Chapter 9 Technical Study for Henkel-Turyag

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This factory is producing liquid/powder detergent and edible oil/fats as major products. Therefore, this factory can be classified as a chemical industry. There are various types of energy consumption, such as utilization of fuel (Lignite and Fuel oil), generated steam and electricity (House generation and receiving from TEK). Thus, the JICA study team conducted an audit of typical types of energy consumption, as described in this Chapter.

9-1 Characteristics of Each Industrial Sub-sector

9-1-1 Liquid and Powder Detergents

The raw material of synthetic detergent is Linear Alkyl Benzene (LAB). It is sulfonated by SO_3, then neutralized by NaOH and formulating Linear Alkylbenzene Sulfonates (LAS), key components of synthetic detergent. Figure 9-4 presents a block flow diagram of the liquid and powder detergent producing process. Short explanations for each unit, putting emphasis on energy consumption, are as follows.

(1) SO_3 Generation

Solid sulfur is used as a raw material. After being melted in a melting vessel, it is converted into SO_2 in a combustion furnace. SO_2 is finally changed to SO_3 by dried air in a catalytic converter. SO_3 is a preferable sulfonation agent, because it reacts nearly quantitatively with LAB. Energy related facilities in this unit are as follows.

Sulfur melting vessel, sulfur combustion furnace, air drying (air compressor, refrigerator, dryer), SO_2 cooler and SO_3 converter (exothermic reaction) with coolers.

(2) Sulfonation

Raw material of LAB is reacted with SO_3 at first in the sulfonator (film reactor) to form Linear Alkylbenzene Sulfonic Acid. Energy related facilities in this unit are as follows.

Sulfonator (exothermic reaction) with jacket cooler

(3) Digestion, Hydration and Neutralization

In the sulfonator, byproduct (Sulfonic Acid Anhydride) is formed and digestion is required to complete the sulfonation of sulfonic acid anhydride with the dissolved SO_3. After digestion, there is still a small amount of sulfonic acid anhydride in the digested oil. It is decomposed in the hydrator by adding water. After finishing hydration, linear alkylbenzene sulfonic acid is neutralized by NaOH with dilution water, forming Linear Alkylbenzene Sulfonates (LAS). There are not so important energy related facilities except for jacket type reactors, such as digester, hydrator and neutralizer.

(4) Liquid Detergent

Liquid detergents are used primarily for dish washing and for washing fine materials such as wool and silk. Some builders such as enzyme, bleaching agent and fluorescent are added to LAS and it is filled into bottles as liquid detergent product. There are not significantly important energy related facilities except for bottle filling machines.

(5) Powder Detergent

Powder detergents are used preliminary for general washing. For powder detergent, similar builders as for liquid detergent are added. Solid detergent materials are eventually converted into powders in a spray dryer, then more solid builders are added for the powder detergent product. A spray dryer system prevails in powder detergent production because LAS and builders are in the form of slurry, and powder is obtained directly from the slurry by the spray dryer. Energy related facilities in this unit are as follows.

Hot air furnace, spray dryer, high pressure slurry pump, solid transfer equipment (air lift, belt conveyer, mixer) and packing machines.

9-1-2 Edible Oils and Fats

The raw materials of edible oils and fats (table margarine, kitchen & indusrial fats) are crude cottonseed oil and palm oil, which are purchased from crude oil producers. The crude oil is refined through several units and processed to final products. Figure 9-5 presents a block flow diagram of the edible oil and fats producing process. Short explanations of each unit, putting emphasis on energy consumption, are as follows.

(1) Neutralization

Certain amounts of impurities, such as free fatty acid, non-glyceride and gum materials are contained in the raw materials, of cottonseed oil and palm oil. These impurities are removed by adding NaOH solution. There are not important energy related facilities except for steam heaters, centrifuge and dryer.

(2) Hardening (Hydrogenation)

Raw material oils are normally too soft because they contain unsaturated and lower boiling points of fatty acid such as linolenic and linoleic acids. In order to heighten the boiling and solidification points, H_2 gas is added from the water electrolysis unit, and they are saturated and hardened by hydrogenation. Energy related facilities in this unit are as follows.

Water electrolysis, MP steam jacket hydrogenator, feed oil heater, steam ejector, catalyst tank and filter press

(3) Decoloring (Bleaching)

In the raw material oils, some coloring materials such as carotenoid (red color) and chlorophyll (green color) are contained, and they are adsorbed on the activated earth and removed. There are not important energy related facilities except for a bleaching vessel with steam coil and steam ejector.

(4) Deodorizing

Some materials with disagreeable odor such as activated earth and decomposed oil remain in the oil and they are eliminated in this unit. Normally, materials with disagreeable odor are separated in a distillation column under high temperature and vacuum, and much steam is required. After deodorizing, edible oil is produced and fats and margarine are processed in additional units. Energy related facilities in this unit are as follows.

Feed oil preheater, deodorizing column with steam injection and steam ejector

(5) Compounding

A Turkish law regulates allowable additives such as emulsifying materials, antioxidant and vitamin in the product margarine. They are added in this unit before plasticizing. There are not important energy related facilities in this unit.

(6) Plasticizing and Ripening

Refined and compounded oil is plasticized in a Kombinator (brand name of a German company) through emulsification, quick cooling by NH_3 refrigerant and kneading process. Product margarine from the plasticizer is finally shipped after ripening in a cold room. Energy related facilities in this unit are as follows.

Plasticizer with emulsification, quick cooling and kneading, NH_3 refrigerating system for Kombinator and ripening with NH_3 compressor

(7) Oil Tank Yards

There are various kinds of oils treated and stocked in this process such as raw materials, intermediate products and final products. Steam is utilized in these tank yards for heating.

9-1-3 Utilities

As mentioned before, there are various kinds of utilities such as fuels, generated steam and electricity in this factory. When compared in terms of annual energy consumption for each source, the following figures are calculated for 1995.

Fuel oil:	14,319 MMkcal/year
Lignite:	52,736 MMkcal/year
Electricity/House generation:	2,727 MkWh/year (2,345/5,863 MMkcal/year)
Electricity/Receiving:	13,400 MkWh/year (11,524/28,810 MMkcal/year)
Electricity/Total:	16,127 Mkwh/year (13,869/34,673 MMKcal/year)
Generated steam:	64,500 tons/year (32,250 MMkcal/year)
Where,	
Electricity converted in heat:	860 (theoretical) / 2150 (actual) kcal/kWh
Steam converted in heat:	500 kcal/kg
MM = Million, M = Thousand	

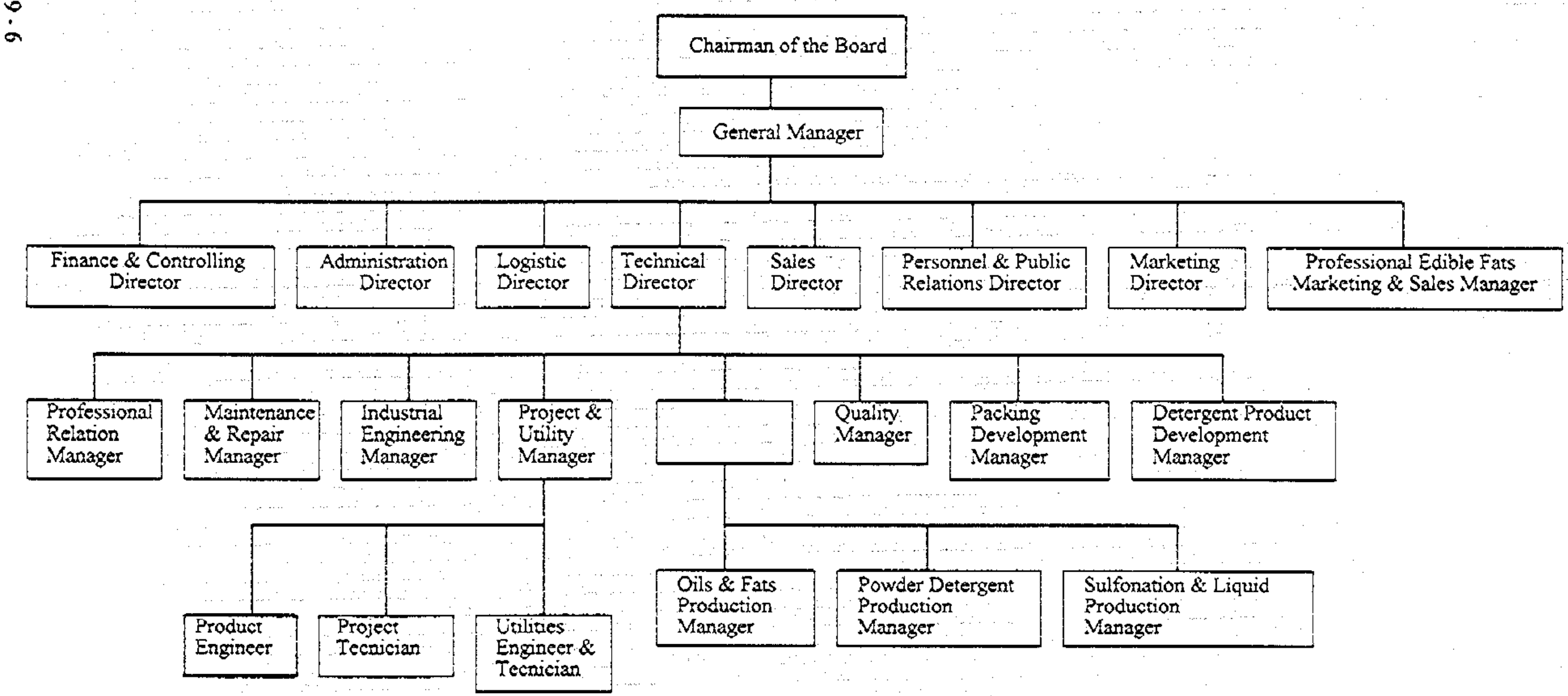
As a result, steam and electricity consumption are nearly on the same level. Thus, this factory has installed two steam boilers, each with a capacity of 10 tons/hour, and a steam turbine generator with a capacity of 16 tons/hour of steam consumption (1,600 kW/h generation).

9-2 Outline of Factory, Facilities and Flowsheet of Major Product

9-2-1 Outline of the Factory

This factory is a chemical industry. The outline of the factory was determined in the first field survey as follows.

1)	Name of the factory:	Turkiye Yag ve Mamulati A.S./Henkel-Turyag A. S. (Turkish Edible Oils, Fats and Products Corporation)
2)	Address:	1649 Sokak No.26 35020 Turan-Izmir Turkey Telephone; (232) 365 92 00
3)	President:	Mr. Kaya SENER Factory manager: Mr. Dundar Cifteioglu Energy manager: Mr. Birol NAZLI/Reha Yalcin
4)	Type of industry:	Chemical Industry (Synthetic Detergent, Edible Oils and Fats)
5)	Capital:	295,000,000,000 TL (as of End of June 1995)
6)	Organization chart:	See Figure 9-1
7)	Number of employees:	Workers 213, Employees 214, Total 427 In Production Department: Employee 79 Worker 213 (as of end of Oct. 1995)
8)	Number of engineers:	Chemical Engineers 11, Mechanical Engineers 8 Industrial Engineers 7, Environmental Engineer 1
9)	Number of energy related engineers:	Electricity 2, Heat 3
10)	Factory area:	45,000 m^2
11)	Building area:	12,600 m^2 Note: Expansion of the building is regulated by law, it is difficult to expand at present.
12)	Factory and plant layout:	See Figure 9-2



Note: Under the control of Technical Director, energy conservation team is organized and it consists of Utility Manager and some utility engineers.

Figure 9-1 Organization Chart of Henkel-Turyag A.S.

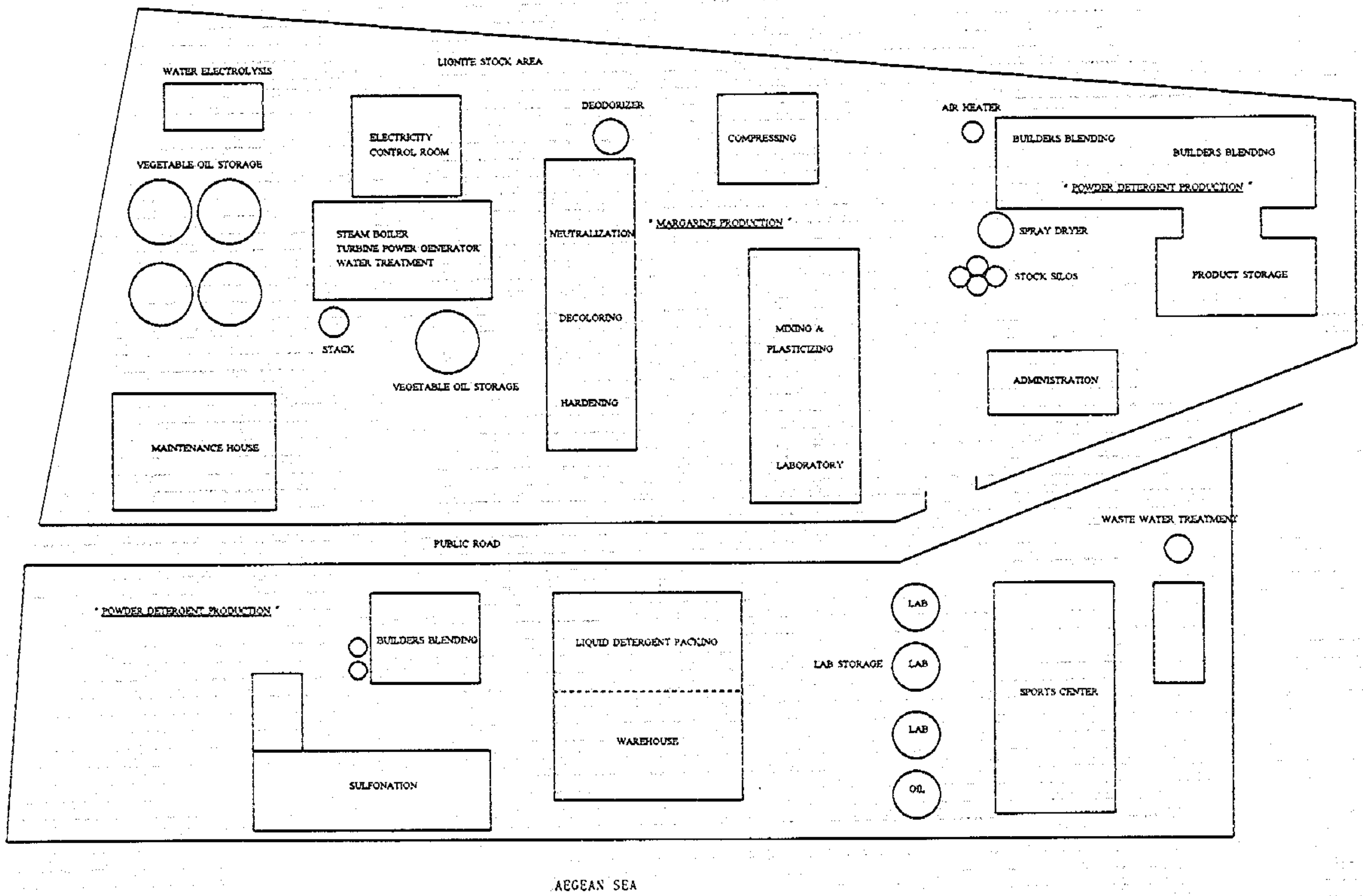


Figure 9-2 Factory and Plant Layout (Turyag A.S.)

13) Major products:

a) Powder Detergents (Persil, Tursil)

b) Liquid Detergents (Pril, Dixi, Velnel)

c) Oils & Fats (Margarine & Food Industrial Oils)

Note: Persil, Tursil, Pril, Dixi and Velnel are brand names.

14) Share and position in its industrial sub-sector:

a) Powder Detergent (20%, third place)

b) Liquid Detergent (50 to 60%, 70 % for the softener, first place)

c) Oils & Fats (18 to 20%, second place)

9-2-2 Outline of Production Facilities

Main products of the factory are powder detergent, liquid detergent and oils & fats as mentioned above. The production scheme is outlined in the following figure. There is no plan for increasing production capacity at present.

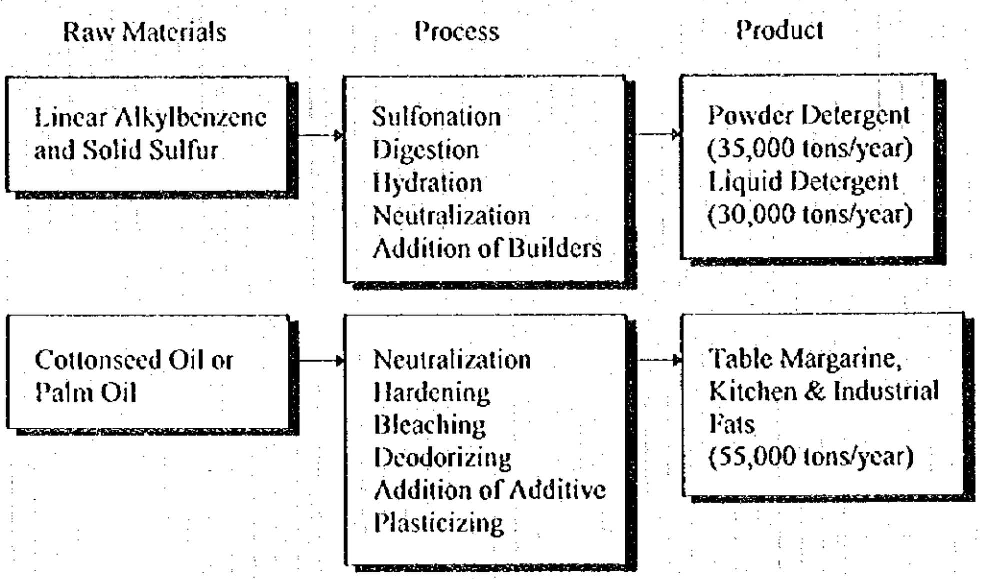


Figure 9-3 Outline of Production Facilities

9-2-3 Flowsheet for Major Products

(1) Liquid and Powder Detergent

An outline of the process flow is shown in Figure 9-4. A short explanation for each unit is described in section 9-1-1.

(2) Edible Oils and Fats

An outline of the process flow is shown in Figure 9-5. And short explanation for each unit is described in section 9-1-2.

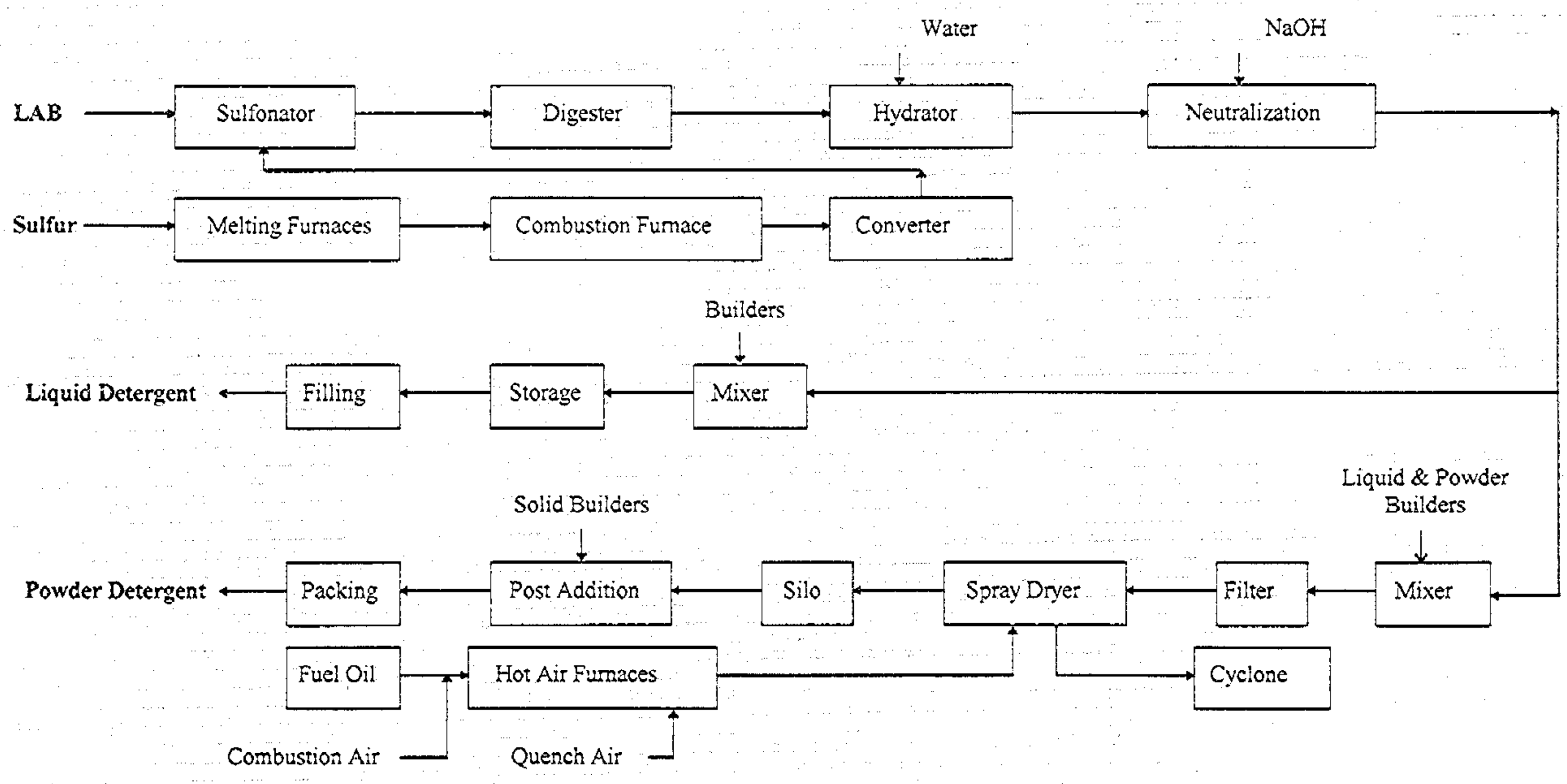


Figure 9-4 Synthetic Detergent Production Flow Sheet

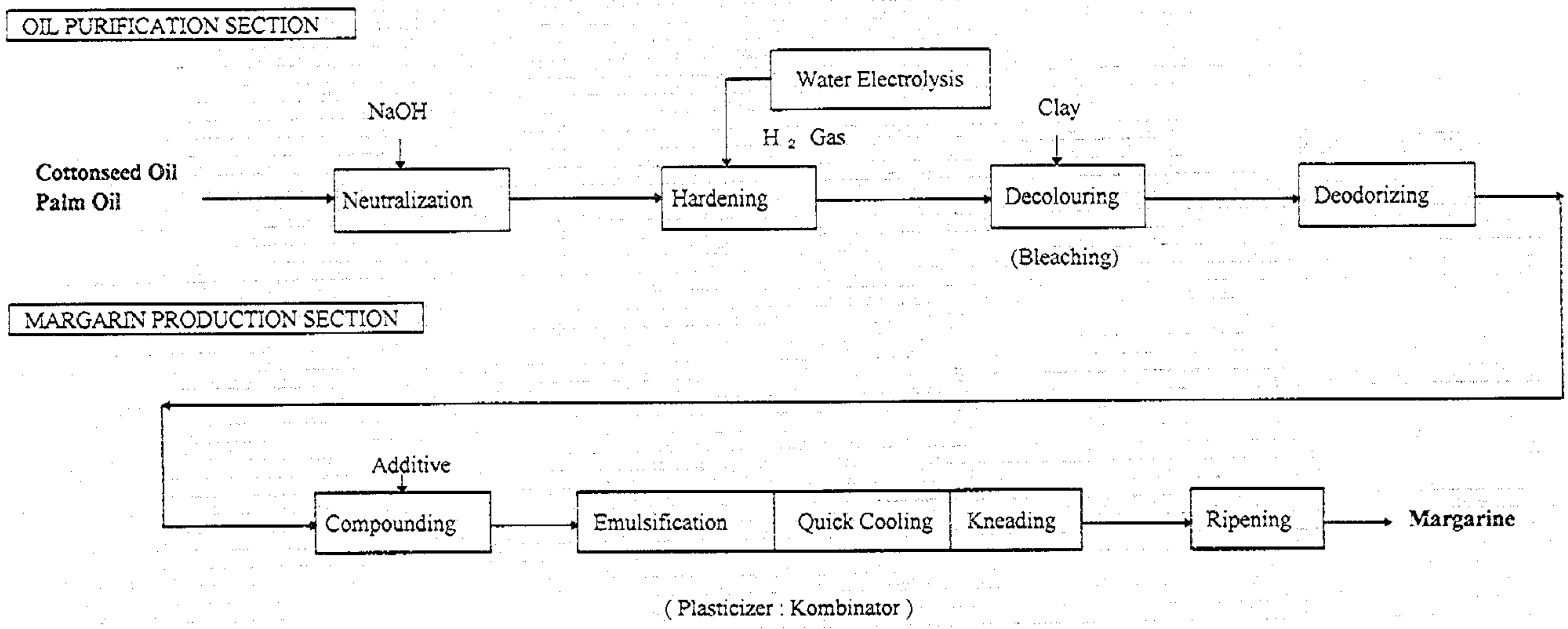


Figure 9-5 **Edible Oils and Fats Production Flow Sheet**

9-3 Outline of Operating Conditions

9-3-1 Operating Mode of the Plant and Factory

(1) Operation Days in Week

The plant operates 6 days per week (startup Monday morning and shutdown Sunday morning except for the sulfonation unit).

