STUDY ON TBM OPERATION AND MAINTENANCE IN HSUEHSHAN TUNNEL

Benny CHU[1] and Yao-Tung LENG[2]

ABSTRACT

Taiwan, Taipei-I lan expressway, Hsuehshan Tunnel, in length of 12.9 Km, the full face TBMs (Tunnel Boring Machines) with an 11.74m boring diameter will be applied for tunnel excavation for both the East Bound and West Bound main tunnels. Since, it is the first time contract specification called for the largest diameter of Telescope / Double Shielded type hard rock designed TBM in the world going to use in domestic tunnel project especially presumption that Hsuehshan main tunnels are among the most difficult TBM tunneling projects in the world in terms of adverse geology, water inrushes, tunnel size and tunnel length, therefore, pre-training of all the necessary and available information, technology and technical know-how in connection with TBM operation and maintenance to all related working crews of the TBM construction teams prior to the TBM mining operation is a great important issue. The most crucial to the success of TBM mining operation is including but not be limited to understanding and commanding ground condition, appropriate planning, normal and correct operate the TBM and its all relevant Back-up equipments and facilities, good performance of cutters inspection and maintenance works on mechanical, hydraulic and electric systems to keep high availability rate of TBM and Back-up system as well as all other supply and distribution of electricity, compressed air, water pipe line, rails and tracks systems. This paper presents our methodology and experience of TBM mining operation and maintenance in Hsuehshan main tunnels construction, with the hope to provide tunnelling and underground construction field experts for references for the future.

INTRODUCTION

The 12.9 Km long Hsuehshan Tunnel, "a renowned difficult project in the world" as recorded in the British Encyclopedia, which is composed of 2 main tunnels (westbound and eastbound) and a pilot tunnel. In view of the environment constrain, water drainage during the construction, mucking delivery and portal facilities area…etc. all 3 tunnels were originally planned to be bored by TBMs from the eastern portal and head west. The tunnels are ascending at gradient of 1.254% from Touchang in the east to Pinglin in the west. It pass under the Hsuehshan Ranges in northern Taiwan, in the tunnel horizon, it cut across strong, hard, abrasive and intensely fractured Szeleng Sandstone on the east and indurate sandstone and siltstone on the west. The entire zone heavily affected by tectonically movement is very much faulted and bears a great amount of water. In additional to six identified water-bearing faults, there are many problematic and unanticipated shear zones.

In the original construction arrangement, the excavation of the pilot tunnel by TBM from east portal would commence 2 years ahead of the main tunnel. It was expected that before tunneling of the main tunnel, the pilot tunnel would have been completed, and could provide sufficient lead time in observing underground, identifying potential problems and providing solutions to the main tunnel construction. But, unfortunately, the pilot tunnel drive was severely delayed by unexpectedly difficult geology with fractured rock and massive inflows of water, it puts the TBM boring of main tunnels in a dilemma. Since the original expected functions of pilot tunnel were vanished especially in exploration of precise geological information along the tunnel alignment and pretreatment of poor strata from

1. Director of Economic Development Bureau, Kaohsiung County
2. Deputy Manager of 2nd site PEI-I Construction Office, RSEA Engineering Corporation

pilot tunnel to the main tunnels, drainage of ground water, therefore, in familiar with TBM's characteristic and capability as well as maintenance of the TBM and Back-up facilities in a superior condition became extraordinarily important so that TBM operator and working crews could react immediately when various adverse ground is encountered in order to avoid or minimize the damage to the minimum. However, this paper would only focus on the TBM mining operation and maintenance of the Hsuehshan main tunnels.

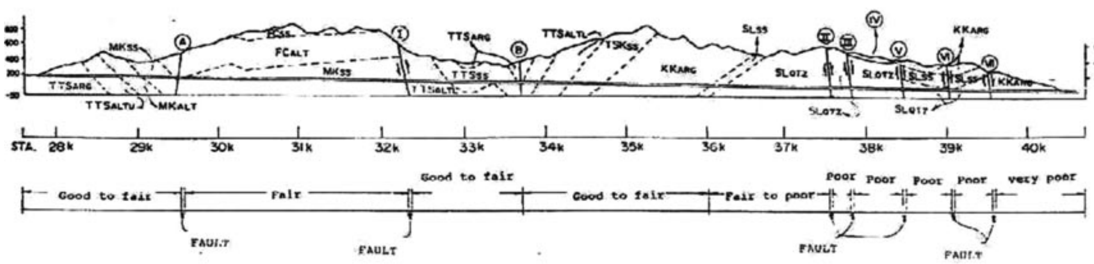
GEOLOGICAL CONDITIONS

Hsuehshan Tunnel, with a maximum overburden of 700 m, is situated within the fold and thrust belt structural region in northern Taiwan. Rock formations based on a few strategically placed bore holes were estimated to be ten expected stratigraphic horizons and twelve structurally homogeneous zones (Figure.1). The identified Faults were Shihtsao (Ⅰ), Northern and Southern Branch of Shiphai (Ⅱ), Tachingmen (Ⅲ), Paling (Ⅳ), Shanghsin (Ⅴ), and Chingyin (Ⅵ), ranging from 10 m to more than 60 m wide. In addition to identified Faults, many problematic lineaments remained in require of further investigation and explanation. Yingtzulai (A) and Taotiaotzu (B) synclines were two major fold structures of regional magnitude. There were other nine or more fold structures of limited extension and magnitude. The following locations were sites of likely higher ground water surge or seepage but there was no indication of the flow quantities and locations were ground water surge was likely to occur:

1. The immediate vicinity of fault zones or where shear gouge was exposed.
2. Sheared rock mass with weak plants that contained abundant clay, especially the Szeleng Sandstone.
3. The fractured mass at the axial part of syncline structure.

