The History of Keage Power Station

Birthplace of Utility Hydropower Generation

Kansai Electric Power Co., Inc.

Thinking of tommorow's energy

Contents

(Historical materials were porvided by the Waterworks Bureau of Kyoto City.)

Outline

Keage Power Station is supplying electricity to the City of Kyoto. The Station attained its 100th anniversary in 1992.

A decisive momentum to the birth of Keage Power Station was provided by the Biwako Canal work.The work was started to encourage the people of Kyoto who were then in low spirits due to the transfer of the capital from Kyoto to Tokyo. The power station was intended to effectively utilize the hydraulic power of the canal.

One of the greatest significance of Keage Power Station is that it is the first hydroelectric power station for general power supply in Japan.

Ever since the first arc lamp was turned on at Kobu Daigakko (technical college) in Tokyo in 1878, use of electricity from private power generation plant began in various places to follow the Government's policy increase of productivity and promotion of industry. In January 1892 the power station was granted a license for general power supply. It had two important meanings. One is that it resulted in the reduction of the generating cost. And the other is that it pioneered the age of predominance of hydropower generation over fossil power which lasted for a long time hence.

Entrance of the Phase Ⅱ Keage Power Station.
The tablet reads "Assisting the work of Nature."
It was written by H.I.H. Prince Kuninomiya

We will see the course of development of Keage Power Station in the following pages.

History of Keage and Other Power Stations of the Canal System

January 1890	Construction work was started.
June 1891	Station was partly completed (two generators).
January 1892	The license was granted to the enterprise.
May 1897	The phase Ⅰ work was completed (20 Pelton turbines and 19 generators:total output of 1,760 kW).
March 1910	The phase Ⅱ work was started.
February 1912	The phase Ⅱ work was completed (7 Francis turbines (2 Francis turbines for excitation), 5 generators:total output of 4,800 kW).
May 1912	The construction of Fushimi Power Station was started.
November 1912	The construction of Ebisugawa Power Station was started.
April 1914	Ebisugawa Power Station was completed (1 horizontal shaft Francis turbine, 1 three-phase a.c. generator:output of 280 kW).
May 1914	Fushimi Power Station was completed (1 vertical shaft Francis turbine, 1 three-phase a.c. generator:output of 1,320 kW).
June 1932	The phase Ⅲ work was started.
Junuary 1936	The phase Ⅲ work was completed (2 vertical shaft Francis turbines, 2 three-phase a.c. generators:total output of 5,700 kW).

History of the Development of Biwako Canal

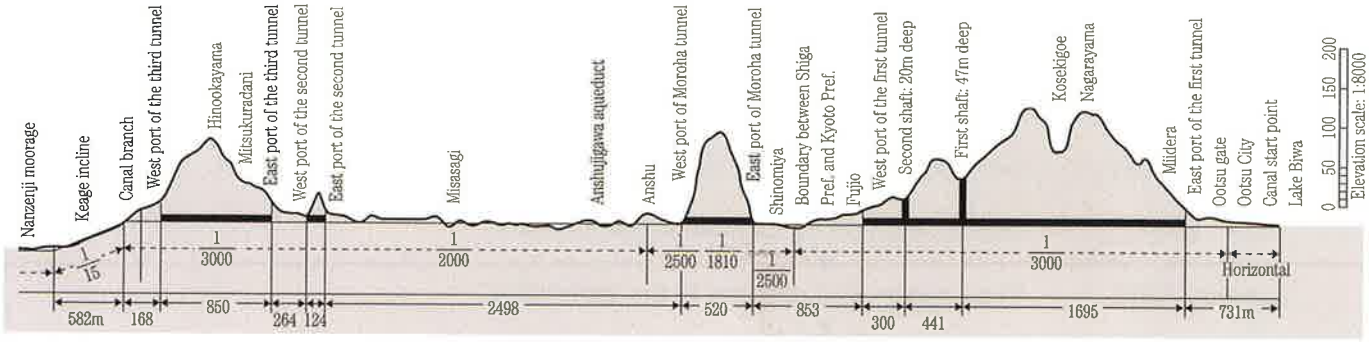
The transfer of the capital from Kyoto to Tokyo in 1869 was a serious blow to Kyoto which had been prosperous as the imperial capital over one thousand years. The market conditions declined and the population was estimated to drop suddenly from 350,000 to 250,000.The general public felt discontented.

In 1881, Mr. Kunimichi Kitagaki became the third governor of Kyoto Prefecture under such conditions. He decided to make a big enterprise to restore the prosperity of Kyoto and to promote its modernization. He took Asaka Canal (Fukushima Prefecture) as a model and made an on-site inspection of Asaka Canal for himself.Then he made a similar canal work plan from Lake Biwa (Biwako).

