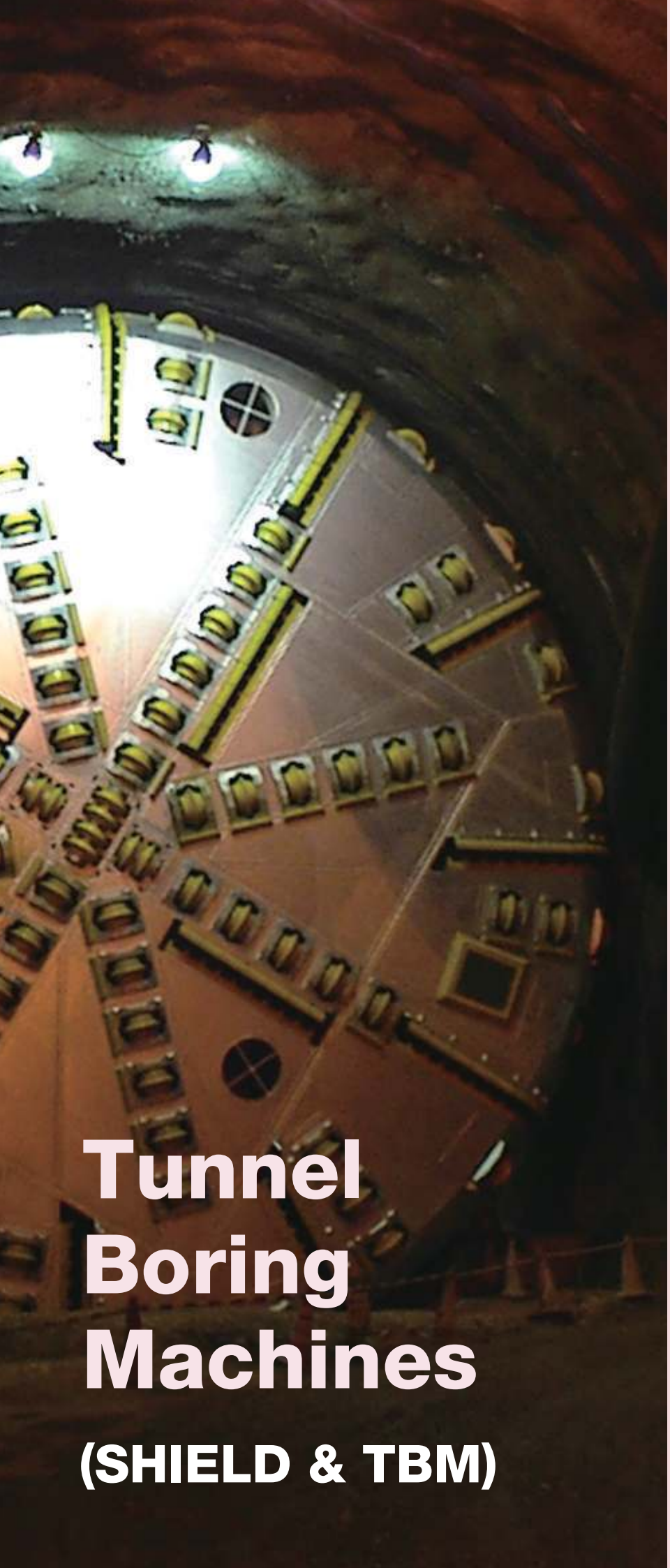


# Tunnel Boring Machines

## (SHIELD & TBM)

Kawasaki

- Slurry Shield Machine
- Earth Pressure Balanced Shield Machine
- Mixed Ground Shield Machine
- Full Shield TBM
- Open Gripper TBM & New Open TBM
- Aporo Cutter
- H & V Shield Machine
- Dual-Mount Branching H & V Shield Machine
- Detachable Three-Section Shield Machine
- Lateral Lead Three-Section Shield Machine
- Branch Route Shield Machine
- MSD Shield Machine
- DPLEX Shield Machine
- Draw Shield Machines Allow Recycling
- MMST Shield Machine

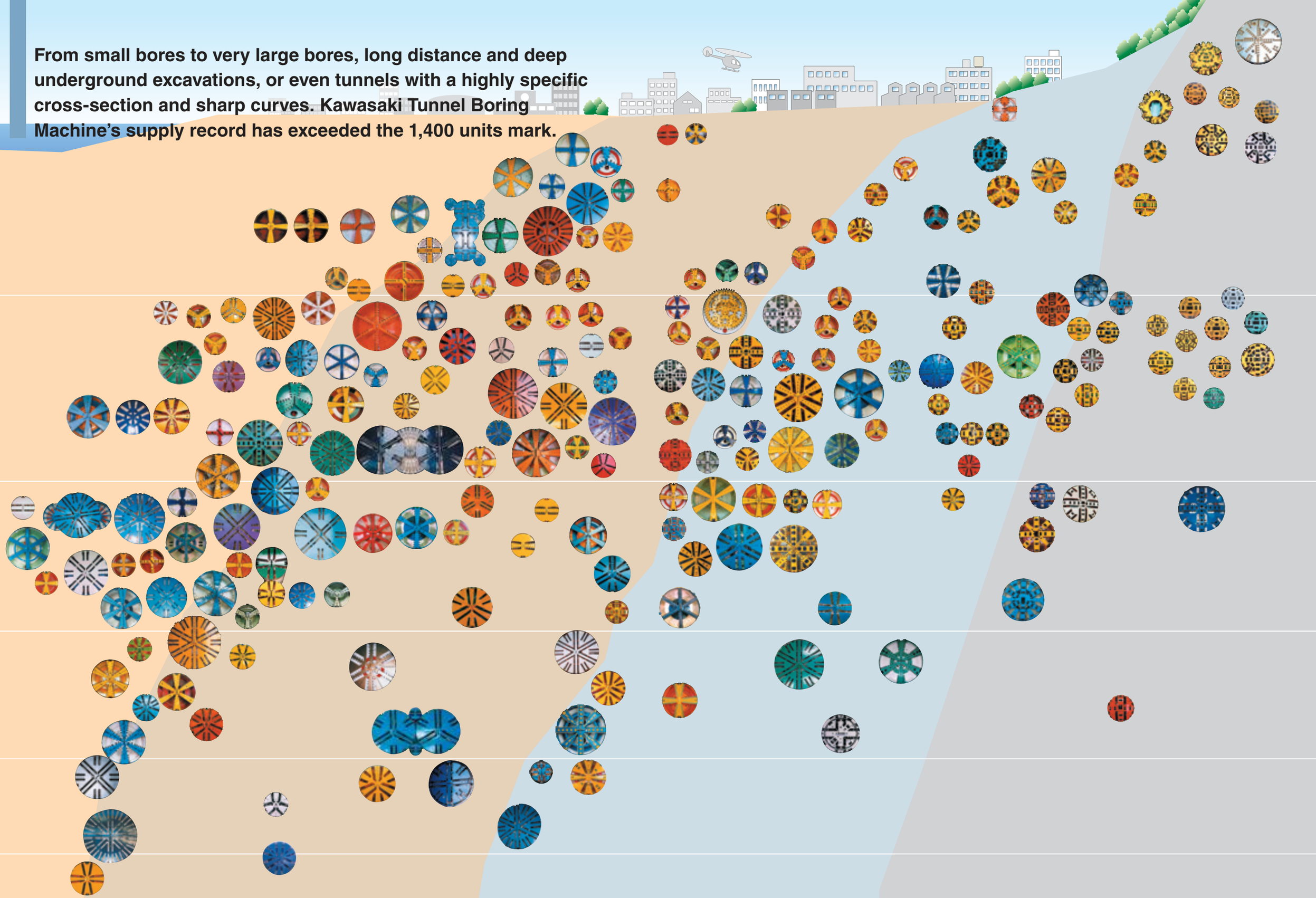
Bringing vision into reality.
Today the technology to realize those dream exists.
Building on our experience.
Applied technologies to make tomorrow's dreams come true....today.

