First pure pumped-storage hydroelectric power plant in Hokkaido

Hokkaido Electric Power Co., Inc.(HEPCO), aiming to ensure a stable supply of power based on long term planning while paying attention to global and regional environments,has been diversifying the sources of electric power for a well-balanced supply of energy by developing thermal and hydroelectric power as well as nuclear power.The Kyogoku Project was planned to take in charge of peak demand of electricity in the daytime,and to store energy through pumping in the nighttime.

The Kyogoku Project is the first pure pumped-storage hydroelectric power plant in Hokkaido and is capable of variable pumping operation. HEPCO began the project in spring of 2002. The project involves the construction of the upper reservoir on a plateau in the north area of Kyogoku town and the Lower reservoir (Kyogoku dam) at the confluence of the Pepenai river and Bihinai river. The gross head of approximately 400m between the upper reservoir and the lower reservoir will be used to produce a maximum output of 600 MW using three turbine generators.

Technical Data

	Upper reservoir	Lower reservoir(Kyogoku dam)
Name of rivers	-	Pepenai river and Bihinai river
Catchment area	-	$51.3km^2$
Reservoir area	$0.16km^2$	$0.39km^2$
Gross storage capacity	$4,400 \times 10^3m^3$	$5,546 \times 10^3m^3$
Effective storage capacity	$4,120 \times 10^3m^3$	$4,120 \times 10^3m^3$
Available depth	45.0m	14.5m
High water level	EL 890.0m	EL 486.0m
Maximum output capacity	600MW (200MW per unit for 3 units)	
Maximum utilizable flow	$190.5m^3/sec$	
Effective head	369m	
Upper reservoir	Rockfill dam with asphalt facing Maximum height 22.6m Crest width 13.0m Crest length 1,140.9m Volume $1,539 \times 10^3m^3$	
Lower reservoir (Kyogoku dam)	Rockfill dam with vertical clay core Maximum height 54.0m Crest width 10.0m Crest length 332.5m Volume $1,318 \times 10^3m^3$	
Intake	I.D. = 11.8-5.0m L=51.7m	
Penstock	I.D.=5.0-1.9m (thickness 19-48mm) From the upper reservoir to the junction: L=583.0m From the junction to the unit, No.1 unit: L=71.9m No.2 unit: L=55.6m No.3 unit: L=97.3m	
Powerhouse	H=45.8m, W=24.0m, L=141.0m (Underground type)	

Draft tunnel	I.D.=3.7m From the unit to the surge tank, No.1 unit: 108.7m No.2 unit: 100.0m No.3 unit: 108.7m	
Surge tank	H=108.0m, I.D.=12.0m, L=25.0m	
Tailrace tunnel	I.D.=6.4m, L=2,483.0m	
Outlet	H=6.4-7.0m, W=6.4-28.6m, L=75.5m	
Reversible pump-turbine	Spiral Francis type 3 units	
	Turbine output	208,000kW
	Effective head	369.0m
	Pump input	230,000kW
	Maximum pump head	436.5m
	Rotational speed	500 ± 25min - 1
Generator/Motor	Synchronous generator/motor 3 units	
	Generator capacity	230,000kVA
	Motor capacity	230,000kW
	Voltage	16.5kV
	Frequency	50Hz
	Starting system	Thyristor starting system + back to back starting system
Main transformer	Disassembled and Transported Transformers 3 units	
	Capacity	240,000kVA
	Voltage	16.5kV / 275kV

Major Steps of the Kyogoku Project

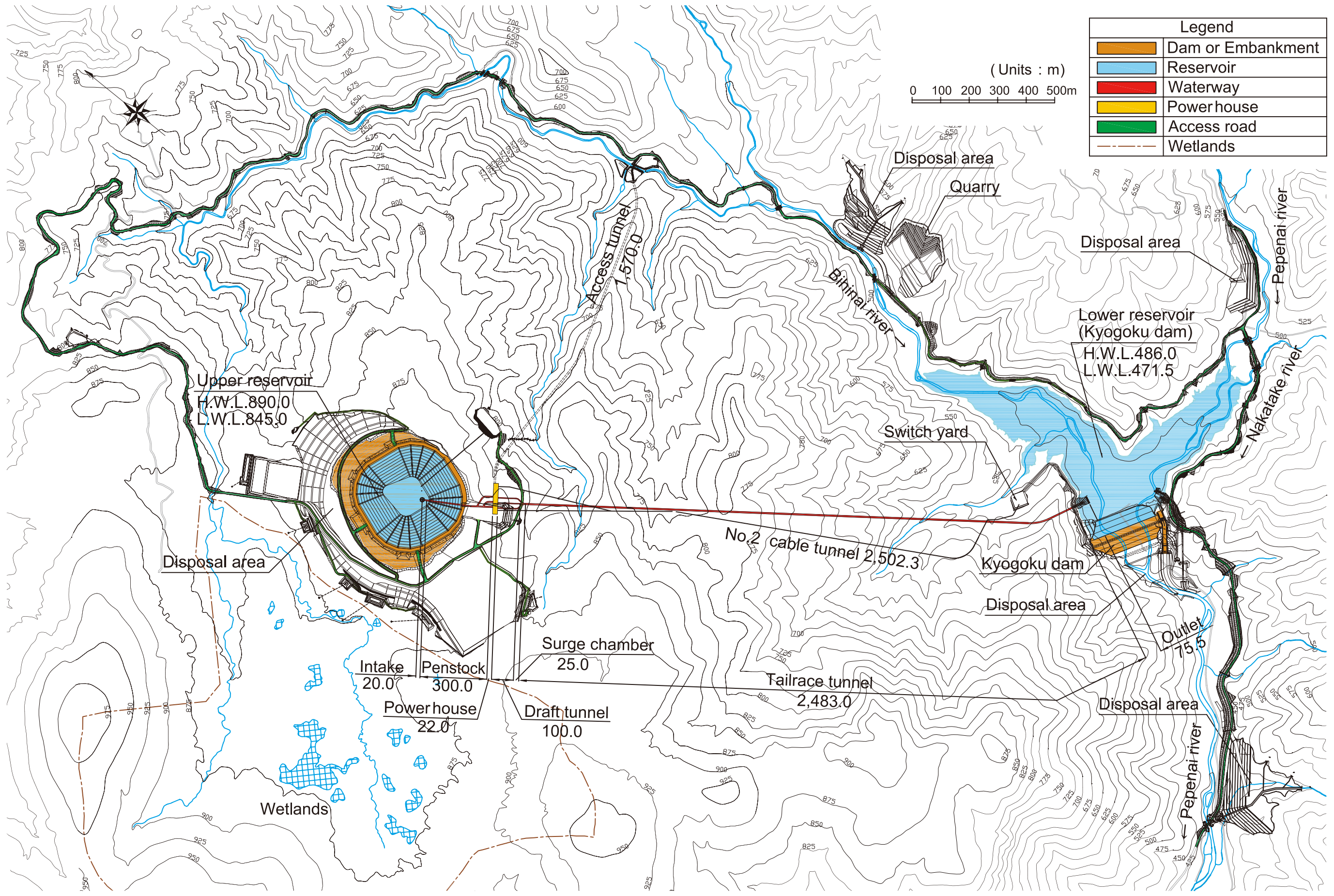
The EIA for the Kyogoku Project began in 1997 with the consent of the local Kyogoku Town Council. At the 142nd meeting of the Electric Power Development Coordination Council held on 17th December, 1999, the Kyogoku Project was included on the list of candidate sites of the Basic Electric Power Development Plan. The actual construction work began in February, 2002 after the completion of legal procedures demanded by relevant laws such as the Electricity Business Act, River Act and Forest Act.

At present, the work is progressing in earnest to commence the commercial operation of the No. 1 Unit in October, 2014.