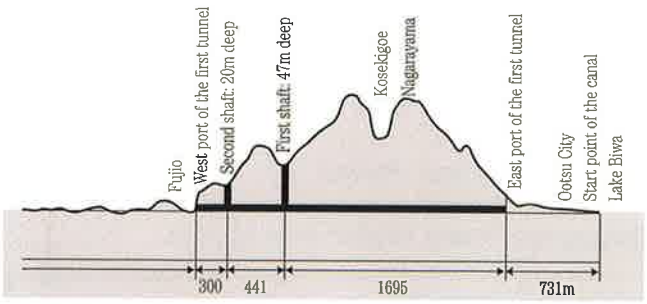
The canal construction work was started in January 1885. Mr.Sakuro Tanabe, young engineer who graduated from Kobu Daigakko, was in charge of the canal work. While he was a student of the civil engineering department of Kobu Daigakko, he was sent to Kyoto for a scientific investigation. He learned by chance that a canal work was projected in Kyoto, and he made an on-site survey from his own viewpoint. He eventually produced his graduation thesis on this subject, "Biwako Canal Project." His thesis gained recognition from Governor Kitagaki, and he was immediately invited to Kyoto to take charge of a great work of the century.

Governor Kitagaki

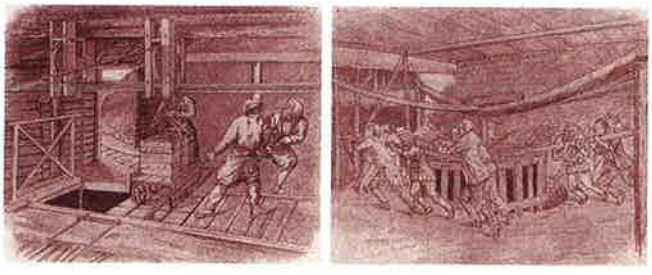
Mr.Sakuro Tanabe



Longitudinal section of the First Canal



Longitudinal section of the First Canal



Illustrations of the canal work

Most of the civil engineering works of those days were still dependent on overseas engineers. In contrast with them, the Biwako Canal work was completed by the Japanese alone. It was a declaration of independence of Japan in civil engineering.

Of the three tunnels of the trunk canal, Nagarayama Tunnel was 2,440 meters long and was the then longest tunnel in Japan. The excavation precision was several centimeters for the centerline and the elevation, indicating the precision achieved by triangulation, which was introduced around that time. The work was mostly made by manpower. There were some records indicating the use of a steam engine for hoisting at a vertical shaft.

Of the materials for the work, bricks were produced at a plant established in Misasagi-mura, Uji-gun (present Misasagi-Haranishi-cho, Yamashina-ku). Cement was also purchased from Onoda Factory, Yamaguchi Prefecture. Thus domestic technologies were utilized to some extent.

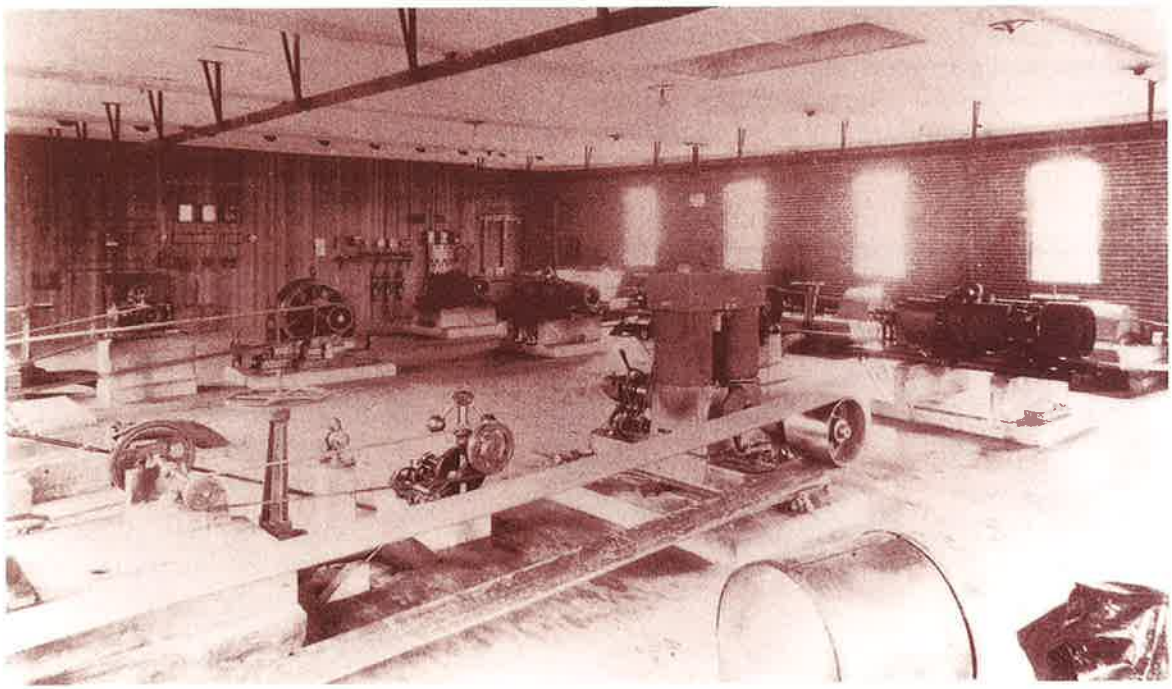
The first canal was completed in March 1890.

