

**IHI**

**S H I E L D  
M A C H I N E**



**Ishikawajima-Harima Heavy Industries Co., Ltd.**



# DEEPER, LONGER, FASTER AND MORE SAFELY: IHI SHIELD MACHINES WILL MEET ALL TECHNICAL NEEDS.

IHI is a developer and manufacturer of "earth pressure balanced shield machines which are a representative type of shield machine. IHI was also the first in the world to develop an automatic segment assembling robot. This robot was built for the Kanagawa utility tunnels and was a pioneering development which led to today's automation. IHI has always led the way and is now concentrating its research and development efforts to produce a new shield machine for the future.

IHI shield machines have been recognized for their technological superiority from many different fields and have received numerous awards.

**12.84 meter special open face shield machine**  
Industrial award from the Japan Steel Structure Association (1983)  
**7.23 meter self-propelled mechanical shield machine**  
Technological development award from the Civil Engineering Society (1985)  
**Automatic segment assembling device**  
Technological award from the Machine Society (1985)

**Articulated shield machine**  
Technological development award from the Civil Engineering Society (1986)  
**Rotating shield machine**  
Eye-catching Invention Award (1993)  
Kato Award from the Japan Construction Mechanization Association (1993)  
Technological development award from the Civil Engineering Society (1994)  
Nikkei BP Award (1995)

## I H I S H I E L D M A C H I N E

### C O N T E N T S

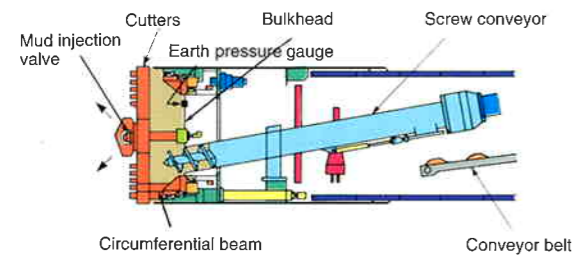
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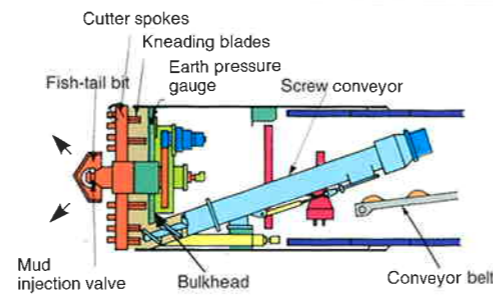
# Various types of shield machines created from IHI's rich history

## Closed-face Type (Earth pressure system)

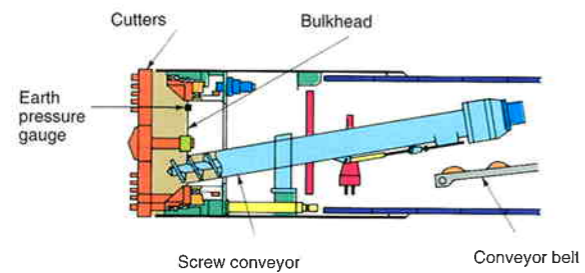
### Mud injection type



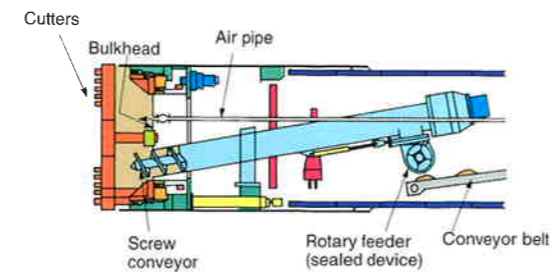
### Muddy soil pressure type



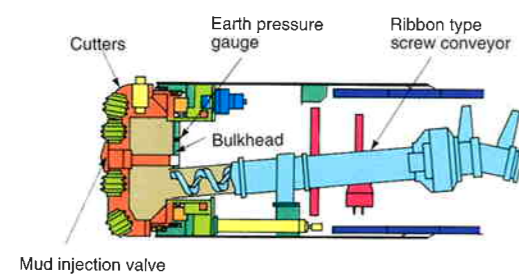
### Earth pressure type



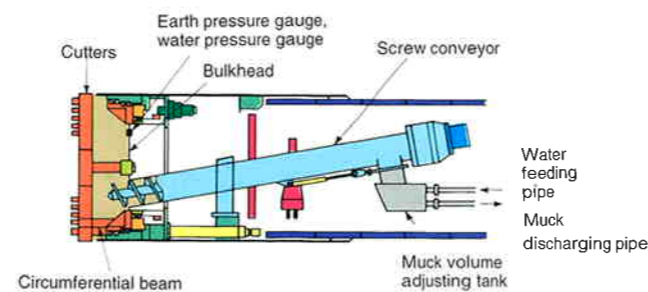
### Confined air-pressure type



### Bedrock and gravel type

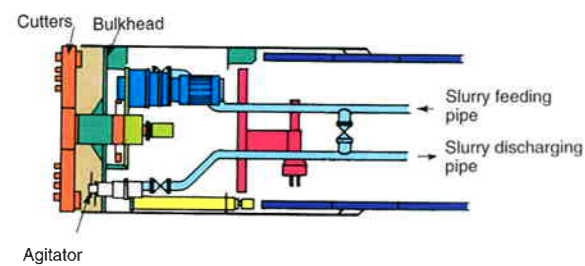


### Water pressure type

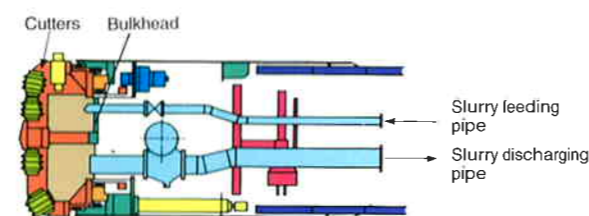


## Closed-face Type (Slurry system)

### Slurry type



### Bedrock and gravel type

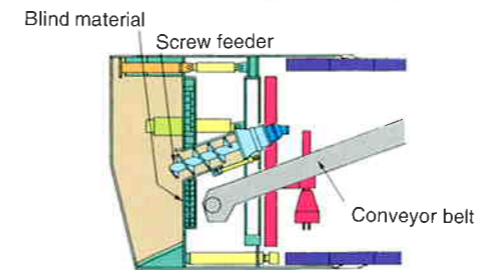


Since 1960 when IHI delivered a shield machine for construction of the Nagoya municipal subway, we have manufactured numerous types of large and small diameter shield machines. We especially have a great deal of experience with closed-face type shield machines and

have a long history of making varied form shield machines. In addition, we are promoting automation to increase the safety of construction work and to improve the quality of tunnels.

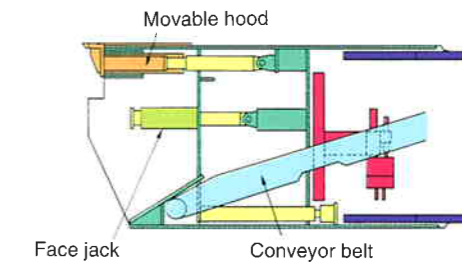
## Partially open face type

### Blind type

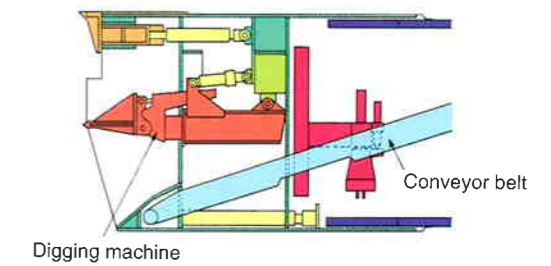


## Fully-open face type

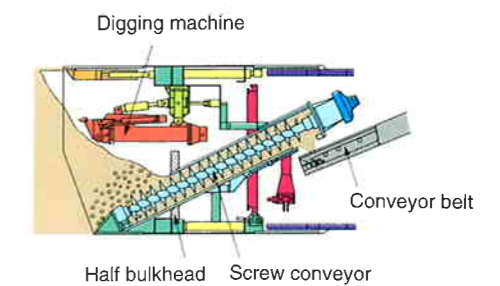
### Manual excavation type



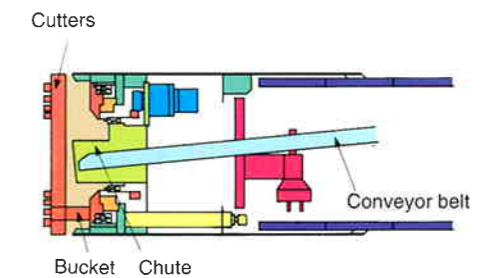
### Semi-manual excavation type



### Half-bulkhead excavation type



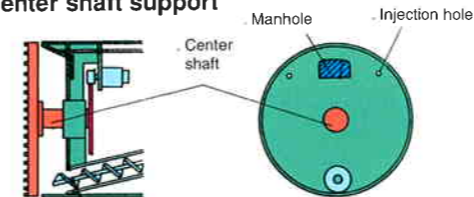
### Machine excavation type



## Cutter supporting system

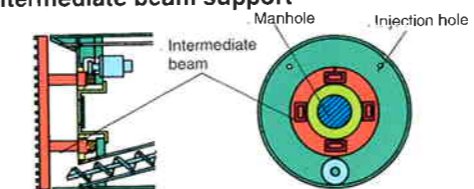
We select the best cutter supporting system to meet the construction conditions.

### Center shaft support



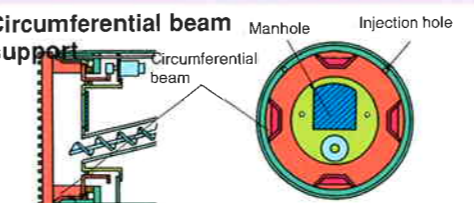
- Simplifies cutter support.

### Intermediate beam support



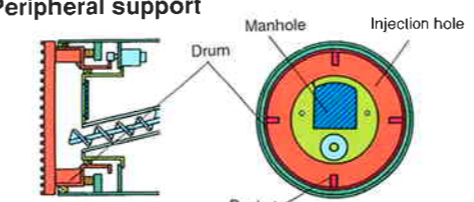
- Small diameter cutter bearings and gaskets.
- Improved agitation function.

### Circumferential beam support



- Prevents hardening of soil around the circumference of the cutter.
- Improved agitation function.
- A large diameter bulkhead.
- Improved soil mixing function.

### Peripheral support



- Large diameter bulkhead
- Improved soil mixing function.





# Earth Pressure Balanced Shield Machines



7.15 mφ mud injection type earth pressure balanced shield machine

## Muddy Soil Pressure Balanced Shield Machines

In the muddy soil pressure balanced shield method soil which is dug out by the cutter bits is injected with muck, then this is forcefully kneaded with the "kneading blades" attached to the back of the cutter spokes. This changes the soil to "mud" which has superior plasticity fluidity and which is not permeable, so that it can be discharged. In addition, because mud is filled in the cutter chamber and screw conveyor to generate muddy soil pressure with the propulsion of the shield jack to resist earth pressure and water pressure when digging, this type of shield machine is applicable to a wide range of ground condition.



