826EM00006	Rev. A	Page. 1/49

DIFFUSION

For Application

For Information

Description of TBM Technical parameters

-

TABRIZ METRO TBM
1331/372/S9
- EPB - ∅ *6880* –

27/03/07	M. ERRAHOUTI		27/03/07	F. JANNEAU		27/03/07	R. LEDIEU		
	Author			**Checked**			**Approved**		
Date	Serv.	Visa	Date	Serv.	Visa	Date	Serv.	Visa	

REVISION SHEET

Revision	Date	Status	Observations
A	27/03/07	Preliminary	Preliminary

TABLE OF CONTENTS

Shield assembly

1.1 DESCRIPTION

The shield unit is mainly composed of:

a **cutter head**

a **shield**

The space between the cutter head and the shield is called the " **cutting chamber** ". Its function is to receive and ensure the mixing of excavated materials.

As the cutting chamber is to be subjected to confining pressure, it is separated from the shield by an airtight bulkhead and connected with the shield by means of a manlock.

This bulkhead is equipped:

with earth pressure sensors distributed symmetrically on either side of the vertical axis.

with pressure sealed tubes that ensure the passage of the necessary products such as water, foam bentonite, recacking, compressed air, electricity, etc.,

with breathable air tubes that pressurise the chamber,

with a safety hatch situated in the lower part (passage of the screw conveyor).

A video circuit composed of 2 cameras allows the muck in the cutting chamber and at the various piers in the belt conveyors to be observed.

1.2 CHARACTERISTICS

Diameter of the front shield ..... 6860 mm

Total length of the shield (front and rear)..... 9925 mm

Total weight of the shield (front and rear)..... 412 t

ELECTRIC AND AIR DISTRIBUTION IN THE CUTTING CHAMBER:

1 × 24V (16A)

Industrial air DN

ELECTRIC AND AIR DISTRIBUTION IN THE SHIELD:

2 × 24V (16A)

3 × 230V (16A)

1 × 400V (32A)

Industrial air DN

1.3 CUTTER HEAD

1.3.1 DESCRIPTION

The cutter head is a welded assembly whose purpose is to excavate the ground. The cutter head is off-centred towards the top of the tunnelling machine's axis. The design of the wheel was chosen in particular to avoid clogging of clays and decomposed granite. Openings on the face are organised so as to limit the dimension of the blocks to the absorption capacity of the screw conveyor.

The cutter head is mainly equipped with:

Cutting tools

2 copy cutters,

an **injection circuit** for supplied products (foam, water) distributed on the surface of the cutter head. A rotary seal connect the tubing from the fixed parts to the rotating parts of the cutter head.

The characteristics and main components of the cutter head are described below.

1.3.2 CHARACTERISTICS

Cutter head length ..... 1405 mm
Opening ratio ..... 31 %
Excavation diameter ..... 6880 mm
Excavation diameter (with copy cutter) ..... 6965 mm
Point number for foam injection 6
Arms number 6

1.3.3 CUTTING TOOLS

1.3.3.1 DESCRIPTION

There are 5 types of cutting tools:

5 types of cutter bits:

Extreme cutter bits, used to calibrate the tunnel diameter

Central cutter bits, used for cutting,

Normal cutter bits, used for cutting

Bucket knife bits, used for cutting

Drag bits, used for cutting

The Drag bits are used to scrape and break down the wall.

They are equipped with tungsten carbide pads. The tools are accessible from the cutting chamber for replacement operations.

A handling device is provided optionaly for the purpose of supplying disk cutters from racks on the backup train to the manlock.

1.3.3.2 CHARACTERISTICS

Number of scraper bit (cutter bit) 98

Number of peripheral bucket tool 12

Number of protection bit 20

Number of ripper :

..... 46

Alternative solution :

Number of cutter disk 22

Number of ripper 24

Drawings (826PE01010)

1.3.4 COPY CUTTER

1.3.4.1 DESCRIPTION

The Cutter Head includes 2 copy cutters (1 + 1 standby).

The copy cutters allow the diameter of the cut to be varied. They are used only during direction change phases. They are mounted on the cutter head, diametrically opposite to each other.

During normal operation only one of these tools can work, the other remains as a backup.

The "copy cutter" is composed of 1 hydraulic cylinder supplied by a pumping unit, JZ 8000 situated in the cutter head.

The hydraulic cylinder controls a knife tool.

The “copy cutters’ are lubricated by the centralized greasing system via the rotary seal.

1.3.4.2 CHARACTERISTICS.

Copy cutter number 2

Stroke ..... 85 mm by radius

HYDRAULIC CYLINDER

JZ 8000 (independent power station)

Power ..... 11 kW

Speed ..... 1 440 rpm

Flow max ..... 26 l/min

Fixed cylinder capacity ..... 18 cm^3/rev

Operating pressure ..... 210 bars

Tank capacity ..... 100 liters

1.3.5 ROTARY SEAL

1.3.5.1 DESCRIPTION

The rotary seal ensures the tubing connection between the fixed parts and the rotating parts of the cutter head. The rotary seal is maintained on the airtight bulkhead of the cutting chamber. It is composed of:

6 lines: Supply of the foam injection ramps

4 lines: Hydraulic supply to the “copy cutter” cylinders,

2 lines: “Copy cutter” lubrication ,

The rotary seal is also equipped with 2 orifices that receive grease to allow its own joints to be lubricated.

1.3.5.2 CHARACTERISTICS

Oil ports 4

Foam ports 6

Internal greasing (NGLI2)..... 2

Greasing (HBW)..... 2

1.4 SHIELD

1.4.1 DESCRIPTION

The shield has a tapered form and is composed of a **front shield** (divided into two parts: the **frontal** and **intermediate** shields) and a **rear shield** joined by a passive articulation. The assemblies between the removable parts are bolted. The shield’s bulkhead is pierced with holes intended to allow the injection of products.

The **front shield** situated behind the cutting chamber has the following main functions:

to support the cutter head’s motor unit,

to confine the machine with respect to the terrain,

to support the manlock and material lock

to support the thrust and articulation cylinders,

to support the screw conveyor,

The different product injections are :

Industrial water

Foam

Bentonite

Breathable air

The **rear shield** situated behind the front shield has the following main functions:

to confine the machine with respect to the terrain,

to support the segment erector,

to support the injection lines for grout.

The characteristics and main components of the shield are described below.

1.4.2 CHARACTERISTICS

Front shield diameter ..... 6860 mm

Intermediary shield diameter ..... 6855 mm

Rear shield diameter ..... 6850 mm

Gap between segment and rear shield ..... 30 mm on radius

Earth pressure sensor 5

ELECTRIC, AIR AND WATER DISTRIBUTION IN THE SHIELD:

3 × 230V (16A)

1 × 400V (32A)

2 x Industrial air DN20

1 x Industrial water DN20

DISTRIBUTIONS IN THE CUTTING CHAMBER:

3 × 24V (16A)

2 x Industrial air DN20

1 x Industrial water DN40

1 x Bentonite recaking DN25

1.4.3 WALKWAYS

Circulation within the shield can occur on two levels.

Two ladders allow passage from one level to another located in each side on the erector beam

A platform provides access to the personnel manlock.

Behind the erector, a platform can be used, only during maintenance operation. The erector must be at a standstill, and the emergency shut down must be activated.

Circulation in the cutting chamber for replacement is described in section 4.

1.4.4 DRIVE UNIT

1.4.4.1 DESCRIPTION

The purpose of the motorization is:

to transmit loads from the cutter head towards the shield,

to drive the rotation of the cutter head,

to transmit the torque required for digging.

The rotation of the cutter head is ensured by 8 hydraulic gear motors that drive a central slewing ring integrated in the cutter head.

The motorization allows the cutter head to rotate very slowly allowing the replacement of the cutting tools.

The motorization is lubricated by 2 lubrication circuits.

The seal between the cutting chamber and the bearing is made using wiper seals. A greasing system injects grease into the compartments of the wiper seals to protect them from contact with the debris.

The bodies of the electric motors, the reduction gears and the wiper seals are cooled by the industrial water circuit.