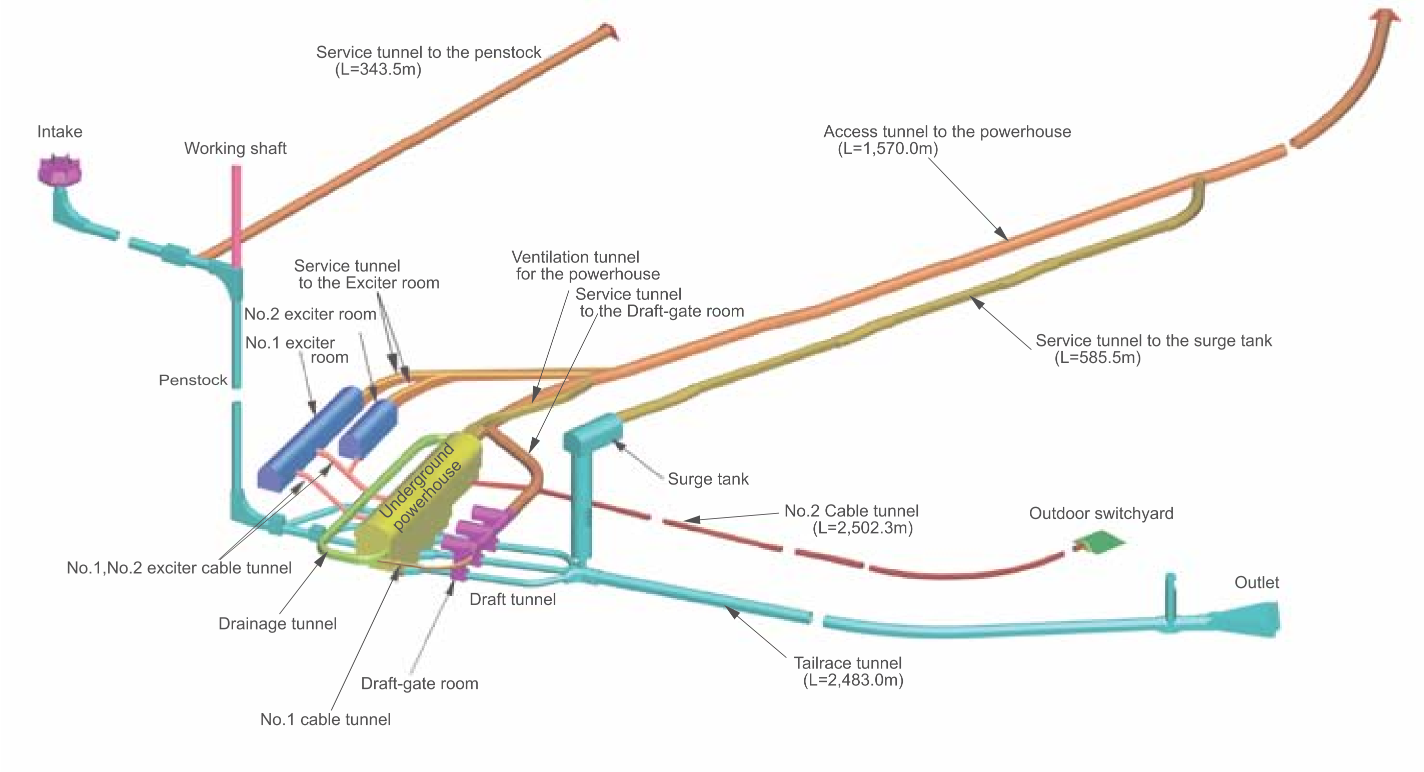
Fiscal Year	Major Steps	
1998	January	Lodge an application for construction to the local Kyogoku Town Council and Hokkaido Prefectural Government. Submit the EIA report to the central government and the Hokkaido Prefectural Government. Hold a meeting to explain the plan to local people.
1999	September December March	Kyogoku Town Council consent the construction. Submit the construction plan to the 142nd meeting of the Electric Power Development Coordination Council. Set up the construction office for the Kyogoku Project.
2000	July	Submit the application under Article 9 of the Electricity Business Act.
2001	September October December February March	Obtain permission under Article 23 and Article 26 of the River Act. Submit the application under Article 48 of the Electricity Business Act. Request for cancellation of protection forest status. Submit the notification of the start of construction work (in accordance with the River Act and Electricity Business Act). Issue the notice of cancellation of protection forest status.
2002	August October	Start the excavation work for the powerhouse maintenance road (tunnel) . Start the excavation work for the upper reservoir and the tailrace tunnel.
2003	July	Start the excavation work for the Kyogoku Dam embankment.

Fiscal Year	Major Steps	
2004	August October	The maintenance road (tunnel) for the powerhouse breaks through. The tailrace tunnel breaks through.
2008	October January	Start the excavation work for the penstock line. Start the excavation work for the powerhouse.
2009	September October	Complete the embankment work for the upper reservoir. Start the lining work for the tailrace tunnel.
2010	April June July December	Start the excavation work for the surge tank. Start the pavement work of asphalt facing at upper reservoir. Start the embankment work for the Kyogoku Dam. Complete the excavation work for the powerhouse.
2011	April July	Start the installation of the draft tube. Start the installation of the penstocks.
2012	May	Start the installation of the pump turbine and outdoor switchgear (planned).
2013	May November February	Complete the connection to a 275 kV power supply line (planned). Start impounding Kyogoku Dam (planned). Start the tests for pumping operation as well as hydroelectric power generation (planned).
2014	October	Start commercial operation of the No.1 Unit (200,000kW) (planned).
2015	December	Start commercial operation of the No. 2 Unit (200,000kW) (planned).

General Plan



Bird's-eye View Graphics of Underground Structures



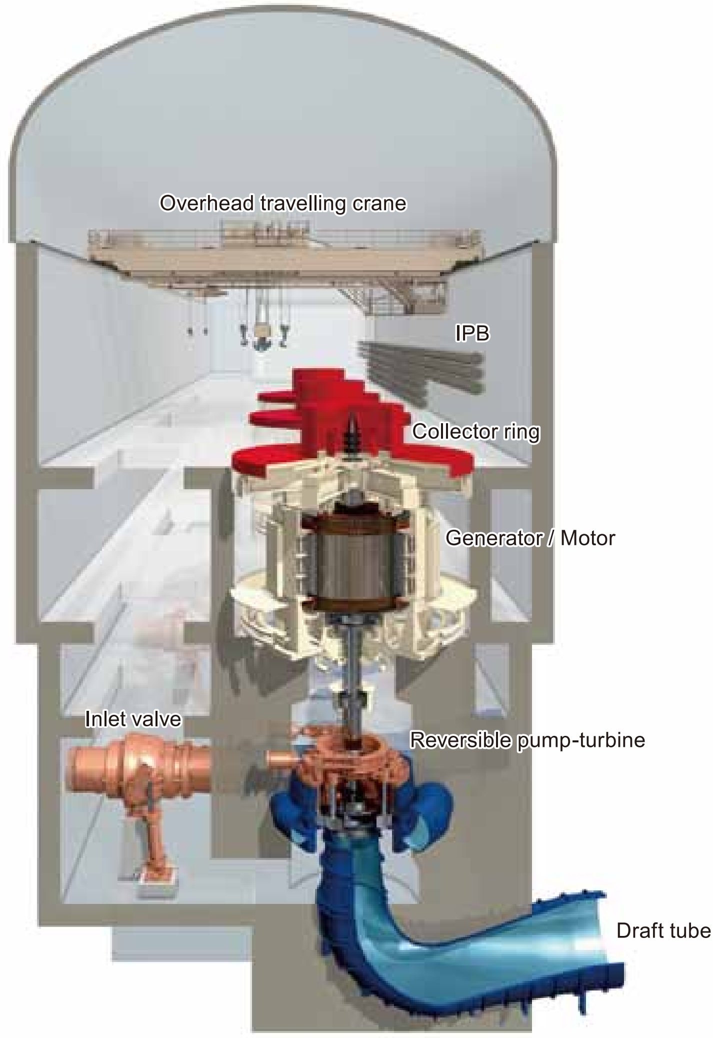
Bird's-eye View Graphics

Upper Reservoir

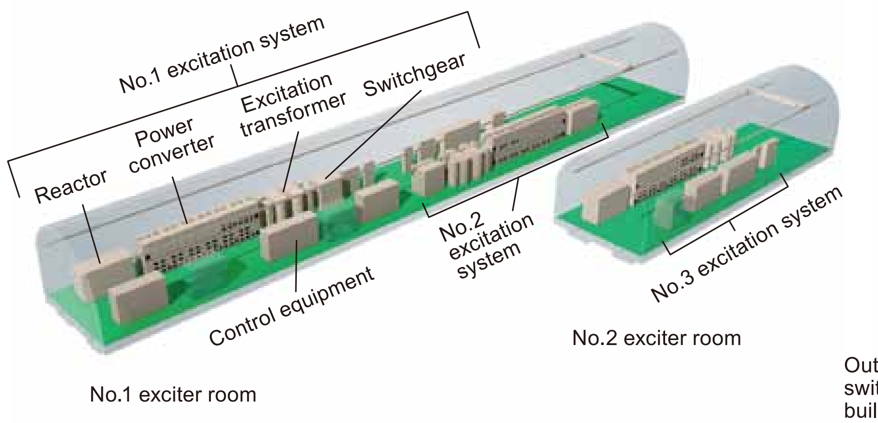
Lower Reservoir (Kyogoku Dam)

