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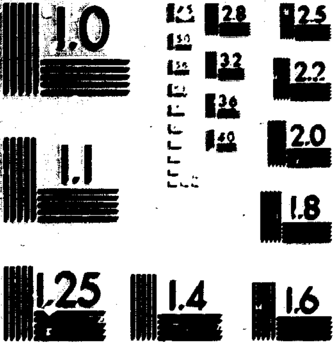
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No 2)

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ENGLISH

GUIDE BOOK FOR FACTORY ENGINEERS ON ENERGY CONSERVATION DIAGNOSIS*

Prepared by UNIDO**

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** This is the advance edition of a UNIDO publication to appear in the Development and Transfer of Technology Series.
Based on the work of:
[illegible], Energy Management Expert (Mission Leader);
K. Takahashi, Thermal Energy Management Expert;
T. Sugimoto, Electrical Energy Management Expert.

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Contents

1. General

1.1 Background Information

This guide book is designed for a plant engineer in charge of energy control of a factory to use as a manual for energy conservation diagnosis.

Based on the experiences of Malaysian factory-survey for energy conservation which Japanese specialists and Malaysian counterparts carried out for 9 factories in march 1983, the contents of this guide book has been prepared, describing important factors for easy Reference.

Accordingly, this manual could serve as a good guide book when the plant engineer of the factory diagnoses and promotes energy conservation.

1.2 Needs of Energy Conservation

Although energy is used in various ways, depending on its purposes, most of used energy is diffused in the atmosphere.

For example, the thermal efficiency of an industrial furnace which uses fuel is generally 20 ∿ 40%. When steam is produced by a boiler, its thermal efficiency is between 80 - 90 %. However, it is reduced to approximately 35% when converted into electric power after the steam has passed through a turbine, and so on. That is, the fuel is effectively used only by approximately 35% in order to produce the electric energy.

Energy conservation means to save energy by making use of the most of wasted or misused energy.

If limited energy resources are carefully and effectively used, it would improve profits of businesses.

1.3 Grasp of Situation

If good seeds are planted in fertile soil and properly taken care of, fine crops can be expected in large quantity. However, if bad seeds are planted in sterile soil, the crops will be produced less or may not be harvested no matter how properly they are taken care of.

It should be noted that the same goes for energy conservation.

The below-mentioned "promotional setup" corresponds to the above soil, and "Grasp of energy control situation" to the seeds. Also, energy conservation methods and know-how correspond to "cares".

1.3.1 Promotional Setup for Energy Conservation

(1) Attitude of management toward energy conservation

Most of manager is greatly concerned with energy conservation. However, what is more important is their attitude toward it. It is one of important factors to promote energy conservation.

In order to effectively promote energy conservation, company's policies and measures on energy conservation should be clarified as follows so that it may be concretely and easily carried out.

- Proper organizational setup
- Training of employees
- Collection and analysis of operational data on energy
- Setting up energy conservation targets by the manager

It depends on the manager's will whether or not such a firm promotional setup can be realized.

(2) Organization and control system

When company set up a target toward energy conservation, at same time, it is necessary to set up an organization and a control system which facilitate effectnely promoting the compant's policies and measures on energy conservation depend on company's size.

For big factories, they can systematically investigate and assess their actual situation and promote energy conservation measures strongly, such as drafting of a practical plan, its practice and evaluation of results, through an energy management department, an energy conservation committee, an energy conservation project team, and so on. For smaller factories, however, they cannot take the same method as the big one, because an energy conservation specialist may be not available or there are not enough employees to be engaged for. In this case, it is important to designate a persons in charge of energy conservation and provide their authority. When it comes to energy conservation control know-how, it is recommended to request for assistance of the specialist from outside.

In Japan, activities of self-controlled small groups have been prosperous from long time ago. These days, all employees ranging from a factory manager to workers tend to participate in energy conservation activities. In this case, the workers at job sites who know the best on facilities and work procedure voluntarily find energy conservation measures with critical minds and cope with this problem. This method has been fruitful so far. In order to technically lead these energy conservation activities and to be a consultant of the workers, an energy conservation promotion committee has been set up with the president or factory manager as its leader. This committee drafts a practical plan and evaluates its results.

(3) Training of employees

Energy conservation cannot be realized by only the management. It becomes fruitful only when cooperation of employees is obtained. In spite of this fact, only some companies, such as joint venture company, actually trains their employees. Under these circumstances, it is difficult to promote energy conservation.

In the first training step, awareness is required to make the employees understand needs of energy conservation. For example, improve employees' conservation minds so that their cooperation may be obtained using various methods, such as providing explanations on energy circumstances, energy cost, an amount of energy used so on and upon starting a daily work or at a meeting in an office, putting up charts on the amount of energy used, energy consumption rates (to be stated later), so on in every office, or putting up improvement proposal system into effect. In the second training step, it is necessary for not only the management but also the employees to attend lecture meetings and institute classes outside their company and listen to basic know-how required for energy conservation and practical examples of other companies in order to broaden their fields of vision and make the most of information obtained for diversion of ideas and improvement of know-how. However, it is difficult to hold the lecture meetings and institute classes without cooperation from the governmental and business organizations.

1.3.2 Energy management

Energy management is a basic factor for promoting energy conservation. Energy conservation starts from the fulfillment of energy management.

(1) Collection and analysis of energy-related data

Quantitatively grasp an energy flow from the acceptance of energy resources, such as electric power, fuel, so on until energy transfer and consumption after the generation of energy, such as steam, electric power, so on. At the same time, it is also required to record and analyse productivity, a temperature, a pressure and a time corresponding to this energy flow.

In other words, if it is identified where and how much energy is lost, energy losses can be improved. These data also serve as basic information when determining priority.

Furthermore, optimum conditions for practicing energy conservation can be found by analyzing an increase or a decrease in the amount of energy used corresponding to changes of operational conditions. Effects will be naturally great, if the eenergy flow can be continuously grasped in the form of quantity per process and facility.

In this case, it is most desirable to express the amount of energy used by consumption rates.

The consumption rate means an amount of energy used for a product lot and is expressed by the following formula.

$$\text{Energy consumption rate} = \frac{\text{Amount of energy used}}{\text{Output}}$$

Units for the amount of energy used:

kcal, kWh, kg, ℓ, m^3, $(cost), and so on

Units for the output:

kg, ℓ, m, m^2, m^3, pcs, $(cost), and so on

When the energy is used in a form of fuel, it is called a fuel consumption rate, when in a form of electric power, an electric power consumption rate, and is a form of steam, a steam consumption rate.

The energy consumption rate is a barometer of energy consumption efficiency. It is used for judging whether energy conservation measures are effective, and whether operation is proper.

(2) Preparation of measuring equipment

In order to diagncse the service condition of energy and promote energy conservation, it is necessary to quantitatively grasp the energy flow as mentioned above.

However, many factories do not have measuring equipment for this purpose, and therefore, the energy consumption cannot be measured not only for each process and facility but also for the whole factories. Also, even though they have the measuring equipment, some of them are left out of order or used without noticing their performance failures.

Under these circumstances, it is difficult to judge where and how to improve.

Even though some improvements are made, it is not clear if they are effective.

For example, there are very many cases that industrial furnaces and boilers are not eqipped with fuel flow meters, or that the boilers are not equipped with feed water meters or steam flow meters even though they are equipped with the fuel flow meters. In this situation, diagnosing energy conservation requires know-how based on many experiences and assumption values are used in an analyzing process.

As for combustion condition, it can be visually judged by a flame color, flame shape, an exhaust gas color, and so on without the measuring equipments, if they have sufficient experiences and knowledge. Thus, the combustion condition can be optimumly improved.

In this case, however, effects of improvement cannot be expressed as numerical values, and if a specialist is not available, the improved condition cannot be maintained.

As mentioned above, it is desirable to install minimum measuring equipment per process and facility.

At least, it is necessary to install proper measuring equipment for correctly understanding the energy flow of the whole factory.

Make a check list of these measuring equipment, and periodically inspect and maintain so that correct values may be always indicated.

(3) Grasp of energy service situations

The first step of an actual work for promoting energy conservation is to grasp energy service situations.

That is; it is to know energy service situations; what kind of energy is used how much, where and how, and what kind of energy is discarded how much and where. For this purpose, it is necessary to have various measuring equipments such as a flow meter, a thermometer, a pressure gauge, a watt-hour meter and an lux meter, and a specialist (engineer).

By analyzing these data, how to carry out energy conservation measures is judged, or its hints can be obtained.

A. Understanding of service situation by circle graph

Classify energy service amount and its service charge into energy types and show their rates by means of a circle graph. Also, show service rates of the same type of energy per each facility and use by means of the circle graph.

a) In Fig. 1.3-1, the energy service amount is classified into energy types and their rates are shown.

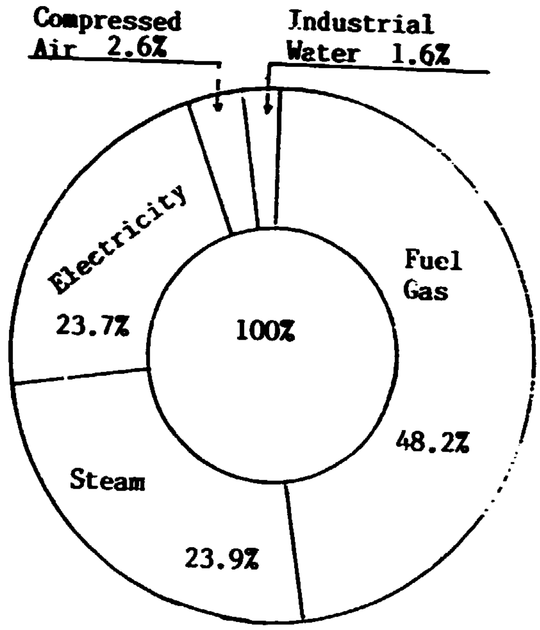


Fig. 1.3-1 Energy Service Situation by Circle Graph

What is important to this graph is to express the fuel, steam and electric energy on the basis of the same thermal unit. As for its conversion rates, use values obtained from actual showings of a factory concerned. For example, if 12.5 kg steam is produced from 1 kg fuel oil having calarific valve of 10,000 kcal/kg by a boiler of the factory concerned, its conversion rate for steam is 800 kcal per kg.

Examples of conversion rates:

Electricity .... 1 kWh = 2450 kcal

Steam .... 1 kg = 800 kcal

Compressed air .... 1 Nm^3 = 600 kcal

Water .... 1 t = 980 kcal

b) In Fig. 1.3-2, energy expense is classified into the energy types and their rates are shown as an example.

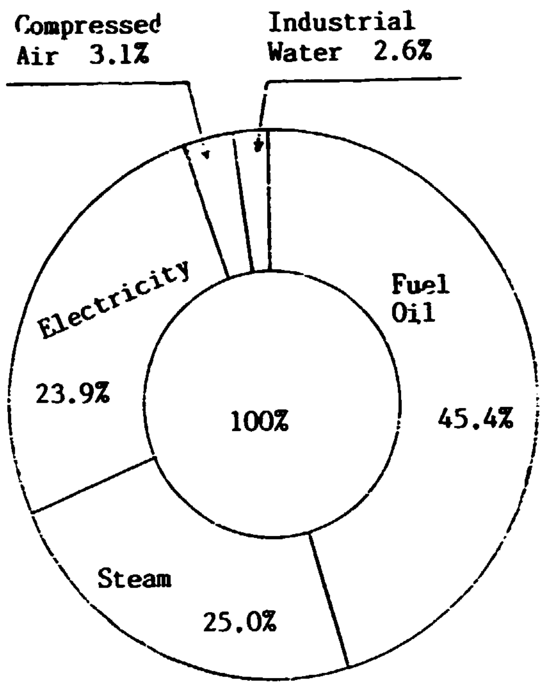


Fig. 1.3-2 Comparison of Energy Expenses

It is also important to compare each service energy in the form of its sum and consider which energy must be conserved first.

c) In Fig. 1.3-3, the steam is picked up as an example to show how the same energy is used.

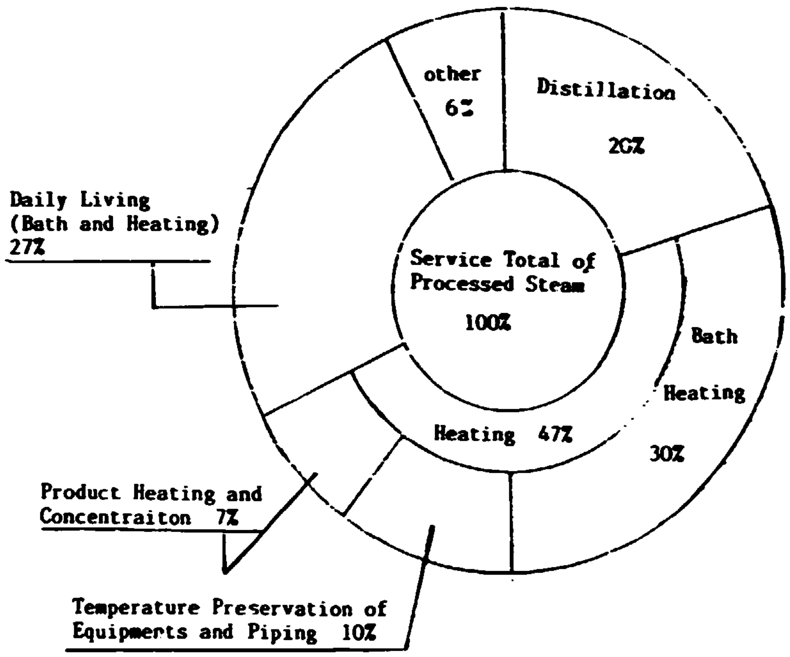


Fig. 1.3-3 Processed Steam Service Situation (by uses)

The point of observation can be narrowed by this figure when promoting steam conservation measures.

B. <u>Energy consumption rate control chart</u>

Fig. 1.3-4 shows a daily output, a fuel service amount and a fuel consumption rate of a certain factory for a month. This is a control chart which is most basic in energy control.

example : $\frac{6,200\ \ell}{148\ t} = 41.9\ \ell/t$

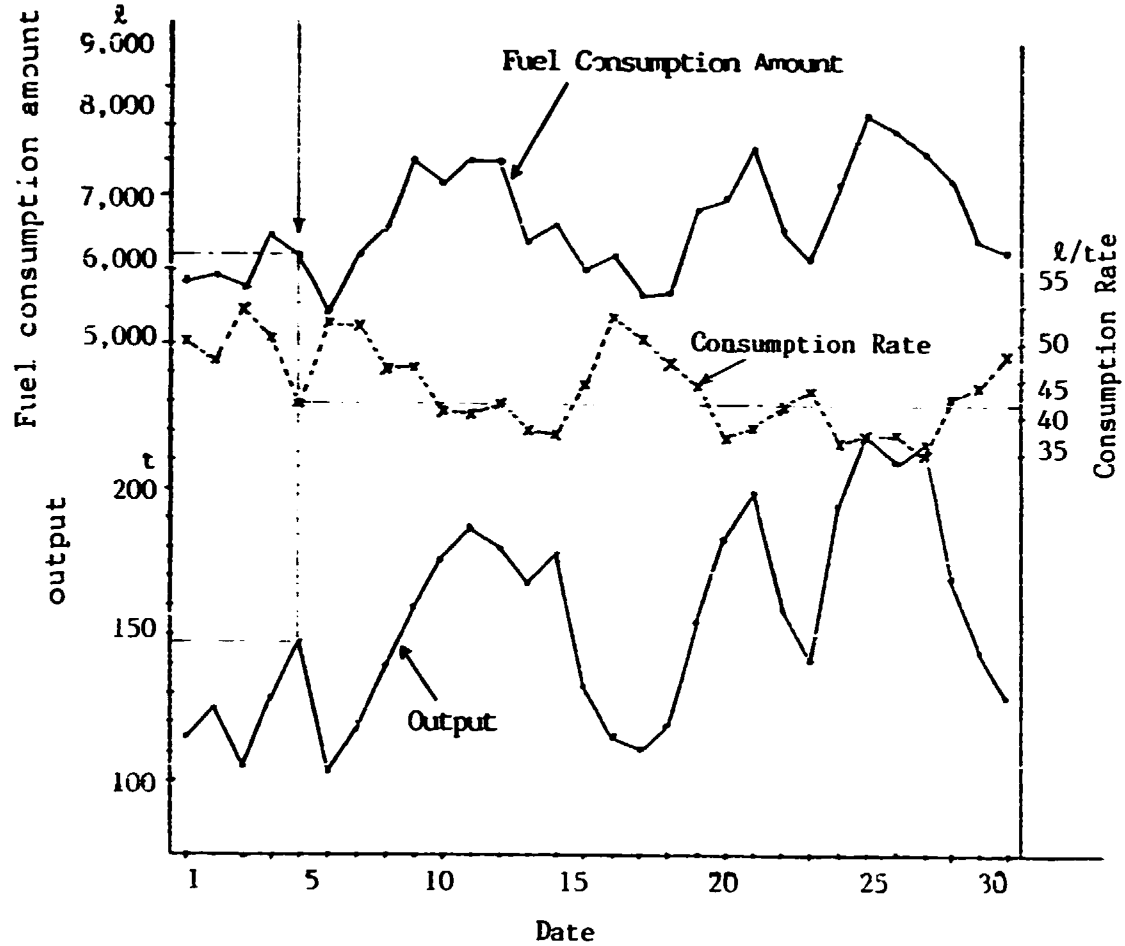


Fig. 1.3-4 Fuel Consumption Rate Control Chart

C. <u>Correlative chart of output, fuel service amount and consumption rate</u>

Fig. 1.3-5 shows correlations among the output rate, fuel service amount and consumption rate, using the data in Fig. 1.3-4.

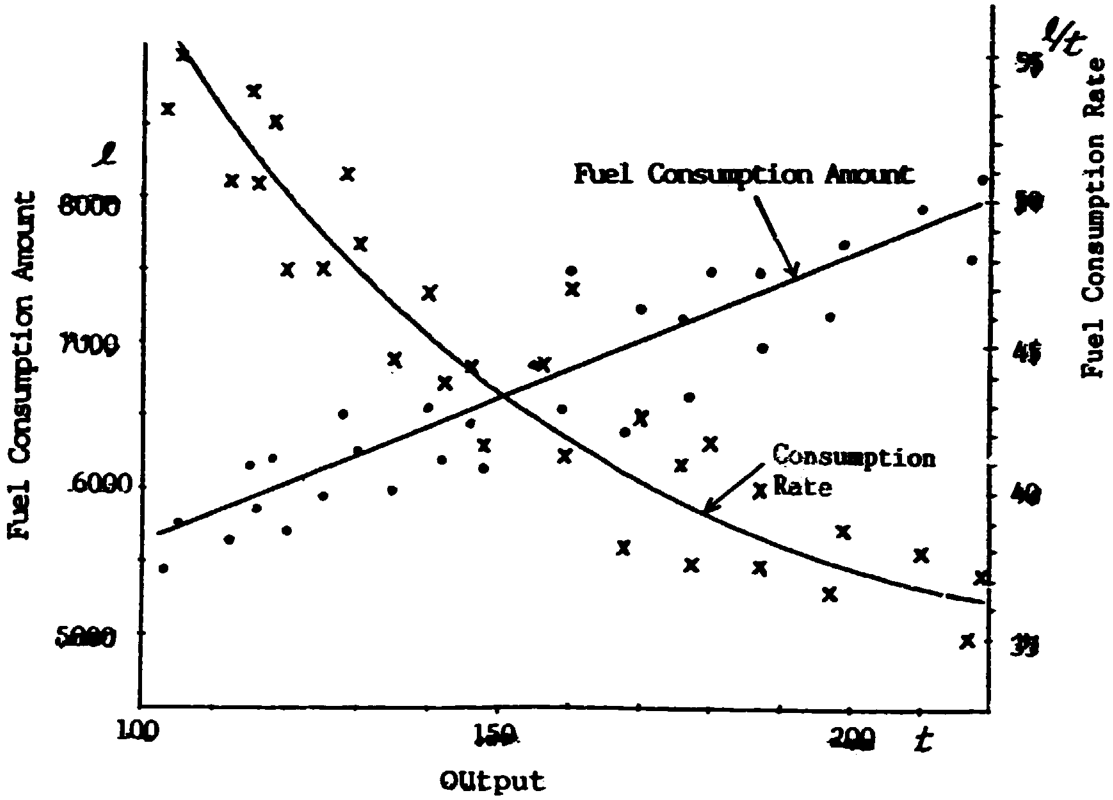


Fig. 1.3-5 Correlative Chart of Output and Fuel Consumption Rate

It is known from this chart that although the fuel consumption amount increases as the output goes up, the fuel consumption rate goes down.

The chart also shows that actual data are scattered from correlative curves. However, if they can be equalized with lower ones, the fuel consumption amount can be reduced on the whole.

D. <u>Energy supply flow chart</u>

This chart is used to know how energy is branched and supplied through which route.

As for the steam energy, this chart is used for integrating pipes and preventing losses of radiant heat. If the chart has values inscribed such as pipe diameters and lengths, flow rates, steam pressures, and so on, it can be effectively used.

E. <u>Energy flow chart in plant</u>

If there is an energy flow chart which provides clear information on energy changes inside facilities such as temperatures, pressures and flow rates, it will help properly understand energy service and recovery situation.

Fig. 1.3-6 shows an example of waste heat recovery and generation facility from a distillation tower.

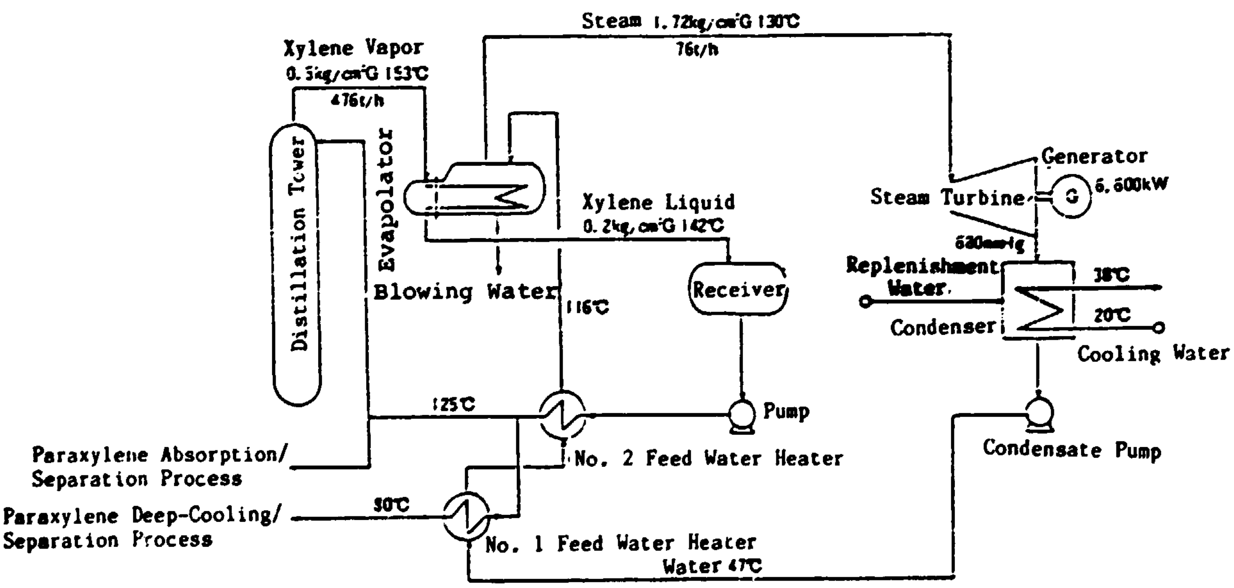


Fig. 1.3-6 Energy Flow

F. <u>Heat balance</u>

Carry out heat balance to know how energy is used, and where the energy is discarded in what form. As a result, energy conservation points can be clarified. Fig. 1.3-7 shows an example of steel material heating with improvement points added.

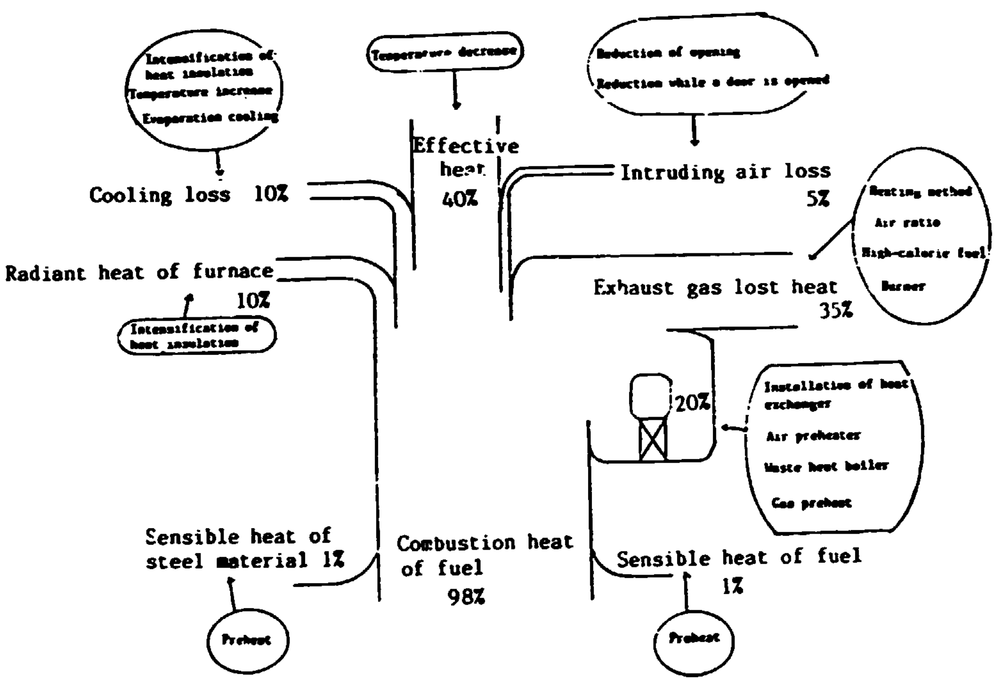


Fig. 1.3-7 Energy Flow by Heat Balance

G. <u>Waste heat actual condition graph</u>

When there are plural cases of waste heat in one factory, if their temperatures and rates are expressed by a graph, it makes clear how much waste heat exists corresponding to an energy level.

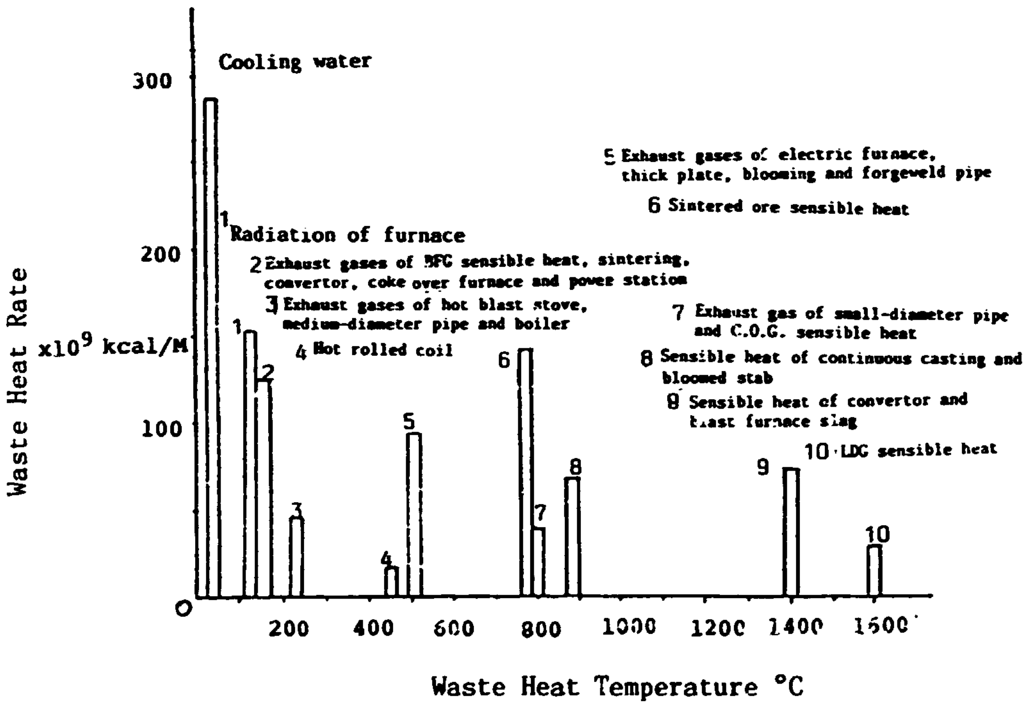


Fig. 1.3-8 Actual Situation of Waste Heat

Fig. 1.3-8 shows an example of a steel work. As it can be observed in the figure, there exists much waste heat ranging from a high temperature to a low one. However, these waste heat cannot be recovered all. If theoretically-possible recovery rates are shown at the same time, it will be convenient.

It is recommendable to review a waste heat recovery method, considering waste heat properties and easiness of recovery from high-temperature waste heat.

H. Comparison between Requirements for energy supply and demand

Compare the requirements of the energy-using side and the energy-supplying side about temperatures and pressures. In this case, if there is a surplus more than necessary on the energy-supplying side, the energy-supplying level can be reduced, and as a result, it improves energy efficiency and helps energy conservation.

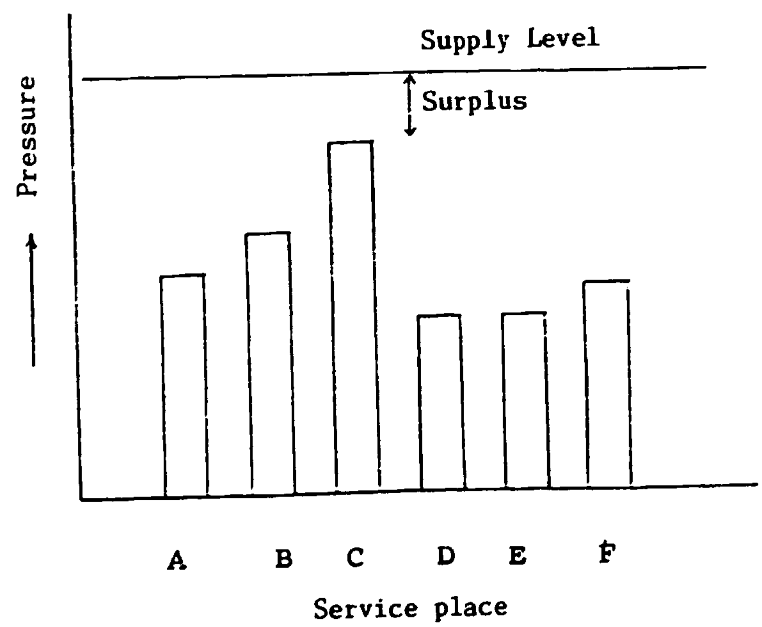


Fig. 1.3-9 Comparison of Required Steam Pressures

Fig. 1.3-9 shows a comparison example on steam pressures. If a service pressure of a service place "C" can be reduced, a steam pressure surplus will increase as a whole and the pressure level of steam supply can be lowered.