Biwako Canal and Hydropower Generation

In 1888 when the canal work was set on its way, Mr.Jinbee Kawashima stated at Kyoto Kamigyo-Shimogyo United Wards Assembly that waterwheels were effectively used in Holyoke, Massachusetts, U.S.A. and would be useful to utilize hydraulic power. Mr. Kawashima was a tapestry dealer and visited America before then. The United Wards Assembly decided to send some delegates for preliminary investigation. This action was based on a sense that the first object of the canal work is the public interest but the canal work can not be a successful work without raising profits.

One delegate was Mr.Sakuro Tanabe in charge of the canal work. The other delegate was Mr.Bunpei Takagi, who was a member of the United Wards Assembly, and later became a promoter of Kyoto Dento Kaisha. They started for America in October 1888.

Mr.Bunpei Takagi

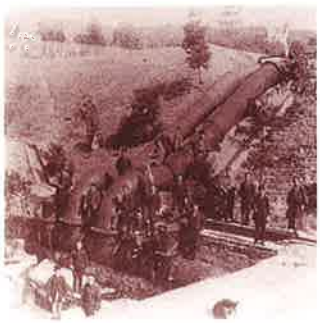


Aspen hydropower generation plant

Mr.Tanabe and Mr.Takagi stayed in the U.S.A. for about two months. They visited Holyoke, a then model town of hydraulic power utilization. They compared Holyoke and Biwako Canal and despaired of effective utilization of hydraulic power, in terms of mill site and turbine discharge. However, they were informed that hydropower generation was in use at a silver mine of Aspen, Colorado. Mr.Tanabe, who had a keen interest in hydropower generation, rushed to Aspen together with Mr.Takagi. There they found hydropower generation with 150 H.P. Pelton turbines. They were deeply impressed and determined to introduce hydropower generation to the canal work.

They returned home in January 1889, and submitted a proposal of introducing hydropower generation to the Biwako Canal work to Kyoto City. Eventually Kyoto City approved it.

Completion of the installation of the penstock at Keage Power Station (May 1891).



The first three generators installed at Keage Power Station (December 1891)

Phase I Keage Power Station

The construction work of Keage Power Station was started in January 1890, and the operation of the Station was started in August 1891. After that the power generation facilities were augmented one after another, and the phase I construction work was completed in May 1897. When the Station started operation in August 1891, it was provided with two 120 H.P. Pelton turbines and two 80 kW d.c. generators. When the phase I construction work was completed, the Station was provided with 20 turbines and 19 generators, with the total output of 1,760 kW.

State of Operation

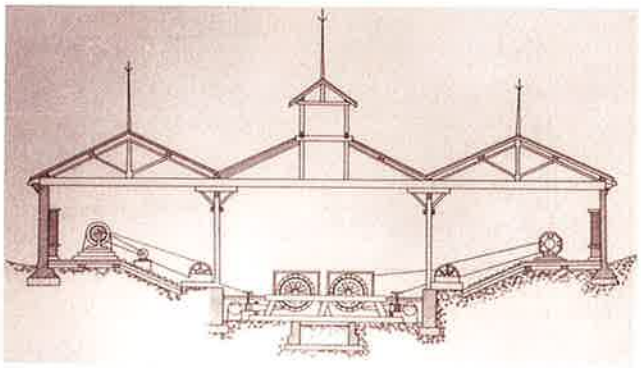
The Station had two runs of iron pipes, and a turbine and a generator were connected with a very long belt.

Both the a.c. and d.c. generators were used, and the generators differed from each other in voltage and frequency. Hence the power from generators was transmitted by an independent transmission line respectively, and the load had to be adjusted continuously according to the output of the generator.

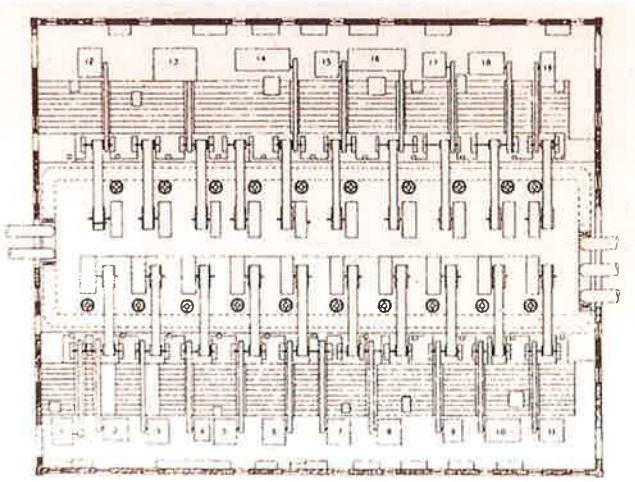
Installation of Generators at Keage Power Station
From Jan. 1891-May 1897.