TBM SPECIFICATION AND DESIGN CONCEPT

The Contract specification of Hsuehshan main tunnels called for two virtually identical and with the same specifications of Double Shielded hard rock TBMs for each of East and West Bound main tunnel. The two Double Shielded TBMs, Type TB 1172 H/TS with a boring diameter of 11.74m are weighing complete with Back-up approx.2300 tons each and are the largest Double Shielded hard rock machines ever built by the



SL	-	Szeleng Sandstone	KK	-	Kankou Formation
TSK	-	Tsuku Sandstone	TTS	-	Tatungshan Formation of Oligocene
MK	-	Miocene Makang	FC	-	Fangchiao Formation
FCss	-	Massive sandstone intercalated with thin shale.	FCalt	-	Alternations of sandstone and shale.
MKss	-	Massive sandstone intercalated with thin shale.	MKalt	-	Alternations of sandstone and shale.
TTSaltl	-	Upper part alternations of fine grain sandstone and argillite (or siltstone) .			
TTSarg	-	Argillite intercalated with thin siltstone.			
TTSss	-	Sandstone intercalated with thin argillite (or siltstone) .			
TTSaltl	-	Lower part alternations of fine grain sandstone and argillite (or siltstone) .			
TSKss	-	Fine grain sandstone intercalated with argillite.			
KKarg	-	Massive argillite.			
SLss	-	Fine to medium grain sandstone intercalated with thin argillite.			
SLqtz	-	Massive quartzite intercalated with coal shale.			

Figure.1 Rock mass classification along the Hsuehshan Tunnel investigation area.

Figure. 2 Wirth TBM Type TB 1172H/TS.

Figure. 3 TBM Operator Cabin.

TBM manufacturer, Wirth Company (figure.2, 3). The machines are equipped with 7550 KW of which 4000 KW are for the fully hydraulic cutter head drive, will generate a maximum torque of 36000 KNm at 0.25rpm speed and are designed to achieve a penetration rate of 4.5m/h. The cutter head rotational speed is 0~ 4.0rpm and the total cutter head thrust is about 50600 KN in double mode and 78700 KN in single mode mining operation.

In addition, bring the feedback from those serious incidents of pilot TBM, the following features are especially incorporated in design of the main tunnel TBMs in order to improve the performance in adverse ground condition, e.g. High water inflow, fracture and blocky rock, squeezing rock, high overburden load, soft and/or sticky soil, running type ground.

1. Cutter head drive:

   High torque.

   Instantaneous reversibility.

   Variable speed hydraulic drive.

   Horsepower limited.

2. Cutter mounts:

   Recessed to limit distance from tunnel face to cutter head face plate.

   Limited space for blocky rock to fall out of face.

   Front and rear cutter loading.

3. Cutter head profile:

   Flat profile for maximum face support.

   Short transition from face to gauge.

   Short distance between cutter head shield and tunnel face.

   Minimum exposure of cutter head top to blocky rock and running ground.

4. Bucket closure doors:

   To close off peripheral buck openings and prevent blocky rock from stopping the cutter head or large amounts of running ground from entering.

5. Cutter head structure:

   Large bucket openings for efficient muck gathering.

   Replaceable bucket and scraper lips.

   Smooth circumferential rim.

   Picks on bucket openings.

   Comb type pick assembly for cutter head center.

   Smooth front plate.

   Scrapers at back wall and circumference of cutter head for cleaning purpose.

6. Grill bars:

   Manually replaceable grill bars to reduce particle size and amount of muck inflow.

7. Movable cutter head with over cutter assemblies:

   Cutter head center moves vertically by 10mm down and 100mm up.

   Three hydraulically extendable over cutter and bucket/scraper assemblies to increase over cut from 55mm to 255mm above front shield to avoid shield from being trapped in squeezing rock.

   Over cutters can mechanically be locked in intermediate positions.

8. Muck gate:

Conveyor hopper can be closed off by a hydraulically operated gate to avoid muck/water mixture from flooding the shield.

Partial closure of gate will limit muck inflow.

9. Muck hopper:

Closed muck hopper design to separate cutter head area from shield by means of gate.

Structure to withstand inflowing muck with a head of 3 times shield diameter.

Access door for maintenance purposes.

Removable machine conveyor.

10.Trough chain conveyor:

The trough chain conveyor, around 3.5m long, is used in heavy water bearing formations as the first element of muck conveyor system in order to separate water from muck. In normal operation it is parked above the machine conveyor in the cutter head shield.

11.Dewatering system:

Pumps with total capacity of 115 l/s in telescope and gripper shield invert.

Trough type chain conveyor system.

Water drainage to shield invert or back to cutter head.

Settling tanks on back-up with muck removal feature.

12.TBM operation in closed mode:

Closed mode operation for tunneling in unstable ground conditions when grippers are ineffective.

Adjustable thrust ring with roll correction feature to counter cutter head torque.

Hinged grippers to allow three point gripping.

Split grippers for increased adaptability.

13.Injection system:

High torque impact drills for probe and injection drilling.

Circumferential guide tubes in gripper shield for 360 ○ drilling pattern.

High pressure grout injection pumps.

14.Telescope section:

Telescope cylinders arranged in parallel.

Torque beam assembly to transmit torque from front to gripper shield.

No interaction between torque reaction and longitudinal forces.

Transmission of thrust and pull forces.

Capability to tilt front shield with cutter head in soft soil to prevent diving.

Active four zone hydraulic control system.

The shield, about 11 m long, consists of four major components, the front shield, the rear or gripper shield, the telescope section connection to two, and the tail skin.

The front shield contains and supports the drive module and the cutter head. It is connected to the rear shield with the telescope cylinders which are arranged in four groups to enable the front shield with cutter head to be steered in any desired direction. The telescope part of the shield assembly connects the front and rear shields structures. Its function and purpose is to enable the machine to excavate and erect pre-cast concrete segments concurrently. The design of the telescope section permits a corrective curve radius of 200 m to be driven. The telescope jacks (18 telescope cylinders) are connecting the two shield sections in a way that push as well as pull forces are transmitted, this feature will prevent the front shield from tilting downward in case unstable ground conditions with high overburden loads are encountered. Two torque support beams with hydraulic cylinder operated guide pads transmit the cutter head torque from the front shield to the rear or gripper shield and roll adjustments between the two shields can be made by means of the torque reaction cylinders.

