1ϕ 167 kVA transformer respectively. As shown in Fig. 3-5, the cable will be used as such, even after the 750 kVA transformer was adopted.

Therefore, it is considered that each phase will have six pieces of the single core. Using parameters such as the resistance 0.0739Ω/km of a 250 mm² single core (1C), the temperature factor 0.00393Ω/km°C of the said conductor resistance and the length approx. 35m per phase of cable from the transformer to the panel, the decrease in the loss by the improvement of the power factor is calculated as follows:

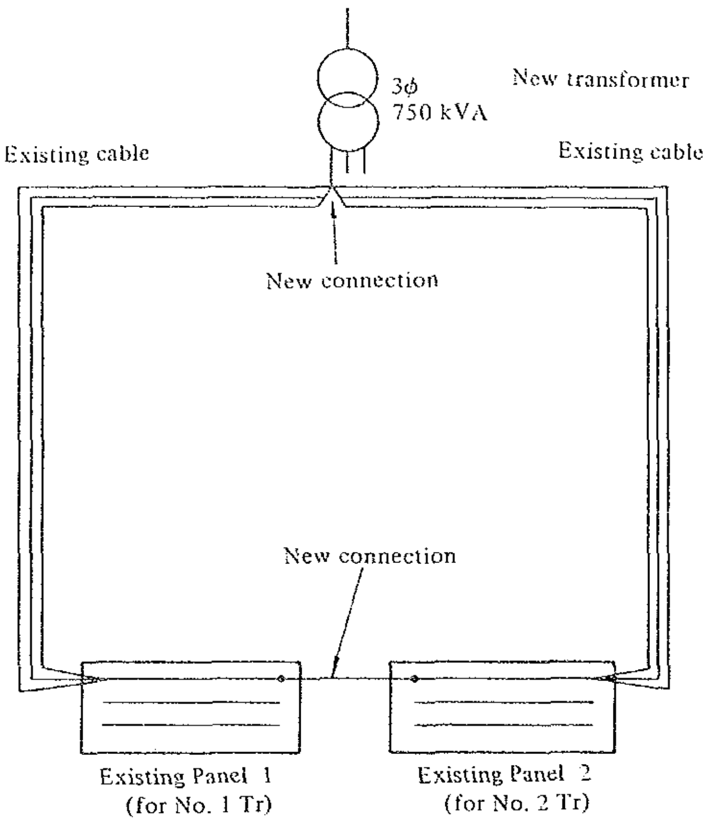


Fig. 3–5 Connection System per One Phase

$$3 \cdot (I_1^2 - I_2^2) \times \gamma \times 10^{-3} \times 8{,}760 = 3 \times \{ (\frac{458 \times 10^3}{\sqrt{3} \times 220})^2 - (\frac{370 \times 10^3}{\sqrt{3} \times 220})^2 \} \times \frac{0.0739}{1{,}000 \times 6}$$

$$\times \{1 + 0.00393(35 - 20)\} \times 35 \text{ m} \times 10^{-3} \times 8{,}760 \text{ h} = 6{,}020 \text{ kWh/year}$$

The estimated total saved cost will be approx. 42,700 Bt/year comprising approx. 22,714 Bt/year equivalent to a decrease in loss of 15,665 kWh/year resulting from transformer and wiring loss mitigation and no penalty fee. The estimated cost of installing a condenser together with a switching unit will be approx. 100,000 Bt. However, this cost will be depreciated in approx. two years and four months.

6.3 Maintenance of Instruments

The indication values of an ammeter and an integrating wattmeter on the receiving power boards are not correct. It is desired that the instruments be adjusted so as to indicate correct values. In addition, only ammeters are mounted on the panels of machines such as thermoforming and blowmolding, so that even power consumption ratio cannot be measured. Therefore, it is desired that a voltmeter and integrating wattmeters be installed so that unit power consumption per finished product may be accurately determined and be reduced.

6.4 Improvement of Illumination

Daylight-color fluorescent lamps of low luminous efficiency are now used as factory illuminations.

Through the replacement of these lamps with the energy conservation-type white fluorescent lamps, the following advantages are expected:

The total number of fluorescent lamps at the factory is 350, so the replacement of the lamps will bring about an energy conservation of five watts per lamps as shown by the following equation:

$5 \times 350 \times 365 \text{ days} \times 10 \text{ h} \times 10^{-3} = 6{,}388 \text{ kWh/year}$ .... (8.9)

Thus the estimated saved cost will be 9,626 Bt/year. It is suggested that whenever the lamps are replaced because of their breakdown, the energy conservation-type fluorescent lamps be newly installed one after another.

6.5 Control of Peak Demand

The factory takes a record of the kWh and kVar values once every week. However, these records do not allow the active follow-up of load fluctuations. Therefore, it is suggested that a load curve be prepared by taking records every hour and be used for the control of a peak load. If the peak demand is controlled, a cost of 95 Bt/month be saved per 1 kW. At the same time, a load loss on the transformer and its distributing line will be reduced as is the case with the improvement of power factor (refer to Fig. 3-6).