Date	Maker	Type	kW	Volt	Hz	Application
1891,6	GE, US	d.c.	80	500	—	Power
1891,6	GE, US	d.c.	80	500	—	Power
1891,12	TH, US	a.c.1	75	1100	125	Light
*1891,6	GE, US	a.c.1	60	2080	125	Light
*1894,4	GE, US	a.c.1	60	1040	125	Light
1894,4	GE, US	a.c.1	60	2080	125	Light
1894,8	ST, US	a.c.2	60	2000	133	Power
*1895,6	TS, J	a.c.2	60	2000	133	Power
1895,8	GE, US	d.c.	200	500	—	Electric rail
1895,9	ST, US	a.c.2	80	2400	133	Power
1895,9	GE, US	d.c.m	75	500	—	Power
1895,12	GE, US	d.c.m	100	500	—	Electric rail
1896,1	SH, G	a.c.3	80	2000	50	Power
1896,4	SH, G	a.c.3	80	2000	50	Power & light
1896,6	GE, US	a.c.3	100	2400	60	Weaving
1896,6	SH, G	a.c.3	80	2000	50	Cotton spin.
1896,9	GE, US	d.c.m	200	500	—	Cotton spin.
1896,6	SH, G	a.c.3	80	200	50	Tobacco
1897,5	GE, US	a.c.3	150	2000	60	Cotton spin.

*GE: General Electric, US. TH, US: Thomson Houston, US.
*ST: Stanley, US. SH, G: Siemens Halske, Germany.
TS, J: Tokyo Shibaura, Japan.
a.c.1: a.c. single phase. a.c.2: a.c. two phase. d.c.m: d.c. multiple phase.
a.c.3: a.c. three phase.



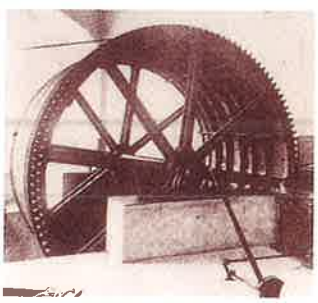
Layout of Pelton turbines



Layout of the power generation facilities of the early Keage Power Station

The building of phase I Keage Power Station

Early transmission lines

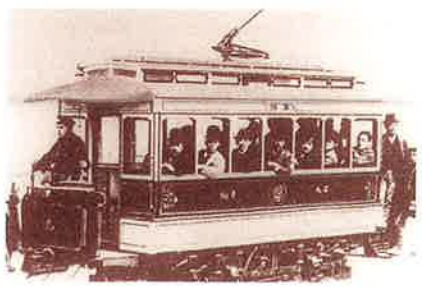


Interior of the incline drum plant

Keage Incline

The power service area of Keage Power Station was limited to an area within about 2 km from it. With the expansion of the power generation and transmission facilities, the service area was expanded gradually.

Kyoto Denki Tetsudo (Kyoto Electric Railway) received power from Keage Power Station to run streetcars over a line of 6.4 km between Shiokoji (Kyoto Station) and Fushimi-Aburakake. The line started operation in January 1895. This was the first streetcars system in Japan.



A scene of trial trip

Phase II Keage Power Station

Development of the Second Canal

In 1895 when Kyoto held the fourth domestic industrial exhibition commemorating the 1100th year after the construction of Heiankyo, the first canal was not able to meet the significant growth in the power demand.

Mr.Kikujiro Saigo, Second Mayor of Kyoto City, planned three great undertakings for Kyoto, defining the construction of a second canal as the core of the undertakings.

The second canal was a new canal which is independent of the first canal. Both canals were joined together to utilize water for power generation. The work of the second canal was started in October 1908 and completed in April 1912.

Mayor Saigo

Three Great Undertakings

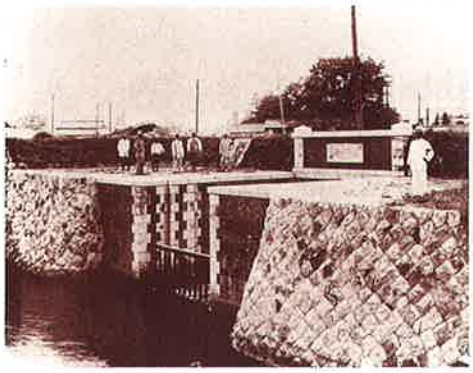
1 Development of the second canal (to increase the power output)