The rear gripper shield houses the push jacks (28 segment cylinders) and the gripper assemblies. The geometry of the gripper arrangement allows the gripper forces to be exerted to the sides and bottom. This results in a solid 3 point anchoring of the shield in the tunnel. The gripper shield resists the full jacking forces of the front shield and allows it to be pulled back as well. The push jacks serve to reposition the gripper shield when the grippers are released or thrust the shield forward when the machine is in single shield operation mode. They are arranged in five groups for the purpose of steering the machine when tunneling in bad ground without the use of the grippers and the telescope shield. As an added feature, three of the push jacks, one in the crown and one each in

Table 1. The general specification of Wirth TBM Type TB1172H/TS.

Item	Description	Spec. and Q'ty	Item	Description	Spec. and Q'ty
1	Cutter Head boring diameter	11.74m	13	Total thrust of 18ea telescope cylinder	50600KN
2	Center Cutter	6ea	14	Total thrust of 28ea segment cylinder	78700KN
3	Face Cutter	71ea	15	Total thrust of 2ea gripper cylinder	65000KN
4	Gauge Cutter	3ea	16	Gripping Type	T (Three points gripping)
5	Reamer Cutter	3ea	17	Hydraulic system pressure (Max.)	405Bar
6	Cutter Disc. diameter	432mm	18	Total power of TBM and B/U	7550KW
7	Cutter Head drive power	4000KW	19	Transformer (690V)	2x3150KVA
8	Cutter Head speed	0~4rpm	20	Transformer (440V)	1x1250KVA
9	75% efficiency rate of torque at 4rpm speed	7200KNm	21	Mucking Capacity	1200t/hr
10	Max. torque at 0.95rpm speed	30000KNm	22	Length in one stroke of mining	1.5m
11	Max. torque at 0.25 rpm speed of break out mode	36000KNm	23	Length of TBM and B/U	250m
12	Cutter head drive motor	18Set	24	Weight of TBM and B/U	2300t

the upper quadrants, are equipped with individual jack shoes to hold the three top segments in place when the thrust ring is retracted. The full tail skin permits the installation of the 1.5 m wide segmental concrete lining including the keystone.

The general specifications of TBM are shown in table 1.

The cutter head generates a standard over cut of 55 mm above the front shield with new cutters. The cutter head is designed with three extendable reamer cutter/scraper assemblies, which allow increasing the bore diameter by 200 mm. The cutter assemblies are extended hydraulically and locked into position for extended duty by mechanical means.

The assemblies also have additional scrapers to assure an efficient muck removal when over cutting. In order to locate the entire over cut above the shield, the center of the cutter head including main bearing and drive housing can be adjusted vertically. After excavating a concentric over cut the cutter head assembly is moved to an eccentric position 100 mm above the shield center and the over cutting assemblies are used again. In this way the cutter head will be able to cut flush with the invert and realize a total over cut of up to 255 mm at the top. The sequence of operation is shown in Figure 4.

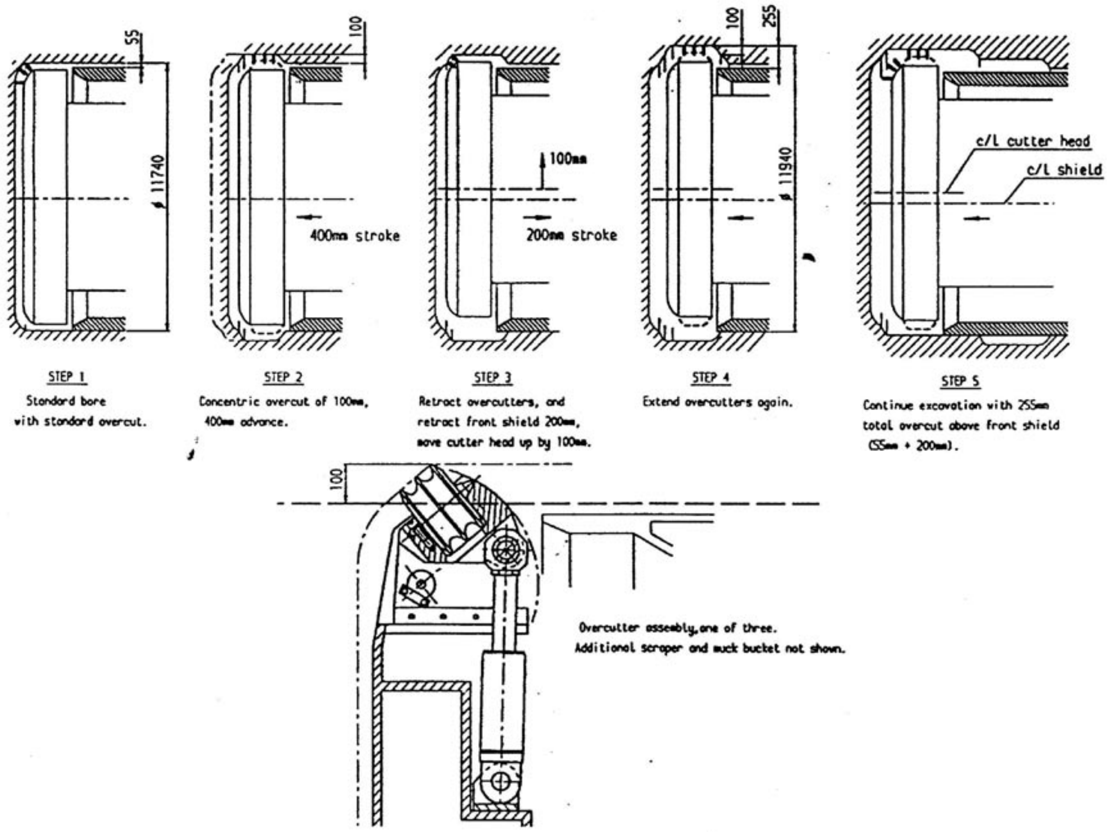


Figure. 4 Cutter head enlargement.