(2) Operation Modes of Plants

There are three types of operation mode such as batch, semi-batch and continuous operation corresponding to the characteristics of each unit as shown in the following table.

Table 9-1 Type of Operation in the Factory

Detergent Process	Batch	Semi-batch	Continuos	Remarks
1. Sulfonator			x	
2. Powder Detergent	x	x		
3. Liquid Detergent	x			
4. Spray Dryer		x		
5. Solid Builder	x	x		
6. Blending	x			

Oils & Fats Process	Batch	Semi-batch	Continuos	Remarks
1. Neutralization		x		
2. Hardening	x			
3. Bleaching		x		
4. Deodorizing		x		
5. Compounding	x	x		
6. Plasticizing	x	x		2 kinds of train

(3) Annual Operating Hours and Days

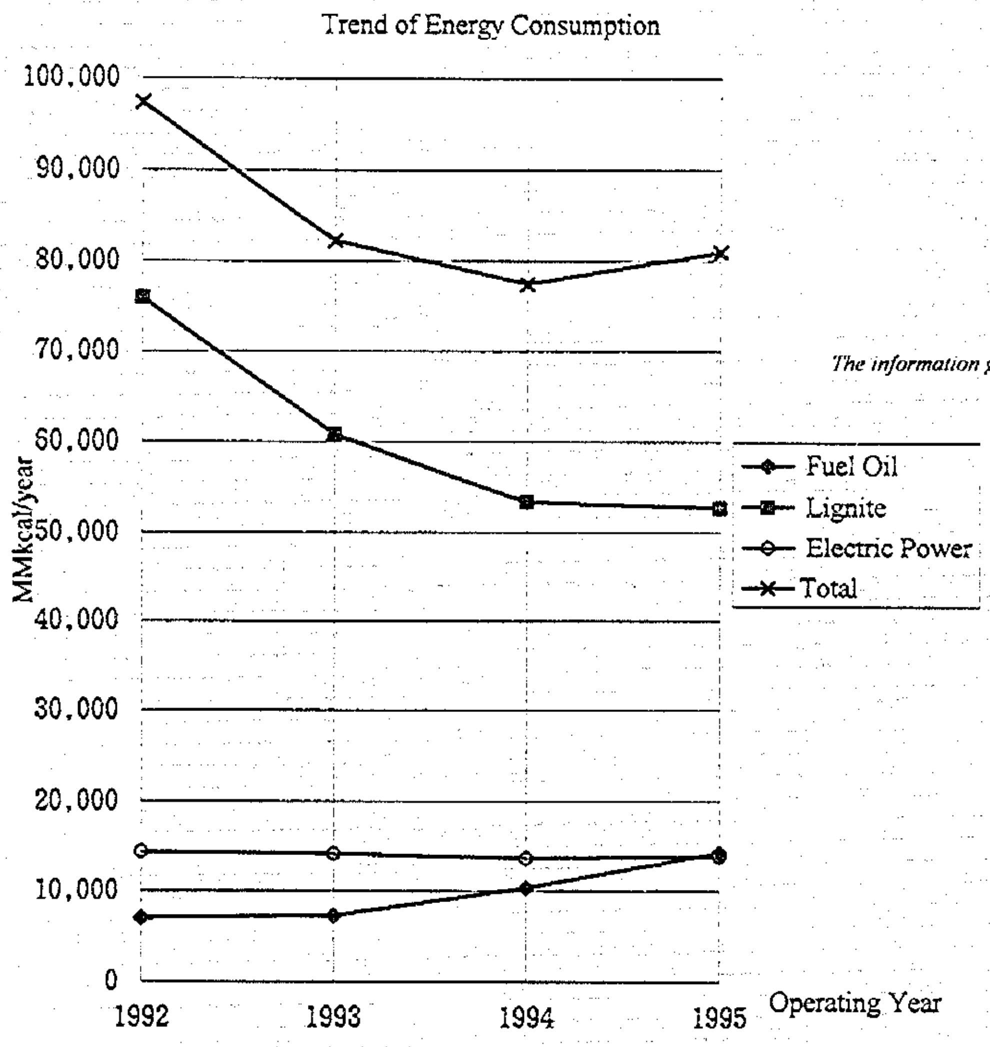
The information given here is withheld from public disclosure because of its confidential nature.

Table 9-2 Production Amount and Annual Operating Hours

The information given here is withheld from public disclosure because of its confidential nature.

(4) Maintenance Mode of Plants

Until now maintenance has been mainly limited to dealing with problems. The factory is planning to change the maintenance mode to preventive maintenance (periodical maintenance). They do not do complete shutdown maintenance covering all units or all plants at once. Instead they execute shutdown maintenance for one plant after another.



The information given here is withheld from public disclosure because of its confidential nature.

Figure 9-6 Trends of Energy Consumption and Production Amount

9-4 Trends of Consumption and Unit Consumption of Energy

(1) Trends of Energy Consumption and Unit Consumption

Kinds of utility and their utilization in the factory are as follows. Energy consumption trends are shown in the following table and Figure 9-6.

a) Fuel Oil	Fuel for the hot air furnace in the spray drying unit in the powder detergent plant
b) Lignite	Fuel for the fluidized bed type steam boilers (2 trains), and it is transported from the Aydin Coal Mine (125 km far to the south from Izmir) by 25 ton trucks
c) Diesel Oil	Fuel for starting up the steam boilers and the emergency power generators
d) Electricity	Power source for all motors and lighting
e) Steam	Energy for steam turbine generator and heating (There is no steam turbine driven equipment.)

Table 9-3 Trends of Energy Consumption and Unit Consumption

Name of Utility	Unit	1992	1993	1994	1995 (estimate)	1996 (plan)
a) Fuel Oil						
Consumption	kg/year	702,060	725,278	1,034,242	1,431,892	
Lower Heating Value	kcal/kg	10,000	10,000	10,000	10,000	
Consumed Total Heat	MMkcal/y	7,020	7,253	10,342	14,319	
b) Lignite						
Consumption	ton/year	23,713	19,010	16,681	16,480	
Lower Heating Value	kcal/kg	3,200	3,200	3,200	3,200	
Consumed Total Heat	MMkcal/y	75,882	60,832	53,379	52,736	
c) Well Water						
Consumption	ton/year	65,000	80,000	80,000	107,460	
d) City Water						
Consumption	ton/year	230,000	170,000	115,000		26,000
e) Electric Power						
Generated Power	MkW/y	5,833	4,023	2,448	2,727	2,500
Received Power	MkW/y	10,936	12,482	13,472	13,400	15,130
Total Consumption	MkW/y	16,769	16,505	15,920	16,127	17,630
f) Steam						
Generated Steam	ton/year	92,000	76,000	67,000	64,500	70,200

Note: All utilities are used for Detergent and Oils & Fats Plant in common without a separate measuring system.

$MM = 10^6$ and $M = 10^3$

(2) Energy Flowchart

Simple flowchart of each utility usage is illustrated as follows. More details of the steam and condensate system are shown in Figure 9-8.

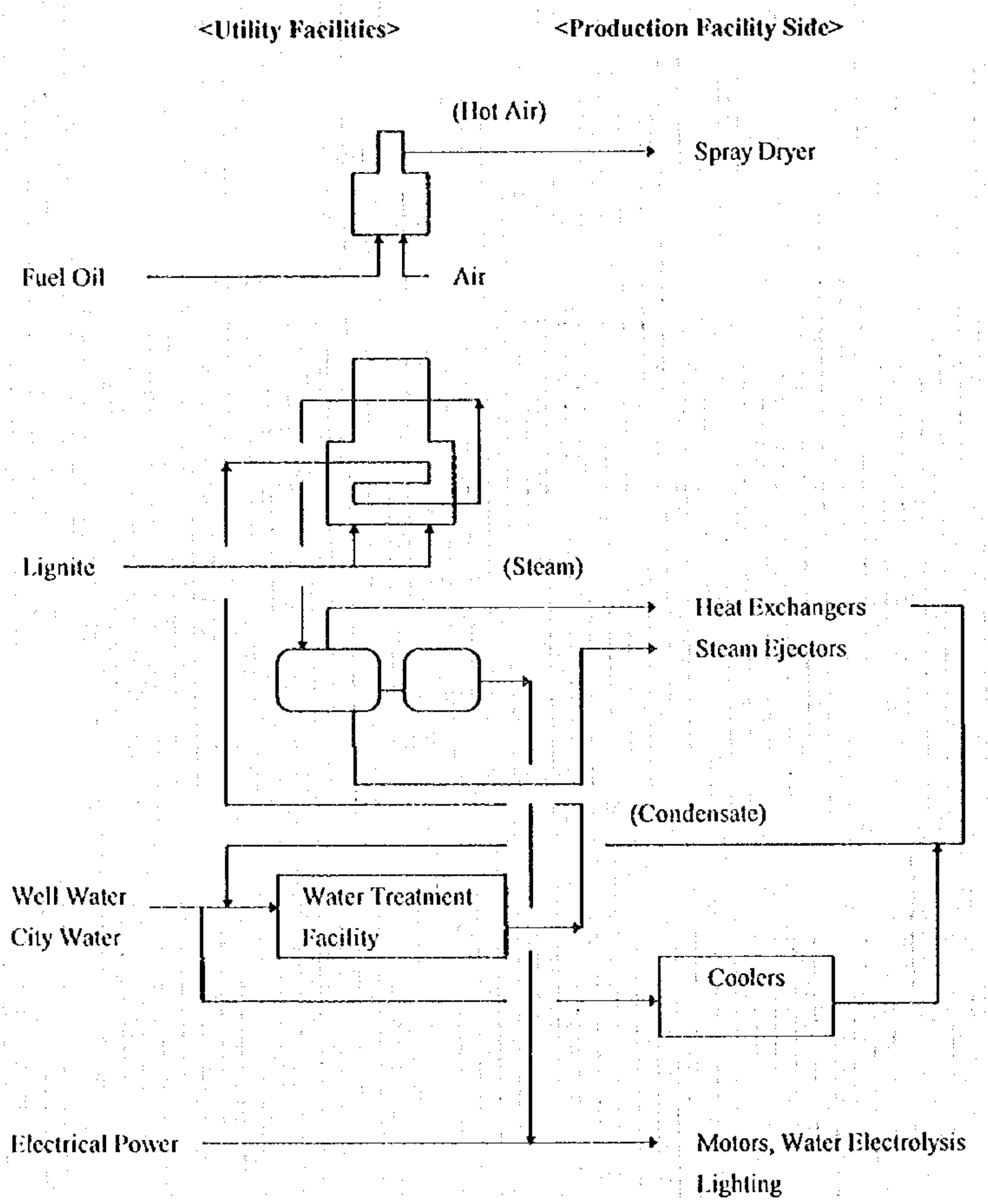


Figure 9-7 Energy Flowchart of the Factory

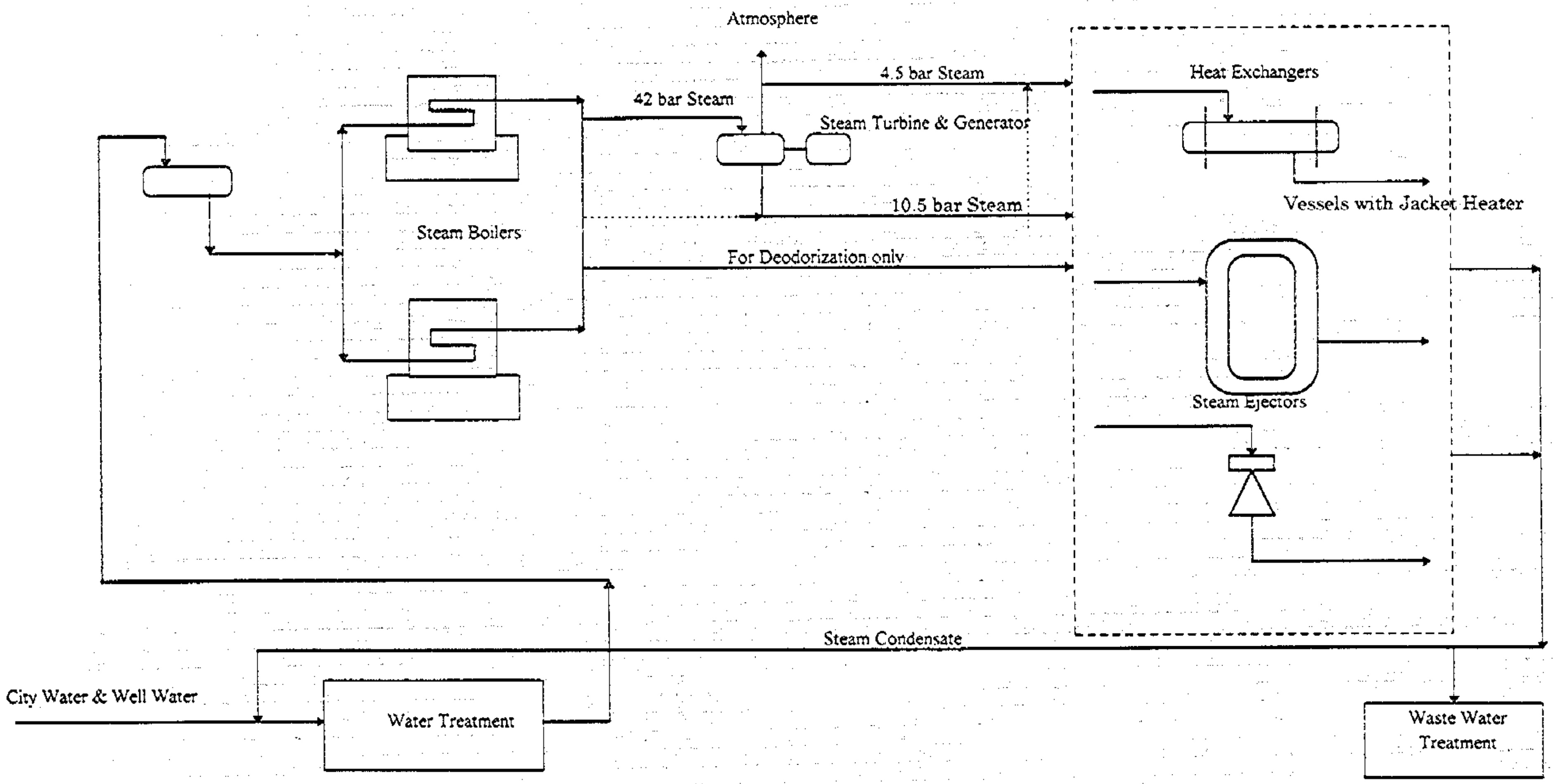


Figure 9-8 Steam and Condensate Flowchart

9-5 Current Condition and Problems with Energy Management

9-5-1 Current Condition of Energy Management

(1) Establishment of Target for Energy Conservation

At the beginning of every year, the factory's executives set targets for energy conservation and reduction of fuel, coal, electricity and water consumption based on unit consumption figures. Then each division sets detailed targets. The results are evaluated at the end of every year.

(2) Energy Management Utilization Data and Records

The Utility and Maintenance Department control the operating data for the steam boilers, demineralized water treatment, electricity. etc. Other data are controlled by each production department respectively without steam and water consumption. Some parts of the production facilities such as detergent plants are operated by computer control; therefore, necessary data can be utilized through the computer records.

(3) Education and Training of Employees for Energy Management

For newly hired employees, operational training is given for a certain period inside the factory; however, energy conservation training is not included directly. On the other hand, EIE publishes an conservation booklet for the factory management's use.

(4) Environmental Pollution Management

Working conditions of waste gas and water are both in good condition mentioned below. One environmental engineer is assigned this year to deal with environmental matter.

Waste gas:	No problem; CO, SO_2 & dust analyzer are installed on the chimney and actual levels are lower than the limits.
Waste water:	No problem after the modification of the waste water treatment system.
Waste disposal:	Coal ash from the steam boilers is disposed of outside of the factory without any problem.

(5) Maintenance of Facilities

About 80 to 90 percent of the maintenance is dealing with problems; the other 10 to 15 percent is preventive maintenance. Such a maintenance system is based on the following reasons:

1. Most of the production facilities are operated batch-wise. and
2. Some facilities have spares, such as steam boilers.
3. If urgently needed, some maintenance work can be done on Sunday, and most maintenance work is completed within a few days.
4. Preventive maintenance is scheduled by facility in each production department, and each maintenance operation is completed within 2 weeks. Most maintenance (about 95 percent) work is carried out by a fixed sub-contractor.

(6) Scheduled Maintenance

Scheduled maintenance is carried out as mentioned above. Only main items of equipment are maintained according to the schedule.

(7) Major Energy Consuming Facilities

Major energy consuming facilities are shown in Figure 9-8. Their main specifications are as follows.

1) Steam Boilers

Type	Fluidized Bed with oil burner
Fuel	Lignite (at normal operation, 2,500 kg/h consumption)
	Diesel oil (at startup only)
Feed water temp.	110 °C
Steam flow	10,000 kg/h
Steam press.	42 bar
Steam temp.	470 °C

2) Steam Turbine Generator

Inlet steam	42 bar
Extracted steam	10.5 bar & 4.5 bar
Power generation	1,600 kWh (design with 15 to 16 t/h steam consumption)
	800 kWh (winter with 10 to 11 t/h steam consumption)
	500 kWh (summer with 7 to 8 t/h steam consumption)

3) Hot Air Furnace

Type	Air direct heating
Fuel	Fuel oil (at normal operation, 400 kg/h consumption)
Feed air temp.	Ambient
Hot air temp.	300 °C (after mixed with quench air)

(8) Electric Power Receiving, etc.

The electric power receiving system and its operating conditions are as follows.

1) Receiving voltage — 10,500 volt

2) Maximum demand — 2,500 kWh

3) Power factor — 95.00

4) Single-line diagram and transformer capacity per unit and number of transformers

See Figure 9-18

5) Capacity of power generation for emergency — There are 3 emergency power generators driven by diesel engines of,
410 kW - 2 generators
524 kW - 1 generator
They had been used only a few times since 3-4 years ago. One of them is now out of repair after fire damage.

6) Charging system — There are three systems corresponding to daytime (6:00 to 17:00, normal price), critical time (17:00 to 22:00, highest price) and night time (22:00 to 6:00, lowest price).

7) Contract for receiving electric power — Maximum capacity is 2,500 kWh, with a penalty for continuos 15 minutes' excess power receiving over the contract capacity.

8) Ratio of house generation power to received power

Unit: 1,000 kWh

	1992	1993	1994	1995	1996
House Generation	5,833	4,023	2,448	2,727	3,000
Percent	34.8	24.4	15.4	16.9	17.0
Received Power	10,936	12,482	13,472	13,400	14,630
Total	16769	16,505	15,920	16,127	17,630

(9) Measures Carried out for Energy Conservation and Their Effects

The following measures were carried out for condensate recovery and energy saving. By installing many steam traps for return lines, stopping steam leakage, improving insulation of the steam lines and replacing city-water with well-water, about 1.5 million DM was saved between April, 1992 and October, 1994 as follows.

Electricity	165,000 DM
City-water	672,000 DM
Steam	715,000 DM

Note: By replacing city water with well water, some water pumps were stopped and electricity consumption was reduced. In addition, all of the city-water has been replaced with well water since last October, however, more steam condensate must be recovered.

9-6 Current Condition and Problems with Facilities

9-6-1 Identification of the Current Problems

(1) Problems in Major Energy Consuming Facilities

The following items are considered as problems in major energy consuming facilities.

1) Low Load Operation of Power Generator

Existing steam boilers and power generator have enough capacity to generate house electric power; however the steam turbine power generator is operated at 30 to 50% load of nominal capacity, because there is no more extracted steam user in the production facilities. Therefore, extracted steam from the turbine-generator is sometimes blown up to the atmosphere. This energy may be used for preheating the drying air for the spray dryer in the powder detergent plant.

2) Corrosion Damage in Sulfonation Unit

Some equipment such as furnace and heat exchanger in the Sulfonation Unit are corroded by sulfuric gas. It is difficult to operate the unit continuously and to use a heat recovery system.

3) Lower Condensate Recovery

Due to the leakage in some points of the steam line, impurities enter the steam condensate and condensate cannot be recovered completely.

4) Steam Loss from the Steam Line

Many steam traps were arranged before time and heat loss was reduced; since then, however, it seems that there has been some steam loss through steam traps.

5) **Insufficient Thermal Insulation**

Steam line and related equipment such as steam boilers & turbine, and heat exchangers are fully insulated; however, thermal insulation is not of sufficient thickness, causing heat loss.

6) **Excessive Electricity Consumption**

Some motors are operated at higher speed than required, causing electricity loss.

(2) Problems in Promotion of Energy Conservation

In addition to problems in energy consuming facilities, the following problems exist for the promotion of energy conservation.

1. Shortage of engineers
2. Insufficient system of research and development
3. Shortage of measuring equipment
4. No time to analyze energy consumption rate

9-6-2 Problems in Energy Consumption Already Recognized and Items Requested for the Audit

Already recognized problems in energy consumption have been described in before, and there is no more problem because it is considered, comparing with other companies' same processes, that each production unit has been improved for energy consumption. Requested items for the audit include countermeasures to problems in major energy consuming facilities and their audit points. The following problems were confirmed in the first field survey for each item, and will be studied in more detail.

(1) Boiler and Steam Turbine Generator

1) There is an inbalance in capacity between the steam boilers (10t/h x 2) and steam turbine generator (15t/h).
2) Steam is utilized only for heating media. Increasing of steam consumption by introducing new users is necessary to increase the in-house power generation.
3) There are three prices for electricity as mentioned above. The lowest price (night time) is cheaper than house power generation.

(2) Heat Exchangers in Sulfonation Unit

1) There are some interruptions which cause burn-out of tubes.
2) A corrosive material (SO_3) is treated in the heat exchangers. Damage to tubes and

plates has caused shut-downs and impaired heat recovery by boiler feed water.

(3) Spray Dryer and Hot Air Furnace

1) Air feed for the hot air furnace is not preheated.

2) Optimum operating condition for the spray dryer is not maintained due to leakage around it.

(4) Condensate Recovery System

1) It seems that damage to heat exchangers is causing some leakage of impurity into the condensate recovery system and water quality is not good enough to be recovered.

2) Leakage points are not certain and they need to be detected.

(5) Steam Trap System

1) Some steam traps are not working correctly.

(6) Thermal Insulation System

1) It is not enough to evaluate the existing insulation system; it should be improved, if necessary.

(7) Reduction of Electricity Consumption

1) For some motors, an adequate speed control system shall be adopted.

9-7 Method and Procedure of Energy Audit

Based on the current condition and problems with facilities, the analysis and measuring plan has been prepared as follows.

(1) Analysis and Measuring Points

Analysis and measuring points for the energy audit are listed up in Table 9-4 for each major item of energy audit. Their main points are shown in the following drawings respectively.

1) Figure 9-11 Steam Boiler System
2) Figure 9-12 Steam and Condensate Flow Diagram
3) Figure 9-13 Powder Detergent Process

(2) Detailed Schedule of Analysis and Measuring

A detailed schedule of analysis and measuring is shown in Table 9-5. They are planned so that actual analysis and measuring work at the factory will be finished within 10 working days. For this purpose, analysis and measuring work are executed by cooperation of EIE and factory personnel; the detailed personnel allocation schedule is adjusted on site. Some analysis items for lignite, light oil, ash and heavy oil are required to be finished within 10 working days.

(3) Necessary Modification for Analysis and Measuring Work

Modification of the facility should be minimized. The following analysis and measuring points shall be checked by the factory side beforehand to determine whether modification work is required or not.

1) Modification for Exhaust Gas Sampling

It is necessary to analyze O_2, CO_2 and CO content in the exhaust gas in order to calculate the exhaust gas flow rate, and it is also required to analyze NOx, SOx and others for the purpose of air pollution control. Equipment for sampling of exhaust gas is shown in Figure 9-9. Some modification shall be carried out, if necessary.

1) Steam boiler exhaust gas
2) Spray dryer exhaust gas
3) Air heater exhaust gas

Figure 9-9 is based on the Japanese Standard; the main points are as follows.

1) Sampling nozzles shall be located in a straight line until the stack, 2 diameter lengths upstream and downstream from the main nozzles.
2) 2 nozzles shall be used when the stack diameter is more than about 1 meter.
3) The flange rating is shown in Japanese Standard; however, API standard will be applied with nearly same nozzle diameter.
4) In case nozzles are installed an elevated place, a temporary ladder and platform shall be provided.

2) Modification for Heat Exchangers

Liquid (including steam condensate) flow rate can be measured using an ultrasonic flow meter without any modification, and fluid temperature in the pipe can be considered to be nearly the same as the pipe surface temperature, which can be measured by a surface thermometer. The measuring plan around heat exchangers is shown in Figure 9-10. It is planned that leakage points of heat exchangers shall be checked by analyzing the condensate from heat exchangers; therefore, some modification shall be done as shown in Figure 9-10 for each heat exchanger. In case some leakage is found through the condensate analysis, a leakage detection test shall be carried out using chlorofluorocarbon gas, and the same nozzles as shown in Figure 9-10 shall be provided for heat exchangers and other equipment where there may be some leakage.