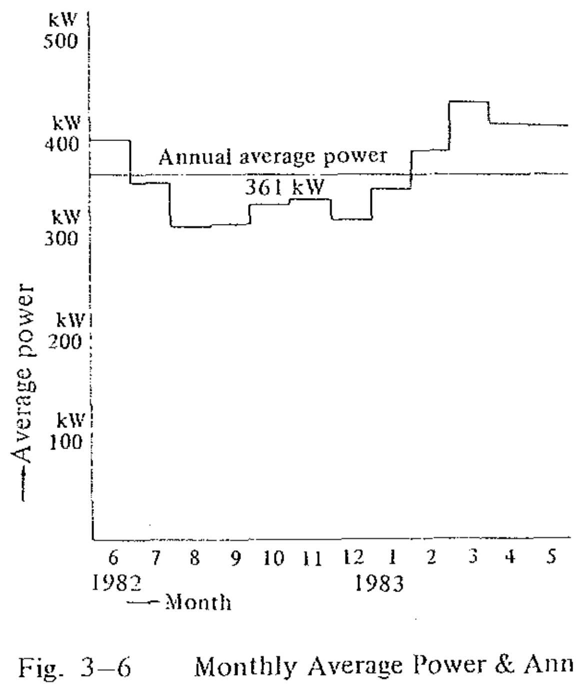


Fig. 3–6 Monthly Average Power & Annual Average Power

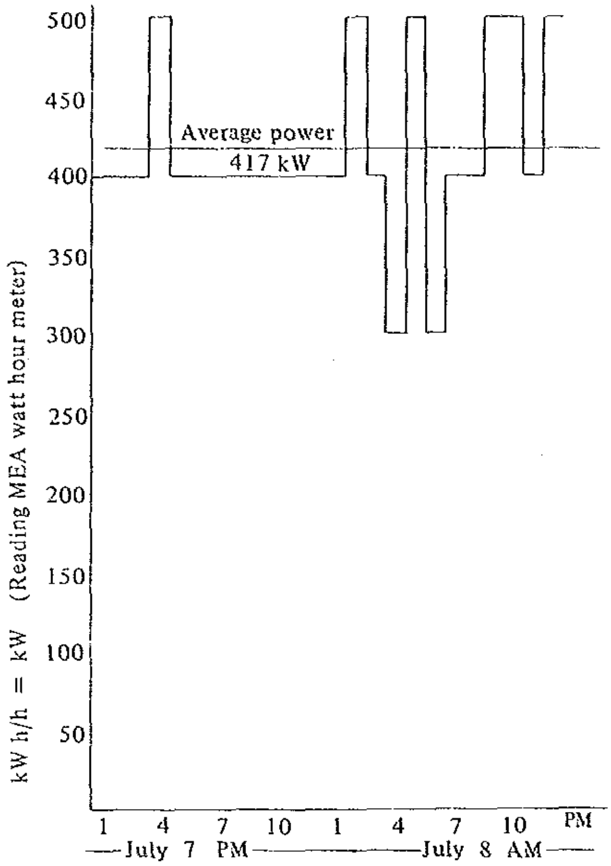


Fig. 3–7 Daily Load Curve (24 hours)

Fig. 3-7 shows that the hourly load fluctuation is remarkable. If the operating schedule of machines is adjusted, it will be possible to suppress peak demand.

6.6 Introduction of Infrared Ray Heaters

Band heaters are alternately arranged at both sides of the conveyor lines for coat drying. However, if they are replaced by infrared ray heaters, the energy will be considerably conserved and the drying time shortened because the radiant energy is selectively absorbed into the coat at high efficiency. Accordingly, the required capacity of a heat source comes down from several tenths to one tenth. At the same time, the line can be shortened. The capacity and size of the heater are decided by the length and speed of a belt conveyor, size of a product to be dried, type of paint and thickness of a coat. For these reasons, please consult with the heater manufacturer sufficiently and decide the specifications of heating equipment when you purchase it.

6.7 Power Conservation for Chiller Units

The air-cooled chiller units of various types are now employed for cooling the mould of plastic extruders. However, on account of the effect of the adjacent air compressor, the ambient temperature of the intake for cooling air is high at 40° C, resulting in the reduction of the cooling effect of the chiller unit. If the air temperature could be lowered from 40° C to 35° C (average open air temperature) by means such as shield, it will be possible to increase the cooling capacity by 1,100 kcal/h as shown in Table 3-5 and reduce the power consumption by 0.21 kW/unit.

Table 3−5 Chilled Water Capacity Tables

(Type 30GW005)

Outside air temp. °C	Leaving chilled water temperature °C			
	10		15	
	TC	kW	TC	kW
25	15.40	5.47	17.20	5.81
30	14.30	5.80	16.00	6.18
35	13.30	6.01	14.90	6.44
40	12.40	6.16	13.80	6.65
45	11.40	6.29	12.70	7.05

TC: Total capacity (1,000 kCal/h)
kW: Compressor motor power input (Kilowatts)

The power consumption reduction rate is (6.65 − 6.44 × 1,380/1,490)/ 6.65 = 0.103.

Based on the actual measurements of six units of the chiller unit now in operation, it is estimated that the input per unit would be 2.0 kW. The estimated annual power consumption of the six units achieved by lowering the air temperature will be:

2.0 kW × 6 × 24 × 365 × 0.103 = 10,827 kWh/year (0.4%)

10,827 kWh × 1.45 Bt/kWh = 15,699 Bt/year

6.8 Reduction of Compressed Air Consumption for Cup Thermoforming Machine

Air blast is adopted for separating a finished product from the machine. However, actually the air is wastefully released even during the period requiring no air blast (approx. 7.5 seconds) other than the required time of approx. 0.5 second. Thus an electric power required for generating a compressed air is wasted.

