經濟部暨所屬機關因公出國人員報告書
（出國類別：其它）

了解冷能發電系統與 LNG 地下式儲槽報告書

出 國 人：　服務機關：中國石油公司
天然氣事業部永安廠
職務：永安廠廠長
姓名：賴顯偉
職務：永安廠技術組企劃控制師
姓名：錢明雄
出國地點：　日本
出國期間：　95 年 12 月 10 日至 12 月 16 日
報告日期：　96 年 2 月 26 日

行政院及所屬各機關出國報告提要

出國報告名稱：了解冷能發電系統與 LNG 地下式儲槽

頁數 11 含附件：■是□否

出國計畫主辦機關/聯絡人/電話

中國石油公司天然氣事業部/顏安民/02-87258995

出國人員姓名/服務機關/單位/職稱/電話

賴顯偉/中國石油天然氣事業部永安廠/廠長/07-6911131-200

錢明雄/中國石油天然氣事業部永安廠/技術組企劃控制師/7-6911131-382

出國類別：□1 考察□2 進修□3 研究□4 實習■5 其他

出國期間：民國 95 年 12 月 10 日至民國 95 年 12 月 16 日

出國地區：日本

報告日期：民國 96 年 2 月 26 日

分類號/目：

關鍵詞：冷能發電、LNG 地下式儲槽、燃料電池、LNG 冷能利用、衛星站

內容摘要

日本大阪瓦斯公司與東京瓦斯公司在地上式與地下式 LNG 儲槽及冷能利用之發展皆屬頂尖公司，世界上第一座下式 LNG 儲槽以及最大容量 LNG 儲槽（20 萬立方公尺，全地下式 LNG 儲槽）皆由東京瓦斯公司所締造，全球發電效率最高之冷能發電工廠爲東京瓦斯公司 NEGISHI 接收站之 MF Rankine 型。

大阪瓦斯公司研發中心已研發出利用 NG 重組方法產製氫氣，且開始應用於汽車燃料，目前已上市機種有 HYSERVE30m^3 N/hr 及 100m^3 N/hr 型， 300m^3 N/hr 型機種預訂今年上市。

富士電機生產之 100KW 燃料電池屬磷酸燃料電池，已歷經 60,000 小時的壽命驗證，燃料電池的特徵之一係發電效率高，其二係同時可利用其排熱產製熱水，所以最適合使用於汽電共生系統，目前已有中型巴士應用實績。

日本大阪瓦斯公司與東京瓦斯公司對冷能廣加利用，除大家耳熟能詳之冷能發電外，尚有冷凍倉儲，更全力發展天然氣重組並運用於燃料電池，不但發揮天然氣最大效用且對於環境保護亦極盡心力。

目錄

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壹、參訪目的

日本大阪瓦斯公司與東京瓦斯公司在地上式與地下式 LNG 儲槽及冷能利用之發展皆屬頂尖公司；因日本氣候及其生活習性較適 LNG 冷能利用發展，造就其在此方面有較亮眼之成績。世界上第一座下式 LNG 儲槽以及最大容量 LNG 儲槽（20 萬立方公尺，全地下式LNG儲槽)皆由東京瓦斯公司所締造。

本廠正進行「永安廠第五期擴建計劃可行性評估與環境影響評估」前置作業，內容涵蓋 LNG 儲槽擴建及冷能利用，須廣泛收集目前業界 LNG 儲槽及冷能利用發展趨勢，以做為將來擴建參考依據，此即職本次奉派出國之主要目的。

貳、參訪過程

1. 行程

日　　期	行　　程	過 程 概 述
96.12.11	大阪、高石市	上午：拜訪 OGC 總公司，及座談。 下午：訪問 SENBOKU 二廠及座談。
96.12.12	大阪、兵庫縣	上午：訪問 OGC 西播磨衛星站（NISHIHARIMA）及座談。 下午：訪問 OGC 研發中心及 NG 重組產氫設備。
96.12.13	大阪、東京	訪問富士電機燃料電池研發中

		心（FUJI Phosphoric Fuel cell ）及座談。
96.12.14	橫濱、東京	上午：訪問 TGC 扇島（OHGISHIMA）LNG 接收站及座談。 下午：拜訪 TGE 總公司及座談。
96.12.15	東京、橫濱	訪問 TGC 根岸（NEGISHI）LNG 接收站及座談。

2. 訪問大阪瓦斯公司

泉北(Senboku)工場位於大阪市南方臨大阪灣，分為一期區及二期區，一期區在 1971 年 10 月完成，二期區在 1977 年 8 月完成，本次參觀的是二期區，該區面積是 733,000M²，接收量是 609 萬噸/年。

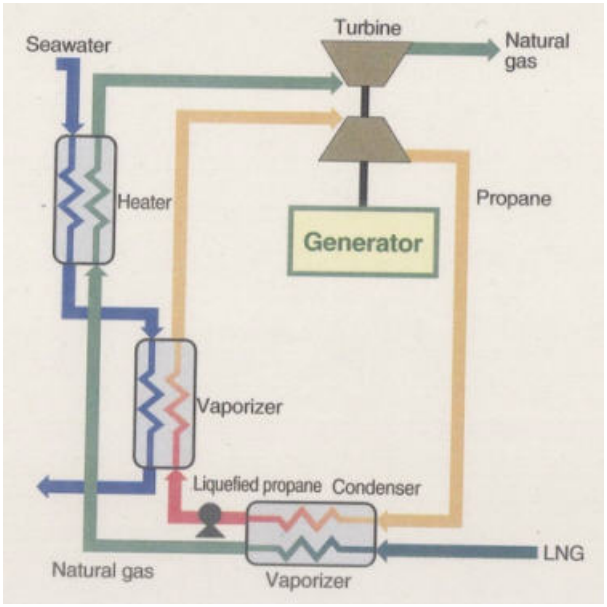
大阪瓦斯公司於 1982 年在泉北工場成立瓦斯科學博物館，利用影片、動畫表演、來賓機智回答及模型剖面等展示與說明「瓦斯科技」、「環境保護」和「節約能源」，每年至少有數萬人次參觀，是最佳的敦親睦鄰活動，也是教育下一代最好教材。

大阪瓦斯公司認為地上式 LNG 儲槽較地下式 LNG 儲槽安全，因此該公司僅發展地上式 LNG 儲槽，無任何地下式 LNG 儲槽，目前最大儲槽容量為 18 萬立方公尺。

泉北二廠設有兩座冷能利用發電工廠，詳細資

料如下 ：

建廠年代	發電量	LNG 用量	海水用量	發電方式
1979	1450 KW	60 T/HR	3000 T/HR	冷能發電（Rankine）
1982	6000 KW	150 T/HR	6000 T/HR	冷、壓能合併發電（Rankine + NG Direct）



冷、壓能合併發電圖示

大阪瓦斯公司已建造 60 幾個衛星接收站，本次訪問西播磨衛星站（NISHIHARIMA），該站建於 1995 年 4 月，1996 年 4 月開始供氣，主要設備如下：

LNG 儲罐：100KL × 3 座

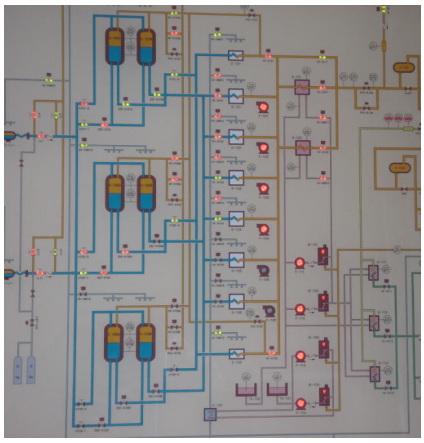
LNG 進料：載量 9.6 T 之槽車供應，灌裝時間 30 分

LNG 氣化器：2T/Hr x 4 座

供氣壓力：低壓：2.5 kPa ； 中壓：0.15 MPa

熱值控制：45MJ/m^3 N

西播磨衛星站氣冷式氣化器



西播磨衛星站操作狀態顯示盤

大阪瓦斯公司研發中心已研發出利用 NG 重組方法產製氫氣，目前已上市機種有 HYSERVE30m^3 N/hr 及 100m^3 N/hr 型， 300m^3 N/hr 型機種預訂今年上市。相關資料如下述：

大阪瓦斯公司研發之 NG 重組氫氣產製設備

由 HYSERVE 產出 30m³ N/hr、壓力 0.85MPaG 之氫氣，經壓縮機加壓至 40MPaG 打入高壓氮氣瓶組儲存，氮氣瓶組由 8 個 80 公升氮氣瓶組成。

氫氣灌裝設備保護箱

氫氣灌裝器具

氫氣可供汽車作為燃料或當燃料電池使用，汽車或載具填充氫氣時可用高壓或低壓填充，其相關資料如下述：

填充壓力	≦ 0.75MPaG	≦ 25MPaG ≦ 35MPaG
填充速度	25 N m^3 /10 分以內	25 N m^3 /5 分以內

3. 訪問富士電機燃料電池研發中心

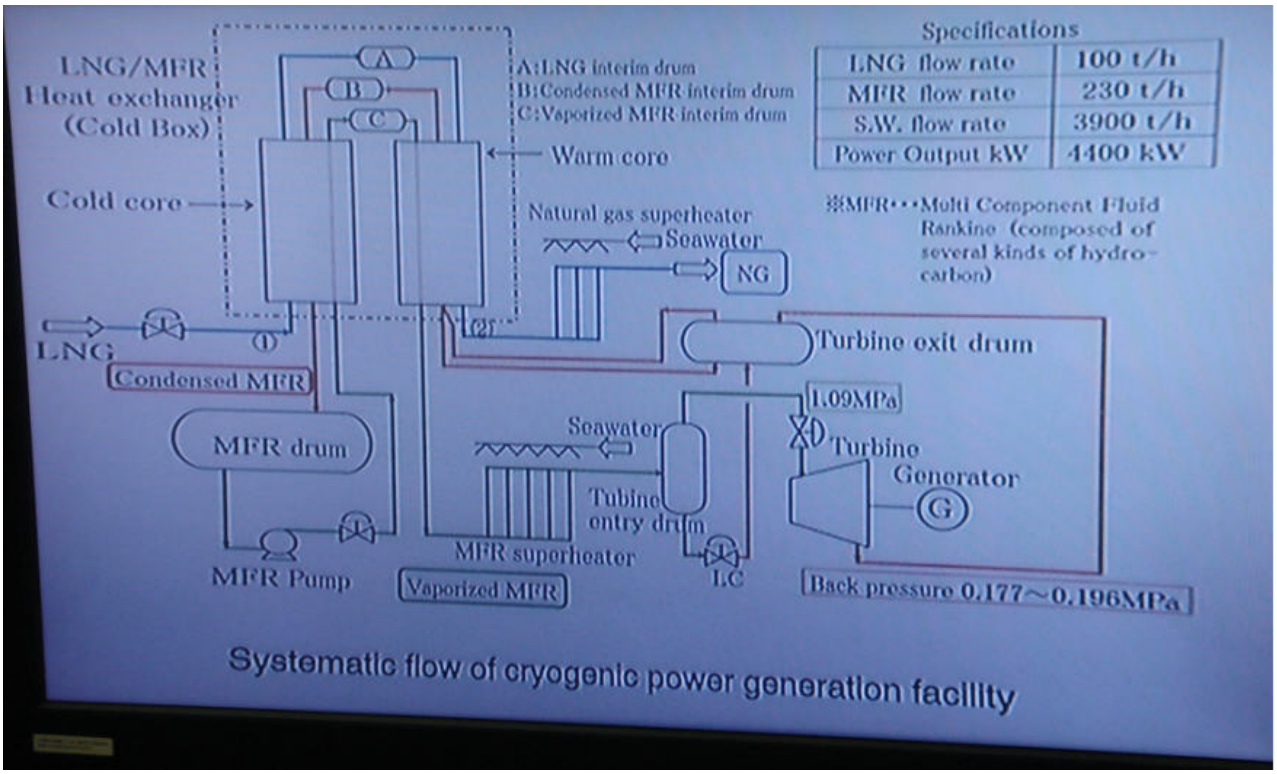
富士電機生產之100KW燃料電池屬磷酸燃料電池，已歷經 60,000 小時的壽命驗證，燃料電池的特徵之一係發電效率高，其二係同時可利用其排熱產製熱水，所以最適合使用於汽電共生系統。富士電機業已實用化的 100 kW 燃料電池基本規格如下：

輸出電力	100 kW AC
電壓/頻率	200V（50Hz），220V（60Hz）
發電效率	40%（LHV，AC）
熱效率	47% (LHV)/ 90℃，50℃ Hot water
燃料	都市瓦斯及天然瓦斯
環境特性	NOx＜ 5ppm SOx： 無
噪音	65 Db（A）@ 1m
裝置尺寸	2.2m(W)×3.8m(L)×3.0m(H)；10ton

4. 訪問東京瓦斯公司

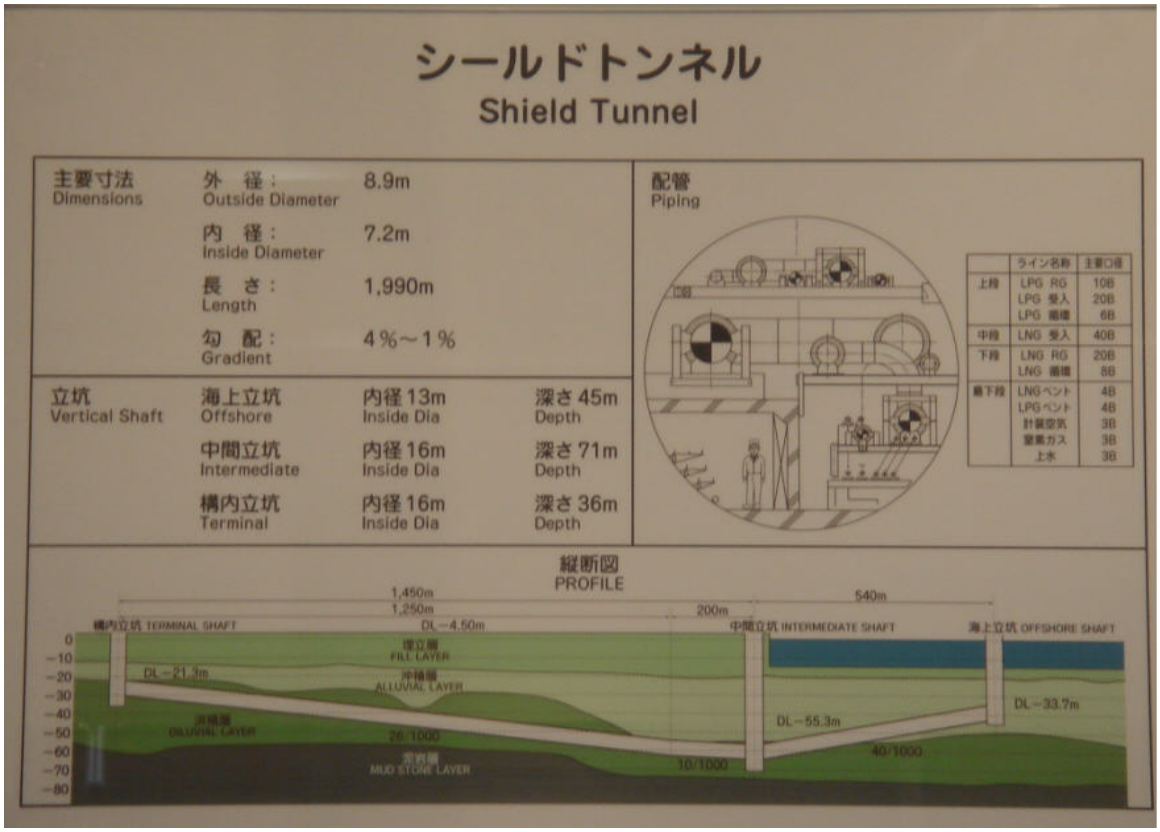
本次除拜訪東京瓦斯工程公司總公司聽取其20萬立方公尺地下式LNG儲槽建廠時程與相關研發技術外，並赴東京瓦斯公司司扇島及根岸接收站，了解其儲槽運作與冷能利用實際案例，其中更親臨體驗零下60℃之冷凍倉儲環境，此地共冰存300萬公噸之黑鮪魚，係大東京地區居民生魚片主要供應來源。相關資料如下述：

全球發電效率最高之冷能發電工廠爲NEGISHI接收站MF Rankine

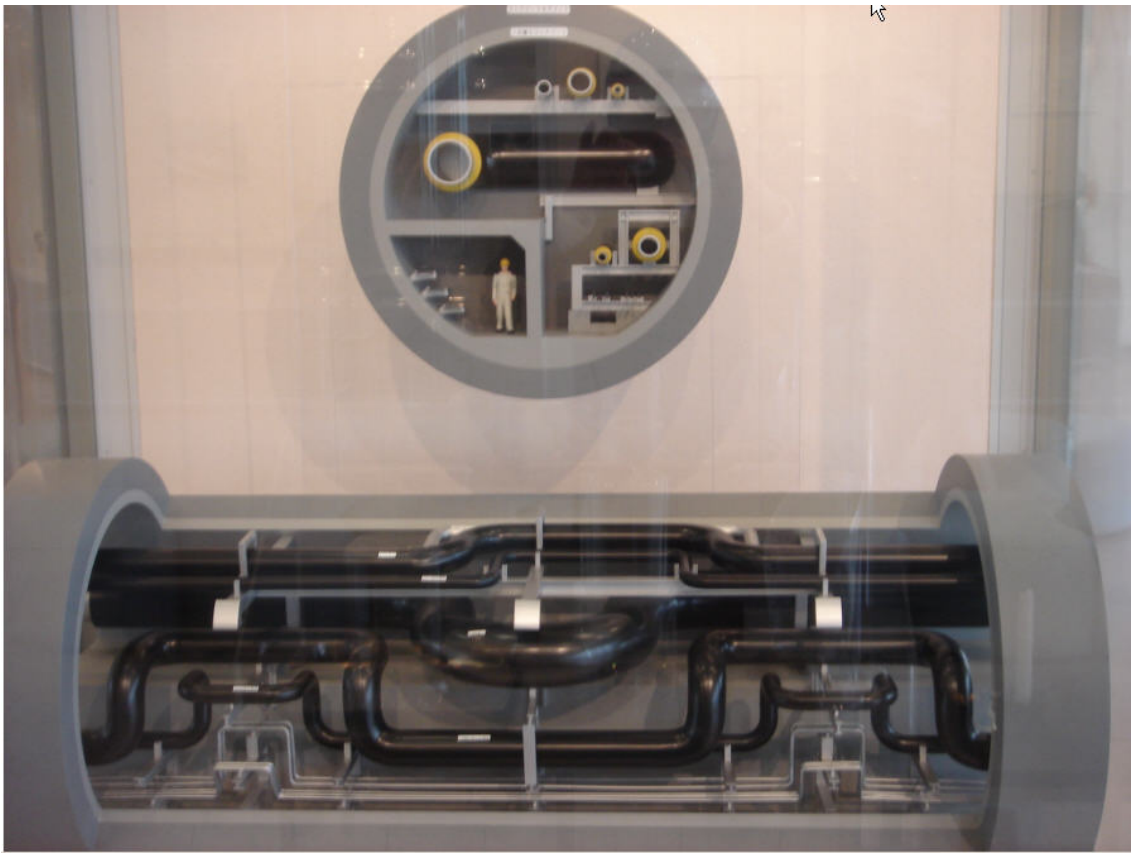


LNG槽車灌裝情形

直徑約 72 公尺、深度 50 公尺、容量 20 萬立方公尺全地下式 LNG 儲槽，其上廣植花草，僅安全閥露於地表面上。



根岸接收站之 **LNG** 接收後經由地下管道輸往工場氣化。



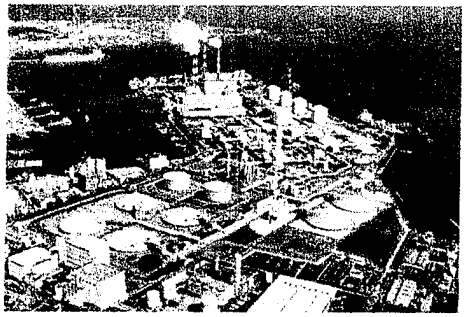
參、研習心得與建議

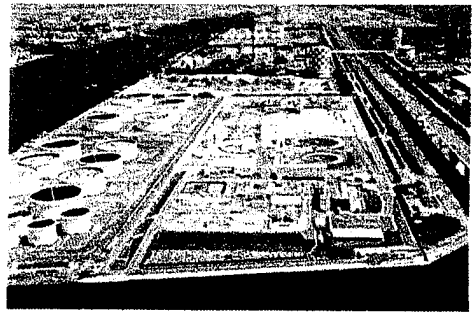
本次前往日本大阪瓦斯公司與東京瓦斯公司體會到其對冷能廣加利用，除大家耳熟能詳之冷能發電外，尚有冷凍倉儲，更全力發展天然氣重組並運用於燃料電池，不但發揮天然氣最大效用且對於環境保護亦極盡心力。

本公司對天然氣之經營幾僅止於將超低溫液化天然氣加工成常溫氣態天然氣，冷能利用率低，開發潛力頗大。由於台灣天氣四季炎熱，難得見雪，因此冷能利用可朝此方面發展，諸如製冰廠、人造雪景等皆是有效利用冷能之不錯商業化模式。建議公司組成研發人員或派遣相關技術人員前往專業製冰廠或人造雪知名公司取經，以厚植本公司冷能利用技術與能力，假以時日，必可創造更大經濟效益。

肆、附錄

1. 東京瓦斯公司 20 萬立方公尺全地下式 LNG 儲槽相關資料。
2. 富士電機燃料電池製程介紹。





Presentation Material for Discussions with

Chinese Petroleum Corporation
Republic of China

in relation to

LNG Storage Tank and Receiving Terminal

December 14, 2006
Tokyo

Tokyo Gas Engineering Co., Ltd.

Notification
(Confidential)

This presentation was prepared exclusively for the benefit and internal use of our possible partner, Tokyo Gas Engineering Co. Ltd ("TGE") and its team members to facilitate the exchange of opinions in relations to the development of a LNG receiving terminal in CPC. (the "Purpose"). Neither this document nor any of its contents may be used for any other purpose without the prior written consent of TGE. Unless agreed otherwise, this presentation shall remain the property of, and shall be treated as confidential and proprietary to TGE.

