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

VOL. 1

—CERAMICS/GLASS AND PAPER FACTORY—

JANUARY, 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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Contents

I. GENERAL REPORT

1. Purposes of the First Study

Japan International Cooperation Agency (JICA) sent a study team comprising the eight members of Energy Conservation Center of Japan (ECC) to Thailand to conduct a 35-day study from August 15 through September 18, 1982.

It is an undertaking entered upon in accordance with the " Scope of Work for the Study on Energy Conservation Project in the Kingdom of Thailand " (the Scope of Work) signed in March of the same year by and between the JICA and the Thai National Energy Administration (NEA).

The framework of this undertaking is defined in the Scope of work as shown in Fig. 1.

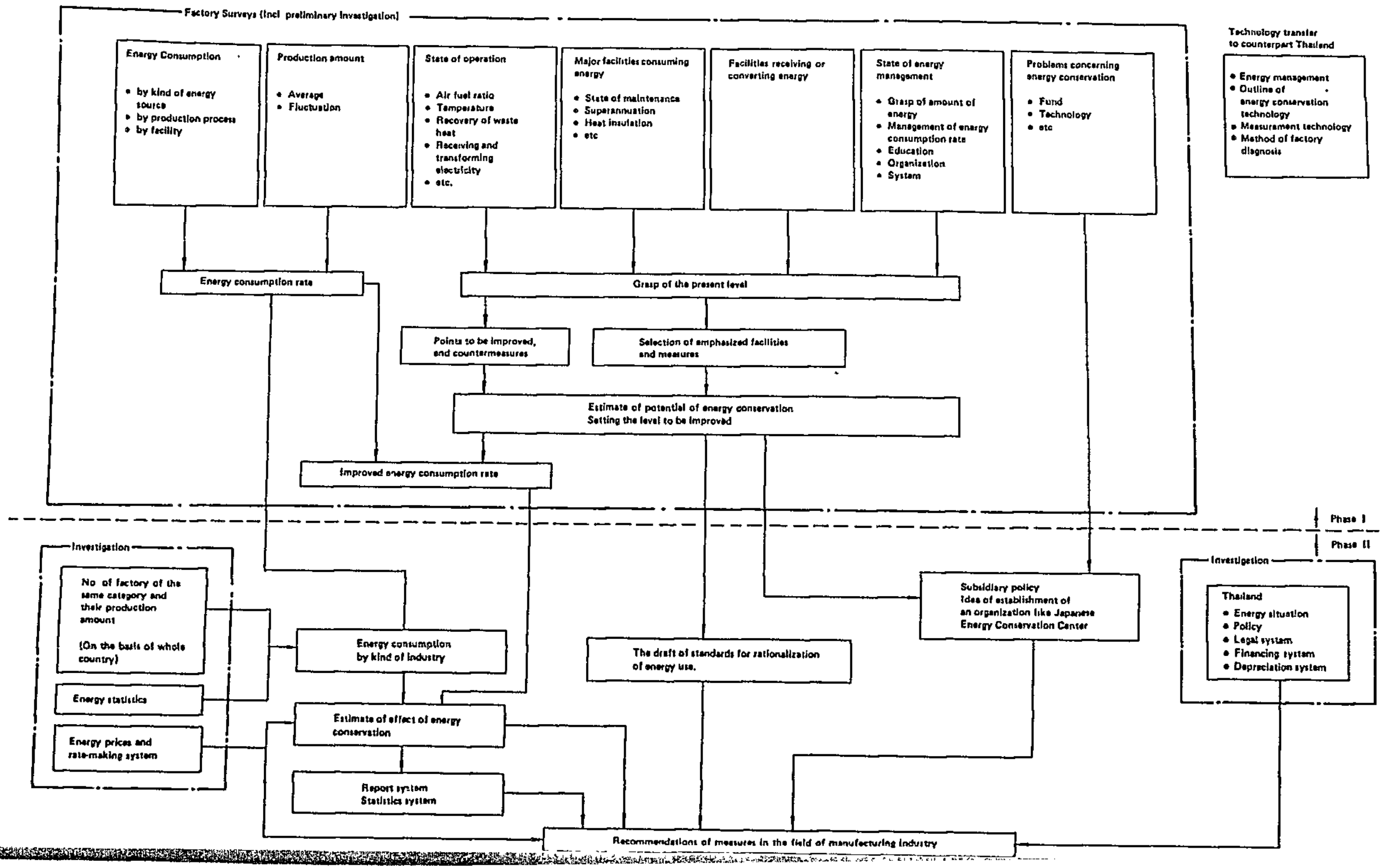
A survey carried out by the study team during the above period of time is the first one constituting a part of Phase I of the undertaking and the purposes of this first study were: -

(1) To make a diagnosis of ten ceramics/glass factories and nine paper mills in Thailand;

(2) To transfer measuring and diagnostic technology for energy conservation to the Thai counterpart and

(3) To gather information concerning the general energy situation in the Thai industrial world.

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



2. Member list of the Study Team

The members of study team are as shown in Table 1 below. The study team is divided into two groups to make a factory diagnosis; one is the ceramics group and the other the paper group. Each group is made up of two diagnosers in charge of thermal energy and one diagnoser in charge of electric energy.

Table 1. Member list of the Study Team

<table>
<tr><th colspan="3"></th><th>Name</th><th>Present Post</th></tr>
<tr><td colspan="3">Leader</td><td>Masakazu Ue</td><td>Executive Director, ECC</td></tr>
<tr><td colspan="3">Deputy leader</td><td>Mitsuo Iguchi</td><td>Managing Director, ECC</td></tr>
<tr><td rowspan="6">Energy diagnoser</td><td rowspan="3">Ceramics group</td><td>Thermal</td><td>Mazumi Ito</td><td>Director General, ECC's Chugoku Branch</td></tr>
<tr><td>Thermal</td><td>Yoshio Ohno</td><td>Registered diagnoser, ECC</td></tr>
<tr><td>Electric</td><td>Toshio Sugimoto</td><td>Registered diagnoser, ECC</td></tr>
<tr><td rowspan="3">Paper group</td><td>Thermal</td><td>Akira Koizumi</td><td>Assistant Director General, ECC's Hokkaido Branch</td></tr>
<tr><td>Thermal</td><td>Kaoru Nakao</td><td>Registered diagnoser, ECC</td></tr>
<tr><td>Electric</td><td>Kenichi Kurita</td><td>Registered diagnoser, ECC</td></tr>
</table>

Meanwhile, the counterpart of NEA and Ministry of Industry (MOI) went together with the study team to extend their cooperation and to learn factory diagnostic technology on the spot.

Table 2. Thai Counterpart

Groups	Name	Attached to:
Ceramics group	Mr. Pramoul Chanpong	NEA
	Mr. Danai Egkamol	NEA
	Mr. Supachok Kusolsong	NEA
	Mr. Banphot Diskul	NEA
	Mr. Derake Wuthichok	MOI
Paper group	Mr. Mingsak Tangtrakul	NEA
	Mr. Supon Khwankongrai	NEA
	Mr. Adisai Pornchai	NEA
	Mr. Tummasak Suwanathep	NEA
	Mr. Tawathai Titivudtiwong	MOI

In addition, those people from the MOI, universities, the Thai-Japan Technological Promotion Association (TPA), and the Thailand Institute of Scientific and Technological Research took part in the diagnosis on occasionaly as observers.

3. Schedule for the Study

Aug. 15, Sun.: To leave Narita and arrive at Bangkok.

16, Mon.: To visit the JICA's Bangkok office, the

Japanese Embassy, the NEA, the JETRO Bangkok, and the TPA, giving details of the study plan and inquiring into what's going on in this country.

17, Tues.: To meet NEA Director of Regulatory Division Mr.Tamachart Sirivadhanakul to make preliminary arrangements for the study.
To unpack and check measuring instruments, and make them ready for use.

18, Wed.: To visit the MOI and the Association of Thai Industries, describing the study plan.
To teach the Thai counterpart how to work measuring instruments.

19, Thurs.: To meet NEA Secretary General Mr.Pravit Ruyabhorn and offer a presentation of the study plan.
To furnish the Thai counterpart with details of a diagnostic checklist.
To make preparations for a diagnosis.

20, Fri.: ~ Sept. 16, Thurs.: To make a diagnosis of the factories.

14, Tues.: To report the progress of the study to the head of the JICA's Bangkok office and Mr. Hideo Tajima, first secretary of the Embassy of Japan.

16, Thurs.: To report the completion of the First Study to Director-General of MOI Dept.of Industrial Works Mr.Vira Susangkarakan and Director of Inspection Division Mr.Yingyong Srithong.

To have a talk with the members of the Energy Conservation Committee at the Association of Thai Industries.

17, Fri.: To visit the TPA.

To inform about the findings of the first study to NEA Secretary General Mr.Pravit Ruyabhorn.

18, Sat.: To leave Bangkok and arrive at Narita.

4. Factories Diagnosed

4.1 Branches of industry and products

The factories diagnosed according to branches of industry and products are as shown in Table 3 below. All of these factories are located in the Bangkok Metropolitan area and its periphery.

Table 3. Factories Diagnosed

Name of Factories	Products	Date
Ceramics/glass factories of:		
Bangkok Glass Industry Co.	glass bottle	Sept. 2-3
Samutprakarn Glass Industry Co.	glass bottle	Aug. 31 - Sept. 1
Thai Neutral Glass Industry Co.	cup, ashtray	Aug. 20
Asia Glass Industry Co.	cup, glass	Aug. 26
Union Mosaic Industry Co.	tile	Sept. 13-14
Thailand Tile and Pottery	tile	Sept. 9-10

Co.		
Super Fibre Cement Co.	slate	Aug. 23-24
APA Industry Co.	injection ampul, tube	Aug. 30-31
Siam Insulator Co.	high-tension insulators	Sept. 6-7
Armitage Shanks (Bangkok) Co.	sanitary ware	Sept. 15-16
Paper mills of:		
Hiang Seng Fibre Container Co.	paper	Sept. 6-8
Thai Develop Paper Co.	paper	Aug. 30-31
Cardboard (Thailand) Co.	paper	Sept. 13
V. Sang Thai Paper Factory Co.	paper	Sept. 15
Industry Krungthai Co.	paper	Sept. 2-3
Arkanae Paper Industry Co.	paper	Aug. 26-27
New Century Paper Co.	paper	Sept. 9
Central Paper Industry Co.	paper	Aug. 20-21
Sang-Ngam Industry Co.	corrugated cardboard	Aug. 23

4.2 Scale of factories diagnosed

With the current status of Thailand's manufacturing industry, the factories diagnosed can be classified into three categories in terms of scale as shown in Table 4 below. From this table, it may well be said that the selection of factories is relatively well balanced.

Table 4. Scale of Factories Diagnosed

Branches of industry	Scale			
	Large	Medium	Small	Total
Ceramics:				
Glass bottle, cup	1	1	2	4
Tile	1	1	-	2
Miscellaneous	1	3	-	4
Subtotal	3	5	2	10
Paper:				
Paper	1	4	3	8
Corrugated cardboard	-	-	1	1
Subtotal	1	4	4	9
Total	4	9	6	19

Note should be taken of the fact, however, that some of these factories might be considered unfit for a diagnosis because they do not have much energy consuming facilities.

5. Study Procedure

5.1 Factory diagnosis

5.1.1 Preliminary study through questionnaire

A questionnaire (Attachment 1) was sent out in advance via the NEA to the selected factories asking them to give the following details: -

a. General information on the factory (name and address of factory, names of officers, type of industry, capital, annual sales, number of workers, number of technicians, major product, and production capacity);

b. Energy consumption (fuel, electricity, and water);

c. Major energy consuming facilities (name, type, year installed, fuel used, and operating hours);

d. Production process chart;

e. Energy flow chart;

f. One-Line diagram

g. Plant layout; and

h. Problems to be solved in pushing forward energy conservation.

5.1.2 Interview with plant managers

In the light of questionnaires recovered as well as the energy management checklist (Attachment 2), an interview was held with plant managers to look into: -

a. Current production and sales conditions;

b. Energy conservation measures so far taken;

c. Energy management situation; and

d. Problems to be solved in terms of production.

5.1.3 Overall factory inspection

An overall inspection was made of each factory following its manufacturing processes to have an understanding of: -

a. General management conditions;

b. Layout; and

c. Priority facilities to be surveyed and measured.

5.1.4 Survey and measurement

Priority facilities were surveyed according to the items stated in the checklist (Attachment 2) by: -

a. Measuring the dimensions of facilities;

b. Collecting data from the factory's records and using meters and gauges; and

c. Carrying out measurement using measuring instruments brought in (Attachment 3),

to go into the conditions of: -

- fuel combustion;
- heating, cooling, and heat transfer;
- prevention of heat reliese;
- waste heat recovery;
- conversion of heat into motive power;
- electricity loss by resistance, etc.; and
- conversion of electricity into motive power and heat.

5.1.5 Discussions

The survey and measurement results were outlined to factory managers and problematical points were discussed.

5.2 Transfer of techniques to the Thai counterpart

5.2.1 Handling of measuring instruments

Before making a factory diagnosis, the Thai counterpart were instructed at the NEA in the performance of measuring instruments, their uses, and how to handle them according to manuals.

Later, they were given practical guidance in measurement when a factory was diagnosed.

5.2.2 Guidance in diagnostic technology

Also at the NEA, the Thai counterpart were provided with necessary information on the items stated in the checklist and their meanings.

Subsequently, they were practically taught how to fill out the checklist each time a factory was diagnosed. While data were pigeonholed after the finish of the diagnosis, the Thai counterpart were given guidance in diagnostic technology; they were taught what points should be considered in diagnosis, how data should be checked and put in order, and what information could be obtained from data.

5.3 Collection of relevant information

Information concerning Thailand's energy policy, energy situation, and production in its manufacturing industry was collected through the NEA and the Thai-Japan Technological Promotion Association.

6. Implementation of the First Study

The First Study came to an end as scheduled. It came out well and satisfactorily thanks to thoroughgoing preparations made by the Thai Goverment,particularly the NEA. These preparatory efforts included: -

- selection of factories to be diagnosed and adjustment of the survey schedule;
- exemption of measuring instruments from taxation;
- distribution and recovery of questionnaires;
- provision of a microbus for the study mission as well as a small truck to carry measuring instrument, etc., and placement of an office at the study mission's service;
- selection and preliminary training of the Thai counterpart to go together with the study mission; and
- contact with, and call to, those organizations and firms concerned for cooperation.

The study mission received most hearty and energetic cooperation from the Thai counterpart, who got highly skilled in operating measuring instruments. It is necessary for them to obtain knowledge of processes and facilities in a plant and accumulate diagnostic experience with the actual conditions of many factories in the future.

The factory pepole kindly extend the study team their cooperation; they willingly showed us various drawings and data, and complied with our request to provide a sampling hole for measurement. Moreover, they discussed with us in a very enthusiastic manner. It was just a few factories where a manager or superintendent did not turn out.

7. Results of Diagnosis

7.1 Factory management

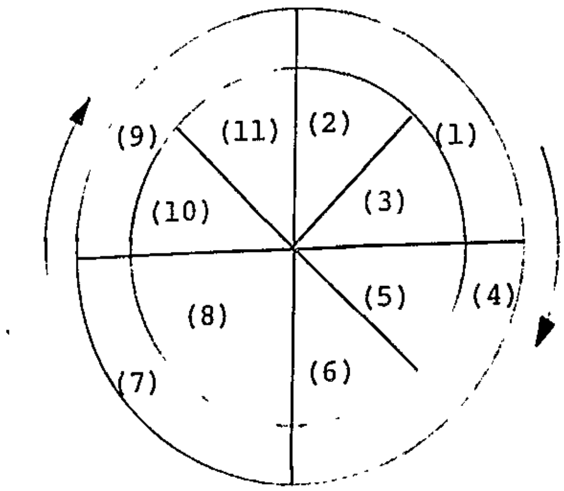
7.1.1 General

A. Generally speaking, all the plant operators and managers, it seemed, are well aware of the necessity for energy conservation in view of soaring energy prices. There are few cases, however, where some specific energy-saving measures are taken. No factories have set the target for energy conservation; few plants have lately made energy-saving investment.

B. The managers of small enterprises tended to be short-sighted seeking for only an immediate profit, rather than working on a long-term strategy for business progress. Some of them said that they would rather make less investment and keep facilities at the minimum level.

C. Almost all the factories did not employ a scientific, numerical data control technology. The level of energy-saving technology can effectively be raised by adopting a management method based on Dr. Deming's PDCA circle.

Fig. 2 Deming's Circle



(1) Plan; (2) To set up a target; (3) To fix the way; (4) Do; (5) To give education and training; (6) To implement; (7) Check; (8) To check; (9) Action; (10) To take a corrective action; (11) To check up once again on the results of action.

In other words, the following process should be repeated to improve matters of importance relating to energy consumption: -

a. To set a target and formulate a plan for improvement based on a full understanding of the existing condition as well as taking into account economic efficiency and the current technological level;

b. To make the aim and details of the plan generally known to all workers before implementing it;

c. To provide complete measuring instruments in order to grasp accurate understanding of the results;

d. If there is a difference between the results and the plan, to clear up the cause and shape a new plan; and

e. To carry out the new plan.

D. Many factories did not keep things in good order. In most of rather large plants, the back side of equipment was found to have been left in a disorderly manner, indicating that efforts are not made to take good care of facilities. This also indicates that the manager's attention does not reach the minutest details. The degree to which facilities are put in order furnishes a good indicator to see how a plant is managed.

In some cases, those people who had been trained in the Thai-Japan Technological Promotion Association took the initiative in making improvements in this aspect so that the plant as a whole is kept remarkably in good order.

7.1.2 Understanding and analysis of energy consumption

A. The starting point of energy conservation is to have a quantitatively accurate understanding of how energy is actually consumed. In general, however, meters and gauges for measuring and control were not installed in enough quantity and, if so, many of them were found to have been out of order.

For instance, it was just one factory where boilers were fitted with feedwater meters. A fuel flow meter alone does not allow to check up on the performance of a boiler all the time.

In many cases, ammeters, voltmeters, and power-factor meters for electric installations were provided in insufficient numbers, or left out of order.

B. Small firms did not try to record data on production and energy consumption, but instead made it a practice to memorize such data.

C. Even in the factories where daily reports and other documents are prepared, data contained in such documents are in most cases kept and shelved by a person in charge; there were few cases where data were analyzed to improve the energy consumption rate.

7.1.3 Quality control

A. In general, the factories surveyed showed a high percent defective in their products; it reached as much as 40 percent in a certain glass factory. Although varied causes can be conceivalbe, the factory diagnosis revealed that defective products were caused by:

- the lack of uniformity in manual operations;
- the mixing in of foreign matters resulting from improper handling of raw materials;
- equipment left in a bad state of repair; and

- the malfunctioning of equipment.

B. In some cases, testing equipment for quality control were not installed and good instruments, if provided, were not effectively used.

C. The manufacture of defective products means that energy consumed goes to waste. Thoroughgoing quality control is one of the very important considerations for energy conservation.
Manufacturing conditions should be made more stable by, for example, quantitatively looking into some factors in the manufacturing process that may contribute to the development of defective products, fixing and standardizing priority control items, or installing automatic control units.

7.1.4 Equipment control

A. Equipment were not adequately checked and put in good repair. Motors and equipment's bases, for instance, were found to have corroded with rust or loosened; struts for piping were not properly fitted; driving belts were excessively loosened or left out; a transformer oil was deteriorated; insulators for steam piping came off, or steam was leaking out of pipes. These irregularities cause energy loss both directly and indirectly as the service life of equipment will be shortened.

B. Most of the plants did not bother to make a one-line diagram to show the wiring of electric equipment.

The one-line diagram should be drawn to know what load is applied to what system; otherwise, relations between the operating condition and the power factor as well as the appropriateness of load distribution cannot be examined. Moreover, an accident, if happened, cannot be coped with quickly.

During the present survey, a one-line diagram was drawn and attached to a report whenever possible with the cooperation of the Thai counterpart.

7.1.5 Safety control

A. Safety measures were found generally inadequate. For instance, platforms and stairways were not equipped with guardrails. No covers were provided for belts and rotary equipment. Workers did not wear protective gears against harmful objects. These were observed in many plants.

B. There seemed almost no public systems to secure safety control at factories, such as installation standards for boilers, high-pressure gas facilities (e.g. LPG tanks), a periodical inspection scheme, standards for operation and handling, and an operator's qualification screening system. In some cases, workers were doing job in a wrong manner. As the industry becomes larger in scale, all this is likely to pose some problem.

7.1.6 Employee's training

A. No training was given to the so-called blue-collar workers. "Workers lack a strong sense of responsibility; we cannot help but relying on machinery and equipment," some plant manager said. It was felt, plant managers did not put confidence in employees, nor they tried to educate workers so that they can be reliable. It is of course important to upgrade the ability of an engineer, but it is also very important in terms of energy conservation to train skilled laborers who are working at a job site where energy is actually consumed and are well acquainted with what is going on.

B. At some factories, engineers were sent to take outside training. With these trained engineers, efforts are now being made to modernize their factory management, showing that there is a good possibility of improvement in this field.

C. No operator's manual was provided, so that technical assets cannot be accumulated. It is likely, therfore, that the working procedure may differ from worker to worker.

D. There was not a system under which employees are invited to present a proposal for remedial measures and, if the proposal of an employee is adopted after screening, he will win official commendation. Workers are allowed to put forward an improvement proposal at some plants, but such a proposal is often laid on the table because nobody knows how to handle it. This system not merely arouses an interest in the improvement of work on the part of employees but also helps develop their will to work as they will be well content to have contributed to their firm.

E. Two of the factories are now paving the way for group activity (QC circle) aimed at operational improvement by workers, and good results are hoped for. In Japan, this group activity has produced many fruits, and an increasing number of enterprises in the United States and Europe are trying to follow suit.

7.1.7 Exchange of information

A. In general, the firms surveyed tend to be closed and strongly wary of their competitors, and they do not try to exchange technological information with one another. By contrast, the exchange of information, not conflicting with free competition, is a common practice among the Japanese enterprises, which can be attributable to the following factors: -

a. Advanced technology is protected by the patent system;

b. The Japanese companies give rather active publicity to what they try to do or have done because they think that technological development and energy-saving achievements not only indicate their technological capability but represent their cooperative attitude toward the nation's policy as well;

c. Each industry has its own technological committee as a forum where opinions as to problems common in the industry are exchanged;

d. Entrepreneurs believe that the provision of technological information does not benefit competitors alone but helps raise the technological level of the industry at large, if based on the give-and-take principle;

e. In most cases, new technology for energy conservation is developed by equipment manufacturers alone or jointly by the manufacturer and the user, and active publicity is usually given to newly developed technology from the manufacturer's marketing policy; and

f. Technical publications and newspapers come out in large quantities.

B. The Thai companies surveyed do not have the exchange of information with suppliers of raw materials and products, nor they try to carry out joint researches. The user's demand for improvement gives an incentive to technological development.

C. A wide variety of questions about technological information were directed to the study mission during discussion hours of the diagnosis, showing the plant operators' and managers' great interest in this field.

7.1.8 Problems facing the Thai factories surveyed in the course of promotion of energy conservation

A. The findings of questionnairing, which was conducted through questionnaires (Attachment 1) sent out in advance to the factories, are shown in Table 5. Six out of the 19 factories diagnosed did not respond to the questionnaire; some were of small scale and had little interest in the questionnaire, and some, though of large scale, did not have a personnel in a position to answer the questionnaire.

B. The questionnairing revealed, above all, the following trends.

a. The first group of problems is related to economical efficiency. Nine out of the 13 factories circled the item (1) in the questionnaire - Prospect of energy price is not clear. Ten gave a circle to the item (3) - Increase of energy cost can be covered by raising the price of products. As for the item (3), however, they told the study mission that they were in no position to pass on higher energy prices to final buyers in their product prices due to keen competition resulting from the current business depression.

b. Some problems are concerned with the quality of employees. Noticeably, ten regarded the item (11) as a problem - that is, Employees' consciousness is low. And nine marked the item (12) with a circle - No personnel is available who can educate the employees. This is associated with the fact that six were concerned about "Shortage of engineers" - the item (5). To push ahead with energy conservation, it is very important to raise the technical level of workers directly operating energy consuming equipment; the findings of the questionnairing shows an urgent need to do something in this direction.

Table 5. Results of the Questionnairing on "Problems in the Course Promotion of Energy Conservation"

(13 out of the 19 factories returned the filled out questionnaire and 6 gave no reply.)

A set of questions	No. of factories replied		
	Paper	Ceramics/ glass	Total
(1) Prospect of energy price is not clear.	2	7	9
(2) The proportion of energy cost in the whole cost of enterprise is small.	0	1	1
(3) Increase of energy cost can be covered by raising the price of products.	4	6	10
(4) Instability of energy supply. (power sotppage, etc.)	2	3	5
(5) Shortage of engineers.	3	3	6
(6) Difficulty in obtaining good energy conservation equipments.	1	1	2
(7) Information such as active cases is not easy to obtain.	1	2	3
(8) System of research and development is not sufficient.	2	0	2

(9) Shortage of fund for facility improvement.	1	1	2
(10) The facilities are superannuated.	0	1	1
(11) Employees' consciousness is low.	5	5	10
(12) No personnel is available who can educate the employees.	4	5	9
(13) Shortage of measuring equipments.	1	4	5
(14) No time to analyze energy consumption rate.	0	1	1
(15) Shortage of information on government's measures.	1	1	2
(16) Shortage of government's subsidiary measures.	3	2	5
(17) Others (market)	2	1	3
Total	32	44	76

7.2 Conditions of energy consumption

Some of the factories diagnosed were found to have good equipment, keeping the energy consumption rate at a reasonable level.

In some cases, however, fine equipment were not utilized to the full, or equipment themselves had some defects; there is much room for improvement at these plants.

Four plants were equipped with lignite- or sawdust-burning boilers in an effort to replace oil, but some of them were just making a test run of these boilers at the capacity below the designed level.

7.2.1 Rationalization of fuel combustion

A. The air for combustion, if in too much supply, lowers the temperature of a flame while increasing the loss of heat in an exhaust gas. And, if in too short supply, it causes incomplete combustion, resulting in the inadequate use of heat. The results of the diagnosis showed that in some cases, furnaces and boilers were supplied with an excessively large or small amount of air and the air ratio was not well balanced on both sides of a furnace. Some furnaces could save energy by about 13 percent simpl by improving the air ratio.

