Report No. 11: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— United Grains Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— United Grains Co., Ltd. —

1. Outline of the factory

Address	51 Poochaosamingpral Road, Phrapradaeng, Samuthprakarn	
Capital	100 Million Bt	
Type of industry	Food	
Major products	Maize handling, drying and storage	
Annual products	Annual handling 600,000 ton	
No. of employees	69	
Annual energy consumption	Electric power	3,906,000 kWh
	Fuel	H.O.A 1,200 kℓ
Interviewees	Plant Engineering Department Manager Mr. Suphote Yhookase	
Date of diagnosis	July 7 ~ 8, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

This company is an affiliate of United flour Mill (U.F.M.) representing the food division of the Metro Group and is located at a part of the site of U.F.M. In addition to U.F.M., companies such as United Silo and Services Co. (U.S.S.), International Warehousing Co.(I.W.C.) and U.G.C. Warehousing Co. exist in the same site. They undertake different activities according to their business nature. However, U.F.M. is exclusively in charge of activities of the engineering division to improve facilities and of the management division for all Group.

United Grains Co.(U.G.C.) operates the largest grain terminal having 32 giant silos in the Kingdom of Thailand. This terminal mainly handling corn is capable of storing 75,000 tons with two units of the 200 t/h dryer. In addition, the terminal maintains 800 t/h loading facilities and a 230-meter-long pier accessible by 20,000-t class vessels. Since its startup, just two years have elapsed. The dryers are operated only during the period from July through January when the corn has an increased moisture content. Especially, they reach an operational peak during the period from August through October.

The plant Engineering Department is now studying a corn drying method using dehumidifying air as means for energy conservation and making up for the short capacity of the existing dryers.

2. Manufacturing Process

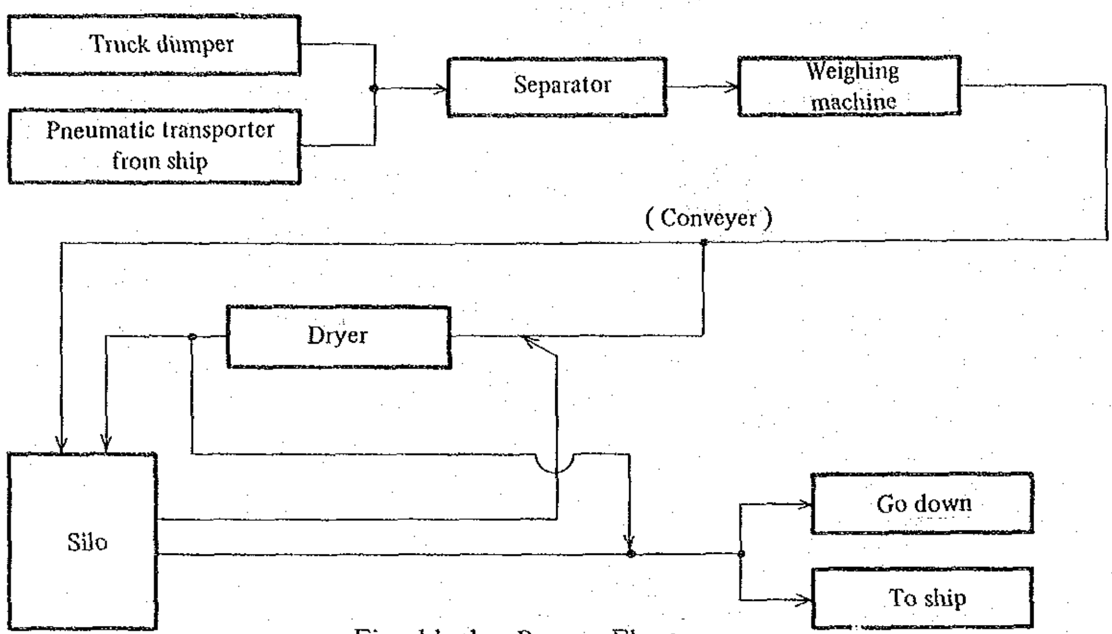


Fig. 11–1 Process Flow

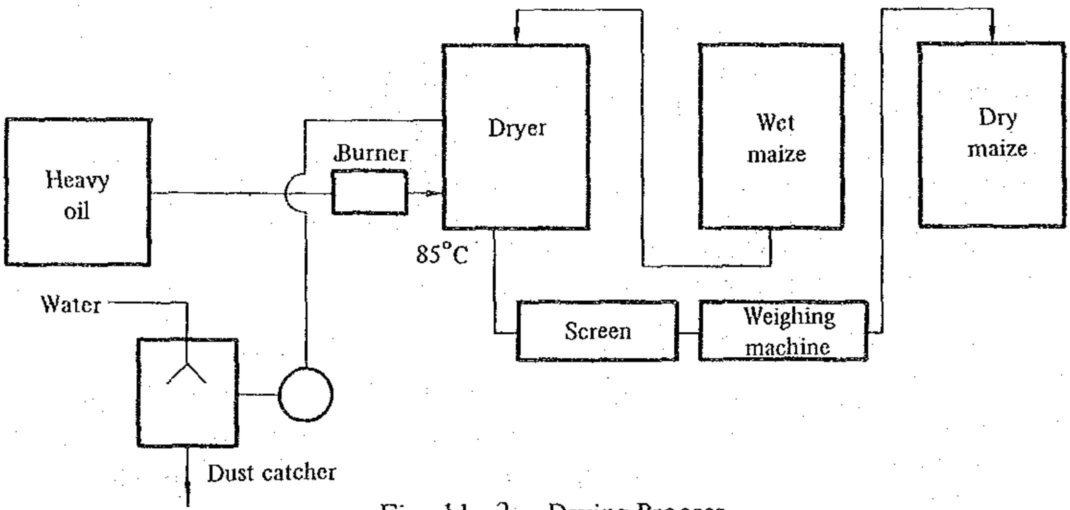


Fig. 11–2 Drying Process

3. Major Equipment

3.1 Major Equipment

Table 11–1

Name	No. of units installed	Type, etc.
Dryer	2	Type: L.S.U dryer Capacity: 200 t/h x 2 61,000 kcal/h Outer dimension 11 m(L) x 6 m(W) x 30 m(H) I.D.F 135,000 cfm x 4 (100 HP) F.D.F. 25,000 cfm x 2 (25 HP)

3.2 Layout

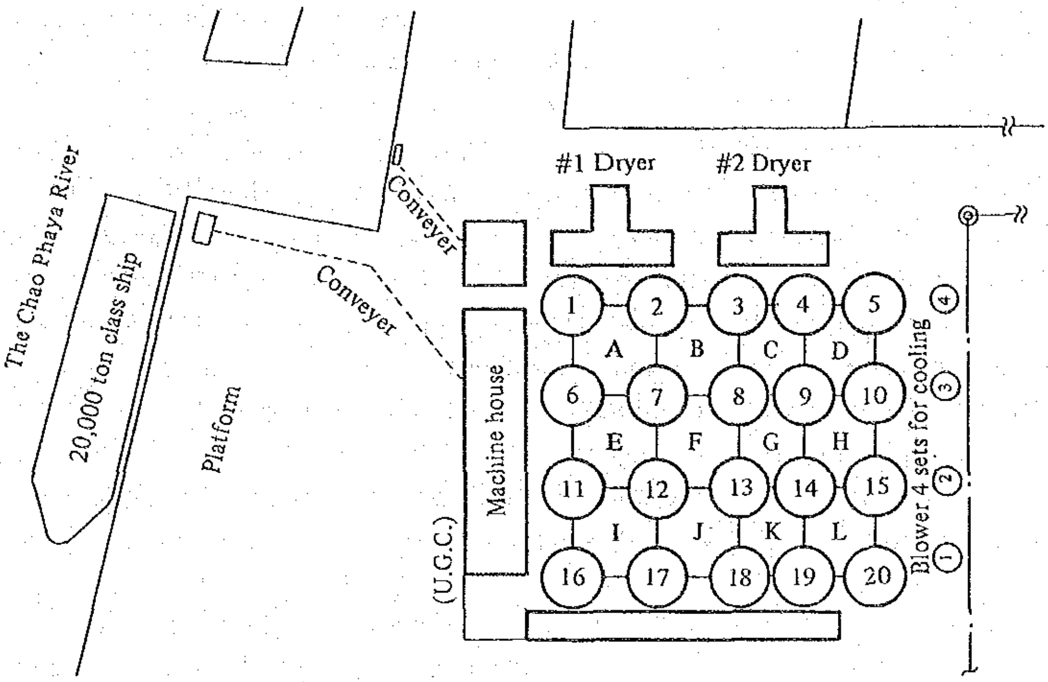


Fig. 11–3

4. State of Energy Management

4.1 Policy for Energy Conservation

We were informed that the company did not have a concrete target of energy conservation. However, the manager of the factory indicated five liters of oil per ton of corn to his workers as a guideline.

Because of a short operational period of two years since its establishment, the company has no experience of actual investment in energy conservation equipment. Therefore, it is considered that "Increased Dryer Capacity Project using Dehumidifying Air" will be the first investment of this type ever.

4.2 Participation by All Employees

Neither U.G.C. nor the U.F.M Group as a whole has ever launched a concrete promotion campaign about participation of all the employees in energy conservation. No committee or no suggestion system has yet been initiated. Employee education is put into practice four to five times a year according to a program of the group's educational institution. It also seems that the companies of the group are sponsoring the visit to each other's factory by their employees. The employees are encouraged to participate in activities aimed at not only energy conservation but also the observation of safety and rules through publicity media such as posters.

4.3 Control through Data

The system for control through data is well organized. As to electric power, data are arranged by process and facility and utilized for the calculation of energy consumption rate, preparation of control charts and analysis of factors. When it comes to fuels, the same control policy as for electric power is adopted during the operation of the dryers. Further, energy cost is calculated every month routinely. Yet the heat balance calculation for dryers has not been implemented.

4.4 Technological Level-Up of Employees

All the functions of U.G.C. Factory are controlled by the central control room. The supervisors and technical staff of the factory are manned centering around the central control room. The employees are well disciplined and neatly dressed. In addition, the working places are in good order, and also safety measures are established. These are considered the results of a well organized educational system. The guidance by the educational division of the Metro Group is also instrumental to the improvement of manpower quality. But all the more important is the fact that the managers of the company have the attitude to actively devote themselves toward the education of their employees.

5. State of Fuel Consumption

5.1 Fuel Consumption Rate

The quantity of dried corn and the consumption and consumption rate of heavy oil A for fiscal 1982 are as shown in Table 11-2.

Table 11—2 Maize Drying Oil Consumption

	Maize weight (Dry ton)	Heavy oil A consumption (ℓ)		Total	Oil ℓ / Maize t
		#1 Dryer	#2 Dryer		
1982 7	21,330	75,893	25,424	101,317	4.75
8	39,751	139,708	68,985	208,693	5.25
9	38,511	131,114	80,311	211,425	5.49
10	33,195	52,535	64,311	116,846	3.52
11	26,443	4,523	66,873	71,396	2.70
12	52,897	120,888	10,829	131,715	2.49
1983 1	19,923	28,712	10,217	38,929	1.95
Total	232,050	553,373	326,950	880,323	3.79

Although the target consumption rate of heavy oil A is 5.0 l/ton, the moisture content of corn varies seasonally. During the period from July through January when the corn is raised and harvested, there are much rain falls and the corn contains a high percentage of moisture ranging from 15 to 22%. In this period, the dryers are active. The moisture content of the dried corn is controlled according to the detailed instructions by storage duration, delivery timing and destination. The moisture content provided for by the export standard of the Commerce Ministry is 14.5% or less. This moisture content does not pose a problem, as far as the destination for export is within a distance of voyage for one month or less. However, if the transportation takes more than one month, it is required that the moisture content be 13% or less. On the contrary, if the destination is within a short radius, the moisture content may be 15.5%.

For the fiscal year, the domestic corn crops show a reduction to approx. 3.2 M tons because of drought. Consequently, the company intends to limit the drying operation to four months during the season. The rated dryer capacity is 200 t/h × 2 units. However, a two-time pass drying operation is sometimes carried out instead of usual one-through, depending on the corn moisture. This operation results in the reduction of the drying capacity, hence the necessity of working out remedial measures during the peak production.

6. Problems in Heat Control and Potential Solutions

6.1 Air blow Drying in Bins

In order to prevent the proliferation of microorganism which darkens the corn core, it is necessary to maintain the temperature of the bin containing the corn at 40°C or less. For this reason, as the company's measures, if the thermometer in the bins stands at 35°C, air is blown from the top to the bottom of the bin by operating the blower. As a result, the temperature distribution in the bin indicates a higher temperature at the bottom than the top as shown in Table 11-3. In addition, the lower layer tends to show a higher percentage of moisture and as such, cause a qualitative deterioration of the corn.

Table 11—3 Temperature Profiles in the Bins

Place		Temperature		
		No. 3 bin	No. 17 bin	Star bin A
		°C	°C	°C
Distance from the top	2.7 m	32.2	29.8	31.2
	7.7	32.4	30.3	31.2
	12.7	33.5	33.5	31.2
	17.7	35.2	32.5	32.9
	22.7	35.2	35.5	35.2
	27.7	37.1	36.5	32.0

To deal with this situation, the company is now studying a cooling and drying method by which to blow from the silo bottom an air having a relative humidity reduced to 40% and a temperature maintained at 25 to 28°C by means of three units of the 150-refrigeration tons refrigerator. The estimated investment will be 15 MBt.

Measurements during the air blow are as shown in Table 11-4 and Table 11-5.

The equation for calculation of the moisture removed by the air is as follows:

Volume of dry air = 87,448 $m^3/h \times (760 - 52.44 \times 0.99)/760$ = 81,474 m^3/h

Weight of dry air = 81,474 $m^3/h \times 1.13\ kg/m^3$ = 92,066 kg/h

Moisture content of air at the inlet (temperature: 34°C, percentage humidity: 80%)

= 92,066 kg/h × 0.03446 kg/kg × 0.8 = 2,538 kg/h

Moisture content of air at the outlet (temperature: 39°C, percentage humidity: 99%)

= 92,066 kg/h × 0.04610 kg/kg × 0.99 = 4,202 kg/h

Therefore, the moisture content transferred into the air = 4,202 − 2,538 = 1,664 kg/h and the quantity of corn in the bins = 53,568 t. On these conditions, removal rate of moisture in the corn is only 1.7/53,568 × 100 = 0.003%/h.

Table 11–4

No. of Bin	3	17
Content ton	1420	2090
Temperature at the top °C	33.7	33.9
Relative humidity %	68.1	68.9
Air intake m^3/h	7812	5076
Temperature at blower inlet °C	35	37
Temperature at blower exit °C	41	39
Relative humidity of exhaust air %	99	99

Table 11–5

Bins' No. and star bins	Overall exhaust air (measured) m^3/h	Temperature at blower exit °C	Temperature at blower inlet °C
2, 7, 12, 17 BFJ	19,476	37	34
3, 8, 13, 18	12,312	37	–
4, 9, 14, 19 CGK	21,564	39	33
1, 6, 11, 16 AEI	16,920	41	35
5, 10, 15, 20 bHL	17,176	39	37
Total	87,448	39	35

Assuming that the air at the inlet is cooled at a temperature of 25°C and a percentage humidity of 40%, the air at the outlet will be at a temperature of 30°C and a percentage humidity of 99%, the following values are given:

Moisture content of air at the inlet = 92,066 kg/h × 0.02007 kg/kg × 0.4 = 739 kg/h

Moisture content of the air at the outlet = 92,066 kg/h × 0.02715 kg/kg × 0.99

= 2,475 kg/h

Moisture content transferred into the air = 2,475 − 739 = 1,736 kg/h

Thus the moisture removal does not increase contrary to our expectations.

The dryer, using an air at 85°C, is capable of removing the moisture by 0.828

kgH₂O/kg air, but requires more quantity of air at a low temperature. If the airflow is increased, the pressure loss will be increased in proportion to the square of a quantity, so that the power consumption will be increased in proportion to the third power of a quantity.

Judging from the above findings, the injection of cooling air into the bins is less effecitve and less economical for the drying operation.

When the corn are cooled by air injection, it is necessary to pay attention to the condensation of water vapor in the interior of the adjoining bins or on the surface of corn taken out of the silos.

(Reference) Measurement of equilibrium moisture content rate (We)[1)]

If the relationship between adsorptive potential "RTln" ($1/\varphi$) and equilibrium moisture "We" at any temperature T[°K] is obtained, it is often shown in a single curve regardless of temperature. "φ" means a relative humidity and "R" a gas constant (62.36 m^3. mmHg/kg-mol K). From this relationship, it is possible to obtain "We" at a different temperature (refer to Table 11-6).

Table 11–6

	Equilibrium moisture (We) %				Temperature
	ϕ 20	40	60	80	°C
Wheat	8.8	11.2	14.0	17.8	10
Wheat	8.5	10.8	13.4	16.8	20
Wheat	7.8	10.4	12.7	16.2	30
Starch	3.9	6.5	8.5	10.5	25

In order to obtain equilibrium moisture of the corn, the under-mentioned basic tests are necessary: Take a sample of 10g into a weighing vial, and leave it in the desiccator for approx. two weeks. During this period, weigh it every day for the first five days so as to determine a decrease of moisture. Prepare at least three desiccators, each containing the under-mentioned saturated solutions of different types at the bottom. The relative humidity of the air in this desiccator can be read in Fig. 11-4.

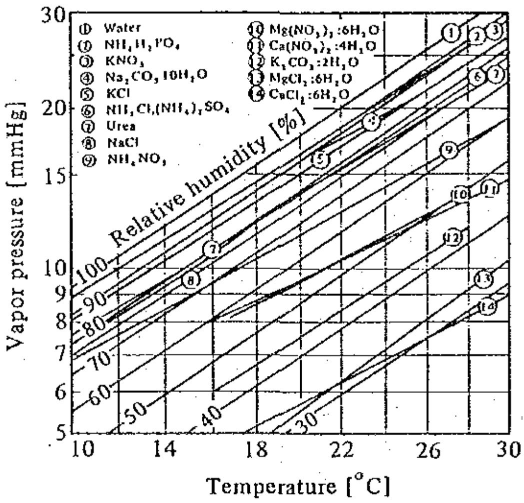


Fig. 11–4 Vapor Pressure of Aqueous Solution of Salts

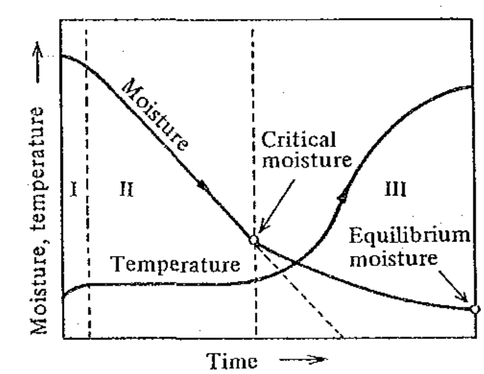


Fig. 11–5 Moisture vs Temperature in Material

In addition, the drying of materials on constant conditions is as shown in Fig.11-5. That is, it is composed of the following: (I) preheating period for materials, (II) constant rate period when the surface-sticking moisture is evaporated and (III) falling-rate period when the internal moisture is evaporated. In the (III) period, the diffusion rate of moisture from the inner part of corn is controlling. Therefore, it is important to collect data by repeating the above-mentioned tests.

Microorganism is apt to be easily viable in the humid environment. If there is a nutrient at an appropriate temperature, bacteria, yeasts and moulds tend to grow. In this respect, the moisture activity value "Aw" is used as a measure for indicating the level of relative humidity which facilitates their growth. "Aw" represents a value equivalent to 1/100 of the marginal relative humidity for the growth of microorganism.

The majority of bacteria cease their growth at "Aw" < 0.92, yeasts at "Aw" < 0.85 and moulds at "Aw" < 0.70. That is, the figures indicate that moulds tend to proliferate in dryer condition compared with other microorganism. The saturataion of air discharged from the bins indicates a saturated state of the interior of the bins. This means that the interior is already a comfortable bed for the microorganism.

Literature 1) Kagaku Kogaku Binran (Chemical Engineering Handbook) p.706 2) Ditto P.40

6.2 Operation of Dryers

On the very day of diagnosis, the dryers were not in operation. However, as a result of tests on the ignition of burners, their burning condition was satisfactory.

These dryers need improved contact between the corn and hot air so that their efficiency may be enhanced. In order to meet this necessity, it shall be so arranged that a channeling of hot air may not occur in the dryer.

For monitoring a drying condition, it is required to measure and record not only the moisture of corn at the inlet and outlet but also the temperature of hot air at the inlet and outlet. If the temperature of hot air at the outlet is unusually high, that means that the contact between the corn and hot air in the dryer has become poor. Therefore, it is necessary to conduct a checkup of the interior.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	2,040 kW (Sept.1982)
Power Consumption	:	$3{,}906 \times 10^5$ kWh/year (1982)
Load Factor	:	Monthly load factor 14 to 59%
Penalty Fee	:	Power factor 111,765 Bt/year
		Peak demand over 1,106,584 Bt/year
Power Factor	:	Monthly power factor 55 to 85%
Transformer	:	3ϕ 1,600 kVA × 3 units
		3ϕ 500 kVA × 2 units

Final Power Cost : Annual average 2.23 Bt/kWh

7.2 One Line Diagram

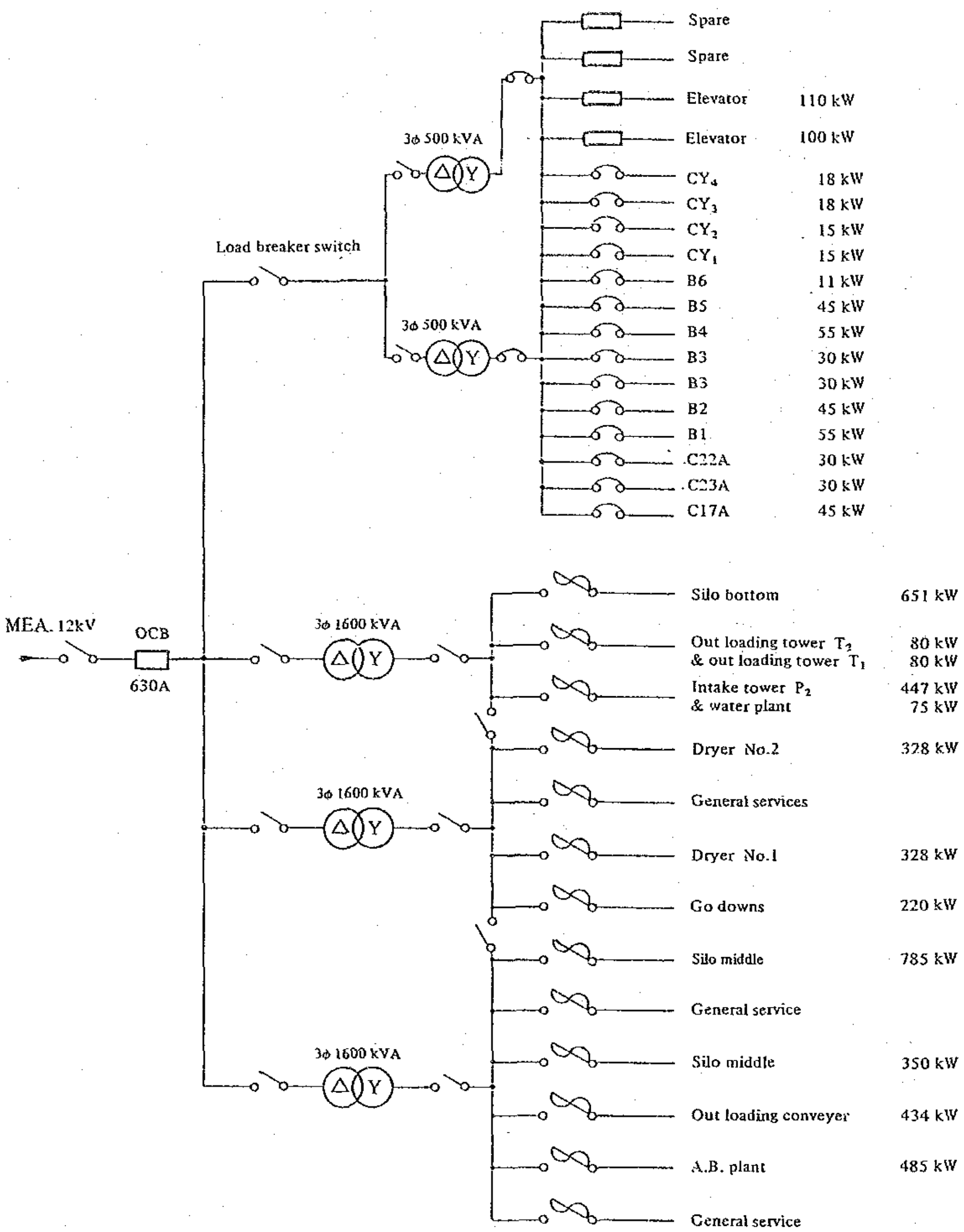


Fig. 11–6 One Line Diagram

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 11–7 Monthly Power Consumption

Date	Consumption power kWh	Maximum demand power kW	Average power kW	Load factor L.F. %	Maximum reactive power kVar	Power factor P.F. %
1/82	216,000	1,140	290	25	1,200	0.69
2/82	282,000	960	420	44	1,260	0.61
3/82	210,000	1,140	282	25	1,260	0.67
4/82	138,000	960	192	20	960	0.71
5/82	144,000	720	194	27	1,080	0.55
6/82	84,000	720	117	16	1,020	0.58
7/82	270,000	1,200	363	30	1,200	0.71
8/82	636,000	1,440	855	59	1,800	0.62
9/82	726,000	2,040	1,008	49	1,285	0.85
10/82	589,324	2,040	792	39	2,040	0.71
11/82	340,668	1,620	473	29	1,860	0.66
12/82	270,000	1,620	363	22	1,680	0.69
	3,905,992		446			
1/83	318,000	1,500	427	28	1,620	0.68
2/83	168,000	1,500	250	17	1,680	0.67
3/83	162,000	1,560	218	14	1,660	0.68
4/83	192,000	1,560	267	17	1,660	0.68
5/83	174,000	1,560	234	15	1,660	0.68
	4,919,992					

7.3.2 Monthly Load Curve

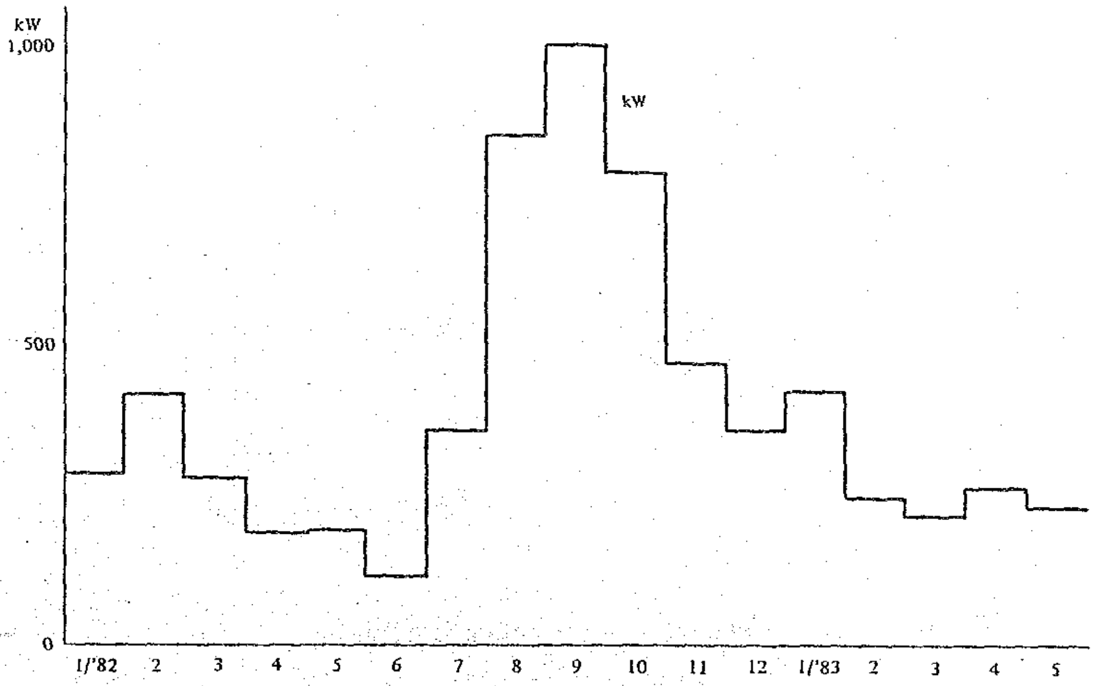


Fig. 11–7 Maximum Average Power

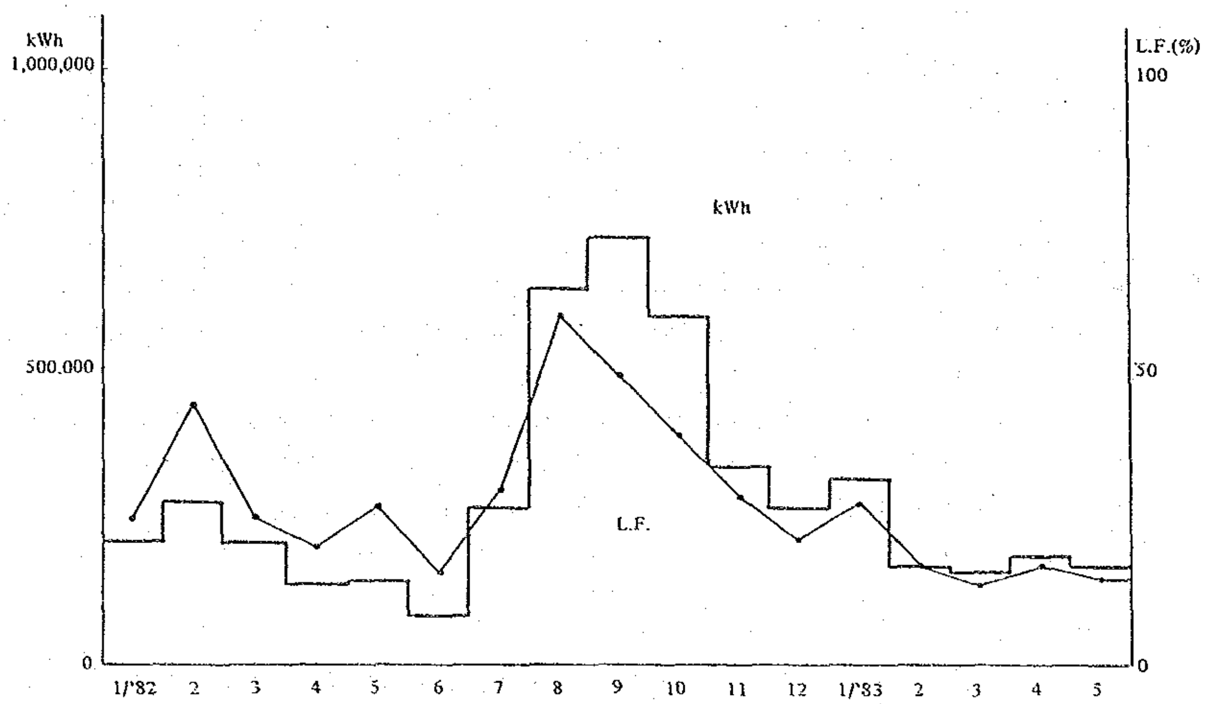


Fig. 11–8 Monthly Consumption Power & Load Factor

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 11–8

	Name plate			Measure			cos ϕ	L.F. %
	kW	V	A	kW	V	A		
E6 Elevator	75	380 Δ/Y	144	On load 46.7	399	87.6	0.77	62.7
Suction blower	260	380 Δ/Y	443	No load 57.1	400	140	0.59	21.9
E14 Line elevator	110	380 Δ/Y	196	No load 24.8	422	97	0.41	22.3
E7 Line	55	380 Δ/Y	104	On load 39.5	394	68.2	0.73	71.8
C17 Conveyer	45	380 Δ/Y	87	On load 16.9	394	37.9	0.65	37.5
C14 Conveyer	75							
C15 Conveyer	75	380 Δ/Y	144	No load 21.2 On load 25.6	397 397	68.9 64.3	0.48 0.58	28.3 34.1
C12 Conveyer	75							

8.2 Power Distribution

8.2.1 Peak Demand Over

The penalty of 1,106,584 Bt per year seems to be a little high. According to Table 11-7, the peak demand ranges from 720 kW to 2,040 kW depending on season. In order to reduce this fluctuating demand, we recommend the following:

The peak demand control monitor be installed and systems, namely three systems for material receiving, four systems for refining process, delivery system, and miscellaneous power systems be operated at a delayed pace of 10 to 20 minutes from each other, depending on a state of operation.

