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LOW-COST PC COMPATIBLE TUNNEL GUIDANCE - THE MINIMISED BASIC SYSTEM, ZED 20

The ZED 20, or Minimised Basic System is a low-cost TBM guidance system which uses an intelligent target unit, including an integral dual-axis inclinometer in one robust and compact enclosure, called the Combined Target Unit (CTU), and ZED designed, Windows compatible software, ZBasic, running on a customer supplied PC as the user interface, for setup and display.

The system is designed primarily for straight or simple tunnel alignments that may include large radius curves. The principle of operation is based on a standard tunnelling laser mounted parallel to the designed axis. Curves are negotiated by the TBM operator manually inputting into the ZBasic software, a series of offsets pre-calculated before each shove.

Two options exist to upgrade the system i.e. :-

- Software upgrade to provide to permit data logging of all guidance & associated survey data, in a format suitable for printing and the direct submission to the Client
- Hardware upgrade to provide mounting brackets to place the target unit on the machine,

The primary system components are :-

Combined Target Unit, CTU

Operating features include :-

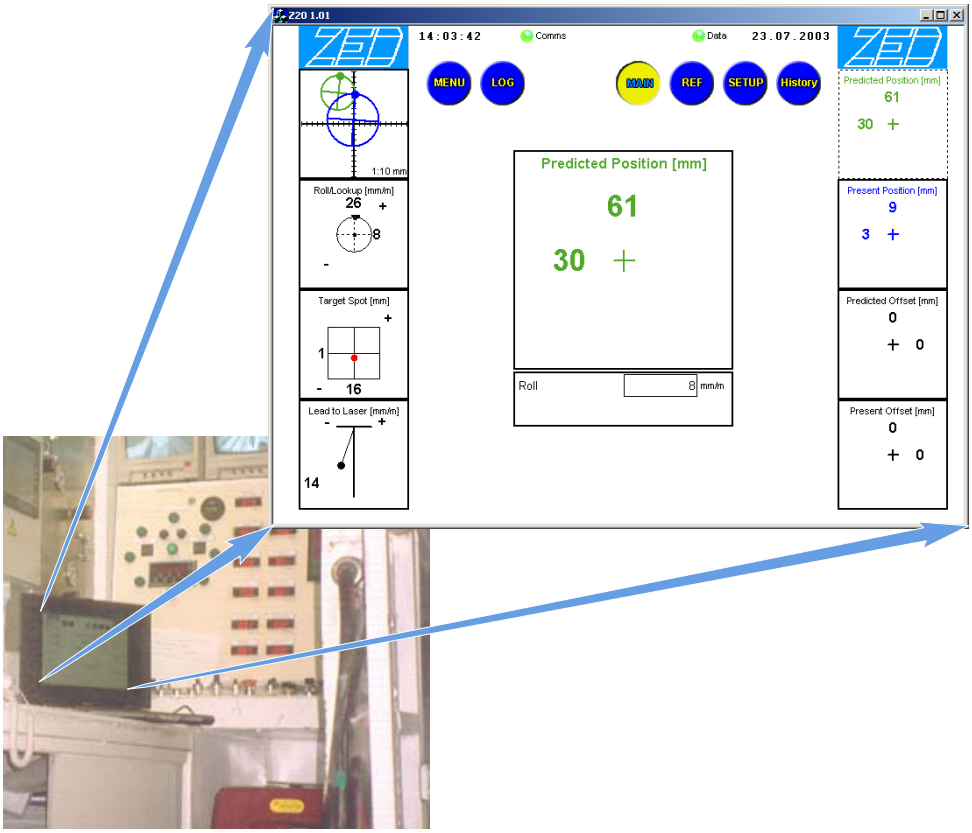
- Laser based – calibrated with laser power set at 0.5mW and 2.0mW, but will operate below 0.5mW and up to approximately 5.0mW, without loss of accuracy.
- Measurements made by the unit :-
  - Optically determines the X & Y coordinate of the incoming laser beam on the front glass screen. Also the angle of incidence between the unit and the laser, to determine the Lead or Tendency.
  - Mechanically measures the Roll and Lookup (Pitch) of the unit, to gravity, with an integral dual axis inclinometer.
- A built-in laser power sensor constantly monitors the beam, with the values displayed by the PDU together with a comprehensive set of diagnostics and error reporting

