PPS
POLTINGER PRECISION SYSTEMS
MACHINE GUIDANCE

Steuerleitsystem für TBM
Guidance System for TBM

Information

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The ℙ ℙ 𝕊-TBM3 Guidance System

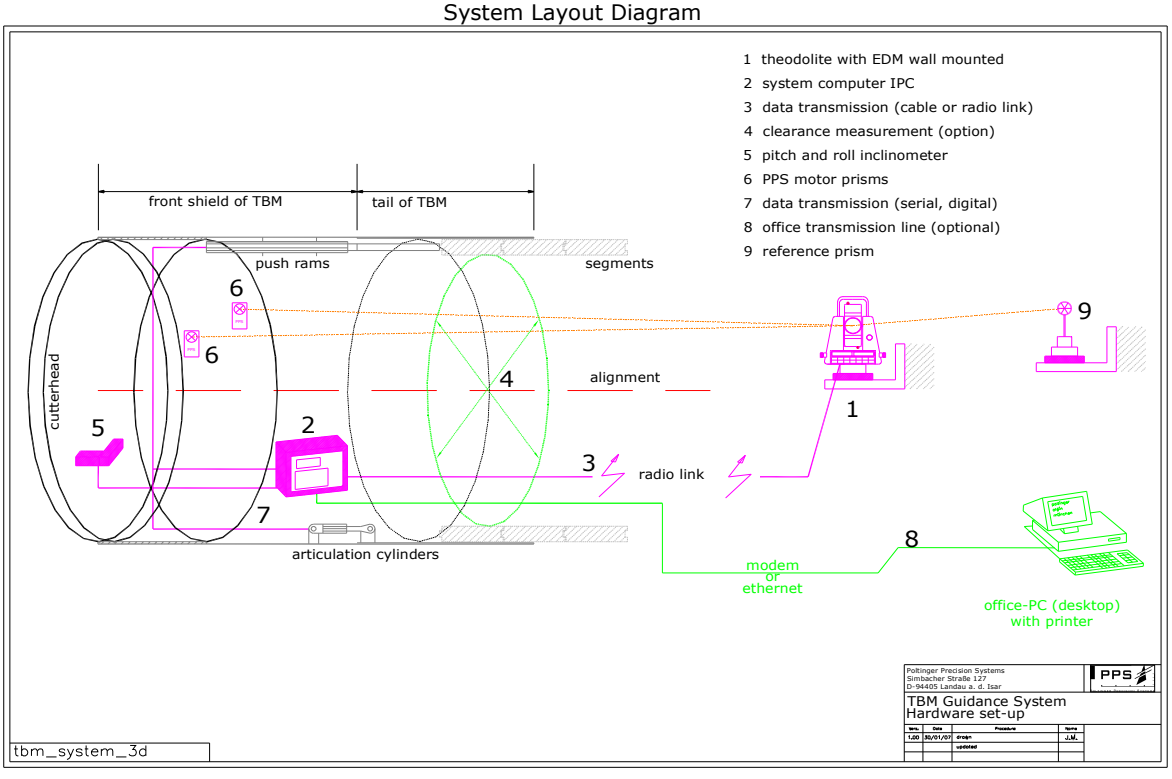
The ℙ ℙ 𝕊 -**TBM3** Guidance System is designed to provide a maximum of information concerning the position of the Tunnel Boring Machine (TBM). The clearly arranged display allows the operator to focus on his main job.
The system automatically determines the exact position and driving direction of a TBM in three-dimensional space. It also gives the operator all necessary information about the deviation of his TBM from the designed centerline. A projected path display is optionally provided to show the operator the optimal course along which to guide a deviated TBM back to the design centerline.
For tunnels with segmented liners, ring calculation software is also available.