As to causes for generating the peak demand such as material, temperature, operating time zone and so forth, it is required to collect data and analyze them in detail over a long stretch of time and operate the power control with close attention. For reference, an estimated investment in the peak demand control monitor is approx. 400,000 Bt.

8.2.2 Transformer

Judging from the numbers of 2,040 kW for the peak demand and 1,008 kW for the average power, the capacity of the transformer is considered too large. Therefore, if an expected advantage of the reduced capacity is calculated, the results are as shown in Table 11-9. In this case, the given data are as follows:

Operating time	:	8,760 h/year
Average power	:	1,008 kW
Power factor	:	85%
Apparent power	:	1,186 kVA
Iron loss of transformer	:	0.3%
Copper loss of transformer	:	1.4%

Table 11–9

	Transformers kVA	Load 1,186 kVA	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year	
Present state	1,600 x 3 500 x 2	1,000 186	126 26	26 4	152 30	182
Improved state	1,600 x 2 500 x 1	1,000 186	84 13	38 8	122 21	143
Different			–55	+16		–39

That is, the loss of $182 - 143 = 39 \times 10^3$ kWh/year will be reduced.

Consequently, the advantage will be 39×10^3 kWh/year $\times$ 1.45 Bt/kWh $\times$ 56,550 Bt/year.

Here there is an advantage that if two units of transformer, each being capacity of 1,600 kVA operated in parallel, the load distributed to each transformer will always be equal. On the other hand, there is a danger that the whole factory might suffer an electric power supply failure, even if one of them became faulty. In addition, there is a disadvantage that the breaking capacity of a circuit breaker on the load side might be increased. For these reasons, it is suggested that each unit of transformer be operated individually.

8.2.3 Power Factor

We studied the best way to improve a power factor based on data of Table 11-7. The compared results of cases are shown in Table 11-10. Of these results, the cases of 2-1 and 2-2 are shown in Fig. 11-8.

Table 11–10

Case	Average power kW	Used condenser kVar	Apparent power kVA	Reactive power kVar	Power factor %
1 – 1	200	0	364	304	55
1 – 2	200	200	225	104	89
2 – 1	400	0	667	533	60
2 – 2	400	200	520	333	77
2 – 3	400	400	421	133	95
3 – 1	855	0	1,379	1,082	62
3 – 2	855	400	1,094	682	78
3 – 3	855	600	982	482	87

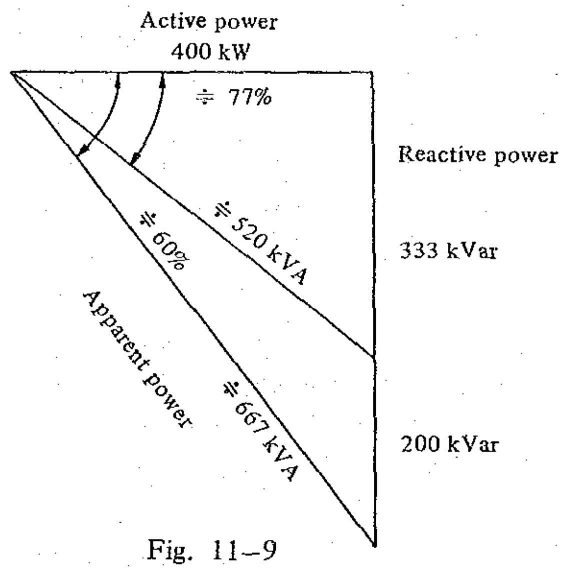


Fig. 11–9

That is, if three units of condenser, each being capable of 200 kVar are installed and controlled at either of 200,400 and 600 kVar depending on a state of load, the estimated penalty will be nothing, contrasting with the present 111,765 Bt/year. Yet, an estimated investment in three units of 200 kVar condenser will be approx. 300,000 to 350,000 Bt.

In the meantime, under a situation of 446 kW as annual average power, 67% as average power factor, and of 666 kVA as apparent power, if an improvement target of 85% as average power factor, and 525 kVA as apparent power will be implemented, reduction of the copper loss in transformer of 3,700 kVA (1,600 kVA × 2 units plus 500 kVA × 1 unit) is expected to produce following advantages:

$$3{,}200\ \text{kVA} \times 0.014\{(\frac{566}{3{,}200})^2 - (\frac{445}{3{,}200})^2\} \times 8{,}760\ \text{h/year} \doteqdot 4{,}688\ \text{kWh/year}$$

$$500\ \text{kVA} \times 0.014\{(\frac{100}{500})^2 - (\frac{80}{500})^2\} \times 8{,}760\ \text{h/year} \doteqdot 883\ \text{kWh/year}$$

Total: 5,571 kWh/year

5.6×10^3 kWh/year × 1.45 Bt/kWh = 8,120 Bt/year

Consequently, the recovery of investment in the condenser facilities will be made following period:

$$\frac{300{,}000}{111{,}765 + 8{,}120} \doteqdot 2.5\ \text{years}$$

8.3 Power Application

8.3.1 Voltage

When we visited, the factory was not operated, so we requested for the operation of some of motors, and measured. On account of a low load, the supply voltage was generally higher ranging from 394 to 422 V as compared with the rated motor voltage of 380 V. Considering this fact, it is recommended that the secondary voltage be lowered to approx. 380 V by switching the transformer tap.

It is said that during a low load operation, the loss of transformer, distribution and motor can be reduced by approx. 2 to 3% by decreasing the voltage by 5%. Therefore, if the annual power consumption is set at $3{,}906 \times 10^3$ kWh/year with the advantage estimated at 2%, the following results will be anticipated:

$3{,}906 \times 10^3$ kWh/year × 0.02 ≒ 78.1×10^3 kWh/year

78.1×10^3 kWh/year × 1.45 Bt/kWh = 113,000 Bt/year

8.4 Others

8.4.1 Management of Operation and Maintenance

Although we could not confirm data on faults and accidents, we can point out common problems at powder-handling factories as follows:

(1) Accidents attributable to deteriorated insulation caused by humidity in the power board and control panel.

(2) Reduced cooling effect and burning caused by the clogging of the motor with powder.

In order to eliminate these troubles, it is important to clean the equipment and put it in order periodically. Specially the burning of the motor is sometimes misunderstood for an overload. So your attention be invited to this point. In addition, a small spark in the powder due to deteriorated insulation and the burning of the motor might cause a large fire. For these reasons, it is suggested that doubled attention be paid to the management of operation and maintenance.

9. Summary

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

	10^3 kWh/year	%
Consolidation of Transformers	39.0	1.0
Improvement of Power Factor	5.6	0.1
Reduction of Motor Supply Voltage	78.1	2.0
Subtotal	122.7	3.1

Report No. 12: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Castor Oil Industries Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Thai Castor Oil Industries Co., Ltd. —

1. Outline of the Factory

Address	23/2 Moo 7, Nanapan Petchahueng Rd. Tambol Bangyor, Prapradaeng, Samutprakarn	
Capital	40 Million Bt	
Type of industry	Food	
Major products	Castor oil	
Annual products	13,500 t	
No. of employees	Factory 102	Office 34
Annual energy consumption	Electric power	2,184,000 kWh
	Fuel	1,290 kℓ
Interviewees	Plant Manager Chief Engineer	Mr. Prasad Mr. Pornpuem
Date of diagnosis	June 30, July 1, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

In 1980, this Company was designed and established as a joint venture company between the Kingdom of Thailand and Federal Republic of Germany based on the technology of the latter. The production facilities are new and capable of processing 100 tons/day of castor seed. The manufacturing process is such that castor seed is fed to the hydraulic press for extraction of 35% of the total oil content. Next, 12 to 13% of residual oil in the meal is continuously extracted with the help of n-hexane. Later the extracted oil is passed through the neutralization equipment for removing free aliphatic acid and the bleaching equipment for decoloration. Thus it was refined into various grades of castor oil such as for medicine and paint. The extraction remnants, "so-called meal" are also crushed into a finished product as fertilizer.

The facilities are laid out in such a way that castor oil is transported by means of piping from storage tanks containing the different grades to a tanker berthed at a loading port approx. 500 m away. The factory is in good order and well protected under safety measures. This is suggestive of a fact that the factory is being maintained by an excellent management and qualified managers.

In order to obtain good raw material containing more oil, the company selects the seeds, which the company sends to farmers, with growing guidance for them. This is an essential measure for energy conservation.

2. Manufacturing Process

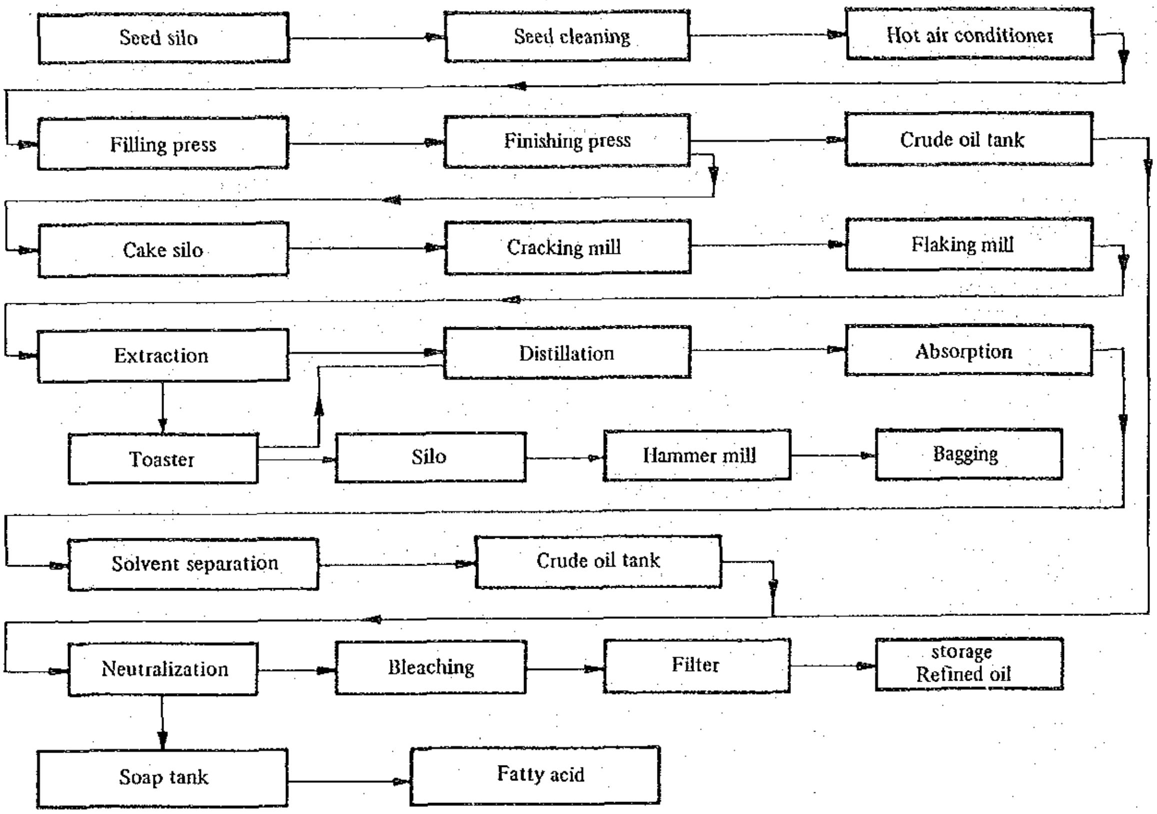


Fig. 12–1

3. Major Equipment

3.1 Major Equipment

Table 12–1

Name	No. of units installed	Type, etc.
Boiler	2	Flue tube boiler 3.2 t/h 10 kg/cm² G
Hot air conditioner	1	Belt dryer 10 m(L) x 4.35 m(W) x 1.9 m(H) Elofin heater 5 sets
Extractor	1	Solvent: Hexane ϕ 4.5 m x h 3.2 m
Toaster Distillation tower Neutralization Bleaching	1 1 set 1 1	ϕ 400 m/m x h 5000 mm

3.2 Layout

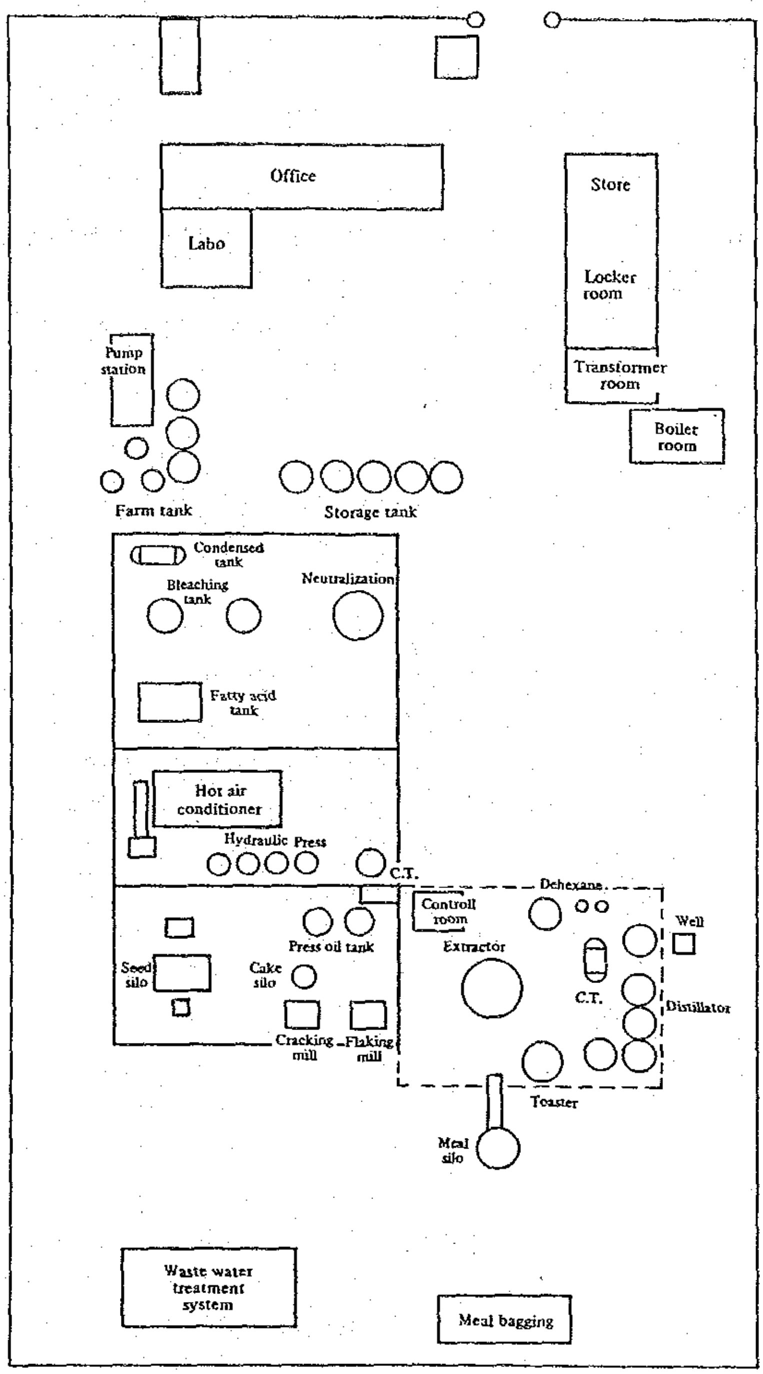


Fig. 12–2

4. State of Energy Consumption

4.1 Policy for Energy Conservation

At the beginning of every month, the general manager of the factory indicates the maximum limit of energy consumption and instructs the employees to keep the consumption below the indicated value. Since the factory is new, there is not yet any investment project for large-scale energy conservation facilities. However, the expansion of the boiler capacity has been completed.

In order to promote systematic activities, the Company holds a improvement measures meeting and a report meeting.

- Member in charge of pollution control
- Member in charge of maintenance services
- Member in charge of laboratories
- Member in charge of labor-related Matters

Remedial Measures Meeting

Report Meeting

The above meetings are held once a month respectively under the chairmanship of the factory general manager. At the meetings, reports on a state of energy conservation and inprovement measures are studied. A project team for prevention and maintenance is also organized and is now studying maintenance of the steam traps.

4.2 Participation by All Employees

For employee education, the company lets approx. 10 employees to participate in external seminars such as TPA through the year. In addition, the company maintains a suggestion system and also regulations for commendation. However, the number of suggestions has been few and no employee entitled to the commendation has been nominated. The general manager enlightens the employees about the importance of energy conservation personally or with the help of publicity media such as posters. Thus the employees are solicited to broach their ideas. Nevertheless, they seem not yet fully cooperative in this system. Therefore, we recommend that an internal seminar be held centering around the employees who have experience in participating in external seminars. It is considered that the instructions and orders by the general manager would not penetrate into the depth, unless the recommended seminar is first held for the employees.

4.3 Control through Data

Important data are hourly recorded in the log-sheets by each process. As to boilers, data on fuel consumption rate are collected so that variable factors involved may be easily analyzed.

Cost calculation is carried out every month distributed into two categories of process such as preparation and extraction. The heat balances are now under calculation.

Amount various factors required for energy control, the yield plays an important role. It is commendable that the factory is deeply concerned about it.

4.4 Education and Training, Leveling-up of Employees

The Company is highly interested in education and this can be supported by the fact that it dispatches its employees to an external seminar. The employees are well disciplined so that they are neatly dressed, and keenly attentive to safety. The factory has a promising future of development.

It is earnestly hoped that the company will keep a more substantial manpower of technical staff, make the employees more conscious about voluntary action and establish an efficient control system as a whole company-level.

5. State of Fuel Consumption

5.1 Fuel Consumption

Heavy oil C 1,296 kl/year

(1) Breakdown of Consumption

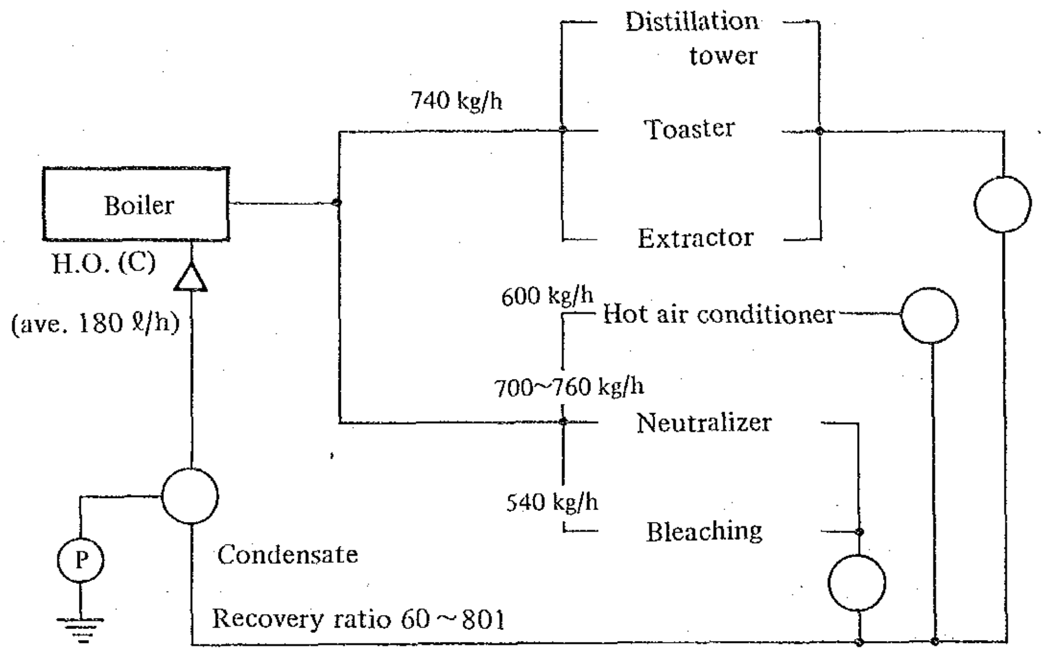


Fig. 12–3

(2) Fuel Consumption Rate

Annual quantity of processed raw seed 31,000 t

1,296 kl/31,000 t = 41.8 l/t

Annual castor oil production will be 13,950 t at an estimated yield of 45%. Consequently, the unit fuel consumption per ton of finished product will be:

1,296 kl/13,950 t = 92.9 l/t finished product

Assuming that 19% of the total fuel is consumed for preheating process, the fuel consumption rate here will be:

246 kl/31,000 t = 7.9 l/t raw material

According to the design specification, 395×10^3 kcal/h of steam are required as the design value for processing 4,200 kg of raw material every hour. If this value is converted in terms of fuel, based on an assumption of 86% for boiler efficiency and 2% for transportation loss, the equation will be:

$$\frac{395 \times 10^3}{(0.86 - 0.02) \times 9,700 \times 0.952} = 50.9 \text{ l/h}$$

Consequently, the design unit consumption will be 50.9/4.2 = 12.1 l/t raw material. The actual unit fuel consumption rate of 7.9 l/t is less than the design consumption.

5.2 Heat Balance of Boiler

We calculated the heat balance based on the actual boiler data on July 1, 1983. The results are as shown in Table 12-2.

Table 12–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	1,582.1	99.6	Heat of steam	1,364.6	85.9
Sensible heat of fuel	6.3	0.4	Heat loss in exhaust gas	175.2	11.0
			Heat loss in blow water	13.6	0.9
			Heat release from boiler body, others	35.0	2.2
Total	1,588.4	100.0	Total	1,588.4	100.0

- Elements for Calculation of Heat Balance

Fuel type		Heavy oil C
Fuel consumption	(F)	163.1 kg/h
Heat content of fuel (low value)	(Hl)	9,700 kcal/kg
Specific gravity of fuel	(SG)	0.952
Specific heat of fuel	(Cp)	0.45kcal/kg°C
Temperature of fuel	(Tf)	120°C
Reference temperature	(To)	34°C
Oxygen content in exhaust gas	(O_2)	6.4%
Temperature of exhaust gas	(Tg)	247°C
Quantity of blow down water	(B)	168 kg/h
Temperature of blow down water	(Tb)	183°C
Quantity of feed water	(W)	2,591 kg/h
Temperature of feed water	(Tw)	102°C
Steam pressure	(P)	10 kg/cm^{2}G
Quantity of steam (S = W − B)	(S)	2,423 kg/h
Enthalpy of steam	(Es)	665.2 kcal/kg
Enthalpy of feed water	(Ef)	102 kcal/kg

- Equation for Calculation of Heat Balance

Input

Heat of fuel combustion (Qc) $1{,}582.1 \times 10^3$kcal/h

$$Qc = F \times Hl$$

Sensible heat of fuel (Qs) 6.3×10^3kcal/h

$$Qs = P \times Cp\,(Tf\text{-}To)$$

Output

Heat of steam	(Qv)	$1,364.6 \times 10^3$kcal/h
$Qv = S \times (Es - Ef)$		
Heat loss in exhaust gas	(Qe)	175.2×10^3kcal/h
$Qe = F \times G \times 0.33\ (Tg\text{-}To)$		
Theoretical amount of air	(Ao)	
$Ao = 0.85\ Hl/1,000 + 2.0 = 10.25\ Nm^3/kg$		
Theoretical amount of exhaust gas	(Go)	
$Go = 1.11\ Hl/1,000 = 10.77\ Nm^3/kg$		
Air ratio (m)		
$m = 21/(21 - O_2) = 1.44$		
Actual amount of exhaust gas	(G)	
$G = Go + Ao(m - 1) = 15.28\ Nm^3/h$		
Heat loss in blow down water	(Qb)	13.6×10^3kcal/h
$Qb = B \times (Tb - Tw)$		
Heat release from body and others	(Qr)	35.0×10^3kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Improvement of Burning in Boiler

There are two units of boiler in use. However, the total steam volume is such that only one unit of boiler can produce it. It is recommended that the idle boilers be preserved by filling it with inhibitor-contained water after being properly given maintenance services, if the idle time is long. In this way, the boiler can be protected from corrosion.

While there is a less significant variation of the quantity of generated steam, the oxygen content of exhaust gas is high. Therefore, it is desired that the air damper be adjusted to keep the oxygen content within 4%. On the day of our diagnosis, we tested the damper and found it possible to adjust the damper for oxygen control. You are kindly requested to contact your local boiler maintenance service company for the adjustment at an early date.

We also request your cooperation in lowering the temperature of exhaust gas by cleaning the inner and outer surfaces of the tube.

If the oxygen content is kept down at 4% and the exhaust gas at 240°C, the under-mentioned energy conservation will be realized.

Air ratio after adjustment	$m' = 1.24$
Volume of exhaust gas after adjustment	$G' = 13.23\ Nm^3/kg$

Assuming that the fuel consumption after adjustment is x kg/h, the energy conservation of 1.9% will be expected according to the boiler heat balance sheet as follows:

$$\frac{1,588.4}{163.1} \cdot x = (1,364.6 + 13.6 + 35.0) + \frac{13.23 \times 0.33\ (240 - 34)}{1,000} x$$

$$\therefore x = 160.0 \text{ kg/h}, \quad \frac{F - x}{F} = \frac{3.1}{163.1} = 0.019$$

That is, the annual amount of conserved energy will be 1,296 kl/year $\times$ 0.019 = 24.6 kl/year at a conservation rate of 1.9%.

We observed an additional boiler built was operating for compensation for a shortage of steam supply. If the operation affected by the shortage lasted for a short time, the use of an accumulator is recommended. The accumulator is a kind of pressure vessel for accumulating surplus steam and feeding it during at peak steam consumption time. It is effective in smoothing the boiler load and stabilizing the burning. It is suggested that the use of the accumulator be separately studied when the need to use it comes in future.

6.2 Recovery of Flash Steam

Condensate is pumped out of three condensate tanks such as for extraction process system, hot air conditioner system and others to the intermediate tank in the boiler room. Further the condensate is fed to the boiler through the deaeration tank.

At present, the recovery rate for condensate is 60 to 80% averaging 70%. Since the condensate tank is of an open type, flash steam escapes into the atmosphere.

Assuming that steam is being used at a pressure rate of 3 kg/cm^3G, the generated condensate is separated into a saturated water and steam at atmospheric pressure, once it has entered into the tank.

If the ratio of flash steam is set at x, the following equation is established:

$143.7 = 100(1 - x) + 639 \qquad \therefore x = 0.08$

That is, it so happens that the amount of steam escaping into the atmosphere accounts for 8% in weight and 36% in calorific value.

At present, construction work for a batch-type deodorizing tank is underway. As a deodorizing process hot water wash and settling is a projected, a heat source will naturally be required. Therefore, if a closed-type flash tank is installed, it will be possible to recover and utilize steam at 1 kg/cm^2G. The amount of flash steam at 1 kg/cm^2G which will be separated by the flash tank, is represented by the following equation:

$143.7 = 119.9(1 - x) + 646.2x \qquad \therefore x = 0.045$

$$\frac{646.2 \times 0.045}{143.7} = 0.20$$

That is, the amount of steam equivalent to 4.5% in weight and 20% in calorific value will be recovered.

Assuming that, of the enthalpy of the steam, the percentage remaining in condensate is 25%, the recovery rate of condensate is 70% and the percentage of heat utilized as flash steam out of the condensate is 20%, the energy conservation rate will be:

$0.25 \times 0.75 \times 0.20 = 0.035$

equivalent heavy oil becomes

1290 kl/year $\times$ 0.035 = 45.2 kl/year

We observed a few (2 or 3) defective traps in the battery limits. Therefore, it is necessary to check up all of the traps one by one and sequentially replace the defective traps.

6.3 Reduction of Boiler Pressure

In case an indirect heating with the saturated steam is carried out, only latent heat is utilized. When comparing the latent heat of steam at 10 kg/cm^2G with that of steam at 3 kg/cm^2G, the latter is advantageous as follows:

	Enthalpy of saturated steam (h″)	Enthalpy of saturated water (h′)	Latent heat (r = h″ − h′)	Saturation temperature
10 kg/cm^2G	663.7 kcal/kg	185.6 kcal/kg	478.1 kcal/kg	183.1°C
3 kg/cm^2G	653.7 kcal/kg	143.7 kcal/kg	510.0 kcal/kg	142.9°C

For the above reason, it is advisable to reduce the pressure of generated steam at as low as possible, unless there is any trouble with the steam supply.

In the case of the Company's factory, the reduction of steam pressure to 3 kg/cm^2G was noticed at many places including the hot air conditioner.

It is also necessary to study the question "possibility of reducing the steam pressure for the extraction system."

6.4 Reevaluation of Blow Down Water for Boiler

The quantity of blow down water for the boiler is comparatively small. According to the record by the factory's boiler room, water is blown down once every hour, each time lasting for five seconds. This means that the total quantity is 120 l per day.

At present, the pH value of the boiler water is 10.9, the electric conductivity 14,800 μS/cm, and the pH value of feed water is 9.4 and the electric conductivity 320 μS/cm.

It is required that the pH value and electric conductivity of the boiler water be maintained at 11.0 to 11.8 and approx. 4500 μS/cm respectively. In order to realize this, the recovery rate of the condensate and the quantity of blow down water need to be increased.

6.5 Maintenance of Instruments

The thermometer for the feed water gathering tank at the boiler room has a dial which is not fixed. Therefore, indication of the needle is less reliable. Please fix it finding time.

6.6 Insulation of Piping and Valves at Boiler Room

The heat lost from the boiler body and three 4″ globe valves is as follows:

$$900 \text{ kcal/mh} \times 3 \times 1.27 \text{ m} \times 24 \text{ h} \times 300 \text{ day} = 24{,}690 \times 10^3 \text{kcal/year}$$

The reduction of heat loss when they are insulated with 30 mm glass wool is as follows:

$$24{,}690 \times 10^3 \text{ kcal/year} \times \frac{900 - 120}{900} = 21{,}400 \times 10^3 \text{ kcal/year}$$

If this heat loss is converted into equivalent heavy oil C, the quantity will be:

$$21{,}400 \times 10^3 \text{kcal}/(9{,}700 \times 0.952 \times 0.859) = 2.7 \text{ kl/year.}$$

As the price of the heavy oil is 4.1 Bt/l, the cost saving will be 11,070 Bt/year. The estimated construction cost for insulation is approx. 2,000 Bt which is recoverable in 0.2 year.

Energy conservation rate 2.7/1,296 × 100 = 0.2%

We also noticed an uninsulated feed water pipe (102°C) 2"× 5 m. If it is insulated with 25mm thick glass wool, the heat loss of (180 − 38) kcal/mh × 5 m × 24 h × 300 days = 5,112,000 kcal/year will be reduced. If this heat loss is converted into equivalent heavy oil C, the quantity will be 5,112,000/7,932 = 644 l/year which costs 2,640 Bt/year. The estimated insulation cost required for the pipe is approx. 1,300 Bt which is recoverable in 0.5 year.

Energy conservation rate 0.6/1,296 × 100 = 0.05%

In addition to the above, we noticed uninsulated valves such as for the condensate tank, manhole and header of the solvent recovery tower, neutralization tank, steam header for bleaching and others.