2 Water supply work

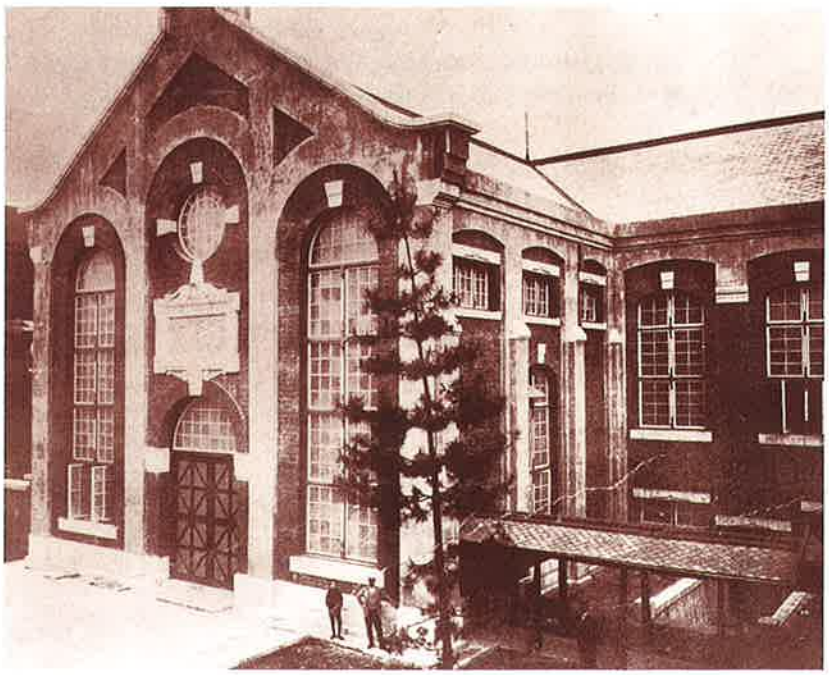
3 Road construction

The joint tunnel of the first and second canals, the head tank and the spillway

The intake of the second canal



Phase II Keage Power Station



The building of Phase II Keage Power Station

Work started in :	March 1910.
Work completed in :	February 1912.
Turbine discharge :	20.87 m³/sec.
Effective head :	32.12 m.
Output :	4,800 kW

Hydraulic turbines

(Type) Horizontal shaft Francis turbine
(Horsepower) 1,700 H.P.
(Speed of rotation) 450 rpm.
Five turbines (one for a spare)

(For exciters)
(Horsepower) 200 H.P.
(Speed of rotation) 700 rpm.
Two turbines (one for a spare)

(Manufacturer) Escher Wythe.

Generators

(Type) AC three-phase rotating field.
(Output) 1,200 kVA. (Voltage) 6,600 V.
(Frequency) 60 Hz.
(Speed of rotation) 450 rpm.
Five generators (one for a spare)
(Manufacturer) U.S. General Electric.

Exciters

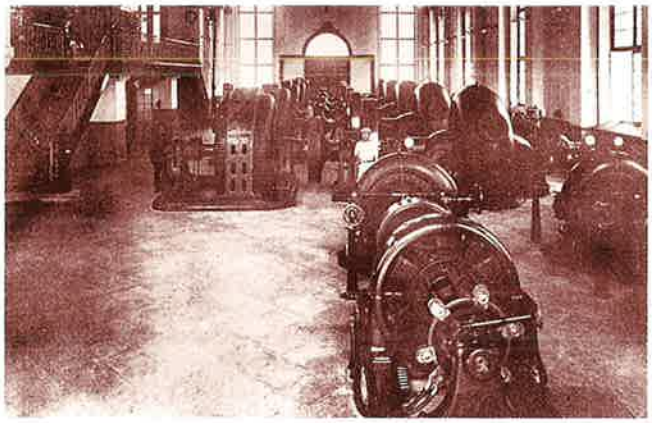
(Type) DC compound generator.
(Output) 125 kW (Voltage) 125 V.
(Manufacturer) U.S. General Electric.

Phase Ⅱ Keage Power Station

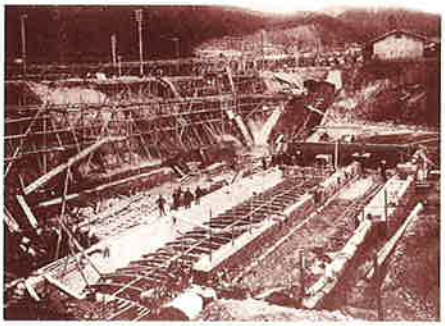
When two of the five generators of Phase Ⅱ Power Station were provisionally licensed in February 1912, Phase Ⅰ Power Station was decommissioned.

The building of Phase Ⅱ Station was located on the southern side of Phase Ⅰ Power Station. The mountain side was excavated to the depth of 19.8 m to place the discharge ports of the turbines and the foundation of the building.

The height of the building was 16.6 m and the underground level was 4.2 m below the ground. The building was made of reinforced concrete including the outlets.

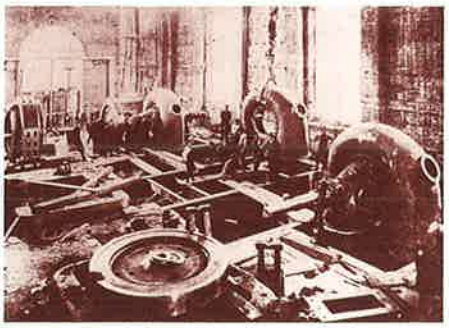


Interior of Phase Ⅱ Keage Power Station



The foundation work of the station building

Installation of penstocks



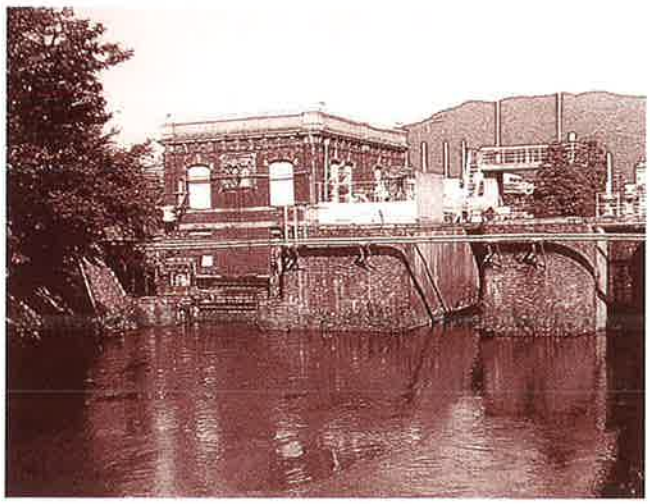
Installation of turbines and generators

Development of the Electric Enterprise

With the completion of the second canal, Keage Power Station was regenerated from Phase Ⅰ Station with 1,760 kW output into a station with 4,800 kW. Furthermore, it was decided to utilize the discharge from Keage Power Station and establish, as a part of the second water utilization work, Ebisugawa Power station and Fushimi Power Station (later renamed Sumizome Power Station).