As an up and down movement mechanism for separating the cup is provided, it is suggested that a device which moves to the right or left through a simple link interlocked to the said mechanism will help to flip the cups. If this method is realized, the electric power now consumed for air compression will be unnecessary. The estimation of this electric power will be:

Assuming that the air pressure is 1 kg/cm^2G, the air blast from a copper tube of 4 mm inside dia. would be equivalent to 300 l/min. Then, if compressed air for four units of the thermoforming machine is compressed through a two-stage compression system, the estimated cost required for the electric power consumption is represented by the following equation:

$$2 \times 1.4/(1.4-1) \times (1,033 \times 10^4 \times 0.3/6,120) \times [(8/1)^{\frac{1.4-1}{1.4\times 2}} - 1] \times 1/(0.65 \times 0.98) \times 4 = 1.93\ kW \times 4 = 7.7\ kW$$

7.7 kW × 24 h × 365 days = 67,444 kWh/year (2.4%)

67,444 kWh/year × 1.45 Bt/kWh = 97,794 Bt/year

7. Summary

The above-mentioned countermeasures, if actually taken, will bring about energy conservation effects as shown below:

	10^3kWh/year	%
Integration of Transformers	15.0	0.5
Improvement of Power Factor	15.7	0.5
Improvement of Illumination	6.4	0.2
Lowering of Air Temperature of Chiller Unit	10.8	0.4
Conservation of Compressed Air	67.4	2.4
Total	115.3	4.0

Report No. 4: Plastic & Chemical

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Industrial Gases Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Industrial Gases Ltd. —

1. Outline of the Factory

Address	Thai Tarua Road, Saraburi	
Capital	72.5 Million Bt	
Type of industry	Chemical	
Major products	Liquid Oxygen / Nitrogen	
Annual product	12 Million m^3	
No. of employees	25	
Annual energy consumption	Electric power	16,055.6 x 10^3 kWh
	Fuel	
Interviewees	Site manager Mr. Chaiyan	
Date of diagnosis	July 11 ~ 12, 1983	
Diagnosers	H. Igarashi, H. Murata, K. Kurita	

This is a joint company consisting of 55% interest owned in Thailand and 45% by the Commonwealth Industrial Gases, Ltd. of Australia. They started operation in January, 1980 and maintains another factory in addition to the factory described below in Thailand. The company keeps a 40 to 50% market share in the liquid oxygen industry.

As the design of the factory, procurement and installation of equipment were carried out by the Australian side, almost all of the machines are of Australian make. Operation at site is now being performed by the Thai side in an extremely rational way and at a high technical level.

Of the total liquid oxygen production, approx. 30% are supplied to the adjacent Siam Iron & Steel Co. The processing system is such that liquid oxygen is evaporated at the factory and cryogenic effect obtained at that time is utilized for cooling the feed air, taking advantage of gasified oxygen transported through the pipeline. Thus the characteristic of this factory is such higher energy efficiency and this characteristic is advantageous from a viewpoint of location.

Generally, the air separation plant attaches importance to the purity of feed air, so the factory of Thai Industrial Gases, Ltd. is ideally located at a rural area more than 100 km from Bangkok.