1.4.4.2 CHARACTERISTICS

Main bearing.....Axial/radial

Sealing system.....2×5 joints

Variable Speed.....0 to 4 rpm

Maximum Nominal torque (efficiency 100%) ..... 8960 kN.m at 1,05 rpm

Maximum Nominal torque (efficiency real)..... 6180 kN.m at 1,05 rpm

Unlocking torque (efficiency 100%) .....11930 kN.m

Unlocking torque (efficiency real).....8112 kN.m

Torque at maximum speed (efficiency 100%)..... 2352 kN.m at 4 rpm

Torque at maximum speed (efficiency reel)..... 1607 kN.m at 4 rpm

Drive by hydraulic motors..... 8

Ratio pinion / gear ..... 15/119 Modulus 22

Ratio of gear box GMH 200 R3..... 109,02

Output maximum speed of gear box.....31,7 rpm

Output torque of gear box (reel efficiency)..... 100,4 kN.m – 8.3 rpm

Power of hydraulic motors JV1100 à JV1300.....945 kW

Nominal speed .....900 rpm

Maximum speed.....3459 rpm

Output torque ..... 979 N.m at 900 rpm

Variable cylinder capacity .....75 to 249 cm^3/rev

Operating pressure ..... 260 / bars

Power supply by 4 hydraulic power packs JZ1100/1200/1300

Unit Power .....3*315 kW

Speed .....1480 rpm

Variable flow .....3 x 706 l/min

Variable cylinder capacity ..... 3 x 492 cm^3/rev

Operating pressure ..... 280 bars

1.4.5 AIR LOCKS

1.4.5.1 DESCRIPTION

The air locks allow the operating personnel and their equipment to access the cutting chamber, by passing from atmospheric pressure to confinement pressure, and the reverse on return.

The air locks are composed of :

2 manlocks (1 transfer manlock named main chamber and 1 emergency manlock named auxiliary chamber) aligned with the upper part of the shield.

The transfer manlock includes all necessary and required equipment for the supply and control of compressed air, lighting and communication (1 telephone, 1 interphone and a genephone).

It is intended for a team of 3 peoples.

The emergency manlock allows access to the transfer manlock for 2 persons equipped with rescue equipments.

Access to the manlock is assisted by a manlock supervisor situated outside the manlocks for the full duration of manlock occupation.

1 material lock (right) near the central axis of the shield.

The material lock allows the storage and transfer of tools and equipment (cutting tools, etc.) from the front Shield to the cutting chamber.

The material lock is equipped with a tilting table to facilitate the transfer of equipment and tools.

1.4.5.2 CHARACTERISTICS

MANLOCK:

Maximum operating pressure.....3,5 bar

Chamber number 2

Number of personnel per chamber ..... 3 + 2

Maximum flow in the cutting chamber - 3 bar ..... 1130 Nm^3/h

MATERIAL LOCK

Quantity 1

Maximum operating pressure.....3,5 bar

1.4.6 MAIN THRUST

1.4.6.1 DESCRIPTION

The purpose of the tunnelling machine's main thrust system is to ensure the **forward motion** of the machine. The thrust cylinders are also used to maintain the segments in place while they are positioned.

The tunnelling machine's thrust is ensured by 22 cylinders distributed around 4 piloting sectors. The cylinders thrust force is transmitted to the segments by 11 pads shared by twin cylinders. There are two types of cylinders:

→ Normal cylinders,

→ Cylinders with elongation sensors sensors that allow the forward progress of the machine to be measured in real time.

*The information is displayed in the monitoring system in the control cabin (see position on scheme **826 SHCZ002**).*

The cylinders are powered by 1 hydraulic pump unit, JZ 2000, JZ 2010, JZ 2020 situated on gantry 2 of the backup train.

The thrust cylinders are managed in 2 hydraulic states:

A "**low pressure**" state used during segment positioning.

In this state, the pad pressure is reduced to a force sufficient to ensure the segments are safely maintained and the seal is pressed between the ring. In "low pressure" the tunnelling machine does not advance.

A "high pressure" state used during forward motion of the tunnelling machine. In this state the pads are under "high pressure". The high pressure generates the thrust force of the pads on the segments.

1.4.6.2 CHARACTERISTICS

Number of thrust cylinders ..... 22 (11 pairs)
Cylinder Stroke ..... 2200 mm
Piston diameter ..... 270 mm
Rod diameter ..... 220 mm
Elongation sensor 4
Initialisation detector 4

EXCAVATION MODE

Maximum advance speed ..... 80 mm/min
Maximum thrust/pressure ..... 44088 kN / 350 bar
Thrust by cylinder ..... 2004 kN
Exceptional thrust/pressure (Unlocking) ..... 385 bar
Test pressure ..... 525 bar
Maximum specific thrust ..... 1191 kN/m²
Adjustable pressure ..... 4 groups

Selection of cylinders 11

SEGMENT PLACING MODE

Max extension speed (4 cylinders) ..... 2 000 mm/min

Max retraction speed (4 cylinders) ..... 3 000 mm/min

Thrust by cylinder (piston side) .....572,5 kN

Maximum pressure..... 100 bars

Hydraulic pump JZ2000/2010

Power .....75 kW

Speed .....1 475 rpm

Variable flow (JZ2000) .....0 à 105 l/min

Variable cylinder capacity (JZ2000)..... 0 à 75 cm^3/rev

Fixed flow (JZ2010).....208 l/min + 180 l/min

Fixed cylinder capacity (JZ2010) ..... 139 cm^3/rev + 122 cm^3/rev

Operating pressure ..... 100 / 350 bars

Maximum pressure (JZ2000) ..... 350 bars

Maximum pressure (JZ2010) ..... 100 bars

Exceptional pressure Unlocking..... 385 bars

1.4.7 ARTICULATION

1.4.7.1 DESCRIPTION

This device allows the front shield to be articulated with respect to the rear shield in an airtight manner to allow the tunnelling machine to follow the curve of the tunnel. The articulation is composed of:

9 hydraulic cylinders,

4 elongation sensors

sealing scales,

1 ball joint,

2 articulation seals.

The elongation sensors give the position of the front body with respect to the rear body. The information is displayed in the monitoring in the cabin control.

The cylinders are motorised by a pumping unit (JZ 2000/JZ2010) situated on gantry G2 of the backup train.

The airtight seal and the ball joint situated between the 2 shields ensure the confinement of the articulation.

A scaled deflector insulates the terrain articulation from external forces.

The cavity created between the seal and the scales is filled sequentially with tail seal grease from 7 injection points distributed on the periphery and in the thickness of the rear shield (**826SHCM001** and **826PE23001)**.

The cavity between the two seals is filled sequentially with NLGI2 grease (**826SHCG001**).

The tail seal grease and the NLGI2 grease are distributed by grease pumping unit situated on connecting beam CB2.

1.4.7.2 CHARACTERISTICS

Driven by hydraulic pump JZ2000/2010 (thrust)

Number of articulation cylinders 9

Cylinder stroke ..... 170 mm

Piston diameter ..... 230 mm

Rod diameter ..... 75 mm

Maximum thrust ..... 11696 kN

Thrust by cylinder ..... 1300 kN

Operating pressure ..... 350 bars

Test pressure ..... 525 bars

Flow ..... 50 l/min

Retraction speed of tail shield ..... 300 mm/min

Maximum angle ..... 1,5°

Elongation sensors 4

1.4.8 ERECTOR

1.4.8.1 DESCRIPTION

The purpose of the erector is to grip, handle and position the segments to build up the rings. The segments are drawn to a loading station via the segment transport table by the backup train.

The erector is composed of 2 main sub-assemblies:

a **rotation/lifting** sub-assembly (2 degrees of freedom),

a **segment gripping table** sub-assembly (3 degrees of freedom),

These 2 sub-assemblies are supported by casing (rotor). This casing is mounted on the fixed framework of the erector (stator) by the intermediary of the slewing ring.

The rotor is driven in **rotation** by a hydraulic motor, a pinion and a toothed annular gear fixed to the erector's stator (the rotation is limited to ± 220° by end of stroke detectors taken from encoder). While the segments are being positioned, the rotation supplied equals the torque required to compress the segment seals.