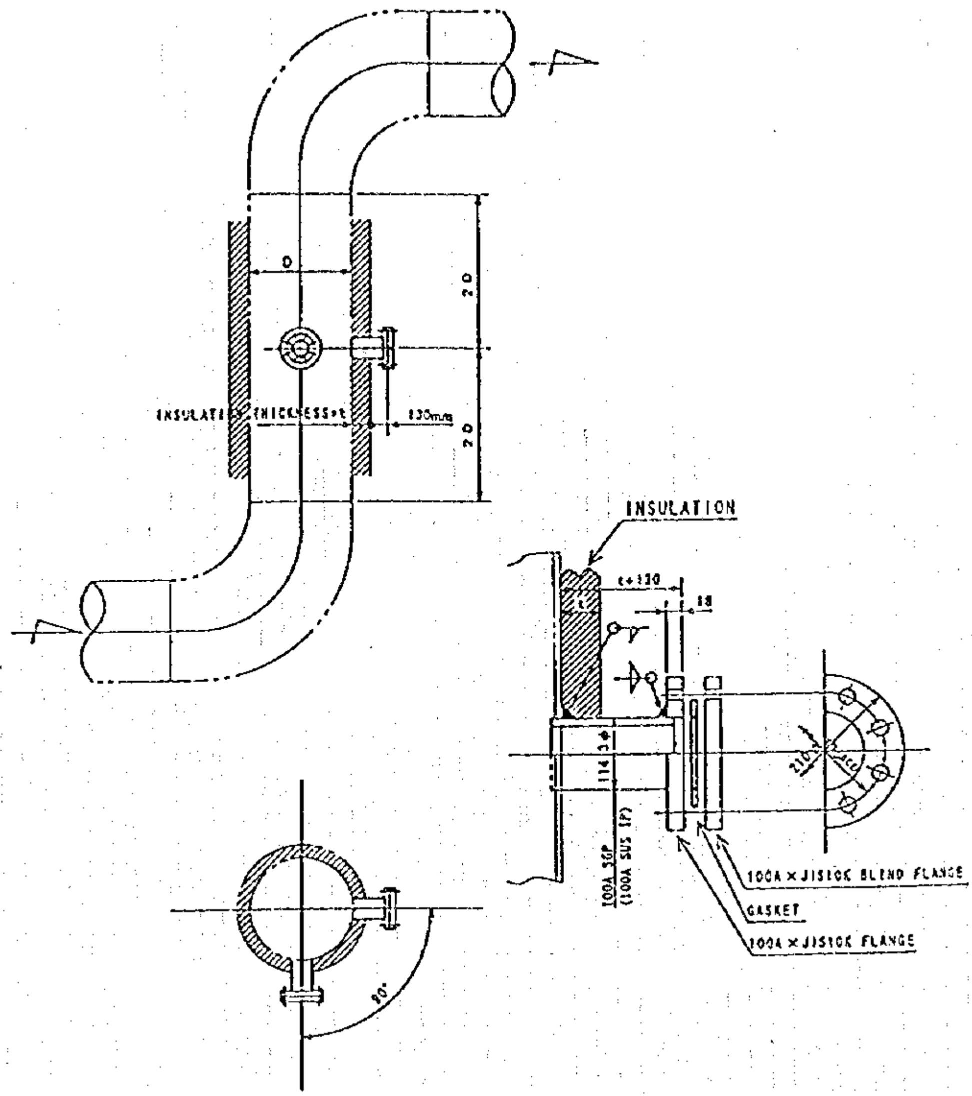


Figure 9-9 Standard Drawing of Measuring Nozzle for Flue Gas

Vent or drain nozzles with valves shall be provided for measuring the operating pressure and for sampling

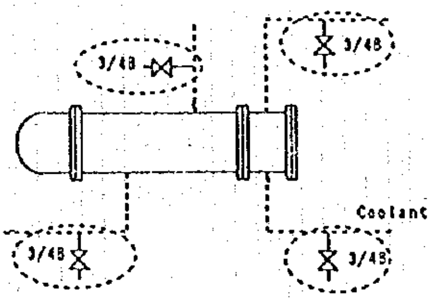


Figure 9-10 Modification Plan around Heat Exchangers

Table 9-4 Outline of Analysis and Measurement Items for Energy Audit (Turyag A.S.)

Analysis and Measurement Method							
Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Analysis and Measurement Equipment					
		Required Equipment	Factory	EIE	JICA	Local Lab	Addition
1. Boilers and steam turbine generator							
<Boiler>							
(1) Lignite							
1) Industrial analysis							
a) Moisture (wt%)	M					x	
b) Ash (wt%)	M					x	
c) Volatile matter (wt%)	M					x	
d) Fixed carbon (wt%)	M					x	
e) Total sulfur (wt%)	M					x	
f) Heating value (LHV & HHV : kcal/kg)	M	Automatic Bomb Calorimeter			x	x	
2) Elemental analysis							
a) Carbon (wt%)	M	Elementary Analyzer				x	
b) Hydrogen (wt%)	M	ditto				x	
c) Nitrogen (wt%)	M	ditto				x	
d) Oxygen (wt%)	M	ditto				x	
3) Consumption (t/h)	E						
(2) Light oil							
a) Heating value (LHV & HHV : kcal/kg)	M	Automatic Bomb Calorimeter			x	x	
b) Specific gravity	M	Hydrometer				x	x
c) Viscosity (c.p.)	M	Saybolt Viscosimeter				x	
d) Flow rate (t/h)	M	Flow indicator	x				
e) Total sulfur (wt%)	M					x	
f) Elemental analysis							
Carbon (wt%)	M	Elementary Analyzer				x	
Hydrogen (wt%)	M	ditto				x	
Nitrogen (wt%)	M	ditto				x	
Oxygen (wt%)	M	ditto				x	
(3) Boiler feed water							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
d) Electric conductivity (μ S/cm)	M	Electric Conductivity Meter			x		
e) pH	M				x		
f) Temperature (C)	M	ditto			x		
g) DO (ppb, ppm)	M	ditto Low Level DO Meter			x		

Analysis and Measurement Method							
Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Analysis and Measurement Equipment					
		Required Equipment	Factory	EIE	JICA	Local Lab.	Addition
(4) Combustion air							
a) Flow rate (Nm^3/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Bar Thermometer					x
c) Pressure (bars)	M	Mercury Manometer					x
(5) Generated steam							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
(6) Exhaust gas							
a) Oxygen (vol%)	M	Portable O_2 Analyzer			x		
b) CO_2 (vol%)	M	Gas Analyzer			x		
c) CO (vol%)	M	ditto			x		
d) Flow rate (Nm^3/h)	E						
e) Temperature (°C)	M	Temperature Indicator	x				
f) SO_2 (ppm)	M	Infra-red Gas Analyzer			x		
(7) Ash							
a) Temperature (°C)	M	Temperature Indicator	x				
(include Ash Cooler outlet)		Thermoelectric Pyrometer			x		
b) Quantity (t/h)	E						
<Steam turbine generator>							
(8) Inlet steam							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
(9) Extracted steam (10.5 bar)							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
(10) Extracted steam (4.5 bar)							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
(11) Extracted steam to Atm							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Temperature (°C)	M	Temp. Indicator	x				
c) Pressure (bars)	M	Pressure Indicator	x				
(12) Generated power (kW/h)	M	Wattmeter	x				
(13) Rotation (rpm)	M	Tachometer	x				
(14) Sound (dB)	M	Sound Level Meter			x		

Analysis and Measurement Method								
Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Analysis and Measurement Equipment						
		Required Equipment	Factory	EIE	JICA	Local Lab.	Addition
2 Spray dryer and hot air furnace							
< Spray Dryer >							
(1) Hot air							
Ref. to Air Heater							
(2) Exhaust gas							
1) Temperature (C)	M	Temp. Indicator	x				
2) Composition							
a) Oxygen (vol%)	M	Portable O_2 Meter					x
b) CO_2 (vol%)	M	Gas Analyzer					x
c) CO (vol%)	M	ditto					x
d) Hydrocarbon (vol ppm)	M	Gas Chromatography			x		
(3) Slurry							
a) Flow rate (kg/h)	E						
b) Temperature (C)	M	Bar Thermometer					x
c) Pressure (bars)	M	Pressure Indicator	x				
d) Water (wt%)	M	Dryer			x		
(4) Powder							
a) Temperature (C)	M	Surface Thermometer					x
b) Moisture content (wt%)	M	Infra-red Moisture Content Meter			x		
c) Particle size distribution	M	Standard Sieve					x
< Air Heater >							
(5) Heavy oil							
1) Elemental analysis							
a) Carbon (wt%)	M	Elementary Analyzer				x	
b) Hydrogen (wt%)	M	ditto				x	
c) Nitrogen (wt%)	M	ditto				x	
d) Oxygen (wt%)	M	ditto				x	
2) Heating value (LHV & HHV : kcal/kg)	M	Automatic Bomb Calorimeter			x	x	
3) Total sulfur (wt%)						x	
4) Temperature (C)	M	Temp. Indicator	x				
5) Pressure (bars)	M	Pressure Gauge			x		x
(6) Atomizing steam							
a) Temperature (C)	M	Surface Thermometer					x
b) Pressure (bars)	M	Pressure Indicator	x				
c) Flow rate (kg/h)	M	Ultrasonic Flow Meter					x
(7) Combustion air	M			x			
a) Flow rate (Nm^3/h)	M	Vane Type Anemometer					x
b) Temperature (C)	M	Bar Thermometer			x		x
c) Pressure (bars)		Pressure Gauge					
(8) Quench air	M						
a) Temperature (C)	M	Bar Thermometer					x

Analysis and Measurement Method

Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	of Analysis and Measurement Equipment: Required Equipment	Factory	EIE	JICA	Local Lab.	Addition
b) Pressure (bar)		Pressure Gauge		x	x		x
(9) Flue gas	M	Portable O_2 Analyzer		x			x
a) Oxygen (vol%)	M	Gas Analyzer		x			x
b) CO_2 (vol%)	M	ditto		x			x
c) CO (vol%)							
d) Flow rate (Nm^3/h)	E						
e) Temperature (℃)	M	Temp. Indicator	x				
f) Pressure (bar)	M	Manometer					x
3. Heat exchangers in sulfonation unit							
< Heat Exchangers >							
(1) Heating materials							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Inlet temperature (℃)	M	Surface Thermometer	x				x
c) Outlet temperature (℃)	M	Surface Thermometer	x				x
d) Outlet pressure (bars)	M	Pressure Gauge	x				
(2) Heated materials							
a) Flow rate (t/h)	M	Flow Indicator	x				
b) Inlet temperature (℃)	M	Surface Thermometer	x				x
c) Outlet temperature (℃)	M	Surface Thermometer	x				x
d) Outlet pressure (bars)	M	Pressure Gauge	x				
4. Condensate recovery system							
<Upstream of Oil Detect Station >							
(1) Condensate analysis							
a) Electric conductivity (μ S/cm))	M	Electric Conductivity Meter			x		
b) pH		ditto			x		
< Facilities utilizing steam >							
(1) Inlet steam							
a) Pressure (bars)	M	Pressure Gauge			x		
b) Temperature (℃)	M	Surface Thermometer					x
(2) Outlet condensate							
a) Pressure (bars)	M	Pressure Gauge			x		
b) Temperature (℃)	M	Surface Thermometer					x
(3) Leakage detection	M	Chlorofluorocarbon Gas Detector					x
5. Steam trap system							
< Steam Traps >							
(1) Working condition	M	Trap Man		x			

Analysis and Measurement Method							
Major Items of Energy Audit & Subject Items and Points	Measurement or Estimate	Analysis and Measurement Equipment					
		Required Equipment	Factory	EIE	JICA	Local Lab.	Addition
6. Thermal insulation system							
< Facilities & Piping >							
(1) Surface temperature (°C)	M	Surface Thermometer					x
< Insulation material >							
(1) Thermal conductivity (kcal/m h°C)	M	Thermal Conductivity Meter			x		
7. Reduction of electricity consumption							
< Motors & equipment >							
(1) Rotation speed (rpm)	M	Tachometer		x			
(2) Electricity consumption (kw/h)	M	Ammeter	x				
< Treated material >	M	Surface Thermometer					x
(1) Inlet temperature (°C)	M	Pressure Gauge			x		x
(2) Inlet pressure (bars)	M	Surface Thermometer					x
(3) Outlet temperature (°C)	M	Pressure Gauge			x		x
(4) Outlet pressure (bars)							

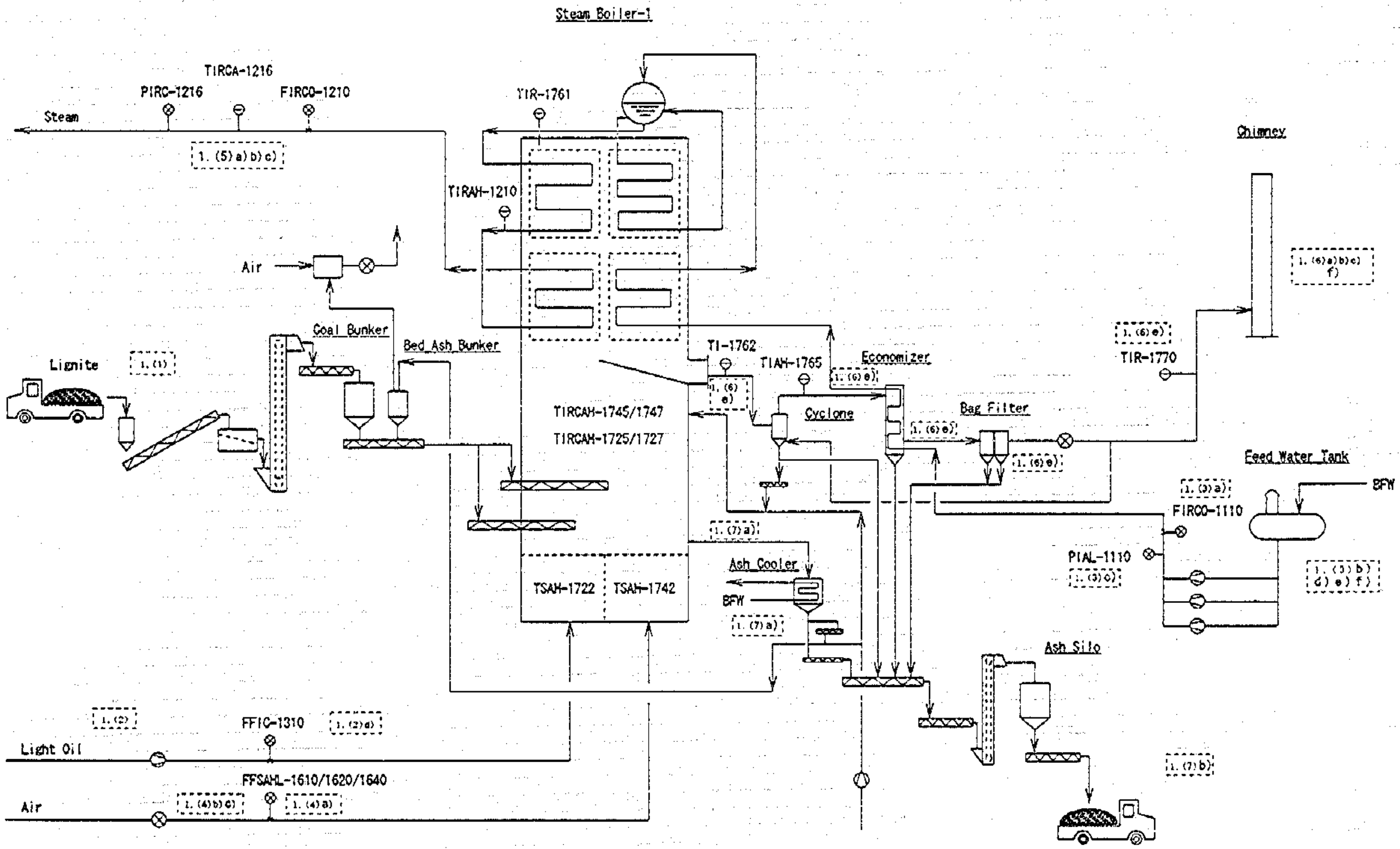


Figure 9-11 Analysis and Measuring Points for Steam Boiler System (Turyag A.S. Boiler-1)

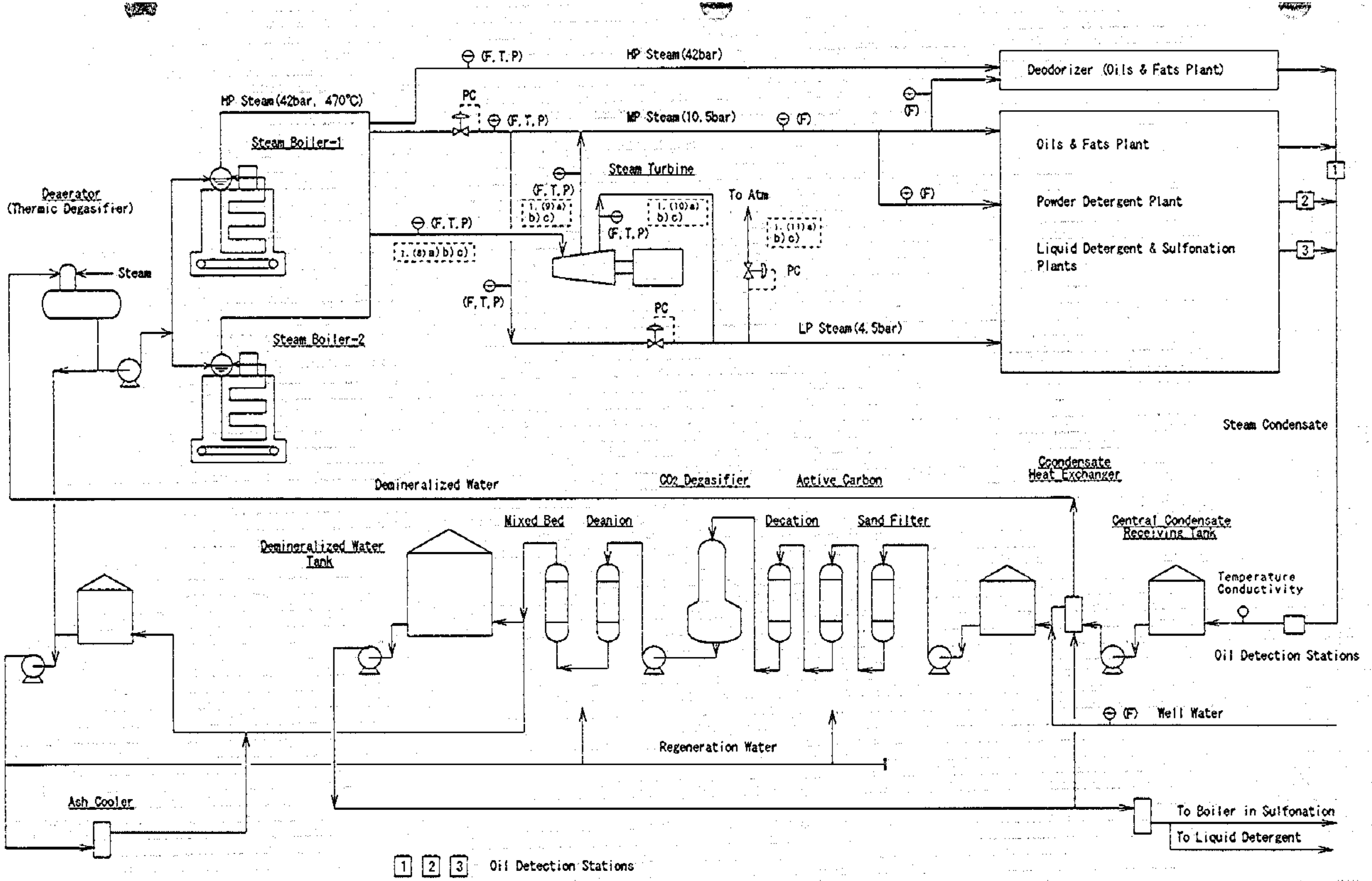


Figure 9-12 Analysis and Measuring Points for Steam and Condensate Flow Diagram (Turyag A.S.)

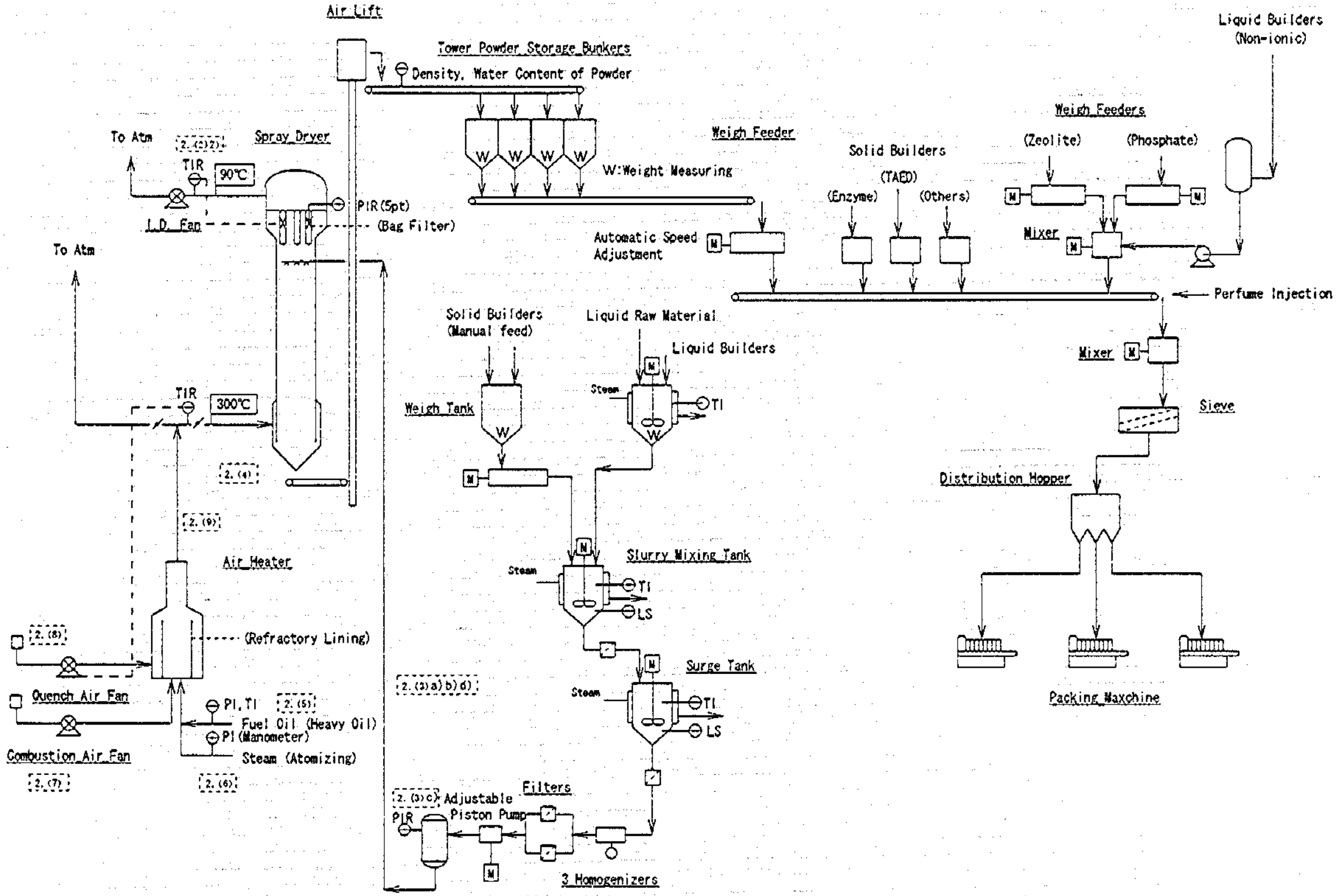


Figure 9-13 Analysis and Measuring Points for Powder Detergent Process (Turyag A.S.)

Table 9-5 Schedule of Analysis and Measurement (Turyag A.S.)