The Theory

To measure the location and driving direction of a TBM, at least two defined points of the TBM, together with pitch and roll, must be measured in three-dimensional space. These two points are the **two prisms (6)** installed in the forward section of the TBM. Their exact location relative to the TBM axis and local TBM co-ordinate system must be determined at the TBM set-up. (see functional diagram)

Because the TBM may roll and pitch, the TBM co-ordinate system is usually not parallel to the global co-ordinate system. Therefore, roll and pitch of the TBM must be measured accurately, accomplished electronically by the **two-axis inclinometer (5)** mounted inside the TBM.

System Layout Diagram



The two prisms inside the TBM are automatically and continuously measured by the **motorised totalstation (1)**, its position on the tunnel wall and orientation defined in advance by measuring the tunnel traverse.

The horizontal angle measurement system of the totalstation must be orientated at the installation by manually measuring to a **reference point (9)**, of which the co-ordinates have been previously determined. All measurement information is inserted and updated in **the system computer IPC (2)** by the survey staff.

The co-ordinates of a new totalstation standpoint can easily be determined by standard surveying methods with an additional interactive feature in the system.

The global co-ordinates of the two machine prisms on the TBM may now be established by measuring the slope distances and horizontal and vertical angles from the orientated totalstation. Since the location of the prisms in the TBM co-ordinate system was established at TBM set-up and the roll and pitch of the TBM are known at all times, any point of the TBM (e.g. the center of the cutter head) can be calculated in global three dimensional space.

The design centerline is also known in the global co-ordinate system and is entered into the system computer in advance.

Subsequently, horizontal and vertical deviation of the TBM from the centerline, together with TBM orientation, can be calculated easily and presented graphically to the TBM operator. A projected path shows the optimum way back to the design centerline.

The importance of the remote prism can not be underestimated. Not only does the remote prism enable the orientation of the totalstation, but it also allows automatic on-line detection of potential errors caused by any movement of the totalstation standpoint. Because the totalstation is mounted on the possibly unstable wall of the just-drilled tunnel, about 25 to 100m behind the TBM, it has a high potential for movement. Such movement, if undetected, can spoil the accuracy of mining. Consequently, the PPS-TBM Guidance System periodically measures the remote prism to check the stability of the theodolite standpoint and notifies the operator if movement has occurred. The interval for these reference measurements is determined by use of a password-protected menu.

The Hardware

Motorised Theodolite / example

Fully automatic, unattended system operation requires the use of a motorised theodolite (totalstation), capable of automatically recognicing and measuring prisms (ATR). The theodolite, under control of the system computer, alternatly measures to the two prisms (6) mounted on the TBM and periodically to the remote prism (9). Furthermore, a two-axis, high accuracy inclinometer (5) is installed in the TBM to detect the pitch and roll occurring on the TBM during mining. The program on the system computer (2) picks up all measurements and calculates the precise global co-ordinates, orientation and inclination of the TBM from these values.

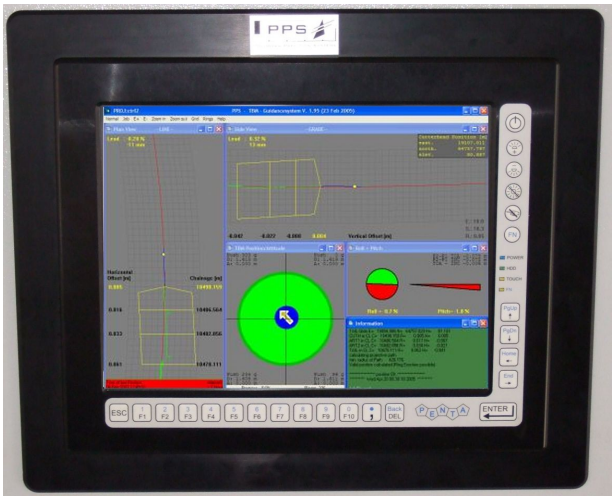
The data transfer between theodolite and the PC is handled by a radio link. This feature eliminates a long cable connection (functional diagram item 3) which must be maintained all the time .

Because the survey window of a TBM is usually located near its perimeter, an inaccuracy of the inclinometer measurement results in a potential positional error. Therefore, the designed accuracy of the inclinometer is always given - even under mining conditions - and is better than 0.03 degree.