B. In many cases, a burner was installed in a wrong direction, driving flames against burner tiles.

C. No attempt was made to check up on the calorific value of fuel.

7.2.2 Rationalization of heating, cooling and heat transfer

A. In most cases, the heat-transfer surfaces of equipment, such as the surface of a roller for the paper machine's dryer part, were not cleaned adequately.

B. Efforts should be made to cut down the amount of energy used for heating something other than the object as is the case with the sagger for tile burning.

C. The pressure of steam for heating was in many cases kept at the much higher level than needed.

7.2.3 Prevention of heat loss by radiation and conduction

(9) Shortage of fund for facility improvement.	1	1	2
(10) The facilities are superannuated.	0	1	1
(11) Employees' consciousness is low.	5	5	10
(12) No personnel is available who can educate the employees.	4	5	9
(13) Shortage of measuring equipments.	1	4	5
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7.2.3 Prevention of heat loss by radiation and conduction

A. Some of the old furnaces release much heat. These furnaces should be more effectively insulated, though bricks making up a furnace are limited in terms of properties.

B. In many cases, heat insulators for steam pipes were broken. Also, there were not a few cases where steam valves, headers, and feedwater tanks were not insulated. Bad steam leakage was strikingly observed at some factories.

C. A paper machine was not fitted with a hood, or if any, it was not adequately high.

D. Many crevices and cracks were found in the door or enclosure of a dryer chamber.

7.2.4 Recovery/reutilization of waste heat

A. More vigorous efforts should be made to recover waste heat from the paper machine and an exhaust gas out of the tunnel kiln, among others.

B. In some cases, waste heat and exhaust were recovered, but they were not fully utilized because transport pipes were not insulated, or equipment were not adequately airtight.

C. There were relatively many plants where steam condensates were recovered, but they were often stored in a small cistern which was left running over. Taken together, condensates are not used to the full.

7.2.5 Rationalization of conversion of heat into power, etc.

No independent power plant in constant operation was installed at the factories diagnosed. However, a power generating unit using a back pressure turbine was under construction at one plant, and another factory was examining the possibility of setting up such a unit.

This system does not merely burn fuel to produce low-pressure steam, but high-pressure steam is produced to generate electricity, and low-pressure steam from the turbine is used for heating. This is highly efficient to make the effective use of energy, so the increased number of factories adopting this system is hoped for.

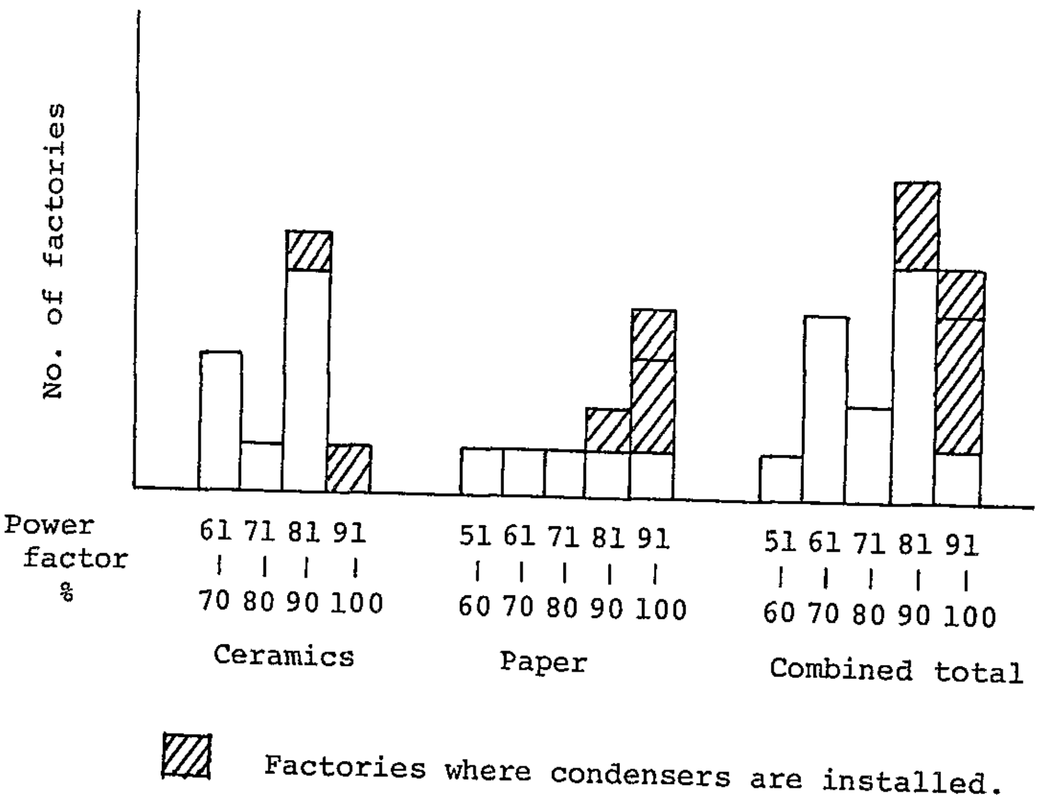
7.2.6 Prevention of electricity loss by resistance, etc.

A. The higher power factor (effective power/apparent power) could result in a reduction in electricity loss in power supply equipment including transformers, transmission lines and generators, as well as in a cutback in their installed capacity.

In Japan, therefore, a system is employed under which, with the power factor of 85 percent fixed as the standard level, a penalty will be levied if the power factor is lower than this level and an incentive will be given if higher.

In Thailand, on the other hand, the MEA imposes a penalty alone. In order to improve the power factor, it is necessary to bring the load on a motor closer the rated level through the adjustment of the number of load equipment in operation and the optimalizing of capacity, as well as to install condensers. It is desirable to adopt an incentive system that may encourage such rationalization effort and investment. Due care should be taken, however, before installing condensers as some factories surveyed were found to have suffered from the leading power factor due to excessively large condensers provided. The power factor varies according to loads. Shown in Fig. 3 are the data on the power factor obtained by the diagnosis of the factories.

Fig. 3 Distribution of Power Factor by Branches of Industry



In many cases, meanwhile, the secondary voltage was set at a rather higher than the rated level. This seems to be due to the fact that taps are set up to provide for a decline in the source voltage, but it may lead to a drop in the power factor as well as in the service life of lighting equipment.

B. Many factories were experiencing an excessive capacity mainly because they have installed additional transformers in keeping with their plant expansion. Being a sort of electric equipment, a reduction in the number of transformers in operation to the minimum will make the overall energy conservation possible.

C. At some factories, there was an inequality in the three-phase due to the wrong application of a single-phase load, resulting in the generation of a negative-phase torque and hence in a drop of the motor output.

7.2.7 Rationalization of conversion of electricity into motive power, heat, etc.

A. In many cases, belts for belt-driven equipment were not fitted as specified, or loosened much.

B. At some factories, it was found that the number of compressors in operation could be reduced, that the air taken in should better be moved more to the low-temperature side, and that valves might have been broken.

C. Energy conservation efforts were found generally satisfactory in terms of lighting; almost all the factories surveyed made it a practice to put out lights and make the most of natural lighting during daytime. It is recommended, however, that an attempt be made to clean lighting apparatuses more often and to switch to more efficient ones such as white fluorescent lights and high pressure sodium lamps.

7.3 Ceramics

7.3.1 General condition

Ceramics produced in Thailand include cement, glass, tiles, sanitary ware, and bricks, among others. In recent years, exports of tiles, sanitary ware and porcelain have been on the steady increase, promising a bright future for the Thai ceramic industry. The industry is, however, confronted by the weak domestic demand for these products and hence an overall decline in the rate of capacity utilization due chiefly to the farmers' decreasing purchasing power resulting from aggravated grain market conditions as well as to sluggish housing construction.

The cement sector was left out of the diagnosis. Among glassworks diagnosed were those manufacturing bottles and glass tableware, tiles, high-tension insulators, sanitary ware, slates, and ampuls.

7.3.2 Glassworks (bottles and glass tableware)

(1) General situation of the industry and positioning of factories diagnosed

The five major glassworks in Thailand are as shown below.

Table 6. Thailand's Major Glassworks

Name	Nominal production capacity	Estimated capacity
Bangkok Glass Ind.	300 t/d	150
Thai Glass Ind.	390	300
Bangna Glassworks	210	
Kaew Prakarn Glass	140	
Samutprakarn Glass Ind.	120	100
Total	1,160	

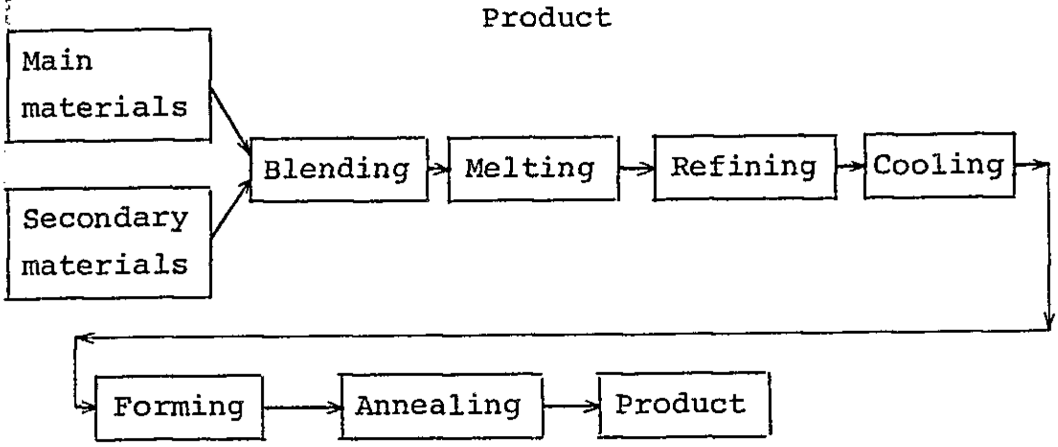
Counting other small factories, Thailand has a total of 32 glassworks, showing the nation's total output of 413×10^3 tons per annum in 1980.

The diagnosis was made of four glassworks: two are among the above five major glassworks and the other two are small glass works. Although Thailand's total production for the current year is not clear, the output of the four glass factories diagnosed is estimated to account for around one third of the total.

(2) Manufacturing processes and equipment

A. A glass product comes out of the following manufacturing processes.

Fig. 4 Manufacturing Process Chart for the Glass Product



B. Of main materials, cullets (waste glass) are used to meet the need for control of product quality in the course of work. As the amount of cullets increases, the amount of heat required for melting decreases. 30 to 40 percent on the total amount of main materials is the most common figure for cullets. It was found that cullets used at the glassworks diagnosed amounted to 40 to 80 percent.

C. A melting furnace is a unit consuming the largest amount of energy, which is available in two types: a crucible furnace and a tank furnace. In general, small plants are equipped with the crucible furnace. All the glassworks diagnosed were using the tank furnace.

A device for recovery of heat from an exhaust gas coming out of the furnace comes in two types: a regenerator and a recuperator. Two factories had one each regenerator and the other two were equipped with one each recuperator.

D. An automatic forming machine was found to be in operation in the forming process at three of the glassworks, of which one was carrying out manual forming in combination with the machine.

E. All of the glassworks diagnosed were operating an annealing furnace working on the continuous system; three of them were employing the radiant type and the remaining one was using the direct-burning type.

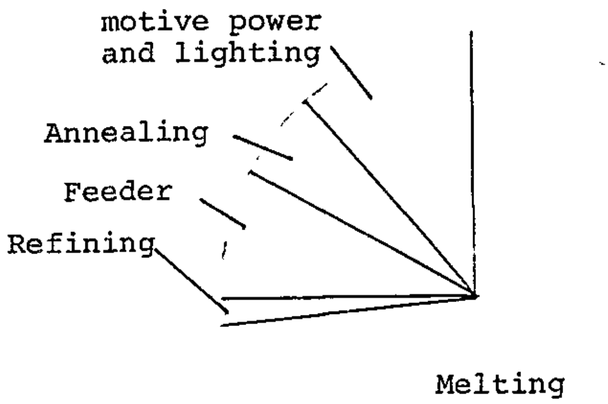
(3) Modes of energy consumption

A. At a glass factory, energy is consumed in the following modes:

Purposes	Equipment	Energy sources
Glass melting	Melting chamber	Fuel oil and electric energy
Refining	Refining chamber	Diesel oil, LPG, and fuel oil
Cooling	Feeder	LPG
Annealing	Lehr	Fuel oil
Air compression	Compressor	Electric energy
Lighting etc.	Lighting apparatuses, etc.	Electric energy

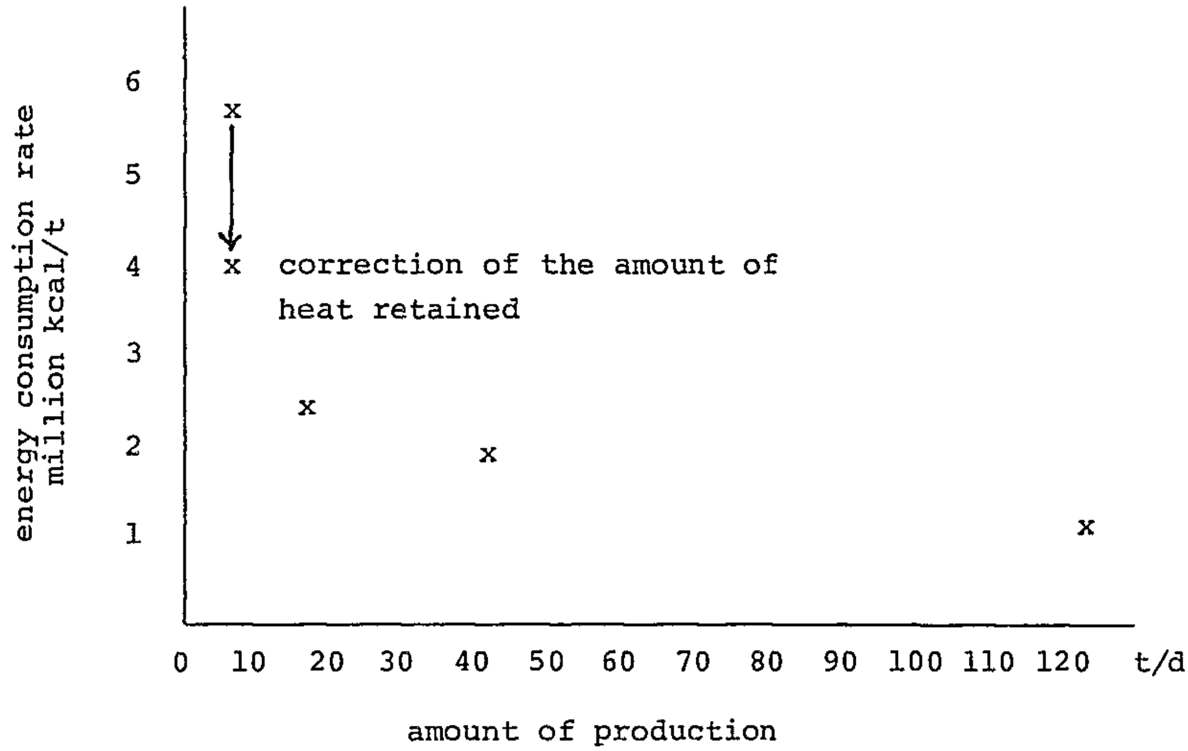
B. Shown in Fig. 5 below by way of example is the percentage of energy consumption by purposes.

Fig. 5 Percentage of Energy Consumption by Purposes: Glass Industry



C. Of all, energy used for melting shows the highest percentage, and its consumption rate per unit of production is as shown in Fig. 6. The energy consumption rate, as discussed later, is affected by a number of factors; in general, this figure is low with a large furnace and high with a small one.

Fig. 6 Consumption Rate of Energy for Melting



It should be pointed out, however, that the smallest furnace has some designing problems and differs from the others in terms of operation.

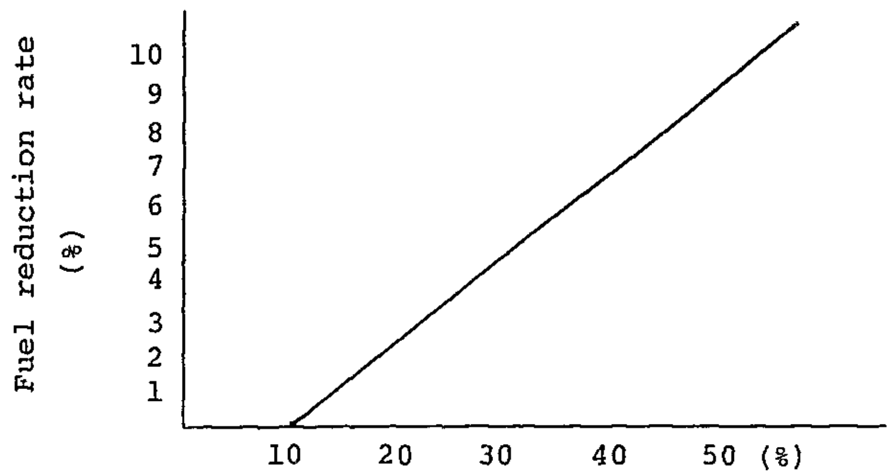
(4) Major points for energy management

A. Melting furnace and refiner

a. Cullet mixture ratio

The use of cullets does not merely mean the recycling of waste glass but also helps improve the work efficiency and makes melting easier, thereby enabling a reduction of fuel. Fig. 7 shows the results obtained at the nine Japanese firms, indicating that with an increase in the cullet use rate, the amount of fuel consumed decreases. It is desirable to increase the cullet mixture ratio within the limits not affecting the quality of products.

Fig. 7 Cullet Use and Fuel Reduction Rates



Cullet use rate (rate of the amount of cullets used to the weight of a product)

* Based on the cullet use rate of 10 percent.

Source: Watanabe and Ogawa, "Ceramics", Vol. 13, No. 3, p.208, 1978

The survey revealed that the glassworks diagnosed were using a relatively large amount of cullets at 40 to 80 percent.

b. Air ratio

To burn fuel, a furnace is normally supplied with

a larger amount of air than theoretically needed in order to prevent incomplete combustion.
If the air is supplied too much, however, the temperature of a flame will be lowered and the loss of heat in an exhaust gas will be increased.
The four glassworks diagnosed were found to have set the air ratio at 1.01, 1.11, 1.14, and 1.83 respectively. The furnace with the air ratio of 1.01 was apparently developing incomplete combustion and carbon was deposited. The furnace with the air ratio of 1.83, meanwhile, was suffering from a large heat loss due to excessive air supply.
To lower the air ratio, it is necessary: -

- To employ a burner with a proper capacity affording good fuel atomization; and
- To cover the shell and openings of a furnace to reduce the amount of air taken in as much as possible, and to keep the in-furnace pressure at a proper level.

c. Prevention of heat release from the walls of furnaces and heat recovery equipment
A melting furnace had not been well insulated due to the limited service life of refractory materials. In recent years, however, refractory materials have been improved in quality, allowing better thermal insulation.
Three of the four glassworks diagnosed were found

to have employed high quality refractory materials. The wall temperature of a furnace was kept at a remarkably good level of 110 to 120°C at some factory, but it was 300 to 440°C for the others.

Better heat insulation is provided more easily and safely while a furnace is being installed, but even with a furnace in operation it may be possible by means of spraying, and others. Examples of providing a regenerator in operation with better thermal insulation abound in Japan.

d. Temperatures of exhaust gas

All the factories diagnosed were equipped with waste heat recovery devices. Temperatures of the exhaust gas stood at the following levels:

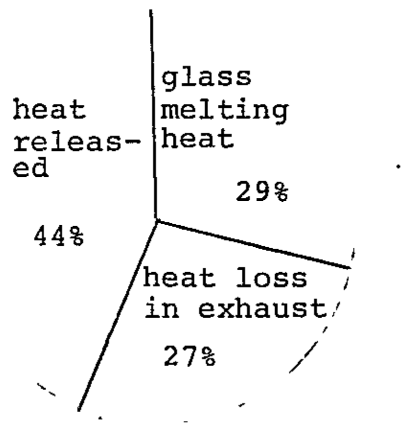
540°C, 550°C - at the outlet of a regenerator

480°C, 672°C - at the outlet of a recuperator

e. Heat balance in the melting furnace

Fig. 8 gives the results of heat balance in a melting furnace.

Fig. 8 Results of Heat Balance in a Melting Furnace (simple average for 3 factories)



B. Annealing furnace

An annealing furnace is the unit in which, to eliminate a strain developed in the cooling process after forming is made, the object will be heated up to higher than the annealing point, and then it will be annealed according to its thickness.

If only something can be done to keep heat coming out of a forming machine, heating inside a annealing furnace is supposed to be practically unnecessary by calculation. So efforts should be made not to let the cold air into the furnace as much as practicable. Equipmentwise, the direct heating type is more efficient than the muffle type; energy could be saved by making the conveyer net lighter in weight to decrease the thermal capacity or by using waste heat.

Viewed in the light of operation, attention has to be paid to the air ratio of a burner and the adjustment of its installation.

The burner was not well adjusted at one of the glassworks diagnosed.

C. Electric energy consuming equipment

About half the power supply is used for compression of the air for the forming machine. To save this electric energy, it is necessary to keep the pressure of the compressed air at the lowest possible level; to abate the air leakage or escape and reduce the number of compressors in operation; to put the compressor valves in perfect repair; to keep the belt from loosening so that motive power can be transmitted more efficiently; to frequently regulate the number of compressors in operation to decrease idle operation hours; and to take in the air from low-temperature sections as much as possible.

The electric energy consumption rate was as follows:

Glassworks operating on:

- Automatic forming	275 kWh/t, 198 kWh/t
- Semi-automatic forming	181
- Manual forming	154

(5) Targets for improvement and anticipated effects

<u>Targets for improvement</u>

A. Cullet mixture ratio; no common targets are set as the cullet mixture ratio is related to the availability of good cullet and quality standards for products.

B. Air ratio; the target value is tentatively fixed at 1.3, considering the fact that the air ratio ran into large figures at some factories.

C. Surface temperature of furnace wall; no target figures can be fixed for existing furnaces in view of the qualitative limitations of bricks lining the furnace wall. As for newly installed furnaces, excluding those parts most likely to be corroded, the target is set at 200°C or below.

No targets are fixed for waste heat recovery equipment as surface temperatures vary from type to type and from part to part.

D. Temperature of exhaust gas; since it is rather difficult to remodel existing equipment and new ones are restricted by space, no specific targets are fixed.

E. Power factor at receiving end; the target is provisionally set at 85% or higher.

Anticipated effects

Remedial measures which we have suggested each factory diagnosed to take as practicable are, in the aggregate, anticipated to bring about a fuel saving of:

	193 kl/y	-	by improvement of the air ratio
	263	-	by prevention of heat release
	112	-	through other measures
Total	568 kl/y		

This amount is equivalent to 4.2 percent of the total fuel consumption of 13,421 kl/y (in fuel oil).

Also, these measures could save electric energy by:

309×10^3 kWh/y

It corresponds to 2.0 percent of the total electric power consumption of $15,349 \times 10^3$ kWh/y.

The factories diagnosed apparently account for one third of the whole glassworks (bottles and glass tableware) in Thailand. Supposing that these factories represent the nation's entire glass industry, therefore, it is expected that an overall saving of 1,700 kl/y in fuel and 930×10^3 kWh/y in electric energy will be achieved.

Note should be taken of the fact, however, that the largest of the four glassworks diagnosed having two thirds of the total output was in a remarkably good state of energy consumption, thus bringing down the average saving rate to a rather low level.

7.3.3 Tiles, insulators, and sanitary ware

(1) General situation of the industry and positioning of factories diagnosed

A. The Thai tile industry made a rapid progress during the 1970s, reaching the production capacity of about 110,000 t/y. Yet the industry's rate of capacity utilization has also been on the decline due to the business slump.

Mosaic tiles are estimated to account for around 70 percent of the whole. Almost all of these mosaic tiles are being produced by the four companies, of which one has a market share of about 50 percent. The current total output runs at about 30,000 tons a year, of which, it is estimated, a little over 50 percent is being manufactured by the two factories diagnosed.

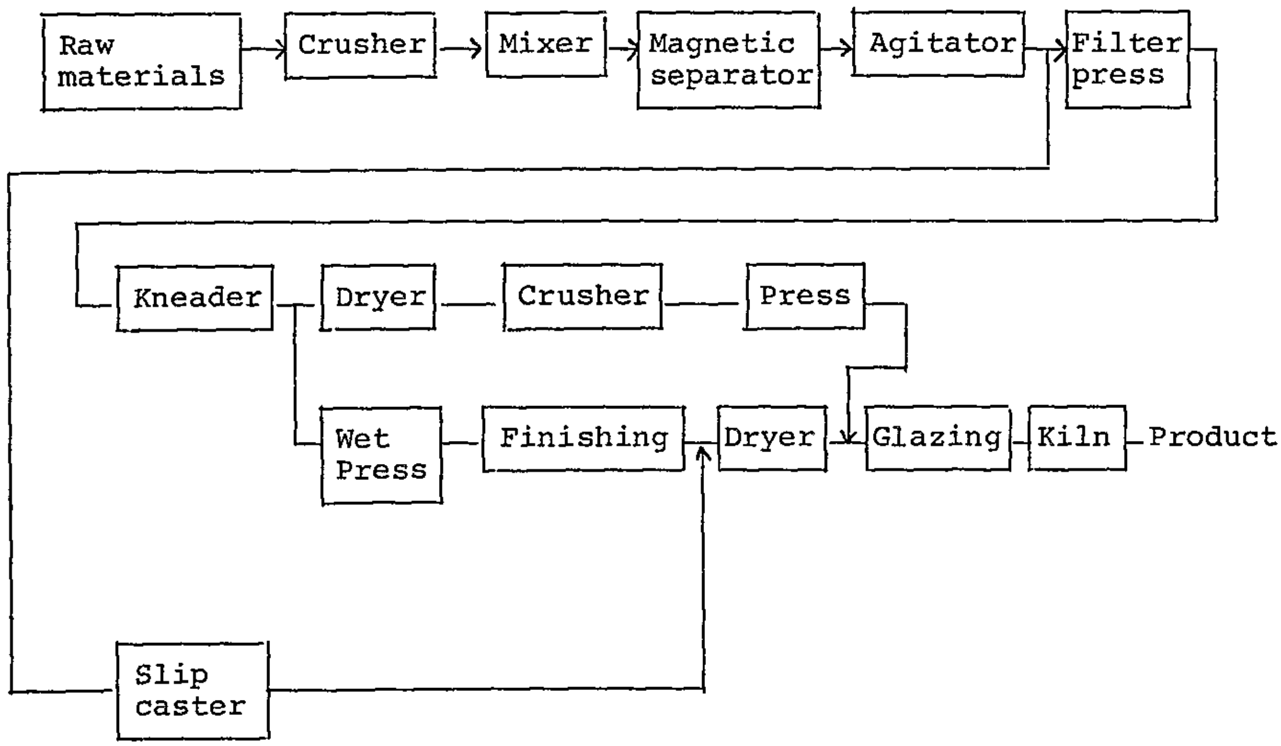
B. Thailand has four insulator factories, and the one diagnosed is the biggest of them, holding a greater share of the market.

