Navigation System for
Microtunneling and Pipejacking

NAV 24

- Enables horizontally and vertically curved tunnels
- Supplies precise control information on position - direction - inclination - roll
- Easy operation and setup

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1  GYRO-SUPPORTED CONTROL OF TUNNELING WORKS

Tunnel24 has accumulated 30 years of experience in the field of survey and Navigation systems.

With its NAV24, Tunnel24 has created a truly economical alternative to other systems known in the market.

The electronic Laser Target as well as the available north-seeking Gyrocompass MK20 and MWDR, the electronic hose levelling unit, the expandable system architecture as well as the easy-to-use operator software with its Windows® user interface allow a precise control of the position.

The high-quality electronic hose levelling unit allows precise determination of the current altitude - exact to the millimetre. The gyrocompass together with the navigation algorithms developed specially for this purpose, allow precise and smooth control of the drive advance in both orientation and position.

Tunnels with an inside diameter of at least 800 mm can be surveyed autonomously, rapidly, simply and reliably.

2  NAV24 OPERATION MODES

The NAV24 can be operated in different Operation modes which can be chosen optional according to the project requirements just be a small change in the program settings.

**Mode 1 – LASER**

This mode is suitable for straight drives up to about 300m

The horizontal and vertical position will be determined by the electronic Target mounted in the TBM.
Mode 2 – LASER with Electronic Water Level System

This mode is suitable for straight drives even longer than 300m, but no longer than 500m. The horizontal deviation will be determined by the electronic Target mounted in the TBM. The vertical deviation will be determined by the Electronic Water Level System.

Mode 3 – Gyrocompass with Hydrostatic Water Level System

This mode is suitable for curved drives or drives that are longer than 500m. The horizontal deviation will be determined by the North Seeking Gyrocompass (MK20 or MWDR). The vertical deviation will be determined by the Electronic Water Level System.
For the Gyrocompass there are two Versions available:

1. MK20 – Measuring only during stand still. Measurement time approx. 2 minutes.

2. MWDR (Measurement Whilst Drilling) – Continuous measurement during tunneling

### 3 ADVANTAGES OF NAV24

Drivages require a great deal of surveying effort that can be substantially reduced by the use of NAV24. This results in higher daily drivage rates and, thus, increased productivity.

In Microtunneling, the decisive advantage in comparison with conventional systems is that the Tunnel Boring Machine (TBM) can be reliably controlled without visual contact with the starting pit, thereby enabling normal curves as well as curves in two planes.

When using Mode 3, the requirement for visual contact is completely unnecessary.

The entire data for the advance are automatically recorded and documented, providing transparency for the complete tunnel project, even after it has been completed.

The north-seeking gyro (optional MK20 or MWDR) integrated in the NAV24 makes it possible to set up the TBM in direct relationship to geographical north, right in the starting pit. The progress for the entire advance is then reliably controlled by using the precise reference to north.
4 SYSTEM COMPONENTS

The system is comprised of several modules and the related control PC.

- **North-seeking, horizontal-adjusting gyrocompass (MK20 or MWDR)**
  
  The main component of the system is securely mounted in the machine pipe of the TBM and measures three attitude angles:
  
  - geographic north direction  \(\Rightarrow\) heading of the tunnel-boring machine
  - longitudinal inclination angle  \(\Rightarrow\) front/back inclination of the tunnel-boring machine
  - roll angle  \(\Rightarrow\) transverse inclination of the tunnel-boring machine

- **Electronic Hose Levelling Unit**
  
  The electronic hose levelling unit determines the current altitude above sea level constantly during the entire advance. It consists of three modules:
  
  - A **hoseline**, approx. 10mm in diam., which moves with the entire tunnel advance. It is comprised of 50-mtr sections supplied on drums. The hoseline connects the altitude sensor in the tunnel-boring machine with the altitude reference sensor in the starting pit.
  
  - The **altitude sensor**, mounted in the machine pipe, determines the static pressure of the water column in the hose line, as well as the roll of the altitude sensor.
  
  - The **altitude reference sensor** is securely mounted in the starting pit
  
  - The Reference module is mounted in the starting pit in such a manner that its altitude is always higher than that of the tunnel-boring machine.
• **Measurement of distance (Chainage)**

The travel sensor (a measuring wheel) is located on the first pipe in the starting pit; it determines the current length of pipe already laid. Expander dimensions - if needed - are entered manually.

• **Control PC / WS-Box**

The control PC is part of the WS-Box and is connected by data lines with all modules. It can be mounted and operated in the machine pipe and/or at an external control station (Control Cabin).

The WS-Box is equipped with a W-LAN Antenna

• **System software**

The NAV24 system software controls the measurement events and calculates the attitude and position of the machine pipe on the basis of the values measured by the sensors. A nominal/actual comparison is performed immediately. The user-friendly control interface is menu-controlled; the data are displayed graphically on a grid, the customary representation form, to which construction-site personnel are accustomed. The software runs under MS Windows®.