Motorprism (EU –Patent)

To prevent measurement errors caused by beam reflection from adjacent prisms, a special motorised prism (6) was developed which can be opened and closed alternately under software control.
An automatic look-ahead measurement for a new theodolite station is only possible with this feature.

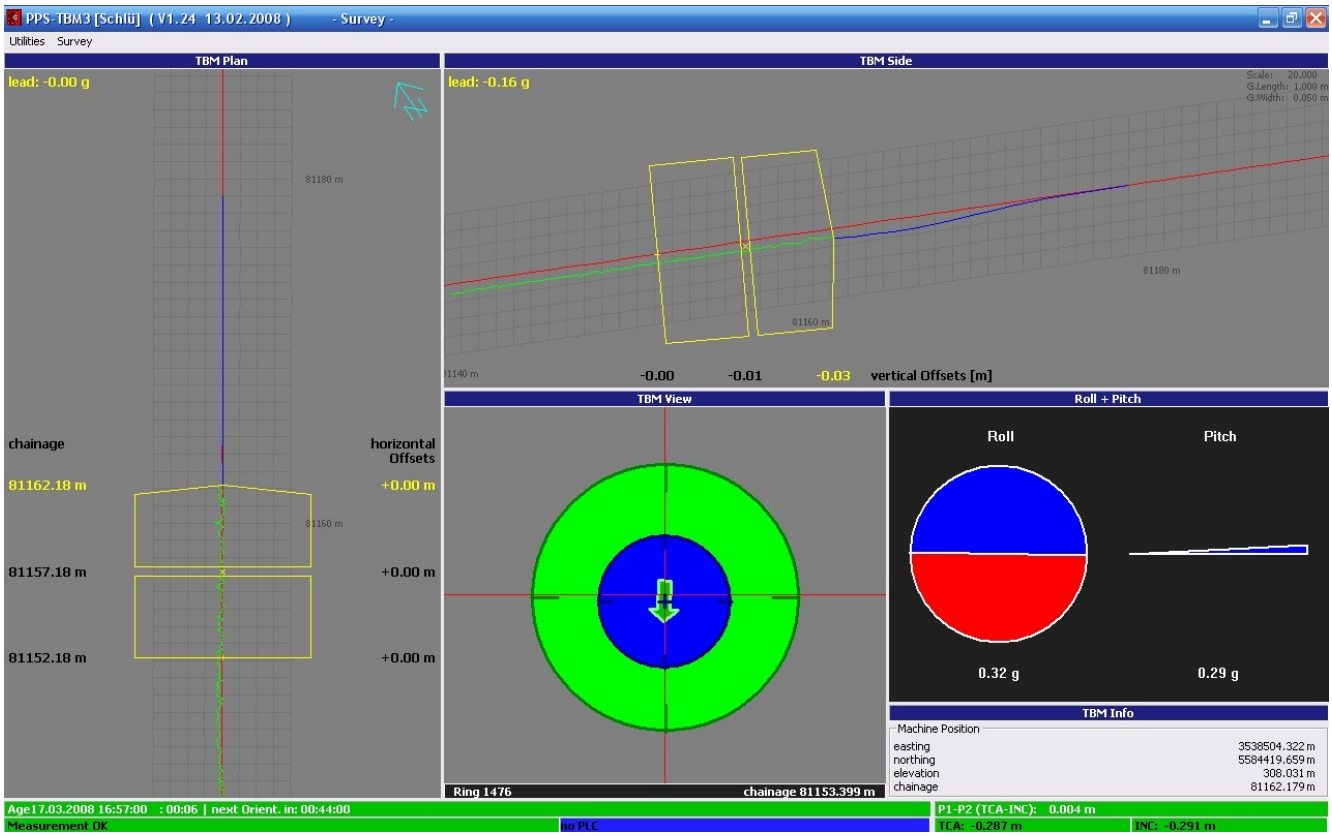
Special precautions have been taken to ensure proper system operation in the harsh environment of tunnelling. Data transfer cables, such as RS232 data lines, often share routing space with high power cables, and, in such cases, may not work properly. Therefore a disturbance-immune data transfer system was developed and integrated into the guidance system. A data radio link is available as an option (3). The system computer is housed in an industrialised, sealed enclosure with a 12”-TFT – touchscreen (2). All electronic components are electrically isolated from each other and from the main electric system of the tunnel.