The gripping table is mounted on the rotor using a cradle guided by two guide bars and **moves radially** with the help of two hydraulic cylinders.

Two translation cylinders ensure the axial movement of the gripping table via horizontal guide bars fixed to the rotor.

The gripping system is integrated to the table and is based on a cylinder which grabs a mushroom head insert screwed in the segment.

The position of the segment on the ring is pre-defined. Its definitive positioning is ensured by 3 degrees of rotational freedom:

a rotation of a few degrees with respect to the vertical axis (pivot). The rotation of the segment is carried out using 1 hydraulic cylinder and a fixed axle..

a tilting based on 3 points (rolling and pitching) ensured by 2 balancing hydraulic cylinders situated on either side of the gripping table and a pivoting cylinder mounted axially in the centre of the table. These 3 cylinders form a triangle and can be activated separately. Operation of a cylinder leads to tilting of the segment with respect to the anchoring points of the other 2 cylinders.

The translation, rotation and radial displacement movements can occur at variable speeds. The other movements are one speed movement.

The rotational hydraulic gear drive is powered by a pumping unit (JZ 5000) situated on gantry 2 of the backup train.

The other cylinders are powered by a pumping unit (JZ 5302) situated on the backup train.

The extension and retraction of the cylinder rods are actuated by the solenoid valves of the distribution blocks.

The erector actuators are all controlled using a radio-control system.

1.4.8.2 CHARACTERISTICS

Nominal capacity ..... 45 kN

Number of driven axis 6

ROTATION

Variable speed ..... 0 to 2 rpm

Stroke ..... ± 220°

Maximal dynamic torque ..... 162 kN.m

Average dynamic torque ..... 110 kN.m

Static torque ..... 330 kN.m

Slewing bearing pitch diameter ..... 2595 mm

Hydraulic gear box 1

Ratio gear / pinion ..... 162 / 13 Module 16

Pinion pitch diameter ..... 208 mm

Gear box ratio 104

Output static torque ..... 26,4 kN.m

Output maxi dynamic torque ..... 13,0 kN.m

Average dynamic torque ..... 8,8 kN.m

Motor speed ..... 2592 rpm

Brake torque ..... 400 N.m

Cylinder capacity ..... 63 cm^3/rev

Motor torque ..... 125 N.m

Hydraulic power pack JZ5000

Power ..... 45 kW
Speed ..... 1465 rpm
Flow variable ..... 0 to 176 l/min
Cylinder capacity ..... 140 cm^3/rev.
Operating pressure ..... 210 bars
Operating pressure (seal compression) ..... 315 bars

LIFTING

Retraction speed ..... 0 to 1,5 m/min
Extension speed ..... 0 to 1,1 m/min
Stroke ..... 800 mm
Driven by 2 hydraulic cylinders
Piston diameter ..... 100 mm
Rod diameter ..... 50 mm
Cylinder section piston side ..... 15700 mm^2
Cylinder section rod side ..... 11800 mm^2
Maximum force piston side ..... 330 kN
Maximum force rod side ..... 240 kN
Operating pressure ..... 210 bars

TABLE TRANSLATION

Retraction speed ..... 0 to 17500 m/min
Extension speed ..... 0 to 10600 m/min
Stroke ..... 2100 mm

Driven by 2 hydraulic cylinders
Piston diameter ..... 80 mm
Rod diameter ..... 45 mm
Cylinder section piston side ..... 10100 mm^2
Cylinder section rod side ..... 6873 mm^2
Stroke ..... 2100 mm
Maximum force piston side ..... 25,1 kN
Maximum force rod side ..... 15,1 kN
Maximum nominal force piston side with two cylinders ..... 181 kN
Maximum nominal force rod side with two cylinders ..... 110 kN
Operating pressure ..... 180 bar

Exceptional pressure rod side (for segment ring dismantling)..... 300 bar

BALANCE

Stroke ..... ±3 ° about 2 axis
Speed (according setting) ..... 1.5 m/min ± 0.6 °/s
Driven by 3 hydraulic cylinders (1 front + 2 rear)
Piston diameter (front/rear) ..... 80/60 mm
Rod diameter (front/rear)..... 45/40 mm

Cylinder section piston side (front/rear) ..... 50,3/28,3 cm^2
Cylinder section rod side (front/rear)..... 34,4/15,7 cm^2
Stroke ..... 60 mm
Maximum force piston side per cylinder (front/rear) .....105,6/59,3 kN
Maximum force rod side per cylinder (front/rear).....72,2/33,0 kN
Operating pressure ..... 210 bar

TABLE ROTATION

Stroke .....±3°
Speed (according setting) ..... 0.5 m/min ± 0.6 °/s
Driven by 1 hydraulic cylinder
Piston diameter ..... 60 mm
Rod diameter..... 40 mm
Cylinder section piston side .....2827 mm^2
Cylinder section rod side.....1570 mm^2
Operating pressure ..... 210 bars
Maximum force piston side .....59,3 kN
Maximum force rod side.....34 kN

SEGMENT GRIPPING SYSTEM

Stroke ..... 100 mm
Retraction speed ..... 3,3 m/min
Extension speed..... 1,9 m/min
Driven by 1 hydraulic cylinder
Piston diameter ..... 80 mm
Rod diameter..... 50 mm
Cylinder section piston side .....5026 mm^2
Cylinder section rod side.....3063 mm^2

Stroke ..... 100 mm

Maximum force piston side ..... 105 kN

Maximum force rod side ..... 64 kN

Operating pressure ..... 210 bars

Driven by hydraulic power pack JZ5302

Power ..... 37 kW

Speed ..... 1 450 RPM

Flow variable ..... 0 to 80 l/min

Variable cylinder capacity ..... 55 cm^3/tr

Operating pressure ..... 210 bars

1.5 CONNECTING BEAM CB1 AND CB2

1.5.1 DESCRIPTION

The connection beam is a structure that ensures the connection between the front shield and the backup train.

The connection beam CB1 supports:

A skid for foam production,

The pumps for tail seal grease and grease.

A storage area for tail seal grease and grease drums,

The bentonite pressure vessel,

The rail handling hoist,

The barrels handling trolley

The travelling rail for segment handling hoist,

A passage area for racks of cutting tools fitted with a carriage for barrels.

A dewatering pump,

The belt conveyor,

The ventilation duct,

The walkways to access the control cabin and the shield,

The electric supply cabinet CDR0,

Disc cutter handling monorails,

The video cameras used for monitoring the screw gate and the segment gripping.

ELECTRIC AND AIR DISTRIBUTION:

1 × 230V (16A)

1 × 400V (32A)

1 valve Industrial water DN20

The loudspeaker,

Lights and a floodlight,

The connection beam CB2 supports:

The segment handling hoist rail,

The barrel handling trolley,

The screw gate accumulator,

The screw gate hydraulic control and accumulator,

The foam solution regulation skid,

The belt conveyor,

The ventilation duct,

The walkway to access the shield,

A dewatering pump,

The erector fixed control panel,

The emergency dewatering pump,

The grouting distributors,

The control cabin,

The bentonite pressure vessels,

The segment conveyor control box,

The connecting beam tows:

The backup train, attached by means of a fork and a dynamometric axle ,

The segment conveyor,

The connecting beam CB1 and CB2 are principally made up of:

Welded frameworks,

Two bogies each equipped with 2 elastic polyurethane wheels that rest on the tunnel lining, thereby ensuring pulling and steering,
Each wheel can be oriented up to an angle of ± 3 degrees. The orientation is adjusted using an oil cylinder (one cylinder per bogie).

The wheel axes are equipped with greasers.

Supports for the belt conveyor and tubes.

1.5.2 WALKWAYS

Lateral walkways allow circulation on the backup train. The walkways are positioned on the right side of the back up train.

From the CB1 to the front shield two walkways exist on the right side and on the left side of the TBM.

Ladders placed at each end of the gantry allow access to the deck and to the belt conveyor.
Note: this zone shall only be accessed by maintenance people after stopping of the belt conveyor.

.