- that bring visions into being.

TBM cutter head monument
Artists: Takeyoshi Inoue, Olivier Debre

Contents

**From small bores to very large bores, long distance and deep underground excavations, or even tunnels with a highly specific cross-section and sharp curves. Kawasaki Tunnel Boring Machine's supply record has exceeded the 1,400 units mark.**



Silt & Clay | Sand | Gravel | Rock

# Slurry Shield Machine

## Stabilized cutting face

By using slurry with a high specific gravity and high viscosity to pressure-control the cutting face, stability is obtained even under high water pressure.

## Super-large diameter tunneling

Kawasaki's self designed periphery and support structure endows wider cutter chamber which enables to develop an extensive range of slurry shield bores, from small to super large, even exceeding 14m diameter.

$\phi$14.14m slurry shield machines (used for Tokyo Bay Aqua-Line Highway)

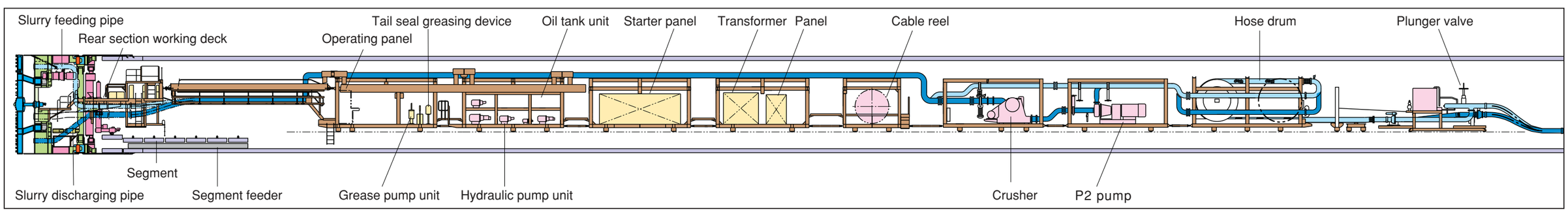
$\phi$13.05m slurry shield machine（Cutter bits exchange device*）

$\phi$11.56m slurry shield machine

$\phi$10.0m slurry shield machine

$\phi$8.99m slurry shield machine
（Cutter bits exchange device*, For 30 m radius curvat）

## ■Slurry shield machine layout




*Cutter bits exchange device

# Earth Pressure Balanced Shield Machine

## Stabilized cutting face

The cutting chamber filled with cutting muck is infused with a suitable additive agent to stabilize the cutting face. Kawasaki continues to improve additives for highly permeable soils. In doing so Kawasaki has developed ever-larger earth pressure balanced shield machines with greater speed and power.

## Ongoing evolution

Kawasaki has developed dual-mode earth pressure shield machines by augmenting mechanisms that efficiently excavate and remove hard soil. Such superior functions have enabled Kawasaki to achieve high-speed tunneling of 600 m or more per month with machines designed for digging subway tunnels.

$\phi$8.17m/$\phi$6.78m earth pressure balanced branching shield machine

$\phi$5.44m earth pressure balanced shield machine

$\phi$10.2m earth pressure balanced shield machine

$\phi$5.33m earth pressure balanced shield machine

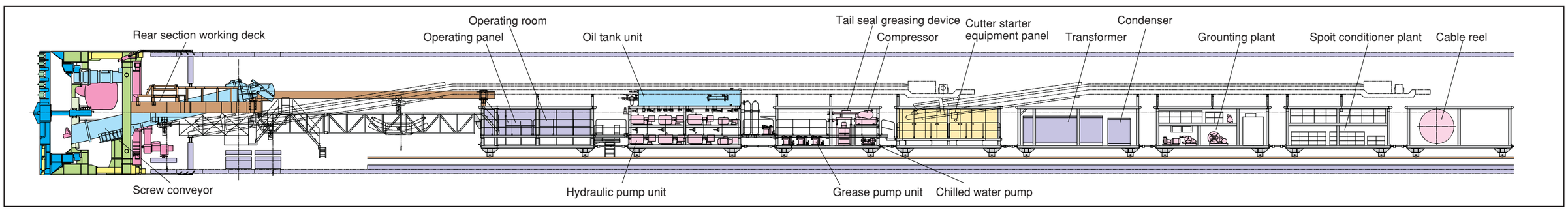
$\phi$6.34m earth pressure balanced shield machine

$\phi$6.34m earth pressure balanced shield machine

$\phi$3.93m earth pressure balanced shield machine

$\phi$2.88m earth pressure balanced shield machine
(Excavated 10 mR sharp curvature)

## ■Earth pressure balanced shield machine layout



# Mixed Ground Shield Machine

## Cutter disk shapes for different types of ground

Either flat or dome-shaped cutter can be selected according to the characteristics of soil such as density, size and strength of gravels, boulders and rocks.

