2003 Survey Report
NEDO－IC－02－ED－03

Infrastructure Improvement Project for Rationalization of International Energy Use (Energy Audits Implemented in Major Industries in ASEAN Countries)

Report on the results of the audits

March, 2004

New Energy and Industrial Technology
Development Organization (NEDO)
Entrusted to The Energy Conservation Center, Japan

Energy Audits Implemented in Major Industries in ASEAN Countries The Energy Conservation Center, Japan March, 2004
Purposes: We have conducted energy audits of typical factories and business establishments in the major industries of ASEAN countries jointly with specialists participating from the ASEAN countries concerned with an aim to establish standardized procedures of energy audit for ASEAN counties based on the results of these surveys and also intending to understand the actual condition of energy consumption in the factories concerned and provide appropriate advice in their energy conservation measures.

Preface

Recently, efforts to prevent global warming have been recognized as a challenge to be shared by all humankind, while sustainable development of economy has been sought for. Mankind is facing with the challenge of overcoming the two different conditions entirely conflicting each other.

In order to get over these severe conditions, what are required are technical innovations such as technologies to use energy efficiently with as little burden on the environment as possible and the development of energy having little impact on the environment, etc.

In order to contribute to the balanced development of economy and environment in developing countries, it is necessary to render support that is adaptable and appropriate to the respective countries concerned based on the understanding of the actual condition of their energy use and environmental measures and on the results of in-depth surveys on the progress in development of infrastructure, living habits, etc.

Having these circumstances as a background, we had conducted energy audits and energy audit technology transfer programs in 8 ASEAN counties regarding one selected industry sector each during the past 3 years. Then, we conducted the mentioned activities in the remaining 2 countries this year, the last year of the project. While problems and methods of improvement clarified in the surveys conducted on the major industries by last year were being shared by ASEAN countries, we continued surveys in the hope that these activities would provide the foundation for creating database/benchmark/guideline to further promote energy conservation. In 2003, we conducted surveys in Thailand and Singapore whose economies have been developing at an increasing speed with new equipment and advanced technologies among ASEAN countries. We conducted energy audits in the factories of the chemical industry (caustic soda industry) in Thailand and the food processing industry in Singapore.

In the job site, we carried out energy audits employing OJT (On the Job Training) system to further ensure technology transfer. In the workshops, we developed specific discussions based on the analysis results of the collected data.

We completed energy audits and workshops on an OJT basis in all 10 ASEAN countries for the past 4 years. We believe that it is very promising and meaningful that we could create a common ground for promoting energy conservation in the major industries and determined its direction in the respective countries.

We hope that this project will contribute to energy conservation and environmental protection in the respective ASEAN countries so that they can eventually achieve environment-friendly and sustainable development in economy and also that this project will serve as a bridge of technical exchange and friendship between Japan and the countries concerned.

March 16, 2004

The Energy Conservation Center, Japan

Summary

The economy in ASEAN countries has been rapidly growing, as a result, it will be more required to efficiently use energy and to consider about the prevention of the global warming because of the quick increase in energy consumption.

The activities of ASEAN Center for Energy (hereinafter referred to as "ACE") have been established, which results in enhancing and disseminating the awareness of reducing energy consumption in the ASEAN countries.
This fiscal year, the target countries were Thailand and Singapore, where energy audits for main industries were not implemented yet.

Energy audits and workshops were carried out at each 2 factories at the two countries. These achievements would be basis of implementation and dissemination based on technology transfer regarding energy conservation improvement policies of major industries of each country.

We had had the opportunity to share experience on energy conservation activities with Japanese experts at all of the ASEAN countries. Every country member experiences and understands basic issues, which means foundation is established to deal, on even ground, with energy conservation activities in ASEAN countries.
This fiscal year is a year to consolidate the past activity accomplishment, and a year to go on to the second phase toward implementation and dissemination of the past achievement.

On-site activities of the project this FY, started at the Inception Workshop in late October of 2003 (same with the Building Project), and ended at the Post Workshop at the end of January of 2004 (same with the Building Project).
To start the project smoothly, action plan was explained and finalized, as well as Japanese technology was introduced for the understanding of auditing points at the Inception Workshop.
At the Post Workshop, there was a report of activity results and achievements of the 2 countries so that they could be shared among other countries, and activity accomplishments of ASEAN taskforce toward establishment of database/ benchmark/ guideline in the future were discussed.
At the end, there was a discussion on implementation and dissemination of improvement measures and approach strategy of creation of database/ benchmark/ guideline.
Specific details of activities through this project for this year are as follows:

Oct. 23-24, 2003;
Participate in "Inception Workshop of The SOME-METI Project on PROMEEC - Buildings and PROMEEC - Industries" (location: Singapore, same as Building project)

(1) Latest policies and legal issues on energy conservation promotion of building and industry sectors in Japan, introduction of energy management of this project and typical energy conservation technology
(2) Implementation and dissemination of improvement measures of each country up to now, and report on the activity
(3) Explanation and discussion of action plan regarding FY2003 projects (building and industry)
(4) Meeting on schedule and arrangement of site surveys of building and industry projects

Oct. & Nov., 2003;
Audit Survey of Main Industries in Thailand & Singapore (primary)
Activity in Thailand (Nov. 24-28)
(1) Introduction of energy conservation activities and technology of the caustic soda industry in Japan
(2) Introduction of EE&C technology and application of the caustic soda industry, audit of 2 caustic soda plants, and summarization

Activity in Singapore (Dec. 1-5)
(3) Introduction of energy conservation activities and technology of food processing industry in Japan
(4) Introduction of EE&C technology and application of the food processing industry, audit of 2 food processing factories, and summarization

Jan., 2004;
Audit Survey of Main Industries of Thailand & Singapore (secondary)
Activity in Singapore (Jan. 6-9)
(1) Introduction of audit points for food processing industry and result report of the primary survey
(2) Explanation and discussion of the audit results at 2 food processing factories and performing additional survey (secondary survey)
(3) Result report of the secondary survey and introduction of database, benchmark and guideline, and introduction of EE&C Management

Activity in Thailand (Jan. 12-15)
(4) Result report of the primary survey at caustic soda factories
(5) Explanation and discussion of the audit results at 2 caustic soda factories, and performing additional survey (secondary survey)
(6) Result report of the secondary survey and introduction of database, benchmark, and guideline and introduction of EE&C Management

Jan. 28-31, 2004;
Participate in "Post Workshop on Promotion of Energy Efficiency and Conservation

(PROMEEC) (Major Industry and Building), SOME - METI Work Program 2003 - 2004 (Location: Singapore, same as Building project)

(1) Special lecture: Introduction of energy management and energy manager system in Japan
(2) Energy audit of factories by industry in FY2003 (caustic soda industry in Thailand and food industry in Singapore) result report, and comments and discussion by target countries
(3) Report and discussion on activity outcomes of taskforce of database, benchmark and guideline establishment for ASEAN
(4) Proposals of activity strategy for the future year and discussion on issues to be considered regarding ASEAN Plan of Action for Energy Cooperation (APAEC) 2004-2009, etc.

2 sites were selected as target factories for auditing in 2 countries. Audits were implemented at caustic soda plants of Rayong district for Thailand, and factories in the city and northern area for Singapore.

We were provided effective cooperation like last year in Thailand and Singapore, this fiscal year's target countries.

We would like to thank, sincerely, the efforts of persons from ACE and governments of each country for selecting factories for survey, and related preparation and cooperation.

Energy conservation of factories in Japan was introduced at the primary survey, and at the second survey, points of audit were introduced in concrete, as well as explanation of management and facility maintenance.

Economically, Thailand and Singapore are pursuing active industrial activities at the level of advanced countries. However, enthusiasm to energy conservation of the participants of this project could be sensed due to its large import share of energy.

Every involved person worked earnestly with us, and businesses were carried out smoothly.

On implementation, OJT for participants of site surveys was emphasized and surveys were carried out.

Accordingly, improvement proposals by Japanese experts were put in practice, or going to be in practice shortly, which could be evaluated as a large achievement.

By the energy audit of major industries in the 2 countries, all 10 countries of ASEAN experienced energy conservation audit activities under the training of Japan experts.

Each country has established basis to develop energy conservation promotion activities in home country and ASEAN countries in the future.

We would very much like to see these proposals put into practice at the earliest opportunity and effective use made of the manuals, thereby enabling us to contribute to the conservation of energy and protection of the environment in the ASEAN countries.

Finally, we would like to thank all those at ACE (ASEAN Center for Energy) along with the organizations and factories involved in each country for their cooperation

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I. Chemical Industry
(Caustic Soda Industry)

Participants in the Workshop of ASEAN Major Industry Energy Audit
(Persons concerned from DEDE and the caustic soda factories audited and members of ACE and ECCJ) at the workshop venue in Bangkok, Thailand (January 12, 2004)

I. Chemical Industry (Caustic Soda Industry)

1. Summary of Project

This project was implemented as part of the Infrastructure Improvement Project for Rationalization of International Energy Use, with an aim to contribute to energy conservation, environmental preservation and sustainable development of economy in ASEAN countries that have achieved remarkable economic growths recently.

This project is designed to promote energy conservation in the major industries of ASEAN countries with ACE as the core organization and with cooperation of ASEAN countries. As one of the countries and industries subject to energy audit for the current year, the chemical industry (caustic soda industry) of Thailand was chosen. Then, energy audit plans were developed based on discussions with persons in charge from Thailand. Energy audits were implemented at the sites of two companies of chemical industry (caustic soda industry) over 6 days for the periods from November 24 through 28, 2003 and January 12 through 15, 2004 with persons in charge from DEDE, Thailand (Department of Alternative Energy Development and Efficiency).

We hereby report on the results of the energy audits along with an overview of the political and economic situations of the country as follows;

1.1 Subjects of Energy audit and Organizations involved

(1) Country and companies subject to energy audit

Country: Thailand
Company: Co. A (caustic soda factory)
Co. B (caustic soda factory)

(2) Organizations involved and participants

1) Thailand

a. DEDE (Department of alternative Energy Development and Efficiency):
Mr. Pravit Teetakaew (the 1st site survey only)
Mr. Thamayos Srichuai
Mr. Chalermchai Phadunghus
Mr. Sarat Prakobchat
Mr. Ittipol Intamat
Mr. Chawalit Boonsang
Mr. Chatchawan Sripetchdee
Ms. Amaraporn Utchawangkul (the 2nd site survey only)
Mr. Sarawutt Preecha (the 2nd site survey only)
Dr. Prasert Sinsookprasert (the 2nd site survey only)

b. Co. A: 3 persons

c. Co. B: 6 persons

d. AC (Accredited Consultants)

Mr. Chaisak Chatriejansakul	Mr. Suwit Maungaram
Mr. Nutdhaoun Ngernbumroong	Mr. Viroj Tethuthapak
Mr. Sanit Athasart	

2) ACE (ASEAN Center for Energy):

Mr. Christopher ZAMORA

3) Japan: The Energy Conservation Center, Japan

Participants from the International Engineering Department of the Energy Conservation Center, Japan (ECCJ)

Hiroshi Shibuya	General Manager (the 1st site survey only)
Shigeru Kumanashi	Technical Expert
Hideyuki Tanaka	Technical Expert (the 2nd site survey only)

1.2 Political and Economic Conditions in Thailand

(1) National indicator

Country name:	Kingdom of Thailand
Area:	514,000 km^2
Population:	61,810,000 (2001)
Capital:	Bangkok
Language:	Thai
Religion:	Buddhism 95%, Muslims 4%, others 1%
Brief history:	The foundation of Kingdom of Thailand was established by Sukhothai Dynasty in the 13th century and then followed by Ayutthaya Dynasty (14–18 century), Thomburi Dynasty (1767–1782) and the present Chakri Dynasty (1782–). In 1932, the king agreed to the abolition of absolute monarchy and the transfer of power to the constitution-based system of government.

(2) Political system and domestic policy

Form of government:	Constitutional monarchy
Head of state:	His Majesty King Bhumibol Adulyadej (Rama IX) (enthroned in June 1946 and has been on throne for 57 years)
Parliament:	Bicameral National Assembly consisting of the Senate (200 seats) and the House of Representative (500 seats) (Members of both the Houses are elected by popular vote)

Government: Prime Minister Taksin Shinawat
Foreign Minister Surakiart Sathirathai

Domestic policy: Since the power transfer to the constitution-based government in 1932, the military-lead government had ruled the country until 1992, when the military forces and pro-democracy movement crashed (May incident). After 1992, the military has refrained from its interference in the politics and the democratic procedures for change of administrations have been established.

(3) Political situation in Thailand

In accordance with the new Constitution established in 1997, the election of the House of Representative members was held in January 2001. Thai Rak Thai Party (TRT) made a landslide victory and the Taksin Administration was installed.

1) Characteristic points of the Taksin Administration
The Taksin Administration has promoted a number of economic reform policies under the strong initiative of Prime Minister and with the support of the majority (366 seats of 500 seats) forming the coalition party in the Lower House [Thai Rak Thai Party, (TRT), Chat Thai Party (TNP Thai National Party) Chat Phattana Party (NDP, National Development Party)]

- In January 2001, in the election of members of the House of Representatives, Thai Rak Thai Party (TRT) lead by the Taksin Shinawat almost solely won the majority of the seats and became the leading party.
- TRT formed the 4-party power-sharing coalition government and on February 18th , 2001, the Taksin Administration was officially installed with a stable majority (325 seats out of 500 seats at that time).
- The Taksin cabinet, in its policy speech, introduced an emergency priority policy package underlining economic reforms that Taksin had promised in the election campaigns as the best priority policy and has implemented each policy in specific ways.
- Prime Minister Taksin has demonstrated his strong leadership and promoted various economic reform measures based on the ruling party’s comfortable majority in the Lower House and his firm power base in the administration. The current administration is characterized with its top-to-down and the policy-driven government management unlike the conventional administrations that focused on coordination of

different interests among the coalition member parties. The foundation of the Taksin Administration is firm and it is a common view that the administration will sustain itself until February 2005 when its term expires.

2) Recent political situation

- On October 3rd, 2002, the law concerning the reorganization of ministries and agencies was enacted. And the government was restructured from the Prime Minister’s Office, 13 ministries and one agency to the Prime Minister’s Office and 19 ministries. In this restructuring, the Agency of University was abolished (integrated into the Ministry of Education), while 6 ministries were newly set up. They are Ministries of Tourism and Sports, Social Development and Human Services, Natural Resources and Environment, Information and Communications Technology, Energy and Culture.

(4) Basic foreign policy

Thailand makes it a basic foreign policy to pursue partnership with ASEAN countries and cooperation with major countries, such as Japan, the United States and China while it is maintaining its traditional policy of flexible and omni-directional diplomacy.
The Taksin Administration demonstrates its proactive and strong initiative in the region by strengthening relationships with neighboring countries, developing active economic diplomacy aiming at the conclusion of Free Trade Agreement (FTA) with the respective counties, proposing Asia Cooperation Dialogue (ACD), etc.

(5) Economy

Major industries: Out of the 2000 GNP, the nonagricultural sector makes up about 90% and the industrial sector alone accounts for 33.4%. Although the portion of agriculture in GNP is shrinking, it is still an important industry having 40% of the employed population.

Table I-1-1 Basic Economic Data

Item		Year	1999	2000	2001	2002
GDP		100 Mln US$			1114	
Per capita GNP		US$			1818	
Economic growth rate		%	4.4	4.6	1.8	5.2
Commodity price increase rate		%			1.6	
Unemployment rate		%			3.3	
Total trade value	Export	100 Mln US			653	
	Import	100 Mln US			618	

(Exchange rate $ 1.0= about 41 baht (as of September 2002))

Major trade items:

Exports: Computer, Computer parts, IC, Automobiles, Clothes, Frozen shrimps, Jewelry, Rice

Imports: Machines and machine parts, Electronics and components, Crude oil, Chemical products, IC board, Iron and steel

Major trade partners (2001):

Exports: 1. US, 2. Japan, 3. Singapore, 4. Hong Kong, 5. China, 6. Malaysia

Imports: 1. Japan, 2. US, 3. China, 4. Malaysia, 5. Singapore, 6. Taiwan

Table I-1-2 Trades with Japan

		1999	2000	2001	2002
Export	100 mln yen	10082	11423	12605	13146
Import	100 mln yen	12848	14694	14425	16486
Major trade item	Export			Exports: Sea foods, Office equipment, AV equipment, Meats, Electronics components including semi-conductors	
	Import			Electronics components including semi-conductors, Iron and steel, Car parts, Plastics, Motors	

(Foreign Trade Statistics of Finance Ministry)

1) Economic overview:

Thailand's economy had rapidly increased having foreign investments including that from Japan as a spur since late 1980's, while current-account deficits expanded, causing the advent of a bubble economy mainly in the real estate sector. Then, following the collapse of the bubble, bad debts increased and the pressure for the devaluation of baht was heightened with this deterioration in economy as a background. In July 1997, after the floating-rate system was introduced, the value of baht drastically dropped and created an economic crisis.

The government of Thailand endeavored to reconstruct its economy implementing structural reforms including disposal of bad loans, etc. with the support from the international society including IMF and Japan. Owning to the government's stimulative measures backed up by its financial policy, growing exports, etc., Thai economy that has long been sluggish started to pick up.

The Taksin Administration inaugurated in February 2001 introduced measures to stimulate agricultural communities and medium- and small-size companies underlining the role of domestic demand as a driving force for economy in addition to promoting the conventional export-oriented economy. Due to the consumer spending invigorated as a result of The Taksin Administration's domestic demand expansion measures and other favorable factors, the economy of Thailand appears to be on a recovery track and the economic growth in 2002 was 5.2%, the highest rate after the recent economic crisis.

2) Economic situation in Thailand (Economic crisis and Thai government's measures)

- The Chavalit Administration implemented a belt-tightening policy based on the IMF program in order to get over the economic crisis with which it was confronted in July 1997. While his policy produced certain results such as stabilized exchange rates, a turnaround to surplus in the current-account balance, etc., the actual economy of Thailand continued to be depressed, causing bankruptcy of a number of financial institutes and other corporations, increases in the unemployed population, a deep social impact on the poor people, etc.
- The Chuan Administration inaugurated in November 1997 made a policy shift from the belt-tightening policy to a policy to promote domestic demand, obtaining agreement from IMF and introduced comprehensive economic packages including tax cuts, job creation, public investments, support for medium- and small-size companies, etc. along with extra budget in three times in order to achieve economic recovery. Particularly, intending to make progress in disposal of bad

debts, the administration proposed that an assets management company be established for each bank and revised and executed economy-related laws such as the law concerning restructuring of private sector's liabilities, bankruptcy laws, etc.

- The Taksin Administration established in February 2001 criticized the Chuan Administration for adopting a policy favoring large-scale companies and started his administration upholding an economic recovery from the grass-root level as a priority political agenda and has promoted domestic demand as well as export conventionally promoted as a driving force of economy. Specifically, it introduced bottom-up income growth-based domestic demand expansion measures such as temporary moratorium on farmers' loan payments, the foundation of development funds in villages, one-product-for-one-village movement, the establishment of people's bank for micro credits, etc., while it aims to improve the nation's international competitiveness by strengthening domestic industries through development of medium- and small-size companies, etc. and proactively inviting foreign capitals. In addition, in order to solve problems of bad debts as early as possible, it set up a government-led organization for non-performing loan purchase.

3) The current status and future prospects

- Supported by growing exports and the government's financial policies, Thai economy came back on an upward trend in 1999. In June 2000, Thai government discontinued IMF proposed Structural Adjustment Programs (SAP). In 2001, Thailand's economic growth slowed down due to slowdown in the US economy, delay in the restructuring of the financial sector including disposal of bad loans, etc. and the economic growth in 2001 resulted in 1.8% on a year-on-year basis.
- Recently the economy of Thailand has been on a recovery track owning to vitalized personal spending, etc. which appear to be the effects of the Taksin Administration's bottom-up policy. The National Economic and Social Development Board (NESDB) announced an economic growth rate of 5.2% for 2002, the highest figure after the recently experienced economic crisis.

1.3 Energy Situation in Thailand

(1) Energy index (2001)

① Primary energy consumption :	75.53 million TOE (about 14.5% of that of Japan)
② Primary energy self-sufficiency rate:	about 47.4% (Japan: about 20%)

③ Final energy consumption: 54.3 million TOE (about 15% of that of Japan)

④ Production of electricity: 102Twh (about 10% of that of Japan)

⑤ Final energy consumption by sector (%):

Industry 39%, Transport 34%, Residence and Business /Agriculture 27%

⑥ Primary energy consumption by fuel (%):

Petroleum 43%, Natural gas 27%, Coal 11%, Renewable energy 17%, Hydropower and other sources 1%

Table I-1-3 Primary Energy Consumption Intensity per Unit GDP
(Unit: toe/1,000US$ in the price of 1995)

	1990	1995	2000	2001
Thailand	0.39	0.38	0.43	0.43
Japan (reference)	0.089	0.094	0.092	0.09

Source: IEA Energy Balances of OECD Countries (2000-2001)
IEA Energy Balances of Non-OECD Countries (2000-2001)

(2) Energy situation

The energy demand structure in Thailand dramatically changed along with the rapid growth in economy resulting from the nation's policy shift from an agriculture-centered economy to an export-oriented economy that had been advanced since the mid 1980's. Although Thailand had depended on rapidly increasing oil import for more than 90% of its commercial energy except for conventional energies (such as wood, straw, bagasse etc.) in around 1980, its energy self-sufficiency improved and exceeded 40% in the 1990's owing to the development and commercialization etc. of natural gas in Gulf of Thailand and brown coal in the inland.

1) Energy resources in Thailand:
While Thailand is not rich in energy resources such as oil, coal, natural gas, it has comparatively large quantities of proven deposits of natural gas. The ratios of R/P for oil and natural gas are 9.5 years and 19.9 years respectively. Thailand is not a so-called resourceful country.

2) Production and consumption of primary energy
The annual average growth of production of primary energy in Thailand for the period from 1995 through 2001 was 0.33% and showed no significant change. However, as an energy source, the use of natural gas dramatically increased and so did the use of oil. On the other hand, biomass decreased. Although the self-sufficiency rate of natural gas was 100% in 1995, domestic production became insufficient to meet the recent increasing

demand and Thailand imported natural gas from neighboring countries (Malaysia, Indonesia). As a result, the self-sufficiency rate dropped to 75.1% in 2001. The government of Thailand had promoted a policy of importing supply from ASEAN pipeline and started importing from Myanmar from 1999 and the import volume increased. Currently, Thailand is planning and studying pipeline supply from Malaysia, Vietnam and Indonesia.

The self-sufficiency rate for oil (2001) was only 17% and Thailand imported oil from Middle East, Asia and other countries (74%, 20% and 6% respectively). As Thailand's dependency on crude oil of Middle East is high, the government is aware of risks that may arise in supply and the necessity of both long-term and short-term approaches in order to improve security of oil supply. Long-tem approaches currently being considered include diversification of oil supply sources, improvement of energy efficiency, development of alternative energies, and improvement of market efficiency through privatization and deregulation. Short-term approaches generally include information sharing, demand control, ensuring technologies for fuel conversion, expansion of oil production and oil storage.

3) Final energy consumption by use:

The average annual growth rate of final energy consumption in Thailand during the period from 1995 through 2000 was about 1.5%. In terms of use, it increased by 0.3% in the transport sector and by comparatively high 3 to 6% in the industrial/agricultural/commercial sectors while it decreased in the residential sector by 2.9%. In the industrial sector, particularly in the chemical field, the energy consumption dramatically grew while it dropped in the fields of nonmetallic minerals (cement, glass, etc.), mining industry, and construction.

Table I-1-4 Changes in Actual Consumption of Final Energy in the Industrial Sector (by line of business)

	1995		2000		2001		Average annual growth rate (1995–2001)
	Volume	Composition ratio (%)	Volume	Composition ratio (%)	Volume	Composition ratio (%)	
Iron and Steel	522	3.2	645	3.2	617	3.0	2.8
Chemical	977	6.1	4040	19.9	4805	23.6	30.4
Non-ferrous metal	-	-	-	-	-	-	-
Non-metallic mineral	4018	24.9	3130	15.4	3509	17.3	-2.2
Transport equipment	-	-	-	-	-	-	-
Machinery	627	3.9	751	3.7	819	4.0	4.6
Mining	28	0.2	11	0.1	17	0.1	-8.0
Food products/ Cigarette	4954	30.7	5428	26.7	4756	23.4	-0.7
Pulp and Paper	269	1.7	381	1.9	388	1.9	6.3
Wood working	101	0.6	123	0.6	156	0.8	7.5
Construction	278	1.7	150	0.7	130	0.6	-11.9
Textile/leather	1249	7.7	1071	5.3	1061	5.2	-2.7
Others	3119	19.3	3777	18.6	4079	20.1	4.6
Total	16142	100.0	19507	95.9	20337	100.0	3.9

In units of 1,000 ton converted into heavy fuel oil (ktoe)

Source : IEA Energy Balances of Non-OECD Countries (1995-1996, 1999-2000)

4) Electric power

The average annual growth rate in electric power generation in Thailand during the period from 1995 through 2001 was 4.2%. In terms of source, the generation by oil-fired power and hydraulic power decreased while natural gas-fired and biomass fuel power generations increased significantly. In 2001, thermal power generation by oil, coal and natural gas accounted for 92.6% and hydraulic/geothermal power generation and biomass power generation made up 6.3% and 1.3% respectively.

Table I-1-5　Changes in Actual Power Generation Volumes (by energy source)

	1995		2000		2001		Average annual growth rate (1995–2001)
	Power generation	Composition ratio (%)	Power generation	Composition ratio (%)	Power generation	Composition ratio (%)	
Oil	24403	30.5	10021	9.8	2926	2.9	-29.8
Coal	14780	18.5	17604	17.2	19622	19.2	4.8
Natural gas	33900	42.3	60808	59.4	72205	70.5	13.4
Hydraulic power	6712	8.4	6026	5.9	6303	6.2	-1.0
Geothermal power	1	0.0	2	0.0	2	0.0	12.2
Biomass	265	0.3	1516	1.5	1362	1.3	31.4
Total	80061	100.0	95977	93.7	102420	100.0	4.2

Unit: GWh

Source : IEA Energy Balances of Non-OECD Countries (1995-1996, 1999-2000)

5) Energy price:

Market-driven energy prices are introduced in Thailand in principle.

Electric power is supplied via 3 organizations: EGAT (Electricity Generating Authority of Thailand) in charge of generation and transmission of electricity, MEA (Metropolitan Electricity Authority) in charge of distribution of electricity in the metropolitan area and PEA (Provincial Electricity Authority) in charge of distribution in other areas. These are all state-owned companies. Electric rate structure in Thailand consists of basic charge and Ft (Fuel Adjustment Clause) charge. Basic charge and Ft charge very depending on demand type and contract. The average prices (Baht/kWh) in 1999 are as follows;

	Urban area (MEA)	Other areas (PEA)
Household use	2.39 Baht/kWh	1.98 Baht/kWh
Business use	2.23	1.94
Industrial use	2.07	2.00
Agricultural use	-	1.59
Total	2.21	1.99

Fuel prices (based on the data from PPT (Petroleum Authority of Thailand) are as follows.

Gasoline (Leaded)	15.19 Baht/L
Gasoline (Unleaded)	16.19
Diesel	13.19
Grade A Heavy fuel oil	7.80
Grade C Heavy fuel oil	7.20

Energy prices as of November 2001 in Thailand (Bangkok) are as follows;

		US$ = ¥120	
Electricity rate for business use	0.037–0.039 US$/kWh	4–5 ¥/kWh
Electricity rate for general use	0.03–0.07 US$/kWh	4–8 ¥/kWh
Gas rate for business use	0.10 US$/m^{3}N	12 ¥/m^{3}N
Gas rate for general use	0.18 US$/m^{3}N	22 ¥/m^{3}N
Regular gasoline	0.30US$/L	36 ¥/L

Source: Comparison of Investment-related costs in major cities and areas in Asia (Issued by JETRO Overseas Research Department, March 2002)

1.4 Caustic soda industry in Thailand

ASEAN key countries have caustic soda factories in their basic material industry. In recently built plants, the ion-exchange membrane process is adopted, while the diaphragm process and the mercury process are still used in some factories.

Thailand has the second highest production capacity of caustic soda following Indonesia. In Thailand, there are 10 plants, out of which 8 were constructed during the past 20 years. Before we started the current survey, we obtained information that only 3 out of these factories were currently in operation. We had an impression that this industry was really a roller-coaster industry. We strongly felt that it was necessary for companies to further advance cost cuts as well as saving energy in order to survive the competition.

Table I-1-6 ASEAN Counties' Production Capacities of Caustic Soda

Country name	Capacity t/y-100%NaOH	Type of process
Brunei Darussalam		
Cambodia		
Indonesia	634700	Ion exchange membrane method in new plants
Lao PDR		
Malaysia	85300	Ion exchange membrane method
Myanmar	Potential capacity	
Philippines	33000	Iron exchange membrane method in new plants
Singapore	65000	Ion exchange membrane method
Thailand	471800	Ion exchange membrane method
Vietnam	92500	Ion exchange membrane method in new plants
Japan	Actual production: 4,350 kt/y (2002)	Ion exchange membrane method

(Blank box means no capacity or data unavailable)

2. Overview of Factories Subject to Energy Audit

In preparing for the implementation of the planned energy audits of the chemical industry (caustic soda factories) in Thailand, ECCJ requested to ACE for selection of two factories in or near the city of Bangkok. DEDE of Thai, in response to the request from ACE, determined the two caustic soda factories in the Rayong area (about 180km southeast of Bangkok), not the Bangkok area. As it was requested from the 2 factories that we would conclude a nondisclosure agreement with them on the site at the time of the first site survey, we note here that the report described hereunder is only on the matters concerning energy conversation.

Brief outlines of the respective 2 caustic soda factories are given below.