1.5.3 SEGMENT CONVEYOR

1.5.3.1 DESCRIPTION

The purpose of the segment conveyor table situated under the connecting beam is to transfer segments from the connecting beam CB1 to the erector.

The unit is made up of a welded supporting rolling structure which is mechanically linked to the connecting beam. This structure supports a table which translation movement is ensured by an hydraulic cylinder with a stroke of 1700 mm.

The table advances by a step of 1700 mm when actuated by the translation cylinder. The table is supported by twelve rollers which can be lifted up by a set of four cylinders thus ensuring a vertical displacement of the table.

The loading sequence of the segment conveyor is:

Table lifting up,
Deposit of segment on the table,
Frontward movement of the table with the segment,
Lowering of the table and deposit of the segment on the structure,
Backward movement of the table without segment.

The segment ring is constituted of 6 segments to be placed always in the same order :

Segment 1- Segment 2 - Segment 3 - Segment T1 - Segment T2 - Key

The translation cylinder and the lifting cylinders are supplied by a pumping unit (JZ 7000) situated on hydraulic skid of the backup train.

The table is controlled either from the erector's control box or from an auxiliary control box situated at the rear of the table.

1.5.3.2 CHARACTERISTICS

Capacity ..... 5+1 segment, 22.5 t

Stroke ..... 1 x 1 700 mm

Table forward speed ..... 127 mm/s

Table backward speed ..... 220 mm/s

Translation driven by hydraulic cylinder

Piston diameter ..... 100 mm

Rod diameter ..... 65 m

Cylinder section piston side ..... 7853 mm^2

Cylinder section rod side ..... 4535 mm^2

Stroke ..... 1700 mm

Maximum force piston side ..... 63 kN

Maximum force rod side ..... 36 kN
Operating pressure ..... 80 bars
Lifting driven by hydraulic cylinders
Number of lifting cylinders 4
Piston diameter ..... 100 mm
Rod diameter ..... 50 mm
Cylinder section piston side ..... 7853 mm^2
Cylinder section rod side ..... 5890 mm^2
Stroke ..... 60 mm
Maximum force piston side ..... 164,9 kN
Maximum force rod side ..... 123,7 kN
Operating pressure ..... 250 bars

Driven by hydraulic pump JZ7000
Power ..... 11 kW
Speed ..... 1 440 rpm
Flow ..... 60 l/min
Fixed cylinder capacity ..... 45 cm^3/tr
Operating pressure ..... 280 bars

1.5.4 CONTROL CABIN

The drive room is situated on connection beam G0 and is equipped with control apparatus and monitors to allow the operators to pilot the tunnelling machine.

The control cabin is air-conditioned.

The drive room is a walled-in area with glazed door.

2 MUCKING OF THE EXCAVATED MATERIAL

2.1 SCREW ASSEMBLY

2.1.1 SCREW CONVEYORS

2.1.1.1 DESCRIPTION

Its purpose is to take debris from the cutting chamber towards the belt conveyor situated on connecting beam CB2.

The screw conveyor is principally composed of:

→ A screw that extracts debris from the cutting chamber and is driven by a two speed hydraulic motor that powers the screw rotation. The variable speed of the screw in association with the opening of discharge gate allows debris extraction to be regulated in such a way that the earth pressure in the cutting chamber remains constant

→ A screw confinement casing composed of several tubes coated with internal wear protection allows retraction of the casing with respect to the shield by 2 hydraulic cylinders,

These cylinders are driven by a pumping unit (JZ 4500) situated on hydraulic skid of the backup train.

Sealing between the casing and the shield is ensured by grout supplied by the centralised greasing system. The grout is distributed from the pumps installed on hydraulic skid of the backup train.

Screw

The screw is equipped with wear parts on its periphery. The wear parts are accessible via removable hatches intended for their maintenance.

Casing

The casing is covered with an inner liner (smelted chromium molybdenum carbide).

Three injection ports in the casing allow injection of supplied products (foam, bentonite, water).

2.1.1.2 CHARACTERISTICS

Maximum discharging capacity	300 m^3/h
Screw internal diameter	900 mm
Screw rod diameter	200 mm
Fly number	14
Protective plate	112
Pitch	720
Maximum earth pressure	3,0 bars
Earth pressure sensor	2
Normal torque (real efficiency)	56 kN.m @ 20 rpm

Maximum torque (real efficiency) ..... 115kN.m @ 10.1 rpm
Normal torque (100% efficiency) ..... 85 kN.m @ 20 rpm
Maximum torque (100% efficiency) ..... 170 kN.m @ 10,1 rpm
Ratio of gear box 4,13
Hydraulic motor 2
Low speed ..... 10,1 rpm
High speed ..... 20 rpm
Cylinder capacity ..... 4996 cm^3 / 2498 cm^3
Maximum motor torque ..... 15,8 kN.m

Driven by 1 hydraulic power pack JZ4100 1
Power ..... 200 kW
Speed ..... 1 480 rpm
Variable flow ..... 0 to 520 l/min
Variable cylinder capacity ..... 355 cm^3/rev
Operating pressure ..... 230 bars

Cooling by integrated pump JZ4100
Flow ..... 120 l/min

2.1.2 SCREW CONVEYOR SAFTEY GATE

2.1.2.1 DESCRIPTION

The screw conveyor safety gate allows the cutting chamber to be isolated from the machine if a strong inflow of water occur or during maintenance period.

Situated in the lower part of the cutting chamber, it is opened and closed by 2 hydraulic cylinders driven by a pumping unit (JZ 4500) situated on hydraulic skid of the backup train.

The gate is composed of 2 guillotines that close the screw conveyor orifice as soon as the screw and casing are retracted.

2.1.2.2 CHARACTERISTICS

Driven by 2 hydraulic cylinders
Piston diameter ..... 160 mm
Rod diameter ..... 90 mm
Cylinder section piston side ..... 20106 mm^2
Cylinder section rod side ..... 13740 mm^2
Stroke ..... 580 mm
Maximum force piston side ..... 400 kN
Maximum force rod side ..... 270 kN

Operating pressure ..... 100 bars

Driven by hydraulic pump JZ4500

Power ..... 11 kW
Speed ..... 1 440 rpm
Variable flow ..... 0 to 60 l/min
Variable cylinder capacity ..... 45 cm^3/rev
Operating pressure ..... 250 bars

2.1.3 SCREW CONVEYOR GATE

2.1.3.1 DESCRIPTION

The screw conveyor is unloaded via a hatch with an adjustable opening. This allows the earth pressure to be regulated, and the machine's cutting chamber to be isolated from the tunnel.

Situated at the end of the casing, it is opened and closed by 2 hydraulic cylinders driven by a pump situated on hydraulic skid.

A hydraulic accumulator allows for emergency closure if an electrical failure should occur.

2.1.3.2 CHARACTERISTICS

Section of the gate ..... 745x720 mm
Driven by 2 hydraulic cylinders
Piston diameter ..... 100 mm
Rod diameter ..... 50 mm
Cylinder section piston side ..... 7853 mm^2
Cylinder section rod side ..... 5890 mm^2
Stroke ..... 910 mm
Maximum force piston side ..... 195 kN
Maximum force rod side ..... 147 kN
Maximum total effort during opening ..... 392 kN
Maximum total effort during closing ..... 294 kN
Operating pressure ..... 250 bar
Closing time ..... 14 s
Powered by hydraulic pump JZ4500
Emergency accumulator ..... 2 x 32 l

2.1.4 SCREW CONVEYOR DRIVE UNIT

The rotation of the hydraulic motor is driven by pump units (JZ 4100), situated on gantry G2 of the backup train.

The screw retraction is performed by means of 2 hydraulic cylinders

Piston diameter ..... 140 mm

Rod diameter ..... 80 mm

Cylinder section piston side ..... 15394 mm^2

Cylinder section rod side ..... 10367 mm^2

Stroke ..... 1200 mm

Maximum force piston side ..... 382 kN

Maximum force rod side ..... 257 kN

Total maximum effort during retraction ..... 764 kN

Total maximum effort during elongation ..... 514 kN

Operating pressure ..... 250 bar

Powered by hydraulic pump JZ4500 (

Power ..... 11 kW

Speed ..... 1 440 rpm

Flow ..... 60 l/min

Variable cylinder capacity ..... 45 cm^3/rev

Operating pressure ..... 250 bars

2.1.5 BELT CONVEYOR C2

2.1.6 DESCRIPTION

The belt conveyor is used to take the mucking from the screw conveyor to the rear of the back-up.