C. Four companies are manufacturing sanitary ware, with their production capacity estimated at about 10,000 tons per year. Almost all the quality toilet fixtures are being manufactured by the top-ranking two firms. The rate of capacity utilization in this sector remains also low, falling short of 50 percent. About half the market share is occupied by the works diagnosed.

(2) Manufacturing processes and equipment

A. The processes of manufacturing ceramics including tiles are as shown in Fig. 9.

Fig. 9 Manufacturing Process Chart for Ceramics



B. For the crusher, almost all the factories employed ball mills, and a factory was using a edgerunner mill.

C. Three out of the four plants were making use of waste heat from a kiln to operate a dryer following the forming process. One factory normally runs a steam drying system, but when the study mission visited, it was applying natural drying instead of this system.

Also, a system was installed under which raw materials crushed and mixed are directly dried in a spray dryer utilizing waste heat from kiln.

D. Three factories were operating a tunnel kiln, of which one plant was using a muffle kiln. This was also equipped with an electric furnace for re-finishing. One of the plants had a shuttle kiln, which was installed comparatively lately and it was lined with ceramic fibers to reduce its thermal capacity.

The exhaust gas coming out of the cooling zone of a tunnel kiln and generated in the oxidation state of the shuttle kiln was used as a heat source for the dryer. Some plants were preheating a burning oil making good use of heat released through top wall of the kiln. Some tunnel kilns were discharging a very hot exhaust gas and some radiating a large amount of heat as the brick walls of the burner section were too thin.

E. There was just one factory where the ball mill and press were fitted with condensers to improve the power factor.

(3) Modes of energy consumption

A. At the ceramic factories, energy is used for the following purposes:

Purposes	Equipment	Energy sources
Crushing	Ball mill, etc.	Electric energy
Mixing	Agitator	Electric energy
Forming	Press	Electric energy
Firing	Kiln, electric furnace	Fuel oil, kerosene, and electric energy
Drying	Dryer	Waste heat, steam
Lighting, etc.		Electric energy

B. The greater part of energy is used for firing and drying; 92 percent of the total energy supply comes from fuel and 8 percent from electric energy. One third of electric energy is consumed by the ball mill and press.

C. The energy consumption rate runs at 5.3 million kcal/t for tiles, 4.0 million kcal/t for insulators, and 7.3 million kcal/t for sanitary ware.

(4) Major points for energy management

As mentioned earlier, 92 percent of the total energy supply comes from fuel for firing and drying. And a greater proportion of energy for drying is supplied by waste heat coming out of a firing furnace. Priority in energy conservation, therefore, should be given to the saving of fuel for firing.

The firing process for ceramics has some distinctive points requiring particular care, which are:

- Attention has to be paid to the evaporation of water and the shrinkage of clay which may often cause the breakage of products;
- The temperature should normally be raised to 1,100°C or higher, though it depends on the categories of products;
- Depending on products, the oxidation property of an ambient gas must be regulated in the burning stage, and care should be exercised not to let materials, after burned, come into contact with a combustion gas;
- Gadgets to retain or protect products, such as shelves and saggers, are needed, and these gadgets weigh heavily so that much energy is required to heat them;
- Products and gadgets both have a bad thermal conductivity and a large specific heat; and
- The bottom of a carriage should be protected from intense heat.

Firing of ceramics, therefore, should be made for many hours in a very hot furnace, so it is a process consuming a large amount of energy.

A. Rationalization of fuel combustion

In combustion, heat loss will become less, if the air ratio (the ratio of fuel to the amount of air

theoretically needed) is brought as close to 1 as possible. In manufacturing ceramics, efforts have to be made, wherever possible, to bring this figure to 1 with due care as it affects the quality.
To achieve this purpose with a tunnel kiln, it is necessary:

- To keep the pressure at a proper level so as to prevent the air from flowing in from the cooling zone;
- To provide sand seals so as to keep off the cold air from the bottom of the carriage;
- To regulate the amount of fuel according to the position of the burner; and
- To leave the door open in as short a time as possible or provide the double door because the pressure level inside may be affected by the opening of the door.

The air ratio was kept at a relatively satisfactory level at the factories diagnosed. In some cases, however, the air supply was not well balanced on both sides of a muffle-type tunnel kiln where there was an excess in air on one side and a shortage on the other. In addition, the air was coming in from the bottom of the carriage in some kiln.
To do away with these irregularities, it is also important to provide a burner capable of atomizing fuel effectively or to set up the burner in the

right position so that the flames won't directly touch the burner tiles.

B. Improvement of heat transfer

To obtain better heat transfer through gas inside, a good means of loading a kiln should be contrived so that a gap between objects and the kiln's walls and ceiling can be lessened as much as possible.

In general, an increase in the firing speed tends to result in the better fuel consumption rate. So efforts have to be made in this direction step by step by controlling raw materials and in-furnace temperatures more effectively.

Since indirect heating with a muffle kiln affords a bad thermal efficiency, a direct burning system should better be adopted.

C. Reduction of thermal capacity

Since the thermal capacity of shelves and saggers is larger than that of products, it is necessary to make these devices lighter in weight. In tile making, the amount of heat used for heating the sagger is four times larger than that for the product.

The process of heating and cooling is repeated in a shuttle kiln, so it is important to decrease the thermal capacity of the kiln body. At the factories diagnosed, the kiln was lined with ceramic fibers so that the thermal capacity could be reduced. It is recommended, however, that care be exercised not to let fiber fragments come off onto products by checking up on the kiln frequently.

D. Stepping up of heat insulation

A tunnel kiln has the large surface area and, therefore, radiates a large amount of heat. With this in view, the recent tendency among many plants is toward spraying the tunnel kiln with rock wool to achieve better heat insulation and lower the surface temperature down to somewhere around 40°C.

All of the tunnel kilns at the factories diagnosed had been installed sometime before the oil crises; one of these showed the surface temperature of 70 to 90°C and one was being operated at the surface temperature of 120 to 140°C.

Since better heat insulation raises the inner temperature, bricks making up the kiln should be fully checked in advance to see if they stand the higher temperature; otherwise, the kiln may be damaged.

As for one of the kilns diagnosed, it seemed difficult to step up heat insulation in view of the formation of bricks, so it is advisable to lay bricks once again to have a better insulated kiln.

Thermal insulation on the surface of the carriage works remarkably. This is usually achieved by covering the carriage with ceramic fibers or using light insulating fire bricks. If the carriage is well insulated and sand sealed, it can be done without taking in the air for cooling.

E. Utilization of waste heat

In a tunnel kiln, a combustion gas is used for preheating the product and shows a relatively low temperature. Heat recovery in the fuel oil-burning kiln has its own limits because heat recovery equipment will corrode due to a sulfurous compound contained in the exhaust gas, if cooled down below 200 to 250°C.

The exhaust from the cooling zone is of great value in use, and it is usually used for drying materials. In some cases, however, a drying chamber was poorly airtight and was not effectively used, and waste heat piping was not insulated.

Also, waste heat can be very efficiently used for preheating of the combustion air, but only one of the four factories was making it a practice to do so. Some plants, meanwhile, were making good use of a radiant heat from the top of the kiln to preheat burning oil.

(5) Targets for improvement and anticipated effects

Targets for improvement

A. Air ratio; no targets are fixed for the tunnel kiln in which the air ratio is changed according to the timing of firing. With this kiln, however, the air ratio should preferably be kept at around 1.4 even when oxidation occurs.

Also, it should be fixed at 1.3 immediately after the firing zone.

B. Improvement of in-furnace heat transfer and heat capacity; no specific targets are set as these factors are difficult to quantify.

C. Insulation improvement; no target figures are given because it may sometimes be difficult to make insulation improvement on existing furnaces depending on the properties of bricks making up the furnace body. As for newly installed furnaces, the surface temperature target is set at 100°C or below over the ceiling in the firing zone.

D. Use of waste heat; the exhaust gas temperature target is set at 250°C or below.

Anticipated effects

Remedial measures which we have suggested each factory diagnosed to take as practicable are, in the aggregate, anticipated to bring about a fuel saving of;

800 kl/y	-	by improvement of the air ratio
957	-	by insulation improvement
633	-	by use of waste heat
Total: 2,390 kl/y		

This amount of saving is equivalent to 21.9 percent of the total fuel consumption of 10,898 kl/y (in fuel oil). Also, these measures could save electric energy by:

73×10^3 kWh/y

It corresponds to 0.7 percent of the total electric power consumption of $10,412 \times 10^3$ kWh/y.

The total output of the factories diagnosed accounts for about one half of the combined total tile production in this country. Supposing that these factories represent the entire scene, therefore, it is expected that about 4,800 kl/y of fuel and about 150 x 10^3 kWh/y of electric energy will be saved in Thailand's tile making sector.

7.4 Paper

(1) General situation of the industry and positioning of factories diagnosed

The Thai paper-manufacturing industry has made a continued growth since 1962. Currently, a total of 49 paper factories are in operation, recording an annual output of about 360,000 tons in 1981.

Table 7 shows the number of paper mills and their production capacity.

Table 7. Number of Paper Mills

Category of paper	No. of mills	Production capacity
Printing paper	8	74,600 t/y
Paper for industrial use	21	285,070
Tissue paper	7	30,550
Miscellaneous	13	21,400
Total	49	411,620 t/y

The major paper-manufacturing companies in Thailand are as shown in Table 8 below.

Table 8. Major Paper-manufacturing Companies

(unit: in tons per annum)

Name	Printing paper	Paper for ind. use	Miscel-laneous
Siam Kraft Paper Co., Ltd.		99,000	
Thai Union Paper Co., Ltd.	24,500	25,000	7,000
Hian-Seng Fibre Container Co., Ltd.		51,000	

Out of these paper mills, a diagnosis was made of one large-scale factory (200 tons a day), four medium-size mills (25 to 38 tons a day), and three small factories (7 to 12 tons a day). The toal output from these paper mills runs at about 120,000 tons per year, which is estimated to account for about one third of the nation's aggregate paper production.

(2) Manufacturing processes and equipment

A. Fig. 10 shows the typical process of manufacture.

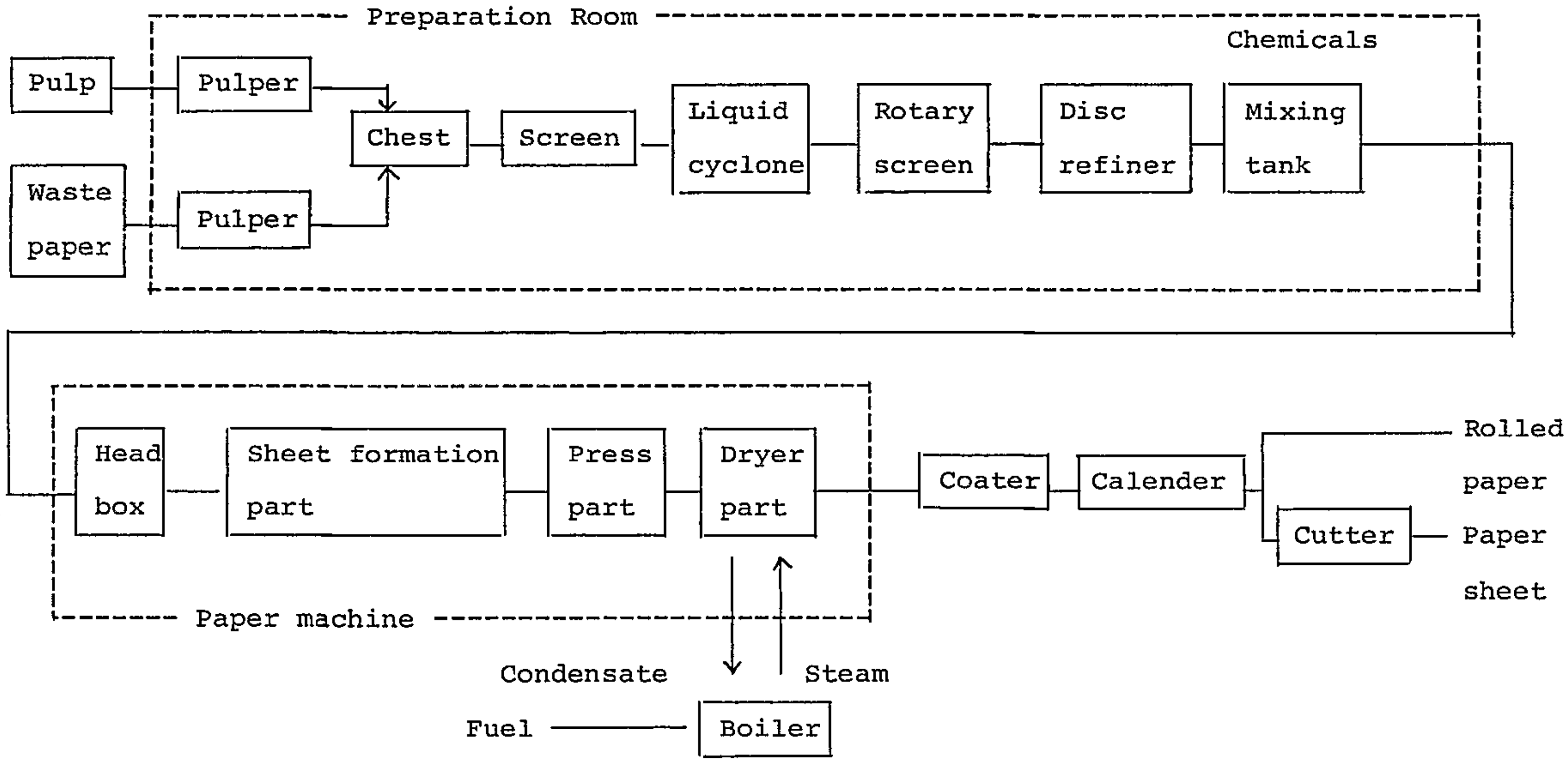


Fig. 10 Paper Manufacturing Process Chart

B. Recycling of waste paper is really an effective measure to save resources, and for that matter, energy. This practice is actively followed in Thailand.
Waste paper accounts for more than 60 percent of the raw materials used in white paper manufacture and more than 85 percent of the materials for corrugated cardboard. Three of the factories were using waste paper alone.

C. Preparation is a process whereby to clean, refine and crush raw materials, and make them into slush. This process was characterized by a diverse combination of equipment. The general tendency was toward a shortage of gauges and meters and inadequate maintenance of equipment.

D. The paper machine is a process in which a wet sheet is dehydrated and dried by means of the press or heating; the machine speed varies with the scale of production and the thickness of paper, coming within the range of 10 to 300 meters per minute.
The dryer part of the machine is normally fitted with a hood to keep heat within. At the factories diagnosed, however, five out of the 15 units were covered with a hood, other five were not well protected, and the remaining five were equipped with no hood. In some cases, the bottom of the hood was left wide open, allowing the cold air to come in freely.

The exhaust coming out through the hood has the temperatures of 50 to 70°C, and heat of this exhaust can be recovered and used for preheating water. But no machines were equipped with a device to recover such heat.

E. Low-pressure steam of 4 to 5 kgs/cm^2 is employed as a heat source for drying. To fuel a boiler producing such steam, lignite and sawdust are increasingly used in place of fuel oil. Two out of the eight factories have started the operation of a lignite-burning boiler, and two brought a sawdust-burning boiler into operation.
All the fuel oil-burning boilers were of flue and fire-tube type but equipped with no waste heat recovery devices. And, only one of these boilers was provided with a feed water meter. Thus, no data was available on the amount of water evaporated.

(3) Modes of energy consumption

A. At a paper mill, energy is used in the following modes:

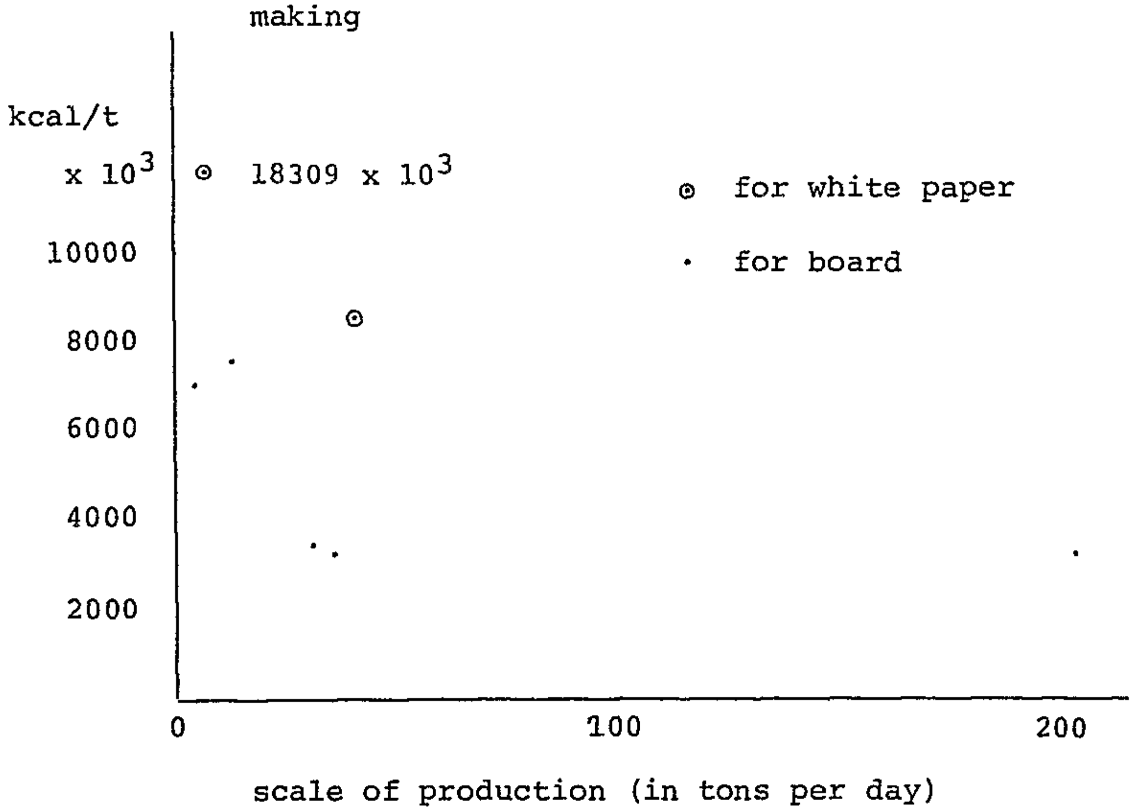
Purposes	Equipment	Energy sources
Generation of steam for drying	Boiler	Fuel oil, lignite, or sawdust
Paper-making	Rotary euqipment	Electric energy
	Pumps	Electric energy
	Paper machine	Electric energy
	Waste water	Electric energy

	treatment equip-ment	
Lighting	Lighting appara-tuses	Electric energy

B. About 82 percent of the total energy consumption is supplied by fuel and about 18 percent by electric energy.

C. Fig. 11 shows the amount of energy consumed to make a ton of paper. The highest value indicates that the mill specializes in white paper manufacture and that the yield is extremely low.

Fig. 11 Consumption Rate of Energy for Paper-making



(4) Major points for energy management

A. The fundamental paper-making process is to disperse pulp or waste paper fibers in water at the concentration of 1 percent or less, form them into a thin wet sheet, and mechanically and thermally dehydrate it. Success or failure in energy conservation, therefore, depends much on how efficiently a large amount of water is eliminated. It is also important to improve the yield by preventing the generation of paper scraps and defective products.

B. Preparation

Attention must be paid to the handling of raw materials so that no impurities such as mud may be mixed in. In the preparation stage, impurities should be removed completely to prevent the development of inferior products as well as an increase in the amount of energy used for drying. At some of the factories diagnosed, workers were walking on paper to be used as raw materials.

C. Press part

a. The pressure should be gauged periodically so that the press works effectively. Only one factory was gauging the pressure regularly.

b. Press rolls should be examined regularly to see if the crown is properly shaped and rubber maintains good elasticity, and if not, they must be cut off or replaced by new ones. All the factories were found to have failed to follow this practice.

c. A felt on the press part should be adequately washed to retain its elasticity and prevent it from being clogged. Its importance was almost totally unrecognized.

D. Dryer part

a. A siphon should be adjusted so that a film of condensate in the roll of the dryer part can be made as thin as possible. This practice was hardly followed.

b. A hood should be provided to keep heat in the dryer part from escaping (which is a point discussed earlier).

c. Good ventilation should be maintained so that vapor can be discharged quickly.

d. The exhaust coming out through the hood preserves heat of 60 to 70°C, so it must be recovered for preheating water (which has also been discussed before).

E. Steam and condensate

a. The pressure of steam for heating should be kept at as low a level as possible [about 3 kg/cm^2 (g)] to make the effective use of latent heat. In general, it was employed at the pressure of 4 to 7 kg/cm^2 (g).

b. Condensate produced is guided into a flash tank where its pressure is lowered to around 0.5 kg/cm^2; flashed steam is employed in the front stage of the dryer. Two of the factories were equipped with the flash tank, but they were not using flashed steam to the full.

c. Condensate is brought together and reused as feed water for a boiler to utilize its sensible heat and to reduce the load of feed water treatment. Six factories were making recovery of condensate, but feed water tanks were not insulated at all and some of them were running over.

d. A steam trap should be inspected regularly to prevent a leakage of steam. At some plants, steam was found flowing into a feed water tank due to malfunctioning trap.

e. Steam piping, headers, and valves should be adequately heat-insulated. Thermal insulation of valves, among others, was found inadequate.

F. Boiler

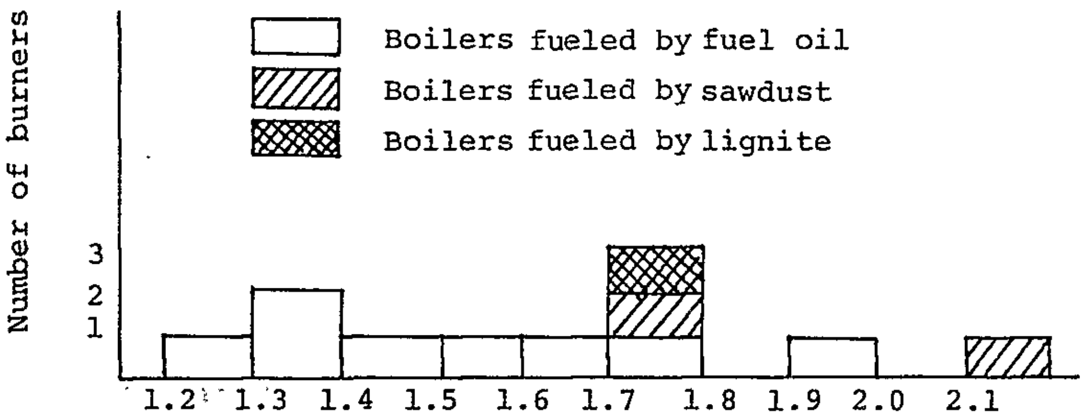
a. Control through the evaporative power
The evaporative power (the amount of water/ the amount of fuel) should be reckoned every day to see how it changes for energy control purposes. At the factories diagnosed, only one boiler was fitted with a feed water meter; the control method of this sort was not employed at all.

b. Reduction of the air ratio

An excessive supply of air into the furnace results in an increase in heat loss in an exhaust gas. Preferably, the air supply should be controlled by gauging the oxygen content in an exhaust gas. Unless an analytical meter is available, it is necessary to keep the amount of forced air at the minimum level to the extent that a smokestack won't give off black smoke, and to regulate a damper and an exhaust gas blower so that the negative pressure inside the furnace won't go up too high.

The air ratio should preferably be kept at around 1.3 for a fuel oil-burnig boiler, or below 1.7 even in the case of solid fuel. Shown in Fig. 12 is the air ratio prevailing among the factories diagnoses.

Fig. 12 Air Ratio at the Factories Diagnosed



c. Prevention of heat release from the boiler body

All in all, the manhole of a boiler was not heat-insulated.

d. Preservation of the boiler tube from stains

Feed water treatment was made at six out of the eight factories diagnosed, but control was not sufficiently conducted.

Although a boiler compound was used, its application was not proper in some cases. Scale was cleared about once a year, and the removal of soot was carried out at intervals of two weeks to twelve months. With sawdust-burning boilers, cleaning was more frequently made.

e. Optimization of the amount of blow

No established method of blowing was employed, nor there were safety measures taken by checking up on a water level gauge.