TBM OPERATION

The TBMs that utilized for excavation of Hsuehshan main tunnels are of a Telescope / Double Shielded type hard rock machines. A telescope shield machine allows bore and erecting a tunnel support simultaneously, when the rock conditions provide a proper gripping of the tunnel wall. In the telescope type mode of excavation, the front shield including the cutter head is thrust forward with the rear shield locked in the rock using the grippers so that neither thrust forces nor torque are transferred to the tunnel lining. Behind the gripper shield, within the protection of the tail skin, a reinforced precast concrete segmental lining is installed with the help of a segment erector. If gripping of the machine is not possible in unstable ground conditions, the machine is operated like a simple shield machine; i.e. telescope section withdrawn, advance by extending the segment cylinders and the boring operation has to be interrupted for the installation of the tunnel support. Telescope shield operating sequence is shown in Figure 5.

The general standard activity of TBM mining operation includes:

* Excavation.
* Pre-cast segments installation.
* Peagravel and grouting.
* Rainfoeced steel ribs installation if necessary in water bearing and weak ground zone.
* Arch cover installation.
* Erection of rails and facilities.
* Probe drill and ground treatment.

The tunnel guidance system that equipped on the TBM was ZED 261 with all the necessary hard and soft wares required for both manual and automatic settings. The correct steering of the TBM is an important factor during operation of the machine. On a correctly steered machine there will seldom be any damage to the cutter discs or any blocked cutter disc bearing. Oversteering is a common

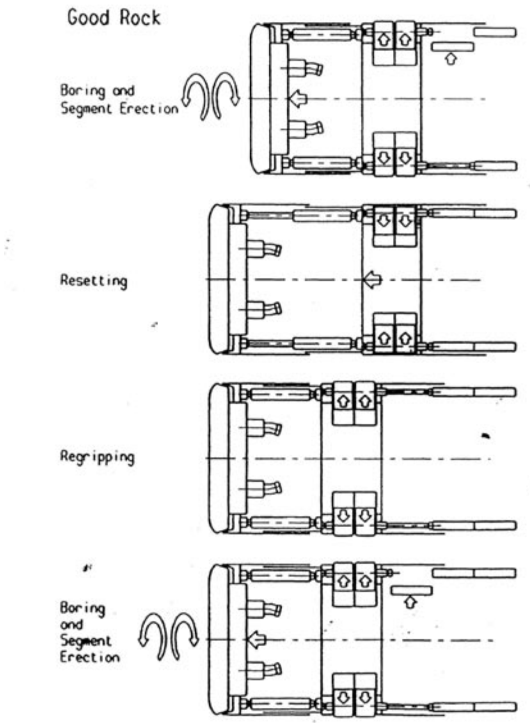


Figure. 5 Operational Cycle of Telescope Shield machines.

reason for damage to the cutter head, its carrying frame and the cutter head scrapers, or even will jam the shield unit in the borehole and deform the shield due to the high compression especially in hard rock formation. If the machine is being steered correctly when the predetermined coordinates are held to, and the tunnel walls show an even surface (i.e. no traces of over steering are evident). With correct steering, no ridges occur in the tunnel walls. Steps are obvious signs of over steering; if they occur, correction of the steering procedure is necessary. A change of direction is not immediately to be seen on the "present Position" display of the ZED 261 Guidance system, but first when the cutter head shield has traveled far enough to have been influenced by the direction change. For this reason it is recommended to avoid extreme direction changes, until the operator can see how the machine reacts.

Precast segments installation is done by the help of a hydraulically powered segment erector which consisting of the ring erector itself, and a spreading and holding device. The pre cast concrete segments are installed in the shield tail. The erector rotates 220 in either direction; the rotating ring of the erector is connected to the running gear via a sealed cross-roll bearing with internal gear. The hydraulic drive has infinitely variable speed control with a maximum speed of 1.5 rpm and a maximum torque of 960 KNm. The segments are held to the erector head with a mechanical clamping device consisting of two extendable pins gripping the grout holes. The erector head with the gripping system is radially extended individually. The head itself is attached with a spherical bearing and can be articulated in three planes to assure a proper positioning of the segments. The head has a total of six degrees of freedom and the clamping and tilting of the erector head is monitored by means of limit switches and travel sensors. A complete 1.5 m long ring comprises 5 segments and a key, and segment erection cycle diagram is shown on Figure 6.

Back filling of the pea gravel to the tunnel behind the installed segments should be done before resetting of the TBM for next stroke mining by means of 2 rotor blowers. In this project, cement grouting was performed during the TBM stopping on night shift due to other activities have to be arranged on that time. Backfill material requirement and diagram is shown on Figure 7.

In order to secure the safety of drive through the weak and water-bearing fault zone, a Montabert HC-80 type probe and injection drill is equipped on TBM. For probing, the drilling machine has a fixed position on the primary bridge directly behind the erector, and probing is executed through a guide tube on the top of the gripper shield structure. For injection drilling, the drilling machine can be attached to the segment erector, so that any drilling position of 24 guide tubes with an inclination of between 7.5 and 14 can be reached. Moreover, to have a better performance of probing and ground pretreatment from inside the TBM to the front of the cutter head, a Krupp HB-40A percussion drills with max. torque of 9700 Nm and rotation speed of 55 rpm was newly equipped. Figure 8 shows the activity of probing from inside the TBM.

Figure 9, 10 shows the train system and operation sequence of main tunnel TBM mining operation.

All the working crews on TBM either during the mining operation or repairs should strictly comply with the following safety regulations.

