

7.0 TUNNEL BORING MACHINE TECHNICAL SPECIFICATIONS:

MODEL Hitachi Zosen 6.44M (DIA.21-FT-1.54-IN) EPB TYPE SHIELD
TYPE Mixed Face – Segment Erecting TBM
EXCAVATION MODE Earth Pressure Balance (EPB)

7.1 Geological Conditions:

Soil character	Till and Till-Like Deposits (TLD), Cohesionless Sand and Gravel (CSG), Cohesionless Silt and Fine Sand (CSF), Cohesive Clay and Silt (CCS)
Max. overburden	20 ~ 131 ft (min. 20 ft at MLP)
Under ground water pressure	0.8 ~ 2.9 bar at tunnel bottom
Unit volume mass of soil	125 +/- 5 – 128 +/- 6 pcf
Unit volume mass of soil in water	10 kN/m ³ (assumed)
Unit volume mass of water	10 kN/m ³ (assumed)
Upper-laden load	10 kN/m ² (assumed)
Max Inner friction angle of soil	39 +/- 4 degrees
Boulders	1926 boulders more than 1' dia. (for twin tunnel : GBR Table 5.3)
Permeability coefficient	10 ⁻² — 10 ⁻⁷ cm/sec

7.2 Working Conditions:

Total excavation length	5,605 m (18,390 ft) × 2 tunnel
Minimum curve radius	R244 m (800ft) (Note)
Gradient	-4.8% ~ +1.3 %

(Note) The TBM is designed to meet 105m (345ft) curve radius.

Calculations verifying the TBM's steering capabilities are included in Appendix 20.

7.3 Initial Support:

(ton = U.S. ton)

Type	Segment Support
Classification	Reinforced concrete segment
Key segment	Axial insertion
Outer diameter	20-ft 6-in [6,248 mm]
Inner diameter	18-ft 10-in [5,740 mm]
Typical width	5-ft [1,524 mm]
Thickness	10-in [254mm]
Number of division	6 pcs. (including 2 key segments)
Maximum mass of one piece	Approx. 3.6 ton/1 pc. 19.3 ton/ring

8.0 SPECIFICATIONS OF MECHANICAL EQUIPMENT:

Name of Type : Earth Pressure Balanced type

8.1 Dimensions of Shield Body:

Excavation diameter by disc cutter	6,640 mm	
Shield outer diameter	6,440 mm	
Shield inner diameter	6,340 mm	
Tail clearance	$33.8 \times 2 = 67.6$ mm	
Overall length (Working deck and screw conveyor are not included.)	10,350 mm	
Skin plate	Front body thickness	50 mm
	Middle body thickness	32 mm
	Rear body thickness	50 mm

	Material (Front & Middle)	Mild steel JIS SS-400 or equivalent
	Material (Rear)	Mild steel JIS SS-400 or equivalent
Tail sealing	Wire brush	3 stages welding type, replaceable
	Spring plate (Outer)	1 stage
Dividing quantity The length of structure shall be less than 3,960mm (13ft) to facilitate transport in Seattle.		Cutter head----1 Cutter drive ---1 Front body-----1 Middle body---1 Rear body-----1

8.1.a Propulsion Equipment:

Shield jack elongation speed (at whole number actuation)		Max. 102 mm(4")/min				
Equipped thrust force per unit area of facing		1,228 kN/m ²				
Total thrust force		40,000 kN				
Propulsion cylinder shoe without developing eccentric loading on segment		Eccentric fitting and ball joint on top on each cylinder				
Application	Thrust (kN)	Stroke (mm)	Operating pressure (MPa)	Quantity	Total thrust (kN)	
Shield Propulsion System	2,500	2,300	35	16	40,000	

Calculations for the shield structure are included Appendix 12.

8.1b Shield Propulsion System:

- Propulsion Cylinders: 16 cylinders @ 280 ton/cylinder
- Total Maximum Thrust: 4,496 ton @ 5076-psi [350 bar]
- Propulsion Stroke: 2,300 mm Constant Thrust with Variable Speed
- Proportional Pressure Control of each cylinder
- Self Aligning Shoes, c/w polyurethane pads
- Maximum Pressure on tunnel lining restricted to prevent damage to segments

8.1c Propulsion Cylinder Control:

- Individual Operation of all cylinders
- Group Operation of Cylinders (according to segment configuration)
- Control of all cylinders simultaneously
- Indication of center of thrust
- Fast Retraction Circuit

- Steering control assisted by selection of center thrust and pressure control to each cylinder
- Propulsion cylinders equipped with non-return systems to maintain pressure during idle state
- Pressure control of cylinder groups by quadrant (TOP, BOTTOM, RIGHT, LEFT) to assist steering of TBM.

9.0 TBM Articulation Equipment:

Active articulation Jack	14 pcs.
Total thrust force	35,000 kN
Articulation angle	Max. 2.5 °
Cutter head retract equipment	Max. 250mm
Articulation seals	V-seal × 2, Dust seal × 1
Additional articulation seal for emergency	O-ring (replaceable)

The Articulation Joint utilizes an advanced design where the interior sealing surface is machined as a spherical surface. This design allows for full articulation of the joint without seal distortion or overloading. This sealing system is designed for a maximum pressure of 10 Bar. The anticipated maximum active face pressures are approximately 3.4 Bar for a safety factor of 2.94. To maintain the specified safety factor of 1.25 the grouting pressures will be kept below 8 Bar. This design is proven to provide optimum sealing without seal failure. This design eliminates the need to have a replaceable seal. To meet Contract Specifications and to provide redundancy in the event of an emergency, there is provision for an addition emergency O-ring seal that can be mounted in the forward section of this joint. This emergency sealing system has been utilized by the manufacturer on previous projects but the need for implementing the emergency seal has never occurred.

The joint is articulated with 14 hydraulic cylinders that have an individual capacity of 281 tons / each. A drawing of the Articulation Joint Assembly is shown in Appendix 8.

10.0 Cutterhead and Main Drive Equipment:

Support type	Intermediate support	
Driving type	Electric motor driving	
Configuration	Semi dome type	
Equipped torque (100% out-put)	0.4~1.1 rpm	5,941 kN-m ($\alpha=22.2$)
	1.1~2.2 rpm	5,941kN-m ($\alpha=22.2$) ~ 3,107 kN-m($\alpha=11.7$)

Rotational speed		0.4 ~ 1.1 ~ 2.2 min ⁻¹
Direction of rotation		Clockwise & counterclockwise
Over cut	Type : Copy cutter	Oil hydraulic jack type
	Equipped quantity	2 (One is for spare)
	Jack stroke	150 mm
Drive structure	Main bearing	Replaceable from within the tunnel
	Lubrication	Grease lubrication
	Seals	Replaceable from within the tunnel
Abrasion resistant (The plate include chromium)		Anti wear plate: Outer rim & cutterhead face Hard facing of all areas where anti-wear plate cannot be installed
Additive outlet port on cutter face		φ40mm with packing : 5 sets
Mixing arms behind cutter head		5
Mixing arms on bulk head		2

The cutter head Drive Structure is shown on Appendix 3.