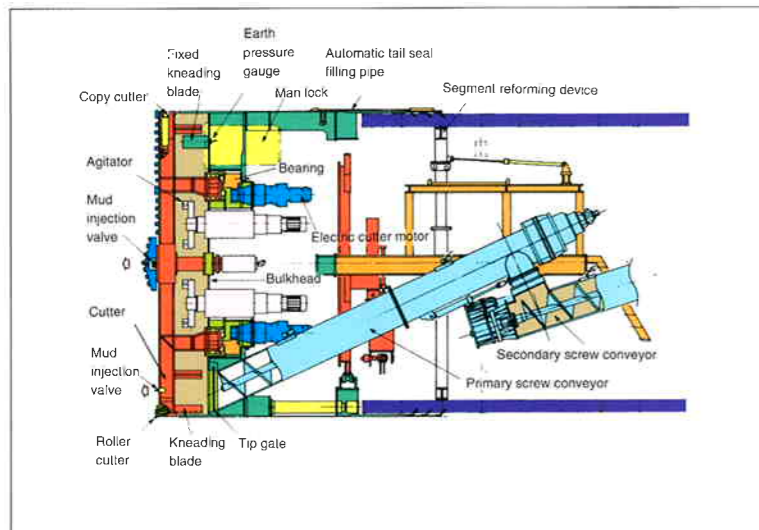
6.44 mφ muddy soil pressure balanced shield machine



3.48 mφ muddy soil pressure balanced shield machine



2.49 mφ muddy soil pressure balanced shield machine

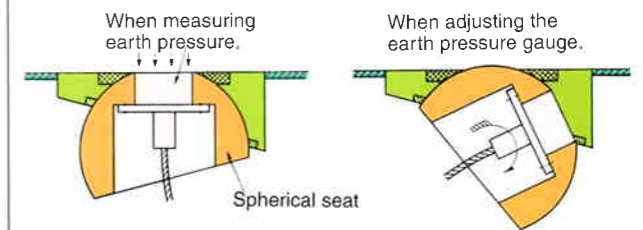


## Mud injection Type Earth Pressure Balanced Shield Machines

Mud which is pressure injected into the cutting face is mechanically mixed and agitated with the soil to produce muck. The volume of this muck is adjusted with the screw conveyor, and it is filled between the cutting face and shield bulkhead, then pressure is applied by the shield's propelling pressure. Because this earth pressure is applied to all the cutting face and excavating is executed while maintaining stability in the cutting face, this type of shield machine is applicable to a wide range of ground condition.

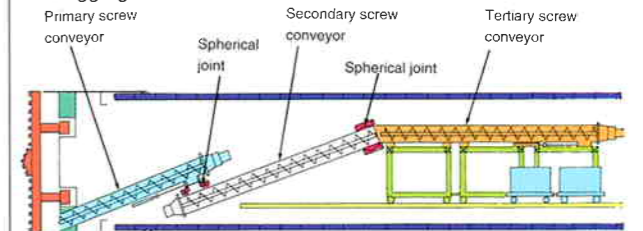
## Spherical Earth Pressure Gauge

Even under high water pressure, calibration and replacement of the earth pressure gauge is possible by rotating the spherical seat, so that highly accurate earth pressure measurement is possible.



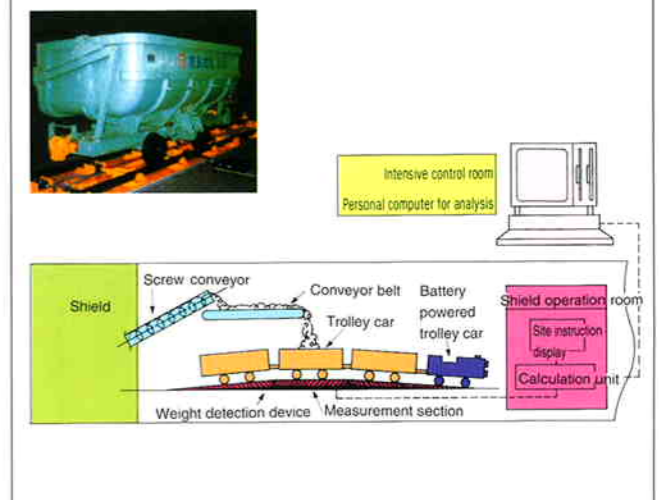
## Secondary and Tertiary Screw Conveyors

These are used to prevent soil from being dropped in the tunnels and to improve water stopping ability. Because a spherical joint is used, these screw conveyors can also be used for digging curves.



## Muck Weight Control System

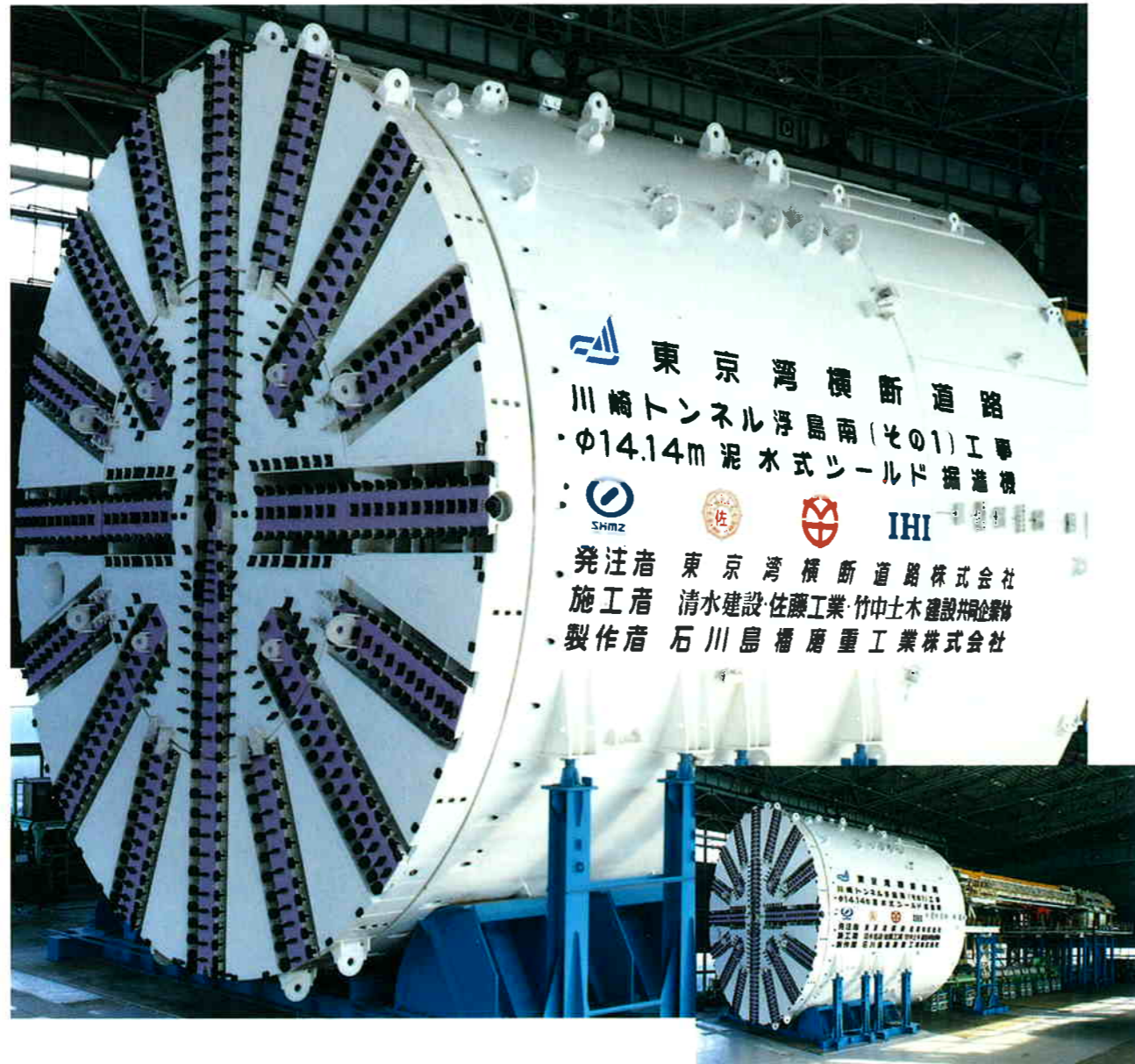
In order to make digging control more accurate, we developed a muck weight control system which can control earth pressure and muck weight continuously with a high degree of accuracy. This system allows numerical control, so that digging control is perfect.







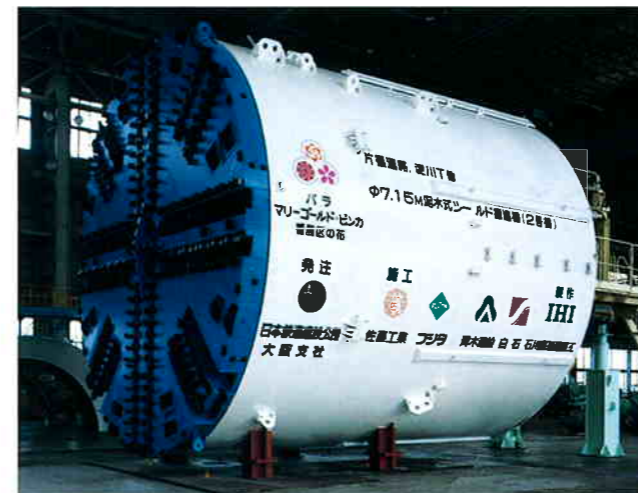
# Slurry Shield Machines



14.14 mφ slurry shield machine



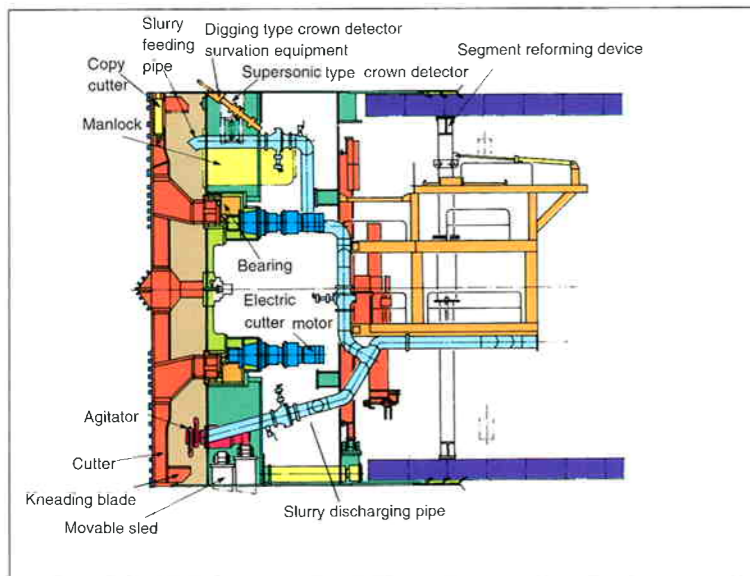
10.5 mφ slurry shield machine



7.15 mφ slurry shield machine



3.18 mφ slurry shield machine

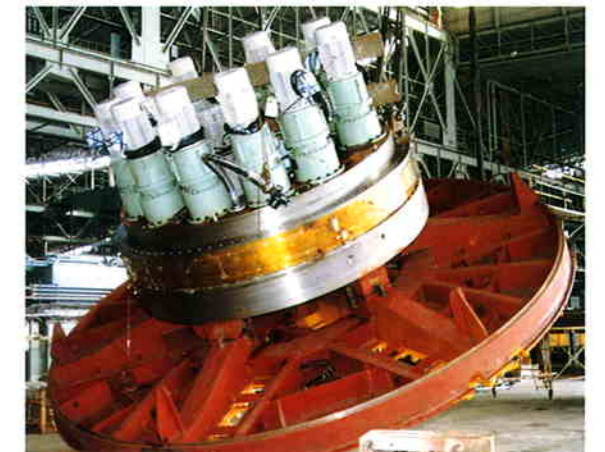


## Large Diameter Slurry Shield Machines

Slurry is fed into the cutter chamber and the properties of slurry and slurry pressure are used to resist the earth pressure and water pressure which work on the cutting face to stabilize the soil being dug. At the same time, the soil which is dug is transported in circulating slurry while the shield machine works its way forward, so that this type of shield machine is applicable to a wide range of ground condition.