2.1 Outline of Co. A (caustic soda factory)

(1) General information

Location:	Rayong area (about 180km southeast of Bangkok)
Products:	Caustic soda, chlorine gas, etc.
Employees:	About 170 persons (including 16 engineers and 150 workers engaged in operation)
Work system:	3-shift operation
Organization:	The organization chart of Co. A is shown in Figure. I-2-1

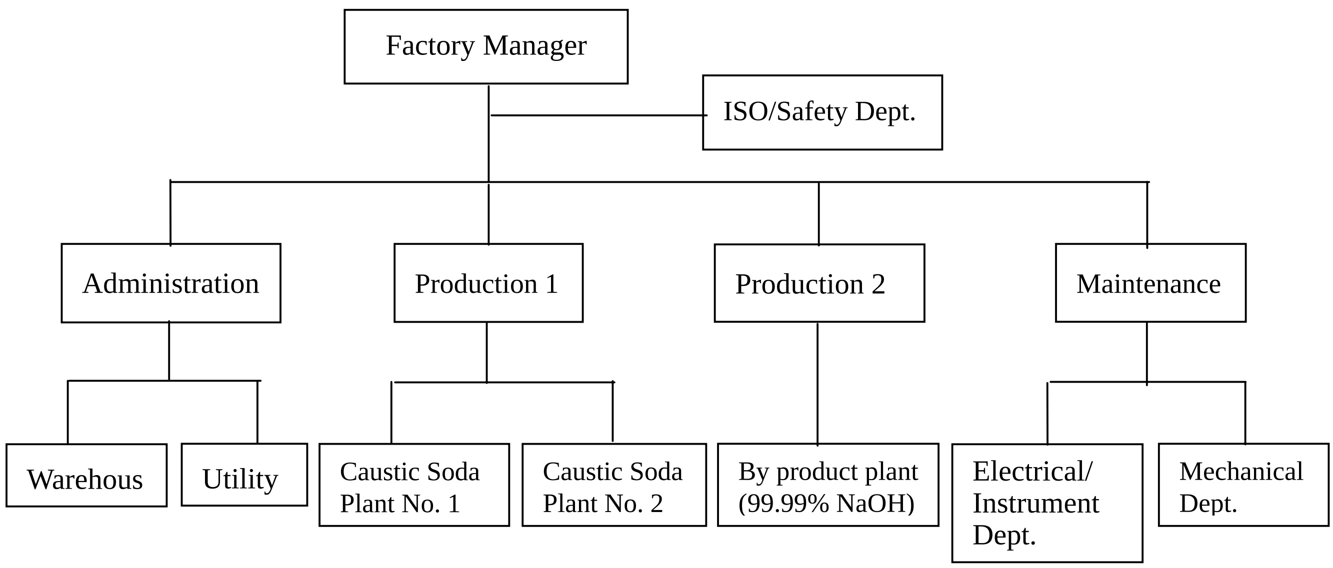


Figure. I-2-1 Organization of Co. A

Operation:	This factory was constructed in 1995 and the operation was started in 1996. The main purpose of the plant is production of caustic soda. In 1998, additional bipolar equipment was installed. Salt used as raw material is rock salt domestically produced and refined on the place of production. 3 shifts are engaged in production and caustic soda (NaOH) is produced for 24 hours (345 days/year). Each line receives regular maintenance for a total of 20days per year.
In-house activities:	Obtained ISO14001 certification and plans to obtain ISO9001 certification in 2004. Small group activities are in practice and there are about 20 groups.

(2) Installation and capacities of Co. A

There are no boilers and steam is supplied from the nearby company. Since the targets of our survey were caustic soda producing electrolytic devices and caustic soda enrichment devices, no utilities-related data such as those on the pumps, air compressors, etc. were provided.

(3) Factory layout

Although the drawing was provided, it was too small to clearly show. In addition, the process of a chemical factory is very complicated and it is protected under the nondisclosure agreement, the attachment of the drawing has been omitted here.

2.2 Outline of Co. B (caustic soda factory)

(1) General information

Location:	Rayong area (180 km southeast of Bangkok)	
Products:	Caustic soda and chlorine gas	
Employees:	Caustic soda factory:	21 persons including Manager (2 are engineers)
Work system:	4 teams on 3 shifts, 325 operation days/year	
Organization:	The organization chart of Co. B is shown in Figure. I-2-2	

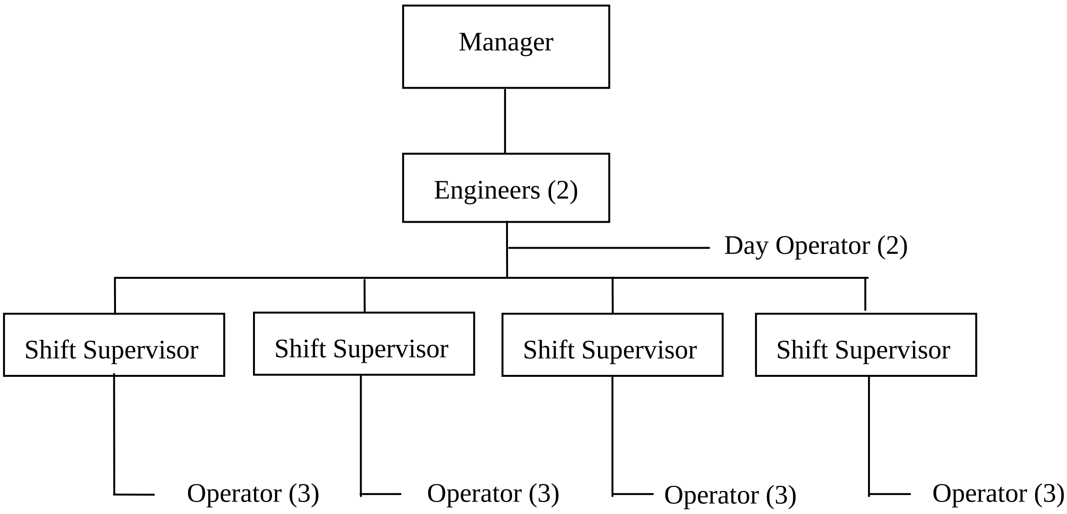


Figure. I-2-2 Organization of the Caustic Soda Factory of Co. B

Operation: This factory was constructed in 1990 for production of chlorine gas. Salt as raw material is rock salt produced in the country and refined in the place of production.

In-house activities: Obtained ISO9001 in 1998, ISO14001 in 1999 and TIS18001 in 2001 Introduced the TPM system and set up an energy conservation council in the factory to promote energy conservation

(2) Installation and capacities of Co. B

There are no boilers and steam is supplied from the nearby company. Since the targets of our survey were caustic soda producing electrolytic devices and caustic soda enrichment devices, no utilities-related data such as those on the pumps, air compressors, etc. were provided.

(3) Factory layout

We could not obtain the drawing due to the nondisclosure agreement.

3. Plan of energy audit

The planned energy audits in Thailand were intended to grasp the actual situations of the production process, energy consumption and the use of exhaust heat in the selected 2 caustic soda factories and to propose improvement plans to advance their energy conservation efforts. The plans of energy audit also included conducting workshops on the sites and introducing energy conservation technologies, activities, etc. in Japan to raise, promote and disseminate the awareness of the energy conservation among those concerned in Thailand. Furthermore, these energy audits were planned with the view to giving support to energy conservation leaders on the side of ASEAN in establishing the standardized energy audit method after the implementation, based on the understanding of the actual situations of the same industry in ASEAN countries, the levels of their energy audit skills, etc.

The survey was conducted twice for the respective facilities.
In the first site survey, the first workshop was conducted. The points for energy audits of caustic soda factories and energy conservation technologies practiced in caustic soda plants in Japan were introduced to help and boost their understanding.
In the actual auditing, a local energy audit group arranged by ACE took specific measurements at the respective sites under the instructions of the experts dispatched from Japan while the points to be checked in energy auditing that we had asked in a preliminary questionnaire to these factories were confirmed. The energy audit group visited each factory twice in two days.
In the second site survey, energy conservation improvement plans determined based on the results of the first survey were explained to DEDE (Department of Alternative Energy Development and Efficiency), the department of the government of Thailand in charge, and the managing persons of the respective companies. Then, we visited the sites again and conducted a one-day energy audit for the respective facilities to confirm the results of the first energy audits and our subsequent proposals.

3.1 Energy Audit Procedure

The main process of caustic soda production consists of dissolution of industrial salt, high-degree refining of salt water, electrolysis of salt water, concentration of diluted caustic soda solution and refining of chlorine gas and hydrogen gas generated.
In preparing for the energy audits, we had obtained a flow sheet of the production from the 2 companies and confirmed that it was almost the same as the standard one used in factories in Japan.
Accordingly, we decided to focus our auditing on brine electrolysis vessels (electrolyzers) and caustic soda evaporators that consume large quantities of energy in the process of caustic soda production.

We confirmed the operation data of these two devices by reading the values indicated on the DCS (Distributed Control System) and the measuring instrument panel in the meter room. On the sites, we observed and then confirmed sometimes using a digital thermometer the condition of heat insulation of the devices with the staff members in charge from the receiving companies.

Photo shooting was strictly prohibited by the both factories and no photopictures could be obtained.

3.2 Selection of Equipment Subject to Energy Audit

Since the number of energy audit days was limited, we focused our energy audit, as we mentioned above, on the salt water electrolysis baths and caustic soda evaporators both of which were energy intensive equipment in the caustic soda production process after discussions with the respective companies. We decided to examine electrolytic cells by series (by type) and caustic soda evaporators individually.

3.3 Energy Audit Schedule

Both of the energy audit sites for the two companies were located in the East Industrial Complex about 30 minutes by car from our accommodation in Rayong where roads were maintained well and we had an impression that the development of infrastructure was completed.
Responses of the two companies undergoing our energy audit were kind and cooperative and they were ready to answer the questionnaire that we had sent in advance. We could conduct our auditing efficiently.
We conducted auditing according to the schedule shown below.

(1) 1st site survey schedule: Implemented in November 2003

November 24 (Mon.)	1st workshop: Introduction of 2 caustic soda manufacturing companies (Co. A and B) Introduction of profile of ECCJ, energy audit procedure and method for these companies
November 25 (Tue.)	Factory energy audit of Co. A
November 26 (Wed.)	Factory energy audit of Co. A, summarization of data and reporting on the energy audit results
November 27 (Thu.)	Factory energy audit of Co. B
November 28 (Fri.)	Factory energy audit of Co. B, summarization of data and reporting on the energy audit results

(2) 2nd site survey schedule: Implemented in January 2004

January 12 (Mon.)	2nd workshop: Reporting on the results of the 1st auditing
January 13 (Tue.)	Factory energy audit of Co. A and proposal of improvement plans
January 14 (Wed.)	Factory energy audit of Co. B and proposal of improvement plans
January 15 (Thu.)	Final workshop: Reporting on and summary of the 2nd auditing and proposal of improvement plans.

4. Equipment Subject to Energy Audit

In caustic soda factories, most of the energy consumption is electricity for brine electrolyzers and steam for concentration of caustic soda. Thus, as mentioned in the previous chapter, we conducted energy audits focusing on brine electrolytic vessels and caustic soda evaporators.

4.1 Brine Electrolysis Cell

(1) Brine electrolyzers of Co. A

Caustic soda production capacity: 250,000 t/y (as 50% caustic soda)

- Series 1 (RCA-1)
  Manufacturer of brine electrolysis vessel:
  Asahi Glass Co., Ltd. - Japan
  Name of brine electrolysis vessel: Ion-exchange membrane method AZEC-F2 (Figure. 1-4-1)
  Type: Unipolar system (Mono-polar)
  Electrolytic current (Max): 154 kA
  No. of electrolyzers possessed: 49

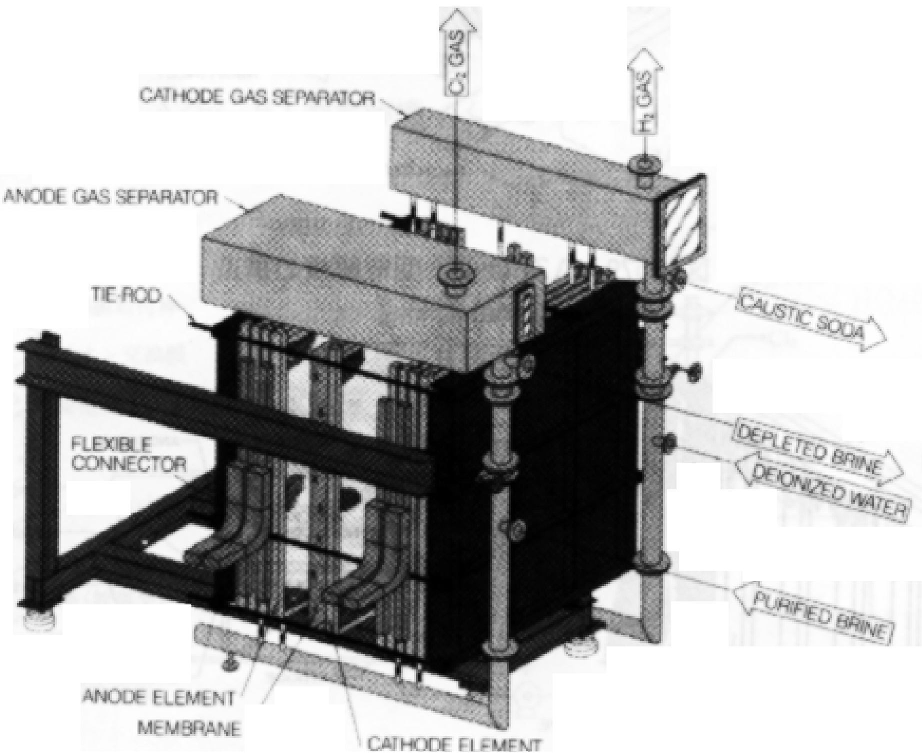


Figure. I-4-1 Structure of AZEC-F2 Electrolyzer

- Series 2 (RCA-2)

  Manufacturer of brine electrolysis vessel:

	Asahi Glass Co., Ltd. - Japan
Name of brine electrolysis vessel:	Ion-exchange membrane method
	AZEC-B1 (Figure. 1-4-2)
Type:	Bipolar system
Electrolytic current (Max):	14.4 kA

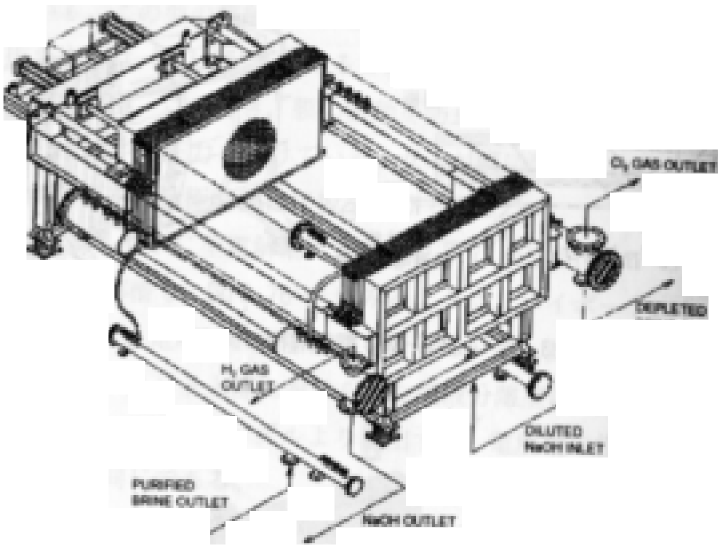


Figure. I-4-2 Structure of AZEC-B1 Electrolyzer

(2) Brine electrolyzers of Co. B

Caustic soda production capacity:	55,000 t/y (in 50% caustic soda)
Manufacturer of brine electrolysis vessel:	
	Asahi Glass Co., Ltd. - Japan
Name of brine electrolysis vessel:	Ion-exchange membrane method AZEC-M3 (Figure. 1-4-3)
Type:	Mono-polar
Electrolytic current (Max):	80 kA
No. of electrolyzers possessed:	30

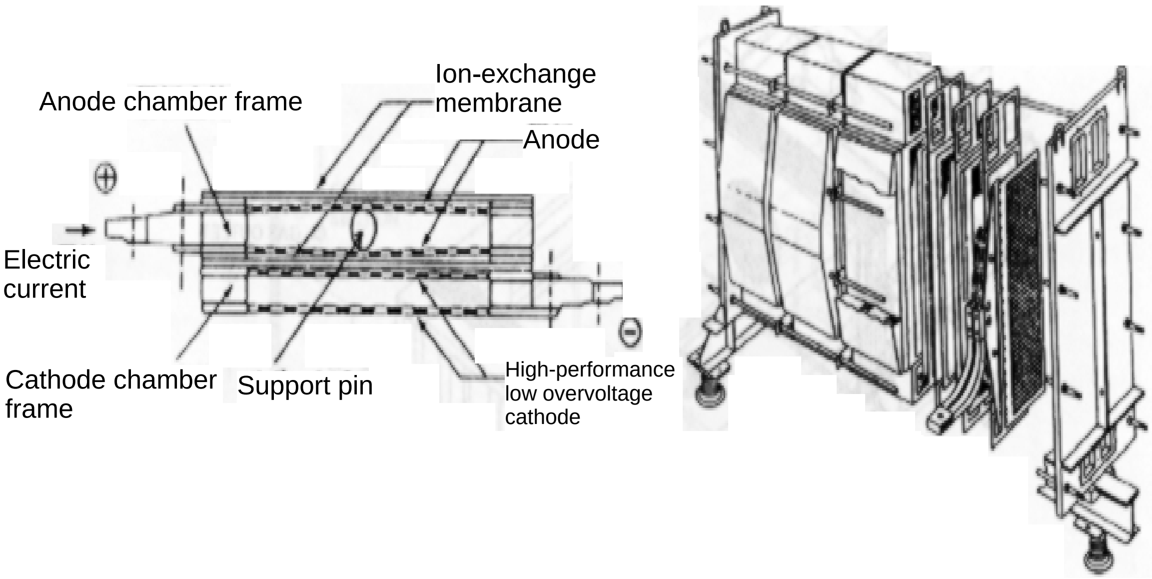


Figure. 1-4-3 Structure of AZEC-M3 Electrolyzer

4.2 Caustic Soda Evaporator

The simple outline of flow of evaporator is shown in Figure. I-4-4.

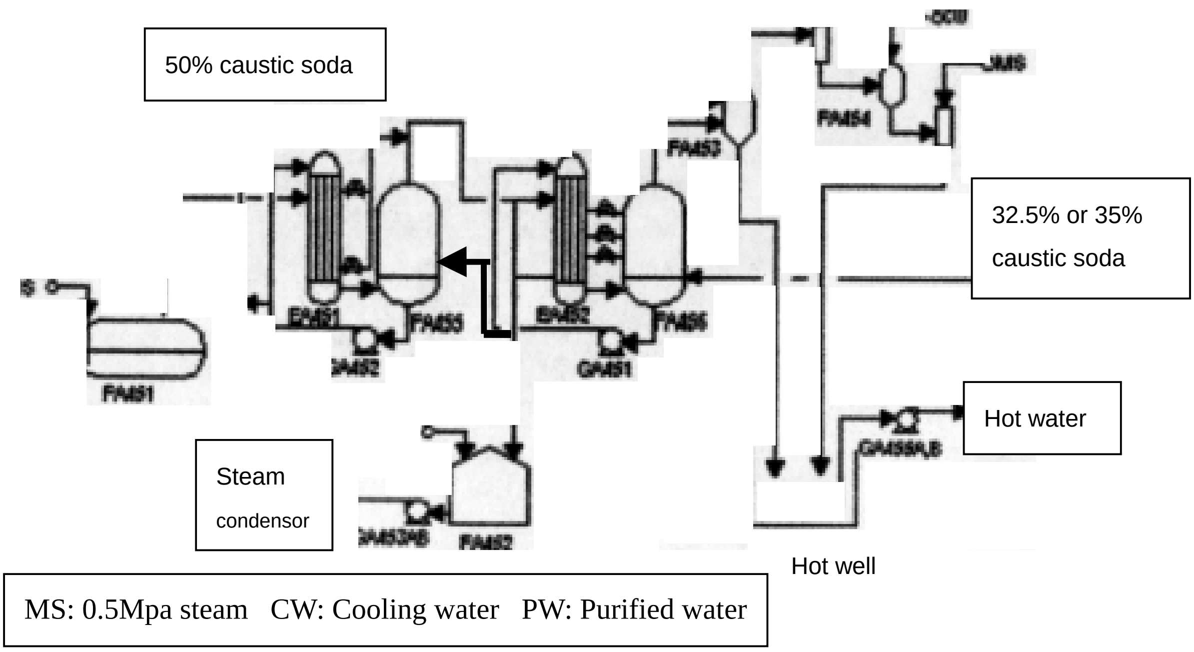


Figure. I-4-5 Simple Flow of Evaporator

(1) Caustic soda evaporators of Co. A

Contractor: Asahi Engineering Co., Ltd.
Type: Double-effect evaporator
Concentration: 32.5%NaOH → 50%NaOH

(2) Caustic soda evaporators of Co. B

Contractor: Toyo Engineering Co., Ltd.
Type: Double-effect evaporator
Concentration: 35%NaOH → 50%NaOH

5. Energy Conservation Survey and Measurement Results

5.1 Measurement Results

The results of the measurements of brine electrolyzers, caustic soda evaporators, etc. of the two companies are respectively shown below.
We carried out measurements by reading the existing installed measuring instrument meters. We also used mobile measuring instruments to measure heat insulation effects. These mobile instruments were prepared by the employees in charge from the two companies. Their response was expeditious and cooperative.

(1) Energy consumption of Co. A (electricity and steam)

1) Electricity for electrolysis
The operation data at the time of the survey was as shown below.

Table I-5-1 Data Shown on Control Panel of Central Operation Room
(14:00 PM November 25, 2003)

Electrolyzer	Electrolytic current (kA)	Full voltage (V)	No. of Electrolyzers
Monopolar	154	206	60
Bipolar No. 1	12.1	497	2 Units (75 Cells/Unit)
Bipolar No. 2	12.1	495	2 Units (75 Cells/Unit)
Bipolar No. 3	12.1	483	2 Units (75 Cells/Unit)

a. Average electrolytic cell voltage
- Monopolar 3.43 V
- Bipolar No. 1 3.31 V
- Bipolar No. 2 3.30 V
- Bipolar No. 3 3.22 V

b. Electric consumption in electrolyzers (DC-kWh/t-100%NaOH)
- Monopolar 2419 ($96492 \times 3.43/3600/40/0.95 \times 1000 = 2419$)
- Bipolar No. 1 2335 ($96492 \times 3.31/3600/40/0.95 \times 1000 = 2335$)
- Bipolar No. 2 2328 ($96492 \times 3.30/3600/40/0.95 \times 1000 = 2328$)
- Bipolar No. 3 2271 ($96492 \times 3.22/3600/40/0.95 \times 1000 = 2271$)

Here: Faraday constant: 96492 (A･sec/mol)
Mass per NaOH 1mol: 40 (g/mol)
Power efficiency: 95%(value reported in the interview)

2) Steam for caustic soda evaporator

The data shown on the control panel of the central operation room at 14:00 on November 25, 2003 was as shown below.

Steam consumption	3.52 t/h
NaOH production	7.5 m^3/h

Unit consumption of steam for caustic soda evaporators was 0.626t-Steam/t-NaOH.

(3.52t-Steam/h)/(7.5 m^3/h)/(1.5 t/m^3)/0.5 = 0.626t-Steam/t-NaOH

Here: specific gravity of 50% NaOH solution: 1.5 t/m^3

(2) Energy consumption of Co. B (electricity and steam)

1) Electricity for electrolysis

The operation data at the time of the survey was as shown below.

Table I-2-2 Data Shown on Control Panel of Central Operation Room (13:30 PM November 27, 2003)

Electrolyzer	Electrolytic current (kA)	Full voltage (V)	No. of Electrolyzers
Monopolar	80	108 (107–109) Cell Voltage =3.72V(Ave.) Normally 102V (reported)	29

a. Average electrolytic cell voltage

- Monopolar 3.72 V

b. Electric consumption in electrolyzers (DC-kWh/t-100% NaOH)

- Monopolar 2652 (96492 × 3.72/3600/40/0.94 × 1000 = 2652)

Here:

Faraday constant:	96492 (A･sec/mol)
Mass per NaOH 1mol:	40 (g/mol)
Power efficiency:	94% (value reported in the interview)

2) Steam for caustic soda evaporator

The data shown on the control panel of the central operation room at 14:00 on November 25, 2003 was as shown below

Steam consumption	1.80 t/h
NaOH production	3.2 m^3/h (2.4–4.0 m^3/h)

Unit consumption of steam for caustic soda evaporators was 0.750t-Steam/t-NaOH.

- (1.80t-Steam/h)/(3.2 m^3/h)/(1.5 t/m^3)/0.5 = 0.750t-Steam/t-NaOH
  Here: specific gravity of 50% NaOH solution: 1.5 t/m^3

5.2 Other Survey Contents

Prior to the energy audit, we obtained the answers to the questionnaires we had sent the two companies in advance. Their answers are summarized below.

(1) Price of electricity, etc.

Both of the companies purchase electricity and steam from other companies.

Supplier: NPC (National Petrochemical Co., Ltd.)

- Power charge: Co. A On peak : 2.6 B/kWh, Off peak : 1.1 B/kWh
  Ave. : 2.1 B/kWh
  Demand Charge : 74 B/kWh
  Co. B 1.9 B/kWh (flat rate)

- Steam charge: 635 B/t
- De-mineralized Water: Purchased
- N-Gas: Used for production of solid soda

(2) Operation status

Both of the companies executed a planned shut down of operation for 20 days in February.

The current operation status is 100% load due to the active demand for vinyl chloride

Thus, brine electrolyzers are in a certain degree of high-load operation around the clock.

6. Energy Conservation Proposals and Expected Effects

6.1 Point of view of energy conservation measures

In studying the potential for energy conservation of the existing equipment in the process of caustic soda production, it is important to review them from the following aspects.

a. Possibility of reduction in energy consumption through the improvement of operation conditions, etc.

b. Reduction in energy discharged from the plant unit
   - Effective use of steam condensate
   - Reduction in heat loss from the outside wall of the equipment
   - Effective use of latent/sensible heat of chlorine and hydrogen generated in brine electrolysis cells.

c. Possibility of reducing energy consumption of general power machine and equipment

As the result of our energy audits from the mentioned specific aspects, we found that energy conservation management was exercised regarding the following points.

(1) Caustic soda factory of Co. A

1) Factors affecting electricity unit consumption of electrolytic cells
Electrolytic voltage in electrolizer represents electricity unit consumption for electrolysis. NaCl concentration of feed brine to electrolizer , one of the factors controlling such electricity unit consumption, is in a state of saturated concentration at a given temperature. The level of impure substances is at a standard level for Japan.

2) Steam unit consumption of caustic soda evaporators
The standard evaporation ratio (quantity of water that can be vaporized by 1ton of steam) for double-effect evaporators is maintained.

3) Effective use of steam condensate in caustic soda evaporators
It is supplied to other plant in the factory as hot water and heat is effectively used.

4) Reduction of heat loss from outside walls of equipment
We mainly checked by eyes and hands the temperature and condition of the outer walls of the caustic soda evaporators. The temperature was low and there was no defect in heat insulation materials. The equipment was extremely well-managed.

5) Effective use of latent/sensible heat of chlorine and hydrogen generated in brine electrolyzers
There was heat recovery equipment installed. Currently it is not actually used, however, because of no heat balance expected at high load. It is maintained so as to be used at the time of low load.

6) Others
Inverter control of cooling fans of cooling towers had been introduced to save electricity consumption.

(2) Caustic soda factory of Co. B

1) Factors affecting electricity unit consumption of brine electrolyzers
Electrolytic voltage in electrolizer represents electricity unit consumption for electrolysis. NaCl concentration of feed brine to electrolizer , one of the factors controlling such electricity unit consumption, is in a state of saturation at a given temperature. The level of impure substances is at a standard level for Japan.

2) Steam unit consumption of caustic soda evaporators
The standard evaporation ratio (quantity of water that can be vaporized by 1ton of steam) for double-effect evaporators is maintained.

3) Effective use of steam condensate in caustic soda evaporators
It is effectively used in the process of dissolving salt, which is raw material for production of caustic soda.

4) Reduction of heat loss from outside walls of equipment
We mainly checked by eyes and hands the temperature and condition of the outer walls of the caustic soda evaporators. Although we found some areas not insulated, most of other areas of the walls were properly insulated. The parts where we pointed out for improvement were immediately insulated after our advice. The response of the staff members in charge was honest and quick showing that their attitude toward energy conservation was positive and serious.

5) Effective use of latent/sensible heat of chlorine and hydrogen generated in brine electrolyzers
There was heat recovery equipment installed. Currently it is not actually used, however, because of no heat balance resulting from high load. It is maintained so as to be used at the time of low load.

6) Others

Turning on and off of lighting in the storehouses of raw salt and other places is thoroughly controlled.

Improvement plans for potential energy conservation based on the results of the current survey were proposed. Their expected effects are described below.

6.2 Reduction of Electricity Unit Consumption for Electrolysis

(1) Caustic soda factory of Co. A

1) Relationship between current density and cell voltage

"Current density vs. Cell voltage" in electrolyzers of this factory compared to standard values for Japan is shown in Figure. I-6-1 and Figure. I-6-2. This factory has cells of both mono-polar and bi-polar types.

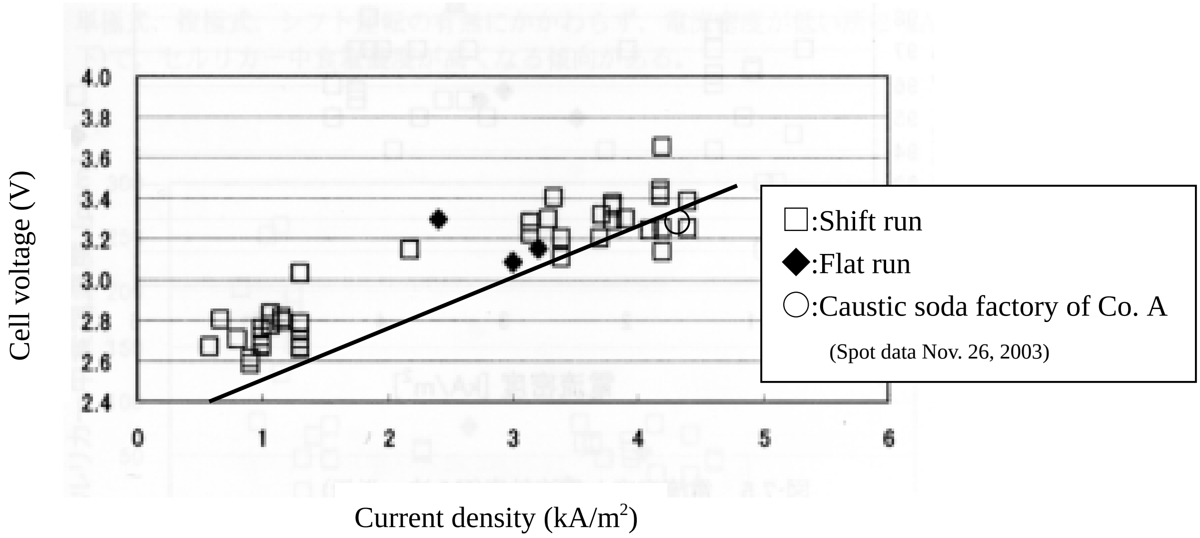


Figure. I-6-1 Relationship Between Current Density and Cell Voltage (Monopolar cell)

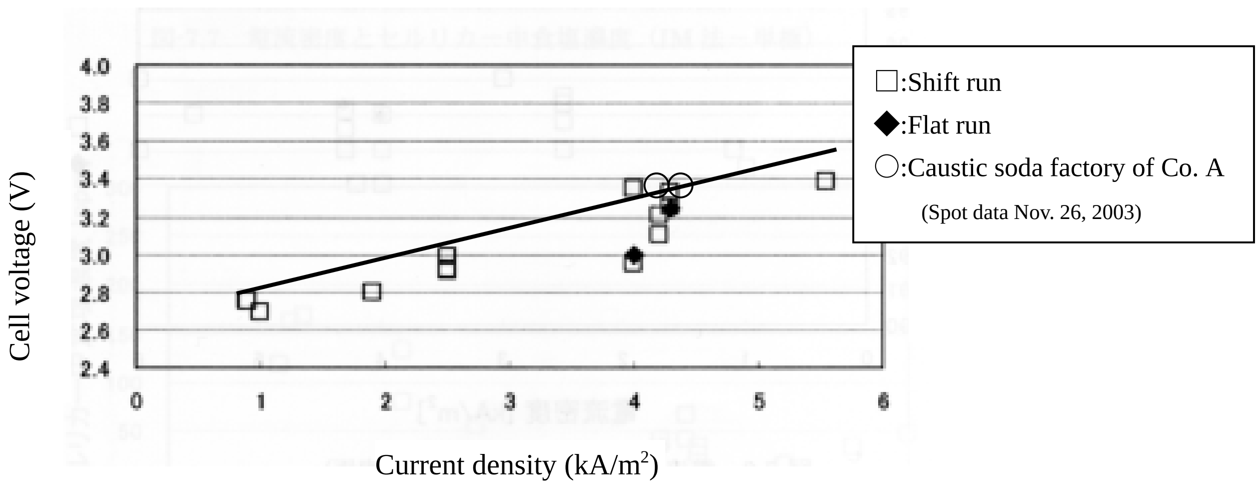


Figure. I-6-2 Relationship Between Current Density and Cell Voltage (Bipolar cell)

Spot data of this factory as of November 26, 2003 are shown in the figures. The electricity unit consumption for electrolysis at that time are compared to corresponding average values of Japan.

a) Monopolar cell
   Current density (kA/m^2): 4.5
   Cell voltage (V): 3.43 (Average value for Japanese factories (J: 3.5)
   Electricity unit consumption (kWh/t): 2.419 (J: 2,468)

b) Bipolar cell
   Current density (kA/m2): 4.2
   Cell voltage (V):
   Line #1: 3.31 (J: 3.30)
   Line #2: 3.30 (J: 3.30)
   Line #3: 3.22 (J: 3.30)
   Electricity unit consumption (kWh/t)
   Line #1: 2,334 (J: 2,327)
   Line #2: 2,327 (J: 2,327)
   Line #3: 2,271 (J: 2,327)

   As learned from the above data, values of both monopolar and bipolar cells of this factory are almost in the same range as the average values in Japan. The solid lines in Figure. I-6-1 and I-6-2 (Relationship between current density and cell voltage) show Japanese average value lines.