Ebisugawa Power Station was first licensed in April 1914. The station has been operating with the following original facilities up to the present. As a part of the refreshing program of the hydropower stations, a modification was made and Phase Ⅱ Ebisugawa Power Station was completed in April 1993.

Ebisugawa Power Station



The building of Ebisugawa Power Station

Facilities in 1914

Hydraulic turbine

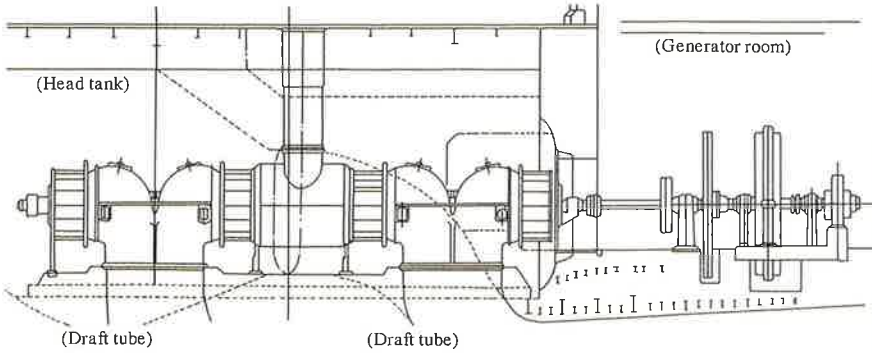
(Type) Horizontal shaft Francis quadruple turbine
(Horsepower) 500 H.P.
(Speed of rotation) 120 rpm. One turbine.
(Manufacturer) Boving, U.K.

Generator

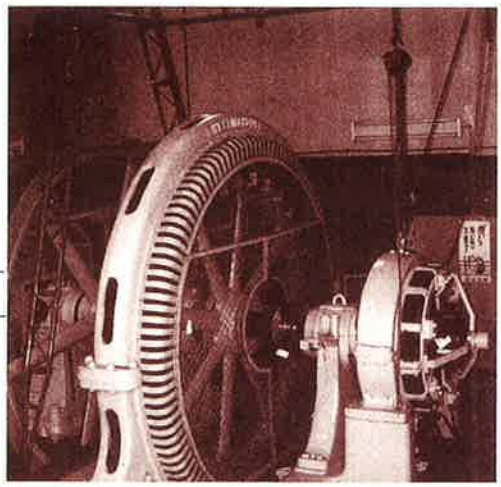
(Type) AC three-phase rotating field.
(Capacity) 350 kVA.
(Voltage) 3,500 V.
(Frequency) 60 Hz.
(Speed of rotation) 120 rpm.
One generator
(Manufacturer) Westinghouse, U.S.

Exciter

(Type) DC compound generator.
(Capacity) 225 kW.
(Voltage) 125 V.
(Speed of rotation) 120 rpm.
(Manufacturer) Westinghouse, U.S.



Section of the hydraulic turbine-generator



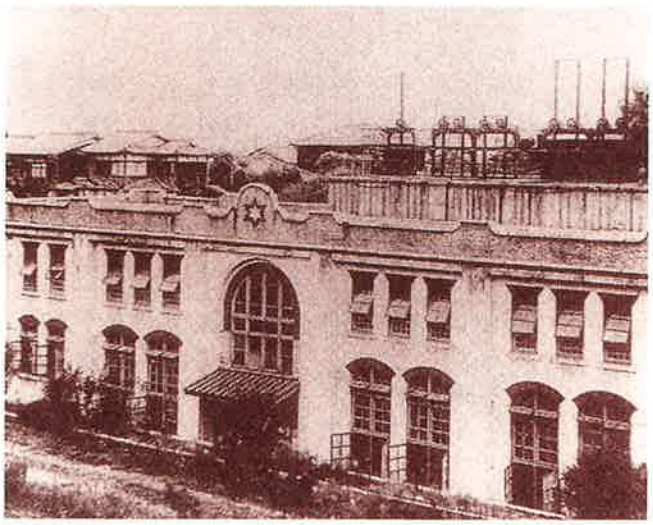
The generator of Ebisugawa Power Station

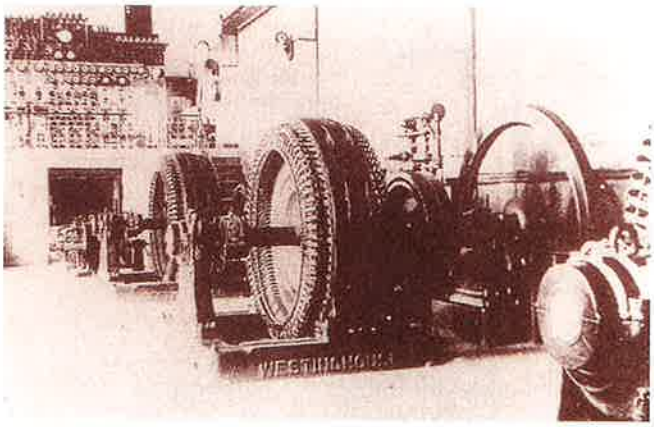
Fushimi (Sumizome) Power Station

Fushimi Power Station is located at Fushimi Sumizome at which the canal ends. It was built to utilize the head of Fushimi Incline which was used for transportation by boats connecting Osaka, Kyoto and Ootsu.