## Selection of cutter disk

There are two types of cutter disk. One is a disk-front-crushing-type (mainly used for Slurry Shield Machines) which crushes boulders by front disk and then carries them into the cutter chamber. And the other is a non-disk-front-crushing-type (mainly used for Earth Pressure Balanced Shield Machines) which carries largest possible boulders into the cutter chamber without crushing them.

## Selection of disk roller cutter

To excavate bedrock strata (Photo A), we use Kawasaki's disk roller cutter which we have developed for TBM and be well proven its performance by a lot of achievements. To excavate gravel and boulder strata (Photo B), we use super-hard-carbide-tip inserted disk roller cutter, which prolongs the life of disk. Both types of disk roller cutter can be easily replaced from the inside of cutter chamber.

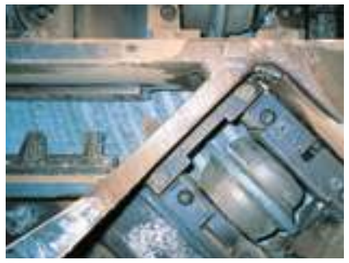
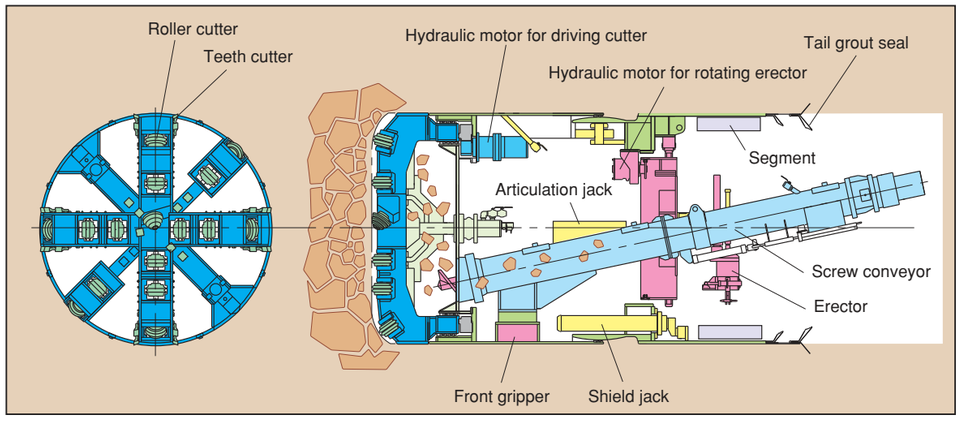


Photo A　Bedrock stratum (granite with compressive strength of 120 MPa)

Photo B　Boulder stratum (density 90%)

$\phi$6.70m earth pressure balanced shield machine

## ■Mixed ground shield machine layout




$\phi$7.93m earth pressure balanced shield machine

$\phi$6.63m slurry shield machine

$\phi$2.63m earth pressure balanced shield machine

$\phi$2.47m slurry shield machine for bedrock

$\phi$3.09m earth pressure balanced shield machine for bedrock

$\phi$3.38m earth pressure balanced shield machine

# Full Shield TBM

## Suitable for broad range of ground conditions

Because of a cylindrical shell structure, the Full Shield TBMs can be suitable for broad range of ground conditions, from tough rocks to soft strata including fracture zones.

## Large internal space

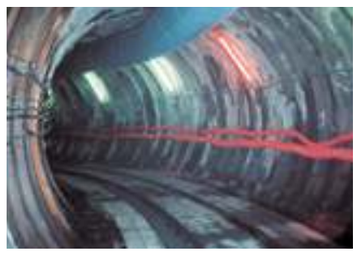
The cylindrical shell structure secures large space of the internal center of TBM, which enables safety maintenance and efficient operation.

## Variety of discharge systems

The best discharge system can be selected from variety of discharge systems, such as belt conveyor, screw conveyor, slurry discharge and jet pump transportation according to diverse ground conditions.

$\phi$5m full shield TBM(30 mR, belt conveyer discharge system)

30 mR, articulate 6°



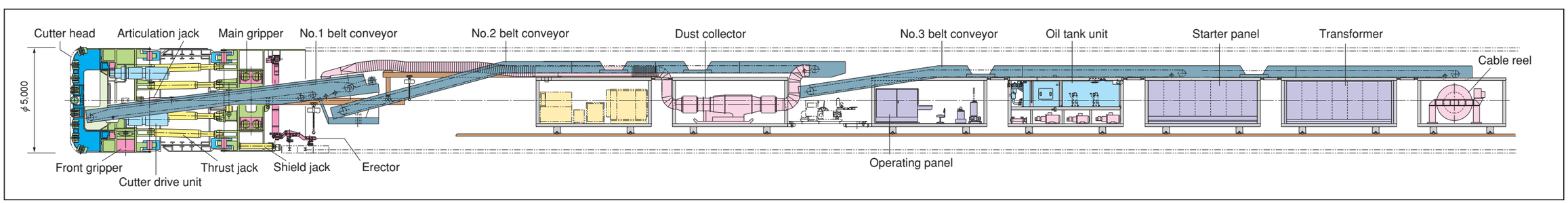
30 mR excavation

Break through

$\phi$4.55m full shield TBM compatible belt conveyor discharge with screw conveyor system.
(screw conveyor/belt conveyor discharge system)