The Mixed Face cutter head excavates the face while rotating. Approximately 35% of the cutter head face is open space to allow for soil particles to enter into the cutter head chamber. Included is the application of chromium carbide plating on cutter head face and rim for abrasion protection. 5 No. Injection Ports are located on the cutter head for ground conditioning. These injection ports can be independently operated. The cutter head is supported by 6 cantilever arms that connect the cutter head to the triple axis roller main bearing. 5 mixing arms are mounted to rear of the cutter head to provide a mixing action in the cutter head chamber as they sweep through the soil against the opposing bulk head mixing arms, during cutter head rotation. Cutter head operation is bi-directional with full electric power and variable speed.

The arrangement of the mixing arms within the cutter head is shown in Appendix 24.

The structure of the cutter head is shown in Appendix 5.

The cutter head drive motor output torque vs. RPM is shown in a chart in Appendix 13. This chart shows the peak torque / RPM occurs at 1.1 RPM. This is RPM that the TBM will likely operate at during most of the tunnel excavation.

10.1 Main Bearing:

- Triple Axis Roller Type
- Internal Gear – Integral with Bearing
- Lubricated by an independent pressurized grease injection system

- B10 Bearing Life of 10,000 hours
- Replaceable from within the tunnel.

The main bearing is new and is replaceable from within the tunnel. The bearing is lubricated with grease that is purged by a continuous flow of new grease. The continuous purging of grease will ensure that unwanted particulates do not get behind the main seals and interfere with the main bearing. This continuous grease purging action will help to ensure that the main bearing will be able to last an entire tunnel drive and remain in excellent condition.

10.2 Sealing System:

- Internal Diameter Sealing System
- Outside Diameter Sealing System
- Positively Pressurized Automatic System controlled by the PLC with input from the Earth Pressure Sensors
- Seals manufactured by HZ.
- Replaceable from within the Cutter head
- Sealing System Operating Pressure: 2.6 bar max. during excavation (seal system capable of 10 Bar pressure)
- Sealing System ‘Fail-safe’ (Malfunction initiates shutdown)

The TBM will be equipped with new main bearing seals on the existing sealing module. This sealing system is rated for a maximum Active Face Support pressure of 10 Bar. The anticipated maximum active face support pressure is expected to be 2.6 Bar. This provides for a safety factor of 3.8.

10.3 Rotary Fluid Joint/Coupling:

- Independent Ground Conditioning Injection Lines – five ports
- Hydraulic Oil for Copy Cutter – four ports
- Hydraulic Oil for Wear Detection System – two ports

11.0 Cutting Tools:

These numbers are initial supply quantity only.

Type of the cutter		Q'ty	Remarks
01)	Inner disc cutter (Tip inserted and back loading type)	12	Double rings dia.400mm Taper roller bearings
02)	Gauge disc cutter (Tip inserted and back loading type)	2	Single ring dia.400mm Taper roller bearings
03a)	Tooth cutter (Bolt mounted on spoke side)	90	W 150mm H 100mm
03b)	Tooth cutter – at center (Bolt mounted on spoke inlet)	4	W 150mm H 100mm
04)	Trim bit(4 pcs. of the wear detection bits (hydraulic type) are included.)	12	W 250mm H 100mm

05)	Gauge bit (Welded)	6	W 60mm×H170mm L 200mm
06a)	Pre cutting bit high (Mounted on the disc cutter holder instead of disc cutter)	12	W 60mm×H150mm L300mm
06b)	Pre cutting bit high (Welded on cutter face)	19	W 60mm×H170mm L300mm
07)	Center plate	1	
08)	Over cutter	4	W60mm×H160mm L300mm
09a)	Over cutter (Mounted on the disc cutter holder instead of disc cutter)	1	W60mm×H148mm L300mm
09b)	Over cutter (Mounted on the disc cutter holder instead of disc cutter)	1	W60mm×H136mm L300mm

The above table shows the list of cutting tools that are initially supplied for use on the TBM. Not all of the tools listed in the table above will be used on the initial dress of the cutterhead. For example, no disc cutters will be used for the initial dress of the cutterhead. Drawings of the cutter head and details of the cutter tools are shown in Appendix 23.

The cutter head is equipped with Tooth Cutters mounted on six spokes. The spokes are also equipped with pre-cutting Ripper Teeth that are interchangeable with Disc Cutters, if the conditions deem necessary. The disc cutters are 305 mm (12") Diameter, twin-tip replaceable ring type cutters with 16 tonne thrust capacity per Disc Cutter, 8 tonne thrust capacity per tip. Discs are hand turn-able as no pre-load is required.

There are wear detection devices built into four of the twelve Trim bits. These wear detection bits have a port drilled to the wear-limit line. This port is filled with pressurized hydraulic fluid and connected to a manual pressure read-out. When tooth wear is exceeded the port will not maintain hydraulic pressure, indicating that a cutter change is necessary.

12.0 Screw Conveyors:

12.1 No.1 Screw Conveyor:

Type	Dia. 850 mm shafted	
Driving type	Hydraulic motor driving	
Equipped torque	64.6 kN-m	
Rotational speed (reversible)	1~17.3 min ⁻¹	
Capacity of soil discharge	310 m ³ /H (@ max rpm)	
Max. discharge boulder diameter	280 mm	
Guillotine gate	Inlet	By right & left hydraulic jacks

	Outlet	For connection to No.2 screw
Retraction of screw		For inlet guillotine gate closing
Earth pressure gauge		1 set (near the inlet)
Maintenance port		3 sets
Front casing		Double piping type (Inside is replaceable)

12.2 No.2 Screw Conveyor:

Type	Dia. 850 mm shafted
Driving type	Hydraulic motor driving
Equipped torque	64.6 kN-m
Rotational speed (reversible)	1~17.3 min ⁻¹
Capacity of soil discharge	310 m ³ /H (@ max rpm)
Max. discharge boulder diameter	280 mm
Guillotine gate	By right & left hydraulic jacks
Retraction of screw	For following No.1 screw sliding
Earth pressure gauge	1 set (near the outlet)
Maintenance port	3 sets
Accumulator to automatically close guillotine gate at power failure	1 pc.