Conceptional Drawing

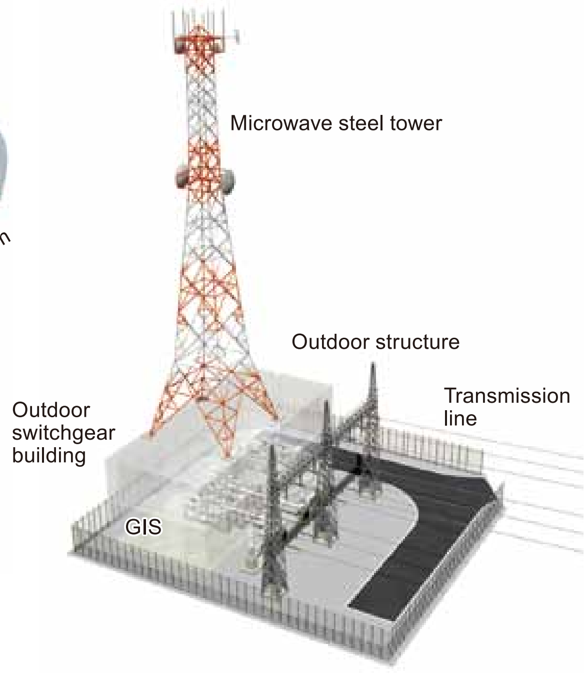
Powerhouse



No.1 Exciter Room , No.2 Exciter Room



Outdoor Switchyard

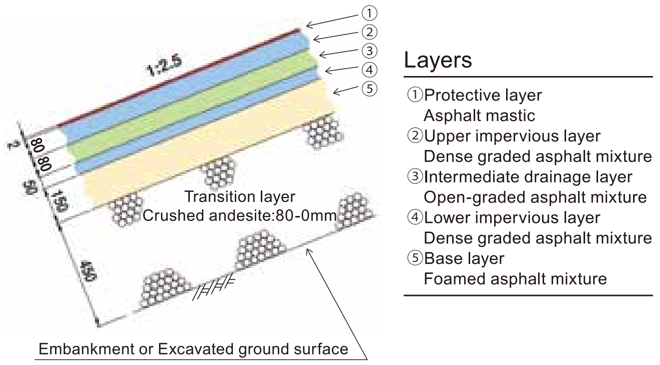


TECHNICAL FEATURES (1)

Composition and Materials of Asphalt Facing

Adoption of New Style Asphalt Facing

The upper reservoir of the Kyogoku Project is located in a cold heavy snowfall area with a minimum temperature of -20°C and snow cover of 5 m in winter. Having considered such severe weather conditions, the thick lift placing method is adopted for the upper impervious layer for the first time in Japan. Moreover, a new style asphalt facing where foamed asphalt mix is used as the base layer is employed for the first time in the world.



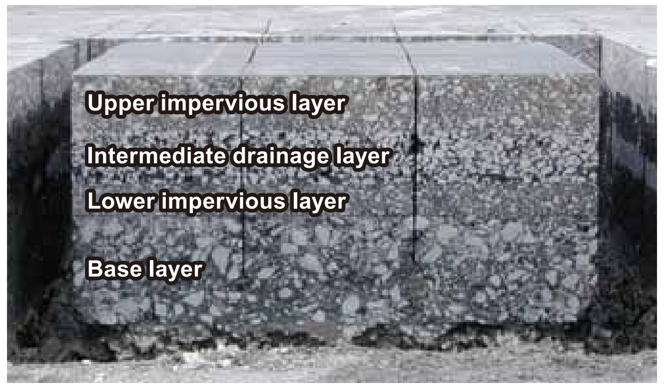
Structure of New Style Asphalt Facing

Functions of Each Layer

Layer	Function
Protective layer	•Protects against damages caused by air,water and ultraviolet. •Protects against erosion caused by sliding of mass of snow.
Upper impervious course	•Seals the storage water directly.
Intermediate drainage layer	•Monitors any leakage from the upper impervious layer. •Leads leakage to the inspection gallery and the drainage tunnel.
Lower impervious layer	•Seals any leakage from the upper impervious layer. •Leads leakage to the inspection gallery and the drainage tunnel. •Seals the underground water in natural ground and embankment body.
Base layer	•Protects the transition from avalanches and sliding or melting ice during winter and early spring. •Maintain the thickness of the lower impervious layer. •Secures the mechanical continuity of the embankment and asphalt facing materials.

Adoption of the Thick Lift Placing Method

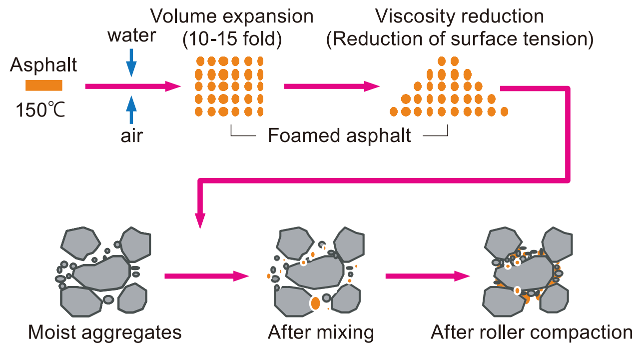
The upper reservoir of the Kyogoku Project is using thick lift placing of a single 8-cm thick layer. Other projects in Japan typically use conventional paving methods to make two or three 5-cm thick layers for the upper impervious layer of asphalt facings. The thick lift placing is expected to control inter-layer blistering by using a single, instead of double, layer. A single layer should ensure high quality by reducing the cooling rate of the asphalt mixtures under the influence of outdoor temperature, reducing costs and shortening the construction period.



Cross-Section of slope paved by field trials

Foamed Asphalt Mixture

Spraying air and water into asphalt at high temperature (approximately 150°C) makes foamed asphalt. Foamed asphalt has its volume increased 10-20 fold and has its viscosity reduced such that one can mix foamed asphalt with wet aggregate. Unlike hot asphalt mixtures, foamed asphalt mixtures do not fully cover coarse aggregate but instead adheres to the fine aggregate, and are integrated with coarse aggregate after compaction.



Adoption of Foamed Asphalt Mixture

Foamed asphalt mixture is a newly developed material with the improvement of the more conventional foamed asphalt mixture used for the upper sub-base of a road. A dispersibility improvement agent is added to the common foamed asphalt mixture to ensure good dispersion of the asphalt so that the asphalt uniformly adheres to individual aggregates in a sufficient manner.

At the upper reservoir site of the Kyogoku Project, excavated andesite is effectively used as the aggregate for this mix. Because it is a mix at normal temperature, allowing rapid work, this new mix is used for the base layer of the asphalt face impervious wall. Prior to the decision to use this mix, a number of laboratory tests, laying tests and exposure tests to assess its workability and dynamic properties were conducted with excellent results.

Verification of Applicability in Large-Scale Laying Test

Large-scale Laying Test

Prior to the construction of the asphalt facing, a large-scale laying test was conducted at the upper reservoir site to verify the quality and workability of this new style of asphalt facing.