$\phi$2.8m full shield TBM(belt conveyor discharge system)

## ■Full shield TBM layout



# Open Gripper TBM & New Open TBM

## Simple structure

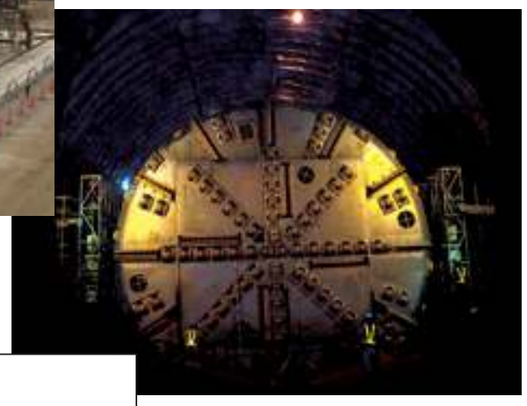
The Open TBM is comprised of cutter head, cutter head drive, main beam, gripper and roof support. This simple structure enables workers to treat cutting face at adjacent point to cutter head.

## Extremely powerful in stable ground conditions

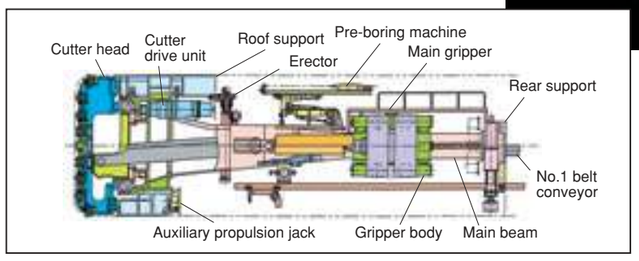
Open TBM shows high performance and economical excavation in solid bedrock conditions. It is suitable for straight excavation as digging direction is regulated by beam structure.

## The advantages of combination of Full Shield TBM and Open TBM

Kawasaki's new Improved Open TBMs have two different strengths from both Full Shield TBMs and Open TBMs. One element comes from Full Shield TBMs which are suited for various ground conditions and another feature comes from Open TBMs which are suited for high-speed operation in solid bedrock conditions. This new Improved Open TBMs can treat looseness from and falling of fragile soil, simultaneously it can enables workers to treat cutting face at adjacent point to cutter head.



## ■Open Gripper TBM layout

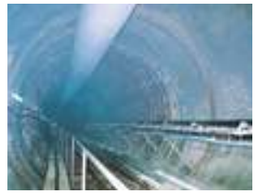



$\phi$6.82m open gripper TBM

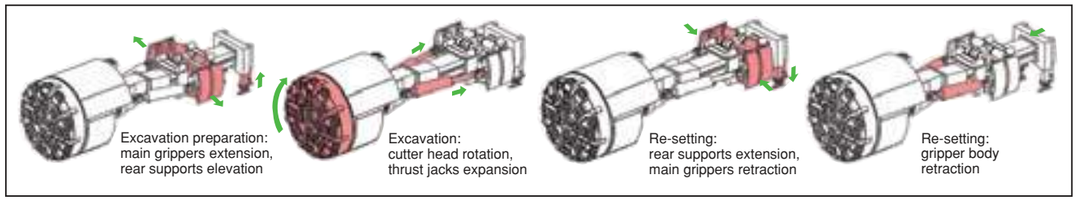
Cutting face

Without supports

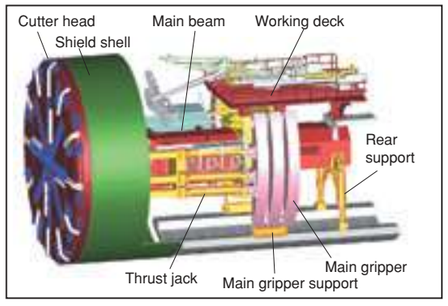
Ring beam supports



Lining supports

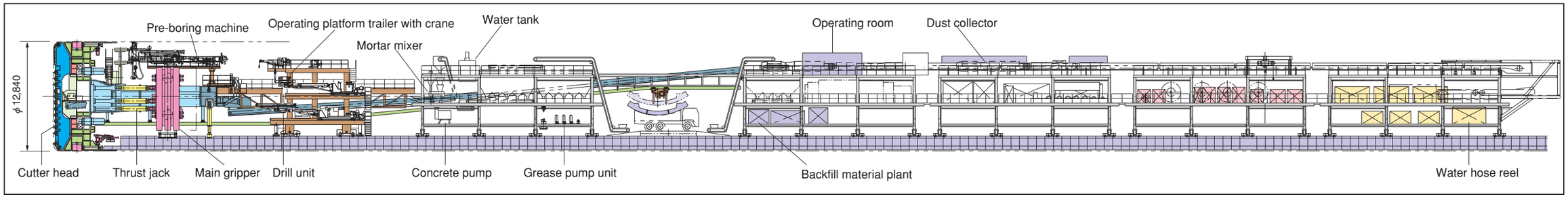



$\phi$12.84m new open TBM




$\phi$12.84m new open TBM structure

## ■New open TBM layout



# Special Shield Machine

## Customized special shield machines for diverse conditions

Kawasaki provides fully customized special combination of shield machines to satisfy customer's various needs for bore size, geological feature, particular ground condition, etc.

## Aporo Cutter

### APORO:All Potential Rotary Cutter

The machine can excavate not only circular shaped sections, but rectangular shaped, horse-shoe shaped, and another non-circular shaped sections. Cutting head has high-precision control system, which can keep planned excavated section.

### ■Features

①Rectangular, horse- shoe shape, and another non-circular shaped can be selected as excavated section.
②It can also cut sound-hard ground and obstacles.
③Cutting head can be reused by remounting to another shaped shield bodies.

4.76m×4.42m earth pressure balanced rectangular shield machine

7.44m×10.64m earth pressure balanced rectangular shield machine

### ■Variation of Aporo Cutter excavation section (example)


## H&V (Horizontal & Vertical) Shield Machine

In the past, the excavation of subway station sections were accomplished using cut-and-cover tunneling methods or by expanding existing tunnels. However, because of the impact on above-ground activities and the large numbers of critical subterranean structures under congested urban areas, four-face H&V shield machine is deployed to excavate simultaneously the subway car tunnel and station platform area.