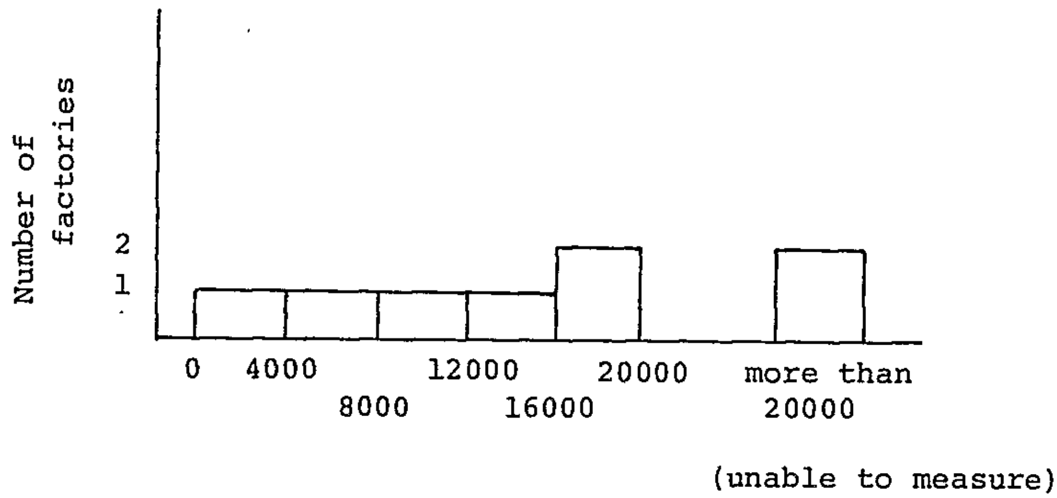
Neither the continuous blowing nor the recovery of waste heat in blow water was carried out. Some factories followed the wrong practice of sending blow water back to a feed water tank.

Shown in Fig. 13 are the results obtained by measuring the conductivity of water in the boiler. These results indicate that blowing was not adequately made. Inadequate blowing may produce scale, resulting in a drop in the heat-transfer coefficient as well as the deterioration of boiler tubes.

The Japanese standards (on the cylindrical boiler with the evaporation rate of 30 kg/m^2h or less) specify that the conductivity of water in the boiler should be kept below 6,000 μs/cm.

Fig. 13 Conductivity of Water in the Boiler

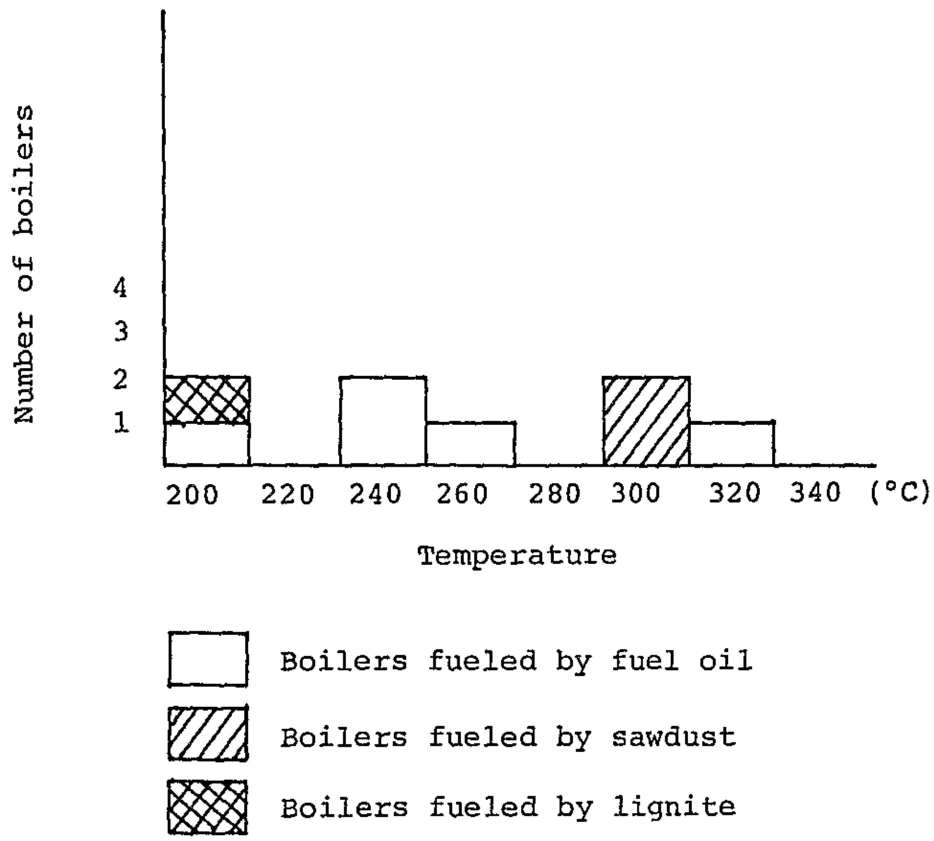
(unit: μs/cm)



f. Recovery of waste heat in an exhaust gas

The temperature of an exhaust gas from the boiler comes within the range shown in Fig. 14 below.

Fig. 14 Temperature of Exhaust Gas from Boiler



Since the exhaust gas from a boiler burning fuel with the high sulfur content causes corrosion, it is rather difficult to lower its temperature down below 200 to 250°C.

G. Electric energy consuming equipment

a. Electric energy requirements should be decreased by improving the tooth profile of a pulper and a refiner.

b. A better layout should be prepared to shorten a piping route, and the number of chests should be decreased to reduce motive power required for operating pumps.

c. Driving belts should be provided in required numbers at any cost and should be adjusted not to loosen. In some cases, equipment was run with one or two belts where three belts must be given.

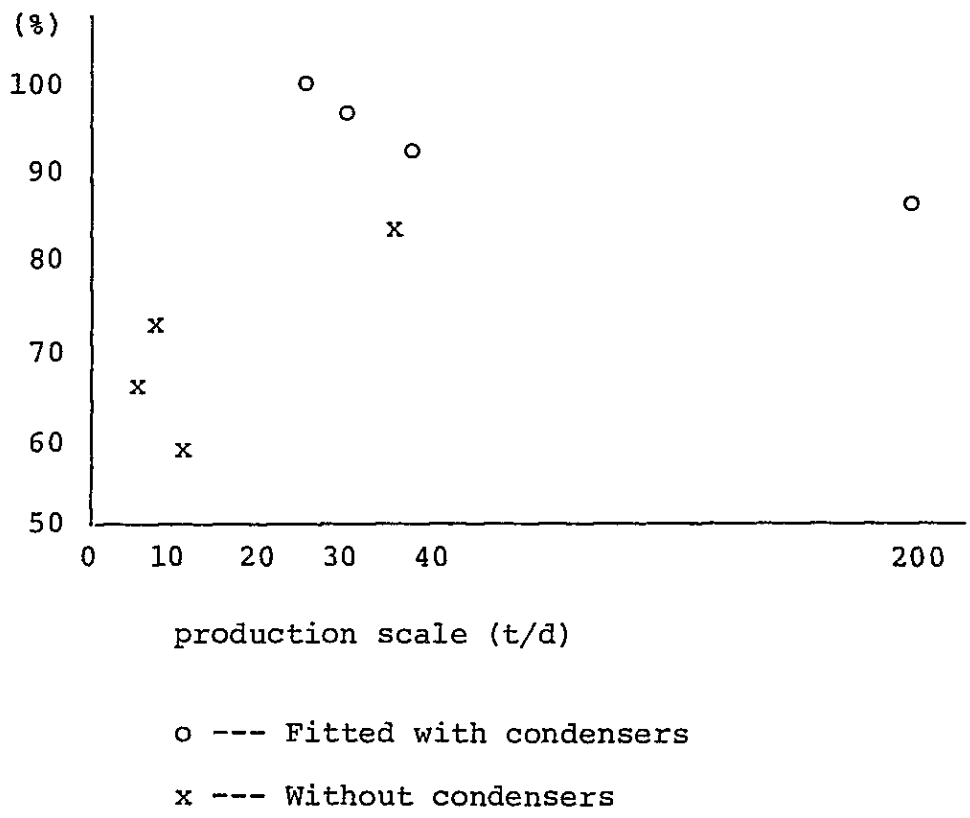
d. A liquid cyclone should be fitted with pressure gauges both at inlet and outlet, so that it can be properly controlled not to lower its capacity due to clogging. There were only two of the factories where pressure gauges were provided and working properly.

e. The Nash pump for a suction box should be perfectly water-sealed. At some factories, the pump was left running idle due to inadequate water-seal.

f. Unity should be established in the number of small-load equipment in operation, such as a pulper, refiner, and transformer. To do so, it is necessary to formulate a production plan on which the efficient operation of equipment for each type of product can be based. Some transformers had a small load, and it was found that three of the factories could reduce the number of transformers in operation.

g. Fig. 15 shows the results of the power factor measurement.

Fig. 15 Power Factor



Generally, the power factor remained at a low level as motors with an excessive capacity were installed. Yet efforts were being made to improve the power factor by fitting equipment with condensers at most of the factories except for small ones.

Some factories, however, were suffering from the leading power factor as the automatic power factor regulator was out of order.

h. By and large, equipment were being blindly operated due to insufficiency of gauges and meters. It is necessary to provide, one by one, gauges and meters, such as a flow meter, pressure gauge, thermometer, voltmeter, ammeter, power factor indicator, and watt meter, and to place equipment under good control while consulting these instruments for data on production.

(5) Targets for improvement and anticipated effects

<u>Targets for improvement</u>

A. - E. No quantitative targets can be fixed in relation to proposed remedies in the stock preparation, press, and drying processes as products and the lineup of equipment vary from factory to factory.

F. Boilers; the targets air ratio is tentatively set at:

1.3 for fuel oil-burning boilers; and

1.5 for solid fuel-burning boilers.

The temperature of exhaust gas coming out of a boiler differs depending on how the boiler is constructed, whether or not it is provided with a heat recovery unit, and whether or not its heat transfer surface is stained; in some cases, something may have to be done equipmentwise.

The target exhaust gas temperature is fixed at 250°C for remodeled or newly installed boilers.

G. Power factor at receiving end; the target power factor is provisionally fixed at 85 percent or higher.

Anticipated effects

Remedial measures which we have suggested each factory diagnosed to take as practicable are, in the aggregate, anticipated to bring about a fuel saving of:

1,668 kl/y	-	by improvement of the air ratio
419	-	by insulation improvement
1,022	-	by use of waste heat
3,106	-	by rationalization of the paper making process

Total:6,215 kl/y

This amount of saving is equivalent to 21.1 percent of the total fuel consumption of 29,397 kl/y (in fuel oil).

Also, these measures could save electric energy by 171 x 10^3 kWh/y, which corresponds to 0.2 percent of the total power consumption of 79,763 x 10^3 kWh/y. The factories diagnosed has a total output accounting for about one third of Thailand's entire paper production. Supposing that these represent the overall picture, then it is expected that a saving of about 18,600 kl/y in fuel (fuel oil) and about 510 x 10^3 kWh/y in electric energy will be achieved in the nation's paper making industry at large.

8. List of Information Material Collected

1. NEA, Thailand Energy Situation, 1980
2. NEA, Oil and Thailand, 1980
3. NEA, Electric Power in Thailand, 1980
4. EGAT, Basic Electricity Wholesale Tariff, April 1982
5. Retail Price of Oil Products
6. Total Oil Based Energy Consumption by Group of Industry, 1979
7. NEA, Thailand's ENCON Measures and Activities up to 1981
8. The 5th National Economic and Social Development Plan: Plan of Implementation for Energy Conservation in Industrial and Transport Sectors (1982-86)
9. The Organization Chart of Thailand Government Offices relating to Energy
10. Chronological Data on the Output of Major Industrial Products (1980, 1981)
11. The Number and Types of Factories in Thailand, 1979
12. Bangkok Nihonjin Shokokaigisho (The Japanese Chamber of Commerce and Industry in Bangkok), Tai Koku Keizai Gaikyo (An Outlook for Thailand's Economy, 1980-81)
13. UNDP/UNIDO, Energy Saving Scheme: Thailand (March, 1982)
14. A Prospectus of The Technological Promotion Association (Thai-Japan)

Attachments

1. Questionnaire
2. Checklists
3. List of Measuring Instruments

Ⅱ. SEPARATE REPORT ON THE INDIVIDUAL FACTORIES

—CERAMICS/GLASS AND PAPER—

CONTENTS

Report No. 1: Glass

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

\- Bangkok Glass Industry Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Bangkok Glass Industry Co., Ltd. -

1. Outline of the Factory

Address : 47/1 Moo 2, Rangsit-Nakornnayok Rd. KM 7,
Tumbol Buengyeeto, Amphur Tanyaburi
Phatumtanee

Capital : 500 million bahts

Type of industry : Glass

Major products : Glass bottles

Annual output : 40,000 t

No. of employees : 500

Annual energy consumption :

- Electric power : 10,512,000 kWh
- Fuel
  - Fuel oil : 5,840 kl
  - Diesel oil : 43.2 kl
  - LPG : 840 t

Interviewees : Sornsong Kiratibotra, factory manager, and others

Date of diagnosis : Sept. 2 - 3, 1982

Diagnosers : M. Ito, Y. Ohno, and T. Sugimoto

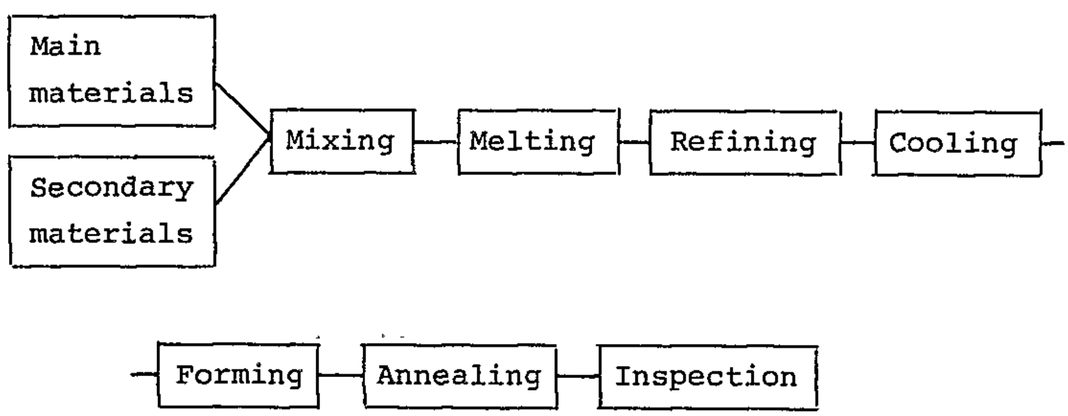
Bangkok Glass Industry Co. is rated second among Thailand's five leading glass manufacturers; the company's factory was built in 1979 upon the design of Sorg Gmbh, a West German firm. As the factory manager said, "We are proud of our somewhat modern factory," it is a well-ordered glassworks set up in a vast compound, paying good attention to the heat insulation of the furnace and instrumentation arrangements.

Although its estimated capacity runs at 150 tons a day, the factory has large inventories due to the business depression and is currently operating at the capacity of 100 to 120 tons a day.

The factory is generally managed well and its energy consumption rate is kept at a remarkably good level.

The cullet mixture ratio stands at 50 to 60 percent, and the yield rate runs at about 90 percent.

2. Manufacturing Process

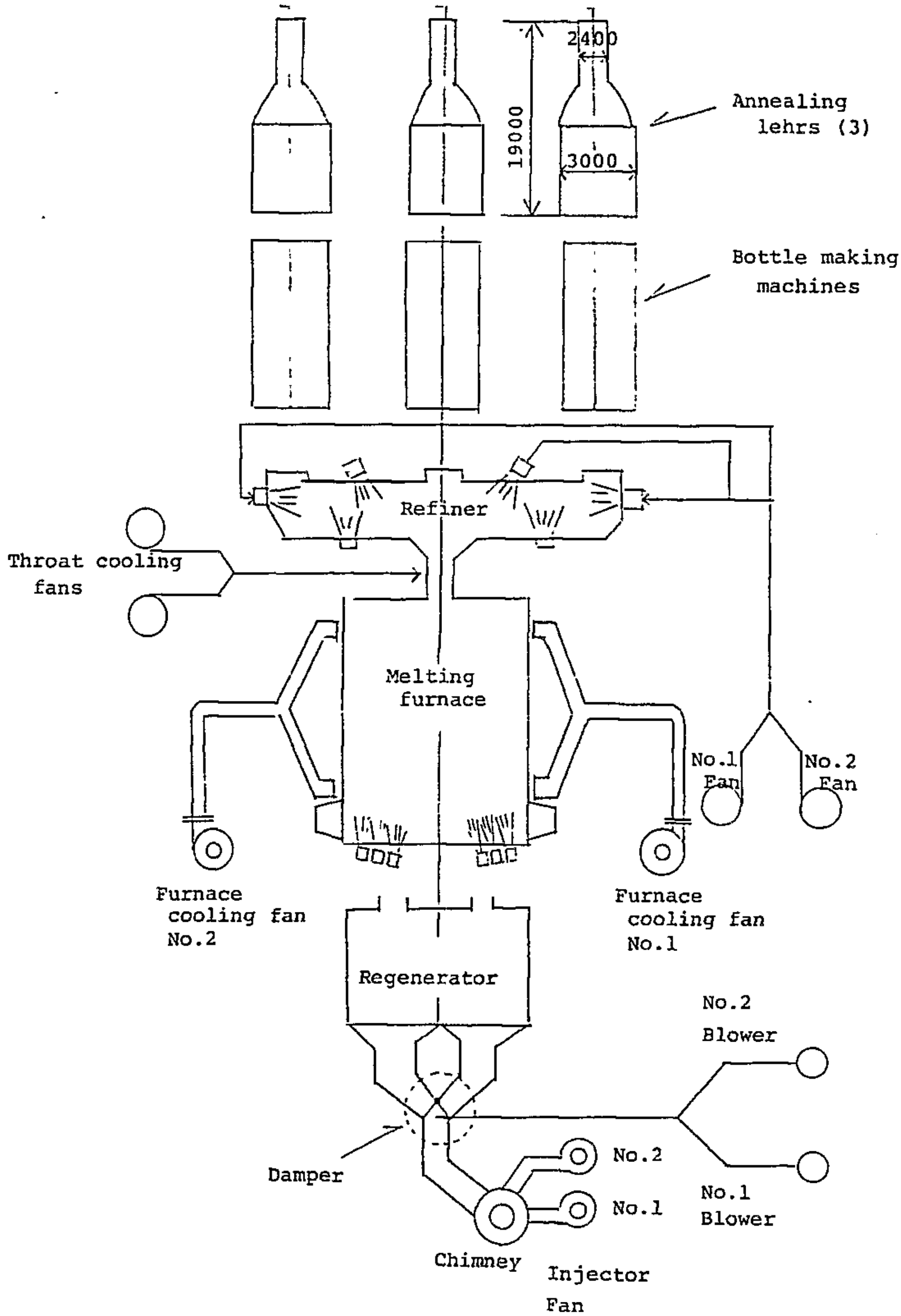


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type, etc.
Melting furnace	1	End-port tank furnace, fuel oil-burning, with 1,300 kW booster, regenerator (waste heat recovery unit)
Refiner	1	LPG-burning
Forehearth	3	LPG-burning
Forming machine	3	
Annealing lehr	3	Direct-heating, hot blast circulating type
Compressor	3	270 HP (one stand-by unit)
	2	75 HP (one stand-by unit)
	2	40 HP

(2) Layout



2400
19000
3000
Annealing lehrs (3)
Bottle making machines
Refiner
Throat cooling fans
Melting furnace
No.1 Fan
No.2 Fan
Furnace cooling fan No.2
Furnace cooling fan No.1
Regenerator
No.2 Blower
Damper
No.2
No.1
No.1 Blower
Chimney
Injector Fan

4. State of Energy Management

Vigorous efforts are being made to reduce the monthly costs of energy as these costs reach as much as 4 to 5 million bahts.

The factory's consumption of energy is recorded by processes every day, and the energy consumption rate is also reckoned. These data are sent to Emhart Corp., a U.S. firm, for analysis. Bangkok Glass Industry Co., we were told, stands among the top ten of the world's glass manufacturers in respect of the energy consumption rate.

The factory is well organized, and competent engineers are placed in charge of electric power, thermal energy, and data analysis.

An attempt is being made to enhance the employees' energy consciousness under the direction of the factory manager; "Save Electricity" stickers are plastered on the wall.

The staff are sent to attend a study meeting two or three times a year, but workers at large are not given systematic training.

5. State of Fuel Consumption

The consumption of fuel is as shown below:

Fuel oil	-	5,840 kl/y
Diesel oil	-	43.2 kl/y
LPG	-	800 t/y

Of these, fuel oil showing the largest figure is mainly used in the melting furnace.

The fuel consumption (fuel consumption rate) per ton of glass melted (pull) stands at a very satisfactory level, or 117 kgs/ton.

Shown in the table below is the heat balance in the melting furnace.

Heat Balance in the Melting Furnace

Input			Output		
Heat of fuel combustion	1,106 x10^3 kcal/t	100%	Heat of glass melting	480x10^3 kcal/t	43%
			Loss of heat in exhaust gas	224	20
			Heat release (melting cistern)	97	37
			Heat release (regenerator)	104	
			Miscellaneous	201	
Total	1,106 x10^3 kcal/t	100%	Total	1,106 x10^3 kcal/t	100%

Notes:

1) Data given for determination of the heat balance -

Output of glass	-	5.05 t/h
Consumption of fuel oil	-	111.5 kgs/t
Heat contents fuel oil (Hl)	-	9,920 kcal/kg
Oxygen content in exhaust gas (%)	-	2.1%
Temperature of exhaust gas at outlet of regenerator	-	540°C
Cullet mixture ratio	-	55%
Heat of glass melting	-	480 kcal/kg
Heat release from furnace wall	-	(To be given later)
Surface area of melting cistern	-	273 m^2
Surface area of regenerator	-	493 m^2

2) Equations for calculating the heat balance -

<u>Input</u>

Heat of fuel combustion = 111.5 kg/t of glass (consumption of fuel oil) x 9,920 kcal/kg (low-level heat contents, Hl) = 1,106 x 10^3 kcal/t of glass

<u>Output</u>

- Heat contents required for melting of glass

Heat of glass melting is 480 kcal/kg where the cullet mixture ratio is 55% and the melting temperature 1,550°C.

- Loss of heat in exhaust gas

  Estimation of the amount of exhaust gas at the outlet of the regenerator (according to Rosin's formula):

  Theoretical amount of air (Ao) $= \frac{0.85\ Hl}{1,000} + 2.0 = 10.43\ Nm^3$/kg of oil

  Theoretical amount of exhaust gas (Go) $= \frac{1.11\ Hl}{1,000} = 11.01\ Nm^3$/kg of oil

  Air ratio : $m = \frac{21}{21 - 2.1} = 1.11$

  Actual amount of exhaust gas = Go + (m - 1)Ao
  $= 11.01 + (1.11 - 1)\ 10.43 = 12.16\ Nm^3$/kg of oil

  Amount of exhaust gas per ton of glass =
  $12.16 \times 111.5 = 1,356\ Nm^3$/t of glass

  Heat contents of exhaust gas =
  1,356 x 0.33 x (540 - 40) = 223,700 kcal/t of glass

- Heat release

  Melting cistern :

  Heat release = 1,790 kcal/m^2·h (at 114°C) x 273 m^2 = 488,670 kcal/h

Amount of glass melted = 5.05 t/h

Heat release per ton of glass = 488,670 ÷ 5.05 = 96,800 kcal/t of glass

Regenerator :

Heat release = 1,200 kcal/m^2·h (at 69°C) x 439 m^2 = 527,160 kcal/h

Heat release per ton of glass = 527,160 ÷ 5.05 = 104,300 kcal/t of glass

6. Problems in Heat Control and Potential Solutions

(1) . Air ratio

The factory shows good values, this is the oxygen content in the exhaust gas runs at 2.1 percent and the air ratio at 1.11.

The air ratio, however, is controlled by proportionally regulating the amount of fuel and air from the blower, not through the feedback of analytical data on the oxygen content in the exhaust gas. This method cannot afford proper control when the combustion load undergoes a change, because the air required for combustion does not merely come from the blower but it is also taken in from a material inlet and other openings.

With the numerical data obtained, these factors are related to one another as shown below.

Amount of fuel (A)	Amount of air required (m = 1.11)	Amount of air taken in from openings	Amount of air to be blow in by the blower (B)	Value to be set for the proportional regulator (B/A)
400 kgs/h	4,632 Nm^3/h	1,647 Nm^3/h	2,985 Nm^3/h	7.46
500	5,790	1,647	4,143	8.29
600	6,948	1,647	5,301	8.84
700	8,106	1,647	6,459	9.23
800	9,264	1,647	7,617	9.52

It is advised, therefore, that the air ratio be adjusted according to some proper standards to be able to raise the set value on the proportional regulator with an increase in the combustion load.

The oxygen content in the exhaust gas at the inlet of a flue increased to about 9 percent and the air was escaping from the seal of the damper. This seems to explain why the temperatures of the exhaust gas at the right and left outlets of the regenerator showed a little different curves. The amount of air escaping was found to have reached some 3,800 Nm^3/h, amounting to as much as 35 percent of the blower's capacity. This may cause an air shortage when the load has increased. So it is necessary to keep an eye, if at times, on the amount of air escaping.

(2) Heat release from the furnace body

Given below are the surface temperatures and heat flux of the melting furnace.

Spots	Surface temperatures (°C)	Heat flux (kcal/m^2·h)
Side of the tank furnace (left of the burner)	110 117 115	1,630 2,016 1,720
(average)	114	1,790
Upper side of the regenerator	69	1,200

Heat insulation was generally good, but it is recommended to spray those load-free sections such as a duct and regenerator with some proper insulating materials to provide better insulation.