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Agenda

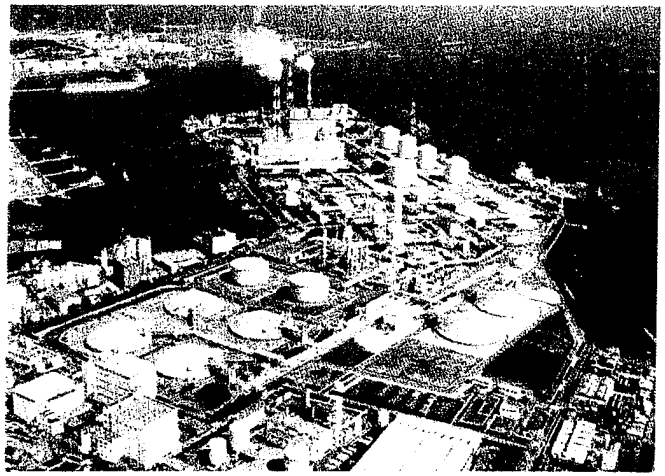
- **Brief Introduction of Tokyo Gas and Tokyo Gas Engineering**
- **LNG Inground Tank and PC Full Containment Tank**
- **Technical Development of LNG Inground Tank**
- **LNG Terminal Emergency Response Plan**
- **QRA of LNG PC Membrane Tank**
- **Reliability Analysis of LNG Receiving Terminal**
- **Training Course for Operation and Maintenance**

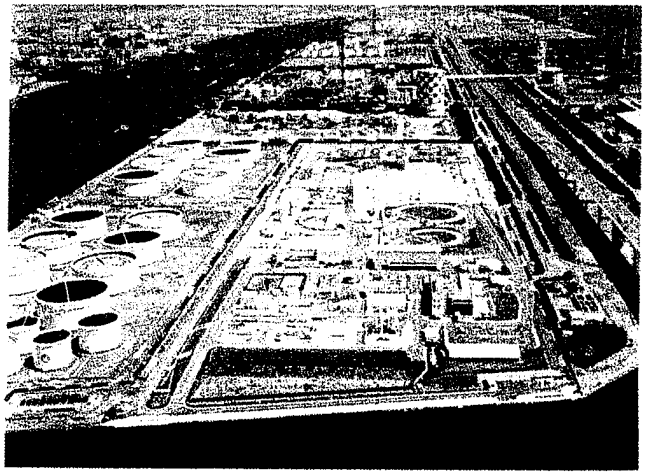
LNG Receiving Terminals of Tokyo Gas

- **Negishi Terminal**
  - the first terminal in Japan
  - started in 1969
  - 3×10^6 ton/year

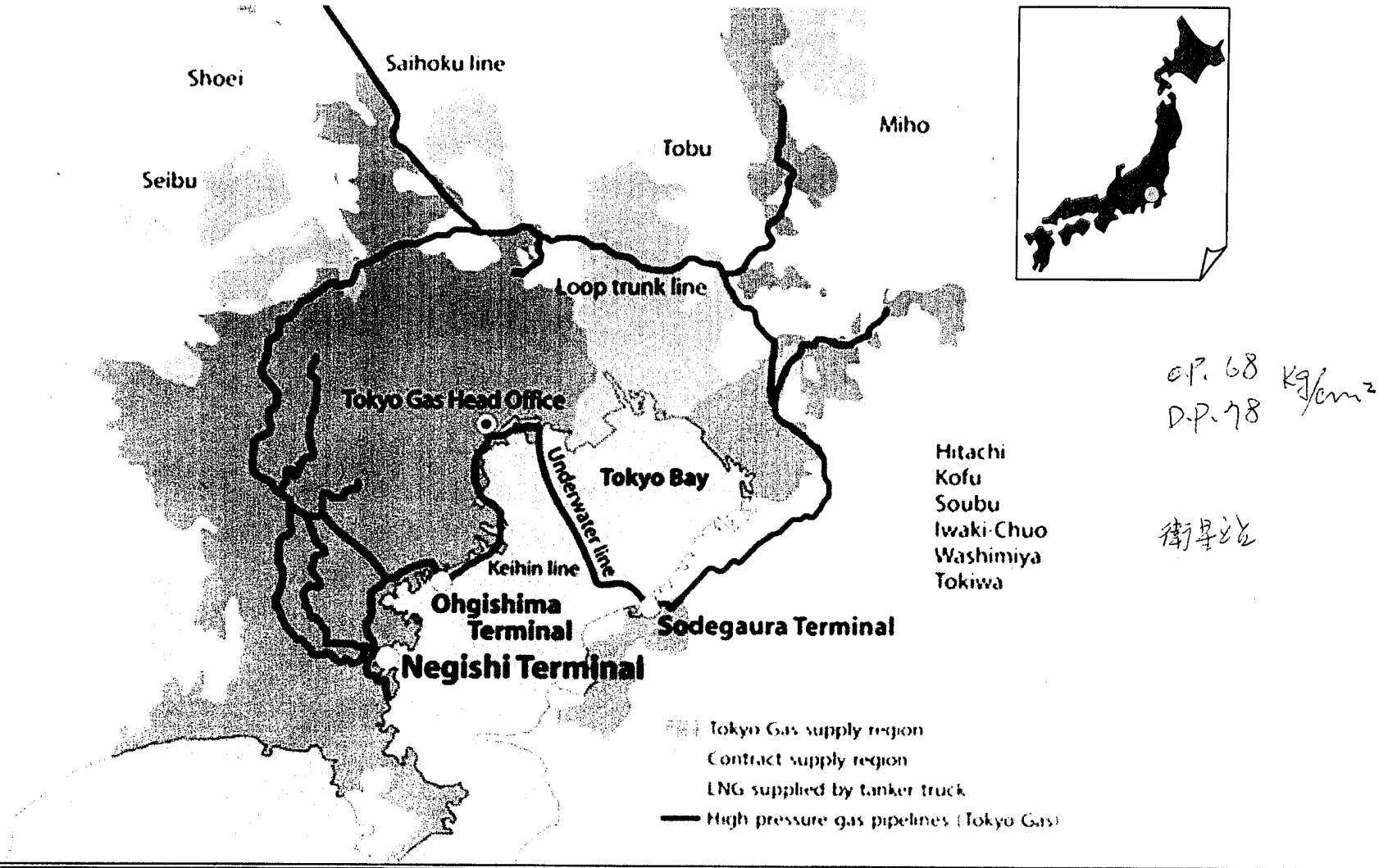
- **Sodegaura Terminal**
  - the largest class terminal in the world
  - started in 1973
  - 10×10^6 ton/year

- **Ohgishima Terminal**
  - the terminal integrated with the state-of-the-art technology
  - started in 1998
  - 3×10^6 ton/year (final stage)





Natural gas supply network of Tokyo Gas



O.P. 68 kg/cm²
D.P. 78

Relation between TG and TGE

TG (Tokyo Gas)

- **The Largest Gas Company in Japan**
  - **Gas Sales: $12 \times 10^9 m^3$/year (2005)**
  - **Customer: 9.8×10^6 household (2005)**
  - **LNG Consumption: 9.0×10^6 ton/year (2004)**
  - **LNG Resources: seven(7) sources, six(6) countries**
- **Abundant Experience**
  - **LNG: 37years (since 1969)**
- **Three (3) LNG Receiving Terminals**
  - **Negishi Terminal (1969)**
  - **Sodegaura Terminal (1973)**
  - **Ohgishima Terminal (1998)**

TGE (Tokyo Gas Engineering)

- **Established in 1974 to promote TG's Technology**
- **100% Subsidiary of TG**
- **Common Engineering Base**

TG's Engineering

↓ ←Worldwide Standard
←Overseas Project Management

TGE's Engineering

1) **Oriented in User's Sense Experiences of Operation/ Maintenance as well as Design / Construction**
2) **Large Engineers Reserved**

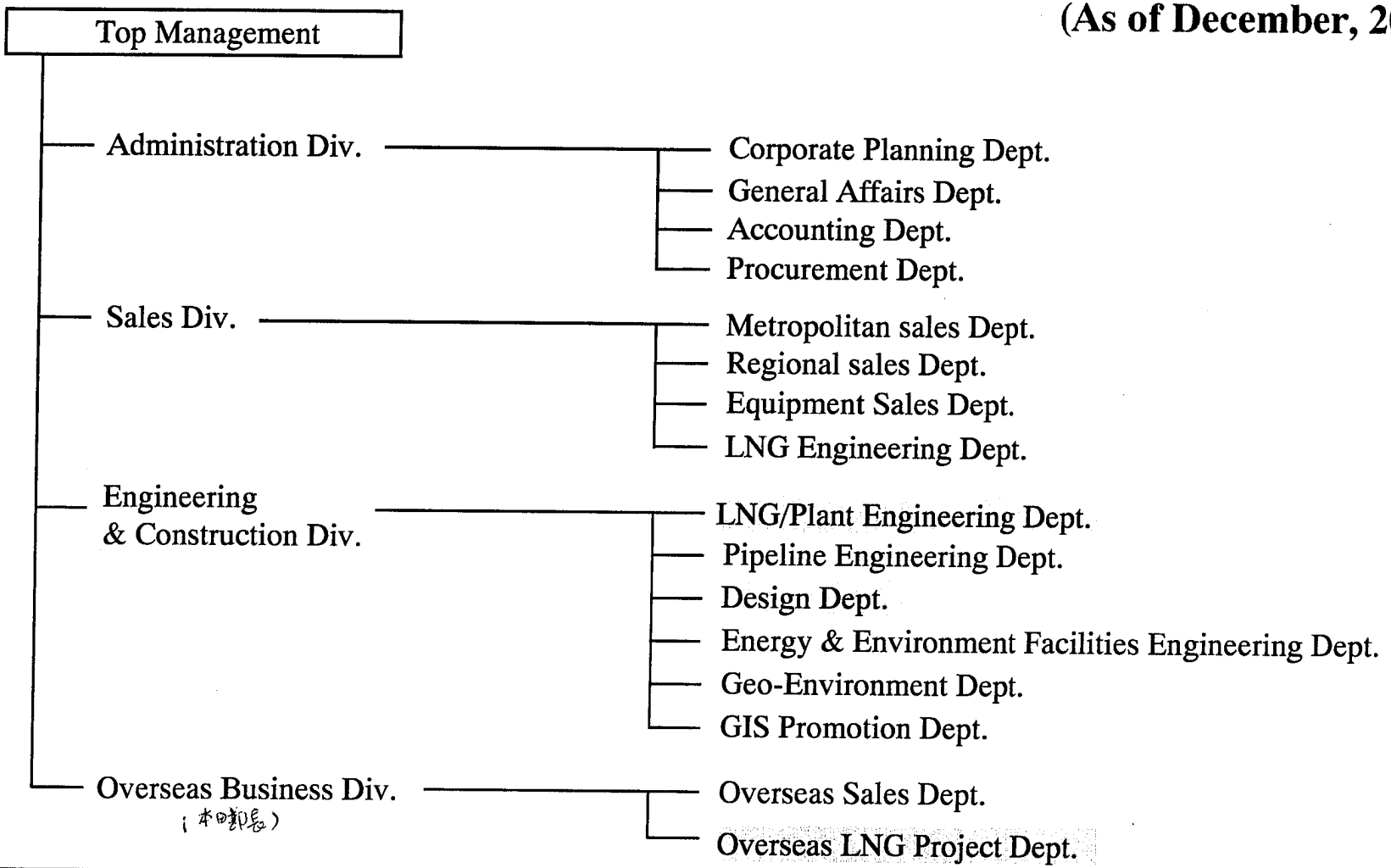
CLIENT of Domestic & Overseas

Engineers

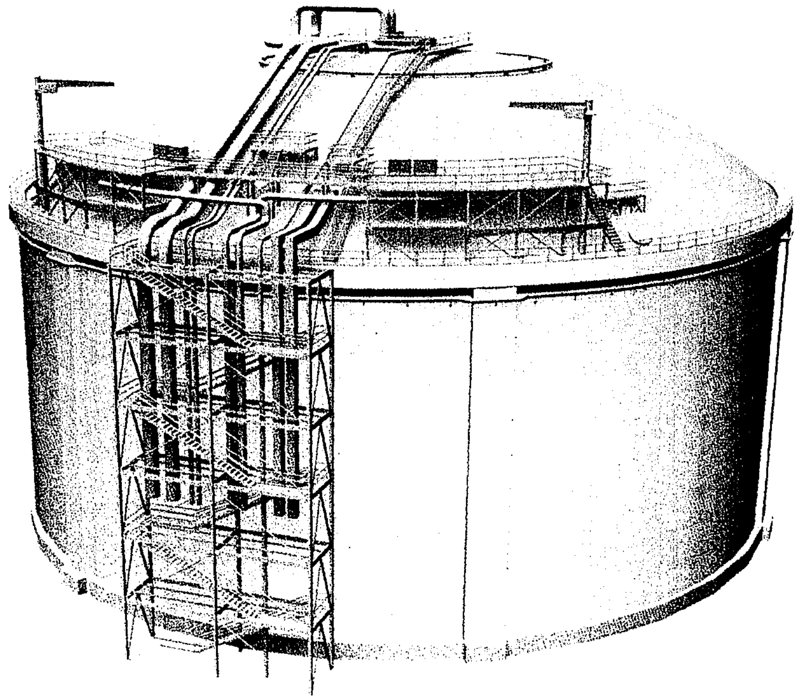
- **Periodical Exchange**
- **Dispatch for TGE's Project as per TGE's Request**

Organization of TGE

(As of December, 2006)



Full Containment Tank

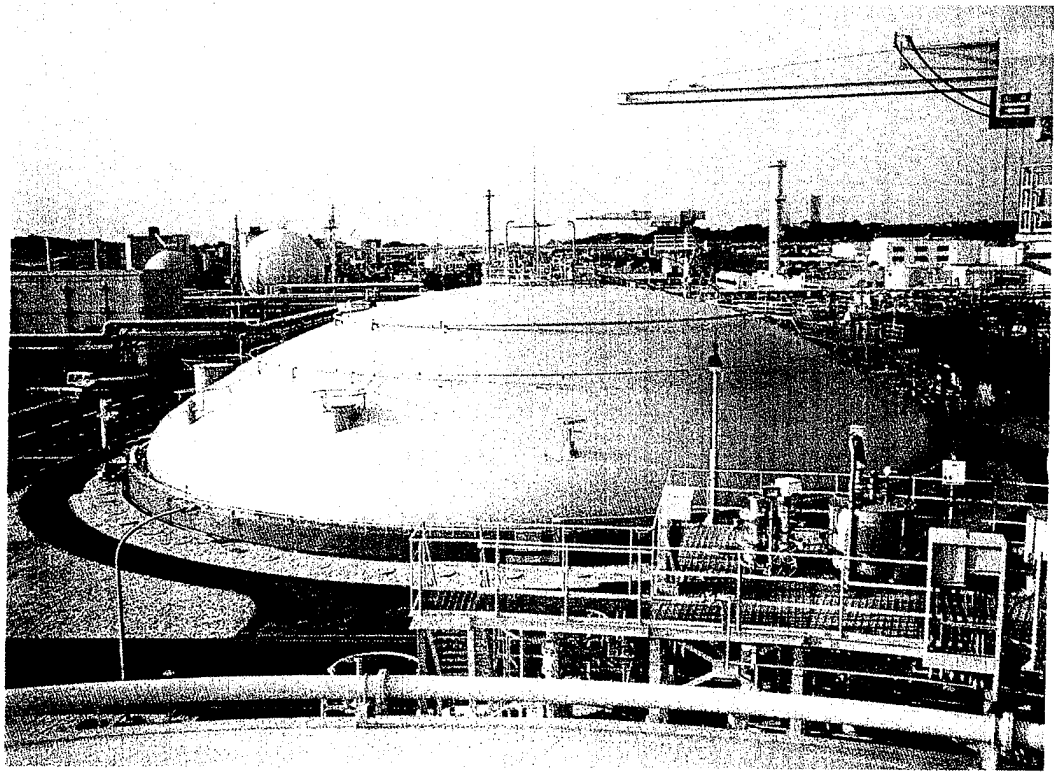


内膽：API-620
形式：BS-7777
安全：EN 1473

- ✓ Applied to many recent LNG receiving terminal
- ✓ High safety feature (No LNG spill, No gas leak) provided by PC concrete wall as 2ry container
- ✓ Collapse of concrete covered roof is not envisaged by EN1473 → 欧标规定，安全距离缩短，削弱 → 安全而言(欠妥) 加顶盖，约1/3。

BS → 结构而言(针对)
API → 内部钢板。

Inground Tank



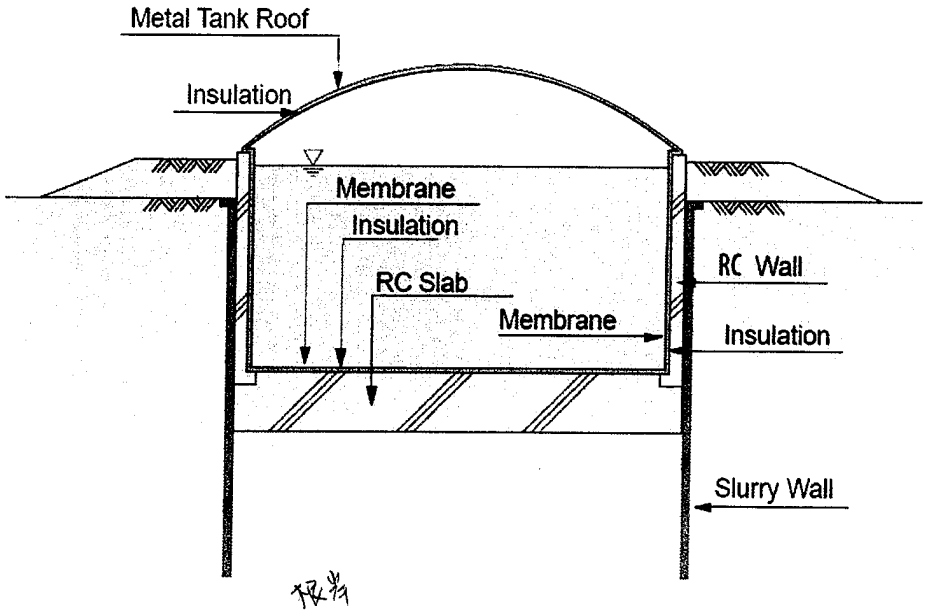
- ✓ More than 50 tanks constructed in Japan, Korea and R.O.C.
  (including 10 of 200,000m^3 tank as world largest capacity)
- ✓ Essential safety realized with NO possibility of LNG spill
- ✓ Reducing visual impact against vicinity area

Underground Tank

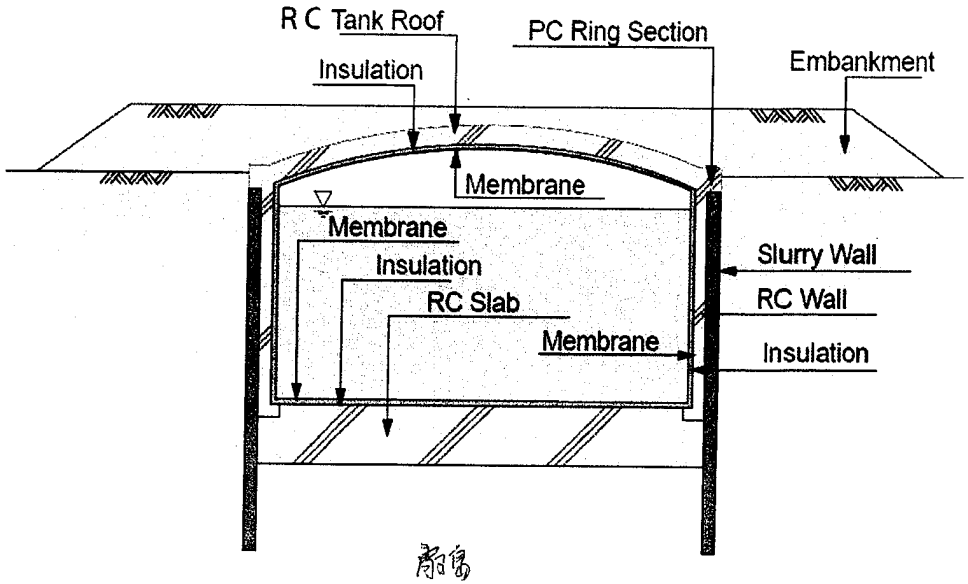
No.1.
第一槽先6月完成
No2.
2000年完成5月.
No3.
2003年完成
5月完成.

- ✓ Essential safety realized with NO possibility of LNG spill
- ✓ Environmental friendly design with beautiful landscape
- ✓ No external impact could be made against tank including roof