Analyzing and Measuring Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Boiler & Steam Turbine Generator															
1) Analysis <Boiler>															
a) Lignite (LHV/HHV & element)	x														
b) Light Oil (LHV/HHV.SG, vis. & elem.)	x														
c) BFW (elect. conduct. pH, temp & DO)		x	x												
d) Exhaust Gas (O_2, CO_2, CO)		x	x												
e) Ash (residual carbon)	x														
2) Measurement															
<Boiler>															
a) BFW (flow, temp & press)		x	x												
b) Combustion Air (flow, temp & press)		x	x												
c) Exhaust Gas (temp, O_2, CO_2, CO, SO_2)		x	x												
d) Generated Steam (flow, temp & press)		x	x												
<Steam Turbine Generator>															
a) Inlet Steam (flow, temp & press)		x	x												
b) 10.5 bar Extracted Steam (ditto)		x	x												
c) 4.5 bar Extracted Steam (ditto)		x	x												
d) Extracted Steam to Atm (ditto)		x	x												
e) Generated Power		x	x												
f) Rotation		x	x												
g) Sound Level		x	x												
2. Spray Dryer and Hot Air Furnace															
1) Analysis															
a) Spray Dryer and Exhaust Gas				x	x										
(O_2, CO_2, C0, HC)															
b) Slurry (H_2O)	x			x	x										
c) Powder (H_2O & particle size)				x	x										
d) Heavy Oil (LHV/HHV, SG, vis etc.)															
e) Flue Gas (O_2, CO_2, CO)				x	x										
2) Measurement															
a) Spray Dryer Exhaust Gas				x	x										
(temp, press, O_2, CO_2, CO)				x	x										
b) Slurry (flow, temp & press)				x	x										
c) Powder (temp)				x	x										
d) Heavy Oil (flow, temp & press)				x	x										
e) Atomizing Steam (ditto)				x	x										
f) Combustion Air (ditto)				x	x										
g) Quench Air (ditto)				x	x										
h) Flue Gas (ditto)															
3. Heat Exchangers in Sulfonation Unit															
1) Measurement						x									
a) Flow Rate						x									
b) Inlet/Outlet (temp & press)															

Analyzing and Measuring Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14
4. Condensate Recovery System															
1) Analysis															
a) Condensate (elect cond, pH & temp)							x	x	x						
2) Measurement															
a) Inlet Steam (flow & press)							x	x	x						
b) Outlet Condensate (flow & press)							x	x	x						
c) Leakage Detection							x	x	x						
5. Steam Trap System															
1) Working Condition								x	x						
6. Thermal Insulation System															
1) Facilities & Piping (surface temp)									x	x					
2) Insulation Material (thermal conduct)									x	x					
7. Reduction of Elect. Consumption															
1) Motor & Equipment (rotation & power)										x	x				
2) Treated Material (flow, temp & press)										x	x				

9-8 Measurement Procedure

9-8-1 Outline of Measurement and Analysis

(1) Major Items and Types of Energy Audit

Measurement and analysis work were carried out in accordance with the following major items and types of energy audit in the factory.

1. Thermal efficiency of steam boiler
2. Energy balance around steam turbine generator
3. Thermal efficiency of furnace (air heater)
4. Thermal efficiency of dryer (spray dryer)
5. Thermal efficiency of heat exchangers (sulfonator)
6. Management of steam and steam condensate lines
7. Management of steam trap system
8. Management of thermal insulation system
9. Reduction of electricity consumption

(2) Participants in the Energy Audit

Measurement and analysis work were executed by the following members at the factory and temporary laboratory at IBF.

1) Factory: Mr. Reha Yalcin, Mr. Sukru Cavdaroglu, Mr. Serdar Degirmenci, Mr. Mustafa Genis and Mr. Tuncay Senkal
2) EIE: Mr. Omer Kedici, Mr. Bora Omurtay, Mr. B. Hakki Buyruk and Mr. Erol Yalcin
3) JICA: Mr. K. Mitani, Mr. H. Yamada, Mr. T. Nimura and Mr. H. Takahashi

9-8-2 Energy Audit Schedule

Energy audit for the factory was carried out from 16th August to 13th September in 1996 as follows including preparation of a progress report on-site.

(1) Preparation Work

16, Aug. (Fri)	Confirmation of points of modification and sampling for measurement
21, Aug. (Wed)	Carrying back samples and transportation of measuring equipment
22, Aug. (Thur)	Final confirmation of points of modification and preparation of measuring equipment, and check of flow sheet around sulfonator

(2) Measurement and Analysis Work

23,Aug. (Fri)	Discussion & confirmation of audit plan and installation of measuring equipment
24 &25, Aug. (Sat & Sun)	Analysis and preparation for audit
26 & 27, Aug. (Mon & Tue)	Audit of boilers and steam turbine generator
28 & 29, Aug. (Wed & Thur)	Audit of spray dryer and hot air heater
30, Aug. (Fri)	Audit of heat exchangers in sulfonation unit
31, Aug. & 1, Sept. (Sat & Sun.)	Analysis of results
2 & 3 ,Sept.(Mon &Tue)	Audit of steam and condensate recovery system
4, Sept. (Wed)	Audit of steam trap system
5,Sept. (Thur)	Audit of thermal insulation system
6,Sept (Fri)	Audit of reduction of electricity consumption
7 & 8, Sept. (Sat & Sun)	Analysis of results
9, Sept. (Mon)	Clarification of measurement and check instruments

(3) Preparation of Progress Report

10 & 11, Sept.(Tue & Wed)	Preparation of progress report
12,Sept.(Thur)	Survey of similar plants
13,Sept.(Fri)	Discussion of preliminary results of audit

Table 9-5 shows a detailed schedule for analysis and measurement

9-8-3 Measuring Items, Points and Measuring Equipment

To calculate and evaluate current condition of energy consumption and to develop an energy balance, the analysis and measurement work described below has been executed according to the prepared schedule corresponding to major energy audit items. Among these, some of the analyzes were done beforehand. Industrial analysis of lignite was done by Bati Cement Incorporated. The exhaust gas analysis was also done by gas chromatograph in parallel with other tests. Regretfully, elemental analysis of fuels, lignite and fuel oil, could not be done, because of the breakdown of the elemental analyzer, therefore, the calculation of low heating values of fuels and exhaust gas volume must have awaited elemental analysis of fuel samples in Japan.

(1) Boilers and Steam Turbine Generator

1) Lignite: Industrial analysis and heating value
2) Light oil: Heating value
3) Boiler feed water: Flow rate, temperature, electric conductivity and pressure
4) Combustion air: Flow rate
5) Generated steam: Flow rate, temperature and pressure
6) Exhaust gas: O_2, CO_2, CO, SO_2 and temperature
7) Ash: Temperature and residual carbon
8) Steam to turbine: Flow rate, temperature and pressure
9) Extracted steam (10.5 bar): Flow rate, temperature and pressure
10) Extracted steam (4.5 bar): Flow rate, temperature and pressure
11) Extracted steam (to atm.): Flow rate, temperature and pressure
12) Generated power: kWh/h
13) Sound level around steam turbine: dB

(2) Spray Dryer and Air Heater

1) Spray dryer exhaust gas: Temperature, O_2, CO_2, CO and hydrocarbons
2) Feeding slurry: Pressure and water content
3) Powder: Moisture content and particle size distribution
4) Heavy oil to air heater: Heating value and temperature
5) Flue gas: O_2, CO_2, CO and temperature

(3) Heat Exchangers in Sulfonation Unit

1) Air flow rate: Compressor outlet and dry air to sulfonator
2) Sulfur combustion: Sulfur flow rate
3) Raw material to sulfonator: Flow rate
4) SO_2, SO_3 temperature: Sulfur combustion, SO_2 cooler, SO_3 converter and Sulfonator

(4) Steam Lines, Steam Utilizing Facilities and Steam Condensate Recovery System

1) Outlines of steam flow chart of every pressure levels (HP, MP, LP)

2) Outlines of steam utilizing facilities in each plant

3) Outlines of condensate recovery system

4) Measurement of water quality in the condensate recovery system

(5) Steam Trap System

1) Confirmation of steam trap list

2) Check working condition of steam traps in steam center (around boiler)

(6) Thermal Insulation System

1) Steam pipe lines:
Check surface temperature with and without insulation, diameter and length of each pipeline, thickness and materials of insulation

2) Hot facilities:
Check surface temperature with and without insulation, surface area of equipment and thickness and materials of insulation

(7) Reduction of Electricity Consumption

1) Clamp test of main transformers

2) Clamp test of major electricity consuming equipment

Details of measuring items, points and measuring equipment are shown in Table 9-4 and section 9-8.

9-8-4 Analysis and Measuring Equipment to be used on-Site

Required equipment of analysis and measurement are shown in Table 9-4 for each energy audit item. Their specifications are as follows.

(1) Equipment for Exhaust Gas Analysis and Measurement

1) Electronic Stack Gas Analyzer (EIE)

a)	Oxygen	O2	0 - 20.9 vol%
b)	Carbon oxides	CO	0 - 2,000 ppm
		CO_2	0 - 20 vol%

c) Chimney Draught ± 12.5 hPa
d) Air Temperature 0 - 60 ℃
e) Exhaust Gas Temperature 0 - 650 ℃
f) Soot Filter Paper Method

2) Sulfur Dioxide Monitor (EIE)
   a) Sulfur dioxide SO_2 0 - 2,000 ppm
   b) Operating Temperature -10 - +40 ℃

3) Vane Type Anemometer (EIE)
   a) Velocity 0.2 - 30 m/s
   b) Temperature -30 - +100 ℃

4) Portable Oxygen Meter (JICA)
   a) Measurement Material O_2 in Flue Gas
   b) Measurement Range 0 - 10/25 vol% O_2
   c) Operating Temperature 5 - 35 ℃

5) Portable Gas Tester (JICA)
   a) Measurement Material CO and CO_2
   b) Measurement Range CO 0 - 0.5 vol%
      CO_2 0 - 15 vol%
   c) Operating Temperature 5 - 40 ℃

6) Laser Dust Content Meter (JICA)
   a) Measurement Range 0.001 - 10 mg/m^3

7) Portable NOx Analyzer (JICA)
   a) Measurement Material NOx in Flue Gas
   b) Measurement Range 0 - 5,000 ppm
   c) Operating Temperature 5 - 37 ℃

8) Infra-red Gas Analyzer (JICA)
   a) Measurement Material SOx in Exhaust Gas
   b) Operating Temperature -5 - +40 ℃

9) Mercury Manometer (JICA Additional)

a) Measurement Range 0 - 200 mmHg

10) Air Velocity Meter (EIE)

a) Pressure 0 - 25 kPa

b) Velocity Range 0 - 28 m/s

c) Operating Temperature 0 - 50 ℃

11) Gas Flow Meter (JICA Additional)

12) Suction Unit for Sampling of Exhaust Gas (JICA Additional)

(2) Equipment for Temperature and Humidity Measurement

1) Non-contact Infra-red Pyrometer (EIE)

a) Measuring Temperature 0 - 1,000 ℃

b) Operating Temperature 0 - 45 ℃

2) Non-contact Infra-red Pyrometer (EIE)

a) Measuring Temperature 600 - 2,000 ℃

b) Operating Temperature 0 - 45 ℃

3) Electronic Temperature Indicator (EIE)

a) Measuring Temperature -50 - +2,000 ℃

b) Operating Temperature 0 - 40℃

4) Optical Pyrometer (JICA)

a) Measuring Temperature 900 - 3,000 ℃

b) Measuring Method Silicone Sensor

5) Thermoelectric Pyrometer (JICA)

a) Measuring Temperature 0 - 1,200 ℃

b) Measurement Method CA Thermo-couple

6) Surface Temperature Meter (JICA Additional)

a) Measuring Temperature -100 - 500 ℃

7) Glass Thermometer (JICA Additional)

a) Measuring Temperature 0 - 150 & 0 - 400 ℃

8) Digital Thermometer (JICA Additional)

a) Measuring Temperature -100 - 500 ℃

9) Relative Humidity Meter (EIE)

a) Temperature 0 - 70 ℃

b) Humidity 0 - 97 %RH

10) Thermal Conductivity Meter for Insulating Material (JICA)

a) Measuring Range 0.02 - 10 kcal/mh℃

b) Temperature Range -10 - +200 ℃

c) Measuring Method Probe

11) Ambient Condition Recorder (JICA)

a) Measurement Range

Temperature -20 - +50 ℃

Humidity 0 - 100 %

Atmospheric Pressure 940 - 1,046 mbar

(3) Equipment for Pressure Measurement

1) Pressure Gauge (JICA)

a) Steam Pressure 10 Kg/cm^2, 20 Kg/cm^2, 50 Kg/cm^2, 70 Kg/cm^2

b) Air Pressure 20 Kg/cm^2

(4) Equipment for Water Analysis

1) Conductivity/resistivity Meter (EIE)

a) Conductivity 0.05 μ s

b) Resistivity 1K - 20M Ohm

c) TDS 0.01 - 20 ppm

d) Temperature -30 - +130 ℃

2) Electric Conductivity Meter (JICA)

a) Measurement Range — 0 - 10,000 μ s/cm (pH 2 - 12)

3) Low Level DO Meter (JICA)

a) Measurement Range DO — 0 - 200 ppb / 0 - 20 ppm

b) Operating Temperature — -5 - +55 ℃

c) Operating Pressure — 700 - 800 mmHg

4) Multi-purpose Water Quality Meter (JICA)

a) Measurement Items — 8 (Depth, Temp., Electric Conductivity, DO, pH, ORP, Turbidity)

(5) Equipment for Electricity Measurement

1) Tachometer (EIE)

a) Contact Type — -0.5 - +19,999 rpm

b) Photo Type — -5 - +99,999 rpm

c) Operating Temperature — 0 - 50 ℃

2) Energy Analyzer (EIE)

a) Voltage — 50 - 600 V-AC

b) Frequency — 20 - 1,000 Hz

c) Currents — -600 V-DC

d) Clip-On Measuring Range — 0.05 - 1,000 A

3) Angular Clamp Meter (JICA)

4) Electrical Tester (JICA Additional)

5) Clamp Tester (JICA Additional)

(6) Other Equipment

1) Standard Sieve (JICA Additional)

a) Size — 4 mm, 2 mm, 1 mm, 0.5 mm, 0.15 mm

2) Computerized Steam Trap Management System (EIE)

a) Ambient Operating Temperature 0 - 40 ℃

b) Steam Trap Surface Temperature 0 - 255 ℃

3) Sound Level Meter (JICA)

a) Measurement Range 30 - 130 dB

4) Multi-channel Recorder (JICA)

a) Number of Channels 12 points

5) Transformer (JICA)

a) Inlet Condition 3 phase, 200 V, 3 lines

b) Outlet Condition Single phase, 200 V, 2 lines, 2 kVA

Single phase, 100 V, 2 lines, 3 kVA

6) Transformer (JICA Additional)

a) Inlet Condition 2 phase, 200 V, 3 5 kVA

b) Outlet Condition Single phase, 100 V, 5 kVA

7) Freon Gas Detector (JICA Additional) For R134a, R22 and R12

8) Ultrasonic Flow Meter (JICA Additional)

a) For Liquid Hydrocarbon : 0 - 7 tons/h Max.

-40 to 260℃

b) For Gas 0 - 100 Nm^3, -50 to 150℃

9) Trap Man (JICA Additional)

9-8-5 Analysis and Measuring Equipment to be used at Laboratory

A central laboratory was set up in Izmil Basma Fabrikasi A.S. (IBF) for analyzing several materials from Henkel Truyag, Dev Blok, IBF and Izmir Demir Celik Sanai (IDC) in common, and the following analysis equipment were prepared.

1) Automatic Bomb Calorimeter (JICA)

a)	Measuring Range	1,000 - 7,500 cal
b)	Measurable Material	Solid and liquid
c)	Operating Temperature	-15 - +55 ℃

2) Saybolt Viscosimeter (JICA)

a)	Temperature Range	30 - 240 ℃

3) Elemental Analyzer (JICA)

a)	Measurable Elements	Carbon, Hydrogen and Nitrogen	
b)	Measurement Range	Carbon	13 - 2,600 μg
		Hydrogen	2 - 400 μg
		Nitrogen	5 - 1,000 μg
c)	Weight of Sample	2 - 3 mg	

4) Gas Chromatography (JICA)

a)	Temperature Range	Room Temperature - 400 ℃

9-8-6 Estimation Method of Exhaust Gas Flow Rate from Steam Boiler and Air Heater

It was difficult to measure the exhaust gas flow rate from boilers and air heater at the site directly, therefore, it was estimated through the following calculation.

(1) Calculation Method - 1

This calculation method could be used when it was impossible to carry out the elemental analysis of the fuel, but it was possible to analyze the exhaust gas composition of CO_2, CO and O_2.
The calculation formula is as follows.

Ao = Theoretical combustion air (Nm^3/kg-Lignite or fuel oil)
= 0.001 x LHV + 0.56 (for lignite)
= 0.00124 x LHV - 1.4 (for fuel oil)
(LHV = Lower Heating Value of Lignite or fuel oil: kcal/kg)

m = Excess air ratio
= $1/\{1-(3.76CO_2 - 0.5CO)/100 - CO_2 - O_2 - CO)\}$

here,

CO_2 : CO_2 content in exhaust gas (vol%)
CO : CO content in exhaust gas (vol%)
O_2 : O_2 content in exhaust gas (vol%)

A = Combustion air (actual)
= mAo (Nm^3/kg-Lignite or fuel oil)

N_2 = N_2 content in exhaust gas (vol%)
= $1 - (CO_2 + CO + O_2)$ (vol%)

G = Dry Exhaust Gas
= $0.79 \times mAo/N_2$ (Nm^3/kg-Lignite or fuel oil)

(2) Calculation Method - 2

This calculation method could be used when it was possible to carry out the elemental analysis of the fuel in addition to the analysis of exhaust gas composition of CO_2, CO and O_2, and its calculated value is more reliable than the value calculated using calculation method -1.

The calculation formula is as follows.

Ao = Theoretical combustion air (Nm^3/kg-Lignite or fuel oil)
= $0.0889C + 0.267H - 0.033O + 0.033S$

here,

C : Carbon content in fuel (wt%)
H : Hydrogen content in fuel (wt%)
O : Oxygen content in fuel (wt%)
S : Sulfur content in fuel (wt%)

m = Excess air ratio
= $1/\{1 - (3.76CO_2 - 0.5CO)/100 - CO_2 - O_2 - CO)\}$

here,

CO_2 : CO_2 content in exhaust gas (vol%)
CO : CO content in exhaust gas (vol%)
O_2 : O_2 content in exhaust gas (vol%)

A = Combustion air (actual)

= mAo (Nm^3/kg-Lignite or fuel oil)

G = Dry exhaust gas

= (m - 0.21)Ao + (1.867C + 11.2H + 0.7S + 0.8N)/100 (Nm^3/kg-Lignite or fuel oil)

here,

N : Nitrogen content in fuel (wt%)

9-8-7 Calculation Method of Heat Loss through Insulation for Equipment and Piping

The heat loss calculation method for equipment and for piping are slightly different; however, their measuring points were nearly the same. The calculation methods are as follows.

(1) Heat Loss Calculation Method for Equipment

Q = Heat loss through insulation per square meter and hour (kcal/m^2·h)

= (to - tr)/(1/a + x/b)

here,

to : Fluid temperature inside equipment (℃)

tr : Ambient temperature (℃)

a : Heat transfer coefficient (kcal/m^2·h·℃)

Normally, 7 kcal/m^2·h·℃ is used.

b : Thermal conductivity (kcal/m·h·℃)

Normally, 0.0193 kcal/m·h·℃ is used.

x : Insulation thickness (m)

(2) Heat Loss Calculation Method for Piping

Q = Heat loss through insulation per meters and hour (kcal/m·h)

= (to - tr)/{Ln(do/di)/2 x 3.14b} + 1/(3.14 x do x a)

here,

to : Fluid temperature in piping (℃)

tr : Ambient temperature (℃)

a : Heat transfer coefficient (kcal/m^2·h·℃)

Normally, 10 kcal/m^2·h·℃ is used.

b : Thermal conductivity (kcal/m·h·℃)

Normally, 0.061 kcal/m·h·℃ is used.

x : Insulation thickness (m)

di : Outside diameter of piping (m)

do : Outside diameter of insulation (m)

Ln : Natural logarithm (-)

9-9 Result of Measurement and Analysis

There were various kind of items to be audited and measuring data in the factory as mentioned before, and results of measurement and analysis are described in this section for the following seven items.

1. Boilers and steam turbine generator
2. Spray dryer and air heater
3. Heat exchangers in sulfonation unit
4. Steam lines, steam utilizing facilities and steam condensate recovery system
5. Steam trap system
6. Thermal insulation system
7. Reduction of electricity consumption

9-9-1 Boilers and Steam Turbine Generator

There were some fluctuations of generated steam due to the batch operations of users. However, the typical data for this unit were as follows.

Table 9-6 Typical Measurement and Analysis Data in Steam Boiler-1

(1) Lignite		**(4) Generated Steam**	
1) Industrial Analysis		a) Flow rate (kg/h)	11,300
a) Moisture (wt%)	21.12	b) Temperature (℃)	435
b) Ash (wt%)	28.74	c) Pressure (bar)	40.9
c) Volatile matter (wt%)	48.50	**(5) Exhaust Gas**	
d) Fixed carbon (wt%)	22.76	a) O_2 content (vol%)	8.7
e) Total sulfur (wt%)	1.16	b) CO_2 content (vol%)	12.7
f) LHV (kcal/kg)	3,169	c) N_2 content (vol%)	78.6
g) HHV (kcal/kg)	3,404	d) Temperature (℃)	133
2) Elemental Analysis		**(6) Ash**	
a) Moisture (wt%)	17.10	1) Temp. (Ash Cooler Out, ℃)	75
b) Carbon (wt%)	34.50	2) Elemental Analysis	
c) Hydrogen (wt%)	3.00	a) Moisture (wt%)	0.1>
d) Nitrogen (wt%)	0.97	b) Carbon (wt%)	1.7
(2) Boiler Feed Water		c) Hydrogen (w%)	0.1
a) Flow rate (kg/h)	11,300	d) Nitrogen (w%)	0.08
b) Temperature (℃)	110	e) Specific heat at 80 ℃ (*)	0.22
c) Pressure (bar)	65.2	at 130 ℃ (*)	0.23
d) Electric conductivity (μS/cm)	10.4	* : cal/℃・g	
e) pH (-)	7.4		
(3) Combustion Air			
a) Flow rate (Nm3/h)	4846/4882		

Note: It was difficult to measure the lignite consumption rate; therefore, it was assumed based on the factory's recorded data that 260 kg of lignite would be required for steam generation of 1,000 kg-steam.

Table 9-7 Typical Measurement Data in Steam Turbine Generator

1) Inlet Steam		4) Steam Released to Atmosphere	
a) Flow rate (kg/h)	9,880	a) Flow rate (kg/h)	2,740
b) Temperature (℃)	461	b) Temperature (℃)	252
c) Pressure (bar)	40.9	c) Pressure (bar)	3.9
2) Extracted Steam (10.5bar)		e) pH (-)	7.4
a) Flow rate (kg/h)	3,750		
b) Temperature (℃)	325	5) Generated Power (kWh)	700
c) Pressure (bar)	10.4	6) Rotation (rpm)	1,575
3) Extracted Steam (4.5bar)		7) Sound (dB)	85-89
a) Flow rate (kg/h)	6,130		
b) Temperature (℃)	276		
c) Pressure (bar)	3.9		

In addition to the data in Tables 9-6 and 9-7, operational data around the steam boiler were measured; they are shown in Figure 9-14.

9-9-2 Spray Dryer and Air Heater

Spray dryer and air heater in the Powder Detergent unit can be considered as an independent facility from the viewpoint of heat balance development because its main heat source is only fuel oil for the air heater. Typical data were as follows.

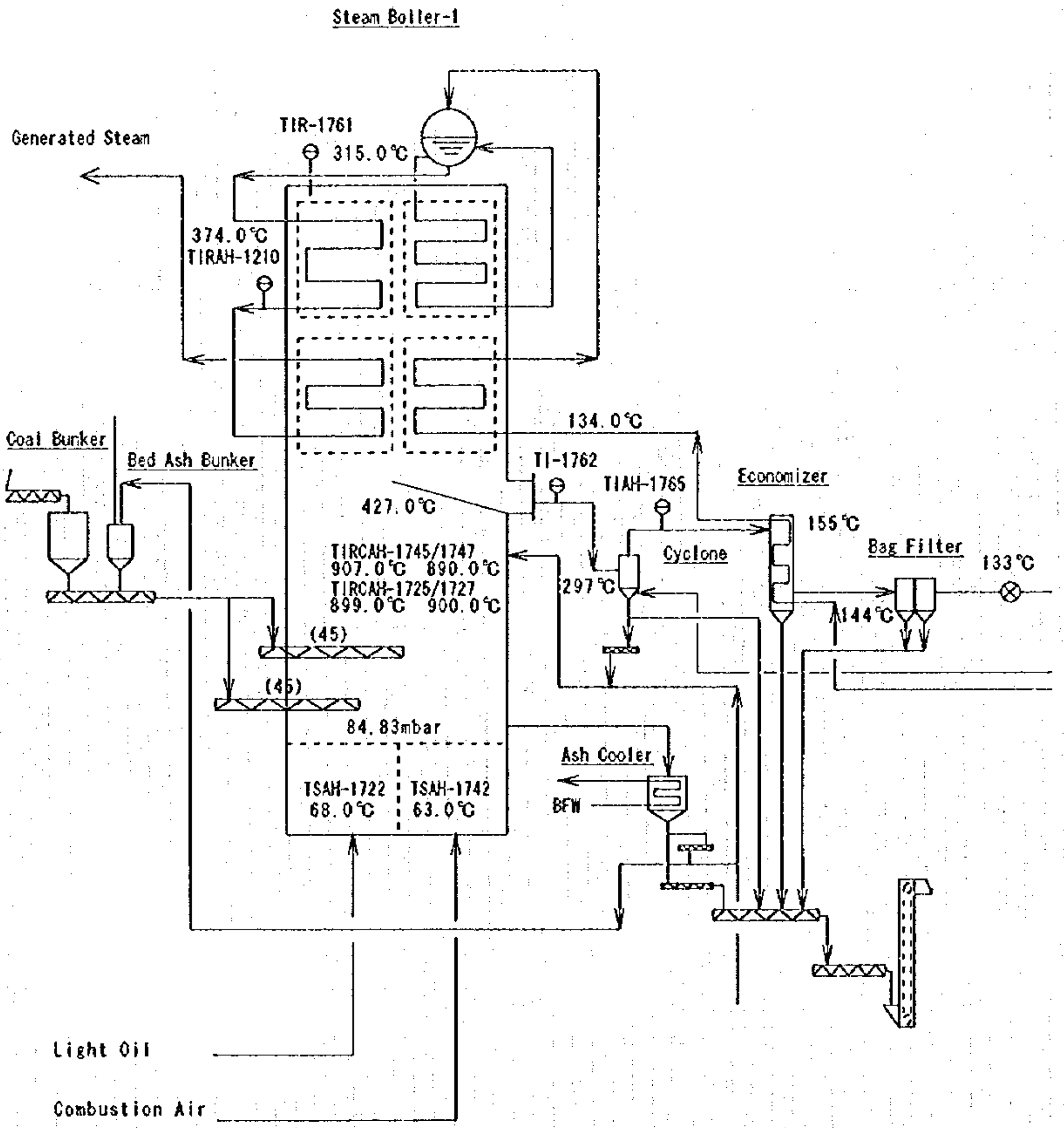


Figure 9-14 Steam Boiler-1 Operating Data (Turyag A.S.)