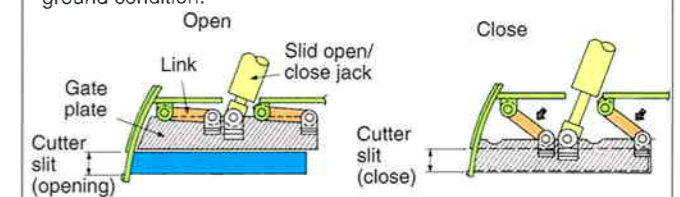
### Electric Drive

In order to save energy and improve the working environment, we were the first to adopt an electric drive. By adopting an electric drive, the trolleys which have to be used are shorter and temporary starting is more efficient.



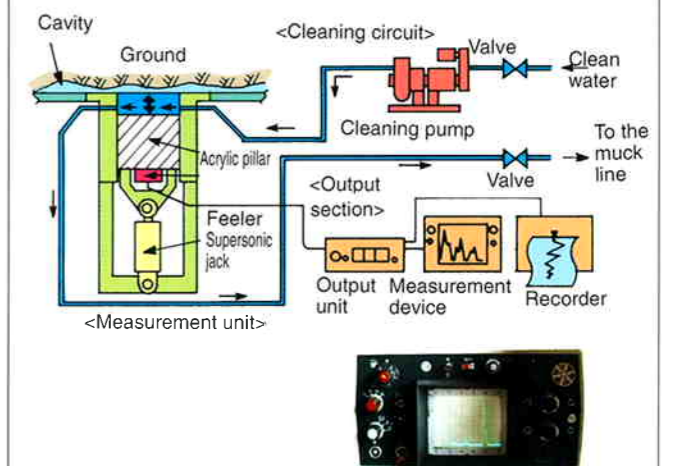
### Link Type Slit Shutter Device

When excavating is stopped, the cutter slits can be closed completely to prevent the cutting face from crumbling. In addition, the slit opening can be adjusted according to the ground condition.



### Excavation Face Monitoring System

Supersonic waves and electromagnetic waves are used to survey for cavities or obstacles around the shield machine.







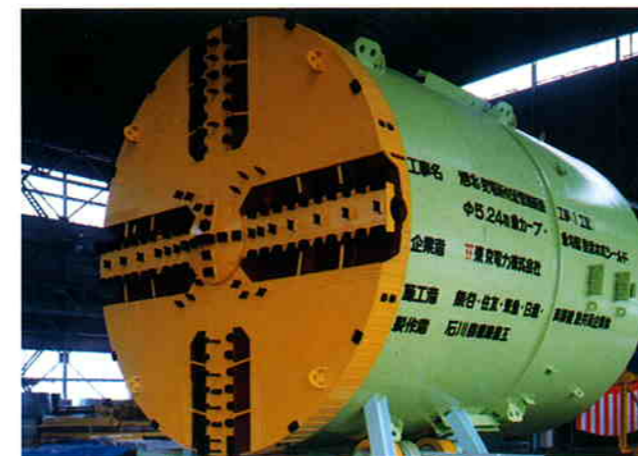
# Articulated Shield Machines for Sharply Curved and Inclined Applications



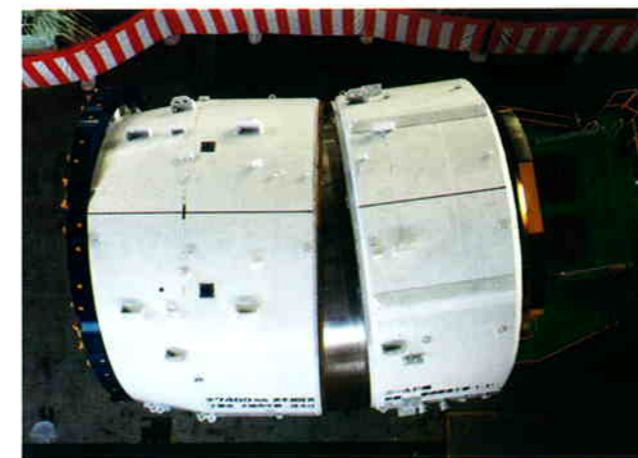
7.46 mφ cutter face eccentric shield



5.85 mφ cutter face eccentric type muddy soil pressure balanced shield machine



5.24 mφ articulated slurry shield machine for curved and inclined applications



## Sharp curves

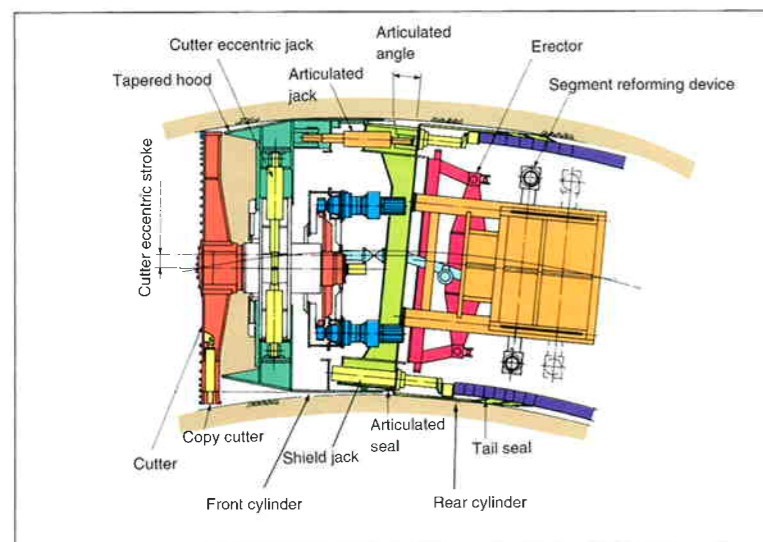


This photograph shows a 6.14 mφ tunnel with a curve radius of 20 meters which was constructed with an articulated shield machine.



## Step inclinations

This photograph shows a 5.24 mφ tunnel with an inclination of 15° which was constructed with a downhill grade shield.



## Cutter Face Eccentric Shield Machines

In recent years in urban areas with heavy flows of traffic, turning shafts cannot be used, so that there has been a rapidly growing demand for sharp curve construction in the small areas under roads. Together with Tokyo Electric Power Co., Inc. IHI has developed a cutter face eccentric shield machine which can cope with such sharp curves while minimizing the effect on segments.

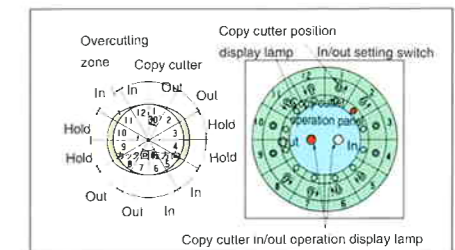
● **Mounting the rear cylinder of the shield jack**  
Because the relative positions of the segment and shield jack do not change even when articulated, the eccentric position of the shield jack pushing point and segment neutral axis remain constant.

● **Adoption of the cutter eccentric mechanism**  
By adopting a mechanism in which the cutter slides to the inside of the curve and a tapered hood, the volume of overcutting has been greatly reduced.

● **Utilizing the grounds resistance (sled effect)**  
Because the shield jack and the articulated jack have approximately the same propulsion, the articulated angle is securely locked. In addition, the ground resistance (sled effect) which is created on the front cylinder side when the rear cylinder is pushed can be used for the rotational inertia of the shield machine.

● **Articulated angles have been greatly increased**  
By mounting the sphere of the articulated seal side surface and the shield jack rear cylinder, the articulated angle is much greater than in conventional machines. In addition, the articulation can be set to any direction, so that attitude control performance is improved.

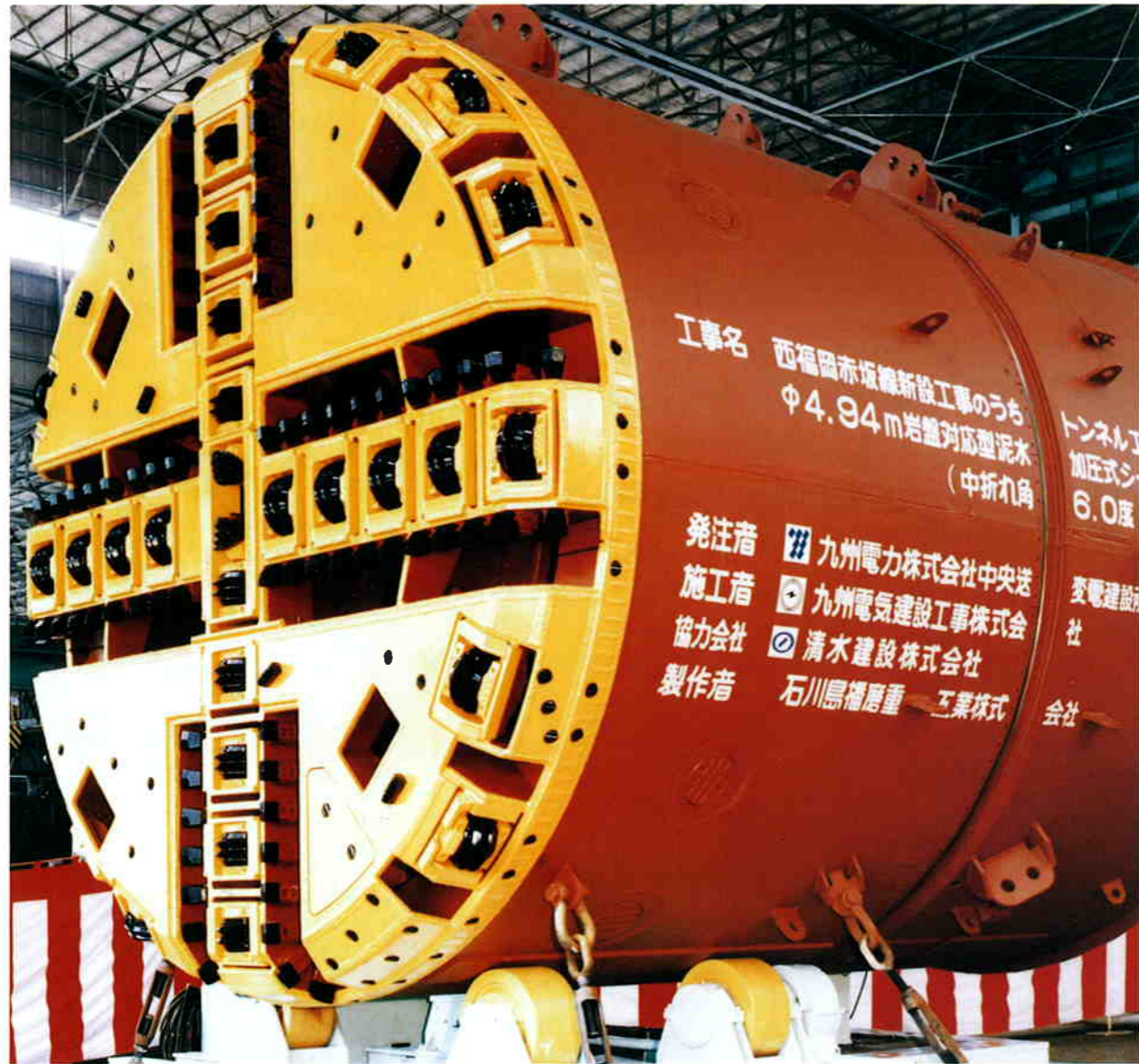
● **Copy cutter**  
Overcutting patterns can be set at 30 degree pitches regardless of the rotational direction of the cutter. In addition, the volume of overcutting can also be set.