1.4 Approach

If the present situation of energy consumption can be grasped, it leads to finding of many points where energy conservation must be carried out.

In order to solve these points, it is necessary to decide the priority of carrying out energy conservation measures, totally reviewing the following conditions.

- ° Amount of energy used
- ° Energy consumption rate
- ° Sum of investment
- ° Refundment period of the investment money
- ° Degree of difficulty from a viewpoint of capability
- ° Effects
- ° Continuity

However, it is general to carry out the energy conservation measures in the following order of the first step through the third step.

1.4.1 First Step (Intensification of Energy Control)

The first step is an energy control intensification method which bear effects without spending any expense.

This is the basis of energy conservation.

Its contents are review and observation of operation standard, service standard, manufacturing standard, facility control standard and repair standard.

It is nothing but to make the most of each facility performance and maintain operation in the best condition from a viewpoint of energy efficiency.

In other words, it is to eliminate uselessness, unreasonableness and irregularity.

"Uselessness" means the condition that light is left turned on, or that combustion air is too much.

"Unreasonableness" means the condition that a motor is run with an overload, or that an excessive amount of fuel is combusted to quickly increase a temperature of a heated material with flame coming out of an opening of a furnace wall. It will cause many damages and troubles to facilities and equipments and consumes more energy.

"Irregularity" means the condition that operational requirements are not fixed due to the uselessness and unreasonableness.

Accordingly, it is essential to train and enlighten employees in order to produce satisfactory results in this step.

1.4.2 Second Step (Introduction of Energy Conservation Equipment)

This is a step to introduce special equipments for automation and use of recovered energy.

What can be named as examples are as follows;

recovery of waste heat by a heat exchanger, a combustion automatic control unit, a high-efficiency lamp, an automatic flasher for outdoor illumination, and so on.

Although an investment sum will increase in this second step because part of processes are required to be reformed, its effects are considerable great.

However, if the energy control in the first step has not been intensified, take note that sufficient effects may not be obtained.

1.4.3 Third Step (Improvement of Process and System)

When scrapping and building facilities, or when expanding their capability, it is required to introduce up-to-date facilities having high energy consumption efficiency, and as a result, a large investment sum is necessary.

Examples:

(1) Process omission

Continuous casting, and so on in the steel industry

(2) Use of heat in cascade

Cogeneration, and so on

(3) Conversion of manufacturing method

NSP (New Suspension Preheater) kiln, and so on in the cement industry

(4) Continuity

Continuous annealing and so on, in the steel industry

2. Thermal Section

The basic procedures for the thermal energy management in factories consist of the measurements, the records and calculations.

Direct cost reduction from the elimination of faulty products because of quality control results ultimately in energy saving. In the final analysis, therefore, the thermal energy management is a problem of engineering economics in factories. Each part of the investment in process division for energy saving, including the instruments, must be justified in terms of the contribution to make a profits on producing a reasonable products.

Therefore an adequate investment cost balance should be considered on between complete instrumentations which improve both product quality and operational efficiency, especially, thermal efficiency of each facilities consuming the fuel and some elimination of equipment which lead to enormous waste energy losses from operating trouble and downgraded products.

The preparation of the heat balance sheets is one of best approaching methods for energy conservation.
In this guide book, mainly the methods of how to prepare the heat balance sheets have been explained in details.

2.1 Measurements

The principal measurements implemented on the thermal energy management are usually as follows ;

(1) Flue gas from boilers or/and furnaces

(A) O_2 content

(B) Temperature

(C) Flow rate

(D) Pressure

(2) Dispersion heat losses from the surface of facilities.

(A) Size or Dimension (area) and configuration

(B) Heat flux

(C) Surface temperature and ambient temperature instead of heat flux

(3) Heat contents

(A) Mass or weight of objective materials

(B) Volume of objective materials

(C) Cross area and linear flowing rate in the ducts

(D) Pressure and temperature of the fluids

(E) Specific heat of respective materials corresponding to subjected temperature from the conventional reference books.

(4) Steam consumption

It is desirable correctly to measure the directly recovered condensate after steam traps of steam consuming facilities. In practice it will be normal that such devices are not ready in use on almost of all factories.

Then inevitably the amount of the steam consumed in the facilities should be indirectly estimated by the summation of the dispersion heat losses from the surfaces of facilities and required heat content of processed materials and facilities from initial to final processing temperature using above (2) and (3) methods.

2.1.1 <u>How to use the measuring instruments.</u>

We would like to leave the principles of measurements for the respective processing factors to the conventional text books and the operating instructions for the instruments or meters to the manuals prepared respectively by those instrument manufacturer as shown later at Annex.

As there are actually a lot of types of instruments and a slight difference in measuring same process factors, it is not possible that in this guide book, the instruction manuals for operation of all instruments which in present have been supplied in the world in dëtails.

Then only the useful notes on measurement using respective sensers would be described in order to prevent to get the fault data. Practically the descriptions here mainly would be limited to the instruments used by our project team for Malatsia factory survey.

(1) <u>Temperature</u>

The choice of sensor instruments for the measurements is governed by the temperature range measured, the degree of accuracy required, the type of installation and the costs.

The temperature range normally covered by common measuring devices are as follows ;

Instrument for temperature	Temperature range
Bimetallic thermometers *	- 18 to + 540
Mercury-in-glass thermometers	- 35 to + 400
Gas-pressure thermometers	- 90 to + 430

			°C
Resistance thermometers	-200	to	+ 1,000
Base-metal thermometers*	- 18	to	+ 1,150
Novel-metal thermometer	- 18	to	+ 1,600
Radiation pyrometer*	- 18	to	+ 1,750
Optical pyrometer	+650	to	+ 2,750

Among the above listed thermometer, *marked meters have been used in diagnosing the assigned factories by this project team.

Generally speaking, on measuring the regular range of temperature for diagnosis, it is recommened that the "chromel-alumel thermocouple" as sensor which is often used considering the cost and accuracy.

The following general notices have to be taken care on measuring temperature;

(a) to choose correct pair of thermocouple,

(b) to confirm on calibration in order to measure correctly the objective temperature,

(c) to have a suitable temperature change,

(d) to set the thermocouple sensor in the representative point of the measuring materials,

(e) to seal the slit formed in circumference between the thermocouple rod and nozzle with a proper packing material to prevent the disturbance of atmosphere around the sensor as following sketch.

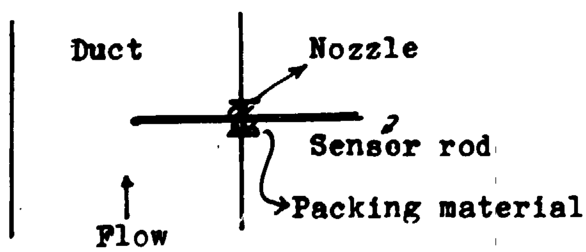


Figure 2.2-1 Inserting procedure of senser

These notices one applicable not only the temperature measurement but also the measurements of pressure, the gas sampling for gas analysis, the flow rate with anemometer, so on.

(A) Internal temperature

On the energy conservation diagnosis, acturally, the temperature of the fluid flowing through the ducts, the temperature of the builded materials of facilities to obtain the heat content, the temperature of the atmosphere inside of furnaces so on, should be often measured finally in order to prepare the heat balance sheets.

In this case, the above general notices are useful, especially (d) and (e).

(B) Surface temperature

For the measurements of surface temperature, special senser with spring would be utilized and the responsibility of its senser is so quick. Therfore this items can be measured without much care relatively.

It is desirable to keep the senser on vertical position.

(C) Heat flux (kcal/m^2hr)

Recently the direct measuring meters for heat flux have been supplied, therefor it has been easy to estimate the dispersion heat losses from the surfaces of facilities. In this project, one heat flux meter was used for the demostration purpose. In use of this meter, the most important notice is to be aware of the maximum allowable temperature of senser made of synthetic rubber, that is, 150°C.

The following other notices should be observed in using the heat flux meter;

(a) to make sure the measureing surface temperature whether it is 150°C or not. Otherwise use another thermometer or body senses.

(b) to contact the senser tightly to measuring surface with magnetic devices, chain binding or a proper methods. Do not press the center part of senser down. It is better to use the instruction book prepared by instrument manufacturere.

(c) When measuring several points, it is recommendable to proceed the measurement from low to high temperature points.

(d) to take the mean values since it is so hard to get the steady values in short time due to the fluctuation as follows;

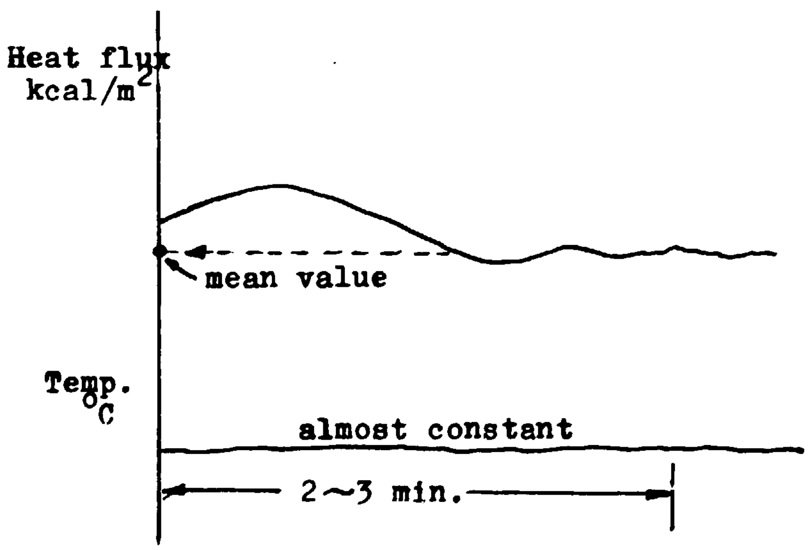


Figure 2.2-2 <u>Pattern of obtained value of meter</u>

(D) Radiation thermometer

This instrument would be convenient on the measuring temperature on the surface where the senser can not be placed in fixed position, for example, as the surface of rotary kiln. In pracice, the values of temperature would be easily obtained, but the calivration to obtain the correct values of temperature is very sophisticated and troublesome works. On the measurements, the instruction manual book should be sufficiently reviewed in advance. Especially the careful considerations are necessary in estimation of the emissivity of respective surface materials.

In practice, although there are a lot of methods for the measurement of temperature, it would be enough for the initial diagnosis to learn only the following measuring techniques;

(i) Atmospheric and/or material temperature using conventional thermocouples

(ii) Heat flux using the heat flux meter, and surface temperature using the surface thermometer or radiation thermometer.

(2) O_2 analyzer

When the effectiveness of combustion plants be investigated, it is often necessary to analyse the flue gas into respective components. For instance, by flue gas analysis, the air ratio is computed and total amount of the flue gas is calculated as described in analysis session later.

The useful matters to be attended on the measurement for O_2 content in the flue gas using Galvanic cell are as follows ;

(a) not to miss the conection of sampling rubber tube and gas inlet nozzle of the O_2 analyzer,

(b) to take care of the direction of fillter cell in way of the sampling tube line as follows ;

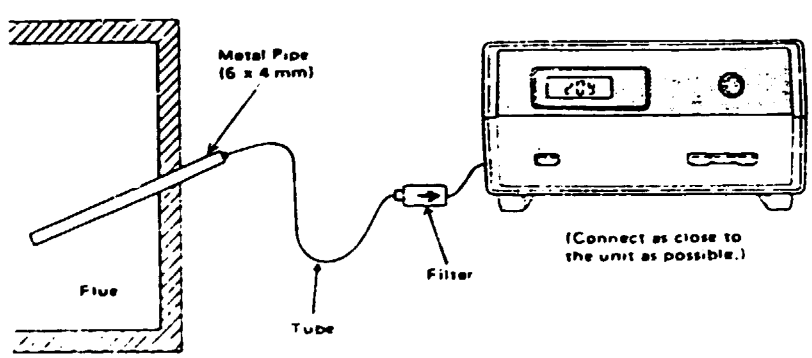


Figure 2.2-3 Direction of sampling tube and filter

(c) In the beginning, to justify and confirm the indicated value of ambient atmosphere as it is to come to 20.9, taking the sampling tube off from nozzle of the instrument.

(d) After the value of O_2 content of measured atmosphere come to steady, the value indicated in meter should be recorded as the correct O_2 content of the measured point.

(e) furthermore in order to obtain more correct O_2 content, it is better to repeat the above operation of (c) so as to confirm the O_2 content of ambient air as 20.9.

(f) if the different value from 20.9 would be observed on operation of (e), the measurement for O_2 content at measured point should be repeated.

(g) the sampling tube inserted into the duct for O_2 content measurement should be made of stainless steel (SUS 316) lest the sampled O_2 is consumed by the oxydation of the metal tube in higher temperature.

(3) Gaseous linear flow velocity by anemometer

In the calculation of heat balance, when the fuel consumtion rate are unknown, it is probably necessary to determine the magnitude of linear velocity at observed point in ducts.

The notices to be taken care on the practical measurement are as follows ;

(a) to insert the probe rod into the observed duct vertically against the the direction of gaseous flow.

(b) to place the probe on centre of the duct.

(c) to pack the gap formed around the part of penetration through the duct.

(d) to gain the maximum value in meter rotating the probe rod little by little.

(e) to choose and set the range of scale in meter.

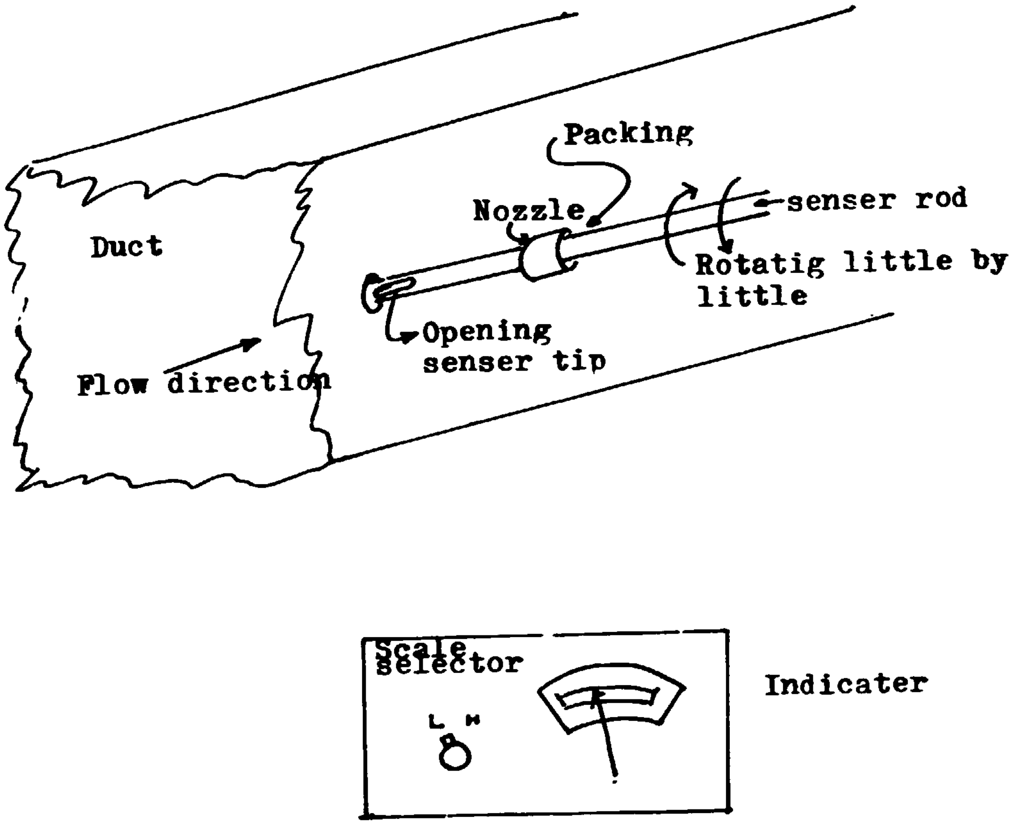


Figure 2.2-4 Inserting procedure of senser rod and selection of indication scale

(4) Pressure

Generally speaking, as there are a lot of methods as to measuring the pressure, on the selection it is desirable to follow to the suggestions of the skilled engineer on instruments.

The normal methods on the measurements of pressure in the process operation or the energy diagnosis are as follows ;

(i) Manometers

U-types, Barometer, inclined types and so on,

(ii) Elastic tranducers

Bourdon tubes, diaphragms, differential bellows and so on.

In practice, some of above pressuremeters have been installed in normal facilities of factories.

In this project, in order to estimate the inner pressure of the furnaces which are operated at pressure very close to ambient and to obtain the informations of waste energy the fine differential pressure indicator has been used.

In measuring, the notices to be taken care are as follows ;

(a) to confirm the pressure of measuring point to be under 1,000 mmH_2O,

(b) to adjust the null pressure by using zero aduster under condition that H and L side are opento ambient.

(c) to take care the gap formed in insert of the senser.

(5) PH and Electric conductivity

These instruments are utilized for the control of the boiler water quality by implementing the proper blow-down operation and/or preventing the corrosion and scaling of the surfaces of boiler tubes.

The following matters are to be taken care,

(a) to calibrate often the respective instrument by using the standard solution, in advance.

(b) to measure the sample solution after cooling down till temperature directed in respective instruction manual books.

(c) to clean alway the tips of the proves with distirated water.

(d) to wash the tip of prove with next solution on subsequently the measurement of the different samples.

2.1.2 Measuring procedures

Although it is desirable on the termal energy conservation audits that the substantial measurements should be planed in accordance with the quantitative data, as the first it would be very useful to be aware quickly but roughly on the situations consuming the energy of the own factories by a visual or senuous audits without to be ready on special instruments. The data obtained from already installed instrument on the facilities should effectively be adapted on this visual audits as a preliminary surveys. In practice, according to the preliminary surveys the regular audits using the proper instruments would be implemented in effect.

(1) Boilers

(A) Preliminary audits with visual.

It is convenient that the preliminary surveys would be conducted on own boilers with the sequence of following ;

(a) to walk and check one or two times around the boilers,

(b) to be aware on the pressure or temperature of producing steam,

(c) to touch the plam of hand to several points of the boiler surface,

(d) to estimate roughly the temperature of boiler surfaces with the following senuous methods ;

(i) under 50°C ; to be able to keep up tatching the plam on the measured surface over 1 min.

(ii) 50 to 100°C ; to be able to tatch only for 0 to 2 sec.

(iii) 100 to 300°C ; to feel hot on approaching 0.5 to 1.0 m close to boiler,

(e) to check the color of the exhaust flue gas from the stack of the boilers,

(f) to prevent the generation of the black smoke by adjusting the combustion air,

(g) to check the working condition of the traps attached on the steam consuming facilities with visual or sound.

If the following events would be disclosed on the preliminary surveys, immediately the proper instrumental audits and improvements should be launched

(i) the appearance of the black smoke from the stack,

(ii) the much more area exposing on higher temperature than 100°

(iii) the steam traps with faulty working.

(B) <u>Diagnosis with instruments</u>

Because of the preliminary surveys as before, the targets to be improved would be decided in effect.

On launching the energy conservation activities, in beginning, it is effective to concentrate the all resources of the factories in the simple improvement so as to obtain the clear results. The most foundamental thechnique for the energy conservation diagnosis is to estimate the amount of wasted energy and to convert it to the money. The common procedures for energy conservation diagnosis on miscelaneous industries would be described here.

(a) Items of instrument or necessary data

(I) Fuel specifications

(i) Fractions of components with weight

C ; c %

H ; h %

S ; s %

(ii) Caloric values of fuels

Gross caloric value H_h ; kcal/kg or m^3,

Net caloric value H_l ; kcal/kg or m^3.

Net caloric value is calculated according to the formula (1) of the section of analysis later.

(iii) Specific gravity or density

The data on the fuel specification are also available from the conventional reference books.

(II) Rate of fuel consumption (l/hr or kg/hr)

(III) Rate of water fed to boiler or rate of produced steam (kg/hr)

On no data, the values are calculated alternatively from the amount of residue of heat balance.

(IV) Heat flux or surface temperature

(i) Values of heat flux (kcal/m^2 hr)

(ii) Surface area (m^2)

to be homogenously representative of the values of above (i),

It's convenient to fill up the respective values of above (i) and (ii) on the calculation forms Table 2.2-1 and to draw the figure developing surface of facilities as Figure 2.2-5.

Table 2.2-1 Calculation format for dispersion heat loss

NAME OF FACILITY: ____________________

MEASURING p/t	HEAT FLUX Kcal/m hr	AREA m^2	HEAT LOSS (1) Kcal/hr	AMB.TEMP. °C	SURFACE TEMP. °C	TEMP.DIF ΔT °C	HEAT TRANSFER OF h=HEAT FLUX/ΔT Kcal/m^2 °C hr	h = 10 (MIN) HEAT LOSS (2) Kcal/hr	h = 20 (MAX) HEAT LOSS (3) Kcal/hr
A_1	875	1.51	1321	32	74	42	20.8		
A_2	377	2.738	1032	"	48	16	23.6		
A_3	195	"	534	"	46	14	13.9		
A_4	193	"	528	"	43	11	17.5		
A_5	196	"	537	"	47	15	13.1		
		12.462	3952						
B_1	234	2.738	641	32	48	16	14.6		
B_2	202	"	553	"	48	16	12.6		
B_3	163	"	446	"	48	16	10.2		
B_4	224	"	627	"	49	17	13.5		
B_5	677	1.51	1022	"	72	40	16.9		
		12.462	3,289						
F_1	240	} 1.806	896	32	55.5	16 } 23.5	16.9		
F_3	252					31	24.2		
F_2	673	0.882	594	"	60		24.0		
		2.688	1.440						
R_1	1165	} 2.433	2370	32	102	63 } 70	18.5		
R_3	783					76	10.3		
R_2	1917	0.255	489	"	146	114	16.8		
		2.688	2,859						
Total		30.3 m^2	11,590						

NOTE: (1) : HEAT LOSS = HEAT FLUX X AREA
(2) & (3) : HEAT LOSS = h x AREA x ΔT

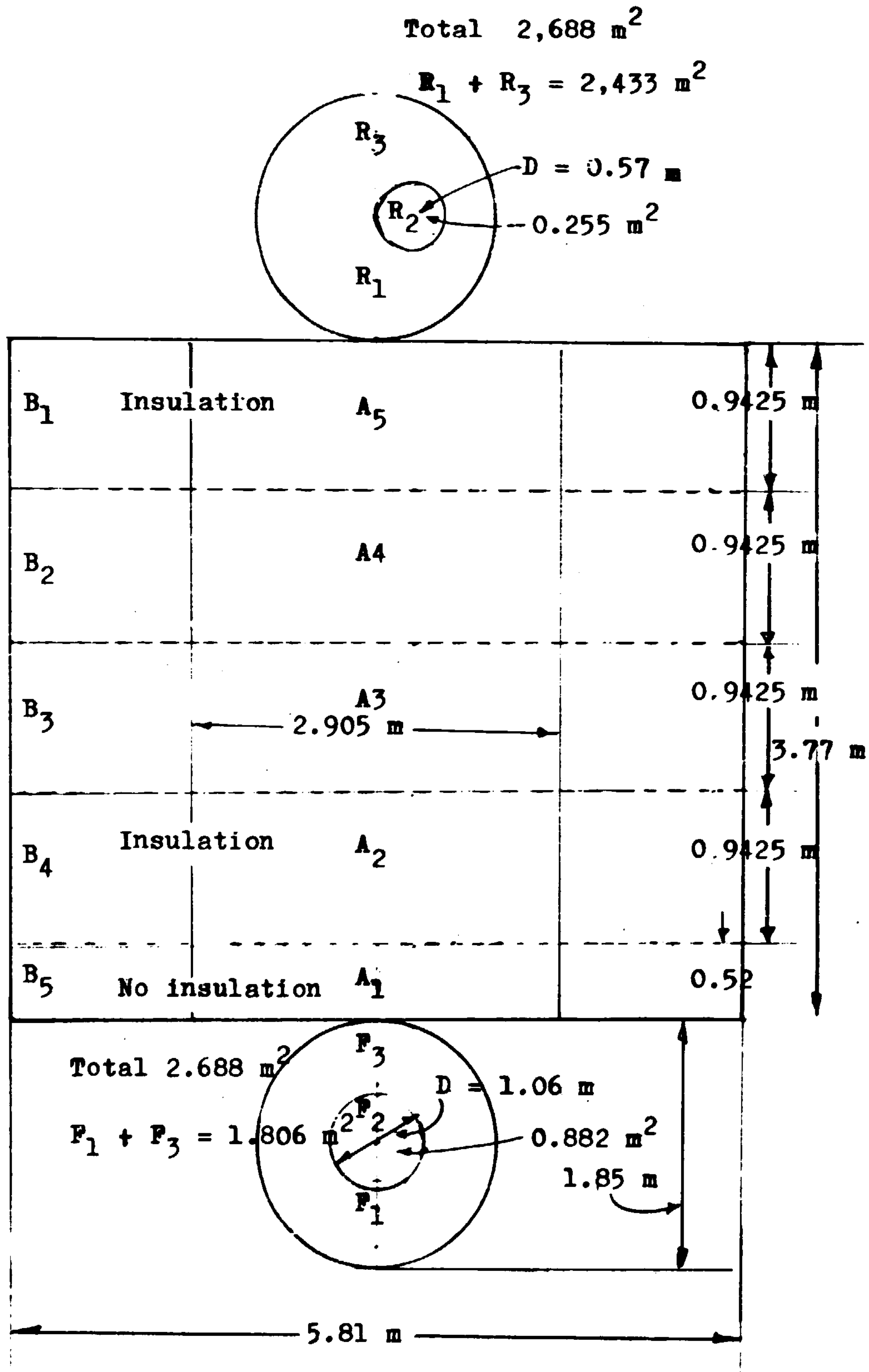


Figure 2.2-5 Spreading surface map of boiler

(iii) With no heat flux meter, the values are roughly substituted by surface temperature and heat transfer coefficient h which in normal is approximately 10 to 20 kcal/m^2 $^{\circ}$C hr using the following equation

$$\text{Heat flux} = h \times (T - T_0) .$$

(V) <u>Temperature and O_2 content in flue gas</u>

The procedure for the estimation of heat content carried out on togather with the flue gas would be described in ditails on the analysis session later.

(VI) <u>Amount of blow-down water</u>

In practice, the operation of blow-down everywhere has been carried on following the instruction manuals of boilers without checking the boiler water quality. For example, the time of opening the valve or cock, 20 to 30 sec., of blow-down piping or the amount of depression of water column in level gauge

The mass or weight of blow-down water is in normal estimated by the boiler dimension and the amount of depression of level gauge as shown later.

(2) Industrial furnaces

The procedures consuming the fuel on the industrial furnaces are basically same as the above boilers. Then there isno special difference between the industrial furnaces and the boilers except higher temperature of products and wider surface area exposed to ambient than the boilers.

(A) Preliminary surveys

(a) to walk and survey around the furnaces,

(b) to be aware of hot surface area over 50^{o}C,

(c) to check the inner pressure of furnace so as to avoid the entry of ambient cold air into the furnaces with smoke or flame detector.

(d) to check the color of flue gas from the stack.

(e) to survey the drip leakage of fuel oil around the working burners.

(B) Instrumental audits

There are many different type of furnaces in accordance with the respective products. It is so hard to describe all different furnaces in ditails.

Here the procedures for diagnosis on the continuous and batch processes would be simply explained.

(B-I) Continuous processes

Generally speaking, the continuous process should be adapted on the mass production. On the ceramic industries, the turnnel kilns and rotary kilns are utilized as normal furnaces. Except the period of start up and shot down, the thermal conditions of continuous operation on furnaces always would be constant. Therefore, the measurement and thermal analysises for diagnosis of the continuous operation would be easily implemented using only the one set of data measured at any point of time.

(a) Items of measurement and necessary data

(I) Fuel specification

(II) Rate of fuel consumption

(III) Heat flux or surface temperature

(IV) Temperature and O_2 content in the flue or exhaust gas

Above items can be obtained by almost same procedure as the boilers.

(V) Processing materials

(i) Feed rate and discharged rate of the processing materials, for exaple, raw materials, products, carrying car and so on.

(ii) Inlet and outlet temperature of respective materials

(iii) Physical properties of processing materials

They are necessary for the thermal analysis, that is
Density or specific gravity,
Specific heat,
Thermal conductivity and so on.

(iv) Thermodynamic properties on physical and chemical change of the materials through the production processes. For example,
Reaction heat,
latent heat, and so on.
They should be search out from the conventional reference books.

(V) Cooling fluids

On some industrial furnaces, in order to avoid the overheat of the body and parts of furnaces, some cooling fluids, that is, air or water, are introduced into the furnaces, or sometime flow outside the wall surfaces of furnaces. In practice, these heat carried out togather with the coolants should be accounted as heat losses on the heat balance analysis.

The necessary data are as follows ;

Flow rate of coolant

Leaving temperature of coolants

Density and specific heat of coolants and so on.

(b) Summary

On the diagnosis of industrial furnaces with continuous operations,

(I) to decide the boundary barrier for accounting of heat balances,

(II) to estimate the amount of materials and heat flowing in or out through the decided boundary barrier,

(III) to prepare the heat balance sheet, and

(IV) to evaluate the operation of furnaces with thermal efficiency.

(B-2) Batch processes

On the batch operation of furnace, that is, shuttle kiln and so on, while the processed materials are fixed in furnace, the atmosphere inside the furnace is variable time to time with controlling the temperature pattern. Therefore the only one set of data at some point of time as the continuous processes will be no meaning and the data should be recorded always during the operation from beginning to ending for thermal analysis.

However practically if even the total amount of fuel consumption for one production cycle and the amount of products is available, the fuel consumption rate can simply be estimated. The evaluation and record of the fuel consumption rate are so useful for the production management.

The deffinition of the fuel consumption rate is as follows ;

$$F.C.R. = \frac{\text{Amount of product (any unit)}}{\text{Fuel consumption (any unit)}}$$

(B-3) Dryer

The procedure of diagnosis on the dryer would be substantially same as the above boiler and industrial furnace. Due to the limitation of paper, procedures are not repeated here.