These uninsulated valves are equivalent to approx. 10 times as many as the uninsulated part of the boiler room. If they are insulated, the estimated energy conservation amount will represent approx. 2.0%. If this amount is converted into equivalent heavy oil C, the quantity will be 1,296 kl × 0.02 = 25.9 kl/year.

6.7 Change of Paint Color for Extraction Tank

The surface temperature of the extraction tank is 47°C which does not require insulation. However, the heat loss is significant because it has a large surface area and is exposed to the free air (installed outdoors). The said tank is not insulated due to the plant manufacturer's instructions. However, if the painted surfacial color is changed, it is possible to reduce the heat loss to considerable extent. It is possible to reduce the heat loss to considerable extent. The emissivity of the wall which is painted in dark green color is estimated at 0.8. If an aluminium paint is applied, the said emissivity will be reduced to 0.3. The following is the results of calculation for the heat loss difference:

(Ambient temperature 30°C)

- Present state

Radiation heat release Q

$$= 4.88 \times 0.8 \times \{(\frac{273+47}{100})^4 - (\frac{273+30}{100})^4\} = 78 \text{ kcal/m}^2\text{h}$$

Convection heat release $Q = 2.2 \times 17 \times 17^{0.25} = 75$ kcal/m²h

Total: 153 kcal/m²h

- After change of paint color

Radiation heat transmission Q

$$= 4.88 \times 0.3 \times \{(\frac{273+47}{100})^4 - (\frac{273+30}{100})^4\} = 29 \text{ kcal/m}^2\text{h}$$

Convection heat transmission $Q = 2.2 \times 17 \times 2.0 = 75$ kcal/m²h

Total: 104 kcal/m²h

- Heat loss reduction rate (153 − 104)/153 × 100 = 32%

The heat loss reduction amount resulting from the application of aluminium paint over the surface area of 215 m² will be:

(153 − 104) × 215 m² × 24h × 300 days

= 75,852,000 kcal/year

• If converted into equivalent heavy oil C,

$75,852,000/9,700 \times 0.859 \times 0.952 = 9,563$ l/year

• Energy conservation rate

$9.6/1,296 \times 100 = 0.7\%$

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	410 kW (October, 1982)
Power Consumption	:	$2,184 \times 10^3$ kWh/year
Load Factor	:	Monthly load factor 72.1 ~ 87.1%
Penalty Fee	:	32,595 Bt/year
Power Factor	:	Monthly power factor 62 ~ 68%
Transformer	:	3φ 375 kVA × 3 units
Power Cost	:	Annual average 1.65 Bt/kWh

7.2 One Line Diagram

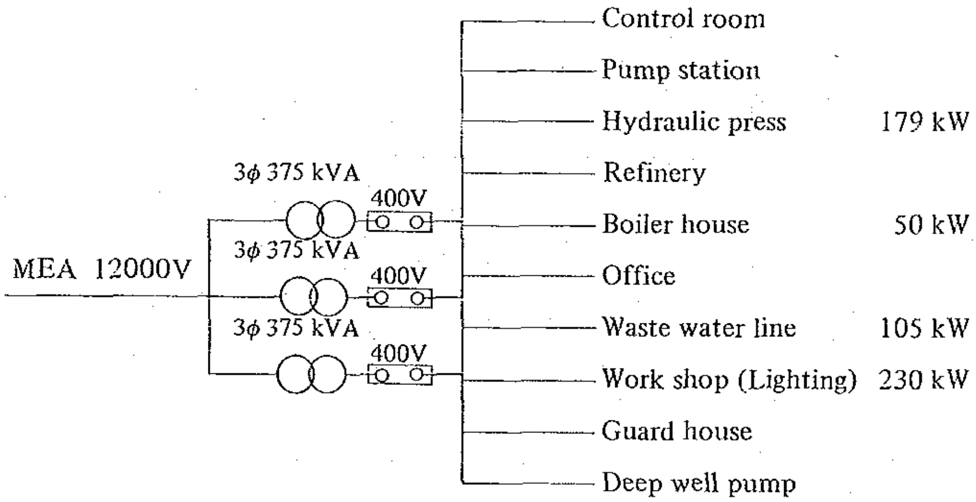


Fig. 12–4 One Line Diagram

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 12–3

Date	Maximum demand power kW	Consumption kWh	Average power kW	Power factor P.F. %	Load factor L.F. %
2/82	380	191,000	318	66	77.9
3/82	400	235,000	392	68	74.0
4/82	400	203,000	338	67	74.0
5/82	380	205,000	342	67	77.9
6/82	400	195,000	325	64	74.0
7/82	380	202,000	337	65	77.9
9/82	350	200,000	333	67	84.6
10/82	410	187,000	312	67	72.2
11/82	340	204,000	340	65	87.1
12/82	380	185,000	308	62	77.9
1/83	400	177,000	295	65	74.0
2/83	350	187,000	312	64	84.6
3/83	410	219,000	365	63	72.2
4/83	390	184,000	307	64	75.8

7.3.2 Monthly Load Curve

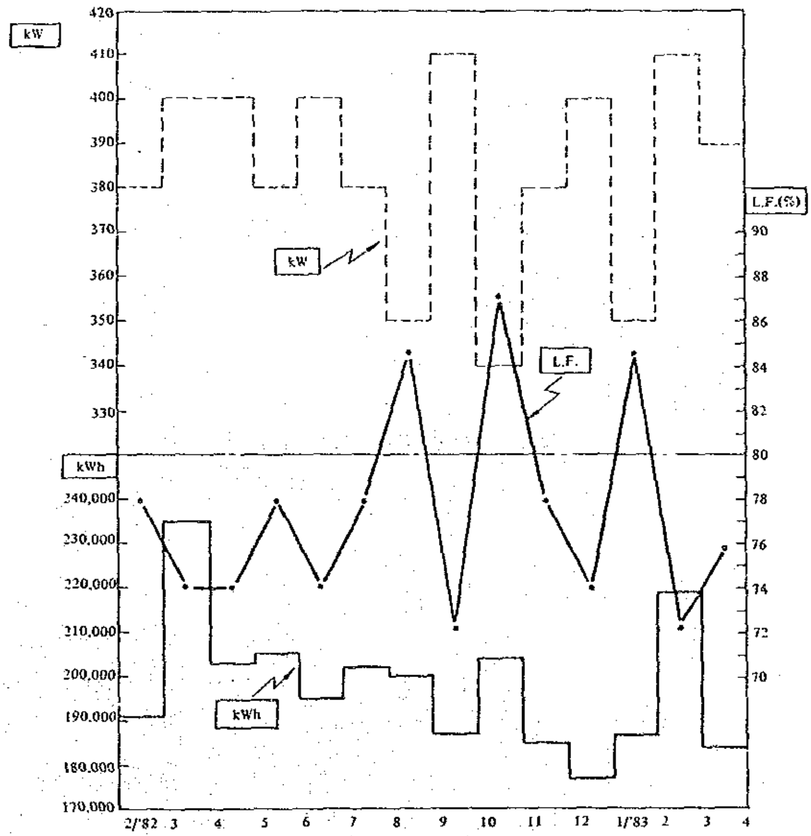


Fig. 12–5 Monthly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 12-4

Instantaneous value 1. July

Machine	V	kW	AR	cos φ	L.F. %
Motor hammer mill 75 kW 141A 380V Operate 10 h/day	No load 388	9.5	27.0	0.52	13.0
Motor oil transfer pump 90 kW cosφ 0.85 Operate 3.5 h/time 7 time/mouth	388	33.3	88.5	0.57	37.0
Waste water treatment 15 kW 380V 28.4A	386	4.6	18.3	0.38	31.3
Air compressor 7.5 kW 380V 11.3A	388	7.1	11.4	0.93	94.6
Deep well pump 15 kW 380V 29.5A	385	10.5	18.5	0.85	69.9
Water feed pump 30 HP rpm 380V 45A	384	21.9	34.8	0.96	99.5
Hydraulic cooling pump 20 HP (15 kW) 380V 28A	384	10.4	17.5	0.89	69.6
Bleaching cooling pump 15 HP (11 kW) 380V 21.4A	383	5.1	10.9	0.74	46.7

8.2 Power Distribution

8.2.1 Transformer

Judging from the fact that the peak demand is 410 kW and the average power demand 392 kW, it is considered that the total capacity of the transformers is too large. Therefore, on the assumption that operating 7,200 h/year, average power as 400 kW, core loss of transformer as 0.3% and copper loss of transformer as 1.4%, the expected advantage on calculating when the capacity of transformer to be reduced is as shown in table 12-5.

Table 12-5

	Transformers kVA	Load 615 kVA	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year
Present state	375 x 3	615	30	31	61
Improved state	375 x 2	615	20	46	66
Difference			–10	+15	5

That is, there is no advantage because of an increase in the power loss of 5 × 10^3kWh/year. Yet it is recommended that two units of the transformer be used for production line, one unit for miscellaneous driving power and off-line use instead of three transformers parallel operation. Thus the spread of trouble can be minimized during the accident.

8.2.2 Power Factor

We studied the best way to improve the power factor based on the data of Table 12-3. The compared results of cases are shown in Table 12-6. Of these results, those of Cases 2-1 and 2-2 are shown in Fig. 12-6.

That is, if one unit of condenser at 200 kVar is installed, the penalty will be nothing instead of the present 32,595 Bt/year.

Table 12-6

Case	Average power kW	Installed condenser kVar	Apparent power kVA	Reactive power kVar	Power factor %
1 – 1	300	0	462	352	65
1 – 2	300	200	337	152	89
1 – 3	300	300	305	52	98
2 – 1	400	0	588	431	68
2 – 2	400	200	462	231	87
2 – 3	400	300	421	131	95

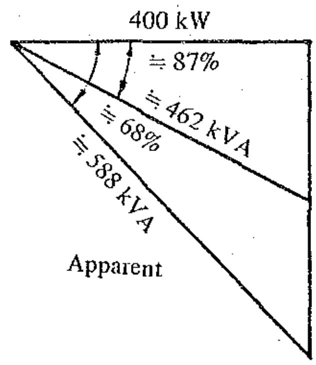


Fig. 12-6

In addition, if the parameters are set at 400 kW for average power, 68% for average power factor and 588 kVA for apparent power, and the target for improvement is set at 87% for average power factor and 462 kVA for apparent power, the expected advantage resulting from the reduced copper loss of three units of transformer 375 kVA by the improvement of power factor, will be as follows:

$$1{,}125\ \text{kVA} \times 0.014 \times \{(\frac{588}{1{,}125})^2 - (\frac{462}{1{,}125})^2\} \times 7{,}200\ \text{h/year} = 11.9 \times 10^3\text{kWh/year}$$

$$11.9 \times 10^3\text{kWh/year} \times 1.45\ \text{Bt/kWh} = 17.200\ \text{Bt/year}$$

The estimated investment in one unit of condenser 200 kVar is approx. 100,000 to 120,000 Bt. Consequently, the time required for the recovery of investment in condenser facilities will be 100,000/(32,595 + 17,200) = 2 years.

8.2.3 Distribution System

Since the factory is only 3 years old and as such updated, the distribution system and distribution equipment are in good order. Especially the voltage drop at the terminal of large equimpent on loading is approx. 10 V. This shows that the size of cable is appropriate one based on considerations of distance and capacity. In addition, the current of each phase is well balanced at approx. 610 to 620 A.

8.3 Motor Application

On the day of our checkup, we were not able to look into the actual loaded operation of a large-size hammer mill 75 kW and an oil transportation pump 90 kW because of the factory working convenience. It is difficult to criticize the appropriate capacity of above motors only by referring to data on the unloaded operation. However, with regard to the other motors, both power factor and load factor of each equipment are generally satisfactory as shown in Table 12-4. In addition, the monthly load factor is an acceptable value as shown in Table 12-3, so there is particular no problem.

8.4 Others

Because of regional conditions, the factory is provided with repair service facilities which have a maintenance crew (4 × 3) + 14 = 26.

We were specially impressed by the studious attitude of "chiefs" responsible for maintenance services. They were devoted in studying through discussion of remedial measures during an accident, protective means for the earthing of equipment, overload, shortcircuit and others.

9. Summary

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

	(Oil Equivalent) kl/year	%
Improvement of fuel combustion	24.6	1.9
Recovery of flash steam	45.2	3.3
Reinforcement of insulation	29.2	2.2
Repainting of extraction tank	9.6	0.7
Subtotal	108.6	8.4
	10^3kWh/year	%
Improvement of power factor	11.9	0.5
Subtotal	11.9	0.5

Report No. 13: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thanakorn Vegetable Oil Products Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Thanakorn Vegetable Oil Products Co., Ltd. —

1. Outline of the Factory

Address	99 801 Thanakorn, Phra Samut Jebi Road, Samutprakarn	
Capital	450 Million Bt	
Type of industry	Food	
Major products	Rice bran oil, Soy bean oil	
Annual product	Crude oil 9,500 t/year	
No. of employees	285	
Annual energy consumption	Electric power	8,640,000 kWh
	Fuel	H.O.(C) 3,000 kℓ Dark oil 2,000 kℓ
Interviewees	Mr. Virat : Works Director Mr. Jaded : Engineering Service Department Chief	
Date of diagnosis	July 11 ~ 12, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

Thanakorn Vegetable Oil Products Co., Ltd. is the largest edible oil manufacturing factory in Southeast Asia. The factory has a production capacity of 25,000 t/year for edible oil and 70,000 t/year for meal from about 140,000 t/year of rice bran, soybean and kapok.

The manufacturing department has the sections of Engineering Service and Project Engineering, and the daily management system is already established.

The factory has actively implemented an energy conservation, for example, a success of the trial combustion of the by-product oil produced from the purification process in the boiler or implementation of the instruction by Australian engineer who diagnosed the plant.

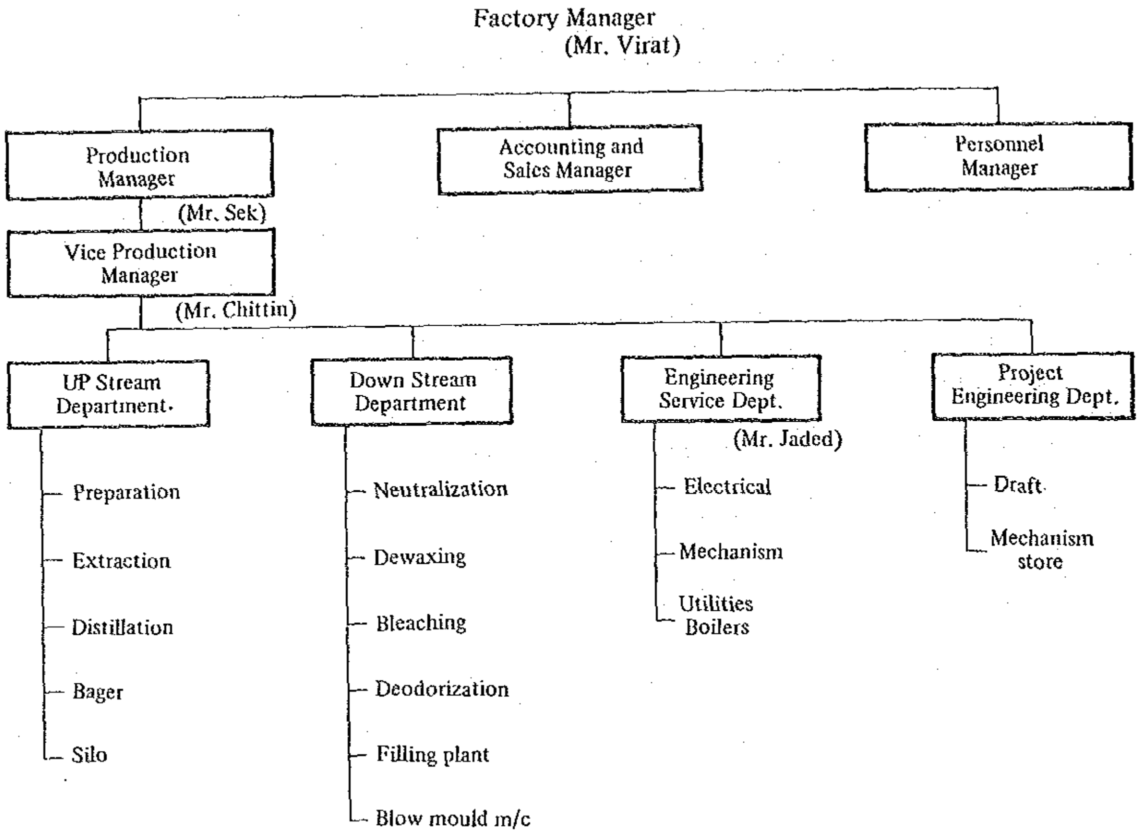


Fig. 13–1

2. Manufacturing Process

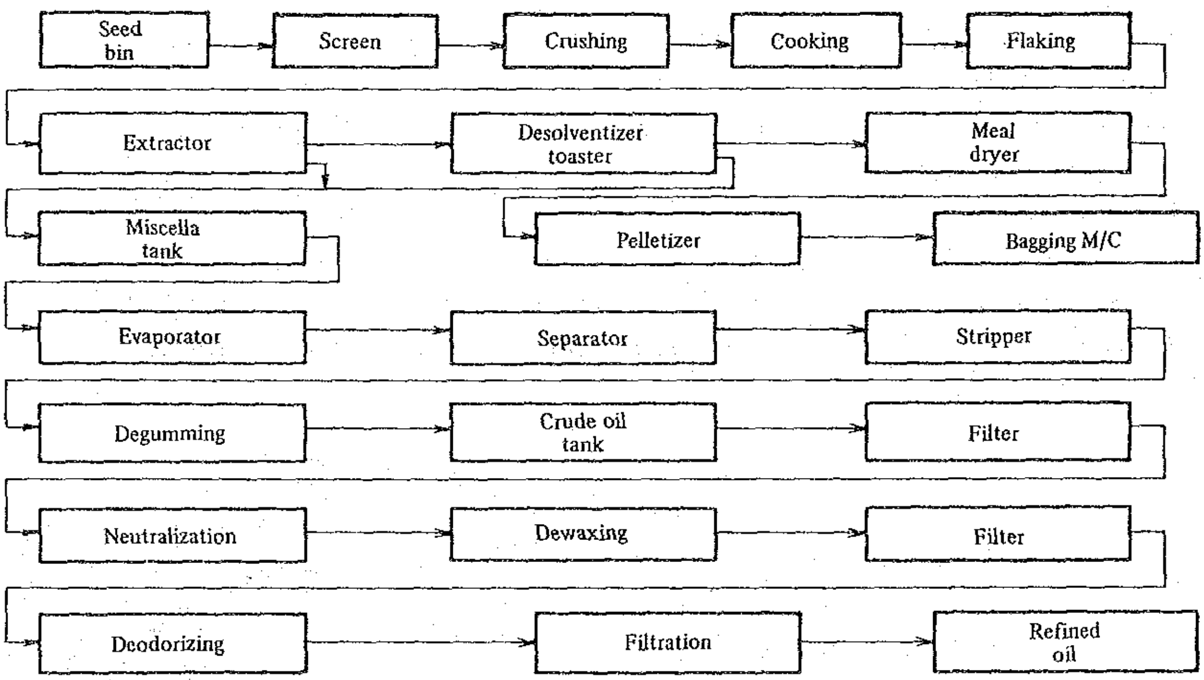


Fig. 13–2

3. Major Equipment

3.1 Major Equipment

Table 13–1

Name	No. of units installed	Type, etc.
Boiler	1	15 t/h 13 kg/cm^2 Water tube super heater
Extractor	1	Roto-cell type ϕ 12,000 mm x H 5,000 mm
Desolventizer – toaster	1	Dome type
Dryer	1	Rotary type
Neutralizer	1	
Bleaching tank	1	
Deodorizer	1	ϕ 300 mm x H 20,000 mm

3.2 Layout

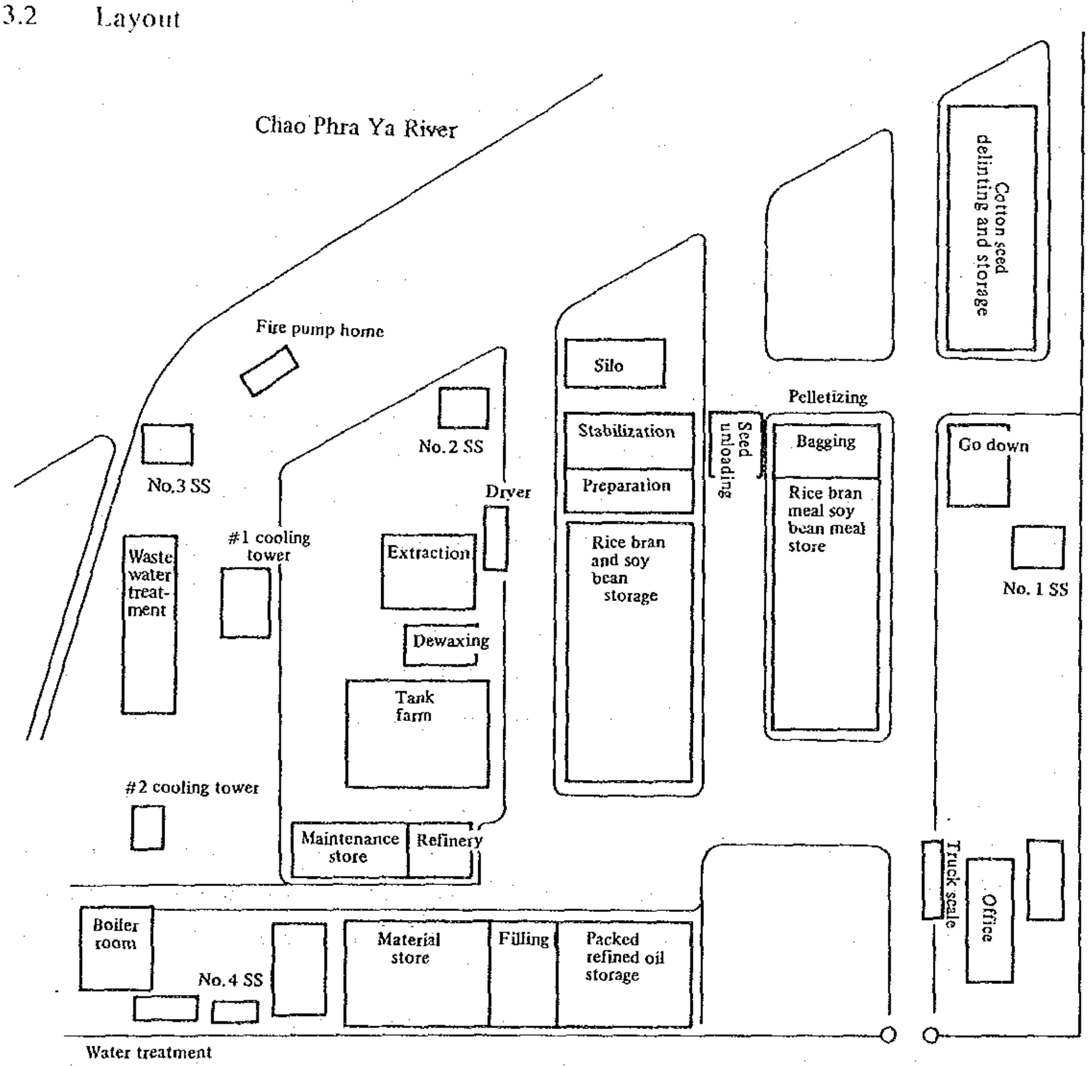


Fig. 13–3

4. State of Energy Management

4.1 Policy for Energy Conservation

Although a target figure of the energy conservation is not established, an attitude to advance the energy conservation is recognized. The project to use a by-product oil as fuel has been pushed forward and has already succeeded in a practical application. The investment of 4 million Bt in 1981 was sunk in a series of this project. Successively the investment of one million Bt was devoted to the arrangement of heat insulation and steam traps in 1982, and in 1983 the energy conserving investment of 5 million Bt is scheduled for installation of a heat recovery system in the deodorizing equipment.

The recovery period of the investment is set up in three years as an marginal investment. The improvement and expansion of equipment that come under this make it a rule to put forward positively.

4.2 Participation by All Employees

In addition to the business organization in the factory, the cost reduction committee has been already established, and appointed the factory manager the chairman, and the managers of each department and the chiefs of each section members of the committee. The committee has been called once a month. In the manufacturing department, an energy conservation project team has been organized and study meeting has been held occasionally with also participation of the foremen. The suggestion system and its awarding provisions have been established, but these seem to be not in an active application.

The factory manager has appealed some considerable points for energy conservation to all the employees by a direct manner or posters. This factory has enough essence of growth.

4.3 Control through Data

The basic data of fuel and power have been collected in every major process and equipment and these have been submitted for the monthly cost accounting. Furthermore, they would like to exert themselves for an increase of the management information and an improvement of its quality with a higher reliability of data by means of supplement of the instruments. Although the renewal and supplement plan of instruments is difficult to forcast the recovery of investment, the plan should be set forward by all means because some advantages may be expected with a decreasing of irregularity in the process condition, a quality stability and decreasing of the substandard rate and a reduction of the labor force.

4.4 Education and Training for Leveling-Up of Employees

Both of the scale and the capability of production in the factory are the premier position in the industry and the technology level is high. Besides they have a prime aspiration, accept positively diagnosis of the outsider, catch the instructed points with modesty and improve them steadily.

They have a higher technique inimitable by other domestic companies, for example the development of a dark oil combustion or a pretreatment equipment of the raw material, and the arrangement of technical information and the quality control are substantial. Because the excellent engineers are arranged in each section to give full pay to their ability.

They are eager in the education of the employees. About 20 persons per year participate in service training held by outsiders. And also trainings in the workshop is executed by the persons who received the outsiders' training. If a small group activity is established by this training, this factory will grow as a much better, efficient one.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil C: 3,000 kl/year,

By-product oil: 2,000 kl/year

Breakdown of steam consumption

- Pretreatment — 10% (300 kl)
- Extraction — 48% (1,440 kl)
- Neutralization — 8% (240 kl)
- Dewaxing — 6% (180 kl)
- Bleaching — 5% (150 kl)
- Deodorization — 21% (630 kl)
- Granulation — 1% (30 kl)
- Soapstock split — 1% (30 kl)

Diesel oil: 50 kl/year For the transfer equipment

Recently, the test to reduce the fuel cost has been carried out with burning mixture of the dark oil (fatty acid and recovered acid) and fuel oil (See Table 13-2).

Table 13–2

		Fuel consumption		Steam generation	Steam / Fuel
		Heavy oil kℓ	Dark oil kℓ	t	
1983	May	222	236	5,145	11.2
	June	571	–	4,604	12.4

Steam consumption rate 1.04 t steam / t

Fuel consumption rate $\frac{\text{Heavy oil } 3{,}000 \text{ k}\ell + \text{dark oil } 2{,}000 \text{ k}\ell}{\text{Crude oil } 9{,}500 \text{ t}} = 526\ \ell/\text{t}$ Crude oiloil

5.2 Heat Balance of Boiler

The heat balance of boiler was calculated from the working data on July 11, 1983. The heat balance is shown in Table 13-3.

Table 13-3

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	7,518.6	99.6	Heat of steam	6,837.8	90.6
Sensible heat of fuel	26.6	0.4	Heat loss in exhaust gas	658.7	8.7
			Heat loss in blow water	6.5	0.1
			Heat release from boiler body, others	42.2	0.6
Total	7,545.2	100.0	Total	7,545.2	100.0

Data given for calculation of heat balance

Fuel type		Fuel oil C
Fuel consumption	(F)	776.8 kg/h
Heating value of fuel (low value)	(Hl)	9,679 kcal/kg
Specific gravity of fuel	(SG)	0.959
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	110°C
Reference temperature	(To)	34°C
Oxygen content of exhaust gas	(O_2)	3.0% (Based on the plant data)
Temperature of exhaust gas	(Tg)	240°C
Quantity of blow down water	(B)	341 kg/h
Temperature of blow down water	(Tb)	70°C
Quantity of feed water	(W)	10,798 kg/h
Temperature of feed water	(Tw)	51°C
Steam pressure	(P)	13 kg/cm²G
Quantity of steam (S = W − B)	(S)	10,457 kg/h
Enthalpy of steam	(Es)	704.9 kcal/kg
Enthalpy of feed water	(Ef)	51 kcal/kg

Equation for calculation of the heat balance

Input

Heat of fuel combustion (Qc) $7{,}518.6 \times 10^3$cal/h

$$Qc = F \times Hl$$

Sensible heat of fuel (Qs) 26.6×10^3kcal/h

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

Output

Heat of steam (Qv) $6{,}837.8 \times 10^3$kcal/h

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

Heat loss in exhaust gas (Qe) 658.7×10^3kcal/h

$$Qe = F \times G \times 0.33(Tg - To)$$

Theoretical amount of air (Ao)

$Ao = 0.85Hl/1,000 + 2.0 = 10.23\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11Hl/1,000 = 10.74\ Nm^3/kg$

Air ratio (m)

$m = 21/(21-O_2) = 1.17$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 12.48\ Nm^3/kg$

Heat loss in blow down water (Qb) 6.5×10^3kcal/h

$Qb = B \times (Tb - Tw)$

Heat release from body and others (Qr) 42.2×10^3kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Reduction of Boiler Blow Down Water

Feed Water is 7 to 8 in pH and 20 to 60 S/cm in electrical conductivity. Boiler water is 9 to 10 in pH and 80 to 200 μS/cm in electrical conductivity. The current blow-off rate of 3.5% seems to be excessive. The electrical conductivity of boiler water is allowable up to 3,000 μS/cm.

In the test cases, for the 7:00 - 18:00 manual operation, the blow of 300 l/h was carried out, but for the 19:00 - 6:00 automatic control by the electrical conductivity, the blow was only 16 l/h. The controller installed on purpose should be put to enough practical use.

The quantity of blow down water may be reduced to about 1% under examing the boiler water. The quantity of blow down water from the heat balance in Table 13-3 is

$10,798 \times 0.01 = 108$ kg/h.

The reduction of the heat loss in blow down water (after heat exchange) results in

$Qb = B \times (Tb - Tw) = (341 - 108) \times (70 - 51)$

$= 4.4 \times 10^3$ kcal/h.

Energy conservation rate: $4.4 \times 10^3 \times 100/7,545.2 \times 10^3 = 0.06\%$

Reduced amount of fuel oil: $3,000 \times 0.0006 = 1.8$ kl/year

It shows a lower pH in the boiler water (the standard value: 10.8 to 11.3) and a deficiency in alkali. However, a reduction of the quantity of blow down water suffices with a small make-up alkali.

6.2 Recovery of Condensate

The hot water tank located in the first floor of the oil purification plant receives the condensate produced by the oil purification plant in the flash steam tank as the hot water of 100°C. And then a part of the hot water is used for soapstock. However, the surplus hot water is discarded through overflow.

Of the quantity of steam, if the consumption in the purification plant is 26%, the produced condensate of 100°C is 90% (as 4kg/cm^{2}G in the steam pressure and 10% in the flash rate) and the surplus quantity used to the soapstock is 50%, — the quantity discarded is as follows;

$10{,}457\ kg/h \times 0.26 \times 0.9 \times 0.5 = 1{,}223\ kg/h$

If 90% of these is utilized as a feed water to the boiler, the energy for conservation results in

$1{,}223\ kg/h \times 0.9 \times (100 - 34) = 72{,}600\ kcal/h$

Energy conservation rate:

$$\frac{72{,}600}{7{,}542.2 \times 10^3} \times 100 = 1.0\%$$

Reduction of fuel oil: 3,000 kl/year × 0.01 = 30 kl/year

6.3 Insulation of Steam Valve

Although the insulation of the steam valves is improved by the inspection in the project team, still, uninsulated valves are found out.

The uninsulated valves and reducers from the boiler room to the service place are picked up in Table 13-4. The heat loss from them is estimated roughly as about 38,000 kcal/h, though there are some mistake in size, duplication of number or oversight because of the visual observation.