- Autoranging sensitivity feature responds to varying laser power levels due to the separation distance between target and laser and the quality of the tunnel air i.e. amount of dust and water vapour present. Extends the use of the target with a wide range of laser powers
- Passive measurement using opto-electronic sensors, and with the inclinometer transducer have no moving parts, reducing the effects of vibration and improving reliability and the units robustness
- Inherently more rugged by using surface mount technology for the electronics
- Error / self test warning lights within unit but visible through the front glass screen
- Packaged within a milled aluminium case with two parts, box & lid, to IP65. No welded joints. Anodised finish.
- Powered from the PDU with over voltage protection
- Internal electronics protected against induced currents from electrical static discharge.
- Includes a software damping module to reduce the effects of vibration
- Anti-vibration mountings also included

ZBasic

- Windows compatible user interface and display software

  Measured parameters from the CTU are transmitted every five seconds to ZBasic, where the TBM position and orientation are calculated with the data displayed graphically. The cable connection between the target and PC can be either a single-pair cable up to 1km long or, optionally, a radio link.



Interconnection cables

Ideal for pipe-jacking

This simple configuration makes the Minimised Basic System ideal for applications such as pipe-jacking on straight drives, with the operator, either on the machine or remotely on the surface, benefiting from the display of real-time guidance information and steering to the Prediction Position.

This system configuration maybe especially useful on long, straight pipe-jacked projects, when upgraded with the Infra-Red Combined Target Unit and Leica TCA or TCRA Total Station; for details refer to the last section Options.

OEM integration

The Combined Target Unit is also available for OEM integration to meet more complex guidance requirements. The format of the data stream is simple to interpret and fully documented. Technical support is available to assist in the integration process, giving machine builders the ability to incorporate low-cost “own label” guidance based on well-proven principles.

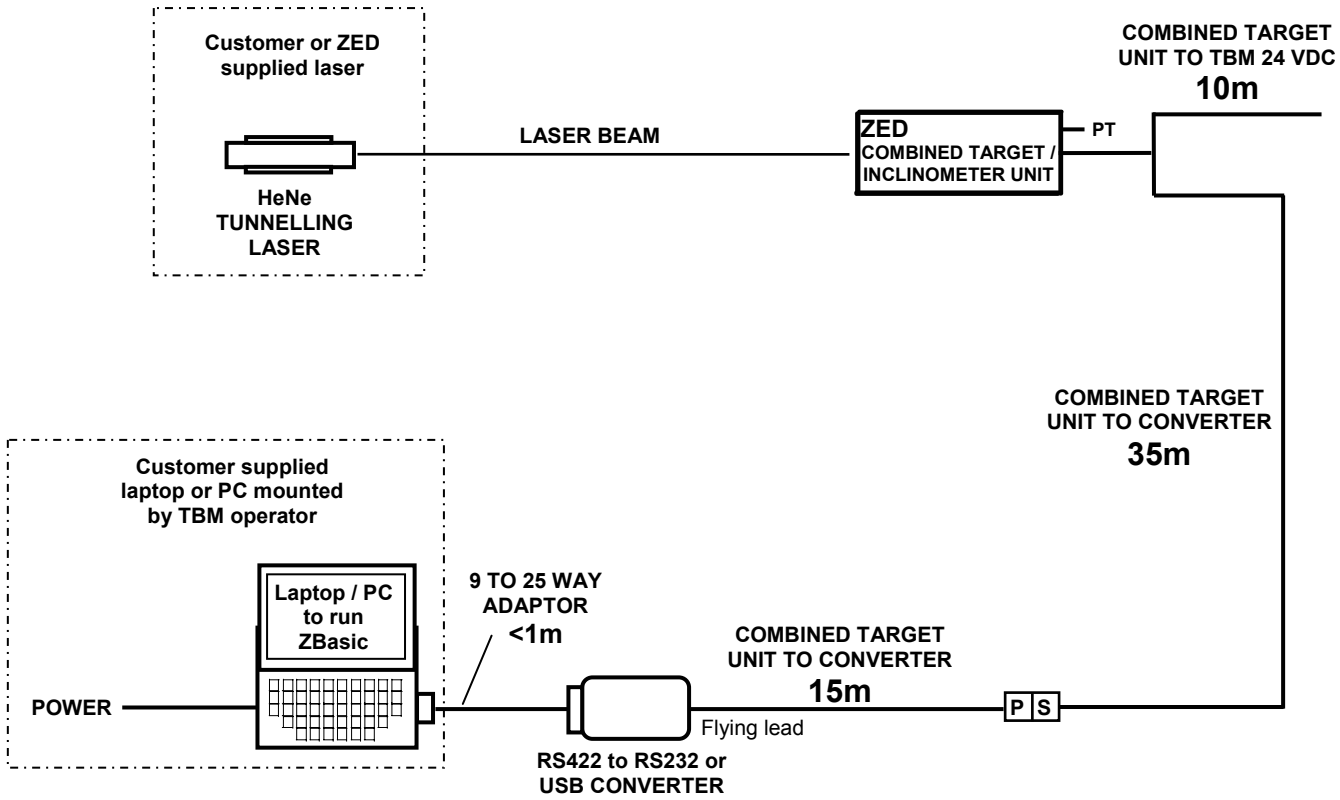
The ZED 20 is available in two versions :-