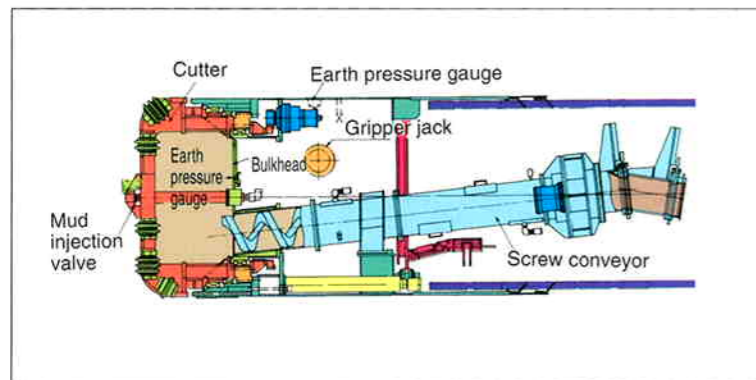




# Bedrock and Gravel Shield Machines



4.94 mφ slurry shield machine for bedrock



## Bedrock and Gravel Shield Machines

These are bedrock and gravel shield machine which utilize IHI's tunnel boring machine technology. Roller cutters and tooth bits can be replaced from inside the cutter chamber.

## Sharply curved and bedrock shield machines

This is a shield which can handle sharply curved and bedrock through a combination of IHI's tunnel boring machine technology and articulated shield machine technology. Roller cutters and tooth bits can be replaced from inside the cutter chamber.



2.13 mφ muddy soil pressure balanced shield machine for bedrock and gravel



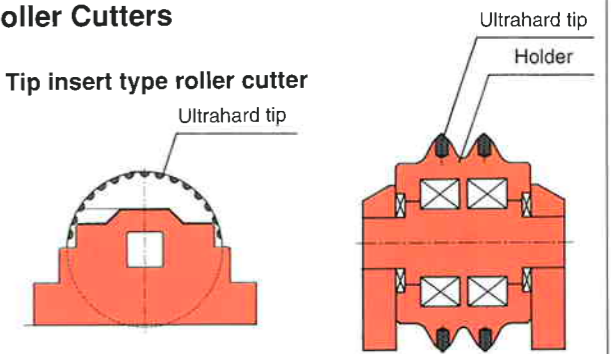
2.13 mφ muddy soil pressure balanced shield machine for bedrock and gravel



2.55 mφ slurry shield machine for bedrock and gravel

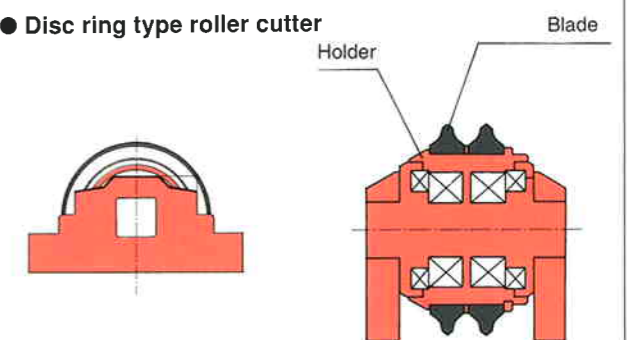
## Roller Cutters

### ● Tip insert type roller cutter



Ultrahard tips are used to increase their life. Because the tips and holder is a single piece, the entire holder is replaced.

### ● Disc ring type roller cutter



In order to make these more economical, the wheel and tempered steel blade are separated, so that only the blade can be replaced.



Face of bedrock cut with a roller cutter.

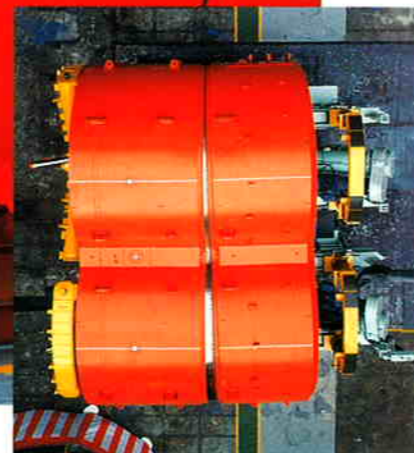




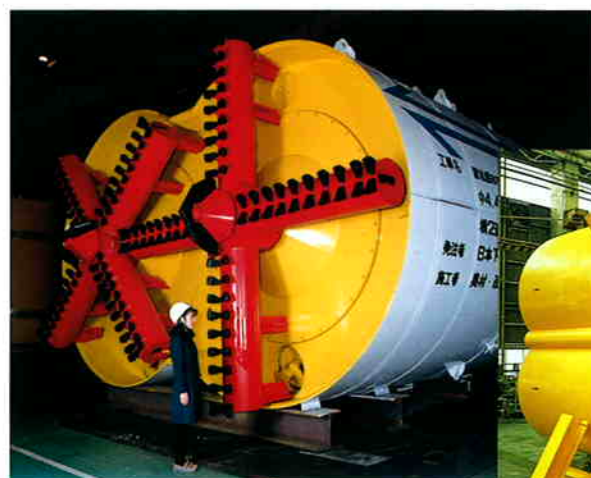
# Varied Form Shield Machines



6.09 mφ × 10.69 mW DOT shield machine



Shown with 1.5 degree articulation



4.45 mφ × 7.65 mW DOT shield machine



Vertical DOT shield

## DOT (Double-O Tube) Shield Machines

By using multiple spoke type cutters and synchronizing rotational control by aligning the cutters so that their spokes rotate with an interlocking movement with each other, the face can be cut on the same plane as with conventional circular cutting profile. The DOT Construction Association has been established for this construction method.



3.98 × 4.38 m DPLEX shield machine

## DPLEX Shield Machines (Developing Parallel Link Excavating Shield Machines)

By making the cutter frame move in a parallel link, rectangular, oval, horseshoe shaped and circular cutting profile can be excavated at will.

This construction method allows the construction of shield tunnels with rational cross sections for the effective use of underground areas.

Daiho Construction Co., Ltd. developed this construction method, and IHI was the first to manufacture a practical model.

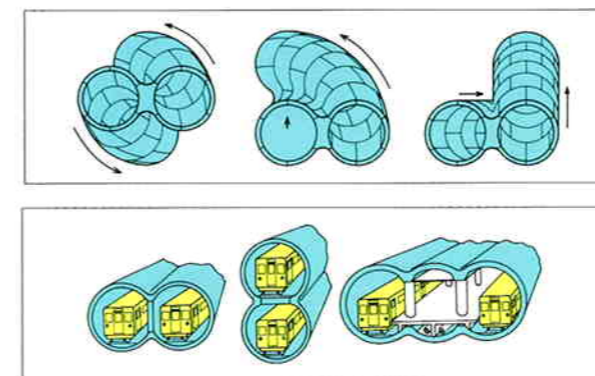
## Excavation Principles

Cutter bits are mounted in a cutter frame similar to the diagram below. This cutter frame is connected to a rotational drive shaft through a crank, so that the cutter has a circular movement while remaining parallel (parallel link movement).

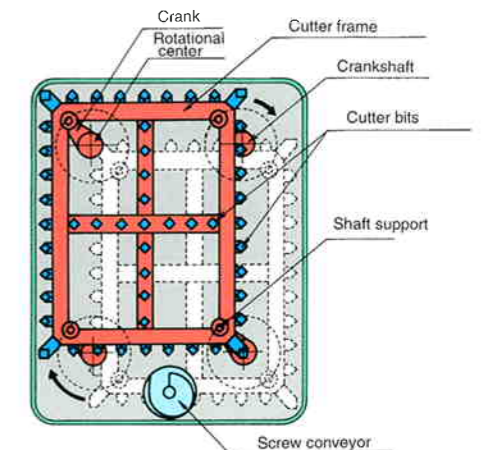
Therefore, by using a cutter frame which is approximately the same shape as the shield section, shield tunnels of any shape can be constructed.

## Multi-face Shield Machines

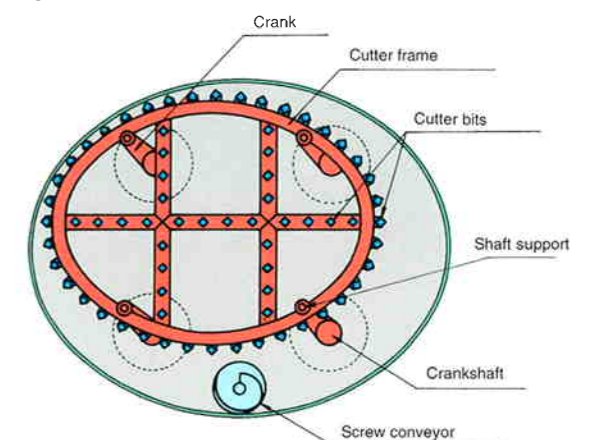
The Multi-face Shield Construction Method Association has been established for this construction method. Through different cutter combinations, multi-face shields can make tunnels such as those shown below.