Laying test in progress
(asphalt finisher with double tamper at work)

TECHNICAL FEATURES (2)

Information Technology Construction System

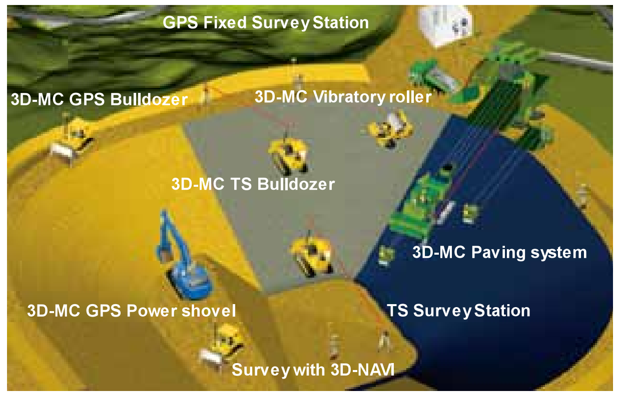
Use of the Information Technology (IT) Construction System

Recent rapid innovations of information technology (IT) have been making it possible to use the IT construction system in civil engineering work. In the construction of the Kyogoku Project, a series of work from investigation to design, survey, construction and construction management are integrated into an IT construction system to save time and labor greatly and increase construction accuracy as compared with conventional methods.The design and construction data will be subsequently used to assist the maintenance of the power station after the start of its commercial operation.

Main system

Three Dimensional Computer Aided Design System for Dam, 3D-DAMCAD	A highly labor-saving, quality-enhancing computer-aided design system that can cope with changes and additions to the plan through three-dimensional graphic processing of large volumes of data required for dam design and construction.
Three Dimensional Machine Control System for Bulldozers, Power shovels, Vibratory rollers, and Paving machines, 3D-MC	A system for automatically positioning of heavy equipment so that it can work according to the design data by checking in real-time the three-dimensional design data against the location of the equipment obtained by surveys using RTK-GPS*1 or auto laser tracking TS*2
Three Dimensional Navigation System for Survey, Dump trucks, 3D-NAVI	A new survey system that enables efficient real-time surveying through the coordination of three-dimensional design data and RTK-GPS or TS. The system is also applied for guiding and managing dump truck operation.

*1 RTK-GPS: Real-Time Kinematic Global Positioning System
*2 Auto Laser Tracking Total Station



The civil engineering works

3D-MC Bulldozer(RTK-GPS)

TECHNICAL FEATURES (3)

Variable Speed Pumped Storage Power Generation System

Adoption of Variable Speed Pumped Storage Power Generation System

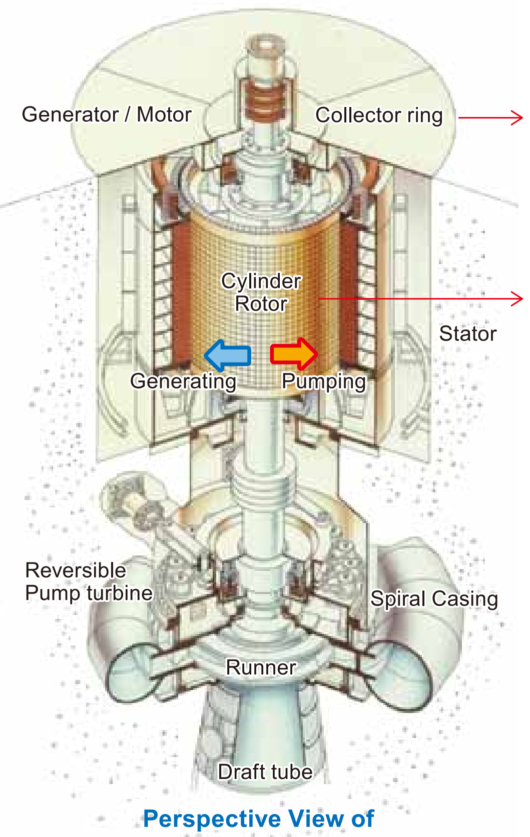
Conventional pumped storage power stations use combined pump turbine and generator motor units which operate at a constant speed. Output conditioning (frequency control) can be done during power generating operation but not during pumping operation.

A variable speed pumped storage power generation system can condition the frequency during pumping operation by means of altering the rotating speed of the generator motor as an additional function to conventional pumped storage power stations, enabling much more efficient operation of the power system.

11 units of this power generating system are already used at 7 sites in Japan. As of April, 2012, a further 5 units, including that at the Kyogoku Project, are being built while 2 units are being converted from fixed speed units, illustrating the growing demand for this type of power generating system.

At the Kyogoku Project, new IEGT*3 devices are selected as semiconductors for an exciting arrangement for the first time in Japan in view of their small size and higher efficiency.

*3 IEGT: Injection Enhanced Gate Thyrister



Perspective View of
Variable Speed Pump Turbine
Generator Motor

Differences Between Variable Speed and Fixed Speed Power Generating Systems

Structure of collector ring (part supplying current to the rotor)	
Variable Speed	Fixed Speed
Three poles due to the supply of low frequency 3-phase AC	Two poles due to the supply of DC

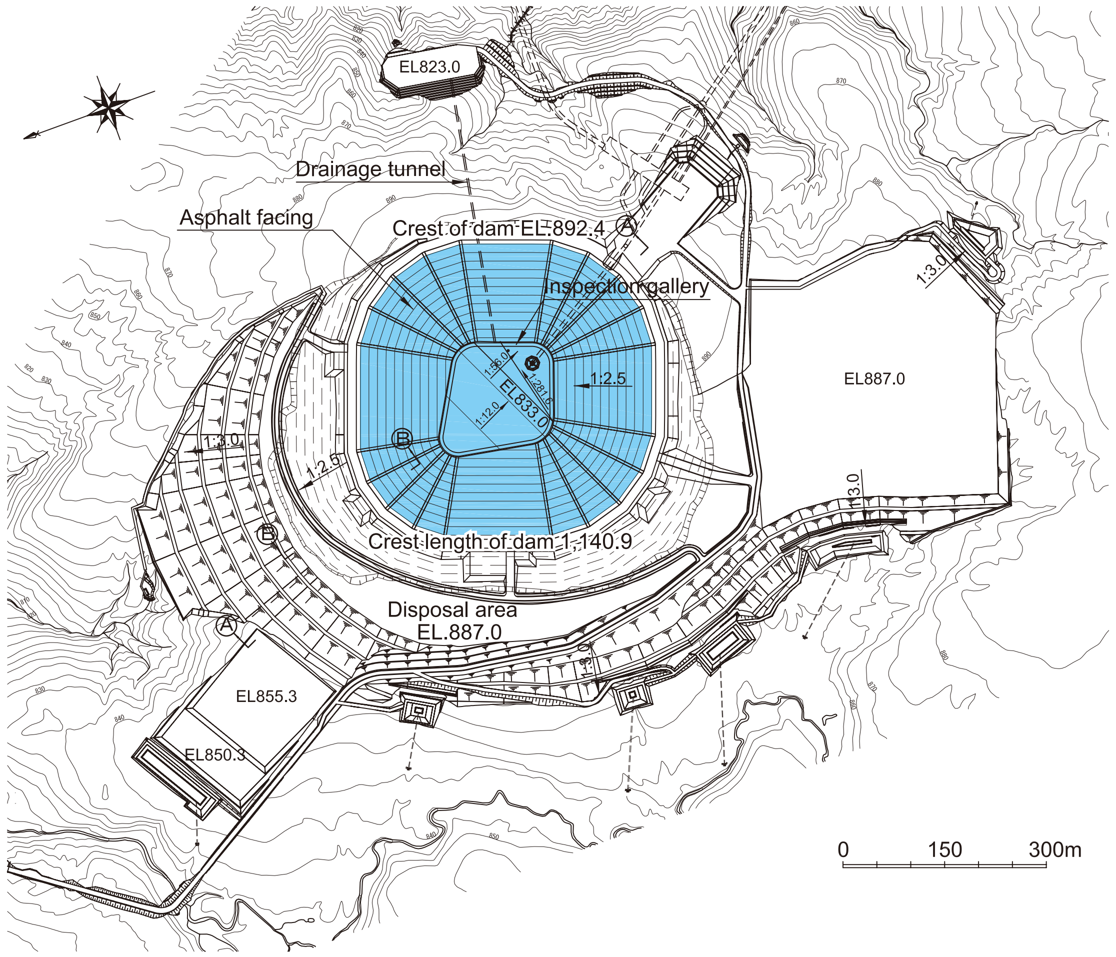
Structure of rotor (part generating magnetic poles)	
Variable Speed	Fixed Speed
<Cylindrical Type> The supply of low frequency 3-phase AC creates a rotating magnetic field (magnetic poles).	<Salient Type> The supply of DC creates an alternating series of P pole and N pole.