(3) Steam consumption facilities

The procedures of diagnosis are completely different whether the steam is consumed for power generation or heating sourses. It is so important for the energy management on higher level, that is, national level to recognize the different between the work and heat. As the steam is consumed only as the heating sourse on the scopes of the survey for factories, the description would be limited only on heating processes.

(A) Items of measurement

According to the batch or continuous heating, there are some differences about items and procedures of measurement as the industrial furnaces.

(I) Heat processing conditions

(i) Steam temperature or pressure

(ii) Required time for heat processing

(iii) Physical properties of processed materials

- Mass or volume
- Density or specific gravity
- Specific heat

(II) Heat content of facilities

(i) kind of material, weight and specific heat,

(ii) Temperature in begin and end,

(iii) Heat pattern on the batch process.

(III) Dispersion heat losses

The estimation of the item is almost same as boiler.

Precisely it is desirable that the values of (II) and (III) are measured by gathering the exhaust condensate water after steam traps.

(B) Steam traps and condensate recovery systems

The steam traps are the most typical devices for discharging the only condensate produced in steam consumtion facilities so as to prevent to escape the live steam which has higher caloric value than the condensate as shown on steam table.

Recently it has been popular to recover the heat of the condensate by recycling the condensate as the boiler water.

Asuming the complete recovery of condensate, the fuel consumption would be reduced by about 15 to 20 %.

In otherwise, it would be so wastable not to notice the leakage of the live steam due to the fault traps.

(I) Check of steam traps

It is so easy to find out the fault traps on exhausting the condensate into open sewage with visual or sound. On the condensate recovery systems, the discover of fault traps should be implemented only with instruments, that is, "Stethoscopes" or "Ultrasonic detector" periodically by factory engineer or workers.

(II) Check of condensate recovery systems

On the case which the condensate discharged from traps would not be contaminated by any impurities. for instance, the case of indirect usage, it is desirable to recover as much condensate as possible.

The condensate recovery is effective for saving not only the heat but also the chemical for boiler water treatment.

2.2 Analysis

The fundamental procedures for thermal energy management are the measurement, record and calculation the own process operation of facilities as described before. The measurement and record have been explained on previous section. The calculations of the amount of material and energy always should be based on the universal conservation principle.

Because of the importance of these calculation, the factory engineer engaging on energy management must be accustomed to the thermal acounting with the basic theory of thermal energy.

On assessing to a problems on energy management, the following knowledges would be required, ;

- The first principle of thermodynamics
- The practical acounting techniques.

2.2.1 How to prepare the heat balance sheets with example

The energy is the essential resources on carrying out the industrial processes.
The production of steam requires the conversion of the chemical energy in fuel throughthe combustion process. The energy which is thus transferred to water converts it to a substance at a higher energy level, that is, to steam. The energy of the steam may be used for heating purposes of some materials, resulting in a transfer of heat. It is essential that the energy should be accounted for analyzing the situation of energy consumption of facilities step by step.

This is accomplished by prepareing the energy balance, which is made in a similar manner as the material balance. The energy balance should be described the following items ;

- how much is consumed in the respective steps of the processes, that is, boiler, furnace, dryer and so on,
- how much mey be converted to the different forms of energy, that is, petentioal, electrical, sonic, chemcal or so on, and finally
- what and how much is left over.

All forms of energy, such as mechanical, potential, electrical, chemical and thermal eneryg may be involved in any processing. the most important matter is usually thermal energy when dealing with combustion or calcination processes. Therefore this section would be mainly concerned with a accounting for thermal energy.

Although it is not necessary to follow the procedure described here on preparing the heat balance sheet, it would be convenient for biginner who wants to get even the roughly and quicklt information on energy co - sumption data. You should notice in this procedures that many simplifications are involved owe to the lack of correct data.

(1) Preparation of flow sheets

(A) Flow sheets

The process schematic flow sheets in (Fig.2.2-6) or the block flow sheets in (Fig. 2.2-7) in fisrt, should be drawn with the directions of inlet and outlet flow of raw material, fuel, product and so on around the meadured main facilities.

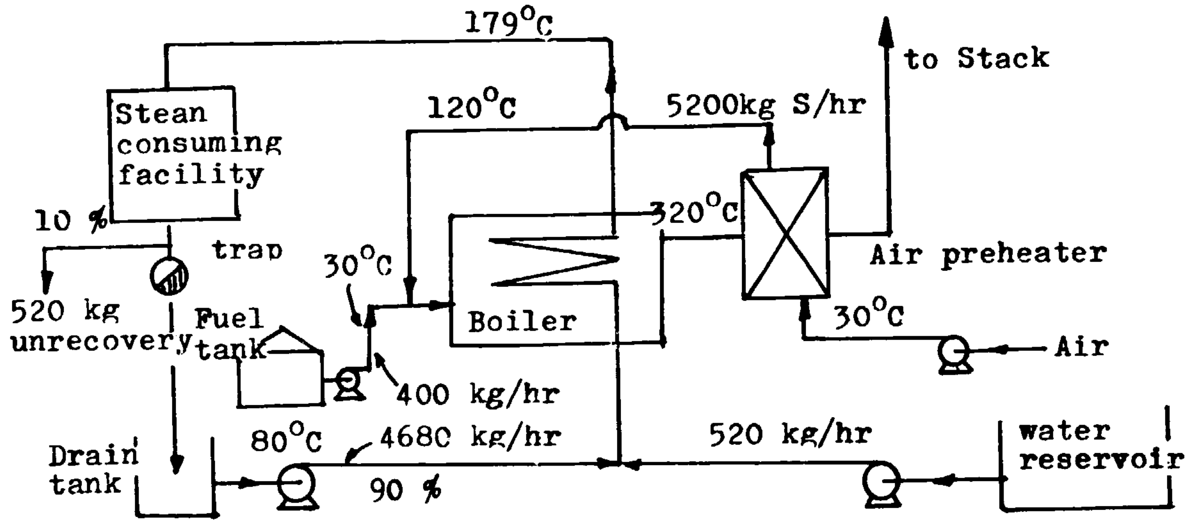


Figure 2.2-6 Example of schematic flow sheet

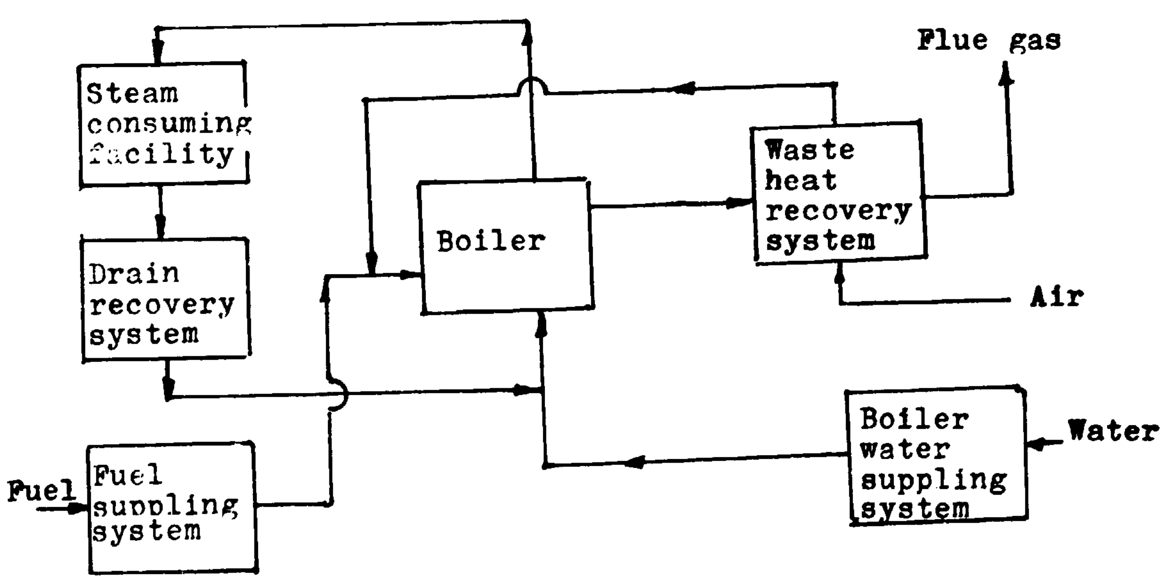


Figure 2.2-7 Example of block flow sheet

(B) Boundary barrier

In general, the scope of barrier would be choosed arbitarily with considering the available data around the measured facilities so as to lessen unknown factors.

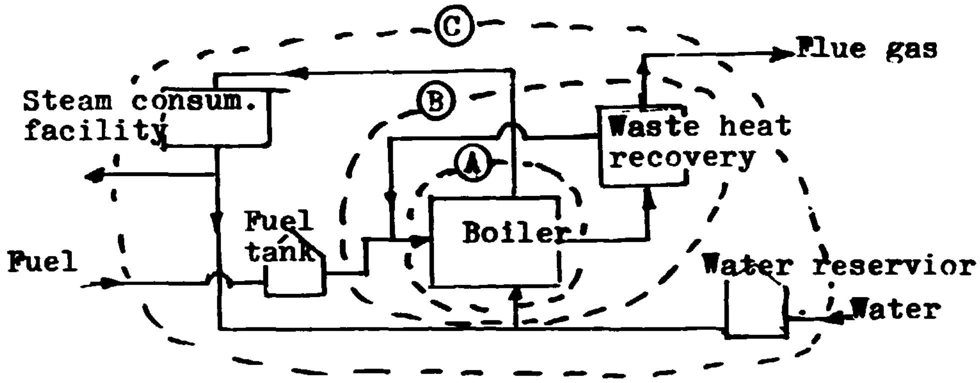


Figure 2.2-8 Choice of boundary barrier for balance

(C) Process conditions

As Fig. 2.2-6 the process conditions should be filled up on flowing lines in more ditail as possible.

(2) Procedure of thermal accounting

(A) Caloric value of fuel or combustion heat of fuel

According as whether the latent heat of moisture in flue gas or combustiongas would be consumed up, two kinds of caloric value should be utilised distinctively referring to the situation of accounting.

In general, the figure in document supplied from oil dealer is often shown with a gross coloric value. Otherwise, in practical cases, the latent heat of moisture would not used up in the flue gas exhausted in the normal processes. Therefore the caloric value in energy management is a net value.

- Gross caloric value ; complete use up
- Net caloric value ; non use

(a) Net calorific value from gross value

Net value Q_1 = Gross value Q_h - 600 x (9 x h + w)   (1)

Here 600 ; latent heat of water

9 ; 18/2   ratio water mol.wt. to hydrogene m.w.

w ; wt. fraction of water in fuel

h ; wt. fraction of hydrogene in fuel

(b) Gross calorific value from ultimate analysis of fuel

Gross value Q_h = 8,100 x c + 34,000 x h + 2,500 x s (2)

Here   c ; wt. fraction of carbon in fuel

s ; wt. fraction of sulphur

Net value is calculated by (1)

(B) Theoretical required air for complete combustion of fuel A_o Nm^3/kg F

Though the value would be estimated by stochiometric theory and ultimate analysis, here for simplicity the value is estimate using "Rosin formula" as belows.

Description	G_o	A_o
Solid fuel	$(\frac{0.89 \times Q_1}{1,000} + 1.65) Nm^3/kg$ F (3)	$(\frac{1.01 \times Q_1}{1,000} + 0.5) Nm^3/kg$ F (7)
Liquid fuel	$(\frac{1.11 \times Q_1}{1,000})$ Nm^3/kg F (4)	$(\frac{0.85 \times Q_1}{1,000})$ Nm^3/kg F (8)
Gaseous fuel low heat value	$(\frac{0.725 \times Q_1}{1,000} + 1.0)$ Nm^3/Nm^3 (5)	$(\frac{0.875 \times Q_1}{1,000})$ Nm^3/Nm^3 (9)
Gaseous fuel high heat value	$(\frac{1.14 \times Q_1}{1,000} + 0.25)$ Nm^3/Nm^3 (6)	$(\frac{1.09 \times Q_1}{1,000} - 0.25)$ Nm^3/Nm^3 (10)

Table 2.2-2 Relation between Q_1 and (G_o and A_o) Rosin Formura

(C) <u>Theoretical wet flue gas G_o (Nm^3/kg F)</u>

The value G_o would be obtained using "Rosin formula".

<u>Example 2.2-1</u>

When the ultimate analysis diesel oil is as follows ;

C 86 % ,

H 13 % and

S 1 % ,

estimate Q_h, Q_l, A_o and G_o of above fuel.

<u>Solution</u>

From (2)

$$\text{Gross value } Q_h = 8{,}100 \times 0.86 + 34{,}000 \times 0.13 + 2{,}500 \times 0.01$$
$$= 6{,}966 + 4{,}420 + 25$$
$$= \underline{11{,}411 \text{ kcal/kg F}}$$

From (1) and w = 0,

$$\text{Net value } Q_l = 11{,}411 - 600 \times (9 \times 0.13 - 0)$$
$$= 11{,}411 - 702$$
$$= \underline{10{,}709 \text{ kcal/kg F}}$$

From (8) of "Rosin formula"

$$A_o = \left(\frac{0.85 \times 10{,}709}{1000} + 2.0 \right) \text{Nm}^3\text{/kg F}$$
$$= 9.103 + 2.0$$
$$= \underline{11.103 \text{ Nm}^3\text{/kg F}}$$

From (4) of "Rosin formula"

$$G_o = \left(\frac{1.11 \times 10{,}709}{1{,}000} \right)$$
$$= \underline{11{,}887 \text{ Nm}^3\text{/kg F}}$$

(D) <u>Air ratio m</u>

If assuming the complete combustion, air ratio m is estimated according to following formula (11)

$$\text{Air ratio } m = \frac{0.21}{0.21 - (O_2)} \tag{11}$$

here O_2 ; O_2 content with mol. fraction or volume fraction

(E) Actual wet flue gas G Nm^3/kg F

$$G = G_o + (m - 1) \times A_o \tag{12}$$

Example 2.2-2

On the boiler operation using diesel oil of Example 2.2-1, the O_2 content in flue gas was 8 %. Estimate air ratio m and actual wet flue gas G.

Solution

From (11)

$$m = \frac{0.21}{0.21 - 0.08} = \frac{0.21}{0.13} = \underline{1.615}$$

From (12)

$$G = 11.887 + (1.615 - 1) \times 11.103$$
$$= 11.887 + 0.615 \times 11.103$$
$$= \underline{18.715 \ Nm^3/kg \ F}$$

(F) Heat content carried out with flue gas

The specific heat of flue gas should accurately calcurated according to its composition and temperature. However, here as the simplified method, it is recomendable that the specific heat of flue gas on 100 to 300°C is unified as 0.33 kcal/m^3 °C.

$$\text{Heat content } Q = G \times C_p \times (T - T_o) \tag{13}$$

Here T ; Temperature of flue gas °C

T_o ; Ambient temperature °C

C_p ; Specific heat of flue gas, 0.33 kcal/m^3 °C

Example 2.2-3

On Example 2.2-2, when the temperature of flue gas and ambient are 200°C and 32°C respectively, how much is the heat loss according to flue gas.

Solution

Heat loss Q = 18.715 x 0.33 x (200 - 32)

= 18.715 x 0.33 x 168

= 1o37.6 kcal/kg F

(G) Calculation procedure on dispersion heat loss from surface of facilities

(a) Sketch drawing presenting the body surfaces

Sample sketch is as following Fig. 2.2-5

(b) Cresponding the heat flux to the surface

On no heat flux meter, the surface tenperatures are measured to respective surface of facilities.as Table 2.2-1 and Figure 2.2-5.

(c) Record

It is convenient to fill up the data to calculation format as Table 2.2-1

Suplemental procedure

(d) Case of no heat flux meter

It is useful procedure to obtain quickly the approximate dispersion heat lossas follows ;

- $(T - T_0)$
- The temporary heat trancfer coefficients h are assumed as 10 to 20 kcal/m^2 hr °C,

However when the dispersion heat loss result in a large portion of output on the heat balance accounting, this procedure is not recommendable.

(e) Calculation

On the data of heat flux meter

$$\text{Heat loss } Q = \sum_i (A_i \times \text{Heat flux}) \qquad (14)$$

On no heat flux meter

$$\text{Heat loss } Q = \sum_i (h_i \times A_i \times (T_i - T_o)) \qquad (15)$$

Approximate heat loss

$$\text{Min. loss} = 10 \times \sum_i (A_i \times (T_i - T_o)) \qquad (16)$$

$$\text{Max. loss} = 20 \times \sum_i (A_i \times (T_i - T_o)) \qquad (17)$$

Example 2.2-4

According to Fig. 2.2-5 and Table 2.2-1 on heat flux, surface temperature, ambient temperature and respectively corresponding surface areas,
estimate the dispersion heat loss from the surfaces.

Solution

Following the calculation format, The dispersion heat loss is obtained as table 2.2-1
On reference, the value of heat trancfer coefficient h calculated from reversely the value of the heat flux are presented.

(H) <u>Heat loss carried out with blow down water</u>

A amount of blow down water is measured with the dimention of boiler and the depression of water column of level gauge. Heat loss is estimate as follows ;

$$\text{Heat loss } Q = B \times C_p \times (T - T_o) \qquad (18)$$

$$= B \times 1.0 \times \Delta T$$

here

B ; weight or volume of blow down water kg or litre

1.0 ; specific heat of liquid water kcal/kg ^{o}C

ΔT ; Differential temperature between steam temperature and ambient

<u>Example 2.2-5</u>

Some boiler is operated as follows ;

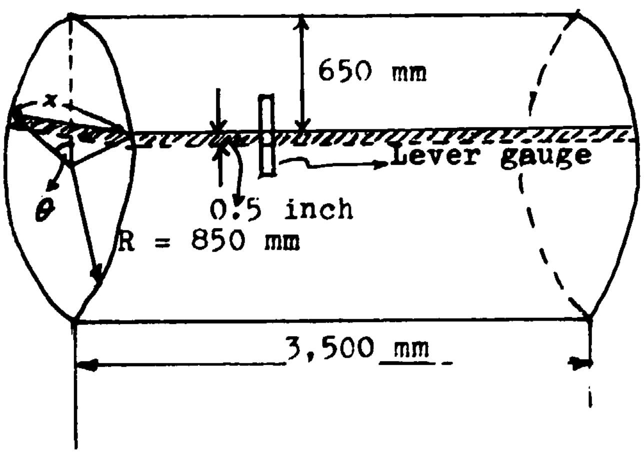
Cycle of blow down operation ; each 4 hrs,

Depression of water column ; 1/2 inches and

Rate of fuel consumption ; 40 kg/hr.

The dimension of boiler is as belows

<u>Sketch of boiler</u>



Solution

$$\sin\theta = 200/850 = 0.2353$$

$$\theta = 13.6^{o}$$

$$\cos 13.6^{o} = \frac{x/2}{850} = 0.97$$

$$x/2 = 826 \text{ mm}$$

$$x = 1652 \text{ mm}$$

Cross area A = 1.652 x 0.0125 = 0.0203 m^2

Vol. of blow down B = 0.0206 x 3.500 = 0.0723 m^3

Enthalpy of steam at 8 kg/cm^2 G = 660.8 kcal/kg

Enthalpy of water at $32^{o}C$ = 32.56 kcal/kg

Heat content of blow down Q

$$Q = (660.8 - 32.56) \times 72.3 = 45,422 \text{ kcal/4 hrs}$$

Converting the basis of heat content to kg of fuel

$$Q = \frac{45,422}{40 \times 4} = \underline{283.9 \text{ kcal/kg F}}$$

(I) Heat content carried in by boiler feed water

When the boiler water is fed over ambient temperature, the heat content of fed water should be counted as input heat. The value on basis of kg of fuel is calculated as follows

$$Q = \{W \times C_p \times (T - T_o)\}/F \quad \text{kcal/kg F} \qquad (19)$$

here W ; amount of fed water kg/hr

F ; rate of fuel consumption kg/hr

T ; temperature of fed water ^{o}C

C_p ; specific heat of water kcal/kg ^{o}C

Example 2.2-6

When a boiler is operated following condition, estimate the heat carryed in by the feed water.

Feed water rate	;	600 kg/hr
Feed fuel rate	;	40 kg F/hr
Temp. of fed water	;	60 °C
Ambient temp.	;	32 °C

Solution

From (19)

$$Q = \frac{600 \times 1.0 \times (60 - 32)}{40} = \underline{420 \text{ kcal/kg F}}$$

(J) Preparation of heat balance sheet

Description	Input		Output	
	kcal/kg F	%	kcal/kg F	%
Input				
Fuel (net)	10,709	96.2		
Feed water (60°C)	420	3.8		
Output				
Flue gas			1,038	9.3
Dispersion heat loss			290	2.6
Blow down water			284	2.6
steam (balance)			9,517	85.5
Total	11,129	100.0	11,129	100.0

Table 2.2-3 Example of heat balance sheet

(K) <u>Drawing of energy flow diagram</u>

Although it is sufficient to make the energy balance sheet for the energy management, furthermore it is more desirable to draw the energy flow diagram in order to let even the factory executive easily in glance understand as belows ;

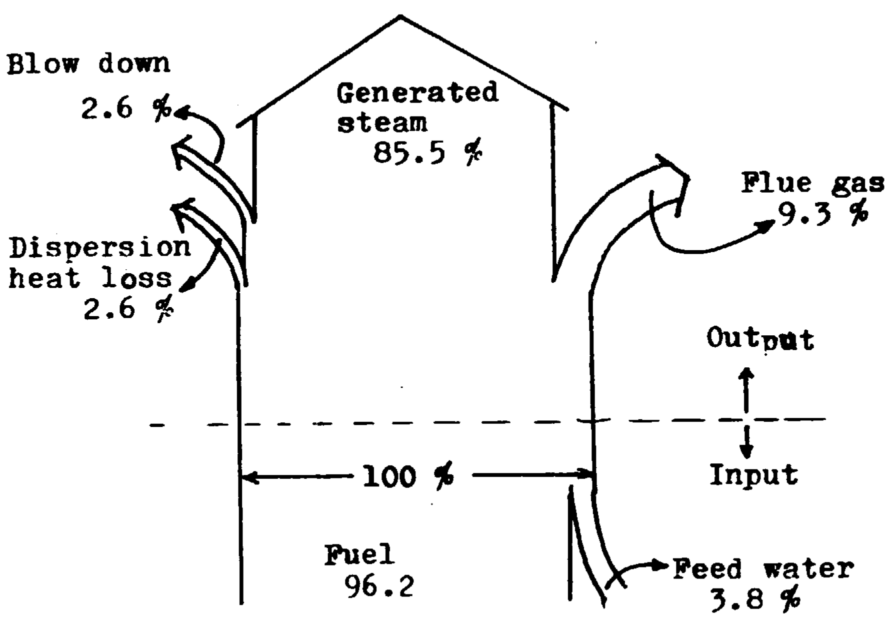


Figure 2.2-9 <u>Energy flow diagram</u>

Above descriptions are all regarding to boiler.

In practice, we must evaluate the heat content of solid materials. Fortunately, the estimating procedures would be almost same as above. The specific heat of solid materials necessary for accounting the heat balance would be listed in appendix.

2.2.2 How to solve the heat transfer problems with examples

We would like to leave the basic theory of the heat transfer, insolving the conduction, radiation and convection, to the conventional text books about heat transfer.
Here only the following practical techniques would be explaind so as to let the factory engineers alone easily solve the problems frequently taking place in energy audits.

(1) Overall heat trasfer problems
(2) Dispersion heat loss on piping systems
(3) Heat exchangers

We would like to expect that almost of all factory engineers become familiar with the techniques as soon as possible.

(1) Overall heat transfer problems

The overall heat transfer is a phenomena to let the heat transfer from a fluid out of hot solid wall to a fluid out of cold solid wall.
The amount of heat to be transfered is calculated by the following equation

Transfered heat $Q = K \times A \times (T_1 - T_2)$ (20)

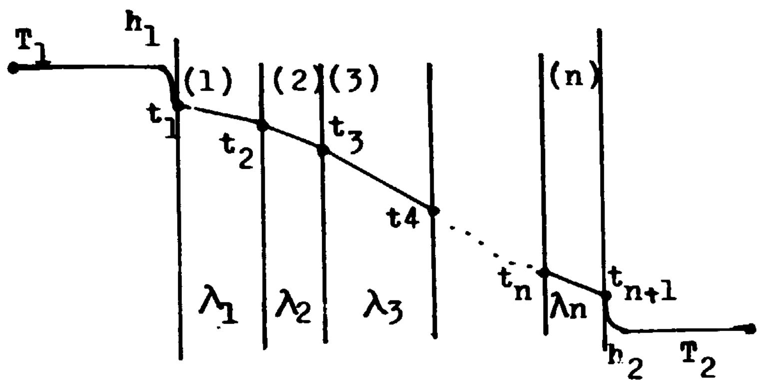
here A ; heat transfer cross area (m^2)

T_1 & T_2 ; fluid temperature of hot and cold side respectively

K ; overall heat transfer coefficient

Now assuming that the wall is composed with many layer of materials whose thermal conductivity are $\lambda_1, \lambda_2, \lambda_3$ --- and whose thickness are b_1, b_2, b_3, --- , the overall heat transfer coefficient is defined as follows ;

$$\frac{1}{K} = \frac{1}{h_1} + \frac{b_1}{\lambda_1} + \frac{b_2}{\lambda_2} + \frac{b_3}{\lambda_3} + - ---- + \frac{1}{h_2} \qquad (21)$$



$$Q = h_1 \times (T_1 - t_1) = \frac{\lambda_1}{b_1} \times (t_1 - t_2)$$

$$= \frac{\lambda_2}{b_2} \times (t_2 - t_3) = \frac{\lambda_3}{b_3} \times (t_3 - t_4)$$

$$= - - - - - \quad = h_2 \times (t_{n+1} - T_2)$$

Example 2.2-7

A wall of furnace is composed of following materials. The temperature of atmosphere in furnace is 1,300 °C, and the film transfer coefficient h_1 is assumed as 1,000 kcal/m² hr °C. On other side, respective values on ambient are 30 °C and 10 kcal/m² hr °C. How much are the temperature of the boundary furfaces of the respective materials, that is, t_1, t_2, t_3, and t_4.

In order of hot side,	λ kcal/m hr °C	b m
Refractory brick (1)	1.3	0.3
Insulation brick (2)	0.2	0.14
Red beick (3)	0.35	0.24

Solution

You must keep in mind that the heat flow rate everywhere in wall is constant.

$$Q = K \times A \times (1{,}300 - 30)$$

here assuming $A = 1\ m^2$,

$$\frac{1}{K} = \frac{1}{1{,}000} + \frac{0.3}{1.3} + \frac{0.14}{.2} + \frac{0.24}{0.35} + \frac{1}{10}$$

$$= 1.718$$

$$Q = \frac{(1{,}300 - 30)}{1.718} = 739.2\ kcal/m^2\ hr$$

$$Q = 1{,}000 \times (1{,}300 - t_1)$$

$$1{,}000 \times t_1 = 1{,}000 \times 1{,}000 - 739.2$$

$$= 1{,}299{,}000$$

then $t_1 = \underline{1{,}299\ ^{o}C}$

$$739.2 = 1.3/0.3 \times (1{,}299 - t_2)$$

$$t_2 = \underline{1{,}128.4\ ^{o}C}$$

$$739.2 = 0.2/0.14 \times (1{,}128.4 - t_3)$$

$$t_3 = \underline{610.8\ ^{o}C}$$

$$739.2 = 0.35/0.24 \times (610.8 - t_4)$$

$$t_4 = \underline{103.8\ ^{o}C}$$

These obtained values are checked as next equation.

$$739.2 = 10 \times (103.8 - 30)$$

$$\fallingdotseq 737 \qquad \text{OK}$$

(2) Dispersion heat loss on piping systems

In order to estimate the effectiveness of the insulation for preventing the dispersion heat from the surface of the piping systems, the calculated dispersion heat per 1 m of pipe length and 1 hr is presented according to the insulation thickness, steam temperature and pipe size in Fig. 2.2-10.

The dispersion heat and the effectiveness after insulating the bared pipe are presented in Fig.2.2-11 to Fig. 2.2-16 .

The definition of effectiveness η % is as follows ;

$$\eta = \frac{Q_o - Q}{Q_o} \times 100 \ \% \qquad (22)$$

Q_o and Q are the dispersion heat kcal/m hr before and after respectively.

Example 2.2-8

How much of the dispersion heat loss on bared pipe and insulated pipe with regular material by 100 mm of 80 A (3 B) on 300 °C of steam temperature.

Solution

In Fig.2.2-10, a point of horizontal axis at 300 °C is raised up and crossed at 80 A (3B) line.

From the point, it is moved horizontally to vertical axis and read the dispersion heat loss with kcal/m hr This value is of bared pipe.

Next, in Fig.2.2-13, a point of 100 mm of horizontal axis is raised up and crossed at 300 °C line, then read the dispersion heat loss with insulation.