The Screw Conveyor is shown in a drawing in Appendix 9. The Guillotine Gates for the Screw Conveyors are shown in drawings in Appendix 10.

The relationship of Excavation speed to screw revolution is shown on a chart in Appendix 14. This Chart shows as an example, a screw speed of 7.1 RPM for a TBM advance rate of 50 mm per minute.

13.0 Erector Equipment:

13.1 Erector Equipment:

Type	Ring type
Segment weight	Max. 3.5 tonne / piece
Number of revolution	0.2/1.5 min ⁻¹
Erector holding force	144 kN
Erector pushing force	210 kN

Segment gripping mechanism	Mechanical type
Adjustment	Six degree of freedom
Grip slide movement	630 mm, 100 mm
Warning light with signal horn	1 pc.
Rotary angle	Clockwise and counterclockwise 210° (restricted by limit switches)
Attachment for disassembling damaged segment	1 pc. (within the first 800mm at next ring)

The erector equipment assembly is shown on a drawing in Appendix 6.

13.2 SEGMENT ERECTOR

- Ring / Lifting Beam Type
- Mechanical Gripping Mechanism
- Erector can remove segments positioned over first two rows of tail seal brushes
- 2 No. Hydraulic motors
- Rotary Hose Reel
- Failsafe Braking Device and over-run prevention of erector rotation
- Heavy Duty wheels and replaceable wear strips, grease lubricated
- Hydraulic Proportional Control of all functions
- Audio / Visual Alarms / 2 No. Emergency Stops
- Design Parameters

Continuous Operation:	130% of W
Testing:	200% of W (Safety factor: 2)
Yield Point:	500% of W
W = Weight of heaviest segment	
- 2 No. Operating Station, Fixed
- 2 No. Wireless - Control of all functions

13.3 SEGMENT TRANSPORT MONORAIL

- Single Segment Lift Operation
- Proportional Hydraulic Control of all functions
- Ball and Cup Type Mechanism

13.4 SEGMENT UNLOADER

- Hydraulic lift system attached to gantry #1 with lifting forks
- Segment unloader is fixed in horizontal direction, jacks move in vertical direction
- Designed to unload half stacks of segments at a time off of the rubber tire segment carrier
- Forks fold in and out so they can be slipped under the segment stack
- Rubber tire vehicle (RTV) pulls in, segments are lifted up, RTV pulls out, segments get lowered

Details of the segment unloader can be seen in Appendix 11.

14.0 Oil Cooler:

14.1 (1) Oil Hydraulic Pump:

	Shield / Screw
Type	Water / Oil
Capacity	12,000 kcal/h
Quantity	1

15.0 Hydraulic Power Unit:

15.1 (1) Oil Hydraulic Pump:

Application	Type	Capacity (ℓ/min)	Operating pressure (MPa)	Quantity
Shield	Piston pump	118/160	35/21	1
Cutter	Piston pump	—	—	—
Erector jack	Piston pump	45	21	1
No.1 screw	Piston pump	202	21	2
No.2 screw	Piston pump	202	21	2
Copy cutter	Piston pump	20	21	2
Gate	Piston pump	27	21	1
Articulation	Piston pump	22	35	1
Shield oil cooler	Gear pump	200	1.5	1

15.1 (2) Electric Motor:

Application	Output (kW)	Number of pole (P)	Voltage, Frequency (V, Hz)	Quantity
Shield	90	4	480, 60	1
Cutterhead	—	—		—
Erector jack	18.5	4		1
No.1 screw	90	4		2
No.2 screw	90	4		2
Copy cutter	11	4		1
Gate	11	4		1

Articulation	18.5	4		1
Shield oil cooler	7.5	4		1

15.1 (3) Oil Tank:

Application	Capacity (ℓ)	Quantity	Total capacity (ℓ)
Shield	5,000	1	5,000

16.0 Hydraulic Cylinder / Jack:

Application	Thrust (kN)	Stroke (mm)	Operating pressure (MPa)	Quantity	Total thrust (kN)
Shield Propulsion System	2,500	2,300	35	16	40,000
Articulation	2,500	250	35	14	35,000
Rear gripper	—	—	—	—	—
Copy cutter	165	150	21	2	—
Erector lift	105	650	21	2	210
Erector slide	41	730	21	2	82
Erector support	22	100	7	4	—
Erector yawing	41	80	21	1	—
No.1 screw inlet guillotine gate	105	435	21	2	—
No.1 screw outlet guillotine gate	65	435	21	4	130
No.1 screw retraction	105	850	21	2	210
No.2 screw guillotine gate	65	435	21	4	130
No.2 screw retraction	105	900	21	2	210
Towing for back-up car	257	400	21	2	514

17.0 Electric Cutter head Drive Motors:

Application	Output axle torque (kN-m)	Output (kW)	Number of pole (P)	Voltage / Base Frequency (V×Hz)	Quantity	Remarks
Cutter head	82.5	90	6	480V / 60Hz	8	i=1/88.77 Variable

						frequency
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* Maximum frequency : 88Hz / Output axle torque : 43.1kN-m

18.0 Hydraulic Driving Motor:

Application	Output axle torque (kN-m)	Operating pressure (MPa)	Quantity	Remarks
Erector rotation	6.83	18	2	With Brake
No1 screw	7.8	21	2	—
No2 screw	7.8	21	2	—

19.0 Back-Up Cars / Gantries:

Application	Dimension	Quantity	Remarks
No.1 Screw supporting car	Width Height Length 4,400 × 2,890 × 7,000	1	
No.2 back-up car	4,400 × 2,890 × 6,000	1	LH: Grout injection equipment. (facing Heading) RH: Operating panel Tunnel Conveyor monitor supplied by JCM-JV on Operation panel
No.3 back-up car	4,400 × 2,890 × 7,000	1	LH: Grout injection equipment RH: Inverter panel
No.4 back-up car	4,400 × 2,890 × 6,000	1	LH: Additive injection device Compressor RH: Grease pump, Tank, Tail seal greasing pump
No.5 back-up car	4,400 × 2,890 × 6,000	1	LH: Additive tank RH: Power unit, Oil tank Accumulator
No.6 back-up car	4,400 × 2,890 × 6,000	1	LH: Foam injection device RH: Power panel

No.7 back-up car	4,400 × 2,890 × 7,000	1	RH: Heat Exchanger / Waste Water Tank LH: High Voltage Transformer
No.8 back-up car	4,400 × 2,890 × 3,500	1	LH: Fan Inverter RH: Walkway/Tool Lockers
No.8a back-up car	4,400 × 2,890 × 3,500	1	LH: Ventilation Fan RH: Walkway/Tool Lockers
No.9 back-up car	4,400 × 2,890 × 6,000	1	LH: Walkway RH: Tunnel Conveyor Advancing Tail Piece
No.9a back-up car	4,400 × 2,890 × 4,750	1	LH: Walkway RH: Tunnel Conveyor Advancing Tail Piece
No.10 back-up car	4,400 × 2,890 × 6,000	1	LH: High Voltage Cable Tray RH: Tunnel Conveyor Assembly Station Top: Duct Cassette – 54”

The layout of the Backup cars are shown in drawings in Appendix 101 and 102.