Table 13–4 Heat Release

Steam pressure	Diameter ϕ		Units	Heat release when non insulation kcal/h
10 kg/cm²	6"	Stop valve	6	9,000
		Reducer & strainer	2	3,200
	4"	Stop valve	8	8,000
		Reducer & strainer	2	2,400
	2"	Stop valve	3	1,530
		Reducer & strainer		—
	1½"	Stop valve	2	800
		Reducer & strainer		—
	1"	Stop valve	6	1,800
3 kg/cm²	2"	Stop valve	7	1,680
		Reducer & strainer	1	340
	1½"	Stop valve	6	1,260
		Reducer & strainer	1	310
	1"	Stop valve	50	8,000
Total				38,320

Assuming that the valves, reducers and strainers more than 2" out of these valves are insulated with glass wool (with an aluminum sheet cover) to cut the heat loss of 90%;

Heat loss possible to be saved: 26,150 kcal/h × 0.9 = 23,535 kcal/h when the heat is converted to the equivalent fuel oil C;

$$\frac{23{,}535\ kcal/h \times 24 \times 285}{9{,}679 \times 0.906 \times 0.959} = 19.1\ kl/year$$

The reduced cost per year: 19.1kl/year × 4.3 × 10^3 = 82,100 Bt/year

The cost of insulation: 30,870 Bt

50mm glass wool blanket: 37.1m^2 × 182Bt/m^2 = 6,752 Bt

Aluminum sheet: 37.1m^2 × 268Bt/m^2 = 9,943 Bt

Working cost of aluminum cover:

29 pieces × 105Bt/piece = 3,045 Bt

Field work charge: 37.1m^2 × 300Bt/m^2 = 11,130 Bt

Consequently, the expenses required to the insulation can be amortized in five months by the reduction of the fuel consumption.

Energy conservation rate: 19.1/3,000 × 100 = 0.6%

Although the steam valves, headers and vessels were mostly insulated, some damage of collapse, crack and wetting on the insulating materials were found out. These insulation should be repaired and the protective measure should be taken.

6.4 Utilization of Waste Heat of Solvent Vapor

In the vegetable oil extraction plant, a desolvent of the micella and the cake is an indispensable process. The solvent vapor generated from the process possesses a lot of latent heat. An effective utilization of this vapor is one of the most significant factors for the energy conservation. In the rice bran oil extraction plant (a continuous system) in Japan, the vapor generated from the desolventizer did not formerly utilize its latent heat through cooling in the condenser. But this vapor has been underwent improvements to be utilized as heat source for desolvent of micella. Thus the energy conservation has been taken with the improvement[1] as shown in the following.

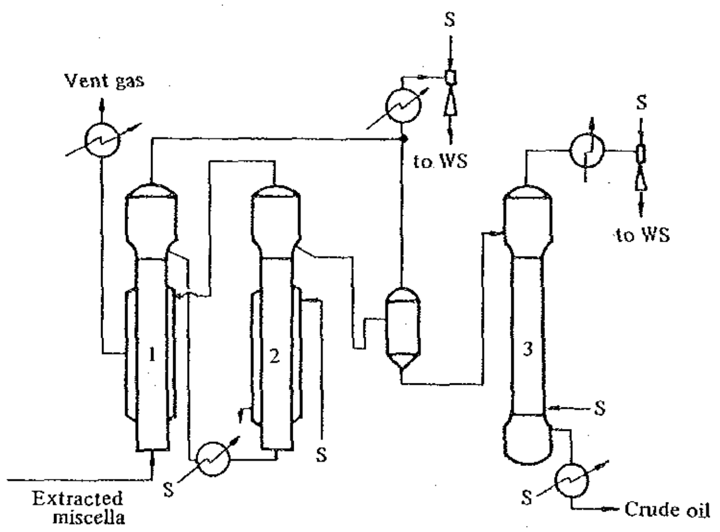
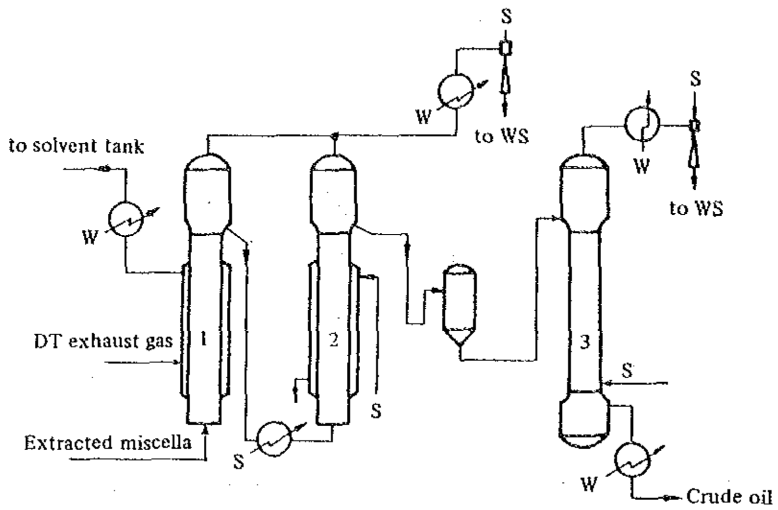


Fig. 13–4 < Original >



1 : Primary evaporator 2 : Secondary evaporator 3 : Stripper
W : Cooling water S : Steam

Fig. 13–5 < Improved >

Fig.13-4 is the flow of the conventional desolvent process of the micella and Fig.13-5 is the improved flow.

Before improvement: As shown in Fig.13-4, the distillation of micella is a double effect system and the first evaporator is heated by the vapor generated in the second evaporator.

After improvement: As shown in Fig.13-5, the first evaporator is remodelled to utilize the solvent vapor of the desolventizer as its heat source.

As the result of remodeling, the heat supplied to the first evaporator increased to a large degree compared with the conventional process and the thickening rate of micella was increased. The operating pressure in the second evaporator was an atomospheric pressure before the remodeling, but the evaporator was remodelled to operate at a reduced pressure (250 to 300 Torr) similar to the first evaporator. Consequently, the evaporation quantity required in the second evaporator decreased to a large extent. Accordingly the energy conservation could be actualized. Since the concentration of the thickened micella transferred from the second evaporator to the stripper was around 93% in the both of before and after the remodeling, the decreasing of the steam consumption in the second evaporator was applied just as it was to the energy conservation. Effect: The steam consumption in the second evaporator before the remodeling was 596 kg/h but was decreased to 296 kg/h after the remodeling. That was, the steam consumption was reduced by 300 kg/h. The raw material treatment in this equipment was 6,500 kg/h. Accordingly the steam was reduced by 46 kg steam/t raw material.

5,000 yen/t steam × 0.3 t/h × 7,200 h/year

= 10,800,000 yen/year (ca.1,000,000 Bt.year)

While the investment cost was the total 15 million yen (ca. 1.5 million Bt) of 10.3 million yen the major equipment cost and 4.7 million yen the field work charge. Therefore, the investment cost could be recovered in about 1.4 years.

Comment for the remolding: Compared with the case of a direct feeding of the vapor generated in the desolventizer to the condenser, the case of the demodeling to feed the vapor through the first evaporator to the condenser should be taken in an enough consideration against the resistance of flow in the piping not to apply the pressure to the desolventizer.

Correlated manufactures: Mitsubishi Kakoki, Yoshino Works and Suehiro Iron Works, etc.

Supposing that this factory is the same scale as the plant in Japan, when the reduction of steam is expected in the same extent, it is

300 kg × 24 × 286 = 2,059.2 t steam/year.

When it is converted to the equivalent of fuel oil from the boiler heat balance, it results in

$$\frac{776.8}{1,045.7}\text{kg} \times 2,059.2 \times 10^3 = 153.0\ \text{t/year}$$

Therefore,

$$\frac{153.0}{0.959} = 159.5\ \text{kl/year}$$

Energy conservation rate:

$$\frac{159.5}{3,000} \times 100 = 5.3\%$$

6.5 Heat Recovery in Deodorizing Process

On the heat recovery through a two-stage heat pipe in a deodorizing equipment, the actual case of an oil purification plant in Japan is described in Fig.13-6.

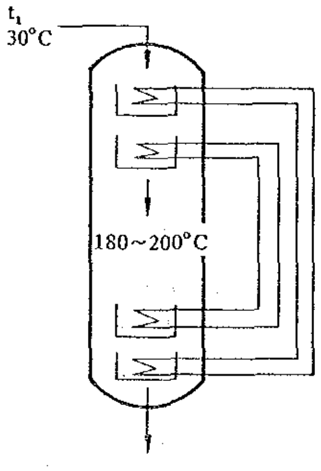


Fig. 13–6 Streams pattern

This system avoids scaling using a water-steam system as a medium of the two-stage heat pipe, and the heat recovery rate of approximately 70% is aimed.

Energy conservation effect:

Inlet temperature $t_1 = 30°C$

Preheating temperature $t_2 = 180 \sim 200°C$

Preheating temperature difference $\Delta t = 150 \sim 170°C$

Steam reduction for preheating

$$W = \frac{(150 \sim 170°C)(1,000\ kg)(0.55\ kcal/kg\ °C)}{500\ kcal/kg}$$

$$= 165 \sim 187\ kg\ steam/t\ oil$$

The steam reduction in case of the 50,000 t/year production capacity plant is taken as $Wr = 50,000\ t \times 165 \sim 187 kg/t = (8,250 \sim 9,350) \times 10^3$ kg/year. If it is put 0.5 yen/kg in the steam unit price (a variable cost), the cost reduction results in 41,250,000 to 46,750,000 yen/year.

In addition to this, the conventional hot oil tank for preheating and the discharge pump (10 kW) becomes useless with a simple process. This is advantageous on the maintenance and the energy conservation.

Economical evaluation: In the case of 50,000 t/year production capacity plant.

Investment cost 70,000,000 yen (ca.7,000,000 Bt)

Cost reduction 41,250,000 to 46,750,000 yen/year (ca. 4,100,000 to 4,700,000 Bt/year)

Investment recovery period

$$\frac{7,000}{4.125 \sim 4.675} = 1.7 \sim 1.5\ \text{years}$$

Comment for practice: Take care to prevent the heat pipe vibration.

Correlated manufacturer: Nikki

The possibility to apply the above example to this factory should be examined in the factory side. We estimated the effect in case of the 9,400 t/year production. If the steam reduction is taken as 165 to 187 kg/t oil, it is $165\ kg/t \times 9,400\ t = 1,551 \times 10^3$ kg/year.

Converted to the equivalent fuel oil,

$$\frac{776.8}{10,457} \times 1,551 \times 10^3 = 115.2 \times 10^3\ kg/year$$

$$115.2 \times 10^3/0.959 = 120.1\ kl/year$$

Energy conservation rate:

$$\frac{120.1}{3,000} \times 100 = 4.0\%$$

Literature: 1) The Energy Conservation Manual in the Vegetable Oil Manufacturers and the Energy Conservation Actual State Reserach Report; March 1982, P28 ~ P29, Food Undertaking Center and Nippon Oils and Fats Association.

2) Ibid, P52

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	2,600 kW (Feb. 1983)
Power Consumption	:	$8,620 \times 10^3$ kWh/year (Feb. 1983)
Load Factor	:	Monthly Load Factor 38 to 69%
Penalty Fee	:	14,295 Bt/year (1982)
Power Factor	:	Monthly Power Factor 73 to 85%

Transformer : 3ϕ 1,000 kVA × 6
Final Power Cost : Annual Average 1.7 Bt/kWh

7.2 One Line Diagram

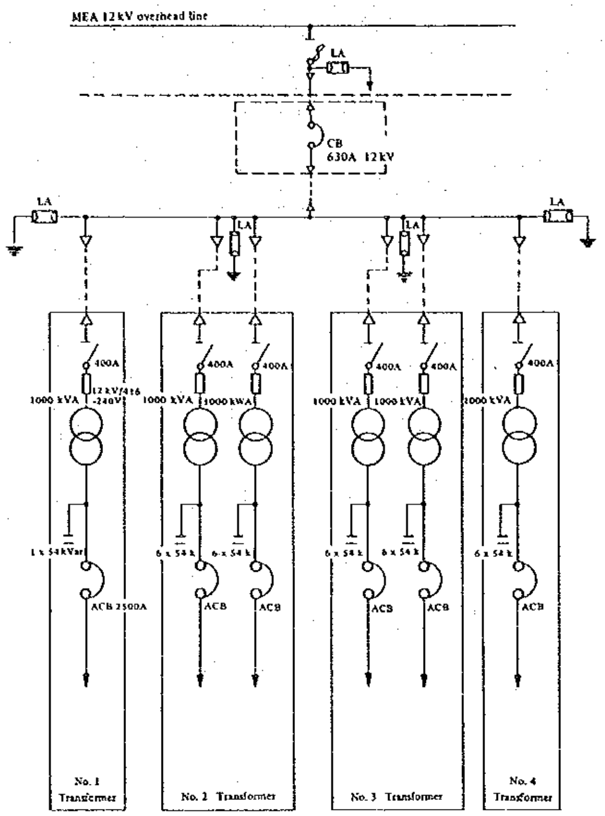


Fig. 13–7

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 13–5 Monthly Power Consumption

Month	Consumption power kWh x 1,000	Maximum demand power Max. kW	Average power kW	Reactive power kVar	Power factor P.F (%)	Load factor L.F (%)
1 / 82	640	1,880	1,123	16	84.3	45.76
2	712	1,880	1,249	–	85.0	56.36
3	920	1,787	1,614	554	72.9	69.2
4	692	1,787	1,214	194	80.4	53.78
5	608	1,787	1,067	–	85.0	45.73
6	832	1,787	1,460	74	83.0	64.66
7	568	1,787	996	–	85.0	42.72
8	672	1,787	1,179	114	82.2	50.54
9	620	1,840	1,088	1	85.0	46.80
10	784	2,160	1,375	–	85.0	48.8
11	872	1,920	1,530	–	85.0	63.1
12	700	1,960	1,228	–	85.0	48.0
1 / 83	828	2,000	1,453	–	85.0	55.6
2	988	2,600	1,733	–	85.0	56.5
3	1,192	2,400	2,091	48	83.8	66.7
4	684	2,520	1,200	–	85.0	37.7
5	532	1,880	933	96	82.7	38.0
6	664	2,320	1,165	18	84.3	39.8

$$\text{Average power per year} \quad \frac{8{,}620 \times 10^3 \text{ kWh}}{6{,}840 \text{ h}} = 1{,}260 \text{ kW (1982)}$$

7.3.2 Monthly Load Curve

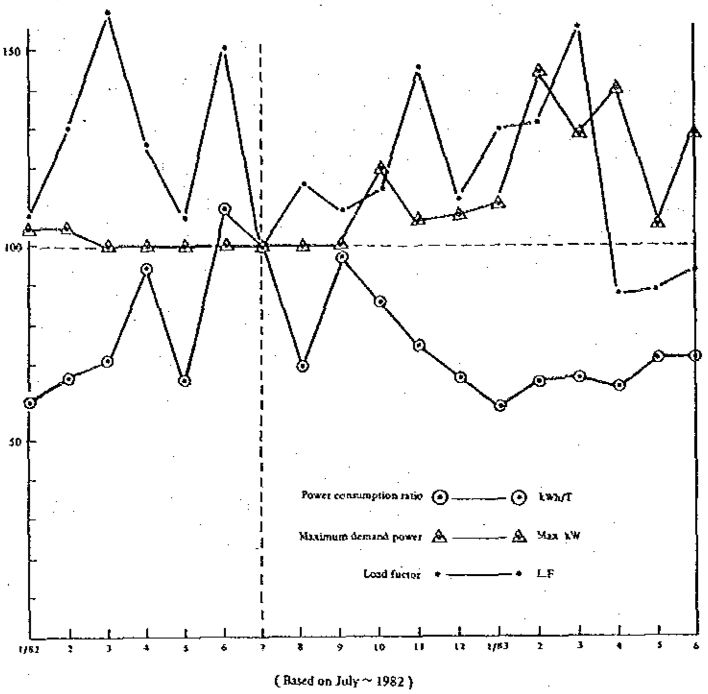


Fig. 13–8 Index Curve

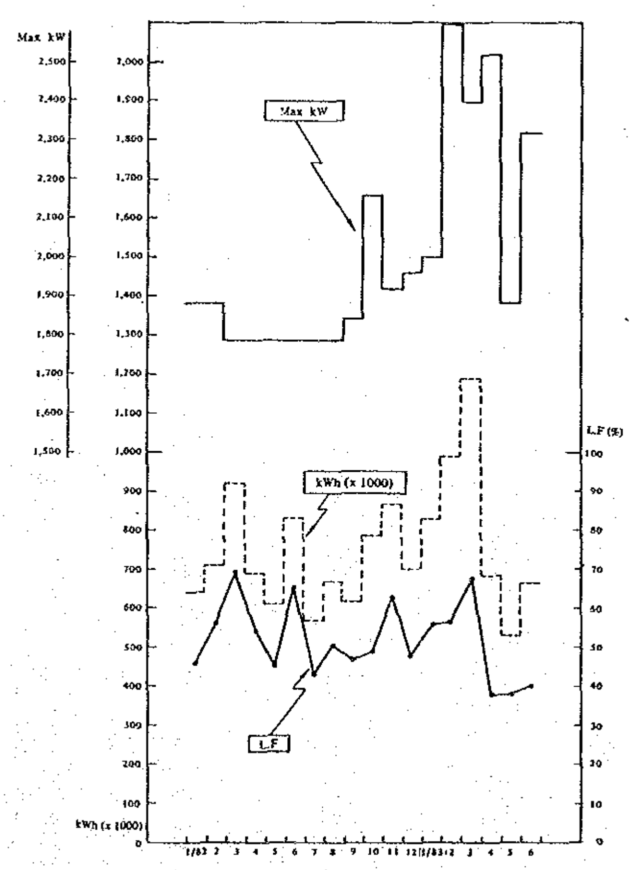


Fig. 13–9 Monthly Load Curve

7.3.3 Hourly Power Consumption

Table 13–6 Situation of Power Consumption

Time	Power consumption kWh/30 min.	Reactive power kVar	Power factor PF %
8.00			
8.30	800	800	71
9.00	800	400	89
9.30	400	400	71
10.00	800	400	89
11.00	1,600	1,200	80
12.00	1,200	800	83
13.00	1,600	400	97
13.30	800	400	89
14.00	360	400	67
14.30	1,200	400	95
15.00	440	400	74
15.30	800	480	86
16.00	800	480	86

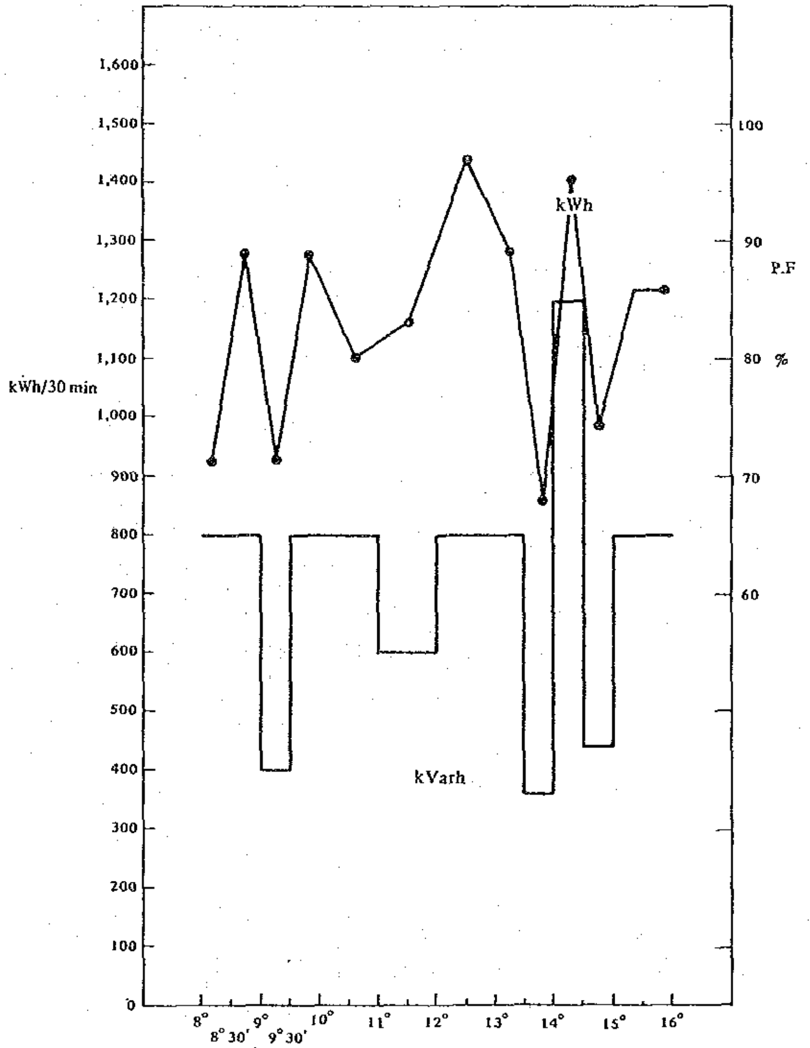


Fig. 13–10 Hourly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 13–7 12 July

	Use for	Name plate kW	Name plate V	Name plate A	Name plate rpm	Measurement kW	Measurement V	Measurement A	P.F %	L.F %
No. 1 Substation	41 - 2818 system					40.3	399	53.2		
	Office, others					38.9	396	67.9		
No. 2 Substation	Flaking 25 - 2883A	90	380	165	1,470	72.9	410	111	92	80.8
	Flaking 25 - 2883B	90	380	165	1,470	47.6	410	79.5	84	52.9
	Expander 25 - 2884	75	380	187	980	70.9	410	129.2	77	94.3
	Expander 25 - 2885	75	380	187	980	74.5	410	120.3	87	99.3
	Cooker 25 - 2850A	37	380	72	970	13.7	410	31.5	60	37
No. 3 Substation	31 - 2702 system					127.7	399	25.3	72	
	VE - 003 system					45.8	398	102.9	64	
	31 - 2701 system					17.9	400	55.5	50	
	23 - 2702 system					13.4	406	20.8	83	
	32 - 2701 system					22	405	38.3	86	
No. 4 Substation	43 - 2701					22.9	399	37.2	89	
	64 - 2701					48.8	391	74.8	79	
	54 - 2867/13					54.6	394	102.5	78	
	58 - 2701					29.7	398	60.3	69	
	57 - 2701					79	397	146.1	77	
	59 - 8701					36.5	398	60.4	86	
	Cooling tower pump	110	380			74.7	396	124	89	
	Fan of cooling tower	37	380			37.5	393	61.8	91	

8.2 Power Distribution

8.2.1 Transformer

(1) Transformer Capacity

Table 13–8

		No. 1 S.S.	No. 2 S.S.	No. 3 S.S.	No. 4 S.S.	Total
Present	Cap. of transformers (Measured)	1,000 kVA x 1	1,000 kVA x 2	1,000 kVA x 2	1,000 kVA x 1	6,000 kVA
		(79.2 kW)	(279.5 kW)	(226.8 kW)	(383.7 kW)	(969.2 kW)
No. 1 Plan		1,000 kVA x 1	1,000 kVA x 1	1,000 kVA x 1	1,000 kVA x 1	4,000 kVA
No. 2 Plan		200 kVA x 1	1,000 kVA x 1	1,000 kVA x 1	1,000 kVA x 1	3,200 kVA
No. 3 Plan		200 kVA x 1	1,000 kVA x 1	500 kVA x 1	1,000 kVA x 1	2,700 kVA

	Iron loss x 10^3 kWh/year	Copper loss x 10^3 kWh/year	Total x 10^3 kWh/year	Difference x 10^3 kWh/year
Present 6,000 kVA	157.7	34.9	192.6	0
No. 1 Plan 4,000 kVA	105.1	52.4	157.5	35.1
No. 2 Plan 3,200 kVA	84.0	66.5	150.5	42.1
No. 3 Plan 2,700 kVA	70.9	81.4	152.3	40.3

According to Table 13-5, the maximum values of the peak demand and the monthly mean power are 2,600 kW and 2,091 kW, respectively. Judging from these values, the transformer capacity of 1,000 kVA × 6 seems to be excessive. A typical example of the expected merit when the capacity is reduced, is shown in Table 13-8.

On the premise, it was calculated as 1,260 kW in the mean power, 85% in the power factor, 1,482 kVA in the apparent power, 6,820 h/year in the operating hours, 0.3% in the iron loss of the transformer and 1.4% in the copper loss.

The second scheme is the maximum loss reduction of 42 × 10^3 kWh/year but must purchase a transformer of 2,200 kVA (investment cost: ca.100,000 Bt). Accordingly the first scheme, which the loss reduction is 35.1 × 10^3 kWh/year), is advisability.

8.2.2 Power Distribution

From the one line diagram (Fig 13-7), it is known to be a very excellent distribution system.

(1) The 12 kV main circuit-breaker with 400 MVA of the breaking capacity is equipped at the combined point with the MEA.

(2) A high speed power fuse is equipped at the receiving points in the each substation to prevent a whole power failure at the time of trouble after the substation.

(3) Even when only one phase of the fuses is melted, the air circuit breaker in the transformer secondary side is cut off interlocking to the fuses to prevent motor single phase operation.

(4) Since a load center system, which feed a high pressure of 12 kV to the center area of load, is adopted, a voltage drop and a distribution loss are extremely small in the low pressure lines of the transformer downward.

(5) As a counterplan for improving power factor, the condensers equipped at the transformer secondary side in each substation are designed so that the switch is turned on and off depending on the load condition. If we are allowed to hope more, since a safety can be held substantially by only one set of the lightning rod in the fourth substation out of the four sets installed at the receiving points in each substation. And the rest three sets should be removed to store as the spare parts. Furthermore, since the overhead line toward the fourth substation is narrow spacing for a high pressure, some measures should be taken, for example an installation of large arm to the electric poles.

8.3 Power Application

8.3.1 Voltage

In Table 13-7, the measured values of the service voltage of the larger motors (110 kW to 75 kW) in the load side of each substation were higher of 398 to 410 V. Accordingly secondary side voltage should be lowered by changeover of the transtap. And it is necessary to confirm the change of power consumption and the temperature rising of motor. If the drop of 5% is possible, its expected merit is considered as follows; In a low loading, it is said that the loss of power in the power distribution line, the transformer and the motor can be reduced by about 2 to 3% through reducing voltage. If the merit is taken as 2% and the annual power consumption is taken as $8{,}620 \times 10^3$ kWh/year, the reduction of loss results in,

$8{,}620 \times 10^3$ kWh/year $\times$ 0.02 = 172.4×10^3 kWh/year

172.4×10^3 kWh/year $\times$ 1.45 Bt/kWh = 250,000 Bt/year.

8.3.2 Index Graph

The index graph of the peak demand, the load factor and the unit power consumption is repaired putting July 1982 as a base point as shown in Fig. 13-8. There are several considerable problems in the graph, they are as follows:

(1) Though the load factor is comparatively higher in the period of April to July 1982, the reverse tendency that the unit power consumption is larger is indicated.

(2) On the other hand, since January 1983, a better tendency is shown so that the unit power consumption lowers as rising of the load factor. But as the peak demand is slightly higher compared with the previous year, it seems to leave room for some reduction.

Thus, there are many points that must investigate. In order to solve them, it is necessary to collect and analyze the data over a long period with comparison of the conditions of raw material, product type, weather and so on. Since October 1982, the power consumption unit is stable in a better tendency with a low value and it is fine.

8.4 Others

8.4.1 Management of Operation and Maintenance

"In April and May 1983, the temperature of transformer went to higher but we have not its detail data," they said. So, the causes and the measures when the temperature being higher are described.

(1) The temperature standard value of transformer is as follows:

Oil temperature standard value

$$°C \leqq 40°C + (50 \sim 55°C)$$

Ambient Temp. Temp. rising limit

Accordingly the oil temperature should be confirmed again by a thermometer.

(2) The causes and the measures when the temperature is high.

(a) Check the difference of voltages in each phase of the transformer. The voltage difference disturbs the circulating current of oil.

(b) Check the difference of phase angle and % impedance in each transformer when two transformers are operated in parallel. If a difference exists, the load goes to unbalance. When the specifications of two transformers do not agree with each other, the transformers must not be operated in parallel.

(c) Check an exposure to direct sunlight.

(d) Check the ventilation in the transformer room. These items should be checked again.

9. Summary

The effect when the above measures are executed is as follows:

	Fuel oil equivalent kl/year	%
Reduction of boiler blow down water	1.8	0.1
Recovery of condensate	30.0	1.0
Insulation of steam valves	19.1	0.6
Utilization of waste heat of desolvent vapor	159.5	5.3
Heat recovery in deodorizing process	120.1	4.0
Subtotal	330.5	11.0

	10^3kWh/year	%
Reduction of transformers (the first scheme)	35.1	0.4
Lowering of motor service voltage	172.4	2.0
Subtotal	207.5	2.4

Report No. 14: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— The Unicord Investment (Thailand) Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— The Unicord Investment (Thailand) Co., Ltd. —

I. Outline of the Factory

Address	39/3 Satthakit Rd. Mo Thombolthasai Ampbhar Meang, Samuthsakorn	
Capital	60 Million Bt	
Type of industry	Food	
Major products	Tuna canning	
Annual product	Raw material : Tuna 18,000 ton, Sardine 10,000 ton	
No. of employees	900	
Annual energy consumption	Electric power	3,609,000 kWh
	Fuel	H.O.(A) 960 kℓ
Interviewees	Mr. Ronnie : Plant Manager, Director Mr. Santud : Engineering Department Chief	
Date of diagnosis	July 14 ~ 15, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

The factory produces canned tuna and canned sardine all to export.

The cold storehouse has the capacity of 2,000 tons for an arrival of the fish caught in the adjacent seas and the frozen fish caught in deep-seas.

In the factory, a can manufacturing equipment is provided to produce the whole quantity of the 7-ounce can.

The production peak is from April to June with operation even on Sundays. The average operating time is two shift with 8-hour service. In this operating condition, the tuna of 55 t/day and the sardine of 30 t/day (15 days/month) are treated.

Most of works are done by hand. Elimination of head, tail, bone, internal organs, skin, etc., and separation of white and red meals are job of female workers. Male workers are engaged in the jobs of cooking and handling. The number of male workers is only less than 10% of the whole 900 workers.