2) Plans to reduce electricity unit consumption and expected effects
   In the interview, it was reported that recoating of anodes and cathodes were carried out at appropriate intervals. Thus, as a challenge in further reducing electricity unit consumption in the future, a shift run was recommended (operation at a low electrolysis current during the daytime and at full load during the night time unlike a flat run in which operation is continued at the same electrolysis current) that had been practiced in the past.
   In order to introduce a shift run, it will be necessary to increase the number of electrolytic cells if output of caustic soda continue to be about the designed production capacity of the facilities like what it is now. In that case, the number of electrolyzers to add must be studied in relation to the production plan with considerations to equipment costs.
   This plan, if implemented, will produce great advantages when the rate difference of purchased electricity between nighttime/holidays and daytime/ weekdays further expands.
   Here, we refrain from any quantitative assessment of the merits because

such potential merits are much subject to the conditions.

(2) Caustic soda factory of Co. B

1) Relationship between current density and cell voltage

Cell voltage, which is the base of electricity unit consumption for electrolizer, is shown in "Current density vs. Cell voltage" in Figure. I-6-3, in comparison with standard values for Japan.

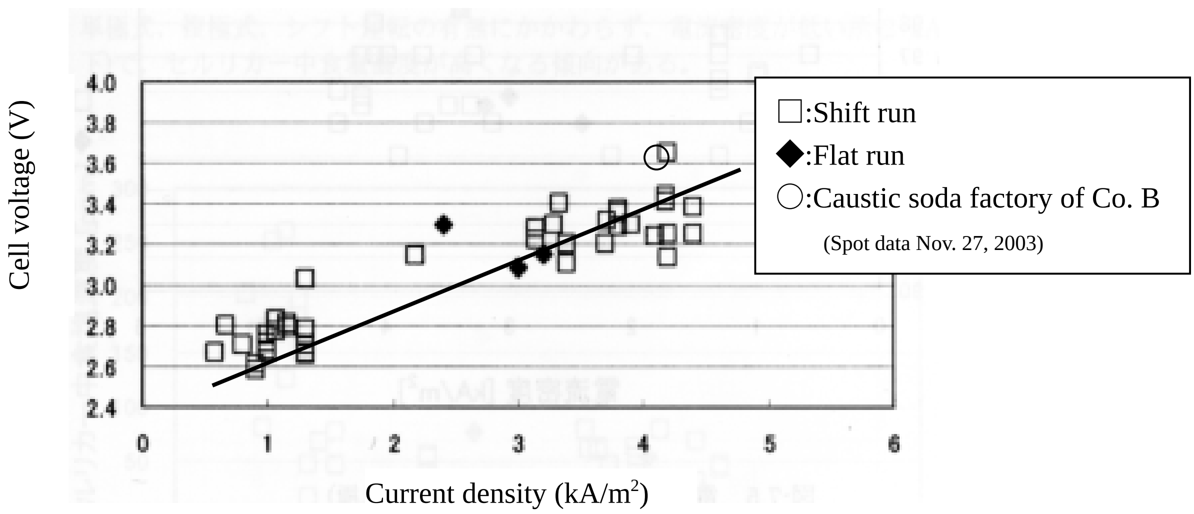


Figure. I-6-3 Relationship Between Current Density and Cell Voltage (Monopolar cell)

Here is a calculating formula for electrolysis energy unit consumption.

Electrolysis energy unit consumption = [Electric power used for electrolysis]/[Output of caustic soda]

Electricity used for electrolysis (MWh/t) = [Electrolytic current (kA)] × [Cell voltage (V)]/[Rectifier efficiency rate (-)]

Output of caustic soda = [Electrolytic current (kA)]/[96492(coulomb/F)] × [3600 (sec/h)] × [40 (gram-NaOH/mol)] × [Current efficiency (-)]

In a more simplified form,

$$\text{Electrolysis electricity unit consumption} = \frac{0.670 \times (\text{Cell voltage})}{(\text{Current efficiency}) \times (\text{Rectifier efficiency})}$$

With the current efficiency set at 0.95

Electrolysis electricity unit consumption = 0.70 × (Cell voltage)/(Rectifier efficiency) (MWh-DC/t-NaOH)

Here, if both current efficiency and rectifier efficiency are set at fixed rates respectively, electricity unit consumption becomes proportional to cell voltage. Knowing cell voltage is enough for us to know an approximate value of electricity unit consumption.

Current density means electrolytic current per unit electrode surface area. Generally "Cell voltage vs. Current density", rather than electrolytic electricity unit consumption itself, is compared in comparison of performances of electrolyzers.

The solid line inserted in Figure. I-6-3 "Current density vs. Cell voltage" shows a line of Japanese average values.

Spot data of this factory as of November 27, 2003 is shown in the figure. The electricity unit consumption for electrolysis at that time is compared to a corresponding average value for Japan.

Current density (kA/m^2): 4.2

Cell voltage (V): 3.72 (Average value for Japanese factories (J):3.45)

Electricity unit consumption (kWh/t): 2.624 (J: 2,433)

These values are quite high compared to the average values in Japan.

Cell voltage has elements such as theoretical electrolytic potential, membrane potential, anode excess voltage, cathode excess voltage, potential drop by membrane, potential drop by electrolyte and potential drop by bubble resistance. In terms of maintenance, in order to maintain the initial performance, it is necessary to change membranes at regular intervals and retain the activity of anode and cathode.

2) Plans to reduce electricity unit consumption and expected effects

Measures proposed to this factory for reduction in electrolytic electricity unit consumption, or reduction in cell voltage and their expected effects are briefed below.

We studied measures to reduce electrolytic electricity unit consumption, conducting a hearing survey to the staff of the factory. We found that the problems were increased excess voltage of anodes and delayed renewal of membranes. Thus, we propose the following improvements.

a) Renewal to new ion-exchange membrane: Reduction by 25–43 kWh/t
b) Recoating of anodes (reactivating treatment of anodes): Reduction by 183 kWh/t
c) Increasing the number of tightening bolts of equalizing bars and flexible bars: Reduction by 3–9 kWh/t

7. Guideline for Promotion of Energy Conservation and Energy audit Manual

7.1 Outline of Caustic Soda Production Process

The caustic soda production industry is a basic material industry where soda, chlorine, etc. are produced mainly from salt. It has a long history and it is not exaggerating to say that it has grown along with the economic growth. It is an essential, infrastructural industry that is deeply associated with products used in daily life.

This manufacturing industry is said to be an electricity intensity industry because large quantities of electricity are consumed when salt water is electrolyzed.

The production methods have been changing from mercury process to asbestos diaphragm process and further energy efficient ion-exchange membrane process.

The whole manufacturing process consists of the following processes.

- Salt water purifying process - dissolve raw salt into water until saturated and remove impure substances in salt solution
- Electrolytic process - electrolyze clarified saturated salt water with direct current electricity
- Concentration process - Heat and vaporize 30% diluted caustic soda solution refined in electrolyser to 50% concentration using steam in vacuum evaporator
- Pressure feed process - After drying and dehydrating chlorine generated in electrolyzer, compress and send to next process in a liquefied or gaseous state.
- Purifying process - Purify hydrogen and send to next process
- Synthesizing process - Directly burn chlorine and hydrogen and make water absorb combustion gas to produce synthetic hydrochloric acid
- Final sodium hypochlorite producing process- Disperse remaining chlorine gas dissolved in dilute salt water after electrolysis and make caustic soda absorb discharged chlorine gas to produce sodium hypochlorite

As mentioned previously, in this production process, electricity used in electrolizers and steam used in concentration of caustic soda are main targets of energy conservation.

Ion-exchange membrane method process flow chart is shown in Figure. I-7-1.

Flow Sheet (Ion Exchange Membrane Method)

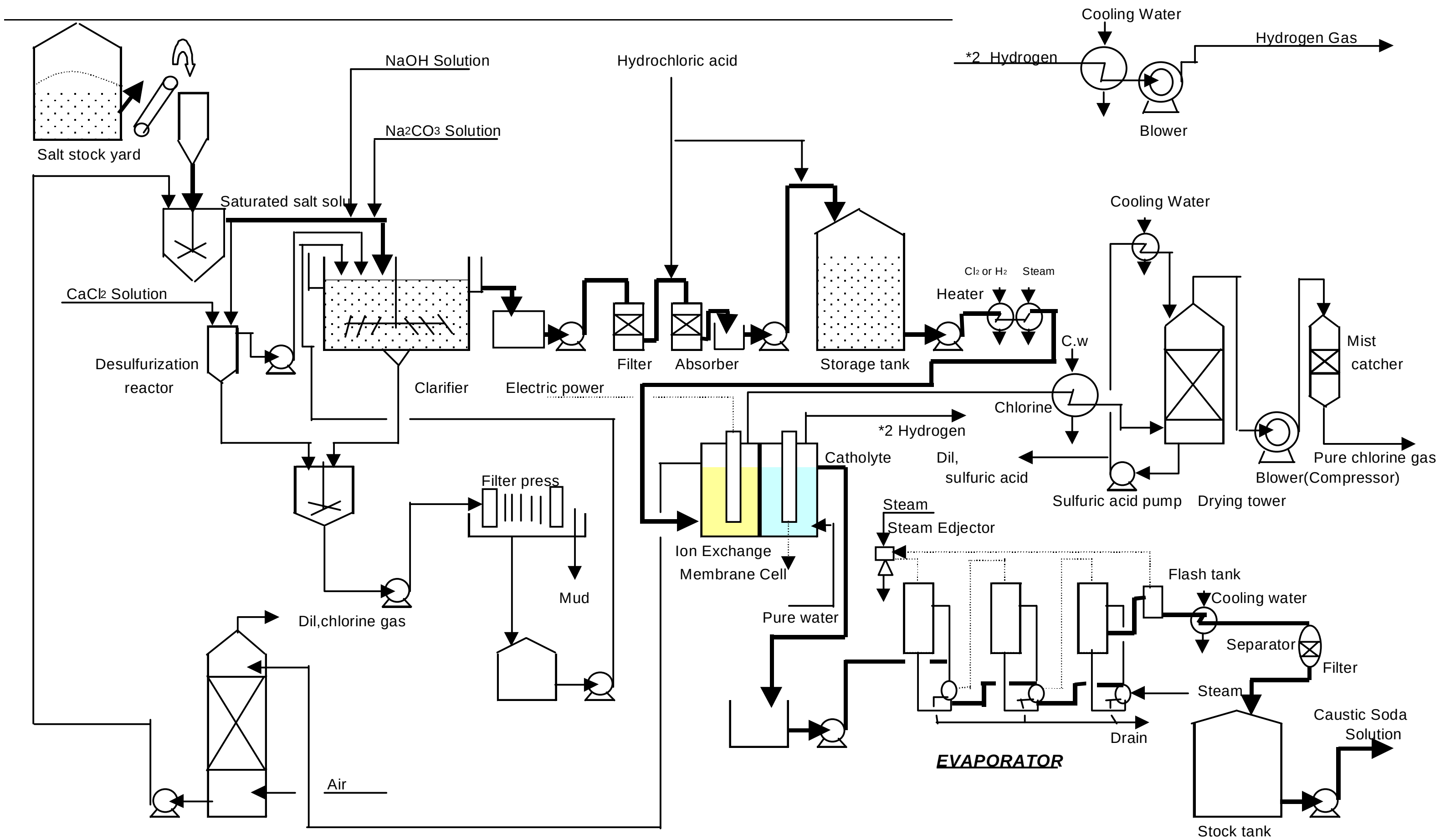


Figure. I-7-1 Ion-exchange Membrane Method Process Flow

(1) Salt water electrolysis cells

Saturated NaCl solution of about 25% after impurities are removed in the salt water purifying process is supplied to electrolysis cells. In the cells, direct current is applied and salt and water are electrolyzed.
In the reaction, chlorine gas is generated on the anode side and caustic soda and hydrogen gas is generated on the cathode side as shown in the formulas below

Anode: $2NaCl \rightarrow Cl_2 + 2Na^{+} + 2e^{-}$
Cathode: $2H_2O + 2Na^{+} + 2e^{-} \rightarrow H_2 + 2NaOH$

Electrolysis cells: $2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$

There are 3 types of methods for electrolytic production of caustic soda; Mercury method, diaphragm method and ion-exchange membrane method.
Currently, the ion-exchange membrane method is the mainstream production method. Two types of cells, mono-polar cells and bipolar cells are used for this method.
These cells are explained in Figure. I-7-2 and -3.

This salt water electrolysis process is the core part of the entire caustic soda production process. Electrolyzers are extremely important and electricity-intensive equipment. Ion-exchange membrane is made of fluorine polymer and prevents products on anode and cathode from mixing up.
Electric consumption depends on potential difference between anode and cathode (i.e. cell voltage) multiplied by current applied and time.
Accordingly, the point of energy conservation (electricity saving) is how much cell voltage can be lowered in the operation.

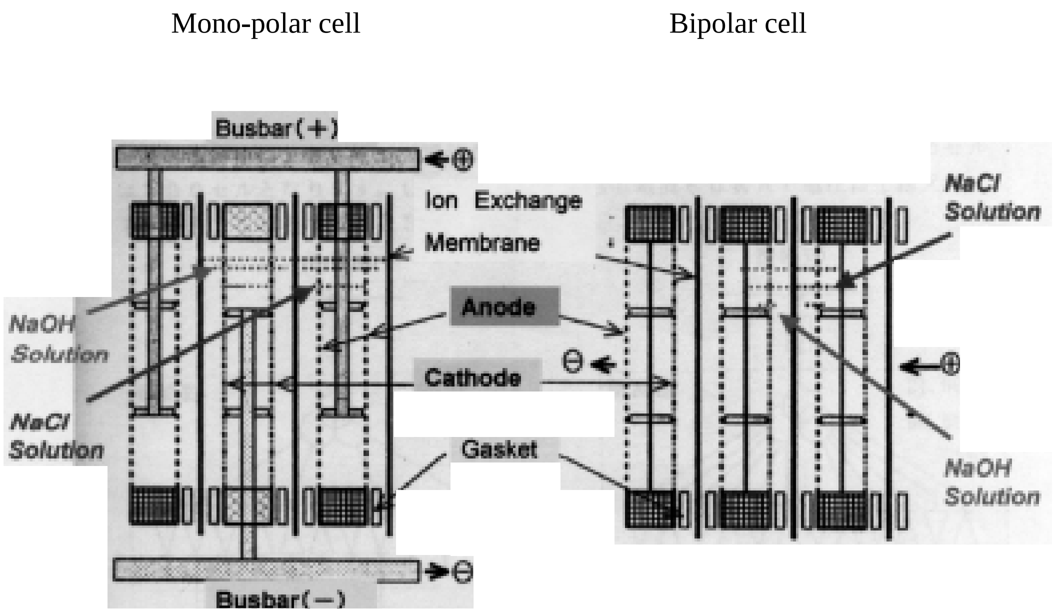


Figure. I-7-2 Electrolysis Cell Types for the Ion-exchange Membrane Method

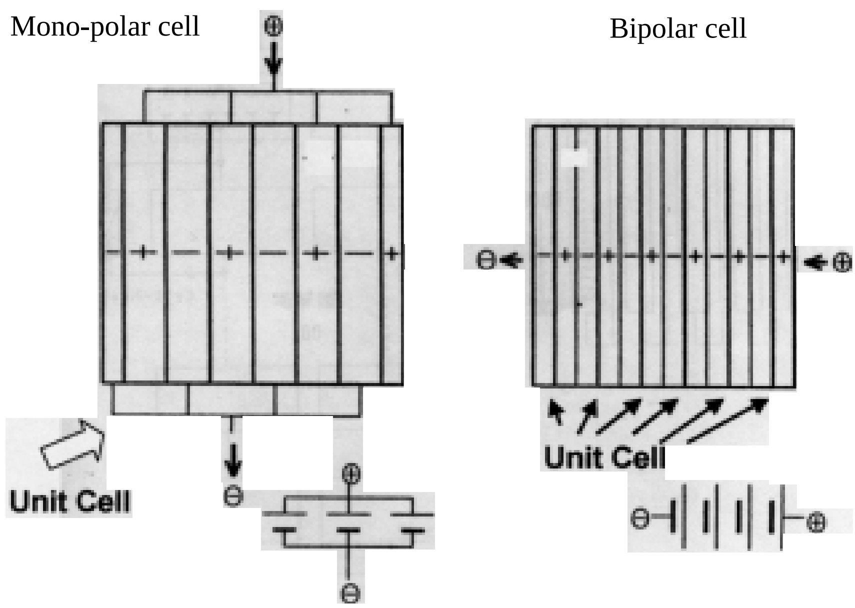


Figure. I-7-3 Electric Current Flows in Electrolysis Cells for the Ion-exchange Membrane Method

"Current Density and Cell Voltage" for the standard ion-exchange membrane electrolysis cells in Japan are shown below.

"Current Density vs. Cell Voltage" (Monopolar cell)

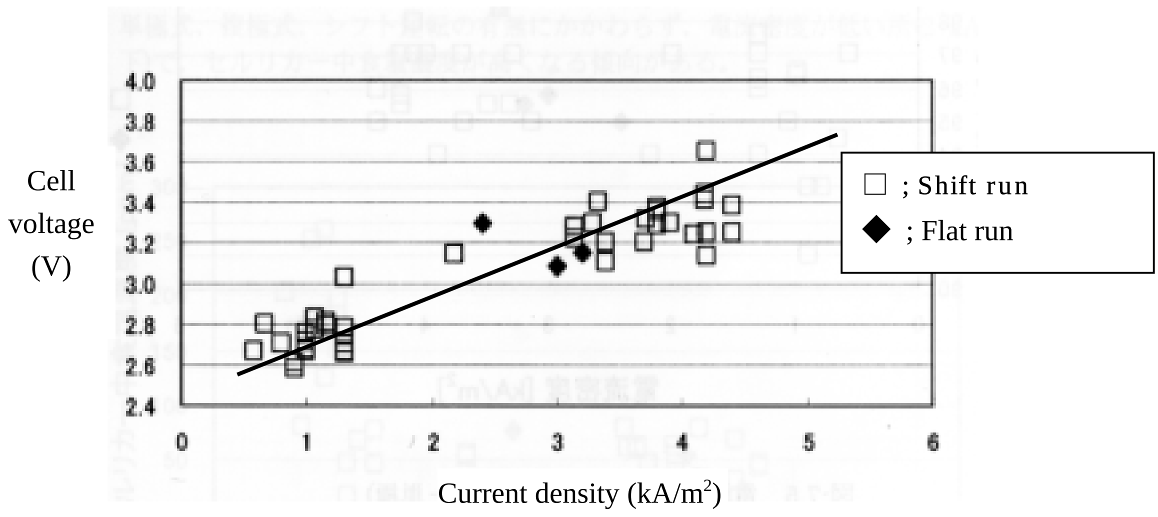


Figure. I-7-4 Relation between Current Density and Cell Voltage (Typical Example for Monopolar Cell Used in Japan)

"Current Density vs. Cell Voltage" (Bipolar cell)

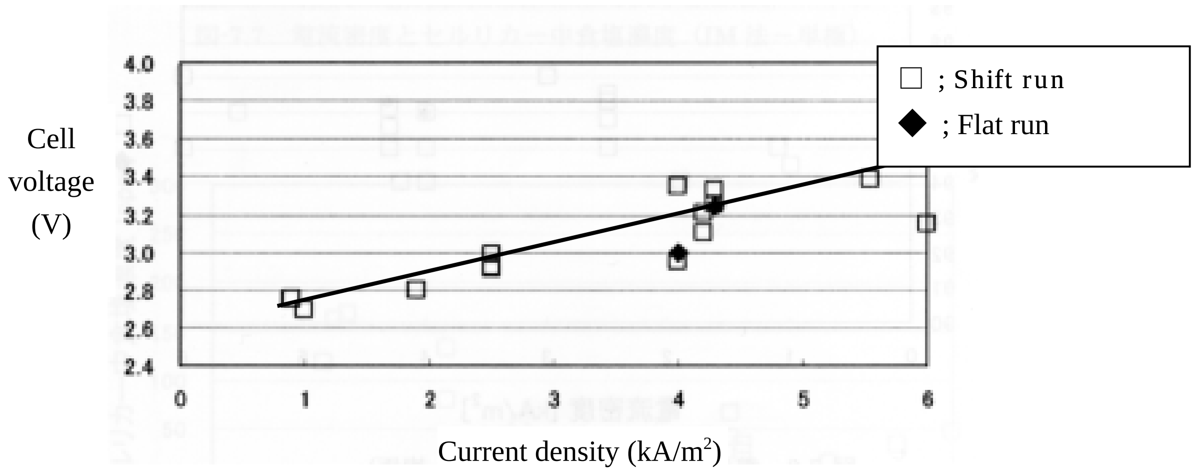


Figure. I-7-5 Relation between Current Density and Cell Voltage (Typical Example for Bipolar Cell Used in Japan)

(2) Caustic soda concentration process

Liquid product on the cathode side in ion-exchange membrane electrolytic cells is dilute solution containing about 30%–35% of caustic soda. As the concentration of commercially available caustic soda is 50%, it is necessary to concentrate it through vaporization.

In order to concentrate to 50%, dilute caustic soda is heated with vapor of about 0.5MPa and drawn into vacuumed evaporators of about 0.005–0.010MPa.

For concentration, multiple-effect evaporators, which are designed for reusing of steam evaporated from dilute solution, are used. The number of effects is 2 to 3 normally and evaporators with multiple effects are called double-effect and triple-effect evaporators.

The point for energy conservation (vapor saving) in this process is to maintain the vacuum degree and to prevent leakage of sealing water of pumps and general service water.

While vapor unit consumption changes depending on the number of effects of evaporator, evaporators' performance is commonly expressed in steam economy (evaporation ratio).

Note: Steam economy (evaporation ratio)

Theoretically, 1 ton of vapor can evaporate 1 ton of water. In effect, however, it is not always the case due to radiation of heat, etc. Therefore, it is used as a gauge to show real efficiency.

A general pattern of the relation of "No. of Effects and Evaporation Ratio" is shown below.

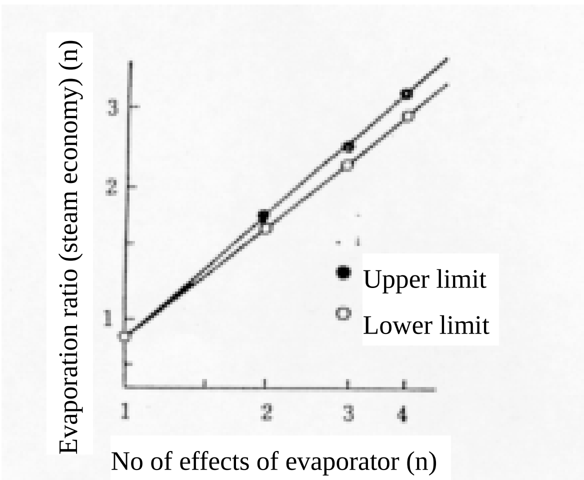


Figure. I-7-6 No. of Effects and Evaporation Ratio

Vapor unit consumption for double-effect evaporator (N=2) is calculated below.

In the above figure, evaporation ratios are normally 1.6–1.7.

Assuming the concentrations of dilute caustic soda solutions at 32.5% and 35%, vapor unit consumption when they are respectively concentrated into 50% is as follows;

32.5% → 50% :

$$[(100\text{-}32.5)/32.5\text{-}(100\text{-}50)/50]/1.6 = 0.67 \text{ (t-steam/t-100\% NaOH)}$$

35% → 50% :

$$[(100\text{-}35)/35\text{-}(100\text{-}50)/50]/1.6 = 0.54 \text{ (t-steam/t-100\% NaOH)}$$

When supply vapor concentrate (hot water) is used in other plants, around 10% of these values are normal values.

7.2 Energy Conservation Measures

Energy conservation measures implemented to date in the caustic soda manufacturing industry include the following:

(1) Downsizing of pumps
(2) Recovery of heat exhaust from other plants
(3) DDS (Daily Start & Stop) of chlorine compressors (in the case where more than one compressor are installed)
(4) Shift to inverter control rotary machine and equipment
(5) On-and-off operation of cooling tower fans
(6) Lowering cell voltage by reactivating cathode
(7) Recovery of latent/sensible heat in chlorine and hydrogen gases
(8) Adoption of low electric resistance membrane
(9) Lowering cell voltage by reactivating anode
(10) Shift from flat run to shift run

7.3 Special Notes for Promotion of Energy Conservation

Points to be kept in mind for promotion of energy conservation in the process of caustic soda production by the ion-exchange membrane method are as follows;

(1) Ion-exchange membrane is a very delicate product and therefore should be handled very carefully. Particularly, impure substances mixed in salt water to feed to electrolytic cells must be controlled so as not exceed their standard level. Accumulated impure substances may not only cause increases in cell voltage but also significantly affect current efficiency.
(2) It is necessary to plot cell voltages, etc. of individual electrolyzers in the control chart everyday to grasp the trends.
(3) Recoating cycle of electrodes should be determined and practiced.
(4) In renewal of ion-exchange membrane, consultation and advice of membrane makers should be sought because they have various types of membranes including low-voltage type, low oxygen type, etc.
(5) Whenever a renewed electrolyzer is set in motion, bolts used at the connection of the conductor should be retightened at the point in time where the cell temperature is balanced. Further bolt tightening can minimize contact resistance of electricity.

Out of the slide pictures of energy use status by Japan Caustic Soda Industry Association that we used in the explanation in the field, some we consider necessary are attached at the end of this report.

4 energy conservation example cases of the ion-exchange membrane method are shown in the ensuing pages.

CS-PE-2

Energy Conservation Technology Directory

[Kind of industry] Chemical (caustic soda)	Name	Caustic soda production process	[Energy source] Electric power
[Technology category] Energy-saving production equipment		Energy-saving ion-exchange membrane electrolyzer	[Practical application] 1994

[General description]

This newly developed electrolyzer is an energy-saving compact brine electrolyzer causing structurally little potential drop and thus achieving high current density in comparison with the conventional bipolar ion-exchange membrane electrolyzers. This equipment can provide an about 6% electricity cut compared with the conventional method.

[Principle/ action]

Electric current flows as shown in Figure. 1. Electric conductivity of Ni is 6 times as that of Ti and electric current running on Ti is minimized and thus, structurally it is possible to reduce potential drop.

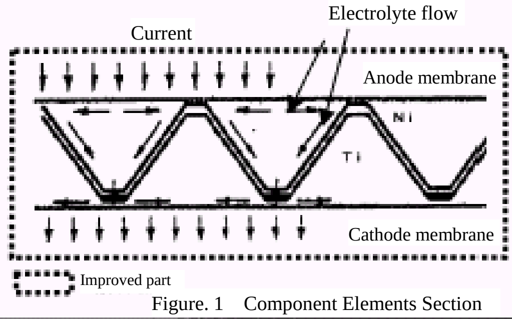


Figure. 1 Component Elements Section

[Details of Improvement]

Structural explanation

Design

Schematic diagram

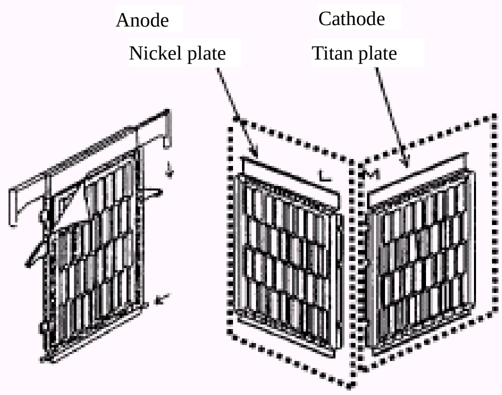


Figure. 2 Bipolar Elements Assembly

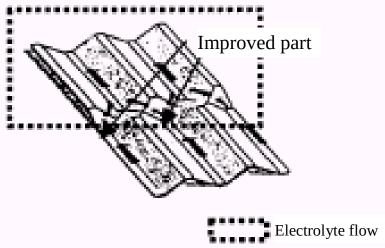


Figure. 3 Electrolyte Flow

[Effects from improvement]

Table 1 Energy Conservation Effects of the Improved Equipment Versus the Conventional Bipolar Ion-exchange Membrane Method Electrolyzer

Reduced electricity unit consumption	131 DC kWh/t-NaOH	Operation condition: Production scale 100,000 t-NaOH/y, Current density 3 kh/m^2
Reduced energy consumption in crude oil	3,183 kL/y	

[Economic effects] Equipment cost

Investment: 120 million yen Saving from improvement: 62 million yen /year

Recovery period: 2 years

[Note]

With this technology, economical high current density operation possible up to 6kA/m^2

[Embodiment] Major business establishments There are working samples using this technology.	[Reference materials] "Soda industry technical information (No. 449) October 1994)"	[Inquiry] Japan Chemical Industry Association → ECCJ (JIEC)

Figure. I-7-7 Energy-saving Ion-Exchange Membrane Electrolyzer

CS-ME-1

Energy Conservation Technology Directory

[Kind of industry] Chemical (caustic soda) [Technology category] Energy-saving equipment	Name: Caustic soda production process Brine electrolysis heat recovery line preheater	[Energy source] Fuel (steam) [Practical application] 1992

[General description]

Installation of preheating equipment that preheats brine to feed electrolyzer using sensible heat of chlorine and hydrogen gases generated from diaphragm process brine electrolyzer

[Details of Improvement]

Structural explanation

Design

Schematic diagram

[Before improvement]

Conventionally, feed brine water was heated with steam by carbide heat exchanger.

[After improvement]

(1) Steam consumption was reduced through heat exchange with the heat of chlorine and hydrogen gases generated from brine electrolyzer (particularly diaphragm process electrolyzers).
(2) Preheating system flow is shown in Figure. 1.
(3) For the heat exchange system, a shell and tube heat exchanger is used. Thematerials of the main parts of the equipment are shown in Table 1.

