# SPHERICAL SHIELD TBM TECHNOLOGY

The world's first omni-directional shield tunneling method



A TBM THAT TURNS CORNERS!



## New Technology for Underground Tunnel Construction

The Spherical Shield TBM technology is capable of continuously boring vertical and horizontal tunnels using a single machine. For the first time, it is possible to "turn a corner" with a TBM. The Spherical Shield TBM can be rotated in any direction to allow a directional change at any time during the tunnel boring process. This mechanism makes the following tunnel configurations possible.

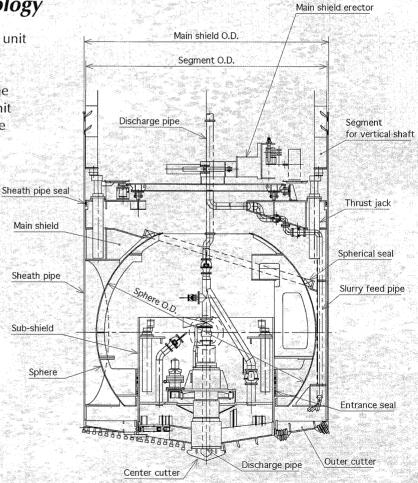
- Vertical (downward) Horizontal
- Horizontal Horizontal
- Horizontal Vertical (upward)

The Spherical Shield TBM technology affords numerous advantages over a conventional TBM. Since the vertical tunnel (access shaft) constructed by the machine can be smaller than the size of shafts with conventional retaining walls, the method enables boring down from confined sites in crowded residential or commercial areas. Access shafts at turning points can also be eliminated. It also shortens construction periods and reduces environmental impacts compared to a conventional TBM. These features of the method allow a wider variety of TBM technology applications.

## Basic Concept of the Technology

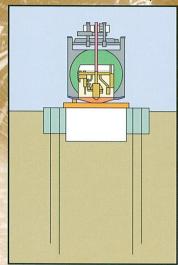
The boring machine has a spherical unit that contains a smaller cutter-head. The larger shield machine tunnels either horizontally or vertically to the planned corner and the spherical unit rotates allowing the smaller machine to bore in the new direction. The machine is sealed mechanically against water; it can bore a tunnel under the water table without affecting the groundwater regime and without causing ground subsidence. It can work conventionally or in

It can work conventionally or in a slurry-shield mode. A schematic diagram of a typical machine structure is shown at right.



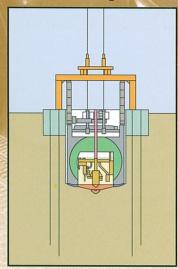
# Vertical-Horizontal Boring Procedure

#### 1. Machine Assembly



The machine is assembled on a platform placed on a concrete ring guide wall.

## 2. Initial boring

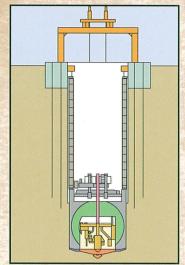


The machine is lowered into the ground by jacks, which are supported by an external bracket resting on the guide wall.

The cutter-head has outer bits

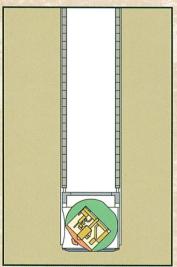
The cutter-head has outer bits connected to inner bits on the spherical unit to provide full face coverage.

#### 3. Normal Boring



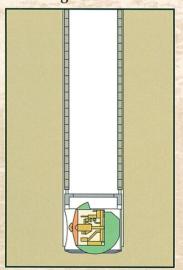
Excavation proceeds by using thrust jacks, with bracing support provided by successively placed concrete segments. Just before reaching the designed level, the shield sheds its outer skin plate, which is anchored to the segments.

#### 4. Rotation of Sub-machine



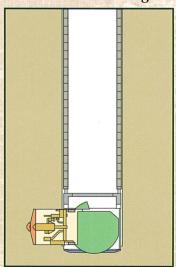
The cutter-head subassembly is retracted into the spherical unit, which is then rotated 90 degrees.

## 5. Boring to new direction



Tail parts are attached and then the cutter-head subassembly starts boring in the new direction.