2. Manufacturing Process

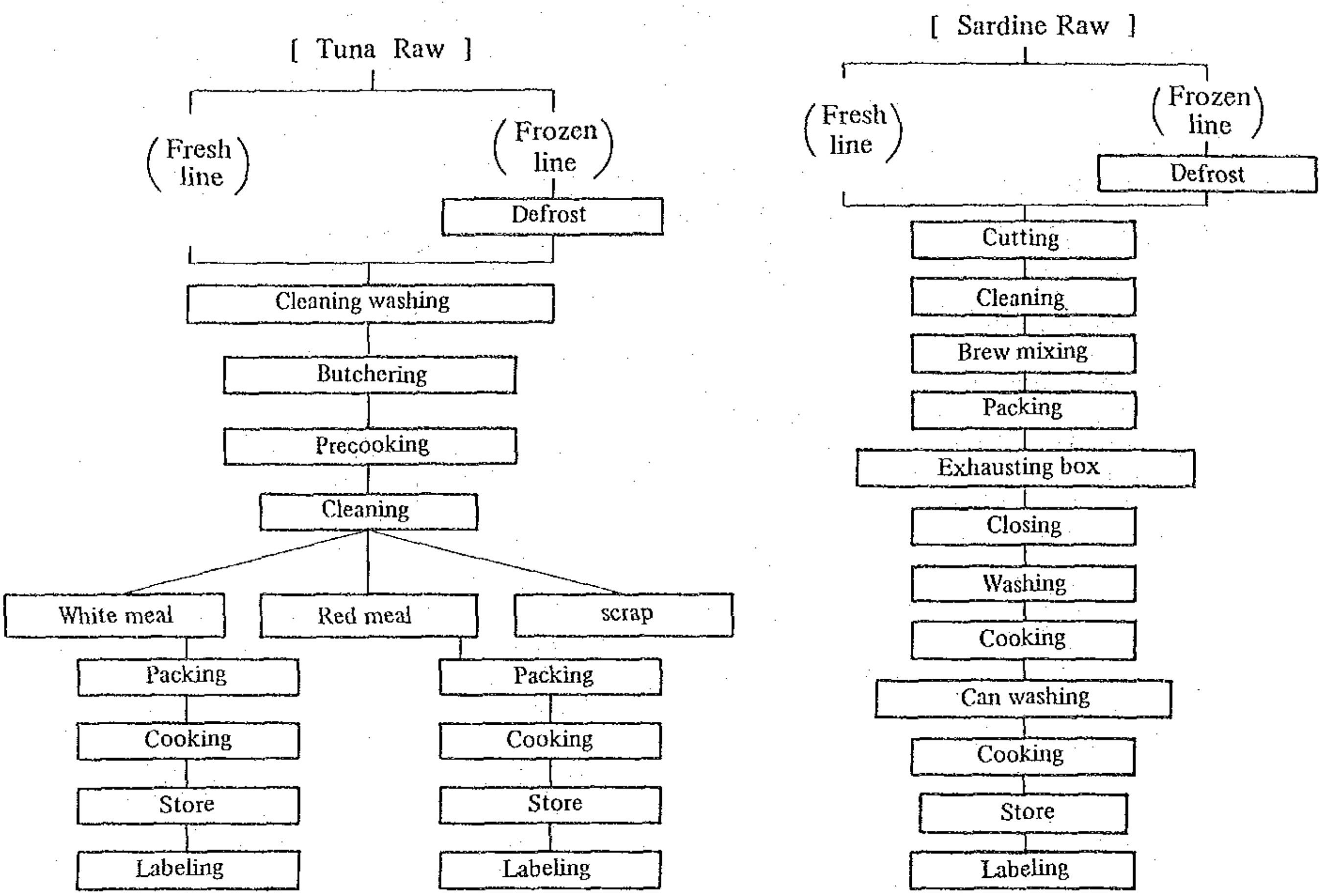


Fig. 14–1

3. Major Equipment

3.1 Major Equipment

Table 14–1

Name	No. of units installed	Type, etc.
Boiler	2	Fire tube boiler, pressure 8 kg/cm^2 capacity 4 t/h
Precooker	7	1.25 m(W) x 1.73 m(H) x 4.15 m(L)
Retort	7	1.25 m(ϕ) x 6.0 m(L)
Refrigerator		

3.2 Layout

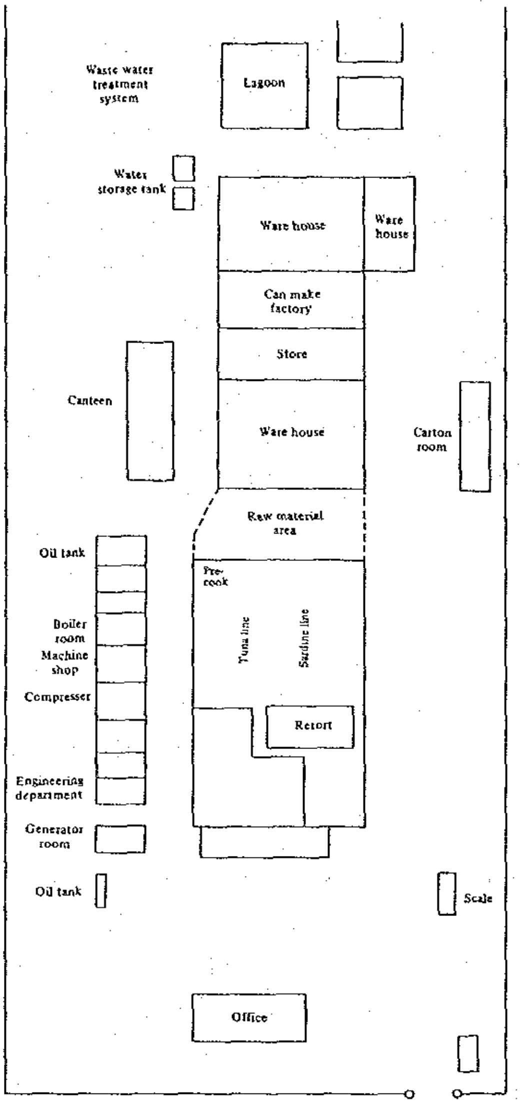


Fig. 14–2

4. State of Energy Management

4.1 Policy of the Management

The improvement of productivity and the attainment of energy conservation are mentioned as the target of the factory. A concrete plan concerning the energy conservation is not established, but interest is growing with a control of the energy cost of 800,000 Bt/ month (3% of the whole cost).

The investment for energy conservation in this year has been budgeted with 40,000 Bt to the equipment in order to recover heat of boiler exhaust gas as hot water.

The technical department is divided into two departments of production and engineering, and all of the technical data are aggregated in the engineering department. This engineering department should be completed as a department having not only the function of a mere data collection but also a preparation of the management index and a function of the process analysis.

4.2 Participation by All Employees

The plant manager has appealed directly or by means of posters, the observation of the operation standard, safety, cleaning and energy conservation, etc., to all the employees in order to drive fully the management policy. However, any committee or a project team for energy conservation has not been organized. Although a suggestion system exists, the system now operates in low tones. The education to the employees has been carried out in the training by the outsider. And the employees have been dispatched to a technical training courses and study visits to other factories in three or four times a year.

As 90% of the employees are women, the cost and the quality of the products are controlled by their working attitude. It is desirable to introduce small group activity (QC circle, etc.) for the education of the woman employees. This technique is recommendable to be introduced by all means because a large fruit is obtainable for improvement of the quality and the efficiency.

4.3 Control through Data

It is very good that all data in the factory are collected in the engineering department. However, these data are not put to practical use for improvement of process, yield and consumption rate. The persons in charge of the engineering have an ability for data analysis, but its actual state is in a shortage of hands.

4.4 Education and Training for Leveling-Up of Employees

Since all of the products are exported, the FDA Standard in U.S. is introduced as the quality standard. Under the agreement for the manufacturing technique with a certain U.S. company, an engineer stayed for proper guidance for one year.

The manufacturing technique is established in outline and the quality is kept. The next step should be taken to improve the productivity. Without activity of the engineering department it is beyond attainment to improve the productivity.

Before everything, a repletion of the engineering department should be arranged and then the quality of products, the productivity and the consumption rates should be enhanced step by step with a repletion of the engineering department and a technical improvement of the employees through a small group activity.

5. State of Fuel Consumption

Fuel oil A 960 kl/year — Fuel for boiler

Breakdown:

- Tuna
  - 25% (Precooker) (240 kl)
  - 45% (Retort) (432 kl)
  - 6% (Seasoning solution tank) (58 kl)
- Sardine
  - 5% (Exhaust box) (48 kl)
  - 4% (Seasoning solution tank, Seamer and hot water tank) (38 kl)
  - 15% (Retort) (144 kl)

Diesel oil		112 kl/year	For forklift
Others	Kerosine	4 kl/year	
	Gasoline	15 kl/year	
	LPG	9.6 kl/year	For soldered can

Dividing the steam into the applications.

Steam ┬ Preheat (30%)
├ Sterilization (60%)
├ Hot water (5%)
└ Mixing, etc. (5%)

Fuel consumption rate

For the peroid from January to March 1983, the actual consumption of fuel oil was 193.7 kl, and the production of canned tuna and canned sardine were 3,036 tons and 1,001 tons respectively, with the total of 4,037 tons. Accordingly, the fuel consumption rate resulted in 48 l/ product ton.

5.2 Heat Balance of Boiler

The heat balance was calculated from the actual data of boiler in July 14, 1983. It is as shown in Table 14-2.

Table 14—2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	1,270.5	99.8	Heat of steam	1,099.9	86.4
Sensible heat of fuel	2.2	0.2	Heat loss in exhaust gas	110.0	8.6
			Heat loss in blow water	28.9	2.3
			Heat release from boiler body, others	33.9	2.7
Total	1,272.7	100.0	Total	1,272.7	100.0

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil A
Fuel consumption	(F)	132.0 kg/h
Heating value of fuel (low value)	(Hl)	9,625 kcal/kg
Specific gravity of fuel	(SG)	0.975
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	72°C
Reference temperature	(To)	35°C
Oxygen content in exhaust gas	(O_2)	4.4%
Temperature of exhaust gas	(Tg)	223°C
Quantity of blow down water	(B)	240 kg/h
Temperature of blow down water	(Tb)	164.7°C

Quantity of feed water	(W)	2,001 kg/h
Temperature of feed water	(Tw)	35°C
Steam pressure	(P)	6.1 kg/cm^2G
Quantity of steam (S = W − B)	(S)	1,761 kg/h
Enthalpy of steam	(Es)	659.6 kcal/kg
Enthalpy of feed water	(Ef)	35 kcal/kg

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) $1,270.5 \times 10^3$ kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 2.2×10^3 kcal/h

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

Output

Heat of steam (Qv) $1,099.9 \times 10^3$ kcal/h

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

Heat loss in exhaust gas (Qe) 110.0×10^3 kcal/h

$Qe = F \times G \times 0.33\,(Tg - To)$

Theoretical amount of air (Ao)

$Ao = 0.85\ Hl/1,000 + 2.0 = 10.18\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\ Hl/1,000 = 10.68\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.27$

Actual amount of exhaust gas (G)

$G = Go + Ao\,(m - 1) = 13.43\ Nm^3/kg$

Heat loss in blow down water (Qb) 28.9×10^3 kcal/h

$Qb = B \times (Tb - Tw)$

Heat release from furnace body and others (Qr) 48.3×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Insulation of Precooker

Six precookers of the total seven were finished with a silver color paint but not insulated. A portable type fan was located in the front of the cookers in order to cool the product cooked. A breath of air is caused around the cookers. Accordingly, it gave a larger heat loss of the cookers.

The heating hour of the precookers was set up according to variety of fish or size with a fine control. The quantity of heat loss from the cookers fluctuated depending on the operating condition. But, the surface temperature was 90°C and the measured heat flux was 1,075 $Kcal/m^2h$ at the time of the diagnosis.

An average heat loss during the heating hour is taken as half of the measured heat flux and the dimensions of precooker taken as 1.25 m in the width, 1.73 m in the height, 4.15 m in the length and 29.0 m^2 in the surface area, and the operating hour per day as five hours, the quantity of heat loss in the six precookers is as follows:

$29\ m^2 \times 6 \times 1.075 \times 0.5 \times 5\ hrs = 467.6 \times 10^3 kcal/day$

Converted the quantity of heat loss per year to the equivalent amount of fuel oil A, it is as follows:

$467.6 \times 10^3 \times 320/(9,625 \times 0.864 \times 0.975) = 18.5\ kl/year$

If the heat loss can be reduced by 80% through the insulation of glass wool of 30mm and aluminum sheet cover, the saved amount of fuel oil is as follows:

$18.5 \times 0.80 = 14.8\ kl/year$

Energy conservation rate: $14.8/960 \times 100 = 1.5\%$

If the price of fuel oil A is taken as 4.32 Bt/l, the saving cost results in 63,936 Bt/year. The insulating cost is estimated as 174,000 Bt, the cost can be recovered in 2.7 years.

The No.4 precooker has a large amount of steam leakage due to a defective packing in the door. Repair is required.

6.2 Insulation of Retort

All the dish plates of 1.25m in the diameter located in the front and the rear of the seven retorts were not insulated. In the conditions of 110°C in the surface temperature and 34°C in the room temperature, 1,135 kcal/m²h in the measured heat flux and 7.6 h/day in the operating hour, the quantity of heat loss per day results in the following.

$1.23\ m^2 \times 2 \times 7 \times 1,135 \times 7.6 = 148.5 \times 10^3\ kcal/day$

Let the operating days per year be 320 days, converted this quantity to the equivalent amount of fuel oil A, it is as follows:

$148.5 \times 10^3 \times 320/(9,625 \times 0.864 \times 0.975) = 5.9\ Kl/year$

If the heat loss of 80% is preserved through insulation of a glass wool of 30mm and an aluminum sheet, the reducing consumption of fuel oil is as follows:

$5.9\ kl/year \times 0.8 = 4.7\ kl/year$

Energy conservation rate: $4.7/960 \times 100 = 0.5\%$

If the price of fuel oil A is taken as 4.32 Bt/l, the saving cost results in 20,300 Bt/year. As the insulating cost expense is estimated as 17,150 Bt, the cost can be recovered in 0.67 years.

6.3 Boiler Waste Heat Recovery

The seven tons capacity boiler of the two boilers is equipped with an economizer and the recovered hot water is utilized for cleaning of the can. But this boiler is now out of operation. While, the four tons capacity boiler has not an economizer. Thus the economizer equipped is not utilized effectively, so that the temperature of feed water to the boiler is low of 35°C. The temperature of exhaust gas is 223°C. If the waste heat is recovered through an economizer similar to the seven tons capacity boiler, the temperature of exhaust gas is expected to be lowered to 200°C.

The recovered quantity of heat calculatd from the boiler heat balance is $110 \times 10^3 \times (223-200)/(223-35) = 13.5 \times 10^3\ kcal/h$. When the recovery heat is utilized to preheating of the feed water, the energy conservation rate is as follows:

$13.5 \times 10^3/(1,272.7 \times 10^3) \times 100 = 1.1\%$

Converted it to the equivalent amount of fuel oil;

960 × 0.011 = 10.6 kl/year

6.4 Insulation of Steam Pipe and Valve

The six 6″ valves in the boiler room are not insulated. The 6″ pipe passing over the boiler is also bare in length of about 6 m. These places not insulated are shown in Table 14-3.

The equivalent pipe length for the no-insulated pipings, except the valves smaller than 1 1/2″, and the quantity of heat loss are as shown in Table 14-4.

If the quantity of heat loss of 90% is reduced through insulation with 50 mm thickness of a glass fiber and an aluminum sheet to the valves larger than 2″ and the bare pipes, the reduced consumption of fuel oil is as follows:

Table 14–3

Room	Stop valve			Control valve			Flange			Bare pipe (m)
	Dia (inch)	No.	Equivalent length of bare pipe (m)	Dia (inch)	No.	Equivalent length of bare pipe (m)	Dia (inch)	No.	Equivalent length of bare pipe (m)	
Boiler	6	5	7.5							6
Sardine Room	4	1	1.3				4	2	0.8	
Tuna Room	4	1	3.9				4	1	0.4	
	4	2					4	2	0.8	2
Cooker (Retort)	4									20
	1½	28	31							140m
	1	28	34	1	7	13				
Exhaust Box	1½	1	1.1							1
	1	4	5							1
Precooker	2	1	1.1							22
	1	14	17	1	7	13				10.5

Table 14–4 Heat release from valve and pipe

	Equivalent length (m)	Unit heat release kcal/m.h	Heat release kcal/h
6″	13.5	900	12,150
4″	29.2	625	18,250
2″	23.1	330	7,623
1½″	141.0	260	36,660
1″	11.5	200	2,300
Total			76,983

$$\frac{76{,}983 \text{ kcal/h} \times 16 \text{ h} \times 320 \text{ days} \times 0.9}{9{,}625 \times 0.864 \times 0.975} = 43.8 \text{ kl/year}$$

This amount is related to the cost reduction of 43.8 kl/year × 4.32 Bt/l × 10^3 = 189,200 Bt/year.

Energy conservation rate: 43.8/960 × 100 = 4.6%

While the cost for the insulation is according to Table 14-5.

Table 14-5 Cost of Insulation

Item	Area (m^2)	Price per area (Bt/m^2)	Cost (Bt)
Glass fiber blanket	37.76	182	6,872
Aluminium sheet	37.76	268	10,120
Valve cover	15 (Unit)	105 (Bt/unit)	1,575
Field work charge	37.76	300	11,328
Total cost			29,895

The insulation cost is possible to be amortized in two months through the reduction cost of fuel oil. It is known that the energy conservation effet is larger. The existing insulating materials damaged, cracked and wetted are found in many places. The insulation in this condition does hardly fill its function. These insulations should be repaired with a fine investigation.

6.5 Leak Prevention of the Valves for Steam in Boiler Room

The valve in the connecting pipe between the No.1 and No.2 boiler is improper. The 6" pipe has a steam leakage corresponding to 1 mm of a hole in diameter. This leakage is heating the pipe for the No.2 boiler not used. The loss quantity based on the steam leakage of 6 kg/cm^2 from a hole of 1 mm is approximately 3 kg/h of dry saturated steam. Therefore, the heat loss is 659.5 kcal/kg × 3 kg/h = 1,978.5 kcal/h. When the leaking is stopped by repair of the valve, its energy conservation rate is as follows from the boiler heat balance;

$1,978.5/(1,272.7 \times 10^3) \times 100 = 0.16\%$

Quantity of energy conservation (as fuel oil):

960 kl/year × 0.16% = 1.5 kl/year

6.6 Sterilization

The reduction of the consumption rate of steam for the sterilization in the retort is the key point of energy consumption for this factory. As air in the retort counteracts the heat transfer, the air must be quickly expelled to allow the heat of blown-in steam to contribute effectually for sterilization.

The specific gravity of air is approximately 1.6 times of that of steam. As the temperature rising of air is slower in the condition blown-in steam into the retort, its difference of specific gravities is increased. Therefore, it is theoretical to blow-in steam from the upper and to expel air from the bottom. But, in Thailand it has been practically done to blow-in steam from the bottom and to expel air from the upper. When the material are packed fully in the retort where the gas flows in turbulence, this may not go theoreticaly. However, a more quick temperature rising way or a much more better operating technique should be investigated. For this matter, the investigation must be pushed forward with a team formation composed of the operator and the persons in charge of manufacturing and quality control. Fig.14-3 is the improved case in Japan.

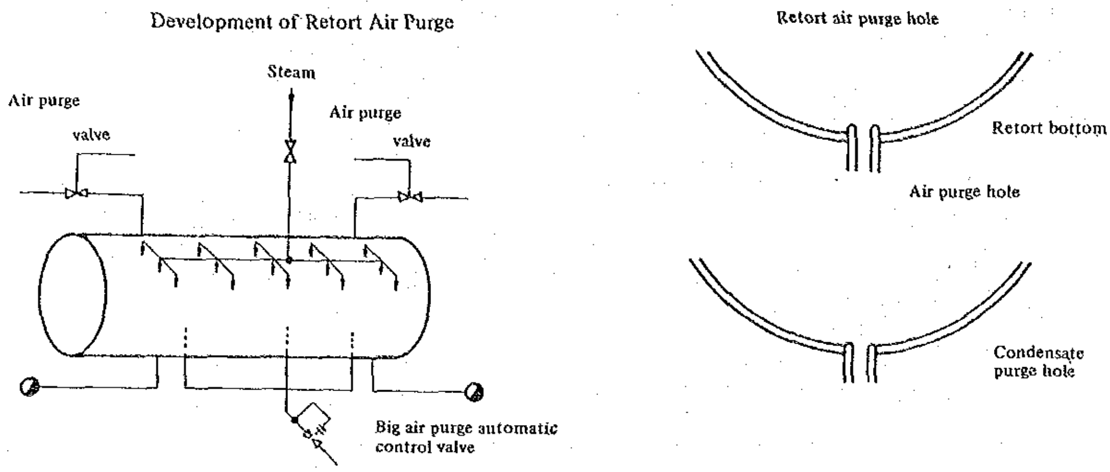


Fig. 14-3

A distribution pipe was installed in the retort as shown in Fig.14-3. The distribution pipe was arranged with many holes of 6 mm diameter so that steam diffuses slowly and thoroughly from the upper toward the bottom. If much steam flows into even one space, steam is mixed with air to counteract the expelling effect of air. And also a punching metal was placed in the spaces where air stays for easy flow of air.

The capacity of this retort was 5 m^3. The above modification reduced the air purge time, the temperature rising time by seven minutes and improved the turnover of retort. The steam blow-off quantity was reduced by about 20%. Although the investment cost was paid to install (a) the steam distributor and (b) the three air vent valves and (c) the installation of the punching metal, this cost was recovered in eight months through the reduction of steam consumption.

In the light of the above case, the energy conservation should be attained with a re-investigation of the sterilization to contribute the cost reduction.

Expected effect: (432 + 144)kl/year × 0.2 = 115.2 kl/year

Energy conservation rate: 115.2/960 × 100 = 12.0%

6.7 Utilization of Hot Water in Retort

Now, the cooling water filled in the retort after sterilization is discarded as hot waste water of a temeprature of 50 to 60° C.

As application of this hot water, it is considerable to use for defrost of the frozen fishes. As shown in the predescribed improved plan, when steam is blown-in from the upper of the retort and air is expelled from the bottom, most of dirt in the retort can be removed and the waste hot water also becomes clean substantially. Consequently the waste hot water may be used to many application such as cleaning of the vessels or containers. At present, the steam used for hot water is 5% of the whole quantity of steam. This should be investigated because of reduction of the quantity of steam.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	PEA
Peak Demand	:	888 kW (May 1983)
Power Consumption	:	$3{,}609 \times 10^3$ kWh/year (1982)
Load Factor	:	Estimated, more than 85% (1982)
Penalty Fee	:	No
Power Factor	:	80 to 97%, Monthly power factor
Transformer	:	3φ, 800 kVA × 2
Final Power Cost	:	Annual average, 1.76 Bt/kWh

7.2 One Line Diagram

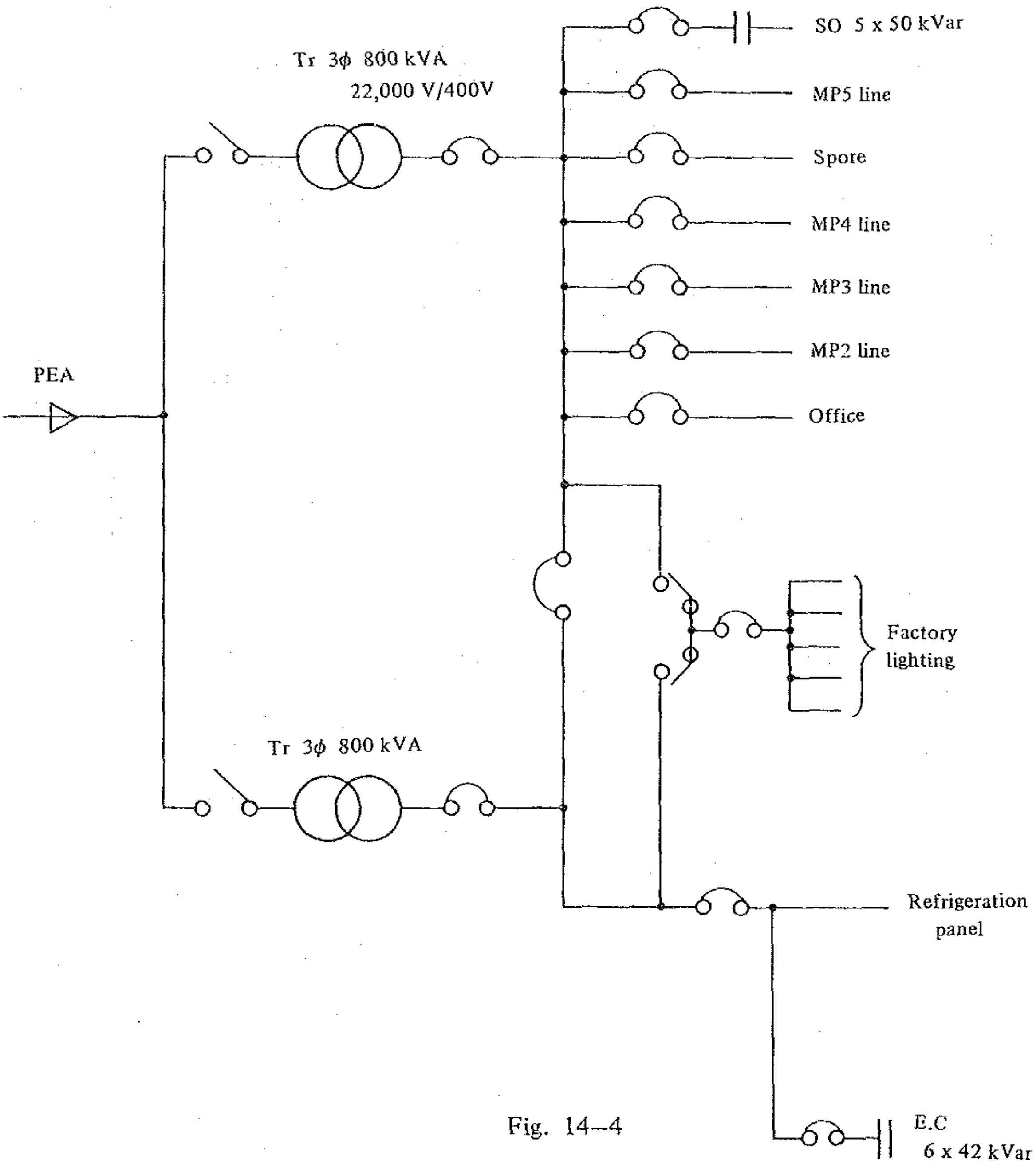


Fig. 14-4

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 14–6 Monthly Power Consumption

Month	Power consumption kWh	Maximum demand power kW
1 / 82	253,544	680
2	299,496	800
3	294,744	728
4	345,160	720
5	312,496	744
6	315,720	768
7	339,728	768
8	333,176	768
9	205,000	832
10	322,808	704
11	320,912	760
12	265,856	712
1 / 83	293,160	760
2	316,824	768
3	360,176	840
4	369,264	808
5	448,848	888
6	408,856	888

Average power per year $\frac{3{,}609 \times 10^3 \text{ kWh}}{8{,}760} = 412\text{kW}$ (1982)

7.3.2 Monthly Load Curve

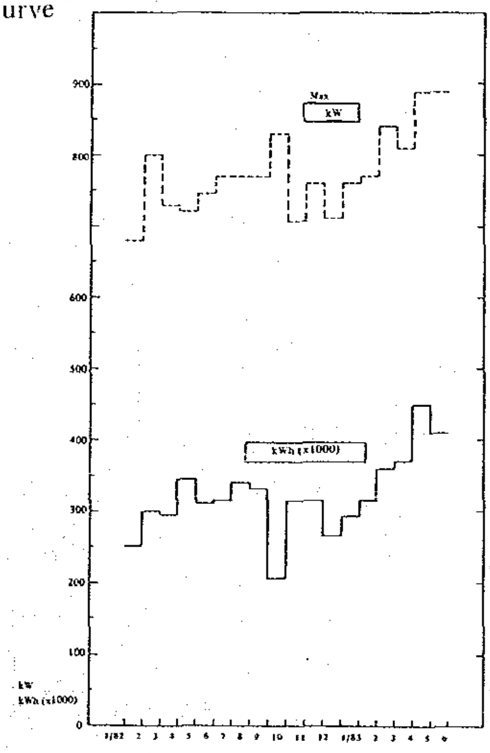


Fig. 14–5

7.3.3 Hourly Power Consumption

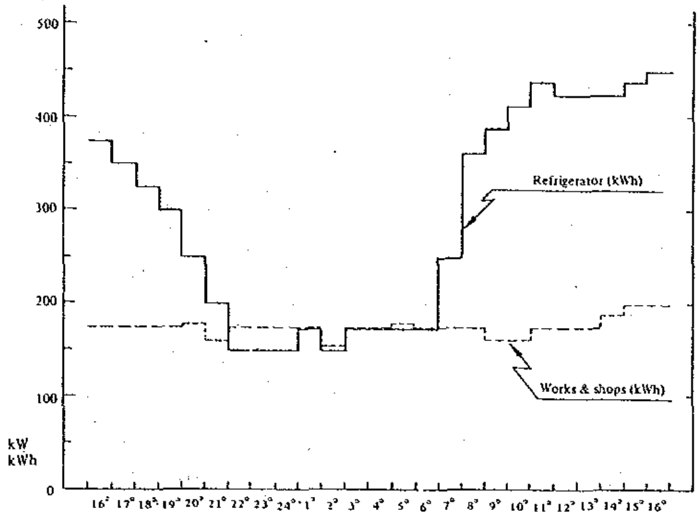


Fig. 14–6 Hourly Load Curve

Table 14–7 Hourly Power Consumption

14 ~ 15 July

Time	Works-shops kWh	Refrigerator kWh
16.00	175	375
17.00	175	350
18.00	175	325
19.00	175	300
20.00	180	250
21.00	160	200
22.00	175	150
23.00	175	150
24.00	175	150
1.00	175	175
2.00	150	150
3.00	175	175
4.00	175	175
5.00	180	175
6.00	175	175
7.00	175	250
8.00	175	363
9.00	163	388
10.00	163	413
11.00	175	438
12.00	175	425
13.00	175	425
14.00	188	425
15.00	200	438
16.00	200	450
Total		7,290 kWh/day

Average power for refrigerator $\frac{7{,}290\ \text{kWh}}{24\ \text{h}} = 303\ \text{kW}$

7.3.4 Power Consumption of Refrigerator

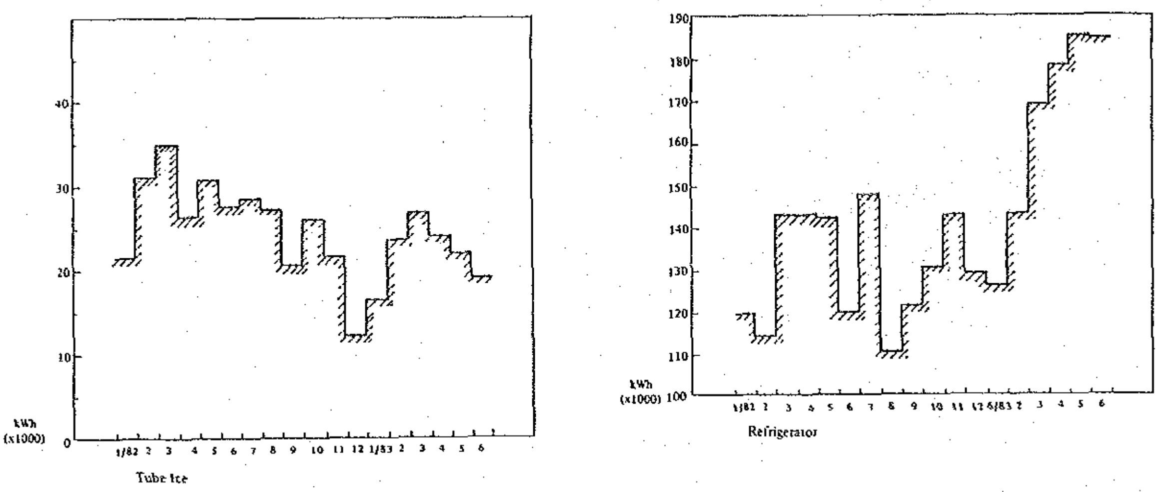


Fig. 14–7 Monthly Load Curve for Refrigerator

Table 14–8 Power Consumption for Refrigerator

Month	Refrigerator kWh	Tube ice kWh
1 / 82	119,688	21,600
2	114,024	31,242
3	143,256	35,004
4	143,088	36,382
5	142,869	30,819
6	119,604	27,417
7	147,756	28,722
8	110,088	27,239
9	121,460	20,682
10	130,536	26,202
11	142,820	21,546
12	129,192	12,318
1 / 83	126,168	16,374
2	143,496	23,640
3	168,936	26,790
4	178,176	23,982
5	185,304	21,792
6	184,824	19,146

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 14–9

14, 15 July

	Name plate				Measurement			
	kVA	kVar	P. Volt	S. Volt	kW	Volt	A	P.F %
Transformer for refrigerator	800		22,000	400	420	403	634	97
Transformer for works	800		22,000	400	370	395	630 ~ 690	80

	Name Plate			Measurement			P.F %	L.F %
	kW	V	A	kW	V	A		
Refrigerator	200	380	355	189.8	401	209.4	91	94.9
Refrigerator	200	380	355	83.5	401	149.5	80	41.75
Refrigerator	90	380	167	62.1	401	103.9	84	69.0
Deep well	22	380	45	14.4	384	24.2	89	65.0
Deep well	22	380	45	18.4	388	31.8	88	83.6
Water treatment WT_1	15	380	29	5.8	359	17.2	55	38.8
Water treatment WT_2	15	380	29	5.8	360	17.7	55	38.8
Water treatment WT_3	11	380	21	6.0	360	17.6	55	54.4
Water treatment WT_4	22	380	45	6.4	360	18.3	57	29.3
Boiler B_1	15	380	29	13.2	394	23.1	84	88.2

8.2 Power Distribution

8.2.1 Power Distribution

(1) Distribution System

According to the one line diagram shown in Fig.14-4, the two transformers are divided usually into the refrigerator system and the other factory system. This distribution system is designed in a good system which an individual corrective treatment is possible for trouble.