The Station started operation in 1914 and contributed to the industrial development hence. A modification work was done in August 1954 to increase the output. The turbines were replaced, but the head tank and the building remain just as initially constructed.

The building of Fushimi Power Station





Generators of Fushimi Power Station

generator

Facilities in 1914

Hydraulic turbine

(Type) Horizontal shaft Francis double turbine.
(Horsepower) 1100H.P.
(Speed of rotation) 360 rpm.
Three turbines (one for standby).
(Manufacturer) Boving, U.K.

(For exciter)
(Type) Horizontal shaft Francis single turbine.
(Horsepower) 75 H.P.
(Speed of rotation) 700 rpm. One turbine.
(Manufacturer) Boving, U.K.

Generator

(Type) Three-phase a.c. rotating field.
(Capacity) 750 kVA. (Voltage) 7,000 V.
(Frequency) 60 Hz.
(Speed of rotation) 360 rpm.
(Manufacturer) Westinghouse, U.S.A

Exciter

(Type) DC compound generator.
(Capacity) 50kW. (Voltage) 125 V.
(Speed of rotation) 700 rpm.
(Manufacturer) Westinghouse, U.S.A.

Phase Ⅲ Keage Power Station

After the completion of Phase Ⅱ Keage Power Station in May 1912, the use of electricity continued to increase year after year. Most of the industrial facilities became dependent on electricity, and the society was heading to the age of electricity.

Kyoto City keenly felt the need of increasing inexpensive hydropower generation, and started the construction work of Phase Ⅲ Power Station. It took three and a half years to construct the power station and the related substation and transmission lines. The work was completed in January 1936. It is the present Keage Power Station.

Work started in :	July 1932.
Work completed in :	January 1936.
Turbine discharge :	20.87 m³/sec.
Effective head :	33.485 m.
Output :	5,700 kW.

Generator

The section of the hydraulic turbine-generator and the building

Present Facilities(in 1999)

Unit No.1(For a spare)

(Hydraulic turbine)

(Type)Vertical shaft Francis turbine.
(Output) 7,833kW.
(Speed of rotation) 257 rpm.
(Manufacturer) Hitachi, Ltd.

Generator

(Type) Three-phase
A. C. Synchronous Generator.
(Output) 7,500 kVA.
(Voltage) 6,600 V.
(Frequency) 60 Hz.
(Speed of rotation) 257 rpm.
(Manufacturer) Hitachi, Ltd

Unit No.2

(Hydraulic turbine)

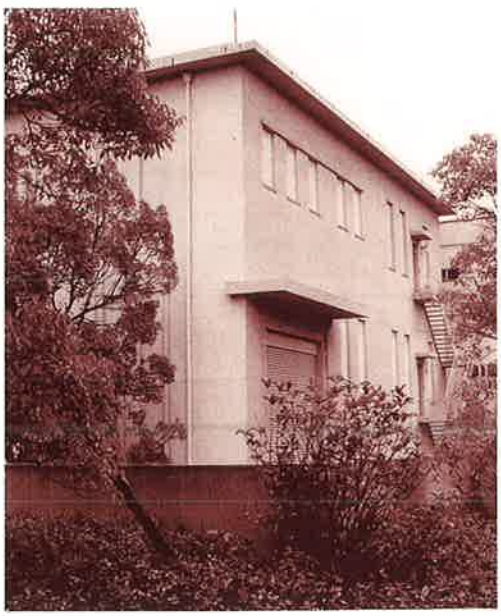
(Type)Vertical shaft Francis turbine.
(Output) 4,740kW.
(Speed of rotation) 257 rpm.
(Manufacturer) Hitachi, Ltd.

Generator

(Type) Three-phase
A. C. Synchronous Generator.
(Output) 5,000 kVA.
(Voltage) 6,600 V.
(Frequency) 60 Hz.
(Speed of rotation) 257 rpm.
(Manufacturer) Hitachi, Ltd

The use of water for water supply has been increasing year after year in comparison with that at the time of the construction of the Station. In April 1979, the output of the Station was changed from 5,700 kW to 4,500 kW.

The operation of the Station was switched to remote control from Kojinguchi Control Office in December 1985. The Station has been generating power up to the present.