### ■Features

①The world's first shield machine equipped with a parallel articulating mechanism (H&V mechanism). It enables the excavation of wide tunnels with uniquely shaped sections, which makes high-precision positioning control possible.
②It equips four cutters on the same surface.

7.06m×13.18m H&V slurry shield machine

## Dual-Mount Branching H&V (horizontal & vertical) Shield Machine

This machine enables excavation of two proximate parallel independent tunnels in the same direction. These tunnels will take apart to the different direction in the middle of tunneling. Each shield continues to excavate as a separate, independent machine after their divergence.

### ■Features

①After tunneling by tandem ream position, upper and lower shield machines excavate independently to different directions subsequently to the divergence in underground.
②When used for tandem tunneling, the articulation angles of the upper and lower shields are calculated by a relative midsection difference to control the roll position.
③These machines perform excavation of sharp curve with a minimum radius of 15m (articulation angle: max.13 ° for both left and right direction) in both positions of tandem ream and independent.

φ3.29m ／φ2.89m dual-mount branching H&V shield machine

## Detachable Three-Section Shield Machine

Previously two simple circular shield machines and one three-section shield machine was required, but nowadays, Kawasaki' s technology enables to excavate both station part and station-to-station tunneling with single shield machine which consists of one circular shield and twin semicircular side shields that are designed to be easily mounted and detached.

The detachable three-section method makes it possible to reduce the size of the shield machine and rear compartment equipment, as well as to centralize the operating base.

### ■Features

①The tunnel between stations is excavated using a simple circular shield.
②After reaching the station drive shaft, semicircular side shields are attached to both sides of the simple circular shield, and the station platform section tunnel is excavated.
③After reaching the station arrival shaft, the semicircular side shield are detached, and the section to the next station is excavated using the unit as a simple circular shield once again.

φ10.04m×15.84m three-section shield machine (with side shields attached)

φ10.04m single shield machine (without side shields)

## Lateral Lead Three-Section Shield Machine

Equipped with advanced rotating cutter heads on each side, an oscillating ("wagging") cutter head ensures space between the machines in the center section and independent rotating cutter heads in the center to achieve even greater excavating efficiency than Kawasaki's detachable three-section shield machine. The slurry removal systems are combined into a single system.

ϕ7.44m×16.44 slurry three-section shield machine

## Draw Shield Machines Allow Recycling

### DSR (Draw a Shield for Recycle system)

The shield's external casing and internal unit are constructed as independent units, and the internal (drive) unit is removed following completion of tunneling of the first section. It is taken to the departure shaft, where a new external casing is fitted, and excavation is then begun on the next construction section.

Because the shield's internal unit is reused, there is no need to construct an arrival shaft. The drive shaft can also be set up anywhere along the construction route.

ϕ2.68m earth pressure balanced shield machine (DSR construction method)

## MMST Shield Machine

H7.86m×W3.05m multi-axial rectangular slurry shield machine

## Branch Route Shield Machine

When the shield machine has reached the divergence point, the divergence shield emerges from inside the machine and each shield continues to perform its own independent excavations.

Because this construction method allows the divergence operation to be completed underground, there is no need to prepare a departure shaft for the divergence shield machine.

### ■Construction method

①The mainline shield machine tunnels as far as the divergence point with the divergence shield machine installed inside.

②At the divergence point, the forward body section and the exterior skin plate of the center body section of the mainline shield slide forward and the divergence shield emerges to begin excavation.

③After divergence, both the mainline and the divergence shield machines simultaneously continue their excavation progress.

ϕ7.26m／ϕ4.24m slurry subterranean stem shield machine

## MSD Shield Machine

ϕ7.26m slurry MSD shield machine

## DPLEX Shield Machine

ϕ7.67m earth pressure balanced DPLEX shield machine



# Supply Record

## Kawasaki plays an active role in projects around the world

ϕ5.03m earth pressure balanced shield machine
(London subway Jubilee Line, England)

ϕ8.11m dual-mode earth pressure balanced shield machine
(CTRL, England)

ϕ8.78m shield TBM
(Channel Tunnel Undersea Railroad Project, France)

ϕ7.65m earth pressure balanced shield machine
(Lille subway No. 2 Line, France)

ϕ7.80m slurry shield machine
(Soul subway No.9, Korea)

ϕ6.14m earth pressure balanced shield machine
(Guangzhou subway No. 1 Line, China)

ϕ9.74m earth pressure balanced shield machine
(Lisbon subway No. 2 Line, Portugal)

ϕ6.43m dual-mode earth pressure balanced shield machine
(Bangkok subway Blue Line, Thailand)

ϕ3.38m earth pressure balanced shield machine
(Malaysia sewage, Malaysia)

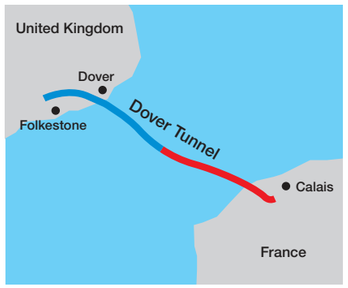
ϕ6.24m earth pressure balanced shield machine
(Taipei subway Nankang Line, Taipei)

ϕ7.16m dual-mode earth pressure balanced shield machine
(Singapore sewage system, Singapore)

ϕ6.34m earth pressure balanced shield machine
(Shanghai subway No. 1 Line, China)

Project reference ①

# The Dover Channel Undersea Railroad Project




## Largest tunneling project in the 20th century——

The 52 km Dover Tunnel, the largest tunneling project of the 20th century, was completed by its Anglo-French operators, Eurotunnel, in 1991.