The belt tensioning is achieved by 2 cylinders suplied by a puming unit (JZ 9100). The tensionning is manually controlled by the means of a handle located nearby the muck diverter.

The rotation of the belt is driven by an electric gear motor located above gantry G7.

2.1.7 CHARACTERISTICS

Belt width ..... 800 mm
Length between drums ..... 75 m
Belt speed ..... 3 m/s
Theoretical flow ..... 450 t/h
Electrical gear box with hydraulic coupling
Reduction ratio 10,7
Maximum speed ..... 135 rpm
Speed of motor ..... 1450 rpm
Power of motor ..... 55 kW

2.2 BELT WEIGHER SYSTEM

2.2.1 DESCRIPTION

The belt weigher system weighs soil that comes from the chamber throught the discharge gate.

4 load cells are located on the belt conveyor. The electronic integrator is linked to the PLC which displays throught the monitoring screen the theoritical weigh and the actual weigh since the beginning of the stroke.

2.2.2 CHARACTERISTICS

Maximum speed ..... 3, 0 m/s
Maximun flow ..... 450 t/h
Nbr of load cells 2
1 speed sensor 1
Junction box 1
Electronic integrator 1

2.3 MUCK DIVERTER

Located in gantry G8, it allows the discharging of muck into buckets of the service train.
A structure controlled by 2 cylinders allows the muck to discharge in a first muck car and, when this one is full, to discharge in an adjacent muck car by displacement of an internal flap without any displacement
of the service train.

3 BACKUP SYSTEM

3.1 DESCRIPTION

The backup train is composed of 9 gantries (1 to 9). The gantries roll on rails fixed on transverse beam placed on the lining.

Each gantry is mainly composed of:

A metal structure with 2 floors composed of welded structure elements assembled together by bolts. The back up train is intended to :

- Support components and equipment,
- Give way to the service train up to the connecting beam CB2,
- Allow the personnel to circulate,

Six independent wheels except gantry G1 which is equipped with for wheels and two bogies of two wheels.

The axle of each wheel is equipped with a greaser.

The backup train is equipped with two separate lighting circuits. 2 x 18 Watt tubes.

The lighting system also includes emergency lighting devices.

3.2 CHARACTERISTICS

Gantries number including connecting beams..... 9 + 2

Total length of backup (without the shield) ..... 92,1 m

Type..... single track

3.3 WALKWAYS

Lateral walkways allow circulation on the backup train. The walkways are on the right side of the back up train. Removable ladders at each end of the backup train give access to the deck and to the belt conveyor.

3.4 GANTRY 1

Gantry 1 supports:

Grouting pumps,

Grouting tank, hopper and filling zone,

Grouting pumps,

Segment hoist travelling beam,

Loudspeaker,

Belt conveyor,

Ventilation duct,

AIR & WATER DISTRIBUTION :

1 * Industrial air DN20,

1 * Industrial water DN20,

3.5 GANTRY 2

Gantry 2 supports:

1000L polymer tanks,
Foam pumping unit,
Hydraulic pumps,
Segment hoist travelling beam,
Belt conveyor,
Ventilation duct,
AIR & WATER DISTRIBUTION :
1* Industrial air DN20,
1* Industrial water DN20,

3.6 GANTRY 3

The gantry 3 supports:

2000L tensio-active product tanks,
Power cabinets (AP07/08/09/10/11/12),
Hydraulic tank,
Oil filtration,
Electric distribution cabinet,
Loudspeaker,
Belt conveyor,
Ventilation duct,
AIR & WATER DISTRIBUTION :
1* Industrial air DN20,
1* Industrial water DN20,

3.7 GANTRY 4

Gantry 4 supports:

Main Transformer,
Power cabinets (AP01/02/03/04/05/06),
Belt conveyor,
Ventilation duct,
AIR & WATER DISTRIBUTION :
1* Industrial air DN20,
1* Industrial water DN20.

3.8 GANTRY 5

Gantry 5 supports:

Breathable air tank 5 m^3 and filter skid,
Industrial air tank 1 m^3 and filter skid,

Dewatering tank,

Dewatering pump unit EXP05,

HV cell,

Industrial and breathable air filter skid.

Belt conveyor

Loudspeaker,

Ventilation duct,

AIR & WATER DISTRIBUTION :

1* Industrial air DN20,

1* Industrial water DN20,

ELECTRIC DISTRIBUTION CDR05:

3 × 230V (16A),

1 × 400V (32A).

3.9 GANTRY 6

Gantry 6 supports:

Breathable air compressor,

Industrial air compressor,

Cooling and hot water tanks,

Water pumps units (EGP1/2/3/4/5, ECP01)

Belt conveyor,

Ventilation duct,

AIR & WATER DISTRIBUTION :

1* Industrial air DN20,

1* Industrial water DN20.

3.10 GANTRY 7

Gantry 7 supports:

Bentonite mixer,

Bentonite tank,

Loudspeaker,

Belt conveyor and belt conveyor drive unit,

Ventilation duct,

AIR & WATER DISTRIBUTION :

1* Industrial air DN20,

1* Industrial water DN20,

3.11 GANTRY 8

Gantry 8 supports:

Bentonite injection unit (tank, bentonite, injection pump EYP01),

Muck diverter,
Breathable air reel,
Hot water exhaust reel,
Belt conveyor,
Video camero for monitoring the position of the muck cars
Ventilation duct,

AIR & WATER DISTRIBUTION :
1* Industrial air DN20,
1* Industrial water DN20.

3.12 GANTRY 9

Gantry 9 supports:

Ventube duct,
Dewatering reel,
Dewatering pump,
Industrial water reel,
HV reel,
Loudspeaker,
Emergency generator,
Air ventilator,
AIR & WATER DISTRIBUTION :
1* Industrial air DN20,
1* Industrial water DN20.

4 HANDLING

4.1 SEGMENT HANDLING HOIST

4.1.1 DESCRIPTION

The segment handling system is used to transfer elements of the ring (segments, counter-keys and key) from the service train to the segment conveyor table.

The handling system is composed of an electric hoist mounted on a trolley driven by an electric motor.

A supporting rail attached to the top of the connecting beam CB1 and CB2 and gantry G0 and gantry 1 structures allow the translation of the handling trolley.

The hoist and the trolley are remote controlled using a portable radio.

The self locking gripping system is mechanic.

4.1.2 CHARACTERISTICS

Lifting capacity (not including safety factor) ..... 4,5 t
Lift height ..... 3 m
Lift speed ..... 4/1 m/min
Translation stroke ..... 24 m
Translation speed ..... 24/6 m/min
Total power: ..... 7 kW

4.2 HANDLING OF THE VENTILATION DUCT CASSETTE

4.2.1 DESCRIPTION

For every 100 meters of tunnel a ventilation duct cassette (cassette containing the ribbed conduit for the air supply) must be removed and replaced with a full cassette. The full and empty cartridges are transported by the service train.

The removal and replacement operations are carried out using 2 electric hoists attached to the upper part of gantry 9 and to a system of return pulleys.

The hoists start-up is controlled electrically by means of a control box situated to the left of the gantry.

4.2.2 CHARACTERISTICS

Quantity ..... 2 double chains
Electric hoist capacity ..... 2x500 kg
Lifting stroke ..... 3.5 m
Lifting speed ..... 2 / 8 m/min.
Power ..... 2,3 / 0,57 kW

4.3 RAIL SECTION HANDLING

4.3.1 DESCRIPTION

As the tunnelling machine progresses, the progression of the service train requires that additional track elements are positioned on the bottom slab.

The segment handling hoist, fitted with hooks and slicks, is used to carry the rails or pipes from the center of the back-up train to their fixing location.