LNG Tank Type - Inground -



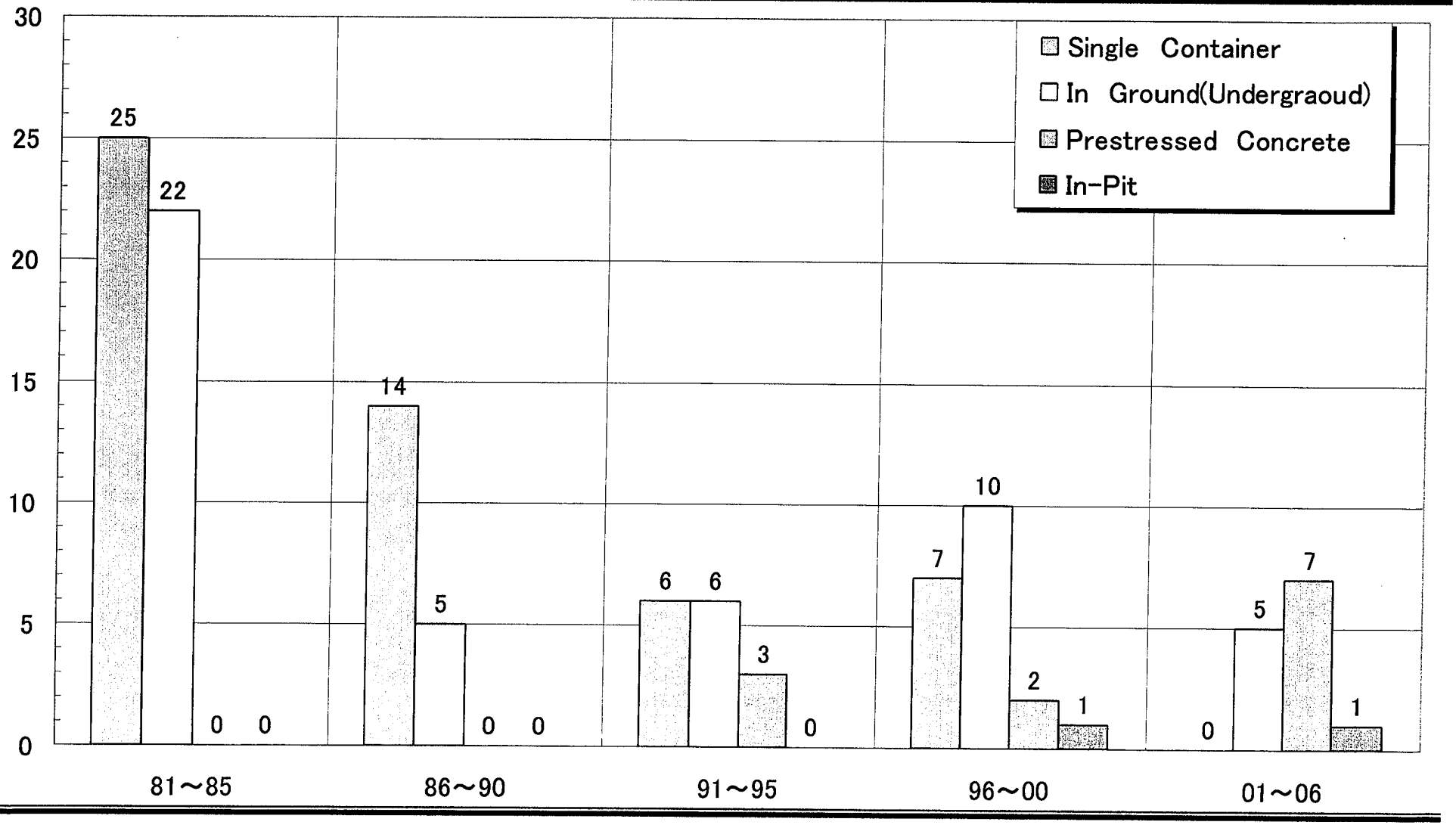
- (Negishi, Sodegaura)
  Embankment



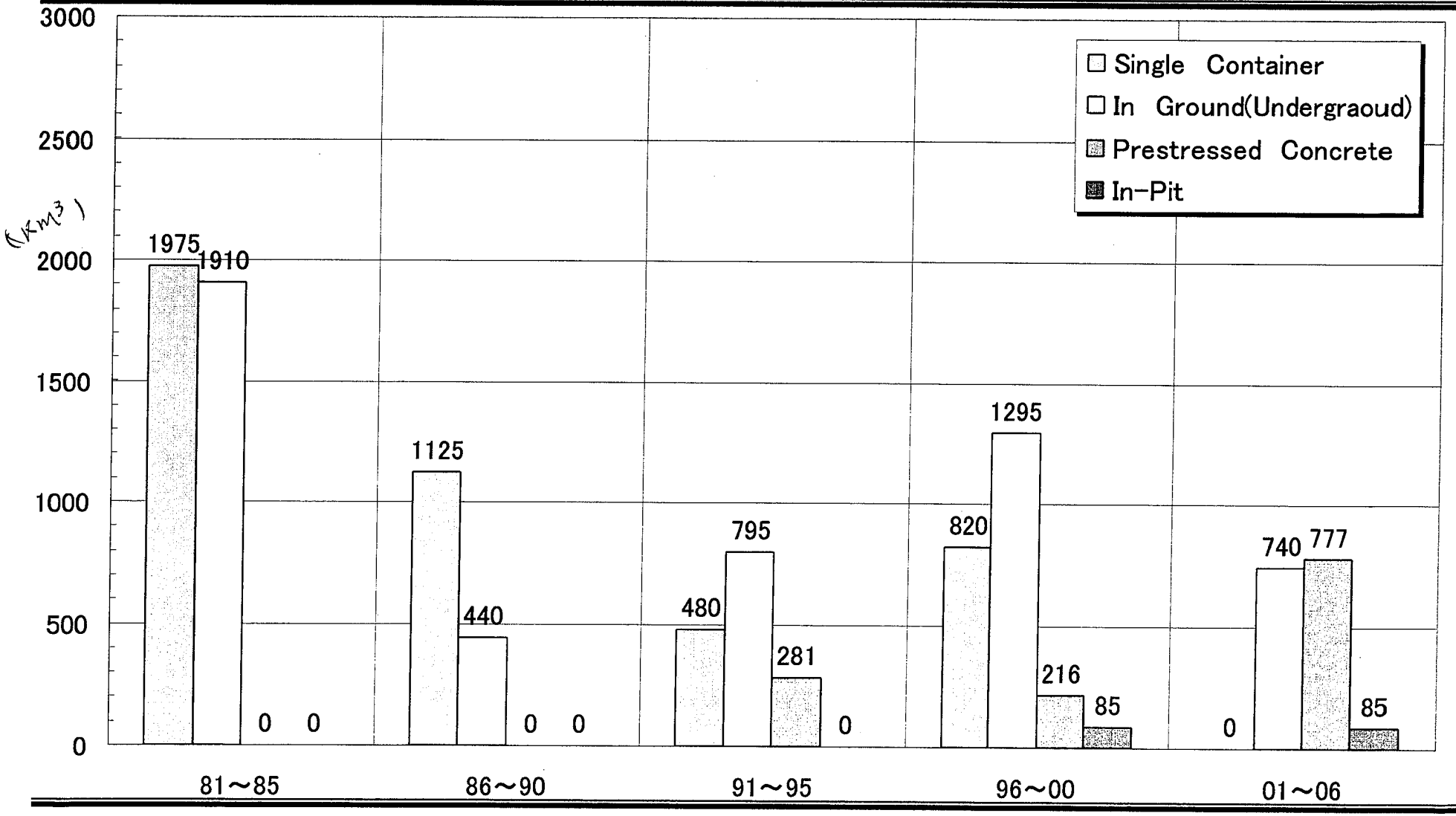
- (Ohgishima)
  Underground

- Highest liquid level is lower than ground level
- Safety against the leakage of inner liquid and gas is much higher
- harmonized with the surrounding environment.

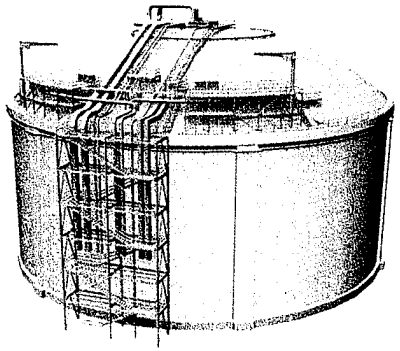
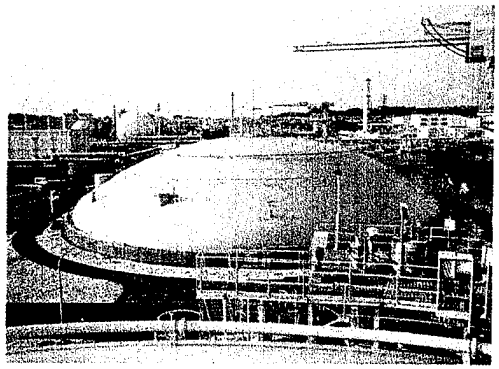
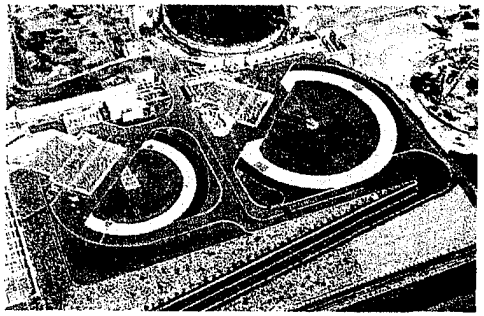
Trend of Tank Construction in Japan - Number-



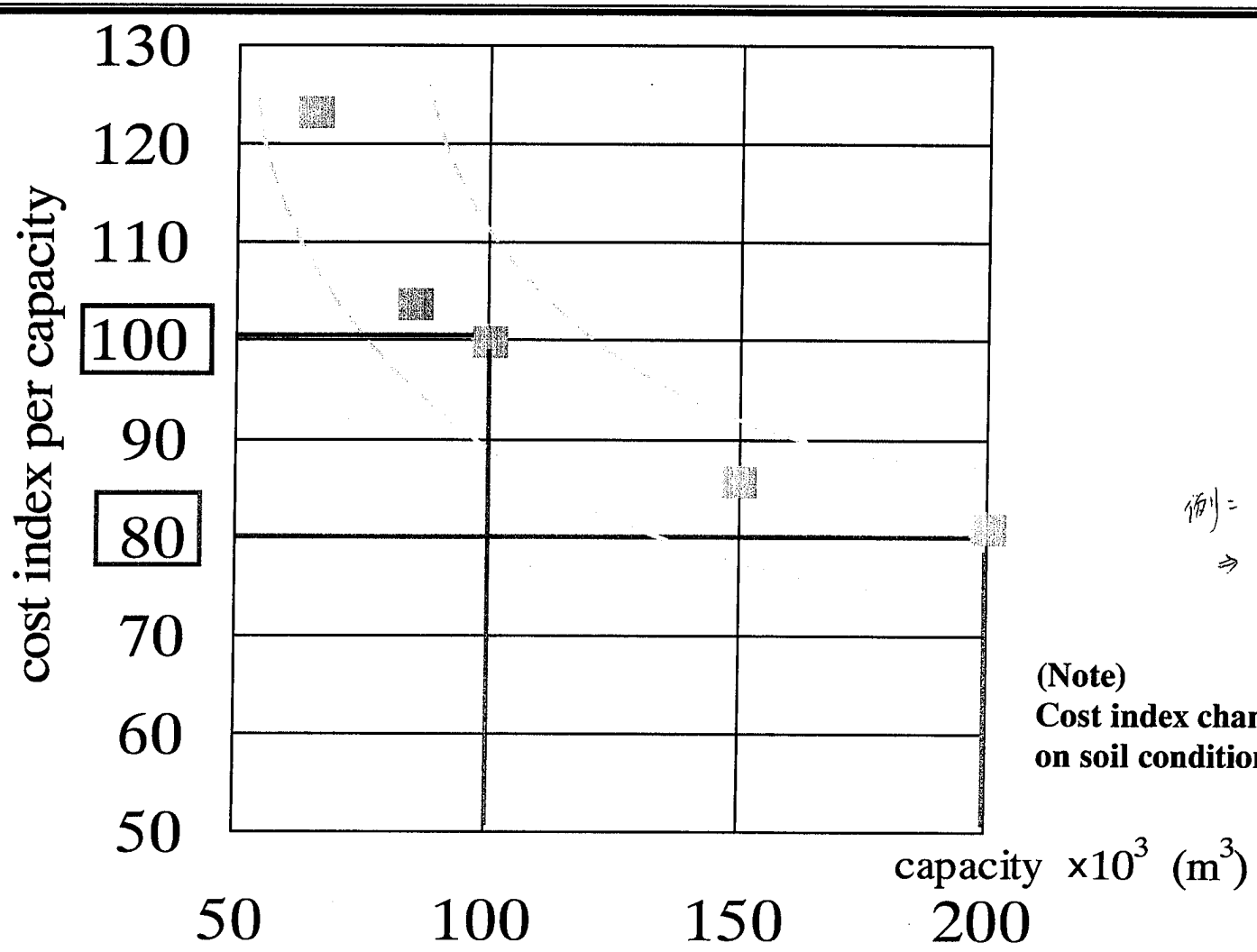
Trend of Tank Construction in Japan - Storage Capacity -



Comparison Table of Storage Tank

	Full Containment	**Inground**	**Underground**
			
Feature	-Global standard -Max. Capa.:188,000m3 (under construction)	-Small visual impact -Popular in Japan, Korea and R.O.C. -Max. Capa.:200,000m3	-Minimized visual impact -Very limited -Max. Capa.:200,000m3
Safety & Security	High safety feature -Secondary container hold LNG spill and gas leakage	Intrinsic Safety -LNG never spill out	Intrinsic Safety - LNG never spill out - No external impact expected
Environmental impact	-Much visual impact -Height: approx. 40 to 50m	-Less visual impact -Only doom roof exposed -Facilities harmonize with environment	-Whole plant can be designed as beautiful landscape -Green field can be generated
Schedule (months)	36 (160,000kl)	40 (160,000kl)	45 (160,00kl)
Cost Index (tentative)	1.0	1.2	1.4

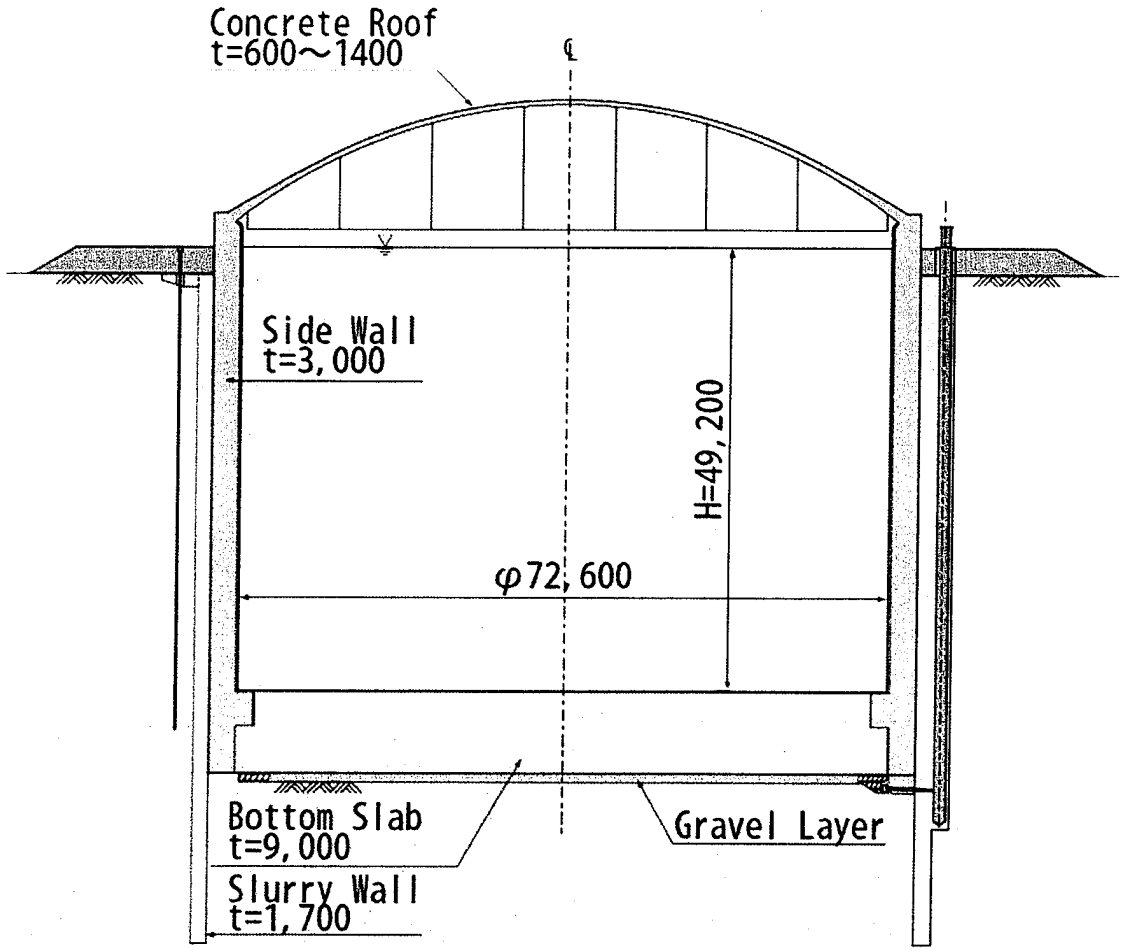
Cost Reduction by Capacity Enlargement



例：10万 → 100元
⇒ 20万 → 160元
100/10×20×0.8=160

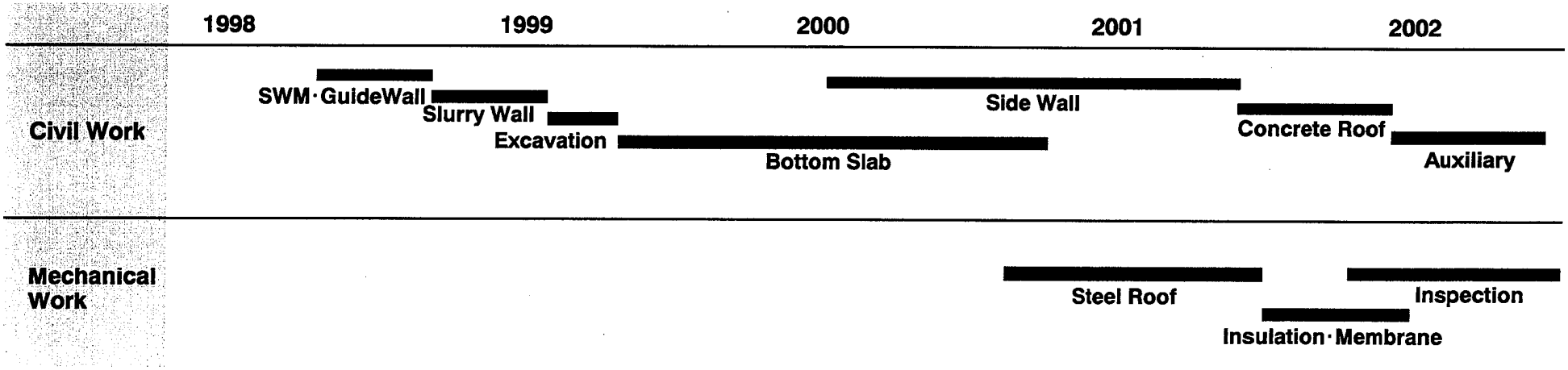
(Note)
Cost index changes depending on soil conditions and so on.

Typical Dimension of 200,000kl Inground Tank

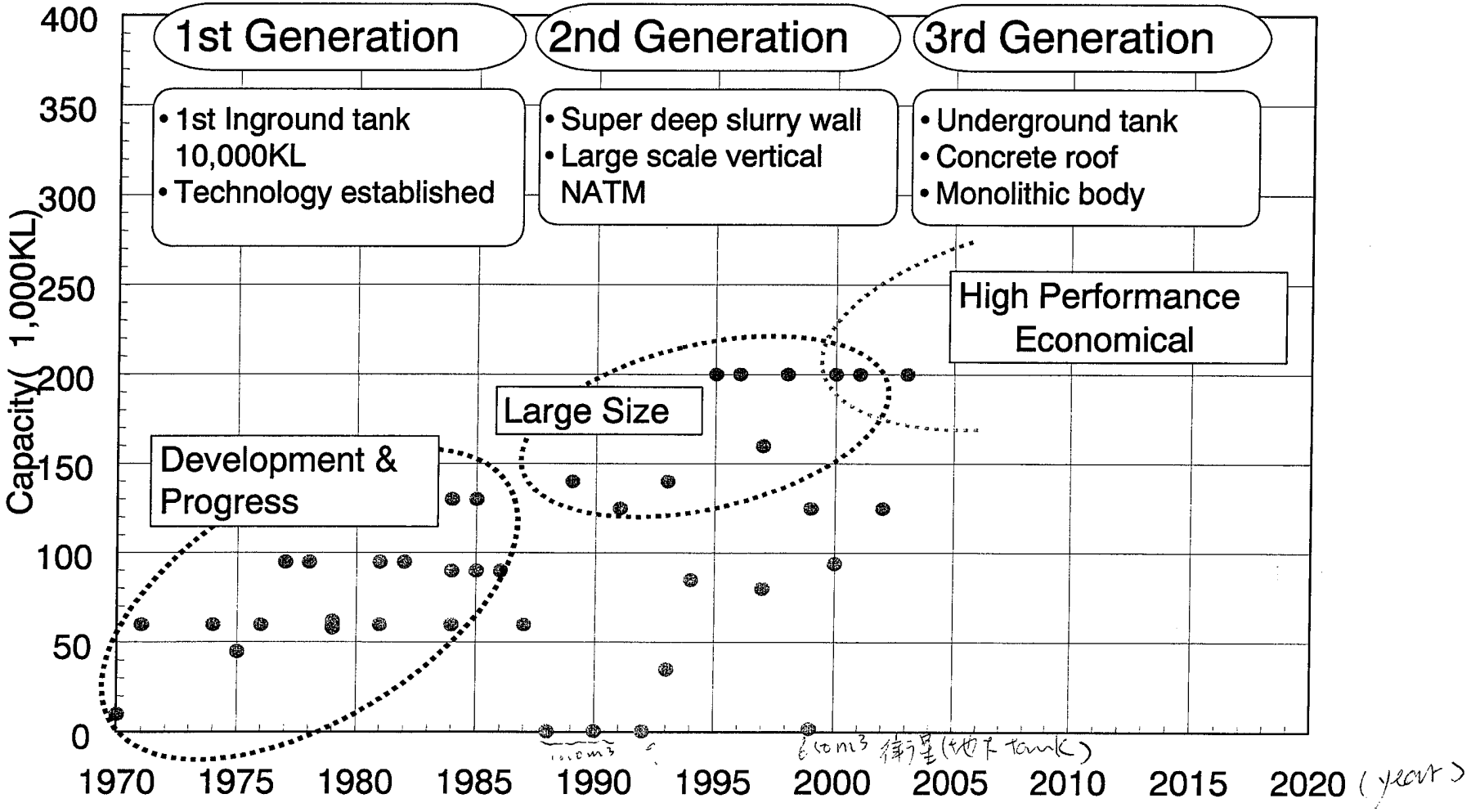


Construction Schedule

Typical Schedule (200,000kl Inground Tank in Overseas)



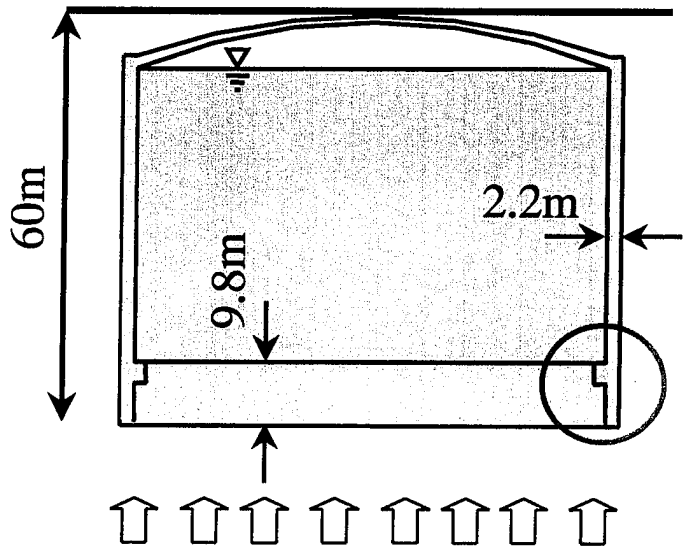
Technical Trend of LNG Tank Development



Pinned Connection System

Ohgishima Case 200,000kl

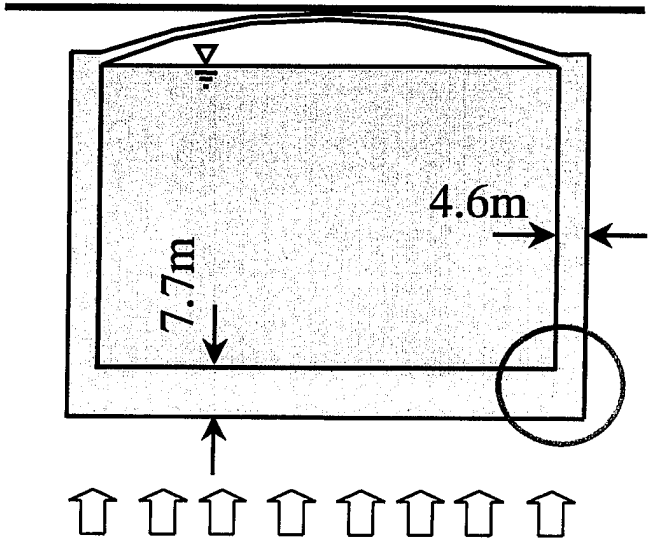
Pinned connection



water pressure 0.6MPa

conventional technology

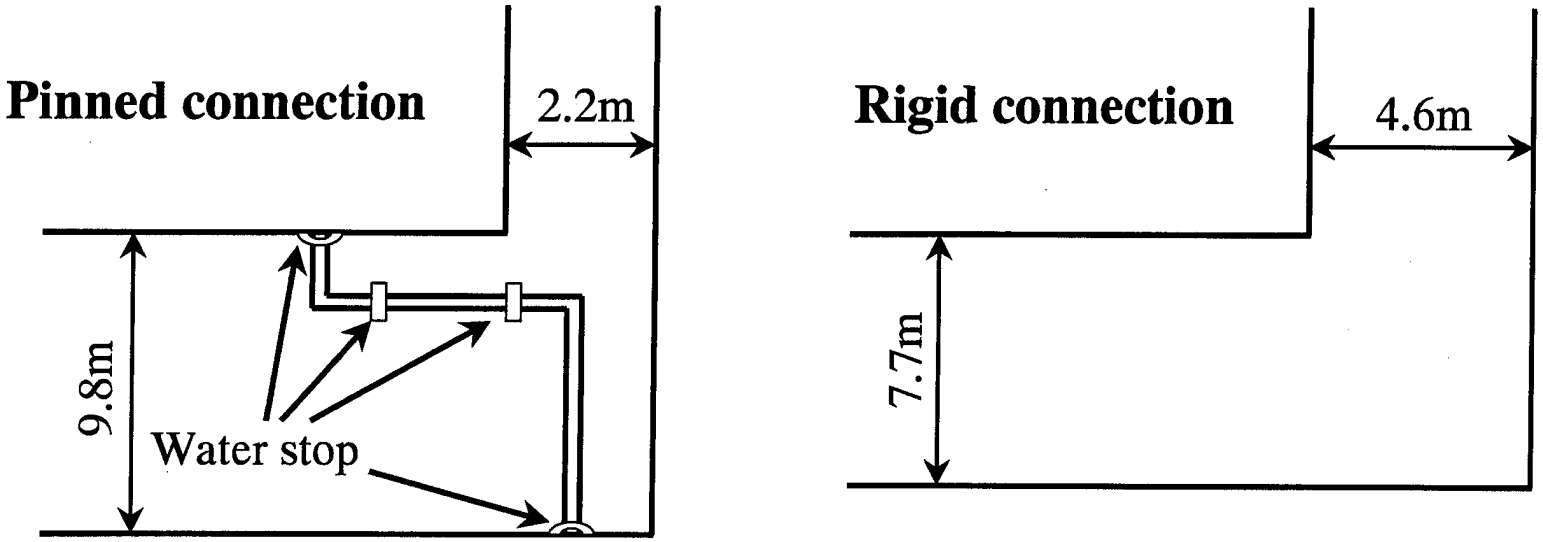
Rigid connection



water pressure 0.6MPa (6Kg/cm²)