1). If the TBM can supply an instrument quality, regulated 24 VDC directly to our equipment.

The following configuration represents the minimum equipment requirements possible to provide ZED tunnel guidance, comprising :-

- x1, Combined Target Unit, RS422 output
- x1, ZBasic Windows compatible user interface software, for setup & display
- x1, RS422 to RS232 or USB Converter
- x1, Laser Power Meter
- x1, Set of interconnecting cables, comprising with standard lengths :-
  - x1, 'Y' cable - Combined Target Unit to TBM 24 VDC @ 10m
    Combined Target Unit to Converter @ 35m
  - x1, Combined Target Unit to Converter @ 15m
  - x1, 9 to 25 way adaptor @ < 1m

System interconnection :-



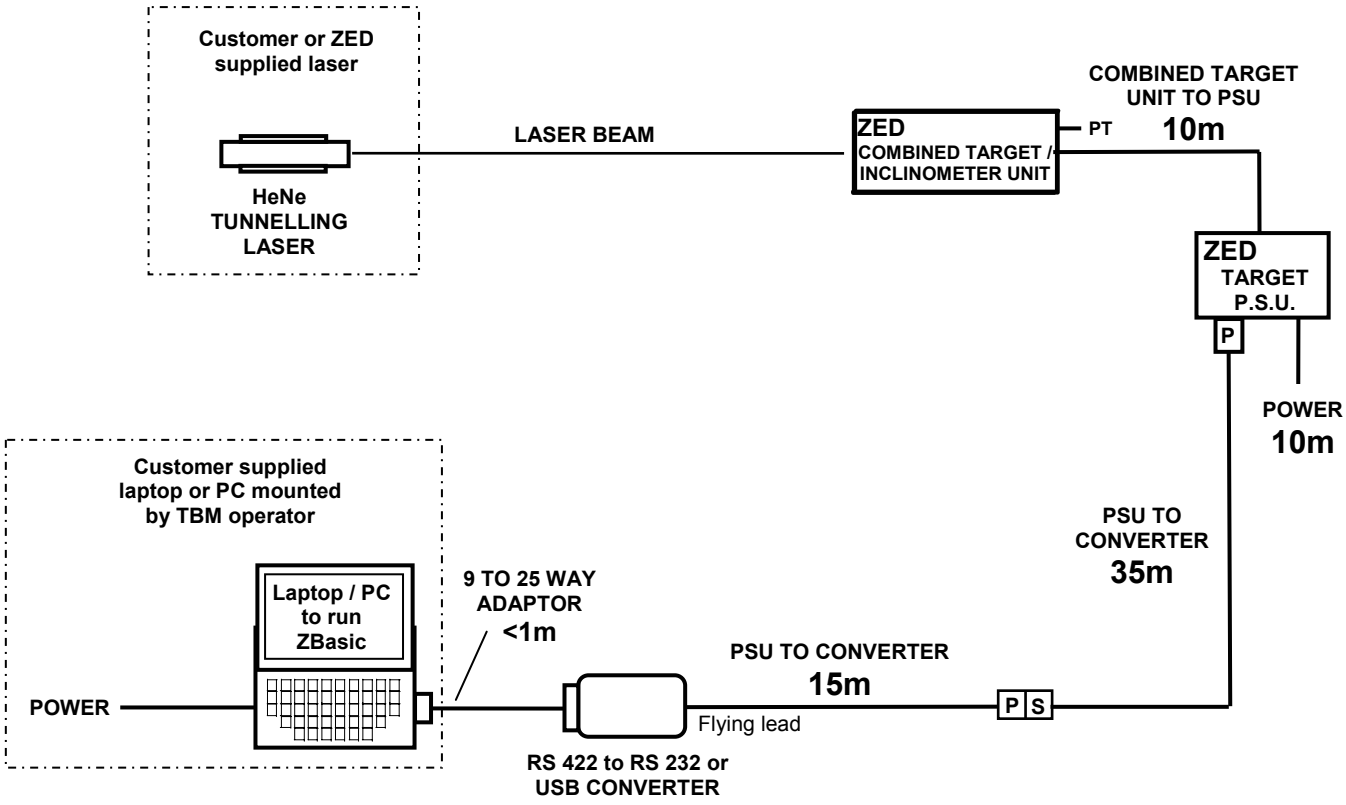
Notes :-

i). If the PC has a RS 422 coms port, then the converter, adaptor cable and Combined Target Unit to Converter cable would not be required, i.e. the link would be direct.
ii). If RS 422 is used as the communications method to link the PC to the target, the maximum separation distance is = 1 Km, i.e. for remotely controlled machines.
iii). If RS 232 is used as the communications method to link the PC to the target, the maximum separation distance is = 15 m, i.e. for manned machines.
iv). The laser is not normally included with the system, however, a suitable tunnelling laser can be supplied by ZED's, if required.

2). Supplied with a ZED Power Supply Unit (PSU), comprising :-