4.3.2 CHARACTERISTICS

Quantity of hoists..... 4

Manuel hoist capacity.....2,5 kN

Lifting stroke ..... 3 m

Manual trolleys 4

4.4 BARREL HANDLING

4.4.1 DESCRIPTION

A monorail fitted with a manual hoist and chain trolley is located on the left side of connecting beam CB1. Arriving from gantry 1, each barrel is placed on a trolley at the front of connecting beam CB2 and pushed sideways towards the barrel handling hoist. Then the barrel is transported to the grease and mastic pump area on the connecting beam CB1.

4.4.2 CHARACTERISTICS

Quantity 1

Electric hoist capacity..... 12.5 KN

Lifting stroke ..... 3 m

5 CIRCUITS

5.1 HIGH PRESSURE FLUID CIRCUIT

5.1.1 MAIN HYDRAULIC SKID

5.1.1.1 DESCRIPTION

The hydraulic powerhouse supplies hydraulic energy to the various components of the tunnelling machine. The energy supplied to the various elements is generated by electrically driven pumps.

The hydraulic powerhouse, situated on hydraulic skid , is mainly composed of:

An oil tank with a capacity of $6m^3$ equipped with a JZ0100 filtration unit and water/oil heat exchanger,

A pump (JZ 4500) supplying hydraulic energy to the screw conveyor gate cylinders, safety gate cylinders and screw conveyor retraction cylinders,

Two pumping units (JZ 2000 + JZ 2010+ JZ 2020+ JZ 2030) supplying hydraulic energy to the thrust cylinders and the articulation cylinders,

Two pumping units (JZ 5000 and JZ 5302) supplying hydraulic energy to the erector cylinders and motorisation,

Three pumping units (JZ 4100, JZ 4200 and JZ 4300) supplying hydraulic energy to the screw conveyor motors,

A pumping unit (JZ 7000) supplying hydraulic energy to the segment conveyor table cylinders and to the bogies cylinder,

a pumping unit (JZ 1100, JZ 1200 JZ 1300, JZ 1400) supplying hydraulic energy to the motors of the drive unit,

The oil tank is filtered to 5 µ and cooled using an air/water heat exchanger.

5.1.1.2 CHARACTERISTICS

MAIN OIL TANK

Capacity ..... $6m^3$

Filtration by pump JZ 0100

Filtration..... 5 µm

Power ..... 11 kW

Speed ..... 1 465 rpm

Flow .....450 l/min

Operating pressure ..... 6 bars

Water cooling flow 11,4 m3/h

5.1.2 GROUTING HYDRAULIC SKID

5.1.2.1 DESCRIPTION

The grouting hydraulic skid is used to control and supply the electrically driven pumps for the mortar injection lines and the mixer in the mortar tank.

The grouting hydraulic skid, situated on gantry G1 is mainly composed of:

An oil tank 800l.

A pumping unit (JZ 0595) driving a motor that operates the agitators,

A pumping unit (JZ 0592) ensuring circulation of the tank's oil for filtration and cooling,

4 pumping units (JZ 0550 /JZ 0560/ JZ 0570/ JZ 0580) driving the 2 mortar injection pumps,

The oil in the tank is filtered to 5 µm and cooled using a water/oil heat exchanger.

5.1.2.2 CHARACTERISTICS

Driven by hydraulic power pack JZ0550/0560/0570/0580

Power ..... 2x30 kW

Speed ..... 1 470 rpm

Flow variable ..... 110,25 l/min

Cylinder capacity ..... 75 cm^3/rev

Operating pressure ..... 180 bar

Hydraulic mortar agitator

Power ..... 15 kW

Speed maxi ..... 11 rpm

Cylinder capacity ..... 3 l/tr

Motor torque ..... 7.5 KN.m

Driven by hydraulic power pack JZ0595

Speed ..... 1 440 rpm

Flow ..... 14 l/min

Cylinder capacity ..... 9,71 cm^3/tr

Operating pressure ..... 300 bar

Driven by hydraulic power pack JZ0592

Speed ..... 1 440 rpm

Flow ..... 100 l/min

Cylinder capacity ..... 71 cm^3/tr

Operating pressure ..... 10 bar

5.2 LOW PRESSURE FLUID CIRCUIT

5.2.1 BEARING LUBRICATION

5.2.1.1 DESCRIPTION

This system lubricates the bearing lines, the annular gear, and the motor drive pinions.

The welded framework of the motor assembly is itself the oil tank in which the bearing, annular gear and drive pinions are immersed.

This structure has a maintenance door, a drainage valve, and, in its upper section a level indicator and a breather.

Lubrication is carried out by one circuit for lubrication of the bearing lines and gear teeth.

This lubrication is ensured by a pumping unit (JZ 0310) with four injection points situated in the upper part of the annular gear and two suction points in the lower part.

A maintenance door is supplied to provide access to each of the pinions.

On the lubrication circuit, a pressure gauge indicates the oil pressure.

A thermostat controls the temperature increase of the oil and flow meter controls the passage of fluid.

5.2.1.2 CHARACTERISTICS

Oil type: ..... VG 680 cst

Oil injection in the main bearing .....4 points

Tank capacity ..... 700 l

Filtration..... 25 µm

Driven by hydraulic pump JZ0310

Power .....2,2 kW

Speed .....1 480 rpm

Flow .....25 l/min

Operating pressure ..... 6 bars

5.2.2 BREATHABLE AIR PRODUCTION UNIT

5.2.2.1 DESCRIPTION

The role of the breathable air is to maintain and renew a sufficient volume of air for the presence of the personnel in the main man lock chamber, emergency man lock and cutting chamber.

Distribution to the cutting chamber is sized to allow confinement of compressed air.

The production of breathable air is carried out by a compressor installed on gantry G6. The compressor is cooled by the cooling water circuit.

The air circuit is permanently connected at a pressure of 7 bar to the customer's air circuit via the breathable air supply reel.

The tank is equipped with a safety valve set at 8 bar, a non-return valve at the tank inlet, a pressure reading valve and a pressure gauge giving the internal pressure of the tank.

As it leaves the 5 m^3 tank, the air passes through 2 filtering stages and is distributed to the man locks and cutting chamber by 2 independent lines.

Each line is equipped with flexible pipes, valves. Only one of these lines is permanently open, the other is used as a backup.

NB: For safety reasons, the breathable air circuit can be connected to the industrial air circuit if the industrial air circuit fails and vice versa.

5.2.2.2 CHARACTERISTICS

Power compressor ..... 110 kW

Needed flow ..... 1130 Nm^3/h

Operating pressure ..... 10 bar

Supplied by 1 pipe installed in the tunnel DN50

Reel hose diameter DN50

Elongation capacity ..... 8 m

Tank capacity ..... 5 m^3

Filtration number ..... 1 + 1

Supply capacity ..... 1130 Nm^3/h

Pressure ..... 7 bars

5.2.3 INDUSTRIAL AIR PRODUCTION UNIT

5.2.3.1 DESCRIPTION

The industrial air circuit supplies compressed air to the pneumatic components and the grease pumps, the grout injection pumps and the foam injection circuit.

An air compressor situated on gantry G6, permanently cooled by the water circuit, supplies a tank of 1 m3.

The tank is equipped with a safety valve set at 10 bar, a back-flow stop valve at the tank inlet and a pressure gauge giving the internal pressure of the tank.

At the tank outflow, the distribution circuit is filtered in 2 filtration levels and dried by a dryer equipped with an automatic bleeder.

Each gantry is served at 1 points.

5.2.3.2 CHARACTERISTICS

Power compressor ..... 45 KW

Flow ..... 350 Nm^3 /h

Operating pressure ..... 10 bars

Tank capacity ..... 1 m^3

Distribution .....1 on each gantry with CB1 exception + 2 in the shield

5.2.4 VENTILATION CIRCUIT

5.2.4.1 DESCRIPTION

The tunnelling machine is supplied with fresh air via a ribbed conduit (vent duct) with a diameter of 1200 mm that arrives at the rear of the tunnelling machine through a ventilation duct cassette attached to gantry G9.

Used air is sucked out from the shield by an extraction fan. The main suction mouth is situated at the front of the tunnelling machine, but the adjustable registers (shutters) ensure ventilation of:

→ The hydraulic units situated on gantry G2 (2m^3/s) ,

→ the electric transformer situated on gantry G4 (1m^3/s).