2. Manufacturing Process

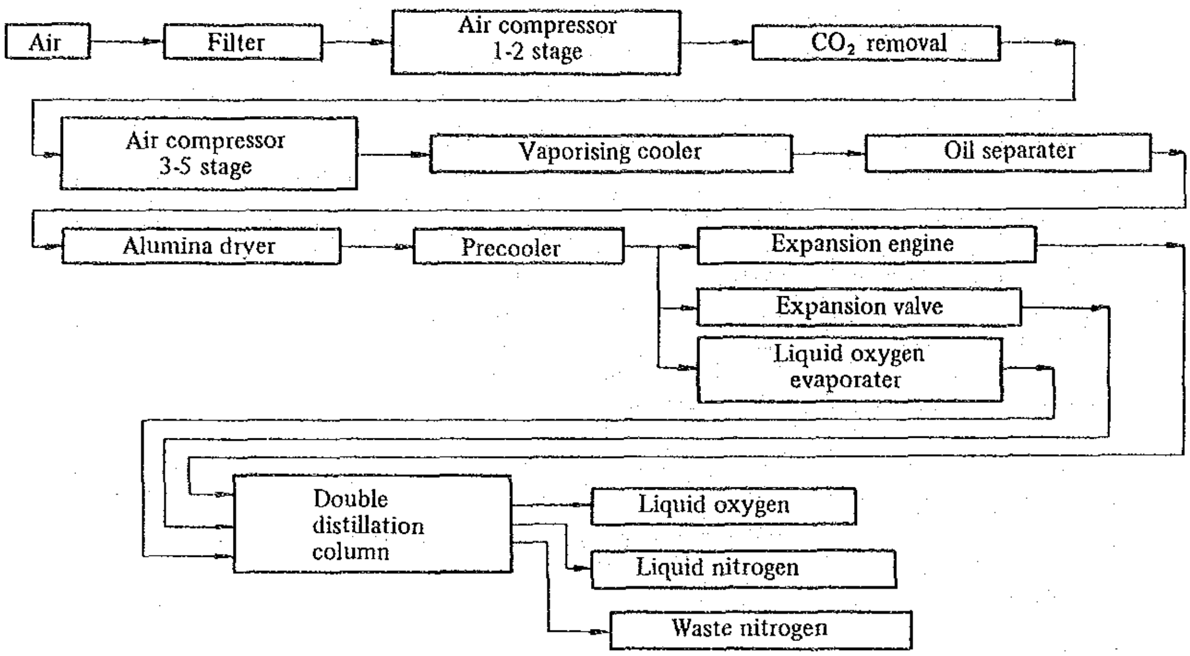


Fig. 4–1

3. Major Equipment

3.1 Major Equipment

Table 4–1

Name	No. of units installed	Type, etc.
Air compressor	1	5 stage reciprocating, 8,670 Nm^3/h, 3,120 psig, 3,050 HP
Expansion engine	3	35 ~ 50 kW
CO_2 removal unit	1	Caustic soda solution washing, 2 towers system
Chiller unit	1	R-22 refrigerater
Air separation unit	1	C.I.G. process
Liquid oxygen tank	1	Horizontal cylinder
Liquid nitrogen tank	2	Horizontal cylinder Vertical cylinder
Cooling tower	1	360 m^3/h

3.2 Layout

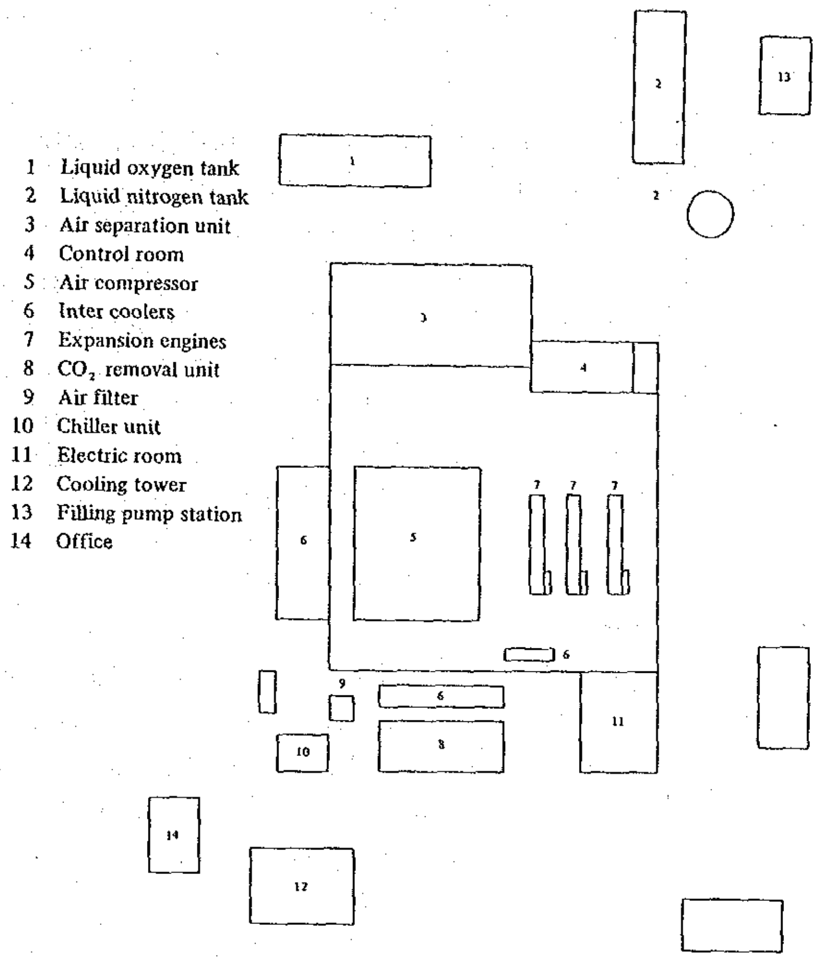


Fig. 4-2

4. State of Energy Management

4.1 Policy for Energy Conservation

The majority of energy consumption goes to an air compression work. Therefore, the under-mentioned design considerations are incorporated into the facilities for energy conservation.

Approximately 60% of the compressed and cooled air generates the cryogenic effect inside three units of the expansion engine and 35 to 50 kW of generated electric power per expansion engine is recovered.

To cool the compressed air, well water is used after being refined to a hardness of 2 to 3 ppm by the water softening unit. This is a procedural consideration over the prevention of an increase in the power for air compression caused by the fouling of the heat transfer area due to water impurities. Cooling water is cooled and recycled at wet-bulb temperature plus 2 to 3°C by means of a high-performance water-cooling unit. The effect of the air temperature at the exit of a intercooler upon the compression power is significant. In addition, the lower the final stage air temperature becomes, the more advantageous results will be brought about to the generation of cryogenic effect in the air separation unit. This will also lead to the possibility of reduction of air pressure.

Due to the cleanness of ambient air, a tall tower for the intake of air is omitted at the factory. So, the energy loss attributed to a suction resistance becomes negligible, beside the saving of equipment cost. This is pointed out as one of the advantages from viewpoint of location.