Table 1 Materials of the Main Parts of Brine Preheater

	Shell side	Tube side
Chlorine gas–brine	TP 35 (Titan)	TTH35W (Titan)
Hydrogen gas–brine	SS40V (SS material)	TTH35W (Titan)

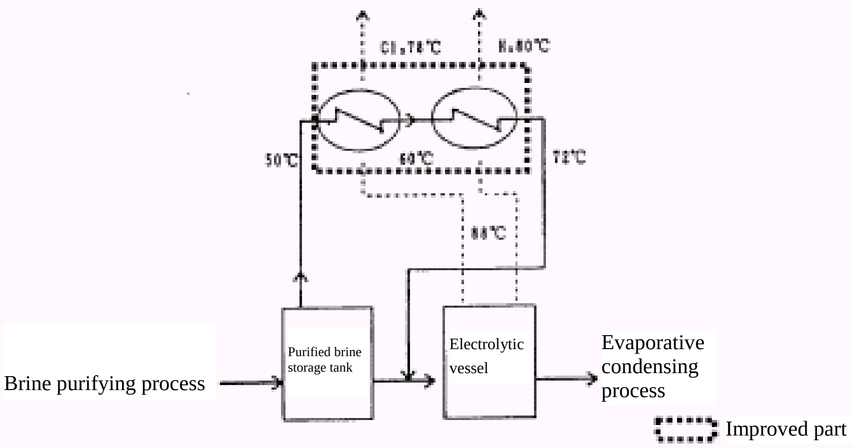


Figure. 1 Preheating System Flow

[Effects from improvement]

Table 2 Heat Recovery Effects by Brine Preheating Equipment

	Effects	Note
Energy recovered (in steam)	18,000 t/y	Production: chlorine 55,000 t/y (hydrogen 17,500 km^3)
Reduced energy consumption in crude oil	1,468 kL/y	

[Economic effects] Equipment cost

Investment: 90 million yen Saving from improvement: 30 million yen/year
Recovery period: 3 years

[Note]

[Embodiment]
Major business establishments
There are working samples using this technology.

[Reference materials]
"Soda industry technical information (No. 449) October 1994)"

[Inquiry]
Japan Chemical Industry Association → ECCJ (JIEC)

Figure. I-7-8 Brine Electrolysis Heat Recovery Line Preheater

CS-ME-2

Energy Conservation Technology Directory

[Kind of industry] Chemical (caustic soda) [Technology category] Energy-saving equipment	Name: Caustic soda production process Improvement of active cathode for ion-exchange membrane method electrolyzer	[Energy source] Electric power [Practical application] 1985

[General description]

[The developed active cathode is designed to reduce excess voltage of cathode that causes big energy loss in the industrial salt ion-exchange membrane electrolysis in the process of caustic soda production. Attention was focused on the fact that excess voltage of electrode depends on electrolytic potential and its surface area. Then, the surface of electrode was dramatically enlarged by the coating method with the result of significant reduction in electricity.

[Principle/ action]

Principle of ion-exchange membrane method and breakdown of energy loss

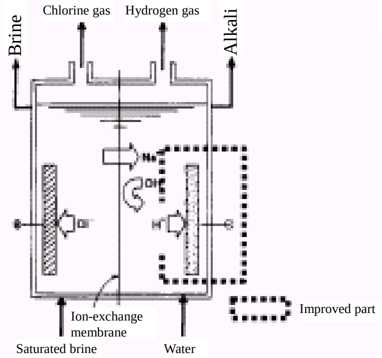


Figure. 1 Principle of Ion-exchange Membrane Method

Table 1 Breakdown of Energy Loss of Ion-exchange Membrane Electrolyzer

	Electricity unit consumption (kWh/tNaOH)	Percentage (%)
Ion-exchange membrane resistance	345	40.3
Anolyte resistance	15	1.8
Catholyte resistance	53	6.1
Anode overvoltage	67	7.9
Cathode overvoltage	263	30.7
Conductor resistance	112	13.2
Total	755	100.0

[Details of Improvement]

Structural explanation

Design

Schematic diagram

Structure of active cathode

(1) Figure. 2 shows mesh cathode and Figure. 3 shows a pattern diagram of its sectional structure. By applying special coating on the stainless or nickel cathode base, hydrogen overpotential is reduced.

(2) Coating layer is porous alloy of Ni-C-S.

(3) In the normal industrial scale, operation current density is 20–40A/dm^3. Active cathode excess voltage is 0.2 V lower than conventional cathode.

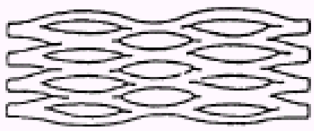


Figure. 1 Mesh Cathode

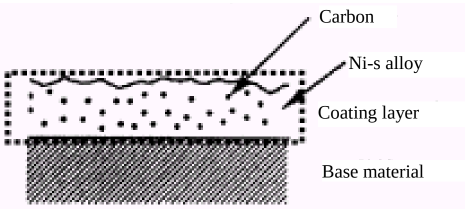


Figure. 2 Pattern Diagram of Section Structure

Improved part

[Effects from improvement]

Table 1 Example of Energy Conservation Improvement Effects (Production scale: 100,000 t/y base)

Reduced electricity unit consumption	150 kWh/(t-NaOH)
Reduced annual electricity consumption	15,000,000 kWh/y
Reduced energy in crude oil	3,645 kL/y

[Economic effects]

Equipment cost

Investment: 2.6 million yen Saving from improvement: 72.9 million yen /year

Recovery period: 3.5 years

[Note]

[Embodiment]
Major business establishments
There are working samples using this technology.

[Reference materials]
"Complete Collection of Energy Conservation Case Examples (1988)" P.197

[Inquiry]
Japan Chemical Industry Association → ECCJ (JIEC)

Figure. I-7-9 Improvement of Active Cathode for Ion-Exchange Membrane Method Electrolyzer

CS-OM-2

Energy Conservation Technology Directory

[Kind of industry] Chemical (caustic soda)	Name	Caustic soda production process Reduction of electrolytic electricity of brine electrolyzer	[Energy source] Electric power
[Technology category] Operation improvement			[Practical application] 1977

[General description]
This is an energy-saving operation method of reducing electrolytic electricity by lowering current load for brine electrolysis at the time of low operation in the process of caustic soda production.

[Principle/ action]

- Electrolytic electricity used in brine electrolyzer (W) is proportional to cell voltage as shown by formula in ① cell voltage is in almost linear relation with current (I) as shown by formula in ②. In addition, production (P) is proportionate to product of current and number of cells (n). (formula in ③)

$$W = \frac{670 \times V}{\eta_c \times \eta_R} \quad ①$$

$$V = a + b \times I \quad ②$$

$$\boxed{P = K \times n \times I} \quad ③$$

Here, W: electrolytic electricity (AC-kWh/t), 670: Electricity chemical equivalent (kA/t), V: Cell voltage (V), η_c: Current efficiency η_k: Current transformation efficiency, I: Load current (kA), a. b: Constants, P: Production, n: Number of cells, K: Coefficient

Improved part

[Details of Improvement]
Structural explanation
Design
Schematic diagram

(1) Formula in ③ shows that when production volume is fixed, an increased number of cells can lower load current and formulas in ① and ② show that electricity can eventually be reduced. However, simply lowering current level will cause;
- Unit consumption of steam for condensation to increase due to reduced electrolyte concentration
- Current efficiency to go down due to increased electrolyte resistance resulting from drops in electrolyte temperature
- Wear and tear/deterioration of diaphragm resulting from change in pH in diaphragm cell and drops in current efficiency, etc

For the countermeasures of these possible outcomes,
- Reduction in electrolyte concentration was prevented through adjustment of diaphragm and thorough management of electrolytic cell
- Temperature of electrolyte was raised by about 2 degree (°C) and current efficiency was maintained through preheating of feed brine by using waste heat from the drain of hydrogen gas generated.

[Effects from improvement]

Table 1 Energy Conservation Effects Example

	Reduction effect	Note
Reduced annual electricity consumption	13,200,000 kWh/y	Reduction rate 7.4%
Reduced energy in crude oil	3,208 kL/y	

[Economic effects] Equipment cost
Investment: 130 million yen Saving from improvement: 64 million yen /year
Recovery period: 2 years

[Note]
Although this is an example of improvement of diaphragm process electrolyzer, this improvement is applicable to electrolytic high-purity chrome and manganese dioxide production processes as well as ion-exchange membrane method brine electrolyzer.

[Embodiment]	[Reference materials]	[Inquiry]
Major business establishments There are working samples using this technology.	"Complete Collection of Energy Conservation Case Examples (1980)" P.803	Japan Chemical Industry Association → ECCJ (JIEC)

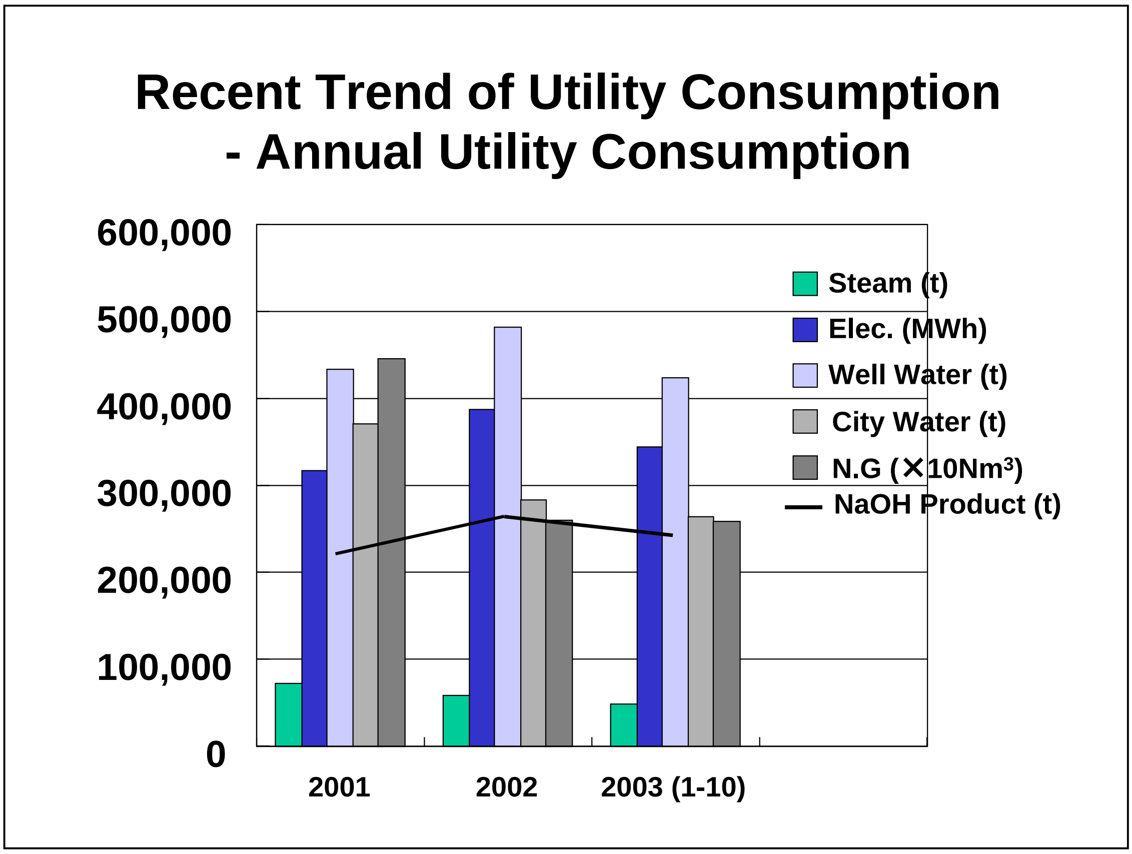
Figure. I-7-10 Reduction of Electrolytic Electricity of Brine Electrolyzer

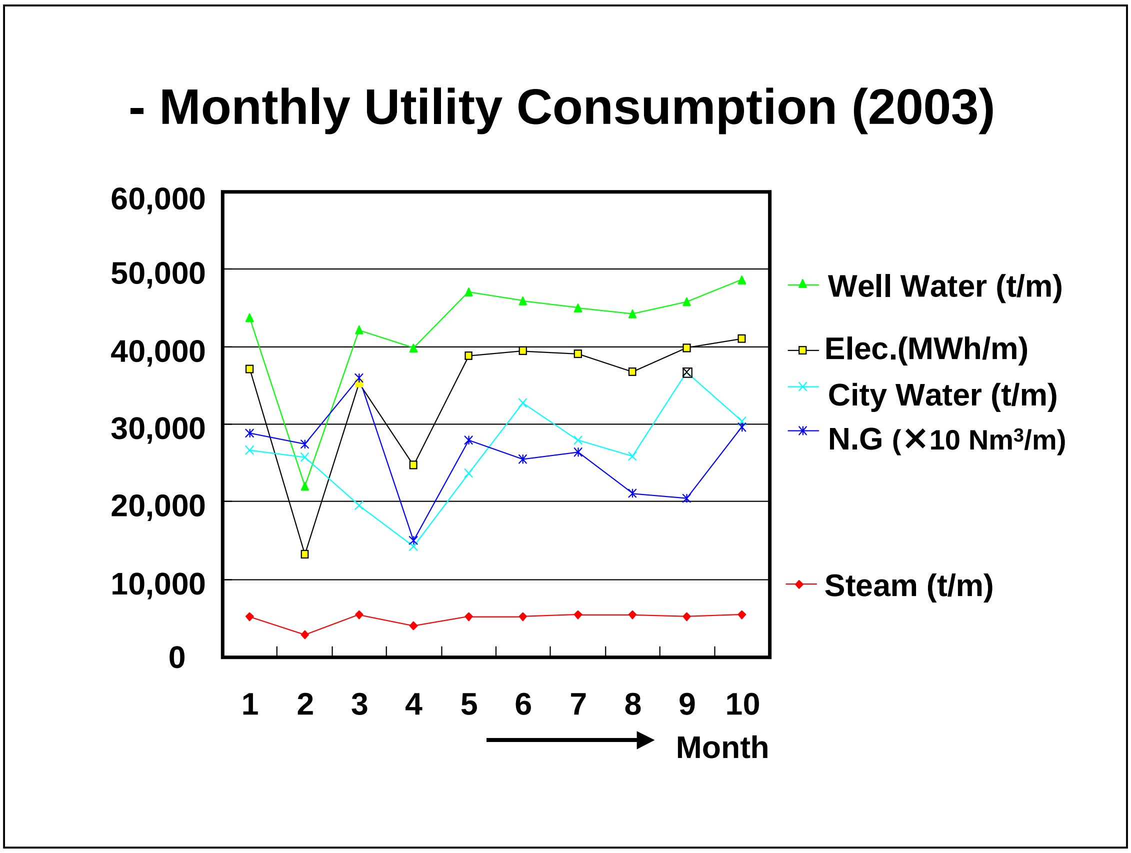
Attachment:

Attachment I-I	Energy Consumption Status of Co. A Annual utility consumption, Monthly utility consumption, Daily utility consumption and unit energy consumption
Attachment I-2	Energy Consumption Status of Co. B Recent trend of production Utility consumption: Annual consumption, Monthly consumption, and Daily consumption
Attachment I-3	Energy Use Status of Caustic Soda Industry in Japan (Excerpts from presentation slide pictures used in the field)

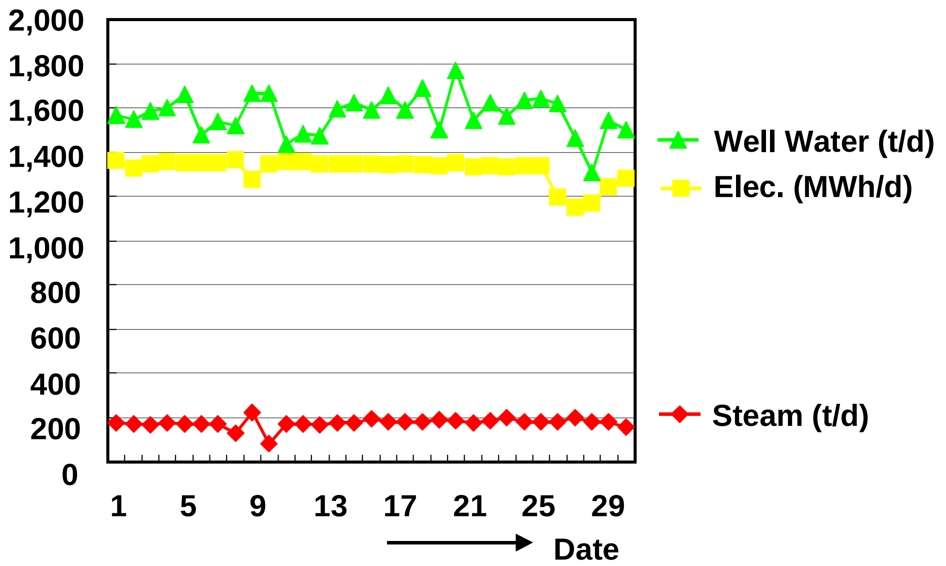
Attachment I-I

Energy Consumption Status of Co. A



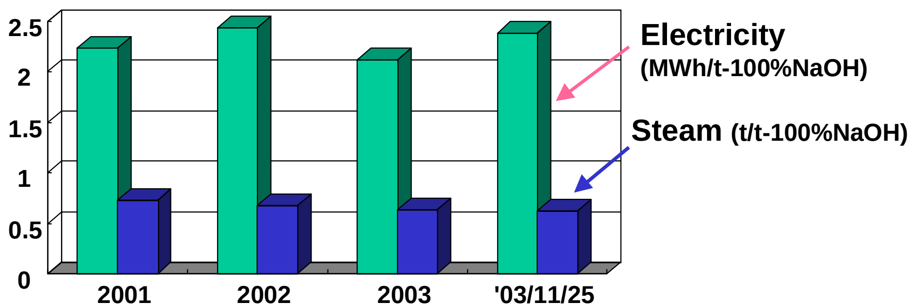


- Daily Utility Consumption (Oct. 2003)



Unit Energy Consumption

Item	Year	2001	2002	2003 (1—10)	'03/11/25 Spot data
Electricity	MWh/t-100%NaOH	2.233	2.433	2.117	2.384
Steam	t/t-100%NaOH	0.731	0.680	0.632	0.625
Catholyte	t-50%NaOH	208,707	265,819	238,964	41.6
Product NaOH	t-100%NaOH	99,136	86,391	77,663	5.63
Steam	t	72,510	58,783	49,098	3.52
Electricity	MWh	232,997	323,389	252,939	49.6

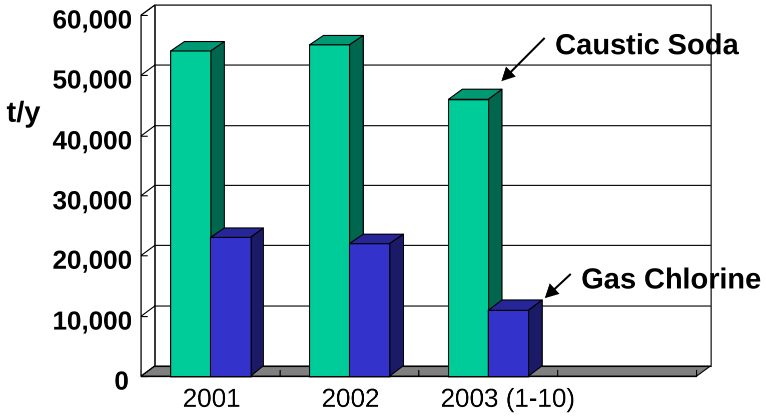


Attachment I-2

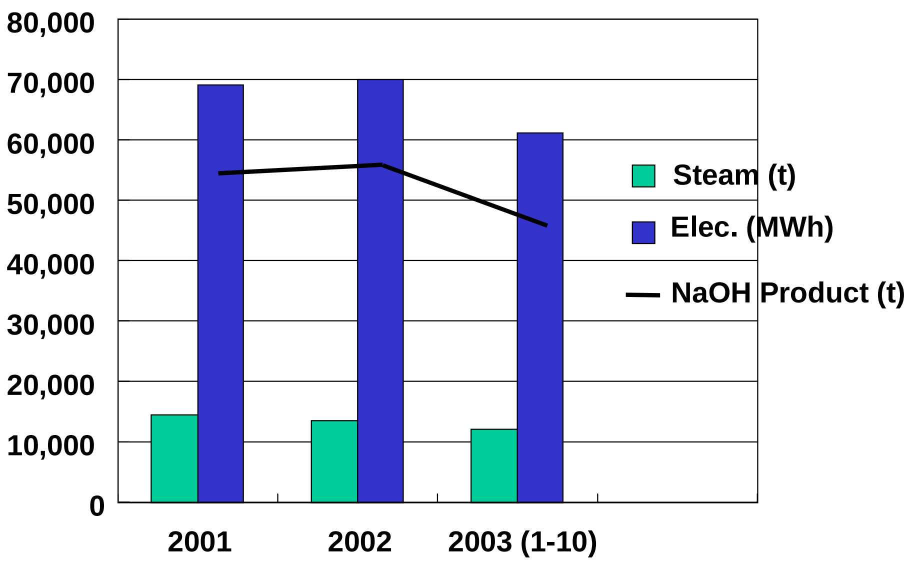
Energy Consumption Status of Co. B

Recent Trend of Production

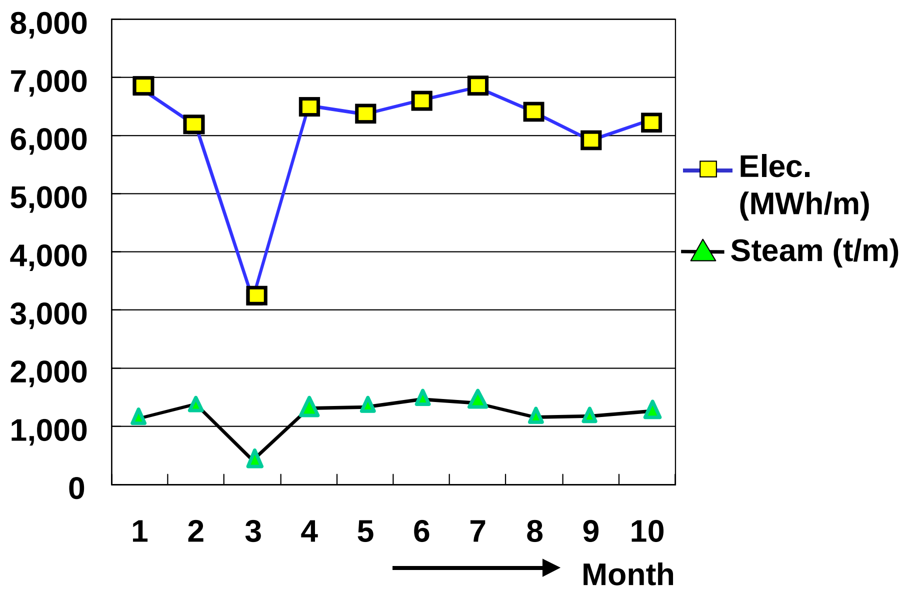
Item	2001	2002	2003(1-10)
Caustic Soda (t-50%NaOH/y)	54,000	55,000	46,000
Gas Chlorine (t/y)	23,000	22,000	11,000



Recent Trend of Utility Consumption - Annual Utility Consumption

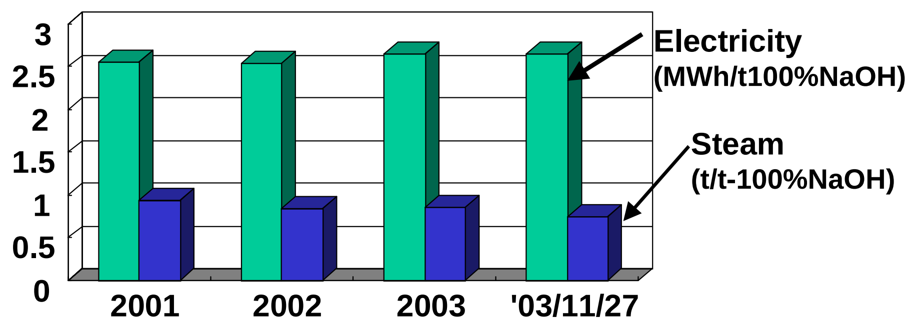


- Monthly Utility Consumption (2003, 1-10)



- Unit Energy Consumption

Items		2001	2002	2003 (1—10)	'03/11/27 Spot data
Electricity	MWh/t-100%NaOH	2.558	2.543	2.654	2.652
Steam	t/t-100%NaOH	0.936	0.849	0.859	0.750
Catholyte	t-50%NaOH	54,000	55,000	46,000	6.51
Product NaOH	t-100%NaOH	31,000	32,000	28,000	2.4
Steam	t/ y	14,502	13,577	12,027	3.52
Electricity	MWh / y	69,069	69,923	61,045	8.64



Attachment I-3 Energy Use Status of Caustic Soda Industry in Japan
(Excerpts from presentation slide pictures used in the field)

添付資料 I－3

Benchmark / Guideline at Caustic Soda Industry

Contents

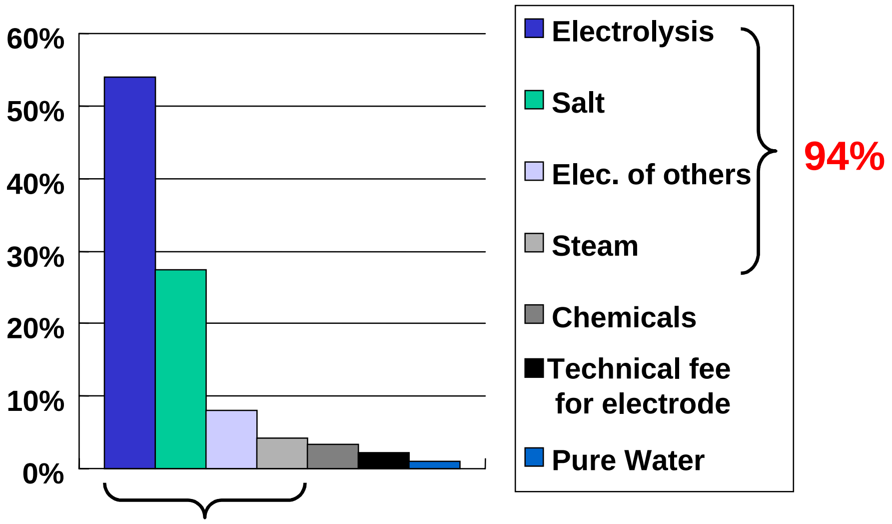
January, 2004

The Energy Conservation Center, Japan

ECCJ

1

1. Composition of Variable Cost



Target for cost reduction!

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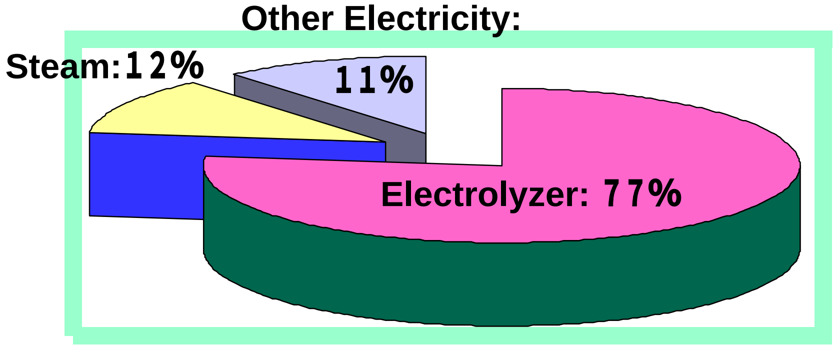
2

Composition of Energy Consumption



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3

2. Benchmark for Caustic Soda Industry (1/2)

- Electrolysis

① Monopolar cell (Current Efficiency: 0.95)

Current density 3 ～ 4.5 (kA/m^2)

⇒ Cell voltage = 3.2 ～ 3.5 (V)

⇒ Unit consumption = 2.260 ～ 2.470 (DC-MWh/t)

② Bipolar cell (Current Efficiency: 0.95)

Current density = 4 ～ 6 (kA/m^2)

⇒ Cell voltage = 3.2 ～ 3.5 (V)

⇒ Unit consumption = 2.260 ～ 2.470 (DC-MWh/t)

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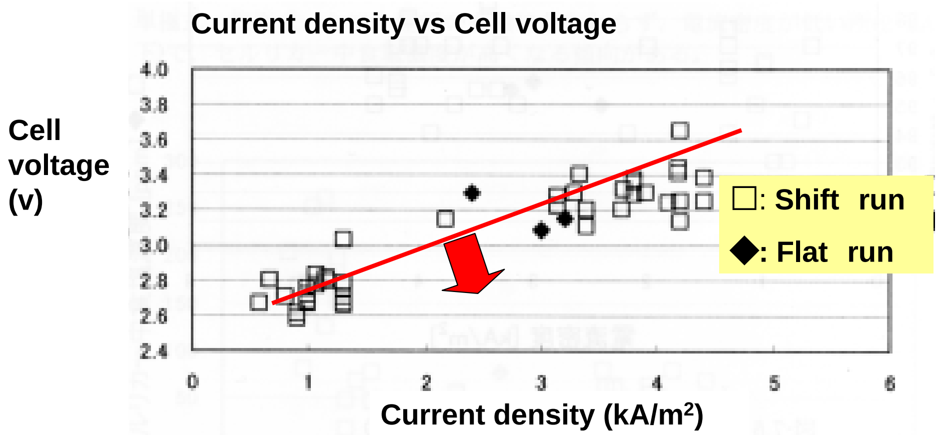
4

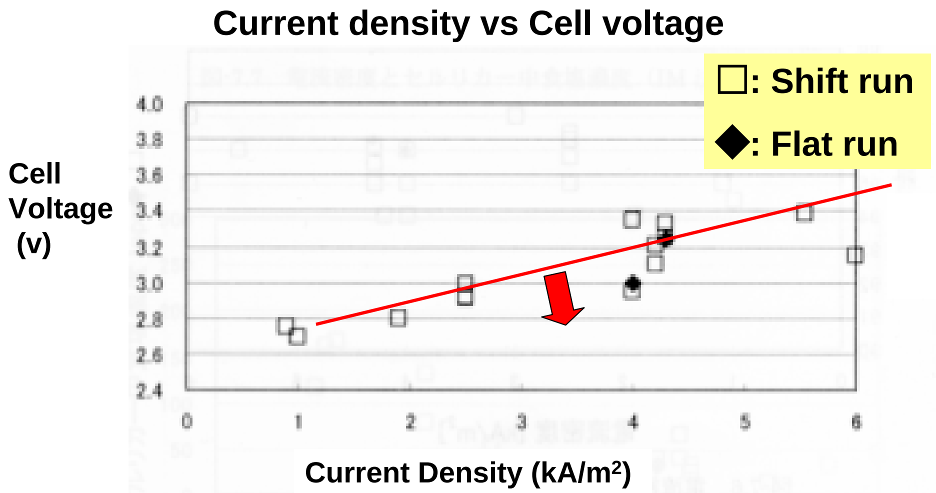
1) Monopolar cell



Current density ⇒ Cell voltage ⇒ Unit consumption
(DC-kWh/t-NaOH, $C_{eff,}$; 0.95)
Example: 2.1kA/m² ⇒ 3.0V ⇒ 2,116, 4.2kA/m² ⇒ 3.5V ⇒ 2,468

ECCJ

2) Bipolar cell



Current density ⇒ Cell voltage ⇒ Unit consumption
(DC-kWh/t-NaOH, C_{eff} ;0.95)
Example: 2.1kA/m² ⇒ 2.9V ⇒ 2,045, 4.2kA/m² ⇒ 3.2V ⇒ 2,257

ECCJ

Electrolyzer:

Cell Voltage ➡ Electricity Unit Consumption

Electricity Unit Consumption

= [Electric Power Consumption] / [Product Volume of NaOH]

= [(Electrolysis Current (kA))×(C. V.) / (R. Eff.] /

[(Electrolysis Current (kA)) / (96492 (Coulomb/F))

×(3600 (s/h))×(40 (g-NaOH/mol))×(C. Eff.)]