Table 9-8 Typical Measuring Data in Air Heater and Spray Dryer

Air Heater		Spray Dryer	
1) Fuel oil (Heavy oil)		1) Slurry	
a) Carbon (wt%)	85.4	a) Flow rate (kg/h)	7,518
b) Hydrogen (wt%)	11.7	b) Temperature (℃)	75
c) Nitrogen (wt%)	0.5	c) Water content (wt%)	48.7
d) Sulfur (wt%)	2.26	2) Powder	
e) LHV (kcal/kg)	10,460	a) Flow rate (kg/h)	4,400
f) HHV (kcal/kg)	10,760	b) Temperature (℃)	65
g) Specific gravity (-)	0.9489	c) Water content (wt%)	48.7
h) Viscosity (mm^2/s)	219.4	b) Temperature (℃)	48.7
i) Flow rate (kg/h)	367	3) Exhaust gas	
j) Temperature (℃)	89	a) O_2 content (vol%)	19.8
k) Pressure (kg/cm^2)	2.5	b) CO_2 content (vol%)	1,6
2) Atomizing steam		c) N_2 content (vol%)	78.6
a) Temperature (℃)	150	d) Temperature (℃)	75
b) Pressure (kg/cm^2)	4.2		
3) Combustion air		Particle size distribution	
a) Flow rate (Nm^3/h)	5,830	a) >2mm (g)	4.4
b) Temperature (℃)	30	b) 2 mm> >1mm (g)	20.6
4) Quench air		c) 1mm> >0.5mm (g)	199.3
a) Flow rate (Nm^3/h)	16,310	d) 0.5mm> >0.15mm (g)	202.4
b) Temperature (℃)	30	e) 0.15mm> (g)	23.2
5) Flue gas			
a) O_2 content (vol%)	17.3		
b) CO_2 content (vol%)	4.2		
c) N_2 content (vol%)	78.5		

Note - 1 : Flow rates of the combustion and quench air were calculated using the flow velocity data and pipe inside diameter, respectively. See section 9-10 (3)

Note - 2 : Flue gas means the mixture of real flue gas and quench air; because quench air is introduced just after the oil combustion section in the heater.

Note - 3 : It was also difficult to measure the flow rate of slurry and powder, therefore, they were adopted from estimated from other data including the flow rate of fuel oil. Ref. section 9-10 (3) based on the factory's experience.

9-9-3 Heat Exchangers in Sulfonation Unit

There are four heat exchangers around the SO_3 Converter (12C1) as shown below. Most of the heat in the sulfonation unit is mostly removed through these heat exchangers to the outside of the unit. It was also considered that this waste heat to the atmosphere should be utilized if possible, the heat loss was audited and calculated as described below.

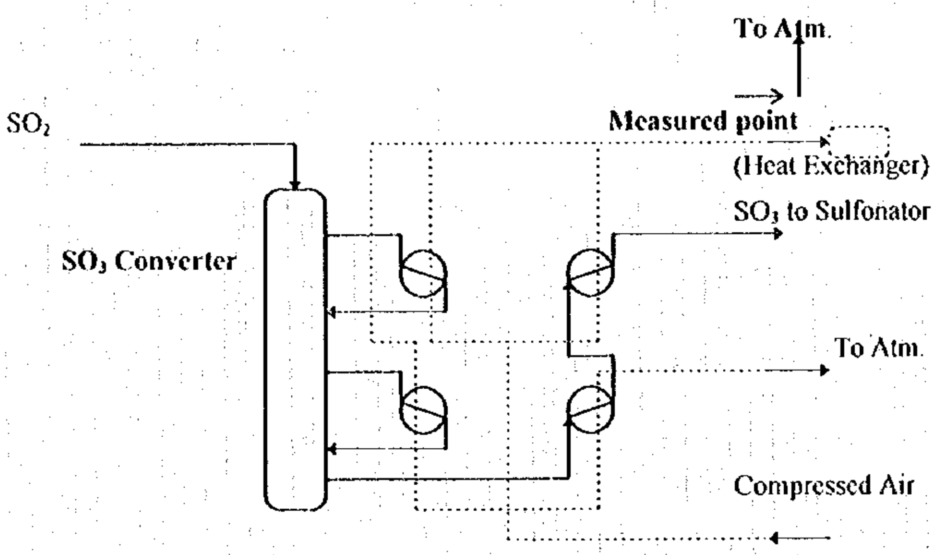


Figure 9-15 Outline of Heat Exchangers around SO_3 Converter

Calculation of air volume

1) Average air velocity : 1,750 ft/min. = 533.4 m/min.
2) Section area of pipe : $(508 - 2 \times 10)^2 \times 0.785 = 200{,}988$ mm^2 $= 0.201$ m^2
3) Air volume : $533.4 \times 0.201 = 107.2$ m^3/min. = 6,432 m^3/h

Calculation of heat loss

1) Air temperature : 180 ℃
2) Average air enthalpy : 0.31 kcal/m^3℃
3) Heat loss : $6{,}432 \times 180 \times 0.31 = 358{,}906$ kcal/h

This heat loss was found to be almost equivalent to the lignite consumption of 100 kg/h, and other data such as sulfur flow rate, temperature around SO_3 converter etc. were measured at the same time in order to calculate the heat balance in the sulfonation unit.

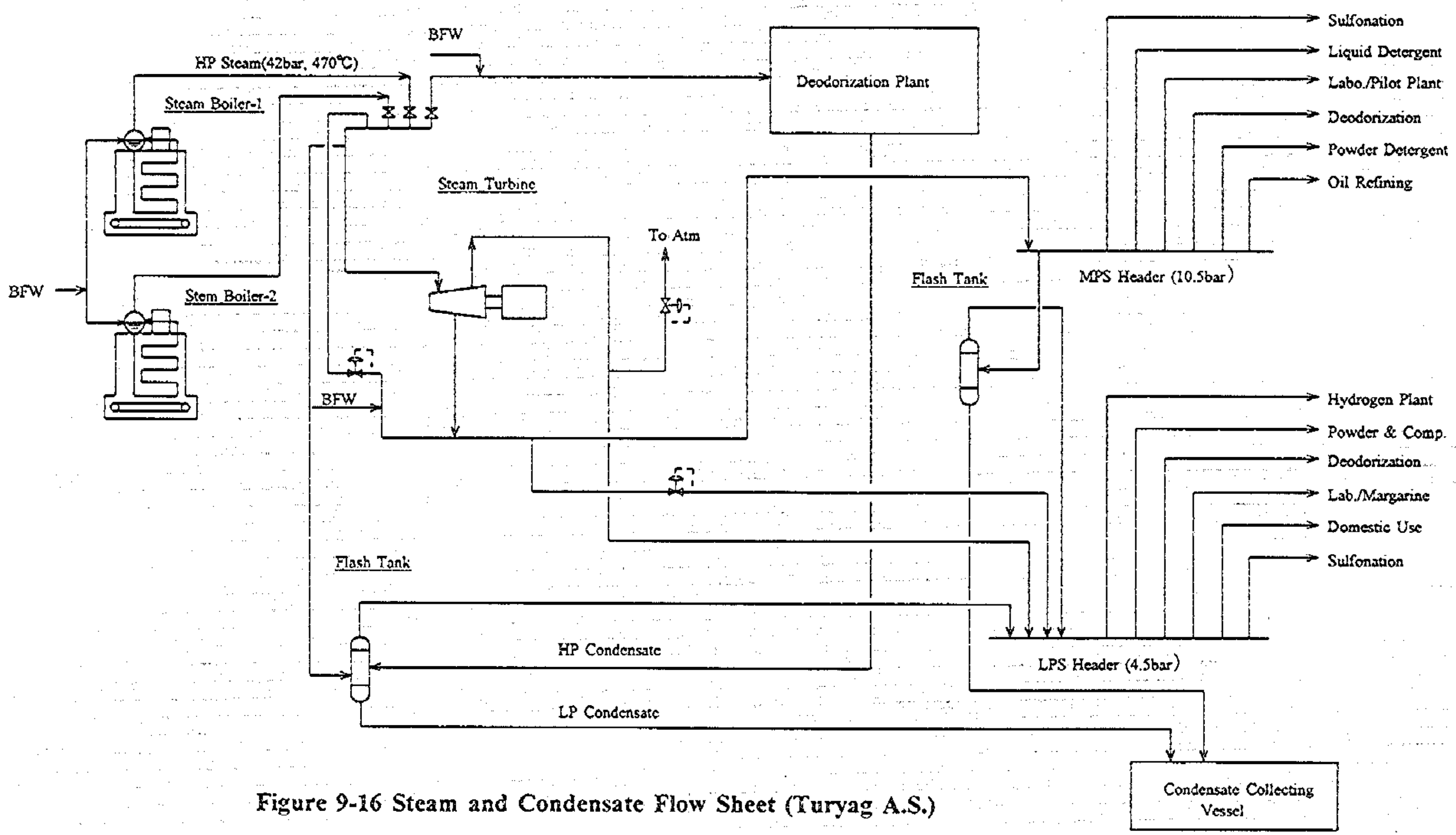


Figure 9-16 Steam and Condensate Flow Sheet (Turyag A.S.)

9-9-4 Steam Lines, Steam Utilizing Facilities and Condensate Recovery System

All steam lines around the steam boiler and steam turbine generator, and main steam lines for production facilities, were checked one by one including main condensate lines. An outline of steam flow chart was made and is shown in Figure 9-16. Electric conductivity and pH value were also checked at each oil detection station in order to confirm the water quality of condensate to be recovered, and their measured data are as shown below.

Table 9-9 Water Quality in the Condensate Recovery System

Location of Detection Station	Electric Conductivity (μ S/cm)	pH
1) Steam boiler house	34	7.7
2) Storage tank yard (Oil & Fat)	6	7.6
3) Sulfonation unit	no operation	no operation
4) Powder detergent area	5.8	6.8

From the above water quality analysis, it seemed that all condensate could be recovered and reused; however, the factory explained that each condensate would not contain any oil normally, but sometimes oil may flow into the condensate line through the steam line after cleaning operation of each piping by steam as shown in Figure 9-17.

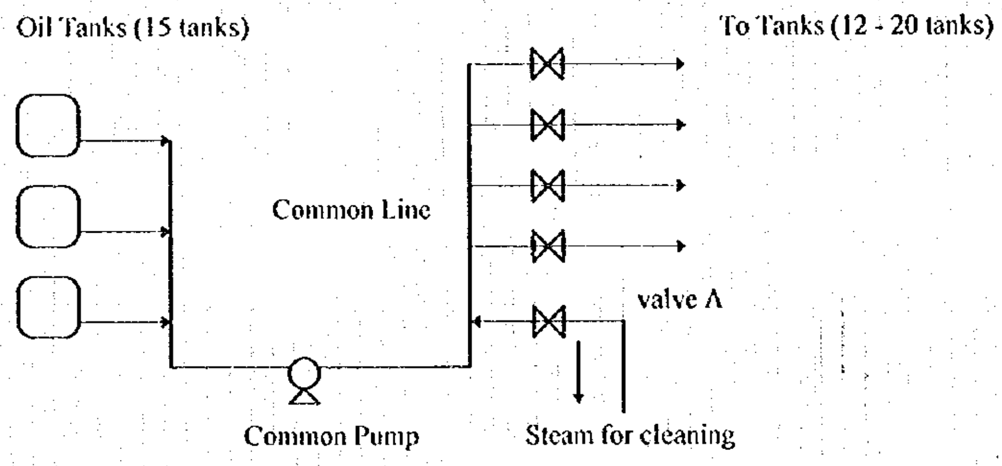


Figure 9-17 Typical Operation Trouble of Line Cleaning by Steam

Note: If valve A is not closed perfectly after the cleaning operation, some oil will flow back into the steam line. Countermeasures are required to avoid these problems.

9-9-5 Steam Trap System

There are about 500 steam traps installed in steam lines and the types of steam traps are judged by estimated flow rate figures. The factory has prepared a list showing the number of steam traps, service for users, working pressures, condensate outlet pressures, size, types and makers of steam traps and renewal and checked date of the steam traps. Table 9-10 presents arrangement of steam traps and measurement of working conditions in the steam center. A check of the working condition of steam traps in the area showed that 14/21 (66.7%) of steam traps were in good condition; in other words, 14/18 of working steam traps were in good condition.

Table 9-10 Arrangement of Steam Traps and Working Conditions in the Steam Center

Type/Area	Th.-static	Th.dyn.	Bimetalic	Bucket	Float	Disc	Total
St. center	13	0	9	2	1	0	25
Sulfonat.	47	0	0	2	0	0	49
L.deterg.	39	0	4	14	0	0	57
P.deterg.	55	0	1	0	4	0	60
Electrysis	3	0	5	2	0	0	10
Hydrogen.	11	0	7	5	3	0	26
Deodoriz.	16	8	0	0	3	0	32
Oil refin.	56	0	12	8	5	5	81
Oil tanks	36	2	1	25	11	0	75
Margarin.	6	2	0	0	3	0	11
P det.tank	13	2	1	2	2	0	20
LAB tank	3	0	0	6	4	0	13
Others	24	0	0	1	0	0	25
Total	322	14	40	67	36	5	484
Working conditions of steam traps in the steam center							
Good	9	0	4	1	0	0	14
Leak	1	0	0	0	0	0	1
Blowing	0	0	3	0	0	0	3
Low temp.	2	0	1	0	0	0	3
Not in work	1	0	1	1	1	0	4
Total	13	0	9	2	1	0	25
Note : Leak - more than 5% leakage, Blowing - more than 15% leakage							

9-9-6 Thermal Insulation System

Thermal insulation conditions of steam lines, equipment around the steam boiler, steam turbine generator and major production facilities were also checked one by one. Heat losses from each steam lines and equipment were calculated using the heat loss calculation methods mentioned in section 9-8-4. The calculation results are summarized in Tables 9-11 and 9-12 for equipment and piping respectively.

Table 9-11 Heat loss from Main Equipment

Equipment	Inside Temp (℃)	Insulation Thick. (cm)	Surface Area (m^2)	Heat Loss (kcal/h)
Steam Boiler	434 - 900	20	128	173,150
Spray Dryer	75 - 290	20	356	125,320
Air Heater	290	20	41	22,490
Hydrogenator	200	20	30	10,680
Deodorizer	225	20	60	24,470

Table 9-12 Heat Loss from Steam Line

Name of Line	Pipe OD (mm)	Insulation Thick. (cm)	Pipe Length (m)	Heat Loss (kcal/h)
MP Steam Header (11 bar, 330 ℃) to Facilities				
Sulfonation	125	50	160	28,640
Liquid Detergent	80	57	185	22,410
Lab. & Pilot	100	63	240	31,730
Deodorizer	80	58	50	6,000
Powder Detergent	100	63	145	19,170
Oil Refinery	100	63	100	14,700
LP Steam Header (4.5 bar, 250 ℃) to Facilities				
Hydrogenation	100	56	100	10,420
Powder Detergent	100	63	145	14,060
Deodorizer	80	57	75	6,660
Liquid Detergent	100	56	240	25,000
Domestic Use	100	56	105	10,940
Sulfonation	125	50	160	21,000
Total (MP Steam + LP Steam)				210,720

Note: Thermal insulation materials are mostly glass wool; each insulation thickness was measured or assumed.

9-9-7 Reduction of Electricity Consumption

(1) Measurement of Transformer Stations

This factory has six transformer stations as shown in Figure 9-18. Electricity consumption was measured for each station. The results are shown in Table 9-13.

Table 9-13 Results of Measurement for Transformer Stations

T/S No. Phase	Rated kVA	Rated Ampere	Max. Voltage	Min. Voltage	Max. Ampere	Min. Ampere	Power kW (Meas.)	Power factor	Power kW (Calc.)
1-A	1250	3125	390	380	850	750	420	0.97	479-557
1-B			390	380	800	750			
1-C			390	380	850	750			
2-A	1000	2500	390	380	900	870	510	0.92	527-578
2-B			390	380	930	920			
2-C			390	380	930	920			
3-A	1000	2500	378	378	650	560	210	0.99	336-421
3-B			370	370	640	620			
3-C			372	372	580	530			
4	1685	4212	10250	10250	70	70		0.95*	1181
5-A	1600	4000	390	390	1150	950	540-600	0.98-0.99	596-836
5-B			390	390	1250	1100			
5-C			390	390	1050	900			
6-A	750	1875	420	400	350	350	160	0.88	183-224
6-B			420	400	300	300			
6-C			420	400	350	350			

Note: The asterisk indicates an assumption (the actual figure was not obtained).

(2) Measurement of Major Motors

This factory has installed about 1,000 motors. The motors may be classified by capacity as follows.

1) Less than 10 kW: 847
2) 10 kW ≦ < 30 kW: 98
3) 30 kW ≦ < 50 kW: 26
4) 50 kW ≦ < 100 kW: 12
5) More than 100 kW: 9 (Total 992)

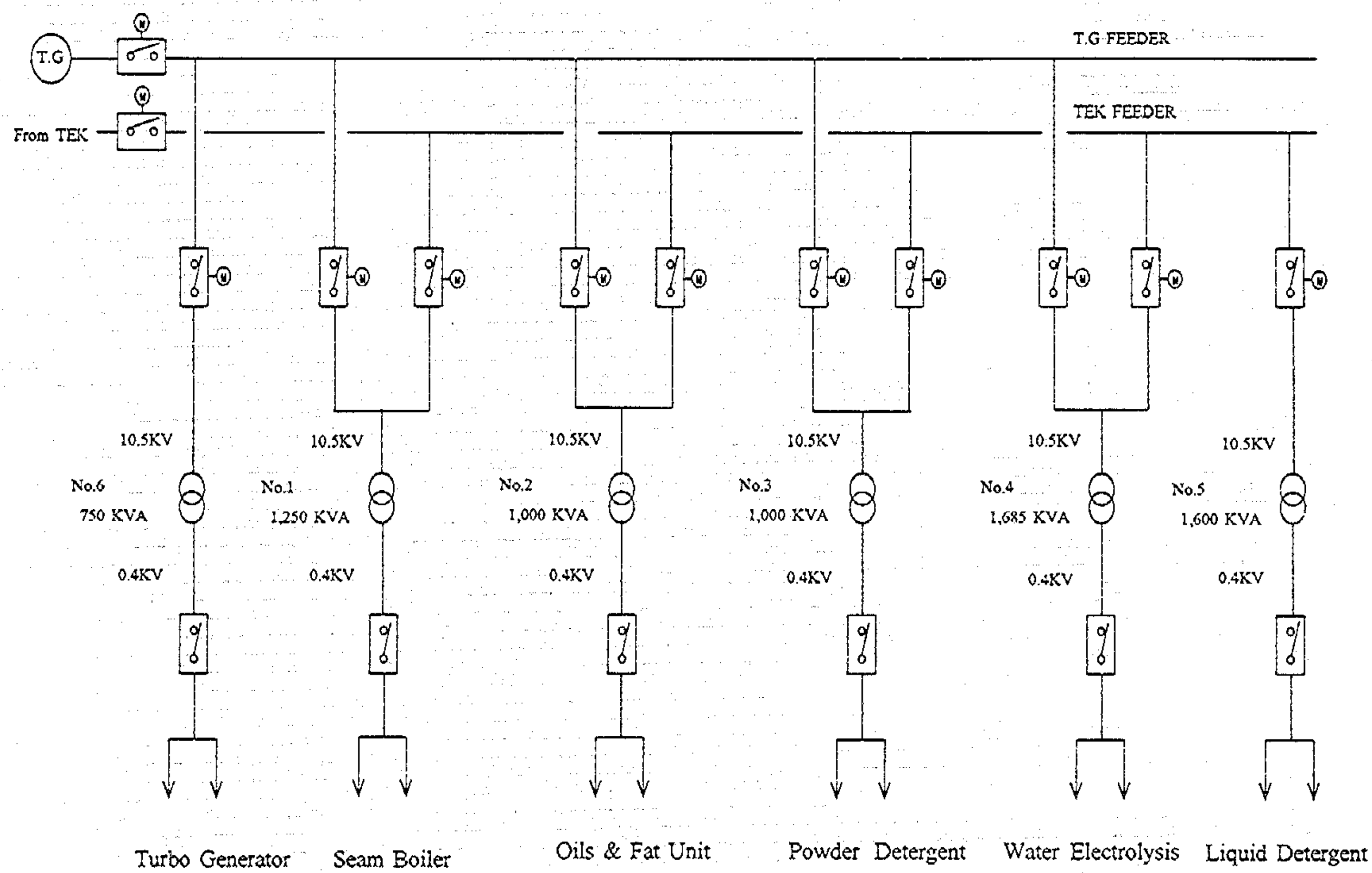


Figure 9-18 Single-line Diagram (Turyag A.S.)

Electric consumption of major motors was measured and is shown in Table 9-14.

Table 9-14 Results of Measurements on Major Motors

Service	Rated kW	Ampere:A	Voltage:V	Power factor (Label Value)	Power:kW (Load)
FDF/Boiler	110	142	385	0.87	84.2(0.749)
IDF/Boiler	55	77	387	0.87	44.9(0.816)
IDF/Spray dryer	132	153	379	0.86*	86.4(0.655)
Air compressor	110	166	382	0.86	94.5(0.859)
NH_3 compressor	160	223-230	380	0.86	126.2(0.789) 130.2(0.814)

Note: The asterisk indicates an assumption (the actual figure was not obtained).

9-10 Energy Flow Chart of Factory and Major Energy Consuming Facilities

There are the following three separate energy sources in the factory.

1. Lignite for steam boilers
2. Fuel oil for an air heater in powder detergent
3. Melting sulfur (SO_3 conversion heat) in Sulfonator

Therefore, energy flowcharts were studied for each energy source instead of the total factory energy flow chart.

9-10-1 Energy Flowchart around Steam Boiler

Based on the result of measurement and analysis, the heat balance was calculated as follows.

Table 9-15 Energy Balance around Steam Boiler

	Quantity	Temp. (°C)	Press.(bar)	Heat (kcal/h)	Ratio (%)
Inlet					
1) Lignite	2,938 kg/h	30	ambient	9,313,460	86.03
2) BFW	11,300 kg/h	110	65.2	1,243,000	11.48
3) Combust. air	28,956 Nm³/h	30	ambient	269,291	2.49
Total				10,825,751	100.00
Outlet					
1) Steam	11,300 kg/h	453	40.9	9,051,300	83.61
2) Exhaust gas	29,472 Nm³/h	133	-	1,215,127	11.22
3) Ash	844 kg/h	75	-	186	0.01
4) Heat Loss				559,138	5.16
Total				10.825,751	100.00

Note-1: 3,170 kcal/kg is used for the lower heating value (LHV) of lignite; it is an average value of three analysis data obtained by Ege University.

Note-2: Quantities of combustion air (28,956 Nm^3/h) and exhaust gas (29,472 Nm^3/h) were calculated using the calculation method -2 in 9-8-3, and they were became 27,923 Nm^3/h and 28,065 Nm^3/h respectively when calculation method -1 was used.

From these calculated results, it is judged that the boiler was operated in good condition with a suitable heat efficiency (steam/lignite) of 83.61 %, which means that a considerable amount of heat in the exhaust gas was recovered through the economizer. Its energy flow chart is shown in Figure 9-19.

9-10-2 Energy Flowchart around Steam Turbine Generator

The heat balance around the steam turbine generator was also calculated as follows; its energy flow chart is shown in Figure 9-20.

Table 9-16 Energy Balance around Steam Turbine Generator

	Quantity	Temp. (°C)	Press.(bar)	Heat (kcal/h)	Ratio (%)
Inlet					
1) Generated Steam	11,300 kg/h	448	40.3	8,983,500	100.00
Total				8,983,500	100.00
Outlet					
1) HP Steam	1,360 kg/h	441	40.3	1,074,400	11.96
2) MP Steam	3,500 kg/h	317	10.1	2,583,000	28.75
3) LP Steam	3,700 kg/h	279	4.0	2,675,100	29.78
4) LPS to atm.	2,740 kg/h	252	4.0	1,939,920	21.60
5) Generated Power	700 kWh	75	-	602,000	6.70
6) Heat Loss				109,080	1.21
Total				8,983,500	100.00

From these calculated results, the following discussion is presented.

1. At the measurement time, the amount of steam released to the atmosphere was 2,740 kg/h; this energy value is equivalent to 3 times the generated power energy.
2. This amount of steam released to the atmosphere also fluctuates from time to time, because the operating load of steam boiler cannot change quickly enough and some steam using facilities are operated in batchwise.
3. The amount of steam released to atmosphere can be reduced to the legal limit by the following plan.