1. The telescopic area is off limits during retraction / re-gripping.
2. During segment handling, it is forbidden for persons to enter the danger area.
3. Before the pumps are put into operation, it must be

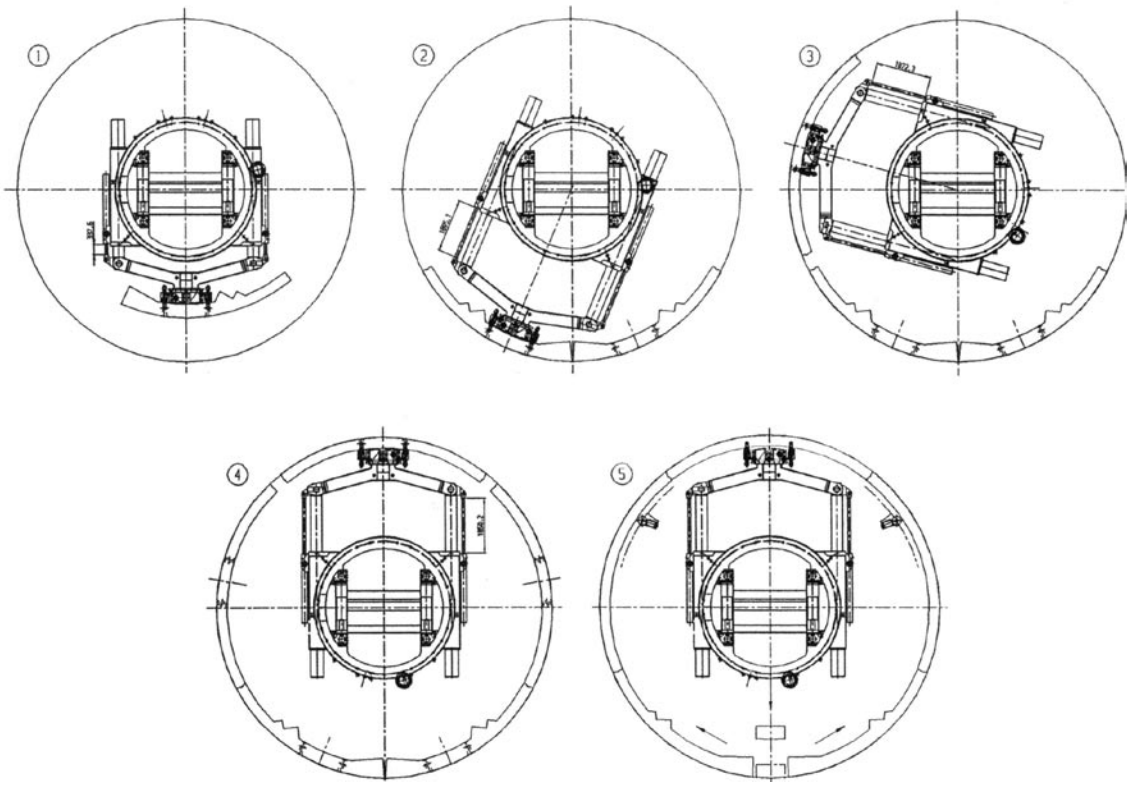


Figure. 6 Segment erection cycle diagram.

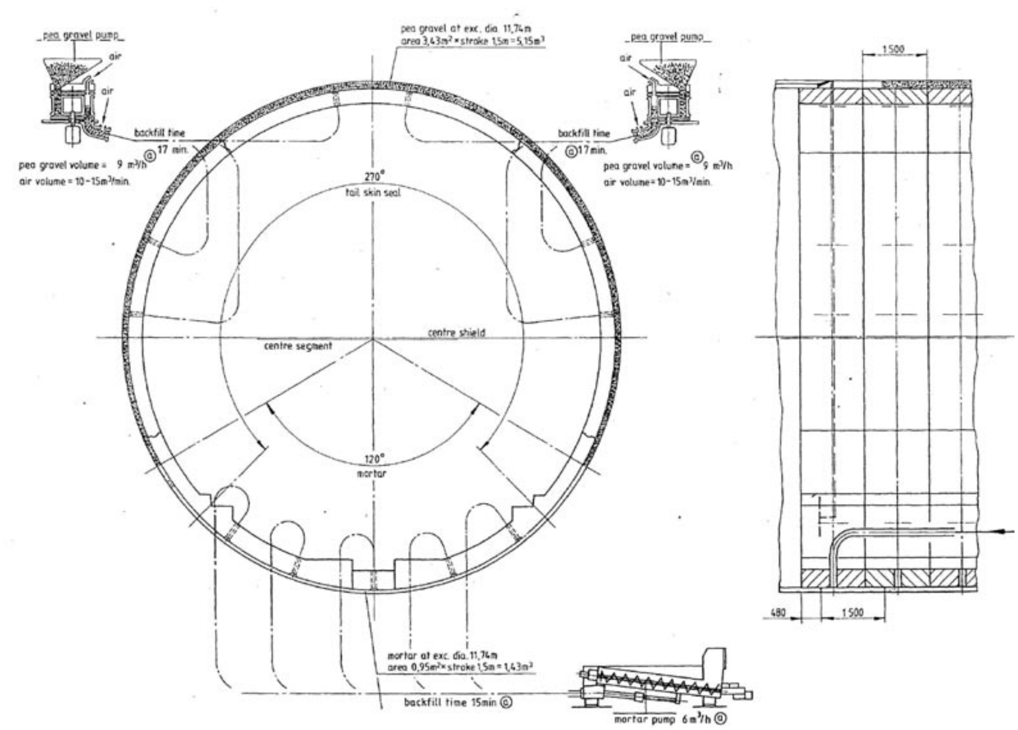


Figure. 7 Backfill material requirement and diagram.

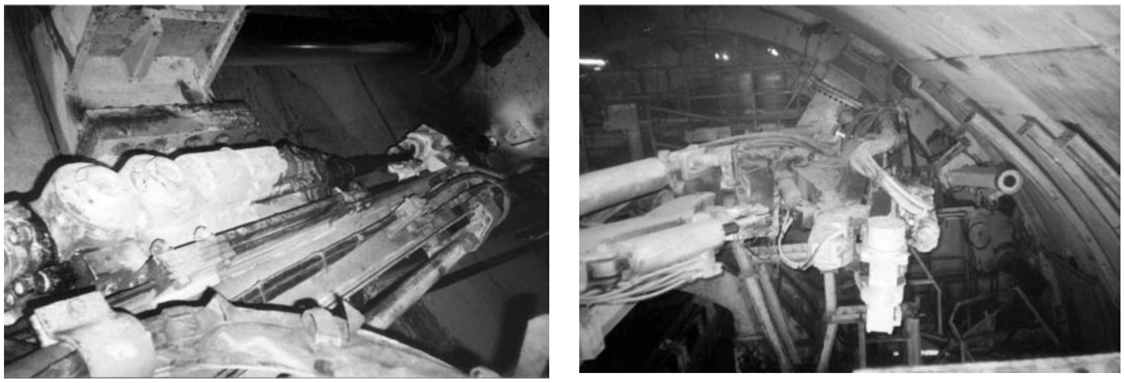


Figure. 8 Probing from inside of TBM.