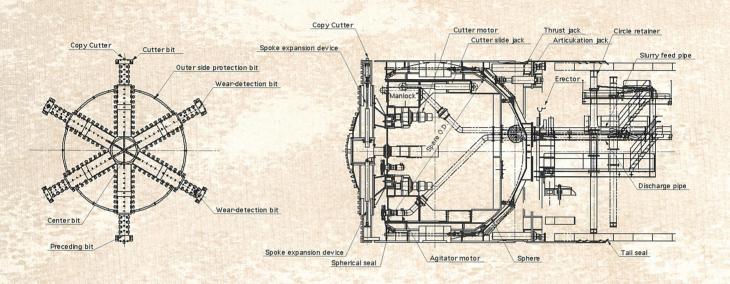
## 6. Horizontal Boring



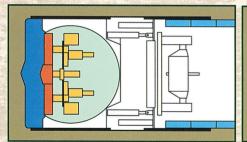
Horizontal boring continues to the designated point in the same manner as a standard TBM.

# Bit Replacement Procedure

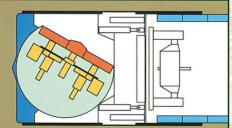
When bits need to be maintained or replaced, the spherical TBM makes it easy. This can be useful on long reaches even when no turns are necessary. A typical machine system and bit replacement procedure are shown below.



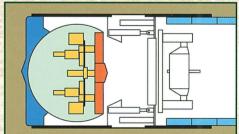
#### 1. Preparation



#### 2. Rotation



#### 3. Bit Replacement



Cutter head is shrunk and pulled back to the spherical unit by jacks. All pipes are disconnected and the spherical unit is sealed

Slurry is pumped into the sealed space until its pressure is balanced to the earth pressure. The sphere is rotated 180 degrees.

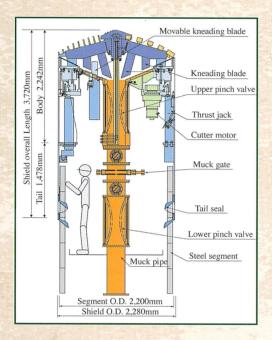
After pumping the slurry out and inspection is done, all worn parts including bits are replaced. The sphere is then returned to its operation position and boring resumes.

## **Upward Boring Method**

Although horizontal-vertical(upward) tunnel boring by the spherical shield TBM has not been done at an actual project yet, upward tunnel boring has been done by a following conventional shield TBM in the sewer project of Osaka in 2001.

The machine manufactured for upward tunnel boring is delivered to the underground location through an existing horizontal tunnel for final assembly. It is set on a pedestal and starts boring toward the surface in the same manner as a standard machine does horizontally. It has the following advantages.

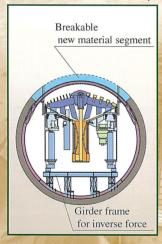
- This method does not need a large area on the surface.
- It can shorten the duration of vertical tunnel boring.
- There is much less influence on the area surrounding the operation because earth pressures are balanced by the upward force of the TBM.





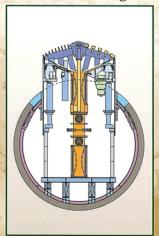
A machine holing through at the surface.

## 1. Machine Assembly



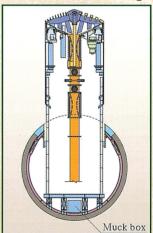
The machine is delivered to the spot through a existing tunnel and set for vertical boring

## 2. Start of Boring



The machine starts boring vertically with shield jacks by cutting the existing segment parts made out of fiber reinforced plastics

## 3. Continued Boring



As the boring proceeds, the tail part of the machine is assembled and it continues excavation as a standard machine does.

# Spherical Shield TBM Configurations

# 1. Vertical-Horizontal Boring Machine



Arakawa Trunk Sewer



Second Junisou Trunk Sewer



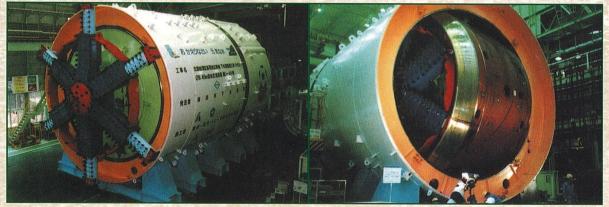
Bandai-Hannan Trunk Sewer

## 2. Horizontal-Horizontal Boring Machine



Toyohashi Public Sewer

## 3. Bit Replacement Machine



Nippa Suehiro Trunk Sewer

## 4. Upward Boring Machine





Bandai-Hannan Trunk Sewer

# **Specifications**

Since the spherical shield TBM was developed in 1991, the machine has been designed and built for the specific requirements of numerous projects. The following are machine specifications based on past applications. Other sizes and configurations are possible.