TRAILING BACKUP

Structural Steel Gantry, mounted on bogie wheel assemblies
Standard Element Dimensions (outside dimensions):

Length: mm
Width: 4333.6 mm
Height: 6696.7 mm

Clearance for Train:

Width: 1727 mm
Height: 2130 mm above invert of segment

Muck Car maximum width of 1768 mm
Muck Car maximum height of 2000mm above top of rail

Rubber tired vehicle (RTV) maximum width of 2188 mm
Rubber tired vehicle (RTV) maximum height of 3015 mm

Gantry Sections

16 No. Standard
Gantry elements are independent

Railing Up System

Storage area for rail beam section

Telescopic movement of rail, created by advancing TBM

New rail inserted and bolted in gap created by TBM

advance Maximum track extension of 10 m

Rail size based on 65lb type

20.0 Additional Data:

20.1 Lubricating Unit:

01) Grease feed pump unit	Grease pump	Operating	Electric type
		Discharge capacity	0.136 ℓ/min
		Operating pressure	21 MPa
	Electric motor	Power	0.4 kW × 4P
		Voltage	480 V × 60 Hz
	Distributor Reservoir	18 liter	
	Quantity	1 set	

20.2 Additive Injection Pipe with Ball Valve:

Position	Size	Quantity	Remarks
Bulkhead	1-1/2"	4	—
No.1,2 Screw	1-1/2"	4	—
Articulation	1-1/2"	4	—
Shield outer body	1-1/2"	6	

The additive injection system is designed to inject bentonite slurry or other additives into the cutter head chamber, into the screw conveyor, and/or into the TBM annulus. The additive injection system provides for an alternative soil conditioner methodology that can be employed if the primary foam-based soil conditioning system is not effective in controlling the EPB pressures. The use of this system for alternative soil conditioning is not anticipated however the system will be available if conditions warrant its use. This system is also available to inject bentonite or other additives into the TBM annulus to reduce TBM skin friction, or to supplement a loss of EPB pressure. This system is also available to inject bentonite or other additive directly into the cutter head chamber to raise the EPB pressure to counter a sudden loss in pressure to prevent ground loss.

This additive injection system consists of three pumps capable of 240 liters per minute / each for a total injection flow rate of 720 liters per minute at pressures of up to 1.0 MPa (10 Bar). The system includes a 9.92 m³ tank that can be filled with bentonite from a pipe fed directly from a batch plant at the surface.

Calculations for additive injection system are shown in Appendix 15.

20.3 Grout Injection Pipe with Ball Valve:

Position	Size	Quantity	Remarks
Bulkhead	2"	4	Swing head included
Rear body	2"	14	—

20.4 Rotary Joint/Union:

Application	Specifications	Quantity	Remarks
Foam injection line	1-1/2" × 7 MPa	5	To front of cutter face
Hydraulic oil	21 MPa	4	Copy cutter
Grease lubrication	21 MPa	2	Copy cutter
Hydraulic oil	21 MPa	4	Wear detection of Cutter tooth

20.5 Hose Reel for Erector:

Hydraulic line	Reeling capacity	6.5 m
	Pressure	21MPa
	Quantity	1 pc.

20.6 Cable Reel for Erector:

Electric line	Reeling capacity	6.5 m
	Quantity	1 pc.

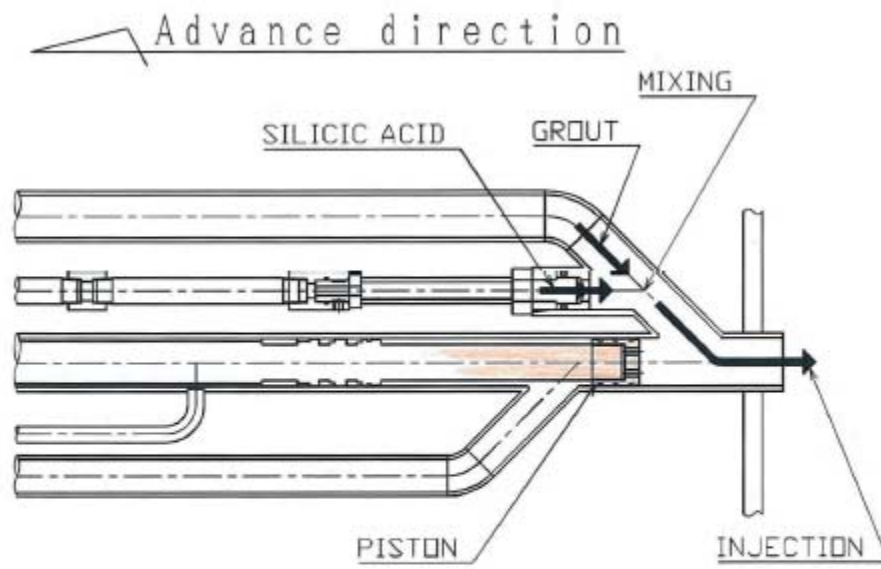
20.7 Back-Filling Piping at Rear Body:

Type of Back-filling grouting	Two liquid type Grout and Silica shall be mixed at the outlet of grout piping.
Automatic cleaning	The grout pipe is cleaned by water after every one ring advancing