But according to the measured values shown in Table 14-9, since the secondary voltage difference of the both is about 2%, the both secondary voltages should be equalled by re-checking of the primary tap in the transformer in order to turn into a possibility of parallel operation of the both systems for emergency.

(2) Current Balance, Power Factor and Transformer Capacity

According to the measured values, the current in each phase of the transformer for the other factory system is 630 to 690 A with difference of 60 A. The cause of imbalance seems to be caused by lighting and air-conditioning equipments. Viewed from the power loss caused by reverse direction component due to imbalanced current, each single phase equipment should be connected with well-balance. The transformers capacity seems to be no problem because of the power of the systems is respectively 450 kW and 200 kW with 80% to 97% power factor.

8.3 Power Application

8.3.1 Voltage

As shown in Table 14-9, not large drop is found in the interval from the transformers to the motors excepted some of the water treating equipment. Therefore, the problems will be described with two divisions as shown in the following.

(1) Countermeasure for Voltage Drop of Water Treating Equipment

The total capacity is 63 kW with the four equipment. The actual load is around 24 kW but the service voltage is 360 V (despite of the service voltage of other motors in the same transformer system being 384 to 394 V). Its causes are considerable as follows:

(a) The single-core cable size 50 mm^2 may be good but the distribution distance of 350 m is too much longer.

(b) The distance of each single-core cable is larger (more than 100 mm) and the reactance is increased.

Countermeasures for them are as follows:

(a) Change to other line with a shorter distribution distance or a small voltage drop.

(b) Take reduction of the reactance with alternating the relative position of each single-core cable in the low-tension distribution line.

(c) Shorten the spacing of the single-core cables and combine like the three-core cables.

With the above examination, the voltage drop should be in the same degree as other lines.

(2) Reduction Measure of Service Voltage

According to Table 14-9 in the transformer system for the refrigerator, the voltage drop is small and the terminal voltage at the motor is 401 V. Accordingly, the secondary voltage is better to come down 380 V through changeover of the transformer tap. In this case, it is necessary to confirm the change of power consumption and the temperature rising. If the drop of 5% is possible, its expected merit is considerable as the following.

In light load, it is said that the power loss in the transformer, distribution line and the motor can be reduced by about 2 to 3% through lowering of voltage. If the merit is taken as 2%, the power consumption per year in the refrigerator taken as 1,564,381 kWh/year and the unit price of power taken as 1.45 Bt/kWh, its merit is as follows.

$1{,}564 \times 10^3$ kWh/year $\times 0.02 = 31.3 \times 10^3$ kWh/year

31.3×10^3 kWh/year $\times$ 1.45 Bt/kWh = 45,400 Bt/year

8.3.2 Refrigerator

According to Table 14-8 and Fig. 14-7, the power consumption in the refrigerator have had a tendency to increase since March, 1983 and especially on May and June the average was 185×10^3kWh/month. This becomes $2{,}220 \times 10^3$kWh/year in the annual estimation. These values were the increase of about 42% to the values in 1982; 130×10^3kWh/month and 1.564×10^3kWh/year in 1982.

And then, a general countermeasure for the energy consumption of the refrigerator is described below.

(1) If the pressure in the discharge side of compressor can be lowered by 1 kg/cm^2, the power consumption is reduced by about 7%.

(2) If an oil sludge is sticked with 0.1mm in the pipe of the cooling oil system, this becomes equal to an increase of about 40mm in the thickness of pipe. Consequently, the cooling effect decreases.

(3) If any deposit is sticked on the pipe surface of cooling water for oil cooling, this becomes equal to an increase of about 40mm in the thickness of pipe. Consequently, the cooling effect decreases.

The temperature difference of the outlet and the inlet of cooling water is within about 10°C as a standard. When any deposit is sticked on the pipe surface, the temperature difference becomes small. Care must be taken not to attach deposit and to decrease the temperature difference.

Next, the energy conservation of the refrigerator in the factory will be described in the concrete.

(1) There is a gap around the door of the refrigerating chamber and icing is found on the floor of passageway. A cold air seem to leak from the refrigerating chamber. In this situation, the circulating quantity of refrigerant increases and so the power consumption of compressor also increases. If the power loss taken as 10%, when the cold loss due to leakage of cold air from the refrigerating chamber is taken as 30%, the expected merit by a prevention of the leakage is as shown in Table 14-10.

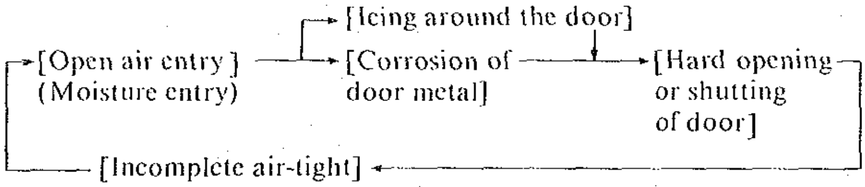
Table 14–10

Refrigerator	Rated	Actual in-put	Working hours for one year	Estimated saving power
	kW	kW	h	10^3 kWh/year
No. 1	90	61	8,760	53.4
No. 2	200	74	4,380	32.4
No. 3	200	156	8,760	136.7
Total				222.5

The cost saved is as follows:

222.5×10^3 kWh/year $\times$ 1.45 Bt/kWh = 320,400 Bt/year

Then, the cause of the cold air leakage appears to be the following vicious circle.



Accordingly it is most important to restore the airtight degree of the refrigerator's door to the original state.

(2) Cold Air Circulation in Refrigerating Chamber

On that day, icing is found accidentally on the blow-off port located in the front of circulating fan. In this condition, the area of blow-off port becomes narrow and the quantity of circulating cold air in the refrigerating chamber is decreased to cause a decline of the whole refrigerating effect.

On this condition it proceeds to a state lowering of the refrigerant temperature in the surge drum. When the temperature of refrigerant in the surge drum falls by 1°C (−35°C → −36°C), the load of No.1 refrigerator 90 kW increases by 3%. If it is possible to rise the temperature by 2°C from −35°C to −33°C, the load of compressor is reduced by 6% and the power loss can be reduced by about 2%.

$61\ kW \times 0.02 \times 8{,}760\ h/year = 10.7 \times 10^3\ kWh/year$

$10.7 \times 10^3\ kWh/year \times 1.45\ Bt/kWh = 15{,}500\ Bt/year$

Accordingly the air-tight of the door of the refrigerating chamber should be carried out strictly in order to prevent icing.

(3) The temperature of cooling water fed from the cooling tower to the condensor should be checked whether the temperature is higher than the initial.

The causes of temperature rising of the cooling water may be in a performance decline of the cooling tower in addition to the seasonal factor. That is, it is a poor atomization state of the nozzles in the cooling tower such as a short flow rate due to plugging of the nozzles or a declining of the cooling effect through enlargement of a water drop due to corrosion of the nozzles. These matters should be checked.

If the temperature of cooling water falls by 1°C, the load of No.3 refrigerator of 200 kW can be reduced by 2%. And the power loss may be reduced by about 0.7%. The expected merit is as follows:

$156\ kW \times 0.007 \times 8{,}760\ h/year \doteqdot 9.6 \times 10^3 kWh/year$

$9.6 \times 10^3 kWh \times 1.45\ Bt/kWh = 13{,}900\ Bt/year$

(4) For the condenser, caution should be paid in cleaning of any dirt on the exterior surface. No good maintenance and arrangement makes the refrigerant to condense insufficiently. Then if good cleaning and maintenance allows the condensating temperature to fall by 1°C, the load in No.3 refrigerator of 200 kW can be reduced by 2.5%. Accordingly the power loss is reduced by about 0.8%. The expected merit is as follows:

$156\ kW \times 0.008 \times 8{,}760\ h/year \doteqdot 10.9 \times 10^3\ kWh/year$

$10.9 \times 10^3\ kWh/year \times 1.45\ Bt/kWh = 15{,}800\ Bt/year$

The cleaning to the exterior surface should be carried out periodically and sufficiently

(5) The increase of the power consumption in the refrigerator may be considered by the following causes in addition to the above.

(a) Dirt on the heat transfer surface of refrigerant in the condenser.

(b) Dirt on the heat transfer surface of refrigerant in the radiator.

(c) Leakage of refrigerant in the system.

(d) Increasing of the inner circulating quantity due to a defective seal in the compressor.

These matters should be re-checked. The extremely higher discharge temperature of No.1 compressor may be affected by these causes.

(6) P-I Chart

The operating state of this refrigerator was tried to put on the P-I chart, but the state could not be described firmly by error of the indication of the pressure gauge and the thermometer.

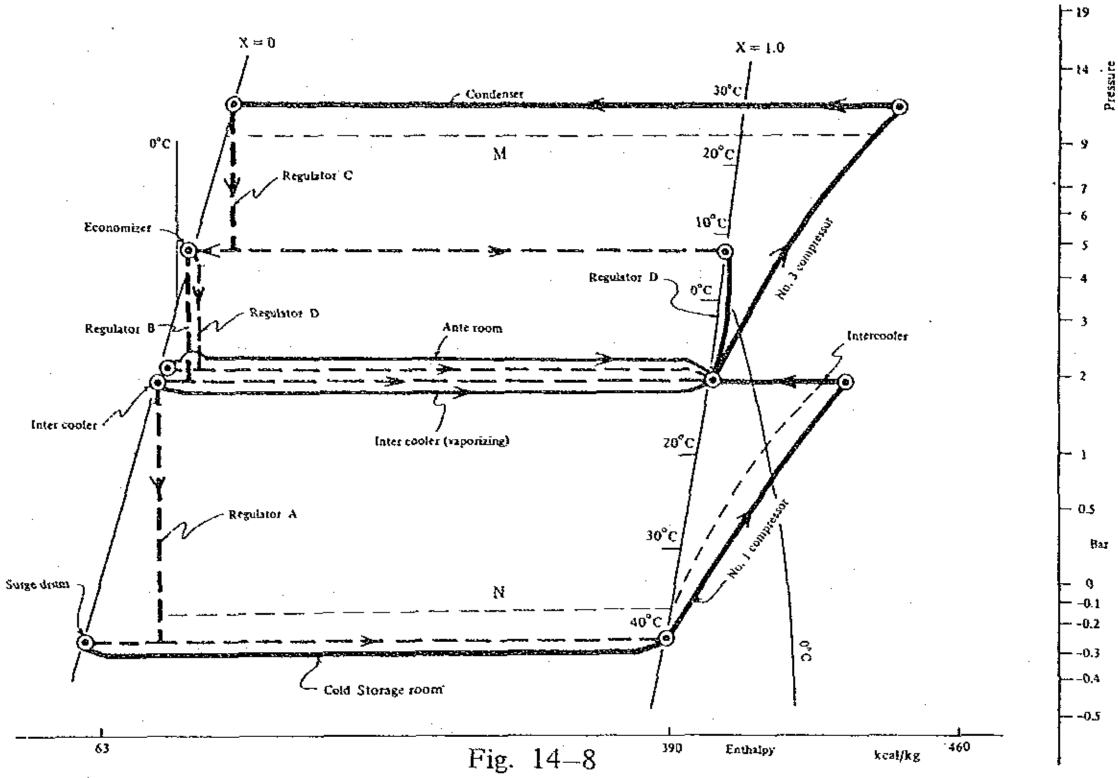


Fig. 14–8

For example, the discharge temperature of No.1 compressor should be around 30°C. The pressure in the discharge side of No.3 compressor has been indicated excessively high or the temperature has been indicated as a low one. With checking of pressure gauge and the thermometer, the P-I chart indicated with the actual operating state should be prepared to compare with the initial chart. However, the P-I chart described tentatively is as shown in Fig.14-8.

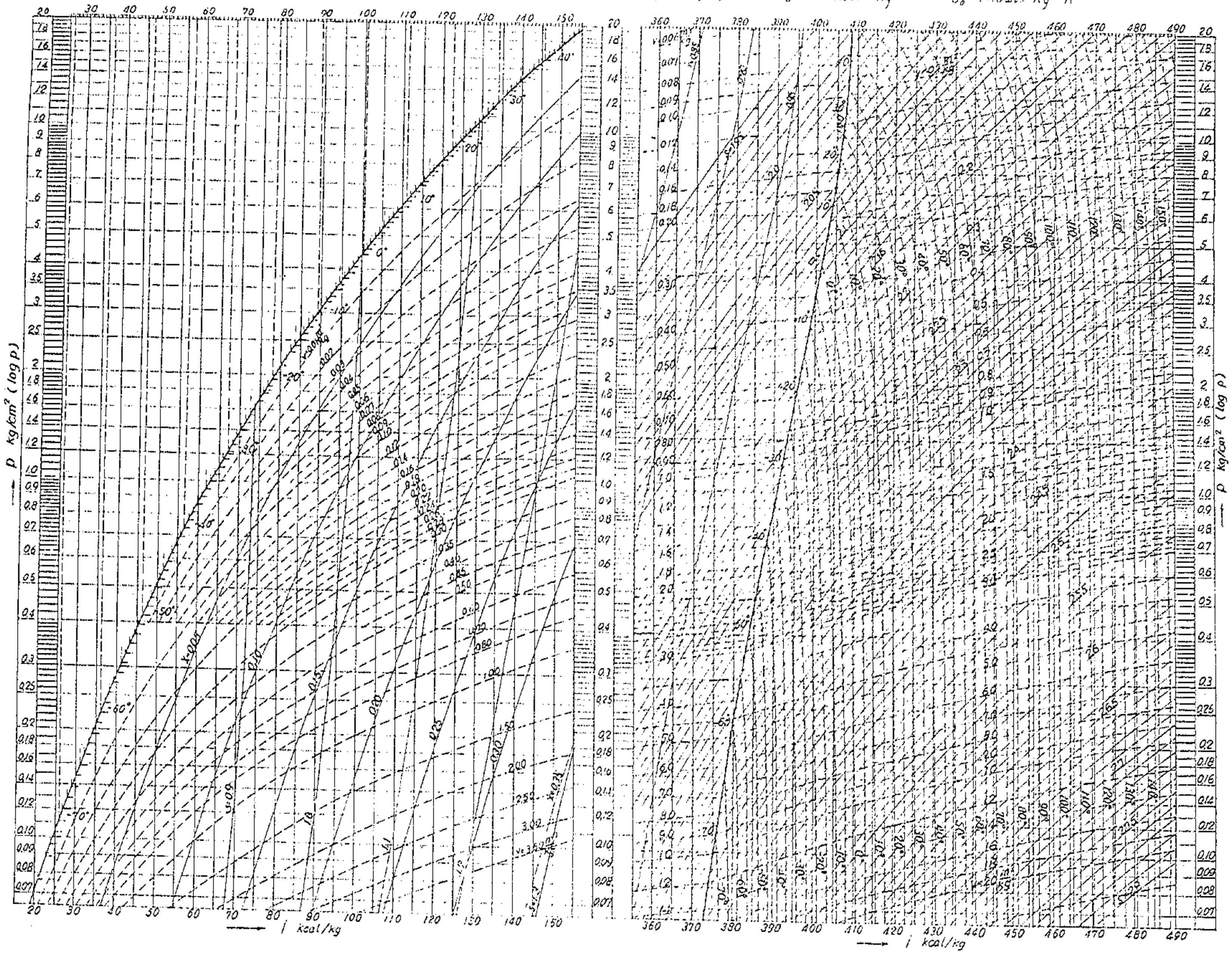
(a) As shown in the arrow M, when the refrigerant temperature in the outlet of the condenser is higher, the causes are of the previous paragraph (1), (3), (4), (1)-(a) and (5)-(b).

(b) As shown in the arrow N, when the refrigerant temperature in the surge drum is lower, the causes are of the previous paragraph , (5)-(b) and (5)-(c).

The power consumption of the refrigerator and its relative equipment occupies about 52% of the whole power consumption and many data have been recorded every day.

Accordingly, if the various energy data during the past four years are investigated carefully in comparison with the arrival quantity and classification of raw material, or atomospheric temperature, much better information will be obtainable.

Fig. 14–9 Mollier Diagram for Ammonia



9. Summary

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

	(Oil equivalent) kl/year	%
Insulation of precooker	14.8	1.5
Insulation of retort	4.7	0.5
Recovery of boiler waste heat	10.6	1.1
Insulation of steam pipe & valve	43.8	4.6
Prevention of steam valve leakage	1.5	0.2
Improvement in sterilization	115.2	12.0
Subtotal	190.6	19.9

	10^3kWh/year	%
Reduction of motor service voltage	31.3	0.9
Repair of entrance door of Refrigerating chamber	233.2	6.5
Arrangement of cooling tower	9.6	0.3
Cleaning of condenser & heat transfer surface	10.9	0.3
Subtotal	285.0	8.0

Report No. 15: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Thai Union Manufacturing Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

— Thai Union Manufacturing Co., Ltd. —

1. Outline of the Factory

Address	94-6 Setthakit Rd. Tumbon Tha-Sai Amphur Muang, Samutsakorn	
Capital	60 Million Bt	
Type of industry	Food	
Major products	Fish canning	
Annual product	Raw material : Tuna 9,000 t/year	
No. of employees	350	
Annual energy consumption	Electric power	1,180,000 kWh
	Fuel	H.O.(A) 340 kℓ/year
Interviewees	Mr. Chan : Factory Manager Mr. Somkiat : Manager of Finance and Personnel Section	
Date of diagnosis	July 21, 22, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

The factory inaugurated as a tuna cannery with rebuilding of an old plant seven years ago. With a new construction of the refrigerator for 800 metric tons storage capacity last year, the storage system of raw material has been arranged. The tuna of raw material is treated with 30 t/day to produce the canned goods of 100,000 cans/day as 6.5 ounce can. The whole quantity of these canned goods is devoted for export. This factory is one of the main enterprises with the production increasing year by year.

The whole number of employees is 350 persons and the number of women occupies 90% of it. The managerial policy of the plant manager passes enough into the employees. The quality of employees is generally good and they are neat and orderly.

2. Manufacturing Process

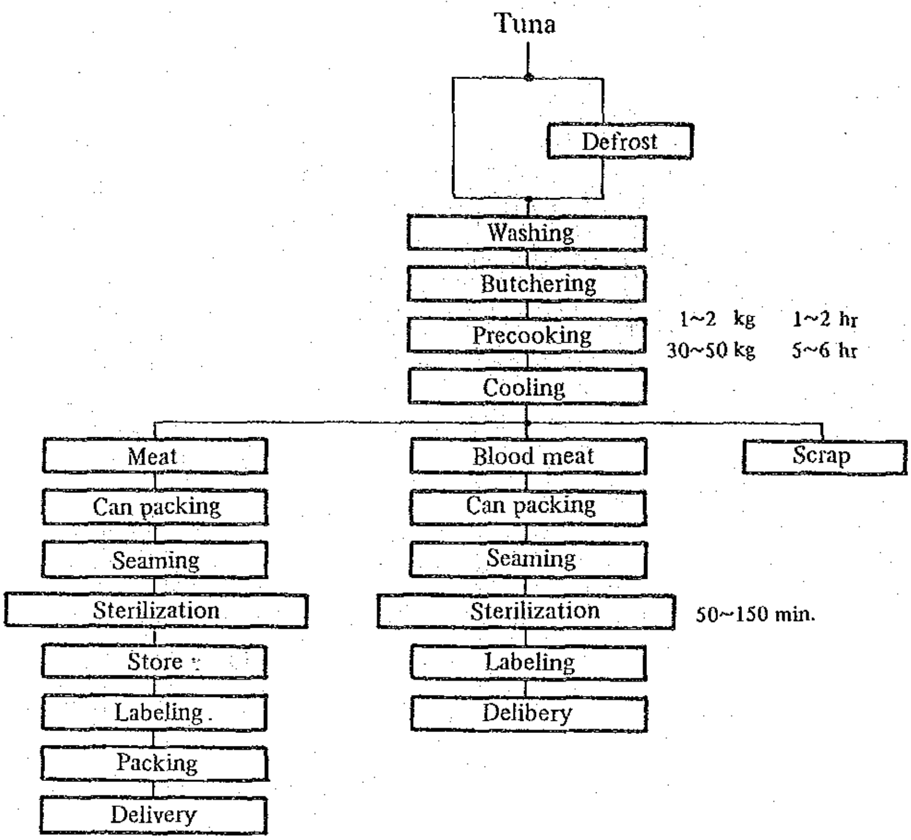


Fig. 15–2

3. Major Equipment

3.1 Major Equipment

Table 15–1

Name	No. of units installed	Type, etc.
Boiler	2	No. 1 3.5 t/h Flue tube, reserve No. 2 6.0 t/h Flue tube
Precooker	4	1.2 m x 1.7 m x 3.9 m
Retort	5 2 2	ϕ 1.2 m x 3 m ϕ 1.2 m x 3.85 m ϕ 1.2 m x 4.6 m

3.2 Layout

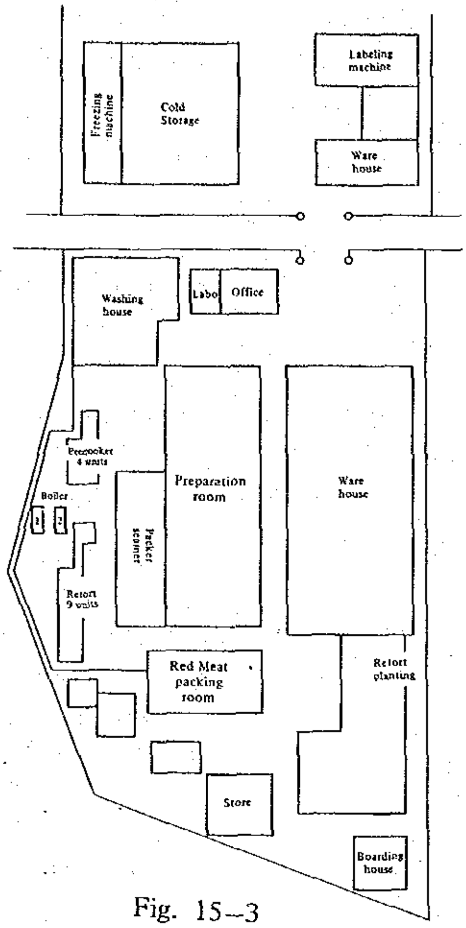


Fig. 15–3

4. State of Energy Management

4.1 Policy for Energy Conservation

The proportion of the energy cost to the sales is small. However, the countermeasures of a renewal of the boiler and the heat insulation budgeting 7,000 Bt are remarked.

The plant manager leads customarily on an improvement of the yield to the employees. Consequently a clean work shop with good order is formed. But a systematic activity such as the engineers' ability are utilized effectively is not carried out. With establishment of an improvement target, its counterplan should be investigated through allotment of each partial charge. After the execution, the result should be checked and then forward to the next step. Thus the technical level of employees is advisable to be improved. Fortunately since some eager young engineers have been working in the factory, a systematic management will render services to further improvement.

4.2 Participation by All Employees

The employees of about ten persons have been dispatched for training seminar to the QC circle held by the TPA to establish a small group activity. But a small group activity does not yet start. To allow the small group activity to take root in the actual shop, the activity should be taken with the trained persons as the center figure under a strong back-up of the plant manager and the persons in charge of personnel management.

Also observation-study of the actual conditions of other near factories, acted with a small group activity can be consulted as a better means. Fortunately, an atomosphere to develop a small group activity and to exert themselves to improve the efficiency, exists in this factory.

4.3 Control through Data

The boiler daily report, the each cooker and retort daily reports or the each recording chart, which record the operating situation and fuel oil consumption every hour, have been checked and preserved exactly.

But the data for control such as the consumption rate of fuel and the control chart has been hardly prepared. To improve the technique, the practical data should be arranged and the production condition must be also arranged to compare with the energy consumption. And its variable factors must be investigated to take the countermeasure.

4.4 Education and Training for Leveling-Up of Engineers

The operating method instructed at the time of the introduction of a new equipment has been observed faithfully by the employees of a good quality. To raise the technical level further, it is better to participate in various seminars held by outsiders and to have many opportunity to visit for study of the plants in other industries as well as the same line of industry.

5. State of Fuel Consumption

5.1 Fuel Consumption

Fuel oil A 340 kl/year

Breakdown
- Tuna 325 kl/year
  - 61% (Precooker) (207 kl)
  - 31% (Retort) (105 kl)
  - 3.7% (Seasoning and hot water tanks (13 kl)
- Crab & Lobster 15 kl/year
  - 4% (Retort) (14 kl)
  - 0.3% (Seasoning tank) (1 kl)

Fuel consumption rate

Canned tuna: 325 kl/5,000t = 65 l/t

Canned crab & lobster: 15 kl/400t = 38 l/t

This calculation was taken as 90% of 5,000 tons per year to the production of canned tuna and as 400 tons per year of the rest to the production of canned crab and lobster.

5.2 Heat balance of boiler

The heat balance of boiler was calculated from the actual results in July 21, 1983. This is shown in Table 15-2.

Table 15–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	996.2	99.8	Heat of steam	848.9	85.0
Sensible heat of fuel	2.1	0.2	Heat loss in exhaust gas	107.2	10.7
			Heat loss in blow water	12.0	1.2
			Heat release from boiler body, others	30.2	3.0
Total	998.3	100.0	Total	998.3	100.0

Data Given for Calculation of the Heat Balance

Fuel type		Fuel oil A
Fuel consumption	(F)	103.5 kg/h
Heating value of fuel (low value)	(HI)	9,625 kcal/kg
Specific gravity of fuel	(SG)	0.938
Specific heat of fuel	(Cp)	0.45 kcal/kg°C
Temperature of fuel	(Tf)	80°C
Reference temperature	(To)	350°C
Oxygen content in exhaust gas	(O_2)	12.6%
Temperature of exhaust gas	(Tg)	156°C
Quantity of blow down water	(B)	87 kg/h
Temperature of blow down water	(Tb)	172.5°C
Quantity of feed water	(W)	1,442 kg/h
Temperature of feed water	(Tw)	35°C
Steam pressure	(P)	7.6 kg/cm²G
Quantity of steam (S = W − B)	(S)	1,355 kg/h
Enthalpy of steam	(Es)	661.5 kcal/kg
Enthalpy of feed water	(Ef)	35 kcal/kg

Equation for Calculation of the Heat Balance

Input

Heat of fuel combustion (Qc) 996.2×10^3 kcal/h

$Qc = F \times HI$

Sensible heat of fuel (Qs) 2.1×10^3 kcal/h

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

Output

Heat of steam (Qv) 848.9×10^3 kcal/h

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

Heat loss in exhaust gas (Qe) 107.2×10^3 kcal/h

$Qe = F \times G \times 0.33(Tg - To)$

Theoretical amount of air (Ao)

$Ao = 0.85\ Hl/1{,}000 + 2.0 = 10.18\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\ Hl/1{,}000 = 10.68\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 2.50$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 25.95\ Nm^3/kg$

Heat loss in blow down water	(Qb)	12.0×10^3 kcal/h
$Qb = B \times (Tb - Tw)$		
Heat release from body and others	(Qr)	30.2×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Combustion Control of Boiler

The investment cost of the new boiler installed two months ago was 1,000,000 Bt. The new boiler seems to be better in comparison with the old boiler with the boiler efficiency of 85% from the result of the boiler heat balance. But the quantity of exhaust gas is too much because the boiler is operated in a low load of 1.4 t/h during the diagnosis in comparison with 3 t/h of the boiler specification, operated repeating ON-OFF very often under a longer OFF time and burnt with excess air. Now stand, the oxygen content in exhaust gas is higher abnormally in 12.6%. Now a retort is under construction and the load will be expected to increase. So till then the oxygen content should be maintained within 4% by replacement to a small capacity burner and adjustment of air. The energy conservation effect as the oxygen content of 4% can be calculated as follows;

$m' = 1.24 \qquad G' = 13.12\ Nm^3/kg$

Let the quantity of fuel oil after improvement take as x kg/h, from the boiler heat balance;

$$\frac{998.3}{103.5} \cdot x = (848.9 + 12.0 + 30.2) + \frac{13.12 \times 0.33 \times (156 - 35)}{1{,}000} \cdot x$$

$\therefore x = 97.7$ kg/h

Energy conservation effect:

$$\frac{103.5 - 97.7}{103.5} \times 100 = 5.6\%$$

The annual saving of fuel oil A results in

$340\ kl \times 0.056 = 19.0$ kl/year.

6.2 Insulation of Precooker

The four precookers are not insulated. These surface temperatures are as shown in Table 15-3.

Table 15-3

	Ceilling °C	Front door °C		Side wall °C		
No. 1 unit	88	85	86	86	86	87
No. 2 unit	90	89	89	90	91	88
No. 3 unit	89	90	92	88	88	89
No. 4 unit	90	91	91	90	90	90
Average	89	89			89	

The surface of anticorrosive paint is extremely soiled. Accordingly its emissivity seems to be larger. The dimensions of the cookers are as follows:

	(Width)	(Height)	(Length)	(Surface area)	(Internal temp.)
No.1 to No.3 Cookers	1.24m	1.7m	4.8m	$32.4m^2$	93 ~ 100°C
No.4 Cooker	1.22m	1.7m	3.9m	$26.9m^2$	96°C

The radiation heat loss of No.1 to No. 3 cookers is obtained as a typical.

Radiant heat transfer

$$Q = 4.88\,\epsilon A\{(\frac{T_1}{100})^4 - (\frac{T_2}{100})^4\} = 4.88 \times 0.8 \times 32.4\,\{(\frac{273+89}{100})^4 - (\frac{273+36}{100})^4\}$$

$$= 10{,}246 \text{ kcal/h}$$

Convective heat loss

$$Q = \alpha c \times A \times \Delta t = 2.2\,\Delta t^{0.25} \times A \times \Delta t = 2.2 \times 32.4 \times 53^{1.25} = 10{,}200 \text{ kcal/h}$$

Total: 10,246 + 10,200 = 20,446 kcal/h

The heat loss is a following when this is insulated with calcium silicate of 25mm and an aluminum sheet, taken the surface temperature as 51°C and the room temperature as 34°C.

Radiant heat loss

$$Q = 4.88 \times 0.3 \times 32.4\,\{(\frac{273+51}{100})^4 - (\frac{273+34}{100})^4\} = 996 \text{ kcal/h}$$

Convective heat loss

$$Q = 2.2 \times 32.4 \times 17^{1.25} = 2{,}460 \text{ kcal/h}$$

Total: 3,456 kcal/h

When all of the four cookers are insulated with the similar manner, the energy conservation is as follows:

No.1 to No.3 Cookers $(20{,}446 - 3{,}456) \times 3 = 50{,}970$ kcal/h

No.4 Cookers $(20{,}446 - 3{,}456) \times \frac{26.9}{32.4} = 14{,}106$ kcal/h

Total: 65,076 kcal/h

If the average operating time per one cooker-day is taken as 8.7 hours, the saved energy per year is $65{,}076 \times 8.7 \times 300 = 169{,}848 \times 10^3$ kcal/year. Converted to equivalent fuel oil A, $169{,}848 \times 10^3/(9{,}625 \times 0.85 \times 0.938) = 22.1$ kl/year. The energy conservation rate results in $22.1/340 \times 100 = 6.5\%$

Taken the price of fuel oil A as 4.32 Bt/l, the reduction cost of fuel oil is 95,500

Bt year. On the other hand, the cost of insulation is about 124,100 Bt. Therefore, this cost can be recovered in 1.3 years.