In order to prevent a soaring room temperature under the sun, the machine room roof is lined with insulation material at inside. Also the structure of the roof is so designed that the air separation unit may not be exposed to the direct sunlight.

Up to now, no particular investment has ever been made in energy conservation equipment, but only operating conditions have been changed or improved, resulting in the achievement of energy conservation by approx. 4% per year. The company has set a target of 3.2% this year.

As objects for investment in energy conservation, the utilization of waste nitrogen gas is enumerated. But its study is now under way. The criterion for pay back time is yet undecided.

4.2 Participation by All Employees

There are neither the QC circle activities nor the work improvement suggestion system and the commendation system. Although the factory maintains facilities which require high-level operating and maintenance techniques, the number of employees engaged in its operation is very few. Especially, even the maintenance work of machinery calling for highly sophisticated and precise skill is being carried out by the employees without depending on external contractors.

The employees have their respective specialized techniques and skills, and also definite shared jobs. The reason why only a few number of employees are able to achieve the above-mentioned work is a proof that the individual employee's capability is being utilized without unnecessary loss. From this fact, the factory can be regarded as one capable of managing its work crew satisfactorily.

There is now no appeal by the factory general manager for energy conservation. However, the present practice is that the improvement method, if determined, will be made known in writing to the entire employees, thus making sure that information on the method will be received by every employee with accuracy.

The staff members patrol routinely to every section of the factory to check on the condition of facilities and operation.

4.3 Control through Data

The entire facilities including the air compressors are now being operated on a two-man per shift basis. The plant is complete with measuring instruments and automatic controllers, and plant operation can be monitored by the control room. Important operating data are read and recorded on an hourly basis or continuously.

Data on power consumption of the air separation unit are read and recorded every day and is analyzed in relation to actual plant operation. Data on the other incidental equipment are collected once a month. Even during the shutdown of the air separator, data on the power consumption of the incidental equipment and office are recorded, thus indicating the perfect control of the factory through data.

4.4 Education and Training, Leveling-Up of Employees

No formally instituted committee for energy conservation exists. However, the energy consumption of the air separation plant has a profound connection with climatic conditions at site such as atmospheric temperature and humidity, cooling water temperature and products distribution. Energy conservation can be achieved by scrupulous management of the actual operation aside from orginal designed values. The air ratio representing a yield is 5.4 at the factory which compares favorably with the value shown by the low pressure type large-capacity air separation unit (air ratio: 5.0 to 5.5).

The factory general manager analyzes the relationship between operation and energy consumption based on daily collected data. If necessary, he immediately revises an operation standard and carries out energy conservation measures without delay.

The air separation unit consumes enormous energy at the time of start-up, because it is necessary to cool down its entire body. Therefore, if the unit failed and shut-down, the energy consumption rate will be sharply increased. For this reason, technology for maintaining facilities and machinery plays a direct important role in energy conservation. As mentioned above, the technical level of the factory is high, so it is helpful for maintaining the operation at high load with the assistance of excellent scientific management technique.

5. State of Electric Power Consumption

5.1 The Principal Data Relating to Power Consumption

Power Company	: PEA
Peak Demand	: 2,400 kW
Power Consumption	: 16,056 × 10^3 kWh/year
Load Factor	: 83.6%
Penalty Fee	: none
Power Factor	: 99.7%
Transformer	: 3ϕ 3,000 kVA for(3,050 HP compressor) 3ϕ 800 kVA
Power Consumption Rate	: 974 kWh/t-O_2
Power Cost	: 1.67 Bt/kWh

5.2 One Line Diagram

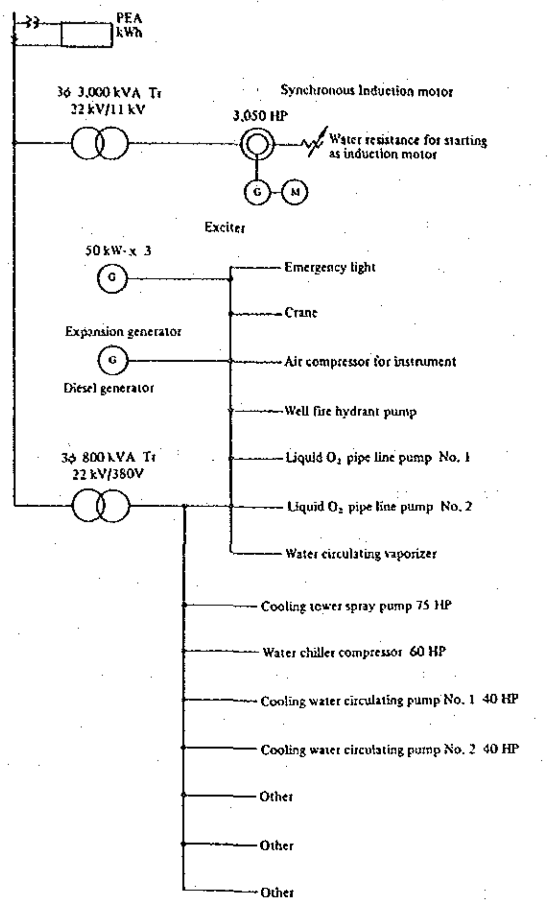


Fig. 4–3

6. Problems of Power Control and Potential Solutions

The majority of the facility capacity of the factory is represented by the 3,050 HP induction synchronous electric motor. The company is able to improve the power factor by adjusting the field, and is keeping the power control in a considerable satisfactory condition. Therefore, though they have less problems, we enumerate some existing problems yet to be resolved and the countermeasures for them.