Thickness of Insulation, Dispersion Heat Loss
and Insulation Effectiveness

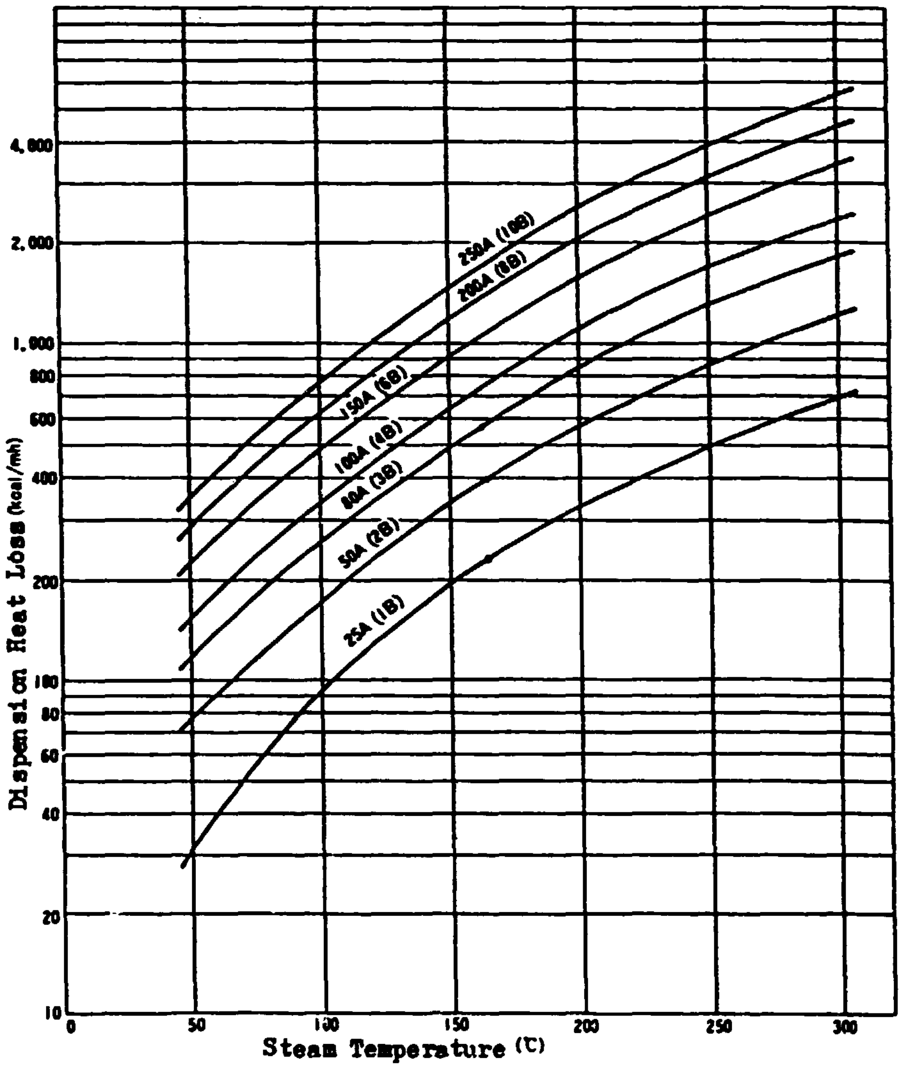


Figure 2.2-10 Dispersion heat loss from bared steam pipe

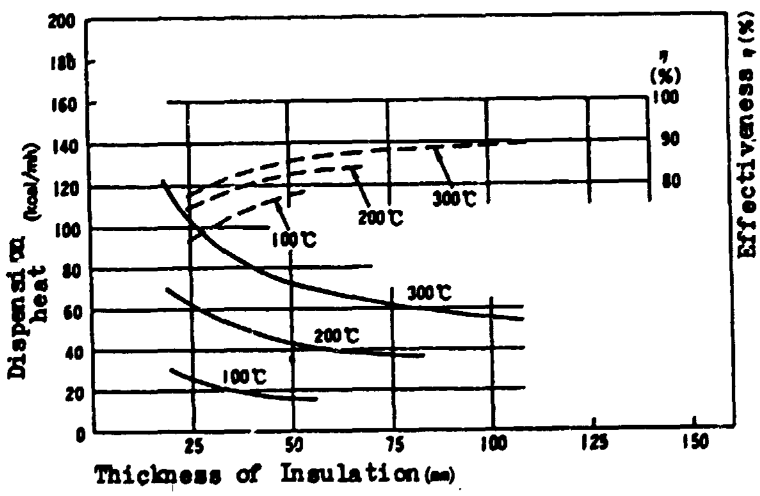


Figure 2.2-11 Insulation effectiveness for 25A(1") pipe

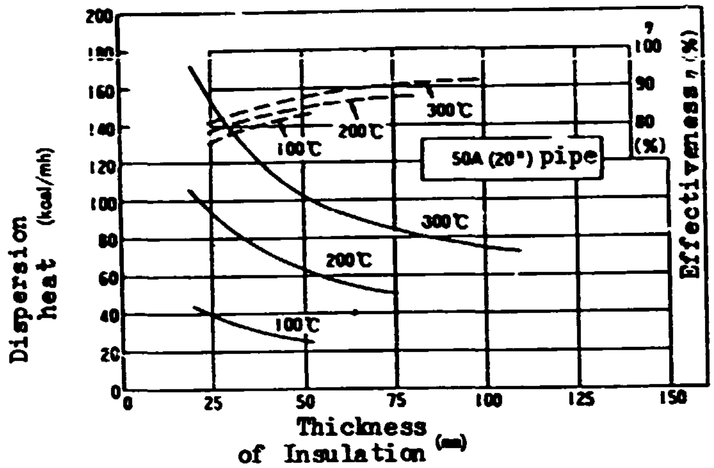


Figure 2.2-12 Insulation effectiveness for 50A(2") pipe

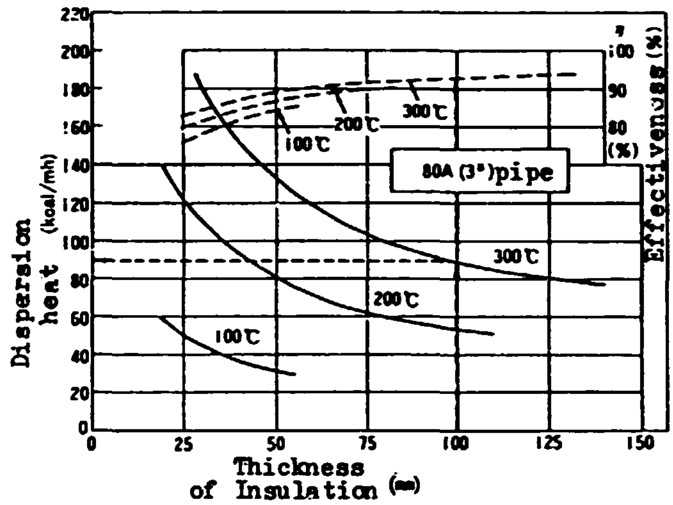


Figure 2.2-13 Insulation effectiveness for 80A(3") pipe

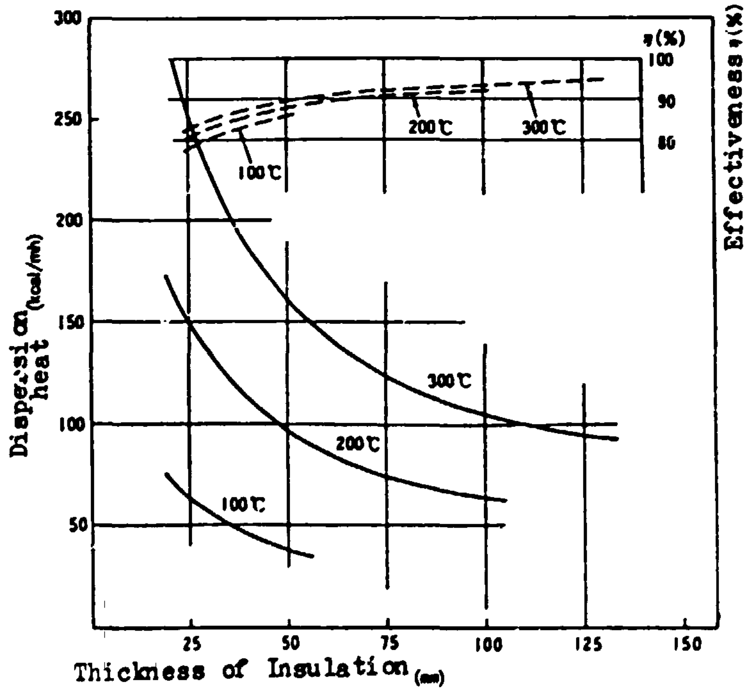


Figure 2.2-14 Insulation effectiveness for 100A(4") pipe

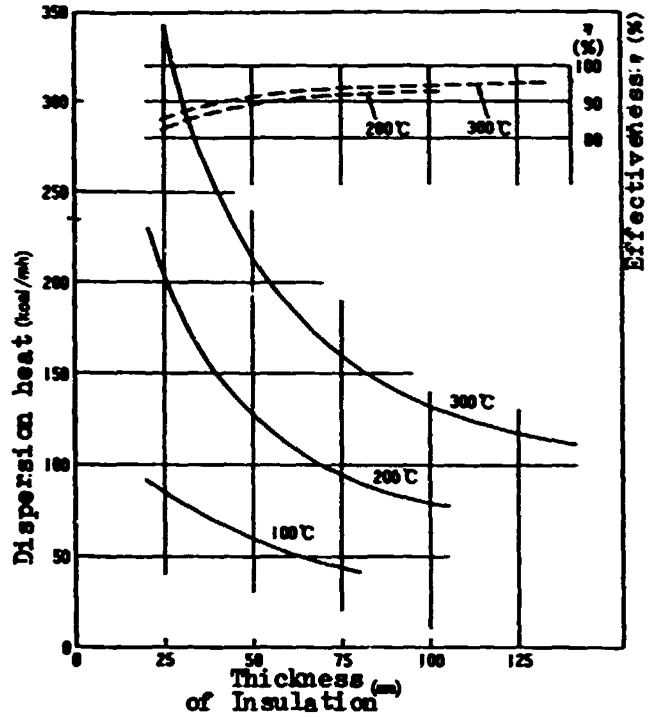


Figure 2.2-15 Insulation effectiveness or 150A(6") pipe

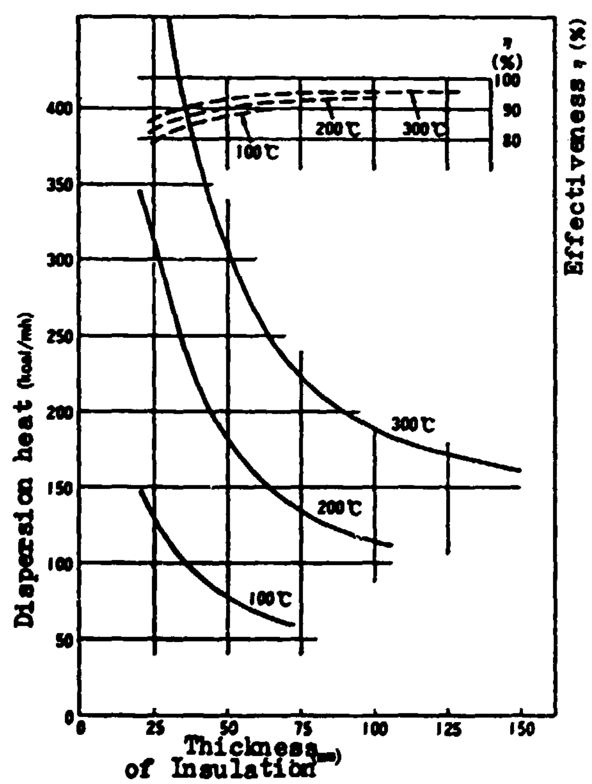


Figure 2.2-16 Insulation effectiveness for 250A(10") pipe

Equivalent length of Valves and Flanges for dispersion heat.

Valve Size	25A	50A	80A	100A	150A	200A
Surface Area of Valves (m^2)	0.131	0.211	0.349	0.455	0.776	1.137
(m) equivalent length	1.22	1.11	1.25	1.28	1.50	1.68

Table 2.2-4 Valves

Flange Size	25A	50A	80A	100A	150A	200A
Surface Area of Flange (m^2)	0.057	0.083	0.113	0.139	0.235	0.301
(m) equivalent length	0.53	0.47	0.42	0.39	0.45	0.44

Table 2.2-5 Flanges

Furthermore, the effectiveness value on the counter-measure of insulation easily is obtained on upper graph line.

In practice, from Fig.2.2-10 and 2.2-13 ,

Dispersion heat loss in bared Q_o = 1,250 kcal/m hr

Dispersion heat loss with insulation

Q = 90 kcal/m hr

From the difinition of effectiveness,

$$\eta = \frac{Q_o - Q}{Q_o} \times 100$$

$$= \frac{1,250 - 90}{1,250} \times 100$$

$$= 92.8\ \%$$

From the upper grapg of Fig. 2.2-13 ,

$$\eta = 93\ \%$$

<u>End of Example</u>

In general, there are many kinds of the pipe fitting parts, that is, many kinds of valves and franges in the piping in factories. The estimation of such parts are substituted by equivalent length of each parts as table 2.2-4 and 2.2-5 as shown later.

(3) Heat exchanger problems

On conducting the energe conservation activities, it often happens that the heat exchanges to recover the exhausted heat, for example, economizer which heat up the boiler feed water to some degree of temperature, the air preheater which heat up the combustion air for the burner and the hot water recovery which is installed in hot sewage lines, should be planed.

Here, in order to obtain the preliminary and rough informations regarding to the dimension or capacity on heat exchanger are described. If in practice you want to install the heat exchanger for energy conservation, you had better consult with a plant engineering or heat exchanger manufacturers about the actual plans.

(A) The simplified design procedures on Heat exchangers

(a) Draw the schematic flow sheet

The flow condition, for example, direction (in or out) temperature, amount of flow material and so on, must be filled up on flow sheet as belows.

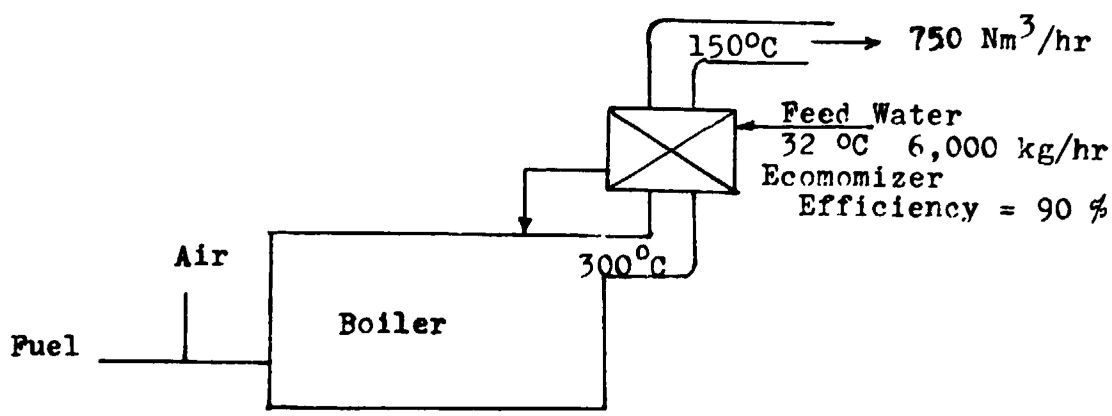


Figure 2.2-17 Economizer installation

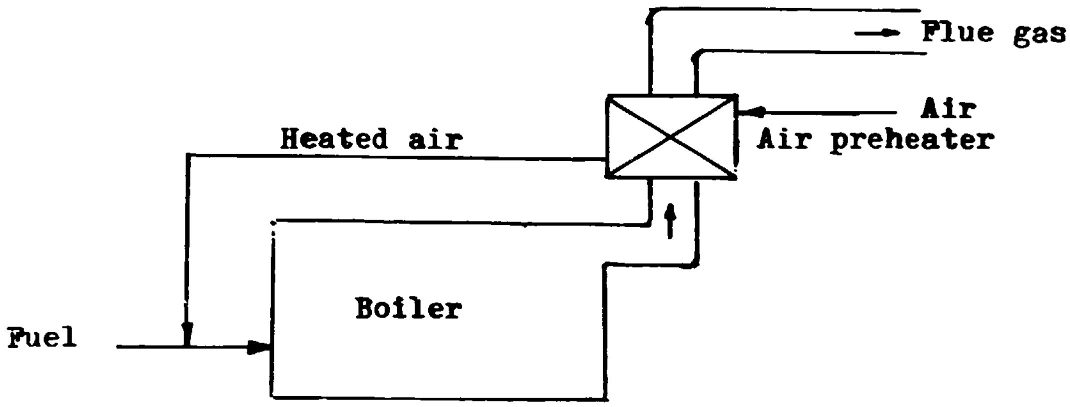


Figure 2.2- 18 Air preheater installation

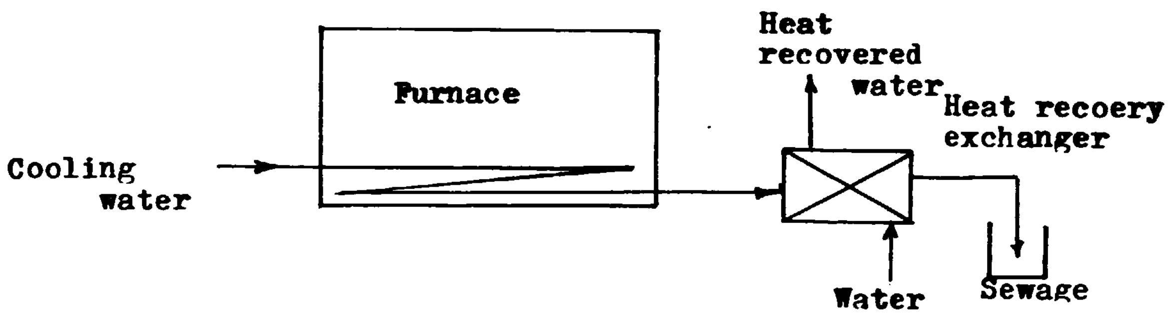


Figure 2.2- 19 Heat recovery exchange

(b) <u>Mean temperature difference</u>

In order to decide the size, dimension or capacity, for the simplicity of design the reasonable mean temperature difference should be calculated as belows,

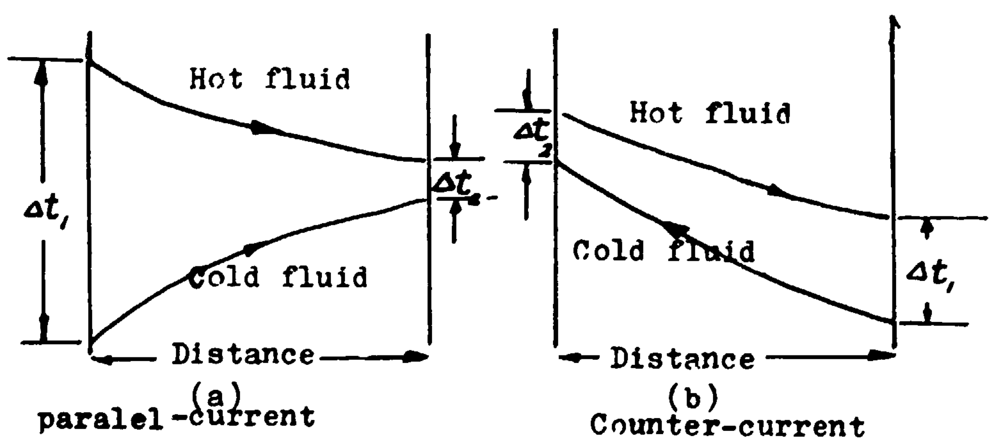


Figure 2.2-20 Temperature pattern in heat exchanger

In practice,

if $\Delta t_1/\Delta t_2 < 1.5$

the mean temperature difference may be substituted with a arithmatic mean as follows ;

$$\Delta t = \frac{\Delta t_1 - \Delta t_2}{2} \tag{23}$$

and if $\Delta t_1/\Delta t_2 > 2$

as the proper temperatire fifference, log. mean temperature difference should be utilized as belows

$$(\Delta t)_{lm} = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}} \tag{24}$$

$$= \frac{\Delta t_1 - \Delta t_2}{2.3 \log \frac{\Delta t_1}{\Delta t_2}} \tag{25}$$

On even the cross flow heat exchanger, log mean may be adapted.

(c) Typical overall heat transfer coefficient

It is very difficalt to assign the coefficient as fixed value, because this coefficient is variable depending to the terms of operation, the physical properties of flowing material of both fluids, the configuration of heat exchanger and so on.

			Typical value
Flue gas	vs	Water	30 kcal/m^2 $^\circ$C hr
Flue gas	vs	air	15 kcal/m^2 $^\circ$C hr
Hot water	vs	Water	100 kcal/m^2 $^\circ$C hr

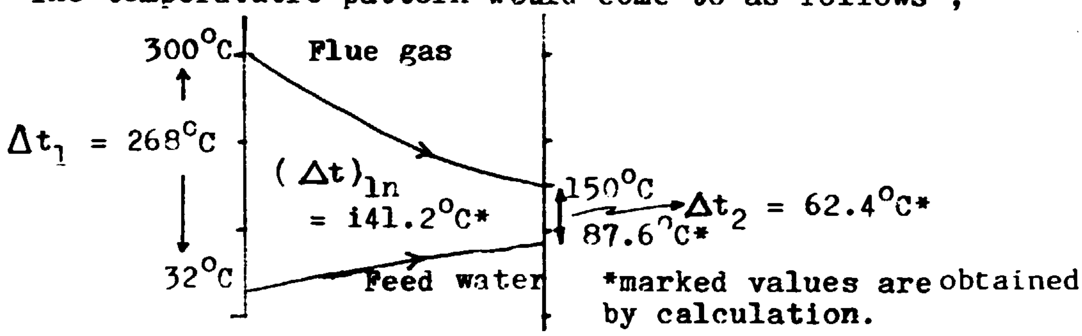
Example 2.2-9

Some factory, the installation of economizer on operating boiler for heat recovery from exhaust flue gas is being planed as Fig. 2.2-17.

assuming the heat efficiency of economizer or heat exchanger is 90 %, estimate the temperature of the feed water to boiler and calculate roughly the area m^2 of heat transfer in economizer.

Solution

The temperatutre pattern would come to as follows ;



Next we must calculate the theoretical transfered heat from flue gas to water, Q kcal/hr.

$$Q = 7,500 \times 150 \times 0.33 = 371,250 \text{ kcal/hr}$$

here 150 ; the temperature difference of flue gas

0.33 ; rough specific heat of fluegas

The temperature of feed water to boiler is as belows

$$t = \frac{371,250 \times 0.9}{6,000} + 32 = \underline{87.6\ ^{\circ}C}$$

Calculation of log mean

$$\Delta t_1 = 300 - 32 = 268$$

$$\Delta t_2 = 150 - 87.6 = 62.4$$

$$(\Delta t)_{ln} = \frac{268 - 62.4}{2.3 \log \frac{268}{62.4}} = 141.2\ ^{\circ}C$$

Choosing 30 kcal/m^2 ^oC hr as the typical overall heat transfer coefficient, the area of heat transfer is estimate as belows

$$\text{transfered heat } Q = 371{,}250 \times 0.9$$
$$= K \times A \times \Delta T$$
$$= 30 \times A \times 141.2$$

Then

$$\text{required area } A = \frac{333{,}500}{30 \times 141.2} = \underline{78.2 \text{ m}^2}$$

End of example

Almost of all heat exchangers can be approximately designed as above procedure.

Therefore more descriptions are skiped.

2.2.3 <u>How to estimate the steam consumptions with example</u>

As previously explained, here the steam is consumed only for heatng some materials. After all, the steam for heating is consumed with the following two ways.

(1) Substantially required steam for heating the processing materials including the heat content of facilities, and

(2) The balanced steam substructing the above required steam from input steam. This heat of steam is completely dispersed to ambient atmosphere and call it waste.

Sometimes, it happens that a amount of heat is recovered from a exhausted heat. It may be considered that this recovered heat is equivalent to the reduction of input heat. Therefore the ratio of (1) to the input heat is called as the efficiency of the heating operation of facilities.

The actual energy conservation activities with regard to the steam consumption are to raise the efficiency or to depress the waste part of heat among the input energy which is obtained by substructing the recovered heat from the initial input heat.

(1) <u>Estimation of required steam for heating</u>

(A) <u>Processing materials</u>

The 1 kg of steam is to be equivalent to 550 kcal.

(a) On only one material

$$S = \frac{Q}{550} = \frac{W \times C_p \times (T - T_o)}{550} \quad \text{kg} \qquad (26)$$

(b) On a few of materials

$$S = \frac{\sum Q_i}{550} = \frac{\sum \{W_i \times C_{pi} \times (T_i - T_o)\}}{550} \quad \text{kg} \qquad (27)$$

here

W and W_i ; amount of materials kg

C_p and C_{pi} ; specific heat of respective maerials

T and T_i ; required temperature ^oC

Q and Q_i ; Required heat kcal

S ; amount of required steam kg

In general, the steam consuming facilities are composing of many kinds of material. Then quantity, temperature and specific heat of respective material should be evaluated and calculated with the almost same equation as a single material as above.

In the biginning survey, it may be useful and convenient that one value of each component as a mean would be adaped to respective materials.

However, on the continuous processing of long period, the heat content of facilities on start-up period may be neglected in order to come to a negligible amount of heat comparing to the total heat of input steam in unit period.

Example 2.2-10

A factory is processing waste tyres for reuse on following operation schedule,

	Big tyre	Small tyre
Weight of a piece kg.	60	30
No. of curing machines	10	6
No. of batch per day	7	16

Temperature of initial raw waste tyre is 30 °C.

Estiamte the substantially required amount of steam per day in this factory.

The steam for curing process is supplied at 180 °C.

Solution

The specific heat of rubber is available with conventional reference book.

The specific heat of rubber ; 0.25 kcal/kg °C

$$Q = (60 \times 10 \times 7 \times 0.25 \times (180 - 30)) - (30 \times 6 \times 16 \times 0.25 \times (180 - 30))$$

$$= 157,500 - 100,000$$

$$= 257,500 \text{ kcal/day}$$

$$S = Q/550 = 257,500/550 = \underline{468.2 \text{ kg steam/day}}$$

(B) Material constituting of facilities

The procedure of estimation is almost same as above (A).

(2) Estimation of dispersion heat loss from surface of facilities

This procedures have been described already at 2.2 Analy sis, 2.2.1, (2) , (G) Calculation procedure on dispersion heat loss from surface of facilities.

This term is skiped.

(3) **Heat loss by evaporation from free surface of hot water vessels**

In practice, the rate of the evaporation of water the free surface variable according with the atmospheric conditions, that is, humidity, wind blowing, ambient temperature and so on and then absolutely the correct values of the heat loss due to evaporation are hardly obtained.

Although the data of Figure 2.2-21 as shown later about a dispersion heat loss from freewater surface are extremely rough because of neglecting completely of any atmospheric conditions over the free water surface, it would be sufficient to estimate the heat loss using Figure 2.2-21 on the first stage of the energy management.

Example 2.2-11

In some textile factory, a treatment of fibre are continuously operated in hot water bath vessel whoese dimensions are as follows ;

length	;	4,5 m
Width	;	1.5 m
depth	;	1.2 m

Bath temperature is 90 °C and the hot water surface is completely exposed to ambient.

How much are the heat loss per hr due to the evaporation from the free surface of vessel and calculated required steam by this heat loss.

Solution

Using Figure 2.2-21 and assuming half agitation because of disturbance on pathing the treated fibre in the hot bath at 90 °C

Agitation ; 9,000 kcal $/m^2$ hr

No disturbance ; 7,000 kcal $/m^2$ hr

Taking the mean value, Dispersion heat loss per m^2 and hr is as follows ;

$$(9{,}000 - 7{,}000)/2 = 8{,}000 \text{ kcal } /m^2 \text{ hr}$$

Total free surface area is

$$4.5 \times 1.5 = 6.75 \ m^2$$

Then the heat loss is as follows ;

$$Q = 7{,}000 \times 6.75$$

$$= \underline{47{,}250 \text{ kcal } /hr}$$

The required steam compensating this heat loss is

$$S = Q/550 = 47{,}250/550 = \underline{85.9 \text{ kg } /hr}$$

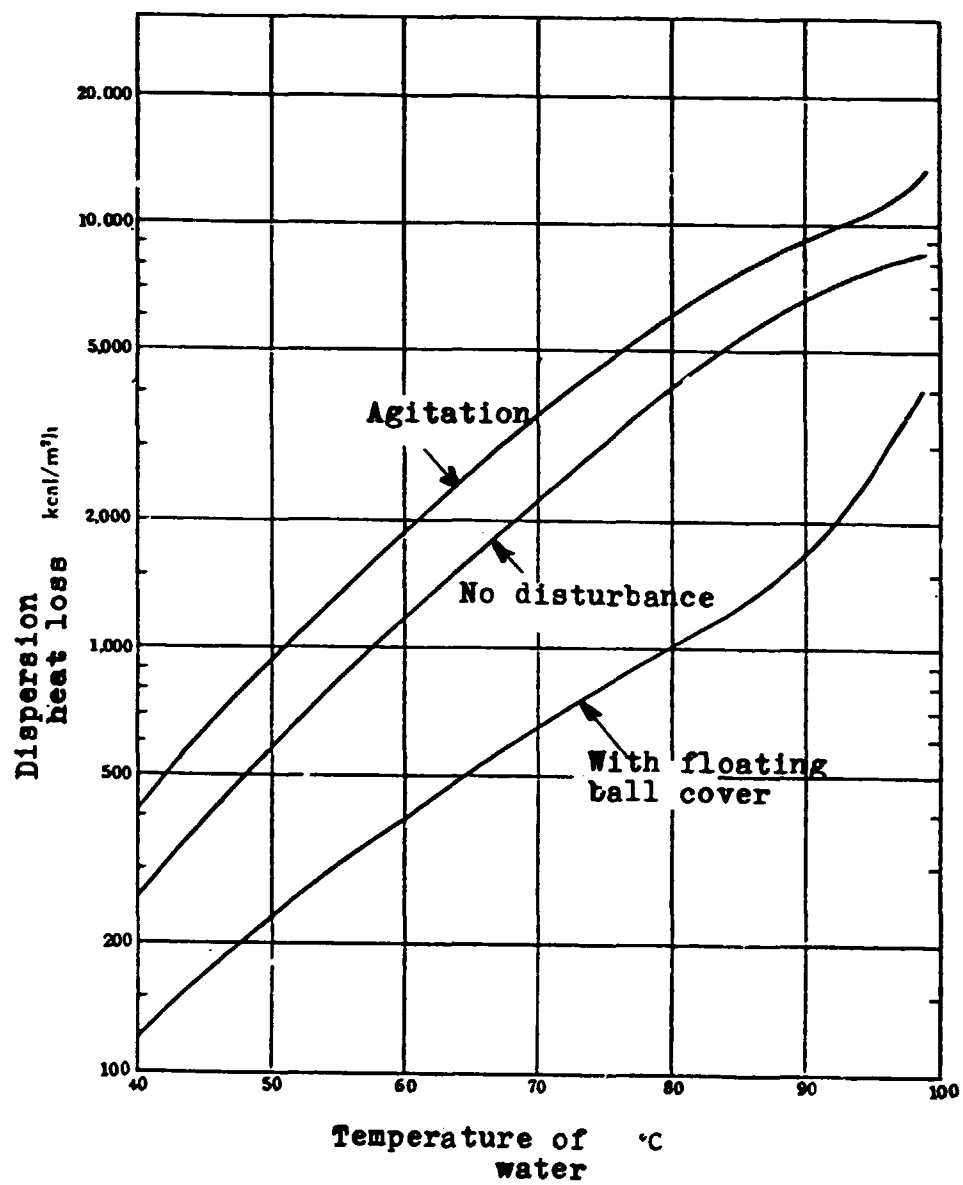


Figure 2.2-21 Dispersion heat loss from the surface of hot water vessel

2.3 Recommendation

In this section, the following values are applied on all examples as common in order to avoid the complexity on a lot of different factors of operation conditions.