6.3 Insulation of Retort

Since the nine retorts shown in Table 15-4 are not insulated, these heat loss is very larger.

Table 15-4

Retort No.	Outer diameter m	Length m	Surface area m^2
No. 1, 2, 3, 4, 9	1.2	3.00	13.6
No. 5, 6	1.2	4.60	19.6
No. 7, 8	1.2	3.85	16.9
Average			15.7

Internal temperature of retort: 110 ~ 122°C. Average 118°C

Surface temperatures and measured heat flux values (See table 15-5)

Table 15-5

	Front door			Drum wall		
	°C		$kcal/m^2h$			
No. 1	108	106	961	104	108	112
No. 4	101	102	870	108	106	106
No. 5	112	113		111	111	110
No. 6	104	106		107	109	107
Average	106	107		107	108	108

Taken the surface temperature as 108°C and ambient temperature as 36°C, the heat loss can be obtained as follows:

Radiant heat loss

$$Q = 4.88 \times 0.5 \times 15.7 \{(\frac{273+108}{100})^4 - (\frac{273+36}{100})^4\} = 4,597 \text{ kcal/h}$$

Convection heat loss

$$Q = 2.2 \times 15.7 \times (108-36)^{1.25} = 7,253 \text{ kcal/h}$$

Total: 11,850 kcal/h

Assuming that the retort is insulated with calcium silicate of 25mm and an aluminum sheet, taken the surface temperature as 58°C and the room temperature as 34°C, the reduction of heat loss is as follows:

Radiant heat loss

$$Q = 4.88 \times 0.3 \times 15.7 \{(\frac{273+58}{100})^4 - (\frac{273+34}{100})^4\} = 713 \text{ kcal/h}$$

Convective heat loss

$$Q = 2.2 \times 15.7 \times 24^{1.25} = 1,835 \text{ kcal/h}$$

Total: 2,548 kcal/h

If the operating time of retort is taken as average 5 h/day and all the nine retorts are insulated, the energy conservation per year is as follows:

$9 \times (11{,}850 - 2{,}548) \times 5\ \text{h} \times 300 = 125{,}577 \times 10^3\ \text{kcal/year}$

If converted to the equivalent fuel oil A, it is $125{,}577 \times 10^3\ \text{kcal}/(9{,}625 \times 0.85 \times 0.938) = 16.4\ \text{kl/year}$. The energy conservation rate is $16.4/340 \times 100 = 4.8\%$. If the price of fuel oil A is taken as 4.32 Bt/l, the reduction of the cost is 70,800 Bt/year.

Since the insulation cost required to this is estimated as 141,000 Bt, the cost can be recovered in about two years. The measured value of heat loss by a heat flowmeter is so to 30% larger than calculated value added with the influence of wind. In the case, the insulating effect can be evaluated with much value.

6.4 Insulation of Steam Line

The insulation of steam line is not enough. The heat loss is occurring in many places by the lack insulation such as the valves mounted on the boiler body, reducing valves and the 3" valves on the header and by the damage of the insulation such as the header.

Obtaining the heat loss from the four valves and the one reducing valve around the boiler and the header out of these valves, it is as follows (See Table 15-6):

The heat loss in the condition of the steam pressure of 7.5 $\text{Kg/cm}^2\text{G}$. and the temperature of 175°C is 1,970 $\text{kcal/m}^2\text{h}$. Converted to the quantity of fuel oil as eleven operating hours per day, the quantity of heat loss per year is as follows:

$$\frac{1{,}970 \times 1.7 \times 11 \times 300}{9{,}625 \times 0.85 \times 0.938} = \frac{11{,}051{,}700}{7{,}674} = 1.4\ \text{kl/year}$$

If the quantity of heat loss of 90% can be prevented through the insulation with a glass fiber of 50mm thickness and an aluminum sheet, the quantity of energy conservation is $1.4\% \times 0.9 = 1.3$ kl/year, the energy conservation rate is $1.3/340 \times 100 = 0.4\%$ and the reduced cost is 6,000 Bt/year. While, as the insulation cost is $855\ \text{Bt/m}^2 \times 1.7\ \text{m}^2 = 1{,}450$ Bt, the cost can be recovered in three months.

Table 15-6

	No. of unit	Outer surface area
3" Stop valve	4 units	$0.314\text{m}^2 \times 4$
3" reducing valve	1 unit	0.42m^2
Overall outer surface area		$1.7\ \text{m}^2$

Repairing must be done to crack, tearing off and wetting of the insulated materials as well as an insulation work to the bare valves and pipes. The current fuel oil consumption may be reduced at least by 2% through the repairing and insulation. Conservation of the energy is equivalent to fuel oil A of $340\ \text{kl/year} \times 0.02 = 6.8\ \text{kl/year}$.

6.5 Sterilization

Lowering of the consumption rate of steam for sterilization of the canned goods is a key point for the energy conservation in this factory. As air in the retort hinders heat transfer, the air must be immediately driven out and the effective heat of blown-in steam must be contributed successfully for sterilization.

The specific gravity of air is larger by 1.6 times than that of steam in the same temperature. In the condition when steam is blown in the retort, since the temperature rising of air is delayed, its difference of the specific gravities increases furthermore.

Accordingly, ideally it is better to drive out steam from the upper and air from the bottom, but in actuality the procedure carried out in the Kingdom of Thailand is to blow-in steam from the bottom and drive-out air from the upper. since the retort is packed with goods and the gas flow is turbulent flow, the ideal procedure may not go on theoretically. However without satisfaction to the present situation, the operator, the persons in charge of manufacturing and quality control should form a team to investigate on the procedure of a rapid temperature rising.

The improved cases in Japan is described in Fig. 15-4 to be referred to.

Some distribution pipes for steam blow-in were installed in the retort as shown in Fig. 15-4 and many holes of 6mm diameter was arranged in these pipes so that steam may diffuse gently and thoroughly from the upper in the retort toward the bottom. If a lot of steam flows in one space, air is mixed with steam and a driving-out effect is obstructed. A remodeling was done to allow air to flow easily with mounting of some punching metal in the space which stay of air in the cage for the canned goods.

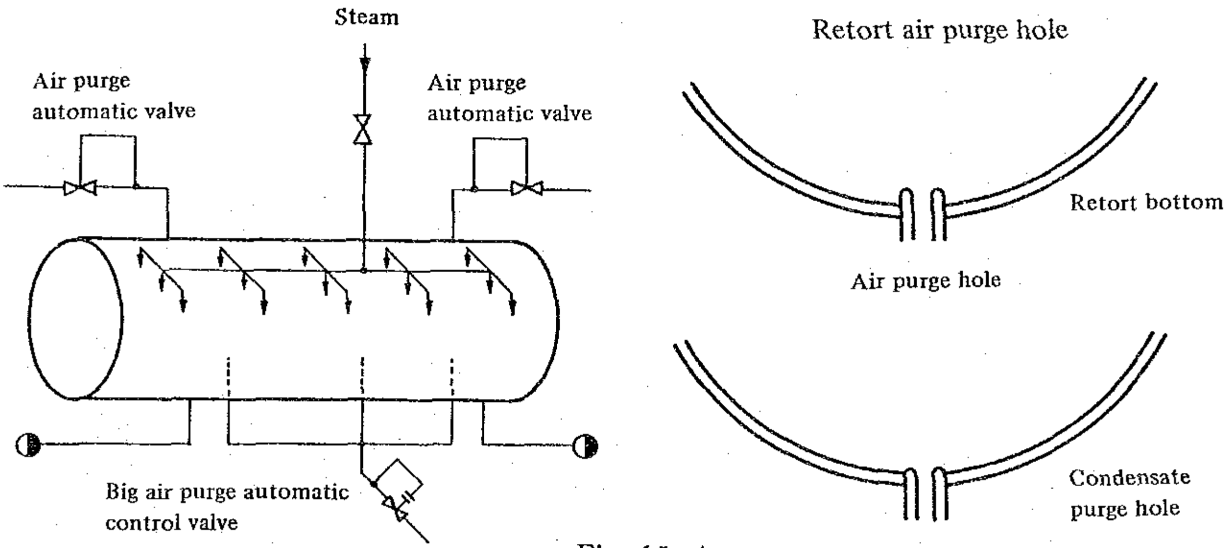


Fig. 15–4

The volume of retort was 5m^3. The above improvement gave a reduction of the air purge time, reduced the temperature rising time by seven minutes and increased the turnover rate of the retort. And also it reduced the quantity of steam by about 20% with a substantial reduction of the quantity of blow off steam. The expenses for the installations of (a) a steam distributor, (b) an air vent valve and (c) a machining of the punched metal were budgeted, but this investment cost was recovered in eight months through the reduction of steam consumption.

The operation should be investigated again with reference of the above case in order to attain the energy conservation. This investigation will contribute to the cost reduction. Its expected effect is (105 + 14) kl/year × 0.2 = 23.8 kl/year. And the energy conservation rate is 23.8/340 × 100 = 7.0%.

6.7 Utilization of Hot Water from Retort

In the current process, the cooling water filled in the retort after sterilization has been discarded as a waste hot water of 50 to 60°C. This hot water may be utilized to defrost the freezed fishes. As shown in the above-mentioned improvement plan of sterilization, when steam is blown from the upper of retort and air is purged from the bottom, it is considerable that most of the dirt existed in the retort are removed and the waste hot water is kept in a considerable clean. Accordingly, the waste hot water may be utilized to various application such as cleansing of the vessels. Now, the steam for hot water is used with 5% of the whole quantity of steam. Utilization of the waste hot water will contribute to reduce the whole quantity of steam. This should be investigated.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	: PEA		
	1,000 kVA System	250 kVA System	50 kVA System
Peak Demand	: 324 kW	109 kW	Unknown
Power consumption	: 774 × 10^3 kWh/year	406 × 10^3 kWh/year	Unknown
Load Factor	: 63%	86%	Unknown
Penalty Fee	: No	No	No
Power Factor	: 76%	84%	Unknown
Transformer	: 3ϕ 1,000 kVA × 1	3ϕ 250 kVA × 1	3ϕ 50 kVA × 1
Power cost	: 2.02 Bt/kWh	1.77 Bt/kWh	Unknown
Operating hour	: 8,760 h/year	4,200 h/year	4,200 h/year

7.2 One Line Diagram

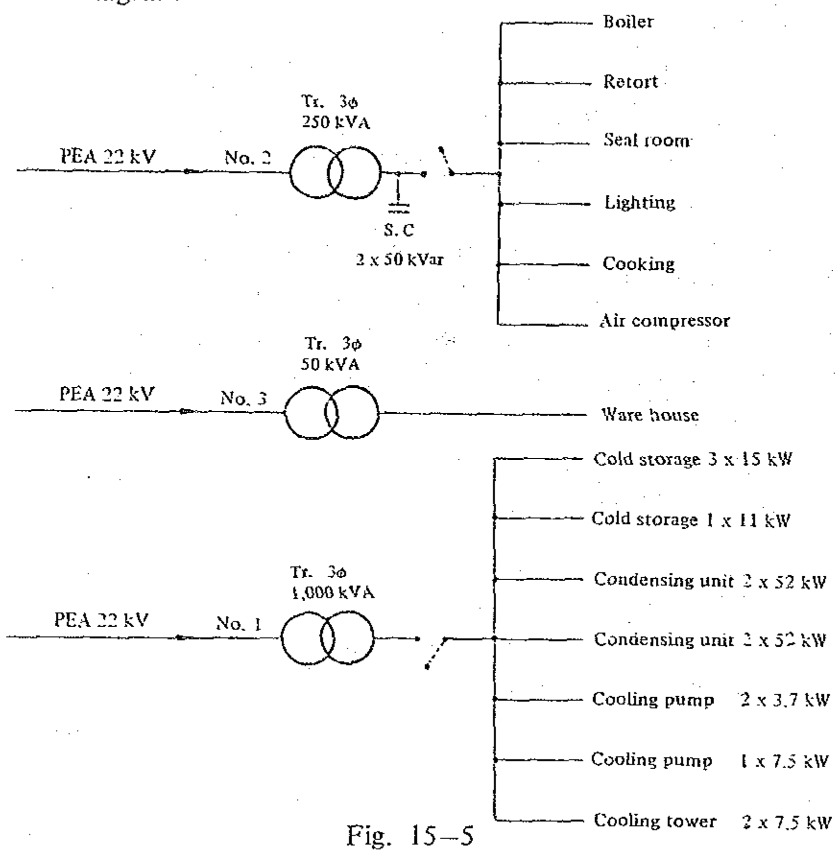


Fig. 15–5

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 15–7

		Power consumption kWh	Maximum demand power kW	Average power kW	Power factor P.F %	Load factor L.F %	Remarks
Tr 3φ 1,000 kVA	12/82	42,720	294	57	Average 76%	20	Annual consumption(Estimated) 774,000 kWh, Average power per year $\frac{774 \times 10^3 \text{kWh}}{8,760 \text{h}}$ = 88 kW
	1/83	69,660	324	94		29	
	2/	56,160	318	84		26	
	3/	68,880	312	93		30	
	4/	56,160	282	73		28	
	5/	70,680	318	95		30	
	6/	64,980	324	90		28	
	Total	429,240					

		Power consumption kWh	Maximum demand power kW	Average per year kW	Power factor P.F %	Load factor L.F %	Remarks
Tr 3φ 250 kVA	12/82	27,240	98	Unknown	Average 80%	Unknown	Annual consumption (Estimated) 406,000 kWh
	1/	32,000	97				
	2/	30,740	109				
	3/	34,680	101				
	4/	36,180	108				
	5/	39,380	104				
	6/	29,900	102				
	Total	230,120					

7.3.2 Monthly Load Curve

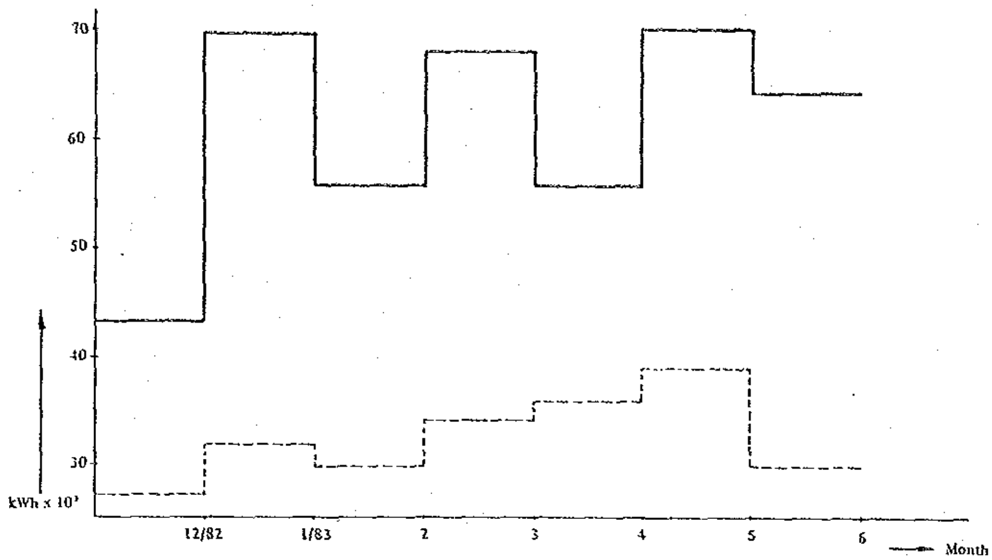


Fig. 15-6 Monthly Load Curve

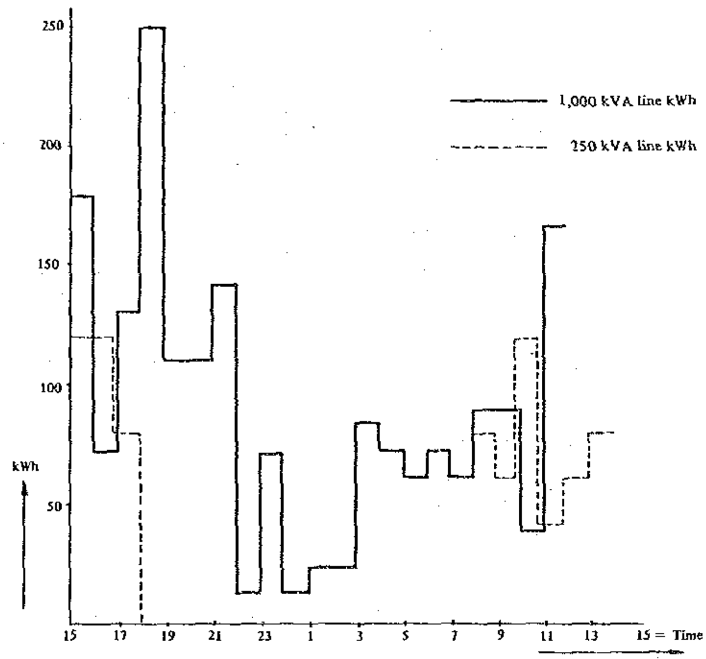


Fig. 15-7 Hourly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 15–8 22 July

	Measurement					cos ϕ P.F %
	kW	V	A_R	A_S	A_T	
Tr. 3ϕ 1,000 kVA	183.8	405	337	353	350	76
No. 1 Feeder	32.1	408	59.4	59.2	60.4	
No. 2 Feeder	59.1	412	105.5	105.4	99.7	
No. 3 Feeder	92.4	405	174.9	174	174	
Tr. 3ϕ 250 kVA	108.3	396	206	218	138.1	84
Boiler	10.04	400	19.78	20.5	20.8	
Retort	3.52	399	8.76	9.21	9.03	
Seal room	29.9	399	53.3	69.1	50.6	
Cooking	41.7	398	90.7	30.6	31.2	
Air compressor	11.56	398	29.9	9.35	17.68	
Tr. 3ϕ 50 kVA	4.77	386	20.25	3.38	6.19	72

	Name Plate			Measurement			cos ϕ	
	kW	V	A	kW	V	A	P.F %	L.F %
Cooling unit 1	52	380	93	48.7	406	72.6	76	93.7
Cooling unit 2	52	380	93	46.3	405	84.1	76	89.0
Cold storage 1	15	380	30	8.63	405	17.6	71	57.6
Cold storage 2	15	380	30	8.64	405	18.15	66	57.5
Cold storage 3	15	380	30	10.92	404	19.51	79	72.8
Cold storage 4	11	380	22	11.68	404	19.94	83	106.2

8.2 Power Distribution

8.2.1 Transformer

(1) In the No.1, 1,000 kVA system, the peak demand is 324 kW and the average power is 95 kW(monthly maximum value) as shown in Table 15-7. This seems to be an excess capacity of the transformer. So, the expected merit when the capacity is reduced is tried to calculate.

Assuming that the operating hour is 8,760 h/year (refrigerator and related equipment), the average power 95kW, the power factor 76%, the apparent power 125kVA, the iron loss of the transformer 0.3%, the copper loss of the 1,000kVA transformer 1.4% and the copper loss of the 500 kVA transformer 1.5%, the expected merit becomes according to Table 15-9.

That is, the merit is 11×10^3kWh/year $\times$ 1.45 Bt/kWh = 15,950 Bt/year

But since the price of transformer 500 kVA is about 250,000 Bt, the investment

cost recovery period is $\dfrac{250{,}000}{15{,}950} \fallingdotseq 16$ years.

Table 15-9

	Transformers kVA	Load	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year
Present state	1,000	125	26	2	28
Improved state	500	125	13	4	17
Difference					11

Accordingly, replacement to a new transformer doesn't pay economically.

(2) When electricity is fed from the No.1, 1,000 kVA system to the No.3, 50 kVA system, assuming that the estimated average power is 100 kW, the power factor 76%, the apparent power 132 kVA and the operating hour 4,200 h, the expected merit becomes according to Table 15-10.

Table 15-10

	Transformers kVA	Load	Iron loss 10^3 kWh/year	Copper loss 10^3 kWh/year	Total 10^3 kWh/year
Present state	1,000 50	90 10	26.3 1.3	0.5 0.1	28.2
Improved state	1,000	100	26.3	0.6	26.8
Difference					1.4

That is, the merit is 1.4×10^3 kWh/year $\times$ 1.45 Bt/kWh = 2,000 Bt/year.

8.2.2 Power Factor

The average power factor of the No.1, 1,000 kVA system is lower of 76%. When this is improved to 85%, the expected merit based on the reduction of copper loss is approximately only 294 kWh/year of 430 Bt/year. While, the condenser of 20 kVar is approximately 10,000 Bt. Accordingly the recovery period is $\frac{10,000}{430} \fallingdotseq 23$ years. That is not economical.

(Precondition: See paragraph 8.2.1 (1))

8.2.3 Unbalanced Current

According to Table 15-8, in the 250 kVA system the transformer secondary current is in an unbalanced condition (about 40%) of 138 to 218.1 A. It is considerable to be by the electric lamps (40 W $\times$ ca. 250 lamps) connected to the cooking systems (30.6 ~ 90.7 A) and the compressor systems (9.3 ~ 29.9 A). In consideration of the power loss of the reverse direction component due to an unbalanced current, the electric lamps and other single-phase equipment should be connected in a balanced condition.

8.2.4 Power Distribution

(1) Suppression of Peak Demand

As shown in the one line diagram of Fig. 15-5, each system is formed as an individual receiving. If, with improvement of the wiring for instrument and the measuring instrument in each system, the receiving systems are unified, some reduction of the deamnd charge will be expected.

Even when the 1,000 kVA goes to a peak at PM 6 o'clock to PM 7 by the arrival peak of raw materials as shown in the load curve of Fig. 15-7, the peak demand comes to lower if the peak of 250 kVA system is in other hour zone.

1,000 kVA system peak demand	324 kW
500 kVA system peak demand	109 kW
50 kVA system peak demand	15 kW (estimated value)
Total	448 kW

When the peak is made to be even by this unification and if the peak is reduced by 15%, the reducing cost of the demand charge is

92 Bt/kW × 448 × 0.15 × 12 month/year = 74,190 Bt/year.

(2) Low Voltage Wiring in The Old Plant (250 kVA System)

The distance between each phase single core cable is larger (300 to 400 mm). As the voltage drop due to increasing of reactance is larger, so the distance should be decreased under 100 mm as far as possible.

8.3 Power Application

8.3.1 Voltage

According to Table 15-8, the service voltage to the motor rating voltage of 380 V is slightly higher of 404 to 406 V. Accordingly the secondary voltage should be reduced to 380 V by changeover of the transtap. After that, the change of power consumption and the temperature rising of motors should be confirmed.

That is, it is said that the loss in the transformer, distribution line and the motor can be reduced by 2 to 3% by reducing of the voltage by 5%. If the merit is taken as 2%, the annual power consumption as 774 × 406 = 1,180 × 10^3 kWh/year, and the unit power price as 1.45 Bt/kWh, its expected merit may be as follows.

1,180 × 10^3 kWh/year × 0.02 = 23.6 × 10^3 kWh/year

23.6 × 10^3 kWh/year × 1.45 Bt/kWh = 34,220 Bt/year

8.3.2 Vibration of Motor

Vibration is violent in the three 15 kW cold storage motor and the one 11 kw motor. The measured temperatures of each section are as follows:

	Iron Core	Bearing
15 kW	64°C	68°C
11 kW	71°C	72°C

In general, when the ambient temperature is 40°C with the E Class insulation, the standard temperatures in each section are as follows:

Iron core : ≤(40°C + 75°C)

Bearing : ≤(40°C + 40°C)

These measured values are within this limit but the temperature of bearing is slightly higher. As the causes of temperature rising and vibration seem to be in a no good centering, the centering should be re-checked and re-adjusted.

8.4 Others

8.4.1 Lighting

The number of ceiling lamp in the preparation plant were about 150 lamps of 40W fluorescent light. These lamps were turned on even in the daytime. The merit when the lamps were put out is as follows:

$40\ W \times 150 \times 3{,}600\ h/year \times 0.8 \doteqdot 17.3 \times 10^3\ kWh/year$

$17.3 \times 10^3\ kWh/year \times 1.45\ Bt/kWh = 25{,}100\ Bt/year$

(Provided that 0.8 is a factor due to the weather)

A fine putting-out operation is desirable.

9. Summary

The effect executed with the above countermeasures is as follows:

	(Fuel oil equivalent) Kl/year	%
Improvement of boiler combustion	19.0	5.6
Insulation of precooker	22.1	6.5
Insulation of retort	16.4	4.8
Insulation of steam line	6.8	2.0
Improvement of sterilization procedure	23.8	7.0
Subtotal	88.1	25.9

	10^3 kwh/year	%
Reduction of transformer	1.4	0.1
Lowering of motor service voltage	23.6	2.0
Putting-out of Fluorescent lamps	17.3	1.5
Subtotal	42.3	3.6

Report No. 16: Food

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

— Union Seri Co., Ltd. —

January, 1984

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation
— Union Seri Co., Ltd. —

1. Outline of the Factory

Address	247, Taiban Rd. Samutprakan 10280	
Capital	40 Million Bt	
Type of industry	Food	
Major products	Tuna canning	
Annual product	Raw materials 3,500 t ~ 5,200 t	
No. of employees	270	
Annual energy consumption	Electric power	247,000 kWh
	Fuel	H.O.(A) 216 kℓ
Interviewees	Mr. Anon : Assistant Managing Director	
Date of diagnosis	July 23, 1983	
Diagnosers	A. Koizumi, S. Honda, Y. Kaneko	

This company belongs to the Saha Union Group and its factory is only one and half years old. The products are canned tuna for export and canned sardine for domestic consumption. They plan to produce canned crab and ark shell in future.

Unprocessed fish is supplied by Thai Seree Co., a sister refrigeration company located adjacent to the company. The factory is now operating at half the rated capacity. The employees are working on a one-shift basis from 8:00 through 17:00, and sometimes work overtime for two to three hours. During these working hours, they process 10 to 15 t/day of fish. The number of working days per year is 350 days. The annual production is 250,000 cases, each case containing 48 pieces of 6-oz can.

The number of employees is 280, 95% of which is represented by female employees. A general manager of the factory and electricians are already quitted and an assistant manager is now acting as a general manager. However, it seems that sufficient technical information has not been passed on to their successors.

In view of this temporary unusual state, the company appears to be deeply concerned about remedial measures against labor affairs. However the morale of the employees is considered slightly down. When we visited the factory, we came across the sight that fish meat was scattered on the floors of the tuna cleaning room and sardine canning room. This easily leads us to believe that the yield should be adversely affected.

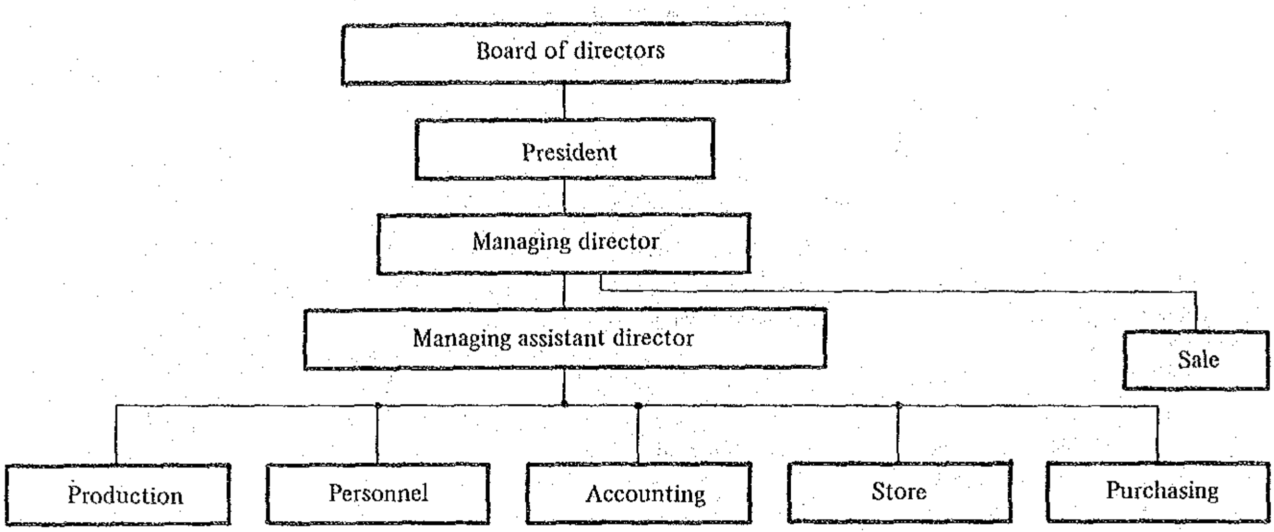


Fig. 16–1

2. Manufacturing Process

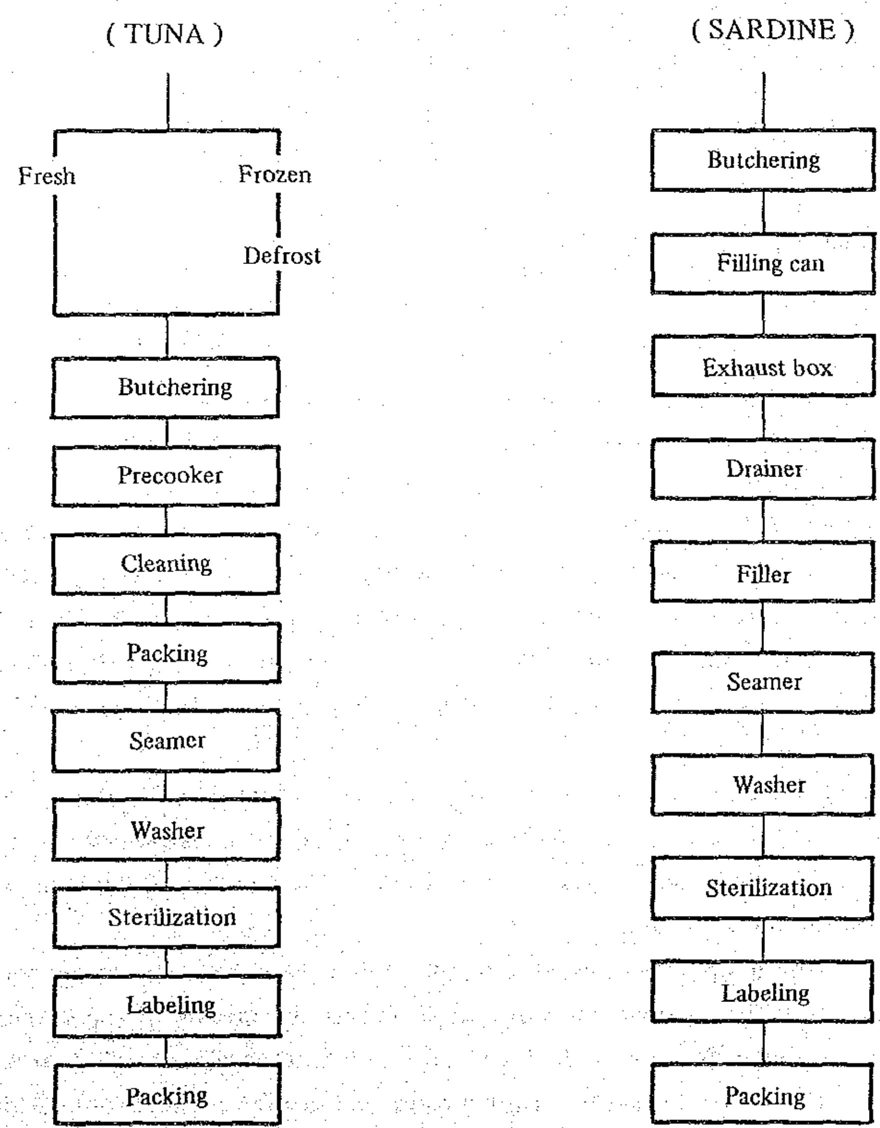


Fig. 16–2

3. Major Equipment

3.1 Major Equipment

Table 16–1

Name	No. of units installed	Type, etc.
Boiler	1	Flue tube 3 t/h 6.5 kg/cm^2
Precooker	3	1.38 m(W) x 1.53 m(H) x 2.15 m(L)
Retort	6	1.25 m(ϕ) x 3.1 m(L)

3.2 Layout

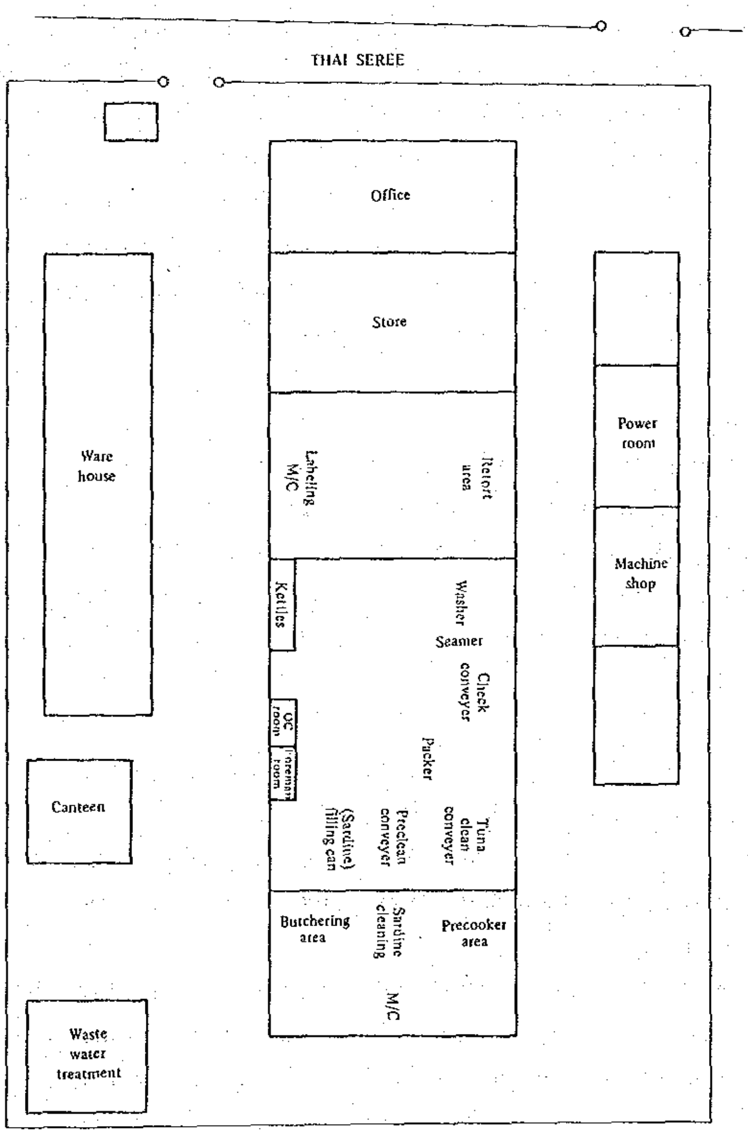


Fig. 16–3

4. State of Energy Management

4.1 Policy for Energy Conservation

As mentioned above, neither targets for energy conservation nor policies for promotion of the activities for these targets have been set up partly because of the recent shift of manager-class personnel. Activities for contributing toward the energy conservation are yet to be organized.