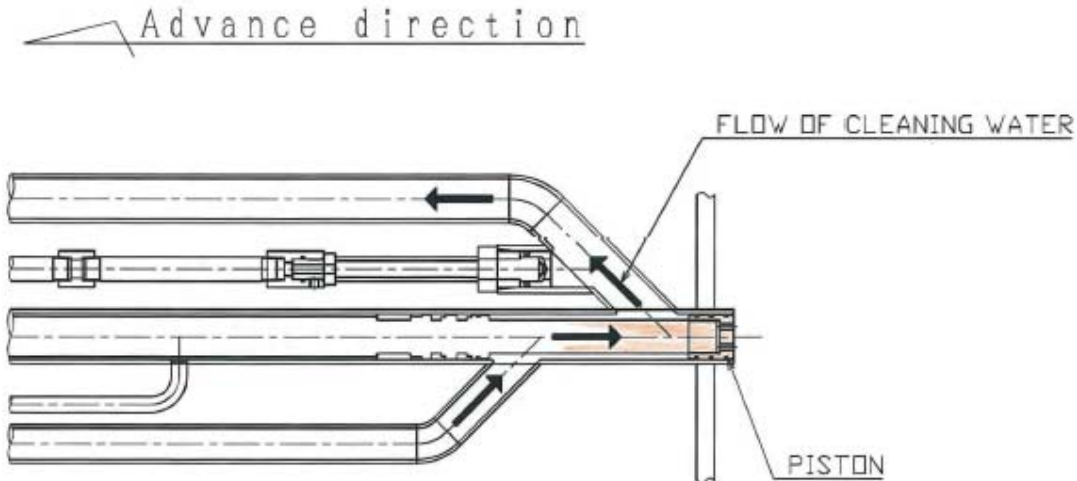
Quantity	2 (operation + spare)×3 location = 6 sets = 6 outlet ports
Grout pipe with valve	Dia.1-1/4" : 6 pcs.
Silica acid pipe with valve	Dia.3/8": 6 pcs.
Water pipe with valve	Dia.1" : 6 pcs.
Outlet cylinder valve	6 pcs.
Position of outlet on the shield body	At 4, 12 and 8 o'clock

The TBM employs an advanced grout injection system that is shown in Appendix 7. This system is designed specifically for the injection of two component grout that consists of Cement/Bentonite/Flyash mixture in water (Part A) injected concurrently with a sodium silicate accelerator (Part B). The two components are injected at a ratio of 10 Part A to 1 Part B thru the injection port device. The injection port device is specially constructed for the injection of this advanced grout such that the injection ports can be readily cleaned with minimal impact to the tunneling cycle. With this design the reliability of the grout injection system is optimized to ensure ready availability of grout injection during TBM advance.

Part A is a cement based material and this line will need to be cleaned after every grouting cycle. After the grouting cycle is complete, the self-cleaning cycle will begin. The injection port is equipped with a hydraulic piston that seals the port from the tail void when grout is not being pumped. An independent pump is utilized for the cleaning operation. This pump is connected to a cleaning water storage tank on the trailing gear. After the piston closes the injection port, cleaning water is used to back flush the grout line.



2. INJECTION STATE
Injection port opens.



3. CLEANING STATE
Injection port is closed by Piston.

An additional drawing of the Grout Backfilling Device Assembly is shown in Appendix 7.

20.8 Working Deck:

Shield inside	Type	Fixed floor
	Quantity	1
Segment erection	Type	Fixed floor
	Quantity	1

20.9 Hydraulic Oil Flow Meter:

Screw guillotine gate stroke	Type	Integrating flowmeter with potentiometer
	Quantity	2
Copy cutter	Type	Integrating flowmeter with potentiometer
	Quantity	2

20.10 Air Conditioner:

Air conditioner unit	1 pc.	Operating cabin
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20.11 Lifting Device Drum for Tail Seal Grease:

Chain block (manual operation)	5kN×1 pc.	No.3 back-up car
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20.12 Towing Beam for Back-Up Cars:

Between machine and back-up car	2 pcs.	With hydraulic jacks
Between back-up cars	1 set par every car	Plate beam only

Towing beams allow the belt tension force of continuance belt conveyor.
 Belt Tension of continuance belt conveyor (30 inches wide belt, 700PIW)
 • Normal operation; 11,400pound(5,170kgf)
 • Maximum; 21,000pound (9,530kgf)
 Tension force on towing beams; Maximum; 42,000lbs (19,051kgf)

20.13 Tail Seal Greasing Injection:

Item	Specification	Remarks
Feed pump	1 pc.	—
Operating type	Air motor driving	—
Feed capacity	0.198 ℓ/cycle	—

Control valve	12 pcs.	
Pressure transmitter	1 pc.	Pressure gauge
Grease hose from gantry to machine	Dia.2" pc.	—
Air compressor	1 pc.	—

Tail shield seal system consists of 3 rows of wire brush seals. The rear-most row of seals includes grout excluder plates that flare inward and outward to minimize the flow of annulus grout around the TBM or into the brush seals. The two forward-most rows of brush seals are replaceable from within the tunnel. An integral part of the sealing system is the injection of tail seal grease (this grease is actually a sealant) into the cavities between each row of brushes. The tail seal grease pump is driven pneumatically. Tail seal grease is pumped into the tail seal brushes automatically during tunnel excavation. It increases sealing capability of the tail seal brushes and reduces wear of the brushes by lubricating the surface of the precast segment extrados as it slides past the brushes. There are 6 grease injection ports that inject grease into each of 2 cavities between brushes (total 12 ports). Grease injection intervals are set by the operator and automatically injected in sequence from each port. The injection pressure is measured by an in-line pressure transmitter, displayed on the touch panel of the operating panel and recorded with the data-logger.

Calculations verifying the design for the tail seal grease injection system are included in Appendix 16.

20.14 Air Lock:

Item		Specification	Remarks
Type		Two chambers	—
Quantity		1 pc.	—
Inner diameter		φ2.03 m	—
Length		3.06 m	—
Capacity	Main	~4 m ³	—
	Sub	~2.7m ³	—
Operating pressure		Max. 3.5 bar	—
Access person		3 persons / each chamber	—
Fluorescent light		20W×2 pc.	—
Telephone		3 pcs (2 in Man lock, 1 out of Man lock)	
Utility lines	Gas monitoring	3/4"	1pc
		Acetylen gas	1/2" 1pc

(place utility cable, pipe or hose in Man lock)	Light	3/4"	1pc	Water	1"	1pc
	Welding cable	1"	1pc	Air	1/2"	1pc
	Oxygen gas	1/2"	1pc	Spare	1-1/4"	1pc

An air-lock is mounted to the rear side of the bulkhead in the crown of the shield for man access to the cutter chamber. The air-lock will be newly fabricated from Reimers. It will be designed to fit in the existing space that the Hitachi Zosen air-lock fit into when the machine was used for the U230 project. The air-lock will also be fabricated to be PVHO certified, and to meet the specifications of the N125 project. Drawings showing the air-lock are shown in appendix 4.