## Example of a Rectangular Cross Section

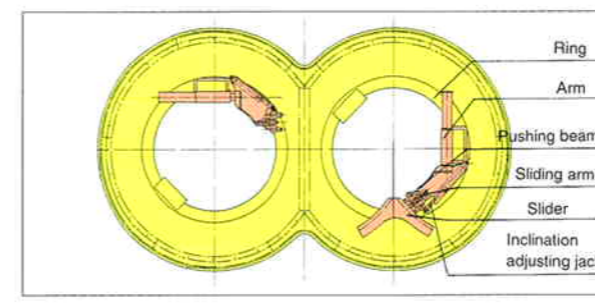


## Example of an Oval Cross Section



## Varied Form Single-arm Erector

When multiple shields are used, a single-arm erector is used to facilitate segment assembly.

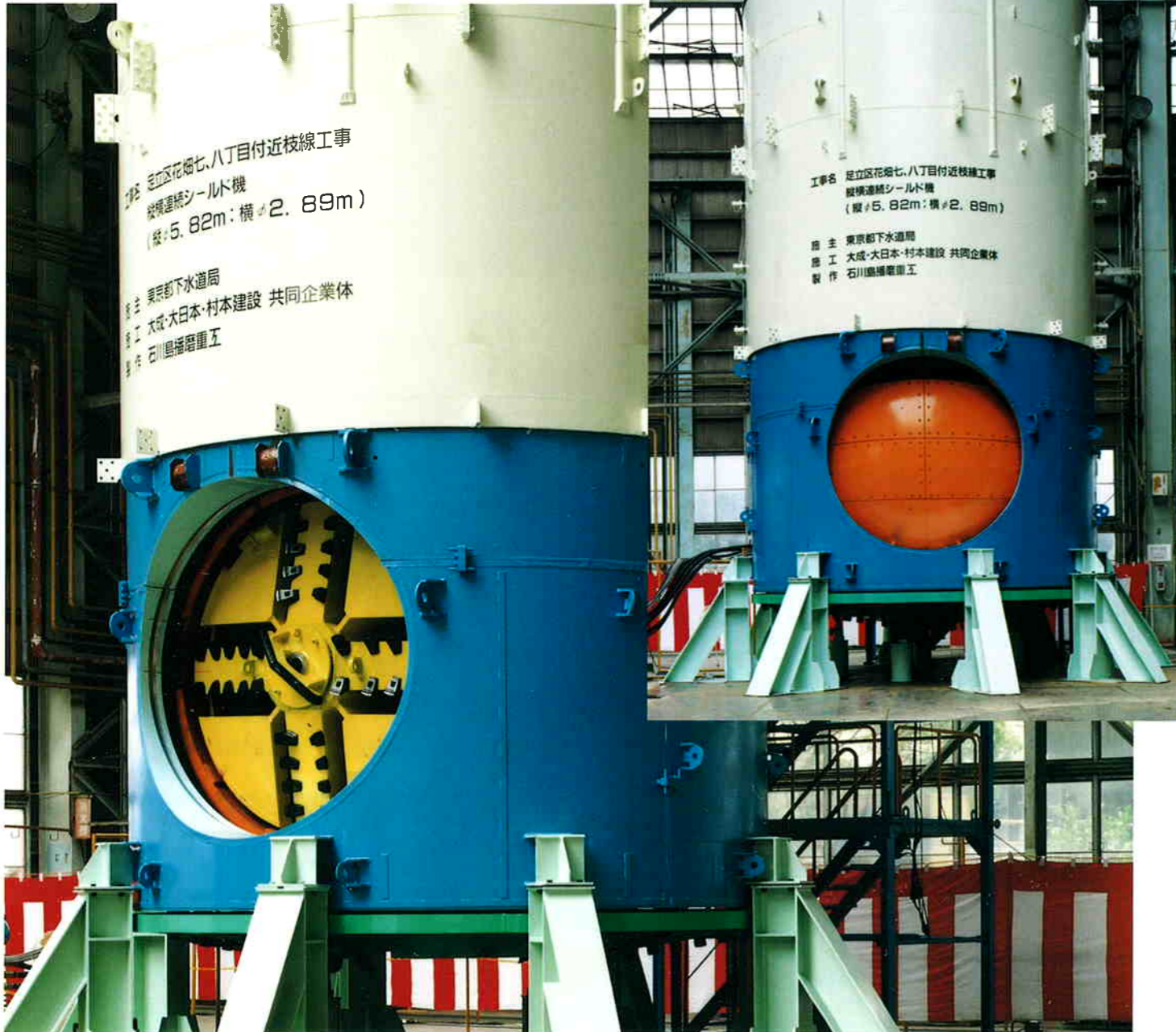






# Rotating Shield Machines

Rotating shield machines allow a single machine to excavate shaft and tunnel continuously from the surface. Applied techniques for rotating shield machines have made various types of next generation shield techniques possible. Inclination shafts can be excavated from an arbitrary diagonal angle and then change to horizontal excavation. In addition, these rotating shield machines have made turning shafts unnecessary, they allow speedy and safe bit replacement, and they also allow construction of shafts under high water pressure. The Association of Rotating Shield Method has been established for this construction method.



5.82 × 2.89 mφ vertical/horizontal continuous rotating shield machine

## Horn Method

### Vertical/Horizontal Continuous Rotating Shield Machines

These shield machines allow a single machine to continuously excavate a tunnel after excavating a shaft from the surface. Because these machines have shaft excavating functions, caissons and continuous diaphragm which were required in conventional methods are no longer needed, so that the land necessary for constructing shafts can be reduced. In addition, construction is simple, construction times are shorter, and expenses can be saved.



5.53 × 3.68 mφ right angle shield machine

## Horn Method

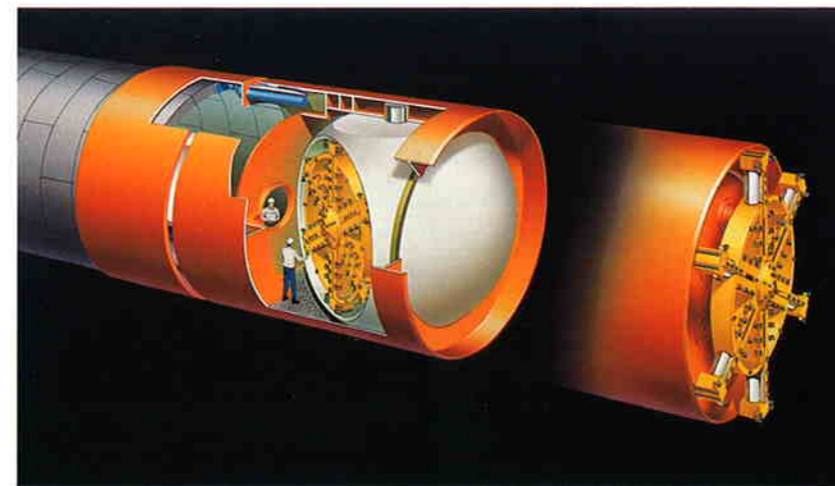
### Right-Angle Rotating Shield Machines

A single shield machine can be used to continuously excavate while turning at a right angle to a flat surface. These machines are especially effective at intersections where the traffic is heavy or where there are existing underground structures which make it impossible to use turning shafts.

## Kurun Method

### Long Distance Shield Machines

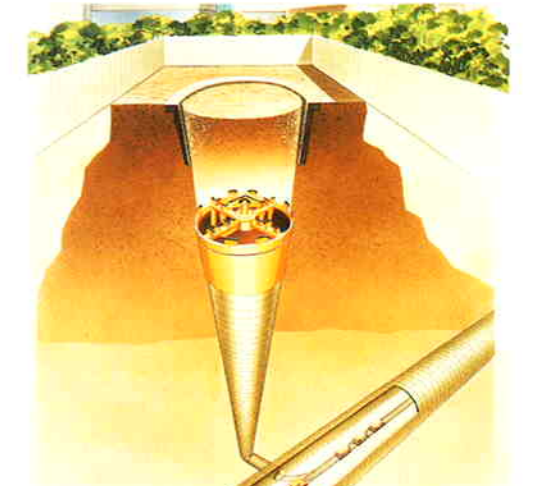
These machines are effective when excavating in the same direction for long distances. Bits can be replaced simply by rotating the cutter, so that conventional ground reforming construction is not necessary. This is a construction method which is very efficient and safe.



## Derun Method

### Ascending Shield Machines

These are shield machines which excavate upward from a tunnel. These machines are effective when land for construction cannot be purchased on the surface.



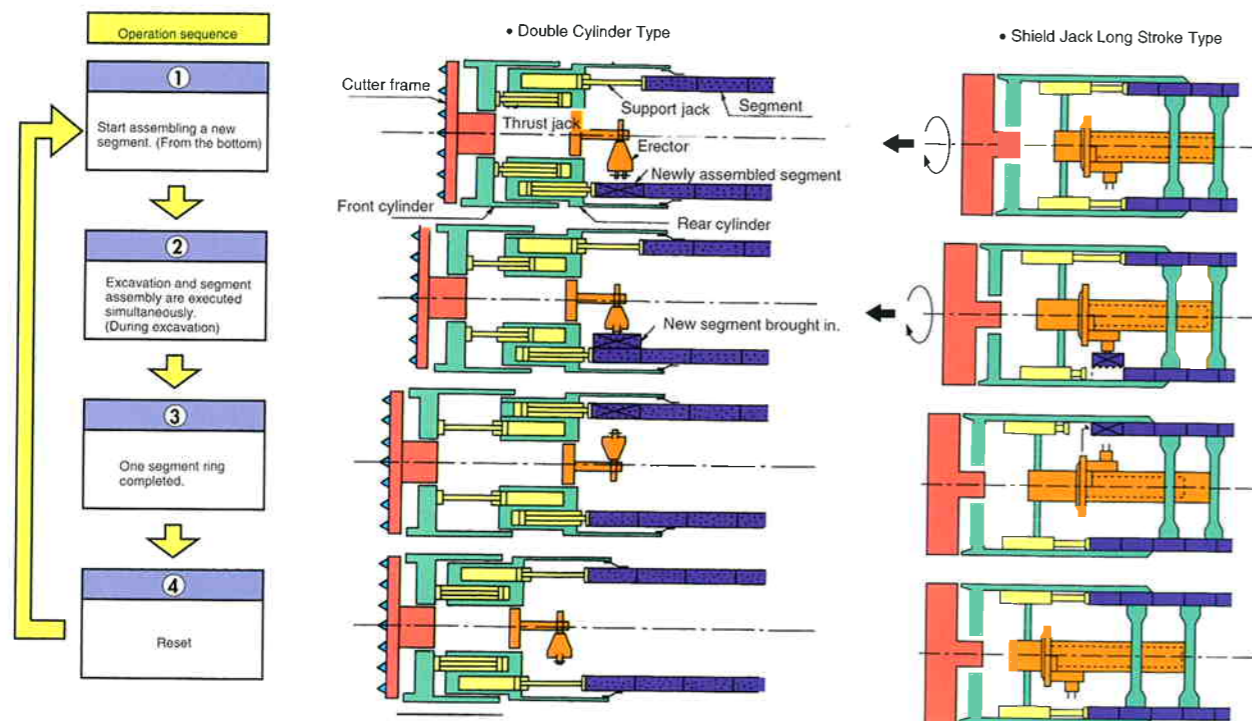




# Long Distance, High Speed Shield Machines

## Simultaneous Cutting and Segment Assembling Shield Machines

These shield machines are able to simultaneously assemble segments while excavating. This greatly reduces construction time.