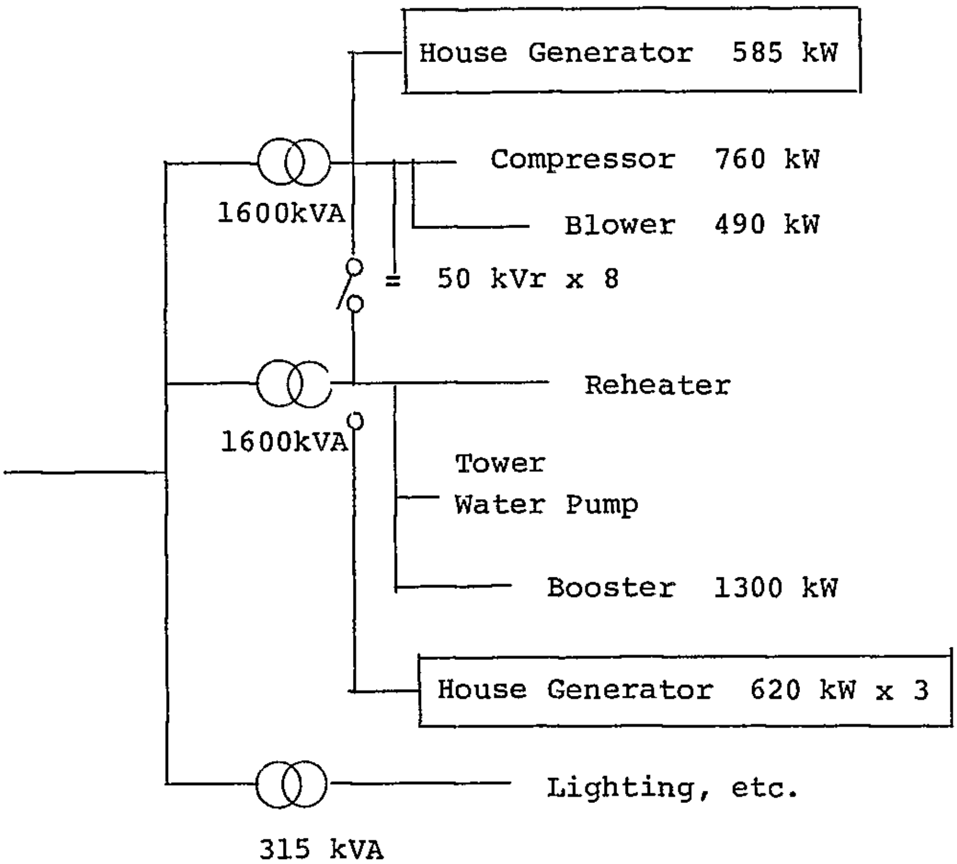
7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	PEA
Peak demand	-	2,500 kW
Electric energy used	-	1,054,244 kWh/m
Load factor	-	58.6%
Penalty	-	No penalty
Power factor	-	90%

Transformers - 2 units of 1,600 kVA,
1 unit of 315 kVA.

(2) One-line diagram



Power-receiving installations are situated near electric equipment, at the center of the factory. Two transformers with the capacity of 1,600 kVA were operated independently; the loads on both transformers were almost balanced, but their load factors stood below 50 percent. A total of 400 kVr condensers were provided to improve the power factor, which was kept at 90 percent.

Also, four Diesel power generators with the capacity of about 2,500 kW were installed for private use, which were kept in good repair so that they could start running in a few seconds in case of emergency.

Among the major loads were 450 kW compressors and 400 kW blowers, which accounted for about 60 percent of the total electric equipment installed at the factory. The power factor for these equipment was kept at around 84 percent.

For lighting, another 315 kVA transformer was installed, serving the factory's lighting apparatuses, air-conditioners, and other facilities as well as the workers' houses in the compound.

A total of 28 street lights (250 W) were installed over some 500 meters from the gate of the factory. In addition, about 20 mercury lamps (1500 W) were set up within the premises. The factory building was fitted with a large number of daylight fluorescent lamps; some 60 units of approximately 100 kW air-conditioners were installed at the office, control room, and dining room, among others.

8. Problems in Electric Power Control and Potential Solutions

(1) Control of peak demand

The peak demand (2,500 kW) seems to be too much in view of the power load (1,441 kW) as well as the capacity utilization rate when the study mission visited the factory.

The booster was at rest when the factory was surveyed. Taking into account the factory's past results, this power load can be estimated to account for 26 percent of the whole, or 300 to 500 kW at most. If this device is counted, therefore, the peak demand still exceeeds the reasonable level by around 500 kW.

It should be apparent from the above that a proper control of the peak demand and an improvement of the power factor could result in a reduction in power (standing) charges as much.

To do so, an attempt has to be made to work out a better monthly production plan and improve the current production process so that the concurrent operation of the major electric equipment can be avoided wherever possible.

It may also be an effective measure to prepare a list of power loads in the order of importance, so that if the whole power load exceeds a base value, equipment can be put at rest in order according to this list.

(2) Condenser

The condenser (400 kVr) box was found to have been overheated. It is necessary to ventilate the condenser box more properly to step up its heat release as well as to keep the voltage below the rated level.

(3) Operation of motors

As shown below, most of the motors were running under good conditions.

Equipment	Capacity A	Load value measured B	Power factor (%)	B/A
Compressors	270 HP (202 kW)	186 kW	85	92
	270 (202)	181	87	90
	75 (55)	51	89	93
Cooling fans	150 (110)	78	92	71
	150 (110)	81		74
	150 (110)	83		75
	75 (55)	40		73
Throat fan	25 (19)	15		79
Injector	50 (37)	27		73
Cooling water pump	60 (45)	44		98
Reheater No.1	47.5 kW	19	60	42
No.2	47.5	22		
No.3	47.5	19		

(4) Lighting

Since there are too many street lamps (fluorescent, mercury lamps of 250 W x 28) installed alongside the road leading to the factory's gate, much energy can be saved if some of them are switched off. Moreover, it is desirable to replace 20 mercury lamps (1,500 W) installed in the compound by more energy efficient ones.

This could afford a saving of about 7 percent in electric energy:

$$\{(250 \times 28) + (1,500 \times 20)\} \times 0.07 \times 10 \text{ h/d} \times 360 \text{ d/y} = 9,300 \text{ kWh/y}$$

$$9,300 \text{ kWh} \times 1.995 \text{ bahts/kWh} = 18,600 \text{ bahts/y}$$

In addition, no efforts should be spared to put out unnecessary lights, and fluorescent lamps should be switched off without fail because their ballast stabilizers consume much electric power

(5) Air-conditioners

As mentioned earlier, the factory as a whole was equipped with some 60 units of air-conditioners with the total capacity of about 100 kW. To save on power bills for air conditioning, control of units should be made more effectively by fixing some specific targets - for example, setting the air-conditioning temperature at a little higher level, or operating equipment for limited hours. At the same time, it is necessary to give walls, windows, and doors better heat insulation as well as to remove heat sources from rooms.

All in all, these efforts could save the company about 2 percent on its electric bills:

100 kW x 0.02 x 10 h/d x 360 d/y

= 7,200 kWh/y

7,200 kWh/y x 1.995 bahts/kWh = 14,000 bahts/y

9. Summary

Taken together, the company's energy consumption is in good condition. Yet, further energy-saving efforts in lighting and air conditioning would result in a saving of electric power amounting to:

9,300 kWh	-	By a reduction in the number of lights and a switchover of existing lamps to highly energy efficient ones
7,200 kWh	-	Through tighter control of air conditioning
Total: 16,500 kWh (0.1%)		

Report No. 2: Glass

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

- Samutprakarn Glass Industry Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Samutprakarn Glass Industry Co., Ltd. -

1. Outline of the Factory

Address : 7/1 Moo 7 SOI, Sukapibal 16,
Poochaosamingpral Rd., PHRA Pradaeng,
Samutprakarn

Capital : 70 million bahts

Type of Industry : Glass

Major products : Vials and bottles

Output : 41 t/d

No. of employees : 198

Annual energy consumption :

- Electric power : 3,960,000 kWh
- Fuel
  - Fuel oil : 2,500 to 3,500 kl
  - Diesel oil : 335 kl

Interviewee : S. Taison, deputy managing director

Date of diagnosis : Aug. 31 - Sept. 1, 1982

Diagnosers : M. Ito, Y. Ohno, and T. Sugimoto

Samutprakarn Glass Industry Company's is a modern glass-works located within about an hour's driving distance to the southeast of the center of Bangkok. The factory was put into operation in 1978 and is now manufacturing bottles for soft drinks under technological tie-up with Yamamura

Glass Co., Ltd., of Japan.

With the ratio of fuel costs to manufacturing costs running at 34 percent, this glassworks' management has a strong interest in energy conservation, being well aware of the fact that a rational use of energy is indispensable to the reduction of manufacturing costs.

They entertain great expectations of the outcome of our survey, saying that they would carry out solutions to the problems pointed out as far as the budget allows to produce satisfactory results.

With the workforce of 198 on a regular basis, the glassworks currently has an output of 41 tons a day.

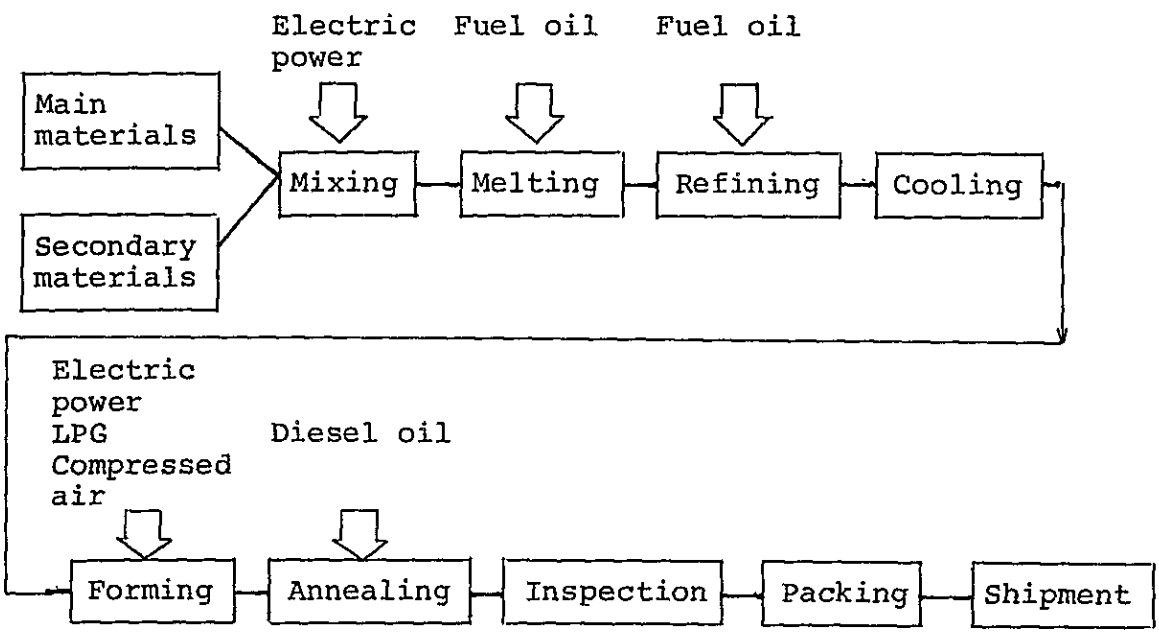
The cullet mixture ratio stands at a rather high level of 80 percent, while the percent defective is somewhat large at 20 to 25 percent.

To date, the inlet and outlet of a melting furnace were given better heat insulation as part of energy-saving efforts. This was done last year, so its effects on furnace materials are yet to be seen, they said.

Most of the machinery and equipment installed as well as bricks are made in Japan; Japanese techniques and systems are adopted predominantly in production control.

Two melting furnaces are installed, but one of them is now at rest due to the economic depression.

2. Manufacturing Process

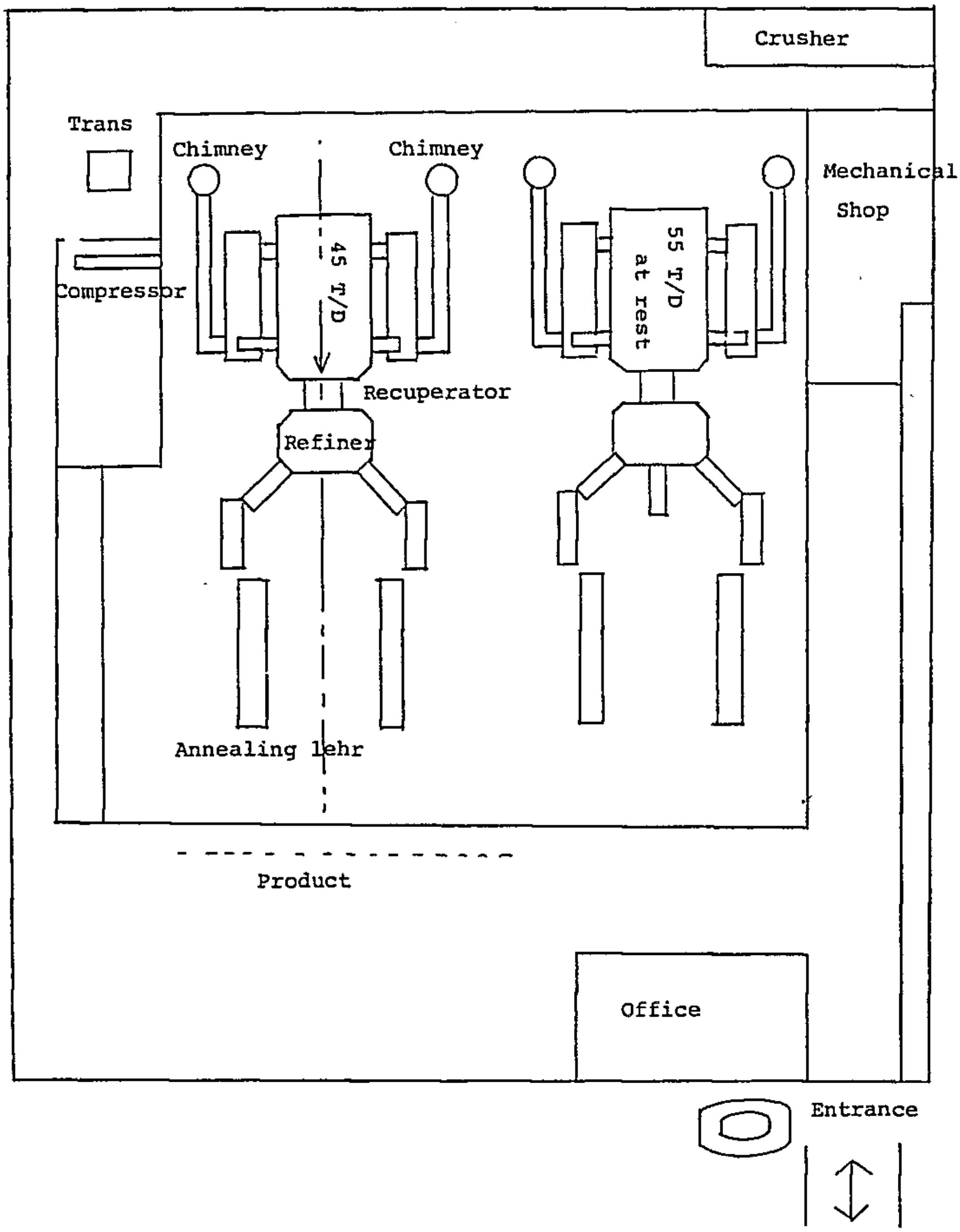


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type, etc.
Melting furnace	1 (45 t/d) 1 (55 t/d, at rest)	Tank furnace, fuel oil-burning, with two ceramic recuperators
Refiner	2 (one at rest)	Fuel oil-burning
Forehearth	4 (two at rest)	
Forming machine	4 (two at rest)	
Annealing lehr	4 (two at rest)	Diesel oil-burning

(2) Layout


Crusher
Trans
Chimney
Chimney
Mechanical
Shop
45 T/D
55 T/D
at rest
Compressor
Recuperator
Refiner
Annealing lehr
Product
Office
Entrance

4. State of Energy Control

The amount of fuel used and the consumption of fuel per ton of glass melted (fuel consumption rate) are both checked every day.

The fuel consumption rate had been at 250 to 260 liters/ton, but it has been gradually lowered down to the present level of 210 to 220 liters/ton. Being not fully contented with these figures, however, the factory people want to do what they can to somehow optimize the consumption rate.

A meeting is held to discuss the subject of energy conservation twice a month, once on the factory level and once on the company level.

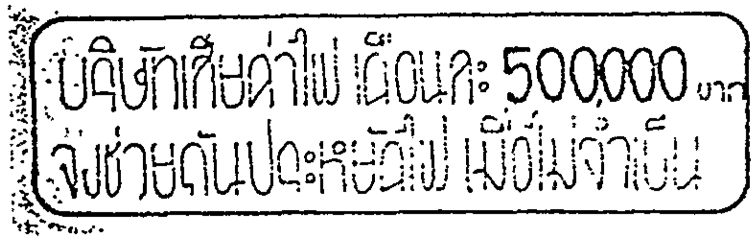
There is a system under which workers are invited to put forward a proposal for energy conservation. Under this system, though no reward is offered on all occasions, any employee, if his proposal is adopted, will receive proper consideration at year-end merits evaluation.

The employee training program is also under way:

a. Employees are given internal training; and
b. The managerial staff are sent to take outside training (at the company's rest house) and to study abroad.

In addition, the following sticker is used to enhance the workers' energy conservation consciousness, which reads:

"We are paying 500,000 bahts a month for electricity."



Asked if Thai glass manufacturers have ever met to discuss industry-wide energy conservation measures, the factory people replied, "Thailand's four leading glass manufacturers met to discuss the energy problem and other issues. As far as technical issues were concerned, the meeting came out satisfactorily to a certain extent, but business-wise it resulted in failure."

5. State of Fuel Consumption

The consumption of fuel is as follows:

Fuel oil	-	2,500 to 3,500 kl/y
Diesel oil	-	355 kl/y

Fuel oil is burnt for melting, a mixture of fuel and Diesel oil (LDO) for annealing, and LPG and LDO for feeders.

Shown below is the heat balance in the melting furnace. It is estimated that the heat loss in the exhaust gas and due to radiation and convection accounts for about 75 percent of the total amount of heat.

Heat Balance in the Melting Furnace

Input			Output		
Heat of fuel combustion	1,918.0 x 10^3 kcal/t	100%	Heat of glass melting	444.0 x 10^3 kcal/t	23.2%
			Loss of heat in exhaust gas	514.6	26.8
			Heat loss due to radiation, convection, etc.	959.4	50.0
Total	1,918.0 x 10^3 kcal/t	100%	Total	1,918.0 x 10^3 kcal/t	100%

Notes:

1) Data given for determination of the heat balance -

Amount of glass melted - 1.71 t/h

Consumption of fuel oil - 342 kgs/h (357 liters/h)

Heat contents of fuel oil (Hl) - 9,590 kcal/kg

Oxygen content in exhaust gas (%)

At the inlet of recuperator - 2.1%

At the outlet of recuperator - 8.6%

Temperature of exhaust gas

At the inlet of recuperator - 1,320°C

At the outlet of recuperator - 480°C

Cullet mixture ratio - 80%

Heat of glass melting - 444 kcal/kg

Temperature of air for preheating

At the outlet of recuperator - 520°C

2) Equations for calculating the heat balance -

Input

Heat of fuel combustion = 200.0 kgs/t of glass (consumption of fuel oil) x 9,590 kcal/kg (low-level heat contents, Hl)

$= 1,918 \times 10^3$ kcal/t of glass

Output

- Heat contents required for melting of glass
  Heat of glass melting is 444×10^3 kcal/kg where the cullet mixture ratio is 80% and the melting temperature 1,400°C.
- Loss of heat in exhaust gas
  Estimation of the amount of exhaust gas at the outlet of the recuperator (according to Rosin's formula):

Theoretical amount of air (Ao) $= \frac{0.85 \times Hl}{1,000} + 2.0$

$= 10.15\ Nm^3$/kg of oil

Theoretical amount of exhaust gas (Go) =

$\frac{1.11 \times Hl}{1,000} = 10.64\ Nm^3$/kg of oil

Air ratio: $m = \frac{21}{21 - 8.6} = 1.69$

Actual amount of exhaust gas = Go + (m - 1) Ao

$= 10.64 + (1.69 - 1)\ 10.15 = 17.64\ Nm^3$/kg

Heat contents of exhaust gas - 17.64 x 200 x 0.33 x (480 - 38) = 514,600 kcal/t of glass

6. Problems in Heat Control and Potential Solutions

(1) Air leakage in the recuperator

The oxygen content in an exhaust gas was measured at the inlet and outlet of the recuperator. As a result of measurement, it was found that the oxygen content was 8.6 percent at the outlet, much higher than 2.1 percent at the inlet.

It can be assumed from this finding that the air is leaking to the exhaust side in the recuperator.

To determine how much the air leaked, a comparison must be made between the amount of exhaust gas at the inlet and outlet of the recuperator:

[Amount of air leakage] = [Amount of exhaust gas at the outlet of recuperator] - [Amount of exhaust gas at the inlet of recuperator]

Given data:

	Oxygen content in exhaust gas (%)	Air ratio (m)	Amount of exhaust gas (Nm^3/kg)
At the inlet of recuperator	2.1	1.12	11.83
At the outlet of recuperator	8.6	1.69	17.60

The amount of air leakage into the exhaust gas in the recuperator is, therefore, as follows:

$(17.60 - 11.83) Nm^3/kg \times 342\ kgs/h = 1,973\ Nm^3/h$

Since what part of the recuperator the air is leaking from is not clear, calculation cannot be made under condition where there is no air leakage.

Assuming that 75 percent of the amount of air required is passing through the recuperator, then:

$10.15 \times 1.12 \times 0.75 \times 342 = 2{,}916\ Nm^3/h$

Compared with the condition under which this amount of air maintains the temperature of 650°C as designed, the input heat should have been decreased by the following amount:

$2{,}916 \times (650 - 520) \times 0.31 = 117{,}500$ kcal/h;

Or,

12 kgs/h (3.6% as compared with the fuel consumption) in terms of fuel.

Also, the amount of air leakage, 1,973 Nm^3/h, accounts for 68 percent of the amount of air required, 2,916 Nm^3/h. This means that the blower must put in the air 1.68 times as much as the required amount, which may result in the insufficiency of capacity.

In fact, the stack was emitting a little black smoke, indicating that the air was in short supply. Since the recuperator cannot be repaired while in operation, it is recommended to control the amount of secondary air by adjusting furnace pressures.

(2) Insulation improvement on the wall of melting furnace

The surface temperatures of the melting furnace were:

Lengthwise surface
temperature of side wall - 215°C (average)

Surface temperature of bottom - 294°C (average)

Heat loss was:

Side wall - 1,420 (due to convection) + 2,082 (due to radiation) = 3,502 kcal/m^{2}h

Bottom - 1,536 (due to convection) + 4,132 (due to radiation) = 5,668 kcal/m^{2}h

Supposing that 70 percent of the side wall and the bottom of the melting furnace have been lined with ceramic fibers (25 mm in thickness, $\lambda = 0.25$), then heat loss can be reduced as shown in the following calculation.

<u>Side wall</u>

Current heat resistance:

$$\frac{1,400 - 215}{R} = 3,502 \qquad R = 0.338$$

Heat resistance after insulation improvement:

$$R' = 0.338 + \frac{0.025}{0.25} = 0.438$$

Heat loss: $\frac{1,400 - 38}{0.438 + 1/20} = 2,791$ kcal/m^{2}h

Temperature at the boundary between insulating materials and bricks:

$$\frac{1,400 - x}{0.338} = 2,791 \qquad x = 456°C$$

Surface temperature of insulating materials:

$$\frac{1,400 - x}{0.438} = 2,791 \qquad x = 178°C$$

Reduction in heat loss:

(3,502 - 2,791) x 24.8 m^2 = 17,633 kcal/h

In fuel oil equivalent:

$$\frac{17,633}{9,590} = 1.8 \text{ kgs/h}$$

Bottom

Current heat resistance:

$$\frac{1,400 - 294}{R} = 5,668$$

$$R = 0.195$$

Heat resistance after insulation improvement:

$$R' = 0.195 + \frac{0.025}{0.25} = 0.295$$

Heat loss:

$$\frac{1,400 - 38}{0.295 + 1/20} = 3,948 \text{ kcal/m}^2\text{h}$$

Temperature at the boundary between insulating materials and bricks:

$$\frac{1,400 - x}{0.195} = 3,948$$

$$x = 630°C$$

Surface temperature of insulating materials:

$$\frac{1,400 - x}{0.295} = 3,948$$

$$x = 235°C$$

Reduction in heat loss:

$$(5,668 - 3,948) \times 31.4 \text{ m}^2 = 54,008 \text{ kcal/h}$$

In fuel oil equivalent:

$$\frac{54,008}{9,590} = 5.6 \text{ kgs/h}$$

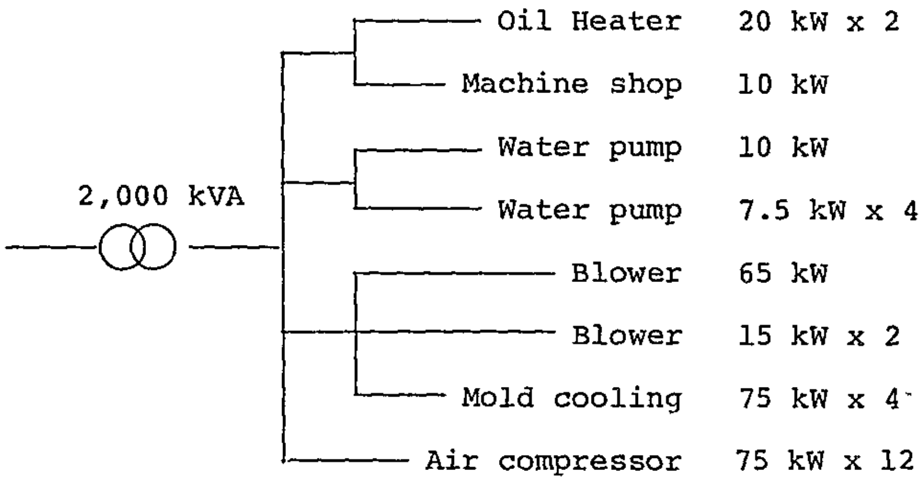
Thus , fuel oil can be saved by 7.4 kgs/h (1.8 + 5.6) in all. This will amount to 64.8 kl a year, accounting for 2 percent of the total consumption of fuel oil. Moneywise, a total of 287,000 bahts can be saved yearly. By contrast, the cost of improvement work is estimated at 120,000 bahts, which can be recovered within a short period of time. This insulation improvement, however, should be carried out after due consideration given to the quality of inner bricks as their temperature will most likely to go up.

7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	PEA
Peak demand	-	500 kW
Electric power used	-	296,000 kWh/m
Load factor	-	85.6%
Penalty	-	315 kVr
Power factor	-	62.8%
Transformers	-	2,000 kVA

(2) One-line diagram



8. Problems in Electric Power Control and Potential Solutions

Electric equipment are installed in numbers to fit in with two glass melting furnaces. Currently, however, one of the melting furnaces is at rest, so the factory is experiencing excess capacity that much. Some of elecric equipment are being idled away.