- x1, Combined Target Unit, RS422 output
- x1, Target Power Supply Unit
- x1, ZBasic Windows compatible user interface software, for setup & display
- x1, RS 422 to RS 232 or USB Converter
- x1, Laser Power Meter
- x1, Set of interconnecting cables, comprising with standard lengths :-
  - x1, Combined Target Unit to Power Supply Unit @ 10m
  - x1, Combined Target Unit to Converter @ 15m
  - x1, Power Supply Unit power 110 / 230 VAC @ 10m
  - x1, Power Supply Unit to Converter @ 35m
  - x1, Power Supply Unit to Converter @ 15
  - x1, 9 to 25 way adaptor @ < 1m

System interconnection :-



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iv). The laser is <u>not</u> normally included with the system, however, a suitable tunnelling laser can be supplied by ZED's, if required.

Principle of Operation

The equipment calculates and displays the position of the machine from a designed tunnel axis. This calculation is based on the system monitoring the deviation of the TBM from a laser beam reference, mounted at a fixed point on the tunnel wall, parallel to the designed axis, and the machines roll & pitch (Lookup) to gravity. The Combined Target Unit is placed on the machine such that its three principle axes are parallel to the same axes of the machine. Slight variations are removed by entering correction values into the system during setup / installation. The following data is also required, for system entry :-