## Long Distance, High Speed Shield Machine Element Tests



Slide seal performance test



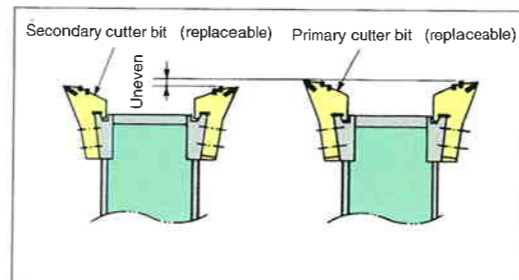
Cutter bit wear test

Slide seals are important elements of high speed shield machines. We conducted water impermeability and durability tests to develop a high performance slide seal.

Cutter bits are the most important element in long distance excavation. We conducted durability tests and developed cutter bits with durability which is superior to conventional cutter bits.

## Uneven Cutter Bit Arrangement

In order to cope with long distance excavation, we used an uneven cutter bit arrangement to increase the life of cutter bits.

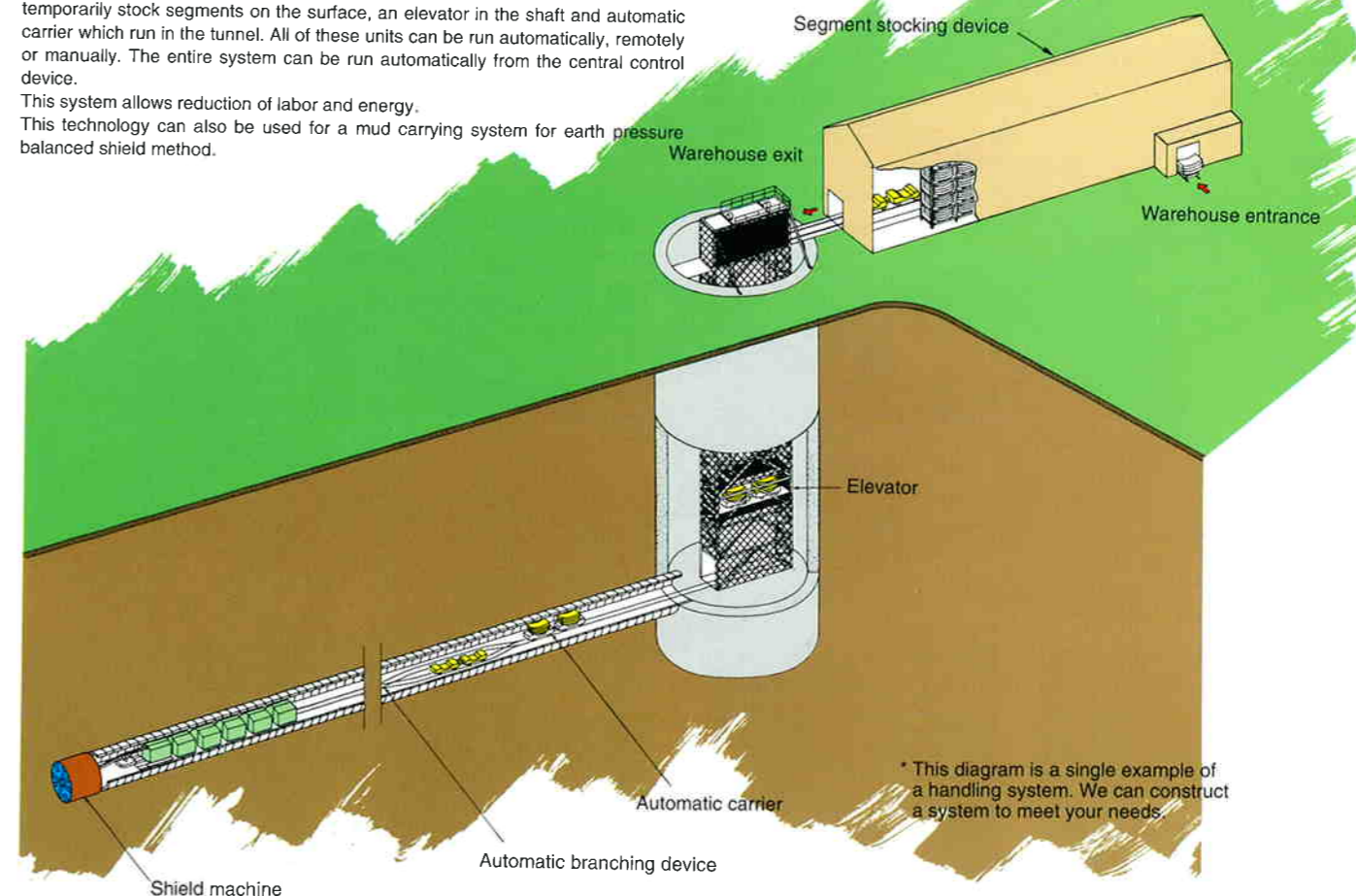


## Automatic Carrying System

IHI has applied its long experience in logistics technology to shield tunnel construction. This system is made up of a segment stock device which is used to temporarily stock segments on the surface, an elevator in the shaft and automatic carrier which run in the tunnel. All of these units can be run automatically, remotely or manually. The entire system can be run automatically from the central control device.

This system allows reduction of labor and energy.

This technology can also be used for a mud carrying system for earth pressure balanced shield method.



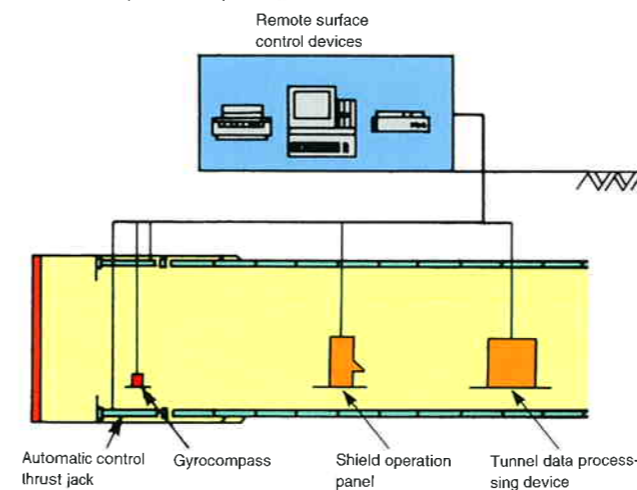
\* This diagram is a single example of a handling system. We can construct a system to meet your needs.

## Automatic Shield Steering System

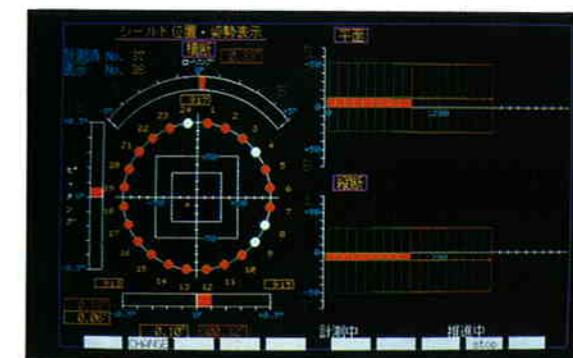
This system is made up of an automatic shield machine location measuring system and an automatic shield machine alignment control system. The automatic shield machine location measuring system uses a gyrocompass and a gravity acceleration meter to detect the attitude of the shield machine, then the position of the shield machine is calculated from the distance it has progressed.

The automatic shield machine alignment control system statistically processes the excavation conditions from the signals sent from the automatic machine location measuring system, and automatically controls the shield jack pattern and jack pressure.

This system can make automatic measurements without being limited by the narrow confines of shield construction shafts and sharp curves, so that shield excavation linearity can be improved.



Automatic Shield Steering System Overview



Automatic shield machine location measuring system



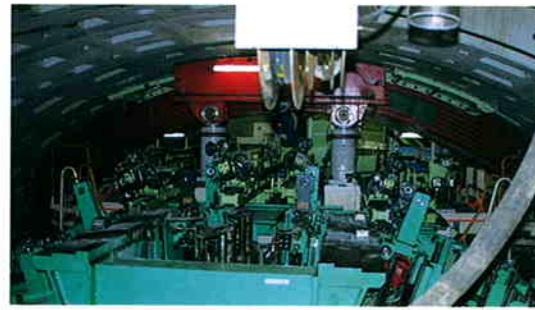
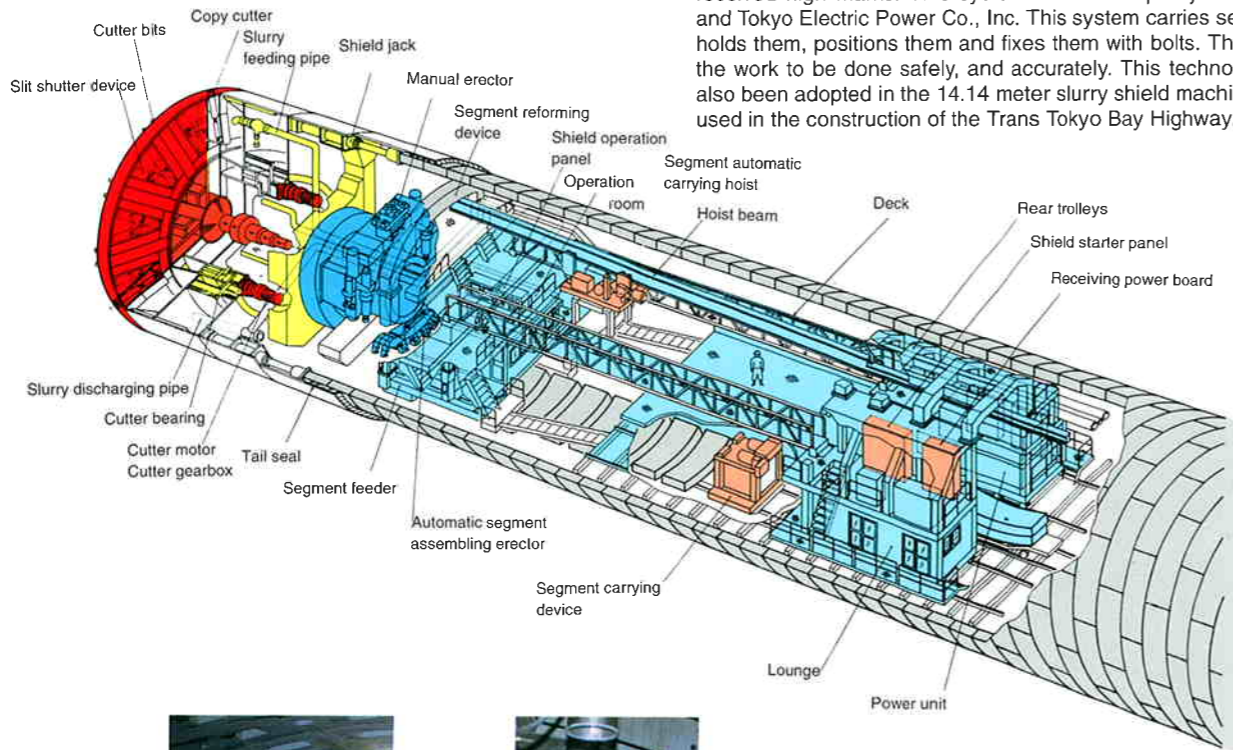
Automatic shield machine alignment control system





# Automatic Segment Assembling System

Automatic segment assembling erector are indispensable for the automation of shield construction. We installed the world's first system in the 7.75 meter slurry shield machine used in the construction of the Kanagawa utility tunnel being conducted by the Ministry of Construction. This system assembled the segments of a total length of 700 meters, including curves, and received high marks. This system was developed jointly by IHI and Tokyo Electric Power Co., Inc. This system carries segments, holds them, positions them and fixes them with bolts. This allows the work to be done safely, and accurately. This technology has also been adopted in the 14.14 meter slurry shield machine being used in the construction of the Trans Tokyo Bay Highway.