The Survey Software

The PPS-TBM3 Guidance System runs on an industrial PC (with a processor Pentium III or higher) under WINDOWS 2000™.
The motorised theodolite, which is under control of the system program, automatically follows the movements of the prisms on the TBM.
In user-programmable intervals, it also checks the remote prism to verify or update the orientation of the theodolite. This automatically includes the stabilisation check of the theodolite station.
Whenever a set of measurement data is collected, (measurement to the two prisms inside the TBM and the readings of the inclinometer) a new position and orientation of the TBM is calculated and displayed. All information is stored and displayed graphically and numerically.
The use of the 2-axis inclinometer also enables an absolute independent check of the measured data.

Guidance screen as presented to the TBM operator (example):



This screen with its five windows provides the information necessary to drive the machine along the designed path (DTA, centerline). The co-ordinates of this centerline must be given, the positions of the theodolite and the reference target are measured and entered by the surveyors.

In the **TBM Plan** view window on the left of the screen you see the machine (schematically) in yellow, following the theoretical centerline (red). The green line shows the past few meters (trace), the blue one the projective path. In numbers: chainage (right), horizontal offset (+ right, - left) to the centerline (left), lead (top). At the bottom, the "Time of last Position" tells when the program calculated the last valid position for the TBM from theodolite and inclinometer measurements and the time passed.

The **TBM Side** view at the top right shows the vertical offset – the value for the cutterhead is written in yellow, for the other parts of the machine in black; the lead is the inclination of the TBM axis to the centerline (in %, degree or mm per m).

The middle section with the window **TBM View** shows the view along the centerline, the position at the moment (blue spot) and the direction of the TBM – CL (arrow). The big circle changes colour depending on the offset to the centerline, the green arrow turns yellow and eventually red when the lead is out of limits.
The values in the corners of this window are only present if chosen (e.g. for ring calculation), showing current extension values of push rams.

The **Roll + Pitch** window shows the inclination of the TBM as measured by the inclinometer mounted on the main beam and calibrated to a zero - position.

In the **Info** window the global position of the TBM is shown.

For more details, click the **TBM Plan** window. All procedures of the program and messages are displayed here after they first came up in the last line.