Other Differences (Composition of an exciting arrangement supplying current to the rotor)	
Variable Speed	Fixed Speed
Complicated configuration of a power converter, powersupply transformer, reactor, switchgear and others, supplying variable low frequency 3-phase AC and requiring a fairly large installation area	Simple configuration of a power-supply transformer and rectifier, supplying DC

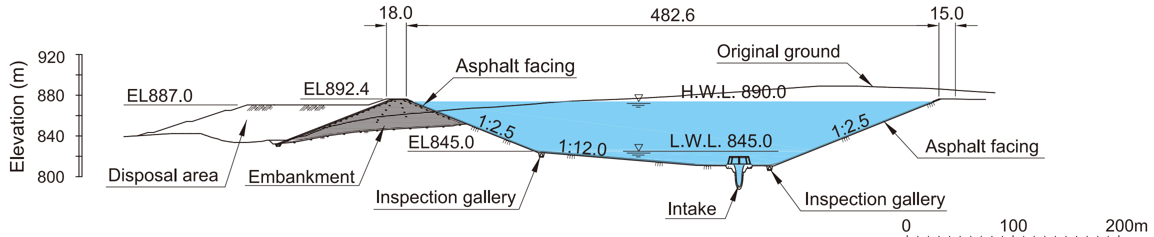
The structure of the pump turbine is the same for both types.

Upper Reservoir

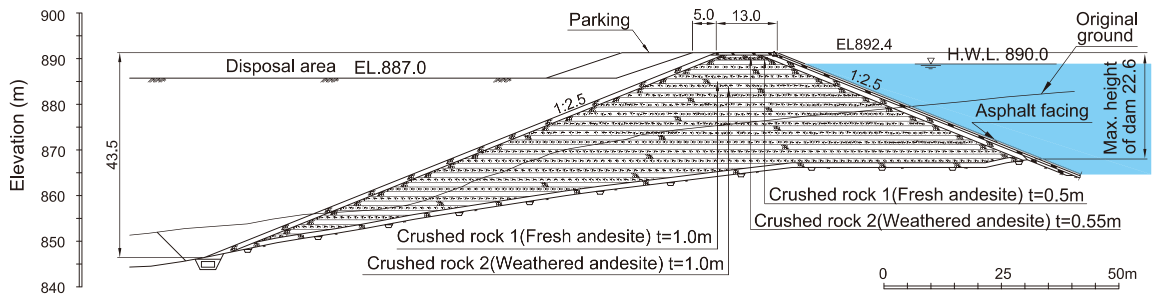
Plan of Upper Reservoir (Unit : m)



Ⓐ-Ⓐ Section of Upper Reservoir (Unit : m)

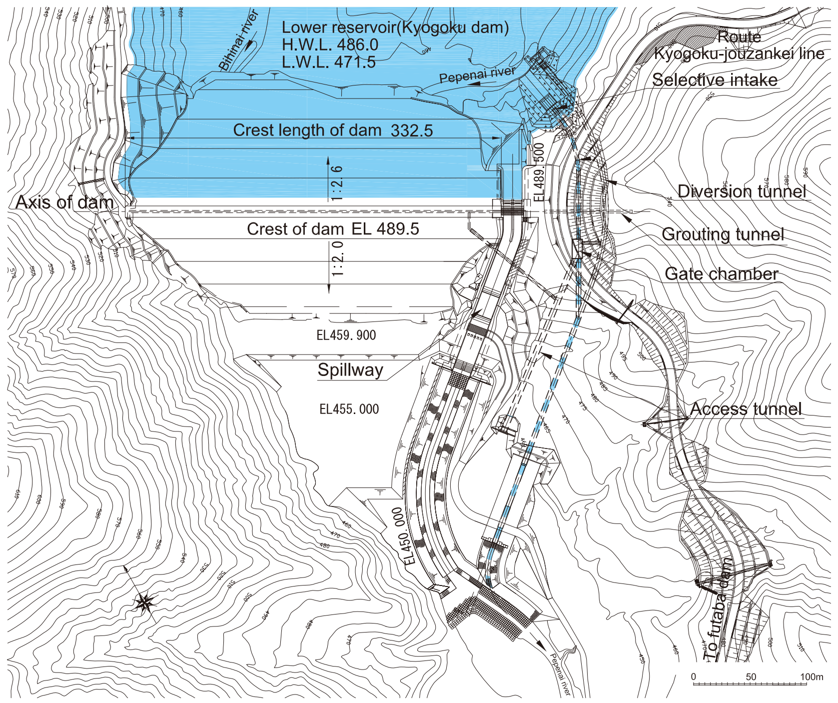


Ⓑ-Ⓑ Section of Embankment (Unit : m)

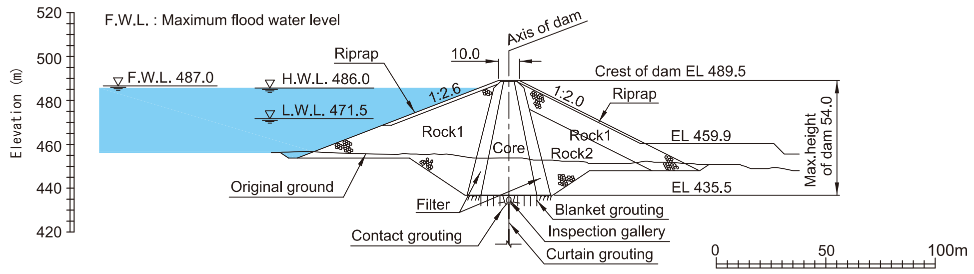


Lower Reservoir (Kyogoku Dam)

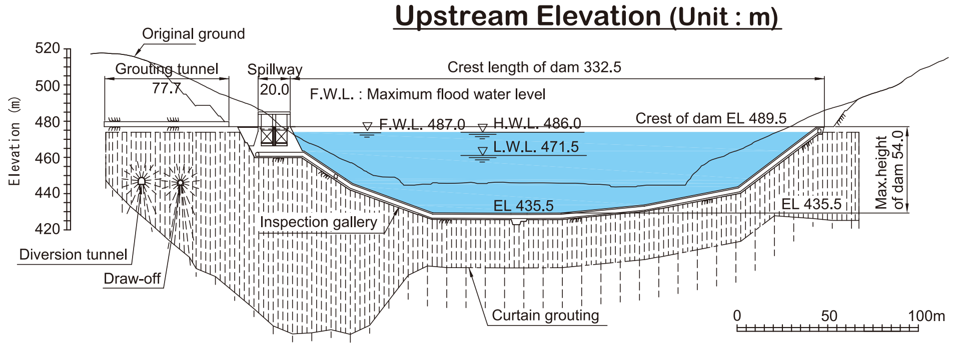
Plan of Lower Reservoir (Kyogoku Dam) (Unit : m)



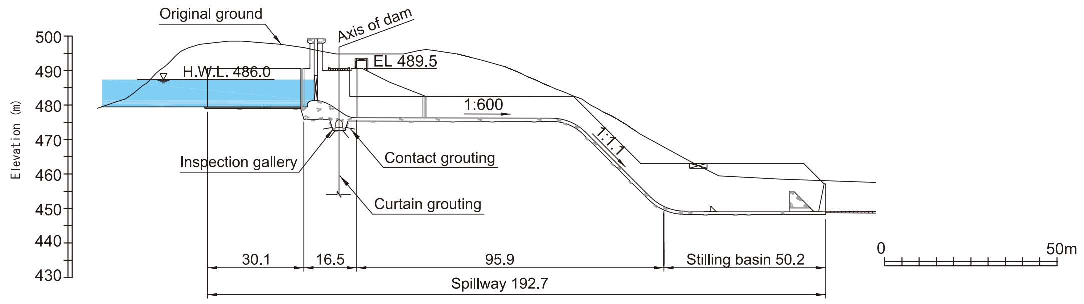
Maximum Section of Lower Reservoir (Kyogoku Dam) (Unit : m)