20.15 Material Lock:

Item	Specification	Remarks
Type	One chamber	—
Quantity	1 pc.	—
Inner diameter	φ0.45 m	—
Length	0.85 m	—
Operating pressure	Max. 3.5 bar	—

A material lock is mounted to the rear side of the bulkhead at the center part of the shield for carriage of tools, disc cutters and other material to the cutter chamber.

21.0 ELECTRICAL- POWER – CONTROL - INSTRUMENTATION

21.1 Power

Division	Voltage (V)	Frequency (Hz)	Number of phase (φ)	Remarks
Primary supply	13,800 AC	60	3	—
Power	480 AC		3	—
Lighting	120 AC		1	—
Control	100 AC		1	—
Instrument	100 AC		1	—
	24 DC		—	—

21.1 Grounding Work:

- (1) The ground bus shall be supplied to the power panel.
- (2) The secondary ground for the equipment in the shield and on the back-up cars

shall be supplied from the power panel.

(3) All secondary ground shall maintain on same electric potential as the ground bus.

21.2 Cable:

Using part	Division	Voltage (V)	Using material
Cable in the tunnel	Power	480	Portable power cables & Hard service cords
	Lighting, Control	100, 120	Hard service cords & Special cables
	Operation box		Hard service cords
Grounding cable	—		Hard service cords

21.3 Starting Type:

Electric motor capacity		480 V system
Starting system	Less than 45kW	Direct
	More than 55kW	Star – delta
	Cutter driving motor	Inverter Drive

21.4 Control Equipment:

Division	Type	Q'ty	Setting place	Remarks
Power & control panel	IP55	1	No.5 Back-up car	
Shield operation panel	IP43	1	No.1 back-up car In the operation Room	Bottom plate open type for cable
Shield jack operation panel	IP55	1	Machine inside	
Machine inside control panel	IP55	1	Machine inside	
Erector joint box	IP55	1	Machine inside	—
Erector operation box	IP65	2	Machine inside	Wireless type (One is for spare.)

Erector operation box	IP55	1	Machine inside	Wire type
Shutter gate operation box	IP55	1	Machine inside	Wire type
Erector wireless receiver box	IP55	1	Machine inside	
Local cutter head operation box	IP55	1	Machine inside	Wire type
Ring holder operating box	IP55	0	Machine inside	
Remote box	IP55	4	Machine inside	
Traction operation box	IP55	1	No.1 back-up car	
Wear detection bit operation box	IP55	1	Machine inside	
Probe drill operation box	IP55	1	Machine inside	Wire type Option
Safe confirmation in the chamber operation box	IP55	1	Machine inside	
Inverter panel	IP55	1	No.2 back-up car	
No.1 Screw retraction operation box	IP55	1	No.2 back-up car	Wire type
No.2 Screw retraction operation box	IP55	1	No.2 back-up car	Wire type

Note *1) The monitor for belt conveyor is not carried on shield operation panel.

21.5 Low-Voltage Transformer:

Application	Specifications		Number of phase (ϕ)	Q'ty	Remarks
	Capacity (KVA)	Voltage V1/V2			
Lighting, Control	15	480 / 120	1	1	—
		480 / 100	1	1	—

21.6 Auxiliary Plug Socket and Lighting

Division		Quantity	Specification
Receptacle for power		2	3 Phase + Ground Voltage : AC480V,Capacity : 3.7kW
Receptacle for lighting	Machine inside	2	Single Phase + Ground Voltage : AC120V,Capacity : 500W
	No1 back-up car	2	
Receptacle for operation cabin		2	Single Phase + Ground Voltage : AC100V,Capacity : 500W

Fluorescent light with battery (Explosion proof)	7	Capacity : 20W Voltage : AC120V (Machine inside)
Fluorescent light With battery (Explosion proof)	3	Capacity : 40W Voltage : AC120V (Back-up car)
Fluorescent light	17	Capacity : 40W Voltage : AC120V (Back-up car)
Warning light with signal horn for erector device	2	Voltage : DC24V

21.7 Instruments

Division	Sensor	Indicator	Quantity
Pitching - rolling	Potentiometer ($\pm 3^\circ$)	Graphic panel ($\pm 3^\circ$)	2 sets
Shield jack stroke & speed	Linear Transducer	Graphic panel Stroke (0-2,300 mm) Speed (0-100mm/min)	4 sets
Cutter head articulation stroke	Linear Transducer	Graphic panel (0- 250 mm)	4 sets
Earth pressure	Strain gauge	Graphic panel	8 sets 6 sets on bulkhead, replaceable from the atmospheric side, 2 sets on screw casings
Shield jack hydraulic pressure	Pressure transmitter	Graphic panel	4 sets
Shield hydraulic pressure	Pressure transmitter	Graphic panel	1 set
Total thrust force	Common use shield jack hydraulic pressure	Graphic panel	1 set
Screw hydraulic pressure	Pressure transmitter	Graphic panel	2 sets
Cutter hydraulic press.	Pressure transmitter	Graphic panel	0 set
Screw revolution	Rotary encoder	Graphic panel	2 set
Screw gate stroke	Potentiometer	Graphic panel	1 set

Copy cutter stroke		Graphic panel	2 sets
Copy cutter control	Rotary encoder	Graphic panel	1 set
Cutter total revolution			1 set
Cutter speed	Rotary encoder		1 set
Erector rotation angle limit switch			1 set
Grease pump limit switch			1 set
Grease measuring valve limit switch			4 sets
Wear detecting bit	Manual	Pressure gage	4 sets
Oil tank temperature	Thermometer	Graphic panel	1 set
Oil tank level	Level switch	Graphic panel	1 set
Cutter bearing grease temperature	Thermometer	Graphic panel	2 sets
Cutter seal temperature	Thermometer	Graphic panel	4sets
Screw limit switch	Guillotine gate, Screw retraction		6 sets

22.0 Belt Conveyor:

Item	Specification	Remarks
Quantity	1 set	—
Type	Articulation type	R150m
Length of the equipment	15+46 = 61 m	—
Width of the belt	750 mm	MSHA
Carriage speed	Approx. 180 m/min	—
Carriage capacity	280 m ³ /H ($\eta=80\%$)	—
Driving motor	37 kW×4P×480 V×60 Hz×1pc.	—
Belt scale	2 pcs.	—
Emergency stop	2 pcs.	Pull wire type
Warning light & alarm	2pcs.	
Operation panel	2 pcs (Operation room & Back-up car)	

A 750mm wide belt conveyor is provided to transport excavated material from the screw conveyor discharge point to the continuance belt conveyor. The belt conveyor is supported throughout the back-up cars and lateral movement is possible to negotiate curve radius. Pull wire type emergency stops are provided along both sides of its length for safety. The amount of excavated material is weighed by two belt scales installed on the conveyor and indicated on the operating panel, and can be compared with calculated amount. The belt conveyor starts operation approx.10 seconds after the notification by warning alarm, when the power is on. Fire resistant conveyor belt is used.