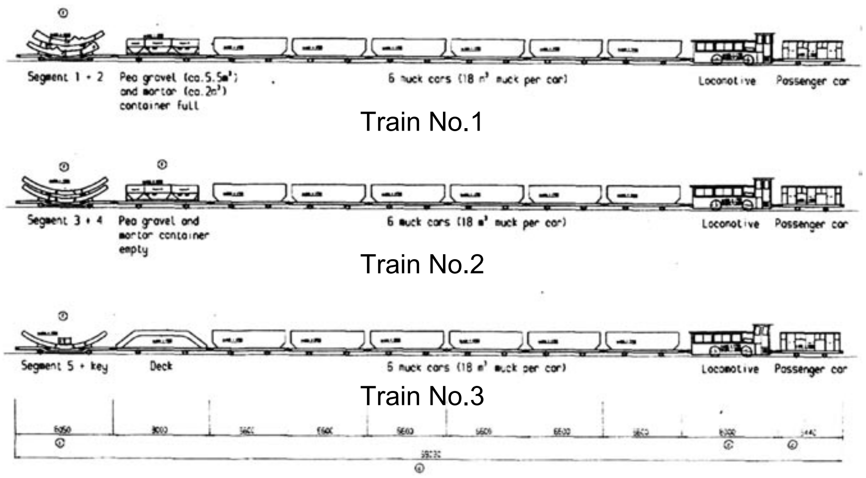


Figure. 9 Train systems for one stroke of 1.5 m.

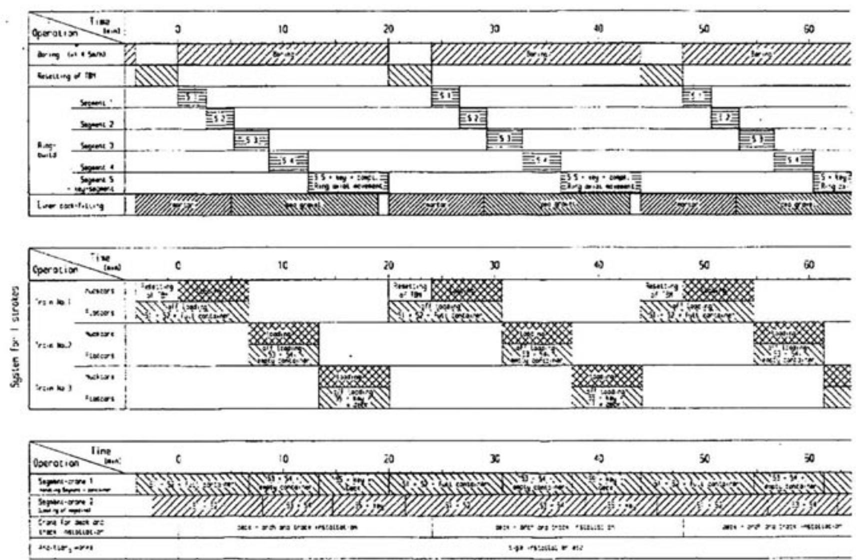


Figure. 10 Operational Sequence of TBM and Back-up System.

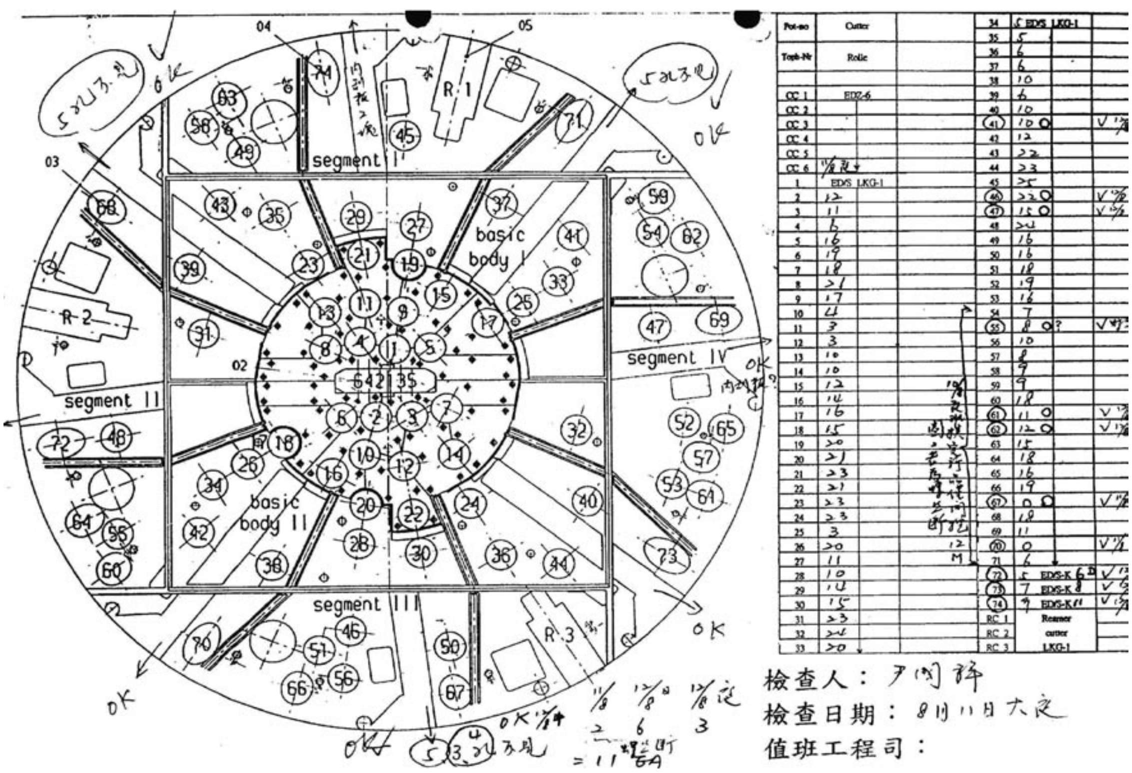


Figure. 11 Daily Cutters Checklist.

ensured that the shut-off valves are open.