Upstream Elevation (Unit : m)

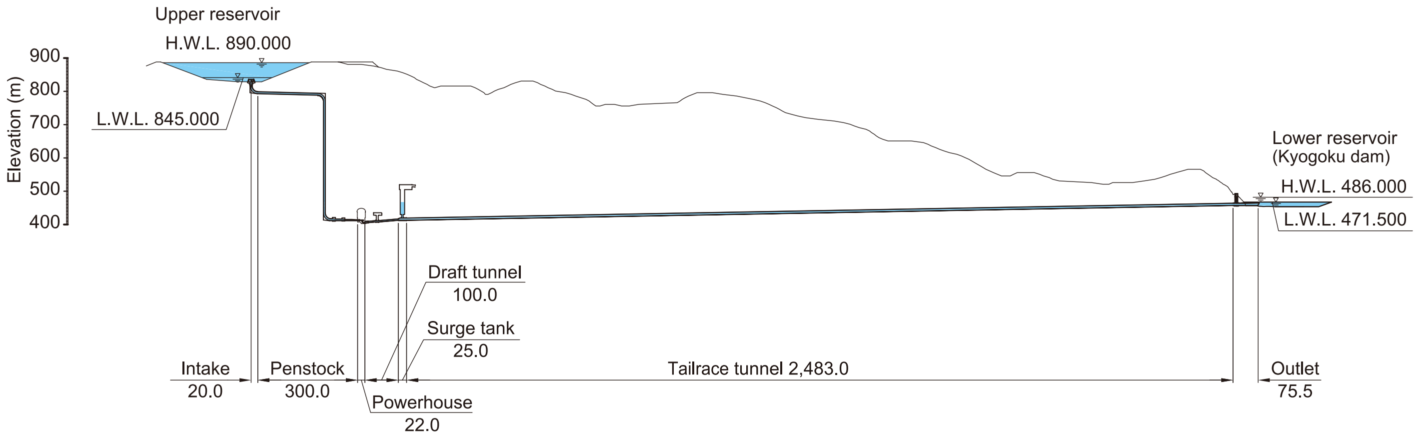


Section of Spillway (Unit : m)

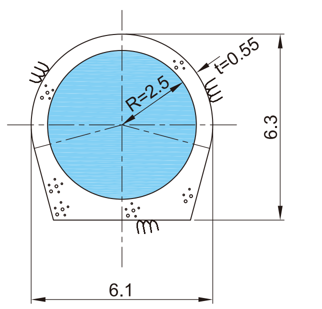


Intake, Penstock, Tunnels, and Outlet

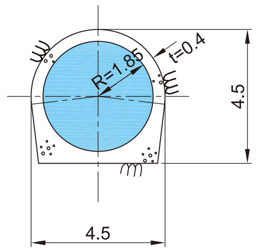
Section of Water Way (Unit : m)



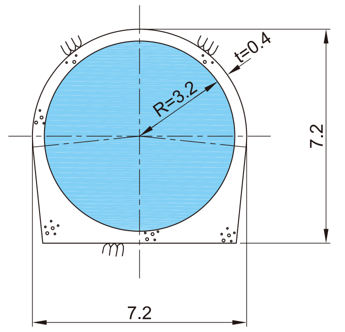
Section of Penstock (Unit : m)



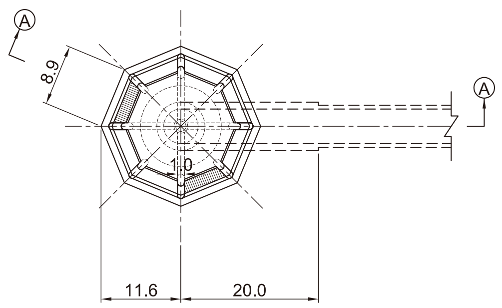
Section of Draft Tunnel (Unit : m)



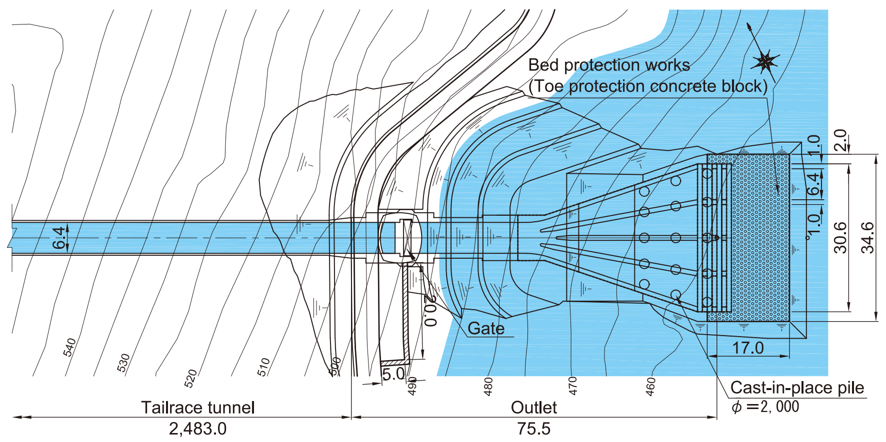
Section of Tailrace Tunnel (Unit : m)



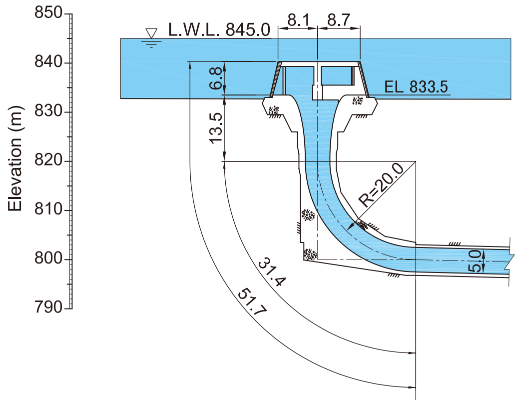
Plan of Intake (Unit : m)



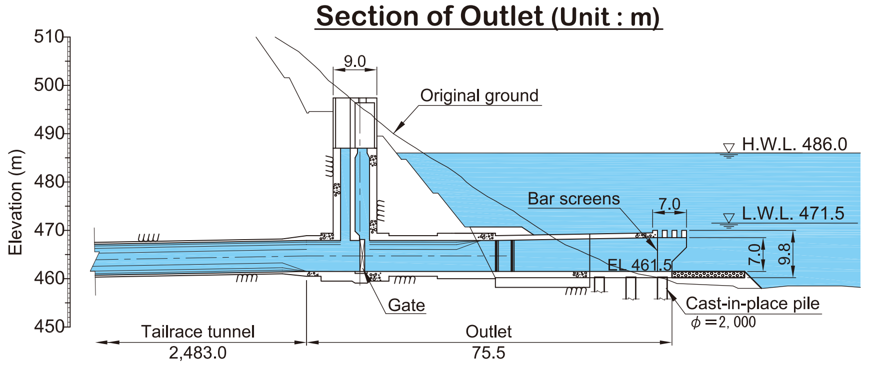
Plan of Outlet (Unit : m)



Ⓐ-Ⓐ Section of Intake (Unit : m)