Structure of the automatic erector



The segment feeder seen from behind.



Segment carrying hoist



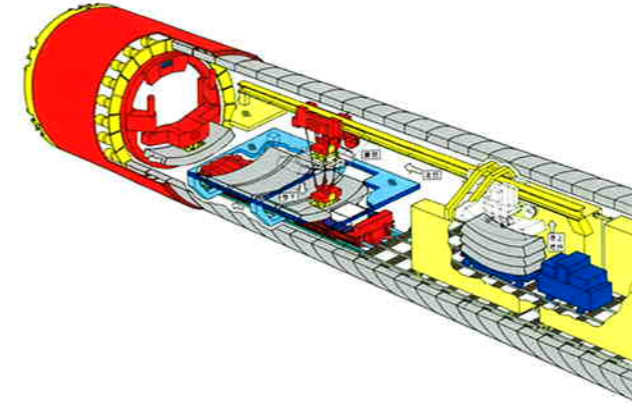
Segment carrying device

## Semi-automatic Segment Assembling System

We have automated segment carrying with hoists, segment feeding to erectors, and rough positioning of segments during assembly.

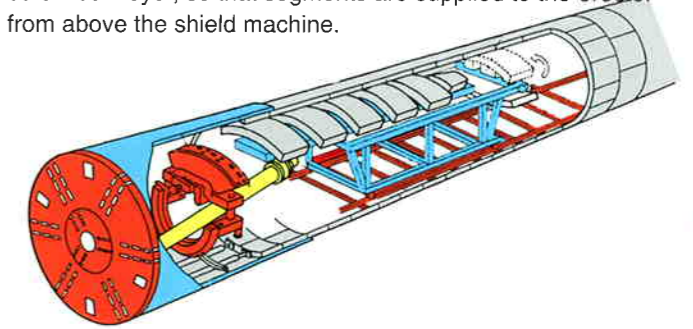
### Segment Under Feeding Method

In order to reduce the segment supplying cycle time to the erector, we created a system in which the segments for one ring are stocked on the segment feeder, and the segments are directly fed from the segment feeder to the erector. This system reduces segment carrying and assembling time.



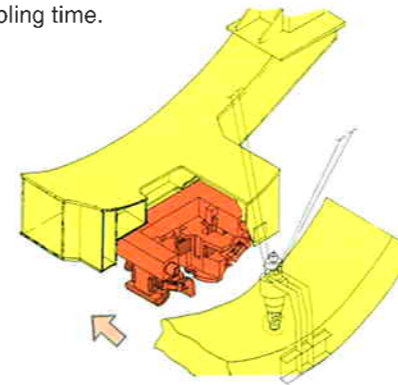
### Segment Upper Feeding Method

In shield machines in which screw conveyors occupy the center of the machine, such as earth pressure balanced shield machines, the segment feeder is located above the screw conveyor, so that segments are supplied to the erector from above the shield machine.



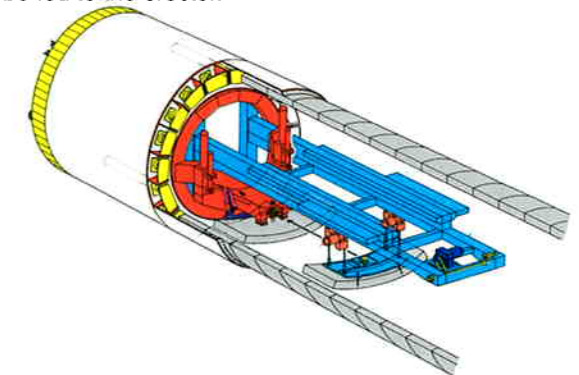
### Single Hoist Type Segment Feeding Method

Because a hoist feeds the segment to the erector in the air, there is no need for the erector to clear the area first as in conventional methods. This system reduces segment assembling time.



### Double Hoist Type Segment Feeding Method

In shield machines in which screw conveyors occupy the center of the machine, such as earth pressure balanced shield machines, using two hoists in parallel allows segments to be fed to the erector.







# Particular Type Shield Machines

## Underground junction technology



### Concentric Interlace Docking Type (CID method)

The cutter section of the docking shield machine is such that it docks deep in the skin plate. The inserting shield machine enters the docking shield machine and a fixing agent is injected into the hood wrap section to dock the shield machines underground. This method was developed jointly by Chubu Electric Power Co., Inc. and IHI.

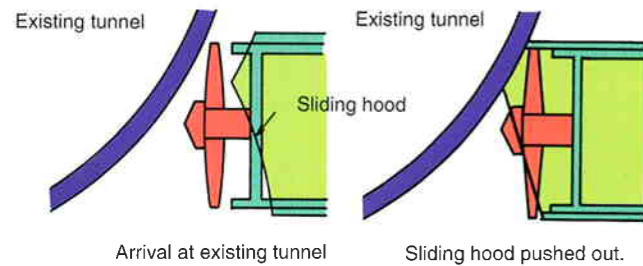


### Sliding Hood Method

When a shield machine arrives at an existing tunnel or other structure, the slide hood is pushed out and the shield machine is docked underground with the structure. This method was developed jointly by Tokyo Electric Power Co., Ltd., Kajima Corporation and IHI.

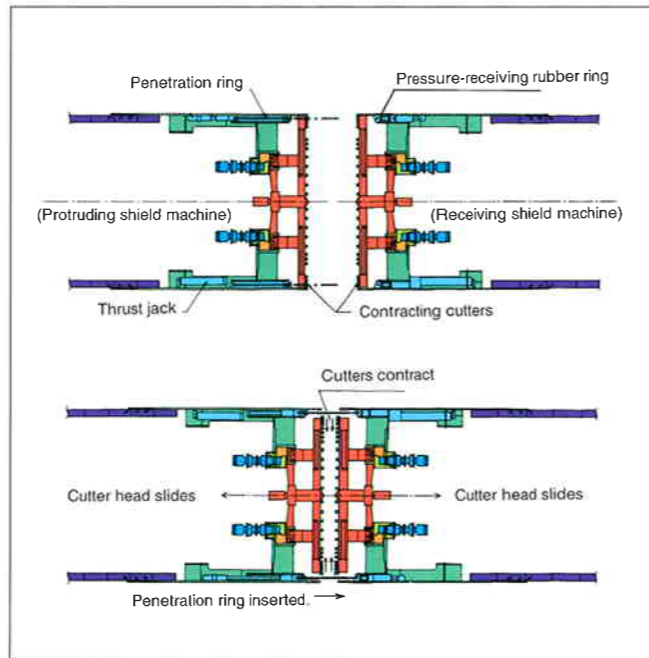


3.08 mφ muddy soil pressure balanced shield machine



### MSD Method

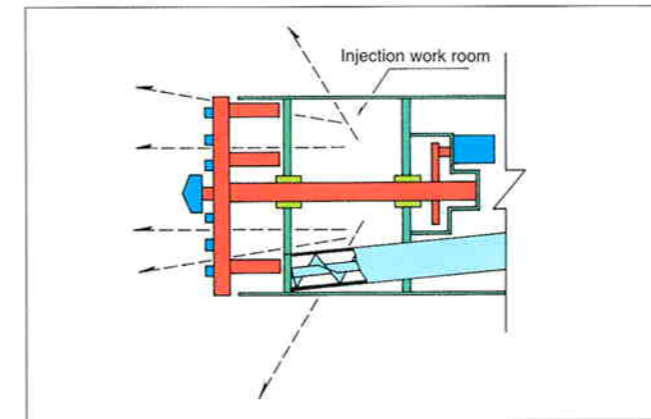
A steel penetration ring on the protruding side is accepted in a pressure-receiving rubber ring to dock the machines. The MSD Method Association has been established for this construction method.



## Full Face Grouting Shield Machines

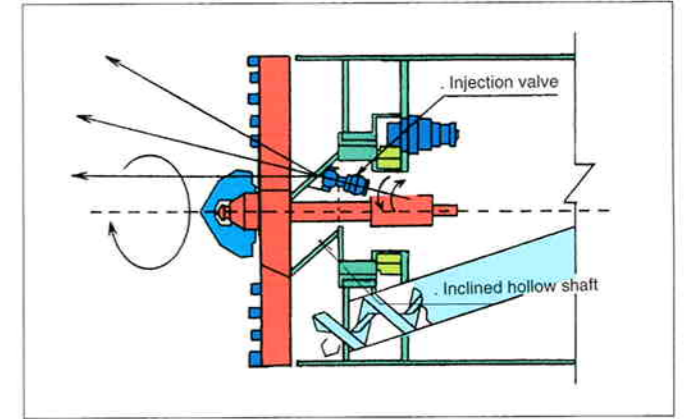
### Double Bulkhead Type

An injection work room is located between the front shield bulkhead and cutter drive. Injection holes in the bulkhead and skin plate are used to reform the ground of the cross section.