The measured and calculated data are displayed graphically on the PC as nominal/actual comparison in a grid. This places an easy-to-use and reliable control aid in the hands of the operator. The attitude of the tunnel-boring machine is displayed three-dimensionally; even the roll is shown graphically. All measurement data and manual inputs are stored automatically, ensuring that the entire advance is documented.
Operation with Open face TBM / Control Computer in TBM
Operation with Full face TBM / Control Computer in Container
5 PRACTICAL APPLICATION OF NAV24

The measurement principle of the NAV24 is based on the coupled navigation method.

The nominal route (DTA) for the drive is entered into the PC as routing elements (x, y, z) before work is started. This means that the nominal axis is divided into segments and the respective coordinates of the points at which a change in direction or altitude occurs are defined in the drivage program.

The starting direction and position of the machine pipe are determined by geodetic surveying: any 90° system of coordinates may be used.

When using a MK20 gyrocompass measurements are then initiated at freely definable distances (less than 2 meters is recommended) by the control PC. Upon completion of each gyro measurement, all system data are stored into the PC. Based on the north direction and the length of pipe already laid, as well as the longitudinal and transverse inclination angles, the heading and position are calculated immediately.

When using a MWDR gyrocompass the measurements are carried out continuously and automatically in an interval of about 20cm or less if required.

The NAV24 determines altitude by measuring the hydrostatic difference pressure. High-precision pressure sensors are installed in the altitude sensor of the machine pipe as well as in the altitude reference module in the starting pit. These measurement data are converted by the PC into a difference in altitude, and compensated for temperature.

The deviation in direction and altitude of the TBM are displayed graphically in a grid and the data are recorded.
Illustration of a survey display

Display of the navigation data on the control PC. The current position of the machine pipe is represented in the form of a NOMINAL / ACTUAL comparison on a grid. Supplementary information such as longitudinal and transverse inclination, heading, present length of pipe laid, as well as the coordinates, are shown in the right margin of the display.

Horizontal and Vertical Deviation is displayed also by means of lines at right side and bottom of the screen.
Setup

The setup of all machine parameters and operation mode takes place via a well-designed and clearly arranged display.
6 INSTALLATION AND OPERATION

Installation

Due to the modular concept of NAV24, all system components can be installed quickly and easily, and adapted to the space available in TBM. Reverse polarity protected connectors and standard, single-phase electric power (available at almost any power distribution point) simplify connection.

Setup

The initial coordinates, direction and altitude of the TBM are determined by geodetic survey. The data representing the nominal route for the advance - divided into segments - are generally fixed before tunnelling starts. All data are entered into the control PC as start or setup parameters.

NAV24 measurements

When using the MK20 gyrocompass the NAV24 measurements are initiated using the control PC (located either in the tunnel-boring machine or in the control cabin a mobile container above ground. When using the MWDR gyrocompass the measurements take place automatically. The distance between measurements can be selected as desired. It should not exceed 2 metre; depending on the local conditions, shorter distances may be necessary. At the moment a measurement is initiated, the NAV24 reads the data from the electronic hose levelling unit and the travel sensor and then starts the gyro measurement. The gyro requires about two minutes for its measurement. If it is disturbed by shock while measuring, the measurement time will be extended until reliable data are ensured.

Since the NAV24 works on the basis of coupled navigation, it is necessary that a geodetic survey be made approx. every 35 to 50 metre. Based on these check surveys, the NAV24 will be re-initialized and the drift angle newly calculated and entered into the PC.
Installation of additional pipe sections

The hoselines and connection cables used by the NAV24 are supplied on 50-mtr drums. Additional hoseline and cable sections are easy to insert. The hoselines of the electronic hose levelling unit are provided with threaded connectors; in the starting pit, a hydraulic quick-connect piece ensures rapid and safe disconnection and connection. A compensation tank - open at the top - prevents air inclusions in the electronic hose levelling unit.

Documentation of the advance

The data recorded automatically by the control PC can be viewed in the evaluation file mode, and can be archived using an external memory stick. The NAV24 software generates an Excel readable CSV File.
7 PICTURES OF THE COMPONENTS

Pic 1  Gyrocompass MK 20

Pic 2  Gyrocompass MWDR

Pic 3  Altitude / Reference Sensor

Pic 4  Electronic Target
Pic 5  TC-Box
Pic 6  Traven sensor
Pic 7  WS-Box (PC inside)
Pic 8  Tough Pad for control
Pic 9  W-LAN Antenna of WS-Box
Pic 10 Quick connector
Pic 11  Cable drum (50m)

Pic 12  Hose drum (50m)
8  TECHNICAL DATA

Accuracy of north measurement, gyrocompass:  <0.0600 gon

Accuracy of attitude measurement, gyrocompass:  <0.0600 gon
  longitudinal inclination:  max. ± 60 gon
  transverse inclination (roll):  max. ± 16 gon

Accuracy of altitude indication (depending on measurement range of pressure transmitters: 0 to 0.2 or 1.0 bar):  <1 to 5 mm
(Other pressure transmitters available on request)

Interfaces:
  sensor units             CAN bus

Temperature range of the sensor units:
(with T24 fluid)  -10 to +50°C

Power supply
  nominal voltage / frequency / current:
    230 V / 50 - 60 Hz