23.0 Segment Transporting Device:

Item	Specification	Remarks
Quantity	2 set	—
Loading capacity	Max. 53.4kN (12 ton) total	2 hoists, 6 ton capacity each, working in tandem
Traveling motor	1.5kW×4P×480 V×1 pc.	10.0m/min
Lifting motor	3.5 kW×3P×460 V×2 pcs.	4.8m/min
Traveling type	Chain & pinion type	—
Frame type	Twin beam	—
Control panel	1 pc.	—
Operating box	1 pc.	—
Limit switch	2 pcs.	Over-run

24.0 Additive (Bentonite and/or Polymer) & Foam Injection Equipment:

Application	Specification	Remarks
Additive holding tank (with agitators)	10.8 m ³ With agitator 1.5 kw×5 pcs.	
Additive injection pump	Max.240 ℓ/min×Max 1.0 MPa + 11 kW × 3 sets	
Additive flow meter	3	
Additive pressure sensor	3 pcs.	
Additive control panel	2 pcs.	
Foam solution injection pump	Max.35ℓ/min× Max1.5 MPa + 3.7 kW × 5 sets	

Foam generator	5 pcs.	
Air flow control & meter	5 pcs.	
Foam air compressor	22 kW, 2pcs.	One is for spare
Foam flow meter	5 pcs. for solution	—
Foam pressure sensor	5 pcs.	—
Foam control panel	5 pcs.	—
Tank with transfer pump	0.7 m ³ x 1 pc. + 0.75 kW x 1pc	—
Solution tank	1.5m ³ x 1 pc. + 0.4 kW agitator	—
Operation panel	1 pc.	Operation cabin
Polymer injection pump	2 pcs.	—

Additive and foam injection equipment is located on the back-up car and delivers the additive or foam to the face during excavation. Additive or foam stored in the tank is delivered to the injection points by injection pumps exclusively installed for additive or foam. Five foam outlets are provided on the face of the cutter head. Each injection point is supplied through an independent line installed through the rotary joint in the center of cutter driving shaft. Injection can also be made in the chamber via valves on bulkhead. Injection volume of additive can be controlled by the control of inverter motor speed.

Calculations verifying the design of the soil conditioner injection system are shown in Appendix 15. The foam injection equipment sizes have been reviewed by JCM and are expected to meet our needs for properly conditioning the excavated soils on this project.

25.0 Annulus Grout Injection Equipment on the Back-Up Car:

25.1a Two Component Type w/ Two Line Injection:

Quantity	1 set
Capacity	330 ℓ/min(110 ℓ/min×3 lines)
Grout injection pump	max100 ℓ/min×max 1.5 MPa×3 pcs. with 7.5kW × inverter mortar×3 pcs. Control panel ×3 pcs.
Silica acid injection pump	max10 ℓ/min×max 1.5 MPa×3 pcs. with 0.75kW × inverter mortar×3 pcs.
Agitator tank	4.7 m ³ ×1 pc. With agitators
Silica tank	1.0 m ³ ×1 pc. with a agitator

Pressure sensor	3 pcs. (each for 3 injection lines)
Flow meter	3 pcs. (each for 3 injection lines)
Valve unit	Electro/Air valve 3 sets
Valve control panel	1 pc.
Solenoid valve control panel	1 pc.
Control panel	1 pc.
Operation panel	1 pc. Operation cabin

25.1b Annulus Grout Cleaning By Water:

(Water will be sent by pumps into grout injection piping to flush out grout into a tank for waste water. The B pipes are exchangeable.)

Capacity	7.5kW× 3 pumps
Water pump	90L/min × 3 pumps
Water tank (Receiver tank from surface)	1.0 m ³ ×1 pc.
	Ultrasonic level sensor ×1 pc.
	Transfer valve ×2 inch ×1 pc.
Drainage tank	1.5 m ³ ×1 pc.
Control valves, Power panel	One set
Operation panel	One panel in the operation room

26.0 Fire Suppression System:

The TBM and trailing equipment will be equipped with a combination of dry chemical and water based fire suppression systems.

- A pre-engineered dry chemical fire suppression system will be installed on the electro-hydraulic power plants on the TBM trailing gear.
- Portable dry chemical fire extinguishers will be installed at regular intervals within the TBM and along the trailing gear.
- Water hose outlet connections will be installed at regular intervals along the trailing gear.
- A water curtain will be installed at the trailing end of the trailing gear.

26.1 Dry Chemical Fire Suppression System:

The fire suppression system is a pre-engineered, self contained, permanently mounted spray nozzle assembly. The system comes complete with containers filled with a dry extinguishing agent, gas filled cartridges for pressurizing the chemical tank, and remote manual actuators.

Electric Detection System

Components:

- Control Module
- Internal Lithium Battery
- Sounder Audio output is 82 Decibels
- Vibration and Shock Resistant
- MSHA and FM Approved
- Manual Detection

Thermal Spot Detectors:

- Spot Detectors, +88°C activation temperature, Strategically Positioned

Dry Chemical Extinguishing Agent:

- Ansul FORAY (mono ammonium phosphate base) dry chemical
- Effective on Class A, B, and C fires

Nitrogen Filled Cartridge:

- 1 No. Cartridge for each Dry Chemical Tank
- Pressurizes Dry Chemical Tank upon manual detection

Remote Actuator:

Manual actuation of system, Nitrogen filled

27.0 Probe Drill:

Item	Specification	
01) Type	Rotary drill / HC-53B	
02) Boring diameter	50 mm (rod)	
03) Boring rod	Length	1 m
	Quantity	30 pcs.
04) Boring length	Max. 20 m	
05) Power unit	Hydraulic unit to be co-used.	

The rotary drill (HC-53B) serves both for forward drilling and sampling. The probe drill can be mounted on the working deck in the shield machine to allow forward drilling through the cutter head for the purpose of probing ground conditions and to carry out ground treatment to the face. The boring rod is driven by hydraulically operated drill unit comprising of a hydraulic motor and a jack. Drill unit drives the boring rod 500 mm forward by one stroke and return to start position repeatedly by hand lever manually.