- The $\mathbf{X_T}$ (horizontal) and $\mathbf{Y_T}$ (vertical) co-ordinates of the centre of the Combined Target Unit with respect to the TBM's longitudinal axis.
- The $\mathbf{X_B}$ (horizontal) and $\mathbf{Y_B}$ (vertical) co-ordinates of the laser beam with respect to the designed tunnel axis.
- Tunnel grade in mm / 10m

On straight drives, with the laser illuminating the target unit, the system displays the machines position as an offset in millimetres, in two planes parallel to the glass screen of the target. Present Position is the offset of the TBM's axis from the designed axis in the plane of the target unit glass screen and Predicted Position, the offset of the machines axis in a plane parallel to the Present Position but set at the head of the machine or just in front. The separation of the two planes is a user settable parameter, Prediction Distance. Additionally, the 3 principle, angular attitudes of the TBM's axis with respect to the designed tunnel axis are also displayed.

To create a curved tunnel alignment, two Offsets are entered into the system. These values represent the horizontal, **X**, and vertical, **Y**, deviations of the designed axis with respect to a theoretical straight line parallel to the laser beam. Note that in this instance, the parameters referred to above $\mathbf{X_B}$ and $\mathbf{Y_B}$ represent the values of the co-ordinates between the laser beam and this, new, theoretical line.

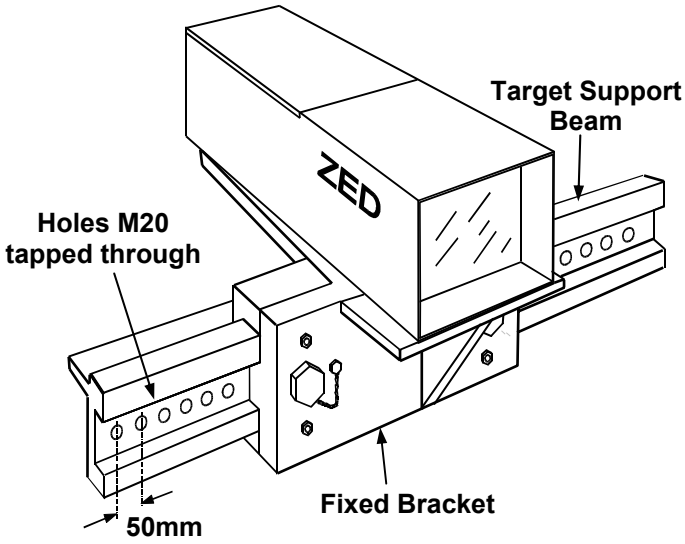
The Offsets can be calculated for either or both, the Present & Predicted Position, although normally the latter and are subtracted from the values determined by the system to give the correct position relative to the curved axis. Note that when based on the Predicted Position the displayed Present Position does not relate to the curved alignment but to the theoretical straight line.

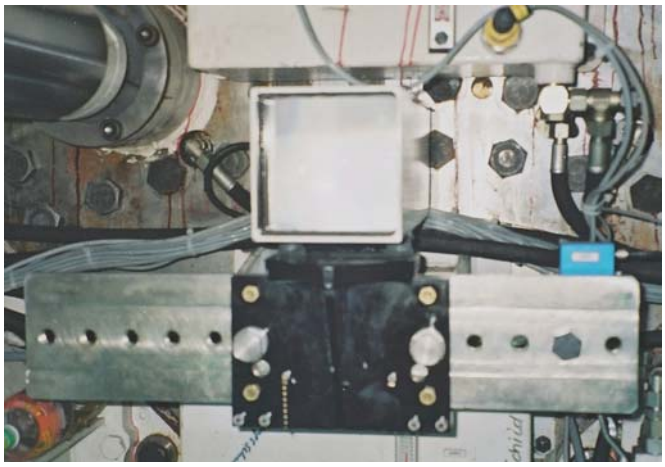
By updating the Offsets manually, at an appropriate point, determined by the distance along the alignment, the machine operator can steer the TBM to maintain a Predicted Position as close to zero as possible and thus follow the designed axis. The Offsets must be continuously updated along the length of the curved section, usually before each successive push. The surveyor has the responsibility of calculating the Offsets and how often they need to be applied, which is dependent on the radius of the curve and the frequency of repositioning the laser. The overall effect of this technique is to develop a curved alignment by a series of steps, as defined by the Offsets.