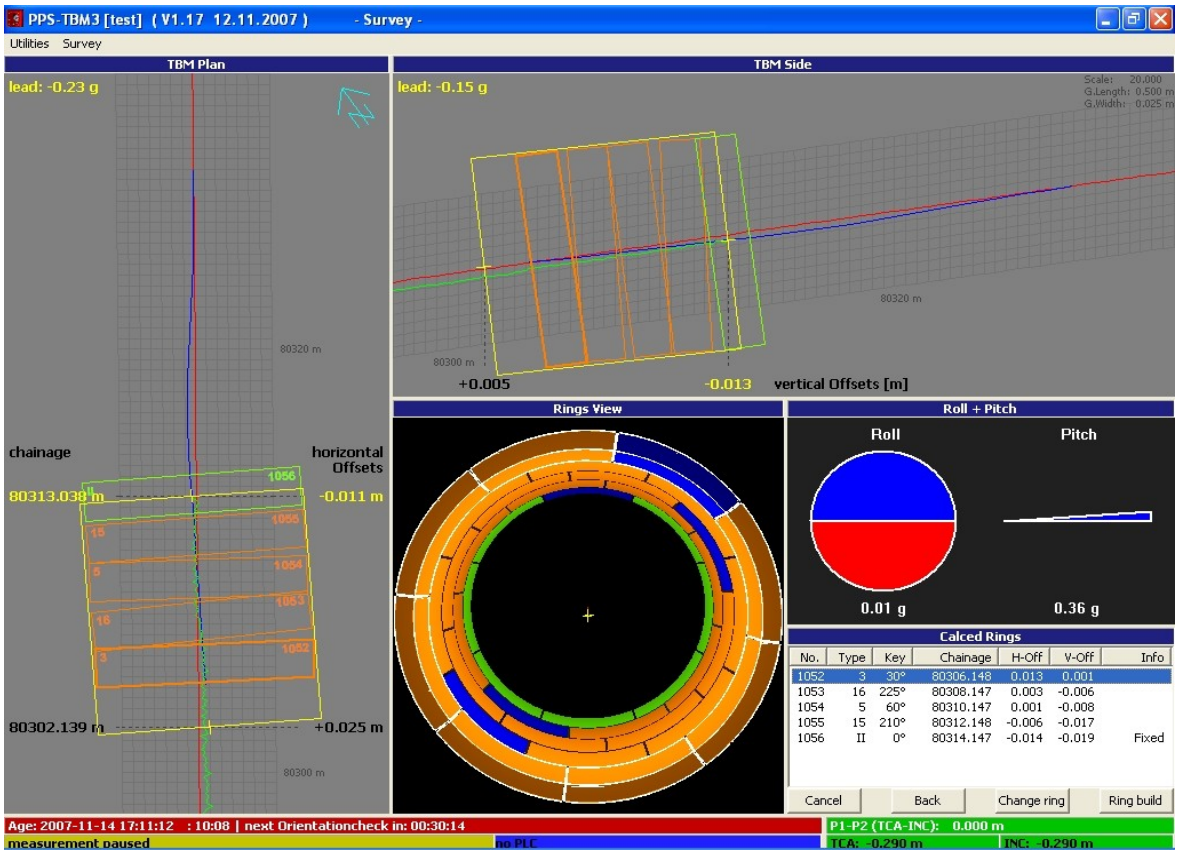
The Survey – Button leads you backto the main menu in which all the parameters are entered by the surveyors or certified personnel.

The display can be personalised by using the arrow buttons.

The Ring Calculation Software (Option)

The result of the "survey section" is transferred into the "Ring Calculation" section.
The ring calculation can handle all possible types of segmented rings: front tapered, rear tapered, double side tapered and straight. Also “fixed” rings are possible if there is the demand that at a certain point of the tunnel a special type of ring must be erected.
The result of the ring calculation is displayed (see below). The program not only calculates the type of ring which best fits the currently mined position, but also calculates the optimum path back to the centerline, using the types of rings available and allowed as consecutive (to avoid aligned joints).

Result of a ring calculation:

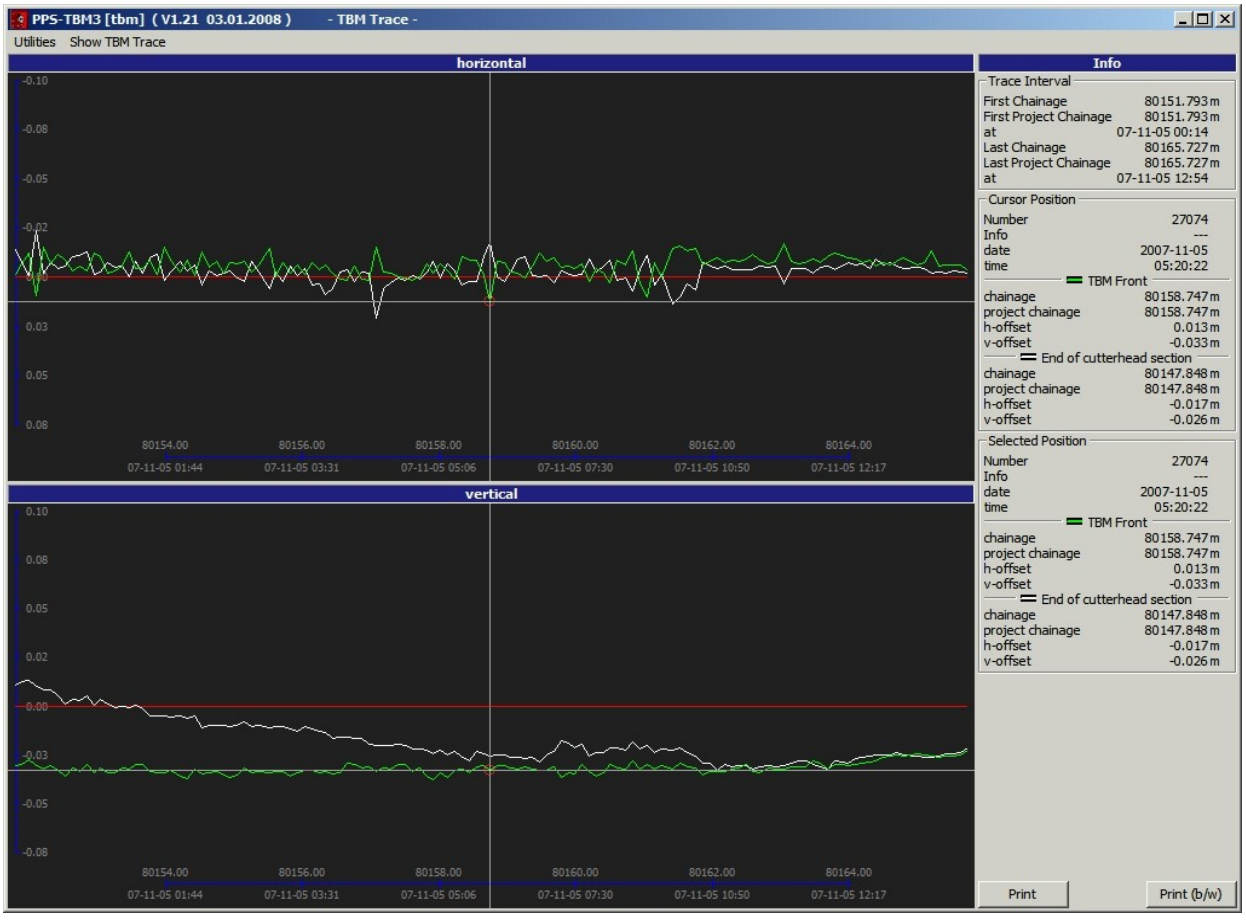


The centerwindow shows a three dimensional view of the tunnel to be built under the present conditions. The first ring represents the one to be built, the other rings (number to be chosen) are yet to follow.
The yellow cross can be used to step through the rings.
The ring record stores all relevant information necessary for the customer.
A ringbuild protocol in PDF format can be created and either stored or printed.

Additional Tools

More tools providing additional convenience for the user of the **ℙ ℙ 𝕊-TBM3** Guidance System are available. For example: the theoretical centerline which may be created manually or by CAD software, can easily be imported from an ASCII file. The information can then be displayed and examined to ensure that all details are correct.

Parameters from the mined tunnel, based on chainage or on time for shift or daily / weekly reports, can also be displayed graphically or printed.



The system database is very comprehensive, with backup functions and various input/ output options available to the customer.

The user may enter any number of site-specific parameters, such as target offsets, minimum turning radius, etc., into the database. These entry points are password-protected to provide maximum security against unauthorised editing.

The **ℙ ℙ 𝕊 - TBM** guidance system is open to be used on all types of machines!

Options

Additional options for the **PPS-TBM3** Guidance System are available to allow system configuration which may be required by the customer:

- A remote computer in the office may be connected to the system computer by a telephone or network link (see functional diagram, item 8) to provide remote on-line check of the guidance system.
- Ring calculation software, according description above.
- Transmission of values from the PPS system to the PLC of the TBM.
- Direct import of the elongation of the "push rams/ thrust jacks" or other parameters (see functional diagram item 7) from the PLC.

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