(1) Transformer

A. The current transformer capacity of 2,000 kVA is too large in view of the measured load of about 800 kVA (480 + j620). If one of the melting furnaces is kept at rest for a long period of time, then it is desirable to run a single 1,000 kVA transformer, instead of 2,000 kVA.

In that case, electric power equivalent to no-load loss of a 1,000 kVA transformer can be saved. Namely,

$$1{,}000 \text{ kVA} \times (1 - 0.985) \times 0.2 \times 8{,}640 \text{ h/y}$$

$$= 25{,}900 \text{ kWh/y}$$

In value, this saving could amount to:

$$25{,}900 \text{ kWh/y} \times 1.61 \text{ bahts/kWh} = 41{,}000 \text{ bahts/y}$$

B. The secondary voltage of the transformer was found to have been kept at rather a high level of 405 V (391 - 398 V even at the motor terminal). Taps should be changed to lower the secondary voltage down to the normal level of 380 V. Then, power loss in the transformer could be reduced and the power factor of motors and other equipment should be improved by 3 to 5 percent.

A reduction of power loss in the transformer will be:

$$2{,}000 \text{ kVA} \times (1 - 0.986) \times 0.2 \times \left\{\left(\frac{405}{390}\right)^2 - 1\right\}$$

$$\times 8{,}640 \text{ h/y} = 2{,}400 \text{ kWh/y}$$

A resultant saving of money will amount to:

$$2{,}400 \text{ kWh/y} \times 1.61 \text{ baht/kWh} = 3{,}900 \text{ bahts/y}$$

In this connection, it is necessary to adjust the indicator on the panel board because it was at 380 V.

(2) Compressors

Electric power used for compressors accounts for about 53 percent of the whole. So it is important to make vigorous energy-saving efforts in this field.

A. As a result of measurement, the load of five 75 kW compressors in operation was found to be 256 kW (256 + j247): the load factor per unit remained at a low level of 70 percent and below (average: about 68 percent). This resulted in a low power factor.

To improve this situation, it is desirable to decrease the number of compressors in operation so that the load factor per unit can be raised.

Supposing that the number of compressors in operation has been decreased to four and each is run at full load, the total capacity will be 300 kW (75 kW x 4), a level reasonable enough to match the current load. This would eliminate no-load loss for a single compressor.

During actual operation, it is advised to run three of the compressors at full load and to make the remaining one stand ready for changes in load by regulating valves.

In general, it is more advantageous to employ a small capacity compressor so as to meet changes in load.

Such being the case, a reduction in power loss by placing a compressor at rest can be estimated at about 42,000 kWh a year:

75 kW x (1 - 0.935) x 8,640 h/y = 42,120 kWh/y

42,120 kWh/y x 1.61 bahts/kWh = 67,813 bahts/y

Moreover, the power factor for the remaining four compressors will be increased from 68 percent, the measured value, to about 84 percent, and their load will be changed from 256 + j247 to 256 + j165. As a consequence, power loss in the transformer, which is supposed to one of 1,000 kVA, will be reduced by the following amount:

$$1{,}000 \times 0.015 \times 0.8 \times \left\{ \left(\frac{572}{1{,}520}\right)^2 - \left(\frac{463}{1{,}520}\right)^2 \right\} \times 8{,}640$$

$$= 5{,}000 \text{ kWh/y}$$

5,000 kWh/y x 1.61 baht/kWh = 8,200 bahts/y

Also, penalties will be reduced by 82 kVr (= 247 - 165), which will amount to:

82 kVr x 15 bahts/kVr x 12 m/y = 14,700 bahts/y

B. The air intake for compressors was installed at the upper, hot part of the factory building.

In general, electric power required for compressors is in proportion to the air pressure and the amount of air on the suction side, and the amount of air is in proportion to the absolute temperature of air taken in (T). Given motive power for compression as P, therefore, then this relationship can be expressed as follows:

$$P = k \times T \quad (T = t°C + 273)$$

Where,

K is a constant proportional.

Accordingly, it is desirable to install the air intake at a different spot so that the cold air can be admitted as much as possible. If the temperature of air taken in is lowered by 10°C from 35°C to 25°C, then the rate of reduction in motive power for compression (ΔP) will be:

$$P = \frac{P - P'}{P} = \frac{(273 + 35) - (273 + 25)}{273 + 35} = 0.032$$

A resultant saving of electric power will be:

256 kW x 0.032 x 8,640 h/y = 71,000 kWh/y

In terms of value, this saving will amount to:

71,000 kWh/y x 1.61 baht/kWh = 114,000 bahts/y

Apart from these, it is an effective energy-saving measure to fully check up on the compressed air to see if it is leaking and to endeavor to bring down the working pressure to the lowest possible level.

(3) Blowers

Two 75 kW mold cooling fans and two 5.6 kW exhaust fans in operation were found to have a remarkably small load.

The load of the former was kept at 45.9 kW (45.9 + j68) or 31 percent of the rated capacity; that of the latter stood at 2.7 kW (2.7 + j6.6) or 24 percent of the rated capacity.

If the mold cooling fan's capacity is halved to 37.5 kW, then its load factor can be improved to about 70 percent. With the capacity remaining unchanged at 75 kW, power loss is 75 x 0.1 x 0.7 = 5.25 kW, whereas if the capacity is reduced to 37.5

kW, it will be 37.5 x 0.12 x 0.85 = 3.83 kW. This difference, therefore, will correspond to a saving of electric power. In other words, a reduction of the mold cooling fan's capacity to half will bring about the saving of:

(5.25 - 3.83) x 2 units x 8,640 h/y

= 24,600 kWh/y

24,600 kWh/y x 1.61 baht/kWh = 39,600 bahts/y

On the other hand, if one of the two exhaust fans, which has a smaller load, is placed at rest, then a saving of 1.08 kW, the measured value, can be afforded. This saving will amount to:

1.08 kW x 8,640 h/y = 9,300 kWh/y

9,300 kWh/y x 1.61 baht/kWh = 145,000 bahts/y

This smaller exhaust fan was actually placed at rest when the study mission diagnosed the factory, but no troubles occurred in operation.

9. Summary

Supposing that the above measures have all been put into practice, their possible effects are as follows:

Measures	Potential energy saving		Rate (%)
Improved insulation of furnace body	fuel oil	65 kl/y	2
Reduction in capacity of transformer	electricity	25,900 kWh/y	
Adjustment of secondary voltage of	electricity	2,400 kWh/y	

transformer			
Placing one compressor at rest	electricity	47,120 kWh/y	
Re-installation of air intake for compressor	electricity	71,000 kWh/y	
Making cooling fans smaller	electricity	24,600 kWh/y	
Placing one exhaust fan at rest	electricity	9,300 kWh/ y	
Total saving of electric power	:	180,320 kWh/y	5.1

Report No. 3: Glass

REPORT ON THE DIAGNOSIS

FOR

ENERGY CONSERVATION

- Thai Neutral Glass Industries Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Thai Neutral Glass Industries Co., Ltd. -

1. Outline of the Factory

Address : 67/1 SOI 58 Kasemsuk, Phetkasem Rd., Bangkok 16, Thailand

Capital : 4 million bahts

Type of industry : Glass

Major products : Glass dish, bowl and cup

Output : 10 t/d

No. of employees : 60

Annual energy consumption :

- Electric power : 54,240 kWh/m
- Fuel
  - Fuel oil : 1,620 kl/y
  - Diesel oil : 324 kl/y

Interviewees : Somsak Chanudomphorn, managing director

Date of diagnosis : Aug. 20 - 21, 1982

Diagnosers : M. Ito, Y. Ohno, and T. Sugimoto

Thai Neutral Glass Industries' factory is located within about an hour's driving distance to the southwest of Bangkok, lying at a corner of the industrial complex which is guided by a byroad of the highway.

The glassworks, which had suspended its operation for about a year, resumed production just two months ago. Though its equipment capacity runs at 20 tons a day, it currently has an output of 10 tons per day.

The president of this company, a man with an experience of thirty years in glass making, said, "To resume production, we have modified a furnace on our own design. Since energy consumption depends much on the design of a furnace, I believe we are in a better position than other factories. Our major products are cups and dishes, but the problem is that a percent defective is rather high. So we make it our immediate task to lower the current percent defective of about 40 percent down to 20 percent."

He is also rather keen on technological improvement; he gets and looks into information on energy conservation in a melting furnace from abroad, and frequently visits factories in foreign countries.

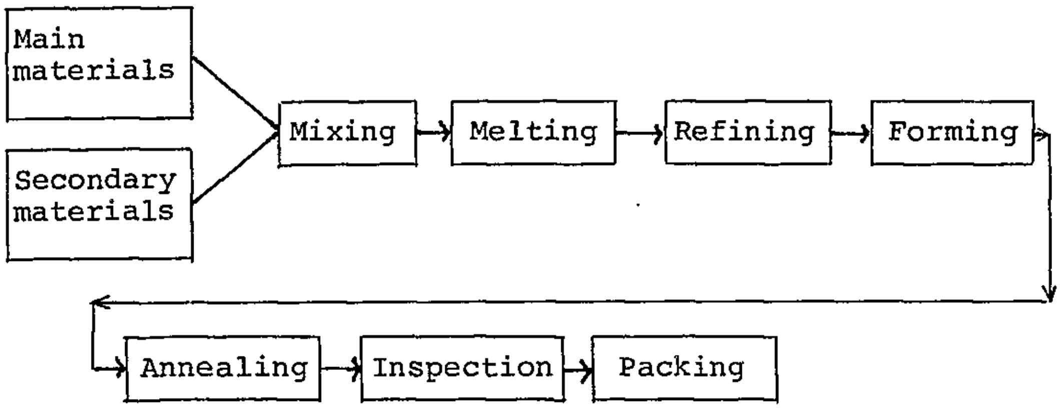
In keeping with the resumption of production two months ago, a product line was switched over from syringes and medicine bottles to cups and dishes. It is not long since then, so the factory people are not so sure of success in the manufacture of these new products.

The factory has a workforce of 60, who are working on a three-shift system in groups of 20.

Product prices have remained on the same level since three years ago; energy price increases are exerting downward pressure on the company's earnings. The ratio of energy costs to sales is estimated to reach 30 percent.

Currently, the company cannot afford to make energy-saving investment mainly because they are unable to pass energy cost increases on to the consumer in higher product prices due to keen competition among glass manufacturers.

2. Manufacturing Process

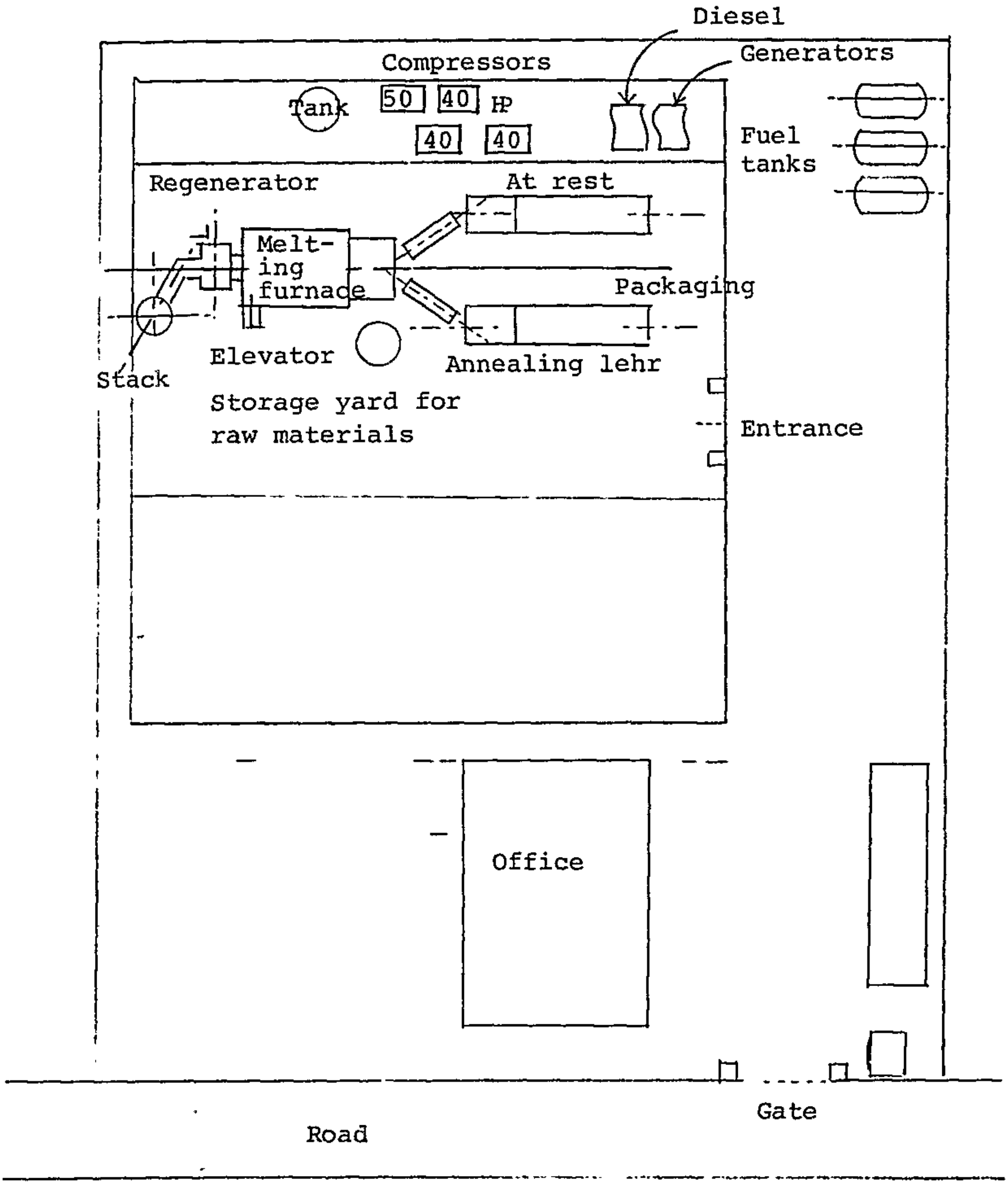


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type, etc.
Melting furnace	1	End-port type, 20 t/d, fuel oil-burning
Waste heat recovery device	1	Regenerator
Annealing lehr	2 (one at rest)	Radiant type, Diesel oil-burning

(2) Layout


Diesel
Generators
Compressors
Tank
50
40
HP
40
40
Fuel
tanks
Regenerator
At rest
Melt-
ing
furnace
Packaging
Stack
Elevator
Annealing lehr
Storage yard for
raw materials
Entrance
Office
Gate
Road

4. State of Energy Management

The whole technological business is now in the hands of the president alone.

The consumption of fuel and electric energy is not necessarily checked every day, but whether the factory's performance figures are good or bad can always be made clear, the factory people said. This means that manufacturing conditions and energy consumption are not numerically examined.

Worker training is not carried out; employees are instructed to turn off unnecessary lights and no more.

5. State of Fuel Consumption

The consumption of fuel is as shown below:

Fuel oil	-	1,620 kl/y	(for melting)
Diesel oil	-	324 kl/y	(for annealing)

The rate of the amount of glass melted to the consumption of fuel (energy consumption rate) stands at 262.5 liters/ton as the put-through of raw materials is 15 to 17 tons/day and the consumption of fuel oil 4,200 liters/day. The energy consumption rate for this factory is rather high due chiefly to its small-capacity furnace as well as to large heat loss in exhaust gas. The common figure with a furnace of 100 tons a day in capacity is 120 to 140 liters/ton.

Shown below is the heat balance in the melting furnace.

Heat Balance in the Melting Furnace

Input			Output		
Heat of fuel combustion	2,392 x 10^3 kcal/t	100%	Heat required for melting of glass	500 x 10^3 kcal/t	21%
			Heat loss in exhaust gas	817	34
			Heat release from melting furnace wall	676	28
			Miscellaneous	399	17
Total	2,392 x 10^3 kcal/t	100%	Total	2,392 x 10^3 kcal/t	100%

Notes:

1) Data given for determination of the heat balance -

Amount of glass melted	-	0.667 t/h
Consumption of fuel oil	-	164.5 kgs/h (specific gravity: 0.94)
Heat contents of fuel oil (Hl)	-	9,700 kcal/kg
Cullet mixture ratio	-	40 - 50%
Melting temperature	-	1,520°C
Heat of glass melting	-	500 kcal/kg
Temperature of exhaust gas at outlet of regenerator	-	550°C
Oxygen content in	-	9.5%

exhaust gas

Area of furnace wall

Top	-	16.64 m^2
Side	-	33.60 m^2
Bottom	-	16.64 m^2

2) Equations for calculating the heat balance -

<u>Input</u>

Heat of fuel combustion = 246.6 kgs/t (fuel consumption) x 9,700 kcal/kg (Hl) = 2,392,000 kcal/t

<u>Output</u>

- Heat contents required for melting of glass

  Heat of glass melting is 500 x 10^3 kcal/t where the cullet mixture ratio is 40% and the melting temperature 1,500°C.

- Loss of heat in exhaust gas

  Theoretical amount of air (Ao) = $\frac{0.85\ Hl}{1,000} + 2$

  = 10.2 Nm^3/kg

  Theoretical amount of exhaust gas (Go)

  = $\frac{1.11\ Hl}{1,000}$ = 10.8 Nm^3/kg

  Air ratio (m) = $\frac{21}{21 - 8.2}$ = 1.83

  Actual amount of exhaust gas = Go + (m - 1) Ao

  = 19.3 Nm^3/kg

  Heat contents of exhaust gas =

  19.3 x 246.6 x (550 - 30) x 0.33

  = 816,710 kcal/t

- Heat release (Q)

Surface temperatures of the furnace wall, which are given in Fig. 1, are supposed to be 300°C.

a. Heat loss due to radiation (Qr)

$$Qr = 4.88\ \varepsilon \cdot A \left\{ \left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4 \right\}$$

$$= 4.88 \times 0.9 \times 66.8 \times \left\{ \left(\frac{300 + 273}{100}\right)^4 - \left(\frac{30 + 273}{100}\right)^4 \right\}$$

$$= 291{,}750 \text{ kcal/h}$$

b. Heat loss due to convection (Qc)

Heat transfer rate on upward horizontal surface ($\delta 1$) = $2.8 \times \Delta t^{0.25}$ = 11.35 kcal/m^2h°C

Heat transfer rate on downward horizontal surface ($\delta 2$) = $1.5 \times \Delta t^{0.25}$ = 6.08 kcal/m^2h°C

Heat transfer rate on vertical surface ($\delta 3$) = $2.2 \times \Delta t^{0.25}$ = 8.92 kcal/m^2h°C

If heat loss from upper part is represented by Qc1, heat loss from lower part by Qc2, and heat loss from side by Qc3, then:

Qc1 = 11.35 x 16.64 x (300 - 30)	= 50,993 kcal/h
Qc2 = 6.08 x 16.64 x (300 - 30)	= 27,316 kcal/h
Qc3 = 8.92 x 33.60 x (300 - 30)	= 80,922 kcal/h
Total Qc	= 159,231 kcal/h

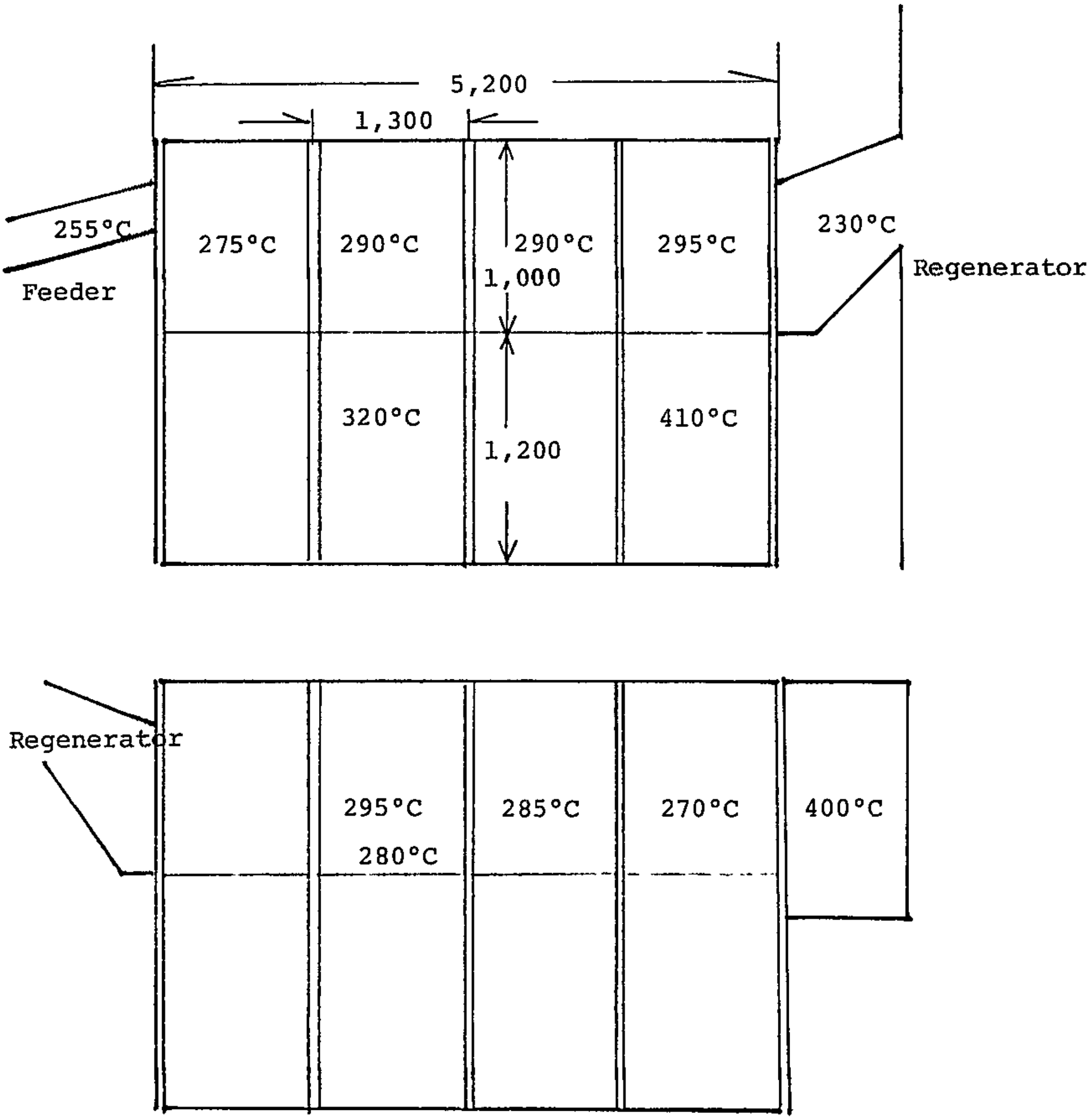
c. Total heat release

Q = Qr + Qc = 450,981 kcal/h

d. Heat release per ton of glass

$$\frac{450{,}981 \text{ kcal/h}}{0.667 \text{ t/h}} = 676{,}000 \text{ kcal/t}$$

Fig. 1 Surface Temperatures of the Furnace Wall



6. Problems in Heat Control and Potential Solutions

(1) Air ratio

According to the results of an analysis made of the oxygen content in exhaust gas from the melting furnace, the oxygen content at the bottom of the regenerator is:

$O_2 = 9.5\%$

And the air ratio is:

$$\frac{21}{21 - 9.5} = 1.83$$

In other words, the actual amount of air is strikingly 1.8 times larger than the theoretical amount of air. An excessive amount of air coming into the furnace lowers flame temperatures and increases heat loss in the exhaust, thereby bringing down the thermal efficiency to a significant degree.

To hold down the air ratio at a proper level, it is necessary:

- To regulate the damper so that furnace pressure won't go down to an excessively minus level (whether the furnace pressure level is plus or minus can easily be seen from the smoke or air flow at the charging hole);
- To stop a gap between furnace wall bricks so as to prevent the cold air from coming in;
- To reduce the area of the charging hole and other openings to the minimum and to keep such openings shut tight whenever unnecessary

so as not to let air in; and

- To employ a burner capable of atomizing fuel very efficiently to reduce the amount of air.

If the air ratio (m) is lowered from 1.83 down to 1.5 or 1.3, resulting energy-saving effects will be as follows:

Air ratio	1.5	1.3
Fuel saving rate (%)	8.4	12.6
Amount of fuel saved (kl/y)	128.8	193
Value of fuel saved (bahts/y)	605,360	907,840

<u>Calculation</u>

Amount of exhaust gas = Go + (m - 1)Ao

$10.8 + (1.83 - 1) \times 10.2 = 19.3\ Nm^3/kg$

Where,

m = 1.83

$10.8 + (1.5 - 1) \times 10.2 = 15.9\ Nm^3/kg$

Where,

m = 1.5

$10.8 + (1.3 - 1) \times 10.2 = 13.9\ Nm^3/kg$

Where,

m = 1.3

If the sum total of effective heat and fixed heat loss is given as A, and the amount of fuel as X_0, X_1, and X_2, then:

$9{,}700\ X_0 = A + 19.3 \times (550 - 30) \times 0.33\ X_0$

Where,

$m = 1.83$

$9,700 X_1 = A + 15.9 \times (550 - 30) \times 0.33 X_1$

Where,

$m = 1.5$

$9,700 X_2 = A + 13.9 \times (550 - 30) \times 0.33 X_2$

Where,

$m = 1.3$

The above results can be obtained by solving these equations.

(2) Insulation improvement on the melting furnace's side wall

The furnace body is made of quality refractory materials. So it is desirable to give better heat insulation to those parts expect glass level.

If 70 percent of the side wall and the bottom of the furnace are lined with ceramic fibers to a thickness of about 25 mm, and the surface temperature is lowered down to 240°C or so, then heat release can be reduced by the following amount:

		Before improvement	After improvement	Reduced heat release
Side	14.6 m^2	6,776 kcal/ m^2h	4,541 kcal/ m^2h	32,631 kcal/ h
Bottom	16.6	6,010	4,186	30,278
Total	39.0 m^2			62,909 kcal/h

This will amount to 6.5 kg/h in terms of fuel oil, accounting for 4 percent of the total consumption.