Options :-

Target Mounting Bracket

When a TBM excavates, typically, a horizontal curve, a mounting can be supplied by ZED that permits movement in the **Y** axis, in fixed steps, to help keep the laser on the units glass screen. If the unit were fixed rigidly to the TBM then moving the laser can be time consuming. The mechanical arrangement preserves the attitude of the target with respect to the machines axes as originally determined during the setup / installation phase.





Yeung Deung Po Power Cable Duct
DaeLim Corp, Seoul, Korea

Data logging

Data logging of all guidance & entered survey values on to the supplied PC hard drive. Logging can be setup to trigger on time and / or a manual command from ZBasic. The data is stored in a standard text / ASCII a format. If a printer is directly connected to the PC then user selectable archive pages maybe printed with a presentation, suitable for direct submission to, or inclusion within, reports to the Client.

Upgraded with a Leica TCA / TCRA Total Station

The system described above can be upgraded to operate with Leica's TPS 1200 Series TCA or TCRA Total Stations, please refer to the diagram on page 8. System operation is based on using Automatic Target Recognition, or ATR, where the instrument self-centres and locks onto a prism, and the recently developed Infra-Red Combined Target Unit that is sensitive to the infra-red laser emitted from the instrument providing this feature.

Apart from this change in the measurement to a reference, the principle of operation is similar to the Minimised Basic System, where the designed tunnel axis is assumed straight. The total stations position is entered as an offset in the X & Y plane perpendicular the designed axis. Initially, the Bearing or Azimuth of the total station is set to be parallel to the designed axis and equal to zero. The Elevation is entered as either a grade in mm / 10m, or directly as an angle.

As the TBM excavates, with the instrument locked onto a prism within the target unit, the changing angular data as the theodolite tracks the machine, together with the inclinometer (TBM ROLL and LOOKUP or pitch) and the LEAD (the horizontal angle between the TBM axis and the infra red laser used for the ATR) from the target, permits the system to determine the TBM's position.

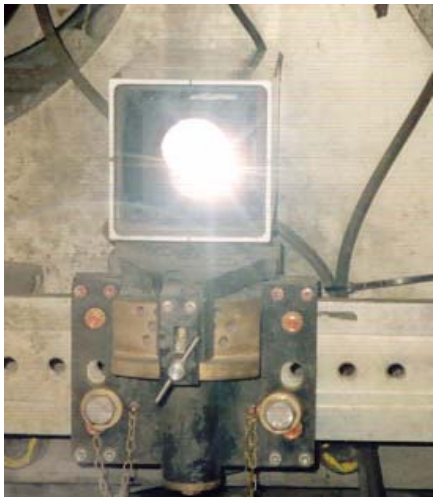
All data processing and entry is made at the PC where it also displays the relevant information to the machine operator. Logging of all guidance data by the PC can be included as an option, permitting the printing of high quality reports suitable for direct submission to the Client.

The main advantage of using this configuration is the greatly extended range, or separation distance between the target unit on the TBM and the theodolite, when compared to using a conventional laser based system. Typically, lasers are limited to approximately 200m, due to a breakdown in the beams quality with diffraction and absorption, but with this method the distance may lie between 400m and 600m.

Successful above ground testing at our factory has been made to approximately 650m. The method has been tested on a 9m hard rock Herrenknecht, with the TUF JV at Fluelen, Switzerland, although the maximum separation achieved was only ~170m, due to limitations imposed by the tunnel alignment and the machines geometry.

Therefore this equipemnt offers the opportuniy for long straight pipejacks

Infra-Red Combined Target Unit



IRCTU on the Abdalajis Tunnel West-Tube, Spain
UTE Abdalajis Oeste

System interconnection, comprising :-

Minimised Basic System + Infra Red Combined Target Unit + Radio Modem link