= 0.670 × (C. V.) / (C. Eff.) / (R. Eff.) (AC- MWh/t- NaOH)

= 0.74 × (C. V.) (AC- MWh/t- NaOH)

= 0.71 × (C. V.) (DC- MWh/t- NaOH)

Here, C. V.: Cell Voltage (v)

C. Eff.: Current Efficiency (-) = 0.95

R. Eff.: Rectifier Efficiency (-) = 0.95 (AC), 1.0 (DC)

ECCJ

7

Benchmark for Caustic Soda Industry (2/2)

- Steam at evaporator

Double Effect Evaporator

(Steam condensate is not used at other plants.)

Unit consumption:

Catholyte NaOH conc. = 32.5 ~ 35 (wt.%)

Product NaOH conc. = 50 (wt.%)

⇒ 0.6 ~ 0.8 (t-steam/t- 100%NaOH)

ECCJ

8

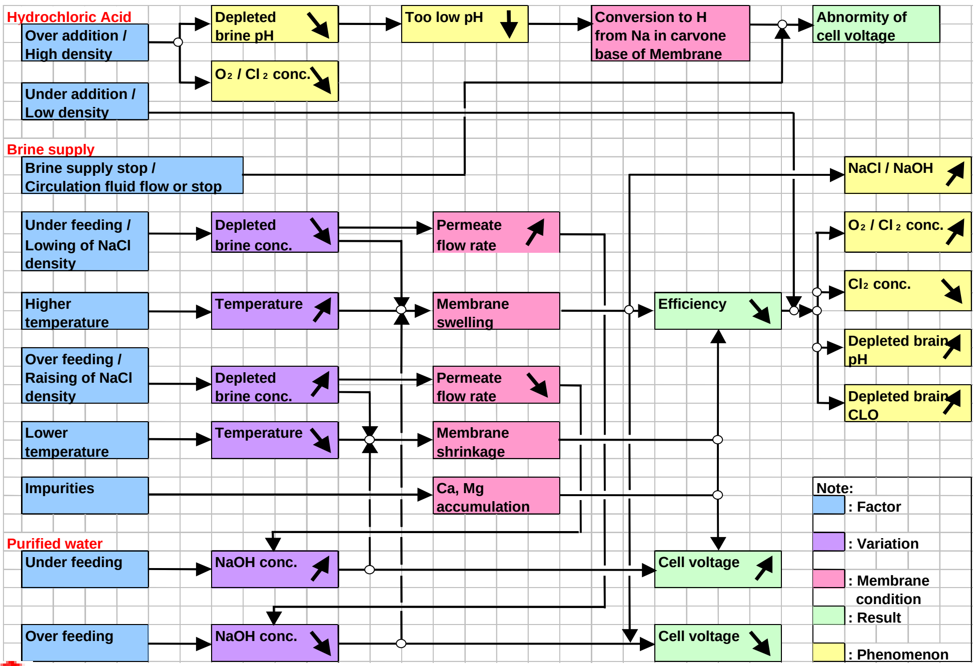
3. Check Items for Plant Operation and Maintenance (Examples in Japan)

1) Operation conditions and factors
2) Feeding brine specification
3) Check items for plant operation (Brine refinement & Electrolyzer)
4) Check & action after maintenance
5) Grasp method of change at Electrolyzer by the day
6) Recoating cycle of cathode & anode

ECCJ

9

1) Operation Conditions and Factors



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10

2) Feeding Brine Specification

Item	Unit	Standard Value	Item	Unit	Standard Value
NaCl	g/L	300～310	Al	ppm	<0.1
Na_2SO_4	g/L	<5	SiO_2	ppm	<5
$NaClO_3$	g/L	<20	Fe	ppm	<0.2
Ca + Mg	ppb	<20 as Ca	Ni	ppm	<0.01
Sr	ppm	<0.06	TOC	ppm	<10
Ba	ppm	<0.5	I (Iodine)	ppm	<0.2
Hg	ppm	<15			

Source ; Chlorine Engineers Corp,,Ltd

ECCJ

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3) Check Items for Plant Operation

(Brine Refinement & Electrolyzer)

Analysis				Continuous data
Feed Brine		$NaClO_3$	> Once/d	Electrolyzer (individual)
NaCl	> Once/d	Na_2SO_4	> Once/d	Cell Volt
Ca	Continuously	Catholyte		Cell Temp.
Mg	> Once/d	NaOH	Continuously	Brine Flow rate
Na_2SO_4	> Once/d	NaCl	Continuously	NaOH Recircula-tion Flow
$NaClO_3$	> Once/w	Electrolyzer (Individual)		
Depleted Brine		NaOH	> Once/w	
NaCl	> Once/d	NaCl / NaOH	> Once/w	
F-Cl_2	> Once/d	Cl_2	> Once/w	

ECCJ

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4) Check and Action after Maintenance

Assembling completion → Air tightness test at 0.2kg/cm^{2}G, To check the leakage from gasket → Tie rod & bus bar for cell main body should be tightening.

→ Electrolyzer START

→ Catholyte & depleted brine over-flow check, Cell temperature check (70℃ up)

→ *Confirmation of cell temp. rise*

Cl_2 conc. Check (97%up)
Once again tightening

→ *1 hour later*

Cl_2 conc. & cell volt check

→ Normal operation

ECCJ

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5) Grasp Method of Change at Electrolyzer by the day

Prepare the data table for following factors by once a week, and make plans for the maintenance.

① Cl_2 concentration
② Cell voltage
③ Cell temperature
④ Cell life (Progress number of days)
⑤ Kind of membrane
⑥ Maintenance record

ECCJ

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6) Recoating Cycle of Cathode & Anode

Cathode:

Electric Potential measurement

(Electrode maker)

Give the instructions by the result

(User)

Anode:

Recoating : 1〜2 times/life

Usual life: Standard type = 10 years

Long life type = 15 years

→ All renewal

ECCJ

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II. Food Industry

Participants in the Workshop of ASEAN Major Industry Energy Audit
(Persons concerned from EMA and the food industry and members of
ACE and ECCJ) at the workshop venue in Singapore (January 6, 2004)

II. Food Industry

1. Summary of Project

This project was implemented as part of the Infrastructure Improvement Project for Rationalization of International Energy Use with an aim to contribute to energy conservation, environmental preservation and sustainable development of economy in ASEAN countries that have recently achieved remarkable progresses in economic growth.

This project is designed to promote energy conservation in the major industries of ASEAN countries with ACE (ASEAN Center for Energy) as the core organization and with cooperation of ASEAN countries. As one of the countries and industries subject to energy audit for the current year, the food industry of Singapore was chosen. Then, audit plans were developed based on discussions with EMA (Energy Market Authority), the department in charge, of Singapore. Energy audits were implemented at the sites of two companies of the food industry over 6 days for the periods from December 1 through 5, 2003 and January 6 through 9, 2004 with persons in charge from EMA of Singapore. The results of the energy audits along with an overview of the political and economic situations of the country is reported as follows;

1.1 Subjects of Energy Audit and Organizations involved

(1) Country and companies subject to energy audit

Country: Republic of Singapore
Company: Co. C (Dairy products processing industry) and
Super Coffeemix Manufacturing Ltd. (SCM)

(2) Organizations involved and participants

1) Republic of Singapore

a. Energy Market Authority (EMA)

Mr. Abdul Rashid B Ibrahim	Deputy Executive Director
Mr. Zulkarnain B H Umar	Engineer, Consumer Education
Ms. Latha Ganesh	Executive Engineer
Mr. Melvin Tom	Engineer, Consumer Education

b. National Environment Agency (NEA)

Mr. Pang Hian Kiat Eddie	Engineer, Resource Conservation
Mr. Andy Wong	

c. Industrial Committee of Energy Efficiency

Mr. Vincent Low Loke Kiong	(Super Solution Pte Ltd)
Mr. Yeo Chee Kiong	(Precision O&C)

Mr. Colon koh	(Precision O&C)
Mr. Francis Plang	(Precision O&C)
Mr. Leow kok Chong	(Honeywell Pte Ltd.)

d. Food factory of Co. C
5 people including Plant Manager

e. SCM

Mr. Muhamad Muhtazam Noor Din	Technical Assistant
Mr. William ONG	General Manager
Mr. Dan Khoo Yew Meng	Technical Manager

2) ASEAN: ASEAN Center for Energy (ACE)
Mr. Christopher Zamora

3) Japan: The Energy Conservation Center, Japan (ECCJ)
Participants from the International Engineering Department of ECCJ

Hiroshi Shibuya	General Manager
Kazuo Morishita	Technical Expert
Hideyuki Tanaka	Technical Expert (the 2nd site survey only)

1.2 Political and Economic Conditions in Singapore

(1) National indicator

Country name:	Republic of Singapore
Area:	682.3 km^2 (Almost the same size as a total of Tokyo 23 wards (617 km^2)
Population:	About 4,131,000 (Including foreign residents living in the country for more than one year)
Capital:	Singapore
Language:	National language: Malay, Official language: English, Chinese, Malay and Tamil
Religion:	Buddhism, Taoism, Christianity, Islam and Hinduism
Brief history:	1959: Acquired autonomy from England and became an autonomous state of Singapore. 1963: Joined as a state at the time of establishment of Federation of Malaysia. 1965: On August 9, after secession from Malaysia, became independent as Republic of Singapore.

(2) Political system and domestic policy

Form of government:	Constitutional republic (Established on August 9, 1965)
Head of state:	President (6-year presidential term, S.R. Nathan, the incumbent president was inaugurated in September 1999 as the 6th president of the country.)
Parliament:	Unicameral Parliament, 84 seats; (members elected by popular vote to serve 5-year term)
Government:	(1) Prime Minister: Goh Chok Tang (People's Action Party [PAP] assumed office in November 1990) (2) Foreign Minister: S.Jayakumar (took office in January 1994)
Domestic policy:	In 1990, Prime Minister Goh succeeded to the post after Lee Kuan Yew, former Prime Minister (currently Senior Minister) who had been in office for 31 years. In the national election carried out in November 2001, PAP acquired 82 seats out of the total of 84 (share of the vote: 75.29%). The nation's domestic policy has been extremely stable. Goh Chok Tong expressed his intention to step down from the post before the next general election is conducted in 2007 or before that.

(3) Political situation in Singapore

Since the establishment of the country to date, People's Action Party, as the ruling party, has been in power, making up the comfortable majority of the parliament and thus, the domestic policy continued to be in a stable condition. In November 1990, Goh Chok Tong took over the post from Lee Kuan Yew, who had been Prime Minister consecutively for 31 years.

- In the nation-wide election in November 2001, PAP comfortably won acquiring 82 seats out of the 84 in total (about 75% share of the vote)appealing to people's sense of insecurity resulting from an economic slump and a series of terrorist attacks on U.S. that they had recently experienced.
- Prime Minister Goh expressed his intention to step down from the post at least 2 years before the next general election scheduled for some time before early 2007, to transfer power to Lee Hsien Loong, the eldest son of Senior Minister Lee Kuan Yew and currently Deputy Prime Minister.

(4) Basic foreign policy

Singapore puts priority on the alliance of ASEAN countries and the power balance among great powers in East Asia. Singapore underlines military presence of the US in the Asia and Pacific region and its political commitment (though as member of the Non-Aligned Countries).

- Singapore has developed strategic foreign policy looking realistically at the country's disadvantageous aspects (small land and population without resources). It has focused its efforts in securing access to world economy by maintaining and advancing its multi-lateral free-trade system while creating a stable international environment in East Asia. Singapore pursues also the integration of ASEAN and the regional cooperation based on the amicable relationship with ASEAN member countries including ASEAN+3, ARF, APEC, etc. Singapore underlines military presence of the US in the Asia and Pacific region and its political commitment for the post-cold war period (though it is one of the Non-Aligned Countries).
- Singapore has put importance on the promotion of bilateral free trade agreements other than WTO negotiations as part of its efforts in establishing and enhancing a free trade system. It has already concluded FTA with NZ, Japan, EFTA (Switzerland, Liechtenstein, Norway, Island), Australia and US (Not effective yet for Australia and US), and is now in the course of negotiation with Canada, Mexico, India, etc.. and started studies with EU, Korea, Sri Lanka, Jordan, Bahrain, etc.

(5) Economy

Major industries: Manufacture (Electronics, transport equipment, petroleum products and metal products), commerce and finance

Table II-1-1 Basic Economic Data

Item	Year	1999	2000	2001	2002
GDP	100 Mln US$	137935	157000	152066	155727
Per capita GNP	US$	20598	22769	20544	20887
Economic growth rate	%	6.9	10.3	-2.0	2.2
Commodity price increase rate	%	0.0	1.3	1.0	-0.4
Unemployment rate	%	4.6	4.4	3.4	5.2
Current account	100 Mln US%	25737	22894	28914	33490

(Exchange rate 1.0 Singapore dollar (S$ = about 68 yen (as of July 2002))

Major trade items:

Exports: Electric and electronic products, oil-related products, telecommunications/ audio equipment, chemical products

Imports: Electric and electronic parts, crude oil, chemicals

Table II-1-2 Trades with Japan

	Trade value (in units of million S$)			Trade items
Year	2000	2001	2002	
Exports to Japan:	39955	28794	26080	Machinery and equipment, petroleum products including gasoline
Imports from Japan	17949	16712	15990	Electronic parts including semiconductors, business machine

1) Economic overview

After the secession and independence from Malaysia (1965), Singapore has proactively promoted “Industrialization centering on the foreign investment”, etc. In January 1996, it “left” the list of developing nations designated by the Organization for Economic Cooperation and Development (OECD).

- In 1998, its real GDP growth rate dropped to a negative figure (-0.9%) for the first time since 1985 being affected by an overall economic slow down in the region, etc. as a result of the Asian currency crisis in 1997. However, after that, supported by favorable winds such as the recovery of Asian economy, the world-wide expansion in the needs for electronics products, the recovery of domestic consumption, etc. it posted high growth rates of 6.4% and 9.4% in 1999 and 2000 respectively.
- In 2001, however, the demand for electronic products diminished due to an economic slowdown in the US, etc. Thus, as a result of significant drops in exports, the growth rate in the manufacturing industry seriously worsened (-11.5%) and the GDP growth rate resulted in an all-time worst (-2.4%) since the foundation of the country.
- Although the negative growth still continued in the first quarter of 2002, it picked up in the second quarter due to dynamic growths in the manufacturing industry, particularly in the chemical-related division and recorded the first positive growth rate (3.9%) in 5 quarters. GDP continued to grow and ended up with a positive growth rate of 2.2% for the full year of 2002.

- For the economic growth for 2003, the government of Singapore had initially projected at 2–5%. However, due to the prevalence of Severe Acute Respiratory Syndrome (SARS) in the country and the region during the period from March to May, its tourist and transport industries were severely damaged causing the growth rate of the second quarter of 2003 drop to -4.2% and thus, the government revised its projected economic growth downward to 0–1% in August. In the third quarter of 2003, the growth rate recovered up to 1.0% (a preliminary figure) reflecting strong overseas demand.

2) Economic measures

- In January 1999, the government of Singapore announced the "Industry 21" program, as its basic industrial policy up to 2010. The government upheld, as its goal, the creation of a world-class hub of the knowledge-based industry centering on the manufacturing and service industries. As strategic industries, the following 9 fields are targeted; electronics, petrochemistry, life science, engineering, educational service, medical service, logistics, telecommunications/media and regional integrated service. In 2000, as industrial policies for individual fields, "Infocom 21 Program (Information-communication, net business)", "Singapore Genome Program (life science)" "Science and Technology 2005 Program (science and technology)" ,etc. were announced.
- While the world economy was drastically changing with the accelerated globalization, the rise of China as a competitor, etc. the government of Singapore, which had faced with a severe recession in domestic economy, set up the Economic Review Committee (ECC chaired by Lee Hsien Loong, Deputy Prime Minister and Minister of Finance) to give a fundamental review of its development strategies and propose a blueprint for economic restructuring. After repeated discussions over one year, the Committee publicized its final report in February 2003. Although the report covered a broad range of issues and topics, its central theme was to strengthen each field's function as a hub in Asia and in the world. In this respect, the report included policy proposals, which would directly/indirectly help economic restructuring, regarding; (1) Taxation system reform, (2) Development in the educational industry, (3) Improvement in medical/health service, (4) Development as a financial center, (5) Progress as a digital hub, (6) Development of the high value-added manufacturing industry, (7) Establishment of distribution networks, etc. Most of these proposals are reflected on the 2003 budget.

1.3 Energy Situation in Singapore

Singapore imports all of the primary energy (petroleum, gas) used home. Although petroleum accounts for a dominant proportion, import of gas has increased year by year. Solar power generation accounts for only about 0.2% of the total energy consumed in the country.

Energy situation in Singapore is shown in Table II-1-3. In the industrial sector, the chemical and petrochemical industries consume more than 70% of the total energy consumed in the sector. As the food processing industry is included in the item for others of the industrial sector, there is no specific data on its actual energy consumption. Although the food processing industry is an important industry in Singapore, it is one of minor industries in terms of energy intensity.

Table II-1-3 Energy Situation in Singapore (unit: 1,000 toe)

Classification	Sector		2000		2001	
			Sector total	Total	Sector total	Total
Supply	Domestic production	Solar energy generation, etc.	64	24591	64	29158
	Import	Oil	23344		25088	
		Gas	1183		4007	
Con-sumption	Power generation		5088	14305	6612	18553
	Oil refining		6177		7409	
	Conversion to others		3040		4532	
	Industry	Iron and steel	93	4001	89	3962
		Chemical/ petrochemical	2895		2888	
		Others	1013		985	
	Transport	Air transportation	2414	4388	2413	4559
		Roads	1949		2120	
		Others	25		26	
	Other sectors	Agriculture	3	1898	3	2084
		Public use	813		990	
		Residence	546		555	
		Others	536		536	

(Data source: IEA 2003 Edition, Energy Balances of Non-OECD Countries, 2000-2001)

2. Overview of the Food Industry (Food Processing Factories) Subject to Audit

In advance of the implementation of the planned energy audits of the food industry (Food processing factories) in Singapore, ECCJ requested to ACE to select two food processing factories. The department of the Singapore government in charge, in response to the request from ACE, determined on the two food processing factories mentioned previously.
These 2 factories requested for conclusion of a nondisclosure agreement prior to their acceptance of our first site survey. Actually, we concluded a nondisclosure agreement with only Co. C. The conclusion of a ND agreement with "Super Coffeemix Manufacturing Ltd. (SCM)" was not necessary and they accepted our energy audits. Accordingly, we note here that the report described hereunder, particularly data on Co. C, is limited to the matters concerning energy conversation.

Brief outlines of the respective 2 food processing factories are given below.

2.1 Outline of Co. C (dairy food processing industry)

(1) General information

Factory location:	City of Singapore
Products:	7 items of diary product
No. of employees:	640
Work system:	3 shift- team operation, 24 h/d, 5.5 d/w (From 7:00 AM on Monday through 7:00 PM on Saturday)

(2) Production volume and energy consumption

1) Production volume (2003)
7 production items and their annual production volumes are shown in the table below.

Table II-2-1 Diary Products and Annual Production Volumes

Product name	Production volume	
	No. of cartons	ML
Sweeten Condensed Milk	1750000 ctns	25.7
Evaporated Milk	1500000 ctns	29.5
Vitagen Cultured Milk Drink	1800000 bottles	0.23
Cup Yogurt	7200000 cups	1.1
Juices	–	5.0
Pasteurized Milk	–	15.0
Jelly & Pudding	2200000 cups	0.26

2) Energy consumption (2003)

Annual energy consumption by Co. C is detailed in the table below.

Table II-2-2 Annual Energy Consumption

Type	Volume consumed	Average unit price (S$)	Use
Electricity	9800000 kWh	0.122	General use
Diesel oil	3200000 L	0.406	Boilers, forklifts, etc.
LPG	7000 kg	15	Sterilization of empty cans

2.2 Outline of SCM

(1) General information

Factory location: 2 Senoko South Road, North of Singapore
Products: 2 items: Coffee mix and cereal
No. of employees: 95
Work system: One team operation, 8 h/d, 5 d/w

(2) Production volume and energy consumption

Although the company had processed cereal in the factory till June 2003, as it outsourced the production to China, it currently does only packaging of coffee mix and cereal there. Only electricity is used for energy in the factory.

Table II-2-3 Monthly Energy Consumption by SCM

Month	Production volume (Million Sachets)	Electric consumption (kWh)
2003 7	55.0	286391
8	55.0	282647
9	60.0	282987
10	56.0	288740

3. Plan of Energy Audit

The primary purpose of the planned audits in Singapore was to grasp the actual situations of the production process, energy consumption and the use of exhaust heat in the selected 2 food factories and to propose improvement plans to advance their energy conservation efforts. The purposes also included conducting workshops on the sites to introduce energy conservation technologies, activities, etc. in Japan to raise, promote and disseminate the awareness of the energy conservation among those concerned in Singapore. Furthermore, these energy audits were aimed at giving support to energy conservation leaders on the side of ASEAN in establishing the standardized energy audit method after these energy audits were carried out, based on our acquired understanding of the actual situations of the same industry in ASEAN countries, the levels of their energy audit skills, etc.

For implementation, a survey was conducted twice for the respective facilities.
In the first site survey, the first work shop was conducted. The points for energy audits of food factories and energy conservation technologies practiced in the food processing industry in Japan were introduced to help and boost their understanding.

In the actual auditing, a local audit group arranged by ACE took specific measurements at the respective sites under the instructions of the experts dispatched from Japan while the points to be checked in energy auditing that we had asked in a preliminary questionnaire to these factories were confirmed.
In the second site survey, energy conservation improvement plans determined based on the results of the first survey were explained to the persons concerned of EMA (Energy Market Authority), a department of the government of Singapore in charge, and the managing persons of the respective companies. Then, we visited the sites again and conducted energy audits for the respective facilities to confirm the results of the first energy audits and our subsequent proposals.

3.1 Energy Audit Procedure

The energy audit group visited the two companies that accepted energy audits in two days for the first site survey and in one day for the second site survey each.
In the first survey, the auditing staff from ACE and ECCJ explained to Plant Managers of the two companies the background and meaning of the current energy audit. In the site survey, the filled-out questionnaire was collected and a site inspection and an energy audit were conducted.

Photo shooting was strictly prohibited in both companies and no information on the actual condition was obtained.

3.2 Selection of Equipment Subject to Audit and Reviewing of Responses to Questionnaire

As the two companies use the two different manufacturing processes, we decided to determine the equipment for energy auditing after reviewing the current condition of the respective companies.

However, the advance questionnaire from ECCJ had been returned from only one company and it contained only part of the company profile and no information on energy management. Therefore we planned to confirm at the site survey but actually they were not prepared to provide us with information that met our request. As both companies had not practiced energy management in terms of unit consumption and collected necessary data, we decided to conduct energy auditing focusing on energy conservation of individual equipment and installations.
Equipment selected for auditing and the questionnaire items confirmed are shown below.

(1) Co. C (Diary products processing industry)

1) Selection of equipment for energy auditing
The factory of Co. C that we visited has been in operation for 40 years and repeatedly expanded its production scale to date. It has 7 product lines and data on each product line has not been collected in the field. Due to the time constraints, we limited our current energy audit to the product lines of condensed milk, evaporated milk and pasteurized milk produced in large quantities.
Energies used in the dairy product factory is as follows :
• Electricity (Purchased power):
Cooling system, air compressor, refrigerator, air-conditioner, pump, fan, conveyer, lighting, equipment motor, etc.
• Steam: Heating, pasteurizing, vacuum equipment, steam cleaning, etc.
We picked up for auditing the steam system, cooling system, air compressor and electricity receiving/transforming installation that consume large quantities of energy.

As we could not obtain necessary data to confirm the questionnaire items for the reason mentioned previously, we report here what were clarified in discussions.

2) Major energy consuming equipment
a. Sweeten Condensed Milk
Production capacity: 200,000 L/d (estimate)

Powder milk dissolving tank, homogenizer (110 Bar, 60 Hp), Pasteurizer (plate heat exchange), Vacuum condenser (2), Middle tank (5), Filling equipment (350 CPM), Labeler, Packing machine, Palletizer

b. Evaporated Milk

Production capacity: 145,000 L/d (estimate)

Powder milk dissolving tank, Balance tank, Pasteurizer, Homogenizer (250 Bar, 100 Hp), Pre-cooler (plate heat exchange), Cooler (plate heat exchange), Middle tank (3), Filling equipment (245 CPM), Rotary sterilizer, Labeler, Packing machine, Palletizer

c. Pasteurized Milk

Production capacity: 134,400 L/d (estimate)

Dissolving tank (2), Pre-pasteurizer (plate heat exchange), Homogenizer (75 Hp), Middle tank (3), Pasteurizer (plate heat exchange, 6000 L/h), Homogenizer (50 Hp), Middle tank (12,000 L × 5), Cooler (plate heat exchange), Filling equipment (500 L/h × 2), Packing machine, Cool storage

d. Utility facilities

① Boiler (steam pressure: 10 Bars × 188℃)

- UK made × 2 @4.5 t/h Installed in 1997/2002
- Singapore made × 2 @2.27 t/h Installed in 1998/1989
- Exhaust gas recuperator: Feed water temperature 30 → 70°C Installed in 2002

② Air compressor (discharge pressure: 8.43 kg/cm^2)

No.of compressors in operation is under sequencer control.

- 4 compressors (KSESAR): @50 HP 5.95 m^3/min
- 3 compressors (IR ML): @25 HP

③ Refrigerating machine (ammonia machine)

- 1 unit (MYCON): 75 kW
- 2 units (MYCON): @55 kW
- 1 unit (MYCON): 45 kW

④ Evaporative condenser

4 units

⑤ Chilled water pump

There are 3 lines and one pump in each line is constantly in operation.

- 2 pumps (Vitagen line): @35 m^3/h 7.5 HP
- 2 pumps (Juice line): @60 m^3/h 15 HP
- 2 pumps (Milk line): @40 m^3/h 10 HP

⑥ Ice thermal storage tank

1 tank: 1,200,000 kcal as Ice (15 ton)

1 tank: 800,000 kcal as Ice (10 ton)

⑦ Refrigerating chamber

One 4°C ice chamber in the factory, Air condensing unit + unit cooler

4°C and -20°C ice chambers outside the factory

⑧ Transformer

2 units: @2.0 MVA Power factor: 96%

3) Other items confirmed

a. Electric rate (in units of S$)

- Basic charge (@kW): Contract rate: 7.3, For electric use exceeding the contract volume: 10.99
- Charge at a metered rate:
  - Off-peak time (23:00–7:00): 0.0725+0.0015
  - Peak time (7:00–23:00): 0.09590+0.0142
- Other charges: Service charge: about 2.5% Tax: 4.0%

b. Boiler feed water cost

c. Vitagen Cultured Milk Drink

Sterile filling machines are sterilized with steam every morning (9:00–11:00)

d. Refrigerating chamber.

Although the standard temperature is set at 4°C, the temperatures recorded in each chamber were respectively, -0.6, -0.5, 1.0, 1.0°C. The lower temperatures are intended to prevent rises in temperature causing from the influx of fresh air at the time of shipping by trucks.

The temperature must be kept below 4°C in accordance to HACCP.

e. Sweeten Condensed Milk

- Although the equipment is 40 years old, it is still in use with repairs and maintenance.
- Steam ejector vacuum condenser (Maximum 4,200 L/batch, Vacuum degree: 2.0–2.9 inHg) consumes vapor at a rate of 700–1000 kg/h.
- The operation of steam ejector (3-staged ejector + auxiliary ejector) was checked.
- The naked pipe surface temperature was measured. 130°C
- The naked end-flange surface temperature was measured. 90°C
- Empty cans to fill the contents are sterilized with LPG direct flame (one can was picked up at random and the temperature over 149°C) was confirmed.

f. Evaporated Milk

Rotary sterilizer (FMC made) consumes steam at a rate of 125 kg/h.

g. Steam system

Drains of the Sweeten Condensed Milk and Evaporated Milk production lines are not collected. They once tried collection of drains but due to the high position of the boilers installed on the 8th floor, it was not successful.

(2) SCM (Coffee blending and packaging)

1) Selection of equipment subject to audit

The SCM factory we visited did only blending and packing of coffee mix and cereal mix.

The energy used in the entire process was electricity. However, data collection in the production site was not practiced and as they received electricity in the same line as the Head Office, it was impossible to estimate their unit electricity consumption.

- Electricity (Purchased power):

  Air conditioning, air compressor, conveyer, lighting, equipment motor and electricity used in the offices

We picked up for auditing the air conditioning system, air compressors, lighting, electricity receiving installation that we assumed would consume large quantities of energy.

As we could not obtain necessary data by the questionnaire entries for the reason mentioned previously, we report here what were clarified in discussions.

2) Major energy consuming equipment

a. Coffee mix

Blending (2 lines), Packing (5 lines)

b. Cereal

Blending (1 line), Packing (3 lines)

c. Air compressor (screw type)

Preset pressure (6.0 kg/cm^2)

- 2 units: @125HP (only one unit is in operation)
- 1 unit: 50 HP Out of service
- 1 unit: 30 HP Out of service

Only one large-size compressor is in operation to supply air. Unload operation is frequently repeated.

d. Air conditioning equipment

Pre-set conditions: Room temperature 20°C Humidity 55–62%RH

- Production line:

  3 units: @ fan 30 kW 2 units are simultaneously in operation at the time of production and only 1 unit is in operation at the non-production time.

- Blending line:

  2 units: @ fan 30 kW One unit is constantly in operation

e. Air condensing apparatus

- 5 units: @40 HP × 2 Comp Linked with the respective air conditioners

f. Transformer

- 2 units: @2.0 MVA, Power factor = 99%

3) Other items confirmed

a. Electric rate (in units of S$)

- Basic charge (@kW): Contract rate: 7.33, For electric use exceeding the contract volume: 10.99
- Charge at a metered rate (@kWh):

  Off-peak time (23:00–7:00): 0.06960 + 0.00150

  Peak time (7:00–23:00): 0.09810 + 0.0142
- Other charges: Service charge: about 3.5% Tax: 4.0%

3.3 Audit Schedule

The two factories that we visited for energy audit were located in the city of Singapore and in the northernmost town about one hour away by car from Singapore city. The one in Singapore city was conveniently located and the staff of the factory was so nice that the planned audits proceeded as scheduled.