   1) Introducing steam turbine drivers instead of large motors
   2) Introducing condenser in steam turbine generator exhaust LP steam line
   3) Introducing air preheater utilizing LP steam for combustion air of air heater
   4) Other conversions from electricity and fuel to steam

This plant has installed a steam turbine generator with maximum steam consumption of 16 tons/h and two boilers with rated steam generation of 10 tons/h. On the other hand, steam consumption is 7 to 8 tons/h in summer and about 11 tons/h in winter. This imbalance is due to stoppage of soap plant operation and reduction of steam consumption, with a steam trap system having been installed, after the steam turbine generator and boilers had been installed.

As a result, power generated from the steam turbine generator is not enough to meet the required power of this factory; sometimes the receiving power received from TEK exceeds the contract capacity (2,500 kW). On such an occasion, this factory is obliged to increase power generation by increasing exhaust steam to the atmosphere. Moreover, there is a problem with this steam turbine generator in that the efficiency is low because of low operation load. To solve these problems, increasing steam consumption in a rational way is necessary.

9-10-3 Energy Balance around Spray Dryer and Air Heater

The energy balance around the spray dryer and air heater was calculated as follows. The calculation method was not simple, because the flue gas from the air heater was exhausted to the atmosphere through the spray dryer and there was some atmospheric air leakage into the spray dryer.

Table 9-17 Energy Balance around Spray Dryer and Air Heater

	Quantity	Temp. (℃)	Press.(bar)	Heat (kcal/h)	Ratio (%)
Inlet					
1) Fuel Oil *1	367 kg/h	89	2.5	3,838,820	87.81
2) Atomizing *2 Steam	31 kg/h	150	4.2	20,370	0.47
3) Combustion Air *3	5,830 Nm^3/h	30	-	54,220	1.24
4) Quench Air *3	16,310 Nm^3/h	30	-	151,680	3.47
5) Slurry *1	7,518 kg/h	75	65	-	
Water *4	3,661 kg/h	75	65	274,580	6.28
6) Leak Air *6	34,625 Nm^3/h	30	-	32,200	0.73
Total				4,371,870	100.00
Outlet					
1) Exhaust Gas *6	55,923 Nm^3/h	75	-	1,300,210	29.74
2) Powder *1	4,400 kg/h	65	-	-	
Water *4	559 kg/h	75	-	41,930	0.96
Vapor Loss *5	3,102 kg/h	75	-	1,954,550	44.71
Heat Loss			-	1,075,180	24.59
Total	2,740 kg/h			4,371,870	100.00

Note-1: As the quantities of fuel oil, slurry and powder, the following factory's recorded data (annual operating data) were used, because it was impossible to measure them within the limited period except for the fuel oil flow rate.

Powder:	1,500 kg/batch	→	4,400 kg/h
Slurry:	2,560 kg/batch	→	7,518 kg/h
Fuel oil:	125 kg/batch	→	367 kg/h

Note-2: The quantity of atomizing steam was calculated as follows.

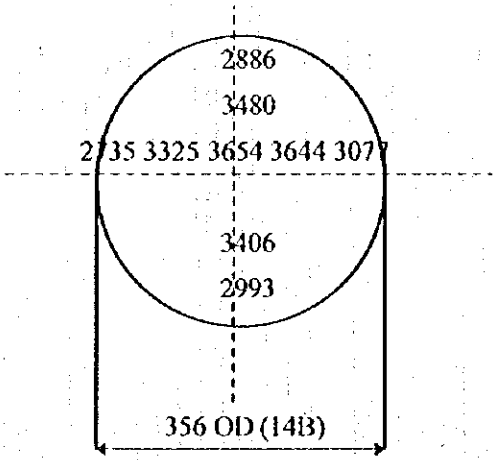
1) Pipe size: 1/2B (21.3 mm OD, 2.76 mm thickness)

2) Sectional area : $(21.3 - 2 \times 2.76)^2 \times 0.785 = 195\ mm^2 = 1.95\ cm^2$

3) Flow velocity: 20 m/s = 2000 cm/s

4) Oil flow rate: 1.95 x 2000 = 3900 cm^3/s = 14.04 m^3/h
= 30.7 kg/h (1 ton steam = 457 m^3)

Note-3: Quantities of combustion air and quench air were calculated as follows.



unit : feet/min.

Calculation of Air Volume

1) Average velocity : 3,250 ft/min = 990.6 m/min
2) Sectional Area : $(356 - 2 \times 10)^2 \times 0.785$ = 98,373 mm^2 = 0.098 m^2
3) Air volume : 990.6 x 0.098 = 97.1 m^3/min = 5,826 m^3/h

Calculation of Air Volume (for Quench Air)

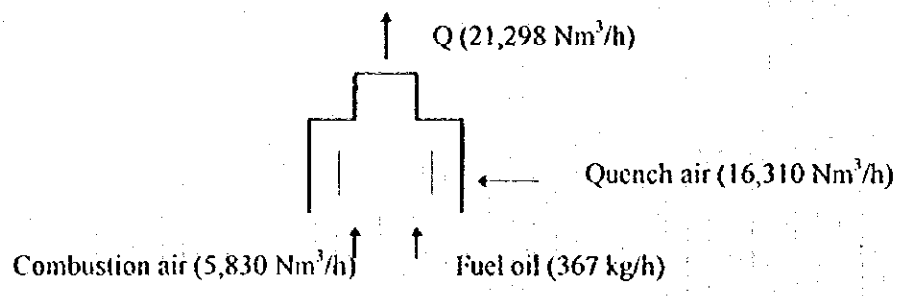
1) Average velocity : 600 m/sec (assumed)
2) Sectional Area : $(762 - 2 \times 10)^2 \times 0.785$ = 453,416 mm^2 = 0.453 m^2
3) Air volume : 600 x 0.453 = 271.8 m^3/min = 16,308 m^3/h

Note-4: Water contents in slurry and powder were calculated as follows.
7.518 kg/h x 0.487 = 3,661 kg/h (Ref. Table 9-8)
4,400 kg/h x 0.127 = 559 kg/h (Ref. Table 9-8)

Note-5: Vapor loss was calculated as follows.

Total water content in slurry:	3,661 kg/h
Water content in powder:	559 kg/h
Vapor loss into exhaust gas:	3,661 - 559 = 3,102 kg/h

Note-6: The exhaust gas from the spray dryer was calculated as follows.
At first, the flue gas from the air heater was calculated.



Ao	=	Theoretical combustion air (Nm^3/kg-fuel oil)
	=	0.0889C + 0.267H + 0.033S
	=	0.0889 x 85.4 + 0.267 x 11.7 + 0.033 x 2.26
	=	10.78 (Nm^3/kg-fuel oil)
	=	10.78 x 367 kg/h = 3,956 (Nm^3/h)
m	=	Excess air ratio
	=	Combustion air / Ao
	=	5,830/3,956 = 1.47
G	=	Dry exhaust gas
	=	(m - 0.21)Ao + (1.867C + 11.2H + 0.7S)/100
	=	4,988 Nm^3/h
Q	=	Dry exhaust gas + Quench air
	=	4,988 + 16,310 = 21,298 Nm^3/h

The quantity of air leakage into the spray dryer (Q') was calculated in the next stage from the CO_2 volume balance between flue gas (CO_2 = 4.2 vol%) and exhaust gas (CO_2 = 1.6 vol%)

21,298 x 0.042 = (21,298 + Q') x 0.016

554 = 0.016Q'   Q' = 34,625 Nm^3/h

Therefore, the quantity of exhaust gas became 55,923 (21,298 + 34,625) Nm^3/h.

From these calculated results, the following discussion is presented.

1) For fuel oil flow rate, the factory's recorded figure of 367 kg/h is used as mentioned before.
   Heat loss decreases if the measured flow rate of 244 kg/h is used.
2) Not only fuel oil flow rate but also water content of the slurry and powder affects the heat balance. The heat loss through the insulation on the concerned equipment appears small as explained in section 9-9-2 (6).
3) A considerable amount of air enters the spray dryer through unnecessary holes and it

lowers the temperature inside the spray dryer. This means that the most suitable flow rate and temperature of hot air for the spray dryer have not been determined. The following countermeasures should be taken in order to establish the most suitable flow rate and temperature of hot air.

a) Fill up the unnecessary holes in the spray dryer
b) Control the flow rate of quench air

Decreasing the flow rate of hot air by installing dampers for quench air and exhaust piping after filling up the unnecessary holes will result in reducing the fuel oil flow rate.

The energy flow chart around the spray dryer and air heater is shown in Figure 9-21.

9-10-4 Energy Balance in Sulfonator

The energy balance of the sulfonator was calculated as follows. Its energy flowchart is shown in Figure 9-22.

Table 9-18 Energy Balance in Sulfonator

	Quantity	Temp. (C)	Heat (kcal/h)	Ratio (%)
Inlet				
1) Melting Sulfur	163 kg/h	140	406,250	100.00
Outlet				
1) Cooling Air to Atmosphere	6,430 Nm^3/h	180	358,910	88.35
2) Heat Loss			47,340	11.65
Total			406,250	100.00

Note: The quantity and heat loss of the air to atmosphere were calculated as follows.

1) Average velocity : 1,750 ft/min ≒ 533.4 m/min
2) Sectional Area : $(508 - 2 \times 10)^2 \times 0.785 = 200,988\ mm^2 = 0.201\ m^2$
3) Air volume : $533.4 \times 0.201 = 107.2\ m^3/min = 6,432\ m^3/h$

Calculation of Heat Loss

1) Air Temperature : 180 °C

2) Enthalpy : 0.31 kcal/m^3 °C

3) Heat Loss : 6,432 x 180 x 0.31 = 358,906 kcal/h

From these calculated results, the following can be deduced at the present time.

1) Heat efficiency in the table means that about 88.56 % of inlet heat can be recovered through the cooling air, if this hot air is used for some purpose.

2) However, this hot air is being released to the atmosphere directly because the heat exchanger is damaged by sulfur attack and cannot be operated. Therefore, utilization of this heat in hot air should be reconsidered.

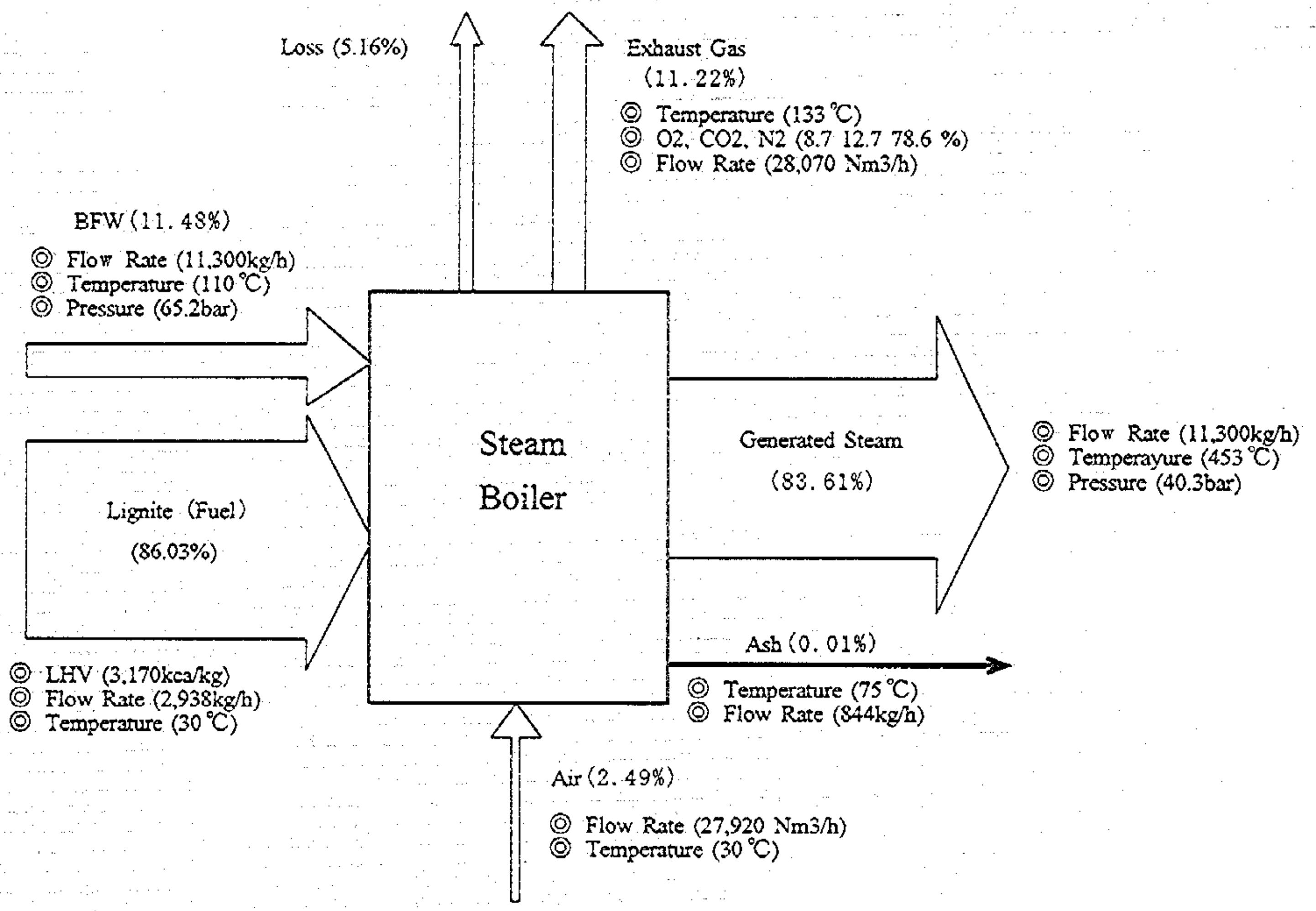


Figure 9-19 Energy Balance around Steam Boiler (Turyag A.S.)

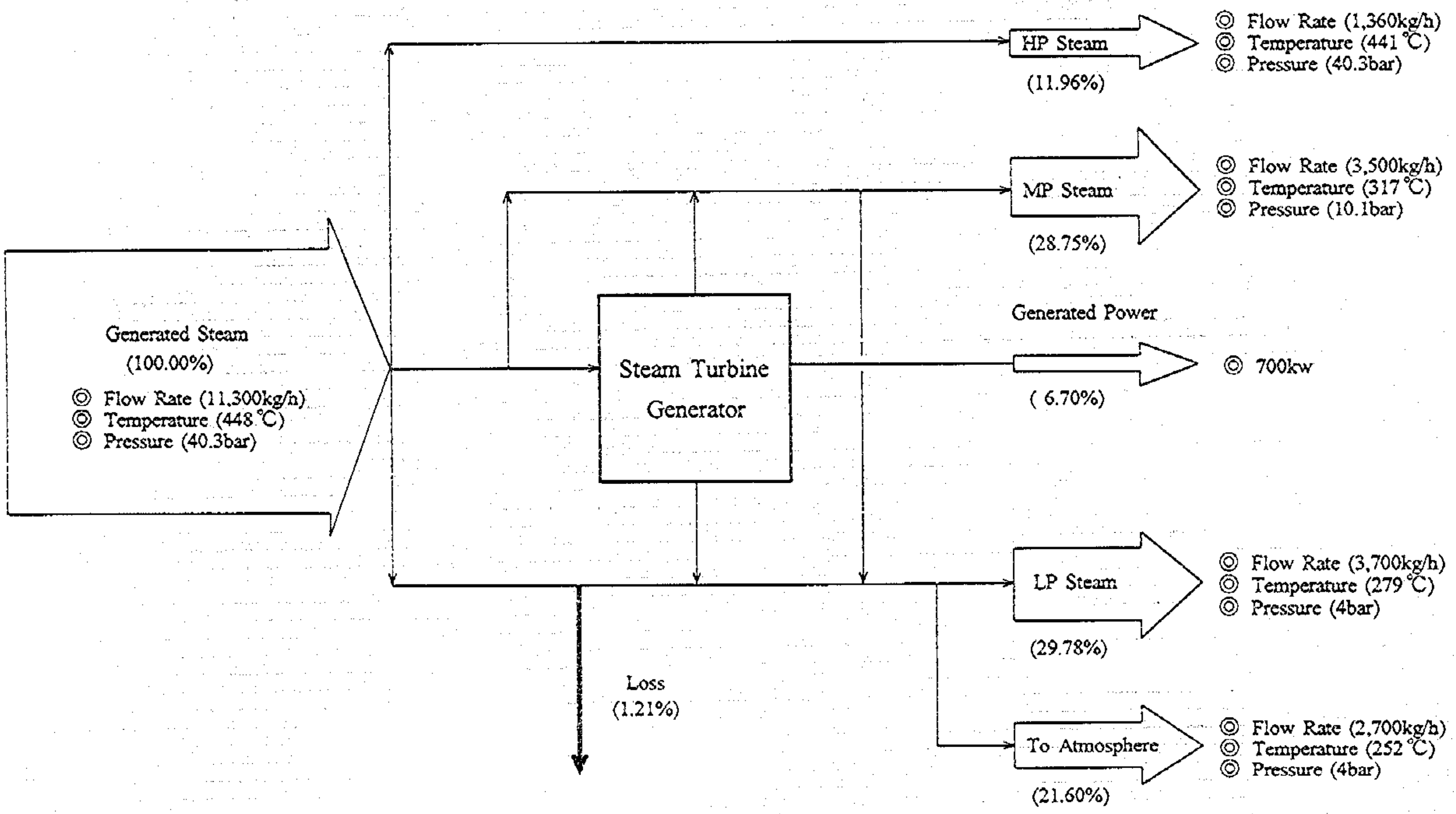


Figure 9-20 Energy Balance around Steam Turbine (Turyag A.S.)

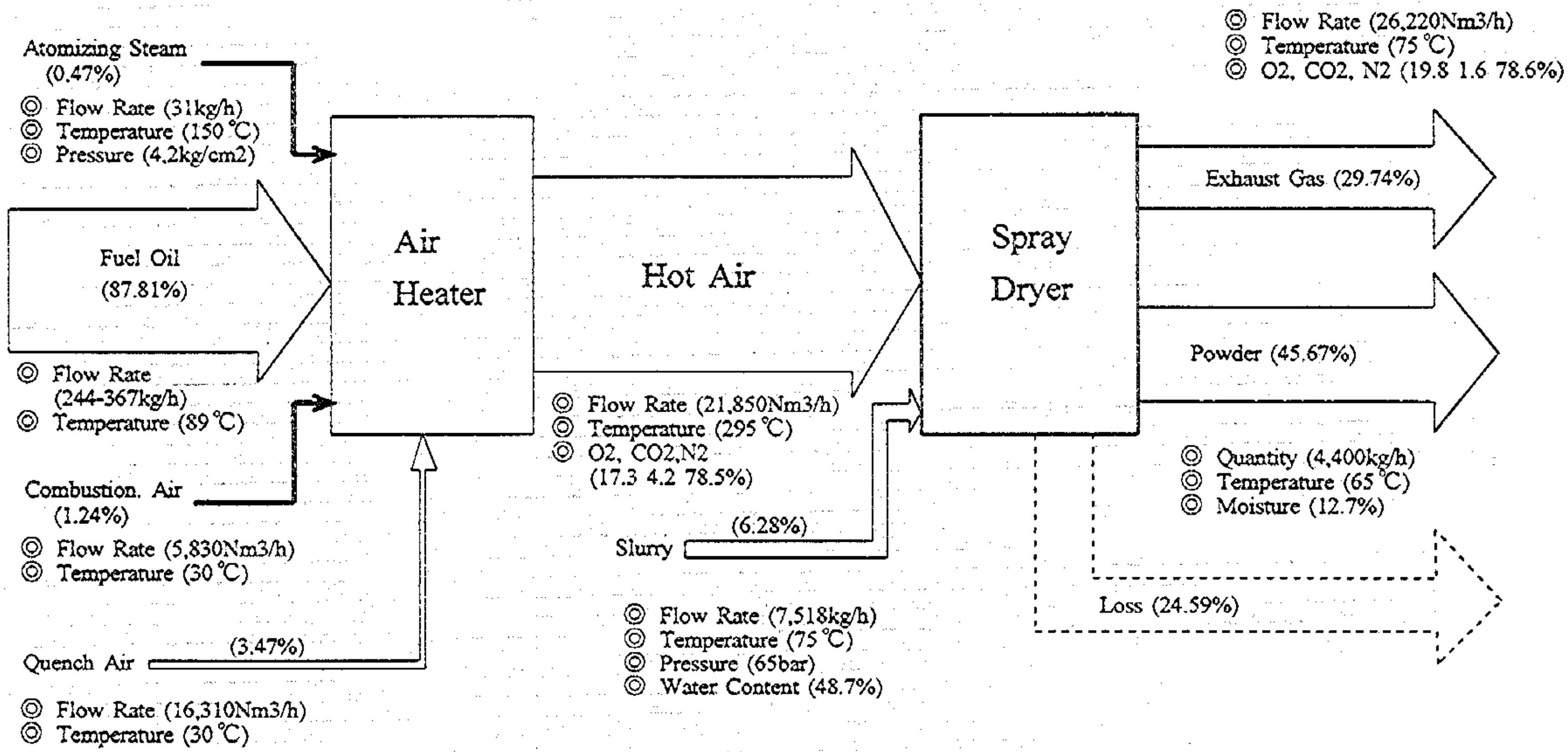


Figure 9-21 Energy Balance around Spray Dryer (Turyag A.S.)

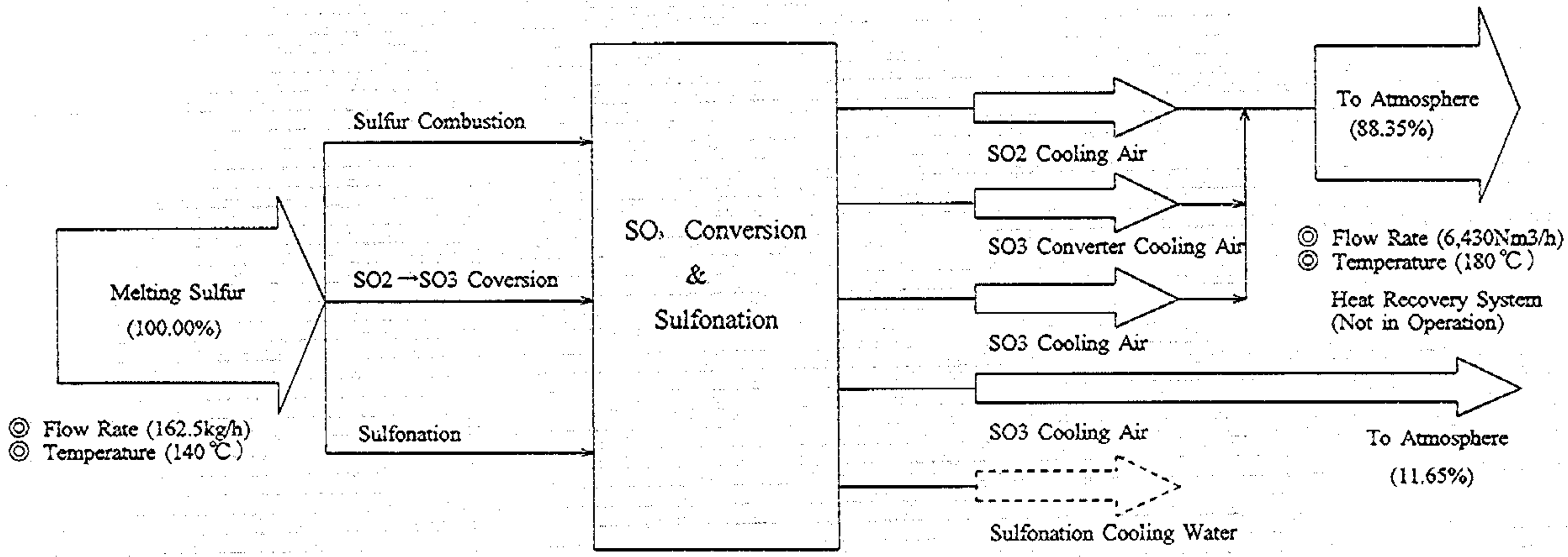


Figure 9-22 Energy Balance in Sulfonator (Turyag A.S.)

9-11 Formulation and Recommendation of Countermeasures for Energy Conservation

The results of measurement and analysis for the factory audit were analyzed and processed in a previous section of this report. In accordance with the results of a factory audit, formulation and recommendation of countermeasures for energy conservation are described and discussed in this section. The major countermeasures are as follows:

1. Improvement of heat balance around boilers
2. Solution for imbalance between steam consumption and necessary power generation
3. Improvement of heat balance around spray dryer and air heater
4. Improvement of heat balance in sulfonation process
5. Improvement in steam condensate recovery system
6. Decreasing heat loss in steam trap system
7. Decreasing heat loss in thermal insulation system
8. Reduction of electricity consumption

9-11-1 Improvement of Heat Balance around Boilers

This factory has not been measuring the lignite consumption rate of boilers. Instead of direct measurement, the lignite consumption rate is judged from amounts purchased monthly and annually. The lignite consumption rate is correlated with the steam generation rate. However, it is important to measure the lignite consumption rate directly, in order to control and manage thermal efficiency continuously around the boilers. This measurement shall be done by load-cell type instrumental equipment as follows.