6.1 Releasing of Transformer during Plant Shutdown

The 3,000 kVA transformer is left working during the plant shutdown. So electric power is wasted by a iron loss. Assuming that iron loss is 9 kW, the annual power loss is as follows based on the annual plant shutdown time of 760 hours:

$9 \times 760 = 6{,}840$ kWh/year, 9,918 Bt/year............................(8.1)

Transformer should be cut-off during shut down time.

6.2 Adjustment of Measuring Instruments

The receiving power board is equipped with only a voltmeter on the high tension side. Because of an ammeter and wattmeter being not installed, it is impossible to know how much load is imposed now. For energy conservation, it is important to grasp the present state and take appropriate countermeasures whenever they are needed.

6.3 Effective Designing of Illumination

A total of approx. 150 illumination lamps are daylight-color fluorescent lamps of inferior luminous efficiency. Therefore, it is suggested that each time any of these lamps run down, it be replaced by an energy conservation-type white-color lamp. Assuming that lamps are turned on for 10 hours a day, the estimated total conservation will be:

$5W \times 150 \times (8{,}760 - 760) \times 10/24 \times 10^{-3} = 2{,}500$ kWh/year ....(8.2)

Thus the estimated saved expense will be 3,625 Bt/year.

Table 4–2

	Peak demand kW	kWh/month	Remark
1982			
10	2,320	1,423,360	Demand for 88 Bt/kW
11	2,400	1,206,080	1,522 Bt/kWh
12	2,400	1,384,480	
1983			
1	2,400	918,400	

Table 4–3 Power Data for One Hour by PEA Meter

Time	kWh/hr kW	Remark
7 – 11		
2:50 PM	2,240	Reading by PEA WHM
3:50 PM	2,320	Reading by PEA WHM

Table 4–4 Instantaneous Value for 800 kVA Tr & 3050 HP Synchronous Induction Motor

Time	3050 HP Synchronous induction motor				800 kVA Transformer			
	Voltage kV	Current A	Cos ϕ %	Power kW	Voltage V	Current A	Cos ϕ %	Power kW
7 – 12								
11:40 AM	11	107	100	2,038	390	550	85	316
2:40 PM	11	107	100	2,038	387	540	84	304

Resultant power factor

11:40 AM

$$\cos\phi = \frac{2{,}038 + 316}{\sqrt{(2{,}038 + 316)^2 + \left(316 \times \frac{\sqrt{1 - 0.85^2}}{0.85}\right)^2}} = 0.997$$

2:40 PM

$$\cos\phi = \frac{2{,}038 + 304}{\sqrt{(2{,}038 + 304)^2 + \left(304 \times \frac{\sqrt{1 - 0.84^2}}{0.84}\right)^2}} = 0.997$$

Table 4–5

	Rating				Measure					
	Out put kW	Voltage V	Current A	RPM	Out put kW	Voltage V	Current A	Cos ϕ	r.p.m.	Remark
Expansion generator No. 1	50kW	400	183	394	36~48		80~150		410	
Expansion generator No. 2	50	400	183	394	36~48		80~140		410	
Expansion generator No. 3	50	400	183	394	28~38		80~130		390	
Compressor	60HP	380	84	985	41	375	72	0.87		
Cooling tower pump	75	380	105	1,475	56	375	102	0.85		
Cooling tower pump	40	380	59	1,460	23	375	40.2	0.87		
Cooling tower pump	40	380	59	1,460	21	375	39.6	0.8		

6.4 Abnormality with Four Stages of Air Compressor

Data on the air compression of the second, third and fourth stages are as follows:

Compression stage	2	3	4
Compression ratio	2.97~2.99	2.92~2.94	2.81~2.85
Suction temperature (°C)	38~39	39~42	35~37
Discharge temperature (°C)	154~156	153~159	168~173

Despite the fact that the above three stages are almost similar in terms of pressure ratio and suction temperature, only the fourth stage discharge temperature is approx. 15°C higher than those of the other two. Generally, the under-mentioned relationship exists between gas compression ratio and temperature:

$$Td/Ts = (Pd/Ps)^{\frac{k-1}{k}} \quad (1)$$

Ts: Suction temperature (K)

Td: Discharge temperature (K)

Ps: Suction pressure (kg/m^2)

Pd: Discharge pressure (kg/m^2)

k: Adiabatic coefficient (1.4 in case of air)

If the equation $Td/Ts = R_T, Td/Ts = (Pd/Ps)^{\frac{k-1}{k}} = Rp$ is set, and more detailed check of the above data is made, the following values will be obtained:

Compression Stage	2	3	4
Rp	1,365~1,368	1,358~1,360	1,343~1,349
R_T	1,374~1,375	1,369~1,370	1,432~1,439
R_T/Rp	1,004~1,007	1,007~1,008	1,062~1,071

The value R_T/Rp represents deviation of the actual measurement from the theoretical calculation. In spite of the fact that in both second and third stages, this deviation represents 0.4 to 0.8%, only the fourth stage indicates the deviation of 6.2 to 7.1% (Note) or approx. 10 times the former value. Hence it is estimated that an abnormality exists in the fourth stage.