Cost reduction will be:

$$6.5 \times 365 \times 24 \times \frac{1}{0.94} \times 4.7 = 284{,}700 \text{ bahts/y}$$

The cost of insulation improvement is estimated at 40,000 bahts, an amount small enough to recover within a short period of time.

Note should be taken, however, of the fact that the surface temperature of the insulating material-covered wall goes up to around 700°C. It is advised, therefore, to carry out insulation improvement one by one, starting with those parts where inner bricks will not corrode so much.

As for the regenerator, there are not so many problems involving a refractory body; better insulation is given to the regenerator at most of the Japanese factories. It is requested to examine the possibility of initiating insulation improvements on the regenerator.

(3) Lehr

The lehr is fitted with oil burners in a wrong way. So burner tiles are found to have been exposed to flames. In addition, one of the burners is found to have been blowing off flames due to excessive air taken in. This lehr has no flue and is giving off flames from its top.

Fuel can be saved by fitting an air preheater to recover waste heat (which necessitates the remodeling of a stand) or by converting the present lehr into a direct heating type. Almost no heat may be required if heat of glass formed is thoroughly used and the air is kept from coming into the lehr.

Insulating materials are found to have come off at the front half of the cooling zone, which may cause improper cooling. A saucer should be installed at the end of the conveyer at the lehr's outlet to prevent products from falling down.

(4) Miscellaneous

A. LPG-oxygen burners for annealing should be put out or throttled down whenever unnecessary (it seems that high-pressure air burners, instead of oxygen burners, will serve the purpose).

B. The floor of the compressor room should be cleaned to remove oil stain. Piping should be provided with supports to prevent vibration.

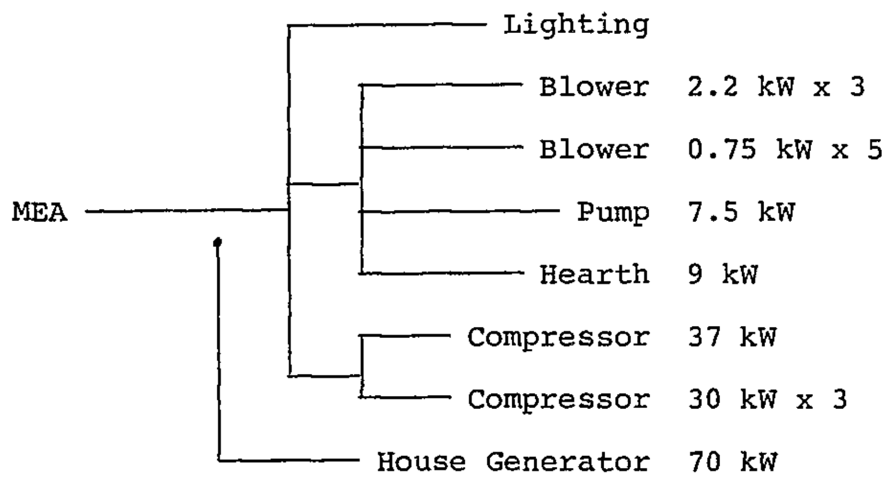
C. As safety measures to protect workers, it is necessary to fit compressor belts and fans with safety covers and to provide staging and ladders with handrails.

7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	MEA
Peak demand	-	112 kW
Electric energy used	-	54,240 kWh/m
Load factor	-	69.2%
Penalty	-	15 kVr
Power factor	-	81%
Transformers	-	No transformers

(2) One-line diagram



8. Problems in Electric Power Control and Potential Solutions

(1) Power factor

With the penalty of 15 kVr in power bills and the peak demand of 112 kW, the power factor stands at a little low level of 81 percent.

(2) Compressors

Four compressors are in parallel operation. Of these, the load of a 50 HP unit is 26 kW (30 kVA) or 71 percent of the rated level; a 40 HP unit has a load of 17 kW (18 kVA) or 57 percent of the rated level; and another unit shows a similar load level. But the remaining one unit was run at almost no load. The total load of these four units was found to be on the low level.

A good way of operating compressors is to run large units at full load while making a small unit ready for changes in load. Load adjustment is made by regulating a pressure valve fitted into each compressor.

In this particular case, operate three units at about 95 percent load and, if pressure can be kept at a proper level, then put the remaining one at rest. If the load is lessened further, then use one of the three units to adjust load.

If each compressor's share of the load is changed like this and a 40 HP unit is put at rest, then electric energy can be saved by: $\sqrt{3}$ x 380 V x 24 A x 0.55 = 8.7 kW. And an annual saving of electricity will amount to 75,000 kWh or 109,500 bahts. Moreover, reactive power can be reduced by 11 kVr/m and a penalty will not be imposed any more. So additional 2,000 bahts a year can be saved.

All of the four compressors were vibrating heavily and some of them had broken belts. Air pipes were also vibrating. Belts should be fitted correctly. And efforts should be dedicated to safety operation as well as to improvement of operating hours.

The current intensity at the power source differ greatly between wires, ranging from 175 A to 198 A. Such a large difference in current intensity is likely to cause vibration and inequality in the source voltage. The electric current level should be better balanced after examination of how to set up loads.

(3) Lighting and others

Unnecessary lights and cooling fans were left switched on when no one was around. Workers should be educated to be more conscious of energy conservation.

9. Summary

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

Measures	Potential energy saving	Rate (%)
Improvement of air ratio	fuel oil 193 kl/y	12
Insulation improvement on melting furnace's wall	fuel oil 61 kl/y	4
Putting one 40 HP compressor at rest	electricity 75,000 kWh/y	12

Report No. 4: Glass

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

- Asia Glassware Co., Ltd. -

January 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- Asia Glassware Co., Ltd. -

1. Outline of the Factory

Address : 72 Suksawat Rd. Soi Wat Kunok Tombol
Bangku, Prapadang, Samutprakarn

Capital : 3 million bahts

Type of industry : Glass

Major products : Glass products

Annual output : 1,460 t

No. of employees : 120

Annual energy consumption :

- Electric power : 225,600 kWh
- Fuel
  - Fuel oil A : 948 kl
  - Diesel oil : 263 kl
  - LPG : 40 kl

Interviewees : Nivat Tesnirunprasert, factory manager,
and Sawai, engineer

Date of diagnosis : Aug. 26 - 27, 1982

Diagnosers : M. Ito, Y. Ohno, and T. Sugimoto

Asia Glassware is located about 40-minutes' car ride south of downtown Bangkok.

In the initial stage of operation, the glassworks used a melting furnace designed by Sorg, a German firm. The furnace was reconditioned by the factory with its own technology in March 1982, when its capacity was reduced from 19 tons a day to 10 tons. However, the recuperator was left unchanged, and one of the two burners remained in operation as it was.

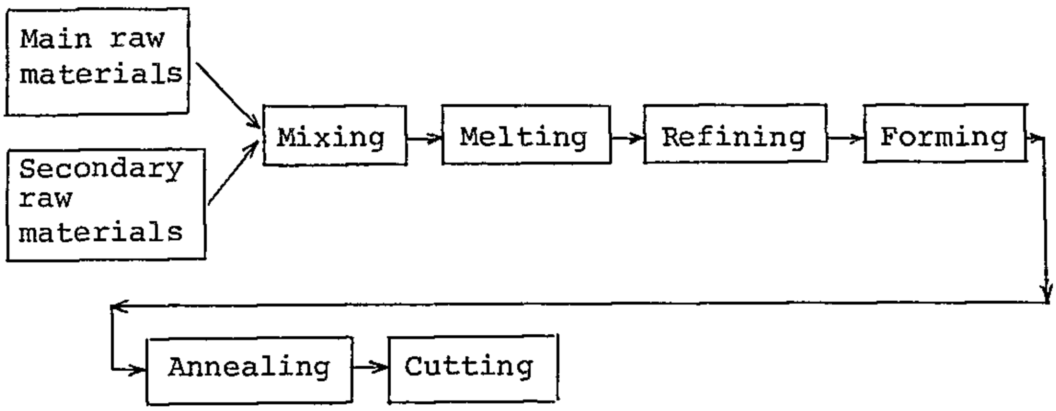
Asia Glassware has a work force of 120 persons, many of whom are engaged in blowing glass surrounding the melting furnace in the center of the large factory building as forming is entirely performed by handwork.

The factory produces some four to six tons of glassware a day on a 16-hour run. The furnace is kept heated idly from 12:00 midnight to 8:00 am.

The operator says that the factory has an 80-percent yield rate now. However, it cannot make highly transparent, quality drinking glasses due to its capability insufficient to completely remove bubbles from molten glass. This is the problem it has to solve most urgently.

Right now the executives are primarily concerned about improvement of product quality, and they have not yet begun considering energy conservation in earnest.

2. Manufacturing Process

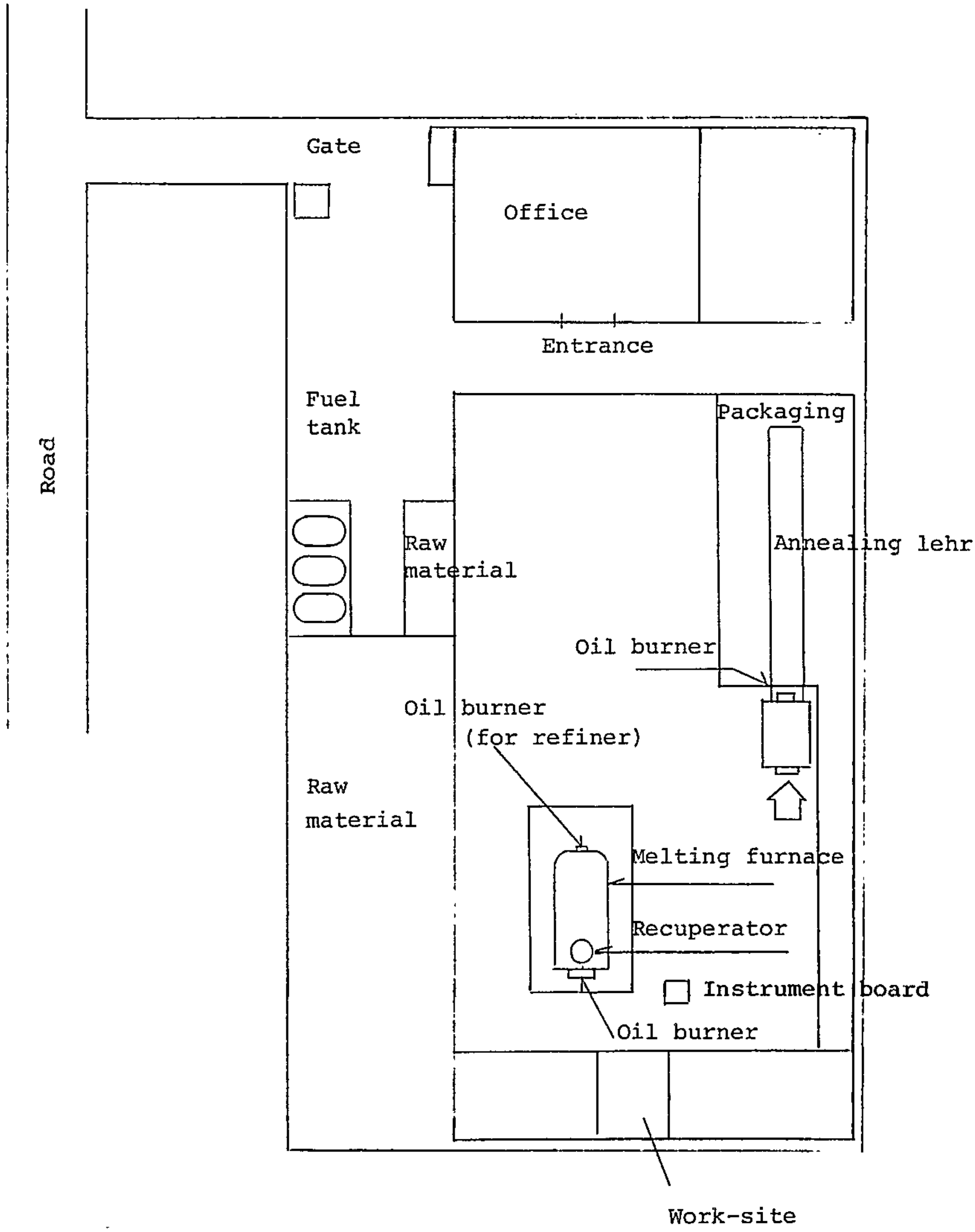


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type, etc.
Melting furnace	1	End-port type; produces 10 t/d; burns fuel oil.
Refiner	1	
Recuperator	1	Metalic type
Annealing lehr	1	Radiant type

(2) Layout


Gate
Office
Entrance
Fuel
tank
Road
Raw
material
Packaging
Annealing lehr
Oil burner
Oil burner
(for refiner)
Raw
material
Melting furnace
Recuperator
Instrument board
Oil burner
Work-site

4. State of Energy Management

The glassworks has not yet set any specific goal for energy conservation. Fuel consumption is recorded once a day, but no attempt is made to analyze data on the consumption rate and other details or maintain energy cost accounting.

The factory has neither an organization nor a system for energy conservation, nor does it provide any educational program or information service for workers on this subject. During our visit to the factory, we saw one engineer noting down every detail of daily operation and energy consumption. Apparently the glassworks entirely depends on him for energy conservation.

5. State of Fuel Consumption

The factory uses 948 kl of fuel oil, 263 kl of diesel oil, and 40 kl of LPG per year. As is apparent from these figures, fuel oil for the melting furnace accounts for the greater part of the total primary energy sources it consumes. Some adjustments have been made to the plant operation since the melting furnace was not properly designed. The system is operated in an unusual manner with the recuperator damper and refiner flue throttled so far that the internal pressure of the furnace becomes positive. In addition, some of melting furnace flames are sent to the refiner to keep the temperature.

The fuel consumption rate is substantially high relative to the output because the factory is off eight hours a day during which the melting furnace is kept heated idly.

Fuel consumption rate

$$\frac{2,596 \text{ liters/d} + (720 \text{ liters/d} \times 10,770/10,239)}{5.76 \text{ t/d}}$$

= 582 litters/t

The melting furnace and refiner have a low thermal efficiency of 8.7 percent. Their heat balance is as shown below:

Heat Balance in the Melting Furnace/Refiner

Input			Output		
	kcal/d	%		kcal/d	%
Heat of fuel combustion	32,506,149	100	Heat of glass melting	2,822,400	8.7
			Loss of heat in exhaust gas	10,111,385	31.1
			Loss of heat through the furnace walls by radiation	12,298,128	37.8
			Other losses of heat - Loss due to incomplete combustion - Loss through openings	7,274,236	22.4
Total	32,506,149	100	Total	32,506,149	100

Notes:

1) Data given for determination of the heat balance -

Amount of glass melted	-	360 kg/h (16 h/d)
Melting temperature	-	1,470°C
Melting heat required	-	490 kcal/kg
Cullet mixture ratio	-	50%

Fuel

	For melting	For refiner
	Fuel oil	Diesel oil
Heat contents (Hl)	10,239 kcal/kg	10,770 kcal/kg
Gravity	0.975	0.85
Consumption	2,596 liters/d	720 liters/d
	2,531 kg/d	612 kg/d

Operating hours

Melting - 16 h/d 365 k/y

Burners on - 24 h/d Reference temp. 33°C

Oxygen content in exhaust gas

Melting furnace outlet - 0.4%

Refiner flue - 3.5%

Exhaust gas temperature

Recuperator outlet - 672°C

Refiner flue - 1,400°C (estimate)

Air temperature

Recuperator inlet - 33°C

Recuperator outlet - 398°C

2) Equations for calculating the heat balance -

Input

Heat of fuel combustion

Melting furnace: 10,239 kcal/kg x 2,531 kg/d =

25,914,909 kcal/d

Refiner: 10,770 kcal/kg x 612 kg/d = 6,591,240 kcal/d

Total: 32,506,149 kcal/d

Output

Heat of glass melting:

490 kcal/kg x 5,760 kg/d = 2,822,400 kcal/d

Loss of heat in exhaust gas:

			Fuel oil A	Diesel oil
Theoretical amount of air	Ao	Nm^3/kg	10.7	11.2
Theoretical amount of exhaust gas	Go	Nm^3/kg	11.4	12.0
Actual amount of exhaust gas	G	Nm^3/kg	11.6	14.2
Air ratio	m		1.02	1.2

Loss of heat in exhaust gas from the furnace: Q_{E1}

Q_{E1} = 11.6 Nm^3/kg x 2,531 kg/d x (672 - 33)°C x 0.33 kcal/Nm^3°C = 6,191,059 kcal/d

Loss of heat in exhaust gas from the refiner: Q_{E2}

Q_{E2} = 14.2 Nm^3/kg x 612 kg/d x (1,400 - 33)°C x 0.33 kcal/Nm^3°C = 3,920,326 kcal/d

$Q_{E1} + Q_{E2}$ = 10,111,385 kcal/d

Loss of heat through the furnace walls:

(a) Loss of heat through convection

Part	α kcal/m²h°C	t°C	Δt°C	A m²	Q=αΔtA kcal/h
Furnace					
Side	9.75	380	347	17.93	60,662
Top	12.40	420	387	7.08	33,976
Bottom	6.65	360	327	7.08	15,396
Stack					
Side	8.1	220	187	15	22,720
Top	10.5	230	197	3	6,206
Bottom	5.4	200	167	2.3	2,074
Recuperator					
Side	7.9	200	167	23	30,344
Total					171,378

(b) Loss of heat through radiation

$\varepsilon = 0.9$

Part	Surface temp. °C	T_1 °K	T_2 °K	A m²	$Q=4,88\ \varepsilon A\left\{\left(\frac{T_1}{100}\right)^4-\left(\frac{T_2}{100}\right)^4\right\}$ kcal/h
Furnace					
Side	380	653	306	17.93	136,392
Top	420	693	306	7.08	69,048
Bottom	360	633	306	7.08	47,236
Stack					
Side	220	493	306	15	33,168
Top	230	503	306	3	9,285
Bottom	200	473	306	2.3	4,174
Recuper-ator	200	473	306	23.0	41,741
Total					341,044

a) + b) 512,422 kcal/h x 24 h = 12,298,128 kcal/d

6. Problems in Heat Control and Potential Solutions

(1) Improvement in furnace burning

Exhaust gas contain only 0.4-percent oxygen, when measured at the outlet of the melting furnace, indicating that insufficient air is sent into the furnace. Yellowish, opaque flames in the furnace and carbon deposits in the flue under the recuperator also indicate that the furnace is burning imperfectly.

Bubbles often remain in glass when temperature of glass is low. It may be assumed that this factory's glassware contains some bubbles partly because it is heated insufficiently due to imperfect combustion of fuel.

Some adjustments are needed to send an increased volume of air into the burner and lower the pressure in the furnace by opening the recuperator damper wider. If the temperature at the recuperator inlet goes up too high during the adjustments, some bricks should be taken out to send in air and keep the temperature in the recuperator at a specified level.

The glassworks is now scaling down the melting furnace. It can burn 293 kg of fuel per hour when its capacity is set at 10 m^3, and its combustion chamber load at 300,000 $kcal/m^3 \cdot h$. We believe that this furnace volume is quite sufficient.

What we have to carefully consider is the length of the furnace. If 150 kg of fuel is to be burned per hour with a single burner, the length of the flame should be:

$$L = \frac{1{,}500{,}000 \text{ kcal/h}}{413{,}000 \times 0.8} = 4.5 \text{ m}$$

Where 413,000 represents the coefficient applicable to the type of the burner used, and 0.8 represents that for the type of fuel burned.

This means that the existing furnace is not long enough for this purpose. The inadequate length of the furnace also causes flames to extend to the refiner as they do now, and therefore fails to ensure a normal heating pattern for glass. To solve this problem, the burner must be divided into two units or it must be replaced by a high-load burner with short flames, such as a vortex burner. In addition, part of the furnace itself should be remodeled to provide a combustion chamber properly designed to ensure steady flames. The improvement will cost some 300,000 bahts, but we believe that fuel could be saved by about 10 percent.

(2) Installation of a booster

Perhaps a better way to improve a melting furnace with low thermal efficiency like the one used in this factory is to install an electric booster which will ensure easy operation and higher energy efficiency. The booster has electrodes that are set in the furnace to directly apply an electric current to glass for heating, and this will probably improve the thermal efficiency to an 80-percent level as far as electric heating is concerned. The booster system, already in operation at many factories in different Southeast Asian countries, can be installed without cooling the furnace. This improvement work will cost about 1 million bahts.

Either of the two alternative steps suggested above will have to be taken to solve the problems in product quality. The improvement work will also bring about substantial energy-conservation effects.

(3) Improvement of Heat Insulation for the Melting Furnace Walls

Currently the melting furnace has an average surface temperature of 390°C, reflecting heat losses as shown below:

Loss of heat through convection:	3,362 $kcal/m^2 \cdot h$
Loss of heat through radiation:	7,874 $kcal/m^2 \cdot h$
Total:	11,236 $kcal/m^2 \cdot h$

Thermal resistance of the furnace walls:

$$11,236 = \frac{1,500 - 390}{R} \qquad \therefore R = 0.099$$

When a ceramic-fiber blanket (25 mm thick and $\lambda = 0.25$) is applied to the walls, their thermal resistance would increase to:

$$0.099 + \frac{0.025}{0.25} = 0.199$$

Provided that the room temperature be kept at 33°C, the heat radiation decreases to:

$$\frac{1,500 - 33}{0.199 + \frac{1}{30}} = 6,323 \text{ kcal/m}^2 \cdot \text{h}$$

Temperature at the boundary between the blanket and the wall surface

$$\frac{1,500 - X}{0.099} = 6,323 \qquad X = 874°C$$

Temperature on the surface:

$$\frac{1,500 - X}{0.199} = 6,323 \qquad X = 242°C$$

Hence, the loss of heat through radiation decreases to:

$$(11,236 - 6,323)\ kcal/m^2 \cdot h \times 32\ m^2 = 157,216\ kcal/h$$

The difference in fuel oil equivalent is:

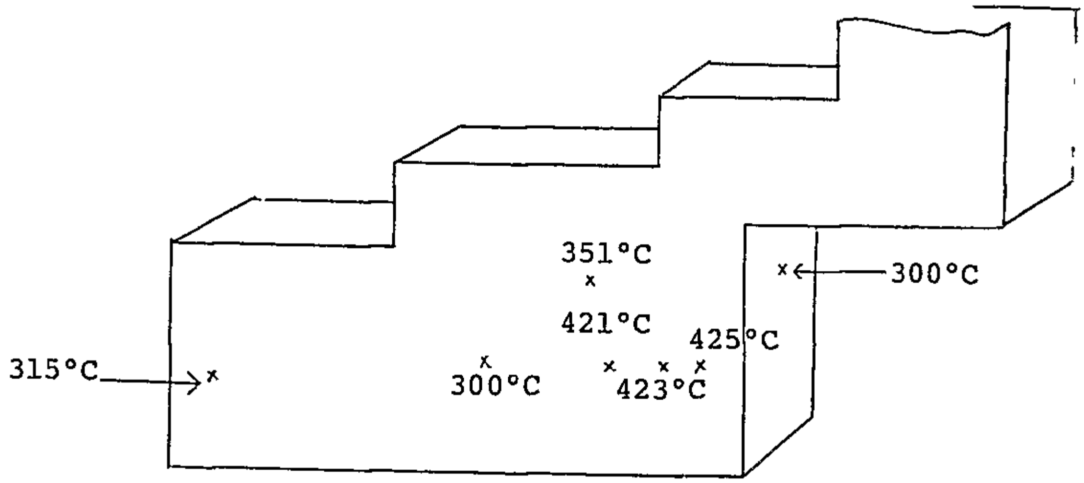
$$\frac{157,216}{10,240} = 15.4\ kg/h$$

$$15.4 \times \frac{1}{0.975} \times 24 \times 365 = 138\ kl/y$$

Therefore, the annual fuel consumption can be saved by 15 percent.

The application of the insulating blanket will cost less than 60,000 bahts, which may be recovered in a short period of time.

However, the life of bricks must be carefully considered as the application of the blanket will increase the temperature of the bricks on the inside of the furnace.



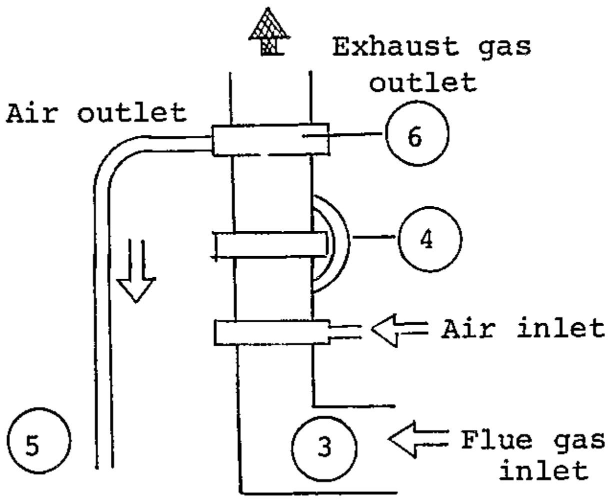
Surface temperature on the side walls of the melting furnace

(4) Improvement of heat insulation for the hot air duct of the recuperator

Following diagram shows measured temperature in different parts of the recuperator. Since the temperature of hot air falls rather too sharply, some steps are needed to improve the heat insulation for this installation.

Measuring points		Temperature (°C)
1	Temperature of the refiner	1,250
2	Temperature in the melting furnace	1,493
3	Temperature of exhaust gas	1,373
4	Temperature of preheated air midway	505
5	The same as the above (in the duct)	398
6	Temperature of exhaust gas outlet	672

Temperature in different parts
of the recuperator



(5) Others

a. Air for the refiner burner can be efficiently pre-heated by use of recovered heat from exhaust gas or hot air collected from the top of the melting furnace.

The latter method will probably save some 16 kl of diesel oil a year.

b. Heat losses from blown glass products through radiation occurs while they are carried to the annealing lehr because it is installed too far away from the melting furnace. This must be borne in mind when the factory layout is reviewed in the future.