Two sets of load cell type measuring equipment for lignite consumption rate
Range of measurement: 0-3,500 kg/h

9-11-2 Solution for Imbalance between Steam Consumption and Necessary Power Generation

This plant has installed a steam turbine generator with a maximum steam consumption of 16 tons/h (1,600 kW) and two boilers with rated steam generation of 10 tons/h. On the other hand, steam consumption is from 7 to 8 tons/h in summer and about 11 tons/h in winter. This imbalance is due to stoppage of the soap plant and reduction of steam consumption, by introduction of a steam trap system following the steam turbine generator and boilers.

As a result, the power generated from the steam turbine generator is not enough to meet the required power of this factory; and sometimes the power received from TEK exceeds the contract capacity (2,500 kW), causing a penalty to be assessed by TEK. On this occasion, this factory is obliged to increase power generation by increasing exhaust steam to the atmosphere. Moreover, there is a problem with this steam turbine generator in that the efficiency is low because of low operation load. To solve these problems, increasing steam consumption and decreasing electricity consumption in a rational way is necessary. The following plans have been evaluated.

1. Introducing steam turbine drivers to replace large motors
2. Introducing condenser in steam turbine generator exhaust LP steam line
3. Introducing condenser in steam turbine outlet of forced draft fan of boilers
4. Introducing air preheater utilizing LP steam for combustion air of air heater

(1) Introducing Steam Turbine Drivers to Replace Large Motors

This countermeasure can be useful for increasing steam consumption (increasing power generation) and decreasing electricity consumption. The following motors are candidates for shift to steam turbine drivers, utilizing MP steam (10.5 bars) extracted from the steam turbine generator.

1.	Forced draft fans (FDF) of boilers:	110 kW x 2
2.	Induced draft fan (IDF) of spray dryer:	132 kW
3.	Air compressor in sulfonation process:	107 kW
4.	Screw type air compressors:	110 kW x 2

As a result of preliminary calculation of steam consumption per kW, 35-38 kg steam/kW is obtained. Therefore, a 100 kW's motor requires 3.5-3.8 tons/h of steam. This means that only one large motor can be replaced by a steam turbine driver and two-boiler operation might be necessary. One of the boiler forced draft fans (FDF) is selected due to its convenient location and operation.

(2) Introducing Condenser in Steam Turbine Generator Exhaust LP Steam Line

This countermeasure is aiming for increasing steam supply to the steam turbine generator in order to improve its efficiency and increase electricity generation. Condensed steam can be recovered as boiler feed water, but latent heat of steam is wasted in cooling water. This means that there is no essential difference between steam condensing and steam exhausting to the atmosphere, and this countermeasure is not recommended.

(3) Introducing Condenser in Steam Turbine Outlet of FDF of Boilers

When the steam turbine outlet of the FDF is recovered as LP steam (4.5 bar), LP steam becomes superfluous and is exhausted to the atmosphere. Instead of this system, steam in the turbine outlet of the FDF should be condensed and the condensate recovered directly.

(4) Introducing Air Preheater Utilizing LP Steam for Combustion Air of Air Heater

To increase LP steam consumption and decrease fuel oil consumption, an air preheater for combustion air of air heater shall be useful.

(5) Conceptual Specifications of Countermeasures around Steam Turbine Generator

Conceptual specifications of countermeasures for solution of imbalance between steam consumption and necessary power generation are summarized as follows.

1) Steam Turbine Driver for FDF of a Boiler

Inlet steam condition:	10.5 bar, 300-320 ℃
Outlet steam condition:	2.0 bar, 150-200 ℃
Rotation speed:	4,000 rpm
Estimated steam consumption:	4 tons/h (110 kW equivalent)

2) Condenser in Steam Turbine Outlet of FDF for a Boiler

Inlet condition:	Steam, 2.0 bar, 150-200 ℃, 4 tons/h
Outlet condition:	Saturated water, 2.0 bar, 120 ℃
Cooling media and estimated volume:	Sea water, 141 tons/h
Inlet/Outlet temperature of sea water:	20/35 ℃
Type and materials:	Shell (Steam & condensate) and Tube (Sea water)
Shell (Carbon steel),	Tube (Copper alloy)
Heating duty and Heating area:	2.116 MMkcal/h, 32.07 m^2
Dimensions of condenser:	Shell I.D 400 mm, Tube length 3000 mm (Tube O.D 19 mm) Number of tubes 184

3) Air Preheater for Combustion Air of Air Heater

Inlet/Outlet air:	20/130 ℃, 6,000 Nm^3/h
Steam inlet/outlet condition:	4.5 bar, 200 ℃/4.5bar, 148 ℃ (Saturated water)
Estimated steam consumption:	404 kg/h
Type and materials:	Plate fin, SUS 304

Heating duty and Heating area: 204,400 kcal/h, 350 m^2

9-11-3 Improvement of Heat Balance around Spray Dryer and Air Heater

The current control points in this unit are mixing volume of raw materials, including additives, and temperature of air heater exhaust gas (drying gas). The final object of this unit is to produce proper water content of powder detergent under rational energy consumption, and the relationship among factors shown below should be detected.

1. Flow rate and water content of slurry
2. Inlet/outlet condition of drying gas (flow rate and temperature)
3. Water content of powder detergent
4. Fuel oil consumption
5. Flow rate of combustion and quench air

To control this unit for energy management, the following countermeasures should be adopted.

(1) Filling up Leakage Points of the Spray Dryer

There are some leakage points in the spray dryer due to corrosion by slurry itself; fresh and cool air is entering through these points. As a result, the actual gas flow rate is larger than the air heater exhaust gas and the maximum temperature of the spray dryer is as low as 75℃. This causes inefficiency in the spray drying performance. Therefore, filling up the leakage points is necessay.

(2) Finding the Relationship between Water Content of Powder and Maximum Temperature

After filling up the leakage points, the correlation between water content of powder detergent and maximum spray dryer temperature should be found, under the same inlet gas temperature.

(3) Inlet and Outlet Gas Temperature Control

Inlet/Outlet gas temperature of the spray dryer should be controlled, reflecting the above correlation, by means of the following system.

Inlet gas temperature: Temperature control by fuel oil (instrumented system with control valve)

Outlet gas temperature: Temperature control by quench air (instrumented system with damper)

9-11-4 Improvement of Heat Balance in Sulfonation Process

There are five heat exchangers, often damaged by SO_2 or SO_3 gas, around the SO_3 converter. Among these, the BFW preheater is currently not in use due to heavy corrosion damage. Whenever treating SO_2 and SO_3, the materials of heat exchangers should be carefully selected.

The most common materials of heat exchangers in this unit are as follows.

Shell and tube type:	Shell side- Carbon steel, Tube side - SUS 316
Plate type:	SUS 304

To improve heat balance in this process, heat recovery from cooling air is most important by reconstruction of the BFW preheater, once named 12 E8. The conceptual specification of BFW preheater is basically the same as the original design of 12 E8 except for materials as follows.

Type and material:	Plate type, SUS 304
Other specifications:	Same as original design of 12 E8

9-11-5 Improvement in Steam Condensate Recovery System

There are four individual vessels for steam condensate collection, and the final collection vessel equipped with a contamination monitoring system. Steam condensate is not recovered through this system currently, due to contamination. No condensate recovery through this system means large energy loss because of additional well water and energy in BFW treatment system (sand filter, activated carbon, ion exchangers, CO_2 degasifier) are necessary. The duration of contamination is short : typical duration is 5 minutes or so, and it means contamination is not due to mechanical trouble but some operation trouble.

Typical operation trouble occurs in case of oil transfer around the tank area as follows:

1. Some oil is transported from vessel A to tank A, utilizing a common pump and transfer line.
2. Cleaning of the common pump and transfer line by LP steam, connecting of steam line.
3. Other oil is transported from vessel B to tank B, utilizing a common pump and transfer line.
4. Failure to close the steam valve after cleaning allows oil to enter the LP steam and condensate lines.

To prevent these operation troubles, the following modifications are necessary.

1. Separation of steam and condensate system from the line cleaning system.
2. Introducing block and bleed valve systems in the line cleaning system.
3. Introducing drain pots in the steam condensate system.
4. Preparation of a standard operation manual for line cleaning, and education and training of workers in the operating procedure.
5. Identification of important valves to be opened or closed with special caution; introducing color coding of on lines and valves

9-11-6 Decreasing Heat Loss in the Steam Trap System

As mentioned before, there are about 500 steam traps installed in steam utilizing facilities. Their working condition and maintenance are generally good. However, some steam traps are leaking and blowing. The steam loss and heat loss have been calculated on some assumptions and the result is about 3% loss. The service life of steam traps is usually 3-5 years; they are considered consumables. Therefore scheduled checking, maintenance and renewal are necessary.

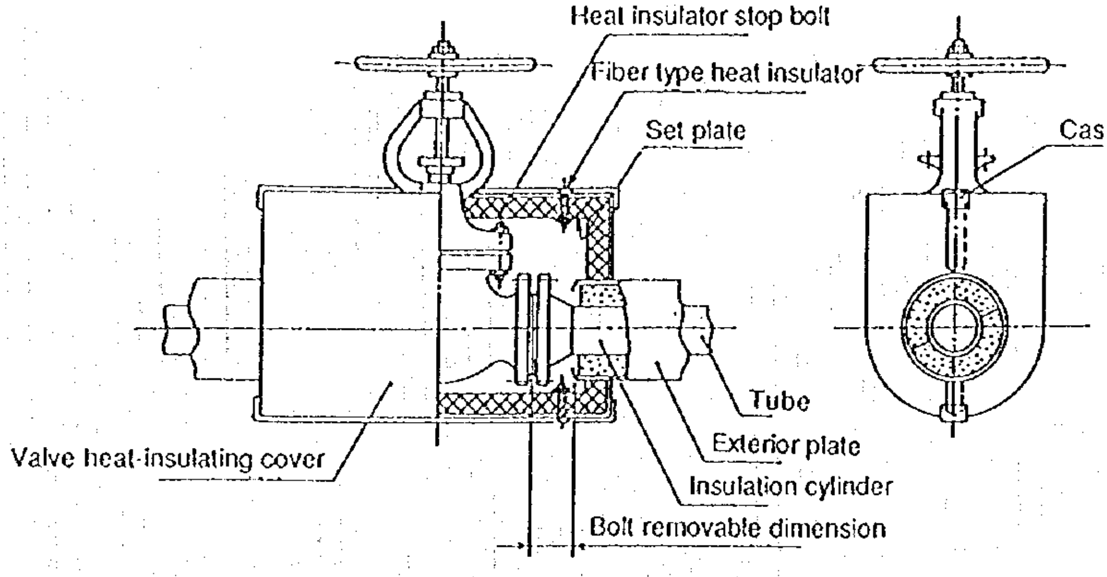
9-11-7 Decreasing Heat Loss in the Thermal Insulation System

As a result of calculation of heat loss from major equipment and steam pipelines, the largest heat loss is from the Steam Boiler, followed by the Spray Dryer. Total heat loss of steam pipelines is comparable to those. Therefore, the first priority for improvement of thermal insulation is the Boiler and the Spray Dryer by increasing insulation thickness. As for steam pipelines, the heat loss of each line is not so large but almost all of the valves and flanges are not insulated. Therefore, thermal insulation of valves and flanges isnecessary. Standard drawings of thermal insulation for valves and flanges are shown in Figure 9-23.

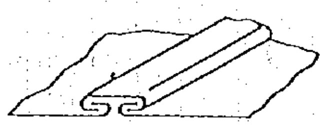
9-11-8 Reduction of Electricity Consumption

There are six transformer stations and 992 motors in this factory as described before. Reduction of electricity consumption of transformers and motors will now be discussed.

Heat Insulation of Valve



Details of case



Heat Insulation of Flange

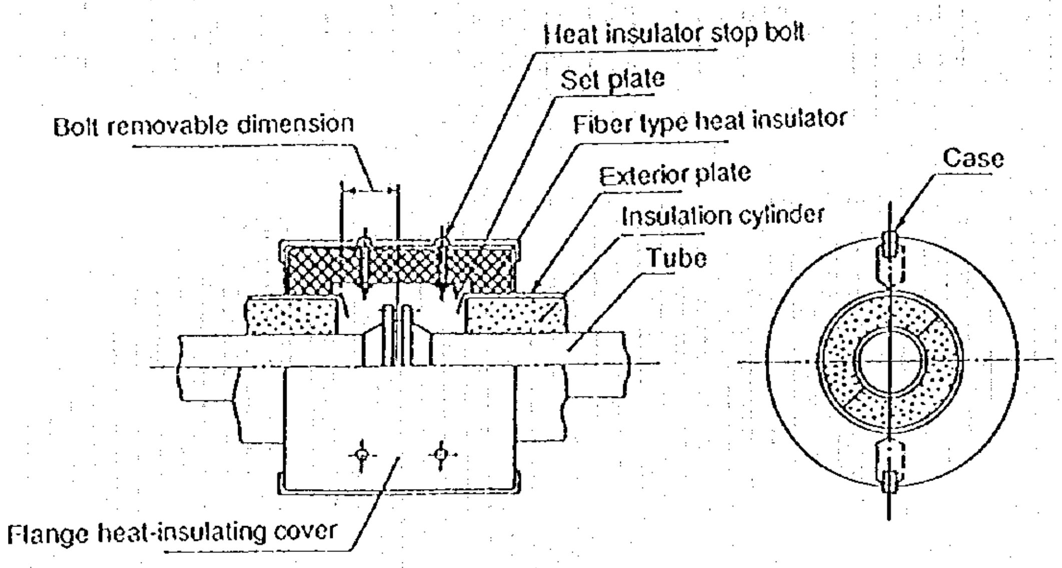


Figure 9-23 Standard Drawings of Thermal Insulation for Valves and Flanges

(1) Transformers

Outlines of each transformer, including motors connected, are shown in Table 9-19. The rated capacity and operating load of each transformer are summarized as follows.

No.1: 1,250 kVA, 33.6 % / 38.3-44.6 % / 26.6 % (Boilers)
No.2: 1,000 kVA, 51.0 % / 52.7-57.8 % / 40.3 % (Oil & Fats)
No.3: 1,000 kVA, 21.0 % / 33.6-42.1 % / 37.6 % (Powder Detergent)
No.4: 1,685 kVA, -- / 70.1 % / 20.6 % (Elecrolysis)
No.5: 1,600 kVA, 33.8-37.5 % / 37.3-52.3 % / 43.4 % (Liquid Detergent)
No.6: 750 kVA, 21.3 % / 24.4-29.9 % / 58.7 % (Steam Turbine Generator)

Notes: The first and second operating load figures were measured and calculated in September, 1996. The third figure is based on total electricity consumption in November, 1995.

It is difficult to evaluate the operating load of transformers from the limited data, because there are many batch and semi-batch operations in this factory. However, these data suggest low operation load of transformers. It is said that the highest efficiency of transformers can be attained at 50-60% of operating load. Therefore, unification of transformers such as No. 1, No. 3 and No. 6 shall be studied. Especially, No. 1 can be integrated with No. 6, after converting an FDF motor to the steam turbine driver and taking other countermeasures around the steam turbine generator.

Table 9-19 Outlines of Transformers

Items	No.1	No.2	No.3	No.4	No.5	No.6
Service	Boilers	Oils & Fats	Powder Detergent	Electrolysis	Liquid Detergent	Turbine Generaror
Rated kVA	1,250	1,000	1,000	1,685	1,600	750
Number of Motors	184	383	225	-	200	-
Total Rated Power (kW)	1,077	2,276.5	1,113	-	1,320	-
Power Factor	0.97	0.92	0.99	-	0.98-0.99	0.88
Measured Power (kW)	420	510	210	-	540-600	160
Calculated Power (kW)	479-557	527-578	336-421	1,181	596-836	183-224
Monthly Average Power (kW)	333	403	376	347	694	443

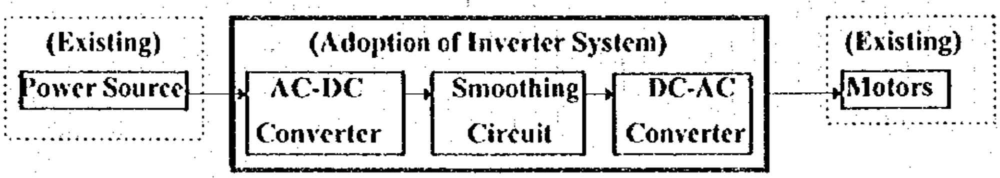
Notes: Measured power; direct measurement by kW meter
Calculated power; calculated from ampere, voltage and power factor
Monthly average power; calculated from total kW consumption as of November, 1995

(2) Motors

This factory is utilizing about one thousand motors to drive equipment. Among these, electricity consumption of five major motors was measured. Operating loads of these motors ranged from 65.5 % (IDF of the Spray Dryer) to 85.9 % (Screw type Air Compressor). Low operating load means that the motor has surplus capacity and it can be operated at lower rotation speed. For this purpose, adoption of an inverter speed controlling system is useful especially for general purpose induction motors. The characteristics of the inverter controlling system are as follows.

1. Control frequency of power source
2. Utilize existing motors by adoption of inverter controlling system.
3. The range of speed control is wide and without steps.
4. Slipping is small and efficiency is high.
5. Power factor is nearly equivalent to power source and motive power is small.
6. Less trouble for frequent start-up and shut-down
7. Cost of installation is relatively low.

An outline of the inverter controlling system structure is shown below.



9-12 Cost Estimation of Countermeasures

The installation cost of the following countermeasures have been estimated and reported by the factory.

The information given here is withheld from public disclosure because of its confidential nature.

9-13 Overall Evaluation of Countermeasures for Energy Conservation

Whenever countermeasures for Energy Conservation are evaluated, the cost of modification or installation of the countermeasures is necessary as the first step, as described section 9-12.

The benefits of the countermeasures such as sawing of thermal and/or electrical energy follows as the second step. To estimate these benefits, decreasing and/or increasing quantity and prices of energy are necessary. As described before, this factory has steam boilers and a steam turbine generator utilizing lignite as a fuel, generating steam and electricity in the factory. And detailed cost structures of generated steam and electricity are not available. Therefore, to evaluate enregy prices of this factory is not so easy, except for Lignite, Fuel Oil and Receiving Power.

Thus, the practical estimation for prices of generated steam and electricity shall be conducted at first, then the quantitative effect of each or integrative countermeasures for energy conservation shall be calculated. The benefits of the countermeasures are evaluated, considering both of them. After evaluation of the benefits, they are compared with the cost of the countermeasures and overall evaluation of the countermeasures shall be conducted.

9-13-1 Estimation for Prices of Generated Steam and Electricity

(1) Consumption Trends and Prices of Related Energy

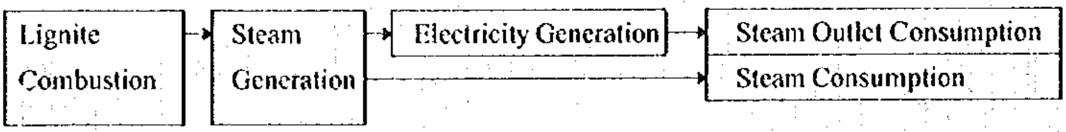
To develop practical estimation for prices of generated steam and electricity, the correlation of consumption rate and prices among Lignite, Generated Steam and Electricity should be considered. Trends of these data are summarized in Table 9-20, utilizing data of 1992 to 1995.

Table 9-20 Trends of Consumption and Prices of Related Energy

Energy		1992	1993	1994	1995
Lignite	Consumption (tons/y)	23,713	19,010	16,681	16,480
	Price (TL/t)	158,000	260,000	435,000	1,200,000
Steam	Generation (tons/y)	92,000	76,000	67,000	64,500
	Price (TL/t)	116,000	198,000	340,000	869,683
Electricity	Generation (MkWh/y)	5,833	4,023	2,448	2,727
	Price (TL/kWh)	332	725	1,862	3,478

(2) Structural Correlation among Three Types of Energy

The structural correlation among Lignite, Generated Steam and Electricity is as follows.



From the above structure, the following correlation among Lignite, Generated Steam and Electricity is suggested.

1) Correlation between Lignite and Generated Steam

Lignite is combusted in the boiler only to generate steam, and there is a close relationship between them. Therefore, the following assumptions are easily deduced. The price of generated steam is easily calculated directly from the price of lignite.

1. The steam generation rate is nearly proportional to the lignite combustion rate. Therefore, the average ratio between them through 1992-1995 is calculated at 3.952 kg-Steam/kg-Lignite. (Equivalent to 253 kg-Lignite/1000 kg-Steam)
2. The steam price is nearly proportional to the lignite price, considering the volumetric correlation between them and that the fixed cost of boilers can be neglected as the sunk cost. Thus, the average ratio between them after adjusting by volumetric ratio through the same period is calculated at 0.751 kg of steam price/ kg of lignite price.

2) Correlation between Generated Steam and Electricity

To find this correlation is somewhat difficult because not all the steam is used to generate electricity through the steam turbine generator. Moreover, the efficiency of the steam turbine generator is influenced by its operating load. Therefore, the following correlation between them is assumed. The price of generated electricity is calculated through the parameters, described below, and price of lignite indirectly.

1. The volumetric ratio of generated electricity and generated steam represents the efficiency of the steam turbine generator.
2. The pricing ratio of generated electricity and generated steam reflects the volumetric ratio between them or efficiency of the steam turbine generator.

Thus, the correlation between the two parameters is useful for practical estimation of the price of the generated electricity. The values of these parameters through 1992 to 1995 were as follows.

Year	Volumetric Ratio (Elec. /Steam)	Price Ratio (Elec. /Steam)
1992	63.40 kWh/tons	2.862 kWh/kg
1993	52.93	3.662
1994	36.54	5.476
1995	42.28	4.000

From the above figures, the following equation can be obtained.

$Y = -0.08535 X + 8.164$

Where,

Y: Price Ratio of Electricity/Steam, X: Volumetric Ratio of Electricity/Steam

However, to find the volumetric ratio between generated electricity and steam is still not so easy. In such a case, we can use the average price of receivied power because the generated power provides the base load, and it does not concern marginal decrease or increase in electricity by countermeasures for energy conservation.

9-13-2 Quantitative Effect of Countermeasures for Energy Conservation

There are eight countermeasures discussed in Section 9-11, and the quantitative effect of the following major countermeasures among them is analyzed here. The effect are based on 7,200 (300 days/year) annual operating hours.

1. Introducing Steam Turbine Driver for FDF of a Boiler
2. Introducing Air Preheater for Combustion Air of Air Heater
3. Increasing Electricity Generation by Increasing Steam Consumption
4. Heat Recovery from Cooling Air in the Sulfonation Process

(1) Prices for Each Type of Energy

To calculate the effect of the countermeasures, the following prices for each type of energy are set as basic prices, as of August, 1996 at an exchange rate of 86,500 TL/US$.

Lignite (3200 kcal/kg):	2,771,500 TL/t (US$ 32.0/t)
Fuel Oil (10,000 kcal/kg):	23,457,700 Tl/t (US$ 271/t)
Generated Steam: (Lignite price x 0.751):	2,081,400 TL/t (US$ 24.1/t)

Increased electricity generation and decreased electricity consumption are based on the average price of receiving electricity from TEK shown below: 5,678 TL/kWh (US$ 0.0656/kWh)

Daytime (6:00 - 17:00):	5,680 TL/kWh
Evening (17:00 - 22:00):	10,110 TL/kWh
Nighttime (22:00 - 6:00):	2,905 TL/kWh

Source of boiler feed water (Well Water): Planned for 1996 Price; 45193 TL/t (US$ 0.522/t)

(2) Introducing Steam Turbine Driver for FDF of a Boiler

By this countermeasure, electricity is reduced by 110 kWh/h and generated steam is increased by 4 tons/h. However, the increase of steam consumption can be considered substitution of LP Steam now vended to atmosphere except for consumption by the air preheater. Then, decreased, increased cost and overall cost reduction are expressed as follows.

Decreased electricity:	110 x 7200 x 0.0656 = US$ 51,955/y
Increased condensate for BFW:	4 x 7200 x 0.522 = US$ 15,034/y
Increased steam:	(4 + 0.4 - 2.74) x 7200 x 24.1 = US$ 288,043/y
Overall cost reduction:	51955 + 15034 - 288043 = US$ - 221,054/y

This result means that replacement of the motor in isolation from other measures is not feasible because the latent heat of steam is not utilized in this system, so integrated countermeasures for reduction of the imbalance around boilers and steam turbine generator shall be considered.

(3) Introducing Air Preheater for Combustion Air of Air Heater

By this countermeasure, 204,400 kcal/h (20.44 kg/h) of fuel oil is reduced and 404 kg/h of generated steam is increased. Although increased steam is considered a substitute for the LP Steam released to the atmosphere, the increased amount can be neglected. Thus, decreased cost is expressed as follows.

Decreased fuel oil: 0.02044 x 7200 x 271 = US$ 39,735/y

This single countermeasure is feasible without integrated measures for decreasing the imbalance around steam boilers and steam turbine generators.