It is considered that possibly because of a partial backward flow of the compressed air, and its recompression due to a failure of the piston ring or the discharge valve in the fourth stage, the abnormal temperature rise may have occurred.

In this way, the backward flow and recompression of a compressed air not only cause the energy to be wasted but also generate a cause for damage on the machine itself. Therefore, it is recommended that the machine be opened, checked and if damaged, repaired.

(Note) If "k" is corrected (k = 1.44) on account of high pressure, the deviation between the actual measurement and the theoretical value will be 3.7 to 4.7%.

6.5 Utilization of Waste Nitrogen

Waste nitrogen amounting to a flow of 7,000 Nm^3/h at approx. 20°C is released into the atmosphere without being utilized. This gas does not contain moisture at all, so if used in the water cooling tower, it is possible to efficiently cool water. If a low temperature cooling water is utilized for intercooler (or after cooler) of the compressor and the air is cooled to a temperature lower than the present temperature, the compression power can be conserved. Or the inlet air pressure can be reduced by a drop of the inlet temperature of the air separation unit.

(1) Present State

Study the intercooler for the third or fourth stage. The temperature of respective fluids are represented by Fig. 4-4.

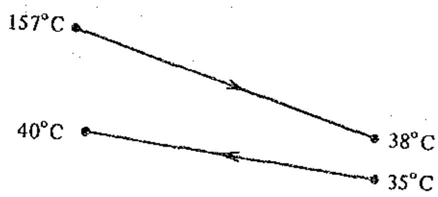


Fig. 4–4

Air flow = 8,670 $Nm^3/h \times 28.97/22.4$ = 11,213 kg/h

Specific heat of air = 0.25 kcal/kg°C

Removal heat = $11,213 \times 0.25 \times (157 - 38) = 333,586$ kcal/h

Flow rate of cooling water = $333,586/(40 - 35) = 66,720$ kg/h

(Heat transfer area) × (Heat transfer coefficient) = (Removal heat)/(Logarithmic mean temperature difference) = $333,586/\{(117 - 3)/\ln(117/3)\} = 10,720$ kcal/h°C

(2) Cooling by cold water obtained through utilization of waste nitrogen

Assuming that cooling water at 20°C obtained through the cooling tower availing waste nitrogen is used and the water volume is 1.6 times the flow of waste nitrogen, the quantity of water is:

$$7,000/22.4 \times 28 \times 1.6 = 14,000 \text{ kg/h}$$

However, considering that the heat transfer coefficient of the water side of the intercooler would be decreased due to the flow rate of cooling water being reduced to approx. 1/4 of the present rate, the following assumption will be made:

$$(\text{Heat transfer area}) \times (\text{Heat transfer coefficient}) = 10,720 \times 0.9 = 9,600 \text{ kcal/h°C.}$$

Then the temperature of the air and the cooling water at the outlets of the coolers will be put as "ta" and "tw". The equation will be:

$$11,213 \times 0.25 \times (157 - ta) = 14,000 \times (tw - 20) = 9,600 \times [(157 - tw) - (ta - 20)]/\ln\left(\frac{157 - tw}{ta - 20}\right)$$

To solve the above equation,

ta = 27°C, tw = 46°C

(3) Reduction of Compression Power

A reduction of the compression power caused by a drop of the suction temperature from 38°C to 27°C is as follows.

The compression power L kW is represented by the following equation:

$$L = k/(k-1) \times Ps \cdot Qs \times = (Pd/Ps)^{\frac{k-1}{k}} - 1\}/6{,}120 \times 1/\eta$$

Qs: Volume of air in a suction state (m^3/min)

Ps: Suction pressure (kg/m^2abs)

η: Adiabatic compression efficiency

Ps = 441 psig = 455.7 psi abs = 32,039 × 10^4 kg/m^2abs

Pd/Ps = 2.9 $\qquad$ $\eta = 0.85$

Then, assuming that the difference in power at 38°C and 27°C is ΔL,

$$\Delta L = k/(k\text{-}1) \times Ps \times (Qo \times 1.033 \times 10^4/Ps) \times$$
$$\{(Pd/Ps)^{\frac{k-1}{k}} - 1\}/6{,}120 \times 1/\eta \times \{(273 + 38)/273 - (273 + 27)$$
$$/273\} = 14.4 \text{ kW}$$

Where Qo represents a suction air volume 8,670/60 Nm^3/min in the first stage under a standard state.

(4) Cost of Water Cooling Tower

Waste nitrogen and cooling water are passed through the counter-flow packed tower using plastic Tellerette packing so that the water temperature may be lowered from 35°C to 20°C.

Assuming that the diameter of the tower is 1.55 m, the height of packing Z m can be calculated by the following equation.

$$Z = H_{OG} \times \int_1^2 di/(is - i)$$

H_{OG}: Height per transfer unit = 0.33 m

is, i: enthalpies of water saturated nitrogen and ascending nitrogen in the tower respectively.

1,2 represent the states of inlet and outlet of the tower.