28.0 Gas Monitoring System:

28.1 Gas Monitoring System

Application		Quantity	Location
01) Detector	Carbon monoxide (CO)	1 pc.	Control Panel
	Nitrogen oxides (NO2)	1 pc.	Control Panel
	Hydrogen sulfide (H2S)	2 pcs.	Forward Bulkhead, Control Panel
	Oxygen (O2)	2 pcs.	Forward Bulkhead Control Panel
	Methane (CH4)	4 pcs.	Forward Bulkhead Screw discharge outlet Belt conveyor discharge Control Panel
02) Indicator		1 set	Operation cabin
03) Warning alarm		2 pcs.	Machine inside No.1 back-up car
04) Uninterrupted power supply (UPS)		—	—

Gas monitoring system is composed of a detector (sensor) and an indicator for each gas. The indicator shows at all times the concentration of gas in the atmosphere. When the concentration of gas exceeds the limitation of each gas concentration value, it is notified by warning alarm. Controller and indicator is installed in the purged panel. This information is continuously data logged.

29.0 High Voltage Transformer:

Application	Specification	Remarks
Capacity	2,000kVA	Supplied by JCM-JV
Primary voltage	13,800 V	—
Secondary voltage	480 V	—
Number of phases	3	—
Quantity	1 pc.	—

30.0 CCTV SYSTEM:

Division	Quantity	Remarks

Video camera	2 pcs.	—
Color monitor	1 pc.	Switching type Operating cabin
Cable	1 set	From cameras to a monitor in the operating cabin

CCTV (closed circuit television) system is provided with two cameras and three monitors. The sight from two cameras can be monitored at the operating cabin. The color monitors can reflect two pictures from two cameras located at the screw gate and the head pulley of the belt conveyor on the same screen. It can be readily changed to one magnified picture.

31.0 Guidance & Data Acquisition Systems:

30.1 Guidance System:

Division	Quantity	Remarks
Target (prism type)	2 pcs.	Machine inside
Back Target (prism type)	1 pc	In the tunnel
Industrial control device	1 pc.	Operation cabin
Control panel	1 pc.	Operation cabin
Motorized theodolite (total station)	1 pc.	—
Theodolite interface box	1 pc.	Tunnel
Cables in TBM and on back up cars	1 set	—
Software	1 set	—
Data analyzer	1 pc.	Site office

Guidance system is composed of the targets, an industrial control device and a motorized theodolite, and related software. This system can display the precise position and orientation of the TBM on a continuous basis with numerical and graphical display of horizontal and vertical deviation from the design tunnel axis calculate the designed tunnel axis and direction with respect to the design tunnel axis This system can display the position and orientation of the erected rings with the horizontal and vertical deviations from the design tunnel axis. This system can calculate and display correction curve with interactive parameter setting. This system monitors, records, and displays the excavation data such as date, time, segment ring, tunnel station values of design tunnel axis, as-driven coordinates and elevations, horizontal and vertical offsets, the number and orientation of tapered segment rings, extensions of propulsion and articulation angles. This data is transmitted to the Data monitoring and recording system and displayed on a monitor for the Data monitoring and recording system in the office on surface.

The guidance system is described in considerable detail in Appendix 18.

30.2 Data Monitoring and Recording System:

Division	Quantity	Remarks
01) Data analyzer	2 pcs.	1 pc is in site office. 1 pc is in operation cabin.
02) Data output device	1 pc.	Site office
03) Software	1 pc.	—
04) Interface	1 pc.	Tunnel, Surface

This system can monitor, acquirer, storage and display the real-time data of the component such as propulsion cylinders, articulation cylinders, cutter head driving, electric motors, main bearing and bearing seals, TBM guidance system, face support pressure, belt conveyor including muck weights, additive and foam injection system including bentonite injection volume for face support and foam injection ratio, No.1 screw conveyor, No.2 screw conveyor, tail seal grease device, back fill grout injection system, and the data supplied by JCM including compressed air pressure and flow.

Hitachi Zosen Data Logging System

The TBM is equipped with a PLC (Programmable Logic Controller). The PLC is used to control the machine and / or to read information from sensors.

Any information in the PLC can be sent to and displayed with MMI software (Man Machine Interface). The MMI software, which must be run on a PC (Windows), can also be used to record information.

The DLB system features one terminal in the TBM (LCD display) and two desktop PC stations at the surface. The unit in the TBM is connected to the surface computers by a cable link and external Short Haul Modem (the communication cable will be supplied by Hitachi Zosen). The terminal in the TBM will display data in real-time; the computers in the office will display data in real-time as well as historic modes and will record information on their hard drives. From the computers in the office, TBM data can be printed (printers are not included) or copied to disks. The personal computers installed at the surface are for display and storage of TBM data only.

As a minimum, the data acquisition and logging system will monitor and record information from the following points / systems of the TBM:

- Automatic Recording of Information
- Cutter head RPM
- Cutter head Torque
- Cutter head Direction

- Total TBM Electric Current Draw
- Main Drive Motor Electric Current Draw

Articulation Cylinder Extension Flood Control Door Opening	Main Bearing Lubrication Flow and Pressure Hydraulic Oil Temperature Earth Pressure Cells
Propulsion Cylinder Pressure Centre of Thrust	TBM Penetration Rate Tunnel Chainage
Belt Drive Motor Hydraulic Pressure	Gas Monitoring Ground Conditioning System Output
Screw Conveyor RPM	Guidance System Output
Screw Conveyor Torque	Grout Injection System Pressure and Flow
Screw Conveyor Internal Pressure Screw Conveyor Guillotine Door Opening	Tail Seal Grease Injection Volume Volume of Soil

Start & Finish Time of Push: Manual input to initiate timer when the push starts and stops
Start & Finish Time of Ring Erection: Manual input to initiate timer when the push starts and stops

* The system is expandable to accommodate the addition of more monitoring points.

Sample TBM operation screens are shown in Appendix 19.

32.0 Back-Up Ventilation/Duct:

32.1 Air Duct

Item	Specification
01) Quantity	1 pc
02) Duct size	φ900 mm.
03) Material	Galvanized steel pipe
04) Position	From No.7 back-up car to TBM inside

32.2 AUXILIARY VENTILATION SYSTEM

- 60-HP MSHA Approved Gassy
- 800 m³/min air flow capacity
- Electric Fan – Bi-Directional
- Silencers
- Rigid and flexible ducting from fan location to front of trailing gantry

33.0 Back-Up Safety Barrier:

33.1 Physical Barrier for Rail Equipment

Item	Specification
01) Quantity	1 pc.
02) Type	Rail stopper, Fixed type
03) Position	At the front end of back-up cars (Front of No.2 screw supporting car)

The barrier is installed at the front end of back-up cars and prevents rubber tire vehicle (RTV) from running away into the working area in the tail of shield machine beyond the back-up cars.