(1) First site survey: December 2003

December 1 (Mon.)	Workshop on the efficient use of energy and energy conservation (16 participants in total from EMA, NEA, Co. C, ACE, ECCJ, etc.)
December 2 (Tue.)	Visit the factory of Co. C Check of the energy management status and inspection/energy audit of the factory
December 3 (Wed.)	Energy audit and wrap-up meeting in the Co. C
December 4 (Thu.)	Visit the factory of Super Coffeemix Manufacturing Ltd. (SCM) Check of the energy management status and inspection/energy audit of the factory
December 5 (Fri.)	Visit the factory of SCM Co. Summary and wrap-up meeting

(2) Second site survey: January 2001

January 6 (Tue.)	Workshop: Points of auditing of food factories and reporting on the results of the 1st site survey etc. (12 participants in total from EMA, NEA, Co. C, ACE, BCCJ, etc.)
January 7 (Wed.)	Visit the factory of Co. C Recheck of the energy management status, detailed explanation on the results of the 1st site survey and estimations of potential energy conservation.
January 8 (Thu.)	Visit the factory of SCM Recheck of the energy management status, detailed explanation on the results of the 1st site survey, estimations of potential energy conservation and reporting to the bureau chief of EMA.
January 9 (Fri.)	Workshop: Benchmark/database for energy conservation and energy-saving potential for each factory (10 participants in total from EMA, NEA, SCM, ACE, BCCJ, etc.)

4. Equipment Subject to Energy Audit

4.1 Energy Audit of Co. C

(1) Specification and operation method of steam generating equipment

1) Boiler

A total of 4 boilers are installed on the top floor (8th) and normally 2 units having better efficiency in a. in Figure II-4-1 are in operation.

An exhaust gas recuperator installed in 2002 preheats feed water from 30°C to 70°C. (Installation cost: 74,000S$ to be recovered in 1.5 years). Boiler piping diagram is shown below.

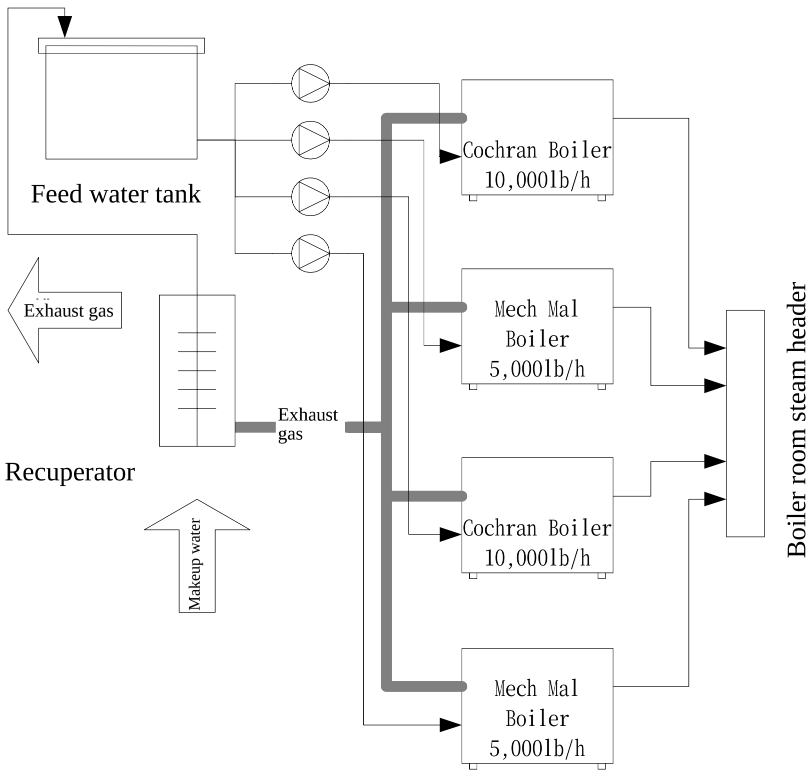


Figure II-4-1 Boiler Piping

a. 4.54 t/h × 10 bar × 2
Cochran Boiler Installed in 1997/2002 UK manufacture
3-path fire tube boiler

b. 2.27 t/h × 10 bar × 2
Mech Mal Boiler Installed in 1988/1989 SG manufacture
2-path fire tube boiler

(2) Specification and operation method of steam-utilizing equipment

Stem is used in the sterilizing, heating and condensing processes. The maximum required steam pressure is 6 Bar.

1) Steam piping

The steam piping of this factory is very complicated because facilities were expanded many times. The data on the main steam piping is as follows:

- 8in (200A): 460ft (140.2 m)
- 6in (150A): 211ft (64.3 m)
- 4in (100A): 277ft (84.4 m)
- 3in (80A): 242ft (73.8 m)

There are many branch pipes and steam piping not in use other than the main piping.

Steam piping schematic diagram and table of flowing capacity in relation to piping diameter and flow speed are shown below

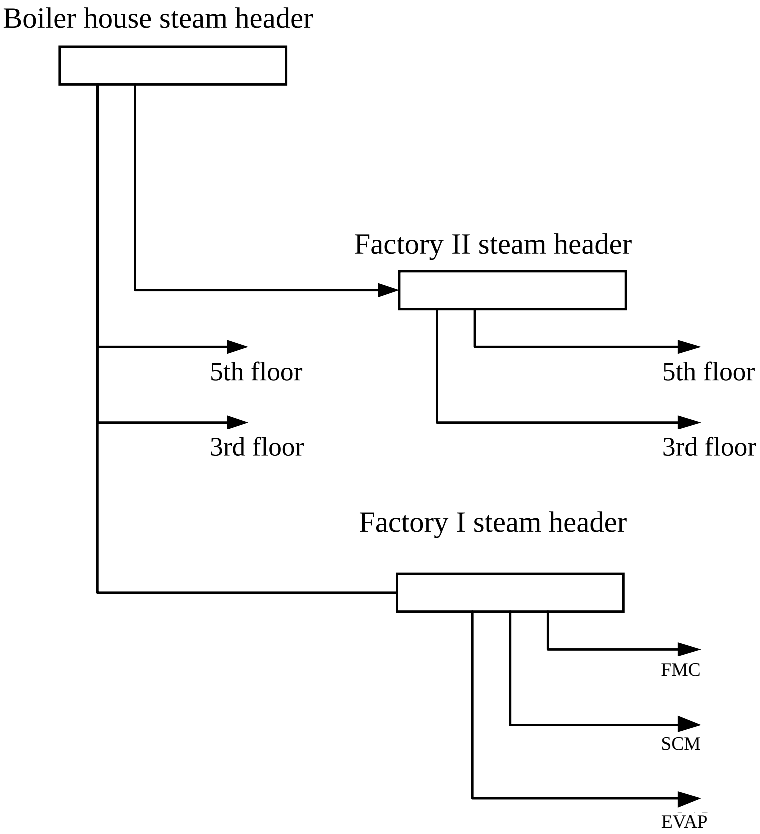


Figure II-4-2 Steam Piping Schematic Diagram

Table II-4-1 Flowing Capacity in Relation to Piping Diameter Bore and Flow Speed

Flow rate (m/s) / Pipe diameter (A)	Flow volume by FR (kg/h) (Pressure: $9kg/cm^2$ Specific volume: $0.1943m^3/kg$)				
	10	15	20	25	30
200	6094	9142	12189	15236	18283
150	3503	5255	7007	8758	10510
100	1613	2419	3225	4032	4838
80	947	1421	1894	2368	2842
50	407	611	814	1018	1221
40	252	378	503	629	755
25	111	166	222	277	332

2) Vacuum condenser

In the condensing process of Sweeten Condensed Milk, steam ejector vacuum condensers are used. Milk is vacuum-condensed using a 3-stage steam ejector system at 27 inHg (50–75 mmHg). The maximum production volume/batch is 4200 L. The maximum production capacity per condenser is 16 batches/d.

Accordingly, the maximum daily production volume is;

42,000 L/batch/condensor × 16 batches/d × 2 condensers = 134,000 L/d

The operation of the vacuum condenser was changed because the production volume per batch was increased.

a. Initially planned operation condition

As a first step, the 1st , start and 3rd ejectors are put in operation and when the pressure in the condenser becomes 20 in (250 mmHg), the 2nd ejector is put in operation. When the inner pressure of the condenser becomes 23 in (175 mmHg), the 1st and start ejectors are stopped and the condensing is continued until it is completed.

b. The current operation condition

All ejectors are put in operation from the beginning, and when the pressure in the condenser becomes 27 in (50–75 mmHg), the first ejector is stopped and the condensing process is continued until it is completed.

The factory’s vacuum condenser piping is shown below.

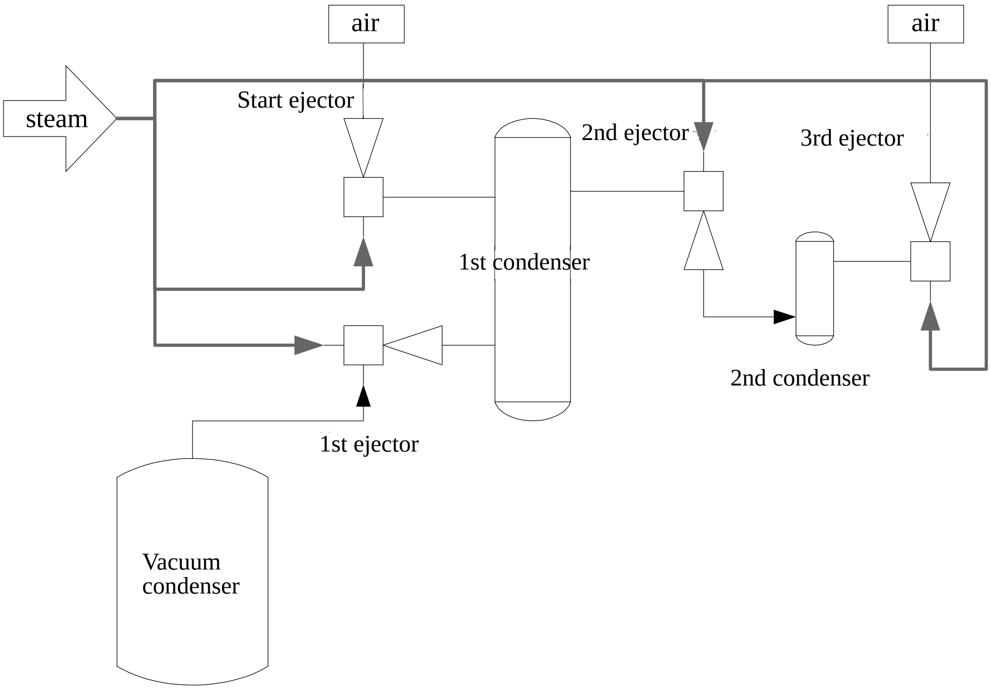


Figure II-4-3 Vacuum Condenser Piping

3) Steam condensate recovery system

Condensate from Sweeten Condensed Milk and Evaporated Milk production line were not collected. Although it had once been tried, it was not successful because of the high position of the boilers installed on the 8th floor.

(3) Specification and operation method of cooling system

0°C cold water produced in the ice thermal storage tank by the combination of ammonia refrigerating machines and evaporative condensers is used for the cooling process through 3 lines of cold water piping. Normally, in dairy plants, large quantities of refrigerated water are used to store raw milk. However as Co. C does not use raw milk as raw material, their facilities are comparatively of a small scale. They have a single-distribution line cooling system in their old factory other than this 3-distbitution line cooling system

Cold water piping and cold water distribution diagrams are shown below.

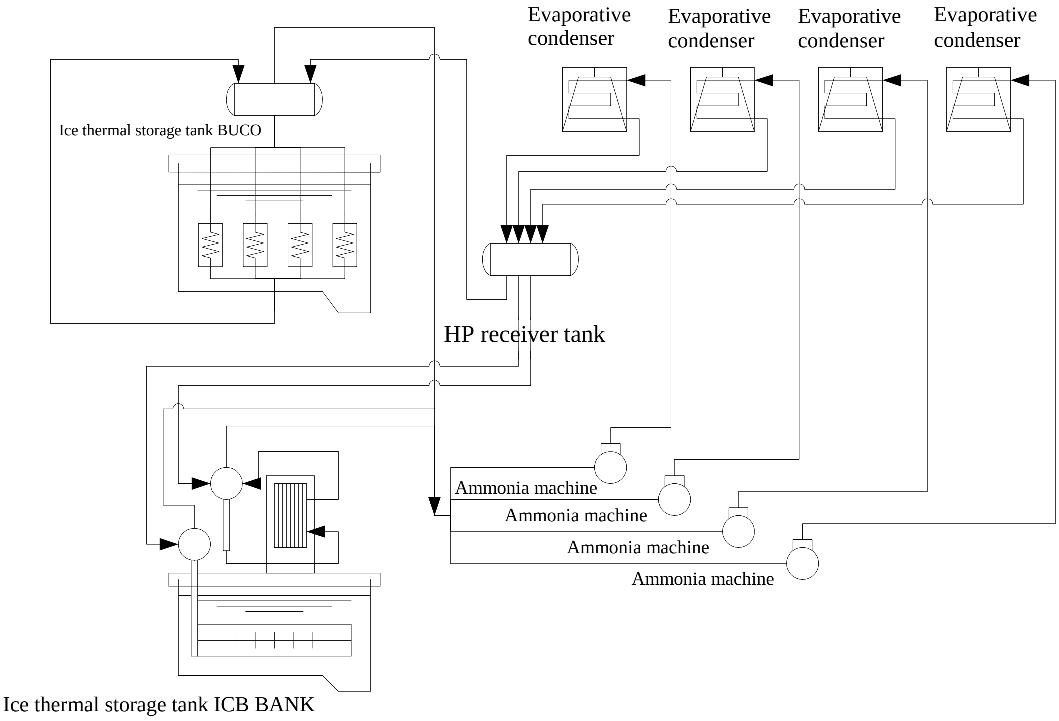


Figure II-4-4　Cold Water System Piping

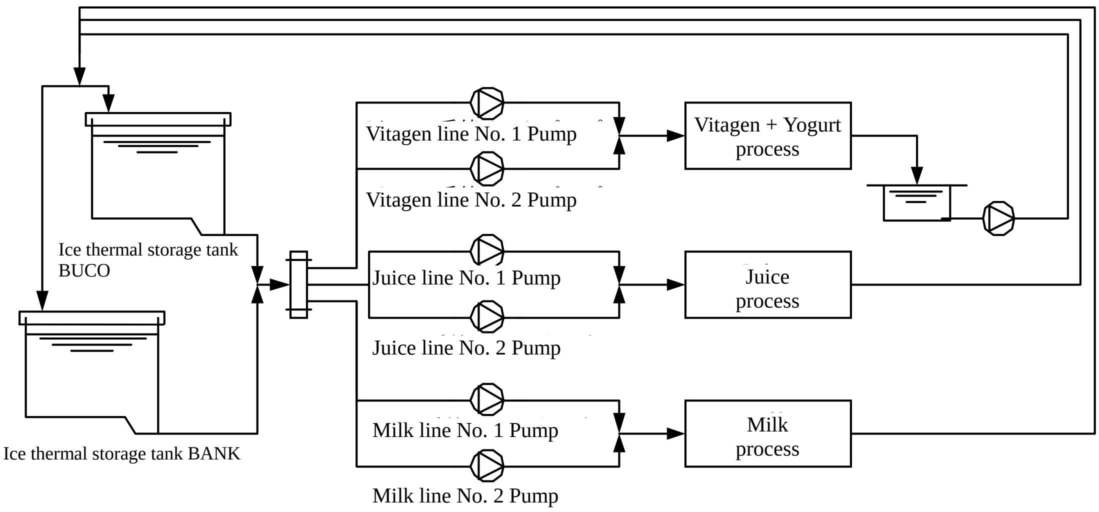


Figure II-4-5　Cold Water Piping Diagram

1) Refrigerating machine
   a. 75 kW Reciprocal ammonia refrigerating machine × 1　MYCON Japanese made

b. 55 kW Reciprocal ammonia refrigerating machine × 2 MYCON Japanese made

c. 45 kW Reciprocal ammonia refrigerating machine × 1 MYCON Japanese made

2) Ice thermal storage

Two ice thermal storage tanks, a. and b. are installed. They are respectively of different types. As the production facilities are in operation for 24 hours, cold water is constantly used. Heat storage operation is not controlled under predetermined schedules but let go until it reaches the limit.

The accumulated ice is measured by a thickness-sensitive sensor and when the maximum amount is detected, the operation of the refrigerating machines is stopped.

a.	1,200,000 kcal as Ice (15 tons):	One tank	BUCO
b.	800,000 kcal as Ice (10 tons):	One tank	Ice Bank

3) Cold water piping system

Cold water is distributed through three lines of piping to cool the respective production processes of Milk, Vitagen and Juice .

a. Vitagen line (Level 3): Cold water pump × 2 (@35 m^3/h 7.5 HP) supply at 0°C, return at 7.0°C

b. Juice line (Level 3): Cold water pump × 2 (@60 m^3/h 15 HP) supply at 0°C, return at 5.0–10°C

a. Milk line (Level 5): Cold water pump × 2 (@40 m^3/h 10 HP) supply at 0°C, return at 5.0–10°C

(4) Specification and operation method of air compressor

The number of compressors in operation out of the 7 installed is controlled by the pressure in the receiver tank (discharge pressure: 8.44 kg/cm^2). The same energy conservation method as that employed in Japan had already been adopted. The air compressor piping is shown below.

a. 50 HP screw compressor × 4 5.95 m^3/min Kaesar

b. 25 HP screw compressor × 3 IR ML

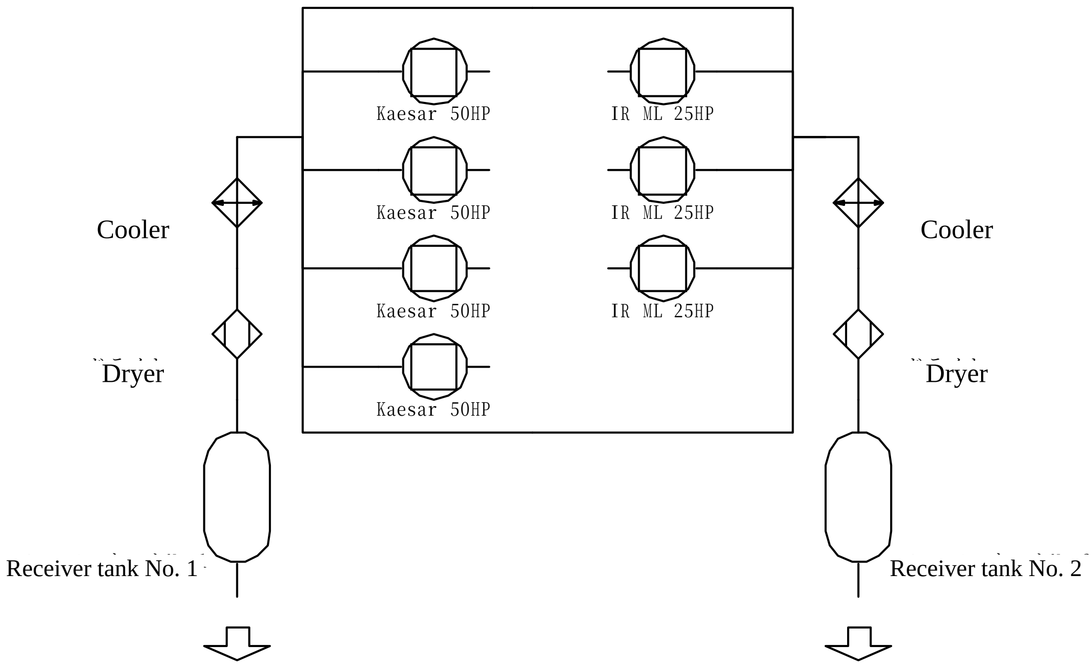


Figure II-4-6 Air Compressor Piping

(5) Specification and operation method of electricity receiving/ transforming facilities

The electricity consumption status at the time of our visit was as follows: (Actual results of October 2003)

Annual electric consumption:	9,800,000 kWh
Monthly electric consumption:	850,000 kWh
Contract demand:	1,650 kW
Maximum electricity use:	1,736 kW
Power factor:	96%

Leveling of power consumption is quite advanced.

a. 2.0 MVA transformer × 2

4.2 Energy Audit of SCM

(1) Specification and operation method of air handling unit

There are two air-conditioning systems in the factory; one is for the production room and the other one for the blending room. They are in operation throughout the year because of the necessity to control humidity. The air conditioning system consists of a condensing unit and direct expansion cooling coil air conditioning equipment The outlet temperature of the air-conditioning equipment is assumed at 10℃ to keep room temperature at 20℃ and humidity at 55–65% RH.

1) Air handling unit

5 air-conditioners of the same specification are installed. The huge space of the factory is air-conditioned by these 5 machines.

Directly reading current meter values

- Production room

  300A (400 V) = 208 kW   2 air conditioners are in operation

- Blending room

  90A (400 V) = 62.3 kW   1 air conditioner is in operation

As we could not obtain information on the specification, it is assumed as follows;

Blower: Capacity 54,000 CMH   Power 30 kW

Cooling coil: 210,000 kcal/h

Schematic diagrams of air conditioning system are shown below.

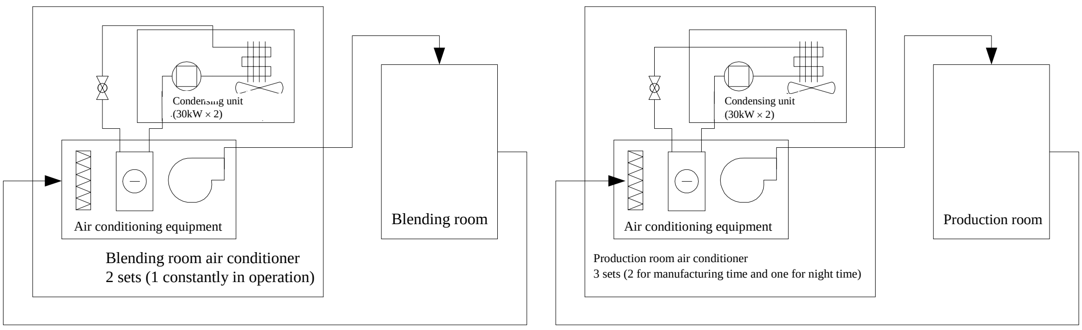


Figure II-4-7 Air Conditioning System

a. Air-conditioning for the production room

   Out of the 3 direct expansion system cooling coil air conditioning machines, 2 sets are used during the manufacturing time and only one set is used during the night time.

b. Air-conditioning for the blending room

   Out of the 2 direct expansion system cooling coil air conditioning machines, 1 set is in operation during the manufacturing time and the night time.

2) Condensing unit

40 HP × 2 Comp. air-cooled condensing unit: 5 sets

They are respectively linked with air conditioning machines.

(2) Specification and operation method of air compressor

Out of the 4 air compressors currently possessed, only 1 compressor of 125 HP is in operation. As there is a lot of unused capacity, unloading is repeated between the maximum pressure of 8.3 kg/cm^3 and the minimum pressure of 7.6 kg/m^3 (at about 15- second intervals)

Directly reading current meter values

At loading: 180 A (400 V) = 125 kW

At unloading: 140 A (400 V) = 97 kW

a. 125 HP Screw compressor: 2 (1 is brand new and unused)
b. 50 HP Screw compressor: 1 (Out of service now)
c. 30 HP Screw compressor: 1 (Out of service now)
d. 2.5 m^3 Receiver tank: 1

Air compressor piping is shown bellow.

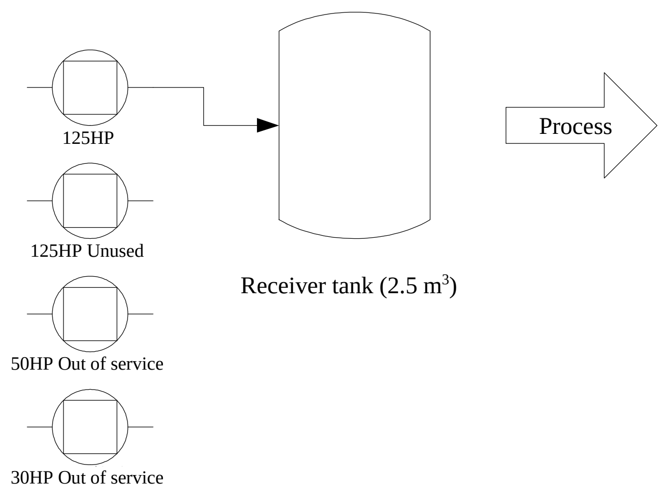


Figure II-4-8 Air Compressor Piping

(3) Specification and operation method of lighting equipment

For lighting in the factory, ceiling lights of 400w are used and there are switches for respective lights. Currently, all lights are turned on during the operation time and spotlighting is used at the packing machine area.

(4) Specification and operation method of electricity receiving/transforming facilities

The electricity consumption status at the time of our visit was as follows: (Actual results of October 2003)

Monthly electric consumption:	289,000 kWh
Contract demand:	850 kW
Maximum electricity use:	749 kW
Power factor:	96%
Load factor:	52%

Electricity is received in two lines with 2 sets of 2.0 MVA transformers

5. Energy Measurement and Survey Results

5.1 Audit and Measurement Results of Co. C

(1) Energy management

ISO 9002 has already been conformed to and monitoring and monitoring records are properly managed. However, data collection that is essential for energy management is no enough. Utilization of collected data is not proper either.
The establishment of a method of energy management and goal setting, the determination on monitoring items based on the established method and the goals set, and the assessment of the results will be challenges for them.

(2) Steam-related equipment

1) Boiler pressure

While the boiler pressure is set at 10 kg/cm^2, the user's maximum demand pressure is 6 kg/cm^2. Even with the long extended pipeline, it will be possible to lower the present pressure. To realize it, the following measures should be considered

a. Enhancing thermal insulation of steam piping

The layout of the existing steam piping is very complicated due to the expansions of the factory, etc. In the on-site survey, we found that the thermal insulation of the main piping was almost properly done and repaired. However, the heat retention of valves, flanges, etc. is not enough or there is no thermal insulation. In addition, we could not grasp the actual condition of the branch piping at all. If heat loss from piping is prevented and drain from piping is reduced, the current piping may be all right for increased flow rates resulting from the lowered steam pressure.

b. Removal of unused piping

As it is a factory with a long history behind, removal, renewal and addition of equipment have been repeated. Unused piping, etc. is considered to be everywhere, causing heat losses. They should be removed.

2) Vacuum condenser

We were explained that the steam consumed in the condensing process of Sweeten Condensed Milk was 700–1000 kg/h. However, the feed volume per batch was not constant and it appeared that workers adjusted the volume by their experience. As the current operation is intended to reduce the condensing time, it should be reviewed from a standpoint of energy conservation. The matters to be studied are summarized below.

a. Start ejector

The start ejector is normally installed to exhaust air in the system at the beginning of the operation. Thus, it should be stopped when the condenser's internal pressure goes down below the standard level. (As the steam outlet is open to air, the system vacuum degree is subject to the starter ejector while it is working)

b. Establishment of operation conditions and management criteria

It is necessary to grasp steam consumption by measuring feed volume and setting an operation schedule and management criteria. We checked a chart where steam consumption was plotted by the hour. But it was old data and we heard that it was not relevant to the current condition because the feed volume increased.

c. Review of steam ejector

While a steam ejector system can provide required vacuum degrees in a short time, it consumes large volumes of steam and should be reviewed in terms of energy conservation. If appropriate operation conditions are established, it may be possible to gain required vacuum degrees by vacuum pump.

d. Prevention of air from entering the system

It is undesirable that the air sneaks into the system during the system at work in terms of productivity and energy conservation. It is necessary to understand the present condition and take preventive measures.

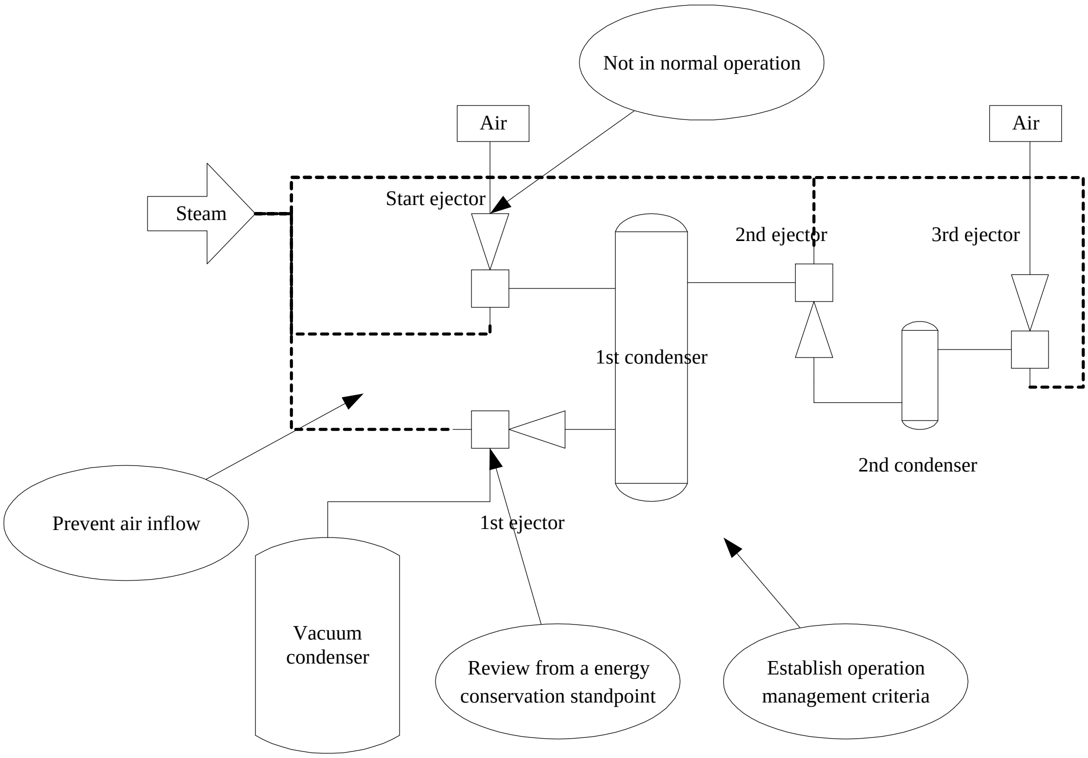


Figure II-5-1　Improvement of Vacuum Condenser

3) If it is assumed that about 20 steam traps are installed in each line, a total number of drain traps and drain recovery systems for the 5 lines combined will be more than 100 in the entire factory. On the site, steam leakage was often observed. It is important to carry out regular checkups and repairs.
As drain recovery is not carried out in the lines of Sweeten Condensed Milk and Evaporated Milk, it should be recovered as much as possible with the installation of drain recovery tanks, etc.

(3) Cold water system

In Singapore, although there aren't incentives in electric rates for the thermal storage system as in Japan, it is necessary to reduce electric consumption through the efficient operation of cold water system. Costs of refrigerating water and the measures to reduce costs are discussed below.

1) Operation of ice thermal storage tank
The log sheets of the cold water system show that accumulated heat (cold) increases from about 7 A.M. and storage is completed at about 2 P.M. We checked it on the site and found that heat (cold) storage and heat (cold) release were controlled only by the thickness of the ice produced, not under

a predetermined schedule. In other words, when the freezing machine's capacity is not used up as a result of the changing production demand, heat (cold) is stored and when the capacity is used up, heat (cold) is released. We heard that thermal storage was in operation 3 hr/d actually.

Judging from the survey results, this thermal storage system is intended for "supply of 0℃ water" rather than "storage". Thus, the freezing machine has reserve capacity to the load of the process and is not effectively functioning for "peak-cut" of electricity use and reduction in freezing equipment cost expected from the introduction of a thermal storage system. In addition, off-peak electric rates are not so advantageous compared to the peak rates for proactively promoting thermal storage and save electricity costs.