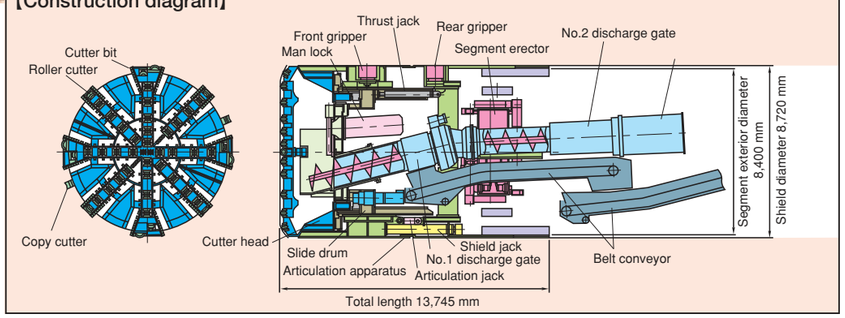
Two Kawasaki TBMs (8.78 m bore, each 13.745 m long) were utilized for this large-scale project linking Calais, France and Folkestone, England with two single-track railroad tunnels (7.3 m$\phi$) and one service tunnel (4.5 m$\phi$)

The state-of-the-art TBMs tunneled approximately 100 m beneath the ocean floor (1 Mpa), with a maximum monthly advance of 1,200 m and continuous underground excavation at distances up to 20 km. Their performance earned worldwide praise for Kawasaki's advanced technological capabilities.

The project was choosen as the best 10 projects in the 20th century of rail way section on "Monuments of Millennium" by ASCE.

| | | |
|---|---|---|
| Type | Shield TBM × 2 | |
| Size | $\phi$8.78m×13.745m | |
| Application | Railroad | |
| Area | Dover channel | |
| Order enterprise | EURO TUNNEL | |
| Customer | T.M.L. | |
| Length | 20,009m | 18,857m |
| Date | Dec.1988 ~ May 1991 | Mar.1989 ~ Jun.1991 |
| Zone | T2 | T3 |

【Construction diagram】



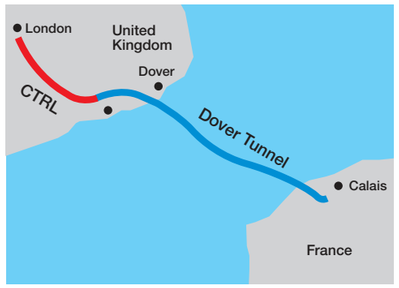

Project reference ②

# CTRL (Channel Tunnel Rail Link)

## Kawasaki shield machine got further credence in Europe.

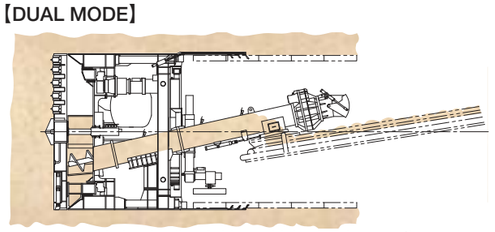
CTRL project consists of Phase-1 which was planned to accelerate the speed of the Eurostar in England terrain after it comes out from the Dover tunnel and Phase-2 which was planned to change the location of hub station from Waterloo to St Pancras at north of Thames river.

Kawasaki supplied two shield machines for Contract-220 section and got the further recognition in Europe.

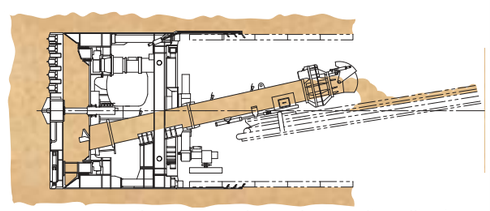




| | | |
|---|---|---|
| Type | Dual-mode earth pressure balanced shield machine × 2 | |
| Size | $\phi$8.11m×11.5m | |
| Application | Railroad | |
| Area | England | |
| Order enterprise | Union Railways | |
| Customer | Nishimatsu- Cementation Skanska JV (NCS) | |
| Length | 7,540.5m | 7,546.5m |
| Date | Sep.2002 ~ Jan.2004 | Nov.2002 ~ Mar.2004 |
| Zone | Up Line | Down Line |

【DUAL MODE】



**MODE 1** In hard soils : Achieves high-speed excavation and highly efficient debris discharge



**MODE 2** In soft soils : Excavates by stabilizing the cutting face with appropriate pressurized muck

## Project reference ③

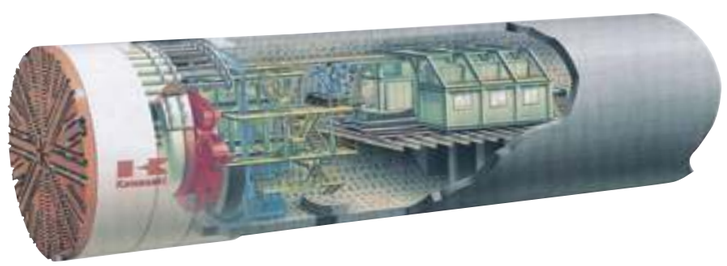
# Tokyo Bay Aqua-Line

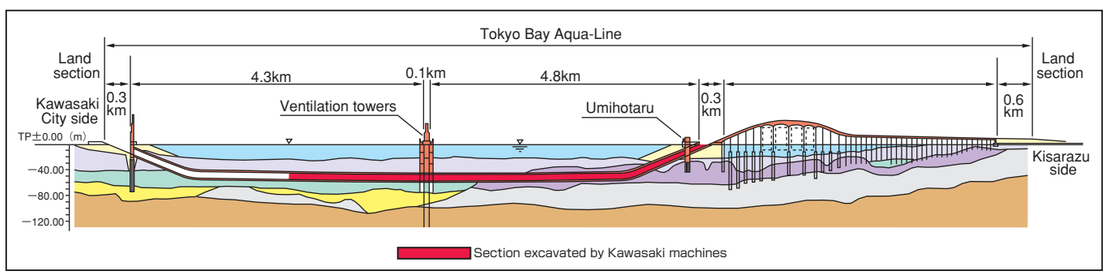
The 15.1 km Tokyo Bay Aqua-Line highway, one of Japan's largest public works projects of the 20th century, opened to traffic in 1997.