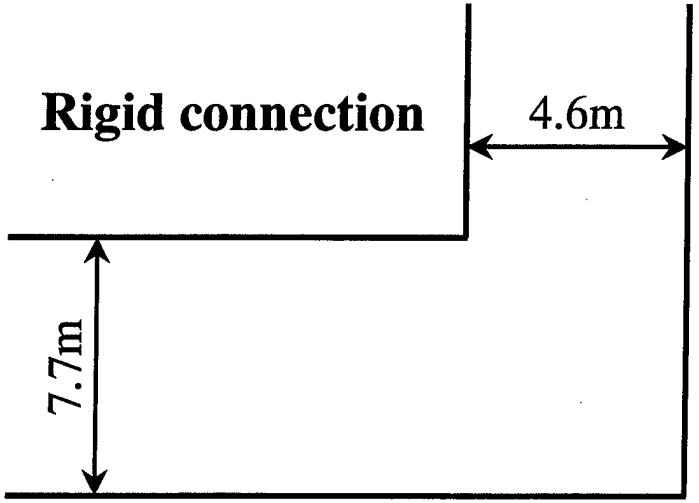
conventional technology

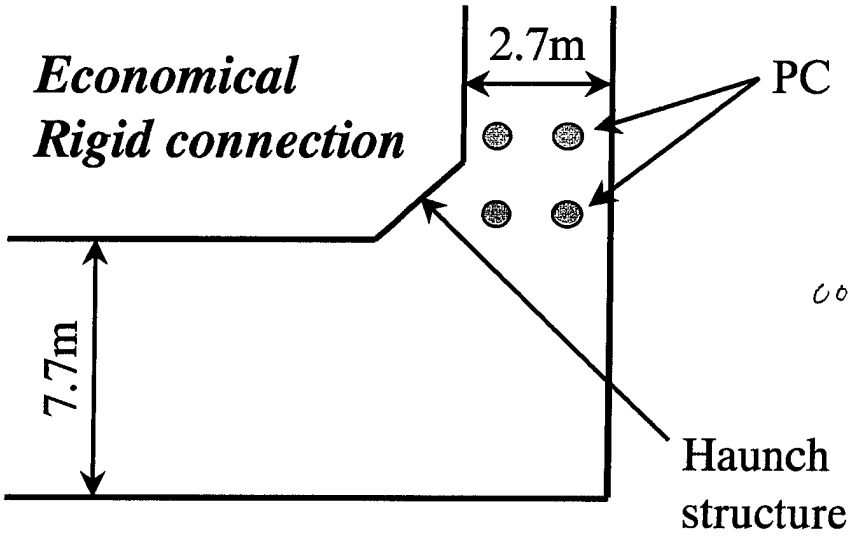
Comparison of Pinned and Rigid Connection System



Construction management	*Strict* construction management for water stops	*General* construction ~~management for water stops~~
Operation	To observe the temperature of water stops is required	To control the temperature of water stops is *not* required
Cost	100	*110*

Challenge for Economical Rigid Connection System



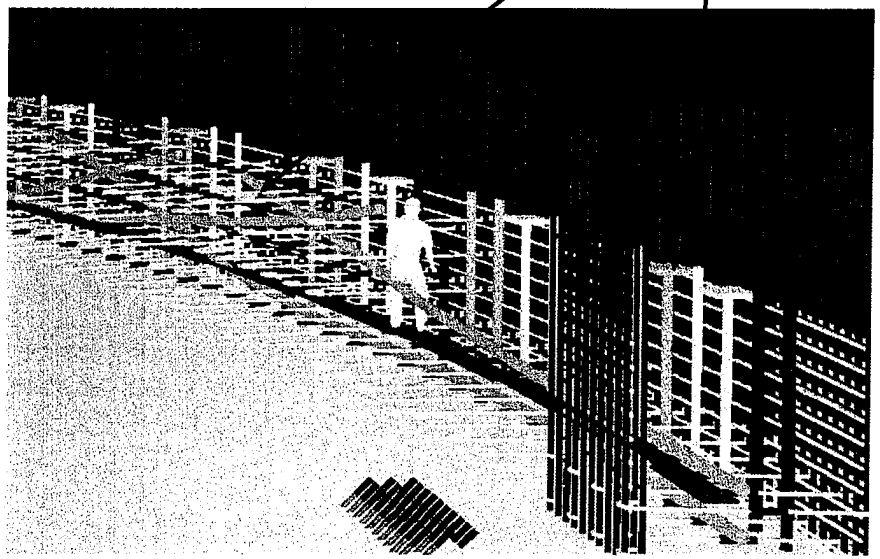


To reduce thickness of side wall ⇨
- **Haunch structure (smooth transmission of stress)**
- **Large-capacity pre-stressing (introduction of compression)**

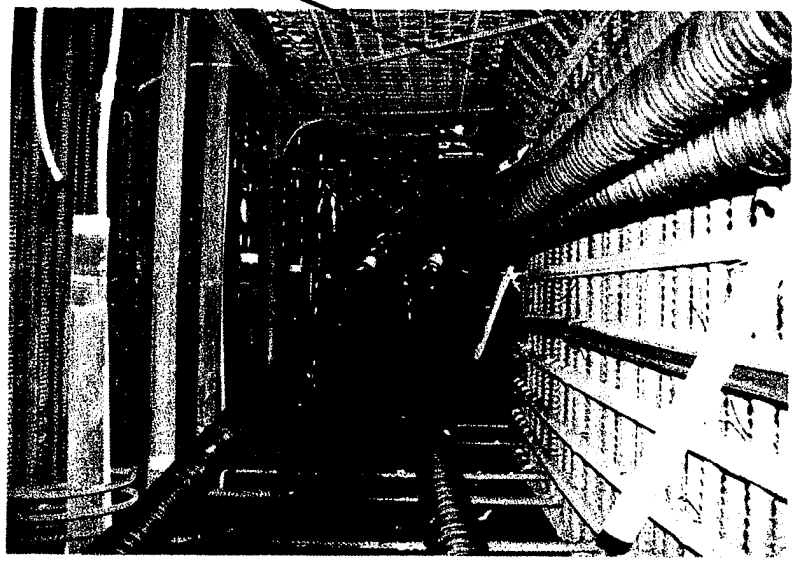
To secure concrete placement ⇨ **Self compacting concrete**

Workability Study – Installation of Sheath

Sheath for Pre-stressing cable



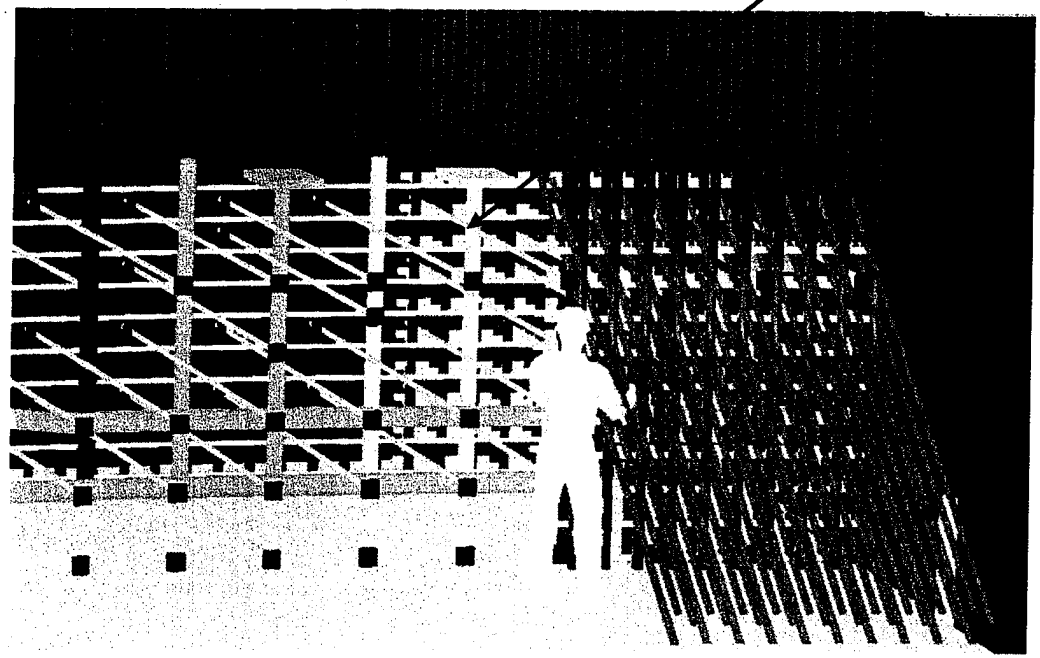
3D-CAD simulation



Actual Construction work

Workability Study –Installation of Rebar

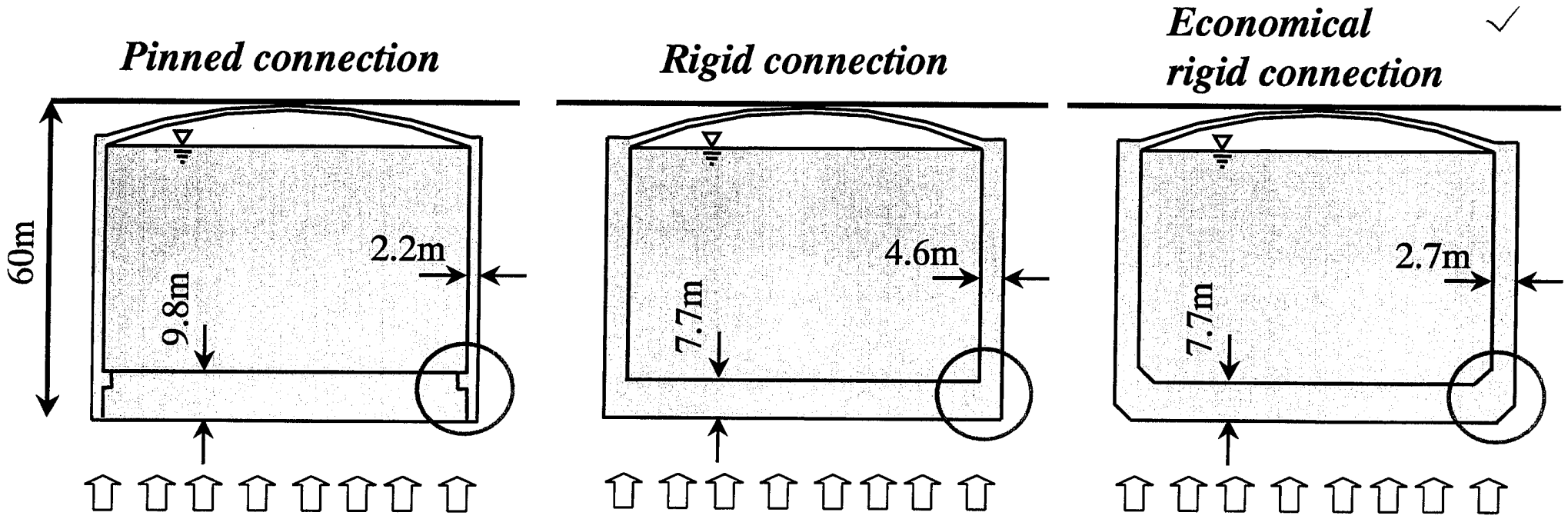
Shear rebars



3D-CAD simulation

Actual Construction work

Design Optimization by Economical Rigid Connection



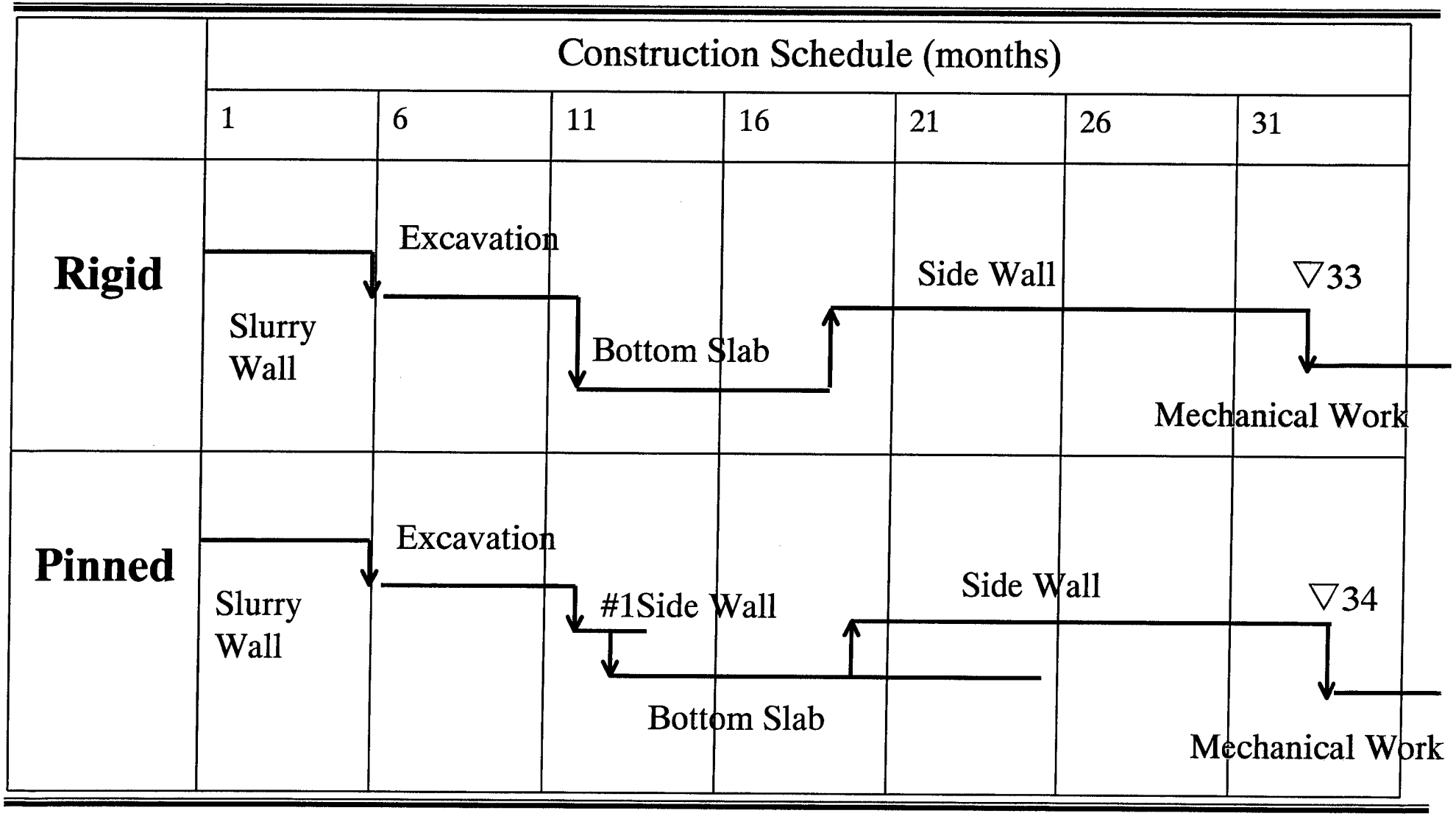
Comparison of Pinned/Rigid Connection (Ohgishima Case; 200,000kl)

	Pinned	Rigid
Merit		・Improve reliability and safety
Construction	・a very close consideration in construction management for the water stop installation is required	・a general construction management for concreting is only required
Operation	・Continuous observation and control of temperature at the joints is required	・Continuous observation and control of temperature at the joints is not required
Cost	100	98
Schedule	56 months	55 months

Cost Study for tank (Ohgishima Case)

Cost Reduction Items	Water Stop System ・Several kinds of water stop at joint portion ・Drainage system at joint portion ・Thermometers including optical fiber type at joint portion	▲1.9%
	Pinned Connection System ・Bearing plates at joint portion ・Suspended re-bars at joint portion	▲0.9%
	Reduction of bottom slab thickness (9.8m→7.7m)	▲0.9%
	Total	▲3.7%
Cost Up Items	Increase of side wall thickness (2.2m→2.7m)	+1.0%
	Increase of re-bar at bottom of side wall	+0.4%
	Increase of PC at bottom of side wall	+0.9%
	Total	+2.3%
Total Cost Reduction		▲1.4%

Construction Schedule (Ohgishima Case)



Fuji Electric Group
New Energy Business

December 13 2006

Fuji Electric Systems Co., Ltd.

Chinese Petroleum Corp.

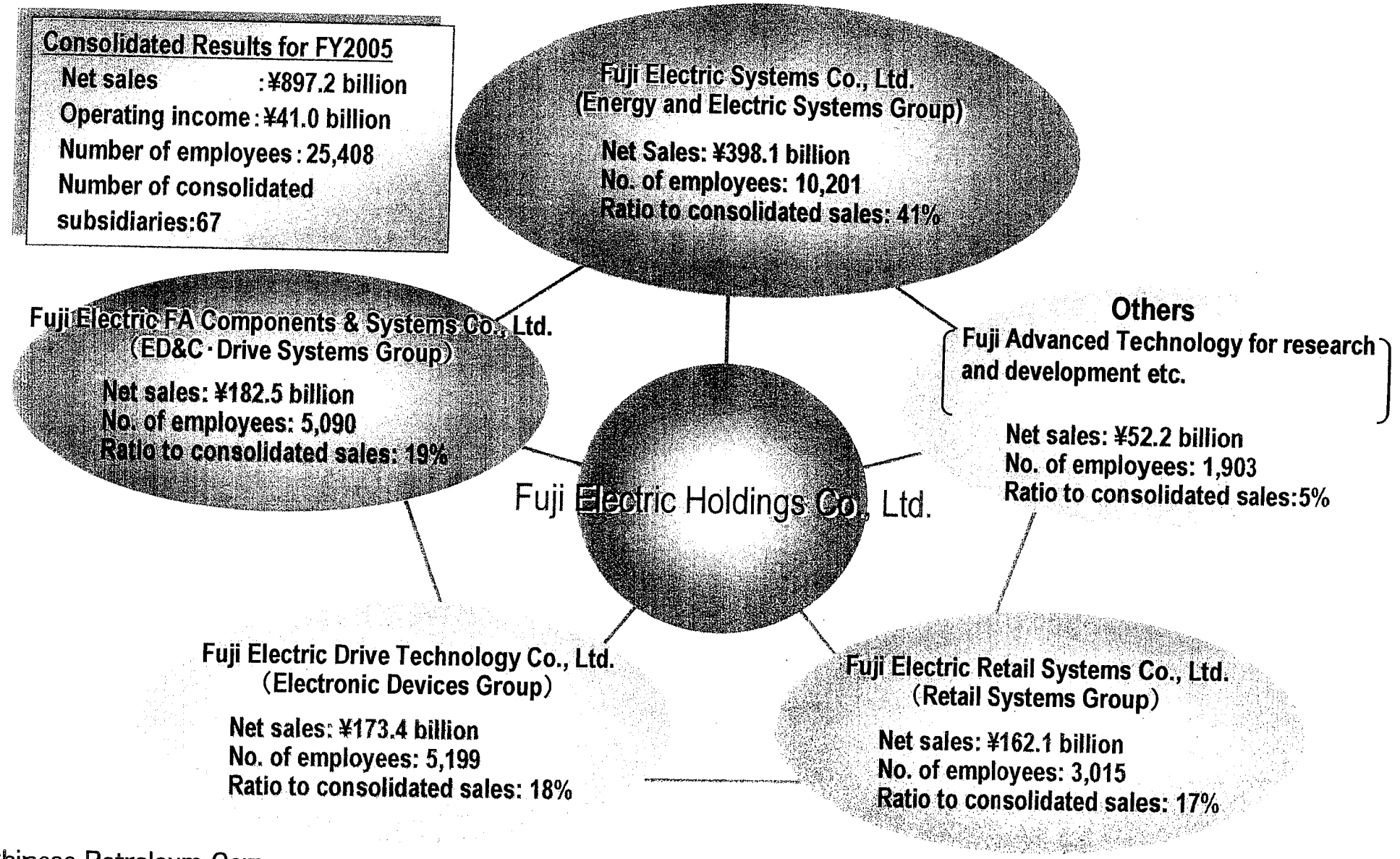
Fuji Electric Group Overview

Chinese Petroleum Corp.

Fuji Electric Overview

Consolidated Results for FY2005

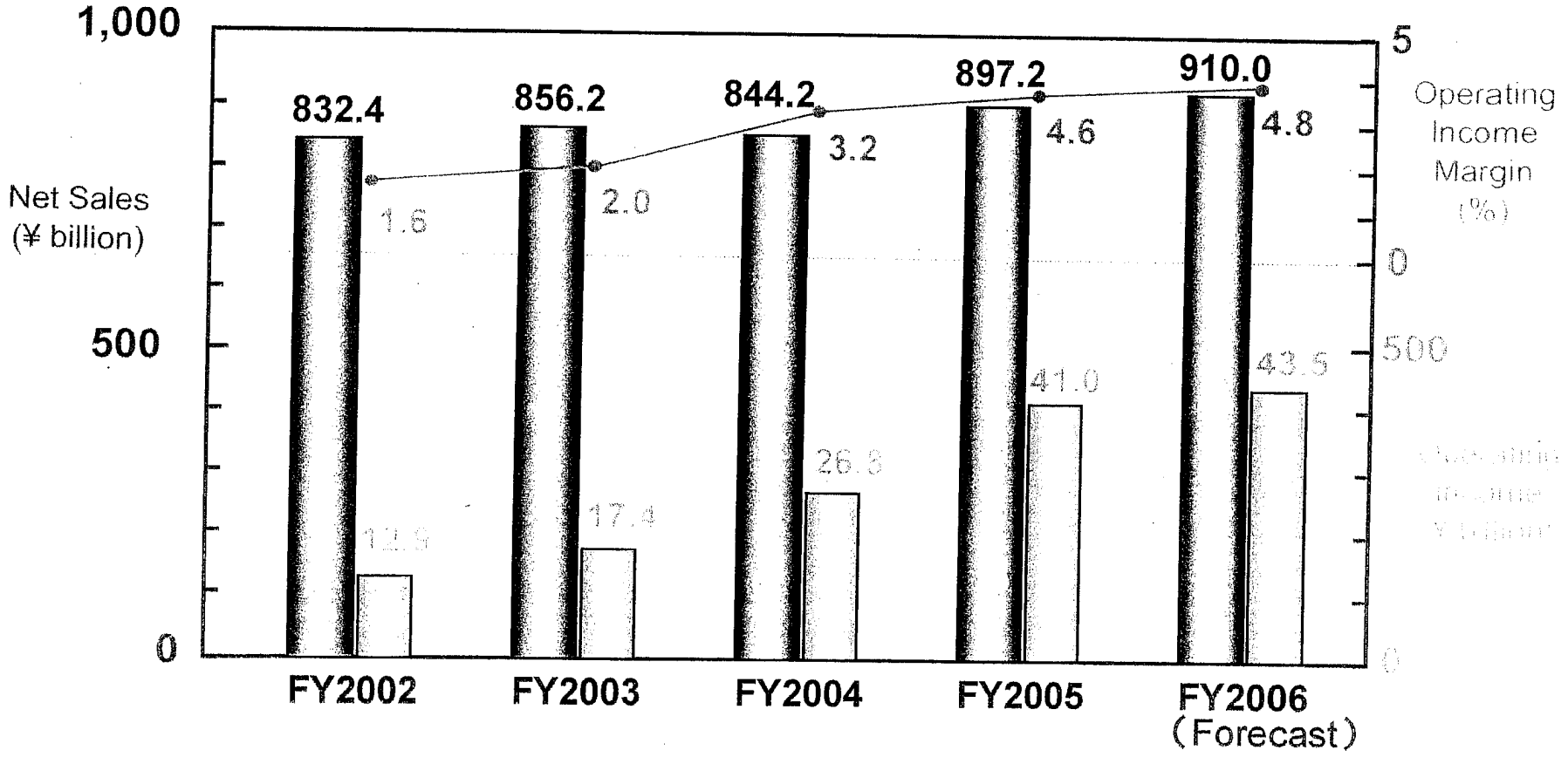
Net sales :¥897.2 billion
Operating income :¥41.0 billion
Number of employees : 25,408
Number of consolidated subsidiaries:67



Chinese Petroleum Corp.