Price per heat of 1,000 kcal ; 0.05 M$

Ultimate analysis of fuel

C : H : S = 86 ; 13 : 1

Q_h ; 11,411 kcal/kg F ≒ 11,500 kcal/kg F

Q_l ; 10,709 kcal/kg F ≒ 10,700 kcal/kg F

A_o ; 11.i03 Nm^3/kg F ≒ 11.1 Nm^3/kg F

G_o ; 11.887 Nm^3/kg F ≒ 11.9 Nm^3/kg F

Ambient temperature ; 30 ^oC

Working hours per day ; 16 hr/day

Working days per year ; 330 day/year

Fuel consumption per hour ; 400 kg/hr

2.3.1 Effects of O_2 control

Example 2.3-1

O_2 content of a flue gas on some boiler was 8 %.
If it could be redused till 3 %, how much are the fuel savings by this improvement, assuming that the temperature is not change and the rate of fuel consumption is 400 kg F/hr.

Solution

Let ' mark indicate the factors after the thus improvement.

$$\text{Air ratio } m = \frac{21}{21 - 8} = 1.615$$

$$m' = \frac{21}{21 - 3} = 1.167$$

Actual vol. of wet flue gas

$$G = G_o + (m - 1) \times A_o$$
$$= 11.9 + (1.615 - 1) \times 11.1$$
$$= 11.9 + 6.8 = 18.7 \text{ Nm}^3/\text{kg F}$$
$$G_o = 11.9 + (1.167 - 1) \times 11.1$$
$$= 11.9 + 1.9 = 13.8 \text{ Nm}^3/\text{kg F}$$

Saved heat per kg F,

$$Q = (18.7 - 13.8) \times 0.33 \times (200 - 30)$$
$$= 4.9 \times 0.33 \times 170$$
$$= 274.9 \text{ kcal/kg F}$$

Per hr $Q = 274.9 \times 400 = 109{,}960$ kcal/hr

$\$ = 109{,}960 \times 0.05/1{,}000 = 5.498$ M\$/hr

Per day $Q = 109{,}960 \times 16 = 1{,}759{,}360$ kcal/day

$\$ = 5.498 \times 16 = 87.97$ M\$/day

Per year $Q = 1{,}759{,}360 \times 330 = 580{,}588{,}800$ kcal/year

$\$ = 87.97 \times 330 = 29{,}030$ M\$/year

2.3.2 Effects of the temperature of flue gas

In practice, it is not so easy to depress the temperature of flue gas on a point leaving the boiler except a fuel would be burned in excess beyond the design capacity.
It often happens that a higher temperature of flue gas results in a insufficient heat transfer ability on boiler tube surface because of a short of surface area or a lot of the scale on the boiler tubes.

If the temperature of flue gas would be over 300 °C in spite of a resonable operations,that is, proper O_2 content, not so much of a fuel feed rate, and so on, you should better check and remove the scale on boiler tube surfaces in order to recover a ability of heat transfer. Especially, on the smoke tube type boilers which are frequently adapted on a small or middle size enterprise, there is no chance to remove the sticky scale depositing on the surface outside of boiler tubes except the perod of of overhaul in regular official inspection. Then the quality control of boiler water should be always taken care.

Example 2.3-2

The temperature of flue gas before the descaling the boiler tubes was 250 °C After the descaling the temperature of flue gas has been operated appropriately at 160 to 220°C until next overhaul after one year. Assuming that the temperature of flue gas rises up graduately and homogeneously according to a operation hours and O_2 content is keeping at 5 % in constant, how much is the amount of saving fuel?

Solution

From (11)

$$m = \frac{21}{21 - 5} = 1.3125 \doteqdot 1.31$$

From (12)

$$G = 11.9 + (1.31 - 1) \times 11.1$$

$$= 11.9 + 3.4 = 15.3\ Nm^3/kg\ F$$

From (13), saved heat per kg F,

$$Q = 15.3 \times 0.33 \times (250 - \frac{160 - 220}{2})$$

$$= 15.3 \times 0.33 \times 60 = 302.94\ kcal/kg\ F$$

Per hr,

$$Q = 302.94 \times 400 = 121,176\ kcal/hr$$

$$\$ = 121,176 \times 0.05/1,000 = 6.06\ M\$/hr$$

Per day,

$$Q = 121,176 \times 16 = 1,939,000\ kcal/day$$

$$\$ = 1,939,000 \times 0.05/1,000 = 96.95\ M\$/day$$

per year,

$$Q = 1,936,000 \times 330 = 639,870,000\ kcal/year$$

$$\$ = 639,870,000 \times 0.05/1,000 = 31,994\ M\$/year$$

Saved fuel per year, SF ; saved fuel

$$SF = 639,870,000/10,700 = 59,800.9\ kg\ F/year$$

2.3.3 Effects of the waste heat recovery

In spite of the complete descaling and the appropriative burning operation with clean burners, the temperature of the flue gas hardly fall down to suitable temperature, under 300 °C, it would be desirable to install the economiser or the air preheater in the way of the exhaust ducts.

Example 2.3-3

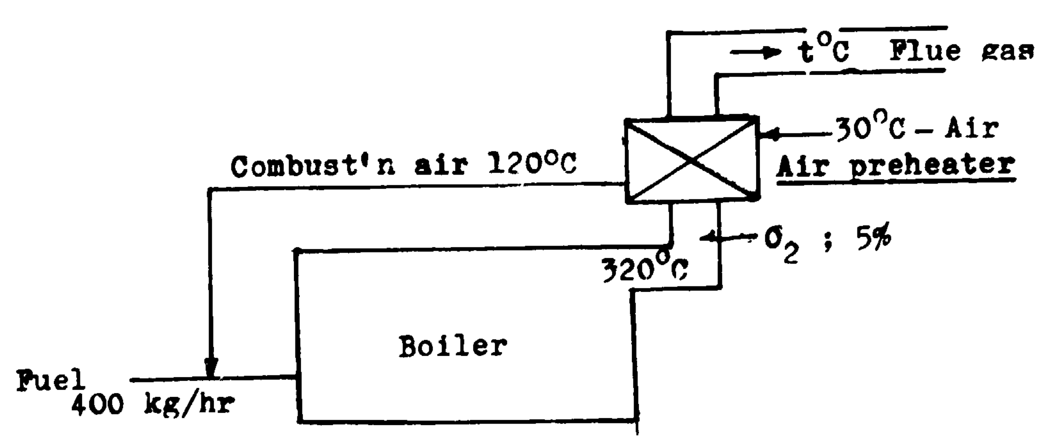
Now, after the descaling at the periodical overhaul the temperature of flue gas hardly has fellen down to under 300 °C, actually it has been 320 °C. The installation of the air preheater in way of exhaust duct line has been planed to save the fuel consumtion. It is expected that the air for combustion is rised pp to 120 °C.

How much is the amount of the saved fuel in this improvement?

and how much is the area m^2 of air preheater?

Solution

To draw the schematic flow sheet of improvement,



From (11)

$$m = \frac{21}{21 - 5} = 1.31$$

Actual required air volume for combustion

$$A = m \times A_o = 11.1 \times 1.31 = 14.5 \ Nm^3/kg\ F.$$

From (12)

$$G = 11.9 - (1.31 - 1) \times 11.1 = 15.3 \ Nm^3/kg\ F.$$

Asuming mean C_p of air at 30^o to 120^o C as 0.25 and the efficiency of air preheater as 90 %, from heat balance,

$$14.5 \times 0.25 \times (120 - 30) = 15.3 \times 0.33 \times (320\ t) \times 0.90$$

$t = 248$ outlet temp of flue gas after preheater

$$Q_w = 15.3 \times 0.33 \times (320 - 30) = 1464.21 \ kcal/kg\ F$$

Recovered heat Q_r per kg F,

$$Q_r = 14.5 \times 0.25 \times (120 - 30) = 326.25 \ kcal/kg\ F$$

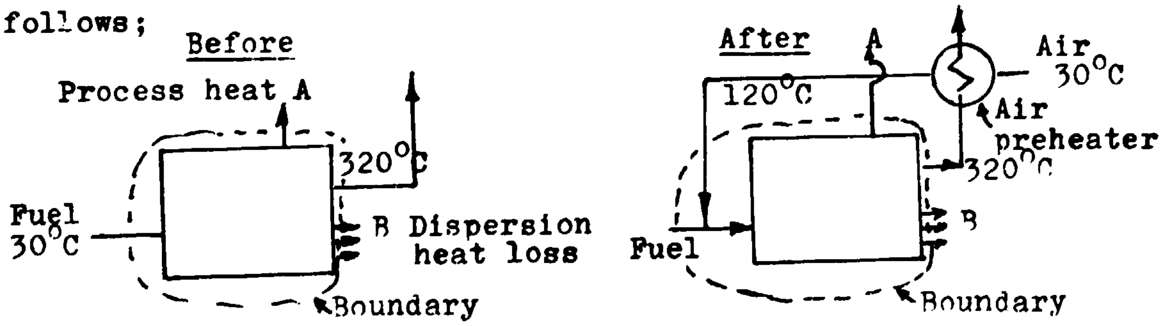
As a primary approximation, recovered heat per year

$$Q_{ry} = 326.25 \times 400 \times 16 \times 330 = 689,040,000 \ kcal/year$$

$$\$ = 689,040,000 \times 0.05/1,000 = 34,452 \ M\$/yeay$$

However in precise, this value should be estimated as follows ; assuming the practically required heat for processing and the dispersed heat loss from surface of facilities are constant with no relation to installation of preheater.

Schematic flow sheets of before and after inprovement are as follows;



Considering the above the flow sheets and assumed coditions following equation is obtained, Let X be a amount of the saving fuel per hour. Then A and B are

before $400 \times (10,700 - 1,464.2)$

after $(400 - X) \times (10,700 + 326.25 - 1,464.2)$

Both equations must be equal due to the assumption

$$400 \times (10,700 - 1,464.2)$$
$$= (400 - X) \times (10,700 + 326.25 - 1,464.2)$$

Solving the linear equation, The X, saving fuel is as follows

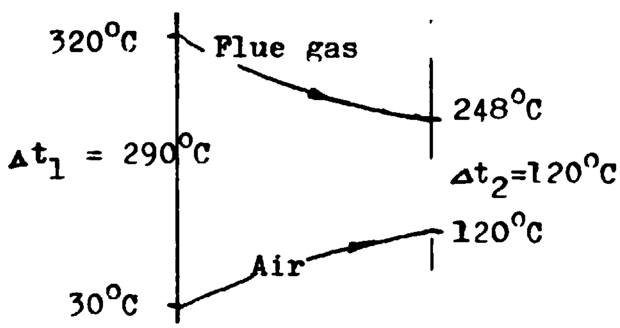
$$X = 13.64 \text{ kg F/hr}$$

Then a mount of saving fuel per year is as follows

$$Q_{ry} = 13.64 \times 10,700 \times 16 \times 330 = \underline{770,605,400 \text{ kcal/year}}$$
$$\$ = 770,605,400 \times 0.05/1,000 = \underline{38,530 \text{ M\$/year}}$$

Preliminary design of air preheater

Draw the temperature pattern.



Log mean temp. difference is as follows

$$\Delta t = \frac{290 - 128}{2.3 \log \frac{290}{128}}$$
$$= 198.3^{\circ}\text{C}.$$

From heat balance,

$$Q \text{ kcal/he} = 326.25 \times 386.36 = \text{Area} \times 15 \times 198.3 \text{ kcal/hr}$$

Required area,

$$\text{Area} = \frac{326.25 \times 386.36}{15 \times 198.3} = 42.4 \text{ m}^2$$

For allowance, design area is 20 % up,

$$\text{Design area} = 42.4 \times 1.2 = 50.9 = 51 \text{ m}^2$$

If unit price (per m^2) of air preheater, would be assumed as 1,000 M\$/m^2 on this improvement, the "Pay back years" is as follows;

$$\text{Pay back years} = \frac{1,000 \times 51.0}{38,530} = \underline{1.3 \text{ years}}$$

2.3.4 Effect of the extensive insulation

The most easy countermeasures for energy conservation would be to prevent the dispersion heat loss from the surface of the piping systems or the facilities with the suitable insulations. The countermeasure with respect to piping systems already the ditail descriptions have been done in analysis section.

In first, the most useful skill is to be familiar on the calculation of how much the waste heat is. Thus skills would be learned through the examples laters.

Example 2.3-4

A refractory brick wall of 20 cm thickness (λ_1 thermal conductivity 1.0 kcal/m hr °C) is to be insulated with a layer of insulation materaal (λ_2 thermal coductivity 0.1 kcal/m hr °C and allowable max. temperature 800 °C). What is the thickness of this insulation material under following condition ;

Temp.of inner surface of furnace ; 1,000 °C

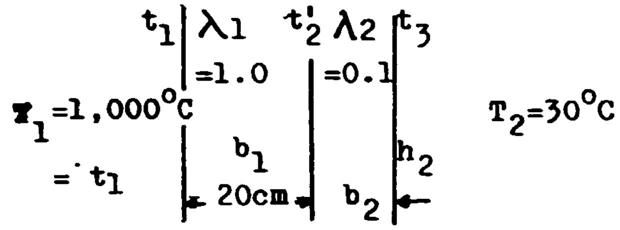
Ambient temp. ; 30 °C

Film heat transfer coef. of outside wall ;

10 kcal/m^2 hr °C

Solution

Given the allowable max. temperature 800 °C for insurating material, the boundary temperature between insulation and the refractory brick, t_2 can be presumed as 800 °C, the amount of heat conduction through the wall in unit hr and unit area,



$$Q = \frac{1 \times (t_1 - t_2)}{b_1} = \frac{1 \times (1{,}000 - 800)}{0.2}$$

$$= 1{,}000 \text{ kcal/m}^2 \text{ hr } ^\circ C$$

A amount of heat transfer through the wall is everywhere constant. Then

$$Q = \frac{t_2 - t_3}{\frac{b_2}{\lambda_2} + \frac{1}{h_2}} = \frac{800 - 30}{\frac{b_2}{0.1} + \frac{1}{10}}$$

$$= 1{,}000 \text{ kcal/m}^2 \text{ hr } ^\circ C$$

Solving a linear equation

$$1{,}000 \times (b_2/0.1 + 1/10) = 770$$

$$10{,}000 \times b_2 = 670$$

$$b_2 = \frac{670}{10{,}000} = 0.067 \text{ m}$$

$$= \underline{67 \text{ mm}}$$

Example 2.3-5

An existing insulation wall as shown in the figure belows has the following particulars ;

temp. at wall surface of high temp. side ; 600 °C

Thermal conductivity of insulation wall

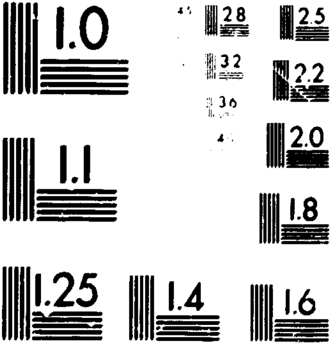
0.20 kcal/m hr °C

Its thickness (b_1) ; 0.20 m

Film heat transfer coef. of cold ambient side (h_2)

10 kcal/m^2 hr °C

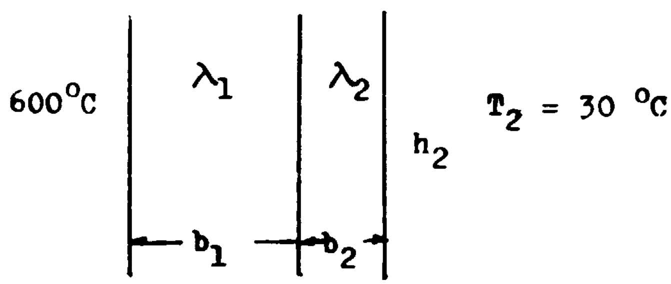
Ambient temp. (T_2) 30 °C



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

In view of conservation of energy, it is decided to reduce the existing heat loss to a half. To achieve this, an additional layer of more effective insulation material will be installed at the outer surface of existing wall.

Given that the thermal conductivity of existing insulation material and the temperature at wall surface of high temperature side un-changed, the thermal conductivity of the additional insulation material (λ_2) 0.10 kcal/m hr ^oC, the film heat transfer coef. at the outer or cold surface of it similar to the existing one, what is the thickness (b_2) of the additional insulation wall?



Solution

Let the heat loss of the existing insulation wall be Q_1 kcal/m^2 hr,

$$Q_1 = \frac{600 - 30}{\frac{1}{h_2} + \frac{b_1}{\lambda_1}} = \frac{570}{\frac{1}{10} + \frac{0.20}{0.20}} = 518.2 \text{ kcal/m}^2 \text{ hr}$$

Let the heat loss after comletion of additional insulation wall be Q_2 kcal/m^2 hr,

$$Q_2 = \frac{600 - 30}{0.1 + 1.0 + b_2/0.1}$$

$$= \frac{570}{1.1 + 10 \times b_2} = \frac{Q_1}{2} = 259.1 \text{ kcal/m}^2 \text{ hr}$$

Solving above equation

b_2 = 0.11 m

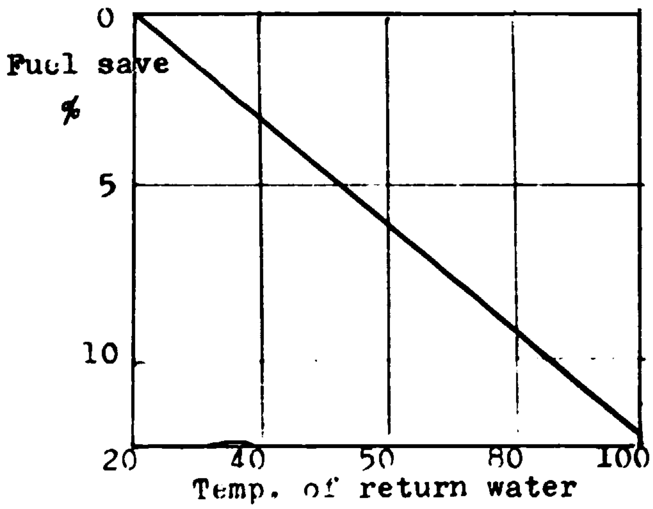
2.3.5 Effects of the condensate recovery

The thermal energy contained in the generated steam would be consisting of a latent heat of about 80 % of total heat content of steam and a sensible heat of about 20 % of total heat content of steam involving in condensate.

If the sensible heat of condensate completely would be recovered as boiler feed water, the fuel saving of about 20 % might be expected in calculation.

The values of latent and sensible heat of steam are presented at appendix 1 Steam tables.

When the condensate is recovered as the thermal source of feed water to boiler, a amount of fuel fed to boiler would be reduced by the same heat value as the recovered heat by the condensate.



Condition;
Temp. of initial supplied water 20 °C
Steam pressure 10ata
Steam temp. 179 °C

Figure 2.3-1 The ratio of fuel saving by conensate recovery

A few examples of the condensate recoery systems would be shown as belows ;

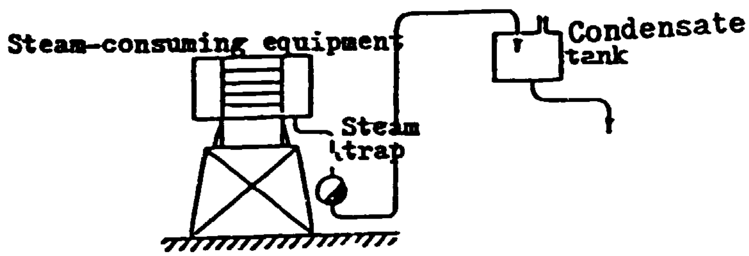


Figure 2.3-2 Open recovery system with only steam trap

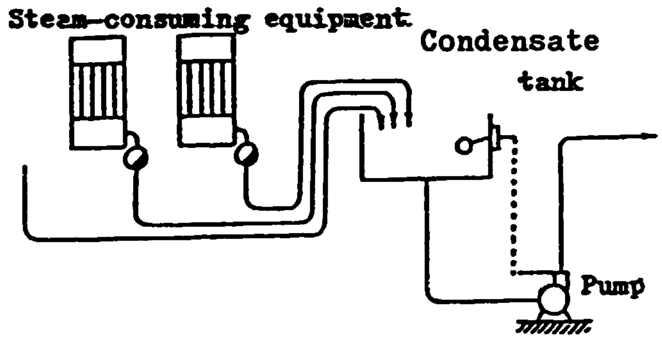


Figure 2.3-3 Open recovery system with trap and pump

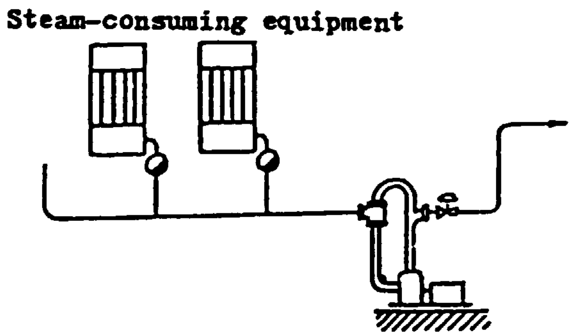


Figure 2.3-4 Closed recovery system with steam trap and Condensate recovery pump

Example 2.3-6

Some boiler up to the present has been operated without to completely recover the condensate flowing from the steam consuming facilities with following condition ;

Boiler efficiency 85 %

Temp. of steam 179 °C

Fuel consumption rate 400 kg F/hr

In order to develpe the energy conservation activitis, the adaption of the condensate recovery system has been considered. The main specification on the condensate recovery systems are as follows ;

Recovery ratio ; 90 %

Temp. of return water to boiler ; 80 °C

Allowable pay back year in finance; 1.5 years

(1) How much is the saving fuel by this improvement per year?

(2) How much is allowable on the investment of the condensate recovery system.

Solution

Heat consumed on generating steam

$$Q = 10,700 \times 0.85 = 9,095 \text{ kcal/kg F}$$

Required heat for steam at 179 °C from water at 30 °C

$$S = 660 - 30 = 630 \text{ kcal/kg steam}$$

Steam ratio

$$Q/S = 9,095/630 = 14.43 \text{ kg steam/kg F}$$

amount of recovered condensate

$$14.43 \times 0.9 = 13.0 \text{ kg condensate}$$

Recovered heat by recovered condensate

$$13.0 \times 1 \times (80 - 30) = 650 \text{ kcal/kg F}$$

Annualy recovered heat

650 x 400 x 16 x 330 = 1,372,800,000 kcal/year

Annualy saved fuel cost

1,372,800,000 x 0.05/1,000 = 68,640 M$/year

Allowable investment cost for condensate recovery system

68,640 x 1.5 = 102,960 M$

End of example

When the condensate under high temp.and pressure is is opened into the low pressure zone, a part of condensate generate a lower flash steam. The resultant flash steam can be used at alternative place as steam.

The relation of pressure after and before flash is shown as belows ;

Pressure before flash (kg/cm²G) \ Pressure after flash (kg/cm²G)	0	0.3	0.5	1.0	1.5	2	3	4	5
1	3.7	2.5	1.7	–	–	–	–	–	–
2	6.2	5.0	4.2	2.6	1.2	–	–	–	–
3	8.1	6.9	6.1	4.5	3.2	2.0	–	–	–
4	9.7	8.5	7.7	6.1	4.8	3.6	1.6	–	–
5	11.0	9.8	9.1	7.5	6.2	5.0	3.1	1.4	–
6	12.2	11.0	10.3	8.7	7.4	6.2	4.3	3.0	1.3
8	14.2	13.1	12.3	10.8	9.5	8.3	6.4	4.8	3.4
10	15.9	14.8	14.2	12.5	11.2	10.1	8.2	6.6	5.3
12	17.4	16.3	15.5	14.0	12.7	11.6	9.8	8.2	6.9
14	18.7	17.6	16.9	15.4	14.1	13.0	11.2	9.6	8.3
16	19.0	18.8	18.1	16.6	15.3	14.3	12.4	10.9	9.6

Table 2.3-1 Amount of flash steam (wt. %)

2.3.6 Effects of inner pressure control in furnace

When the pressure in furnace is in the plus side and too higher than ambient pressure, resultant flame causes heat loss. When the pressure in furnace is in the minus side, the cold air outside the furnace enter into the furnace and cools down the inside of the furnace, which results in heterogeneity of temperature pattern. The opening hole of the furnace wall should be as small as possible and , at the same time, the furnace pressure around the opening hole should be held at about ± 0 mmH_2O

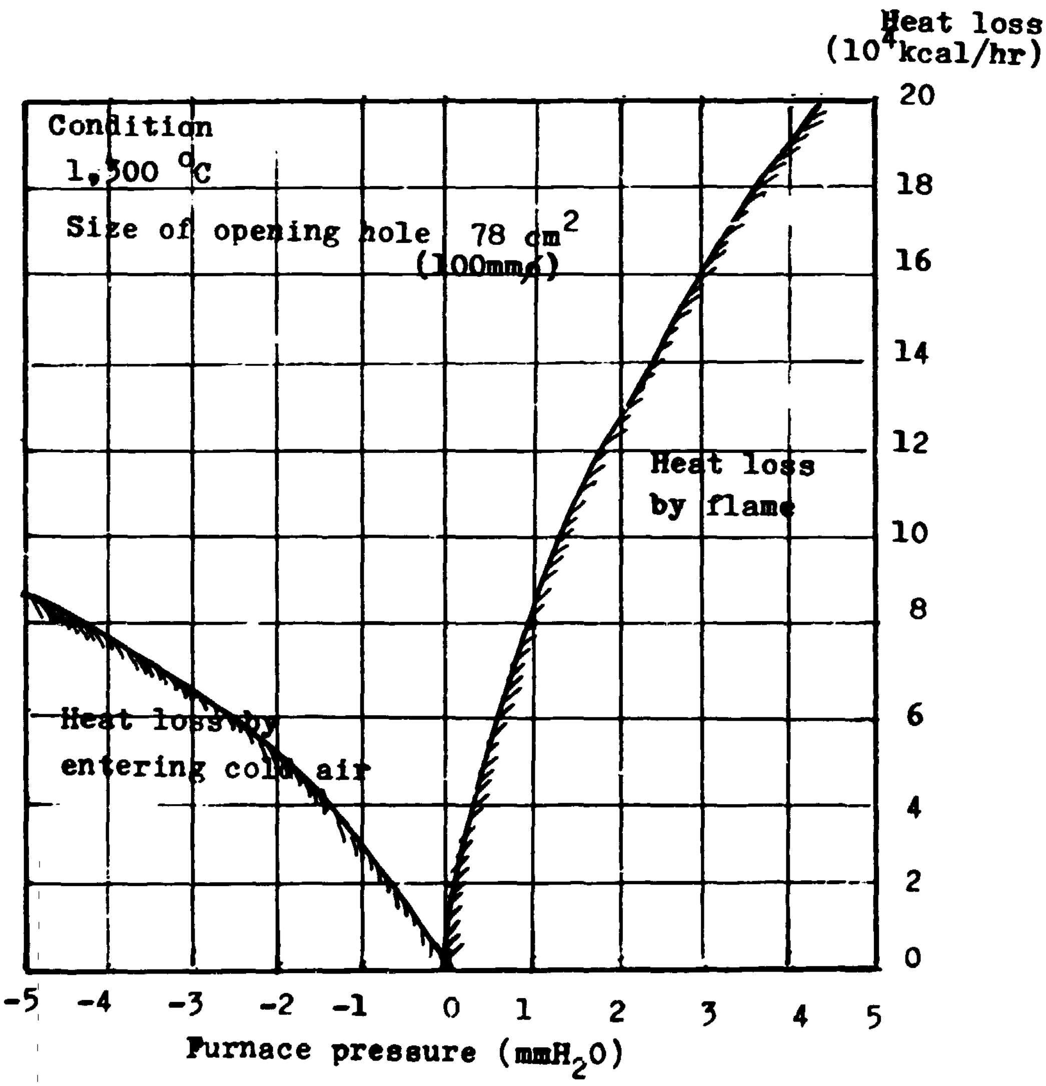


Figure 2.3-5 Heat loss around opening hole

Annualy recovered heat

650 x 400 x 16 x 330 = 1,372,800,000 kcal/year

Annualy saved fuel cost

1,372,800,000 x 0.05/1,000 = 68,640 M$/year

Allowable investment cost for condensate recovery system

68,640 x 1.5 = 102,960 M$

End of example

When the condensate under high temp.and pressure is is opened into the low pressure zone, a part of condensate generate a lower flash steam. The resultant flash steam can be used at alternative place as steam.