The 9.6 km section between Kawasaki City and Umihotaru is the world's largest seabed shield tunnel. Three Kawasaki super large diameter shield machines (14.14 m$\phi$, 13.5 m long) were utilized for the project.

To meet the challenge of the ultralarge diameter and long-distance tunneling under intense water pressure (0.5 MPa), Kawasaki's shield machines were equipped with devices for underground clocking and a high-precision automatic segment erector combining the most advanced technology and know-how in the industry. These shields were recognized globally as introducing a new chapter in the history of Japanese shield technology.

| Type | Slurry shield machine × 3 | | |
|---|---|---|---|
| Size | $\phi$14.14m × 13.5m | | |
| Application | Road | | |
| Area | Tokyo Bay (Kawasaki—Kisarazu) | | |
| Order enterprise | Trans - Tokyo Bay Highway Corporation | | |
| Customer | MAEDA TEKKEN FUJITA JV | NISHIMATSU TODA ZENITAKA JV | KAJIMA KONOIKE SUMITOMO JV |
| Length | 2,419 m | 2,100 m | 1,800 m |
| Date | Oct.1994 ～ Apr.1996 | Apr.1995年～ Jul.1996 | Apr.1995 ～ Jun.1996 |
| Zone | Central Tunnel Kisarazu North (No.1) | Central Tunnel Kawajin North (No.1) | Kawasaki Tunnel Kawajin North (No.1) |




## Project reference ④

# Tokyo Bay Gas pipe - Line

Long - distance, High Pressure, High speed excavation

| | |
|---|---|
| Owner | : The Tokyo Electric Power Co, Ltd. |
| Area | : Tokyo Bay |
| Period | : Nov. 2003 ～ Mar. 2005 |
| Machine | : $\phi$3.62 m Slurry shield machine |
| Boring Length | : 9,030 m |
| Soil Condition | : Sandy, Clay, Gravel |
| Water Pressire | : Max. 0.67 MPa |
| Max. Monthly Advance | : 1,168 m / month |
| Average Monthly Advance | : 665 m / month |

## Project reference ⑤

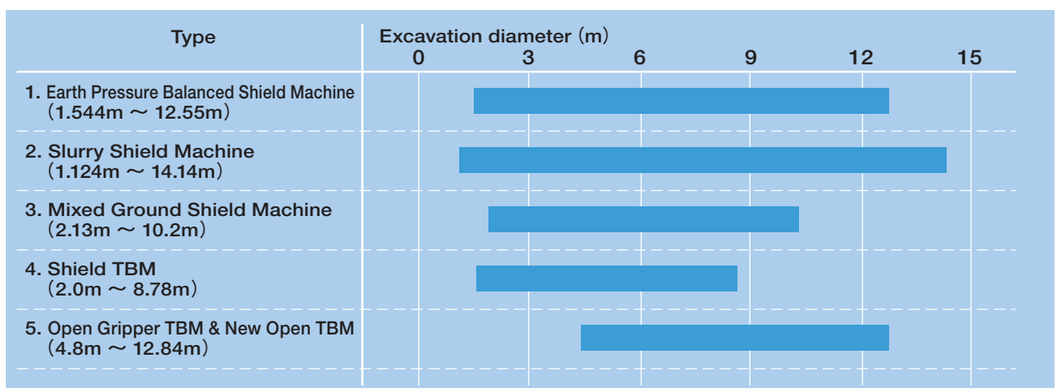
# The Central Circular Route Shinagawa North Line

Large bore, Long - distance

| | |
|---|---|
| Owner | : Metro politon Expressway Co, Lrd. |
| Area | : Tokyo (Shinagawa ～ Meguro) |
| Machine | : $\phi$12.55 m E.P.B Shield machine |
| Boring Length | : 8,030 m |
| Soil Condition | : Sand, Gravel, Mediun sand, Mad stone, Sandy stone |
| Water Pressire | : 0.5 MPa |
| Minimum radius of Carves | : R=230 m |

## ■Range

For all uses and all diameters, for all geological condition there is a Kawasaki solution.



# Fundamental Technologies

## Cutter bits

Kawasaki selects the optimum cutting edge shape and cemented carbide tip arrangements based on Kawasaki's expertise and achievements. Kawasaki is also conducting studies to improve the wear-resistance of carbide tips in long-distance tunneling.

Auxiliary cutter

Auxiliary cutter for gravel

Auxiliary cutter for glass fibered entrance wall excavation

Center cutter

Teeth cutter

Teeth cutter for gravel

## Cutter changing device

Kawasaki has developed cutter changing device which enables workers to change cutters safely at anytime. Workers can enter into cutter-head from pit situated at rear part of machine so there are no possibilities to expose themselves to dangers of encountering excavated soil and/or water. Using cutter changing device, suitable type of cutters can be selected according to soil condition, and worn cutters can be replaceds.

### ■Features

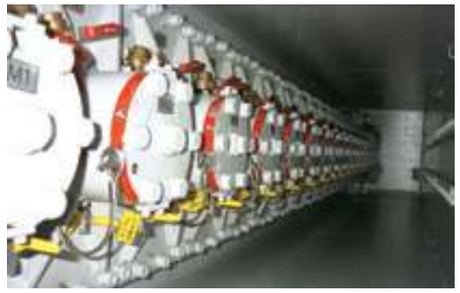
①Simple procedure and a short time to replace
- by using special jig and multi-use air tools.

②High reliability and safety for water-shutoff
- by shutoff gate and multi seals
- by checking valves and safety lock system

③High durability
- Proved by durability test of hundred thousand times replacement work.

④Space- saving
- Minimum space requirement by compact design.

⑤The extreme peripheral part arrangement
- Inclined cutter arrangements make it possible to install cutters at the extreme peripheral angle part.



Cutter changing device

During cutter change from outside

During cutter change from inside

## Disk roller cutters

Kawasaki has developed a variety of disk roller cutters through our extensive supply records in various project conditions. These provide maximum performance in bedrock or large gravel.