Phase Ⅲ (present) Keage Power Station

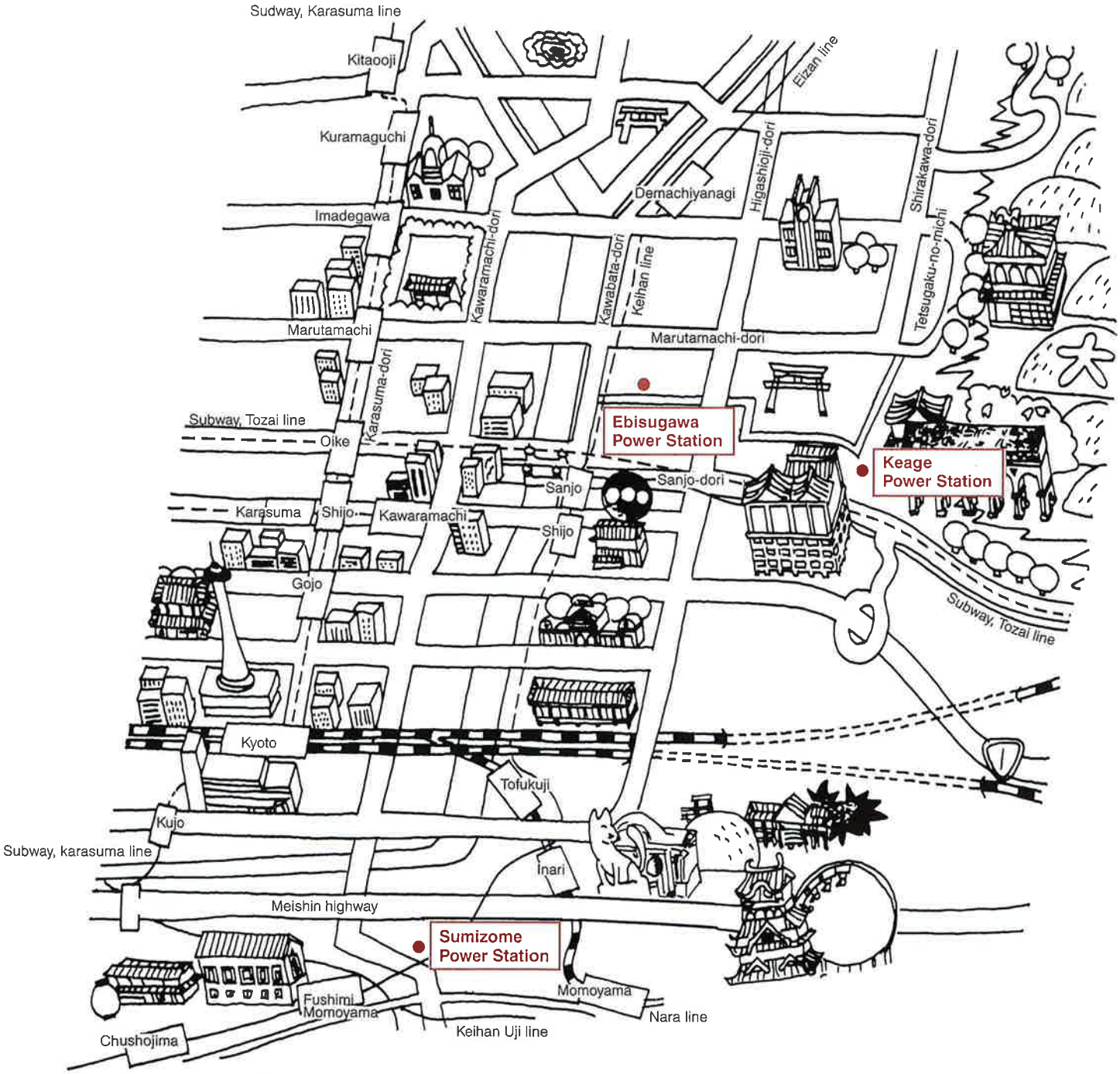
Future of Three Power Stations of the Canal System

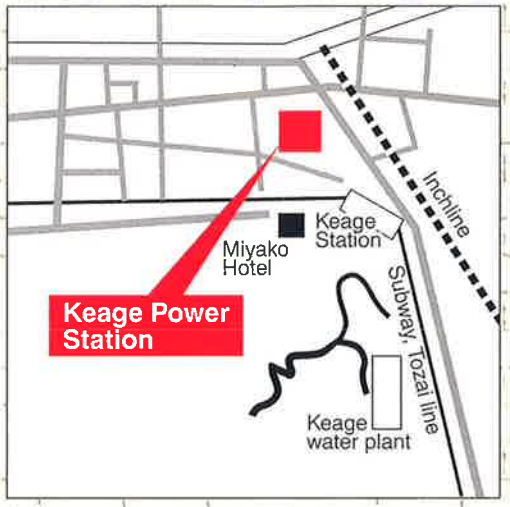
The great Biwako Canal, which was built by the pioneers of Meiji era, constantly giving its favor to us. No doubt, Phase I Keage Power Station, utilizing the Canal to make hydropower generation, greatly stimulated the modernization of Japan.

The demand for electricity has increased greatly year by year. Power generation systems have been diversified, including thermal power and nuclear power. The importance of hydropower generation is still intact.

The three stations, Keage, Ebisugawa and Sumizome, will continue to generate electricty by fully utilizing the precious gifts of Biwako Canal.

Three Power Stations of the Canal





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