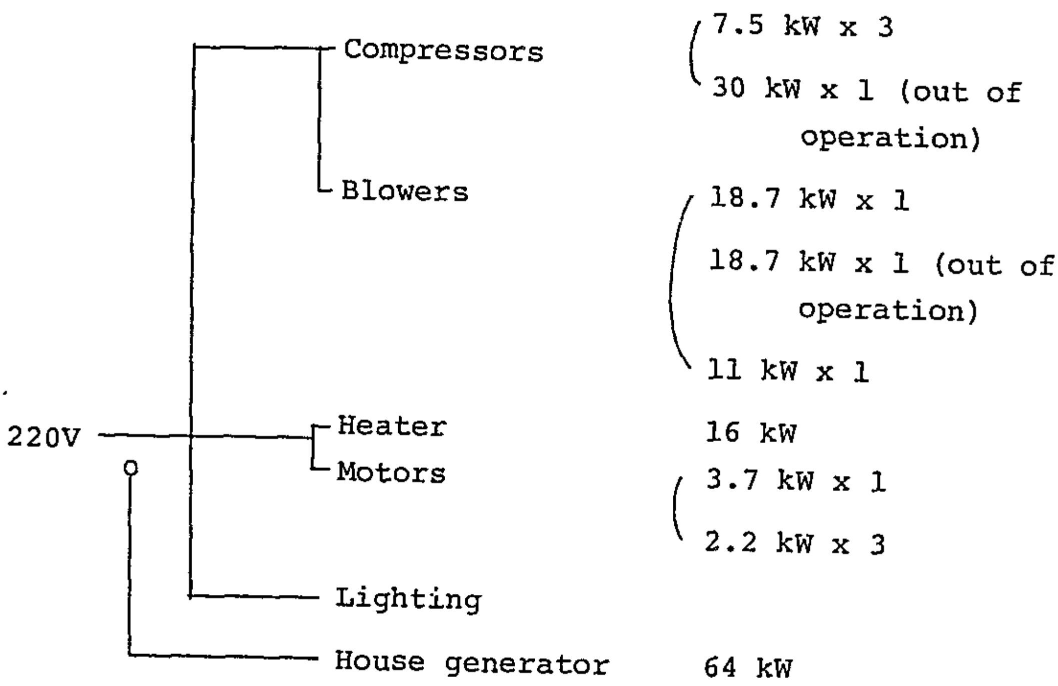
c. The LPG burner for mouth finishing should be turned off during a break.

7. State of Electric Power Consumption

(1) The principal data relating to power consumption are as follows:

Power company	-	MEA
Peak demand	-	27 kW (33 kW measured)
Electric energy used	-	18,800 kWh/m
Load factor	-	96.7%
Penalty	-	No penalty
Power factor	-	66% measured
Transformer	-	None

(2) One-line diagram



8. Problems in Electric Power Control and Potential Solutions

(1) Power factor and voltage drop

The total power factor of the glasswork equipment is too low as it reaches only 66 percent. In addition, an 8-to-9 volt drop occurs within the distance of only about 30 meters from the receiving end to the major electric equipment, i.e., compressors. These problems can be solved by installing a 20 kVr condenser in the major electric equipment or increasing the wiring diameter through replacement work. This will help the motors start more easily, while decreasing power losses in the wiring.

(2) Compressors

Of the three compressors (with 7.5 kW capacity each), two have a low power factor of only about 70 percent, and the voltage at the motor terminals is also insufficient, reaching only about 213 volts.

This can be properly corrected through installation of a 20 kVr condenser at the compressor switch.

The three compressors have an average load factor of 75 percent, but the two of them, when measured individually, show a lower factor of 70 percent. Preferably, some improvements should be carried out in the future to increase the load factor of the two compressors to a 95-percent level, while using the third one for load adjustment through pressure valve regulation.

Currently the factory regulates the compressor pressure by using air release from the air tank. Replacement of the method with pressure valve regulation will probably enable the factory to leave one compressor out of operation. This will save electric power appreciably as shown below:

$$4 \text{ kW} \times 24 \text{ h} \times 360 \text{ d} = 34{,}000 \text{ kWh/y}$$

(3) Blowers

The two blower motors, with a combined capacity of 29.7 kW, have a load of only 9 kW and a low power factor of 51 percent.

If the load still remains at a low level even after the air flow is regulated properly, the blower motors may be replaced with smaller ones. Replacement of the larger motor (18.7 kW) by a smaller one of 11 kW will save about 3,540 kWh of power per year.

Power loss in 18.7 kW motor:

$$18.7 \text{ kW} \times (1 - 0.86) \times 0.64 = 1.68 \text{ kW}$$

Power loss in 11 kW motor:

$$11 \text{ kW} \times (1 - 0.84) \times 0.72 = 1.27 \text{ kW}$$

Difference:

$$(1.68 - 1.27) \times 24 \text{ h} \times 360 \text{ d} \doteqdot 3{,}540 \text{ kWh}$$

9. Summary

When all the remedies suggested above are carried out, the glassworks could substantially save energy as shown below:

Replacement of burners	95 kl of fuel oil per year	10%
Better insulation for the melting furnace walls	138 kl of fuel oil per year	15%
Use of hotter air for refiner burning	16 kl of diesel oil per year	6%
Total		31%
Reduction of compressors	34,000 kWh/y	
Use of smaller blowers	3,540 kWh/y	
Total:	37,540 kWh/y	17%

The installation of an electric booster in the melting furnace could reduce the heat input to less than half. When power generating efficiency is taken into account, however, it will contribute little or nothing to energy conservation of Thailand as a whole.

Report No. 5: Ceramics

REPORT ON THE DIAGNOSIS
FOR
ENERGY CONSERVATION

- The Union Mosaic Industry Co., Ltd. -

January, 1983

Japan International Cooperation Agency

Contents

The Diagnosis for Energy Conservation

- The Union Mosaic Industry Co., Ltd. -

1. Outline of the Factory

Address A.Nangkou Saraburi

Capital :

Type of industry : Ceramics

Major products : Mosaic tiles

Annual output : 15,000,000 square feet

No. of employees : 863

Annual energy consumption :

- Electric power : 558,420 kWh/m
- Fuel
  - Fuel oil : 6,500 kl
  - Diesel oil : 90 kl

Interviewees : Niwat Udompongsanon, assistant managing director, and Surachai Meetunkij, electrical engineer

Date of diagnosis : Sept. 13 - 14, 1982

Diagnosers : M. Ito, Y. Ohno, and T. Sugimoto

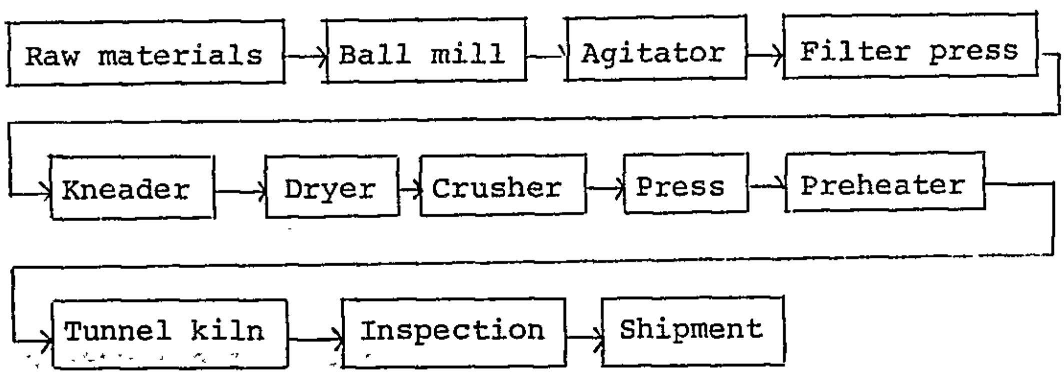
The Union Mosaic Industry is the largest of all mosaic tile manufacturers in Thailand and has an annual production capacity of 15 million ft^2, with some 50 percent market share. Its factory was brought into operation nine years ago with technological cooperation from Tanto Ceramic Company, of Japan. With subsequently accumulated experiences, the firm is currently operating its factory on its own technology.

The factory is planned in an orderly manner and generally cleaned well.

The factory staff comprise well-trained personnel. So far, a number of rationalization efforts have been made, including replacement of burners, installation of fuel preheating equipment using waste heat, and construction of a waste-heat-using spray dryer oven (on a test run) for raw materials.

In addition, some steps have been taken in operation to improve the energy consumption rate, reflecting the management's active attitude toward energy conservation. The yield rate runs at about 90 percent.

2. Manufacturing Process

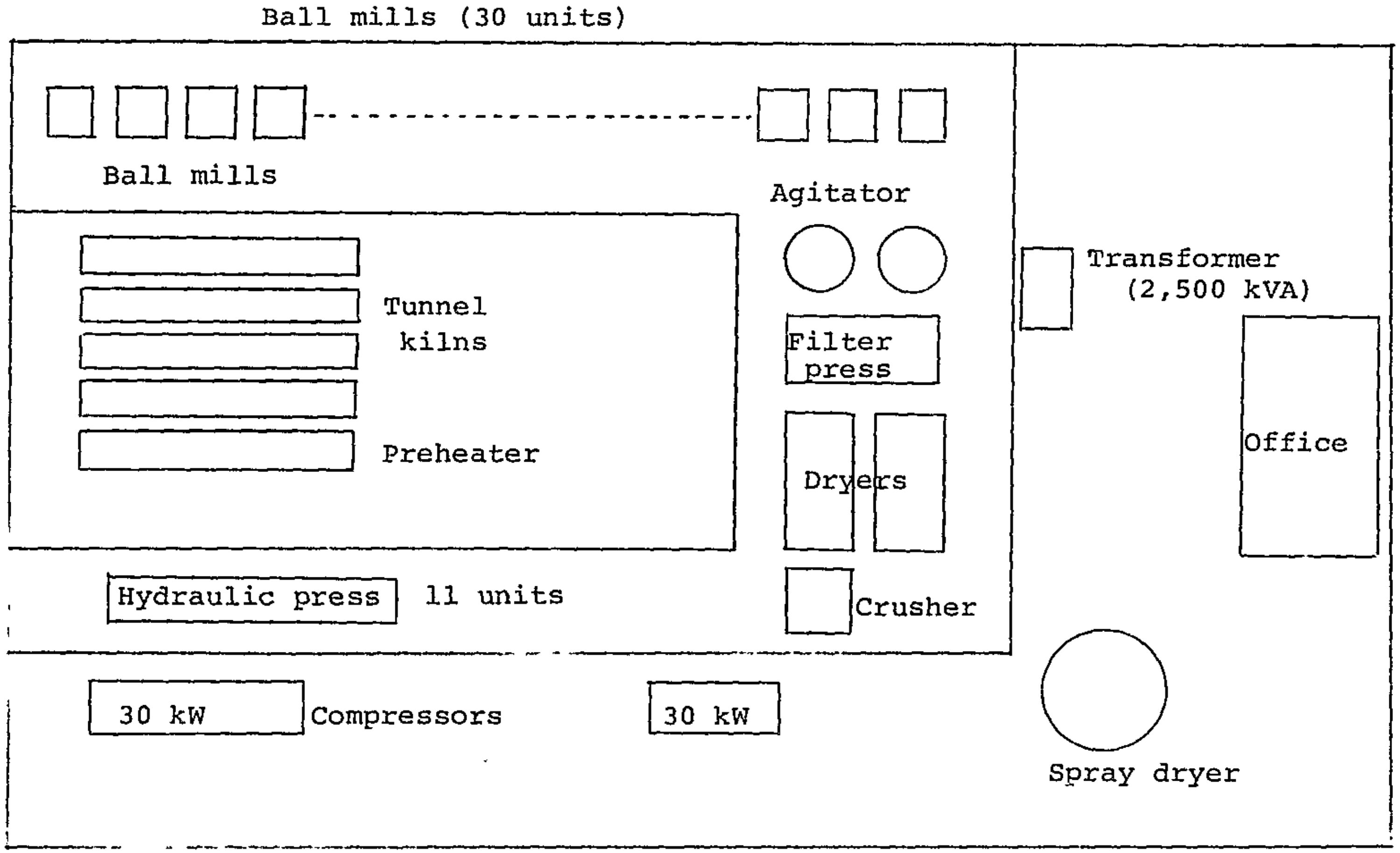


3. Major Equipment

(1) Major equipment

Name	No. of units installed	Type, etc.
Ball mill	30	
Dryer	2	Mesh conveyer type, using waste heat of exhaust from kiln
Preheater	1	Tunnel type, using waste heat of exhaust from kiln
Tunnel kiln	4	Made by Takasago Industry, side burners

(2) Layout


Ball mills (30 units)
Ball mills
Agitator
Tunnel
kilns
Preheater
Filter
press
Dryers
Transformer
(2,500 kVA)
Office
Hydraulic press
11 units
Crusher
30 kW
Compressors
30 kW
Spray dryer

4. State of Energy Management

Although an energy conservation policy is adopted, specific targets such as a fuel saving rate and time limit have not yet been fixed.

Data on fuel consumption are compiled on a monthly basis, but this practice is not applied to electric power. Also, data on the energy consumption rate are collected and analyzed every month; analytical results to find factors affecting the energy consumption rate, however, are kept by a person in charge.

Though there is no organization for stepping up conservation, energy-saving measures are examined chiefly by competent personnel (in charge of factory, furnaces, and electric power). In addition to the aforementioned steps in terms of equipment, other conservation efforts have thus far been made - for example, bringing together product with a similar firing curve in each kiln, or lowering the weight ratio of a sagger to a product through better use of the inner space of the saggers.

Proposals for improvement are put forward once in a while, but a worker, if his plan has been adopted, will not be officially commended because it is rather difficult to decide whether or not such a plan works effectively. Thus, this system does not function well.

5. State of Fuel Consumption

The consumption of fuel is as follows:

Fuel oil - 6,500 kl/y (Heat contents: 9,500 kcal/liter, specific gravity: 0.93)

Diesel oil - 90 kl/y

Fuel oil is burnt in tunnel kilns alone, whereas dryers and the preheater are operated by waste heat of the exhaust gas coming out of kilns.

The spray dryer, which is now on a test run, is fitted with a heating furnace.

The fuel consumption rate stands at 0.433 liter/ft^2 (433 liters/ton).

The tunnel kilns have the thermal efficiency of 8.8 percent, which corresponds to the average level for old-fashioned tunnel kilns:

Effective heat (Q_E) = 1,000 kgs/ton x (1,200 - 30°C) x 0.31 kcal/kg·°C = 362,700 kcal/ton

Input heat (Q_I) = 433 liters/ton x 9,500 kcal/liter = 4,113,500 kcal/ton

$$\text{Thermal efficiency } (\eta) = \frac{Q_E}{Q_I} \times 100 = 8.8\%$$

6. Problems in Heat Control and Potential Solutions

(1) Control of the air ratio

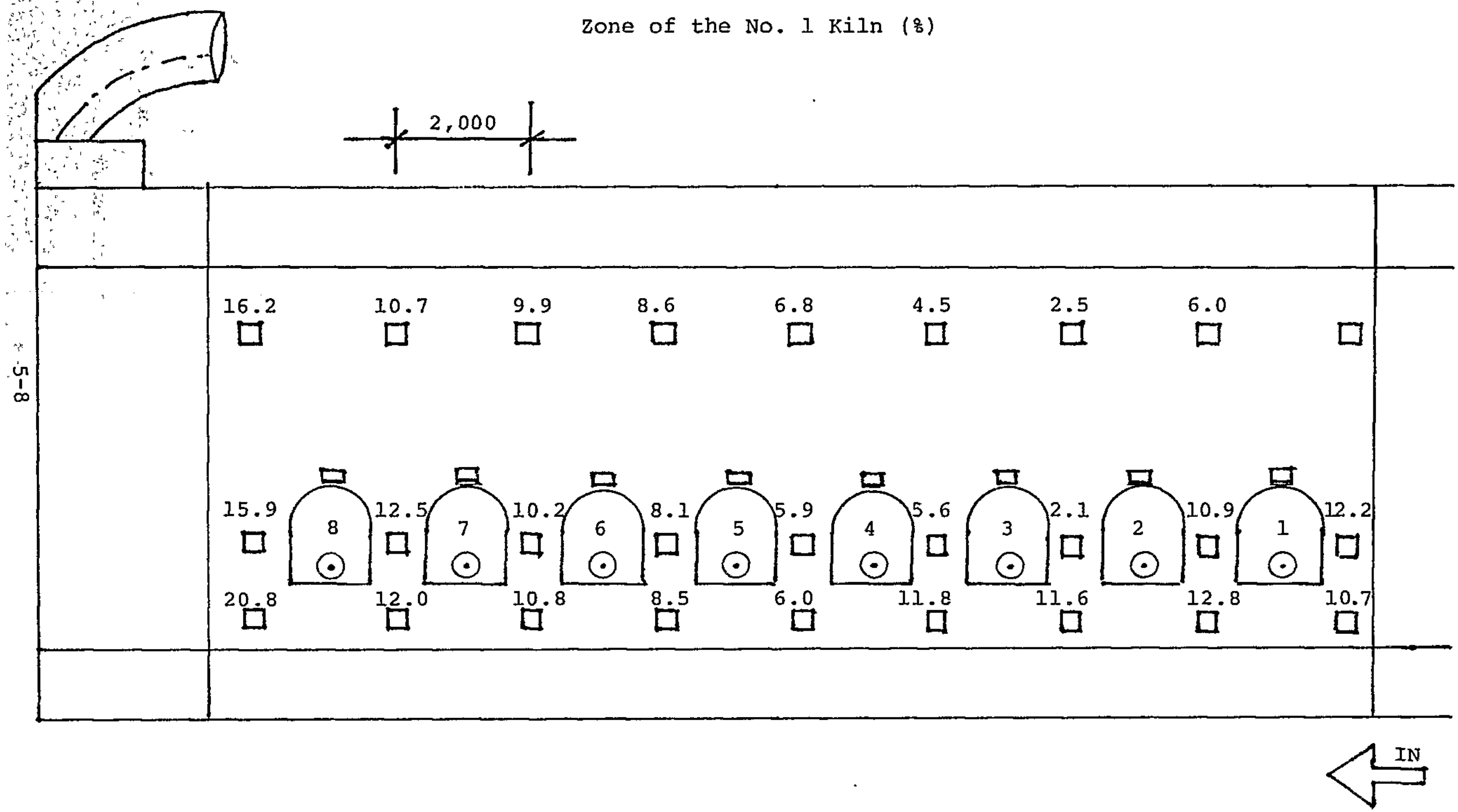
An analysis was made of the oxygen content in gases inside the No. 1 kiln, mainly in its firing zone. The measured values are given in Fig. 1. From these results, the following observations can be made:

- Measurement was carried out heightwise through the three checking points provided in the upper, middle, and lower sides of the kiln. A difference in the oxygen content between the upper and lower sides was observed at some areas (e.g., the area between the Nos. 1 and 4 burners); this seems to be due to an escape of air from under the carriage. Since the air escape of this sort may cause unevenness in temperatures and hence in the quality of the product, the carriage should be put in good condition to stop it.

- There was just a small difference among the values on the upper side in relation to the direction in which the carriage moved. And this difference was gradually narrowed in a direction parallel to the gas flow. So it can be assumed that gas was flowing properly.
- The values on the upper side were mostly smaller than those on the lower side. It indicates that no air was coming in through the outlet to creep under the ceiling as products were piled up on the carriage in a proper manner and the inlet and outlet doors shut adequately tight.

Fig. 1 Oxygen Content in Gases in the Firing

Zone of the No. 1 Kiln (%)



These observations lead us to recommend that the following measures be taken.

A. Prevention of the cooling air leakage from under the carriage

Heat loss resulting from the cooling air leak from under the carriage can be estimated as follows:

Heat contents of fuel oil -

$$Hl = 10{,}200 \text{ kcal/kg}$$

Theoretical amount of air -

$$Ao = \frac{0.85\ Hl}{1{,}000} + 2.0 = 10.67\ \text{Nm}^3\text{/kg of oil}$$

Theoretical amount of exhaust gas -

$$Go = \frac{1.11\ Hl}{1{,}000} = 11.32\ \text{Nm}^3\text{/kg of oil}$$

Actual amount of exhaust gas -

$$G = Go + (m - 1)\ Ao$$

Air ratio -

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

From Fig. 1 it can be presumed that the oxygen content in the exhaust gas may have increased from 3 percent to 11 percent due to the cooling air coming in.

$$m1 = \frac{21}{21 - 3} = 1.17 \qquad G1 = 13.13\ \text{Nm}^3\text{/kg}$$

$$m2 = \frac{21}{21 - 11} = 2.10 \qquad G2 = 23.06\ \text{Nm}^3\text{/kg}$$

Increase in the amount of exhaust gas -

$$G2 - G1 = 9.93\ \text{Nm}^3\text{/kg}$$

Supposing that the temperature of exhaust gas at the outlet is 250°C, the increase in heat loss will be:

181 liters/h (amount of fuel) x 0.93 (specific gravity) x 4 (cardinal number) x 9.93 (increase in amount of exhaust gas) x 0.33 (specific heat) x 250°C (temperature) = 551,600 kcal/h

This will amount to 58 liters/h in terms of fuel, corresponding to 8 percent of the total fuel consumption.

To prevent the cooling air leakage from under the carriage, it is necessary:

- To refit a skirt into each carriage correctly so that the skirt of a carriage comes in a straight line with that of the adjoining one;
- To rearrange carriages in an orderly manner so that they come close to one another (as bricks were lengthwise jutting out of the iron frames of some carriages); and
- To keep an eye on the skirt of each carriage to see how it glistens and to supply sand, if necessary, to provide good sealing.

Efforts should also be made to reduce the amount of cooling air taken in, while keeping carriages in good order.

B. Reducing changes in gas pressure to minimum

When the carriage is put in and out, time to keep the door open should be made as short as possible to reduce changes in gas pressure to the minimum.

The results of a continuous analysis of the oxygen content at some Japanese factories show that it may take about ten minutes to bring the disturbed gas flow back to its former condition. With this in mind, many factories here provide a double door.

C. Kilns were fitted with proportional regulating burners, but with these burners the amount of air would automatically change in response to variations in the amount of oil, thereby disturbing the gas flow in the kiln.

The air ratio should be regulated in connection with control of kiln pressure; a proportional regulator must be removed from a burner so that the amount of oil alone can be controlled.

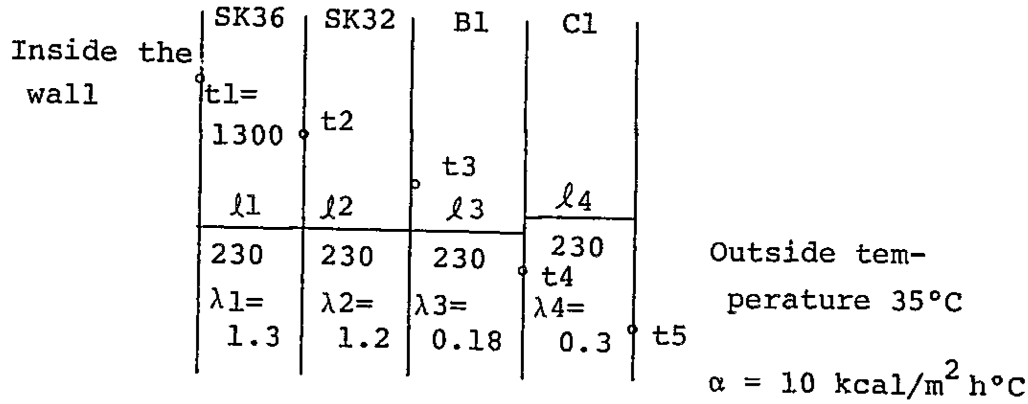
(2) Heat insulation of the kiln body

A. In view of significant heat release from the kiln body, some remedies were examined.

Some of the Japanese factories have succeeded in achieving a saving of about 10% of energy by spraying the kiln in operation with insulating material.

To carry out insulation improvement of this sort, it is necessary to look into the refractoriness of materials making up the kiln, such as refractory and insulated bricks, as well as into the construction of arch holders.

a. Composition and condition of kiln wall



b. Heat transfer resistance R

$$R = \frac{\ell 1}{\lambda 1} + \frac{\ell 2}{\lambda 2} + \frac{\ell 3}{\lambda 3} + \frac{\ell 4}{\lambda 4} + \frac{1}{\alpha} = \frac{0.23}{1.3} + \frac{0.23}{1.2} + \frac{0.23}{0.18} + \frac{0.23}{0.3} + \frac{1}{10}$$

c. Coefficient of overall heat transmission K

$K = \frac{1}{R}$ $\quad$ $K = 0.398\ \text{kcal/m}^2\ \text{h°C}$

d. Amount of heat transmitted Q

$$Q = q1 = q2 = q3 = q4 = q5$$
$$= K\ (t1 - t0)$$
$$= 0.398\ (1{,}300 - 35) = 503\ \text{kcal/m}^2\text{h}$$

This value almost corresponds to the figures 540 $\text{kcal/m}^2\text{h}$ - 510 $\text{kcal/m}^2\text{h}$ actually measured on that day.

e. Temperature at the boundary point between bricks

$$q1 = \frac{\lambda 1}{\ell 1}\ (t1 - t2)$$
$$= \frac{1.3}{0.23}\ (1{,}300 - t2) = 503$$
$$t2 = 1.211°C$$

$$q2 = \frac{\lambda 2}{\ell 2} (t2 - t3)$$

$$= \frac{1.2}{0.23} (1{,}211 - t3) = 503$$

$$t3 = 1{,}115°C$$

$$q3 = \frac{\lambda 3}{\ell 3} (t3 - t4)$$

$$= \frac{0.18}{0.23} (1{,}115 - t4) = 503$$

$$t4 = 473°C$$

$$q4 = \frac{\lambda 4}{\ell 4} (t4 - t5)$$

$$= \frac{0.3}{0.23} (473 - t5) = 503$$

$$t5 = 87°C$$

t3 stands at 1,115°C, a level far exceeding the working, safety temperature of 900°C for B1 refractory bricks. So it is impossible to provide additional outside heat insulation.

A kiln manufacturer said that, contrary to common sense, firebricks with low refractoriness were laid to make up the inner wall of a kiln taking into account possible damage to its surface due to mechanical shock. Unfortunately, therefore, overall insulation improvement cannot be carried out. It is advised to examine the possibility of making a new kiln wall at some convenient time.

B. Insulation improvement solely on burner part

Considering that the kiln wall is thin (230 mm