Roller cutter
(1 ring type)

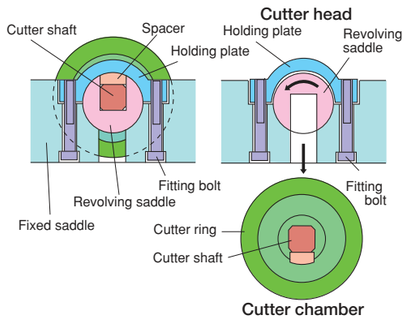
Roller cutter
(2 rings type)

Roller cutter
(chip insert type)

Center cutter
(for soft / medium rock)

### ■Easy cutter replacement

Kawasaki has developed a revolving-saddle-cutter-mounting-mechanism to replace cutters easily and safely from machine inside. This assures great safety as operators are not required to go outside of machine to replace cutters especially when excavating under collapsible strata condition.

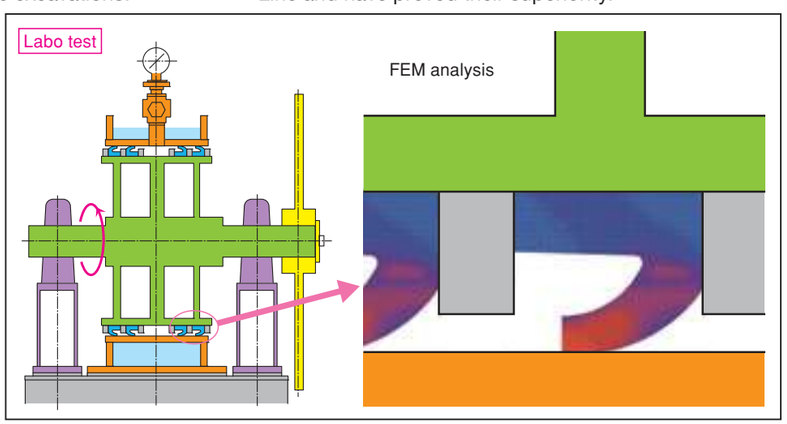



## Bearing seals for cutter head and articulation sections

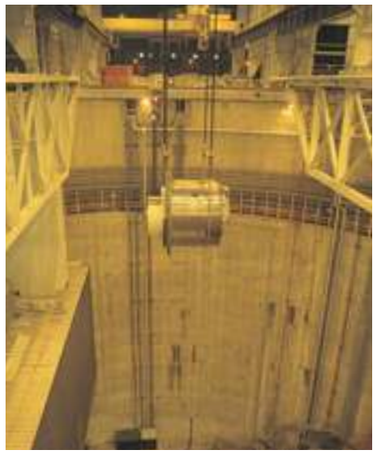
### ■Corresponds to high water pressure, rotation speed, and long distance excavation

The large-diameter bearing seals were developed by Kawasaki's design which was improved through many projects experiences. Such bearing seals show their advantages under harsh conditions like long distance, high slurry and high earth pressure excavations.

This technology demonstrates its performance under difficult conditions. These bearing seals were equipped in machines for long-distance high water pressure projects such as the Dover Tunnel and Tokyo Bay Aqua-Line and have proved their superiority.



# AFTER SERVICE / SUPPORT



## ■Field service

Skilled engineers support for all technical aspects in project execution from site erection, commissioning to maintenance.

## ■Spare parts

Optimum spares are selected by accumulated experiences to meet customer's various requirements.

## ■Training

Trainings for machine maintenance, operation and erection in both factory and site enhance operator's skill and improve project execution efficiency.

## ■Remote support system

Online remote-monitoring system observes machines simultaneously as precautious measure to prevent potential troubles.

## ■Overhaul

TBMs can be reused by overhauling and refurbishment.



# Harima Works

8, Niijima, Harima-cho, Kako-gun, Hyogo 675-0155, Japan

Harima works takes full advantage of its coastal location at the center of the Harima Industrial area facing the Seto Inland's Sea.

### ●Size

**Site area**: 444,581 m²

**Bilding area**: 100,400 m²

**Employees**: approx.1,000

**Main products**: Shield machines, TBMs, Storage tanks (LNG, LPG, other low temperature liquid storage tanks), pressure vessels and pipings. Euipment related to the space, airport & harbor facilities. Boilers (thermal power plant boilers, Industrial boilers, marine boilers), nuclear power plants. Industrial plants (steel plants, chemical plants, cement plants, material handling system, etc.)


3,000T Pressing machine

2,000T Bending roller

## Inquiries (Please fill out following form for our estimation.)

### ■Client Information

| | |
|---|---|
| Customer name | |
| Person in charge | |
| Phone No. | |
| E-Mail | |
| Website | |

### ■Project information

| | |
|---|---|
| Country & Area | |
| Owner | |
| Project name | |
| Application | ☐ Railroad ☐ Road ☐ Waterway / Reservoir ☐ Aqueduct<br>☐ Electrical / Gas ☐ Multi duct ☐ Others（ ） |
| Order schedule | |
| Desirable day of delivered | |

### ■Machine Information

| | | |
|---|---|---|
| Type | ☐ Open Gripper TBM | ☐ Earth pressire balanced shield machine |
| | ☐ Full shield TBM | ☐ Mixed Ground Shield Machine |
| | ☐ Slurry shield machine | ☐ Others（ ） |
| Required number of machines | | |
| Excavation diameter | | φm |
| Construction length | | m |
| Gradient | | ⁰/₀₀ |
| Minimum radius of curves | | m |
| Earth covering | | m |
| Underground water level | GL. | m |
| Soil conditions | Soil type | |
| | Maximum gravelsize | mm |
| | N-value | |
| | Uniaxial compressive strength | MPa |
| Segments | ☐ Radial insert ☐ Axial insert | |
| | Material | |
| | Dimensions | |
| | Outside diameter m ／ Inside diameter m ／ Width m | |
| Planning drawing | ☐ （ ） | |
| Any special requirements | | |


# Kawasaki Heavy Industries, Ltd.

## Plant & Infrastructure Company

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