It appears that 2 different types of thermal storage tanks are connected in parallel with each other by piping and controlled under their common operation method. They should normally have different operation methods and management criteria. Although we could not confirm it, we assume that improvements are worth making.

2) Cold water piping system

There are 3 cold water piping systems for: Vitagen line (level 3), Juice line (level 3) and Milk line (level 5). Only the system for Vitagen is an open-loop piping having a cold water return tank and other systems are closed-loop piping. The respective cooling water pumps are in operation throughout the production time and consume large quantities of electricity.

a. Cooling water pump control

Cold water is supplied to the respective heat exchangers to cool products and tanks. Its flow volume is controlled either automatically or manually. Although we could not grasp changes in flow volume, the effects of inverter control should be studied.

b. Preset chilled water temperature

For a cooling purpose, 0°C chiller water and about 30°C cooling tower water are used in the process. Cooling tower water is used for the primary cooling of high-temperature products and chiller water is used for the secondary cooling so as to save energy.

(4) Receiving/transforming equipment

1) Operation of transformer

Based on the electric charge slip for October 2003, the capacity of the electricity receiving equipment is calculated as follows: 1736 kW/0.96 = 1,808 kVA. Electricity is received via 2 MVA transformers.

2) Improvement in power factor
The current power factor is about 96% and may be further improved.

5.2 Audit and Measurement Results of SCM

(1) Energy management

Equipment directly related to production is maintained well and operated in a good condition. However, efforts for energy conservation are not sufficient and no management criteria and no goals for monitoring and energy conservation have ever been set. As we could recognize potential energy conservation even from a short-time audit, we believe that great effects can be expected if a proper energy management methodology is established, and goal setting, the determination on monitoring items based on the methodology and the goals set and the assessment of results, etc are implemented.

(2) Air conditioning

A strict humidity control is required because raw materials and products handled in the factory are powder and fine particles. Currently the entire spaces of the production room and the blending room are respectively air-conditioned. As regards the air conditioning of the production room, if local air-conditioning is introduced for the area of packing machines, energy consumption can be reduced. Humidity in the production room is not even, causing overcooling in some areas. Further energy conservation can be expected from the equalization of the air distribution and the installation of multiple sensors.

(3) Air compressor

In the first site survey, we made comments on the management of the number of compressors to put in operation. At the time of the second survey, a plan to shift from the operation with only one compressor of 125 HP to the controlled operation with 3 compressors of 30 HP, 50 HP and 50 HP was underway.
(A plan to purchase a new compressor of 50 HP and transfer 2 compressors of 125 HP to affiliated companies)

(4) Lighting

Currently no energy conservation in lighting is studied. It is comparatively easy and cheap to take improvement measures and worth while to study them.

(5) Operation of transformer

Based on the electric charge slip for October 2003, the capacity of the electricity receiving equipment is calculated as follows: 749 kW/0.88 = 851 kVA. Electricity is received via 2 MVA transformers.
If equal load on each transformer is assumed, their respective load factors are
851 kVA/2/2 MVA = 0.21 (21%)
The operation efficiency is 96–97%. When the load factor goes below 40%, it should be considered to stop the operation of one transformer.

1) Improvement in power factor
   The current power factor is about 88% and may be further improved.

6. Energy Conservation Proposals and Expected Effects

6.1 Proposals to Co. C and Expected Effects

(1) Review of boiler pressure setting

The maximum steam pressure required in the process is 6kg/cm^2. It is possible to lower the set boiler pressure to 8 kg/cm^2 by enhancing heat insulation of the steam piping. If boiler pressure is lowered to 8 kg/cm^2;

- Boiler efficiency: Assumed to be unchanged
- Steam latent heat for 10 kg/cm^2: 477.2 kcal/kg
- Steam latent heat for 8 kg/cm^2: 484.5 kcal/kg
- Fuel cost (annual): 1,300,000 S$
- Annual fuel saving = approx. 1,300,000 S$ × (1-477.2 kcal/kg / 484.5 kcal/kg
  = 19,600 S$/year

(2) Enhancement of heat insulation of piping and prevention of heat loss

Steam saving amount is estimated regarding the main steam piping the length of which is clearly known.

- Boiler efficiency: 85%
- Calorific value of light oil: 9,200 kcal/L
- Light oil unit price: 0.406 S$/L
- Feed water unit price: 2.2 S$/m^2 (0.0022 S$/L)
- Annual operation time: 6552 hr/y
- 10kg/cm2 steam latent heat: 477.2 kcal/kg
- Reduced heat loss: 4,0827 kcal/hr (See the table below)

Table II-6-1 Estimation of Heat Losses of Steam Piping

Piping Size	Unit	80A			100A			150A			200A		
		Pipe	Valve	Flange	Pipe	Valve	Flange	Pipe	Valve	Flange	Pipe	Valve	Flange
Heat Loss from Bare portion	kcal/hr.m	650	813	273	850	1080	332	####	1950	585	####	2856	748
Thickness of Insulation	mm	50	50	50	50	50	50	50	50	50	50	50	50
Heat Loss after Insulation	kcal/hr.m	65	81	27	85	108	33	130	195	59	170	286	75
Reduced Heat Loss	kcal/hr.m	585	731	246	765	972	298	####	1755	527	####	2570	673

Length of Piping	ft	242			460			211			460		
		74			140			64			140		
Number of Valve and Flange			2	7		5	14		2	6		5	14
Total Heat Loss	kcal/hr		1793	1808		4529	4172		3752	3377		#####	9414
													40827

Assumption;
Number of Valves 1 Valve for each 30 m of Piping
Number of Flange 1 pair Flange for each 10 m of Piping

Enthalpy of 10kg team 478 kcal/kg
Total Steam Loss 85 kg/hr

Annual fuel cost saving amount

= 40827 kcal/hr / (9200 kcal/L × 85%) × 6552 hr/y × 0.406 S$/L = 13900 S$/y

Annual feed water cost saving amount

= 40827 kcal/hr / 477.2 kcal/L × 6552 hr/y × 0.0022 S$/L = 1230 S$/y

- Enthalpy of 70°C feed water: 70 kcal/kg
- Enthalpy of 10 kg/cm^3 steam: 634 kcal/kg

Steam cost (estimate) = 0.406 S$/L / (9200 kcal/L × 85% /
(634 kcal/kg - 70 kcal/kg)) + 0.0022 S$/kg
= 0.0315 S$/kg

Although we could not confirm the entire piping system in the current audit, we suspect that there is more heat loss from branch steam piping. Thus, the potential for energy conservation by strengthening heat insulation of the piping may be about several times of the above values.

(3) Improvement of vacuum condenser

Steam ejectors for the vacuum condenser consume large quantities of steam. The effects expected from the replacement of steam ejectors by vacuum pumps have been estimated. However, as the operation conditions for the current vacuum evaporator are not clear, the following assumptions have been used. The system structure with vacuum pumps is shown below.

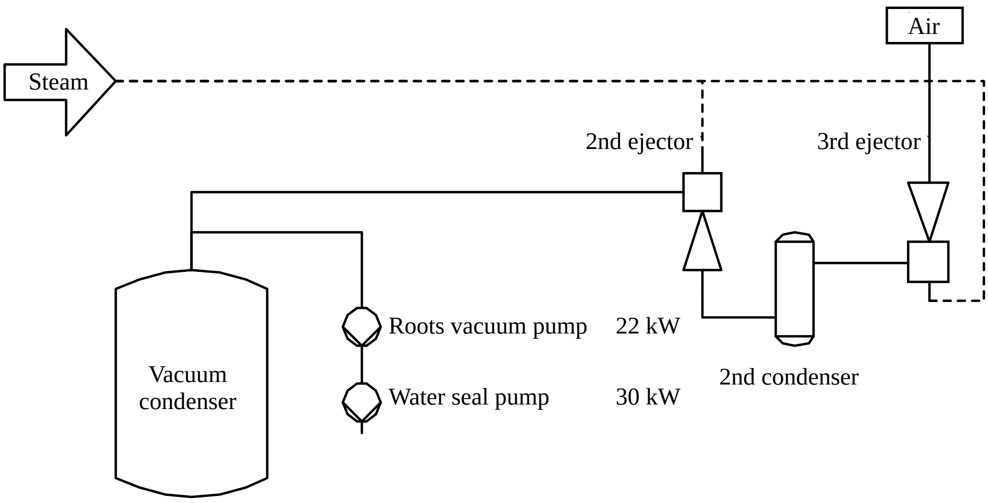


Figure II-6-1 Study of Vacuum Condenser Using Vacuum Pumps

1) Vacuum pumps to be used

a. Operation

- In 15 minutes from the starting of operation of vacuum ejectors, 40°C saturated steam pressure (55.32 mmHg) is reached. Steam consumption during that time is assumed at 900 kg/hr.
- After 15 minutes, the 1st ejector is stopped and only the 2nd and 3rd ejectors are put in operation. Steam consumption during that time is assumed at 300 kg/hr. When 20°C saturated steam pressure (17.54 mmHg) is reached, the condensation is completed.

b. Initial state of raw material

- Temperature 60°C
- Latent heat of vaporization 563.3 kcal/kg
- Specific heat 1.0 kcal/kg･°C

c. Estimation of condensate water volume

As we could not confirm the required volume of condensate water on the site, we have estimated as follows:

Calculations of volumes of feed raw material, partly-finished product and required condensate water for production of 4,200 L of product:

- Feed raw material (60°C): X_{60}L
- Partly-finished product (40°C): X_{40}L

The required condensate water is gained from the following formulae

$(X_{60} - X_{40}) \times 563.3$ kcal/kg $= X_{40} \times (60°C - 40°C) \times 1.0$ kcal/kg･°C (A)

$(X_{40} - 4200L) \times 563.3$ kcal/kg $= 4200L \times (40°C - 20°C) \times 1.0$ kcal/kg･°C (B)

From (A) and (B),

$$X_{60} = 4503L,\ X_{40} = 4349L$$

The required condensate water volume

$= X_{60} - X_{40} = 4503L - 4349L = 154L$

This amount corresponds to steam of 191.6 m^3 in a standard state.

d. Calculation of necessary air volume displacement of vacuum pump

If space capacity of the evaporator is assumed at 5.0m3, the required air volume displacement will be calculated as follows;

Air volume displacement

$= (191.6\ m^3 + 5.0\ m^3) / 15\ min \times 1n\ (760\ mmHg / 55.32\ mmHg) \times 60\ min/h$

$= 2008\ m^3/h$

e. Vacuum pumps to be used

In the light of vacuum, a combination of a roots vacuum pump and a water seal vacuum pump is employed.

According to the maker’s catalog, their respective electric motor powers are:

Roots vacuum pump: 22 kW
Water seal vacuum pump: 30 kW
The installation cost if about 9,300,000 yen in Japan's market price (approx. 143,000 S$)

2) Estimated effects

a. Reduction in steam consumption

Steam cost: 0.0315 S$/kg as already calculated in the previous item (2)
Annual operation hours: 6552 hr/y (273 d/y)
No. of batches: 32 batches/d
Reduction in steam consumption
= (900 kg/h - 300 kg/h) × 15/60h × 32 batches/d × 73 d/y
= 1,31,0400 kg/y
Reduction in steam cost
= 1,310,400 kg/y × 0.0315 S$/kg = 41,277.6 S$/y

b. Electric consumption of vacuum pumps

Electric cost: 0.112 S$/kWh (from the survey report)
Electric consumption of vacuum pumps
= (22 kW + 30 kW) × 15/60 h × 32 batches/d × 273d/y
= 113,568kWh
Electric power charge
= 113,568 kWh/y × 0.122 S$/kWh = 13,855.3 S$/y
Total cost reduction effect is
(41,277.6 S$/y - 13,855.3 S$/y = 27,422.3 S$/y)

(4) Inverter control of cooling water pump

In the factory, 3 pumps (5 kW, 7.5 kW, 11 kW) for 3 cooling water lines are constantly in operation. We have estimated effects of the introduction of inverter control with an assumed average load factor at 60%.
We assumed a constant pressure in piping for inverter control as the figures below shows.
It is desirable that a pressure sensor is installed as distant as possible. (point C in the illustration)

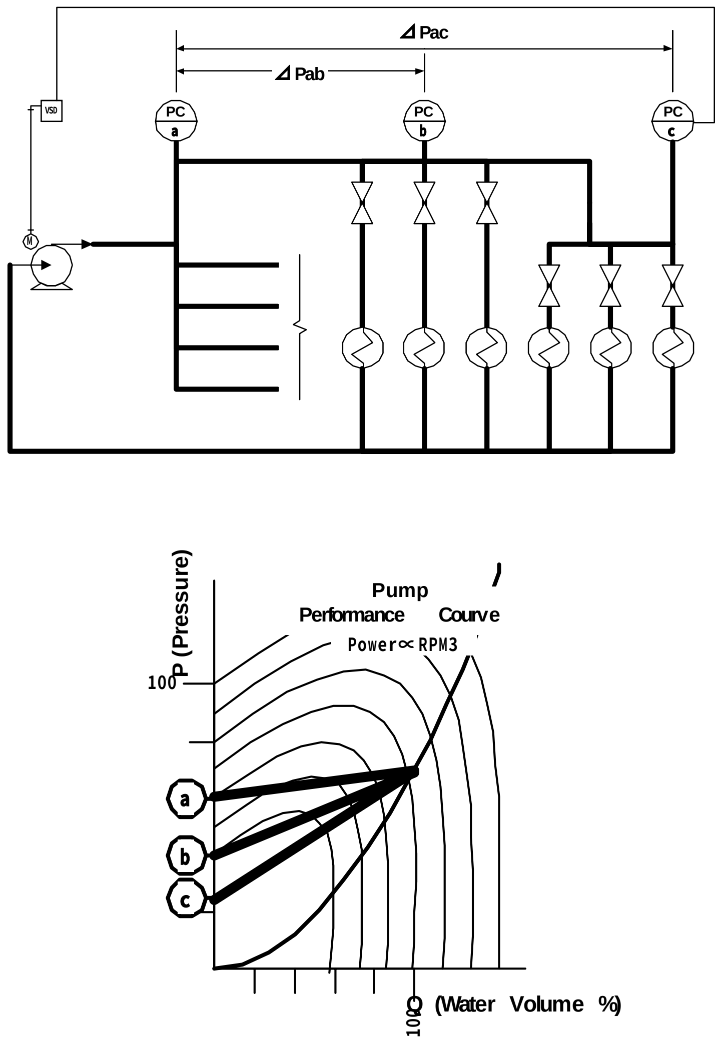


Figure II-6-2 Inverter Control of Cooling Water Pump

1) Estimated effects

a. Reduction in electric consumption

Electric consumption rate under valve control at 60% load factor:

90%

Electric consumption rate under inverter control at 60% load factor:

30%

Reduced power consumption

= (5 kW + 7.5 kW + 11 kW) × (90% - 30%) × 552 h/y

= 92383.2 kWh/y

Reduced power charge

= 92383.2 kWh/h × 122 S$/kWh = 11270.8 S$/y

b. Investment in equipment

Inverter (3 sets)	350,000 yen
Controller	750,000 yen
Remodeling of power board	?
Installation cost	200,000 yen
Total	1,300,000 yen (= 20,000 S$)

(5) Improvement of transformer efficiency

If the 2 transformers (2 MVA × 2) are in an evenly load-balanced state;
Load factor is: 1808 kVA / 2 / 2 MVA = 0.45 (45%) and efficiency is 97-98%. Under the condition of load factor below 40% each, one transformer should be stopped.

1) Estimated effects

If it is assumed that the load factor drops below 35% and the efficiency decreases by 1%,

Annual electric consumption: 9,800,000 kWh/y
Power factor: 96%
Average electric power cost: 0.122 S$/kWh
Reduced electric consumption:
9,800,000 kWh/y / 96% × % = 102,083 kWh/y
Reduced electric power charge:
102,083 kWh/y × 0.112 S$/kWh = 12,454 S$/y.

(6) Improvement of power factor

The electric power charge for October 2003 includes a charge for reactive power. The yearly total amount of the charge for reactive power will be measurable. It is worth reviewing.
Reduced electricity charge = 147,386 S$ × 12 = 17,686.32 S$/y

6.2 Proposals to SCM and Expected Effects

(1) Local air conditioning

The production room has an area of 2500 m^2 and its ceiling is 6.7 m high. It is a huge space (Space capacity: 16,750 m^3). In that space, it is a limited area to which raw materials, etc. in fine particles are actually exposed. If this area is partitioned and locally air-conditioned, energy consumption may be reduced. The basic concept is as follows;

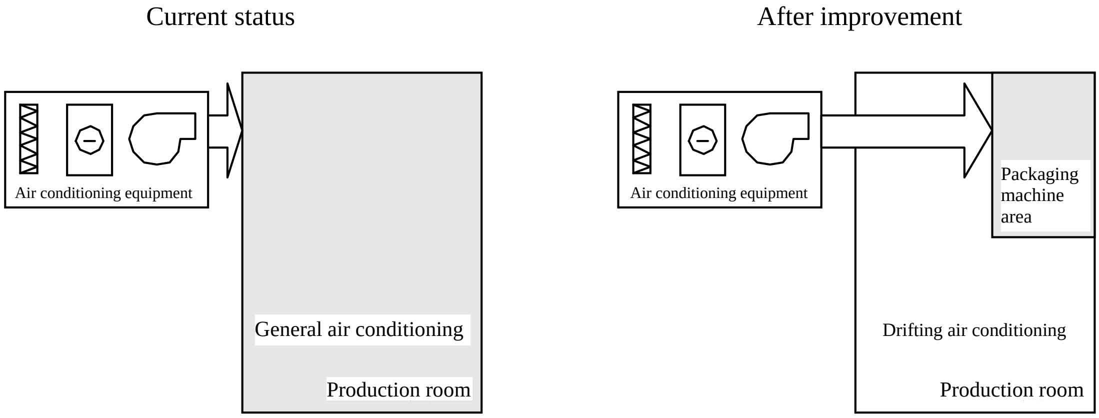


Figure II-6-3 Basic Concept of Local Air Conditioning System

1) Estimations of the area for local air conditioning and electricity used for air conditioning

   a. Estimations concerning the area for local air conditioning

      Floor area: 720 m^2

      Necessary ceiling height: 4.5 m

      Cubic capacity of the area for local air conditioning

      = 720 m^2 × 4.5 m = 3,240 m^3

   b. Estimations of electricity used for air-conditioning

      Operating durations of the air conditioning equipment were estimated based on the assumption of yearly manufacturing days and daily manufacturing hours at 260 days/y and 8 hours/d respectively.

      Two units are in operation (during manufacturing):

      Operating hours for 2 units = 260 days × 8 hours/d = 2,080 h/y

      One unit is in operation (during non-manufacturing):

      Operating hours for one unit

      = 365 days × 24 hours/d - 2,080 h = 7,045 h/y

      We assumed load factor of 70% and that load of manufacturing equipment would not significantly affect load on air conditioning equipment because they are packaging and conveying equipment.

      Current air conditioning electricity

      = (208 kW × 2,080 h/y + 104 kW × 7,045 h/y) × 70%

      = 815,724 kWh/y

      Local air conditioning electricity

      = 815,724 kWh/y × 3,240 m^3 / 16,750 m^3 = 157,788 kWh/y

      Reduced electricity

      = 815,724 kWh/h - 157,788 kWh/y = 657,936 kWh/y

2) Estimated effects

The above calculations show that a significant energy conservation effect is expected. However, as measures for the currently air-conditioned area and prevention of incoming heat must be taken into account, the effect should be estimated at 50%

Reduced electric consumption = 657,936 kWh/y × 50% = 328,968 kWh/y

Reduced electric charge = 328,968 kWh/y × 0.122 S$/kWh = 40,34 S$/y

(2) Equalization of temperature distribution

If a damper is set at each blowout outlet of the duct and the temperature is controlled by individual temperature sensors, an even temperature distribution may be possible. In addition, by introducing inverter control of revolution frequencies of fans of air conditioners, further energy conservation can be expected (VAS control). The basic concept is shown below.

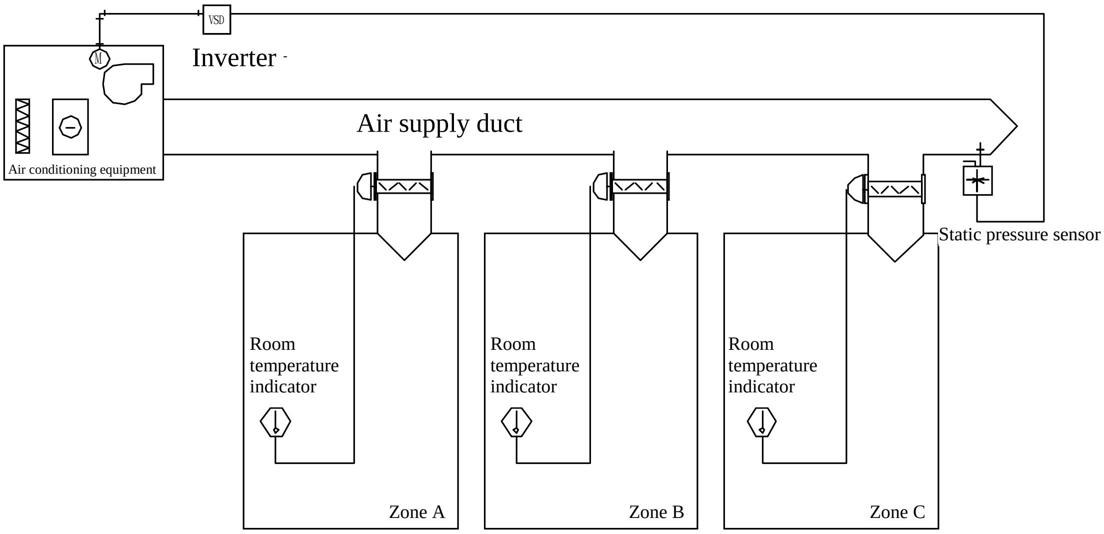


Figure II-6-4 Basic Concept of Equalization of Temperature Distribution

(3) Improvement of operation of air compressor

Change to a no. of units-controlling operation with 3 air compressors of 30HP-50HP-50-HP is planned.

(4) Energy conservation of lighting

Lighting fixtures are fixed on the ceiling of the production room and all lights are on during manufacturing. It will be possible to save energy by grasping the current energy consumption for lighting and setting of appropriate standards of illumination.

(5) Improvement of transformer efficiency

While the capacity of the receiving equipment is 749 kW / 0.88 = 851 kVA, the current transformer load factor is only 20%. By shifting to one-transformer operation (Out of the two, one is reserved for backup), the efficiency increases by about 1%. If electricity consumption and power factor are assumed respectively at 285,000 kW and 88%,

Reduction in electric consumption

$= 285{,}000 \text{ kWh} \times 12 \text{ m/y} / 88\% \times 1\% = 38{,}864 \text{ kWh/y}$

Reduction in electric charge = $38{,}864 \text{ kWh/y} \times 0.122 \text{ S\$/kWh} = 4{,}941 \text{ S\$/y}$

(6) Improvement of power factor

Although we were reported a 99% power factor in the site survey, the value estimated from the electric power charge slip is 88%. However it does not include a charge for reactive power. (It is necessary to check electric power charge system)

6.3 Summary of Energy Conservation Effects

(1) Summary of energy conservation effects for Co. C.

Table II-6-2 Energy Conservation Effects for Co. C.

Proposals	Estimated effects	Equipment investment	Remarks
Review of boiler pressure setting	19600 S$/y	Not required	
Enhancement of heat insulation of piping and prevention of heat loss	15130 S$/y	Estimation not possible	Was estimated only about the main piping. Further effects to be expected from improvements on branch piping.
Improvement of vacuum condenser	27422 S$/y	143000S$	Replace steam ejectors by vacuum pumps
Inverter control of cooling water pump	11270 S$/y	20000S$	
Improvement of transformer efficiency	12454 S$/y	Estimation not possible	
Improvement of power factor	17686 S$/y	Estimation not possible	
Total	103562 S$/y		

(2) Summary of energy conservation effects for SCM

Table II-6-3 Energy Conservation Effects for SCM

Proposals	Estimated effects	Equipment investment	Remarks
Local air conditioning	40134 S$/y	Estimation not possible	
Equalization of temperature distribution	Estimation not possible	Estimation not possible	
Improvement of operation of air compressor	In progress	In progress	
Energy conservation of lighting	Estimation not possible	Estimation not possible	
Improvement of transformer efficiency	4941 S$/y	Estimation not possible	
Improvement of power factor	Estimation not possible		

7. Guideline for Promotion of Energy Conservation and Audit Manual

7.1 Outline of Production Process

The production process of food factories is often distinguished from manufacturing processes of other industrial products in the following points;

- A large number of production items
- Variation in ingredients
- Micro organism management

The batch process is generally used. In the food manufacturing industry, it is difficult to determine energy unit consumption that is used for energy management except in food material manufacturing industry (flour, sugar, fat and oil, etc.), beer brewery, beverage manufacturing, etc. In addition, as the same product is not always manufactured in the same process, macro-management based on the comparison of unit energy consumption among competitors is often inapplicable. In this sense, it will be necessary to understand the current energy consumption status by factory, building, production line, etc. and prioritize improvements of the respective processes based on the potential for energy conservation and financial and human resources in order to achieve improvement one by one. The goals of improvement will be determined based on the analysis of daily log data. The manufacturing processes of the major products of the factories we visited for audits are shown below.

(1) Processes used in the dairy products factory of Co. C

1) Sweeten Condensed Milk

Major energy consuming processes are as follows;

a. Steam Vacuum condenser, pasteurizer

b. Electricity Homogenizer

c. Cold water Cooling for inter tanks

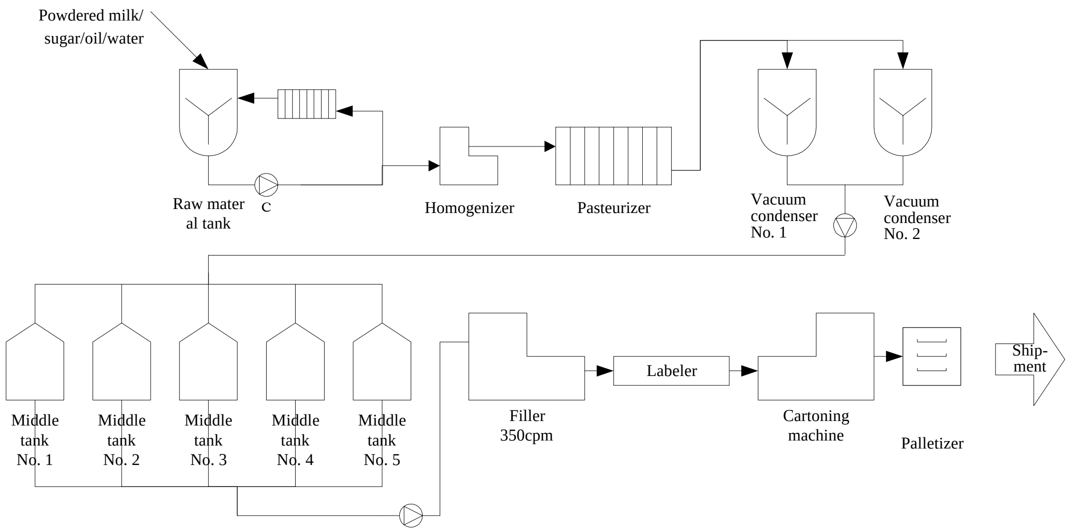


Figure II-7-1 Process of Sweeten Condensed Milk

2) Evaporated Milk

Major energy consuming processes are as follows;

a. Steam Pasteurizer, Rotary sterilizer

b. Electricity Homogenizer

c. Cold water Cooler, Cooling for inter tanks

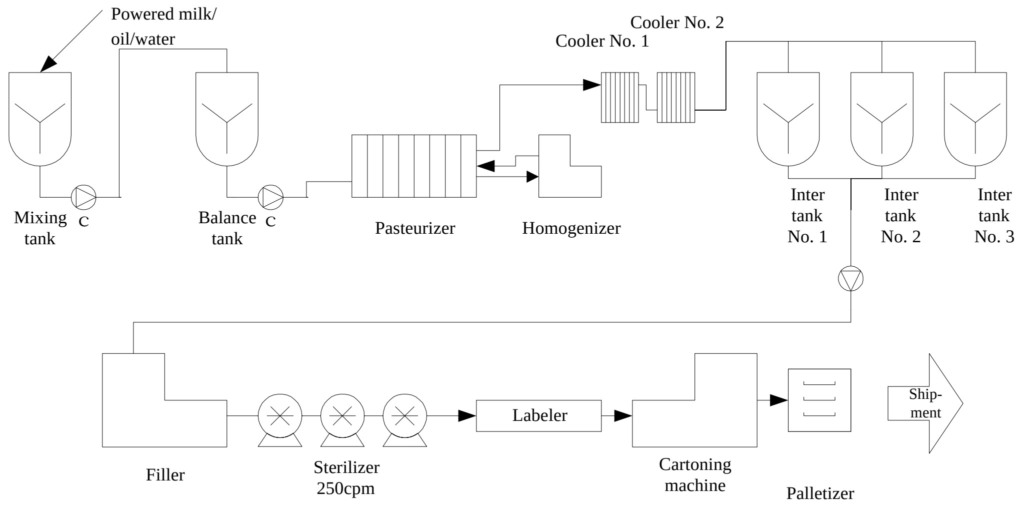


Figure II-7-2 Process of Evaporated Milk

3) Pasteurized Milk

Major energy consuming processes are as follows;

a. Steam Pasteurizer, Sterilizer

b. Electricity Homogenizer

c. Cold water Sterilizer, Cooling for inter tanks, Cooler

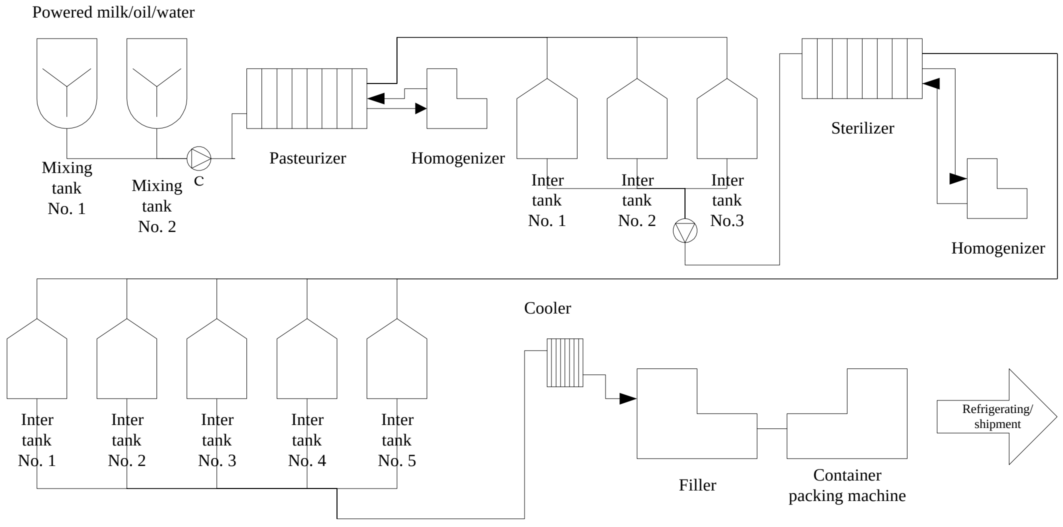


Figure II-7-3 Process of Pasteurized Milk

(2) Processes used in SCM

The major energy consuming process is shown below.