4. Before opening fittings or doors in the bulk head and entering the cutter head it must be ensured that, the cutter head chamber is free of water.
5. During work on the cutter head any form of adjustment work on the hydraulics and electrical system is forbidden.
6. The shutdown switch must be operated before any repair work is carried out on the conveyors.
7. All switching operations as well as service functions may only be carried out by especially trained authorized specialists.
8. The person in charge on site shall be responsible for initiating and proceeding with suitable measures as well as for shutting down the machine if Methane or Fire warning system is activated. Once the machine has been switched off because gas or fire has been detected as aforesaid, only the person in charge on site shall be responsible for having the machine switching back on again when the cause for machine shut-down has been eliminated.
9. Before the machine is put into operation, personnel working on the machine must be instructed in the function of the fire alarm system, extinguishing and with regard to the fire prevention concept.
10. The function of Video camera monitoring and Recording systems should be checked daily to ensure the machine sections are being monitored and recorded properly.

MAINTENANCE OF TBM & BACK UP SYSTEM

TBM maintenance operation is one of the most important measures to avoid or minimize the mechanical breakdown and to keep high availability rate of TBM and Back-up system. The list of TBM maintenance operation is including but not be limited to the following Table 2.

TBM maintenance operation is mainly split into a daily, weekly and monthly checklist and to be checked by well trained specialists with their signatures after checking operation was done. In the mean time, maintenance and repair job or a repair plan on the mechanic, hydraulic and electrical systems were carried out according to the marks on the checklist by other mechanics and electricians under the supervision of shift engineer. Figures 11 and 12 shows the daily cutters and drive module checklists as samples.

Figure 13 shows a general arrangement of TBM and Back-up system's lubrication scheme.

CONCLUSION

It is really hard to operate and maintenance the TBMs in particular Hsueshan main tunnels due to the first use of TBMs in extremely poor ground with huge amount of water inrush especially it is by far the largest diameter of Double Shielded hard rock machines in the world. TBM operators have to strictly concentrate in operating the TBM during the mining, and must react immediately according to the exchanging of the ground from a centimeter by centimeter. However, the value of breakout torque obtained for the type of areas such as running ground, faults with clay gouge, and fractured rock, even in the absence of water, is higher than the 36000 KNm available on the TBMs of Hsueshan main tunnels. That is why the TBM of west bound main tunnel boring a total of 456 m was stuck five times and still can not avert from a disaster and had been faced a destiny of abortion, and east bound TBM also had been stuck two times in the full face mining.

Because of the characteristic geological conditions especially in Szeleng Sandstone formation, fracture, strong (310Mpa), and abrasive (quartz content 90%), east bound TBM cutter head front plate especially in some area of circumference of the cutter head were worn down from 40 mm to 6 mm, and had been re-built 3 times by welding of the wear-plates, besides, re-built several times for the basis structure of scrapers. Furthermore, after a long term bearing of the un-even and centralized stress higher than 30000 kg/cm2, caused gripper pads with 40 mm thickness of steel plate deformed badly, and spent more than one month to repair. It was a hard job to maintenance and repairs the TBM no matter cutters exchange, repairing of the equipment and/or facility inside the shield, on the equipment bridges and back-up system, but, it was gratified that, east bound TBM and Back-up system was still in a good function after the break-through of the tunnel.

Nevertheless, there still remains that we need to gain more experiences in operating and maintenance a mechanized tunneling system, to enhance our ability to cope with those difficult ground conditions that might be frequently encountered in the future tunneling projects.

REFERENCES

* Hermann Hamburger. Wirth TBM's for the Pinglin Main Tunnels. Wirth GmbH, Germany. Noted; Pinglin Tunnel was re-named as Hsuehshan Tunnel.

* Technical documentation of Wirth Maschinen und Bohrgerate Fabrik GmbH.

* Tseng Y.Y, Wong S.L, Wong C.H, Bennie Chu. 1998. 8 Congress of the "International Association of Engineering Geology and the Environment".

Table 2. List of TBM and Back-up maintenance operations

Item	Description	Item	Description
1	Cutter Head: * Cutters * Teeth * Main gear box * TBM main seal centralized greasing * Stud tensioner	18	Back-up bogies
		19	Auxiliary fan
		20	Dust collector
		21	Crane No. 1
		22	Crane No. 2
		23	Crane No. 3
2	Bucket and gate	24	Track laying system
3	Front shield	25	Belt conveyors (#1 ~ #5)
4	Telescope shield	26	Electrical net works
5	Gripper shield	27	HT / BT transformers
6	Grippers	28	Dispatching cabinets
7	Erector	29	Power generator
8	Pressure ring	30	Hydraulic piping and oil tanks
9	Spreading device	31	Hydraulic pumps and motors
10	Segment magazine	32	Hydraulic cylinders
11	Mortar back filling	33	Air piping and tanks
12	Pea-gravel back filling	34	Air compressor
13	Pilot cabin	35	Water piping and tanks
14	ZED system	36	Pumps and boosters
15	Measurement cylinders	37	Montabert and Krupp drill and power pack
16	Data acquisition system	38	Miscellaneous
17	Back-up structure		

2

每日檢查表： Daily Checklist

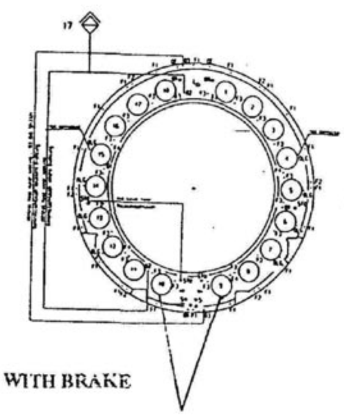
驅動齒輪箱潤滑檢查
DRIVE MODULE LUBRICATION AND INSPECTION (GEAR BOX)