If it is calculated using temperature-enthalpy chart of wet air substituting one for nitrogen, Z = 0.33 × 6.72 = 2.21 m. So if the volume of packing is calculated on assumption that Z equals 2.5 m, it will be 4.7 m^3. Putting that the height of the tower body is 6 m, the estimated total cost of the tower, pumps, packing, foundation work and pipe installation will be approx. 150,000 Bt. Next, a conserved amount of power for feeding the cooling water is as follows. Assuming that the present heads of water being fed and returned at a rate of 66.7 t/h are 15 m and 30 m respectively, and that the pumping efficiency is 80%, the power Po will be:

Po = 0.163 × 1 × (66.7/60) × (15 b2| 30)/0.8 = 10.2 kW

Then, assuming that the flow in the case of a cooling tower being installed is as indicated in Fig. 4-5, pumps A and C are the existing ones, pump B is a new one and the head and efficiency of pump B are 15 m and 60% respectively, the power P for feeding and returning water will be:

P = 0.163 × 1 × (14/60) × [(15 + 30)/0.8 + 15/0.6] = 3.1 kW

The conserved amount ΔP of a water transport power is

ΔP = Po − P = 10.2 − 3.1 = 7.1 kW

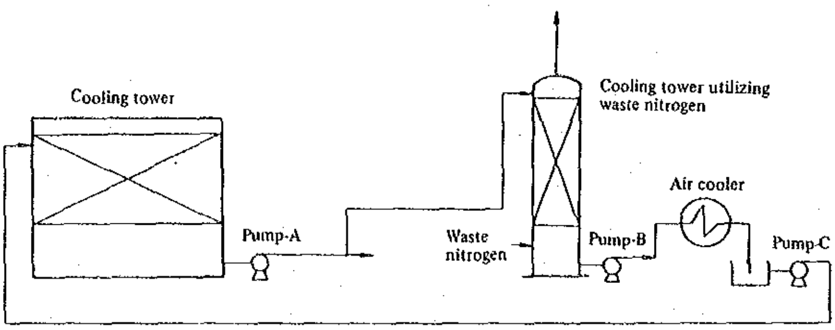


Fig. 4–5

(5) Economics of installation of cooling tower

Conservation of electric power $= \Delta L + \Delta P = 14.4$ kW + 7.1 kW = 21.5 kW

21.5 kW × 8,000 h = 172,000 kWh/year

172,000 × 1.45 Bt/kWh = 249,400 Bt/year

Pay back time = 150,000/249,400 = 0.6 year

6.6 Improvement of Insulation of Heater for Alumina Reactivation

According to the measurement, the surface temperature under the present condition is approx. 85°C. Assuming that the internal temperature is 150°C, the surface temperature will drop to approx. 50°C, if the external surface is insulated with 50 mm thick glass wool. The estimated heat loss will be reduced by 476 kcal/h per 1 m^2 of surface area as the following calculation:

Assuming that the ambient temperature stands at 35°C when the surface temperature is 85°C,

Heat loss from the surface $= 2.2 \times (85\text{-}35)^{1.25} + 4.88 \times 0.92 \times [(273 + 85)^4/100^4 - (273 + 35)^4/100^4] = 292.5 + 333 = 625.5$ kcal/m^2h

When the surface temperature is 50°C,

Heat loss from the surface $= 2.2 \times (50 - 35)^{1.25} + 4.88 \times 0.92 \times [(273 + 50)^4/100^4 - (273 + 35)_4/100^4] = 64.9 + 84.6 = 149.5$ kcal/m^2h

Differential of heat loss = 625.5 − 149.5 = 476 kcal/m^2h

If this value is converted in terms of wattage,

476/860 = 0.553kWh/m^2h, 0.553 × 1.45 Bt/kWh = 0.8026 Bt/m^2h

If the estimated insulation cost is 650 Bt/m^2, it will be possible to pay it back in 650/0.8026 = 810 h

It is suggested that the economics of insulation improvement be studied based on the service time of the heater.

6.7 Suction Air for Air Compressor

The suction filter is installed in the shadow of a structure so that it may not be exposed to the direct sunshine. In addition, chilled water is injected so that a low-temperature air may be sucked in. However, the first and second stage inter coolers are arranged nearby. Therefore, the atmospheric air temperature in the neighborhood of the suction filter is high because of heat release from the said inter coolers. It is desirable that a simple shield be set up between the suction filter and the inter cooler so that the suction of the hot air may be prevented.

6.8 Air Leakage around Expansion Engine

Low-temperature air was found leaking from the shaft stuffing boxes and the flanges connected to outlet pipe. This means a direct loss of the cryogenic effect and a subsequent undesirable increase of the required power.

Therefore, it is suggested that the teflon gaskets reinforced with low-temperature resistant metals such as stainless steel and aluminum be studied and properly selected for test use. This is because the teflon material is superb in performance and as such, is quite suitable for use as gaskets for the moving and vibrating parts.

7. Summary

The above-mentioned remedial measures, if actually taken, will bring about energy conservation effects as shown below:

	10^3kWh/year	%
Releasing of Transformer during Shutdown	6.8	0.0
Effective Designing of Illumination	2.5	0.0
Lowering of Cooling Water Temperature through Utilization of Waste Nitrogen	172.0	1.1
Total	181.3	1.1