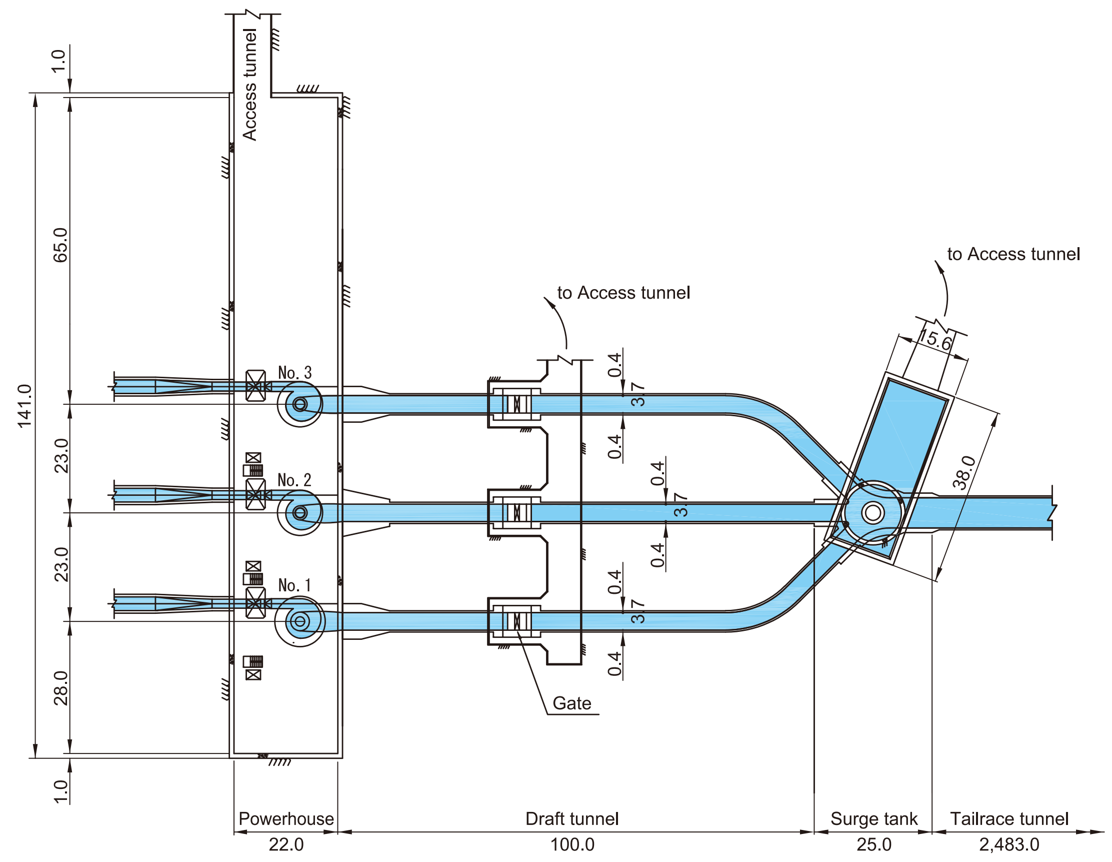


Section of Outlet (Unit : m)

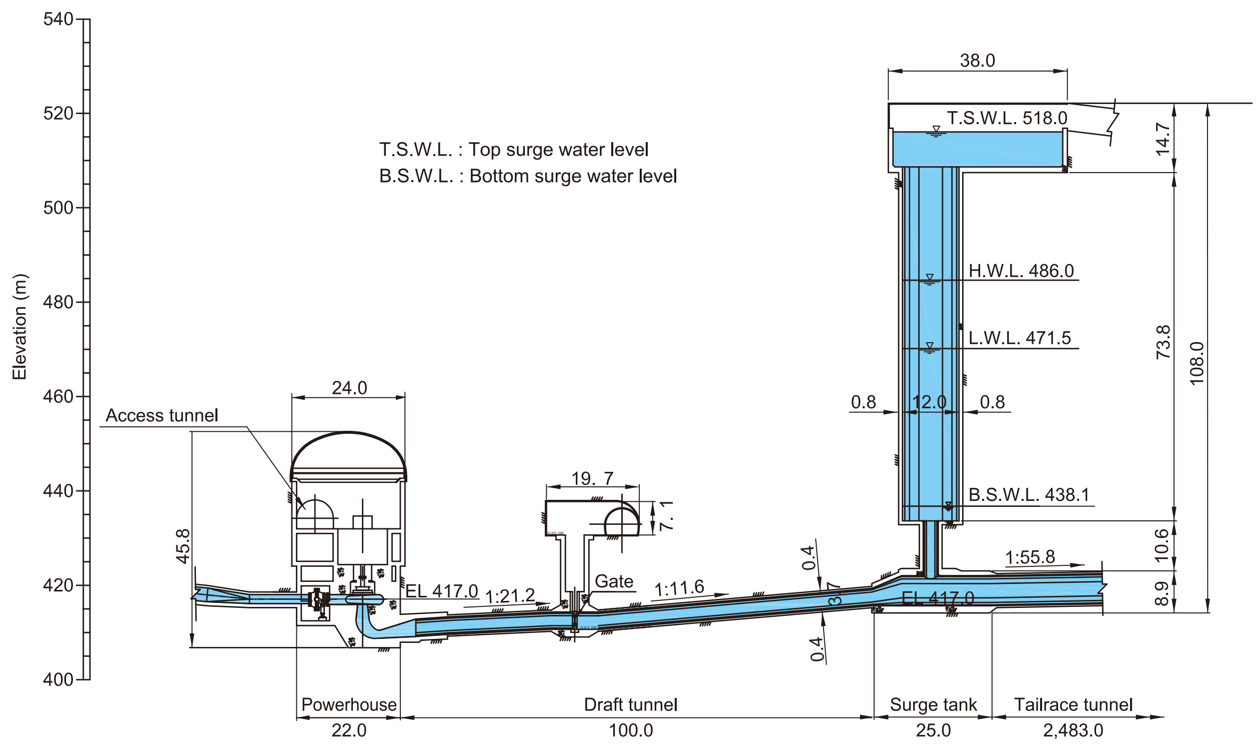


Powerhouse, Draft Tunnel, and Surge Tank

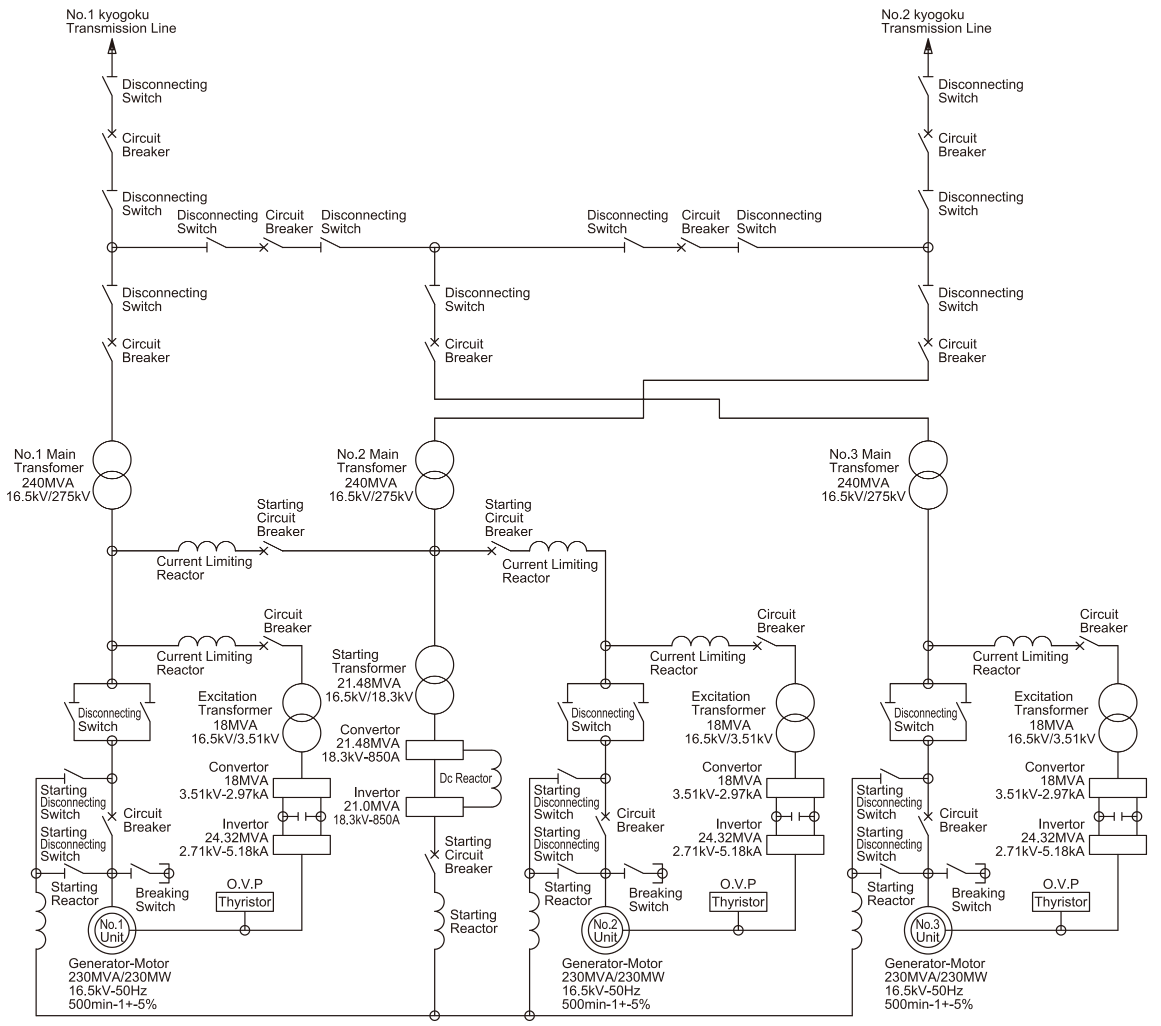
Plan of Powerhouse,Draft Tunnel,and Surge Tank (Unit : m)