日期：DATE: 85.9.28.	計時表讀數：Meter hours:	環數：Ring Number: 647

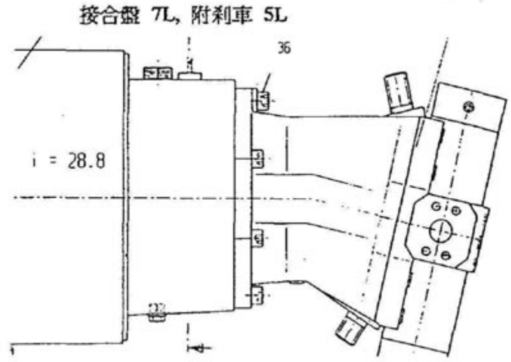
檢查部位 CHECK NUMBER	齒輪油平面 LEVEL OF GEAR OIL		檢查結果 REMARKS	檢查人 INITIALS
	行星齒輪 PLANETARY	液壓馬達接合盤殼室 INTERMEDIATE		
1.			✓	周安[illegible]
2.			✓	
3.			✓	
4.	油變質		✓	
5.			✓	
6.			✓	
7.	油變質		✓	
8.			✓	
9.			✓	
10.			✓	
11.			✓	
12.			✓	
13.			✓	
14.			✓	
15.			✓	
16.			✓	
17.			✓	
18.			✓	

視需要添加 HD220 齒輪油
TOP UP REQUIRED WITH OMALA 220.

行星齒輪箱 13 L (附油面觀測窗)
OIL CONTEND PLANETARY GEAR 13L
接合盤 7L, 附剎車 5L



WITH BRAKE



OIL CONTENT INTORMEDIATE HOUSE : 7L
OIL CONTENT INTORMEDIATE:LWITH RAKE

Figure. 12 Daily Drive Module Checklist.

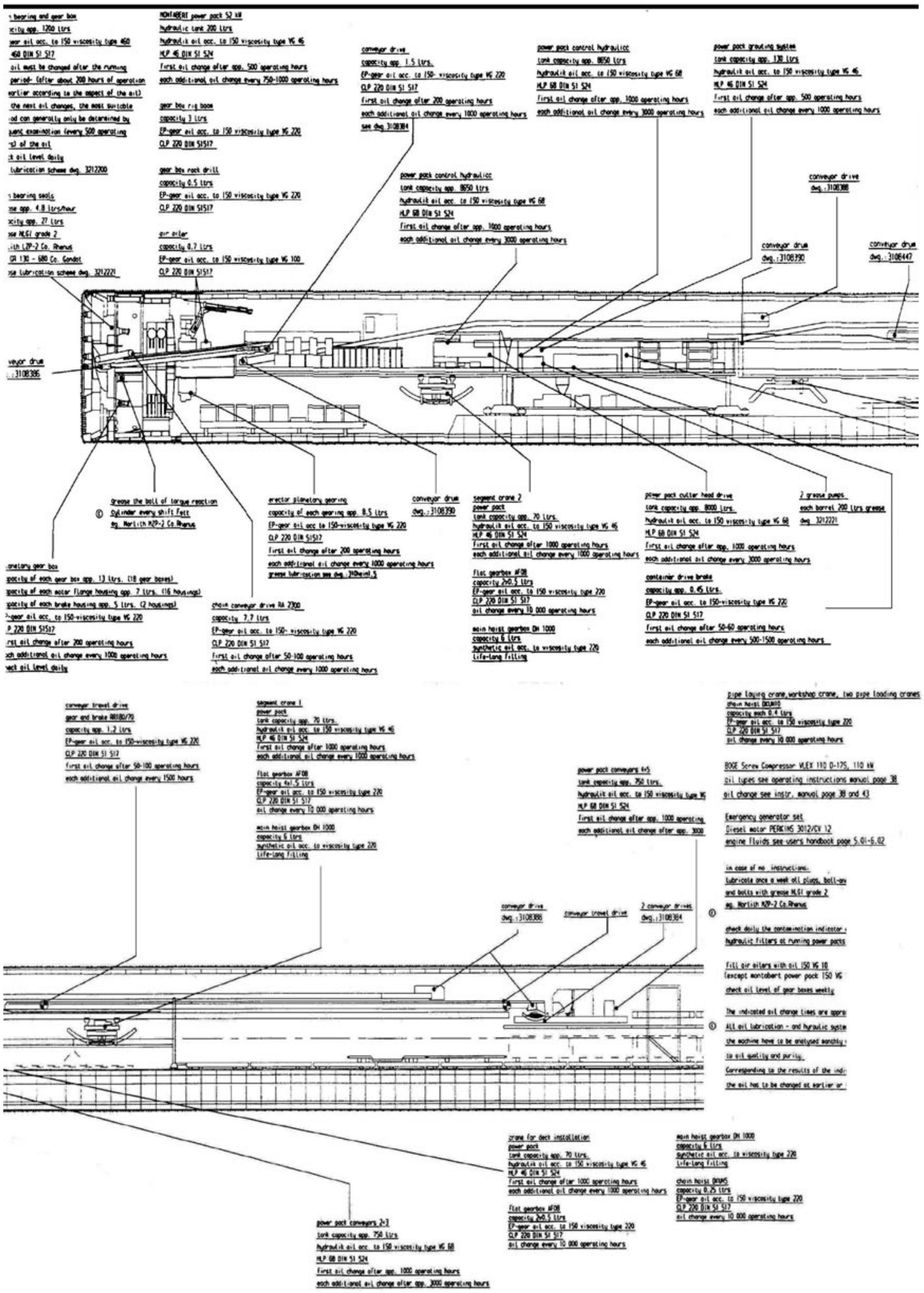


Figure. 13 Lubrication scheme general arrangements.