5.2.4.2 CHARACTERISTICS

Primary ventilation (contractor) :

Flexible ventilation shaft: ..... ∅ 1200 mm

Elongation capacity: ..... 100 m

Air flow: ..... 10 m^3/s

Extraction fan : 1

Flow: ..... 6 m^3/s

Total loss ..... 1900 Pa

Power: 15kW

Rotation speed of the motor: ..... 3000 rpm

Extraction conduit ..... ∅ 710 mm

5.2.5 CENTRALISED GREASING

5.2.5.1 DESCRIPTION

The purpose of the centralised greasing is to provide an adjustable supply of grease to the motor seals, the screw conveyor casings, the copy cutters and the articulation seals of the shields and rotary seal.

All these components are installed on connecting beam CB2.

Two types of grease are used:

5.2.5.2 NLGI2 GREASE

Cutter head seal greasing is carried out by one pumping unit (JZ 0400).

Centralised greasing by 1 extruder pump JZ0400 for 200 kg barrel

Grease type ..... NLGI 2

Number of injection points of drive seals:

Front external chamber ..... 9 points × 2,3 cm^3/min

Middle external chamber ..... 7 points × 1,3 cm^3/min

Front internal chamber .....6 points × 3,3cm^3/min

Middle internal chamber.....6 points × 3, 3 cm^3/min

Injection in the screw drive.....3 points x 5 cm^3/min

Injection in the screw telescope ..... 3 points × 1,7 cm^3/h in excavation mode

3 points × 1,7 cm^3/min in retraction mode

Injection in the articulation seals ..... 7 points × 14 cm^3/h in excavation mode

7 points × 14 cm^3/min in articulation mode

Injection in the rotary joint .....1 points x 0,1 cm^3/min

Injection in the copy cutter .....2 points x 0,3 cm^3/min

Power .....pneumatic

Flow ..... 100 cm^3/min

Operating pressure ..... 100 bar

Maximum pressure.....200 bar

Inlet pressure required for the pump ..... 10 bar

5.2.5.3 HBW GREASE

One pumping unit (JZ 0450) is used for other injection points.

Greasing by 1 extruder pump JZ0450 for 200 kg barrel

Grease type.....HBW

Number of injection points in the labyrinth:

internal.....7 points × 30 cm^3/min

external.....9 points × 30 cm^3/min

Injection in the rotary joint ..... 1 point × 30 cm^3/min

Power .....pneumatic

Flow ..... 500 cm^3/min

Operating pressure ..... 100 bar

Maximum pressure.....200 bar

Inlet pressure required for the pump ..... 10 bar

5.2.6 TAIL SEAL GREASING

5.2.6.1 DESCRIPTION

The greasing is injected to maintain the tightness in the brushes between the terrain and the inside of the tunnelling machine.

Centralised greasing by a sequential type pneumatic pump JZ 0601 for 200 kg barrel situated on gantry CB2 which feeds pneumatic distributors supplying in turn :

The 16 tail seal injection points,

The 4 articulation injection points

The injection points for the screw conveyor casing

At the pneumatic distributor, the order of passage from one point to another is determined by the number of pump strokes. This can be set as a parameter. If the pressure reaches the maximum set threshold at a given point, the order is given to pass to another point and an alarm is displayed in the drive room.

The injection is monitored at each of the tail seal brush injection line by pressure sensors.

The flow is stopped automatically when the head is stopped, but can also be forced from the control cabin by the switch on the control panel of the cabin.

5.2.6.2 CHARACTERISTICS

Grease type ..... WR 89

Injection of taill seal ..... 2 × 8 points

Injection in the articulation ..... 4 points

Injection in the screw telescope ..... 2 points

Injection in the safety gate of screw ..... 4 points

Tail grease supply by pneumatic pump with 200 kg barrel

Maximum operating pressure /rear shield ..... 10 bar

Maximum pressure / pump output ..... 200 bar

Expected Flow ..... 1,5 kg/min

5.2.7 DEWATERING CIRCUIT

The dewatering circuit evacuates surplus water accumulated in the various parts of the tunnelling machine. The accumulated water is of 2 types:

Water infiltration,

Consumed water for cleaning and cooling.

The dewatering circuit is composed of:

1 pump EXP04 at the rear of gantry G9,

1 pump EX P 01 in the rear shield,

1 pump EX P 02 on CB1 located under the belt conveyor,

1 emergency pump EX P 03 situated under the connecting beam CB2,

1 evacuation pump EXP05 in the G5.

EXP05 and EXP03 allows evacuation of used water to the surface via the exhaust water reel located on gantry G9

All the other pumps are connected to a tank located in gantry 5 that collects the water coming from the cooling circuit.

The emergency pump EX P 03 may sometimes operate when the tunnel is flooded.

The pump EXP02 is often operating for sucking water that falls down from the belt conveyor.

5.2.7.1 CHARACTERISTICS

Analogic pressure sensor 1

5.2.8 GROUTING INJECTION

5.2.8.1 DESCRIPTION

The backup train is equipped with a tank situated on gantry 1.

This tank is regularly supplied with mortar by transfer pumps from a transportation tank on the service train. A hopper allows the mortar mixing during storage in the tank.

The mortar is distributed from the tank to the 8 injections lines (4 normal lines and 4 emergency lines) by 2 double action mortar pumps, each piston injects mortar into a line.

Each line is equipped with a mortar pressure sensor.

The mortar pumps and the tank mixer are supplied by an independent hydraulic skid.

If one of the pumps is unavailable (maintenance, failure, etc.), an alternative distributor can be connected to the operational pump so that all 4 distribution lines are supplied.

The mortar pumps are installed above a tank that catches the drops. This tank shall be manually cleaned very oftenly.

5.2.8.2 CHARACTERISTICS

Injection by 2 twin piston pumps

Theoretical flow ..... $2 \times 7{,}5\ m^3/h$

Effective flow ..... $2 \times 7{,}5\ m^3/h$

Number of injection points (normal & emergency)..... 4 + 4

Pump pressure..... 30 bar

Pressure at injection point ..... 3 bar

Agitator tank capacity..... $5{,}5\ m^3$

5.2.9 BENTONITE INJECTION

5.2.9.1 DESCRIPTION

Bentonite is injected to lubricate the cutting tools, and to favour sliding of the shield over sticky terrain while partially dissolving the humidity of the excavated terrain and making the tunnel walls more rigid.

The bentonite injection circuit is composed of :

- A tank situated on gantry 8 equipped with two hoppers that constantly agitates the product,
- Two mixer agitators located on gantry 7 to prepare the bentonite,
- Two pressure vessels located on connecting beam CB2,

Before injection in the cutting chamber by the means of pumping unit EYP01, the bentonite fills up two pressure shells, EYR.02 and EYR.03, located on CB2. A quantity of air is kept in these pressure vessel in order to damp the increase of pressure in the bentonite circuit when the cutting chamber is filled up.
After use, the bentonite is collected from the bottom of the front shield to the muck car by the pump EYP02.
Bentonite may be injected into several foam injection points.

5.2.9.2 CHARACTERISTICS

MIXER: 2
Electric mixer power: ..... 2 x 22 kW + 2x 3 kW
Capacity ..... 2 x 1300 l
Agitator motor speed ..... 2100 rpm
Tank 2
Capacity ..... 8000 l
Hoppers 2
Power ..... 0,75 kW
Analogic level detector 1
PUMPING UNIT EYP01
Power ..... 30 kW
PRESSURE VESSEL
Capacity 2x900l
Pressure transducer 1
Analogic level detector 1
PUMPING UNIT EYP02
Power 15kW

5.2.10 FOAM INJECTION UNIT

5.2.10.1 DESCRIPTION

The injection of foam to the working face allows the friction of the cutter head against the terrain and the infiltration of water to be reduced, and homogenises the excavated material.

The **foam** is a mixture of **water**, **tensio-active** products (a product capable of producing bubbles like soap, with good stability under pressure and in time), **polymers** (product composed of long chain molecules giving a real characteristic to the bubble) and **air**.