(4) Increasing Electricity Generation by Increasing Steam Consumption

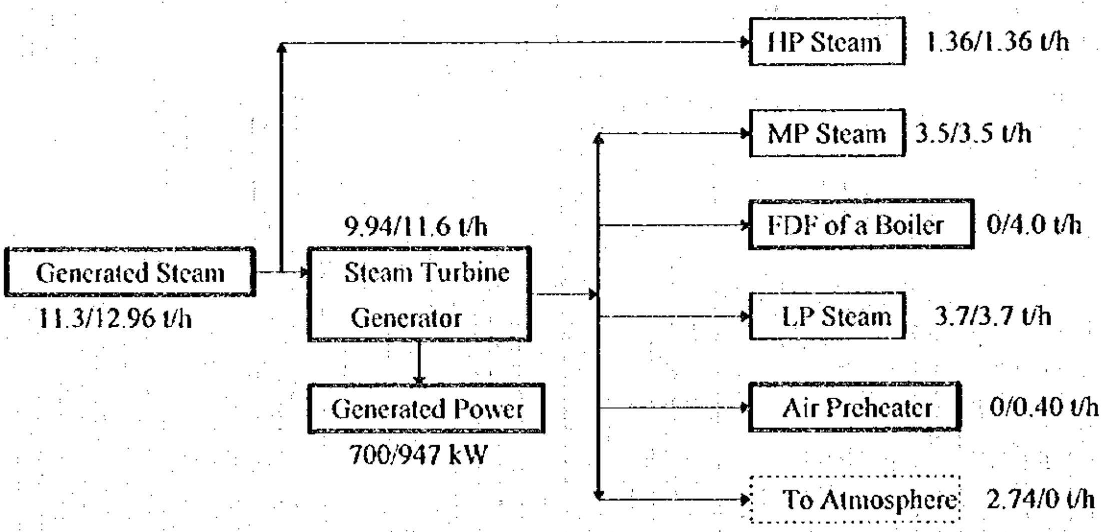
This countermesure is an integrated one, including the above two countermeasures. The objects of this integrative countermeasure are as follows.

1. To increase efficiency of the steam turbine generator by means of higher operating load
2. To increase house power generation to prevent extra charge for over-receiving

3. To utilize marginal capacity of steam boilers and turbine generator and increase house power generation

1) Steam Balance around Steam Turbine Generator

The current and estimated balances, with the countermeasures, around this system are shown below.



(Remarks): The left figures presents current and the right is estimated after countermeasures.

Figure 9-24 Estimated Balance of Steam and Generated Power

Note 1. Releasing LP Steam to the atmosphere shall be avoided due to increase in generated power and decrease in electricity consumption.

2. Generated power is estimated on the basis of a linear correlation with the steam to the turbine generators (16 t/h Steam to 1,600 kW and 9.94 t/h Steam to 700 kW/h).

2) Integrative Effect of Coutermeasures around Steam Turbine Generator

There are the following five effects with these countermeasures around Steam Turbine Generator. Among them, Nos. 4 and 5 are already discussed.

1. Increase in Generated Power:

(Case-1) Based on price of received electricity

Value of the Increased Power: (947 - 700) x 7200 x 0.0656 = US$ 116,663/y

Increase in Steam Generation: (12.96 - 11.3) x 7200 x 24.1 = US$ 288,043/y

Changes in the Total cost: Increase of US$ 171,380 /y

(Case-2): Based on correlationship between generated steam and Electricity

Current Price of Generated Electricity: US$ 0.0693/kWh

Estimated Price with Countermeasures: US$ 0.0464/kWh

Benefit with Coutermeasures: Current price shall be compensated with estimated price as far as the current volume concerns and receiving price shall be compensated with estimated price for increased portion.

Thus, the total benefit is calculated as follows:

(0.0693 - 0.0464) x 700 x 7200 + (0.0656 - 0.0464) x 247 x 7200 = US$ 149,561/y

Increase in Steam Generation (same as the above) = US$ 288,043/y

Changes in the total cost: Increase of US$ 138,482/y

2. Increase efficiency of the steam turbine generator by means of higher operating load
   Figure 9-24 shows that the operating load of the turbine is increased from 62.2 % (9.94t/h) to 72.5 % (11.6 t/h), and efficiency should be improved. However, a detailed performance curve is not available, and evaluation of this effect is also not available.

3. Increase House Power Generation to Prevent Extra Charge for Over Receiving
   By means of these countermeasures, electricity consumption is reduced by 110 kW and electricity generation is increased by 247 kW. Therefore, received electricity should be reduced by 357 kW and a penalty due to over receiving thus avoided. However, the frequency and duration of over receiving are not clear and evaluation of this effect is also not clear.

4. Introducing steam turbine driver for FDF of a boiler

5. Introducing air preheater for combustion air of air heater

3) Quantitative Effect of Integrative Countermeasures around Steam Turbine Generator

The overall quantitative effect of the above five factors, gives the following resulting figures.

1.	Introducing steam turbine driver for FDF of a boiler:	US$ - 221,054/y
2.	Introducing air preheater for combustion air of air heater:	US$ 39,735/y
3.	Increase in generated power by increasing steam:	US$ - 171,380/-138,482/y
	(Total)	US$ - 352,699/- 319,801/y

(4) Heat Recovery from Cooling Air in the Sulfonation Process

The inlet/outlet condition of the heat exchanger is assumed to be as follows.

1. Cooling air: 180/130 ℃, 6,430 Nm3 (Q = 101,690 kcal/h)
2. Boiler feed water: 110/150 ℃

The boiler feed water is preheated and the energy to be reduced is lignite in the boiler (31.8 kg/h). The benefit is as calculated below.

0.0318 x 32 x 7200 = US$ 7,327/y

9-13-3 Overall Evaluation of Countermeasures for Energy Conservation

The major eight countermeasures are formulated and recommended in 9-11. Among these, the quantitative effect of the four countermeasures is evaluated in this section. The overall evaluation of countermeasures for energy conservation in this factory is summarized below.

1. Introducing steam turbine driver for FDF of a boiler:
   This is not feasible as far as it does not concern utilizing latent heat of generated steam. The integrative effect for increasing generated power shall be investigated by the factory.

2. Introducing air preheater for combustion air of air heater:
   This can be feasible, because the installation cost of air preheater is 4,500 DM and the effect is US$ 39,735/y. Moreover, this countermeasure utilizes the latent heat of generated steam and contributes to an increase in electricity generation.

3. Increasing electricity generation by increasing steam consumption:
   This countermeasure is an integrated one. It is not feasible, unless the following three effect are investigated in detail.
   To increase the efficiency of the steam turbine generator by means of higher operating load
   To increase house power generation to prevent extra charge for over receiving
   To seek a suitable use for the latent heat of the steam

4. Improvement of heat balance in sulfonation process:
   This cannot be feasible, because installation cost of the heat exchanger is 50,000 DM and the effect is US$ 7,327/y. And other effective methods of heat recovery shall be studied instead of lignite reduction.

5. Improvement of heat balance around spray dryer and air heater

This countermeasure is probably very effective, in order to reduce consumption of expensive fuel oil by filling up the leakage points. This filling up is one of the first priories in this factories.

6. Improvement in the steam condensate recovery system

This countermeasure does not need expensive modification, but it is a matter of management. Therefore, persons in charge of energy management in this factory should investigate this countermeasrure in detail.

7. Decreasing heat loss in the steam trap system

This countermeasure also is a matter of management. Periodic checking and replacement of steam traps are necessary.

8. Decreasing heat loss in thermal insulation system

Reinforcement in thermal insulation of the boiler and the spray dryer may be feasible, depending on the cost of the modification. Installation of removable boxes of insulation for flanges and valves is usually feasible; moreover, these protect workers from injury.

9. Reduction of electricity consumption

Integration of the transformers may be effective, depending on their operating loads. And introducing inverter speed control systems may be feasible, depending on their installation cost and operating conditions.

9-14 Technical Guidelines for Energy Audit

9-14-1 Audit Procedure for Rational Use of Energy

A general factory audit procedure is shown in Figure 8-1. It is necessary to put in order the following audit items before starting the audit work for rational use of energy in detergent and oil & fats factories.

1. Preparatory work
2. Recognize current condition through the first factory survey
3. Identify current problems
4. Formulate and prepare factory audit plan
5. Execute factory audit
6. Identify problems requiring countermeasures
7. Assess and recommend countermeasures

(1) Preparatory Work

Before visiting the factory, it is required to study some related reports including this report, and to prepare the documents and data concerning the following.

1) Process flow sheet

Each factory has own production scheme and it is impossible to know the factory's process flow sheet beforehand. However, it is enough to know the officially opened process flow sheet because the major purpose of the audit is to know where and what kind of energy is mostly consumed but not to improve the production scheme itself.

2) Energy consumption equipment

Boiler, heat exchanger, reactor, blower, compressor and pump are energy consuming equipment, and it is required to know in advance what kinds of equipment there are normally and how these consume energy. If auditors have some knowledge about them, it becomes easier to grasp the general condition of energy consumption in the factory at the first site survey.

3) Energy sources

Fuel oil, coal and electricity are energy sources generally, and it is desirable to prepare related data on them such as properties of oil and coal.

4) Questionnaire

It is difficult to prepare a questionnaire from the beginning; however, many questions will arise in the course of the preparatory work mentioned above. In this report, the following sections are mainly based on the questionnaire.

Section 9-2	Outline of factory, facilities and flow sheet of major product
Section 9-3	Outline of operating conditions
Section 9-4	Trends of consumption and unit consumption of energy
Section 9-5	Current condition and problems with energy management
Section 9-6	Current condition and problems with facilities

Therefore, the auditors shall prepare the questionnaire in consideration of the content of the sections mentioned above. However, a questionnaire should not include too many questions; therefore, only important matters shall be included in the questionnaire.

(2) Recognize Current Condition through the first Factory Survey

The first survey is carried out in accordance with the prepared questionnaire, and it is desirable to look around the production plant, including the energy consumption facilities and equipment, at first. As current conditions, the following items shall be included as described in this report.

1) Outline of the factory
2) Outline of the production facilities
3) Flow sheet for major products
4) Outline of operating conditions
5) Trends of consumption and unit consumption of energy

Here, recognized conditions of outline of the factory and outline of operating conditions are useful data for the study of the factory's capacity and possibility to take some energy saving countermeasures, for example, and measuring and analysis points shall be also checked at the first factory survey.

(3) Identify Current Problems

After the recognized current condition of the factory is learned, the current problems shall also be identified through the first survey. In this report, two current problems are presented. One problem concerns major energy consuming facilities and the other problem concerns energy conservation. It is normally necessary to identify the current problems separating into facility problems and management problems.

(4) Formulate and Prepare Factory Audit Plan

After the factory survey, the following two kinds of preparation for the audit are required.

1) Method and procedure of energy audit

Energy audit method and procedure include the following.

(a) Analysis and measurement points

At the factory survey, a more detailed process flow sheet and data sheet, and drawings for the major equipment concerned, shall be obtained from the factory, and analysis and measuring points for the audit are decided using them. The analysis and measuring points are shown in Table 9-4 and Figures 9-11 to 9-13 in this report. It is important to select suitable and useful analysis equipment. There is only one chance for analysis and measurement work in the factory audit, therefore, more analysis and measuring than required points shall be considered.

(b) Schedule of analysis and measurement

The analysis and measurement schedule is shown in Table 9-5 in this report. This schedule has been prepared following the factory's request so that analysis and measuring work can be finished within two weeks. Analysis work such as the exhaust gas composition analysis takes considerable time including the setup of analysis equipment, therefore, the analysis and measuring schedule shall be prepared considering the analysis working hours. It is also important that some auditors can master analysis and measuring equipment because the operation of recent equipment is not so simple.

(c) Request of modification for analysis and measurement work

If some modifications of the facilities are required for the analysis and measuring work, the factory will be asked to make them. However, such modification work shall be minimized, because the factory cannot stop the facility's operation only for these purposes. Other analysis and measuring equipment or related data will be found in place of them in case of need.

2) Measurement Procedure

Audit of the factory is carried out based on the energy audit method and procedure which is mentioned above, and in addition, the following preparation shall be planned.

(a) Preparation of Data Sheet

The production facilities are not always operated in steady conditions. This means that only one time operating datum cannot be typical of the facilities, and multiple data shall be obtained at the same analysis and measurement points. For this purpose, a data sheet for the analysis and measuring shall be prepared beforehand, and one sample of them is illustrated in Table 9-21.

(b) Preparation of Calculation Sheet

The following data cannot be obtained directly from the analysis and measuring work. They are found as the result of some calculation.

- o Dry exhaust gas flow rate from boiler or furnace
- o Heat loss through insulation for equipment or piping
- o Heat loss without insulation

These calculation methods are not so simple, therefore, some calculation formulas shall be put into personal computers using calculation software such as EXCEL. Calculation methods for dry exhaust gas flow rate and heat loss through insulation are shown in section 9-8-6. Heat loss without insulation is calculated as follows.

$$Q = A \times a \times (ts - ta) \quad (kcal/h)$$

Here,

A:	Surface area (m^2)
	3.14 x diameter x length (for piping)
a:	Heat transfer coefficient (kcal/m2·h·℃)
	Normally, 10 kcal/m2·h·℃ is used.
ts:	Surface temperature (℃)
ta:	Atmospheric temperature (℃)

Table 9-22 shows the relation among atmosphere temperature, pipe surface temperature, pipe outside diameter and heat loss. If such a table or calculation method is programmed on a personal computer beforehand, heat loss can be calculated easily and quickly.

(5) Execute Factory Audit

The factory audit is executed in accordance with the planned schedule, and analysis and measuring work are also executed in conformity to the prepared analysis and measuring points of the facilities. As mentioned above, a few data shall be obtained for the same analysis and measuring points. It is essential to review and analyze the obtained data every day before the day is over. Normally, it is believed that the obtained data are all correct; however, some inadequate data are found during the review and analyzing work of the related data. If inadequate data are found, other data shall be obtained again at the same analysis and measuring points on the next day or another day.

(6) Identify Problems Requiring Countermeasures

Problems requiring countermeasures are found as a result of analyzing the obtained data, and the detailed procedure for identifying problems is described in section 9-14-3.

(7) Asses and Recommend Countermeasures

As the final stage of the audit process, assessment and recommendation work are required; its detailed procedure is described in section 9-14-4..

Table 9-21 Analysis and Measuring Data Sheet (Sample)

1. Boilers and Steam Turbine Generator

Analysis and Measuring Date				
(1) Boiler Feed Water				
a) Flow Rate	t/h	FIRCQ-1110		
b) Temperature	℃			
c) Pressure	bar	PIAL-1110		
d) Electric Conductivity e) pH	μ S/cm	Electric Codut. Meter		
f)DO	ppb	DO Meter		
(2) Combustion Air				
a) Flow Rate	Nm^3/h	FFIIL-1610		
b) Temperature	℃	Bar Thermo.		
c) Pressure	bar	Press. Gauge		
(3) Generated Steam				
a) Flow Rate	t/h	FIRCQ-1210		
b) Temperature	℃	TIRCA-1216		
c) Pressure	bar	PIRC-1216		
(4) Exhaust Gas				
a) O_2	vol%	Gas		
b) CO_2	vol%	Chromat.		
c) N_2	vol%	Analyzer		
d) Temperature	℃	TIR-1770		
e) Dust Content				
f) NO_X	ppm	NO_X Analyzer		
g) SO_X	ppm	Infra-red GA		
h) H_2O	ppm	Suction Unit		
(5) Ash				
a) Temperature	℃	TSAH-1742		
b) Specific Heat	kcal/C・kg			

Table 9-22 Heat Loss from Piping without Insulation (kcal/mh)

Atmos. Temp	30 deg.						15 deg.						Pipe Size
Surface Temp.	100	150	200	250	300	350	100	150	200	250	300	350	
Pipe O.D. (mm) 33.4	73	126	178	231	283	336	89	142	194	246	299	351	1B
48.3	106	182	258	334	409	485	129	205	281	356	432	508	1-1/2B
60.3	133	227	322	417	511	606	161	256	350	445	540	634	2B
88.9	195	335	475	614	754	893	237	377	516	656	796	935	3B
114.3	251	431	610	790	969	1148	305	485	664	843	1023	1202	4B
140.6	309	530	751	971	1192	1413	375	596	817	1037	1258	1479	5B
168.3	370	634	898	1163	1427	1691	449	713	978	1242	1506	1770	6B
219.1	482	826	1170	1514	1858	2202	585	929	1273	1617	1961	2305	8B
273.1	600	1029	1458	1887	2315	2744	729	1158	1586	2015	2444	2873	10B
323.9	712	1220	1729	2238	2746	3255	864	1373	1882	2390	2899	3407	12B
355.6	782	1340	1898	2456	3015	3573	949	1507	2066	2624	3182	3741	14B
406.4	893	1531	2169	2807	3445	4084	1085	1723	2361	2999	3637	4275	16B
457.2	1005	1723	2441	3158	3876	4594	1220	1938	2656	3374	4091	4809	18B
508.0	1117	1914	2712	3509	4307	5104	1356	2153	2951	3749	4546	5344	20B

Equivalent Length of Valve

Valve Size	Equivalent Length
1B	1.21 m/valve
1-1/2B	1.20 m/valve
2B	1.28 m/valve
3B	1.56 m/valve
4B	1.58 m/valve
5B	1.68 m/valve
6B	1.78 m/valve
8B	1.87 m/valve
10B	1.95 m/valve
12B	2.00 m/valve
14B	2.00 m/valve
16B	2.00 m/valve
18B	2.00 m/valve
20B	2.00 m/valve

Heat Loss Calculation Sheet (Example: kcal/h)

Size	Length	Valve	Length		Length	A.Temp	S.Temp	H.Loss
1B	100	15	18.15		118.15	25	150	15,489
1-1/2B	50	8	9.6		59.6	25	120	8,587
2B	140	30	38.4		178.4	25	170	48,979
3B	80	20	31.2		111.2	25	250	69,842
4B	150	10	15.8		165.8	25	240	127,938
5B	0	0	0		0	0	0	0
6B	90	4	7.12		97.12	25	200	89,817
8B	60	6	11.22		71.22	25	180	75,946
10B	30	4	7.8		37.8	25	240	69,692
12B	50	4	8		58	25	230	120,927
14B	20	4	8		28	25	245	68,782
16B	40	4	8		48	25	255	140,881
18B	0	0	0		0	25	0	0
20B	0	0	0		0	25	0	0
Total								836,880

9-14-2 Outline of Factory to be Audited

At the very beginning of a energy audit, it is important to investigate an outline of the factory by means of interview based on a prepared questionnaire. This investigation is very useful to recognize the current condition of the factory and the results shall be developed to identify current problems in energy consumption. It includes the following items.

(1) Outlines of the Factory

1. Name, address and capital of the factory
2. Type of industry and major products
3. Organization chart, name of the president, factory manager and energy manager
4. Number of employees, engineers and energy related engineers
5. Area of the factory and buildings
6. Layout of the factory and plans
7. Trends of annual sales amount, total and for each major product
8. History and current activity of the factory
9. Share and position in its industrial subsector

(2) Production and Energy Consumption

1. Production capacity and trends of production amount of major products
2. Plan for modification and/or expansion of production capacity
3. Flow sheet of each major product
4. Trends of unit consumption figure of raw materials for each major product
5. Details of major production facilities
6. Annual operating hours and days and operating modes of each major product
7. Trends of annual consumption and unit consumption of energy
8. Production and utility cost of each major product
9. Trends of unit price of energy
10. Energy flow chart of the factory, each major product and major facilities
11. Details of major energy consuming facilities
12. Ratio of house power generation to receiving power
13. Detail of electric power receiving

(3) Energy Management and Conservation

1. Establishment of target for energy conservation
2. Systematic approach for energy management in the organization

3. Energy management utilizing data and records
4. Education and training of employees for energy management
5. Maintenance mode and schedule of annual maintenance
6. Countermeasures carried out for energy conservation and their effects
7. Planning countermeasures for energy conservation and their expected effects
8. Economic conditions of the factory and its industrial sub-sector
9. Problems in promotion of energy consumption
10. Outlines of environmental pollution management

9-14-3 Viewpoints of Implementation of Energy Audit

There are various types of energy consumption in this field of industry, such as some kinds of fuel, heat generated through reactions, steam and electricity. General viewpoints of the energy audit can be itemized as follows.

1. Improving efficiency of fuel combustion
2. Improving methods of heating, cooling and heat transfer
3. Prevention of heat loss through radiation and heat conduction
4. Utilization of waste heat trough heat recovery
5. Improving of thermal energy conservation to mechanical power
6. Prevention of loss in electricity due to electrical resistance and other causes
7. Improvement of electricity conversion to mechanical power and heart

More details on each of these topics are given below.

(1) Improving efficiency of fuel combustion

1. Selection of burner (type, capacity, turn down ratio, maintenance, etc.)
2. Improvement of spraying (fuel temp., viscosity, atomizing air and steam, etc.)
3. Prevention of air leakage (draft control, reduction of holes, reinforcement of seal, etc.)
4. Improvement of air ratio (O_2, CO control, cascade control, etc.)
5. Stabilizing of operating duty (improvement of allocation of duty, etc.)
6. Raising combustion temperature (gas atomizing, fluidized bed combustion, etc.)
7. Perfect combustion at low temperature (catalytic combustion, etc.)

(2) Improving of Methods of Heating, Cooling and Heat Transfer

1. Industrial furnace (optimization of heating temp. and duty, improvement of heating

pattern and dimensions, introducing direct firing, etc.)

2. Steam heating (optimization of steam pressure, improvement of direct steam injection)
3. Heat transfer (thermal resistance reduction, improvement of thermal coefficient, improvement of heat exchangers and its system, etc.)
4. Operation (optimization of start up and shut down, reduction of operating duty, etc.)
5. Production process (improvement of control system, automation, multi-staged utilization of heat, changes in separation unit or layout, optimization of reaction, etc.)

(3) Prevention of Heat Loss through Radiation and Heat Conduction

1. Prevention of leakage (periodical check and maintenance, selection of steam traps, etc.)
2. Reduction of section with heat loss (improvement of piping route, removal of unnecessary pipes, shut down of pipes not in operation, etc.)
3. Thermal insulation (installation of insulation on valves and flanges, shift to insulation materials with lower thermal conductivity, etc.)
4. Blowing of furnace gas (reduce size of or close holes, decrease opening time of doors, etc.)

(4) Utilization of Waste Heat through Heat Recovery

1. Set standard temperature of exhaust gas (solid/liquid/gas classified by capacity)
2. Waste energy (exhaust gas, waste water, condensate, solid with high temp., etc.)
3. Users (heating of raw materials, combustion air, preheating of BFW and fuel oil, etc.)
4. Methods (heat exchangers, heat pump, heating media, waste heat boiler, etc.)

(5) Improving of Thermal Energy Conversion to Mechanical Power

1. Improvement of energy efficiency (improvement of steam condition, cogeneration, etc.)
2. Improvement of power generation (improvement of type of turbine and nozzles, optimization of extraction and back pressure, peak shift, etc.)
3. Improvement of steam ejectors (optimization of stages and steam pressure, etc.)

(6) Prevention of Loss in Electricity due to Electrical Resistance and Other Causes

1. Distribution (minimization of lines, improvement of distribution system, etc.)
2. Transformers (optimization of capacity, duty allotment, adjustment of number in operation, method of connection, etc.)
3. Equipment (reduction of contract resistance, etc.)
4. Improvement of power factor (optimization of operating duty of equipment, etc.)
5. Operation (peak cut, optimization of voltage in circuit, etc.)

6. Introduction of equipment with low electrical loss

(7) Improvement of Electricity Conversion to Mechanical Power and Heat

1. Motor (adoption of type with high efficiency, optimization of capacity, etc.)
2. Power transmission (improvement of transmission device, lubrication, etc.)
3. Operation (prevention of rotation with no load, intermittent operation, etc.)
4. Fluid transfer (reduction of load, optimization of capacity of equipment, etc.)
5. Electrical heating (reduction of load, introduction of equipment with high efficiency, direct heating, comparison with heating by combustion, etc.)

9-14-4 Evaluation Method and Reporting of Energy Audit

(1) Evaluation Method of Energy Audit

The general energy audit procedure is described in Chapter 8; the actual procedure follows the former sections in this Chapter. After the measurement and analysis of subject items for energy audit, the following procedure and items should be conducted.

1. Identify problems requiring countermeasures

   From the initial stage of energy audit, problems in energy consumption and major energy consuming facilities have been investigated and discussed with factory representatives. After obtaining data and information regarding subject items, problems requiring countermeasures are identified through the following procedures.

   (a) Review and analysis of results of measurement and other information
   (b) Review and analysis of results of relevant data and information
   (c) Identifying problems and judgment on necessity for improvement
   (d) Scrutiny and formulation of items for improvement
   (e) Preparation for some prospective countermeasures

2. Assessment and Recommend Countermeasures

   As the final step of the overall energy audit, the following items are assessed and formulated. Recommendations are based on overall results of energy audit.

   (a) Calculation and analysis of the effect of energy saving
   (b) Examination and selection of proper countermeasures from prospective ones
   (c) Cost estimation of modification for countermeasures

(d) Estimation and prediction of the effect of the countermeasures

(e) Overall evaluation of countermeasures for energy conservation

(f) Recommendation of countermeasures for energy conservation

(2) Reporting of Energy Audit

Reporting is very important not only for final result but also at intermediate stages, because an energy audit requires close cooperation with the factory audited. These reports shall be utilized for confirmation of the results of survey and discussion. Moreover, they will be utilized as a forecast and explanation of the proceeding energy audit. The ideal timing for these reports is as follows, according to Chapter 8.

1. After recognition and identification of current condition and problems
2. After formulation and preparation of factory audit plan
3. After implementation factory audit with measurement
4. After assessment and recommendation of countermeasures
5. Final report