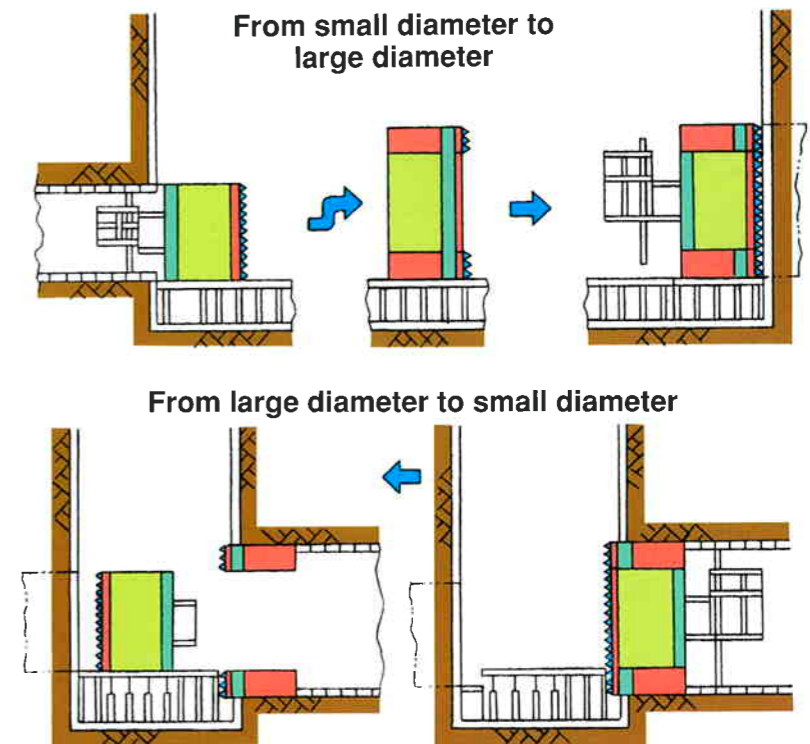
### Inclined Hollow Shaft Type

The cutter support method used is the inclined hollow shaft method. This allows grouting to be injected to the cutting face of the cross section. Compared with conventional full face chemical grouting, this method allows injection of grouting from inside the shield machine, and agitation effects in the cutter chamber are better.



## Detachable Shield Machines

These are small diameter shield machines which allow large diameter excavating units to be attached. This allows one machine to excavate both large and small tunnels.





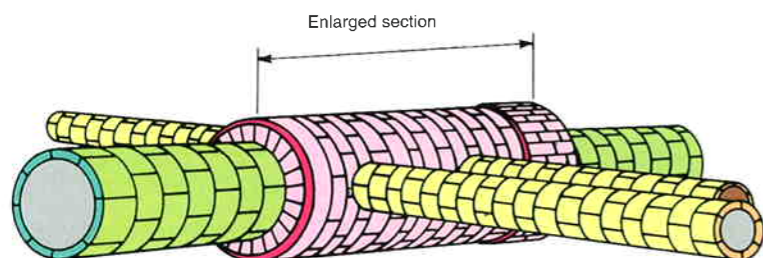
## ECL Shield machines

This construction method was developed by Sato Kogyo Co., Ltd. to rationalize construction, make construction more economical, prevent land sinkage, and to improve the impermeability of tunnels. IHI was the first company to manufacture a production unit. The SECL method is propelled by a two stage jack system which uses the press resistance of concrete and the press resistance from the inside frame of the concrete. The tunnel covering is formed by applying pressure to the unhardened concrete in the steel reinforced concrete construction, and this pressure is also used to propel the shield.



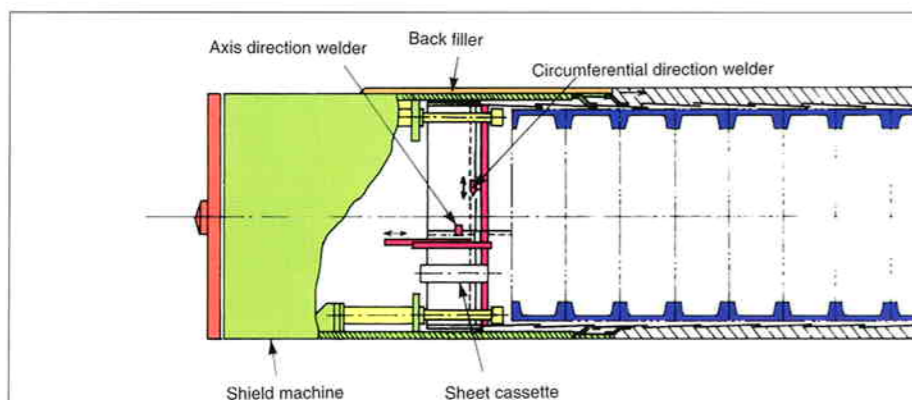
## Enlargement Shield

In the enlargement shield method, the outside of an existing shield tunnel is excavated in the shape of a ring to expand the shield. This method is advantageous in that it does not affect the surrounding environment and an enlargement area can be constructed from inside the tunnel. The Association of Enlargement Shield Tunneling Method was established for this method.



## Pipe Wrapping Shields

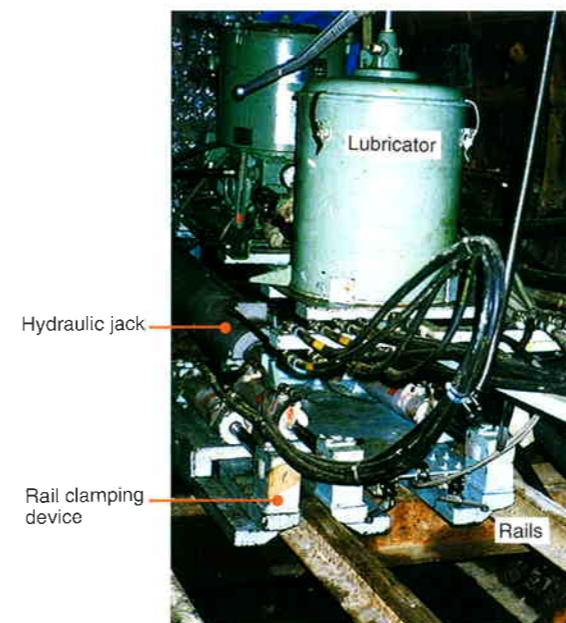
In the pipe wrapping shield method, a durable and impermeable film is applied to the outside of the segments. This prevents leaking of underground water into the joints. This method was jointly developed by the Okumura Corporation, Toa Grout Kogyo Co., Mitsui Toatsu Chemicals, Inc., Okumura Machinery Corporation and IHI under the direction of the Japan Sewage Agency.



## Elements

### Self Propelling Device for Trolley Cars

When the trolley cars cannot be pulled by the shield machine, clamping them to rails will allow them to be self-propelled.



### High Water Pressure Cutter Seal

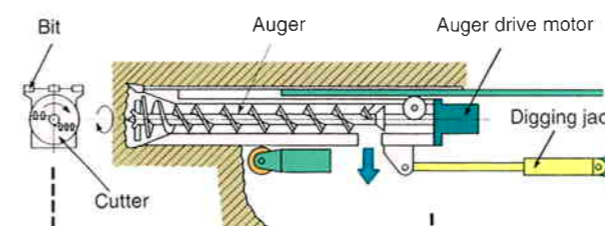


Cutter seals are the most important element of mechanical shield machines. We conducted full scale water impermeability and durability tests to develop a high water pressure cutter seal. This seal is used in many shield machines and has received high marks.

Cutter seal performance test

### Cutting Movable Hood

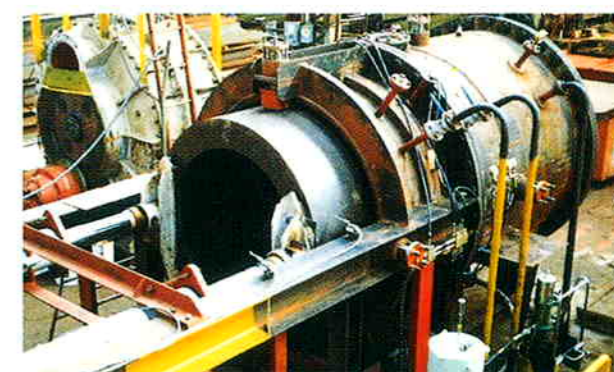
An auger is used to bore into the cutting face, then a movable hood is inserted. This allows deep penetration without hurting the cutting face, and the roof is maintained.



Cutter movable hood penetration

### High Water Pressure Tail Seal

The high water pressure tail seal and special tail sealer we jointly developed with Tokyo Electric Power Co., Inc. is highly impermeable and can cope with high water pressures.



Tail seal performance test



# We Will Meet Your Expectations With Our Thorough Quality Control Organization

## Shop Manufacturing

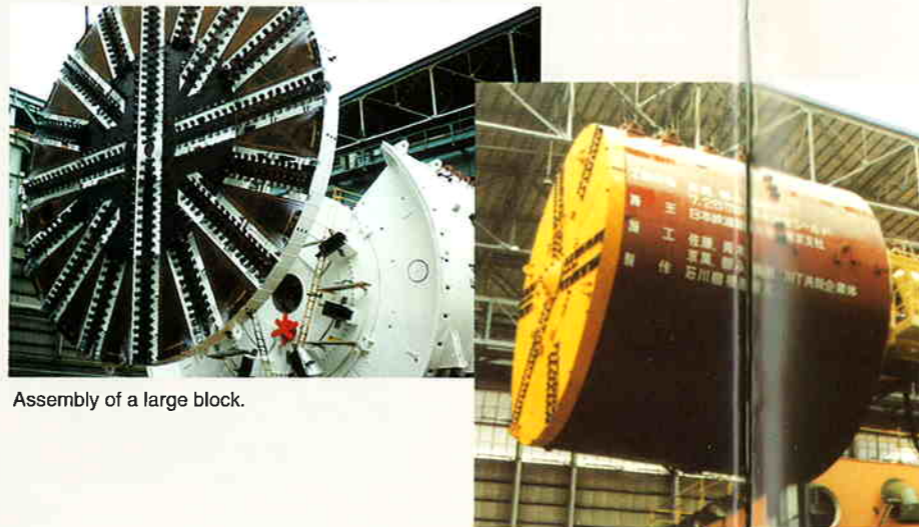
### ● Aichi Works ●

- The Aichi Works has a Goliath crane which can lift a maximum block of 800 tons.
- This factory has the facilities and manufacturing technology to make the largest shield machines.



### Goliath Crane

(Capable of lifting 800 ton blocks.)



Assembly of a large block.

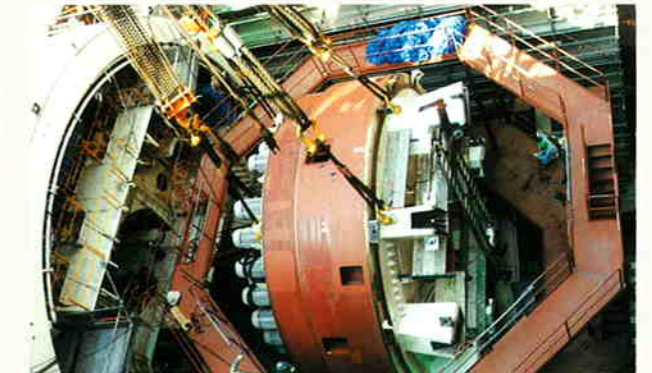
7.25 m $\phi$  slurry shield machine being lifted.



Rotating shield machine assembly

## On-site Assembly

- Skilled engineers will provide the same assembly as that in the factories.
- Skilled engineers do thorough preparatory engineering to safely and securely conduct the construction.



## After-sales Service

- Skilled engineers are assigned to our service centers, so that they can provide timely answers.

## ISO 9001 Certified

- We have established a quality system which has received the ISO 9001 certification.

### ● Nagoya Works ●

- The Nagoya Works also manufactures hydraulic pumps and motors. It is capable of manufacturing products which require high precision.
- A complete quality control organization is in place.