The installation is mainly composed of:

A solution preparation plant including the polymer pumping unit and the tensio_active pumping unit.

A polymer tank ,

A tensio-active tank,

A foam solution regulation skid,

An air regulation skid

8 foam generators.

The tanks are regularly supplied by pneumatic transfer pumps (contractor supply) from 200 litres barrels situated on the service train.

Each product (tensioactive, polymer) is injected in the water by a feed pump to obtain the foam solution. The solution is then directed to the foam solution regulation skid where it is divided into 8 independent lines.

The air regulation skids generates 8 independent air flow lines from the industrial air supply that are mixed to the 8 foam solution lines in the 8 foam generators.

Valves allow each product to be isolated (tensioactive and polymer) of each foam line to be isolated.

The foam is distributed to the working face via the rotary seal.

5.2.10.2 CHARACTERISTICS

Number of injection lines:

- Bulkhead 3
- Screw conveyor..... 3
- Cutter head 6

Number of cutter head injector..... 6

Total injection capacity - 10 bars..... 265 Nm^3/h

Tensio-active product (gantry 3)

Tank capacity ..... 2 000 l

Pumping unit EO.P.01..... 1

Maximum variable flow.....0,6 m^3/h

Maximum pressure.....10 bar

Polymer product (gantry 2)

Tank capacity ..... 1 000 l

Pumping unit EO.P.02..... 1

Maximum variable flow.....0,18 m^3/h

Maximum pressure..... 10 bars

5.2.11 INDUSTRIAL AND COOLING WATER SYSTEM

5.2.11.1 DESCRIPTION

The industrial water circulates through piping in the tunnel. The piping is connected to a winding reel situated on gantry 5 and feeds a tank.

The tank is made of two compartments, a 3.5 m^3 compartment ("cold" tank) and a 1 m^3 compartment ("hot" tank). The 3.5 m^3 compartment is used as a heat exchanger. The cooling water return circuit is connected to the 1 m^3 hot tank and overflows in the 3.5 m^3 cold tank compartment. When the cold tank is too hot, the return circuit is diverted to the dewatering tank and fresh waters coming from the G9 reel flows in.

An over-pressuring installation composed of pumps situated under the tank ensure the total flow and pressure of the distribution circuit.

The industrial water circuit connects up :

Distribution points equipped with valves on each platform of the gantry,

The cooling circuit for compressors, drive unit reducers, back grouting hydraulic pack, main hydraulic power pack,

The manlock,

The injection in the cutting chamber,

The foam manufacturing circuit

5.2.11.2 CHARACTERISTICS

Supplied by 1 pipe installed in the tunnel DN65

Hose diameter DN65

Elongation capacity ..... 8 m

Normal pressure of supply ..... 3 bar

Normal flow supply ..... 40 m^3/h

Normal pressure of supply ..... 7 bar

Required maximum flow ..... 80 m^3/h

Filtration ..... 500 µ

Required maximum temperature ..... 20 °C

COOLING PUMP EGP01:

Flow ..... 4,5 m^3/h

Maximum pressure ..... 7 bar

Power 2.2kW

Mortar Hydraulic power pack and reducers cooling circuit pump EGP01:

Required flow ..... (2,4+2,1) 4,5m^3/h

Pressure ..... 7 bar

Water temperature inlet/outlet ..... 25/45°C

Power ..... 2,2 kW

Hydraulic power pack cooling circuit EGP02:

Required flow 11,4 m3/h

Pressure ..... 7 bar

Maximum oil temperature ..... 50°C

Water temperature inlet/outlet ..... 25/45°C

Power ..... 4 kW

Breathable and industrial air compressor cooling circuit and cutting chamber injection and water supply network EGP04:

Flow ..... (2,8+1) 3,8 m3/h

Maximum pressure ..... 3 bar

Power ..... 4 kW

Cutting chamber water injection

Flow ..... 8 m^3/h

Maximum pressure ..... 10 bars

Industrial water constant pressure pump for foam circuit :

Required flow ..... 12 m^3

Maximum pressure ..... 10 bar

Water temperature inlet/outlet ..... 25/45°C

Power ..... 5.5 kW

DEWATERING CIRCUIT

Supplied by 1 pipe installed in the tunnel DN125

Hose diameter DN80

Required maxim flow 19 m3/h

Pressure ..... 3,5 bars

5.2.12 FLUID HOSE REELS

The backup train is equipped with the following additional winding REELS:

A dewatering circuit winding reel situated on gantry 9,

An industrial water winding drum situated on gantry 9,

A breathable air winding reel situated on gantry 8,

A cooling water exhaust winding reel situated on gantry G8.

These winding reels are connected to their respective networks.

5.3 ELECTRIC AND TELECOMMUNICATION CIRCUITS

5.3.1 TRANSFORMER

5.3.1.1 DESCRIPTION

Electrical energy for the tunnelling machine is transformed from high voltage to low voltage by one transformer, located on gantry 4, and some auxiliary transformers located in gantry 3 and gantry 4. It supplies the electric power cabinets.

The electrical connection for the transformer is connected on a HV winding drum situated on gantry 9

5.3.1.2 CHARACTERISTICS

MAIN TRANSFORMER: 1
Supply Tension ..... 20 kV
Outlet Tension ..... 400 V
Frequency ..... 50 Hz
Power ..... 2000 kV.A
type ..... silicone oil cooled
Available tensions ..... 400 V

AUXILIARY TRANSFORMERS 6
Supply Tension ..... 400 V
Outlet Tension ..... 230 V
Frequency ..... 50 Hz
Power ..... (8+10+0,4+2,5+10+10) 40,9 kV.A

5.3.2 EMERGENCY GENERATOR

5.3.2.1 DESCRIPTION

The alternator situated on gantry 9 supplies electric power when the electricity supply circuits are cut off during cable lengthening phases or as a backup for :

The dewatering circuit pumps,

The HV cable winding reel,

The ventilation (blowing),

The electrical distribution boxes,

The backup lighting system,

The elements ensuring that the confining pressure is maintained,

The sensors, actuators and automations.

Its main component is a Diesel powered heat engine that drives an alternator by means of a coupling. A removable safety hood protects the assembly. The smoke is expulsed by the means of the ventilator.

The full-load output voltage ensured by the alternator is 400 Volts.

5.3.2.2 CHARACTERISTICS

Power .....200 kVA

5.3.3 LIGHTING

5.3.3.1 DESCRIPTION

Lighting is made of 2 types of neon tubes (normal lights, emergency lights), and some floodlights (sodium lights).
Normal lights are located on each gantry and into the shield assembly. Emergency lights are approximately located on one gantry over two.

5.3.3.2 CHARACTERISTICS

Normal lighting ..... 30 lights of 2x18 W

Emergency lighting..... 10 lights of 2x18 W

Sodium lighting with cold window..... 4 lights of 150 W

5.3.4 HV REEL

5.3.4.1 DESCRIPTION

The backup train is equipped with a HV cable reel**.**

Cable guides equipped with bobbins are supplied on the wall to guide the cables during unwinding (contractor supply).

The HV reel installed on gantry G9 unwinds and rewinds electric cable supplying the electric transformer, as the tunnelling machine advances.

As the tunnelling machine moves forward, the cable unwinds slowly from the reel on which it is mounted. It is connected at its end to a connector on the customer's circuit.

The HV reel is equipped with a limit switch that stops the progress of the tunnelling machine approximately every 300 meters.

After it is disconnected from the customer's circuit, the freed cable is wound around the drum. During this time the alternator powers the backup circuits.

The drum is rotated by a belt linked to the pulley of an electric motor.

When the cable is wound, its end is connected again to the customer's connector, who has at the same time added a 300 meter long fixed cable in the tunnel.

5.3.4.2 CHARACTERISTICS

Drum capacity ..... 300 m
Winding /unwinding speed ..... 15 m/min
Maximum traction .....2100 N
Motor power ..... 1.5 kW
Cable used .....Panzerflex 12/20 kV – 3 x 25mm^2 / 3 x 10mm^2

5.3.5 COMMUNICATION CABLE

Cable