The relation of pressure after and before flash is shown as belows ;

kg/cm²G \ kg/cm²G		Pressure after flash								
		0	0.3	0.5	1.0	1.[illegible]	2	3	4	5
Pressure before flash	1	3.7	[illegible]	1.7	–	–	–	–	–	–
	2	6.2	5.0	4.2	2.6	1.2	[illegible]	..	–	–
	3	[illegible]	6.9	6.1	4.5	3.2	1.6	–	–	–
	4	[illegible]	8.5	7.7	6.1	4.8	3.6	1.6	–	–
	5	11.0	9.8	9.1	7.5	6.2	5.0	[illegible]	1.4	–
	[illegible]	12.2	11.0	10.3	8.7	7.4	6.2	4.3	3.0	1.3
	8	14.2	13.1	12.3	10.8	9.5	8.3	6.4	[illegible]	3.4
	10	15.9	14.8	14.2	12.5	11.2	10.1	8.2	6.	5.3
	12	17.4	16.3	15.5	14.0	12.7	11.6	9.8	8.2	6.9
	14	18.7	17.6	16.9	15.4	14.1	13.0	11.2	9.6	[illegible]
	16	19.0	18.8	18.1	16.6	15.3	14.3	12.4	10.9	9.6

Table 2.3-1 Amount of flash steam (wt. %)

Appendix 1 Steam table (pressure base)

(the socisty of mech. eng. Japan)

Pressure at p	Pressure mmHg	Temp. °C t	Specific Volume m³/kg v'	Specific Volume m³/kg v''	Spec. Weight kg/m³ $1/v''$	Specific Enthalpy kcal/kg h'	Specific Enthalpy kcal/kg h''	Specific Enthalpy kcal/kg r	Pressure at p
0.010	7.4	6.699	0.00100006	131.62401	0.0075974	6.722	600.42	593.70	0.010
0.015	11.0	12.737	0.00100052	89.6244	0.011158	12.770	603.07	590.30	0.015
0.020	14.7	17.204	0.00100119	68.2556	0.014651	17.236	605.02	587.78	0.020
0.025	18.4	20.779	0.00100189	55.2671	0.018094	20.808	606.57	585.77	0.025
0.030	22.1	23.775	0.00100258	46.5177	0.021497	23.800	607.88	584.08	0.030
0.035	25.7	26.362	0.00100325	40.2134	0.024867	26.383	609.00	582.62	0.035
0.040	29.4	28.645	0.00100390	35.4496	0.028209	28.662	609.99	581.33	0.040
0.045	33.1	30.69	0.00100452	31.7199	0.031526	30.705	610.87	580.17	0.045
0.050	36.8	32.55	0.00100511	28.7184	0.034821	32.560	611.68	579.12	0.050
0.055	40.5	34.25	0.00100569	26.2495	0.038096	34.260	612.41	578.15	0.055
0.060	44.1	35.83	0.00100625	24.1820	0.041353	35.831	613.09	577.26	0.060
0.065	47.8	37.29	0.00100677	22.4247	0.044594	37.292	613.72	576.42	0.065
0.070	51.5	38.66	0.00100729	20.9122	0.047819	38.659	614.30	575.64	0.070
0.075	55.2	39.95	0.00100779	19.5962	0.051030	39.944	614.85	574.91	0.075
0.080	58.8	41.16	0.00100827	18.4405	0.054228	41.158	615.37	574.22	0.080
0.085	62.5	42.32	0.00100873	17.4173	0.057414	42.307	615.87	573.56	0.085
0.090	66.2	43.41	0.00100919	16.5048	0.060588	43.400	616.33	572.93	0.090
0.095	69.9	44.45	0.00100963	15.6859	0.063752	44.442	616.78	572.34	0.095
0.10	73.6	45.45	0.00101006	14.9467	0.066904	45.438	617.20	571.76	0.10
0.11	80.9	47.32	0.00101089	13.6647	0.073181	47.307	618.00	570.69	0.11
0.12	88.3	49.05	0.00101167	12.5910	0.079422	49.035	618.73	569.69	0.12
0.13	95.6	50.67	0.00101242	11.6781	0.085630	50.645	619.41	568.77	0.13
0.14	103.0	52.17	0.00101314	10.8923	0.091808	52.152	620.05	567.89	0.14
0.15	110.3	53.59	0.00101384	10.2084	0.097958	53.569	620.64	567.07	0.15
0.16	117.7	54.93	0.00101451	9.60776	0.10408	54.908	621.20	566.30	0.16
0.17	125.0	56.20	0.00101515	9.07588	0.11018	56.177	621.74	565.56	0.17
0.18	132.4	57.41	0.00101577	8.60149	0.11626	57.385	622.24	564.86	0.18
0.19	139.8	58.56	0.00101638	8.17568	0.12231	58.536	622.72	564.18	0.19
0.20	147.1	59.66	0.00101696	7.79127	0.12835	59.637	623.18	563.54	0.20
0.21	154.5	60.72	0.00101753	7.44247	0.13436	60.692	623.62	562.92	0.21
0.22	161.8	61.73	0.00101808	7.12450	0.14036	61.706	624.04	562.33	0.22
0.23	169.2	62.71	0.00101862	6.83340	0.14634	62.681	624.44	561.76	0.23
0.24	176.5	63.65	0.00101915	6.56588	0.15230	63.621	624.83	561.21	0.24
0.25	183.9	64.56	0.00101966	6.31916	0.15825	64.528	625.20	560.67	0.25
0.26	191.2	65.43	0.00102016	6.09088	0.16418	65.405	625.56	560.16	0.26
0.27	198.6	66.28	0.00102065	5.87903	0.17010	66.254	625.91	559.66	0.27
0.28	206.0	67.10	0.00102112	5.68183	0.17600	67.076	626.25	559.17	0.28
0.29	213.3	67.90	0.00102159	5.49795	0.18189	67.875	626.57	558.70	0.29
0.30	220.7	68.68	0.00102206	5.32592	0.18776	68.650	626.89	558.24	0.30
0.31	228.0	69.43	0.00102250	5.16466	0.19362	69.404	627.20	557.79	0.31
0.32	235.4	70.16	0.00102294	5.01320	0.19947	70.138	627.50	557.36	0.32
0.33	242.7	70.88	0.00102337	4.87065	0.20531	70.852	627.79	556.93	0.33
0.34	250.1	71.57	0.00102380	4.73624	0.21114	71.549	628.07	556.52	0.34
0.35	257.4	72.25	0.00102422	4.60929	0.21695	72.228	628.34	556.11	0.35
0.36	264.8	72.91	0.00102463	4.48919	0.22276	72.892	628.61	555.72	0.36
0.37	272.2	73.56	0.00102504	4.37538	0.22855	73.540	628.87	555.33	0.37
0.38	279.5	74.19	0.00102543	4.26739	0.23434	74.174	629.13	554.95	0.38
0.39	286.9	74.81	0.00102582	4.16478	0.24011	74.793	629.38	554.58	0.39
0.40	294.2	75.42	0.00102621	4.06715	0.24587	75.400	629.62	554.22	0.40
0.41	301.6	76.01	0.00102659	3.97413	0.25163	75.994	629.86	553.86	0.41
0.42	308.9	76.59	0.00102696	3.88542	0.25737	76.576	630.09	553.51	0.42
0.43	316.3	77.16	0.00102732	3.80071	0.26311	77.146	630.32	553.17	0.43
0.44	323.6	77.72	0.00102769	3.71973	0.26884	77.706	630.54	552.84	0.44
0.45	331.0	78.27	0.00102805	3.64225	0.27456	78.255	630.76	552.51	0.45
0.46	338.4	78.80	0.00102840	3.56804	0.28027	78.794	630.97	552.18	0.46
0.47	345.7	79.33	0.00102875	3.49688	0.28597	79.323	631.18	551.86	0.47
0.48	353.1	79.85	0.00102909	3.42861	0.29166	79.842	631.39	551.55	0.48
0.49	360.4	80.36	0.00102943	3.36304	0.29735	80.353	631.59	551.24	0.49
0.50	367.8	80.86	0.00102976	3.30001	0.30303	80.855	631.79	550.94	0.50
0.52	382.5	81.84	0.00103042	3.18101	0.31437	81.835	632.18	550.34	0.52
0.54	397.2	82.78	0.00103106	3.07056	0.32567	82.784	632.55	549.77	0.54
0.56	411.9	83.70	0.00103169	2.96777	0.33695	83.704	632.91	549.21	0.56
0.58	426.6	84.59	0.00103231	2.87185	0.34821	84.597	633.26	548.66	0.58
0.60	441.3	85.45	0.00103291	2.78214	0.35944	85.465	633.60	548.13	0.60
0.62	456.0	86.29	0.00103350	2.69804	0.37064	86.309	633.93	547.62	0.62
0.64	470.8	87.11	0.00103407	2.61904	0.38182	87.131	634.24	547.11	0.64
0.66	485.5	87.91	0.00103464	2.54469	0.39298	87.931	634.55	546.62	0.66
0.68	500.2	88.69	0.00103520	2.47457	0.40411	88.712	634.86	546.14	0.68
0.70	514.9	89.45	0.00103574	2.40834	0.41522	89.474	635.15	545.68	0.70
0.72	529.6	90.19	0.00103628	2.34567	0.42632	90.218	635.43	545.22	0.72
0.74	544.3	90.91	0.00103681	2.28629	0.43739	90.945	635.71	544.77	0.74
0.76	559.0	91.62	0.00103733	2.22994	0.44844	91.657	635.98	544.33	0.76
0.78	573.7	92.31	0.00103784	2.17639	0.45948	92.353	636.25	543.90	0.78
0.80	588.4	92.99	0.00103834	2.12544	0.47049	93.034	636.51	543.48	0.80
0.82	603.2	93.65	0.00103883	2.07689	0.48149	93.701	636.76	543.06	0.82
0.84	617.9	94.20	0.00103933	2.03059	0.49247	94.355	637.01	542.65	0.84
0.86	632.6	94.94	0.00103980	1.98637	0.50343	94.997	637.25	542.25	0.86
0.88	647.3	95.56	0.00104028	1.94410	0.51438	95.626	637.49	541.86	0.88

Pressure		Temp.	Specific Volume		Spec. Weight	Specific Enthalpy			Pressure
at	mmHg	°C	m³/kg		kg/m³	kcal/kg			at
p		t	v'	v''	1/v''	h'	h''	r	p
0.90	662.0	96.18	0.00104074	1.90365	0.52531	96.244	637.72	541.48	0.90
0.92	676.7	96.78	0.00104120	1.86490	0.53622	96.850	637.95	541.10	0.92
0.94	691.4	97.37	0.00104166	1.82776	0.54712	97.446	638.17	540.72	0.94
0.96	706.1	97.95	0.00104211	1.79211	0.55800	98.031	638.39	540.36	0.96
0.98	720.8	98.53	0.00104255	1.75787	0.56887	98.606	638.60	540.00	0.98
1.00	735.6	99.09	0.00104299	1.72495	0.57973	99.172	638.81	539.64	1.00
1.03323	760.0	100.00	0.0010437[illegible]	1.67300	0.59773	100.092	639.15	539.06	1.03323
1.05	772.3	100.45	0.00104406	1.64799	0.60680	100.547	639.32	539.77	1.05
1.10	809.1	101.76	0.00104510	1.57780	0.63379	101.869	639.81	537.94	1.10
1.15	845.9	103.03	0.00104611	1.51353	0.66071	103.143	640.27	537.13	1.15
1.20	882.7	104.25	0.00104710	1.454[illegible]5	0.68754	104.373	640.72	536.35	1.20
1.25	919.4	105.42	0.00104805	1.39995	0.7143[illegible]	105.561	641.15	535.59	1.25
1.30	956.2	106.56	0.00104899	1.34952	0.74101	106.711	641.57	534.86	1.30
1.35	993.0	107.67	0.00104991	1.30270	0.76764	107.826	641.97	534.14	1.35
1.40	1029.8	108.74	0.00105080	1.25912	0.79421	108.907	642.35	533.45	1.40
1.45	1066.6	109.78	0.00105167	1.21845	0.82072	109.958	642.73	532.77	1.45
1.50	1103.3	110.79	0.00105253	1.18041	0.84717	110.980	643.09	532.11	1.50
1.55	1140.1	111.77	0.00105337	1.14474	0.87356	111.974	643.44	531.46	1.55
1.60	1176.9	112.73	0.00105419	1.11123	0.89990	112.943	643.78	530.84	1.60
1.65	1213.7	113.66	0.00105500	1.07969	0.92619	113.887	644.11	530.22	1.65
1.70	1250.5	114.57	0.00105579	1.04994	0.95243	114.809	644.43	529.62	1.70
1.75	1287.2	115.46	0.00105657	1.02184	0.97863	115.709	644.74	529.03	1.75
1.80	1324.0	116.33	0.00105734	0.995249	1.0048	116.588	645.04	528.45	1.80
1.85	1360.8	117.18	0.00105809	0.970050	1.0309	117.448	645.34	527.89	1.85
1.90	1397.6	118.01	0.00105883	0.946134	1.0569	118.290	645.62	527.33	1.90
1.95	1434.[illegible]	118.82	0.00105956	0.923405	1.0829	119.114	645.90	526.79	1.95
2.00	1471.1	119.61	0.00106028	0.901776	1.1089	119.921	646.18	526.26	2.00
2.05	1507.9	120.39	0.00106099	0.881167	1.1349	120.712	646.44	525.73	2.05
2.10	1544.7	121.16	0.00106169	0.861508	1.1608	121.487	646.70	525.22	2.10
2.15	1581.5	121.91	0.00106237	0.842733	1.1866	122.248	645.96	524.71	2.15
2.20	1618.2	122.64	0.00106305	0.824784	1.2124	122.995	647.20	524.21	2.20
2.25	1655.0	123.36	0.00106372	0.807606	1.2382	123.728	647.45	523.72	2.25
2.30	1691.8	124.07	0.00106438	0.791151	1.2640	124.449	647.69	523.24	2.30
2.35	1728.6	124.77	0.00106503	0.775373	1.2897	125.157	647.92	522.76	2.35
2.40	1765.3	125.45	0.00106567	0.760230	1.3154	125.853	648.15	522.29	2.40
2.45	1802.1	126.13	0.00106630	0.745686	1.3410	126.537	648.37	521.83	2.45
2.50	1838.9	126.79	0.00106693	0.731704	1.3667	127.211	648.59	521.38	2.50
2.55	1675.7	127.44	0.00106756	0.718252	1.3923	127.874	648.80	520.93	2.55
2.60	1912.5	128.08	0.00106817	0.705300	1.4178	128.527	649.01	520.49	2.60
2.65	1949.2	128.71	0.00106877	0.692821	1.4434	129.169	649.22	520.05	2.65
2.70	1986.0	129.33	0.00106937	0.680789	1.4689	129.802	649.42	519.62	2.70
2.75	2022.8	129.94	0.00106996	0.669180	1.4944	130.426	649.62	519.19	2.75
2.80	2059.6	130.55	0.00107055	0.657972	1.5198	131.041	649.82	518.77	2.80
2.85	2096.3	131.14	0.00107113	0.647143	1.5453	131.647	650.01	518.36	2.85
2.90	2133.1	131.73	0.00107171	0.636676	1.5707	132.245	650.20	517.95	2.90
2.95	2169.9	132.31	0.00107227	0.626552	1.5960	132.835	650.38	517.55	2.95
3.00	2206.7	132.88	0.00107284	0.616754	1.6214	133.417	650.56	517.15	3.00
3.10	2280.2	133.99	0.00107395	0.598074	1.6720	134.558	650.92	516.36	3.10
3.20	2353.8	135.08	0.00107504	0.580523	1.7226	135.670	651.26	515.59	3.20
3.30	2427.3	136.14	0.00107610	0.564001	1.7730	136.755	651.59	514.84	3.30
3.40	2500.9	137.18	0.00107716	0.548419	1.8234	137.815	651.91	514.10	3.40
3.50	2574.5	138.19	0.00107819	0.533697	1.8737	138.850	652.23	513.38	3.50
3.60	2648.0	139.18	0.00107921	0.519766	1.9239	139.862	652.53	512.67	3.60
3.70	2721.6	140.14	0.00108021	0.506563	1.9741	140.852	652.83	511.97	3.70
3.80	2795.1	141.09	0.00108119	0.494031	2.0242	141.821	653.11	511.29	3.80
3.90	2868.7	142.01	0.00108216	0.482120	2.0742	142.771	653.39	510.62	3.90
4.00	2942.2	142.92	0.00108312	0.470785	2.1241	143.702	653.66	509.96	4.00
4.10	3015.8	143.81	0.00108406	0.459984	2.1740	144.614	653.93	509.31	4.10
4.20	3089.3	144.68	0.00108499	0.449680	2.2238	145.510	654.18	508.67	4.20
4.30	3162.9	145.54	0.00108591	0.439840	2.2736	146.389	654.43	508.05	4.30
4.40	3236.5	146.37	0.00108681	0.430431	2.3233	147.252	654.68	507.43	4.40
4.50	3310.0	147.20	0.00108770	0.421426	2.3729	148.100	654.92	506.82	4.50
4.60	3383.6	148.01	0.00108859	0.412800	2.4225	148.933	655.15	506.22	4.60
4.70	3457.1	148.80	0.00108946	0.404528	2.4720	149.752	655.38	505.63	4.70
4.80	3530.7	149.58	0.00109032	0.396589	2.5215	150.558	655.60	505.04	4.80
4.90	3604.2	150.35	0.00109117	0.388963	2.5709	151.351	655.82	504.47	4.90
5.00	3677.8	151.11	0.00109202	0.381632	2.6203	152.131	656.03	503.90	5.00
5.20	3824.9	152.59	0.00109367	0.367786	2.7190	153.657	656.44	502.79	5.20
5.40	3972.0	154.02	0.00109529	0.354932	2.8174	155.137	656.84	501.70	5.40
5.60	4119.1	155.41	0.00109688	0.342965	2.9158	156.576	657.22	500.64	5.60
5.80	4266.2	156.76	0.00109844	0.331795	3.0139	157.975	657.58	499.60	5.80
6.00	4413.4	158.08	0.00109997	0.321345	3.1119	159.338	657.93	498.59	6.00
6.20	4560.5	159.36	0.00110147	0.311546	3.2098	160.666	658.27	497.60	6.20
6.40	4707.6	160.60	0.00110295	0.307338	3.3076	161.962	658.59	496.63	6.40
6.60	4854.7	161.82	0.00110439	0.293669	3.4052	163.227	658.90	495.67	6.60
6.80	5001.8	163.01	0.00110582	0.285493	3.5027	164.463	659.20	494.74	6.80

Pressure	Temp	Specific Volume		Spec. Weight	Specific Enthalpy			Pressure
at	°C	m³/kg		kg/m³	kcal/kg			at
p	t	v'	v''	$1/v''$	h'	h''	r	p
7.00	164.17	0.00110723	0.277768	3.6001	165.672	659.49	493.82	7.00
7.20	165.30	0.00110861	0.270458	3.6974	166.854	659.77	492.92	7.20
7.40	166.01	0.00110997	0.263528	3.7947	168.012	660.05	492.03	7.40
7.60	167.50	0.00111132	0.256952	3.8918	169.146	660.31	491.16	7.60
7.80	168.56	0.00111265	0.250700	3.9888	170.257	660.56	490.30	7.80
8.00	169.61	0.00111396	0.244751	4.0858	171.347	660.81	489.46	8.00
8.20	170.63	0.00111525	0.239081	4.1827	172.417	661.05	488.63	8.20
8.40	171.63	0.00111653	0.233672	4.2795	173.467	661.28	487.81	8.40
8.60	172.62	0.00111779	0.228506	4.3762	174.498	661.50	487.00	8.60
8.80	173.58	0.00111903	0.223567	4.4729	175.511	661.72	486.21	8.80
9.00	174.53	0.00112026	0.218840	4.5696	176.508	661.93	485.42	9.00
9.20	175.46	0.00112148	0.214311	4.6661	177.487	662.14	484.65	9.20
9.40	176.38	0.00112268	0.209968	4.7626	178.451	662.34	483.88	9.40
9.60	177.28	0.00112388	0.205799	4.8591	179.399	662.53	483.13	9.60
9.80	178.17	0.00112505	0.201795	4.9555	180.333	662.72	482.38	9.80
10.00	179.04	0.00112622	0.197945	5.0519	181.252	662.90	481.65	10.00
10.20	179.90	0.00112738	0.194241	5.1482	182.158	663.08	480.92	10.20
10.40	180.74	0.00112852	0.190675	5.2445	183.051	663.25	480.20	10.40
10.60	181.57	0.00112966	0.187238	5.3408	183.930	663.42	479.49	10.60
10.80	182.40	0.00113078	0.183924	5.4370	184.796	663.58	478.79	10.80
11.00	183.20	0.00113189	0.180727	5.5332	185.654	663.74	478.09	11.00
11.20	184.00	0.00113299	0.177639	5.6294	186.498	663.90	477.40	11.20
11.40	184.79	0.00113409	0.174656	5.7255	187.331	664.05	476.72	11.40
11.60	185.56	0.00113518	0.171773	5.8216	188.153	664.20	476.05	11.60
11.80	186.33	0.00113625	0.168984	5.9177	188.965	664.34	475.38	11.80
12.00	187.08	0.00113732	0.166284	6.0138	189.766	664.48	474.72	12.00
12.20	187.83	0.00113838	0.163670	6.1099	190.558	664.62	474.06	12.20
12.40	188.56	0.00113943	0.161137	6.2059	191.340	664.75	473.41	12.40
12.60	189.29	0.00114048	0.158682	6.3019	192.113	664.88	472.77	12.60
12.80	190.00	0.00114151	0.156300	6.3979	192.877	665.01	472.13	12.80
13.00	190.71	0.00114254	0.153990	6.4939	193.632	665.13	471.50	13.00
13.20	191.41	0.00114356	0.151747	6.5899	194.379	665.25	470.88	13.20
13.40	192.10	0.00114457	0.149568	6.6859	195.117	665.37	470.25	13.40
13.60	192.79	0.00114558	0.147452	6.7819	195.848	665.49	469.64	13.60
13.80	193.46	0.00114658	0.145394	6.8778	196.570	665.60	469.03	13.80
14.00	194.13	0.00114757	0.143394	6.9738	197.285	665.71	468.42	14.00
14.20	194.79	0.00114855	0.141447	7.0698	197.993	665.81	467.82	14.20
14.40	195.45	0.00114954	0.139553	7.1657	198.693	665.92	467.23	14.40
14.60	196.09	0.00115051	0.137709	7.2617	199.386	666.02	466.63	14.60
14.80	196.73	0.00115148	0.135913	7.3577	200.072	666.12	466.05	14.80
15.00	197.37	0.00115244	0.134163	7.4536	200.752	666.22	465.46	15.00
15.20	197.99	0.00115339	0.132457	7.5496	201.425	666.31	464.89	15.20
15.40	198.61	0.00115435	0.130795	7.6456	202.091	666.40	464.31	15.40
15.60	199.23	0.00115529	0.129173	7.7415	202.751	666.49	463.74	15.60
15.80	199.83	0.00115623	0.127591	7.8375	203.405	666.58	463.18	15.80
16.00	200.43	0.00115717	0.126047	7.9335	204.053	666.67	462.61	16.00
16.20	201.03	0.00115810	0.124540	8.0295	204.696	666.75	462.05	16.20
16.40	201.62	0.00115903	0.123069	8.1255	205.332	666.83	461.50	16.40
16.60	202.20	0.00115994	0.121631	8.2216	205.963	666.91	460.95	16.60
16.80	202.78	0.00116086	0.120227	8.3176	206.589	666.99	460.40	16.80
17.00	203.36	0.00116177	0.118854	8.4137	207.209	667.07	459.86	17.00
17.20	203.93	0.00116268	0.117513	8.5097	207.824	667.14	459.32	17.20
17.40	204.49	0.00116358	0.116201	8.6058	208.433	667.21	458.78	17.40
17.60	205.05	0.00116447	0.114917	8.7019	209.038	667.28	458.24	17.60
17.80	205.60	0.00116537	0.113662	8.7980	209.638	667.35	457.71	17.80
18.00	206.15	0.00116625	0.112434	8.8941	210.233	667.42	457.19	18.00
18.20	206.69	0.00116714	0.111231	8.9903	210.823	667.48	456.66	18.20
18.40	207.23	0.00116802	0.110054	9.0865	211.409	667.55	456.14	18.40
18.60	207.77	0.00116890	0.108901	9.1826	211.990	667.61	455.62	18.60
18.80	208.30	0.00116977	0.107772	9.2788	212.566	667.67	455.11	18.80
19.00	208.82	0.00117064	0.106666	9.3751	213.138	667.73	454.59	19.00
19.20	209.34	0.00117151	0.105582	9.4713	213.706	667.79	454.08	19.20
19.40	209.86	0.00117237	0.104519	9.5676	214.270	667.85	453.58	19.40
19.60	210.38	0.00117323	0.103478	9.6639	214.830	667.90	453.07	19.60
19.80	210.88	0.00117408	0.102457	9.7602	215.385	667.95	452.57	19.80
20.0	211.39	0.00117493	0.101455	9.8566	215.937	668.01	452.07	20.0
20.5	212.64	0.00117705	0.0990339	10.098	217.299	668.13	450.83	20.5
21.0	213.86	0.00117914	0.0967239	10.339	218.637	668.25	449.61	21.0
21.5	215.06	0.00118122	0.0945176	10.580	219.953	668.36	448.40	21.5
22.0	216.24	0.00118327	0.0924081	10.822	221.248	668.46	447.21	22.0
22.5	217.40	0.00118531	0.0903891	11.063	222.522	668.55	446.03	22.5
23.0	218.54	0.00118733	0.0884548	11.305	223.776	668.64	444.87	23.0
23.5	219.66	0.00118934	0.0865999	11.547	225.012	668.72	443.71	23.5
24.0	220.76	0.00119133	0.0848196	11.790	226.229	668.80	442.57	24.0
24.5	221.84	0.00119330	0.0831094	12.032	227.428	668.87	441.44	24.5
25.0	222.91	0.00119526	0.0814653	12.275	228.611	668.93	440.32	25.0
25.5	223.96	0.00119720	0.0798833	12.518	229.777	668.99	439.22	25.5
26.0	224.99	0.00119913	0.0783601	12.762	230.928	669.05	438.12	26.0
26.5	226.01	0.00120106	0.0768924	13.005	232.063	669.09	437.03	26.5
27.0	227.02	0.00120296	0.0754771	13.249	233.183	669.14	435.95	27.0

Appendix 2 Overall heat transfer coefficient from solid surf'ce

T_s	60	80	100	120	140	160	200
T	30	50	70	90	110	130	170
h_c	5.2	5.8	6.3	6.8	7.0	7.4	8.0
h_r	5.6	6.4	7.1	7.8	8.4	9.2	12.0
$h = h_c + h_r$	10.8	12.2	13.4	14.6	15.4	16.6	20.0

Notes T_s ; Surface temperature

ΔT ; Temperature difference $= T_s - T_o$

h_c ; Heat trancfer coefficient regard to convection

h_r ; Heat transfer coefficient regard to radiation

h ; Overall heat transfer coefficient $= h_c - h_r$

T_o ; Ambient temperature 30 °C

Appendix 3 **Physical Properties of miscellanious materials**

Physical property	Specific gravity	Specific heat	Thermal conduct'y	Allowable Temp.
Unit	(-)	kcal/kg °C	kcal/m hr°C	C
Steel	7.85	0.11	45.	400
Cupper	8.95	0.09	320.	400
Aluminum	2.70	0.22	175.	250
Clay (Soil)	2.0	0.28	0.5	-
Red brick	1.5	0.24	0.6	400
Refractory B.	2.0	0.25	1.0	1400
Asbesto	0.5	0.20	0,05	650
Rock wool	0.20	0.20	0.04	600
Glass wool	0.20	0.16	0.04	350
Perlite	0.25	0.30	0.05	650
Ceramic fibre	0.20	0.20	0.25	1500
Polystylene	0 03	0.30	0.03	80
Rubber	1.00	0.34	0.13	150
Limber	0.3	0.60	0.09	100
Cotton	0.081	0.31	0.05	100
Wool	0.10	0.30	0.03	100
Glass	2.2	0.18	0.60	300
Concrete	2.0	0.21	1.00	200

Appendix 4 Standard criteria presented in Japanese acts for the energy conservation

(1) Standard air ratio m

(A) Boilers

Item		Loading Ratio %	Standard Air Ratio			
			Solid Fuel	Liquid Fuel	Gaseous Fuel	BFG or etal
For Elec. Supplier		75-100	1.2-1.3	1.05-1.1	1.05-1.1	1.2
Other Boiler	Steam Generated over 30 Ton/hr	75-100	1.2-1.3	1.1-1.2	1.1-1.2	1.3
	From 10 to 30 Ton/hr	75-100	-	1.2-1.3	1.2-1.3	-
	Under 10 Ton/hr	75-100	-	1.3	1.3	-

(B) Industrial furnaces

Item	Stand. Air Ratio
Metal Foundry Melting Furnace	1.3
Continuous Steel Slab Furnace	1.25
Metal Heating Furnace except above	1.3
Continuous Heat Treatment Furnace	1.3
Gas Producer and Gas Furnace	1.4
Petroleum Heating Furnace	1.4
Thermal Cracker and Reformer	1.3
Cement Kiln	1.3
Almina and lime incinerator	1.4
Continous Glass Melting Furnace	1.3

(2) The criteria of the surface temperature outside furnace

Temperature inside Furnace °C	Criteria of Surface Temp outside F	
	Ceiling	Side Wall
1.300	140	120
1.100	125	110
900	110	95
700	90	80

(3) The criteria of the temperature of exhaust flue gas on boilers

Item		Criteria of Waste Flue Gas Temperature			
		Solid Fuel	Liquid Fuel	Gaseous Fuel	BFG etal
for Elect. Supplier		145	145	110	200
Other Boiler	Steam Generated over 30 Ton/hr	200	200	170	200
	From 10 to 30 Ton/hr	-	200	170	-
	Under 10 Ton/hr	-	320	300	-

(4) The criteria of the temperature of exhaust flue gas and the recovery ratio

Flue Gas Temp. °C	Capacity (1)	Criteria of Recovery Ratio %	for Reference	
			Waste gas Temp °C	Preheated air Temp °C
500	A B	20	200	130
600	A B	20	290	155
700	A	30	200	260
	B	25	330	220
	C	20	370	180
800	A	30	370	300
	B	25	410	250
	C	20	450	205
900	A	35	400	385
	B	25	470	285
	C	20	530	230
1000	A	40	420	490
	B	30	520	375
	C	25	570	315
over 1000	A	40		
	B	30		
	C	25		

Note * ; A. Nominal capacity, over 20,000,000 kcal/hr

B. Nominal capacity, from 5,000,000 to 20,000,000 kcal/hr

C. Nominal capacity from 1,000,000 to 5,000,000 kcal/hr

Appendix 5 Conversion factors

(1) Length equivalents

cm	m	in	ft
1	1×10^{-2}	0.3937	0.03281
1×10^{2}	1	39.37	3.281
2.540	0.02540	1	0.08333
30.48	0.3048	12.000	1
30.30	0.3030	11.930	0.9942

1 mile = 80 chain = 1760 yard = 5280 ft

(2) Area equivalents

cm^2	m^2	in^2	ft^2
1	1×10^{-4}	0.15500	0.0010764
1×10^{4}	1	1550.0	10.764
6.452	6.452×10^{-4}	1	0.006944
929.0	0.09290	144.00	1
918.3	0.09183	142.33	0.9884

(3) Volume equivalents

dm^3(lit)	m^3(kl)	ft^3	I gal	US gal
1	1×10^{-3}	0.03531	0.2200	0.2642
1×10^{3}	1	35.31	220.0	264.2
28.32	0.02832	1	6.229	7.480
4.546	0.004546	0.16054	1	1.2010
3.785	0.003785	0.13368	0.8327	1
180.39	0.18039	6.370	39.68	47.65
27.83	0.02783	0.9827	6.121	7.351

(4) Mass equivalents

Kg.	Grains	Ounces		Pounds		Tons			Grams
		Troy and apoth.	Avdp.	Troy and apoth.	Avdp.	Short	Long	Metric	
1	15,432	32.15	35.27	2.6792	2.205	0.001102	[illegible]	0.001	1,000.0
[illegible]	1	0.002083	0.002286	0.000174	0.0001429	0.07143	[illegible]	[illegible]	0.0648
0.03110	480	1	1.09714	0.08333	0.06857	0.03429	0.03061	0.03110	31.1
0.02835	437.5	0.9115	1	0.07595	0.0625	0.03125	0.02790	0.02835	28.35
0.3732	5,760	12	13.17	1	0.8229	0.04114	0.03673	0.03732	373.2
0.4536	7,000	14.58	16	1.215	1	0.0005	0.04464	0.04536	453.59
907.2	14,000	29,167	32,000	2,431	2,000	1	0.8929	0.9072	907,184
1,016	15,680,000	32,667	35,840	2,722	2,240	1.12	1	1.016	1,016,047
1,000	15,432,356	32,151	35,274	2,679	2,205	1.102	0.9842	1	1,000,000
0.001	15.432	0.03215	0.03527	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1