On account of insufficient transfer of work details at the time of replacement of the manager-class personnel, the successors have no enough knowledge about the whereabouts of ledgers for equipment or drawings. Therefore, during our recent visit to the factory, the succeeding manager-class people were not able to sufficiently respond to our questions of diagnosis. These ledgers and drawings should be well arranged and kept in custody for an organization but not for an individual person. These data should be accessible by anybody and should not be a cause for confusion even after the replacement of manager-class personnel.

4.2 Participation by All Employees

In order to promote energy conservation, it is necessary that all the employees including the general workers participate in the activities aimed at energy conservation. For this target, the effective means are considered "small group activities" or "suggestion system". At the factory, these activities have not yet been well organized.

Although these observations have directly nothing to do with energy conservation, we noticed the display of commercial posters and bulletins in the name of general manager for the enlightenment of employees about neat dressing, and safety measures. The employees also were seen paying their keen attention to these appeals.

4.3 Control through Data

Routine data are sufficiently collected, but are not fully utilized for improvement of energy consumption rate through analysis of variable factors.

Considering a fact that the factory does not have sufficient experience, it is advisable that data obtained through the past activities be fully utilized for establishing the most efficient working standards. In this sense, it is an urgent matter for the Company to bring up the capable staff.

4.4 Education and Training, technical Leveling-Up of Employees

The staff members often attend the gathering occasions sponsored by the industry, exchanging information among the attendants. In addition, the general workers are encouraged to participate in technical seminars and the visit to factories of other manufactures (3 to 4 times in the past).

In order to expect the fruitful results of their activities through these occasions of information gathering or education, it is necessary to hold an internal seminar under the guidance of employees who have attended the seminar. In this way, all the employees will obtain the knowledge passed by the instructors and also the circle leaders will be brought up.

In view of a fact that the number of staff members is now few, it is recommended that manpower of this class devoted toward energy control, maintenance and quality control be substantially replenished.

5. State of Fuel Consumption

5.1 Fuel Consumption and Breakdown

Heavy oil A 216 kl/year

Breakdown of fuel consumption

Tuna ── 48% (precooker) (103 kl)
── 32% (retort) (69 kl)
── 5% (seasoning, warm water tank and seamer)(11 kl)

Sardine ── 10% (exhaust box) (22 kl)
── 5% (seasoning tank, warm water tank and seamer)(11 kl)

Diesel oil 8 kl/year for forklift

Fuel consumption rate

Production: 6 oz × 48 pcs × 250,000 cases = 2,041 t/year

Consumption rate: $\frac{216}{2,041}$ = 106 l/t final product

Although the accuracy of the values used may have yet to be confirmed, the above-mentioned consumption rate is high, so that it is suggestive of there being room for energy conservation.

5.2 Heat Balance of Boiler

On July 23, 1983, we calculated the heat balance based on the results of our diagnosis of the boiler as shown in Table 16-2.

Table 16–2

Input			Output		
Item	10^3 kcal/h	%	Item	10^3 kcal/h	%
Heat of fuel combustion	385.0	100.0	Heat of steam	320.1	83.1
Sensible heat of fuel	0.0	0.0	Heat loss in exhaust gas	49.6	12.9
			Heat loss in blow water	7.6	2.0
			Heat release from boiler body, others	7.7	2.0
Total	385.0	100.0	Total	385.0	100.0

- Elements for Calculation of Heat Balance

Fuel type		Heavy oil A
Fuel consumption	(F)	40.0 kg/h
Heat content of fuel (low value)	(Hl)	9,625 kcal/kg
Specific gravity of fuel	(SG)	0.938
Specific heat of fuel	(Cp)	0.45 kcal/kg°C

Temperature of fuel	(Tf)	35°C
Reference temperature	(To)	34°C
Oxygen content in exhaust gas	(O_2)	6.3%
Temperature of exhaust gas	(Tg)	285°C
Quantity of blow down water	(B)	57 kg/h
Temperature of blow down water	(Tb)	168°C
Quantity of feed water	(W)	568 kg/h
Temperature of feed water	(Tw)	34°C
Steam pressure	(P)	6.7 kg/cm^2G
Quantity of steam (S = W − B)	(S)	511 kg/h
Enthalpy of steam	(Es)	660.4 kcal/kg
Enthalpy of feed water	(Ef)	34 kcal/kg

- Equation for Calculation of Heat Balance

Input

Heat of fuel combustion (Qc) 385.0×10^3 kcal/h

$Qc = F \times Hl$

Sensible heat of fuel (Qs) 0.0×10^3 kcal/h

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

Output

Heat of steam (Qv) 320.1×10^3 kcal/h

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

Heat loss in exhaust gas (Qe) 49.6×10^3 kcal/h

$Qe = F \times G \times 0.33\,(Tf - To)$

Theoretical amount of air (Ao)

$Ao = 0.85Hl/1{,}000 + 2.0 = 10.18\ Nm^3/kg$

Theoretical amount of exhaust gas (Go)

$Go = 1.11\ Hl/1{,}000 = 10.68\ Nm^3/kg$

Air ratio (m)

$m = 21/(21 - O_2) = 1.43$

Actual amount of exhaust gas (G)

$G = Go + Ao(m - 1) = 15.06\ Nm^3/h$

Heat loss in blow down water (Qb) 7.6×10^3 kcal/h

$Gb = B \times (Tb - Tw)$

Heat release from body and others (Qr) 7.7×10^3 kcal/h

6. Problems in Heat Control and Potential Solutions

6.1 Improvement of Burning in Boiler

The oxygen content of exhaust gas is high at 6.3%. Therefore, it is desired that the oxygen content be kept within 4% by adjusting the air damper. The temperature of exhaust gas is also high. For this reason, it is necessary to reduce the quantity of exhaust gas by adjusting the air ratio and clean the boiler tube. The effect of energy conservation calculated at a reduced O_2 concentration at 4% and lowering temperature of exhaust gas to 210°C is as follows:

$m' = 1.24$

$G' = 13.12\ Nm^3/kg$

Assuming that the fuel consumption after adjustment is x kg/h, following equation can be obtained referring to the boiler heat balance table:

$$\frac{385}{40} \cdot x = (320.1 + 7.6 + 7.7) + \frac{13.12 \times 0.33 \times (210 - 34)}{1,000} \cdot x$$

$\therefore x = 37.8$ kg/h

Energy conservation rate $\frac{40 - 37.8}{40} \times 100 = 5.5\%$

The annual amount of heavy oil A conservation will be $216 \times 0.055 = 11.9$ kl

6.2 Reduction of Boiler Blow Down

Boiler water is blown down for four to five minutes every hour. The pH value of blow down water for boiler is 8.61 and the electric conductivity 1,000 μS/cm. These value are low, so it is suggested that the said pH and electric conductivity be adjusted at 11.0 to 11.8 and approx. 6,000 μS/cm respectively. The actually required quantity of blow down water may be half as much as done now. Energy will be conserved by approx. one percent by reducing the blow down water.

6.3 Insulation Cover for Warm Water Tank

The 77°C warm water tank located beside the cleaning conveyor has no cover, so there is 3,000 kcal/m²h of heat release from the water surface. If the tank is shielded with double plate cover of stainless steel, thus reducing the heat loss by 75%, the results will be as follows:

Decrease in heat loss $3,000\ kcal/m^2h \times 5.12\ m^2 \times 11\ h \times 350 \times 0.75$
$= 44,352 \times 10^3$ kcal/year

If this heat loss is changed into heavy oil, the equivalent quantity will be:

$44,352 \times 10^3$ kcal/year/$(9,625 \times 0.938 \times 0.831) = 5.9$ kl/year

The saved cost will be 4.36 Bt/l $\times$ 5.9 kl/year = 25,700 Bt/year.

Energy conservation rate $5.9/216 \times 100 = 2.7\%$

On the other hand, the estimated fabrication and installation cost for the cover will be approx. 12,000 Bt which is recoverable in 6 months.

6.4 Insulation of Precookers

Three units of the precooker are not insulated at all. Although finished with rustproof paint and less of stain, the precookers have a high percentage of heat loss because of high emissivity. Therefore, we calculated the amount of heat release and the insulation effect based on the following conditions:

106°C for internal temperature, 5.3 h/day for average heating time, dimensions of cooker (1.38 m wide, 1.53 m high and 2.15 m long), 16.7 m² for surface area, 32°C for room temperature, 93 to 97°C for external wall temperature (average: 95°C)

- Radiation heat loss

$$Q = 4.88\ \epsilon A\ \{(\frac{T_1}{100})^4 - (\frac{T_2}{100})^4\} = 4.88 \times 0.7 \times 16.7\ \{(\frac{273+95}{100})^4$$

$$- (\frac{273+32}{100})^4\} = 5{,}534\ kcal/h$$

- Convection heat loss

$Q = \alpha c \times A \times \Delta t = 2.2 \times \Delta t^{0.25} \times A \times \Delta t = 2.2 \times 16.7 \times 63^{1.25} = 6{,}517$ kcal/h

Radiation heat loss + Convection heat loss = 12,051 kcal/h

(Reference: Reading of heat flow meter 810 kcal/m^2h × 16.7 m^2 = 13.527 kcal/h)

If a 80% heat loss is prevented by insulation with 30mm thick glass wool and galvanized steel plate, the estimated energy conservation amount will be 12,051 × 0.80 = 9,641 kcal/h. If three units of precooker are used, the reduction of annual total heat loss will be 9,641 kcal/h × 3 × 5.3h × 350 days = 53,652.1 × 10^3 kcal/year. If this saving is changed into heavy oil A, the equivalent quantity will be 53,652.1 × 10^3 kcal/year/(9,625 × 0.938 × 0.831) = 7.2 kl/year.

The estimated saved fuel cost will be 7.2 kl/year × 4.32 Bt/l = 31,100 Bt/year. In the meantime, the estimated insulation cost will be approx. 50,000 Bt which will be recoverable in 1.6 years.

Energy conservation rate 7.2/206 × 100 = 3.3 %

6.5 Insulation of Retorts

The inlet side dish plates of six units of retort are not insulated and the two units have an uninsulated drum. If the outer drum surface of the retort is uninsulated, the under-mentioned insulation effect can be expected where given conditions are as follows:

118°C for internal temperature, 4.1 hours for average heating time per retort/day, 125cm in dia., 310cm long and 12.2 m^2 of drum surface area, 34°C for room temperature and 87°C for surface temperature.

- Radiation heat loss

$$Q = 4.88 \times 0.5 \times 12.2\ \{(\frac{273+87}{273})^4 - (\frac{273+34}{273})^4\} = 2{,}356\ kcal/h$$

- Convection heat loss

$Q = 2.2 \times 12.2 \times (87 - 34)^{1.25} = 3{,}838$ kcal/h

Total: 6,194 kcal/h. If two units of retort are used, the annual heat loss will be 6,194 × 2 × 4.1 × 350 = 17,777 × 10^3 kcal/year. However, if they are insulated with 30mm glass wool and galvanized iron plate, the 80% loss will be prevented and the following annual fuel conservation realized:

17,777 × 10^3 × 0.8 = 14,221 × 10^3 kcal/year

If changed into heavy oil A, the equivalent conserved fuel amount will be

$$\frac{14{,}221 \times 10^3}{9{,}625 \times 0.938 \times 0.831} = 1.9\ kl/year$$

If the dish plates are insulated, the under-mentioned effects can be expected:

• Radiation heat loss

$$Q = 4.88 \times 0.5 \times 1.25\ m^2 \times \{(\frac{273+87}{273})^4 - (\frac{273+34}{273})^4\} = 241\ kcal/h$$

• Convection heat loss

$$Q = 2.2 \times 1.25 \times (87 - 34)^{1.25} = 394\ kcal/h$$

Heat loss is 635 kcal/h

Altogether, and the total heat loss of six units per year will be 635 kcal/h $\times$ 6 $\times$ 4.1 $\times$ 350 = 5,467 $\times 10^3$ kcal/year

If they are insulated, the total conserved fuel amount per year will be 5,467 $\times 10^3 \times$ 0.8 = 4,373.9 $\times 10^3$ kcal/year. If this amount is changed into heavy oil A, the equivalent conserved quantity will be 0.6 kl/year. The total equivalent conserved heavy oil A will be 2.5 kl/year in quantity and 10,800 Bt/year in cost.

Energy conservation rate: 2.5/216 $\times$ 100 = 1.2%

The estimated insulation cost will be approx. 32,000 Bt and it will be recoverable in approx. 3 years.

6.6 Prevention of Fall of Intermediate Products onto Floor

Improvement of the yield in the manufacturing process is very effective for energy conservation. The quantity of fish meat that has fallen from the cleaning table onto the floor is large. Assuming that the consumption of heavy oil A by the precookers per year is 103 kl, when yield of canned tuna is increased from 50% to 52% under the same production, the fuel conservation.

$$103\ kl \times (1 - \frac{0.50}{0.52}) = 3.9\ kl/year$$

Energy conservation rate: 1.8%

6.7 Recovery of Condensate

Steam is used in the hot brine and vitamin tanks located on the second floor of the factory building, and condensate is generated here. Assuming that the annual heavy oil consumption for this process is equivalent to 2 kl, we recommend that condensate at 100°C be recovered, and recycled to the water wash tank for canned tuna before the retorts.

When using steam at 5 kg/cm^2G, the ratio of the heat content of 100°C condensate to that of steam is approx. 13%. Assuming that, 10% of this is utilized, the conerved heavy oil A quantity will be 2 $\times$ 0.1 = 0.2 kl/year.

Energy conservation rate is 0.2/216 $\times$ 100 = 0.1%

6.8 Insulation of Steam Line

The 2" and 2-m-long steam pipe at the inlet of the cooker and the 2" steam valve at the inlet of the exhaust box are not insulated (refer to Table 16-3).

· Insulation effect

$$\frac{(1,700 - 160)\ kcal/h \times 5.3 \times 350}{9,625\ kcal/kg \times 0.831 \times 0.938} = 0.4\ kl/year$$

Energy conservation rate is $0.4/216 \times 100 = 0.2\%$

While the conserved heavy oil cost is 1,600 Bt/year, the estimated insulation cost is approx. 900 Bt. This cost can be recovered in seven months. It is estimated that the total number of the uninsulated parts such as steam valves throughout the entire factory may be approx. 10 times as many as the number of those already found. Therefore, the effect of the insulation upon energy conservation will be 1.8% or equivalent to 3.8 kl/year in heavy oil.

Table 16–3

	Actual heat loss	Heat loss through glass wool insulation of 30mm thickness
Steam piping	1,100 kcal/h	100 kcal/h
Steam valves	600 kcal/h	60 kcal/h
Total	1,700 kcal/h	160 kcal/h

6.9 Sterilization

The reduction of the consumption rate of steam for the sterilization in the retort is the key point of energy consumption for this factory. As air in the retort counteracts the heat transfer, the air must be quickly expelled to allow the heat of blown-in steam to contribute effectually for sterilization.

The specific gravity of air is approximately 1.6 times of that of steam. As the temperature rising of air is slower in the condition blown-in steam into the retort, its difference of specific gravities is increased. Therefore, it is theoretical to blow-in steam from the upper and to expel air from the bottom. But, in Thailand it has been practically done to blow-in steam from the bottom and to expel air from the upper. When the material are packed fully in the retort where the gas flows in turbulence, this may not go theoreticaly. However, a more quick temperature rising way or a much more better operating technique should be investigated. For this matter, the investigation must be pushed forward with a team formation composed of the operator and the persons in charge of manufacturing and quality control. Fig. 16-4 is the improved case in Japan.

A distribution pipe was installed in the retort as shown in Fig. 16-4. The distribution pipe was arranged with many holes of 6 mm diameter so that steam diffuses slowly and thoroughly from the upper toward the bottom. If much steam flows into even one space, steam is mixed with air to counteract the expelling effect of air. And also a punching metal was placed in the spaces where air stays for easy flow of air.

The capacity of this retort was 5 m^3. The above modification reduced the air purge time, the temperature rising time by seven minutes and improved the turnover of retort. The steam blow-off quantity was reduced by about 20%. Although the investment cost was paid to install (a) the steam distributor and (b) the three air vent valves and (c) the installation of the punching metal, this cost was recovered in eight months through the reduction of steam consumption.

In the light of the above case, the energy conservation should be attained with a re-investigation of the sterilization to contribute the cost reduction.

Expected effect: (69 + 22) kl/year × 0.2 = 18.2 kl/year

Energy conservation rate: 18.2/216 × 100 = 8.4

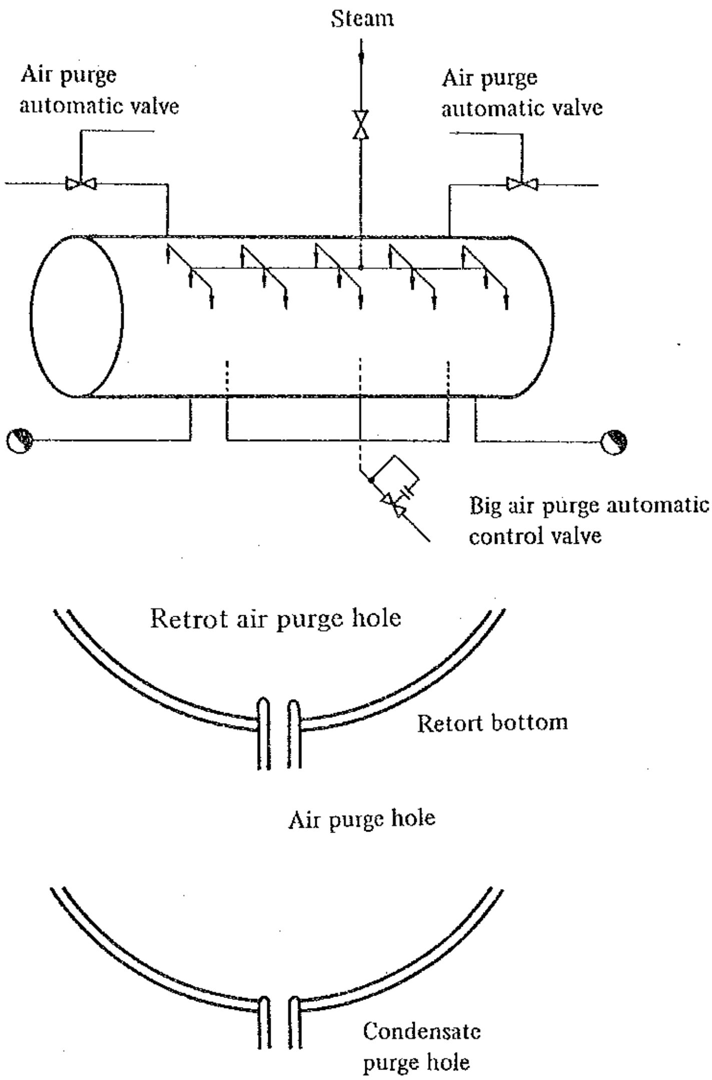


Fig. 16–4

6.10 Utilization of Hot Water in Retort

Now, the cooling water filled in the retort after sterilization is discarded as hot waste water of a temperature of 50 to 60°C.

As application of this hot water, it is considerable to use for defrost of the frozen fishes. As shown in the predescribed improved plan, when steam is blown-in from the upper of the retort and air is expelled from the bottom, most of dirt in the retort can be removed and the waste hot water also becomes clean substantially. Consequently the waste hot water may be used to many application such as cleaning of the vessels or containers. At present, the steam used for hot water is 5% of the whole quantity of steam. This should be investigated because of reduction of the quantity of steam.

7. State of Electric Power Consumption

7.1 The Principal Data Relating to Power Consumption

Power Company	:	MEA
Peak Demand	:	104 KW (Sept., 1982)
Power Consumption	:	247×10^3 kWh/year
Load Factor	:	Annual load factor 90% (estimate)
Penalty	:	8,130 Bt/year
Power Factor	:	Monthly power factor 45 to 74%
Transformer	:	14,167 kVA x 3 units
Power Cost	:	Annual average 1.80 Bt/kWh

7.2 One Line Diagram

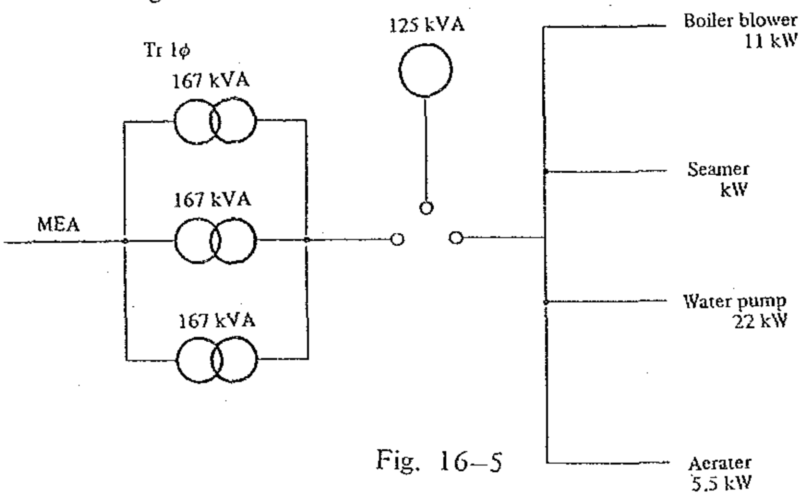


Fig. 16–5

7.3 State of Consumption

7.3.1 Monthly Power Consumption

Table 16-4 Monthly Power Consumption

By MEA Meter

	Power consumption kWh	Maximum demand power kW	Average power kW	Reactive power kVar	Power factor P.F (%)	Load factor L.F (%)
1 / 82	9,600	56		72	62	
2	11,200	56		68	64	
3	18,000	56		80	57	
4	14,800	56	50	80	57	90
5	14,800	56		80	57	
6	18,000	56		80	57	
7	22,800	56		100	49	
8	27,200	56		112	45	
9	27,640	104		108	69	
10	28,400	100		112	67	
11	24,800	100		92	74	
12			90			90
1 / 83	30,000	104		96	73	
2	24,000	100		100	70.7	
3	20,400	56	50	80	57	90

7.3.2 Monthly Load Curve

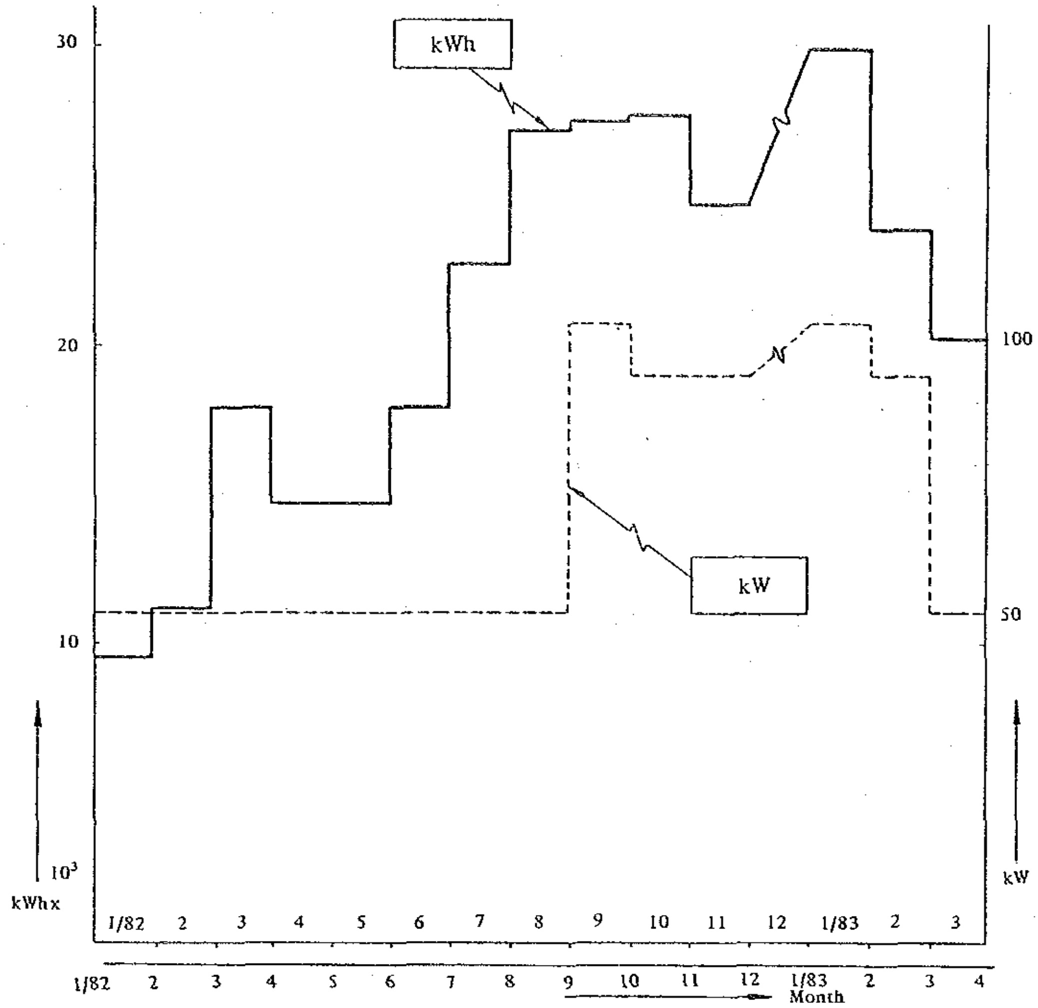


Fig. 16–6 Monthly Load Curve

8. Problems of Power Control and Potential Solutions

8.1 Measuring Data

Table 16–5 Instantaneous Value

23 July

Use for	Name Plate			Measurement			P.F (%)	L.F (%)
	kW	V	A	kW	V	A		
1φ Transformer 3 x 167 kVA				26.5	410	R 54.6 S 46.4	68	5.0
Boiler blower	11	380	22.5	8.4	405	16.2	52	76.4
Seamer	11	380	22.5	11.12	400	19.6	81	10.0
Water pump	22	380	29.0	5.76	401	26.4	32	25.7
Aerator	5.5	380	12.0	1.27	396	3.15	60	23

8.2 Power Distribution

8.2.1 Unbalanced Current

According to Table 16-5, the transformers secondary current of each phase indicates 46.4 to 60.5A, thus concluding an unbalance of approx. 30% of the current. The conceivable cause may be lamp illumination at the workshop and office. As some amount of electric power loss due to the reverse direction current being occured by the unbalanced current is considered, it should be arranged so that the connections of illumination load and single-phase equipment may be well balanced to each phase.

8.3 Application of Electric Power

8.3.1 Voltage

According to Table 16-5, the service voltage to the electric motor is slightly high at 396 to 405V as against the rated voltage of 380V. Therefore, it is suggested that the secondary voltage be reduced to 380V by changing the tap of the transformer. Then, it should be made sure that there is no problem with the rising of the motor temperature.

It is said that if the voltage of motor is decreased by 5% for a light loaded operation, the loss of electric power in the transformer distribution line and the motor is reduced by approx. 2 to 3%. Therefore, assuming the advantage as 2%, the annual power consumption 247×10^3 kWh/year, the conserved power amount will be as follows:

247×10^3 kWh/year $\times 0.02 \fallingdotseq 4.9 \times 10^3$ kWh/year

For this reason, we expect your trial.

8.4 Others

8.4.1 Lamp Illumination

The ceiling lamps (40W $\times$ 2) $\times$ 45 pcs in the canning workshop are switched on even bright daytime. If these lamps are switched off, the expected advantage will be:

(40W $\times$ 2) $\times$ 45 $\times$ (10h/day $\times$ 300 day/year) $\times$ 0.8 $\fallingdotseq 8.6 \times 10^3$ kWh/year

8.6×10^3 kWh/year $\times$ 1.45 Bt/kWh = 12,500 Bt/year

(Note) 0.8 : coefficient to be considered by weather. Therefore, be careful for lamps which are unnecessarily on, and turn them off whenever found.

9. Summary

If the above-mentioned measures are actually taken, it will bring about energy conservation effects as shown below:

	(Oil equivalent) kl/year	%
Improvement of Burning in Boiler	11.9	5.5
Reduction of Boiler Blow	2.2	1.0
Insulation Cover for Warm Water Tank	5.9	2.7
Insulation of Precookers	7.2	3.3

Insulation of Retorts	2.5	1.2
Improvement of Yield	3.9	1.8
Recovery of Condensate	0.2	0.1
Insulation of Steam Line	3.8	1.8
Improvement of Sterilization Method	18.2	8.4
Subtotal	55.8	25.8

	10^3kWh/year	%
Reduction of Service Voltage to the Motor	4.9	2.0
Ceiling Lamps Switch Off	8.6	3.5
Subtotal	13.5	5.5