Fuji Electric Group Overview

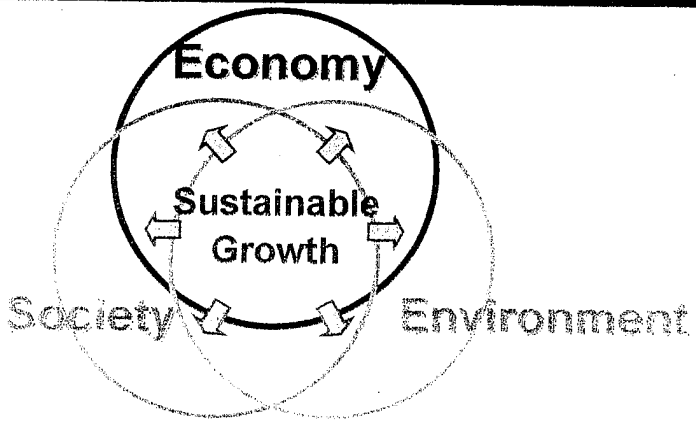
Consolidated Net Sales and Operating Income



Chinese Petroleum Corp.

Fuji Electric Group

In line with the Group management philosophy, we will aim to become a corporate group that has high social value and be in tune with the changing operating environment.



Third-party Ratings

Selection as constituent of Dow Jones Sustainability Indexes (DJSI)

Social Responsibility	Economic Responsibility	Environmental Responsibility
Benefit society through our corporate activities	Generate and boost economic profit by maximizing corporate value	Reduce the environmental impact of products at manufacturing and application stages and deliver technologies, products and services to help protect the environment
Create a sound and transparent corporate structure	**Achieve sustainable growth and increase profitability**	**Deliver technologies and products to help protect the environment**

Chinese Petroleum Corp.

About Fuji Electric Systems

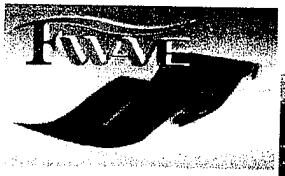
Chinese Petroleum Corp.

Initiatives for New Energy Development and Energy Conservation

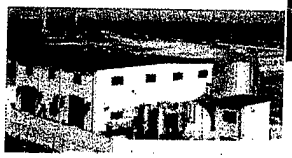
— Deliver technologies and products that help protect environment —

Fuji Electric Systems

Eco-power distributors



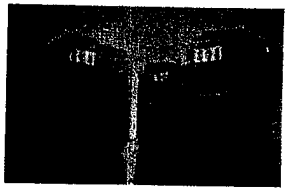
Solar Modules



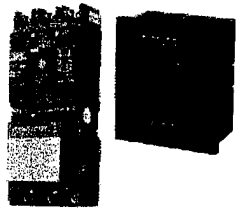
Bio-gas plants

Geothermal power generation

Fuji Electric FA Components & Systems

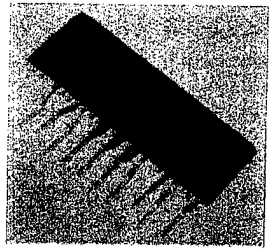


General-purpose inverters

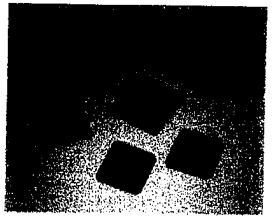


Molded case circuit-breakers with a power monitoring function (Energy conservation supporting equipment)

Fuji Electric Device Technology

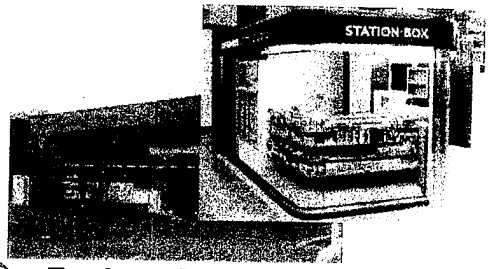


Low-loss power supply devices



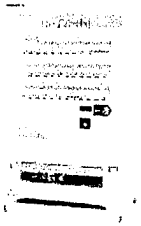
Low-power consumption CMOS power supply ICs

Fuji Electric Retail Systems



Ecolo units

R-CUBEs



Power-saving vending machines

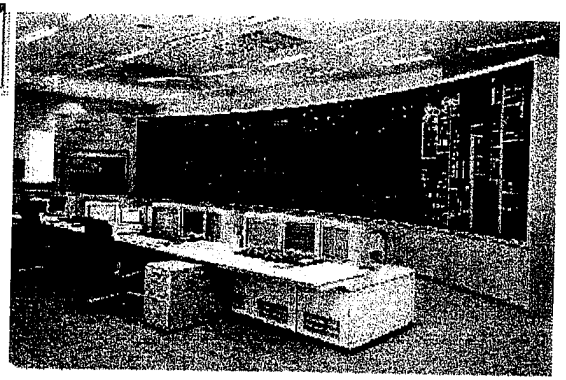
(Labor and material-saving outlet stores)

Chinese Petroleum Corp.

Our Businesses

e-Solutions

- **e-Municipalities**
- **Information control systems**
- **Energy measurement and management**
- **New energy**
- **Power information control systems**
- **Industrial instruments**
- **Radiation control systems**

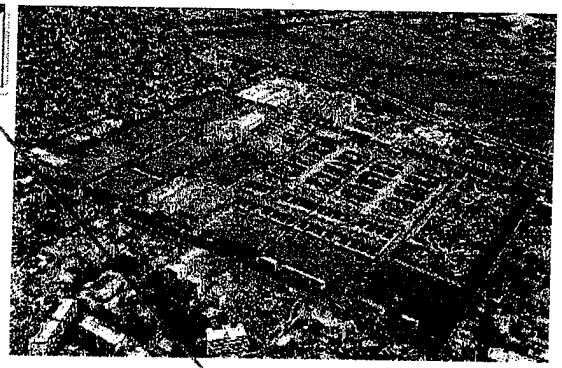


Industrial Plant Systems

- **Power electronics**
- **Electric plant systems**
- **Electrical machinery equipment for facilities**
- **Instrumentation plant**
- **Cleanrooms**
- **Transportation equipment and systems**

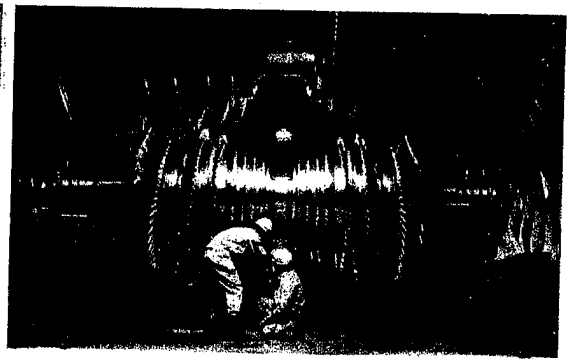
Environment Systems

- Water treatment systems
- Water environment systems
- Waste disposal systems
- Recycling systems



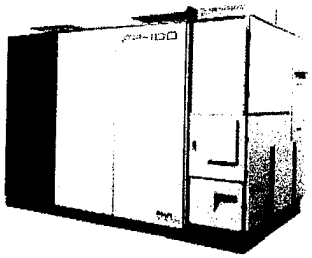
Energy Systems

- Thermal power generation equipment
- Hydraulic power generation equipment
- Nuclear power-related equipment



PAFC

(Phosphoric Acid Fuel Cell)

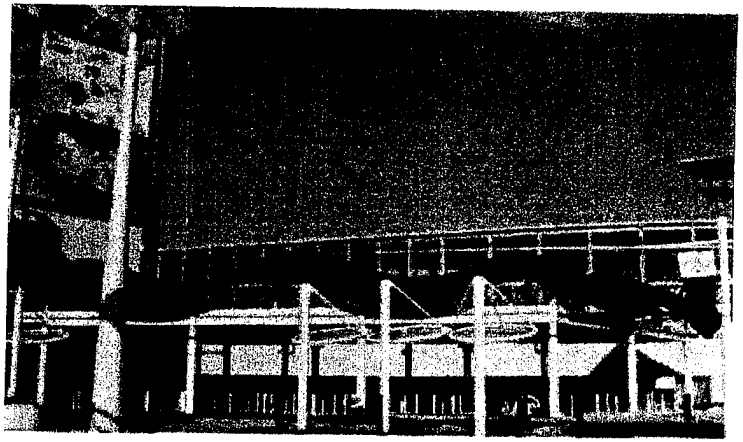


Chinese Petroleum Corp.

Examples of Practical Use of New Energy

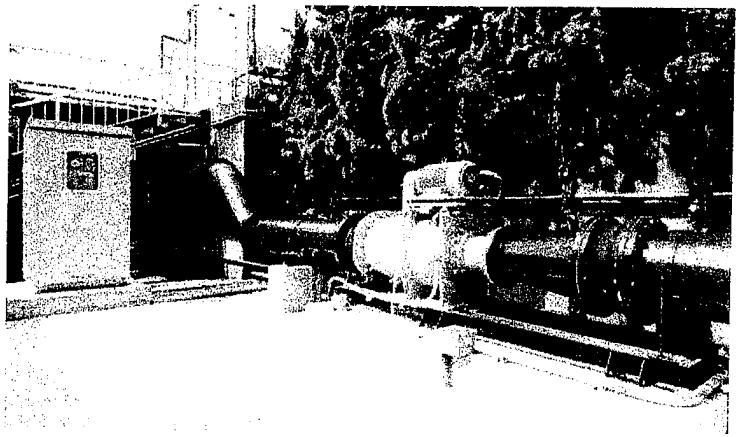
Wind-power generation facility (Nishime)

Wind turbines (1250kW, 600kW) made by DeWind, which were commercialized in Nishime, Akita by Win-power Co., Ltd.



Solar Modules (at the 2005 World Exposition in Aichi)

Installed on wavy roofs at the Electric Power Pavilion (10kW)



Microtubular turbine hydraulic power generation (Morigasaki sewage-treatment plant in Tokyo)

It is applicable to heads from low (2m) to high and meets flow rate changes by adjusting runner vane angles (95kWx2, 4kWx1)

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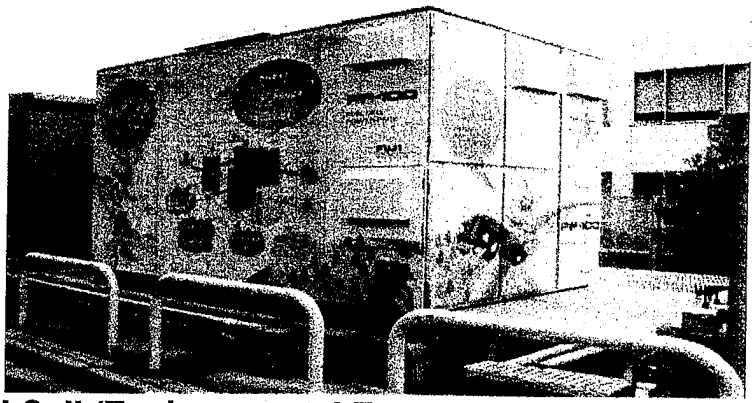


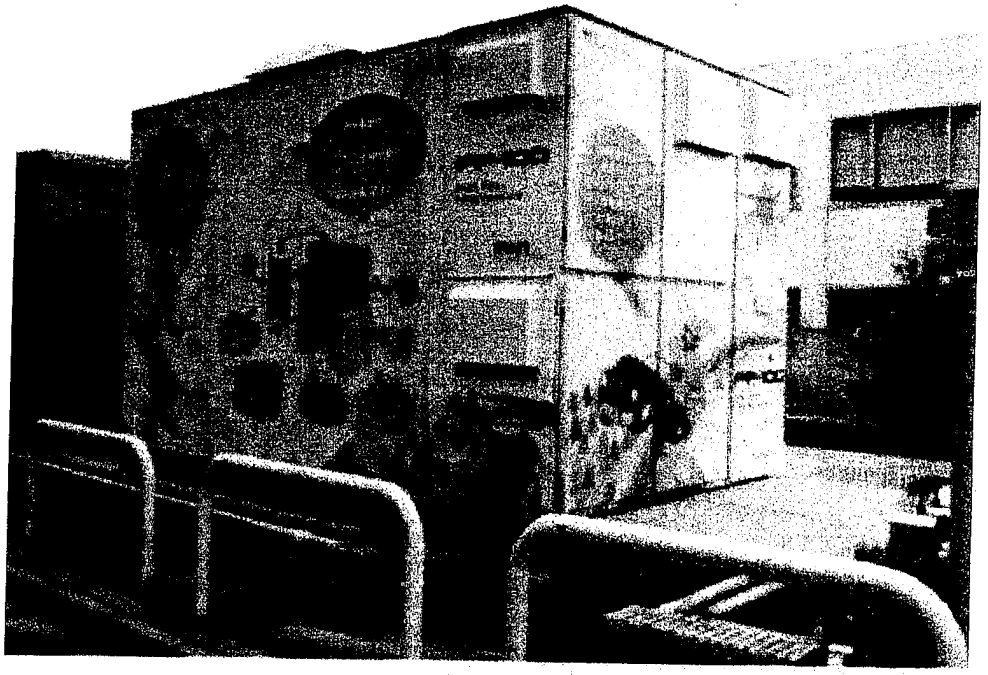
Fuel Cell (Environmental Energy Museum of Tokyo Gas Co., Ltd.)

Its longer service life and less overhaul work will lower total life cycle costs (100kW)

Fuji Phosphoric Acid Fuel Cell

e-Front runners

Fuji Electric Systems Co.,Ltd



December 13 2006

Chinese Petroleum Corp.

Why do people want to see more fuel cells around them?

Because with fuel cells,

- *Global warming can be prevented.*

  Even small capacity fuel cells are highly efficient.

- *Energy can be produced cleanly.*

  Exhaust gas is clean.

- *Energy security can be improved.*

  The use of natural gas, LPG, biogas and by-product hydrogen, etc., will make us less dependent on oil.

- *More distributed power supply systems can be made possible.*

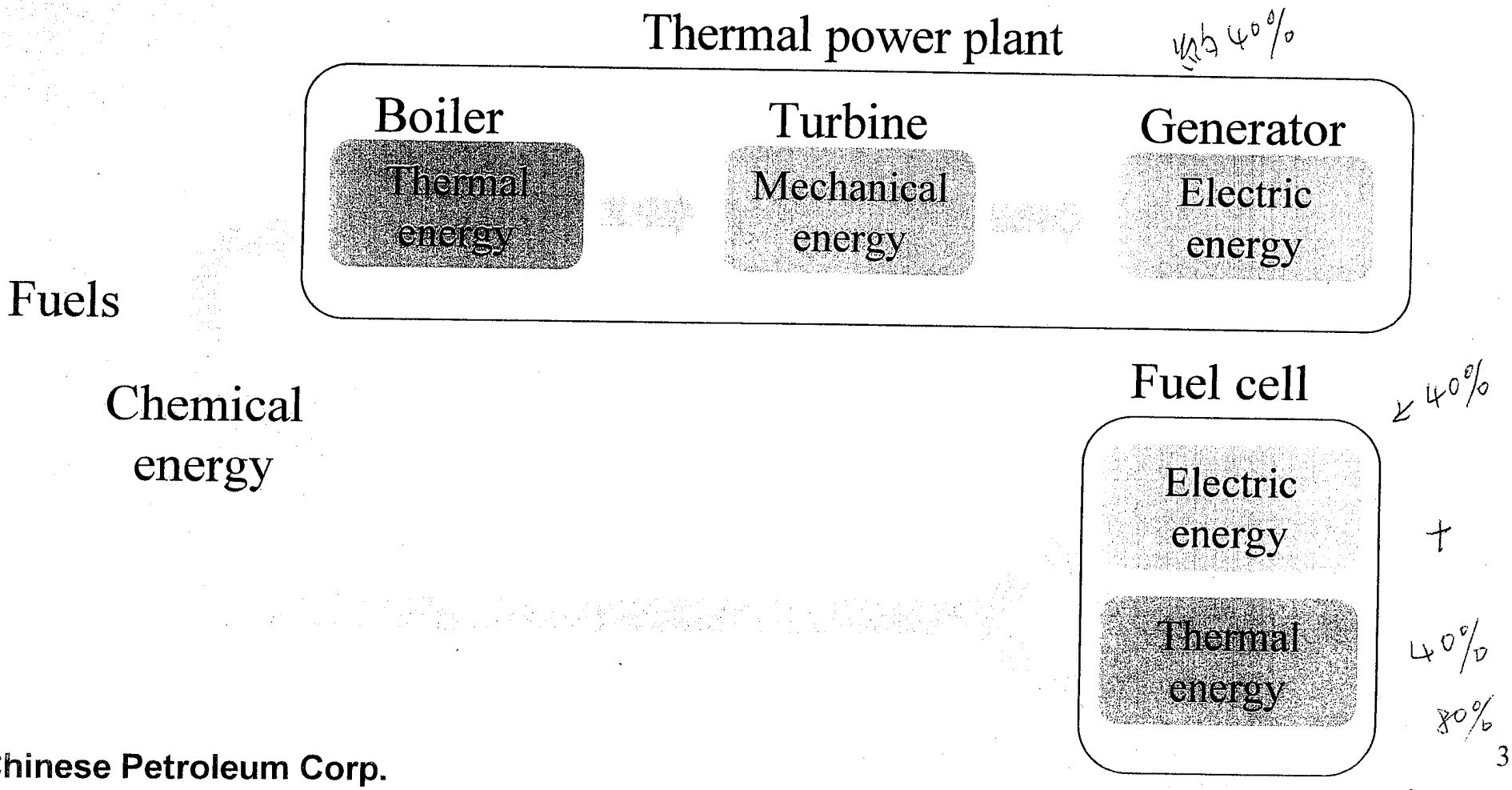
  Less dependence on large generation facilities will increase the reliability of power supply.

- *New values can be created.*

  Fuel cells raise awareness of environmental protection. Fuel cell users can demonstrate their CSR (Corporate Social Responsibility) activities in a tangible way.

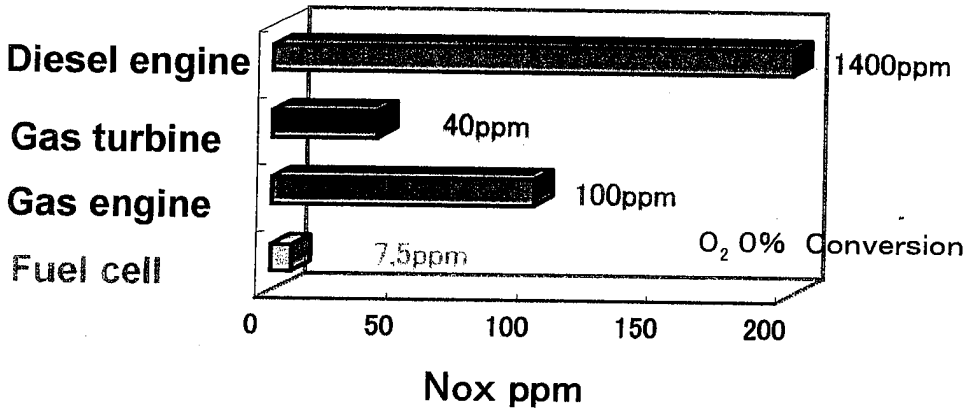
Comparison of energy conversion with thermal and fuel-cell power generation

Fuel cells are highly efficient at generating energy because fuel cells convert the chemical energy of fuels directly into electric energy.

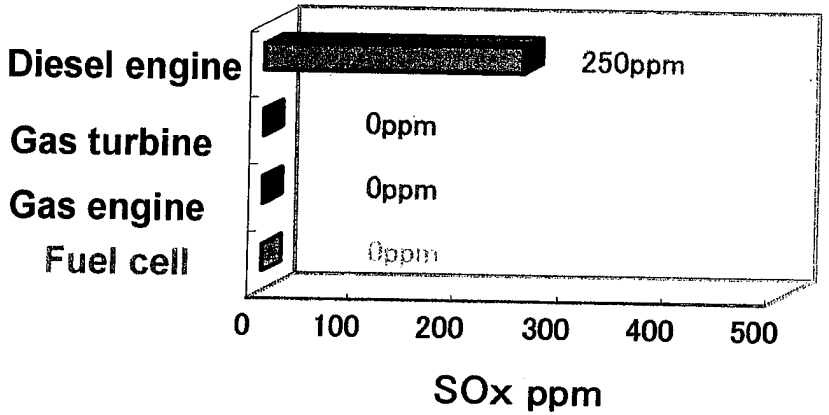


Features of Phosphoric Acid Fuel Cell

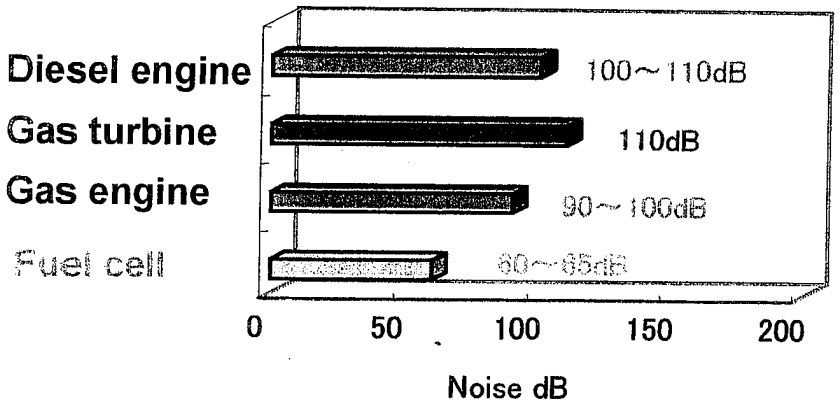
NOx emissions



SOx emissions

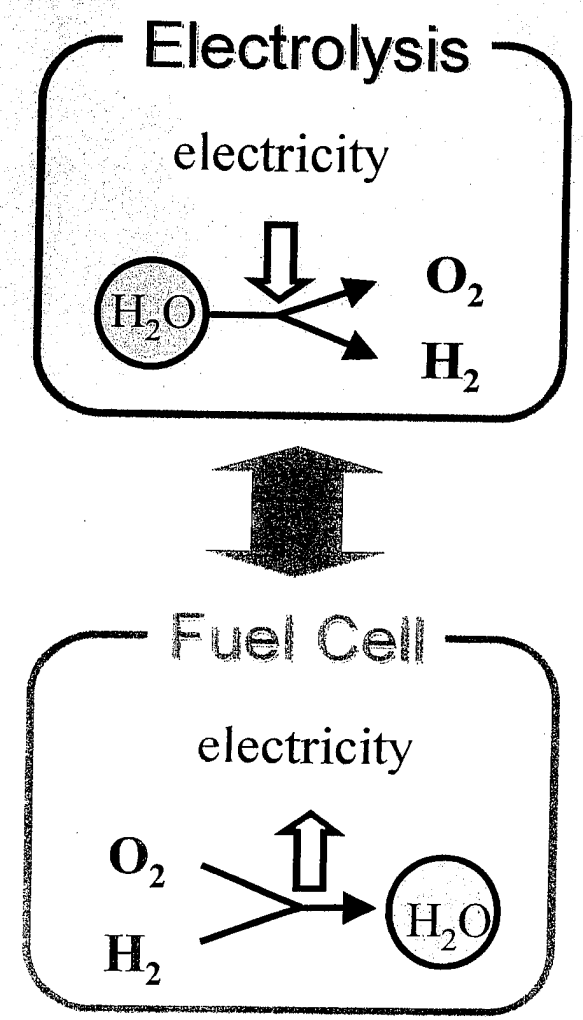


Noise



- ◆Exhaust gas is clean.
- ◆Noise level is low.
- ◆Electrical efficiency is high even when operated at low outputs.
- ◆Waste heat can be recovered.