#### **Outside Diameter of Machine:**

Main Machine: 3.9 – 7.9 meters (13 – 26 feet) Sub Machine: 2.7 – 4.8 meter (9 – 16 feet)

**Cutter Torque:** 392 – 1700kN-m (290k – 1250k ft-lb)

**Total Thrust:** 7000 – 40000kN (1570k – 8990k lbs)

# Advantages of the Method

The time required for access shaft construction is greatly accelerated.

 The machine bores its own access shaft, reducing cost by eliminating specialized shoring systems for the shaft.

• The area needed for a standard access shaft is greatly reduced.

• Where an access shaft is needed at a turning point for a standard TBM, the access shaft can be eliminated.

• The cost of soil improvement work around the connection of two intersecting tunnels can be eliminated.

• The Spherical Shield TBM allows the easy replacement of bits, possibly eliminating an intermediate access shaft or other high-cost maintenance activities.

## Appropriate Applications for the Spherical Shield TBM

Tunnels in urban areas are increasingly being installed under difficult and tight surface access conditions and in difficult subsurface conditions. When these conditions exist, the Spherical Shield TBM may be the best answer. When tunnels must take a turn, consider this method. When groundwater or surface subsidence issues are important, the Spherical Shield TBM technology may provide the best factor of safety. Soil conditions can range through variety of soil type and hardness, from soft clays to boulder profiles.

## **Award and Patent**

The Spherical Shield TBM technology has received the Japan Society of Civil Engineering Award for 1994 and the Imperial Invention Award for 1997 in Japan and it has been patented in the United States and European countries. (US Patent No. 5,634,692)

# Selected Project References

#### Horizontal Tunnels with Turns

Project Name	Client	Main Machine		Sub Machine		
		Outside Diameter	Tunnel Length	Outside Diameter	Tunnel Length	Type
Kannon Rive Water Storage (Yokohama, Japan)	Japan Sewage Bureau	φ5.53m	259m	$\phi$ 3.68m	65m	Earth Pressure Balance
Public Sewer Construction (Toyohashi,Japan)	Toyohashi City	∮3.93m	579m	∲2.68m	898m	Slurry

#### Vertical-Horizontal Tunnels

		Main Machine		Sub Machine		
Project Name	Client	Outside Diameter.	Tunnel Length	Outside Diameter	Tunnel Length	Туре
Hanahata Branch Sewer (Tokyo, Japan)	Tokyo City	∮5.82m	38.0m	<i>∲</i> 2.89m	434m	Slurry
Arakawa Trunk Sewer (Tokyo, Japan)	Tokyo City	∮7.92m	39.3m	φ4.84m	2,396m	Slurry
Second Junisou Trunk Sewer (Tokyo, Japan)	Tokyo City	φ7.40m	46.6m	<i>∲</i> 4.45m	985m	Slurry
Bandai-Hannan Trunk Sewer (Osaka, Japan)	Osaka City	φ5.90m	19.3m	<i>∲</i> 4.20m	2,017m	Slurry/Earth Pres. Balance
Second Asakusa Trunk Sewer (Tokyo, Japan)	Tokyo City	∮7.92m	37.7m	<i>∲</i> 4.45m	1,905m	Slurry

## Cutter Bits Replacement

Project Name	Client	Outside Dia.	Tunnel Length	Depth	Type
Nippa Suehiro Trunk (Yokohama, Japan)	Yokohama City	<i>∲</i> 9.45m	4.435m	52~60m	Slurry

## **Upward Boring Tunnel**

Project Name	Client	Outside Dia.	Tunnel Length	Depth	Туре
Bandai Hannan Trunk Sewer (Osaka, Japan)	Osaka City	<i>∲</i> 2.28m	32.8/32.4/20.3m	Same as left	Earth Pressure Balance



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