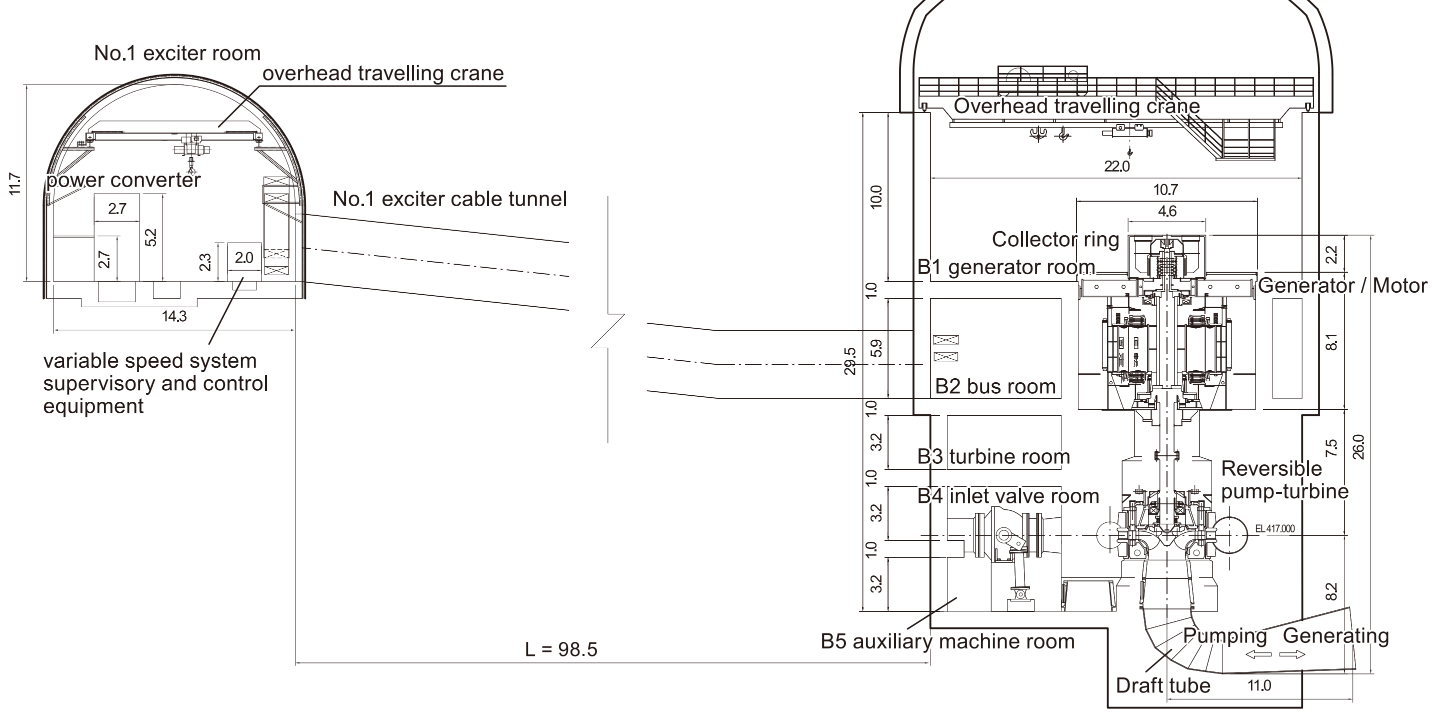
Section of Powerhouse,Draft Tunnel,and Surge Tank (Unit : m)



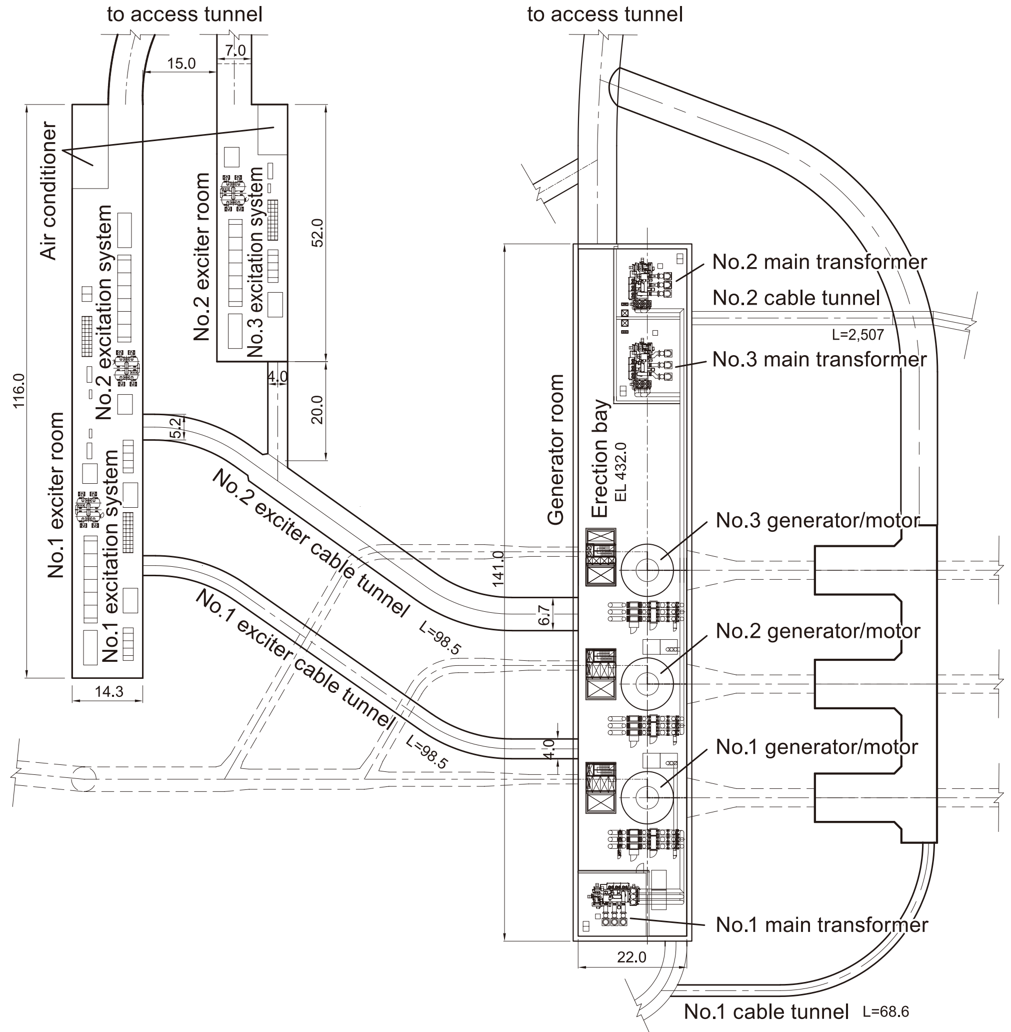
Skeleton Diagram



Exciter Room, Powerhouse Cross Section (Unit : m)



Exciter Room, Generator Room Plan (Unit : m)



Outdoor Switchyard Plan,Cross Section (Unit : m)