Principle of operation of fuel cell



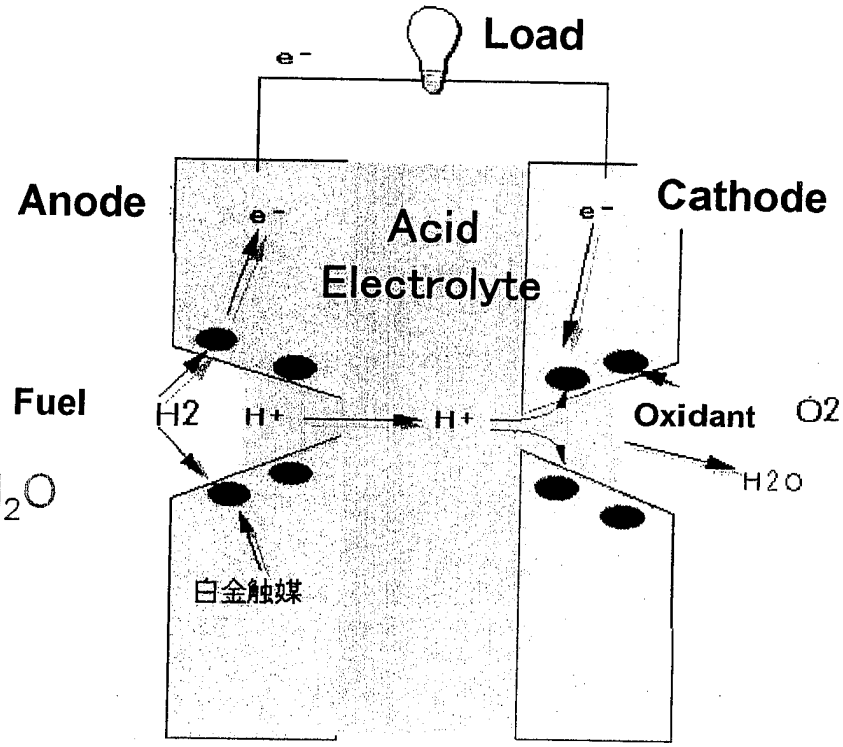
A fuel cell is a device that directly converts the chemical energy of reactants (a fuel and an oxidant) into low voltage d.c. electricity.

Anode

$H_2 \Rightarrow 2H^+ + 2e^-$

Cathode

$1/2O_2 + 2H^+ 2e^- \Rightarrow H_2O$



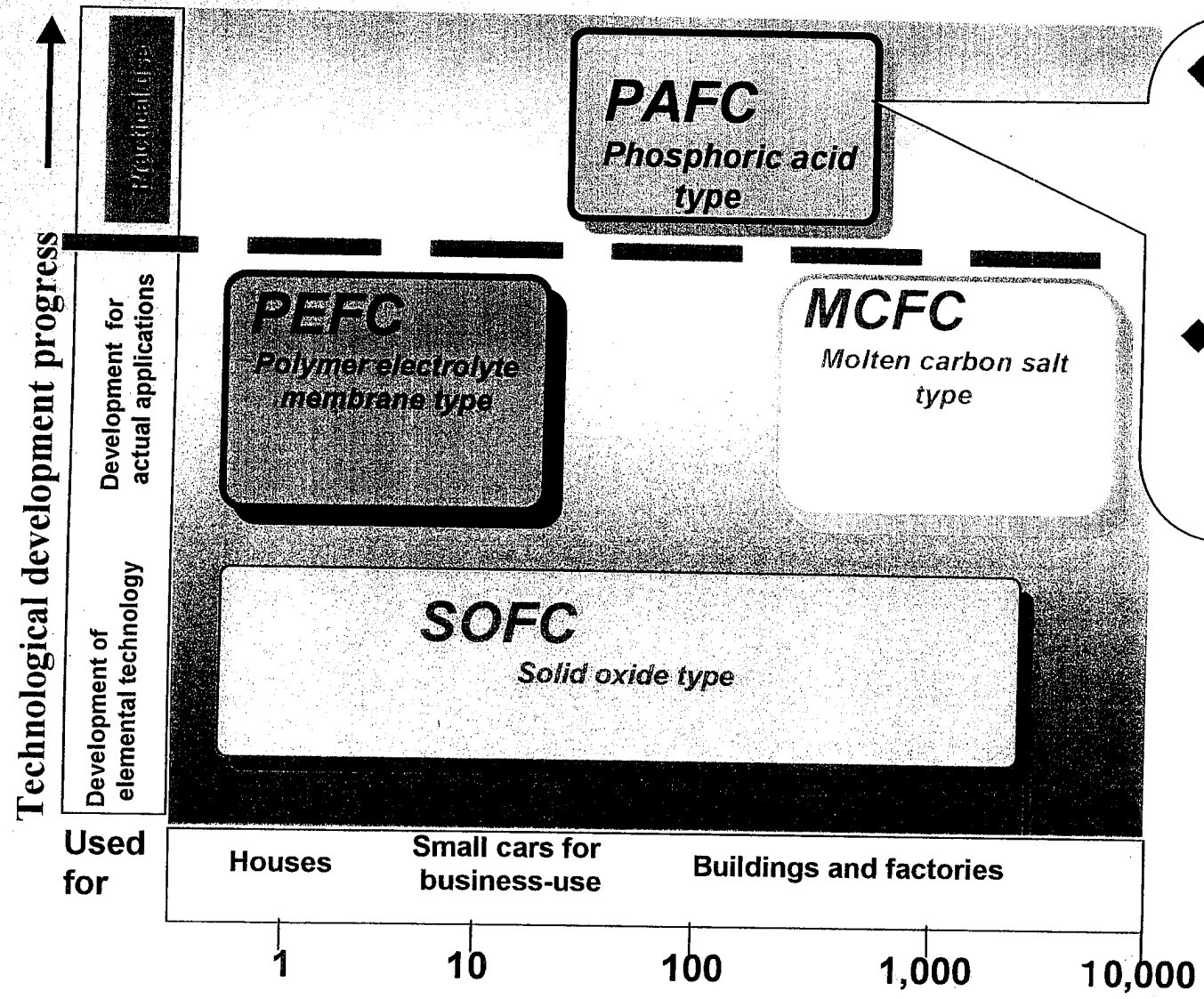
Principle of operation of fuel cell

Types of fuel cells

	Phosphoric acid type (PAFC)	Polymer electrolyte membrane type (PEFC)	Molten carbonate type (MCFC)	Solid oxide type (SOFC)
Electrolysis	Phosphoric acid (H_3PO_4)	Ion exchange membrane	Molten carbon salt (Li_2CO_3,K_2CO_3)	Stable zirconate (ZrO_2+Y_2O_3)
Ion conductor	H^+	H^+	CO_3^{2-}	O^{2-}
Operating temperature (°C)	170-200	80-100	600-700	800-1000
Fuel	Natural gas, Naphtha, LPG, Methanol	Natural gas, Naphtha, LPG, Methanol	Oil, LPG, Natural gas, Methanol, Coal gas	Oil, LPG, Natural gas, Methanol, Coal gas
Development status	Being commercialized	Early stage of being put to practical use	Early stage commercial model larger than 250kW being tested	Performance being tested
Major applications	For buildings and factories	For portable equipment, houses, buildings and automobiles	For buildings and factories	For houses, buildings and factories

Based on Fuel Cell Introduction Guide Book by *NEDO*

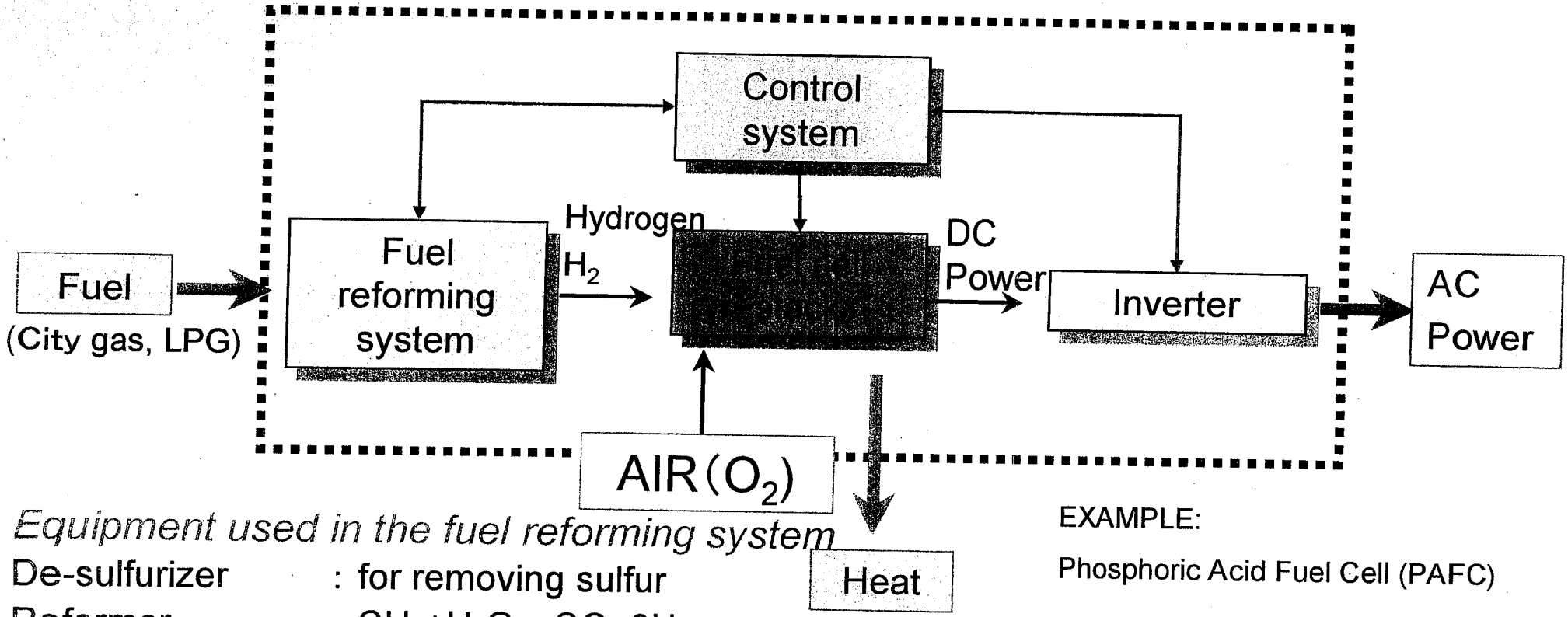
Fuel cell technological trend



- Only PAFCs have been operating reliably and can be used in many applications.
- Only PAFCs have many proven operation and application records.

Configuration of fuel cell system

After reforming a fuel such as city gas into hydrogen, the fuel cell system, including the inverter, generates AC electric power and heat.



Equipment used in the fuel reforming system

De-sulfurizer : for removing sulfur

Reformer : $CH_4+H_2O \rightarrow CO+3H_2$

CO shift converter : $CO+H_2O \rightarrow CO_2+H_2$

EXAMPLE:

Phosphoric Acid Fuel Cell (PAFC)

Environmentally friendly fuel cells

- The goal has been set by the Kyoto Protocol to globally reduce CO_2 emissions by 2010.
- The following goal has been set for Japan:

  6% reduction of **CO2 emissions by 2010 from the 1990 level**
- The Japanese government has set a fuel cell target of a 3 million ton reduction in CO_2 emissions by 2010.

If city gas-fed fuel cells are used,

CO_2 emissions will be reduced by *281 tons per year.*
(when compared with thermal power generation)
Energy saved will be *2,323 GJ per year.*

60 kL per year (in terms of oil quantity)

If digester gas-fed fuel cells are used,

CO_2 emissions will be reduced by *720 tons per year.*
(when compared with thermal power generation)
Energy saved will be *10,919 GJ per year.*

282 kL per year (in terms of oil quantity)

Fuji Fuel Cells

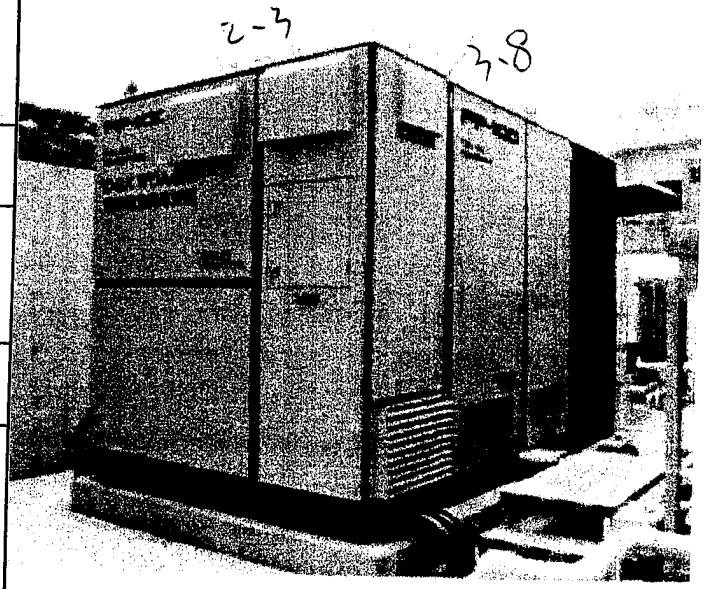
- The Fuji Electric Group has been delivering 100kW phosphoric acid fuel cell (PAFC) systems since 1998. We have achieved our initial goal of 40,000 hours (or about five years)of operation with the first commercial model. We have delivered the even more reliable second commercial model to customers at a lower cost than the first one since 2001.

- This describes examples of applications and records of operation for FP-100F systems, such as city-gas-fed systems for hospitals and digester-gas-fed systems for sewage disposal plants as well as the principle of operation of fuel cells and the specifications for FP-100F systems.

100kW PAFC power package

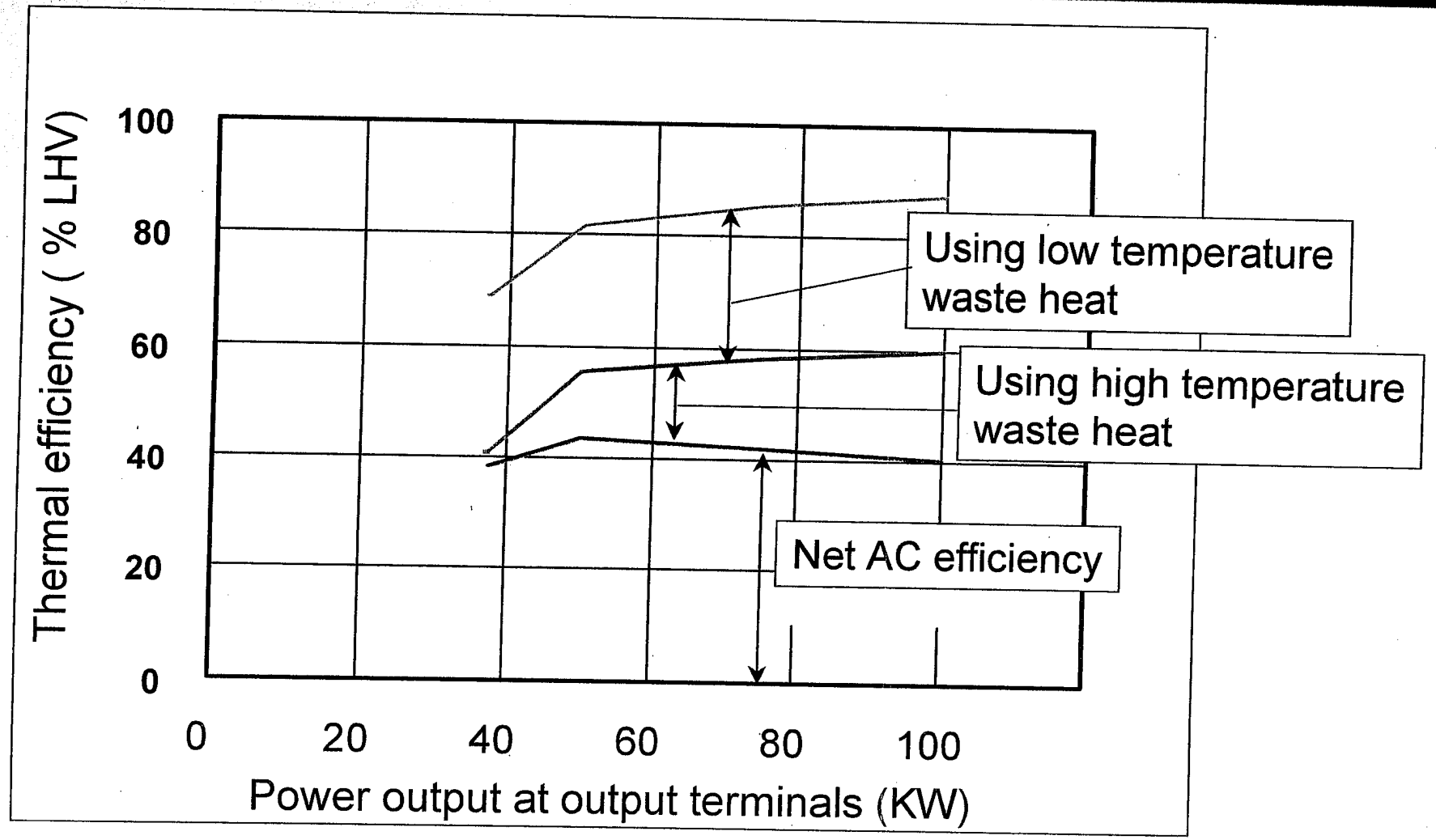
Specifications

Rated output power	100kW
Output voltage and frequency	200/210/220V 50/60Hz
Electrical efficiency	40%(LHV)
Heat recovery efficiency	47%(LHV)
Total efficiency	87%(LHV)
Exhaust gas	NOx:less than 5ppm (O_2=7%) SOx, dust:less than the detection limit
Consumption of gas	22Nm3/h (City gas) 45Nm3/h (digester gas)
Operating system	Fully automated/Grid-connected

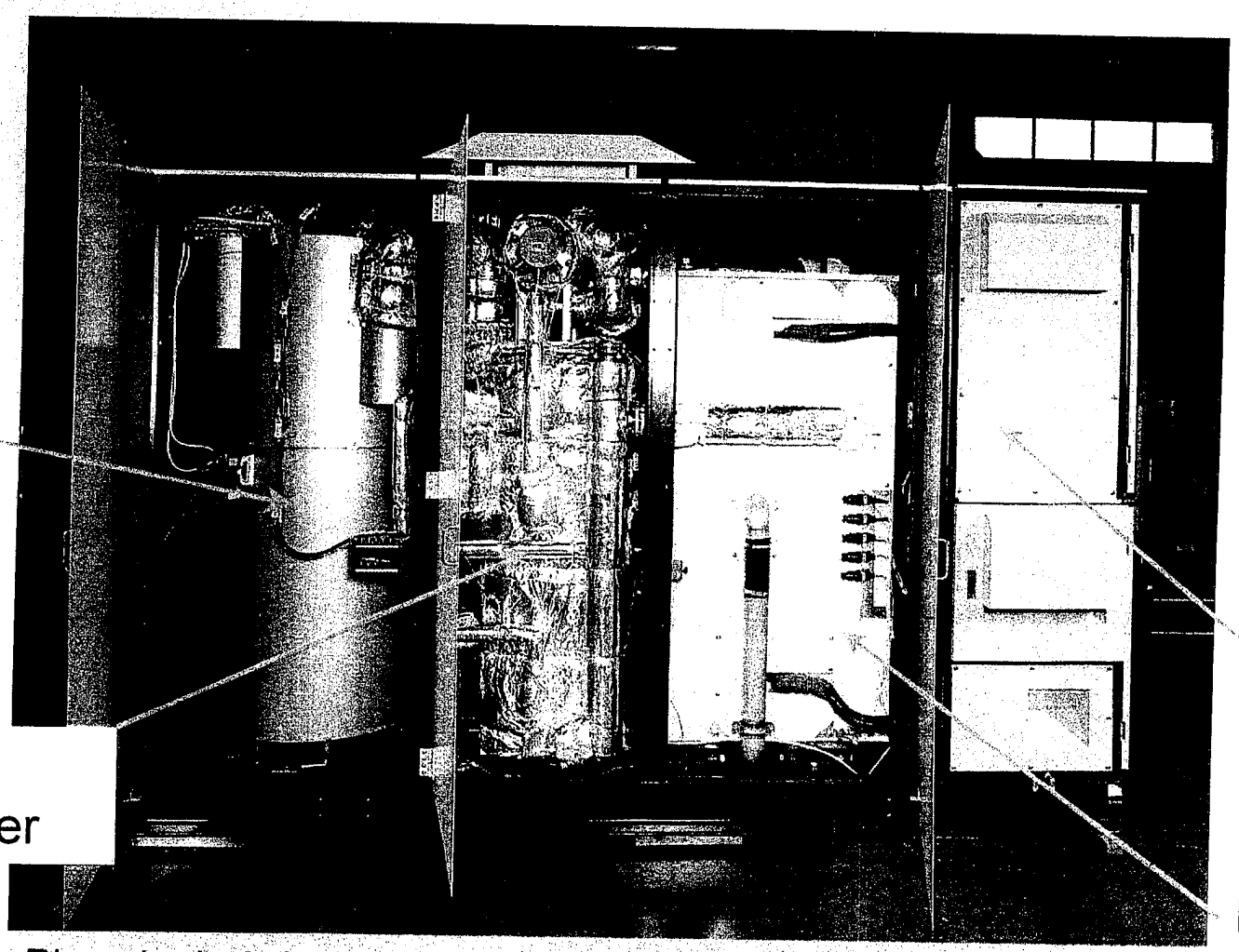


100kW Fuji Fuel Cell Power Package

Efficiency of 100kW PAFC



Inside of 100kW PAFC power package (Fuji Electric)



Phosphoric Acid Fuel Cell （PAFC） 2.2m(W) × 3.8m(L) × 3.0m(H)