1) Coffee mix/packaging process

a. Electricity Air conditioning, Air compressor

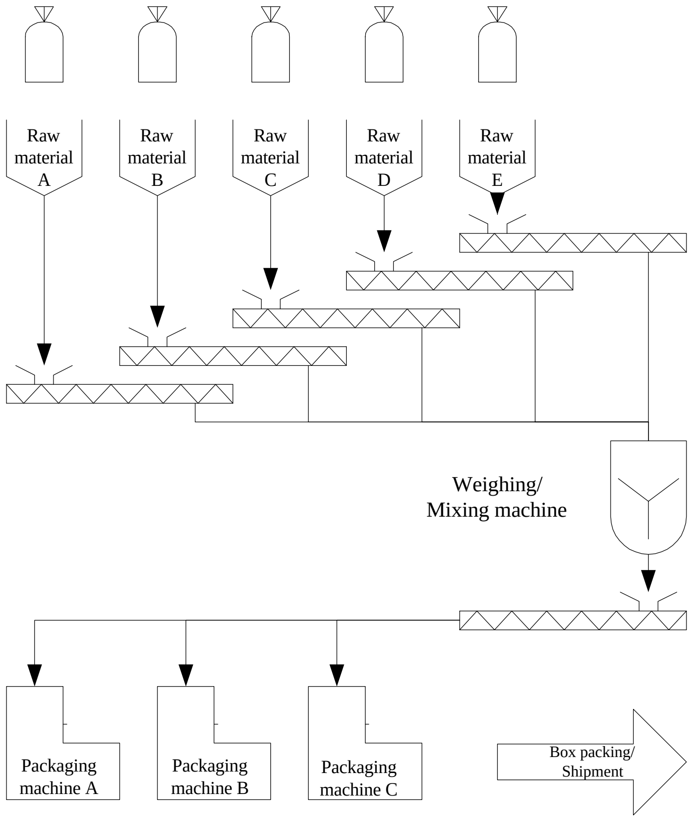


Figure II-7-4 Process of Coffee Mix

7.2 Guideline for Promotion of Energy Conservation and Audit Manual

On the site, we explained identification of problems by checklist and guideline for promotion of energy conservation using slide pictures. Relevant and necessary slides are excerpted from those used on the site and attached hereto as Attachments.

Attachment

Attachment II-1	Check Items at Factory Energy Audit (Excerption from presentation slides used in the field)
Attachment II-2	Guideline for Promotion of Energy Conservation (Excerption from presentation slides used in the field)

添付資料 II ー1

Check Items at Factory Energy Audit

The Energy Conservation Center, Japan

ECCJ 1

Items to be Checked for Factory Energy Audits

1. General Management (1/2)

1. Energy management	• Organization setup and personnel training • Consistency with environmental management • Energy conservation targets and investment budget • Mid-and-long term planning • Use of public preferential system • State of energy conservation implementation
2. State of measuring and recording	• State of installation and use of measuring instruments • State of maintenance and checks for measuring instruments • Implementation of periodic measurements and recording
3. Maintenance and management of equipment	• Periodic and daily checks • Repairing leaks (water, air and steam) • Thermal Insulation • Equipment cleaning (filters, strainers)
4. Energy consumption management	• State of daily record keeping • Daily consumption volume and daily load curve • Monthly consumption volume and year- on- year comparative graphs

ECCJ 2

1. General Management (2/2)

5. Managing major products by energy intensity	• Energy intensity against shipping value • Energy intensity against production volume
6. Environment related management	• Prevention measures against global warming State of reduction measures against CO_2 emission • Utilization state of the energy conservation, recycle support law (energy conservation measures, promotion using recycle resources, measures against ozone layer destruction: introduction of freon-free type equipment, etc.) → presence of project application, projected time • Using state of "LCA" (Life Cycle Assessment) (procurement → production → use → disposal/recycle) •Disposal of wastes: measures for volume reduction, segmentation, resource recycling • Waste water treatment • LCA: Evaluation of effect on environment in an overall flow (materials procurement, production, uses, disposal and recycle)
7. Process improvement	• Operation improvement • Line reviews • Use of continuous production, higher efficiency, etc.

ECCJ 3

2. Air Conditioning and Cooling Systems (1/2)

1. Operation management	• Optimization of setting temperature and moisture • Reduction in intake of outside air • Management of unit numbers in operation of heat source equipment • Change in temperature setting at cold water outlet • Operation on schedule • State of shutoff of outside air inflow and ventilation • Radiation heat insulation for high temperature equipment
2. Energy conservation measures	• Enhancement of building insulation, shield against insolation • Use of outside air • Recovery of exhaust heat, heat pumps • Revolution control (VAV etc.) • Local cleaning, local exhaust ventilation • Reduction in air-conditioning volume • Use of ice thermal storage system

ECCJ 4

2. Air Conditioning and Cooling Systems (2/2)

3. Operation management for cooling equipment	• Operating power of refrigerators • Inlet/outlet pressures of refrigerant • Inlet/outlet temperature and pressure of water
4. Operation management for auxiliary equipment	• Operating power of cooling towers • Water quality control (Electric conductivity) • Pump operation power (water volume, lifting range) • Higher efficiency
5. Cold insulation/freezing equipment	• In/out control • Thermal insulation control

3. Pumps, fans, compressors, co-generations, etc.

1. Operation management for pumps and fans	• State of valve opening/closing • Route modification (piping and ducts) • Flow-rate and operating pressure • Design margin check • Control of revolution and number of units in operation
2. Operation management for compressor systems	• Type review (screw/reciprocal/ blower) • Capacity and model matching • Reducing discharge pressure and final working pressure • Dividing high/low pressure lines • Ventilating systems and surrounding temperature • Review of piping size and route • Air receiver installation • Number control of units in operation • Capacity optimization control • Countermeasures to leakage • Use of waste heat

4. Boilers, Industrial Furnaces, Steam Systems, Heat Exchangers, Waste Heat, Waste Water, etc. (1/2)

1. Managing boiler/furnace combustion	• Managing air ratio and exhaust gas • Burner, fuel and draft systems • Automatic combustion control system • Regenerative combustion system • Fuel conversion
2. Boiler/Furnace operation & efficiency management	• Load factor & state of starting/stopping • Controlling number of units in operation • Heat efficiency, heat balance, heat distribution • Water quality and blow management
3. Boiler/Furnace insulation and radiating heat prevention	• Furnace wall and duct temperature • Insulation and insulation materials (thermal storage loss) • Seals on openings and furnace internal pressure
4. Boiler/Furnace exhaust gas temperature management and waste heat recovery	• Exhaust gas temperature • Heat recovery (Feed water and air pre-heat) • Exhaust gas circulation
5. Operation management for steam	• Dryness and carry-over • System setting in steam pressure and temperature • Steam flow-rate

ECCJ 7

4. Boilers, Industrial Furnaces, Steam Systems, Heat Exchangers, Waste Heat, Waste Water, etc. (2/2)

6. Managing steam leaks and thermal insulation	• Piping system, tanks, etc. • Load side equipment
7. Optimizing steam piping systems	• Route and piping size • Eliminating unneeded pipes • Integrating multiple steam lines
8. Load leveling in steam system	• Accumulator installation • Modification from steam ejector to vacuum pump • Measures for load side
9. Recovery and use of steam drainage	• Steam pressure recovery (back pressure turbine) • Steam trap management • Drainage recovery point and system
10. Operation management for heat exchangers	• Model adequacy • Adequacy of use and heating medium • State of system maintenance (fouling and pressure loss) • Temperature of heating medium and materials heated
11. Reducing waste heat and waste water	• Recovery heat from hot water • Streamlining waste air ducts •Circulating cooling water for reuse • Managing impurity concentration in water

ECCJ 8

5. Power Receiving/Transforming Equipment, Motors, Lighting and Electric Heating Systems (1/2)

1. Power receiving equipment management	• Managing demand, load factor and power factor • Managing consumption • Charges management (contracted power) • Use of nighttime power
2. Substation facilities management	• Transformer capacity and voltage • Demand factor and load adjustment • Unneeded loads shutoff
3. Motor capacity and operation management	• Equipment capacity, voltage, number of units in use • Revolution control • Non-load operation stop
4. Operation management of lighting systems	• Use of high efficiency lamps and fixtures • Use of automatic flashing and localized lighting • Light installation location and divided circuitry • Proper illumination management • Turn off lights when unnecessary and use daylight • Cleaning or changing lighting fixtures
5. Operation management of electric heating systems	• Improvements in supply voltage and power factor • Material preheating at product in/out • Temperature and heating management • Insulation management • Load factor improvement • Continuous operation • Reuse of exhaust heat

ECCJ 9

5. Power Receiving/Transforming Equipment, Motors, Lighting and Electric Heating Systems (2/2)

6. Load leveling measures	• Reviewing operating pattern (operating time, operation rate, load factor, etc.) • Adaptation with proper equipment (accumulator, absorbing type cold/hot water equipment)
7. Electric power adjusting contracts, etc.	• Charges management (use of nighttime electricity) - Heat storing contract - Contracts in accordance with seasons and time zones - Peak time adjusting contract
8. Co-generation introducing plans	• Equipment type, capacity, fuels • Seasonal load fluctuation • Using rate, heat/electricity ratio • Checks, spare powers, measures against pollution
9. New energies etc.	• Fuel cell • Photovoltaic generation • Solar heat

ECCJ 10

添付資料Ⅱ－2

The Present Conditions of Food Industries in Japan

The Energy Conservation Center, Japan

ECCJ 1

Summary of Main Findings of "Walk Through" Audit

Energy management

- To establish good energy management
- To use of monitoring and targeting methodology

Steam System

- To strengthen insulation on piping and valves
- To stop steam leakage
- To reduce steam pressure
- To study the use of waste condensate
- To check and maintain steam traps

Power Receiving and Transformer

- To check power factor and load of transformer
- To record and check the power consumption

Fans and Pumps

- To study on adoption of inverters for Fans and Pumps

ECCJ 2

Summary of Main Findings of "Walk Through" Audit

Refrigeration

- To study of enhanced utilization of ice storage
- To reexamine the set temperature of cold room

Compressed air

- To check air leakage

Lighting

- To study the appropriate luminance at the separated zone

ECCJ 3

Voluntary Action Plans for EE&C of Japan Dairy Products Association

Type of business	Target for battle against global warming	Countermeasures
Dairy products [Japan Dairy Products Association]	Energy intensity should be cut down 0.5% of 1997 per annual rate of 5 years average between 1998 and 2002, and 1.0% of 1997 shall be cut down from 2003 to 2010. (Actual achievement was +1.3% in 1998.)	1. Regroup / integration of dairy factories beyond individual corporate frameworks, regroup of transportation method of milk and dairy products 2. Introduction of energy saving equipment like boiler/co-generation, saving of energy in refrigerator, de-CFC 3. Reduction of product defective fraction and product scrap, etc. by quality and distribution management 4. Review of frequency and a small amount of deliveries etc.

ECCJ 4

Energy Intensity of Food Processing Factories (1/2)

Type of industry		Beer brewing					
Plant name	Unit	All over plant			Kobe plant		
Fiscal year		1,999	2,000	2,001	1,999	2,000	2,001
Production	kl/y	2,857,000	2,737,000	2,580,000			
Electricity consumption	mWh/y	410,000	386,000	359,000			
Fuel consumption	ml/y	117,000	107,000	101,000			
Steam consumption							
Electricity intensity	kWh/kl	143	141	139	113	100	95
Fuel intensity	l/kl	41.1	39.1	39.2			
Steam intensity	t/kl				0.26	0.26	0.26

Type of industry		Beverage (Soft drink)					
Plant name	Unit	Kashiwa plant			Akashi plant		
Fiscal year		2,000	2,001	2,002	2,000	2,001	2,002
Production	kl/y	117,607	118,725	104,183	229,234	217,497	207,667
Electricity consumption	kWh/y	1,785,611	1,901,395	1,913,723	5,495,589	5,734,760	5,708,868
Fuel consumption	l/y	2,293,136	2,442,520	2,643,038	5,414,044	5,876,083	5,295,269
Steam consumption							
Electricity intensity	kWh/kl	15.18	16.02	18.37	23.97	26.37	27.49
Fuel intensity	l/kl	19.50	20.57	25.37	23.62	27.02	25.50
Steam intensity							

ECCJ 5

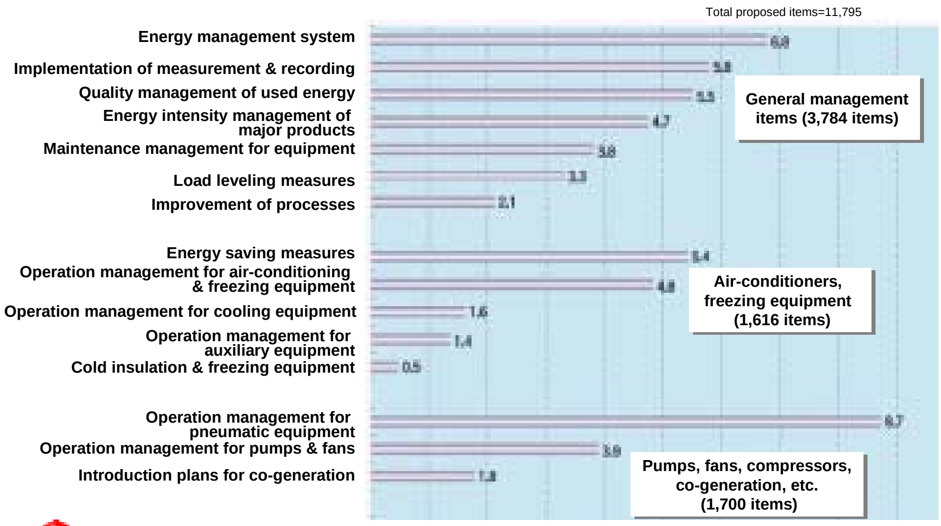
Energy Intensity of Food Processing Factories (2/2)

Type of industry		Dairy products					
Plant name	Unit	Sapporo	Atsugi	Noda	Nagoya	Fukuoka	Yokohama
Fiscal year		2,000	2,000	2,000	2,000	2,000	2,000
Production	t/y	74,451	81,279	74,829	70,791	60,559	24,203
Electricity consumption	mWh/y	10,993	20,814	14,974	13,253	13,308	10,418
Fuel consumption	kl/y	2,490	3,297	1,307	1,620	1,545	1,057
Steam consumption							
Electricity intensity	kWh/t	147.7	256.1	200.1	187.2	219.8	430.4
Fuel intensity	l/tn	33.44	40.56	17.47	22.88	25.51	43.67
Steam intensity							

Type of industry		Meat processing		
Plant name	Unit	All over plant		
Fiscal year		2,000	2,001	2,002
Production	t/y	132,000	135,000	149,000
Electricity consumption	mWh/y	157,081	154,470	161,990
Fuel consumption	kl/y	19,599	20,228	26,385
Steam consumption				
Electricity intensity	kWh/t	1,188	1,146	1,087
Fuel intensity	l/t	148	150	177
Steam intensity				

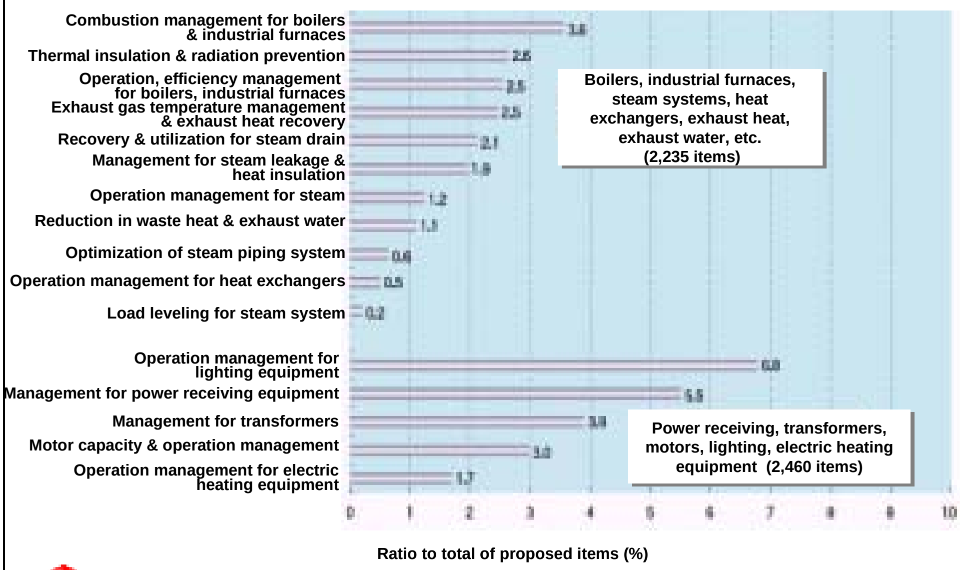
ECCJ 6

Improvement Items Proposed by Professional Auditors



ECCJ

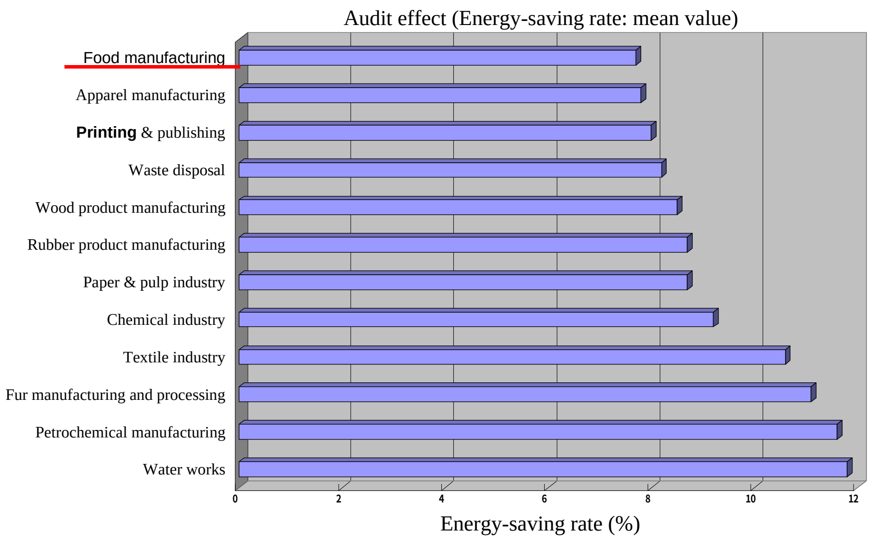
7



ECCJ

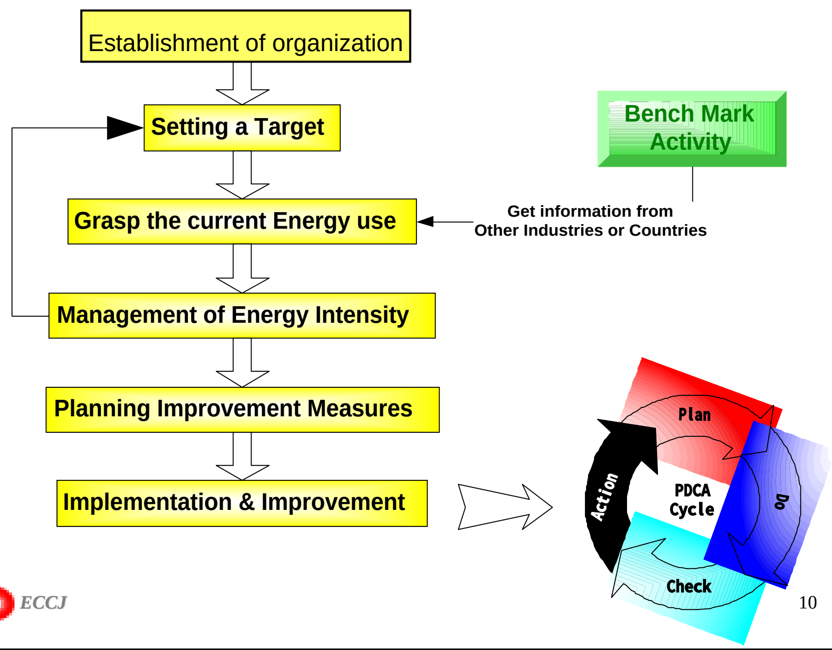
8

Audit Result
(Average energy-saving rate by industrial Sector)



ECCJ 9

Flow Chart of Energy Management



ECCJ 10

Energy Efficiency Improvement in Steam

Boiler

- Type
- Rating matching
- Type of burner
- Burner controls
- Combustion Monitoring and Control
- Adequate water treatment
- Heat recovery from flue gases
- On-line cleaning
- Heat recovery from blow-down

Distribution

- Pressure
- Pipe size
- Drainage
- Right steam trapping and air venting
- Maximize condensate return
- Insulation

End user

- Suitable pressure
- Steam trap and air vent
- Insulation
- Minimize film formation
- Temperature control

ECCJ 11

Recommendation for Steam System

Boiler

- Measurement of Boiler Efficiency

  Boiler efficiency is calculated from the amount of steam generating, and fuel consumption.
  When the amount of direct steam generating cannot be measured, it judges from the amount of water supply.

- Optimum Air Ratio = $0.21/(0.21-O_2)$

  O_2: Measured by Handy Type Oxygen Analyzer

- To Minimize Supply Steam Pressure

  Minimum pressure to satisfy process temperature

- To Reduce Heat Loss from Boiler Parts

  Valves, piping, water level gage, etc

ECCJ 12

Recommendation for Steam System

Steam Distribution

- **Minimize Leakage**

  If there is one 2mm hole on 5kg/ cm^2 steam piping, the amount of steam leakage will go up to 8kg/hr.

- **Maximize Condensate Return**
- **Improve Insulation Piping and Fittings**

Piping Size		25A Pipe	25A Valve	80A Pipe	80A Valve	100A Pipe	100A Valve
Heat Loss from Bare portion	kcal/h/m	225	272	550	825	700	1,100
Thickness of Insulation	mm	50	50	50	50	50	50
Heat Loss after Insulation	kcal/h/m	35	42	60	90	75	115
Reduced Heat Loss	kcal/h/m	190	230	490	735	625	985

ECCJ 13

Air/Fuel Ratio for Boilers

Standard Air/Fuel Ratio
Target Air/Fuel Ratio

(−)

Category		Load factor (Unit: %)	Solid Fuel: Fixed Bed	Solid Fuel: Fluidized Bed	Liquid Fuel	Gas Fuel	Byproduct Gas such as Blast Furnace Gas
Electric Power Industry Use		75~100	− −	− −	1.05~1.2 1.05~1.1	1.05~1.1 1.05~1.1	1.2 1.15~1.2
Others: Amount of Evaporation	>= 30t/h	50~100	1.3~1.45 1.2~1.3	1.2~1.45 1.2~1.25	1.1~1.25 1.05~1.15	1.1~1.2 1.05~1.15	1.2~1.3 1.2~1.3
Others: Amount of Evaporation	30t/h > >=10t/h	50~100	1.3~1.45 1.2~1.3	1.2~1.45 1.2~1.25	1.15~1.3 1.15~1.25	1.15~1.3 1.15~1.25	− −
Others: Amount of Evaporation	10t/h > >=5t/h	50~100	− −	− −	1.2~1.3 1.15~1.3	1.2~1.3 1.15~1.25	− −
Others: Amount of Evaporation	5t/h >	50~100	− −	− −	1.2~1.3 1.15~1.3	1.2~1.3 1.15~1.25	− −

ECCJ 14

Waste Gas Temperature for Boilers

Standard Air/Fuel Ratio
Target Air/Fuel Ratio

(℃)

Category			Load factor (Unit: %)	Solid Fuel		Liquid Fuel	Gas Fuel	Byproduct Gas such as Blast Furnace Gas
				Fixed Bed	Fluidized Bed			
Electric Power Industry Use			75~100	– –	– –	145 135	110 110	200 190
Others	Amount of Evaporation	>= 30t/h	50~100	200 180	200 170	200 160	170 140	200 190
		30t/h > >=10t/h	50~100	200 180	200 170	200 160	170 140	– –
		10t/h > >=5t/h	50~100	– –	– 300	200 180	200 160	– –
		5t/h >	50~100	– –	– 320	250 200	220 180	– –

ECCJ 15

Equipment for which the Power Factor should be Improved

Equipment Name	Capacity (Units: kW)
Cage-Type Induction Motor	75
Coil-Type Induction Motor	100
Induction Furnace	50
Vacuum Melting Furnace	50
Induction Heating Equipment	50
Arc Furnace	---
Flash-Bat Welder (excluding portable types)	10
Arc Welder (excluding portable types)	10
Rectifier	10,000

ECCJ 16

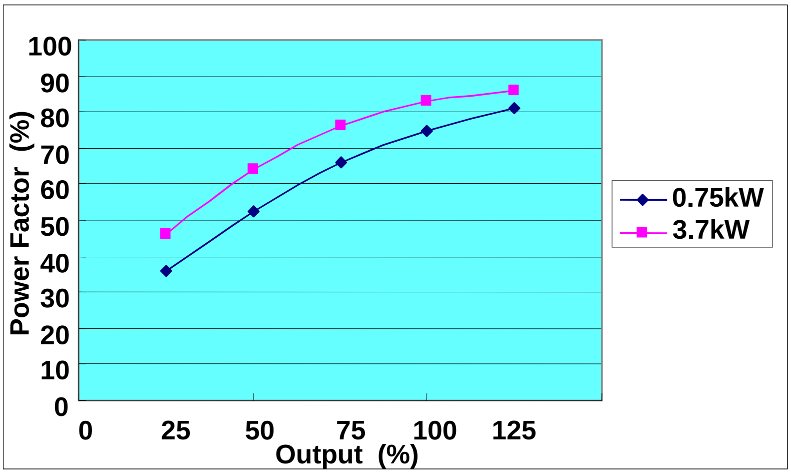
Target Efficiencies for High-efficiency, Totally Enclosed Type Electric Motor

(0.2 – 37kW)

Output (kW)	Standard Efficiency at Full Load (%)					
	2 Poles		4 Poles		6 Poles	
	50Hz	60Hz	50Hz	60Hz	50Hz	60Hz
0.2	73.8	75.3	72.6	75.4	–	–
0.4	78	79.4	77.5	80	74.6	78
0.75	81.8	82.4	81.4	83.2	80	82
1.5	84.4	84.8	84.4	85.8	83.5	85
2.2	86.5	86.3	86.6	87.6	85.8	86.8
3.7	88	87.8	88.4	89.2	87.4	88
5.5	89.3	89	89.8	90.3	88.8	89.3
7.5	90.4	90	90.8	91	89.8	90.3
11	91.2	90.8	91.6	91.8	90.8	91.2
15	91.8	91.5	92.2	92.2	91.6	91.8
18.5	92.4	92	92.6	92.6	92.2	92.4
22	92.9	92.3	93	92.8	92.7	92.8
30	93.3	92.6	93.3	93	93	93
37	93.5	92.8	93.5	93.2	–	–

ECCJ 17

Power Factor of Induction Motor



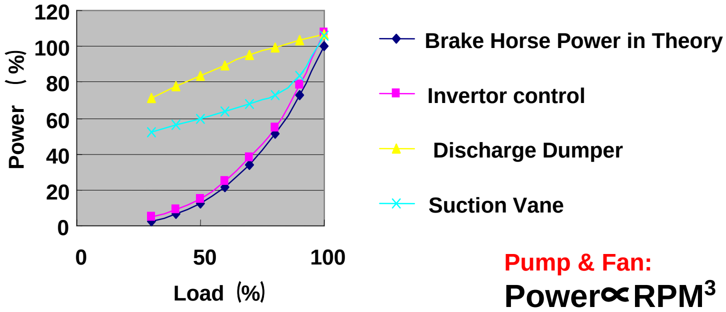
ECCJ 18

Refrigeration

- **Chilled Water Pump Control**

  Inverter control is good for continuous running machine

Power Consumption Rate of Fan or Pump



Pump & Fan:

Power∝RPM^3

ECCJ

Compressed Air System

- **Compressor Selection:**

  Type: Small size = Reciprocal type
  Medium size = Screw type
  Large size = Turbo type

  Selection: Lubrication or oil-less,
  Number of compression stage,
  Level of vibration and noise,
  Capacity and Control method

- **Control of number of compressors in operation:**

  High compressor efficiency is kept during partial load

- **The first to start is saving on the process side.**

  \- Control optimum air pressure, reduce leakage & blow-off.

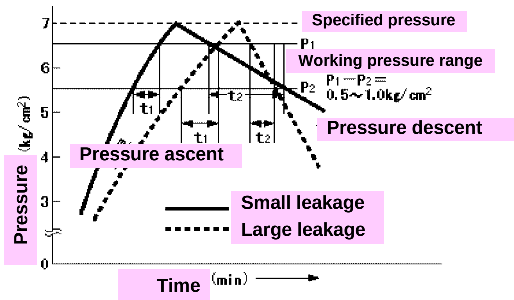
ECCJ

To check air leakage

- To check air leakage

L: Air leakage per cent

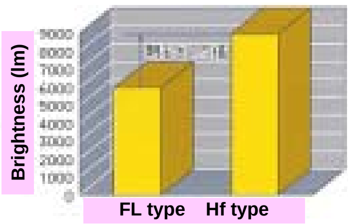
$$L = \frac{t_1}{t_1 + t_2} \times 100(\%)$$



Pressure change in Air Compressor

ECCJ

Lighting



The electric power for lighting can be reduced about 50% by the saved type lighting system of energy

High efficient lamp

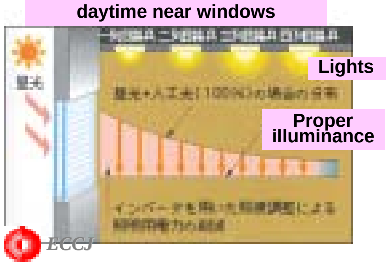
+

Lighting management using day light

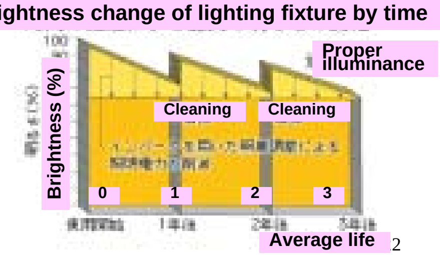
+

Proper illumination maintenance system

Illuminance distribution at daytime near windows



Brightness change of lighting fixture by time

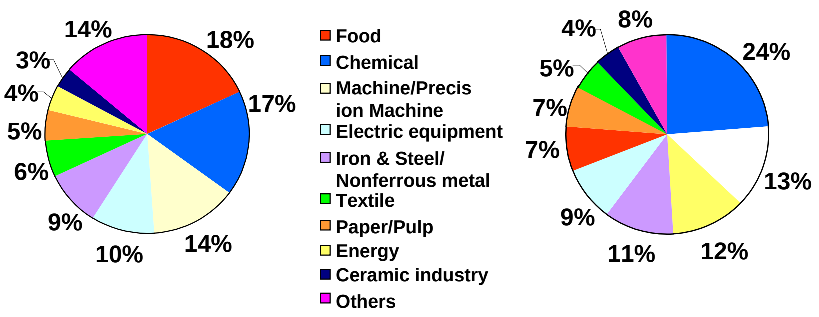


ECCJ

Installation Record of Industrial Co-generation (Up until March, 2003)

Installation Percentage
by Industrial Sector
(Total installations =1,600)

Power Generation Percentage
by Industrial Sector
(Total Generation =5.074MW)



ECCJ 23

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