(5) Density equivalents

G. per cu. cm	Kg. per cu. m.	Lb. per cu. in.	Lb. per cu. ft.	Lb. per cu. yd.	Lb. per U.S. gal.	Tons (2000 lb.) per cu. yard	Tons (2240 lb.) per cu. yard	Tons (metric) per cu. m.
1	1,000	0.03613	62.43	1,686	8.345	0.8428	0.7525	1.000
0.001	1	0.00003613	0.06243	1.686	0.008345	0.8428×10^{-3}	0.7525×10^{-3}	0.001
27.68	27,680	1	1,728	46,656	231	23.33	20.83	27.68
0.01602	16.02	0.0005787	1	27	0.1337	0.01350	0.012054	0.01602
0.000593	0.5933	0.00002143	0.03704	1	0.004951	0.0005	0.0004464	0.000593
0.1198	119.8	0.004329	7.481	202.0	1	0.1010	0.09017	0.1198
1.187	1,187	0.04287	74.07	2,000	9.902	1	0.8929	1.187
1.329	1,329	0.0481	82.96	2,240	11.09	1.12	1	1.329

(6) Pressure equivalents

Mdyne/cm² (bar)	kg/cm²	lb/in²	atm	Hg (0°C) m	Hg (0°C) in	Water (15°C) m	Water (15°C) in
1	1.0204	14.514	0.9869	0.7506	29.55	10.213	402.1
0.9800	1	14.223	0.9672	0.7355	28.96	10.009	394.0
0.06890	0.07031	1	0.06800	0.05171	2.036	0.7037	27.70
1.0133	1.0340	14.706	1	0.7605	29.94	10.349	407.4
1.3324	1.3595	19.337	1.3149	1	39.37	13.607	535.8
0.03384	0.03453	0.4912	0.03340	0.02540	1	0.3456	13.607
0.09791	0.09991	1.4211	0.09663	0.07349	2.893	1	39.37
0.002487	0.002538	0.03610	0.0024564	0.0018666	0.07349	0.02540	1

(7) Flow rate equivalents

lit/sec	m³/hr	m³/sec	I. gal/min	US. gal/min	ft³/hr	ft³/sec
1	3.6	0.001	13.198	15.850	127.13	0.03531
0.2778	1	2.778×10^{-4}	3.666	4.403	35.31	9.810×10^{-3}
1000	3600	1	1.3198×10^{4}	1.5850×10^{4}	1.2713×10^{5}	35.31
0.07578	0.2728	7.577×10^{-5}	1	1.2010	9.632	0.002676
0.06309	0.2271	6.309×10^{-5}	0.8327	1	8.021	0.002228
7.866×10^{-3}	0.02832	7.866×10^{-6}	0.10381	0.12468	1	2.778×10^{-4}
28.32	101.94	0.02832	373.7	448.8	3600	1

(8) Force or weight equivalents

gr	dyne	kg	lb	poundal
1	980.0	1×10^{-3}	0.002205	0.07088
1.0204×10^{-3}	1	1.0204×10^{-6}	2.250×10^{-6}	7.233×10^{-5}
1×10^{3}	9.8×10^{5}	1	2.205	70.88
453.6	4.445×10^{5}	0.4536	1	32.15
14.108	1.3825×10^{4}	0.014108	0.03110	1

(9) Energy, work or heat calorie equivalents

Joule $=10^7$ erg	kg-m	ft-lb	kW-hr	PS-hr	HP-hr	lit-atm	kcal	B.t.u.
1	0.10204	0.7381	2.778×10^{-7}	3.777×10^{-7}	3.725×10^{-7}	9.869×10^{-3}	2.389×10^{-4}	9.480×10^{-4}
9.800	1	7.233	2.723×10^{-6}	3.704×10^{-6}	3.651×10^{-6}	9.672×10^{-2}	2.341×10^{-3}	9.291×10^{-3}
1.3549	0.13826	1	3.764×10^{-7}	5.117×10^{-7}	5.047×10^{-7}	0.013371	3.237×10^{-4}	1.2845×10^{-3}
3.6×10^6	3.673×10^5	2.657×10^6	1	1.3596	1.3410	3.553×10^4	860.0	3413
2.648×10^6	2.702×10^5	1.9540×10^6	0.7355	1	0.9863	2.613×10^4	632.5	2510
2.685×10^6	2.739×10^5	1.9813×10^6	0.7457	1.0139	1	2.649×10^4	641.3	2545
101.33	10.340	74.73	2.815×10^{-5}	3.827×10^{-5}	3.774×10^{-5}	1	2.421×10^{-2}	9.606×10^{-2}
4186	427.1	3090	1.1628×10^{-3}	1.5809×10^{-3}	1.5593×10^{-3}	41.31	1	3.969
1054.8	107.63	778.5	2.930×10^{-4}	3.984×10^{-4}	3.929×10^{-4}	10.409	0.2520	1

(10) Power equivalents

kw (1000 J/sec)	kg-m/sec	ft-lb/sec	PS	HP	kcal/sec	B.t.u./sec
1	102.04	0.7381	1.3596	1.3410	0.2389	0.9480
0.009800	1	7.233	0.013324	1.3142×10^{-2}	2.341×10^{-3}	9.291×10^{-3}
1.3549×10^{-3}	0.13826	1	1.8422×10^{-3}	1.8169×10^{-3}	3.237×10^{-4}	1.2845×10^{-3}
0.7355	75.05	542.8	1	0.9863	0.17570	0.6973
0.7457	76.09	550.4	1.0139	1	0.17814	0.7070
4.186	427.1	3.000×10^3	5.691	5.613	1	3.969
1.0548	107.63	778.5	1.4341	1.4145	0.2520	1

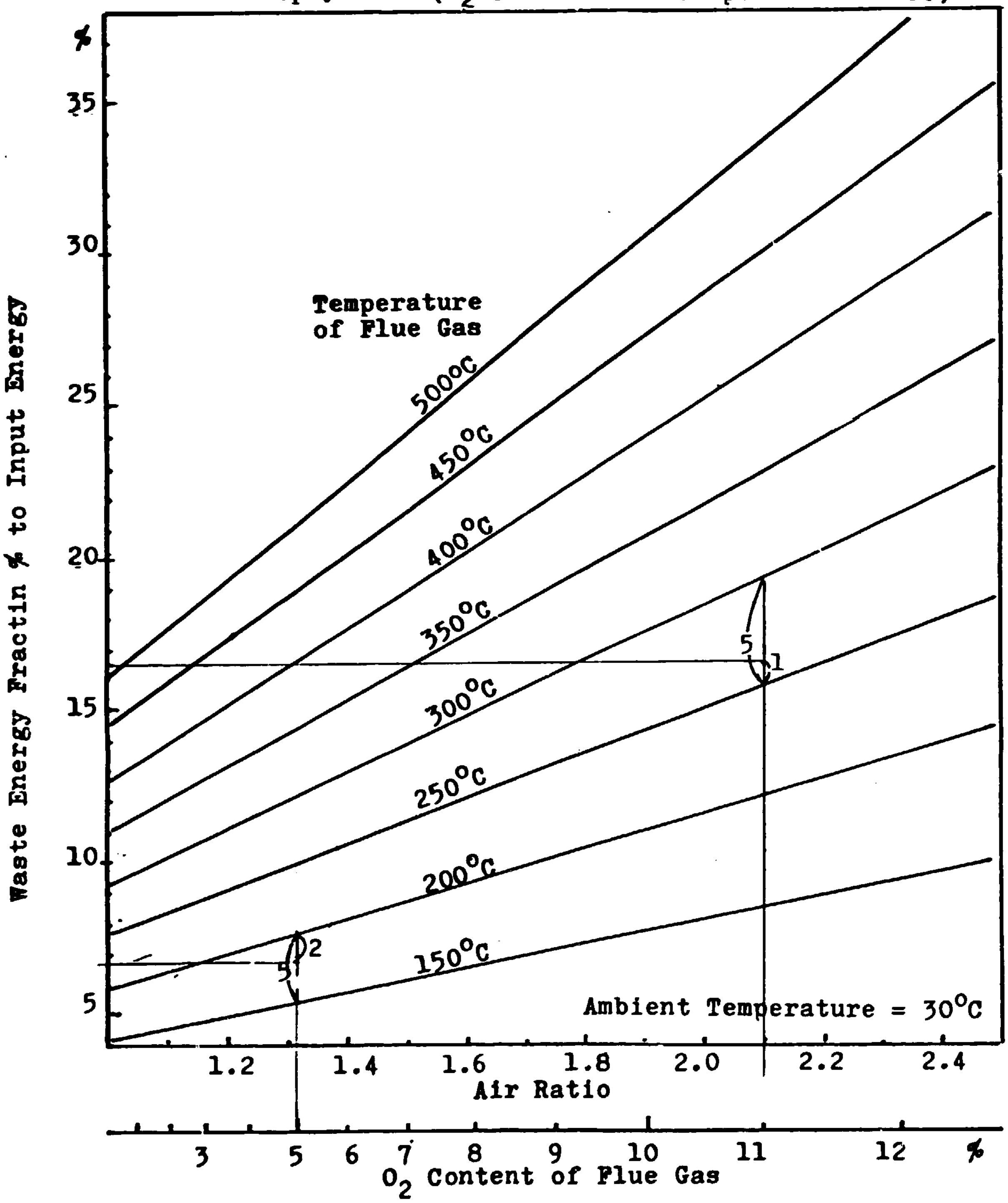
(11) Thermal conductivity

kcal/m·hr·°C	cal/cm·sec·°C	B.t.u./ft·hr·°F	B.t.u./in·hr·°F
1	0.002778	0.6720	0.05600
360	1	241.9	20.16
1.4881	0.004136	1	0.08333
17.857	0.04960	12	1

(12) Heat transfer coefficient equivalents

kcal/m²·hr·°C	cal/cm²·sec·°C	B.t.u./ft²·hr·°F
1	2.778×10^{-5}	0.2048
3.6×10^4	1	7374
4.882	1.3562×10^{-4}	1

App'x 6 Quick Evaluation Figure for Effectiveness of Improvement on Boiler Operation (O_2 Content and Temp. of Flue Gas)



Example of Usage

	O_2	Temp. of Flue Gas
Original Operation	11%	260°C
Target of Improvement	5%	180°C

How much of fuel saving with % ?

Solution Vertically, up to 260°C from 11% O_2, then holizontally crossing verticl axis. 16.5%
Similarly, 180°C from 5% O_2, then 6.8%
Saving energy with % = 16.5 - 6.8 = 9.7 %

Annex **List of Instruments for Thermal Energy Conservation**

No. of Items	Name of Instruments	Main Measuring Compornents [2)]	Specification of Instruments [1)]	Anticipated Factors for Energy Conservation Surveys from Measured Data.	Alternative Instruments
1	Heat Insulation Tester (Heat Flux Meter)	Dispersion Heat Flux from heated Surface of Facilities Kcal/m^2 hr	Range of Heat Flux ; 0 to 5,000 Kcal/m^2 hr Allowable Temp. of Sensor ; -20 to 150°C	1 Outlet fraction on Dispersion Heat Loss 2 Confirmation of effect on improvement by Insulation	Surface Thermometer (assuming empirical heat transfer coefficient)
2	Pocket Thermometer (with Sensor for Surface and rod Themocouple)	Temperature °C of heated Surface, Space or Material with proper Sensor	Range -50 to 600°C	1 Outlet fraction on Dispersion Heat Loss in case of no Heat Flux Meter 2 Heat Content of entering or leaving Fluids and Solid Materials	Other pair of Thermocouple as sensor Bimetal Thermometer with Rod-sensor
3	Portable Thermo-Indicator	Temperature °C of higher Temp. Range of Space or Material	Range 0 to 1,200°C	1 Almost same as above No. 2 Thermometer 2 Supplemental Thermometer of above.	mV Meter Other pair of Thermocouple as sensor
4-1	Portable Radiation Thermometer	Temperature °C of Surface or Mater'l to be difficult on touching of sensor, for ex., Comb'n frame high speed moving material	Range 50 to 500°C	1 Almost same as No. 2 Thermometer 2 Combustion Control by measuring Frame Temperature 3 Prompt comprehension of Temp. pattern on Equipment Surfaces	Radiation Pyrometer Optical Pyrometer Two Color Radiation Thermometer
4-2			Range 200 to 1,500°C		
5	Thermopetter	Temperature °C	Range 0 to 400°C	Quick and Easy Determination of Surface Temp. Equipment covered by Steel Plates.	
6	Portable Oxygen Meter (Galvanic Cell Type)	O_2 Content % in Flue Gas on Fuel Combustion	Range 0 to 25% O_2.	1 Fuel Combustion Control with O_2 % in Flue Gas. 2 Outlet fraction of Waste Heat Loss carried out with Flue Gas from Stack.	Orsat Chemical Analyser CO_2 Absorption Analyser Zirconium O_2 Analyser
7	Hot-wire Anemometer	Wind Linear Velocity m/sec	Range Low; 0 to 5 m/sec High; o to 50 m/sec	Flowing Gas Volume, then its Heat Content.	Orifice Flow Meter Pitot Tube Flow Meter Venturi Flow Meter
8	Digital Pressure Gauge	Ultra-fine Pressure Difference mmH_2O	Range -50 to -50mmH_2O	Energy-saving Operation by Control of inner-pressure in Furnace	Smoke Test U tube Pressure Gauge with Water Column
9	Pocket Conductivity Meter	Conductivity s/cm of boiler feed water	Range 0 to 20 ms/cm (20,000 s/cm)	1 Reviewing of Blow-down Operation. 2 Preventing unnecessary Blow-down water 3 Monitoring of Scale Compornent.	Chemical Analysis
10	Pocket PH Meter	PH of boiler feed water	Range 0 to 14 PH	1 Monitoring of Acidication of Boiler Water 2 Reviewing of Blow-down Operation	
11	Ultrasonic Audio-Visual Checker	Detection of Steam Leakage of Trap, Valve and Piping	Sensive and Easy Detecting system with Audio and Visual	Quick detection of spoiled Steam Traps and Steam Leakage of Piping Systems	Stethoscopes

Notes 1) ; Instrument with similar specification as above may be also applicable for similar surveys.

2) ; On actual measurement, the operation-manuals which are prepared by instrument supplier should be sufficiently reviewed.

3.1 Management of consumption of electric power

3.1.1 Procedures of energy saving

Essential procedures for energy saving in various factories are as follows;

(a) To grasp kind and quantity of consumed energy, monthly and in each division.

(b) To analyze the data of electric power consumed in whole factory. That of noticeable equipments and that of countermeasure for saving energy.

(c) To decide countermeasures and implementation of saving energy.

(d) Check and follow-up of result of saving energy.

(e) To train electric measurement procedure (load factor, power factor, etc.), methodology of saving enerry and information about energy consumption.

3.1.2 Technical matters for electrical energy saving

Technical subjects for electrical energy saving in factory are as follows;

(a) To prevent electric ohmic losses in equipments and distribution lines.

(b) To utilize electric power effectively for electromotive force and electric heaters of various equipments and machines.

3.1.3 Manager and partners to promote electrical energy saving in factory

Manager of saving energy must be able to do electric measurements and analysis of problems in the saving energy.

Usually he should have on the job training experience in saving energy, also cooperative partners are required in factory.

3.1.4 Management of electric power consumption

(1) The bases of electrical energy saving

(a) Always keep electrical equipments in safe place.

(b) To examine if energy is being used economicaly.

(c) Electric equipments must always be utilized at high efficiency for working.

(d) Always switch off equipments not working. Whole factory employee must cooperate.

(2) How to grasp consumption of electric power

We always have to check various kinds of items as follows;

Description	Item of checking
Grasp of the situation of electric consumption	1) Recording power consumption for every month. 2) Recording daily load and peak demand 3) Culculation of power factor of factory 4) Examination of the cause of various changes of power consumption
Understanding of the cont-ractual power system	5) Contracted power factor 6) Cost of electric charge system by electricity authority
preparation table on the right items	7) Calculation of electric power consump-tion rate (kWh/ton) of major products 8) Calcuration of the ratio of electric power to total cost

Reduction of target and carrying out	9) Reduction of target of electric power consumption rate and carrying out 10) Obtaing the information on electric energy saving

Table 3.1 To grasp various checking items for energy saving

Above checking items should be examined periodically (once a year), or be reivewed in case factory production has changed.

3.2 Electric measurement and analysis of power receiving and power distribution facilities

3.2.1 How to measure receiving facilities

Energy saving in power receiving, transformers and distribution facilities are required always to be of optimum capacities, suitable voltages, high power factor and distribution lines with the least loss.

We always have to check various kinds of items as follows;

	Items of checking	remark
General	1) Ventilation of various equipment rooms	
Facilities of power receiving and distribution	2) Optimum capacity of transformers should be identified 3) Optimum systems of distribution line should be identified 4) Contracted power should be checked	Fig. 3.1 Fig. 3.2

Voltage and and power factor	5) Rating voltage of various equipments and supply voltage must be identical 6) Power factor should be kept high	Fig. 3.3 Fig. 3.4
Phase balance	7) Current of neutral wire in 3 phases are must be as small as possible	
Indicators and measurements	8) Indicators for measurement must be calibrated and kept well maintained	
maintenance	9) Standard maintenance procedure of major equipments should be made and maintained well 10) Cleaning of equipments	

Table 3.2 Measurement and check item of power receiving system for energy saving

3.2.2 How to analyze the electrical receiving facilities

(1) How tc decide capacities of the transformers

Generally, capacity of transformer for various lots of motors and other loads are calculated by the formula below;

$$\text{Capacity of transformer} \geqq \text{conbined max. load} = \frac{\text{Total sum of mounting load} \times \text{demand factor}}{\text{diversity factor}}$$

where

$$\text{demand factor} = \frac{\text{maximum power demand (kW)}}{\text{total rated output of load facilities (kW)}} < 1$$

$$\text{diversity factor} = \frac{\text{sum of max. power demand of individual loads (kW)}}{\text{max. power demand of whole system's loads (kW)}} > 1$$

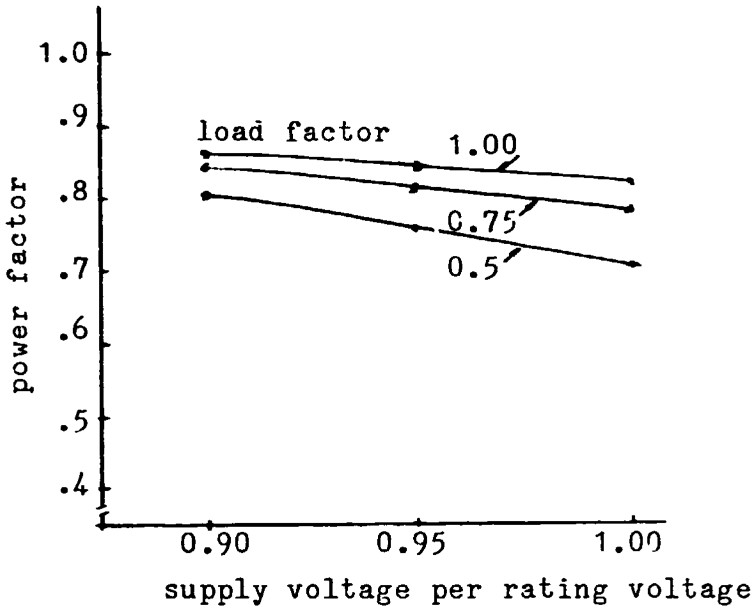


Figure 3.3 Relation between power factor of motor and supply voltage

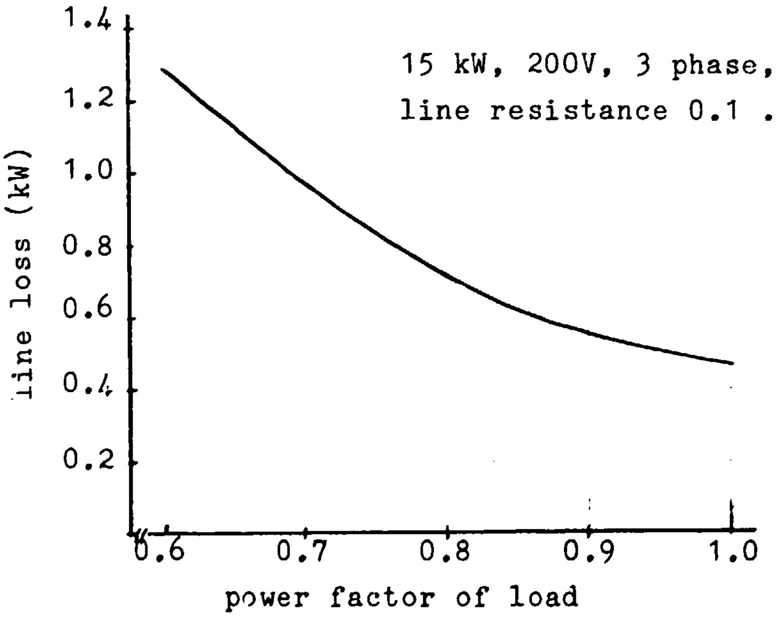


Figure 3.4 Relation between power factor and line losses

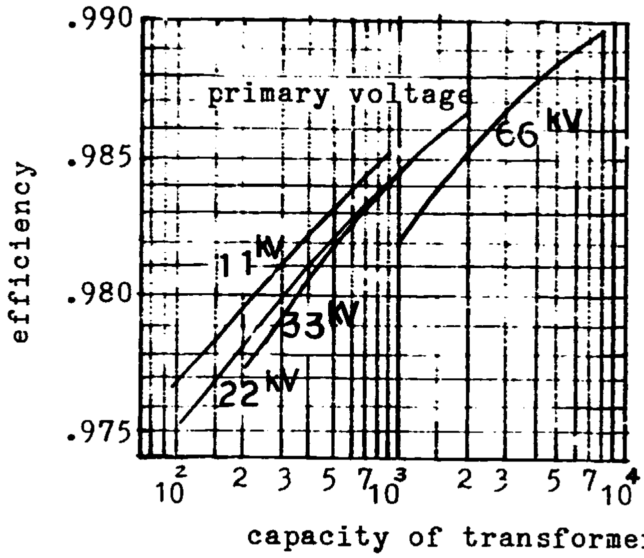


Figure 3.1 Capacity - efficiency of transformer at full loads

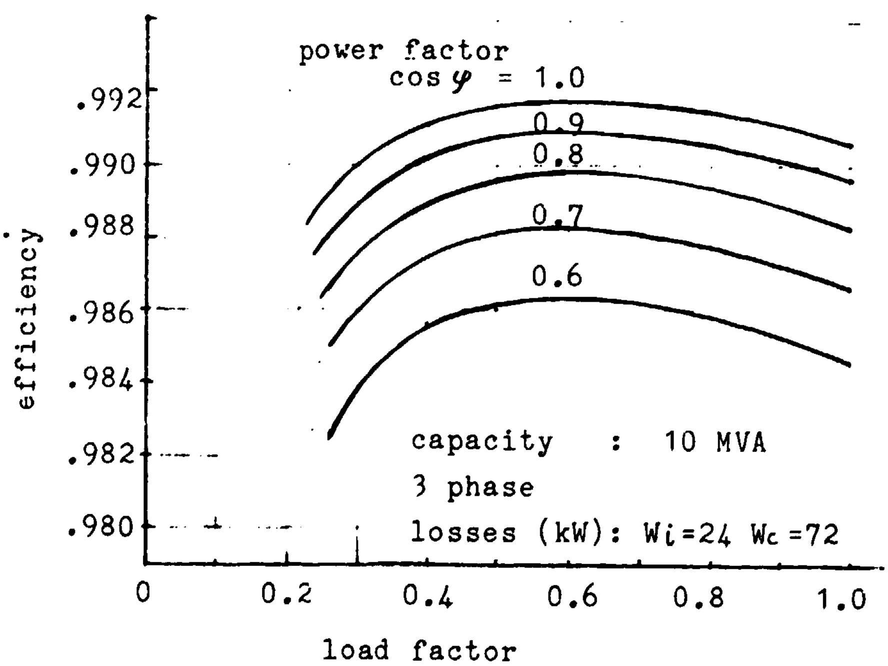


Figure 3.2 Output - efficiency curve of transformer

(2) <u>How to analyze the transformer losses</u>

Losses of transformer are as shown below. It has to be as small as possible.

$$\text{Losses of transformer} \doteqdot \text{output capacity of transformer (kVA)} \times (1 - \text{efficiency})$$

$$= \text{Iron loss } (W_i) + \text{Copper loss } (W_c)$$

Examples of efficiency of transformers are shown in figures 3.1 to 3.4.

Generally, maximum efficiency of transformers is obtained with 60% to 70% of rating output loads. On the other hand, iron losses of transformers are constant as far as supply voltage are constant. But copper losses are in propotion to the square of load current and usually rate of iron losses per copper losses are 1 : 4 at full loads.

(3) <u>Analyzing of transformer losses for energy saving</u>

(A) <u>Decreasing loss of transformer for improved power factor</u>

$$\text{Saving power} = P \times (1 - \eta) \times 0.8 \times \left\{ \left(\frac{L_2}{P}\right)^2 - \left(\frac{L_1}{P}\right)^2 \right\} \times h \quad \text{(kWh/year)}$$

where P : output capacity of transformer (kVA)

η : efficiency of transformer

0.8 : copper loss factor

L_1 : loads of after improving power factor (kVA)

L_2 : loads of before improving power factor (kVA)

h : working hours per year

(B) Reducing loss for changing capacity of the transformer

Reducing loss for changing capacity of the transformer is as follows;

$$\text{Saving power} = L \times \left(\frac{1}{\eta_1} - \frac{1}{\eta_2}\right) \times h \qquad \text{(kWh/year)}$$

were L : loads of transformer (kW)

η_1 : efficiency of existing transformer

η_2 : efficiency of changed transformer

h : working hours per year

(C) Decreasing of the distribution line loss

Decreasing loss of distribution line and equipments are explained below.

(a) Optimum load for distribution line and equipments.

(b) Improving power factor better be done on motor side. (see figure 3.4)

(c) Try to make the three phases balanced as possible. (output voltage of transformer, load current of each distribution lines)

As the losses on line increase, voltage of line down, vibration and baking-out of motor are feared, therefore, line losses should be minimized.

3.3 How to measure and analyze electrical loads

3.3.1 Motors

(1) Motor and it's applications

Electric motor are widely used in allmost all electrical equipments. Because mechanical force are obtained effectively, easily and conveniently, but power factor prior to accumulate loads in factory is usually low. This is due to lots of small motors or light loads for big motor etc.. Therefore we have to know characteristics of motors well. How to choose of motor and how to check of motor or application equipments are shown in the following table 3.3.

		Items of checking
condition of electric loads		1) Measurement of voltage, current and consumed power for major loads. 2) Calculation of power factor and load factor for major loads. 3) Check of alarming systems for light loads of big motors.
Varied loads of equipments	flow control (pumps, blowers, etc.)	4) Valves being always used : To be replaced by small capacity motor. 5) Flow always changing : To be equipped with speed gear box
	Air compressors	6) Discharged pressure to be as small as possible 7) Basical loads for big compressor, and remainder with smaller machines, in parallel operation. 8) Air leakege have to be checked periodically and must be stopped.
maintenance		9) Maintenance of major equipments should be made periodically. (cleaning, measuring temperature, dust, vibration, noise and coupled condition, lubrication, etc.)

Table 3.5 <u>Measurements and checking items of load equipments</u>

(2) Characteristics of three phase induction motors

(A) Efficiency and power factor of motors

According to specification of JAPAN JIS C 4210 efficiency and power factor of induction motor in full loads are shown in table 3.4, but above values to which special attention should be paid are changing by supply voltage and load factor. These are shown in table 3.5 and figure 3.5 to 3.7.