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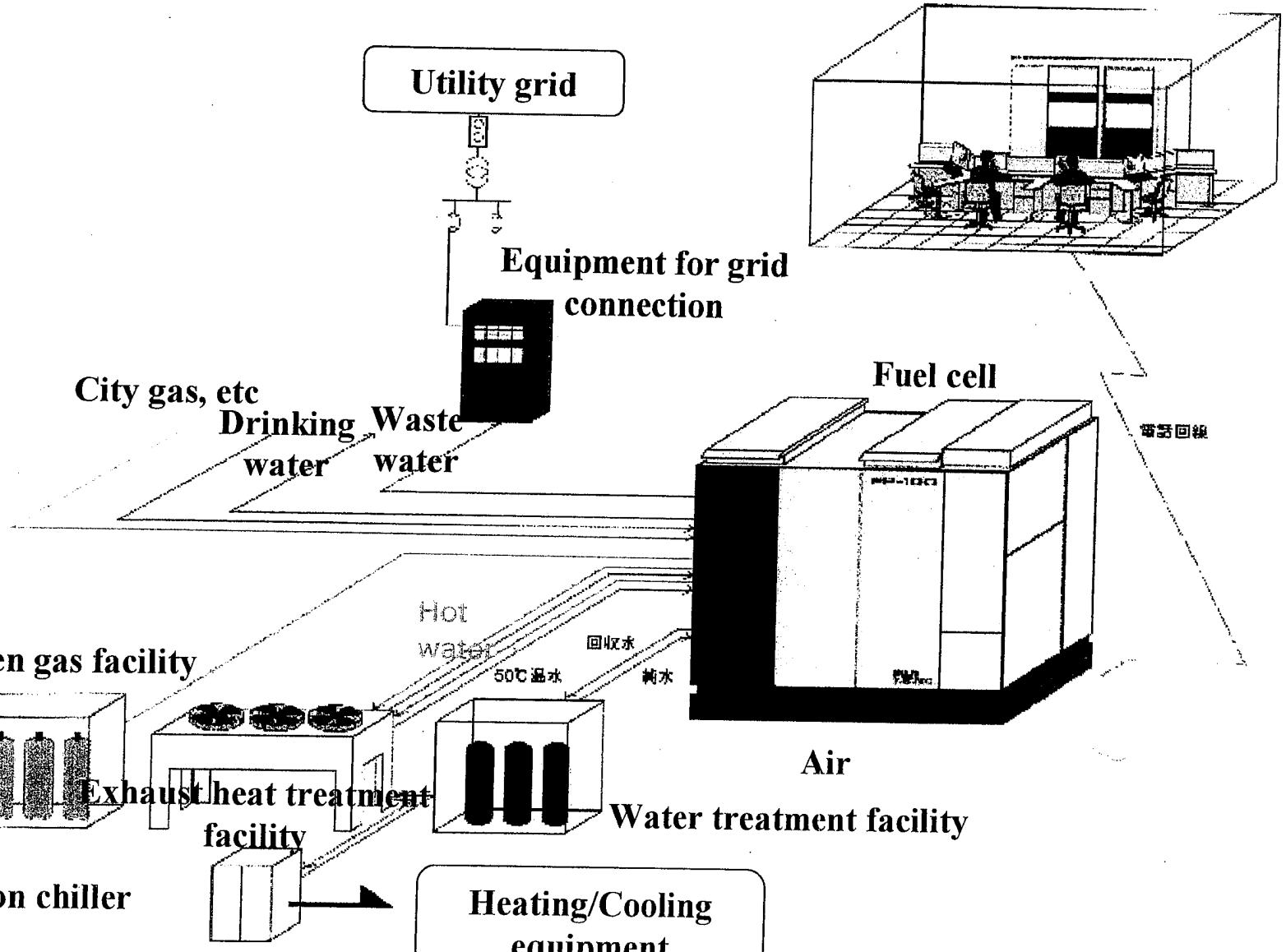
Example of auxiliary equipment for fuel cells



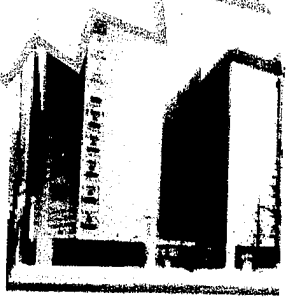
Fuji PAFC operation records (As of October 2006)

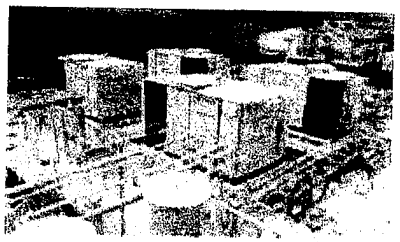
FC	Installation site	Fuel	Date of delivery	Hours of operation (h)	designed lifetime	note
1st Commercial Model	Hospital	City Gas(13A)	Aug 1999	**44,265**	40,000	
	Hotel		Oct 1999	**64,956**		Note 1)
	College		Apr 2000	**41,735**		
	Office Building		Mar 2001	**47,837**		
	Office Building			**46,588**		
	Office Building		Jul 2000	**42,666**		
				48,579		
2nd Commercial Model	Induction Center		Dec 2001	**37,783**		
	Sewage Disposal Plant	Digester Gas	Mar 2002	**38,088**		
				38,383		
	Hospital	City Gas(13A)	Jul 2003	**28,114**		
	Hotel		Oct 2003	**19,913**		
	Exhibit facilities		Nov 2003	**23,000**		
	Hospital		Mar 2004	**18,848**		
	Office Buiding		Jun 2004	**21,638**		
	Exhibit facilities		Mar 2006	**4,337**	60,000	
	Hospital		Mar 2006	**2,236**		
	Hospital		Mar 2006	**2,140**		
	Sewage Disposal Plant	Digester gas	Sep 2006	during tuned		100kW ×4

Note 1) Reformer related equipment was replaced after 42,000 hours of operation

Over 40,000 hours !

More than **60,000** hours

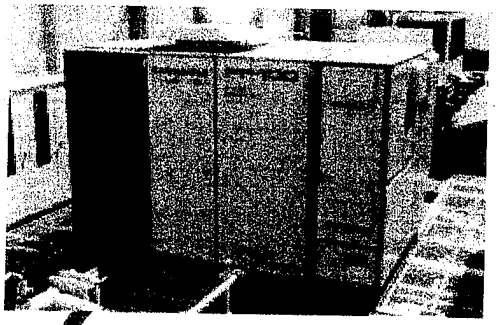




Chinese Petroleum Corp. **We have exceeded 60,000 hours of operation.**

Fuji Fuel Cell operating at Daido Hospital

Daido Hospital



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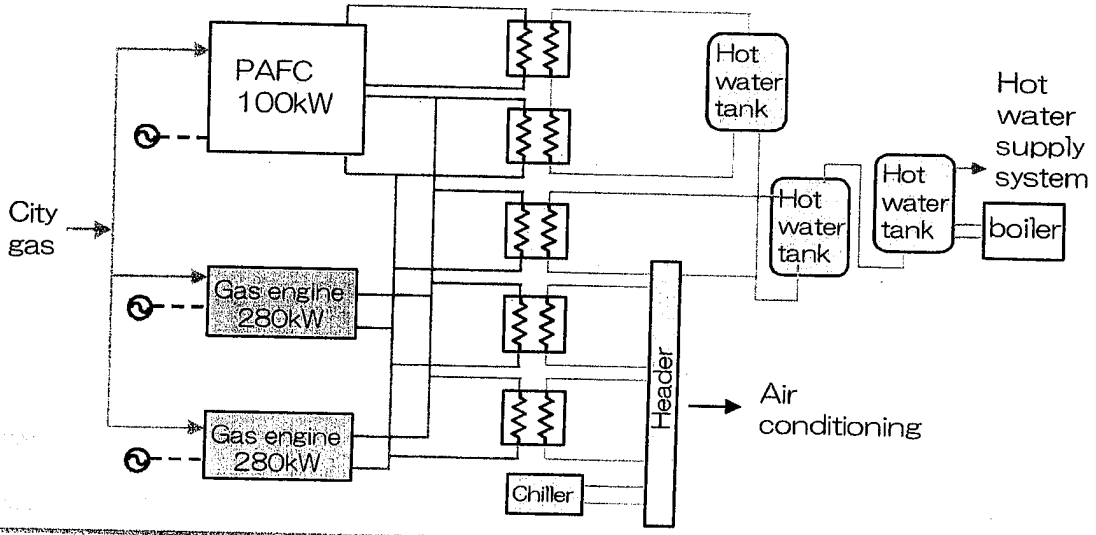
Schematic Flow

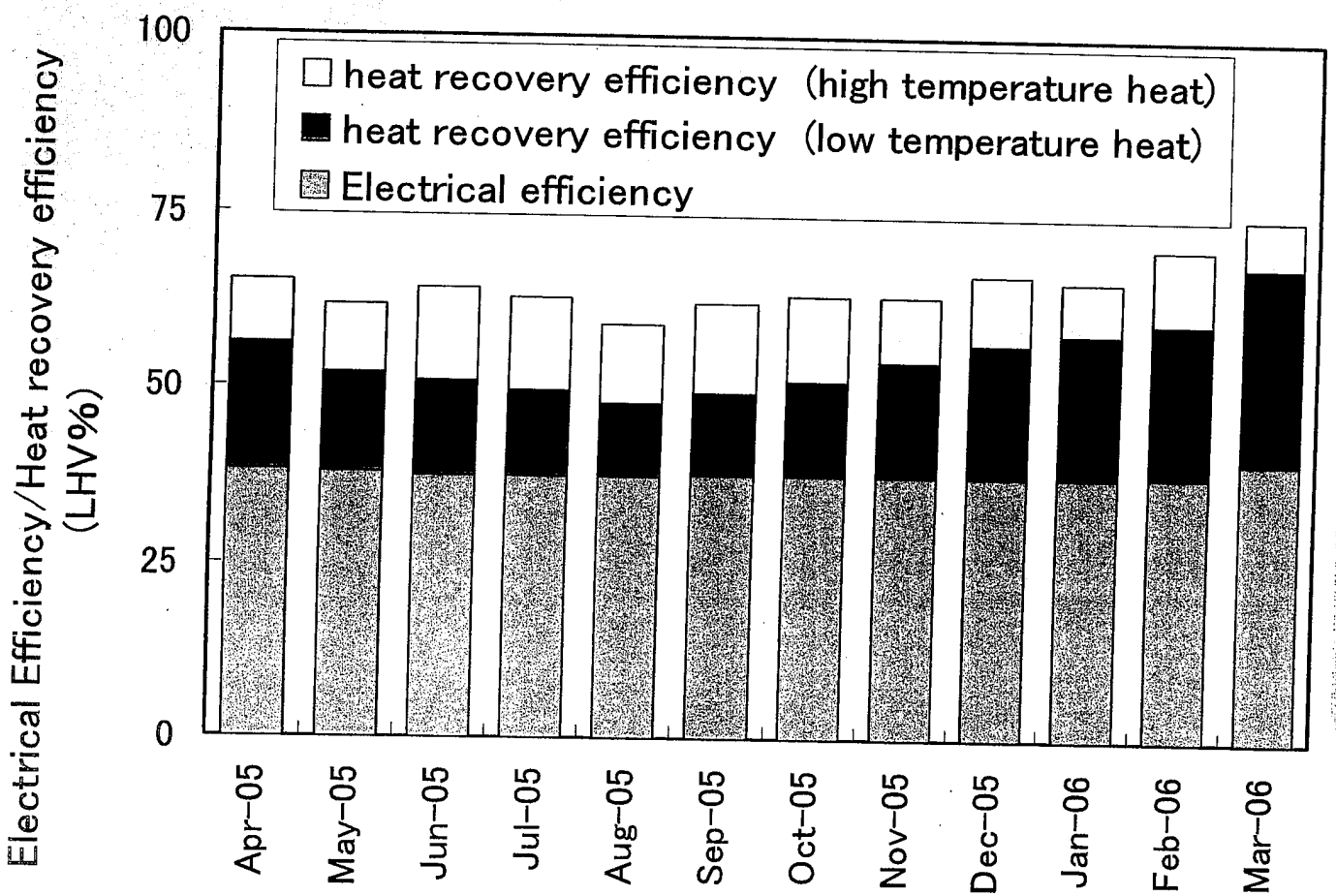


Operation

- The fuel cell has been operating continuously for 24 hours a day as the primary power source.
  (Its night-time load is reduced to 50% of the daytime load when a heat load is small).
- Two gas engines are operated only during the daytime on weekdays to power excessive loads.
- Recovery heat is used for preheating water and for air-conditioning.
- This system can provide 50% of the electrical power, 80% of the hot water, and 10% of the air conditioning needed at this hospital.

Fuji Fuel Cell operating at Daido Hospital in 2005

Results of operation in 2005



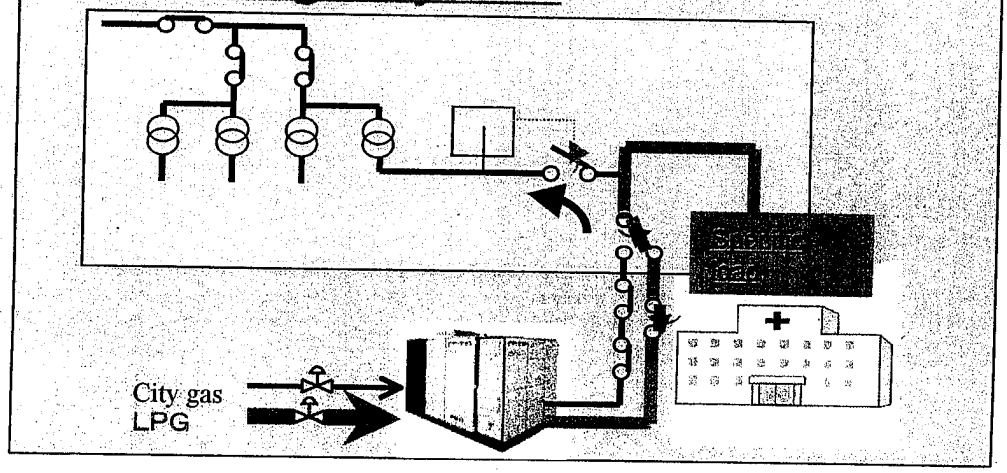
Major results

- **Total hours of operation: 24,700 hours (Mar. 2006)**
- **Reduction of primary energy : 1,249GJ/year**
- **Energy-savings rate : 17%**
- **Reduction of CO_2 emissions : 162t/year (38%)**

Total Efficiency (Average) : 65%

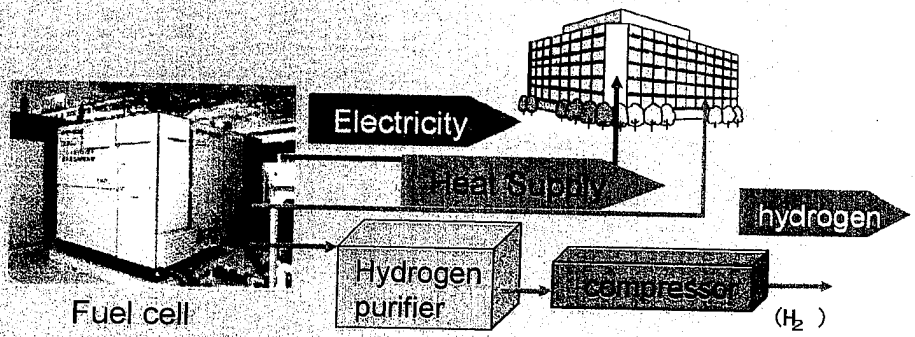
Future Applications of PAFCs

For Emergency Use



For Hydrogen Supply

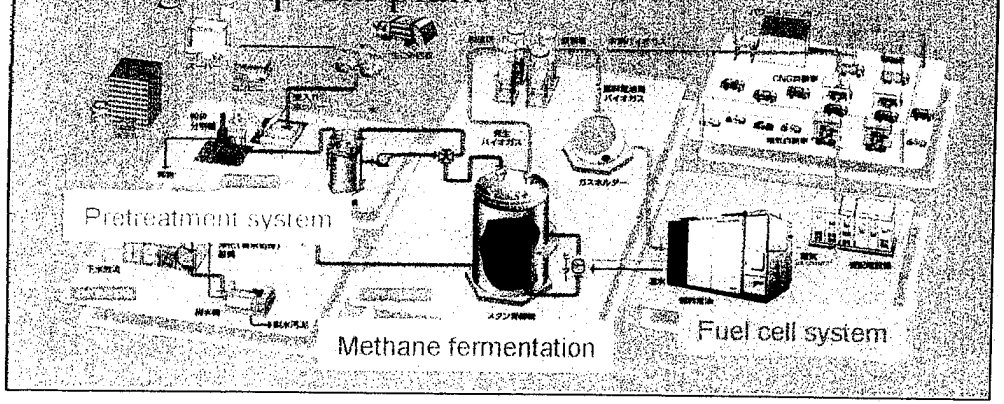
•Hydrogen station



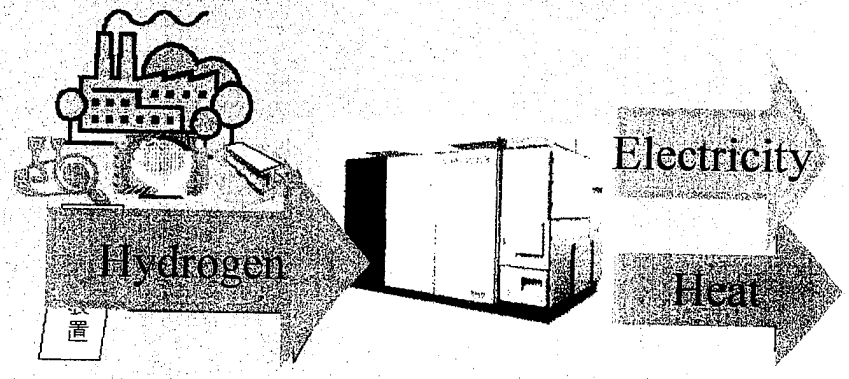
For Biological Gas and Digester Gas

•Methane fermentation for garbage

•Sewage disposal plant

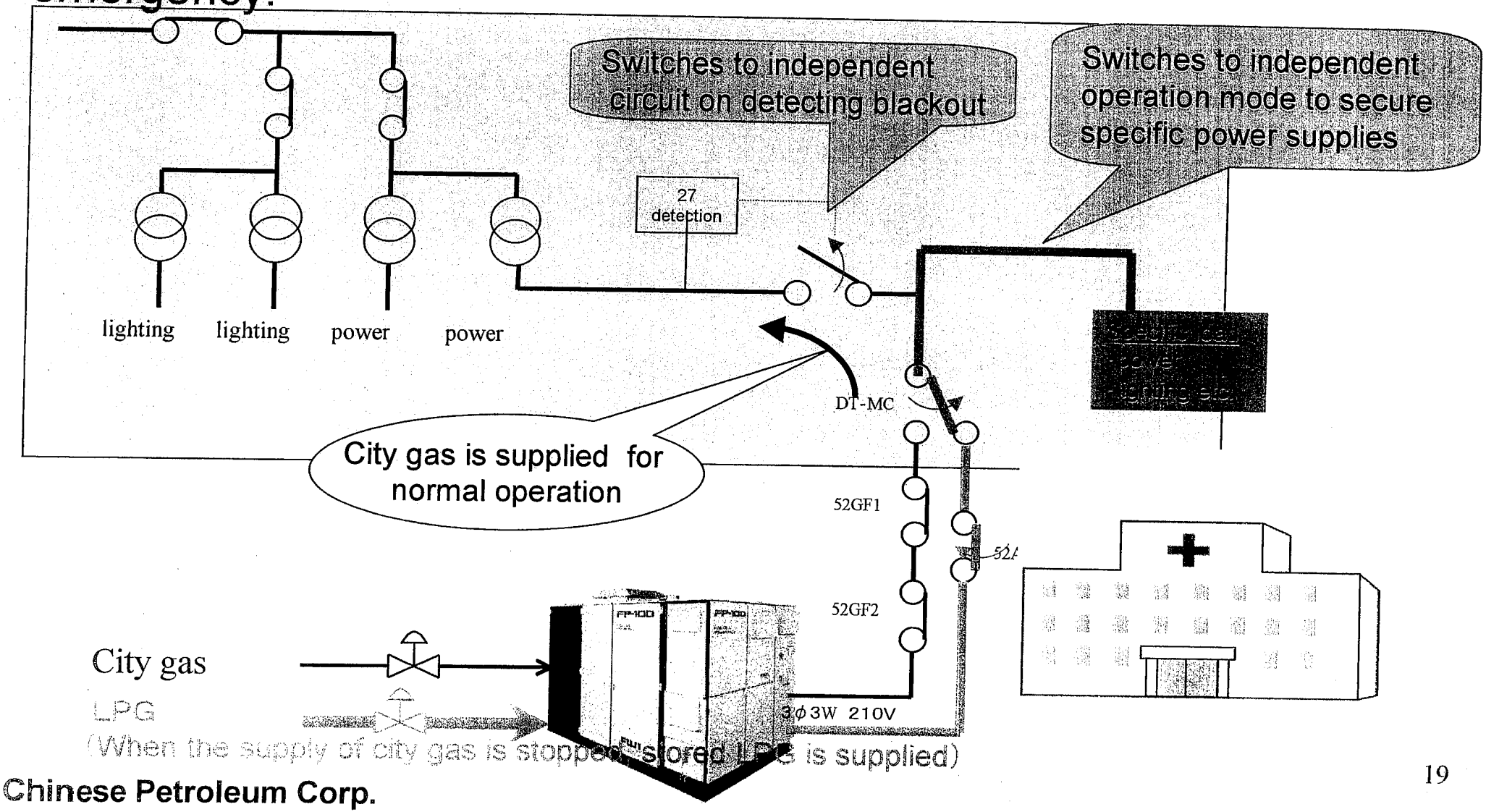


For By-Product Hydrogen



Application example: City gas for apartments & hospitals

Normal operation switches to stand-alone operation in case of an emergency.



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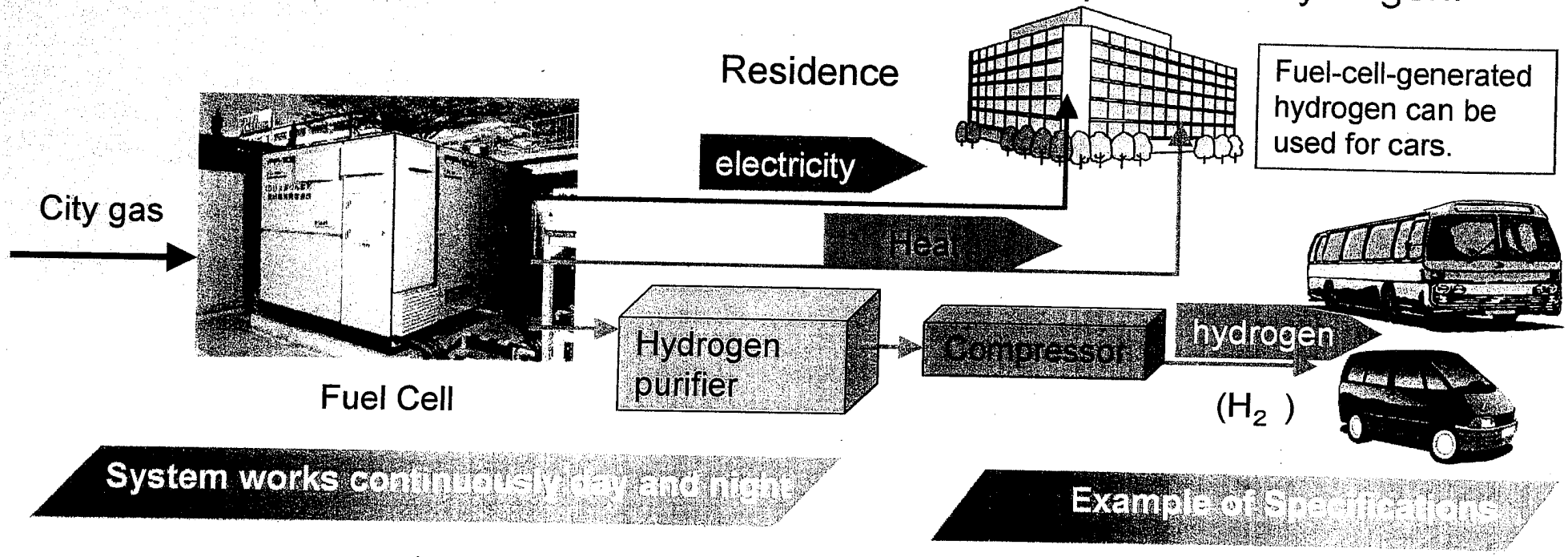
Application example : PAFC-produced hydrogen

PAFCs supply not only electricity and heat but also self-produced hydrogen.



Daytime

Power is generated.

Nighttime

Power is generated and hydrogen is stored.

Input
City gas
22Nm3/h

Outputs
- Electric power
  100kW
- Heat
  90℃(max 180MJ/h)
  50℃(max 243MJ/h)
- Hydrogen
  Daytime: 75kW load/8Nm^3/h
  Night: 50kW load/20Nm^3/h

INPUT

OUTPUT

Note) The above figures are designed values and may vary according to applications.

Total system : Tokyo Gas; Fuji Electric 100kW fuel cell

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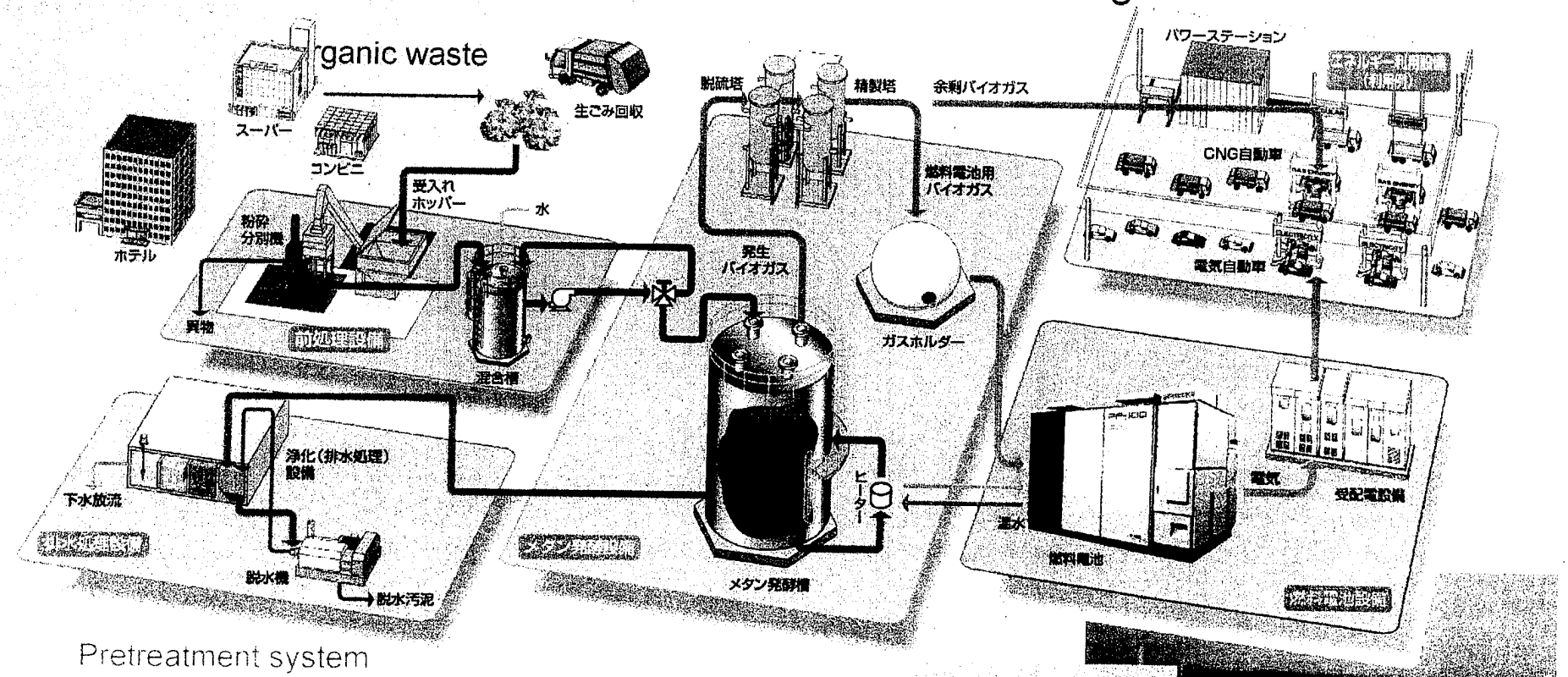
Application example: Methane fermentation from garbage

PAFCs are suitable for biological power generation with organic waste



Our PAFC at Kobe Port Island has been operating stably for more than 10,000 hours.

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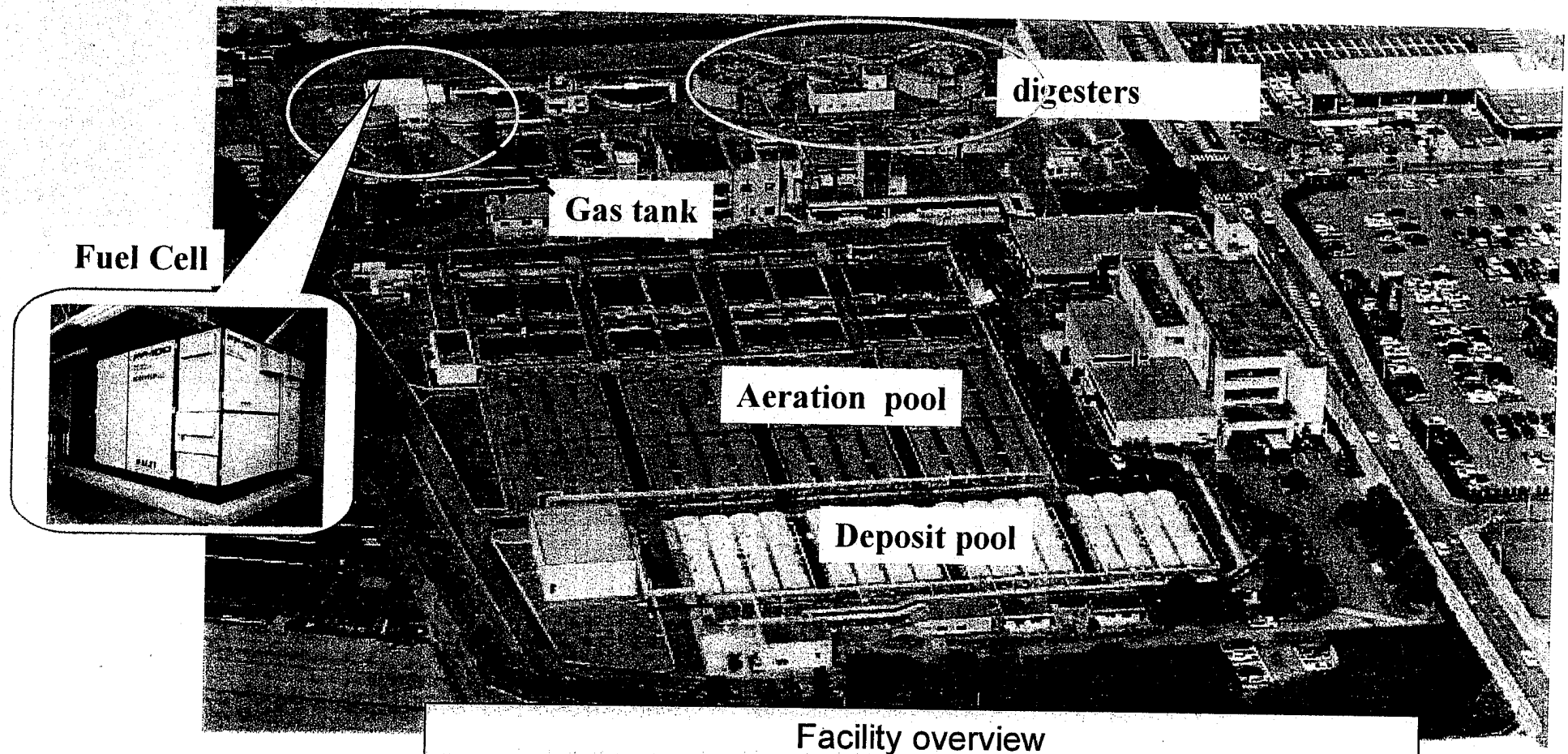
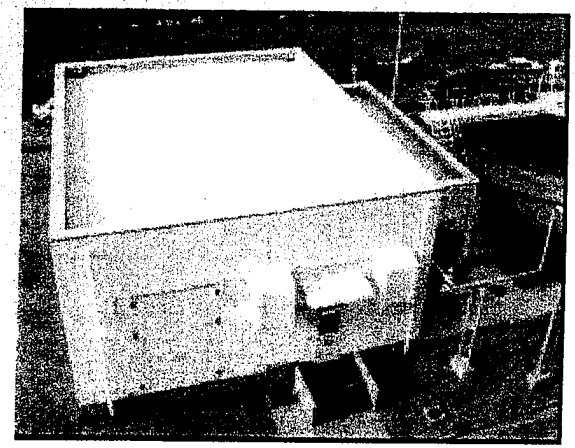
Application example: Yamagata Sewage Plant



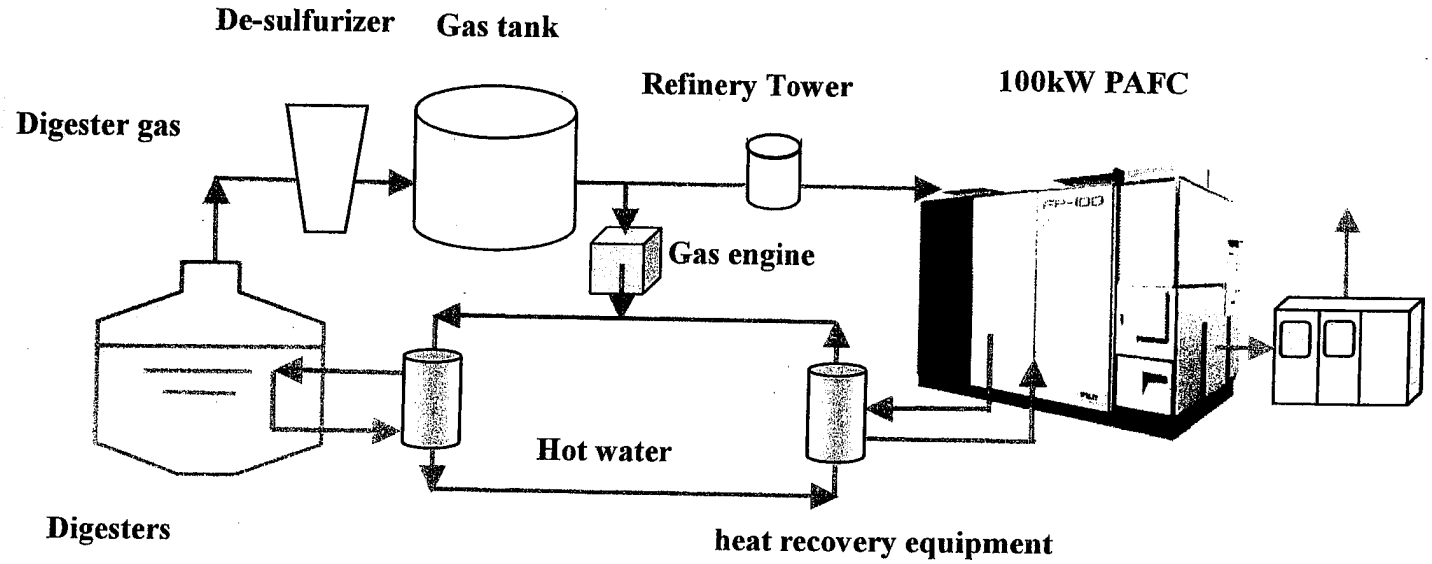
Facility overview	
Ground area	7.74ha
Amount of sewage sludge	40,000m^3/day
Amount of digester gas generated	3,800m^3/day
Amount of electricity consumed	17,200kWh/day

Application example: Yamagata Sewage Plant

Yamagata Sewage plant



Schematic Flow



Operation

- PAFCs are operating continuously 24 hours a day as the primary power source and are 100% loaded.
- A 78kW gas engine is operated only during the daytime to power excessive loads.
- Recovered heat is used for warming digestion tanks.

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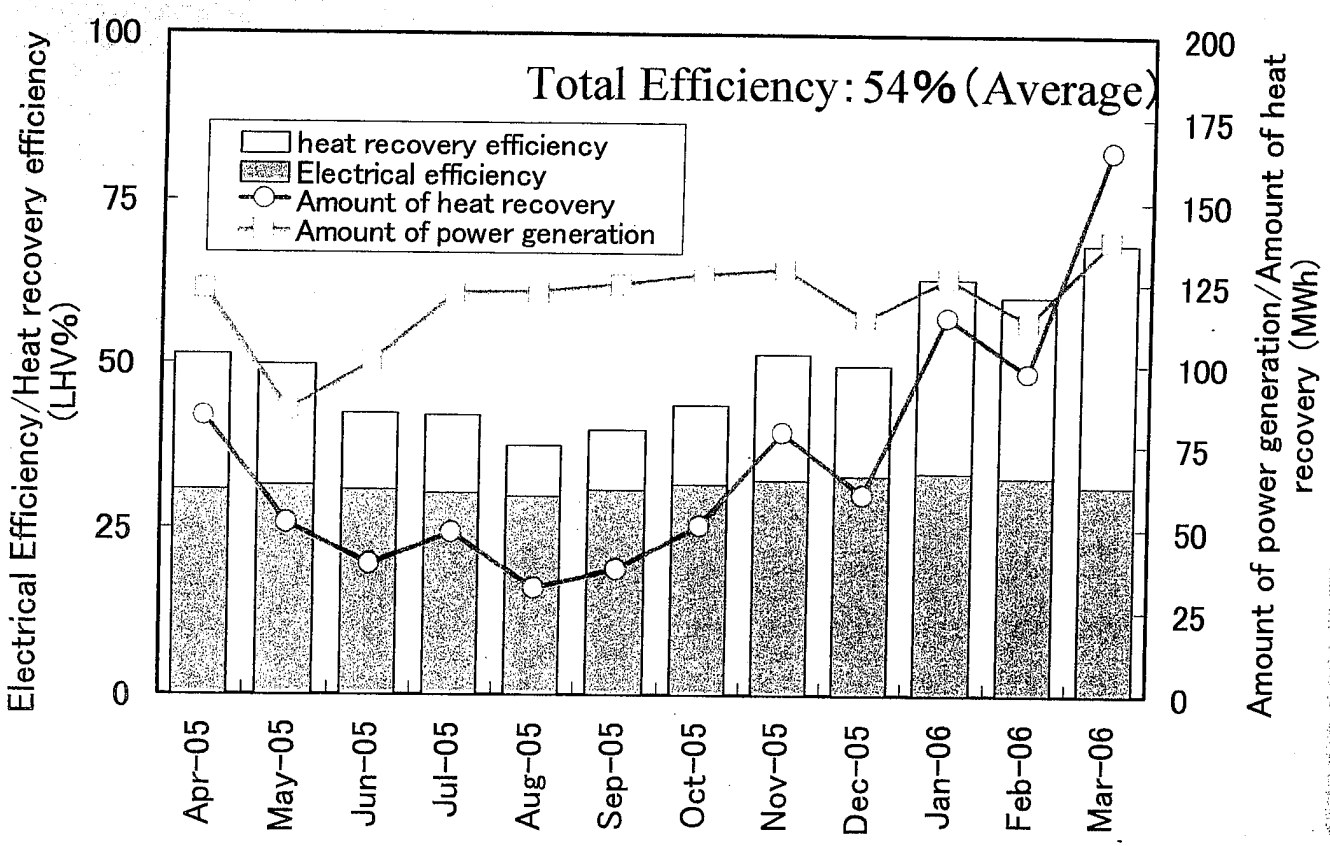
Result of operation at Yamagata Sewage Plant in 2005

Stable operation throughout the year !!

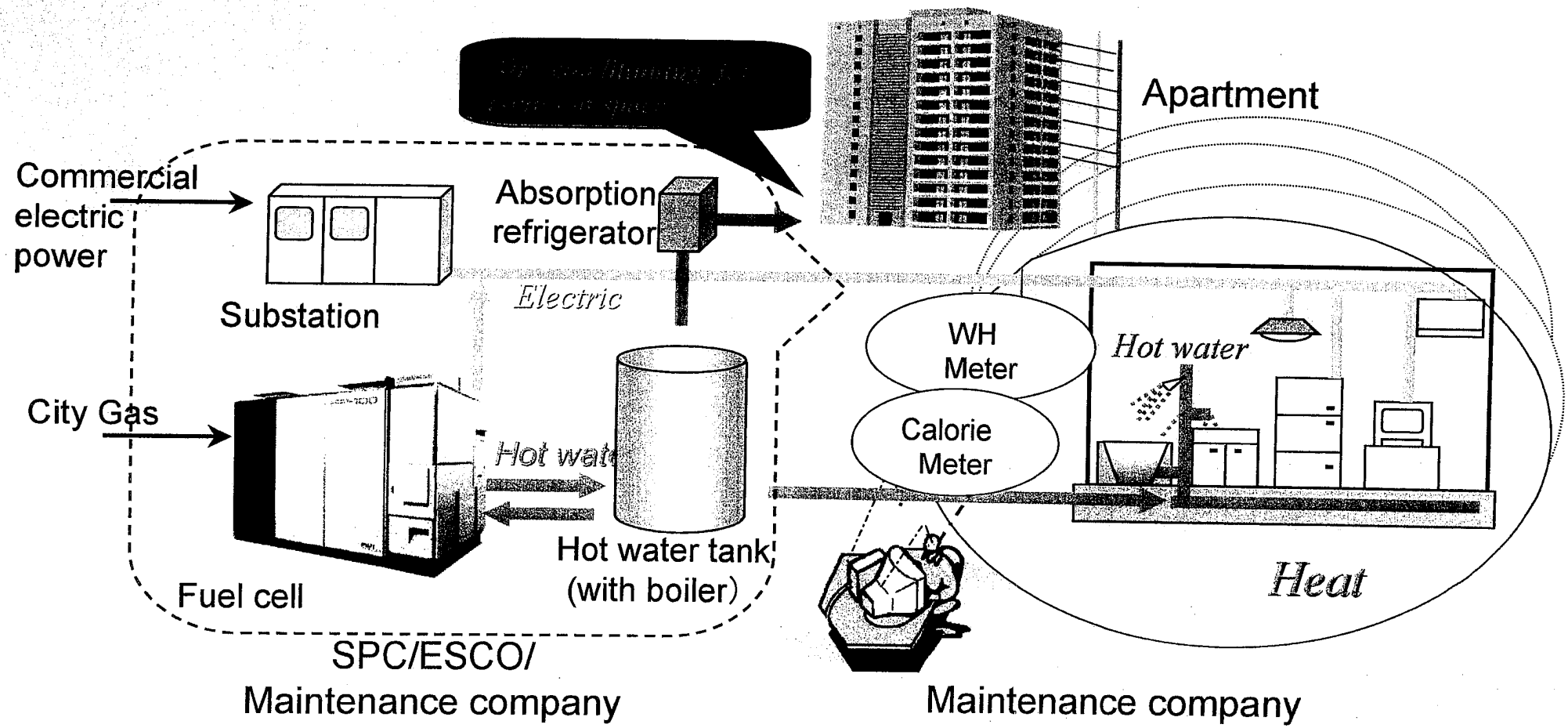


Major results

- Total hours of operation: 34,700 hours (as of Mar. 2006)
- Reduction of primary energy consumption: 16,534GJ/year
- CO_2 reduction rate: 656t/year
- Ratio of electricity supplied by PAFC in the sewage plant: 24% (4,200kWh/day)

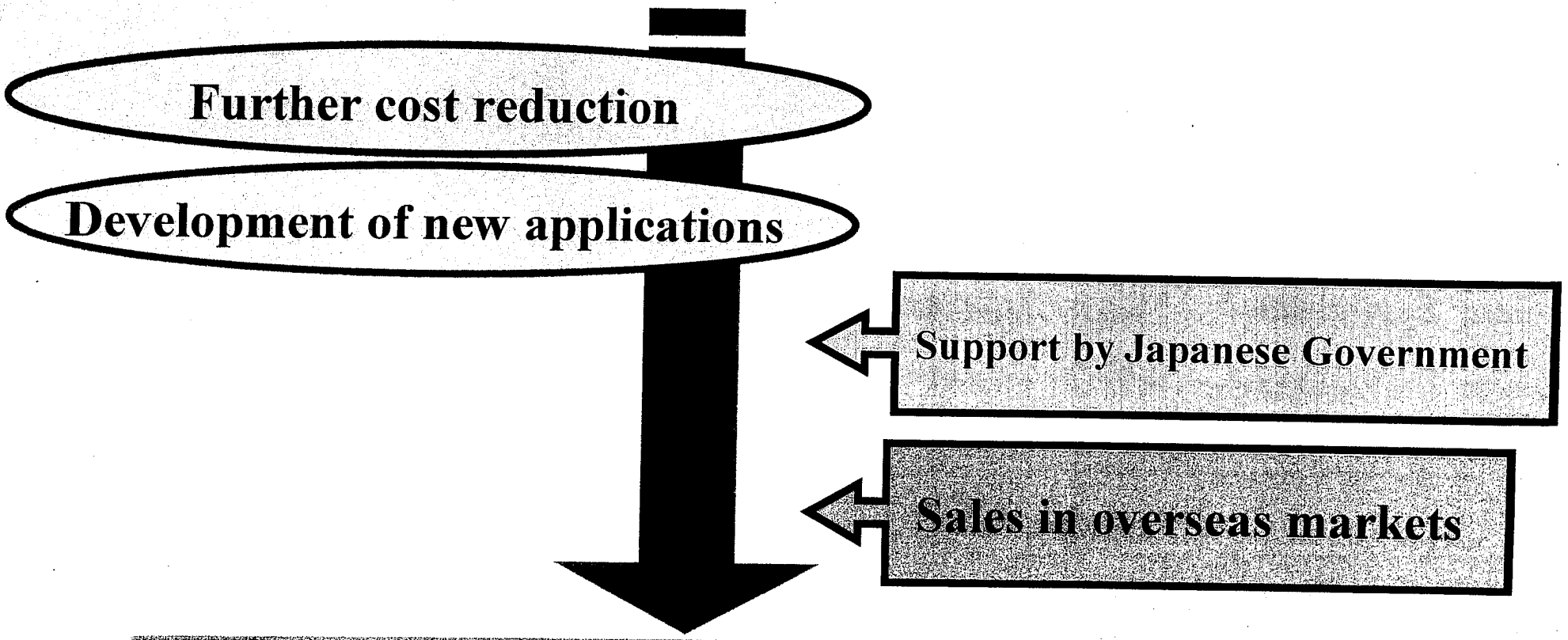
Application example: City gas for apartments & hospitals

PAFCs use high temperature water for cooling, which makes heating and cooling systems economical to run.



Conclusions

Fuji Electric 100kW PAFCs have performed reliably over long hours in practical use in many places.



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Thank you for your attention.