(B) Losses of induction motors

Loss of three phase induction motor can be calculated as follows;

Losses = input power of motor (1 - efficiency) (kW)

generally loss of squirrel cage motor is divided as shown in figure 3.8.

output rating (kW)	4 pole (%)		6 pole (%)	
	efficie-ncy	power factor	efficie-ncy	power factor
5.5	82.5	77	82	72
7.5	83.5	78	83	73
11.0	84.5	79	84	74.5
15.	85.5	79.5	84.5	75
18.5	86	80	85.5	76.5
22.	86.5	80.5	85.5	76.5
30.	87.0	81.0	86.0	77.5
37.	87.5	81.5	-	-

Table 3.4 <u>Efficiency,power factor of 3phase squirrel induction motors</u>

(200 V, 50 hz, enclose type motors)

		supply voltages		
		0.9x normal volts.	normal volts.	1.1x normal volts.
starting torque		81 %	100 %	121%
total current		111	100	93
revolution speeds		98.5	100	101
effi-cien-cy (see fig.7)	full loads	decrease a little	100	increase a little
	below 0.5 loads	101-102	100	98-99
power factor (see fig. 3.3)		102-103	100	95-97

Table 3.5 <u>Influence of supply voltages for induction motor.</u>

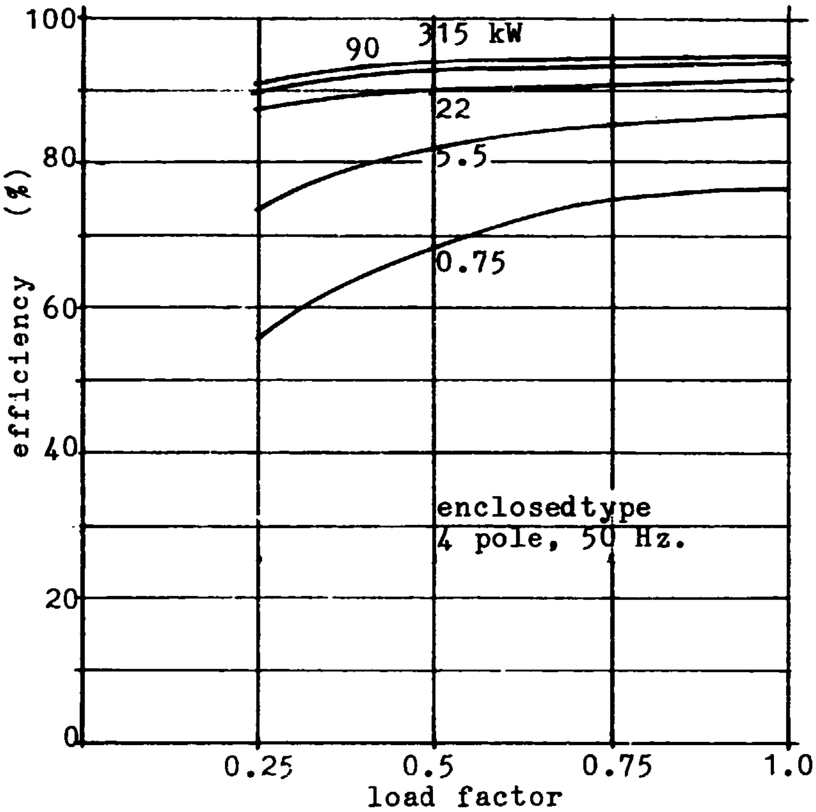


Figure 3.5 Efficiency of induction motors

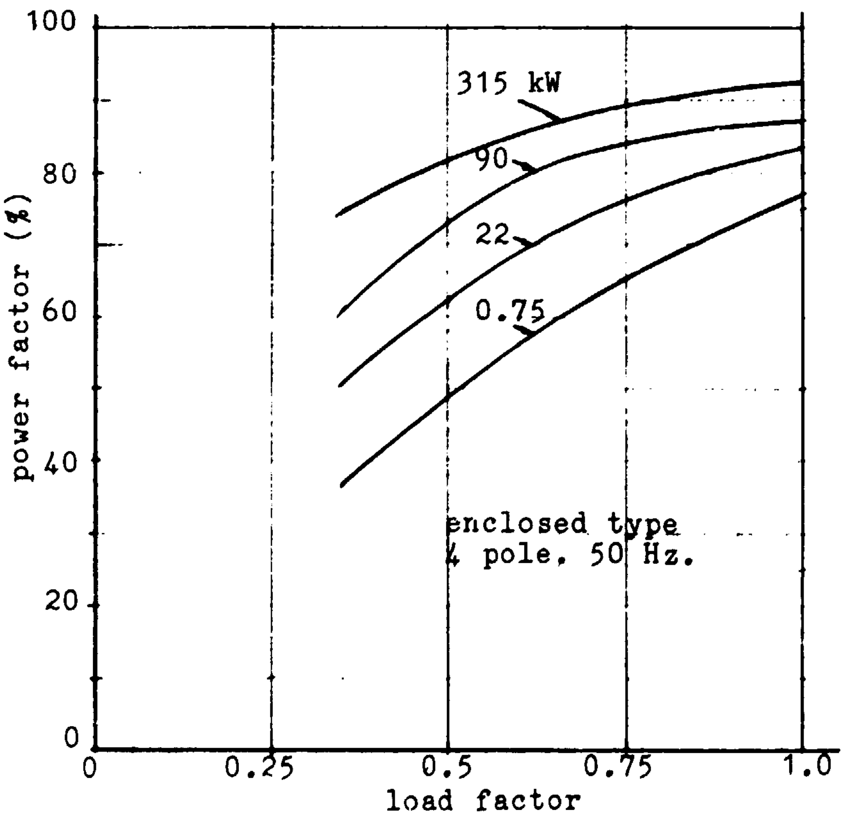


Figure 3.6 Power factor of induction motors

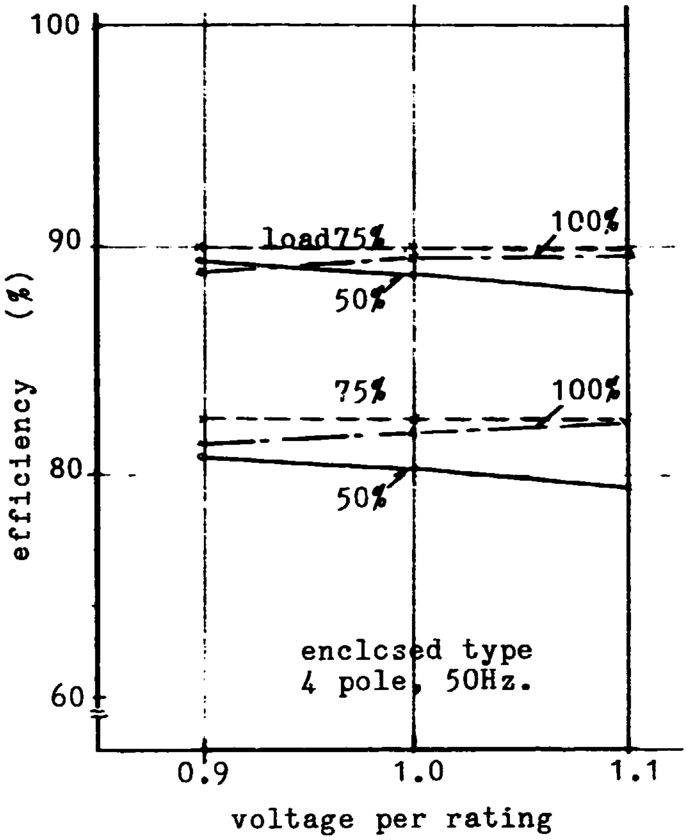


Figure 3.7 Efficiency of induction motors

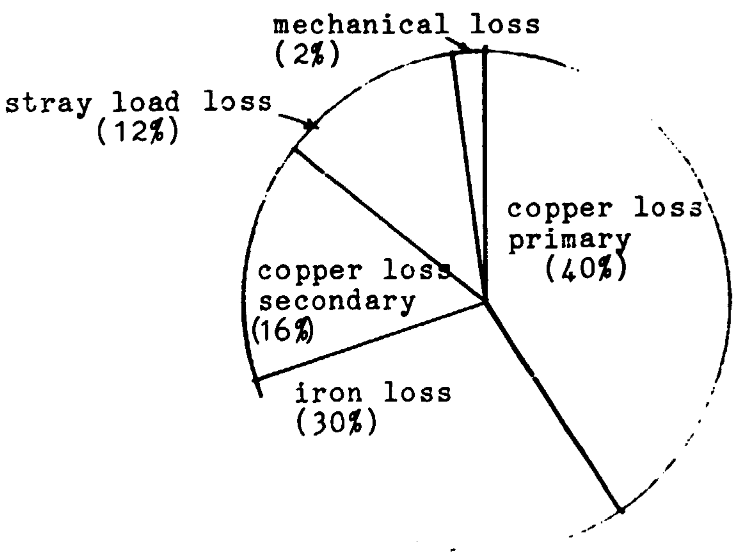


Figure 3.8 Example of analysis on loss of standard induction motor

(3) Analysis of energy saving of motors

(A) Relation of load and losses of motor

$$\text{Losses/year} = \left\{ 0.44 \times l + 0.56 \times l \times \left(\frac{P_i}{P}\right)^2 \right\} \times h \qquad \text{(kWh)}$$

where $l = P \times (1 - \eta)$: loss of motor in full loads (kW)

P : rating of input power of motor (kW)
= rating of output power $/\eta$

η : efficiency of motor in full loads

P_i : input power of motor (kW)

0.44 : iron loss factor of motor including stray load loss, mechanical loss

0.56 : copper loss factor of motor

h : working hours per year

(B) Decreasing loss of advanced efficiency by changing motors

(a) Calculation of loss from efficiency of motors

$$\text{Losses/year} = L \times \left(\frac{1}{\eta_1} - \frac{1}{\eta_2} \right) \times h \qquad \text{(kWh)}$$

where L : load of output power of motor (kW)

η_1 : efficiency of the existing motor (see fig. 3.5)

η_2 : efficiency of the motor after changing (see fig. 3.5)

(b) Calculation of loss from iron loss and copper loss

$$\text{Losses/year} = (L_1 - L_2) \times h \qquad \text{(kWh)}$$

losses of existing motor (see fig. 3.8)

$$L_1 = l_1 \times 0.44 + l_1 \times 0.56 \left(\frac{i_1}{I_1} \right)^2 \qquad \text{(kW)}$$

losses of after changing motor (see fig. 3.8)

$$L_2 = l_2 \times 0.44 + l_2 \times 0.56 \left(\frac{i_2}{I_2} \right)^2 \qquad \text{(kW)}$$

where l_1 : loss of existing motor in full loads (kW)

l_2 : loss of after changing motor in full loads (kW)

i_1 : corresponding current of load of existing motor (A)

i_2 : corresponding current of load of after changing motor (A)

I_1, I_2 : rating current of each motors (A)

(C) Calculation of the effect of changing of supply voltage for saving energy

These losses are calculated by (B)-(a) formulation and figure 3.7.

(4) Know-how to use equipments for saving energy

(A) Revolution control of motor for rotating machines

In equipment of pump, blower and fan the relation of the amount of flow (Q), pressure (P) and electric consumed power (W) of equipments were formulated by revolution (N) as follows;

$$Q \propto N$$

$$P \propto N^2$$

$$W \propto Q \times P \propto N^3$$

Generally valve and damper are used for flow control of air, water and various fluid in factories. Losses are induced by increasing exhaust pressure of fluid. Therefore capacity of the equipments should always be conformed to using condition and revolution speed of motor be controlled suitably without valve to lessen the loss.

How to choose flow control are given in table 3.6 below;

	pole changing	coupling by eddy-current	control of voltage (thyristor)	control of primary voltage and frequency
range of revolution speed per rating	1 : 0.7 ~ 1 : 0.75	0.1 ~ 1.0	0.7 ~ 1.0	0.11 ~ 1.0
suitable capacity of motor	small middle	small low voltage	small low voltage	all
effect of energy saving	middle	middle	middle	large
maintainability	well	very well	very well	well
feature	non continuous changing of speed	efficiency was decreased proportional to speed	can be mild starting inexpensiveness	expensiveness

Table 3.6 Major control of rotating speed of motors

(B) Air compressors

General items to be checked for energy saving are shown before in table 3.5.

(a) Consumed power by air compressor

Characteristics of air compressor of reciprocating motion type is shown in figure 3.9.

According to figure 3.9 and documents, power consumed by compressor is proportionate to the product of amount of compressed air by compressor and exhaust pressure. Therefore, in order to obtain more compressed air with the same amount of consumed power, lower exhaust pressure should be applied, and intake air of lower temperature and lower pressure is

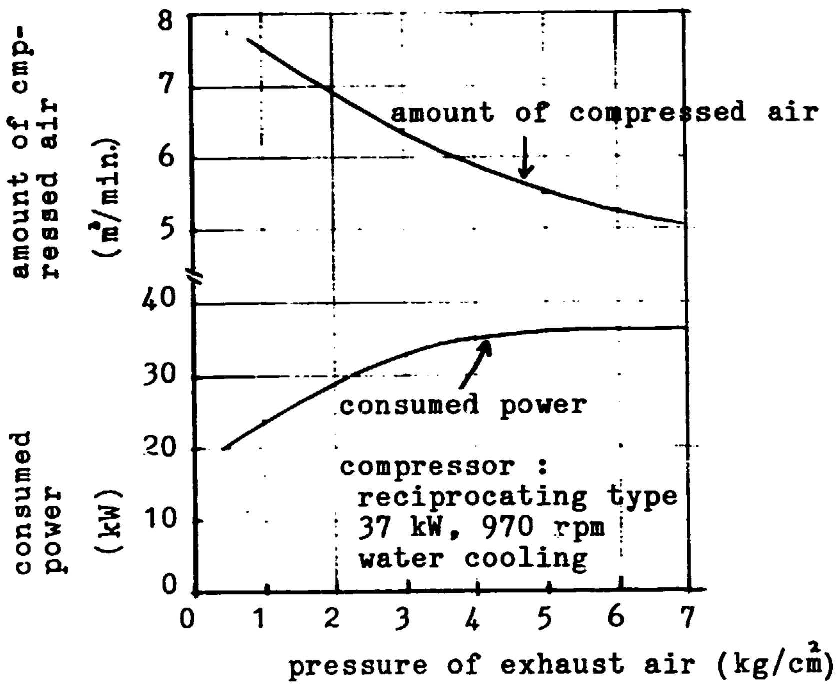


Figure 3.9 Characteristics of 37kW air compressor

(b) How to measure leakage for compressed air system

In no working hour, first put the compressor switch on and measure necessary time (t_1) through 2 points (low to high) by pressure gauge, then put the compressor switch off (stop) and measure necessary time (t_2) through the same 2 points (high to low). Then calculate loss as follows;

$$\text{Losses/year} = P \times \frac{t_1}{t_1 + t_2} \times h \qquad (\text{kW})$$

where
- P : consumed power of air compressor in working (kW)
- t_1 : time of increasing pressure through 2 points (sec.)
- t_2 : time of decreasing pressure through 2 points (sec.)
- h : working hours of compressor (hour) (not including idling hours)

(C) Others

In factory the idle hour of motor must be prevented. Measures should be taken as follows;

(a) Install alarming system the idle hours of motor.

(b) Install switch at place where on-off operation is easy.

(c) Make process and equipments be operated automaticaly.

(d) Reduce working time by improved tools and layout of processes.

3.3.2 Electrical loads (other than electro-motive force)

(1) Electric heaters

Most of electric power are changed from the fuel energy, so total efficiency of heat are not good. Usually converting factor is represented by 1 kWh = 2450 kcal = 860/efficiency of electricity generation.

Therefore generally electrical energy is used in the following three cases only and in other cases fuel energy must be used.

(a) Case of precision control of temperature in the furnace.

(b) Case of electrostatic heating, electromagnetic heating, electric arc heating and heating by infrared ray.

(c) Some special furnace for atmospheric controls.

Also facility of the electric heaters have to be coverd by insulation and radiation of heat have to be reduced as much as possible. Then heat efficiency to be improved for the electric furnace by precision control and uniform temperature of furnace must be kept. In addition, cut off switch of electric equipments while not working and maintenance of equipments have to be kept well.

(2) Air conditioner (air cooler)

In ASEAN countries air conditioner is used widely and operation rate of cooler is very high. In particular, in the case of a factory having some coolig section, rate of cooling power consumption to total power consumption is comparatively high. Therefore energy saving of air conditioner is important.

(A) Heat loads of cooler and loads decrease

Heat loads of cooler of factory and office is shown in figure 3.10.

In JAPAN summer time usually we try to save energy as follows;

(a) To decrease heat of sun light and transmissive heat from high temperature bodies.

(b) Intake air of ventilation to be limited to minimum amount and to be dry and cool.

(c) Heat dissipating apparatuses such as compressor and heating equipments located in air conditioned room to be replaced to non air conditioned space. And some generated heat of equipments should be released out of air conditioning room by ventilating fan.

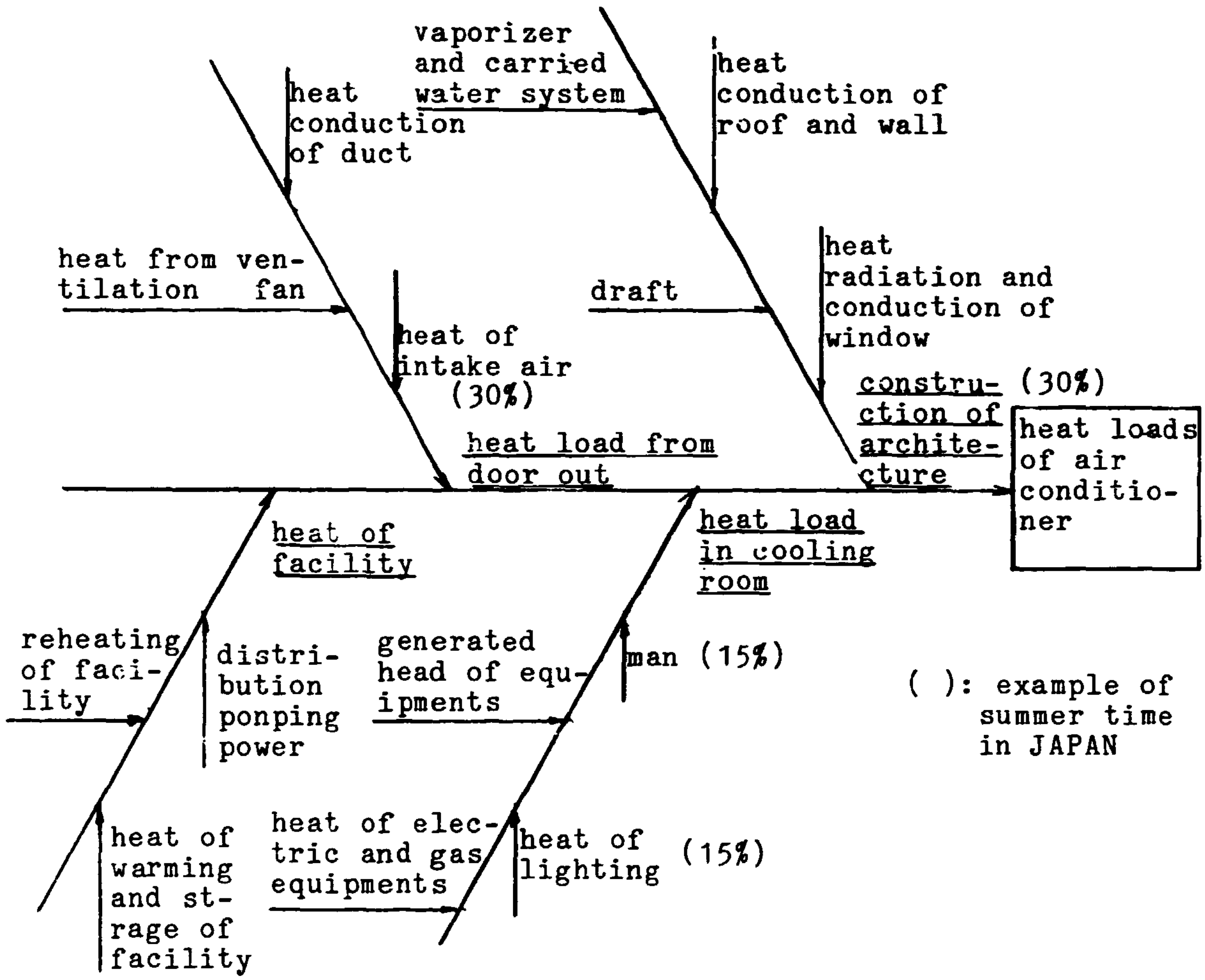


Figure 3.10 Heat load of air conditioner

(B) Check items of air conditioner

How to check, how to operate and their effects of air conditioner are shown in table 3.7.

	purpose	procedure	effect
target of temperature	set up of temperature and it's controling	1) To stop cooling during non working hours 2) To raise set up temperature	decreasing 1°C corresponds to 8-10% saving
maintenance	increaed efficiency of air conditioner	3) To clean air filters periodically 4) To test water and clean water tube	to prevent increasing pressure of ventilating fan

		5) To improve ventilation of cooling tower 6) To prevent draft from opening space	to prevent scaling decreasing 25% corresponds to 6% power saving
others	controling of maximum demand	7) Decreasing to use while peak demand hours of whole factory	to increase load factor of factory
	optimum size of coolig fan	8) Rotating control of cooling fan	

Table 3.7 Check items of air conditioner

(3) Lighting

In factories security and productivity have to be kept. Then improve the lighting effectively.

(A) Check items of lighting

How to check and how to measure lighting for energy saving are shown in figure 3.11.

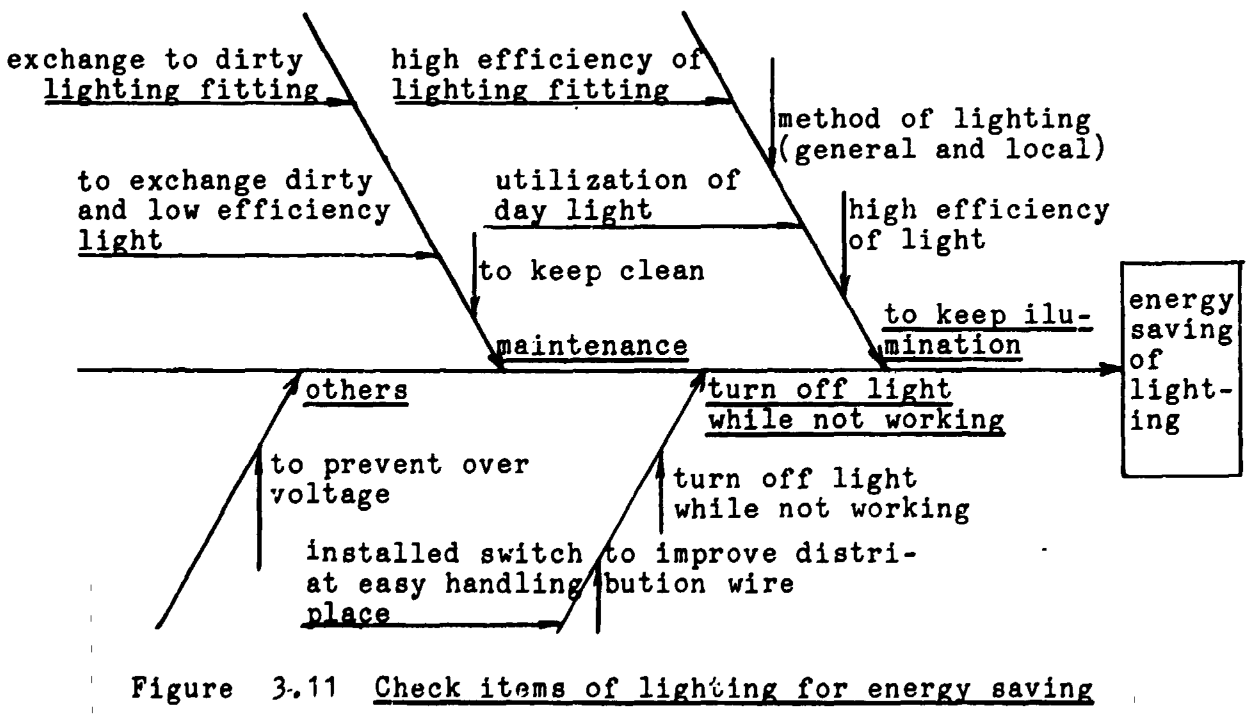


Figure 3.11 Check items of lighting for energy saving

(B) Analysis of electric power for lighting

Electric power of lighting is shown by the following formula;

$$\text{electric power of lighting (W)} = \text{consumed power cf one lamp (W)} \times \text{lighting hours(h)} \times \frac{L \times A}{\phi \times k_l \times k_m}$$

where L : brightness (lux) (see figure 3.12)

A : lighting area (m)

ϕ : lighting flux of fitting (lumen/unit) (see table 3.8)

k_l : factor of lighting
factor of lighting corresponding to area and reflection of wall etc. (0.3 - 0.8)

k_m : factor of maintenance
this value are correspondes to dirt of lights and lighting fittings [(0.55 - 0.95)/6month]

	size (W)	lighting flux (lumen)	consumed power (W)	total efficiency (lumen/W)	average life (h)
incandescent lamp	60 100	485 1520	40 100	12.1 15.1	1000 1000
fluorescent lamps(white)	40 110	3200 9500	49 140	65.3 67.9	10000 10000
fluorescent mercury lamp	400	24000	425	56.5	12000
metal halide lamp	400	32000	445	71.9	6000
high pressure sodium lamp	400	46000	450	102.2	9000

Table 3.8 Characteristics of various kinds of lamp

brightness(lux)	place	working
3000 2000 1500	panel board of control room	product of precision machine, electronic parts and printing factory--closed visual work--
1500 1000 750	design, drawing	inspection of textile, typesettingand asse ble work -- fine visual work--
750 500 300	control room	normal visual work example; assembling, inspection, and testing
300 200 150	electric and air conditioning machine room	rough visual work example; packing
150 100 75	way out (in), lobby, stair and lavatory	very rough visual work
75 50 30	store and facility of out door	loading and unloading
30 20 10	out door street of the premise	

Figure 3.12 Lighting standard in JAPAN JIS z 9110 (extract)

3.4 Recommendation of electrical energy saving

Recommendation of electrical energy saving are shown in table 3.9.

	Recommendable items	State requiring measures	Main measures	Effect on power saving
General items	1) to determine power saving target (power consumption rate, etc.)	in case of no target or obsolete target	to determine target	
	2) to cut off switches when not necessary (transformer, motors, lamps and air conditioners)	low load or no load	load re-distribution, change of facility capacity, installation of switches, etc.	remarkable
	3) maintenance, cleaning of equipment	lots of dirt in factory, insufficient maintenance	to determine maintenance items, to maintain periodically	remarkable
Receiving and distribution facilities	4) to review contracted power	when actual power demand is much different	contract to be changed	
	5) optimum capacity of transformer	load factor less than 0.5	to change transformer capacity, or re-distribution of load	transformer loss decreases
	6) to rationalize transformer voltage on low-voltage side	in case defference between actual and rated voltage $\geqslant 5\%$	to re-locate tap of transformer	efficiency, power factor of motor, life of lamps are influenced
	7) to raise power factor of entire factory	in case power factor falls outside $0.9 < \text{power factor}$	to install adequate condenser for improvement of power factor	electricity charge changes
	8) to minimize voltage-down on distribution line	in case voltage-down $\geqslant 5\%$	load re-distribution	same as 6)

	9) to watch maximum demand automatically	in case of comparatively large factories	installation of supervisory equipment at place of incoming panel	contracted power can be secured
Load facilities	10) to select adequate motor capacity	load factor < 0.5	motor replaced by small one	high power factor and efficiency
	11) to keep high power factor of main facility	power factor < 0.7	high load factor, rational supply voltage	ditto
	12) to supervise light-load automatically	in case of light-load of large motor	installation of light-load supervision equipment	ditto
	13) optimum capacity and optimum revolution speed of large motors of pump, blower, fan, etc.	in case valve is always slightly open	to change motor capacity to be correct one	ditto
		in case flow rate fluctuates often	to control motor revolution speed	ditto
	14) exhaust pressure of compressor and air leakage on compressed air line	case of exhaust pressure ≥ 8kg/cm²	study for lowering applied pressure	ditto
		in case of leakage in pipes and valves, etc.	to stop leakage	ditto
	air conditioner: 15) temperature set for the room	in case room temp. ≤ 19 °C	make room temp. ≥ 19 °C	cooling load decreases
	air conditioner: 16) heat load of room and air-conditioner	in case there are conduction heat from outside into room and heat produced in room	to insulate bldg. equipment producing heat to be put out of room	ditto

	17) high efficiency operation and maintenance	in case of much draft	to minimize draft and ventilation	ditto
		in case of bad maintenance	to clean water cooling machine and ventilation filter,etc.	
Electric heater	18) to limit electric heating to special use	in case general furnace byheating wire is used	to change to heating by fuel or steam	energy cost decreases
Lighting	19) sufficient illuminance	in case illuminance is insufficient	to obtain sufficient illuminance	improved productivity and safety
	20) good maintenance and adoption of high efficiency lamps	in case lamps and apparatuses are dirted	adoption of lamps, maintenance which is easy, and ofhigh efficiency	low power cost

Table 3.9 Main recommendable items for power saving

3.5 How to measure and how to use instruments for energy saving

In electrical energy saving, as electricity can not be seen and moreover can not be contacted, measurements of equipments are very important.

3.5.1 How to measure

Electric measurement are only one of solutions of problem for electrical energy saving and mistake for safety must not be permitted. Therefore, instruments of measurement should be well knowne. On the other hand, characteristics of equipments are examined by name plate i.e, voltage, consuming power, current and power factor etc.. Then examination and calculation items are shown in table 3.10.

3.5.2 How to use instruments

Specifications, precautions on measuring instruments for energy conservation are shown in table 3.11.

		Measuring items	Calculation	Rating by name-plate
Receiving and distribution	Receiving Wh meter	kWh, times/ 1 revolution	kWh/h	revolution /kWh
	transformer and main switch	P, E, I, phase balance, temperature	$\cos\varphi$, LF,	kVA, E, I
	capacitor	E, I, phase balance, temperature	kVAr	kVAr
	main distribution line	I, temperature		
Load	panelboards switch	P, E, I, phase balance,	I per rating, $\cos\varphi$	I
	main load or large motor	P, E, I, load duration and period (intermittent load)	$\cos\varphi$, LF	P_r , H, E, $\cos\varphi$
	electric heater	P, E, I	thermal eff.	P_r , E, I
	special load	P, E, I		P_r , E, I
	load far from power source	E	Voltage-drops	P_r , E, I
	illuminance of workshop	Lux change in period (6 monthes)	illuminance decrease	

P :electric consumed power (kW) P_r :rated power (kW) E :voltage (V) I :current (A) $\cos\varphi$:power factor = $P/(\sqrt{3} \times E \times I)$
LF:load power per rating power = $(\sqrt{3} \times E \times I)/kVA$ (transformer)
= P/P_r (motor)

Figure 3.10 Measurements, calculation and survey items required for power saving

Items of using	Name of instrument	Specification	constraction and appli-cation	caution
voltage current power	Clip-on AC power meter	range of measurement AC voltage :200/600 V current :20/200 A power : 20/200 kW indicater :digital source :battery (using hour 15/1 set)	this instrument consists of a current sensor inclu-ding battery and three lead wires. It is used to measuring of balanced 3 phase and single phase AC circuit in hot line	don't contact battery and lead wire while measur-ing. in case of measurement of power make sure of corre-ctly wire connection see instruction manual
voltage current power reactive power	Clamp-on power HI tester	range of measurement AC voltage :200/600 V current :200/1000A power :200/1000 kW reactive power :200/1000kVAr indicater : digital source : AC 100/240 V	this instrument consists of 3 current sensors, 4 lead wires and main body. It is used to measuring of 3 phase AC circuit of 3 or 4 wires in hot line (3- wattmeter methode)	don't over load the met-er circuit. in case of measurement of power make sure of corre-ctly wire connection (color of lead wire and clampsensor also rota-ting of phase etc.) see instruction manual
integrat-ing power and current	Integrator	display :six digit (max. 999999) input voltage : 2 V time setting range :1-99 min. or hours power : 100 V AC,	this instrument displays integrated power and current by connecting Clamp-on power HI tester	can not be used to measu-re reactive power avoid introducing exces-sive input. see instruction manual
voltage, current, resistan-ce of circuit	Multitest-er	range of measurement DC voltage :0.25-1000 V current :25 A-10A AC voltage :10-1000V current :10A Ohm :2-20 M	this instrument consists a DC ammeter,battery, 2 wire and main body.	always make certain the range setting of instru-ment. before using , it make sure that test the fuse by ohm range
illumina-nce	Lux-meter	display :digital range of measurement x 1: 0～1000 lux x10: 0～10000 lux atomosphere temp. 0-40°C R.H 80%	pocketable selenic photo-cell type	it never use below 0 °C and upper 40 °C atomosph-eric temperature

Table 3.11 List of measuring instruments
(using during factory survay in Malaysia)